Data Warehouse Service

# Developer Guide

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# Contents

**1 Welcome** ..... **1**
1.1 Target Readers ..... 1
1.2 Reading Guide ..... 2
1.3 Conventions ..... 3
1.4 Prerequisites ..... 4
**2 System Overview** ..... **5**
2.1 Highly Reliable Transaction Processing ..... 5
2.2 High Query Performance ..... 6
2.3 Related Concepts ..... 6
**3 Data Migration** ..... **8**
3.1 Data Migration to GaussDB(DWS) ..... 8
3.2 Data Import ..... 11
3.2.1 Importing Data from OBS in Parallel ..... 11
3.2.1.1 About Parallel Data Import from OBS ..... 11
3.2.1.2 Importing CSV/TXT Data from the OBS ..... 16
3.2.1.2.1 Creating Access Keys (AK and SK) ..... 16
3.2.1.2.2 Uploading Data to OBS ..... 18
3.2.1.2.3 Creating an OBS Foreign Table ..... 20
3.2.1.2.4 Importing Data ..... 22
3.2.1.2.5 Handling Import Errors ..... 24
3.2.1.3 Importing ORC/CarbonData Data from OBS ..... 26
3.2.1.3.1 Preparing Data on OBS ..... 27
3.2.1.3.2 Creating a Foreign Server ..... 28
3.2.1.3.3 Creating a Foreign Table ..... 31
3.2.1.3.4 Querying Data on OBS Through Foreign Tables ..... 33
3.2.1.3.5 Deleting Resources ..... 34
3.2.1.3.6 Supported Data Types ..... 36
3.2.2 Using GDS to Import Data from a Remote Server ..... 40
3.2.2.1 Importing Data In Parallel Using GDS ..... 40
3.2.2.2 Preparing Source Data ..... 44
3.2.2.3 Installing, Configuring, and Starting GDS ..... 45
3.2.2.4 Creating a GDS Foreign Table ..... 49

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3.2.2.5 Importing Data ... 51
3.2.2.6 Handling Import Errors ... 53
3.2.2.7 Stopping GDS ... 55
3.2.2.8 Example of Importing Data Using GDS ... 56
3.2.3 Importing Data from MRS to a Cluster ... 62
3.2.3.1 Overview ... 62
3.2.3.2 Preparing Data in an MRS Cluster ... 63
3.2.3.3 Manually Creating a Foreign Server ... 66
3.2.3.4 Creating a Foreign Table ... 70
3.2.3.5 Importing Data ... 75
3.2.3.6 Deleting Resources ... 77
3.2.3.7 Error Handling ... 78
3.2.4 Importing Data from One GaussDB(DWS) Cluster to Another ... 79
3.2.5 Using the gsql Meta-Command \COPY to Import Data ... 81
3.2.6 Running the COPY FROM STDIN Statement to Import Data ... 85
3.2.6.1 Data Import Using COPY FROM STDIN ... 85
3.2.6.2 Introduction to the CopyManager Class ... 85
3.2.6.3 Example: Importing and Exporting Data Through Local Files ... 86
3.2.6.4 Example: Migrating Data from MySQL to GaussDB(DWS) ... 88
3.3 Full Database Migration ... 89
3.3.1 Using CDM to Migrate Data to GaussDB(DWS) ... 90
3.3.2 Using DSC to Migrate SQL Scripts ... 90
3.4 Metadata Migration ... 91
3.4.1 Using gs_dump and gs_dumpall to Export Metadata ... 91
3.4.1.1 Overview ... 91
3.4.1.2 Exporting a Single Database ... 93
3.4.1.2.1 Exporting a Database ... 93
3.4.1.2.2 Exporting a Schema ... 96
3.4.1.2.3 Exporting a Table ... 99
3.4.1.3 Exporting All Databases ... 103
3.4.1.3.1 Exporting All Databases ... 103
3.4.1.3.2 Exporting Global Objects ... 106
3.4.1.4 Data Export By a User Without Required Permissions ... 108
3.4.2 Using gs_restore to Import Data ... 111
3.5 Data Export ... 116
3.5.1 Exporting Data to OBS ... 116
3.5.1.1 Parallel OBS Data Export ... 116
3.5.1.2 Exporting CSV/TXT Data to OBS ... 120
3.5.1.2.1 Planning Data Export ... 120
3.5.1.2.2 Creating an OBS Foreign Table ... 122
3.5.1.2.3 Exporting Data ... 123
3.5.1.2.4 Examples ... 124

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3.5.1.3 Exporting ORC Data to OBS 127
3.5.1.3.1 Planning Data Export 127
3.5.1.3.2 Creating a Foreign Server 128
3.5.1.3.3 Creating a Foreign Table 128
3.5.1.3.4 Exporting Data 130
3.5.2 Exporting ORC Data to MRS 130
3.5.2.1 Overview 130
3.5.2.2 Planning Data Export 131
3.5.2.3 Creating a Foreign Server 131
3.5.2.4 Creating a Foreign Table 131
3.5.2.5 Exporting Data 133
3.5.3 Using GDS to Export Data to a Remote Server 134
3.5.3.1 Exporting Data In Parallel Using GDS 134
3.5.3.2 Planning Data Export 137
3.5.3.3 Installing, Configuring, and Starting GDS 138
3.5.3.4 Creating a GDS Foreign Table 138
3.5.3.5 Exporting Data 139
3.5.3.6 Stopping GDS 140
3.5.3.7 Examples of Exporting Data Using GDS 140
3.6 Other Operations 144
3.6.1 GDS Pipe FAQs 144
3.6.2 Checking for Data Skew 146
**4 Syntax Compatibility Differences Among Oracle, Teradata, and MySQL 150**
**5 Database Security Management 156**
5.1 Managing Users and Their Permissions 156
5.1.1 Default Permission Mechanism 156
5.1.2 System Administrator 157
5.1.3 Separation of Permissions 157
5.1.4 Users 159
5.1.5 Roles 160
5.1.6 Schema 161
5.1.7 User Permission Setting 162
5.1.8 Row-Level Access Control 163
5.1.9 Data Redaction 164
5.2 Setting Security Policies 168
5.2.1 Setting Account Security Policies 168
5.2.2 Setting the Validity Period of an Account 168
5.2.3 Setting a User Password 169
5.3 Querying Audit Results 171
**6 Development and Design Proposal 173**
6.1 Development and Design Proposal 173

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6.2 Database Object Naming Conventions....173
6.3 Database Object Design....174
6.3.1 Database and Schema Design....174
6.3.2 Table Design....175
6.3.3 Column Design....177
6.3.4 Constraint Design....179
6.3.5 View and Joined Table Design....180
6.4 JDBC Configuration....180
6.5 SQL Compilation....181
6.6 PL/Java Usage....185
6.7 PL/pgSQL Usage....186
**7 Guide: JDBC- or ODBC-Based Development....190**
7.1 Development Specifications....190
7.2 Downloading Drivers....190
7.3 JDBC-Based Development....190
7.3.1 JDBC Package and Driver Class....190
7.3.2 Development Process....192
7.3.3 Loading a Driver....192
7.3.4 Connecting to a Database....192
7.3.5 Executing SQL Statements....196
7.3.6 Processing Data in a Result Set....199
7.3.7 Closing the Connection....202
7.3.8 Example: Common Operations....202
7.3.9 Example: Retrying SQL Queries for Applications....206
7.3.10 Example: Importing and Exporting Data Through Local Files....209
7.3.11 Example: Migrating Data from MySQL to GaussDB(DWS)....210
7.3.12 JDBC Interface Reference....212
7.3.12.1 java.sql.Connection....212
7.3.12.2 java.sql.CallableStatement....213
7.3.12.3 java.sql.DatabaseMetaData....214
7.3.12.4 java.sql.Driver....216
7.3.12.5 java.sql.PreparedStatement....217
7.3.12.6 java.sql.ResultSet....218
7.3.12.7 java.sql.ResultSetMetaData....220
7.3.12.8 java.sql.Statement....220
7.3.12.9 javax.sql.ConnectionPoolDataSource....221
7.3.12.10 javax.sql.DataSource....222
7.3.12.11 javax.sql.PooledConnection....222
7.3.12.12 javax.naming.Context....223
7.3.12.13 javax.naming.spi.InitialContextFactory....223
7.3.12.14 CopyManager....224
7.4 ODBC-Based Development....225

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7.4.1 ODBC Package and Its Dependent Libraries and Header Files....227
7.4.2 Configuring a Data Source in the Linux OS....227
7.4.3 Configuring a Data Source in the Windows OS....235
7.4.4 ODBC Development Example....239
7.4.5 ODBC Interfaces....244
7.4.5.1 SQLAllocEnv....244
7.4.5.2 SQLAllocConnect....244
7.4.5.3 SQLAllocHandle....245
7.4.5.4 SQLAllocStmt....246
7.4.5.5 SQLBindCol....246
7.4.5.6 SQLBindParameter....247
7.4.5.7 SQLColAttribute....249
7.4.5.8 SQLConnect....250
7.4.5.9 SQLDisconnect....251
7.4.5.10 SQLExecDirect....252
7.4.5.11 SQLExecute....253
7.4.5.12 SQLFetch....254
7.4.5.13 SQLFreeStmt....255
7.4.5.14 SQLFreeConnect....255
7.4.5.15 SQLFreeHandle....255
7.4.5.16 SQLFreeEnv....256
7.4.5.17 SQLPrepare....256
7.4.5.18 SQLGetData....257
7.4.5.19 SQLGetDiagRec....258
7.4.5.20 SQLSetConnectAttr....260
7.4.5.21 SQLSetEnvAttr....261
7.4.5.22 SQLSetStmtAttr....262
**8 PostGIS Extension....264**
8.1 PostGIS....264
8.2 Using PostGIS....264
8.3 PostGIS Support and Constraints....265
8.4 OPEN SOURCE SOFTWARE NOTICE (For PostGIS)....269
**9 Resource Load Management....317**
9.1 Overview....317
9.2 Query Band Load Identification....318
9.3 Schema Space Control....322
9.4 Memory Management....326
9.4.1 Overview....326
9.4.2 Job-Level Memory Control....328
9.5 Basic Framework for Resource Load Management....328
9.5.1 Resource Pools....328
9.5.2 Associated Jobs....337

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9.6 Priority-based Scheduling 337
9.6.1 CPU 337
9.6.2 I/O 339
9.7 Storage Space Management 341
**10 Resource Monitoring 342**
10.1 User Resource Query 342
10.2 Monitoring Memory Resources 344
10.3 Instance Resource Monitoring 345
10.4 Real-time TopSQL 347
10.5 Historical TopSQL 349
10.6 TopSQL Query Example 353
**11 Query Performance Optimization 357**
11.1 Overview of Query Performance Optimization 357
11.2 Query Analysis 357
11.2.1 Query Execution Process 357
11.2.2 Overview of the SQL Execution Plan 360
11.2.3 Deep Dive on the SQL Execution Plan 361
11.2.4 Querying SQL Statements That Affect Performance Most 367
11.2.5 Checking Blocked Statements 368
11.3 Query Improvement 369
11.3.1 Optimization Process 369
11.3.2 Updating Statistics 370
11.3.3 Reviewing and Modifying a Table Definition 371
11.3.3.1 Reviewing and Modifying a Table Definition 371
11.3.3.2 Selecting a Storage Model 372
11.3.3.3 Selecting a Distribution Mode 372
11.3.3.4 Selecting a Distribution Column 373
11.3.3.5 Using Partial Clustering 374
11.3.3.6 Using Partitioned Tables 374
11.3.3.7 Selecting a Data Type 374
11.3.4 Typical SQL Optimization Methods 375
11.3.4.1 SQL Self-Diagnosis 375
11.3.4.2 Optimizing Statement Pushdown 378
11.3.4.3 Optimizing Subqueries 385
11.3.4.4 Optimizing Statistics 393
11.3.4.5 Optimizing Operators 398
11.3.4.6 Optimizing Data Skew 400
11.3.5 Experience in Rewriting SQL Statements 406
11.3.6 Adjusting Key Parameters During SQL Tuning 407
11.3.7 Hint-based Tuning 409
11.3.7.1 Plan Hint Optimization 409
11.3.7.2 Join Order Hints 411

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11.3.7.3 Join Operation Hints ..... 413
11.3.7.4 Rows Hints ..... 414
11.3.7.5 Stream Operation Hints ..... 415
11.3.7.6 Scan Operation Hints ..... 416
11.3.7.7 Sublink Name Hints ..... 417
11.3.7.8 Skew Hints ..... 418
11.3.7.9 Configuration Parameter Hints ..... 422
11.3.7.10 Hint Errors, Conflicts, and Other Warnings ..... 423
11.3.7.11 Plan Hint Cases ..... 426
11.3.8 Routinely Maintaining Tables ..... 430
11.3.9 Routinely Recreating an Index ..... 432
11.3.10 Configuring the SMP ..... 433
11.3.10.1 Application Scenarios and Restrictions ..... 433
11.3.10.2 Resource Impact on SMP Performance ..... 434
11.3.10.3 Other Factors Affecting SMP Performance ..... 435
11.3.10.4 Suggestions for SMP Parameter Settings ..... 436
11.3.10.5 SMP Manual Optimization Suggestions ..... 436
11.4 Optimization Cases ..... 437
11.4.1 Case: Selecting an Appropriate Distribution Column ..... 437
11.4.2 Case: Creating an Appropriate Index ..... 438
11.4.3 Case: Adding NOT NULL for JOIN Columns ..... 439
11.4.4 Case: Pushing Down Sort Operations to DNs ..... 441
11.4.5 Case: Configuring cost_param for Better Query Performance ..... 442
11.4.6 Case: Adjusting the Distribution Key ..... 446
11.4.7 Case: Adjusting the Partial Clustering Key ..... 446
11.4.8 Case: Adjusting the Table Storage Mode in a Medium Table ..... 447
11.4.9 Case: Adjusting the Local Clustering Column ..... 448
11.4.10 Case: Reconstructing Partition Tables ..... 449
11.4.11 Case: Adjusting the GUC Parameter best_agg_plan ..... 450
11.4.12 Case: Rewriting SQL and Deleting Subqueries (Case 1) ..... 451
11.4.13 Case: Rewriting SQL and Deleting Subqueries (Case 2) ..... 452
11.4.14 Case: Rewriting SQL Statements and Eliminating Prune Interference ..... 453
11.4.15 Case: Rewriting SQL Statements and Deleting in-clause ..... 454
11.4.16 Case: Setting Partial Cluster Keys ..... 455
11.5 SQL Execution Troubleshooting ..... 458
11.5.1 Low Query Efficiency ..... 458
11.5.2 DROP TABLE Fails to Be Executed ..... 459
11.5.3 Different Data Is Displayed for the Same Table Queried By Multiple Users ..... 459
11.5.4 An Error Occurs During the Integer Conversion ..... 460
11.5.5 Automatic Retry upon SQL Statement Execution Errors ..... 460
11.6 Common Performance Parameter Optimization Design ..... 463
**12 User-Defined Functions ..... 468**

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12.1 PL/Java Functions....468
12.2 PL/pgSQL Functions....478
**13 Stored Procedures....479**
13.1 Stored Procedure....479
13.2 Data Types....479
13.3 Data Type Conversion....479
13.4 Arrays and Records....480
13.4.1 Arrays....481
13.4.2 record....487
13.5 Syntax....489
13.5.1 Basic Structure....489
13.5.2 Anonymous Block....490
13.5.3 Subprogram....491
13.6 Basic Statements....491
13.6.1 Variable Definition Statement....491
13.6.2 Assignment Statement....493
13.6.3 Call Statement....494
13.7 Dynamic Statements....495
13.7.1 Executing Dynamic Query Statements....495
13.7.2 Executing Dynamic Non-query Statements....497
13.7.3 Dynamically Calling Stored Procedures....498
13.7.4 Dynamically Calling Anonymous Blocks....500
13.8 Control Statements....501
13.8.1 RETURN Statements....502
13.8.1.1 RETURN....502
13.8.1.2 RETURN NEXT and RETURN QUERY....502
13.8.2 Conditional Statements....503
13.8.3 Loop Statements....505
13.8.4 Branch Statements....508
13.8.5 NULL Statements....510
13.8.6 Error Trapping Statements....510
13.8.7 GOTO Statements....512
13.9 Other Statements....514
13.9.1 Lock Operations....514
13.9.2 Cursor Operations....514
13.10 Cursors....514
13.10.1 Overview....514
13.10.2 Explicit Cursor....515
13.10.3 Implicit Cursor....519
13.10.4 Cursor Loop....520
13.11 Advanced Packages....521
13.11.1 DBMS_LOB....521

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13.11.2 DBMS_RANDOM ..... 530
13.11.3 DBMS_OUTPUT ..... 531
13.11.4 UTL_RAW ..... 533
13.11.5 DBMS_JOB ..... 535
13.11.6 DBMS_SQL ..... 542
13.12 Debugging ..... 553
**14 System Catalogs and System Views ..... 557**
14.1 Overview of System Catalogs and System Views ..... 557
14.2 System Catalogs ..... 557
14.2.1 GS_OBSSCANINFO ..... 557
14.2.2 GS_WLM_INSTANCE_HISTORY ..... 558
14.2.3 GS_WLM_OPERATOR_INFO ..... 559
14.2.4 GS_WLM_SESSION_INFO ..... 561
14.2.5 GS_WLM_USER_RESOURCE_HISTORY ..... 561
14.2.6 PG_AGGREGATE ..... 563
14.2.7 PG_AM ..... 564
14.2.8 PG_AMOP ..... 566
14.2.9 PG_AMPROC ..... 567
14.2.10 PG_ATTRDEF ..... 568
14.2.11 PG_ATTRIBUTE ..... 568
14.2.12 PG_AUTHID ..... 570
14.2.13 PG_AUTH_HISTORY ..... 572
14.2.14 PG_AUTH_MEMBERS ..... 572
14.2.15 PG_CAST ..... 573
14.2.16 PG_CLASS ..... 573
14.2.17 PG_COLLATION ..... 578
14.2.18 PG_CONSTRAINT ..... 578
14.2.19 PG_CONVERSION ..... 581
14.2.20 PG_DATABASE ..... 581
14.2.21 PG_DB_ROLE_SETTING ..... 582
14.2.22 PG_DEFAULT_ACL ..... 583
14.2.23 PG_DEPEND ..... 583
14.2.24 PG_DESCRIPTION ..... 585
14.2.25 PG_ENUM ..... 585
14.2.26 PG_EXTENSION ..... 586
14.2.27 PG_EXTENSION_DATA_SOURCE ..... 586
14.2.28 PG_FOREIGN_DATA_WRAPPER ..... 587
14.2.29 PG_FOREIGN_SERVER ..... 588
14.2.30 PG_FOREIGN_TABLE ..... 589
14.2.31 PG_INDEX ..... 589
14.2.32 PG_INHERITS ..... 591
14.2.33 PG_JOBS ..... 591

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14.2.34 PG_LANGUAGE ... 592
14.2.35 PG_LARGEOBJECT ... 593
14.2.36 PG_LARGEOBJECT_METADATA ... 594
14.2.37 PG_NAMESPACE ... 594
14.2.38 PG_OBJECT ... 595
14.2.39 PG_OBSSCANINFO ... 596
14.2.40 PG_OPCLASS ... 596
14.2.41 PG_OPERATOR ... 597
14.2.42 PG_OPFAMILY ... 598
14.2.43 PG_PARTITION ... 599
14.2.44 PG_PLTEMPLATE ... 601
14.2.45 PG_PROC ... 601
14.2.46 PG_RANGE ... 604
14.2.47 PG_REDACTION_COLUMN ... 605
14.2.48 PG_REDACTION_POLICY ... 606
14.2.49 PG_RLSPOLICY ... 606
14.2.50 PG_RESOURCE_POOL ... 607
14.2.51 PG_REWRITE ... 608
14.2.52 PG_SECLABEL ... 609
14.2.53 PG_SHDEPEND ... 609
14.2.54 PG_SHDESCRIPTION ... 611
14.2.55 PG_SHSECLABEL ... 611
14.2.56 PG_STATISTIC ... 612
14.2.57 PG_STATISTIC_EXT ... 613
14.2.58 PG_SYNONYM ... 615
14.2.59 PG_TABLESPACE ... 615
14.2.60 PG_TRIGGER ... 615
14.2.61 PG_TS_CONFIG ... 616
14.2.62 PG_TS_CONFIG_MAP ... 617
14.2.63 PG_TS_DICT ... 617
14.2.64 PG_TS_PARSER ... 618
14.2.65 PG_TS_TEMPLATE ... 619
14.2.66 PG_TYPE ... 619
14.2.67 PG_USER_MAPPING ... 623
14.2.68 PG_USER_STATUS ... 624
14.2.69 PG_WORKLOAD_ACTION ... 624
14.2.70 PGXC_CLASS ... 625
14.2.71 PGXC_GROUP ... 625
14.2.72 PGXC_NODE ... 626
14.3 System Views ... 627
14.3.1 ALL_ALL_TABLES ... 627
14.3.2 ALL_CONSTRAINTS ... 628

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14.3.3 ALL_CONS_COLUMNS 628
14.3.4 ALL_COL_COMMENTS 629
14.3.5 ALL_DEPENDENCIES 629
14.3.6 ALL_IND_COLUMNS 630
14.3.7 ALL_IND_EXPRESSIONS 630
14.3.8 ALL_INDEXES 631
14.3.9 ALL_OBJECTS 631
14.3.10 ALL_PROCEDURES 632
14.3.11 ALL_SEQUENCES 632
14.3.12 ALL_SOURCE 632
14.3.13 ALL_SYNONYMS 633
14.3.14 ALL_TAB_COLUMNS 633
14.3.15 ALL_TAB_COMMENTS 634
14.3.16 ALL_TABLES 634
14.3.17 ALL_USERS 635
14.3.18 ALL_VIEWS 635
14.3.19 DBA_DATA_FILES 636
14.3.20 DBA_USERS 636
14.3.21 DBA_COL_COMMENTS 636
14.3.22 DBA_CONSTRAINTS 637
14.3.23 DBA_CONS_COLUMNS 637
14.3.24 DBA_IND_COLUMNS 638
14.3.25 DBA_IND_EXPRESSIONS 638
14.3.26 DBA_IND_PARTITIONS 639
14.3.27 DBA_INDEXES 639
14.3.28 DBA_OBJECTS 640
14.3.29 DBA_PART_INDEXES 640
14.3.30 DBA_PART_TABLES 641
14.3.31 DBA_PROCEDURES 642
14.3.32 DBA_SEQUENCES 642
14.3.33 DBA_SOURCE 643
14.3.34 DBA_SYNONYMS 643
14.3.35 DBA_TAB_COLUMNS 643
14.3.36 DBA_TAB_COMMENTS 644
14.3.37 DBA_TAB_PARTITIONS 645
14.3.38 DBA_TABLES 645
14.3.39 DBA_TABLESPACES 646
14.3.40 DBA_TRIGGERS 646
14.3.41 DBA_VIEWS 647
14.3.42 DUAL 647
14.3.43 GLOBAL_REDO_STAT 647
14.3.44 GLOBAL_REL_IOSTAT 647

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14.3.45 GLOBAL_STAT_DATABASE 647
14.3.46 GLOBAL_WORKLOAD_SQL_COUNT 649
14.3.47 GLOBAL_WORKLOAD_SQL_ELAPSE_TIME 650
14.3.48 GLOBAL_WORKLOAD_TRANSACTION 651
14.3.49 GS_ALL_CONTROL_GROUP_INFO 652
14.3.50 GS_CLUSTER_RESOURCE_INFO 652
14.3.51 GS_INSTR_UNIQUE_SQL 653
14.3.52 GS_REL_IOSTAT 657
14.3.53 GS_NODE_STAT_RESET_TIME 657
14.3.54 GS_SESSION_CPU_STATISTICS 658
14.3.55 GS_SESSION_MEMORY_STATISTICS 658
14.3.56 GS_SQL_COUNT 659
14.3.57 GS_WAIT_EVENTS 661
14.3.58 GS_WLM_OPERAROR_INFO 662
14.3.59 GS_WLM_OPERATOR_HISTORY 663
14.3.60 GS_WLM_OPERATOR_STATISTICS 663
14.3.61 GS_WLM_SESSION_INFO 664
14.3.62 GS_WLM_SESSION_HISTORY 664
14.3.63 GS_WLM_SESSION_STATISTICS 668
14.3.64 GS_WLM_SQL_ALLOW 671
14.3.65 GS_WORKLOAD_SQL_COUNT 671
14.3.66 GS_WORKLOAD_SQL_ELAPSE_TIME 671
14.3.67 GS_WORKLOAD_TRANSACTION 673
14.3.68 GS_STAT_DB_CU 673
14.3.69 GS_STAT_SESSION_CU 673
14.3.70 GS_TOTAL_NODEGROUP_MEMORY_DETAIL 674
14.3.71 GS_USER_TRANSACTION 675
14.3.72 GS_VIEW_DEPENDENCY 675
14.3.73 GS_VIEW_DEPENDENCY_PATH 676
14.3.74 GS_VIEW_INVALID 676
14.3.75 PG_AVAILABLE_EXTENSION_VERSIONS 676
14.3.76 PG_AVAILABLE_EXTENSIONS 677
14.3.77 PG_BULKLOAD_STATISTICS 677
14.3.78 PG_COMM_CLIENT_INFO 678
14.3.79 PG_COMM_DELAY 679
14.3.80 PG_COMM_STATUS 680
14.3.81 PG_COMM_RECV_STREAM 680
14.3.82 PG_COMM_SEND_STREAM 681
14.3.83 PG_CONTROL_GROUP_CONFIG 682
14.3.84 PG_CURSORS 683
14.3.85 PG_EXT_STATS 683
14.3.86 PG_GET_INVALID_BACKENDS 685

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14.3.87 PG_GET_SENDERS_CATCHUP_TIME ..... 686
14.3.88 PG_GROUP ..... 687
14.3.89 PG_INDEXES ..... 687
14.3.90 PG_JOB ..... 687
14.3.91 PG_JOB_PROC ..... 689
14.3.92 PG_JOB_SINGLE ..... 689
14.3.93 PG_LIFECYCLE_DATA_DISTRIBUTE ..... 691
14.3.94 PG_LOCKS ..... 692
14.3.95 PG_NODE_ENV ..... 693
14.3.96 PG_OS_THREADS ..... 694
14.3.97 PG_POOLER_STATUS ..... 694
14.3.98 PG_PREPARED_STATEMENTS ..... 695
14.3.99 PG_PREPARED_XACTS ..... 696
14.3.100 PG_QUERYBAND_ACTION ..... 696
14.3.101 PG_REPLICATION_SLOTS ..... 697
14.3.102 PG_ROLES ..... 697
14.3.103 PG_RULES ..... 699
14.3.104 PG_RUNNING_XACTS ..... 699
14.3.105 PG_SECLABELS ..... 700
14.3.106 PG_SESSION_WLMSTAT ..... 700
14.3.107 PG_SESSION_IOSTAT ..... 703
14.3.108 PG_SETTINGS ..... 703
14.3.109 PG_SHADOW ..... 704
14.3.110 PG_SHARED_MEMORY_DETAIL ..... 705
14.3.111 PG_STATS ..... 706
14.3.112 PG_STAT_ACTIVITY ..... 708
14.3.113 PG_STAT_ALL_INDEXES ..... 712
14.3.114 PG_STAT_ALL_TABLES ..... 713
14.3.115 PG_STAT_BAD_BLOCK ..... 714
14.3.116 PG_STAT_BGWRITER ..... 714
14.3.117 PG_STAT_DATABASE ..... 715
14.3.118 PG_STAT_DATABASE_CONFLICTS ..... 717
14.3.119 PG_STAT_GET_MEM_MBYTES_RESERVED ..... 717
14.3.120 PG_STAT_USER_FUNCTIONS ..... 718
14.3.121 PG_STAT_USER_INDEXES ..... 718
14.3.122 PG_STAT_USER_TABLES ..... 719
14.3.123 PG_STAT_REPLICATION ..... 720
14.3.124 PG_STAT_SYS_INDEXES ..... 721
14.3.125 PG_STAT_SYS_TABLES ..... 722
14.3.126 PG_STAT_XACT_ALL_TABLES ..... 723
14.3.127 PG_STAT_XACT_SYS_TABLES ..... 724
14.3.128 PG_STAT_XACT_USER_FUNCTIONS ..... 724

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14.3.129 PG_STAT_XACT_USER_TABLES 725
14.3.130 PG_STATIO_ALL_INDEXES 725
14.3.131 PG_STATIO_ALL_SEQUENCES 726
14.3.132 PG_STATIO_ALL_TABLES 726
14.3.133 PG_STATIO_SYS_INDEXES 727
14.3.134 PG_STATIO_SYS_SEQUENCES 727
14.3.135 PG_STATIO_SYS_TABLES 728
14.3.136 PG_STATIO_USER_INDEXES 729
14.3.137 PG_STATIO_USER_SEQUENCES 729
14.3.138 PG_STATIO_USER_TABLES 729
14.3.139 PG_THREAD_WAIT_STATUS 730
14.3.140 PG_TABLES 742
14.3.141 PG_TDE_INFO 743
14.3.142 PG_TIMEZONE_ABBREVS 744
14.3.143 PG_TIMEZONE_NAMES 744
14.3.144 PG_TOTAL_MEMORY_DETAIL 745
14.3.145 PG_TOTAL_SCHEMA_INFO 747
14.3.146 PG_TOTAL_USER_RESOURCE_INFO 747
14.3.147 PG_USER 749
14.3.148 PG_USER_MAPPINGS 750
14.3.149 PG_VIEWS 751
14.3.150 PG_WLM_STATISTICS 751
14.3.151 PGXC_BULKLOAD_PROGRESS 752
14.3.152 PGXC_BULKLOAD_STATISTICS 752
14.3.153 PGXC_COMM_CLIENT_INFO 754
14.3.154 PGXC_COMM_DELAY 754
14.3.155 PGXC_COMM_RECV_STREAM 755
14.3.156 PGXC_COMM_SEND_STREAM 756
14.3.157 PGXC_COMM_STATUS 757
14.3.158 PGXC_DEADLOCK 758
14.3.159 PGXC_GET_STAT_ALL_TABLES 759
14.3.160 PGXC_GET_STAT_ALL_PARTITIONS 760
14.3.161 PGXC_GET_TABLE_SKEWNESS 761
14.3.162 PGXC_GTM_SNAPSHOT_STATUS 761
14.3.163 PGXC_INSTANCE_TIME 762
14.3.164 PGXC_INSTR_UNIQUE_SQL 762
14.3.165 PGXC_LOCK_CONFLICTS 762
14.3.166 PGXC_NODE_ENV 763
14.3.167 PGXC_NODE_STAT_RESET_TIME 764
14.3.168 PGXC_OS_RUN_INFO 764
14.3.169 PGXC_OS_THREADS 764
14.3.170 PGXC_PREPARED_XACTS 765

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14.3.171 PGXC_REDO_STAT ... 765
14.3.172 PGXC_REL_IOSTAT ... 765
14.3.173 PGXC_REPLICATION_SLOTS ... 765
14.3.174 PGXC_RUNNING_XACTS ... 765
14.3.175 PGXC_SETTINGS ... 766
14.3.176 PGXC_STAT_ACTIVITY ... 766
14.3.177 PGXC_STAT_BAD_BLOCK ... 769
14.3.178 PGXC_STAT_BGWRITER ... 769
14.3.179 PGXC_STAT_DATABASE ... 769
14.3.180 PGXC_STAT_REPLICATION ... 770
14.3.181 PGXC_SQL_COUNT ... 770
14.3.182 PGXC_THREAD_WAIT_STATUS ... 770
14.3.183 PGXC_TOTAL_MEMORY_DETAIL ... 772
14.3.184 PGXC_TOTAL_SCHEMA_INFO ... 774
14.3.185 PGXC_TOTAL_SCHEMA_INFO_ANALYZE ... 774
14.3.186 PGXC_USER_TRANSACTION ... 775
14.3.187 PGXC_VARIABLE_INFO ... 776
14.3.188 PGXC_WAIT_EVENTS ... 776
14.3.189 PGXC_WLM_OPERATOR_HISTORY ... 776
14.3.190 PGXC_WLM_OPERATOR_INFO ... 777
14.3.191 PGXC_WLM_OPERATOR_STATISTICS ... 777
14.3.192 PGXC_WLM_SESSION_INFO ... 777
14.3.193 PGXC_WLM_SESSION_HISTORY ... 777
14.3.194 PGXC_WLM_SESSION_STATISTICS ... 777
14.3.195 PGXC_WLM_WORKLOAD_RECORDS ... 777
14.3.196 PGXC_WORKLOAD_SQL_COUNT ... 778
14.3.197 PGXC_WORKLOAD_SQL_ELAPSE_TIME ... 779
14.3.198 PGXC_WORKLOAD_TRANSACTION ... 780
14.3.199 PLAN_TABLE ... 781
14.3.200 PLAN_TABLE_DATA ... 782
14.3.201 PV_FILE_STAT ... 783
14.3.202 PV_INSTANCE_TIME ... 784
14.3.203 PV_OS_RUN_INFO ... 784
14.3.204 PV_SESSION_MEMORY ... 785
14.3.205 PV_SESSION_MEMORY_DETAIL ... 785
14.3.206 PV_SESSION_STAT ... 786
14.3.207 PV_SESSION_TIME ... 786
14.3.208 PV_TOTAL_MEMORY_DETAIL ... 787
14.3.209 PV_REDO_STAT ... 789
14.3.210 REDACTION_COLUMNS ... 789
14.3.211 REDACTION_POLICIES ... 790
14.3.212 USER_COL_COMMENTS ... 791

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14.3.213 USER_CONSTRAINTS 791
14.3.214 USER_CONS_COLUMNS 792
14.3.215 USER_INDEXES 792
14.3.216 USER_IND_COLUMNS 792
14.3.217 USER_IND_EXPRESSIONS 793
14.3.218 USER_IND_PARTITIONS 793
14.3.219 USER_JOBS 794
14.3.220 USER_OBJECTS 795
14.3.221 USER_PART_INDEXES 796
14.3.222 USER_PART_TABLES 797
14.3.223 USER_PROCEDURES 797
14.3.224 USER_SEQUENCES 798
14.3.225 USER_SOURCE 798
14.3.226 USER_SYNONYMS 798
14.3.227 USER_TAB_COLUMNS 799
14.3.228 USER_TAB_COMMENTS 800
14.3.229 USER_TAB_PARTITIONS 800
14.3.230 USER_TABLES 801
14.3.231 USER_TRIGGERS 801
14.3.232 USER_VIEWS 802
14.3.233 V$SESSION 802
14.3.234 V$SESSION_LONGOPS 802
**15 GUC Parameters 804**
15.1 Viewing GUC Parameters 804
15.2 Configuring GUC Parameters 805
15.3 GUC Parameter Usage 806
15.4 Connection and Authentication 807
15.4.1 Connection Settings 807
15.4.2 Security and Authentication (postgresql.conf) 808
15.4.3 Communication Library Parameters 815
15.5 Resource Consumption 821
15.5.1 Memory 821
15.5.2 Disk Space 828
15.5.3 Kernel Resources 829
15.5.4 Cost-based Vacuum Delay 830
15.5.5 Asynchronous I/O Operations 832
15.6 Parallel Data Import 834
15.7 Write Ahead Logs 835
15.7.1 Settings 835
15.7.2 Checkpoints 839
15.7.3 Archiving 840
15.8 HA Replication 842

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15.8.1 Sending Server 842
15.8.2 Primary Server 844
15.9 Query Planning 845
15.9.1 Optimizer Method Configuration 845
15.9.2 Optimizer Cost Constants 854
15.9.3 Genetic Query Optimizer 856
15.9.4 Other Optimizer Options 858
15.10 Error Reporting and Logging 869
15.10.1 Logging Destination 869
15.10.2 Logging Time 870
15.10.3 Logging Content 874
15.11 Alarm Detection 880
15.12 Statistics During the Database Running 881
15.12.1 Query and Index Statistics Collector 881
15.12.2 Performance Statistics 886
15.13 Workload Management 887
15.14 Automatic Cleanup 899
15.15 Default Settings of Client Connection 903
15.15.1 Statement Behavior 903
15.15.2 Zone and Formatting 910
15.15.3 Other Default Parameters 914
15.16 Lock Management 915
15.17 Version and Platform Compatibility 917
15.17.1 Compatibility with Earlier Versions 917
15.17.2 Platform and Client Compatibility 920
15.18 Fault Tolerance 922
15.19 Connection Pool Parameters 923
15.20 Cluster Transaction Parameters 925
15.21 Developer Operations 929
15.22 Auditing 947
15.22.1 Audit Switch 947
15.22.2 Operation Audit 949
15.23 Transaction Monitoring 957
15.24 Miscellaneous Parameters 958
**16 Glossary 979**

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# 1 Welcome

## 1.1 Target Readers

This document is intended for database designers, application developers, and database administrators, and provides information required for designing, building, querying and maintaining data warehouses.

As a database administrator or application developer, you need to be familiar with:

- Knowledge about OSs, which is the basis for everything.
- SQL syntax, which is the necessary skill for database operation.

### Statement

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# 1.2 Reading Guide

If you are a new GaussDB(DWS) user, you are advised to read the following contents first:

- Sections describing the features, functions, and application scenarios of GaussDB(DWS).
- "Getting Started": guides you through creating a data warehouse cluster, creating a database table, uploading data, and testing queries.

If you intend to or are migrating applications from other data warehouses to GaussDB(DWS), you might want to know how GaussDB(DWS) differs from them.

You can find useful information from the following table for GaussDB(DWS) database application development.

| If you want to... | Query Suggestions |
| --- | --- |
| Quickly get started with GaussDB(DWS). | Deploy a cluster, connect to the database, and perform some queries by following the instructions provided in "Getting Started" in the *Data Warehouse Service (DWS) User Guide*.<br>When you are ready to construct a database, load data to tables and compile the query content to operate the data in the data warehouse. Then, you can return to the *Data Warehouse Service Database Developer Guide*. |
| Understand the internal architecture of a GaussDB(DWS) data warehouse. | To know more about GaussDB(DWS), go to the GaussDB(DWS) home page. |
| Learn how to design tables to achieve the excellent performance. | **Development and Design Proposal** introduces the design specifications that should be complied with during the development of database applications. Modeling compliant with these specifications fits the distributed processing architecture of GaussDB(DWS) and provides efficient SQL code.<br>To facilitate service execution through optimization, you can refer to **Query Performance Optimization**. Successful performance optimization depends more on database administrators' experience and judgment than on instructions and explanation. However, **Query Performance Optimization** still tries to systematically illustrate the performance optimization methods for application development personnel and new GaussDB(DWS) database administrators. |

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| If you want to... | Query Suggestions |
| --- | --- |
| Load data. | **Data Import** describes how to import data to GaussDB(DWS). |
| Manage users, groups, and database security. | **Database Security Management** covers database security topics. |
| Monitor and optimize system performance. | **System Catalogs and System Views** describes the system catalogs where you can query the database status and monitor the query content and process.<br>You can learn how to check the system running status and monitoring metrics on the GaussDB(DWS) console by referring to "Monitoring Clusters" in the *Data Warehouse Service (DWS) User Guide*. |

# 1.3 Conventions

## Example Conventions

| Example | Description |
| --- | --- |
| dbadmin | Indicates the user operating and maintaining GaussDB(DWS) appointed when the cluster is created. |
| 8000 | Indicates the port number used by GaussDB(DWS) to monitor connection requests from the client. |

SQL examples in this manual are developed based on the TPC-DS model. Before you execute the examples, install the TPC-DS benchmark by following the instructions on the official website **https://www.tpc.org/tpcds/**.

## SQL Syntax Text Conventions

To better understand the syntax usage, you can refer to the SQL syntax text conventions described as follows:

| Format | Description |
| --- | --- |
| Uppercase characters | Indicates that keywords must be in uppercase. |
| Lowercase characters | Indicates that parameters must be in lowercase. |
| [ ] | Indicates that the items in brackets [] are optional. |


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| Format | Description |
| --- | --- |
| ... | Indicates that preceding elements can appear repeatedly. |
| [ x \| y \| ... ] | Indicates that one item is selected from two or more options or no item is selected. |
| { x \| y \| ... } | Indicates that one item is selected from two or more options. |
| [x \| y \| ... ] [ ... ] | Indicates that multiple parameters or no parameter can be selected. If multiple parameters are selected, separate them with spaces. |
| [ x \| y \| ... ] [ ,... ] | Indicates that multiple parameters or no parameter can be selected. If multiple parameters are selected, separate them with commas (,). |
| { x \| y \| ... } [ ... ] | Indicates that at least one parameter can be selected. If multiple parameters are selected, separate them with spaces. |
| { x \| y \| ... } [ ,... ] | Indicates that at least one parameter can be selected. If multiple parameters are selected, separate them with commas (,). |

# 1.4 Prerequisites

Complete the following tasks before you perform operations described in this document:

- Create a GaussDB(DWS) cluster.
- Install an SQL client.
- Connect the SQL client to the default database of the cluster.

For details about the preceding tasks, see "Getting Started" in the *Data Warehouse Service (DWS) User Guide*.

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# 2 System Overview

## 2.1 Highly Reliable Transaction Processing

GaussDB(DWS) manages cluster transactions, the basis of HA and failovers. This ensures speedy fault recovery, guarantees the Atomicity, Consistency, Isolation, Durability (ACID) properties for transactions and after a recovery, and enables concurrent control.

**Fault Rectification**

GaussDB(DWS) provides an HA mechanism to reduce the service interruption time when a cluster is faulty. It protects key user programs to continuously provide external services, minimizing the impact of hardware, software, and human faults on services and ensuring service continuity.

- Hardware HA: Disk RAID, switch stacking, NIC bond, and uninterruptible power supply (UPS)
- Software HA: HA mechanism used for instances in the GaussDB(DWS) cluster, such as CNs, GTMs, and DNs)

**Transaction Management**

- Transaction blocks are supported. You can run **start transaction** to make the startup of a transaction block explicit.
- Single-statement transactions are supported. If you do not explicitly start a transaction, a single statement is processed as a transaction.
- Distributed transaction management and global transaction information management are supported. This includes gxid, snapshot, timestamp management, distributed transaction status management, and gxid overflow processing.
- Distributed transactions have ACID properties.
- Deadlocks are prevented in the distributed system. A transaction will be unlocked immediately after a deadlock (if any).

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# 2.2 High Query Performance

The following GaussDB(DWS) features help achieve high query performance.

## Fully Parallel Query

GaussDB(DWS) is an MPP system with the shared-nothing architecture. It consists of multiple independent logical nodes that do not share system resources, such as the CPU, memory, and storage units. In such a system architecture, service data is separately stored on numerous nodes. Data analysis tasks are executed in parallel on the nodes where data is stored. The massively parallel data processing significantly improves response speed.

In addition, GaussDB(DWS) improves data query performance by executing operators in parallel, executing commands in registers in parallel, and using LLVM to dynamically compile the logical conditions of redundancy prune.

## Hybrid Row-Column Storage

GaussDB(DWS) supports both the row and column storage models. You can choose a row- or column-store table as needed.

The hybrid row-column storage engine achieves higher data compression ratio (column storage), index performance (column storage), and point update and point query (row storage) performance.

## Data Compression in Column Storage

You can compress old, inactive data to free up space, reducing procurement and O&M costs.

In GaussDB(DWS), data can be compressed using the Delta Value Encoding, Dictionary, RLE, LZ4, and ZLIB algorithms. The system automatically selects a compression algorithm based on data characteristics. The average compression ratio is 7:1. Compressed data can be directly accessed and is transparent to services, greatly reducing the preparation time before accessing historical data.

# 2.3 Related Concepts

## Database

A database manages data objects and is isolated from other databases. While creating a database, you can specify a tablespace. If you do not specify it, database objects will be saved to the **PG_DEFAULT** by default. Objects managed by a database can be distributed to multiple tablespaces.

## Instance

In GaussDB(DWS), instances are a group of database processes running in the memory. An instance can manage one or more databases that form a cluster. A cluster is an area in the storage disk. This area is initialized during installation and

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composed of a directory. The directory, called data directory, stores all data and is created by **initdb**. Theoretically, one server can start multiple instances on different ports, but GaussDB(DWS) manages only one instance at a time. The start and stop of an instance rely on the specific data directory. For compatibility purposes, the concept of instance name may be introduced.

## Tablespaces

In GaussDB(DWS), a tablespace is a directory storing physical files of the databases the tablespace contains. Multiple tablespaces can coexist. Files are physically isolated using tablespaces and managed by a file system.

## schema

GaussDB(DWS) schemas logically separate databases. All database objects are created under certain schemas. In GaussDB(DWS), schemas and users are loosely bound. When you create a user, a schema with the same name as the user will be created automatically. You can also create a schema or specify another schema.

## User and Role

GaussDB(DWS) uses users and roles to control the access to databases. A role can be a database user or a group of database users, depending on role settings. In GaussDB(DWS), the difference between roles and users is that a role does not have the LOGIN permission by default. In GaussDB(DWS), one user can have only one role, but you can put a user's role under a parent role to grant multiple permissions to the user.

## Transaction Management

In GaussDB(DWS), transactions are managed by multi-version concurrency control (MVCC) and two-phase locking (2PL). It enables smooth data reads and writes. In GaussDB(DWS), MVCC saves historical version data together with the current tuple version. GaussDB(DWS) uses the VACUUM process instead of rollback segments to routinely delete historical version data. Unless in performance optimization, you do not need to pay attention to the VACUUM process. Transactions are automatically submitted in GaussDB(DWS).

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# 3 Data Migration

## 3.1 Data Migration to GaussDB(DWS)

GaussDB(DWS) provides flexible methods for importing data. You can import data from different sources to GaussDB(DWS). The features of each method are listed in **Table 3-1**. You can select a method as required. You are advised to use GaussDB(DWS) with Cloud Data Migration (CDM), and Data Lake Factory (DLF). CDM is used for batch data migration, and DLF orchestrates and schedules the entire ETL process and provides a visualized development environment.

NOTE

- DRS, CDM, OBS, and MRS are cloud services.
- GDS, DSC, and **gs_restore**, and **gs_dump** are internal tools.

**Table 3-1** Data migration methods

| Data Migration Mode | Supported Data Source/ Database | Description | Advantage |
| --- | --- | --- | --- |
| **Importing Data from OBS in Parallel** | TEXT, CSV, ORC, and CarbonData data file formats | You can import data in TEXT, CSV, ORC, or CarbonData format from OBS to GaussDB(DWS) for query, and can remotely read data from OBS.<br>It is recommended for GaussDB(DWS). | This method features high performance and flexible scale-out. |

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| Data Migration Mode | Supported Data Source/ Database | Description | Advantage |
| --- | --- | --- | --- |
| **Using GDS to Import Data from a Remote Server** | TEXT and CSV data file formats | You can use the GDS tool provided by GaussDB(DWS) to import data from the remote server to GaussDB(DWS) in parallel. Multiple DNs are used for the import. This method is efficient and applicable to importing a large amount of data to the database. | |
| **Importing Data from MRS to a Cluster** | • Hive<br>• Spark | You can configure a GaussDB(DWS) cluster to connect to an MRS cluster, and read data from the HDFS of MRS to GaussDB(DWS).<br>**NOTE**<br>This import method is not supported currently. | This method features high performance and flexible scale-out. |
| **Importing Data from One GaussDB(DWS) Cluster to Another** | - | Data communication between two GaussDB(DWS) clusters is supported. You can use foreign tables to access and import data across GaussDB(DWS) clusters. | This method is applicable to data synchronization between multiple GaussDB(DWS) clusters. |
| **Using the gsql Meta-Command \COPY to Import Data** | Local files | Unlike the SQL **COPY** statement, the **\copy** command can be used to read data from or write data to only local files on a gsql client. | This method is easy-to-operate and suitable for importing a small amount of data to the database. |
| **Running the COPY FROM STDIN Statement to Import Data** | Other files or databases | When you use Java to develop applications, the CopyManager interface of the JDBC driver is invoked to write data from files or other databases to GaussDB(DWS). | Data is directly written from other databases to GaussDB(DWS). Service data does not need to be stored in files. |

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| Data Migration Mode | Supported Data Source/ Database | Description | Advantage |
| --- | --- | --- | --- |
| **Using CDM to Migrate Data to GaussDB(DWS)** | • MySQL<br>• PostgreSQL<br>• Microsoft SQL Server<br>• Oracle<br>• IBM Db2<br>• SAP HANA<br>• GaussDB(DWS)<br>• Hive | CDM can migrate various types of data in batches between homogeneous and heterogeneous data sources. CDM migrates data to GaussDB(DWS) using the **COPY** statement or the GDS parallel import method. | This method supports data import from abundant data sources and is easy-to-operate. |
| **Using DSC to Migrate SQL Scripts** | Databases, NoSQL, file systems, and big data platforms | For details, see the documents of the third-party ETL tool.<br>GaussDB(DWS) provides the DSC tool to migrate Teradata/Oracle scripts to GaussDB(DWS). | This method supports abundant data sources and provides powerful data conversion through OBS. |
| **Using gs_dump and gs_dumpall to Export Metadata** | • Plaintext<br>• Custom<br>• Directory<br>• .tar | **gs_dump** exports a single database or its objects. **gs_dumpall** exports all databases or global objects in a cluster.<br>To migrate database information, you can use a tool to import the exported metadata to a target database. | This method is applicable to metadata migration. |


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| Data Migration Mode | Supported Data Source/ Database | Description | Advantage |
| --- | --- | --- | --- |
| Using gs_restore to Import Data | SQL, TMP, and TAR file formats | During database migration, you can use the gs_restore tool to import the file exported using the gs_dump tool to a GaussDB(DWS) cluster. In this way, metadata, such as table definitions and database object definitions, is imported. The following data needs to be imported:<br>• All database object definitions<br>• Definition of each database object<br>• Definition of each schema<br>• Definition of each table | |

# 3.2 Data Import

## 3.2.1 Importing Data from OBS in Parallel

### 3.2.1.1 About Parallel Data Import from OBS

The object storage service (OBS) is an object-based cloud storage service, featuring data storage of high security, proven reliability, and cost-effectiveness. OBS provides large storage capacity for you to store files of any type.

GaussDB(DWS), a data warehouse service, uses OBS as a platform for converting cluster data and external data, satisfying the requirements for secure, reliable, and cost-effective storage.

You can import data in TXT, CSV, ORC, or CarbonData format from OBS to GaussDB(DWS) for query, and can remotely read data from OBS. You are advised to import frequently accessed hot data to GaussDB(DWS) to facilitate queries and store cold data to OBS for remote read to reduce cost.

Currently, data can be imported using either of the following methods:

- Method 1: You do not need to create a server. Use the default server to create a foreign table. Data in TXT or CSV format is supported. For details, see **Importing CSV/TXT Data from the OBS**.
- Method 2: You need to create a server and use the server to create a foreign table. Data in ORC, CarbonData, TXT, or CSV format is supported. For details, see **Importing ORC/CarbonData Data from OBS**.


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**NOTICE**

- Ensure that no Chinese characters are contained in paths used for importing data to or exporting data from OBS.
- Data cannot be imported to or exported from OBS across regions. Ensure that OBS and the DWS cluster are in the same region.

## Overview

During data migration and Extract-Transform-Load (ETL), a massive volume of data needs to be imported to GaussDB(DWS) in parallel. The common import mode is time-consuming. When you import data in parallel using OBS foreign tables, source data files to be imported are identified based on the import URL and data formats specified in the tables. Data is imported in parallel through DNs to GaussDB(DWS), which improves the overall import performance.

**Advantages:**

- The CN only plans and delivers data import tasks, and the DNs execute these tasks. This reduces CN resource usage, enabling the CN to process external requests.
- In this way, the computing capabilities and bandwidths of all the DNs are fully leveraged to import data.
- You can preprocess data before the import.
- Fault tolerance can be configured for data format errors during the data import. You can locate incorrect data based on displayed error information after the data is imported.

**Disadvantage:**

You need to create OBS foreign tables and store to-be-imported data on OBS.

**Application Scenario**:

A large volume of local data is imported concurrently on many DNs.

## Related Concepts

- **Source data file**: a TEXT, CSV, ORC, or CarbonData file that stores data to be imported in parallel.
- **OBS**: a cloud storage service used to store unstructured data, such as documents, images, and videos. Data is imported in parallel from the OBS server to GaussDB(DWS).
- **Bucket**: a container storing objects on OBS.
  - Object storage is a flat storage mode. Layered file system structures are not needed because all objects in buckets are at the same logical layer.
  - In OBS, each bucket name must be unique and cannot be changed. A default access control list (ACL) is created with a bucket. Each item in the ACL contains permissions granted to certain users, such as **READ**, **WRITE**, and **FULL_CONTROL**. Only authorized users can perform bucket operations, such as creating, deleting, viewing, and setting ACLs for buckets.

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  - A user can create a maximum of 100 buckets. The total data size and the number of objects and files in each bucket are not limited.

- **Object**: a basic data storage unit in OBS. Data uploaded by users is stored in OBS buckets as objects. Object attributes include **Key**, **Metadata**, and **Data**.

  Generally, objects are managed as files. However, OBS has no file system–related concepts, such as files and folders. To let users easily manage data, OBS allows them to simulate folders. Users can add a slash (/) in the object name, for example, **tpcds1000/stock.csv**. In this name, **tpcds1000** is regarded as the folder name and **stock.csv** the file name. The value of **key** (object name) is still **tpcds1000/stock.csv**, and the content of the object is the content of the **stock.csv** file.
- **Key**: name of an object. It is a UTF-8 character sequence containing 1 to 1024 characters. A key value must be unique in a bucket. Users can name the objects they stored or obtained as *Bucket name*+*Object name*.
- **Metadata**: object metadata, which contains information about the object. There are system metadata and user metadata. The metadata is uploaded to OBS as key-value pairs together with HTTP headers.
  - System metadata is generated by OBS and used for processing object data. System metadata includes **Date**, **Content-length**, **last-modify**, and **Content-MD5**.
  - User metadata contains object descriptions specified by users for uploading objects.
- **Data**: object content. OBS does not sense the content and regards it as stateless binary data.
- **Ordinary table**: A database table that stores data imported to data files in parallel. Ordinary tables are classified into row-store tables and column-store tables.
- **Foreign table**: A foreign table is used to identify data in a source data file. The foreign table stores information, such as the location, format, encoding, and inter-data delimiter of a source data file.

## How Data Is Imported

**Figure 3-1** shows how data is imported from OBS. The CN plans and delivers data import tasks. It delivers tasks to each DN by file.

The delivery method is as follows:

In **Figure 3-1**, there are four DNs (DN0 to DN3) and OBS stores six files numbered from t1.data.0 to t1.data.5. The files are delivered as follows:

t1.data.0 -> DN0

t1.data.1 -> DN1

t1.data.2 -> DN2

t1.data.3 -> DN3

t1.data.4 -> DN0

t1.data.5 -> DN1

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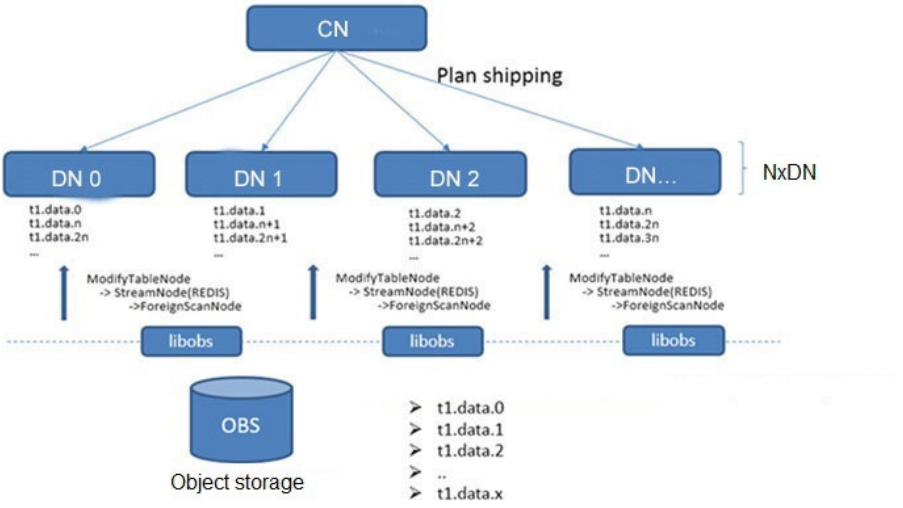
Two files are delivered to DN0 and DN1, respectively. One file is delivered to each of the other DNs.

The import performance is the best when one OBS file is delivered to each DN and all the files have the same size. To improve the performance of loading data from OBS, split the data file into multiple files as evenly as possible before storing it to OBS. The recommended number of split files is an integer multiple of the DN quantity.

**Figure 3-1** Parallel data import using OBS foreign tables

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## Import Flowchart

**Figure 3-2** Parallel import procedure

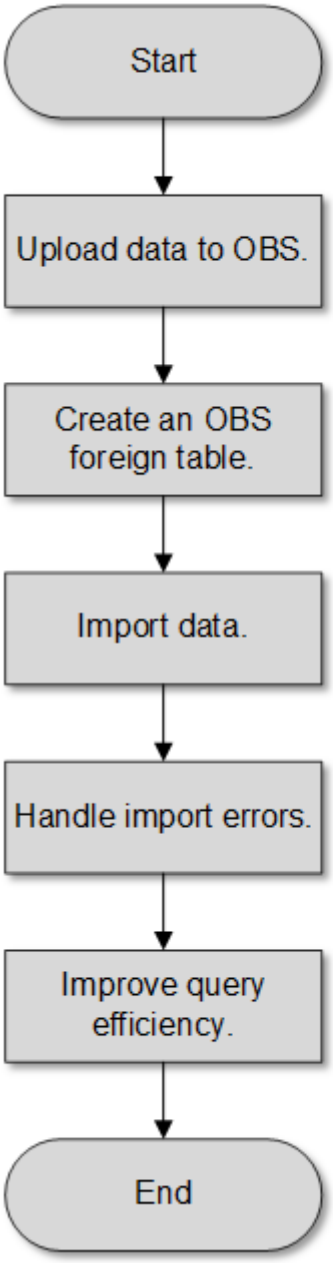


**Table 3-2** Procedure description

| Procedure | Description | Subtask |
| --- | --- | --- |
| Upload data to OBS. | Plan the storage path on the OBS server and upload data files.<br>For details, see **Uploading Data to OBS**. | - |

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| Procedure | Description | Subtask |
| --- | --- | --- |
| Create an OBS foreign table. | Create a foreign table to identify source data files on the OBS server. The OBS foreign table stores data source information, such as its bucket name, object name, file format, storage location, encoding format, and delimiter.<br>For details, see **Creating an OBS Foreign Table**. | - |
| Import data. | After creating the foreign table, run the **INSERT** statement to efficiently import data to the target tables.<br>For details, see **Importing Data**. | - |
| Handle the table with import errors. | If errors occur during data import, handle them based on the displayed error information described in **Handling Import Errors** to ensure data integrity. | - |
| Improve query efficiency. | After data is imported, run the **ANALYZE** statement to generate table statistics. The **ANALYZE** statement stores the statistics in the **PG_STATISTIC** system catalog. When you run the plan generator, the statistics help you generate an efficient query execution plan. | - |

## 3.2.1.2 Importing CSV/TXT Data from the OBS

### 3.2.1.2.1 Creating Access Keys (AK and SK)

In this example, OBS data is imported to GaussDB(DWS) databases. When users who have registered with the cloud platform access OBS using clients, call APIs, or SDKs, access keys (AK/SK) are required for user authentication. Therefore, if you want to connect to the GaussDB(DWS) database through a client or a JDBC/ODBC application to access OBS, obtain the access keys (AK and SK) first.


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- Access Key ID (AK): indicates the ID of the access key, which is a unique identifier used in conjunction with a Secret Access Key to sign requests cryptographically.
- Secret Access Key (SK): indicates the key used with its associated AK to cryptographically sign requests and identify request senders to prevent requests from being modified.

## Creating Access Keys (AK and SK)

Before creating an AK/SK pair, ensure that your account (used to log in to the management console) has passed real-name authentication.

To create an AK/SK pair on the management console, perform the following steps:

**Step 1** Log in to the GaussDB(DWS) management console.

**Step 2** Click the username in the upper right corner and choose **My Credentials** from the drop-down list.

**Step 3** Select the **Access Keys** tab.

If an access key already exists in the access key list, you can directly use it. However, you can view only **Access Key ID** in the access key list. You can download the key file containing the AK and SK only when adding an access key. If you do not have the key file, click **Create Access Key** to create one.

NOTE

- Each user can create a maximum of two valid access keys. If there are already two access keys, delete them and create one. To delete an access key, you need to enter the current login password and email address or SMS verification code. Deletion is successful only after the verification is passed.
- To ensure account security, change your access keys periodically and keep them secure.

**Step 4** Click **Add Access Key**.

**Step 5** In the displayed **Add Access Key** dialog box, enter the password and its verification code and click **OK**.

NOTE

- If you have not bound an email address or a mobile number, enter only the login password.
- If you have bound an email address and a mobile phone number, you can use either of them for verification.

**Step 6** In the displayed **Download Access Key** dialog box, click **OK** to save the access keys to your browser's default download path.

NOTE

- Keep the access keys secure to prevent them from being leaked.
- If you click **Cancel** in the dialog box, the access keys will not be downloaded, and you cannot download them later. In this case, re-create access keys.

**Step 7** Open the downloaded **credentials.csv** file to obtain the access keys (AK and SK).

**----End**

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## Precautions

If you find that your AK/SK pair is abnormally used (for example, the AK/SK pair is lost or leaked) or will be no longer used, delete your AK/SK pair in the access key list or contact the administrator to reset your AK/SK pair.

When deleting the access keys, you need to enter the login password and either an email or mobile verification code.

NOTE

Deleted AK/SK pairs cannot be restored.

### 3.2.1.2.2 Uploading Data to OBS

## Scenarios

Before importing data from OBS to a cluster, prepare source data files and upload these files to OBS. If the data files have been stored on OBS, you only need to complete **Step 2** to **Step 3** in **Uploading Data to OBS**.

## Preparing Data Files

Prepare source data files to be uploaded to OBS. GaussDB(DWS) supports only source data files in CSV, TXT, ORC, or CarbonData format.

If user data cannot be saved in CSV format, store the data as any text file.

NOTE

According to **How Data Is Imported**, when the source data file contains a large volume of data, evenly split the file into multiple files before storing it to OBS. The import performance is better when the number of files is an integer multiple of the DN quantity.

Assume that you have stored the following three CSV files in OBS:

- Data file **product_info.0**

  The file contains the following data:

  ```
  100,XHDK-A-1293-#fJ3,2017-09-01,A,2017 Autumn New Shirt Women,red,M,
  328,2017-09-04,715,good!
  205,KDKE-B-9947-#kL5,2017-09-01,A,2017 Autumn New Knitwear Women,pink,L,
  584,2017-09-05,406,very good!
  300,JODL-X-1937-#pV7,2017-09-01,A,2017 autumn new T-shirt men,red,XL,1245,2017-09-03,502,Bad.
  310,QQPX-R-3956-#aD8,2017-09-02,B,2017 autumn new jacket women,red,L,411,2017-09-05,436,It's
  really super nice.
  150,ABEF-C-1820-#mC6,2017-09-03,B,2017 Autumn New Jeans Women,blue,M,
  1223,2017-09-06,1200,The seller's packaging is exquisite.
  ```

- Data file **product_info.1**

  The file contains the following data:

  ```
  200,BCQP-E-2365-#qE4,2017-09-04,B,2017 autumn new casual pants men,black,L,
  997,2017-09-10,301,The clothes are of good quality.
  250,EABE-D-1476-#oB1,2017-09-10,A,2017 autumn new dress women,black,S,
  841,2017-09-15,299,Follow the store for a long time.
  108,CDXK-F-1527-#pL2,2017-09-11,A,2017 autumn new dress women,red,M,85,2017-09-14,22,It's
  really amazing to buy.
  450,MMCE-H-4728-#nP9,2017-09-11,A,2017 autumn new jacket women,white,M,
  114,2017-09-14,22,Open the package and the clothes have no odor.
  260,OCDA-G-2817-#bD3,2017-09-12,B,2017 autumn new woolen coat women,red,L,
  2004,2017-09-15,826,Very favorite clothes.
  ```

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- Data file **product_info.2**

  The file contains the following data:

  ```
  980,"ZKDS-J",2017-09-13,"B","2017 Women's Cotton Clothing","red","M",112,,,
  98,"FKQB-I",2017-09-15,"B","2017 new shoes men","red","M",4345,2017-09-18,5473
  50,"DMQY-K",2017-09-21,"A","2017 pants men","red","37",28,2017-09-25,58,"good","good","good"
  80,"GKLW-l",2017-09-22,"A","2017 Jeans Men","red","39",58,2017-09-25,72,"Very comfortable."
  30,"HWEC-L",2017-09-23,"A","2017 shoes women","red","M",403,2017-09-26,607,"good!"
  40,"IQPD-M",2017-09-24,"B","2017 new pants Women","red","M",35,2017-09-27,52,"very good."
  50,"LPEC-N",2017-09-25,"B","2017 dress Women","red","M",29,2017-09-28,47,"not good at all."
  60,"NQAB-O",2017-09-26,"B","2017 jacket women","red","S",69,2017-09-29,70,"It's beautiful."
  70,"HWNB-P",2017-09-27,"B","2017 jacket women","red","L",30,2017-09-30,55,"I like it so much"
  80,"JKHU-Q",2017-09-29,"C","2017 T-shirt","red","M",90,2017-10-02,82,"very good."
  ```

## Uploading Data to OBS

**Step 1** Upload data to OBS.

Store the source data files to be imported in the OBS bucket in advance.

1. Log in to the OBS management console.

   Click **Service List** and choose **Object Storage Service** to open the OBS management console.

2. Create a bucket.

   For details about how to create an OBS bucket, see "OBS Console Operation Guide > Managing Buckets > Creating a Bucket" in the *Object Storage Service User Guide*..

   For example, create two buckets named **mybucket** and **mybucket02**.

3. Create a folder.

   For details, see "OBS Console Operation Guide > Managing Objects > Creating a Folder" in the *Object Storage Service User Guide*.

   For example:

   - Create a folder named **input_data** in the **mybucket** OBS bucket.
   - Create a folder named **input_data** in the **mybucket02** OBS bucket.

4. Upload the files.

   For details, see "OBS Console Operation Guide > Managing Objects > Uploading a File" in the *Object Storage Service User Guide*..

   For example:

   - Upload the following data files to the **input_data** folder in the **mybucket** OBS bucket:

     ```
     product_info.0
     product_info.1
     ```

   - Upload the following data file to the **input_data** folder in the **mybucket02** OBS bucket:

     ```
     product_info.2
     ```

**Step 2** Obtain the OBS path for storing source data files.

After the source data files are uploaded to an OBS bucket, a globally unique access path is generated. The OBS path of the source data files is the value of the **location** parameter used for creating a foreign table.

The OBS path in the **location** parameter is in the format of **obs://***bucket_name*/*file_path*/

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For example, the OBS paths are as follows:

```
obs://mybucket/input_data/product_info.0
obs://mybucket/input_data/product_info.1
obs://mybucket02/input_data/product_info.2
```

**Step 3** Grant the OBS bucket read permission for the user who will import data.

When importing data from OBS to a cluster, the user must have the read permission for the OBS buckets where the source data files are located. You can configure the ACL for the OBS buckets to grant the read permission to a specific user.

For details, see "OBS Console Operation Guide > Permission Control > Configuring a Bucket ACL" in the *Object Storage Service User Guide*.

**----End**

### 3.2.1.2.3 Creating an OBS Foreign Table

## Procedure

**Step 1** Set **location** of the foreign table based on the path planned in **Uploading Data to OBS**.

**Step 2** Obtain the access keys (AK and SK) to access OBS. To obtain access keys, log in to the management console, click the username in the upper right corner, and select **My Credentials** from the menu. Then choose **Access Keys** in the navigation tree on the left. On the **Access Keys** page, you can view the existing AKs or click **Add Access Key** to create an AK/SK pair.

**Step 3** Set data format parameters for the foreign table based on the formats of data to be imported. You need to collect the following source data information:

- **format**: format of the source data file in the foreign table. OBS foreign tables support CSV and TEXT formats. The default value is **TEXT**.
- **header**: Whether the data file contains a table header. Only CSV files can have headers.
- **delimiter**: Delimiter specified to separate data fields in a file. If no delimiter is specified, the default one will be used.
- For more parameters used for foreign tables, see data format parameters.

**Step 4** Plan the error tolerance of parallel import to specify how errors are handled during the import.

- **fill_missing_fields**: When the last column in a row of the source data file is empty, this parameter specifies whether to report an error or set this field in the row to **NULL**.
- **ignore_extra_data**: When the number of columns in the source data file is greater than that specified in the foreign table, this parameter specifies whether to report an error or ignore the extra columns.
- **per node reject limit**: This parameter specifies the number of data format errors allowed on each DN. If the number of errors recorded in the error table on a DN exceeds the specified value, the import fails and an error message will be reported. This parameter is optional.

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- **compatible_illegal_chars**: When an illegal character is encountered, this parameter specifies whether to import an error, or convert it and proceed with the import.

  The following describes the rules for converting an invalid character:

  - **\0** is converted to a space.
  - Other invalid characters are converted to question marks (?).
  - If **NULL**, **DELIMITER**, **QUOTE**, or **ESCAPE** is also set to a space or question mark, an error message such as "illegal chars conversion may confuse COPY escape 0x20" is displayed, prompting you to modify parameter settings that may cause import errors.
- **error_table_name**: This parameter specifies the name of the table that records data format errors. After the parallel import, you can query this table for error details.
- For details about the parameters, see error tolerance parameters.

**Step 5** Create an OBS table based on the parameter settings in the preceding steps. For details about how to create a foreign table, see CREATE FOREIGN TABLE (for GDS Import and Export).

**----End**

## Example

Create a foreign table in the GaussDB(DWS) database. Parameters are described as follows:

- **Data format parameter access keys (AK and SK)**
  - Set **access_key** to the AK you have obtained.
  - Set **secret_access_key** to the SK you have obtained.

  NOTE

  The values of **access_key** and **secret_access_key** are examples only.
- **Set data format parameters.**
  - Set **format** to **CSV**.
  - Set **encoding** to **UTF-8**.
  - Configure **encrypt**. Its default value is **off**.
  - Set **delimiter** to **,**.
  - Retain the default value (double quotation marks) of **quote**.
  - Set **null** (null value in a source data file) to a null string without quotation marks.
  - Set **header** (whether the exported data file contains the header row) to the default value **false**. If the first row of the data file is not a header, retain the default value.

    NOTE

    When exporting data from OBS, this parameter cannot be set to **true**. Use the default value **false**.
- **Set fault-tolerant parameters for data import.**

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- Set **PER NODE REJECT LIMIT** to **'unlimited'**, indicating that all data format errors detected during data import are allowed.
- Set **LOG INTO** to **product_info_err**, indicating that the data format errors detected during data import are recorded in the **product_info_err** table.
- If **fill_missing_fields** is set to **true** and the last column of a data row in a source data file is lost, the column is replaced with **NULL** and no error message will be generated.
- If **ignore_extra_data** is set to **true** and the number of columns of the source data file is greater than that defined for the foreign table, the extra columns at the end of the row are ignored and no error message will be generated.

Based on the preceding settings, the foreign table is created using the following statements:

```
DROP FOREIGN TABLE product_info_ext;

CREATE FOREIGN TABLE product_info_ext
(
    product_price               integer        not null,
    product_id                  char(30)       not null,
    product_time                date           ,
    product_level               char(10)       ,
    product_name                varchar(200)   ,
    product_type1               varchar(20)    ,
    product_type2               char(10)       ,
    product_monthly_sales_cnt   integer        ,
    product_comment_time        date           ,
    product_comment_num         integer        ,
    product_comment_content     varchar(200)
)
SERVER gsmpp_server
OPTIONS(

LOCATION 'obs://mybucket/input_data/product_info | obs://mybucket02/input_data/product_info',
FORMAT 'CSV' ,
DELIMITER ',',
encoding 'utf8',
header 'false',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
fill_missing_fields 'true',
ignore_extra_data 'true'
)
READ ONLY
LOG INTO product_info_err
PER NODE REJECT LIMIT 'unlimited';
```

If the following information is displayed, the foreign table has been created:

```
CREATE FOREIGN TABLE
```

### 3.2.1.2.4 Importing Data

## Context

Before importing data, you are advised to optimize your design and deployment based on the following excellent practices, helping maximize system resource utilization and improving data import performance.

- In most cases, OBS data import performance is limited by concurrent network access rate. Therefore, you are advised to deploy multiple buckets on the OBS

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server to import data in parallel from buckets, better utilizing DN data transfer.

- Similar to the single table import, ensure that the I/O performance is greater than the maximum network throughput in the concurrent import.
- Set GUC parameters **raise_errors_if_no_files**, **partition_mem_batch**, and **partition_max_cache_size**. When importing data, specify whether to distinguish between the following two cases: no records exist in the data file or the data file does not exist. You also need to specify the number of caches and the size of data buffers.
- If a table has an index, the index information is incrementally updated during the import, affecting data import performance. You are advised to delete the index from the target table before the import. You can create index again after the import is complete.

## Procedure

**Step 1** Create a table in the GaussDB(DWS) database to store the data imported from the OBS. For details about the syntax, see CREATE TABLE.

The structure of the table must be consistent with that of the fields in the source data file. That is, the number of fields and field types must be the same. In addition, the structure of the target table must be the same as that of the foreign table. The field names can be different.

**Step 2** (Optional) If the target table has an index, the index information is incrementally updated during the import, affecting data import performance. You are advised to delete the index from the target table before the import. You can create index again after the import is complete.

**Step 3** Import data.

```
INSERT INTO [Target table name] SELECT * FROM [Foreign table name]
```

- If information similar to the following is displayed, the data has been imported. Query the error information table to check whether any data format errors occurred. For details, see **Handling Import Errors**.

  ```
  INSERT 0 20
  ```

- If data fails to be loaded, rectify the problem by following the instructions provided in **Handling Import Errors** and try again.

**----End**

## Example

For example, create a table named *product_info*.

```
DROP TABLE IF EXISTS product_info;
CREATE TABLE product_info
(
    product_price               integer       not null,
    product_id                  char(30)      not null,
    product_time                date          ,
    product_level               char(10)      ,
    product_name                varchar(200)  ,
    product_type1               varchar(20)   ,
    product_type2               char(10)      ,
    product_monthly_sales_cnt   integer       ,
    product_comment_time        date          ,
```

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```
    product_comment_num         integer       ,
    product_comment_content     varchar(200)
)
with (
orientation = column,
compression=middle
)
DISTRIBUTE BY HASH (product_id);
```

Run the following statement to import data from the *product_info*_**ext** foreign table to the *product_info* table:

```
INSERT INTO product_info SELECT * FROM product_info_ext;
```

### 3.2.1.2.5 Handling Import Errors

## Scenarios

Handle errors that occurred during data import.

## Querying Error Information

Errors that occur when data is imported are divided into data format errors and non-data format errors.

- Data format error

  When creating a foreign table, specify **LOG INTO** *error_table_name*. Data format errors occurring during the data import will be written into the specified table. You can run the following SQL statement to query error details:

  ```
  SELECT * FROM error_table_name;
  ```

  Table 3-3 lists the columns of the **error_table_name** table.

  **Table 3-3** Columns of the **error_table_name** table

| Column | Type | Description |
| --- | --- | --- |
| nodeid | integer | ID of the node where an error is reported |
| begintime | timestamp with time zone | Time when a data format error is reported |
| filename | character varying | Name of the source data file where an error about data format occurs |
| rownum | bigint | Number of the row where an error occurs in a source data file |
| rawrecord | text | Raw record of the data format error in the source data file |
| detail | text | Error details |

- Non-data format error


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A non-data format error leads to the failure of an entire data import task. You can locate and troubleshoot a non-data format error based on the error message displayed during data import.

## Handling data import errors

Troubleshoot data import errors based on obtained error information and the description in the following table.

**Table 3-4** Handling data import errors

| Error Information | Cause | Solution |
| --- | --- | --- |
| missing data for column "r_reason_desc" | 1. The number of columns in the source data file is less than that in the foreign table.<br>2. In a TEXT format source data file, an escape character (for example, \) leads to delimiter or quote mislocation. Example: The target table contains three columns as shown in the following command output. The escape character (\) converts the delimiter (\|) into the value of the second column, causing loss of the value of the third column.<br>`BE\|Belgium\\|1` | 1. If an error is reported due to missing columns, perform the following operations:<br>• Add the **r_reason_desc** column to the source data file.<br>• When creating a foreign table, set the parameter **fill_missing_fields** to **on**. In this way, if the last column of a row in the source data file is missing, it is set to **NULL** and no error will be reported.<br>2. Check whether the row where an error occurred contains the escape character (\). If the row contains such a character, you are advised to set the parameter **noescaping** to **true** when creating a foreign table, indicating that the escape character (\) and the characters following it are not escaped. |

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| Error Information | Cause | Solution |
| --- | --- | --- |
| extra data after last expected column | The number of columns in the source data file is greater than that in the foreign table. | • Delete the unnecessary columns from the source data file.<br>• When creating a foreign table, set the parameter **ignore_extra_data** to **on**. In this way, if the number of columns in a source data file is greater than that in the foreign table, the extra columns at the end of rows will not be imported. |
| invalid input syntax for type numeric: "a" | The data type is incorrect. | In the source data file, change the data type of the columns to be imported. If this error information is displayed, change the data type to **numeric**. |
| null value in column "staff_id" violates not-null constraint | The not-null constraint is violated. | In the source data file, add values to the specified columns. If this error information is displayed, add values to the **staff_id** column. |
| duplicate key value violates unique constraint "reg_id_pk" | The unique constraint is violated. | • Delete the duplicate rows from the source data file.<br>• Run the **SELECT** statement with the **DISTINCT** keyword to ensure that all imported rows are unique.<br>**INSERT INTO** reasons **SELECT DISTINCT * FROM** foreign_tpcds_reasons; |
| value too long for type character varying(16) | The column length exceeds the upper limit. | In the source data file, change the column length. If this error information is displayed, reduce the column length to no greater than 16 bytes. |

## 3.2.1.3 Importing ORC/CarbonData Data from OBS

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### 3.2.1.3.1 Preparing Data on OBS

## Scenarios

Before you use the SQL on OBS feature to query OBS data:

1. You have stored the ORC data on OBS.

   For example, the ORC table has been created when you use the Hive or Spark component, and the ORC data has been stored on OBS.

   Assume that there are two ORC data files, named **product_info.0** and **product_info.1**, whose original data is stored in the **demo.db/product_info_orc/** directory of the **mybucket** OBS bucket. You can view their original data in **Original Data**.

2. If your data files are already on OBS, perform steps in **Obtaining the OBS Path of Original Data and Setting Read Permission**.

   NOTE

   This section uses the ORC format as an example to describe how to import data. The method for importing CarbonData data is similar.

## Original Data

Assume that you have stored the two ORC data files on OBS and their original data is as follows:

- Data file **product_info.0**

  The file contains the following data:

  ```
  100,XHDK-A-1293-#fJ3,2017-09-01,A,2017 Autumn New Shirt Women,red,M,
  328,2017-09-04,715,good!
  205,KDKE-B-9947-#kL5,2017-09-01,A,2017 Autumn New Knitwear Women,pink,L,
  584,2017-09-05,406,very good!
  300,JODL-X-1937-#pV7,2017-09-01,A,2017 autumn new T-shirt men,red,XL,1245,2017-09-03,502,Bad.
  310,QQPX-R-3956-#aD8,2017-09-02,B,2017 autumn new jacket women,red,L,411,2017-09-05,436,It's
  really super nice.
  150,ABEF-C-1820-#mC6,2017-09-03,B,2017 Autumn New Jeans Women,blue,M,
  1223,2017-09-06,1200,The seller's packaging is exquisite.
  ```

- Data file **product_info.1**

  The file contains the following data:

  ```
  200,BCQP-E-2365-#qE4,2017-09-04,B,2017 autumn new casual pants men,black,L,
  997,2017-09-10,301,The clothes are of good quality.
  250,EABE-D-1476-#oB1,2017-09-10,A,2017 autumn new dress women,black,S,
  841,2017-09-15,299,Follow the store for a long time.
  108,CDXK-F-1527-#pL2,2017-09-11,A,2017 autumn new dress women,red,M,85,2017-09-14,22,It's
  really amazing to buy.
  450,MMCE-H-4728-#nP9,2017-09-11,A,2017 autumn new jacket women,white,M,
  114,2017-09-14,22,Open the package and the clothes have no odor.
  260,OCDA-G-2817-#bD3,2017-09-12,B,2017 autumn new woolen coat women,red,L,
  2004,2017-09-15,826,Very favorite clothes.
  ```

## Obtaining the OBS Path of Original Data and Setting Read Permission

**Step 1** Log in to the OBS management console.

Click **Service List** and choose **Object Storage Service** to open the OBS management console.

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**Step 2** Obtain the OBS path for storing source data files.

After the source data files are uploaded to an OBS bucket, a globally unique access path is generated. You need to specify the OBS paths of source data files when creating a foreign table.

For details about how to view an OBS path, see "OBS Console Operation Guide > Managing Objects > Accessing an Object Using Its Object URL" in the *Object Storage Service User Guide*.

For example, the OBS paths are as follows:

```
https://obs.xxx.com/mybucket/demo.db/product_info_orc/product_info.0
https://obs.xxx.com/mybucket/demo.db/product_info_orc/product_info.1
```

**Step 3** Grant the OBS bucket read permission for the user.

The user who executes the SQL on OBS function needs to obtain the read permission on the OBS bucket where the source data file is located. You can configure the ACL for the OBS buckets to grant the read permission to a specific user.

For details, see "OBS Console Operation Guide > Permission Control > Configuring a Bucket ACL" in the *Object Storage Service User Guide*.

**----End**

#### 3.2.1.3.2 Creating a Foreign Server

This section describes how to create a foreign server that is used to define the information about OBS servers and is invoked by foreign tables. For details about the syntax for creating foreign servers, see CREATE SERVER.

## (Optional) Creating a User and a Database and Granting the User Foreign Table Permissions

Common users do not have permissions to create foreign servers and tables. If you want to use a common user to create foreign servers and tables in a customized database, perform the following steps to create a user and a database, and grant the user foreign table permissions.

In the following example, a common user **dbuser** and a database **mydatabase** are created. Then, an administrator is used to grant foreign table permissions to user **dbuser**.

**Step 1** Connect to the default database **gaussdb** as a database administrator through the database client tool provided by GaussDB(DWS).

For example, use the gsql client to connect to the database by running the following command:

```
gsql -d gaussdb -h 192.168.2.30 -U dbadmin -p 8000 -W password -r
```

**Step 2** Create a common user and use it to create a database.

Create a user named **dbuser** that has the permission to create databases.

```
CREATE USER dbuser WITH CREATEDB PASSWORD 'password';
```

Switch to the created user.

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```
SET ROLE dbuser PASSWORD 'password';
```

Run the following command to create the database demo:

```
CREATE DATABASE mydatabase;
```

Query the database.

```
SELECT * FROM pg_database;
```

The database is successfully created if the returned result contains information about **mydatabase**.

```
datname   | datdba | encoding | datcollate | datctype | datistemplate | datallowconn | datconnlimit |
datlastsysoid | datfrozenxid | dattablespace | datcompatibility |                  datacl

------------+---------+----------+------------+----------+---------------+--------------+--------------
+--------------+---------------+------------------+-------------------------------------
--------------
 template1  |     10 |        0 | C          | C        | t             | t            |           -1 |        14146 |        1351
|          1663 | ORA             | {=c/Ruby,Ruby=CTc/Ruby}
 template0  |     10 |        0 | C          | C        | t             | f            |           -1 |        14146 |        1350
|          1663 | ORA             | {=c/Ruby,Ruby=CTc/Ruby}
 gaussdb    |     10 |        0 | C          | C        | f             | t            |           -1 |        14146 |        1352 |
1663 | ORA             | {=Tc/Ruby,Ruby=CTc/Ruby,chaojun=C/Ruby,hu
obinru=C/Ruby}
 mydatabase |  17000 |        0 | C          | C        | f             | t            |           -1 |        14146 |        1351
|          1663 | ORA             |
(4 rows)
```

**Step 3** Grant the permissions for creating foreign servers and using foreign tables to a common user as the administrator.

Connect to the new database as a database administrator through the database client tool provided by GaussDB(DWS).

You can use the gsql client to run the following command to switch to an administrator user and connect to the new database:

```
\c mydatabase dbadmin;
```

Enter the password of the system administrator as prompted.

**NOTE**

Note that you must use the administrator account to connect to the database where a foreign server is to be created and foreign tables are used; and then grant permissions to the common user.

By default, only system administrators can create foreign servers. Common users can create foreign servers only after being authorized. Run the following command to grant the permission:

```
GRANT ALL ON SCHEMA public TO dbuser;
GRANT ALL ON FOREIGN DATA WRAPPER dfs_fdw TO dbuser;
```

where *fdw_name* can be **hdfs_fdw** or **dfs_fdw**, and **dbuser** is the name of the user who creates SERVER.

Run the following command to grant the user the permission to use foreign tables:

```
ALTER USER dbuser USEFT;
```

Query for the user.

```
SELECT r.rolname, r.rolsuper, r.rolinherit,
  r.rolcreaterole, r.rolcreatedb, r.rolcanlogin,
```

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```
  r.rolconnlimit, r.rolvalidbegin, r.rolvaliduntil,
  ARRAY(SELECT b.rolname
        FROM pg_catalog.pg_auth_members m
        JOIN pg_catalog.pg_roles b ON (m.roleid = b.oid)
        WHERE m.member = r.oid) as memberof
, r.rolreplication
, r.rolauditadmin
, r.rolsystemadmin
, r.roluseft
FROM pg_catalog.pg_roles r
ORDER BY 1;
```

The authorization is successful if the **dbuser** information in the returned result contains the UseFT permission.

```
rolname  | rolsuper | rolinherit | rolcreaterole | rolcreatedb | rolcanlogin | rolconnlimit | rolvalidbegin |
rolvaliduntil | memberof | rolreplication | rolauditadmin | rolsystemadmin | roluseft
----------+----------+------------+---------------+-------------+-------------+--------------+---------------
+---------------+----------+----------------+---------------+----------------+----------
 dbuser   | f        | t          | f             | t           | t           |           -1 |               |               | {}       | f
| f             | f             | t
 lily     | f        | t          | f             | f           | t           |           -1 |               |               | {}       | f             |
f             | f             | f
 Ruby     | t        | t          | t             | t           | t           |           -1 |               |               | {}       | t
| t             | t             | t
```

**----End**

## Creating a Foreign Server

**Step 1** Use the user who is about to create a foreign server to connect to the corresponding database.

In this example, use common user **dbuser** created in **(Optional) Creating a User and a Database and Granting the User Foreign Table Permissions** to connect to **mydatabase** created by the user. You need to connect to the database through the database client tool provided by GaussDB(DWS).

You can use the **gsql** client to log in to the database in either of the following ways:

- If you have logged in to the gsql client, run the following command to switch the database and user:
  ```
  \c mydatabase dbuser;
  ```
  Enter the password as prompted.
- If you have not logged in to the gsql client or have exited the gsql client by running the **\q** command, run the following command to reconnect to it:
  ```
  gsql -d mydatabase -h 192.168.2.30 -U dbuser -p 8000 -r
  ```
  Enter the password as prompted.

**Step 2** Create a foreign server.

For details about the syntax for creating foreign servers, see CREATE SERVER.

For example, run the following command to create a foreign server named **obs_server**.

```
CREATE SERVER obs_server FOREIGN DATA WRAPPER dfs_fdw
OPTIONS (
  address 'obs.xxx.com' ,
  ACCESS_KEY 'access_key_value_to_be_replaced',
  SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
  encrypt 'on',
```

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```
 type 'obs'
);
```

Mandatory parameters are described as follows:

- *Name of the foreign server*

  You can customize a name.

  In this example, the name is set to **obs_server**.

- **FOREIGN DATA WRAPPER**

  *fdw_name* can be **hdfs_fdw** or **dfs_fdw**, which already exists in the database.

- **OPTIONS parameters**
  - **address**

    Specifies the endpoint of the OBS service.

    Obtain the address as follows:

    i. Obtain the OBS path by performing 2 in **Preparing Data on OBS**.

    ii. The OBS endpoint viewed on the OBS is **obs.*xxx*.myhuaweicloud.com**.

  - (Mandatory) **Access keys (AK and SK)**

    GaussDB(DWS) needs to use the access keys (AK and SK) to access OBS. Therefore, you must obtain the access keys first.

    - (Mandatory) **access_key**: specifies users' AK information.
    - (Mandatory) **secret_access_key**: specifies users' SK information.

    For details about how to obtain the access keys, see **Creating Access Keys (AK and SK)**.

  - **type**

    Its value is **obs**, which indicates that **dfs_fdw** connects to OBS.

**Step 3** View the foreign server.

```
SELECT * FROM pg_foreign_server WHERE srvname='obs_server';
```

The server is successfully created if the returned result is as follows:

```
 srvname   | srvowner | srvfdw | srvtype | srvversion | srvacl
|                                                
```

## Creating a Foreign Table

The syntax for creating a foreign table is as follows. For details, see the syntax **CREATE FOREIGN TABLE (SQL on Hadoop or OBS)**.

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name
( [ { column_name type_name
   [ { [CONSTRAINT constraint_name] NULL |
   [CONSTRAINT constraint_name] NOT NULL |
     column_constraint [...]} ] |
     table_constraint [, ...]} [, ...] ] )
   SERVER dfs_server
   OPTIONS ( { option_name ' value ' } [, ...] )
   DISTRIBUTE BY {ROUNDROBIN | REPLICATION}
   [ PARTITION BY ( column_name ) [ AUTOMAPPED ] ] ;
```

For example, when creating a foreign table named *product_info_ext_obs*, set parameters in the syntax as follows:

- **table_name**

  Specifies the name of the foreign table to be created.

- **Table column definitions**
  - **column_name**: specifies the name of a column in the foreign table.
  - **type_name**: specifies the data type of the column.

  Multiple columns are separate by commas (,).

  The number of fields and field types in the foreign table must be the same as those in the data stored on OBS.

- **SERVER dfs_server**

  This parameter specifies the foreign server name of the foreign table. This server must exist. The foreign server connects to OBS to read data by setting its foreign server.

  Enter the name of the foreign server created by following steps in **Creating a Foreign Server**.

- **OPTIONS parameters**

  These are parameters associated with the foreign table. The key parameters are as follows:
  - **format**: indicates the file format on OBS. The ORC and CarbonData formats are supported.
  - **foldername**: This parameter is mandatory. It indicates the OBS path of the data source file. You only need to enter */Bucket name/Folder directory level/*.

    You can perform **2** in **Preparing Data on OBS** to obtain the complete OBS path of the data source file. The path is the endpoint of the OBS service.
  - **totalrows**: This parameter is optional. It does not indicate the total rows of the imported data. Because OBS may store many files, it is slow to analyze data. This parameter allows you to set an estimated value so that the optimizer can estimate the table size according to the value. Generally, query efficiency is relatively high when the estimated value is almost the same as the actual value.
  - **encoding**: encoding of data source files in foreign tables. The default value is **utf8**. This parameter is mandatory for OBS foreign tables.

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- **DISTRIBUTE BY**:

  This clause is mandatory. Currently, OBS foreign tables support only the **ROUNDROBIN** distribution mode.

  It indicates that when a foreign table reads data from the data source, each node in the GaussDB(DWS) cluster randomly reads some data and integrates the random data to a complete data set.

- **Other parameters in the syntax**

  Other parameters are optional. You can set them as required. In this example, you do not need to set these parameters.

Based on the preceding settings, the command for creating the foreign table is as follows:

```
DROP FOREIGN TABLE IF EXISTS product_info_ext_obs;

-- Create an OBS foreign table that does not contain partition columns. The foreign server associated with the table is obs_server, the file format on OBS corresponding to the table is ORC, and the data storage path on OBS is/mybucket/data/.

CREATE FOREIGN TABLE product_info_ext_obs
(
    product_price                integer        not null,
    product_id                   char(30)       not null,
    product_time                 date           ,
    product_level                char(10)       ,
    product_name                 varchar(200)   ,
    product_type1                varchar(20)    ,
    product_type2                char(10)       ,
    product_monthly_sales_cnt    integer        ,
    product_comment_time         date           ,
    product_comment_num          integer        ,
    product_comment_content      varchar(200)
) SERVER obs_server
OPTIONS (
format 'orc',
foldername '/mybucket/demo.db/product_info_orc/',
encoding 'utf8',
totalrows '10'
)
DISTRIBUTE BY ROUNDROBIN;
```

### 3.2.1.3.4 Querying Data on OBS Through Foreign Tables

## Viewing Data on OBS by Directly Querying the Foreign Table

If the data amount is small, you can directly run **SELECT** to query the foreign table and view the data on OBS.

**Step 1** Run the following command to query data from the foreign table:

```
SELECT * FROM product_info_ext_obs;
```

If the query result is the same as the data in **Original Data**, the import is successful. The following information is displayed at the end of the query result:

```
(10 rows)
```

After data is queried, you can insert the data to common tables in the database.

**----End**

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## Querying Data After Importing It

**Step 1** Create a table in GaussDB(DWS) to store imported data.

The target table structure must be the same as the structure of the foreign table created in **Creating a Foreign Table**. That is, both tables must have the same number of columns and column types.

For example, create a table named *product_info*. The table example is as follows:

```
DROP TABLE IF EXISTS product_info;

CREATE TABLE product_info
(
    product_price               integer        not null,
    product_id                  char(30)       not null,
    product_time                date           ,
    product_level               char(10)       ,
    product_name                varchar(200)   ,
    product_type1               varchar(20)    ,
    product_type2               char(10)       ,
    product_monthly_sales_cnt   integer        ,
    product_comment_time        date           ,
    product_comment_num         integer        ,
    product_comment_content     varchar(200)
)
with (
orientation = column,
compression=middle
)
DISTRIBUTE BY HASH (product_id);
```

**Step 2** Run the **INSERT INTO.. SELECT ..** command to import data from the foreign table to the target table.

Example:

```
INSERT INTO product_info SELECT * FROM product_info_ext_obs;
```

If information similar to the following is displayed, the data has been imported.

```
INSERT 0 10
```

**Step 3** Run the following **SELECT** command to view data imported from OBS to GaussDB(DWS):

```
SELECT * FROM product_info;
```

If the query result is the same as the data in **Original Data**, the import is successful. The following information is displayed at the end of the query result:

```
(10 rows)
```

**----End**

### 3.2.1.3.5 Deleting Resources

After completing operations in this tutorial, if you no longer need to use the resources created during the operations, you can delete them to avoid resource waste or quota occupation. The procedure is as follows:

1. **Deleting the Foreign Table and Target Table**
2. **Deleting the Created Foreign Server**
3. **Deleting the Database and the User to Which the Database Belongs**

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If you have performed steps in **(Optional) Creating a User and a Database and Granting the User Foreign Table Permissions**, delete the database and the user to which the database belongs.

## Deleting the Foreign Table and Target Table

**Step 1** (Optional) If you have performed steps in **Querying Data After Importing It**, run the following command to delete the target table:

```
DROP TABLE product_info;
```

If the following information is displayed, the table has been deleted.

```
DROP TABLE
```

**Step 2** Run the following statement to delete the foreign table:

```
DROP FOREIGN TABLE product_info_ext_obs;
```

If the following information is displayed, the table has been deleted.

```
DROP FOREIGN TABLE
```

**----End**

## Deleting the Created Foreign Server

**Step 1** Use the user who created the foreign server to connect to the database where the foreign server is located.

In this example, common user **dbuser** is used to create the foreign server in **mydatabase**. You need to connect to the database through the database client tool provided by GaussDB(DWS). You can use the gsql client to log in to the database in either of the following ways:

- If you have logged in to the gsql client, run the following command to switch the database and user:

  ```
  \c mydatabase dbuser;
  ```

  Enter the password as prompted.
- If you have logged in to the gsql client, you can run the **\q** command to exit gsql, and run the following command to reconnect to it:

  ```
  gsql -d mydatabase -h 192.168.2.30 -U dbuser -p 8000 -r
  ```

  Enter the password as prompted.

**Step 2** Delete the created foreign server.

Run the following command to delete the server. For details about the syntax, see DROP SERVER.

```
DROP SERVER obs_server;
```

The database is deleted if the following information is displayed:

```
DROP SERVER
```

View the foreign server.

```
SELECT * FROM pg_foreign_server WHERE srvname='obs_server';
```

The server is successfully deleted if the returned result is as follows:

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```
 srvname | srvowner | srvfdw | srvtype | srvversion | srvacl | srvoptions
---------+----------+--------+---------+------------+--------+------------
(0 rows)
```

**----End**

## Deleting the Database and the User to Which the Database Belongs

If you have performed steps in **(Optional) Creating a User and a Database and Granting the User Foreign Table Permissions**, perform the following steps to delete the database and the user to which the database belongs.

**Step 1** Delete the customized database.

Connect to the default database **gaussdb** through the database client tool provided by GaussDB(DWS).

If you have logged in to the database using the gsql client, run the following command to switch the database and user:

Switch to the default database.

```
\c gaussdb
```

Enter your password as prompted.

Run the following command to delete the customized database:

```
DROP DATABASE mydatabase;
```

The database is deleted if the following information is displayed:

```
DROP DATABASE
```

**Step 2** Delete the common user created in this example as the administrator.

Connect to the database as a database administrator through the database client tool provided by GaussDB(DWS).

If you have logged in to the database using the **gsql** client, run the following command to switch the database and user:

```
\c gaussdb dbadmin
```

Run the following command to reclaim the permission for creating foreign servers:

```
REVOKE ALL ON FOREIGN DATA WRAPPER dfs_fdw FROM dbuser;
```

The name of **FOREIGN DATA WRAPPER** must be **dfs_fdw**. **dbuser** is the username for creating **SERVER**.

Run the following command to delete the user:

```
DROP USER dbuser;
```

You can run the **\du** command to query for the user and check whether the user has been deleted.

**----End**

### 3.2.1.3.6 Supported Data Types

In the big data field, the mainstream file format is ORC, which is supported by GaussDB(DWS). You can use Hive to export data to an ORC file and use a read-

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only foreign table to query and analyze the data in the ORC file. Therefore, you need to map the data types supported by the ORC file format with the data types supported by GaussDB(DWS). For details, see **Table 3-5**. Similarly, GaussDB(DWS) exports data through a write-only foreign table, and stores the data in the ORC format. Using Hive to read the ORC file content also requires matched data types. **Table 3-6** shows the matching relationship.

**Table 3-5** Mapping between ORC read-only foreign tables and Hive data types

| Type | Type Supported by GaussDB(DWS) Foreign Tables | Hive Table Type |
| --- | --- | --- |
| 1-byte integer | TINYINT (not recommended) | TINYINT |
| | SMALLINT (recommended) | TINYINT |
| 2-byte integer | SMALLINT | SMALLINT |
| 4-byte integer | INTEGER | INT |
| 8-byte integer | BIGINT | BIGINT |
| Single-precision floating point number | FLOAT4 (REAL) | FLOAT |
| Double-precision floating point number | FLOAT8(DOUBLE PRECISION) | DOUBLE |
| Scientific data type | DECIMAL[p (,s)] (The maximum precision can reach up to 38.) | DECIMAL (The maximum precision can reach up to 38.) (HIVE 0.11) |
| Date type | DATE | DATE |
| Time type | TIMESTAMP | TIMESTAMP |
| Boolean type | BOOLEAN | BOOLEAN |
| CHAR type | CHAR(n) | CHAR (n) |
| VARCHAR type | VARCHAR(n) | VARCHAR (n) |
| String (large text object) | TEXT(CLOB) | STRING |


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**Table 3-6** Mapping between ORC write-only foreign tables and Hive data types

| Type | Type Supported by GaussDB(DWS) Internal Tables (Data Source Table) | Type Supported by GaussDB(DWS) Write-only Foreign Tables | Hive Table Type |
| --- | --- | --- | --- |
| 1-byte integer | TINYINT | TINYINT (not recommended) | SMALLINT |
| | | SMALLINT (recommended) | SMALLINT |
| 2-byte integer | SMALLINT | SMALLINT | SMALLINT |
| 4-byte integer | INTEGER, BINARY_INTEGER | INTEGER | INT |
| 8-byte integer | BIGINT | BIGINT | BIGINT |
| Single-precision floating point number | FLOAT4, REAL | FLOAT4, REAL | FLOAT |
| Double-precision floating point number | DOUBLE PRECISION, FLOAT8, BINARY_DOUBLE | DOUBLE PRECISION, FLOAT8, BINARY_DOUBLE | DOUBLE |
| Scientific data type | DECIMAL, NUMERIC | DECIMAL[p (,s)] (The maximum precision can reach up to 38.) | *precision* ≤ **38**: DECIMAL; *precision* > **38**: STRING |
| Date type | DATE | TIMESTAMP[(p)] [WITHOUT TIME ZONE] | TIMESTAMP |
| Time type | TIME [(p)] [WITHOUT TIME ZONE], TIME [(p)] [WITH TIME ZONE] | TEXT | STRING |

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| Type | Type Supported by GaussDB(DWS) Internal Tables (Data Source Table) | Type Supported by GaussDB(DWS) Write-only Foreign Tables | Hive Table Type |
| --- | --- | --- | --- |
| | TIMESTAMP[(p)] [WITHOUT TIME ZONE], TIMESTAMP[(p)][WITH TIME ZONE], SMALLDATETIME | TIMESTAMP[(p)] [WITHOUT TIME ZONE] | TIMESTAMP |
| | INTERVAL DAY (l) TO SECOND (p), INTERVAL [FIELDS] [(p)] | VARCHAR(n) | VARCHAR(n) |
| Boolean type | BOOLEAN | BOOLEAN | BOOLEAN |
| CHAR type | CHAR(n), CHARACTER(n), NCHAR(n) | CHAR(n), CHARACTER(n), NCHAR(n) | *n* ≤ **255**: CHAR(n); *n* > **255**: STRING |
| VARCHAR type | VARCHAR(n), CHARACTER VARYING(n), VARCHAR2(n) | VARCHAR(n) | *n* ≤ **65535**: VARCHAR(n); *n* > **65535**: STRING |
| | NVARCHAR2(n) | TEXT | STRING |
| String (large text object) | TEXT, CLOB | TEXT, CLOB | STRING |
| Monetary type | MONEY | NUMERIC | BIGINT |


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NOTICE

1. The GaussDB(DWS) foreign table supports the NULL definition, and the Hive data table supports and uses the corresponding NULL definition.
2. The value range of TINYINT in the Hive data table is [-128, 127], and the value range of TINYINT in GaussDB(DWS) is [0, 255]. You are advised to use the SMALLINT type when creating the GaussDB(DWS) read-only foreign table for TINYINT in the Hive table. If TINYINT is used, the read value may be different from the actual value. Similarly, when exporting data of the TINYINT type from GaussDB(DWS), you are advised to use the SMALLINT type for write-only foreign tables and Hive tables.
3. The time zone definition is not supported by the date and time types of the GaussDB(DWS) foreign table, or by the Hive table.
4. The date type in Hive contains only date. The date type in GaussDB(DWS) contains date and time.
5. In GaussDB(DWS), ORC files can be compressed in ZLIB, SNAPPY, LZ4, or NONE mode.
6. The FLOAT4 format itself is not accurate, and the sum operation results vary with environments. You are advised to use the DECIMAL type in high-precision scenarios.
7. In Teradata-compatible mode, foreign tables do not support the DATE type.

## 3.2.2 Using GDS to Import Data from a Remote Server

### 3.2.2.1 Importing Data In Parallel Using GDS

**INSERT** and **COPY** statements are serially executed to import a small volume of data. To import a large volume of data to GaussDB(DWS), you can use GDS to import data in parallel using a foreign table.

In the current GDS version, you can import data to databases from pipe files.

- If the local disk space of the GDS user is insufficient:
  - Data in HDFS can be directly written to a pipe file without occupying extra disk space.
- If you need to cleanse data before importing data:
  - You can compile a program as needed and write the data to be processed into a pipe file.

  NOTE

  - The current version does not support data import through GDS in SSL mode. Do not use GDS in SSL mode.
  - All pipe files mentioned in this section refer to named pipes on Linux.

### Overview

You can import data in parallel from the common file system (excluding HDFS) of a server to GaussDB(DWS).

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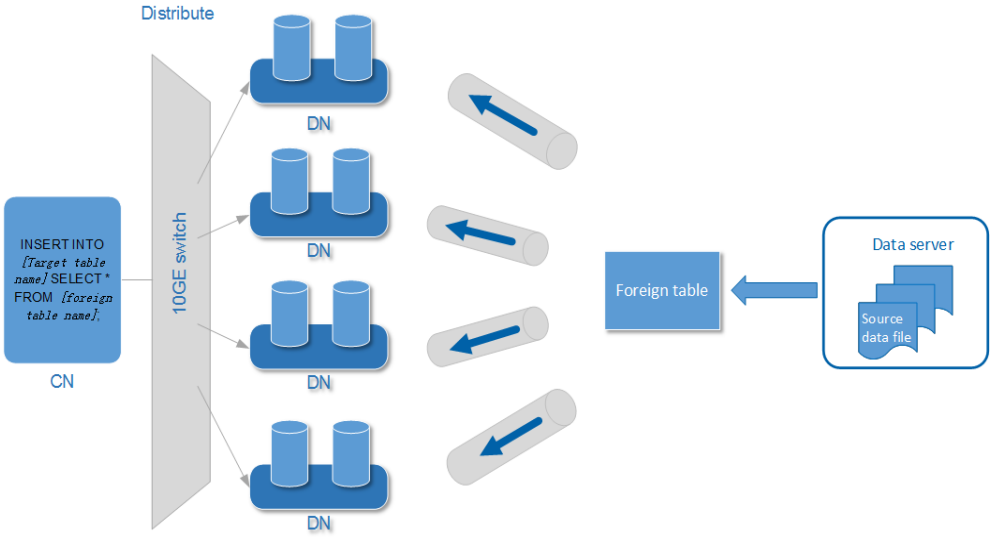
Data files to be imported are specified based on the import policy and data formats set in a foreign table. Data is imported in parallel through multiple DNs from source data files to the database, which improves the overall data import performance. **Figure 3-3** shows an example.

- The CN only plans data import tasks and delivers the tasks to DNs. Then the CN is released to process other tasks.
- In this way, the computing capability and bandwidth of all the DNs are fully leveraged to improve the data import performance.

You can pre-process data, such as replacing invalid characters and processing fault tolerance, by configuring parameters in a foreign table.

**Figure 3-3** Importing data in parallel




The concepts mentioned in the preceding figure are described as follows:

- **CN**: Coordinator of GaussDB(DWS). After receiving import SQL requests from an application or client, the CN plans import tasks and delivers the tasks to DNs.
- **DN**: Datanode of GaussDB(DWS). After receiving the import tasks delivered by the CN, DNs import data from the source data file to the target table in the database using a foreign table.
- **Source data file**: a file that stores data to be imported.
- **Data server**: a server that stores source data files. For security purposes, it is recommended that the data server and GaussDB(DWS) be on the same intranet.
- **Foreign table**: a table that stores information of a source data file, such as location, format, destination location, encoding format, and data delimiter. It is used to associate source data files with the target table.
- **Target table**: a table in the database. It can be a row-store table or column-store table. Data in the source data files will be imported to this table.

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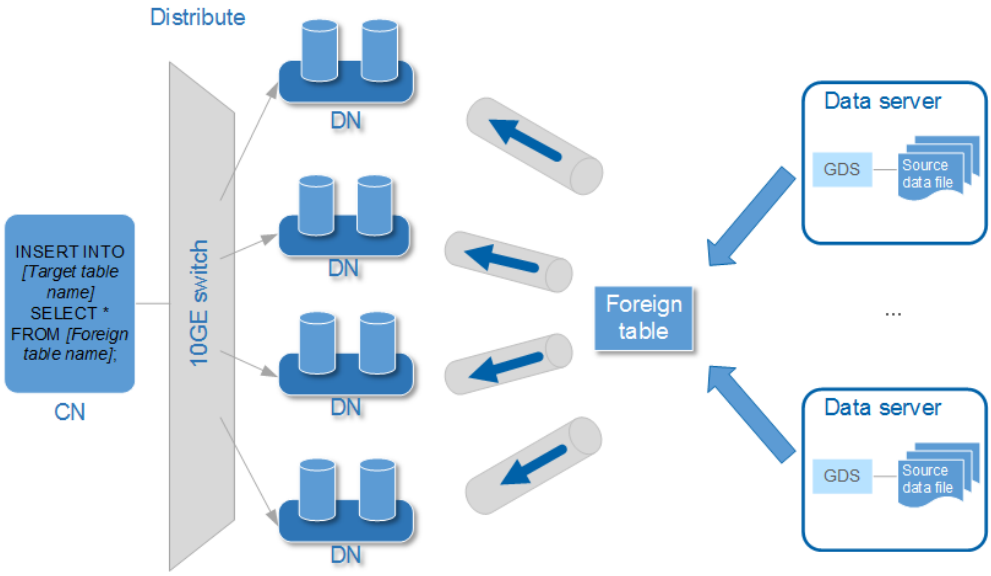
## Parallel Import Using GDS

- If a large volume of data is stored on multiple servers, install, configure, and start GDS on each server. Then, data on all the servers can be imported in parallel, as shown in **Figure 3-4**.

  **Figure 3-4** Parallel import from multiple data servers

  **NOTICE**

  The number of GDS processes cannot exceed that of DNs. If multiple GDS processes are connected to one DN, some of the processes may become abnormal.

- If data is stored on one data server and both GaussDB(DWS) and the data server have available I/O resources, you can use GDS for multi-thread concurrent import.

  GDS determines the number of threads based on the number of concurrent import transactions. That is, even if multi-thread import is configured before GDS startup, the import of a single transaction will not be accelerated. By default, an **INSERT** statement is an import transaction.

  Multi-thread concurrent import enables you to:

  - Fully use resources and improve the concurrent import efficiency when you import multiple tables to the database.
  - Speed up the import of a table with a large volume of data.

    Table data is split into multiple data files, and multi-thread concurrent import is implemented by importing data using multiple foreign tables at the same time. Ensure that a data file can be read only by one foreign table.

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## Import Process

**Figure 3-5** Concurrent import process using GDS

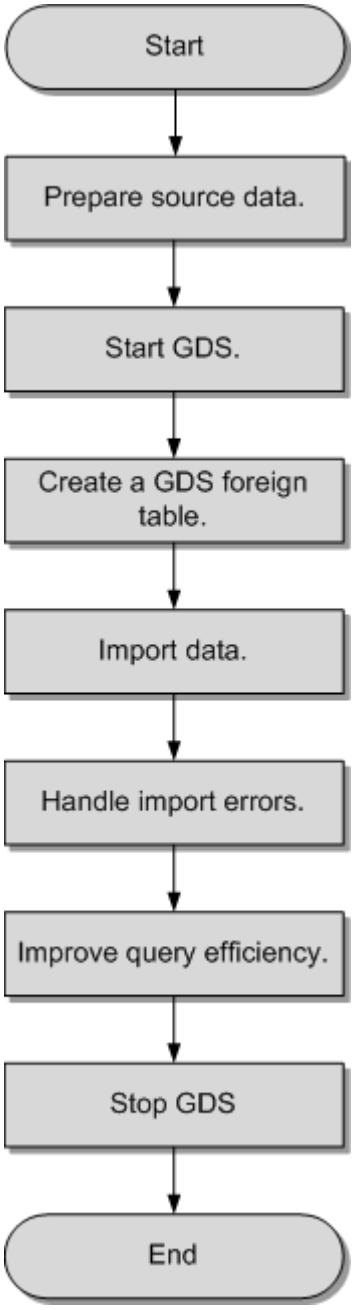


**Table 3-7** Process description

| Process | Description |
| --- | --- |
| Prepare source data. | Prepare the source data files to be imported to the database and upload the files to the data server.<br>For details, see **Preparing Source Data**. |


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| Process | Description |
| --- | --- |
| Start GDS. | Install, configure, and start GDS on the data server.<br>For details, see **Installing, Configuring, and Starting GDS**. |
| Create a foreign table. | A foreign table is used to identify source files. The foreign table stores information of a source data file, such as location, format, destination location, encoding format, and data delimiter.<br>For details, see **Creating a GDS Foreign Table**. |
| Import data. | After creating the foreign table, run the **INSERT** statement to quickly import data to the target table. For details, see **Importing Data**. |
| Handle import errors. | If errors occur during parallel data import, handle errors based on the error information to ensure data integrity.<br>For details, see **Handling Import Errors**. |
| Improve query efficiency. | After data is imported, run the **ANALYZE** statement to generate table statistics. The **ANALYZE** statement stores the statistics in the **PG_STATISTIC** system catalog. When you run the plan generator, the statistics help you generate an efficient query execution plan. |
| Stop GDS. | After data is imported, log in to each data server and stop GDS.<br>For details, see **Stopping GDS**. |

### 3.2.2.2 Preparing Source Data

## Scenario

Generally, the data to be imported has been uploaded to the data server. In this case, you only need to check the communication between the data server and GaussDB(DWS), and record the data storage directory on the data server before the import.

If the data has not been uploaded to the data server, perform the following operations to upload it:

## Procedure

**Step 1** Log in to the data server as user **root**.

**Step 2** Create the directory **/input_data**.

```
mkdir -p /input_data
```

**Step 3** Upload the source data files to the created directory.

GDS parallel import supports source data only in CSV or TEXT format.

**----End**

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### 3.2.2.3 Installing, Configuring, and Starting GDS

## Scenario

GaussDB(DWS) uses GDS to allocate the source data for parallel data import. Deploy GDS on the data server.

If a large volume of data is stored on multiple data servers, install, configure, and start GDS on each server. Then, data on all the servers can be imported in parallel. The procedure for installing, configuring, and starting GDS is the same on each data server. This section describes how to perform this procedure on one data server.

## Context

1. The GDS version must match the cluster version. For example, GDS V100R008C00 matches DWS 1.3.*X*. Otherwise, the import or export may fail, or the import or export process may fail to respond.

   Therefore, use the latest version of GDS. After the database is upgraded, download the latest version of GaussDB(DWS) GDS as instructed in **Procedure**. When the import or export starts, GaussDB(DWS) checks the GDS versions. If the versions do not match, an error message is displayed and the import or export is terminated.

   To obtain the version number of GDS, run the following command in the GDS decompression directory:

   ```
   gds -V
   ```

   To view the database version, run the following SQL statement after connecting to the database:

   ```
   SELECT version();
   ```

## Procedure

**Step 1** For details about how to import or export data using GDS, see "Tutorial: Using GDS to Import Data > Step 1: Preparing an ECS as the GDS Server" in the *Data Warehouse Service User Guide*.

**Step 2** Log in as user **root** to the data server where GDS is to be installed and run the following command to create the directory for storing the GDS package:

```
mkdir -p /opt/bin/dws
```

**Step 3** Upload the GDS package to the created directory.

Use the SUSE Linux package as an example. Upload the GDS package **dws_client_8.1.*x*_suse_x64.zip** to the directory created in the previous step.

**Step 4** (Optional) If SSL is used, upload the SSL certificates to the directory created in **Step 2**.

**Step 5** Go to the directory and decompress the package.

```
cd /opt/bin/dws
unzip dws_client_8.1.x_suse_x64.zip
```

**Step 6** Create a GDS user and the user group to which the user belongs. This user is used to start GDS and read source data.

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```
groupadd gdsgrp
useradd -g gdsgrp gds_user
```

**Step 7** Change the owner of the GDS package directory and source data file directory to the GDS user.

```
chown -R gds_user:gdsgrp /opt/bin/dws/gds
chown -R gds_user:gdsgrp /input_data
```

**Step 8** Switch to user **gds_user**.

```
su - gds_user
```

If the current cluster version is 8.0.*x* or earlier, skip **Step 9** and go to **Step 10**.

If the current cluster version is 8.1.*x*, go to the next step.

**Step 9** Execute the script on which the environment depends (applicable only to 8.1.*x*).

```
cd /opt/bin/dws/gds/bin
source gds_env
```

**Step 10** Start GDS.

GDS is green software and can be started after being decompressed. There are two ways to start GDS. One is to run the **gds** command to configure startup parameters. The other is to write the startup parameters into the **gds.conf** configuration file and run the **gds_ctl.py** command to start GDS.

The first method is recommended when you do not need to import data again. The second method is recommended when you need to import data regularly.

- Method 1: Run the **gds** command to start GDS.
  - If data is transmitted in non-SSL mode, run the following command to start GDS:

    ```
    gds -d dir -p ip:port -H address_string -l log_file -D -t worker_num
    ```

    Example:

    ```
    /opt/bin/dws/gds/bin/gds -d /input_data/ -p 192.168.0.90:5000 -H 10.10.0.1/24 -
    l /opt/bin/dws/gds/gds_log.txt -D -t 2
    ```

  - If data is transmitted in SSL mode, run the following command to start GDS:

    ```
    gds -d dir -p ip:port -H address_string -l log_file -D
    -t worker_num --enable-ssl --ssl-dir Cert_file
    ```

    Example:

    Run the following command to upload the SSL certificate mentioned in **Step 4** to **/opt/bin**:

    ```
    /opt/bin/dws/gds/bin/gds -d /input_data/ -p 192.168.0.90:5000 -H 10.10.0.1/24 -
    l /opt/bin/dws/gds/gds_log.txt -D --enable-ssl --ssl-dir /opt/bin/
    ```

  Replace the information in italic as required.

  - **-d** *dir*: directory for storing data files that contain data to be imported. This tutorial uses **/input_data/** as an example.
  - **-p** *ip:port*: listening IP address and port for GDS. The default value is **127.0.0.1**. Replace it with the IP address of a 10GE network that can communicate with GaussDB(DWS). The port number ranges from 1024 to 65535. The default port is **8098**. This tutorial uses **192.168.0.90:5000** as an example.
  - **-H** *address_string*: specifies the hosts that are allowed to connect to and use GDS. The value must be in CIDR format. Configure this parameter to

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enable a GaussDB(DWS) cluster to access GDS for data import. Ensure that the network segment covers all hosts in a GaussDB(DWS) cluster.

- **-l** *log_file*: GDS log directory and log file name. This tutorial uses **/opt/bin/dws/gds/gds_log.txt** as an example.
- **-D**: GDS in daemon mode. This parameter is used only in Linux.
- **-t** *worker_num*: number of concurrent GDS threads. If the data server and GaussDB(DWS) have available I/O resources, you can increase the number of concurrent GDS threads.

  GDS determines the number of threads based on the number of concurrent import transactions. Even if multi-thread import is configured before GDS startup, the import of a single transaction will not be accelerated. By default, an **INSERT** statement is an import transaction.
- **--enable-ssl**: enables SSL for data transmission.
- **--ssl-dir** *Cert_file*: SSL certificate directory. Set this parameter to the certificate directory in **Step 4**.
- For details about GDS parameters, see "GDS - Parallel Data Loader > gds" in the *Data Warehouse Service (DWS) Tool Guide*.

- Method 2: Write the startup parameters into the **gds.conf** configuration file and run the **gds_ctl.py** command to start GDS.

  a. Run the following command to go to the **config** directory of the GDS package and modify the **gds.conf** configuration file. For details about the parameters in the **gds.conf** configuration file, see **Table 3-8**.

  ```
  vim /opt/bin/dws/gds/config/gds.conf
  ```

  Example:

  The **gds.conf** configuration file contains the following information:

  ```
  <?xml version="1.0"?>
  <config>
  <gds name="gds1" ip="192.168.0.90" port="5000" data_dir="/input_data/" err_dir="/err"
  data_seg="100MB" err_seg="100MB" log_file="/log/gds_log.txt" host="10.10.0.1/24"
  daemon='true' recursive="true" parallel="32"></gds>
  </config>
  ```

  Information in the configuration file is described as follows:

  - The data server IP address is **192.168.0.90** and the GDS listening port is **5000**.
  - Data files are stored in the **/input_data/** directory.
  - Error log files are stored in the **/err** directory. The directory must be created by a user who has the GDS read and write permissions.
  - The size of a single data file is 100 MB.
  - The size of a single error log file is 100 MB.
  - Logs are stored in the **/log/gds_log.txt** file. The directory must be created by a user who has the GDS read and write permissions.
  - Only nodes with the IP address **10.10.0.***** can be connected.
  - The GDS process is running in daemon mode.

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- Recursive data file directories are used.
- The number of concurrent import threads is 2.

b. Start GDS and check whether it has been started.

```
python3 gds_ctl.py start
```

Example:

```
cd /opt/bin/dws/gds/bin
python3 gds_ctl.py start
Start GDS gds1                  [OK]
gds [options]:
 -d dir             Set data directory.
 -p port            Set GDS listening port.
    ip:port         Set GDS listening ip address and port.
 -l log_file        Set log file.
 -H secure_ip_range
                    Set secure IP checklist in CIDR notation. Required for GDS to start.
 -e dir             Set error log directory.
 -E size            Set size of per error log segment.(0 < size < 1TB)
 -S size            Set size of data segment.(1MB < size < 100TB)
 -t worker_num      Set number of worker thread in multi-thread mode, the upper limit is 32. If
without setting, the default value is 1.
 -s status_file     Enable GDS status report.
 -D                 Run the GDS as a daemon process.
 -r                 Read the working directory recursively.
 -h                 Display usage.
```

**----End**

## gds.conf Parameter Description

**Table 3-8** gds.conf configuration description

| Attribute | Description | Value Range |
| --- | --- | --- |
| name | Identifier | - |
| ip | Listening IP address | The IP address must be valid.<br>Default value: **127.0.0.1** |
| port | Listening port | Value range: 1024 to 65535 (integer)<br>Default value: **8098** |
| data_dir | Data file directory | - |
| err_dir | Error log file directory | Default value: data file directory |
| log_file | Log file Path | - |
| host | Host IP address allowed to be connected to GDS (The value must in CIDR format and this parameter is available for the Linux OS only.) | - |


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| Attribute | Description | Value Range |
| --- | --- | --- |
| recursive | Whether the data file directories are recursive | Value range:<br>• **true**: recursive<br>• **false**: not recursive<br>Default value: **false** |
| daemon | Whether the process is running in daemon mode | Value range:<br>• **true**: The process is running in daemon mode.<br>• **false**: The process is not running in daemon mode.<br>Default value: **false** |
| parallel | Number of concurrent data import threads | Value range: 0 to 32 (integer)<br>Default value: **1** |

### 3.2.2.4 Creating a GDS Foreign Table

The source data information and GDS access information are configured in a foreign table. Then, GaussDB(DWS) can import data from a data server to a database table based on the configuration in the foreign table.

## Procedure

**Step 1** Collect source data information and GDS access information.

You need to collect the following source data information:

- **format**: format of the data to be imported. Only data in CSV, TEXT, or FIXED format can be imported using GDS in parallel.
- **header**: whether a source data file has a header. This parameter is set only for files in CSV or FIXED format.
- **delimiter**: delimiter in the source data file. For example, it can be a comma (,).
- **encoding**: encoding format of the data source file. Assume that the encoding format is UTF-8.
- **eol**: line break character in the data file. It can be a default character, such as 0x0D0A or 0X0A, or a customized line break character, such as a string: **!@#**. This parameter can be set only for TEXT import.
- For details about more source data information configured in a foreign table, see data format parameters.

You need to collect the following GDS access information:

**location**: GDS URL. GDS information in **Installing, Configuring, and Starting GDS** is used as an example. In non-SSL mode, **location** is set to **gsfs**://*192.168.0.90:5000*|*/input_data/*. In SSL mode, **location** is set to **gsfss**://*192.168.0.90:5000*|*/input_data/*. **192.168.0.90:5000** indicates the IP address and

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port number of GDS. **input_data** indicates the path of data source files managed by GDS. Replace the values as required.

**Step 2** Design an error tolerance mechanism for data import.

GaussDB(DWS) supports the following error tolerance in data import:

- **fill_missing_fields**: This parameter specifies whether to report an error when the last column in a row of the source data file is empty, or to fill the column with **NULL**.
- **ignore_extra_data**: This parameter specifies whether to report an error when the number of columns in the source data file is greater than that specified in the foreign table, or to ignore the extra columns.
- **per node reject_limit**: This parameter specifies the number of data format errors allowed on each DN. If the number of errors recorded in the error table on a DN exceeds the specified value, the import will fail and an error message will be reported. You can also set it to **unlimited**.
- **compatible_illegal_chars**: This parameter specifies whether to report an error when an illegal character is encountered, or to convert it and proceed with the import.

  The following describes the rules for converting an illegal character:

  – **\0** is converted to a space.
  – Other illegal characters are converted to question marks.
  – If **NULL**, **DELIMITER**, **QUOTE**, or **ESCAPE** is also set to a space or question mark, an error message such as "illegal chars conversion may confuse COPY escape 0x20" is displayed, prompting you to modify parameter settings that may cause import errors.
- **error_table_name**: This parameter specifies the name of the table that records data format errors. After the parallel import, you can query this table for error details.
- **remote log 'name'**: This parameter specifies whether to store data format errors in files on the GDS server. **name** is the prefix of the error data file.
- For details about more error tolerance parameters, see error tolerance parameters.

**Step 3** After connecting to the database using **gsql** or Data Studio, create a GDS foreign table based on the collected and design information.

For example:

```
CREATE FOREIGN TABLE foreign_tpcds_reasons
(
  r_reason_sk integer not null,
  r_reason_id char(16) not null,
  r_reason_desc char(100)
)
 SERVER gsmpp_server
 OPTIONS
(
LOCATION 'gsfs://192.168.0.90:5000/input_data | gsfs://192.168.0.91:5000/input_data',
FORMAT 'CSV' ,
DELIMITER ',',
ENCODING 'utf8',
HEADER 'false',
FILL_MISSING_FIELDS 'true',
IGNORE_EXTRA_DATA 'true'
)
```

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```
LOG INTO product_info_err
PER NODE REJECT LIMIT 'unlimited';
```

The following describes information in the preceding command:

- The columns specified in the foreign table must be the same as those in the target table.
- Retain the value **gsmpp_server** for **SERVER**.
- Set **location** based on the GDS access information collected in **Step 1**. If SSL is used, replace **gsfs** with **gsfss**.
- Set **FORMAT**, **DELIMITER**, **ENCODING**, and **HEADER** based on the source data information collected in **Step 1**.
- Set **FILL_MISSING_FIELDS**, **IGNORE_EXTRA_DATA**, **LOG INTO**, and **PER NODE REJECT LIMIT** based on the error tolerance mechanism designed in **Step 2**. **LOG INTO** specifies the name of the error table.

For details about the CREATE FOREIGN TABLE syntax, see CREATE FOREIGN TABLE (for GDS Import and Export).

**----End**

## Example

For more examples, see **Example of Importing Data Using GDS**.

- Example 1: Create a GDS foreign table named **foreign_tpcds_reasons**. The data format is CSV.

```
CREATE FOREIGN TABLE foreign_tpcds_reasons
(
  r_reason_sk integer not null,
  r_reason_id char(16) not null,
  r_reason_desc char(100)
)
 SERVER gsmpp_server OPTIONS (location 'gsfs://192.168.0.90:5000/* | gsfs://192.168.0.91:5000/*',
FORMAT 'CSV',MODE 'Normal', ENCODING 'utf8', DELIMITER E'\x08', QUOTE E'\x1b', NULL '');
```

- Example 2: Create a GDS foreign table named **foreign_tpcds_reasons_SSL**. SSL is used and the data format is CSV.

```
CREATE FOREIGN TABLE foreign_tpcds_reasons_SSL
(
  r_reason_sk integer not null,
  r_reason_id char(16) not null,
  r_reason_desc char(100)
)
 SERVER gsmpp_server OPTIONS (location 'gsfss://192.168.0.90:5000/* | gsfss://192.168.0.91:5000/*',
FORMAT 'CSV',MODE 'Normal', ENCODING 'utf8', DELIMITER E'\x08', QUOTE E'\x1b', NULL '');
```

- Example 3: Create a GDS foreign table named **foreign_tpcds_reasons**. The data format is TEXT.

```
CREATE FOREIGN TABLE foreign_tpcds_reasons
(
  r_reason_sk integer not null,
  r_reason_id char(16) not null,
  r_reason_desc char(100)
) SERVER gsmpp_server OPTIONS (location 'gsfs://192.168.0.90:5000/* | gsfs://192.168.0.91:5000/*',
FORMAT 'TEXT', delimiter E'\x08',  null '',reject_limit '2',EOL '0x0D') WITH err_foreign_tpcds_reasons;
```

## 3.2.2.5 Importing Data

This section describes how to create tables in GaussDB(DWS) and import data to the tables.

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Before importing all the data from a table containing over 10 million records, you are advised to import some of the data, and check whether there is data skew and whether the distribution keys need to be changed. Troubleshoot the data skew if any. It is costly to address data skew and change the distribution keys after a large amount of data has been imported.

## Prerequisites

The GDS server can communicate with GaussDB(DWS).

- You need to create an ECS as the GDS server.
- The created ECS and GaussDB(DWS) must belong to the same region, VPC, and subnet.

## Procedure

**Step 1** Create a table in GaussDB(DWS) to store imported data. For details, see CREATE TABLE.

**Step 2** Import data.

```
INSERT INTO [Target table name] SELECT * FROM [Foreign table name]
```

- If information similar to the following is displayed, the data has been imported. Query the error information table to check whether any data format errors occurred. For details, see **Handling Import Errors**.

  ```
  INSERT 0 9
  ```

- If data fails to be loaded, troubleshoot the problem by following the instructions provided in **Handling Import Errors** and try again.

NOTE

- If a data loading error occurs, the entire data import task will fail.
- Compile a batch-processing task script to concurrently import data. The degree of parallelism (DOP) depends on the server resource usage. You can test-import several tables, monitor resource utilization, and increase or reduce concurrency accordingly. Common resource monitoring commands include **top** for monitoring memory and CPU usage, **iostat** for monitoring I/O usage, and **sar** for monitoring networks. For details about application cases, see .
- If possible, more GDS servers can significantly improve the data import efficiency. For details about application cases, see **Importing Data in Parallel from Multiple Data Servers**.
- In a scenario where many GDS servers import data concurrently, you can increase the TCP Keepalive interval for connections between GDS servers and DNs to ensure connection stability. (The recommended interval is 5 minutes.) TCP Keepalive settings of the cluster affect its fault detection response time.

**----End**

## Example:

**Step 1** Create a target table named **reasons**.

```
CREATE TABLE reasons
(
  r_reason_sk   integer  not null,
  r_reason_id   char(16) not null,
  r_reason_desc char(100)
)
DISTRIBUTE BY HASH (r_reason_sk);
```

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**Step 2** Import data from source data files through the **foreign_tpcds_reasons** foreign table to the **reasons** table.

```
INSERT INTO reasons SELECT * FROM foreign_tpcds_reasons ;
```

**Step 3** You can create indexes again after the import is complete.

```
CREATE INDEX reasons_idx ON reasons(r_reasons_id);
```

**----End**

## 3.2.2.6 Handling Import Errors

## Scenarios

Handle errors that occurred during data import.

## Querying Error Information

Errors that occur when data is imported are divided into data format errors and non-data format errors.

- Data format error

  When creating a foreign table, specify **LOG INTO** *error_table_name*. Data format errors occurring during the data import will be written into the specified table. You can run the following SQL statement to query error details:

  ```
  SELECT * FROM error_table_name;
  ```

  **Table 3-9** lists the columns of the *error_table_name* table.

  **Table 3-9** Columns in the *error_table_name* table

| Column | Type | Description |
| --- | --- | --- |
| nodeid | integer | ID of the node where an error is reported |
| begintime | timestamp with time zone | Time when a data format error is reported |
| filename | character varying | Name of the source data file where a data format error occurs<br>If you use GDS for importing data, the error information includes the IP address and port number of the GDS server. |
| rownum | bigint | Number of the row where an error occurs in a source data file |
| rawrecord | text | Raw record of the data format error in the source data file |
| detail | text | Error details |


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- Non-data format error

  A non-data format error leads to the failure of an entire data import task. You can locate and troubleshoot a non-data format error based on the error message displayed during data import.

## Handling data import errors

Troubleshoot data import errors based on obtained error information and the description in the following table.

**Table 3-10** Handling data import errors

| Error Information | Cause | Solution |
| --- | --- | --- |
| missing data for column "r_reason_desc" | 1. The number of columns in the source data file is less than that in the foreign table.<br>2. In a TEXT format source data file, an escape character (for example, \) leads to delimiter or quote mislocation. Example: The target table contains three columns as shown in the following command output. The escape character (\) converts the delimiter (\|) into the value of the second column, causing loss of the value of the third column.<br>`BE\|Belgium\|1` | 1. If an error is reported due to missing columns, perform the following operations:<br>● Add the **r_reason_desc** column to the source data file.<br>● When creating a foreign table, set the parameter **fill_missing_fields** to **on**. In this way, if the last column of a row in the source data file is missing, it is set to **NULL** and no error will be reported.<br>2. Check whether the row where an error occurred contains the escape character (\). If the row contains such a character, you are advised to set the parameter **noescaping** to **true** when creating a foreign table, indicating that the escape character (\) and the characters following it are not escaped. |

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| Error Information | Cause | Solution |
| --- | --- | --- |
| extra data after last expected column | The number of columns in the source data file is greater than that in the foreign table. | • Delete the unnecessary columns from the source data file.<br>• When creating a foreign table, set the parameter **ignore_extra_data** to **on**. In this way, if the number of columns in a source data file is greater than that in the foreign table, the extra columns at the end of rows will not be imported. |
| invalid input syntax for type numeric: "a" | The data type is incorrect. | In the source data file, change the data type of the columns to be imported. If this error information is displayed, change the data type to **numeric**. |
| null value in column "staff_id" violates not-null constraint | The not-null constraint is violated. | In the source data file, add values to the specified columns. If this error information is displayed, add values to the **staff_id** column. |
| duplicate key value violates unique constraint "reg_id_pk" | The unique constraint is violated. | • Delete the duplicate rows from the source data file.<br>• Run the **SELECT** statement with the **DISTINCT** keyword to ensure that all imported rows are unique.<br>**INSERT INTO** reasons **SELECT DISTINCT * FROM** foreign_tpcds_reasons; |
| value too long for type character varying(16) | The column length exceeds the upper limit. | In the source data file, change the column length. If this error information is displayed, reduce the column length to no greater than 16 bytes (VARCHAR2). |

## 3.2.2.7 Stopping GDS

## Scenarios

Stop GDS after data is imported successfully.

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## Procedure

**Step 1** Log in as user **gds_user** to the data server where GDS is installed.

**Step 2** Select the mode of stopping GDS based on the mode of starting it.

- If GDS is started using the **gds** command, perform the following operations to stop GDS:
  a. Query the GDS process ID:
  ```
  ps -ef|grep gds
  ```
  For example, the GDS process ID is 128954.
  ```
  ps -ef|grep gds
  gds_user 128954      1  0 15:03 ?        00:00:00 gds -d /input_data/ -p 192.168.0.90:5000 -l /log/gds_log.txt -D
  gds_user 129003 118723  0 15:04 pts/0    00:00:00 grep gds
  ```
  b. Run the **kill** command to stop GDS. **128954** in the command is the GDS process ID.
  ```
  kill -9 128954
  ```

**----End**

## 3.2.2.8 Example of Importing Data Using GDS

## Importing Data in Parallel from Multiple Data Servers

The data servers and the cluster reside on the same intranet. The IP addresses are **192.168.0.90** and **192.168.0.91**. Source data files are in CSV format.

1. Create the target table **tpcds.reasons**.
   ```
   CREATE TABLE tpcds.reasons
   (
     r_reason_sk integer not null,
     r_reason_id char(16) not null,
     r_reason_desc char(100)
   );
   ```
2. Log in to each GDS data server as user **root** and create the **/input_data** directory for storing data files on the servers. The following takes the data server whose IP address is **192.168.0.90** as an example. Operations on the other server are the same.
   ```
   mkdir -p /input_data
   ```
3. (Optional) Create a user and the user group it belongs to. The user is used to start GDS. If the user and user group exist, skip this step.
   ```
   groupadd gdsgrp
   useradd -g gdsgrp gds_user
   ```
4. Evenly distribute source data files to the **/input_data** directories on the data servers.
5. Change the owners of source data files and the **/input_data** directory on each data server to **gds_user**. The data server whose IP address is **192.168.0.90** is used as an example.
   ```
   chown -R gds_user:gdsgrp /input_data
   ```
6. Log in to each data server as user **gds_user** and start GDS.

   The GDS installation path is **/opt/bin/dws/gds**. Source data files are stored in **/input_data/**. The IP addresses of the data servers are **192.168.0.90** and **192.168.0.91**. The GDS listening port is **5000**. GDS runs in daemon mode.

   Start GDS on the data server whose IP address is **192.168.0.90**.

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```
/opt/bin/dws/gds/bin/gds -d /input_data -p 192.168.0.90:5000 -H 10.10.0.1/24 -D
```

Start GDS on the data server whose IP address is **192.168.0.91**.

```
/opt/bin/dws/gds/bin/gds -d /input_data -p 192.168.0.91:5000 -H 10.10.0.1/24  -D
```

7. Create the foreign table **tpcds.foreign_tpcds_reasons** for receiving data from the data server.

   Data export mode settings are as follows:

   - Set the import mode to **Normal**.
   - When GDS is started, the source data file directory is **/input_data** and the GDS listening port is **5000**. Therefore, set **location** to **gsfs://192.168.0.90:5000/* | gsfs://192.168.0.91:5000/***.

   Information about the data format is configured based on data format parameters specified during data export. The parameter configurations are as follows:

   - **format** is set to **CSV**.
   - **encoding** is set to **UTF-8**.
   - **delimiter** is set to **E'\x08'**.
   - **quote** is set to **E'\x1b'**.
   - **null** is set to an empty string without quotation marks.
   - **escape** defaults to the value of **quote**.
   - **header** is set to **false**, indicating that the first row is identified as a data row in an imported file.

   Configure import error tolerance parameters as follows:

   - Set **PER NODE REJECT LIMIT** (number of allowed data format errors) to **unlimited**. In this case, all the data format errors detected during data import will be tolerated.
   - Set **LOG INTO** to **err_tpcds_reasons**. The data format errors detected during data import will be recorded in the **err_tpcds_reasons** table.

   Based on the above settings, the foreign table is created using the following statement:

   ```
   CREATE FOREIGN TABLE tpcds.foreign_tpcds_reasons
   (
     r_reason_sk integer not null,
     r_reason_id char(16) not null,
     r_reason_desc char(100)
   )
   SERVER gsmpp_server OPTIONS (location 'gsfs://192.168.0.90:5000/* | gsfs://192.168.0.91:5000/*',
   format 'CSV',mode 'Normal', encoding 'utf8', delimiter E'\x08', quote E'\x1b', null '', fill_missing_fields
   'false') LOG INTO err_tpcds_reasons PER NODE REJECT LIMIT 'unlimited';
   ```

8. Import data through the foreign table **tpcds.foreign_tpcds_reasons** to the target table **tpcds.reasons**.

   ```
   INSERT INTO tpcds.reasons SELECT * FROM tpcds.foreign_tpcds_reasons;
   ```

9. Query data import errors in the **err_tpcds_reasons** table and rectify the errors (if any). For details, see **Handling Import Errors**.

   ```
   SELECT * FROM err_tpcds_reasons;
   ```

10. After data import is complete, log in to each data server as user **gds_user** and stop GDS.

    The data server whose IP address is **192.168.0.90** is used as an example. The GDS process ID is **128954**.

    ```
    ps -ef|grep gds
    gds_user 128954     1  0 15:03 ?        00:00:00 gds -d /input_data -p 192.168.0.90:5000 -D
    ```

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```
gds_user 129003 118723  0 15:04 pts/0    00:00:00 grep gds
kill -9 128954
```

## Importing Data Using Multiple Threads

The data servers and the cluster reside on the same intranet. The server IP address is **192.168.0.90**. Source data files are in CSV format. Data will be imported to two tables using multiple threads in **Normal** mode.

1. In the database, create the target tables **tpcds.reasons1** and **tpcds.reasons2**.
   ```
   CREATE TABLE tpcds.reasons1
   (
     r_reason_sk integer not null,
     r_reason_id char(16) not null,
     r_reason_desc char(100)
   ) ;
   CREATE TABLE tpcds.reasons2
   (
     r_reason_sk integer not null,
     r_reason_id char(16) not null,
     r_reason_desc char(100)
   ) ;
   ```
2. Log in to the GDS data server as user **root**, and then create the data file directory **/input_data** and its sub-directories **/input_data/import1/** and **/input_data/import2/**.
   ```
   mkdir -p /input_data
   ```
3. Store the source data files of the target table **tpcds.reasons1** in **/input_data/import1/** and the source data files of the target table **tpcds.reasons2** in **/input_data/import2/**.
4. (Optional) Create a user and the user group it belongs to. The user is used to start GDS. If the user and user group already exist, skip this step.
   ```
   groupadd gdsgrp
   useradd -g gdsgrp gds_user
   ```
5. Change the owners of source data files and the **/input_data** directory on the data server to **gds_user**.
   ```
   chown -R gds_user:gdsgrp /input_data
   ```
6. Log in to the data server as user **gds_user** and start GDS.

   The GDS installation path is **/gds**. Source data files are stored in **/input_data/**. The IP address of the data server is **192.168.0.90**. The GDS listening port is **5000**. GDS runs in daemon mode. The degree of parallelism is 2. A recursive directory is specified.
   ```
   /gds/gds -d /input_data -p 192.168.0.90:5000 -H 10.10.0.1/24  -D -t 2 -r
   ```
7. In the database, create the foreign tables **tpcds.foreign_tpcds_reasons1** and **tpcds.foreign_tpcds_reasons2** for the source data.

   The foreign table **tpcds.foreign_tpcds_reasons1** is used as an example to describe how to configure parameters in a foreign table.

   Data export mode settings are as follows:

   - Set the import mode to **Normal**.
   - When GDS is started, the configured source data file directory is **/input_data** and the GDS listening port is **5000**. However, source data files are actually stored in **/input_data/import1/**. Therefore, set **location** to **gsfs://192.168.0.90:5000/import1/***.

   Information about the data format is configured based on data format parameters specified during data export. The parameter configurations are as follows:

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- **format** is set to **CSV**.
- **encoding** is set to **UTF-8**.
- **delimiter** is set to **E'\x08'**.
- **quote** is set to **E'\x1b'**.
- **null** is set to an empty string without quotation marks.
- **escape** defaults to the value of **quote**.
- **header** is set to **false**, indicating that the first row is identified as a data row in an imported file.

Configure import error tolerance parameters as follows:

- Set **PER NODE REJECT LIMIT** (number of allowed data format errors) to **unlimited**. In this case, all the data format errors detected during data import will be tolerated.
- Set **LOG INTO** to **err_tpcds_reasons1**. The data format errors detected during data import will be recorded in the **err_tpcds_reasons1** table.
- If the last column of a source data file is missing, the **fill_missing_fields** parameter is automatically set to **NULL**.

Based on the preceding settings, the foreign table **tpcds.foreign_tpcds_reasons1** is created using the following statement:

```
CREATE FOREIGN TABLE tpcds.foreign_tpcds_reasons1
(
  r_reason_sk integer not null,
  r_reason_id char(16) not null,
  r_reason_desc char(100)
) SERVER gsmpp_server OPTIONS (location 'gsfs://192.168.0.90:5000/import1/*', format 'CSV',mode 'Normal', encoding 'utf8', delimiter E'\x08', quote E'\x1b', null '',fill_missing_fields 'on')LOG INTO err_tpcds_reasons1 PER NODE REJECT LIMIT 'unlimited';
```

Based on the preceding settings, the foreign table **tpcds.foreign_tpcds_reasons2** is created using the following statement:

```
CREATE FOREIGN TABLE tpcds.foreign_tpcds_reasons2
(
  r_reason_sk integer not null,
  r_reason_id char(16) not null,
  r_reason_desc char(100)
) SERVER gsmpp_server OPTIONS (location 'gsfs://192.168.0.90:5000/import2/*', format 'CSV',mode 'Normal', encoding 'utf8', delimiter E'\x08', quote E'\x1b', null '',fill_missing_fields 'on')LOG INTO err_tpcds_reasons2 PER NODE REJECT LIMIT 'unlimited';
```

8. Import data through the foreign table **tpcds.foreign_tpcds_reasons1** to **tpcds.reasons1** and through **tpcds.foreign_tpcds_reasons2** to **tpcds.reasons2**.

   ```
   INSERT INTO tpcds.reasons1 SELECT * FROM tpcds.foreign_tpcds_reasons1;
   INSERT INTO tpcds.reasons2 SELECT * FROM tpcds.foreign_tpcds_reasons2;
   ```

9. Query data import errors in the **err_tpcds_reasons1** and **err_tpcds_reasons2** tables and rectify the errors (if any). For details, see **Handling Import Errors**.

   ```
   SELECT * FROM err_tpcds_reasons1;
   SELECT * FROM err_tpcds_reasons2;
   ```

10. After data import is complete, log in to the data server as user **gds_user** and stop GDS.

    The GDS process ID is **128954**.

    ```
    ps -ef|grep gds
    gds_user 128954      1  0 15:03 ?        00:00:00 gds -d /input_data -p 192.168.0.90:5000 -D -t 2 -r
    gds_user 129003 118723  0 15:04 pts/0    00:00:00 grep gds
    kill -9 128954
    ```

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## Importing Data Through a Pipe File

**Step 1** Start GDS.

```
gds -d /***/gds_data/ -D -p 192.168.0.1:7789 -l /***/gds_log/aa.log -H 0/0 -t 10 -D
```

If you need to set the timeout interval of a pipe, use the **--pipe-timeout** parameter.

**Step 2** Import data.

1. Log in to the database and create an internal table.
   ```
   CREATE TABLE test_pipe_1( id integer not null, sex text not null, name  text );
   ```
2. Create a read-only foreign table.
   ```
   CREATE FOREIGN TABLE foreign_test_pipe_tr( like test_pipe ) SERVER gsmpp_server OPTIONS
   (LOCATION 'gsfs://192.168.0.1:7789/foreign_test_pipe.pipe', FORMAT 'text', DELIMITER ',',  NULL '',
   EOL '0x0a' ,file_type 'pipe',auto_create_pipe 'false');
   ```
3. Execute the import statement. The statement will be blocked.
   ```
   INSERT INTO test_pipe_1 select * from foreign_test_pipe_tr;
   ```

**Step 3** Import data through a GDS pipe file.

1. Log in to the GDS server and go to the GDS data directory.
   ```
   cd /***/gds_data/
   ```
2. Create a pipe. If **auto_create_pipe** is set to **true**, skip this step.
   ```
   mkfifo foreign_test_pipe.pipe;
   ```

   **NOTE**

   A pipe will be automatically cleared after an operation is complete. To perform another operation, create a pipe again.
3. Write data to the pipe.
   ```
   cat postgres_public_foreign_test_pipe_tw.txt > foreign_test_pipe.pipe
   ```
4. To read the compressed file to the pipe, run the following command:
   ```
   gzip -d < out.gz > foreign_test_pipe.pipe
   ```
5. To read the HDFS file to the pipe, run the following command:
   ```
   hdfs dfs -cat - /user/hive/***/test_pipe.txt > foreign_test_pipe.pipe
   ```

**Step 4** View the result returned by the import statement.

```
INSERT INTO test_pipe_1 select * from foreign_test_pipe_tr;
INSERT 0 4
SELECT * FROM test_pipe_1;
id | sex |      name
----+-----+----------------
3 | 2   | 11111111111111
1 | 2   | 11111111111111
2 | 2   | 11111111111111
4 | 2   | 11111111111111
(4 rows)
```

**----End**

## Importing Data Through Multi-Process Pipes

GDS also supports importing data through multi-process pipes. That is, one foreign table corresponds to multiple GDSs.

The following takes importing a local file as an example.

**Step 1** Start multiple GDSs. If the GDSs have been started, skip this step.

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```
gds -d /***/gds_data/ -D -p 192.168.0.1:7789 -l /***/gds_log/aa.log -H 0/0 -t 10 -D
gds -d /***/gds_data_1/ -D -p 192.168.0.1:7790 -l /***/gds_log_1/aa.log -H 0/0 -t 10 -D
```

If you need to set the timeout interval of a pipe, use the **--pipe-timeout** parameter.

**Step 2** Import data.

1. Log in to the database and create an internal table.
   ```
   CREATE TABLE test_pipe( id integer not null, sex text not null, name  text );
   ```
2. Create a read-only foreign table.
   ```
   CREATE FOREIGN TABLE foreign_test_pipe_tr( like test_pipe ) SERVER gsmpp_server OPTIONS
   (LOCATION 'gsfs://192.168.0.1:7789/foreign_test_pipe.pipe|gsfs://192.168.0.1:7790/
   foreign_test_pipe.pipe', FORMAT 'text', DELIMITER ',', NULL '', EOL '0x0a' , file_type 'pipe',
   auto_create_pipe 'false');
   ```
3. Execute the import statement. The statement is blocked.
   ```
   INSERT INTO test_pipe_1 select * from foreign_test_pipe_tr;
   ```

**Step 3** Import data through a GDS pipe file.

1. Log in to GDS and go to each GDS data directory.
   ```
   cd /***/gds_data/
   cd /***/gds_data_1/
   ```
2. Create a pipe. If **auto_create_pipe** is set to **true**, skip this step.
   ```
   mkfifo foreign_test_pipe.pipe;
   ```
3. Read each pipe and write the new file to the pipes.
   ```
   cat postgres_public_foreign_test_pipe_tw.txt > foreign_test_pipe.pipe
   ```

**Step 4** View the result returned by the import statement.

```
INSERT INTO test_pipe_1 select * from foreign_test_pipe_tr;
INSERT 0 4
SELECT * FROM test_pipe_1;
id | sex |      name
----+-----+----------------
3 | 2   | 11111111111111
1 | 2   | 11111111111111
2 | 2   | 11111111111111
4 | 2   | 11111111111111
(4 rows)
```

**----End**

## Direct Data Import Between Clusters

**Step 1** Start GDS. (If the process has been started, skip this step.)

```
gds -d /***/gds_data/ -D -p GDS_IP:GDS_PORT -l /***/gds_log/aa.log -H 0/0 -t 10 -D
```

If you need to set the timeout interval of a pipe, use the **--pipe-timeout** parameter.

**Step 2** Export data from the source database.

1. Log in to the target database, create an internal table, and write data to the table.
   ```
   CREATE TABLE test_pipe( id integer not null, sex text not null, name  text );
   INSERT INTO test_pipe values(1,2,'11111111111111');
   INSERT INTO test_pipe values(2,2,'11111111111111');
   INSERT INTO test_pipe values(3,2,'11111111111111');
   INSERT INTO test_pipe values(4,2,'11111111111111');
   INSERT INTO test_pipe values(5,2,'11111111111111');
   ```
2. Create a write-only foreign table.

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```
CREATE FOREIGN TABLE foreign_test_pipe( id integer not null, age text not null, name  text ) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://GDS_IP:GDS_PORT/', FORMAT 'text', DELIMITER ',', NULL '', EOL '0x0a' ,file_type 'pipe') WRITE ONLY;
```

3. Execute the import statement. The statement will be blocked.
   ```
   INSERT INTO foreign_test_pipe SELECT * FROM test_pipe;
   ```

**Step 3** Import data to the target cluster.

1. Create an internal table.
   ```
   CREATE TABLE test_pipe (id integer not null, sex text not null, name text);
   ```
2. Create a read-only foreign table.
   ```
   CREATE FOREIGN TABLE foreign_test_pipe(like test_pipe) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://GDS_IP:GDS_PORT/', FORMAT 'text', DELIMITER ',', NULL '', EOL '0x0a' , file_type 'pipe', auto_create_pipe 'false');
   ```
3. Run the following command to import data to the table:
   ```
   INSERT INTO test_pipe SELECT * FROM foreign_test_pipe;
   ```

**Step 4** View the result returned by the import statement from the target cluster.

```
SELECT * FROM test_pipe;
 id | sex |      name
----+-----+----------------
  3 | 2   | 11111111111111
  6 | 2   | 11111111111111
  7 | 2   | 11111111111111
  1 | 2   | 11111111111111
  2 | 2   | 11111111111111
  4 | 2   | 11111111111111
  5 | 2   | 11111111111111
  8 | 2   | 11111111111111
  9 | 2   | 11111111111111
(9 rows)
```

**----End**

NOTE

By default, the pipeline file exported from or imported to GDS is named in the format of *Database name_Schema name_Foreign table name* **.pipe**. Therefore, the database name and schema name of the target cluster must be the same as those of the source cluster. If the database or schema is inconsistent, you can specify the same pipe file in the URL of the **location**.

For example:

- Pipe name specified by a write-only foreign table
  ```
  CREATE FOREIGN TABLE foreign_test_pipe(id integer not null, age text not null, name  text) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://GDS_IP:GDS_PORT/foreign_test_pipe.pipe', FORMAT 'text', DELIMITER ',',  NULL '', EOL '0x0a' ,file_type 'pipe') WRITE ONLY;
  ```
- Pipe name specified by a read-only foreign table
  ```
  CREATE FOREIGN TABLE foreign_test_pipe(like test_pipe) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://GDS_IP:GDS_PORT/foreign_test_pipe.pipe', FORMAT 'text', DELIMITER ',',  NULL '', EOL '0x0a' ,file_type 'pipe',auto_create_pipe 'false');
  ```

# 3.2.3 Importing Data from MRS to a Cluster

## 3.2.3.1 Overview

MRS is a big data cluster running based on the open-source Hadoop ecosystem. It provides the industry's latest cutting-edge storage and analytical capabilities of massive volumes of data, satisfying your data storage and processing requirements. For details, see the *MapReduce Service User Guide*.

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You can use Hive/Spark (analysis cluster of MRS) to store massive volumes of service data. Hive/Spark data files are stored on HDFS. On GaussDB(DWS), you can connect a GaussDB(DWS) cluster to an MRS cluster, read data from HDFS files, and write the data to GaussDB(DWS) when the clusters are on the same network.

## Importing Data from MRS to a GaussDB(DWS) Cluster

1. **Preparing Data in an MRS Cluster**
2. (Optional) **Manually Creating a Foreign Server**
3. **Creating a Foreign Table**
4. **Importing Data**
5. **Deleting Resources**

## 3.2.3.2 Preparing Data in an MRS Cluster

Before importing data from MRS to a GaussDB(DWS) cluster, you must have:

1. Created an MRS cluster.
2. Created the Hive/Spark ORC table in the MRS cluster and stored the table data to the HDFS path corresponding to the table.

If you have completed the preparations, skip this section.

In this tutorial, the Hive ORC table will be created in the MRS cluster as an example to complete the preparation work. The process for creating the Spark ORC table in the MRS cluster and the SQL syntax are similar to those of Hive.

## Data File

The sample data of the **product_info.txt** data file is as follows:

```
100,XHDK-A-1293-#fJ3,2017-09-01,A,2017 Autumn New Shirt Women,red,M,328,2017-09-04,715,good
205,KDKE-B-9947-#kL5,2017-09-01,A,2017 Autumn New Knitwear Women,pink,L,584,2017-09-05,406,very good!
300,JODL-X-1937-#pV7,2017-09-01,A,2017 autumn new T-shirt men,red,XL,1245,2017-09-03,502,Bad.
310,QQPX-R-3956-#aD8,2017-09-02,B,2017 autumn new jacket women,red,L,411,2017-09-05,436,It's really super nice
150,ABEF-C-1820-#mC6,2017-09-03,B,2017 Autumn New Jeans Women,blue,M,1223,2017-09-06,1200,The seller's packaging is exquisite
200,BCQP-E-2365-#qE4,2017-09-04,B,2017 autumn new casual pants men,black,L,997,2017-09-10,301,The clothes are of good quality.
250,EABE-D-1476-#oB1,2017-09-10,A,2017 autumn new dress women,black,S,841,2017-09-15,299,Follow the store for a long time.
108,CDXK-F-1527-#pL2,2017-09-11,A,2017 autumn new dress women,red,M,85,2017-09-14,22,It's really amazing to buy
450,MMCE-H-4728-#nP9,2017-09-11,A,2017 autumn new jacket women,white,M,114,2017-09-14,22,Open the package and the clothes have no odor
260,OCDA-G-2817-#bD3,2017-09-12,B,2017 autumn new woolen coat women,red,L,
2004,2017-09-15,826,Very favorite clothes
980,ZKDS-J-5490-#cW4,2017-09-13,B,2017 Autumn New Women's Cotton Clothing,red,M,
112,2017-09-16,219,The clothes are small
98,FKQB-I-2564-#dA5,2017-09-15,B,2017 autumn new shoes men,green,M,4345,2017-09-18,5473,The clothes are thick and it's better this winter.
150,DMQY-K-6579-#eS6,2017-09-21,A,2017 autumn new underwear men,yellow,
37,2840,2017-09-25,5831,This price is very cost effective
200,GKLW-l-2897-#wQ7,2017-09-22,A,2017 Autumn New Jeans Men,blue,39,5879,2017-09-25,7200,The clothes are very comfortable to wear
300,HWEC-L-2531-#xP8,2017-09-23,A,2017 autumn new shoes women,brown,M,403,2017-09-26,607,good
100,IQPD-M-3214-#yQ1,2017-09-24,B,2017 Autumn New Wide Leg Pants Women,black,M,
```

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```
3045,2017-09-27,5021,very good.
350,LPEC-N-4572-#zX2,2017-09-25,B,2017 Autumn New Underwear Women,red,M,239,2017-09-28,407,The seller's service is very good
110,NQAB-O-3768-#sM3,2017-09-26,B,2017 autumn new underwear women,red,S,
6089,2017-09-29,7021,The color is very good
210,HWNB-P-7879-#tN4,2017-09-27,B,2017 autumn new underwear women,red,L,3201,2017-09-30,4059,I like it very much and the quality is good.
230,JKHU-Q-8865-#uO5,2017-09-29,C,2017 Autumn New Clothes with Chiffon Shirt,black,M,
2056,2017-10-02,3842,very good
```

## Creating a Hive ORC Table in an MRS Cluster

1. Create an MRS cluster.

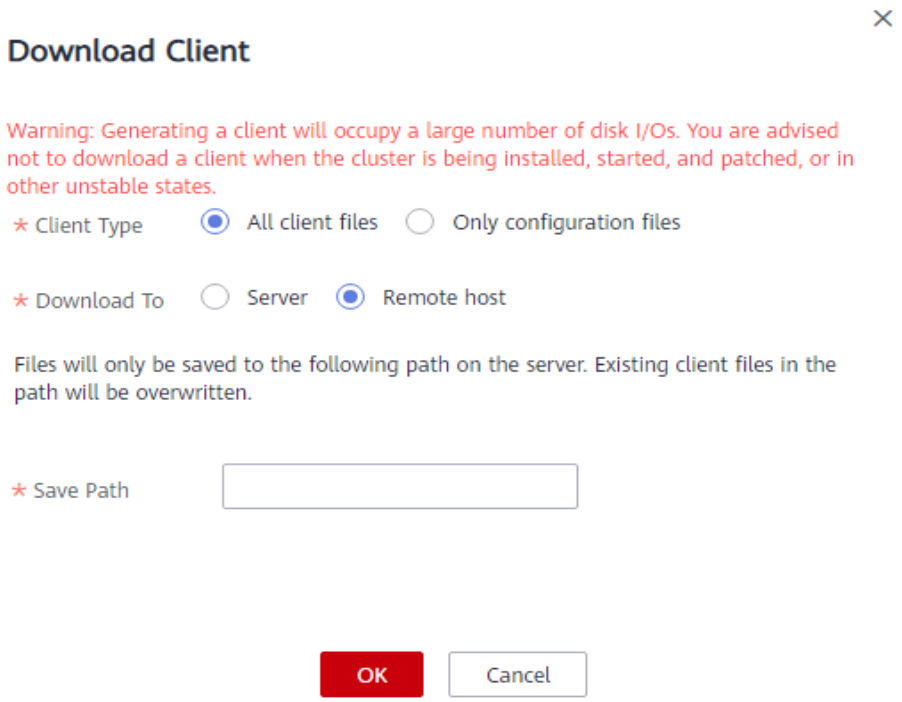
   For details, see "Creating a Cluster > Custom Creation of a Cluster" in the *MapReduce Service User Guide*.

2. Download the client.

   a. Go back to the MRS cluster page. Click the cluster name. On the **Dashboard** tab page of the cluster details page, click **Access Manager**. If a message is displayed indicating that EIP needs to be bound, bind an EIP first.

   b. Enter the username **admin** and its password for logging in to MRS Manager. The password is the one you entered when creating the MRS cluster.

   c. Choose **Services** > **Download Client**. Set **Client Type** to **Only configuration files** and set **Download To** to **Server**. Click **OK**.




3. Log in to the Hive client of the MRS cluster.

   a. Log in to a Master node.

      For details, see "Remote Login Guide > Logging In to a Master Node" in the *MapReduce Service User Guide*.

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b. Run the following command to switch the user:
```
sudo su - omm
```

c. Run the following command to go to the client directory:
```
cd /opt/client
```

d. Run the following command to configure the environment variables:
```
source bigdata_env
```

e. If Kerberos authentication is enabled for the current cluster, run the following command to authenticate the current user. The current user must have the permission for creating Hive tables. For details, see "Creating a Role" in the *MapReduce Service User Guide*. Configure a role with the required permissions. For details, see "Creating a Role" in the *MapReduce Service User Guide*. Bind a role to the user. If the Kerberos authentication is disabled for the current cluster, skip this step.
```
kinit MRS cluster user
```
Example: **kinit hiveuser**

f. Run the following command to start the Hive client:
```
beeline
```

4. Create a database demo on Hive.

   Run the following command to create the database demo:
```
CREATE DATABASE demo;
```

5. Create table **product_info** of the **Hive TEXTFILE** type in the database demo and import the **Data File** (**product_info.txt**) to the HDFS path corresponding to the table.

   Run the following command to switch to the database demo:
```
USE demo;
```

   Run the following command to create table **product_info** and define the table fields based on data in the **Data File**.
```
DROP TABLE product_info;

CREATE TABLE product_info
(
    product_price               int           ,
    product_id                  char(30)      ,
    product_time                date          ,
    product_level               char(10)      ,
    product_name                varchar(200)  ,
    product_type1               varchar(20)   ,
    product_type2               char(10)      ,
    product_monthly_sales_cnt   int           ,
    product_comment_time        date          ,
    product_comment_num         int           ,
    product_comment_content     varchar(200)
)
row format delimited fields terminated by ','
stored as TEXTFILE;
```

   For details about how to import data to an MRS cluster, see "Cluster Operation Guide > Managing Active Clusters > Managing Data Files" in the *MapReduce Service User Guide*.

6. Create a Hive ORC table named **product_info_orc** in the database demo.

   Run the following command to create the Hive ORC table **product_info_orc**. The table fields are the same as those of the **product_info** table created in the previous step.
```
DROP TABLE product_info_orc;
```

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```
CREATE TABLE product_info_orc
(
    product_price                int           ,
    product_id                   char(30)      ,
    product_time                 date          ,
    product_level                char(10)      ,
    product_name                 varchar(200)  ,
    product_type1                varchar(20)   ,
    product_type2                char(10)      ,
    product_monthly_sales_cnt    int           ,
    product_comment_time         date          ,
    product_comment_num          int           ,
    product_comment_content      varchar(200)
)
row format delimited fields terminated by ','
stored as orc;
```

7. Insert data in the **product_info** table to the Hive ORC table **product_info_orc**.

   ```
   insert into product_info_orc select * from product_info;
   ```

   Query table **product_info_orc**.

   ```
   select * from product_info_orc;
   ```

   If data displayed in the **Data File** can be queried, the data has been successfully inserted to the ORC table.

### 3.2.3.3 Manually Creating a Foreign Server

In the syntax **CREATE FOREIGN TABLE (SQL on Hadoop or OBS)** for creating a foreign table, you need to specify a foreign server associated with the MRS data source connection.

When you create an MRS data source connection on the GaussDB(DWS) management console, the database administrator **dbadmin** automatically creates a foreign server in the default database **postgres**. If you want to create a foreign table in the default database **postgres** to read MRS data, skip this section.

If you want to use a common user to create a foreign table in a customized database to read MRS data, you must manually create a foreign server in the customized database. This section describes how to create a foreign server in a customized database as a common user. The procedure is as follows:

1. Ensure that an MRS data source connection has been created for the GaussDB(DWS) cluster.

   For details, see "Managing MRS Data Sources > Creating an MRS Data Source Connection" in the *Data Warehouse Service User Guide*.

2. **Creating a User and a Database and Granting the User Foreign Table Permissions**
3. **Manually Creating a Foreign Server**

NOTE

If you no longer need to read data from the MRS data source and have deleted the MRS data source on the GaussDB(DWS) management console, only the foreign server automatically created in the default database **gaussdb** will be deleted, and the manually created foreign server needs to be deleted manually. For details about the deletion, see **Deleting the Manually Created Foreign Server**.


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## Creating a User and a Database and Granting the User Foreign Table Permissions

In the following example, a common user **dbuser** and a database **mydatabase** are created. Then, an administrator is used to grant foreign table permissions to user **dbuser**.

**Step 1** Connect to the default database **gaussdb** as a database administrator through the database client tool provided by GaussDB(DWS).

For example, use the **gsql** client to connect to the database by running the following command:

```
gsql -d postgres -h 192.168.2.30 -U dbadmin -p 8000 -W password -r
```

Enter your password as prompted.

**Step 2** Create a common user and use it to create a database.

Create a user named **dbuser** that has the permission to create databases.

```
CREATE USER dbuser WITH CREATEDB PASSWORD 'password';
```

Switch to the created user.

```
SET ROLE dbuser PASSWORD 'password';
```

Run the following command to create a database:

```
CREATE DATABASE mydatabase;
```

Query the database.

```
SELECT * FROM pg_database;
```

The database is successfully created if the returned result contains information about **mydatabase**.

```
datname   | datdba | encoding | datcollate | datctype | datistemplate | datallowconn | datconnlimit |
datlastsysoid | datfrozenxid | dattablespace | datcompatibility |                  datacl

------------+---------+----------+------------+----------+---------------+--------------+--------------+---------------
+--------------+---------------+------------------+-------------------------------------
--------------
 template1  |     10 |        0 | C          | C        | t             | t            |           -1 |        14146 |        1351
|          1663 | ORA             | {=c/Ruby,omm=CTc/Ruby}
 template0  |     10 |        0 | C          | C        | t             | f            |           -1 |        14146 |        1350
|          1663 | ORA             | {=c/Ruby,Ruby=CTc/Ruby}
 postgres   |     10 |        0 | C          | C        | f             | t            |           -1 |        14146 |        1352 |
1663 | ORA             | {=Tc/Ruby,Ruby=CTc/Ruby,chaojun=C/Ruby,hu
obinru=C/Ruby}
 mydatabase |  17000 |        0 | C          | C        | f             | t            |           -1 |        14146 |        1351
|          1663 | ORA             |
(4 rows)
```

**Step 3** Grant the permissions for creating foreign servers and using foreign tables to a common user as the administrator.

Use the connection to create a database as a database administrator.

You can use the **gsql** client to run the following command, switching to an administrator user, and connect to the new database:

```
\c mydatabase dbadmin;
```

Enter the password as prompted.

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**NOTE**

Note that you must use the administrator account to connect to the database where a foreign server is to be created and foreign tables are used; and then grant permissions to the common user.

By default, only system administrators can create foreign servers. Common users can create foreign servers only after being authorized. Run the following command to grant the permission:

```
GRANT ALL ON FOREIGN DATA WRAPPER hdfs_fdw TO dbuser;
```

The name of **FOREIGN DATA WRAPPER** must be **hdfs_fdw**. **dbuser** is the username for creating **SERVER**.

Run the following command to grant the user the permission to use foreign tables:

```
ALTER USER dbuser USEFT;
```

Query for the user.

```
SELECT r.rolname, r.rolsuper, r.rolinherit,
  r.rolcreaterole, r.rolcreatedb, r.rolcanlogin,
  r.rolconnlimit, r.rolvalidbegin, r.rolvaliduntil,
  ARRAY(SELECT b.rolname
        FROM pg_catalog.pg_auth_members m
        JOIN pg_catalog.pg_roles b ON (m.roleid = b.oid)
        WHERE m.member = r.oid) as memberof
, r.rolreplication
, r.rolauditadmin
, r.rolsystemadmin
, r.roluseft
FROM pg_catalog.pg_roles r
ORDER BY 1;
```

The authorization is successful if the **dbuser** information in the returned result contains the **UseFT** permission.

```
 rolname  | rolsuper | rolinherit | rolcreaterole | rolcreatedb | rolcanlogin | rolconnlimit | rolvalidbegin |
rolvaliduntil | memberof | rolreplication | rolauditadmin | rolsystemadmin | roluseft
-----------+----------+------------+---------------+-------------+-------------+--------------+---------------
+---------------+----------+----------------+---------------+----------------+----------
 dbuser    | f       | t        | f           | t         | t         |         -1 |            |            | {}      | f
| f           | f           | t
 lily      | f       | t        | f           | f         | t         |         -1 |            |            | {}      | f           |
f           | f           | f
 Ruby      | t       | t        | t           | t         | t         |         -1 |            |            | {}      | t
| t           | t           | t
```

**----End**

## Manually Creating a Foreign Server

**Step 1** Connect to the default database **gaussdb** as a database administrator through the database client tool provided by GaussDB(DWS).

You can use the **gsql** client to log in to the database in either of the following ways:

You can use either of the following methods to create the connection:

- If you have logged in to the gsql client, run the following command to switch the database and user:

```
\c postgres dbadmin;
```

Enter the password as prompted.

- If you have not logged in to the gsql client or have exited the gsql client by running the **\q** command, run the following command to reconnect to it:
  ```
  gsql -d postgres -h 192.168.2.30 -U dbadmin -p 8000 -W password -r
  ```

**Step 2** Run the following command to query the information about the foreign server that is automatically created:

```
SELECT * FROM pg_foreign_server;
```

The returned result is as follows:

```
                srvname                 | srvowner | srvfdw | srvtype | srvversion | srvacl
|                                      srvoptions
------------------------------------------------+----------+--------+---------+------------+--------
+-------------------------------------------------------------------------------------------------------------------------
 gsmpp_server                                   |       10 |  13673 |         |            |
 gsmpp_errorinfo_server                         |       10 |  13678 |         |            |
 hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca |    16476 |  13685 |         |            |
{"address=192.168.1.245:25000,192.168.1.218:25000",hdfscfgpath=/MRS/8f79ada0-
d998-4026-9020-80d6de2692ca,type=hdfs}
(3 rows)
```

In the query result, each row contains the information about a foreign server. The foreign server associated with the MRS data source connection contains the following information:

- The value of **srvname** contains **hdfs_server** and the ID of the MRS cluster, which is the same as the MRS ID in the cluster list on the MRS management console.
- The **address** parameter in the **srvoptions** field contains the IP addresses and ports of the active and standby nodes in the MRS cluster.

You can find the foreign server you want based on the above information and record the values of its **srvname** and **srvoptions**.

**Step 3** Switch to the user who is about to create a foreign server to connect to the corresponding database.

In this example, run the following command to use common user **dbuser** created in **Creating a User and a Database and Granting the User Foreign Table Permissions** to connect to **mydatabase** created by the user:

```
\c mydatabase dbuser;
```

**Step 4** Create a foreign server.

For details about the syntax for creating foreign servers, see CREATE SERVER. For example:

```
CREATE SERVER hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca FOREIGN DATA WRAPPER
HDFS_FDW
OPTIONS
(
address '192.168.1.245:25000,192.168.1.218:25000',
hdfscfgpath '/MRS/8f79ada0-d998-4026-9020-80d6de2692ca',
type 'hdfs'
);
```

Mandatory parameters are described as follows:

- *Name of the foreign server*

  You can customize a name.

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In this example, specify the name to the value of the **srvname** field recorded in **Step 2**, such as *hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca*.

Resources in different databases are isolated. Therefore, the names of foreign servers in different databases can be the same.

- **FOREIGN DATA WRAPPER**

  This parameter can only be set to **HDFS_FDW**, which already exists in the database.

- **OPTIONS** parameters

  Set the following parameters to the values under **srvoptions** recorded in **Step 2**.

  – address

    Specifies the IP address and port number of the primary and standby nodes of the HDFS cluster.

  – hdfscfgpath

    Specifies the configuration file path of the HDFS cluster. This parameter is available only when **type** is **HDFS**. You can set only one path.

  – type

    Its value is **hdfs**, which indicates that **HDFS_FDW** connects to HDFS.

**Step 5** View the foreign server.

```
SELECT * FROM pg_foreign_server WHERE
srvname='hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca';
```

The server is successfully created if the returned result is as follows:

```
                srvname                 | srvowner | srvfdw | srvtype | srvversion | srvacl
|                                       srvoptions
------------------------------------------------+----------+--------+---------+------------+--------
+-------------------------------------------------------------------------------------------------------------------------
 hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca |    16476 |  13685 |         |            |        |
{"address=192.168.1.245:25000,192.168.1.218:25000",hdfscfgpath=/MRS/8f79ada0-
d998-4026-9020-80d6de2692ca,type=hdfs}
(1 row)
```

**----End**

## 3.2.3.4 Creating a Foreign Table

This section describes how to create a Hadoop foreign table in the GaussDB(DWS) database to access the Hadoop structured data stored on MRS HDFS. A Hadoop foreign table is read-only. It can only be queried using **SELECT**.

You can perform the following steps to create a foreign table:

1. Ensure that you have completed preparations in **Prerequisites**.
2. According to the description of the syntax **CREATE FOREIGN TABLE (SQL on Hadoop or OBS)**, you need to obtain the following information:
   a. **Obtaining the HDFS Path of the MRS Data Source**
   b. **Obtaining Information About the Foreign Server Connected to the MRS Data Source**
3. **Creating a Foreign Table**

   Reference information: **Data Type Conversion**

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## Prerequisites

- You have created an MRS cluster and imported data to the ORC table in the Hive/Spark database.

  For details, see **Preparing Data in an MRS Cluster**.
- You have created an MRS data source connection for the GaussDB(DWS) cluster.

## Obtaining the HDFS Path of the MRS Data Source

There are two methods for you to obtain the HDFS path.

- **Method 1**

  For Hive data, log in to the Hive client of MRS (see **2**), run the following command to view the detailed information about the table, and record the data storage path in the **location** parameter:

  ```
  use <database_name>;
  desc formatted <table_name>;
  ```

  For example, if the value of the **location** parameter in the returned result is **hdfs://hacluster/user/hive/warehouse/demo.db/product_info_orc/**, the HDFS path is **/user/hive/warehouse/demo.db/product_info_orc/**.
- **Method 2**

  Perform the following steps to obtain the HDFS path:

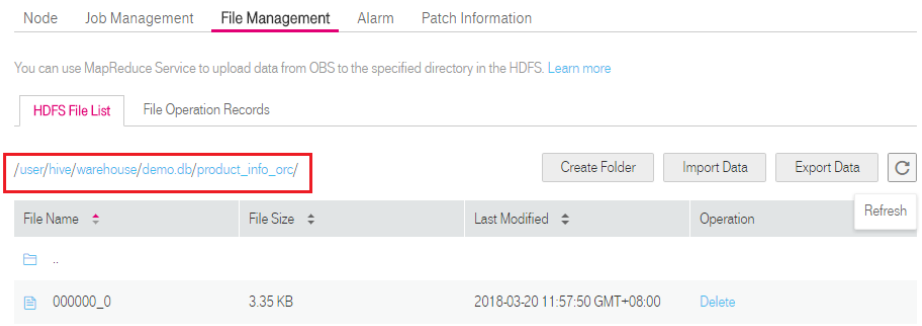
  a. Log in to the MRS management console.

  b. Choose **Cluster** > **Active Cluster** and click the name of the cluster to be queried to enter the page displaying the cluster's basic information.

  c. Click **File Management** and select **HDFS File List**.

  d. Go to the storage directory of the data to be imported to the GaussDB(DWS) cluster and record the path.

  **Figure 3-6** Checking the data storage path on MRS

## Obtaining Information About the Foreign Server Connected to the MRS Data Source

**Step 1** Use the user who creates the foreign server to connect to the corresponding database.

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Determine whether to use a common user to create a foreign table in the customized database based on requirements.

- **Yes**

  a. Ensure that you have created the common user **dbuser** and its database **mydatabase**, and manually created a foreign server in **mydatabase** by following steps in **Manually Creating a Foreign Server**.

  b. Connect to the database **mydatabase** as user **dbuser** through the database client tool provided by GaussDB(DWS).

     If you have connected to the database using the gsql client, run the following command to switch the user and database:

     ```
     \c mydatabase dbuser;
     ```

     Enter your password as prompted.

- **No**

  When you create an MRS data source connection on the GaussDB(DWS) management console, the database administrator **dbadmin** automatically creates a foreign server in the default database **postgres**. To create a foreign table in the default database **postgres** as the database administrator **dbadmin**, you need to use the database client tool provided by GaussDB(DWS) to connect to the database. For example, use the **gsql** client to connect to the database by running the following command:

  ```
  gsql -d postgres -h 192.168.2.30 -U dbadmin -p 8000 -W password -r
  ```

  Enter your password as prompted.

**Step 2** Run the following command to view the information about the created foreign server connected to the MRS data source:

```
SELECT * FROM pg_foreign_server;
```

NOTE

You can also run the **\desc+** command to view the information about the foreign server.

The returned result is as follows:

```
                srvname                 | srvowner | srvfdw | srvtype | srvversion | srvacl
|                                        srvoptions
------------------------------------------------+----------+--------+---------+------------+--------
+-----------------------------------------------------------------------------------------------------------------------------------
 gsmpp_server                                   |       10 |  13673 |         |            |
 gsmpp_errorinfo_server                         |       10 |  13678 |         |            |
 hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca |    16476 |  13685 |         |            |
{"address=192.168.1.245:25000,192.168.1.218:25000",hdfscfgpath=/MRS/8f79ada0-
d998-4026-9020-80d6de2692ca,type=hdfs}
(3 rows)
```

In the query result, each row contains the information about a foreign server. The foreign server associated with the MRS data source connection contains the following information:

- The value of **srvname** contains **hdfs_server** and the ID of the MRS cluster, which is the same as the MRS ID in the cluster list on the MRS management console.
- The **address** parameter in the **srvoptions** field contains the IP addresses and ports of the active and standby nodes in the MRS cluster.

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You can find the foreign server you want based on the above information and record the values of its **srvname** and **srvoptions**.

**----End**

## Creating a Foreign Table

After **Obtaining Information About the Foreign Server Connected to the MRS Data Source** and **Obtaining the HDFS Path of the MRS Data Source** are completed, you can create a foreign table to read data from the MRS data source.

The syntax for creating a foreign table is as follows. For details, see the syntax **CREATE FOREIGN TABLE (SQL on Hadoop or OBS)**.

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name
( [ { column_name type_name
   [ { [CONSTRAINT constraint_name] NULL |
   [CONSTRAINT constraint_name] NOT NULL |
     column_constraint [...]} ] |
     table_constraint [, ...]} [, ...] ] )
   SERVER dfs_server
   OPTIONS ( { option_name ' value ' } [, ...] )
   DISTRIBUTE BY {ROUNDROBIN | REPLICATION}
   [ PARTITION BY ( column_name ) [ AUTOMAPPED ] ] ;
```

For example, when creating a foreign table named *foreign_product_info*, set parameters in the syntax as follows:

- **table_name**

  Mandatory. This parameter specifies the name of the foreign table to be created.

- Table column definitions
  - **column_name**: specifies the name of a column in the foreign table.
  - **type_name**: specifies the data type of the column.

  Multiple columns are separate by commas (,).

  The number of columns and column types in the foreign table must be the same as those in the data stored on MRS. Learn **Data Type Conversion** before defining column data types.

- **SERVER dfs_server**

  This parameter specifies the foreign server name of the foreign table. This server must exist. The foreign table can read data from an MRS cluster by configuring the foreign server and connecting to the MRS data source.

  Enter the value of the **srvname** field queried in **Obtaining Information About the Foreign Server Connected to the MRS Data Source**.

- **OPTIONS** parameters

  These are parameters associated with the foreign table. The key parameters are as follows:
  - **format**: This parameter is mandatory. The value can only be **orc**. It specifies the format of the source data file. Only Hive ORC files are supported.
  - **foldername**: This parameter is mandatory. It specifies the HDFS directory for storing data or data file path.

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If the MRS analysis cluster has enabled Kerberos authentication, ensure that the MRS user having the MRS data source connection has the read and write permissions for the directory.

Follow the steps in **Obtaining the HDFS Path of the MRS Data Source** to obtain the HDFS path, which is the value of parameter **foldername**.

- **encoding**: This parameter is optional. It specifies the encoding format of a source data file in the foreign table. Its default value is **utf8**.
- **DISTRIBUTE BY**

  This parameter specifies the data read mode for the foreign table. There are two read modes supported. In this example, **ROUNDROBIN** is selected.

  - **ROUNDROBIN**: When a foreign table reads data from the data source, each node in a GaussDB(DWS) cluster randomly reads some data and integrates the random data to a complete data set.
  - **REPLICATION**: When a foreign table reads data from the data source, each node in the GaussDB(DWS) cluster reads a complete data set.
- Other parameters in the syntax

  Other parameters are optional. You can set them as required. In this example, you do not need to set these parameters.

Based on the above settings, the foreign table is created using the following statements:

```
DROP FOREIGN TABLE IF EXISTS foreign_product_info;

CREATE FOREIGN TABLE foreign_product_info
(
    product_price                integer        ,
    product_id                   char(30)       ,
    product_time                 date           ,
    product_level                char(10)       ,
    product_name                 varchar(200)   ,
    product_type1                varchar(20)    ,
    product_type2                char(10)       ,
    product_monthly_sales_cnt    integer        ,
    product_comment_time         date           ,
    product_comment_num          integer        ,
    product_comment_content      varchar(200)
) SERVER hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca
OPTIONS (
format 'orc',
encoding 'utf8',
foldername '/user/hive/warehouse/demo.db/product_info_orc/'
)
DISTRIBUTE BY ROUNDROBIN;
```

## Data Type Conversion

Data is imported to Hive/Spark and then stored on HDFS in ORC format. Actually, GaussDB(DWS) reads ORC files on HDFS, and queries and analyzes data in these files.

Data types supported by Hive/Spark are different from those supported by GaussDB(DWS). Therefore, you need to learn the mapping between them. **Table 3-11** describes the mapping in detail.

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**Table 3-11** Data type mapping

| Type | Column Type Supported by an HDFS/OBS Foreign Table of GaussDB(DWS) | Column Type Supported by a Hive Table | Column Type Supported by a Spark Table |
| --- | --- | --- | --- |
| Integer in two bytes | SMALLINT | SMALLINT | SMALLINT |
| Integer in four bytes | INTEGER | INT | INT |
| Integer in eight bytes | BIGINT | BIGINT | BIGINT |
| Single-precision floating point number | FLOAT4 (REAL) | FLOAT | FLOAT |
| Double-precision floating point number | FLOAT8(DOUBLE PRECISION) | DOUBLE | FLOAT |
| Scientific data type | DECIMAL[p (,s)]<br>The maximum precision can reach up to 38. | DECIMAL<br>The maximum precision can reach up to 38 (Hive 0.11). | DECIMAL |
| Date type | DATE | DATE | DATE |
| Time type | TIMESTAMP | TIMESTAMP | TIMESTAMP |
| BOOLEAN type | BOOLEAN | BOOLEAN | BOOLEAN |
| CHAR type | CHAR(n) | CHAR (n) | STRING |
| VARCHAR type | VARCHAR(n) | VARCHAR (n) | VARCHAR (n) |
| String | TEXT(CLOB) | STRING | STRING |

### 3.2.3.5 Importing Data

## Viewing Data in the MRS Data Source by Directly Querying the Foreign Table

If the data amount is small, you can directly run SELECT to query the foreign table and view the data in the MRS data source.

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**Step 1** Run the following command to query data from the foreign table:

```
SELECT * FROM foreign_product_info;
```

If the query result is the same as the data in **Data File**, the import is successful. The following information is displayed at the end of the query result:

```
(20 rows)
```

After data is queried, you can insert the data to common tables in the database.

**----End**

## Querying Data After Importing It

You can query the MRS data after importing it to GaussDB(DWS).

**Step 1** Create a table in GaussDB(DWS) to store imported data.

The target table structure must be the same as the structure of the foreign table created in **Creating a Foreign Table**. That is, both tables must have the same number of columns and column types.

For example, create a table named **product_info**. The table example is as follows:

```
DROP TABLE IF EXISTS product_info;
CREATE TABLE product_info
(
    product_price               integer        ,
    product_id                  char(30)       ,
    product_time                date           ,
    product_level               char(10)       ,
    product_name                varchar(200)   ,
    product_type1               varchar(20)    ,
    product_type2               char(10)       ,
    product_monthly_sales_cnt   integer        ,
    product_comment_time        date           ,
    product_comment_num         integer        ,
    product_comment_content     varchar(200)
)
with (
orientation = column,
compression=middle
)
DISTRIBUTE BY HASH (product_id);
```

**Step 2** Run the **INSERT INTO .. SELECT ..** command to import data from the foreign table to the target table.

Example:

```
INSERT INTO product_info SELECT * FROM foreign_product_info;
```

If information similar to the following is displayed, the data has been imported.

```
INSERT 0 20
```

**Step 3** Run the following **SELECT** command to view data imported from MRS to GaussDB(DWS):

```
SELECT * FROM product_info;
```

If the query result is the same as the data in **Data File**, the import is successful. The following information is displayed at the end of the query result:

```
(20 rows)
```

**----End**

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### 3.2.3.6 Deleting Resources

After completing operations in this tutorial, if you no longer need to use the resources created during the operations, you can delete them to avoid resource waste or quota occupation.

## Deleting the Foreign Table and Target Table

**Step 1** (Optional) If operations in **Querying Data After Importing It** have been performed, run the following command to delete the target table:

```
DROP TABLE product_info;
```

**Step 2** Run the following command to delete the foreign table:

```
DROP FOREIGN TABLE foreign_product_info;
```

**----End**

## Deleting the Manually Created Foreign Server

If operations in **Manually Creating a Foreign Server** have been performed, perform the following steps to delete the foreign server, database, and user:

**Step 1** Use the client provided by GaussDB(DWS) to connect to the database where the foreign server resides as the user who created the foreign server.

You can use the **gsql** client to log in to the database in either of the following ways:

- If you have logged in to the gsql client, run the following command to switch the database and user:
  ```
  \c mydatabase dbuser;
  ```
  Enter the password as prompted.
- If you have logged in to the gsql client, you can run the **\q** command to exit gsql, and run the following command to reconnect to it:
  ```
  gsql -d mydatabase -h 192.168.2.30 -U dbuser -p 8000 -r
  ```
  Enter the password as prompted.

**Step 2** Delete the manually created foreign server.

Run the following command to delete the server. For details about the syntax, see DROP SERVER.

```
DROP SERVER hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca;
```

The foreign server is deleted if the following information is displayed:

```
DROP SERVER
```

View the foreign server.

```
SELECT * FROM pg_foreign_server WHERE
srvname='hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca';
```

The server is successfully deleted if the returned result is as follows:

```
 srvname | srvowner | srvfdw | srvtype | srvversion | srvacl | srvoptions
---------+----------+--------+---------+------------+--------+------------
(0 rows)
```

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**Step 3** Delete the customized database.

Connect to the default database **gaussdb** through the database client tool provided by GaussDB(DWS).

If you have logged in to the database using the **gsql** client, run the following command to switch the database and user:

```
\c gaussdb
```

Enter your password as prompted.

Run the following command to delete the customized database:

```
DROP DATABASE mydatabase;
```

The database is deleted if the following information is displayed:

```
DROP DATABASE
```

**Step 4** Delete the common user created in this example as the administrator.

Connect to the database as a database administrator through the database client tool provided by GaussDB(DWS).

If you have logged in to the database using the **gsql** client, run the following command to switch the database and user:

```
\c gaussdb dbadmin
```

Run the following command to reclaim the permission for creating foreign servers:

```
REVOKE ALL ON FOREIGN DATA WRAPPER hdfs_fdw FROM dbuser;
```

The name of **FOREIGN DATA WRAPPER** must be **hdfs_fdw**. **dbuser** is the username for creating **SERVER**.

Run the following command to delete the user:

```
DROP USER dbuser;
```

You can run the **\du** command to query for the user and check whether the user has been deleted.

**----End**

## 3.2.3.7 Error Handling

The following error information indicates that GaussDB(DWS) is to read an ORC data file but the actual file is in text format. Therefore, create a table of the Hive ORC type and store the data to the table.

```
ERROR:  dn_6009_6010: Error occurs while creating an orc reader for file /user/hive/warehouse/
products_info.txt, detail can be found in dn log of dn_6009_6010.
```

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# 3.2.4 Importing Data from One GaussDB(DWS) Cluster to Another

## Function

You can create foreign tables to perform associated queries and import data between clusters.

## Scenarios

- Import data from one GaussDB(DWS) cluster to another.
- Perform associated queries between clusters.

## Precautions

- The two clusters must be in the same region and AZ, and can communicate with each other through the VPC network.
- The created foreign table must be of the same type and have the same columns as its corresponding remote table, which can only be a row-store, column-store, hash, or replication table.
- If the associated table in another cluster is a replication table or has data skew, the query performance may be poor.
- The status of the two clusters is **Normal**.
- Do not modify, add, or delete the DDL of the source data table in the remote cluster. Otherwise, the query results may be inconsistent.
- The two clusters can process SQL on other GaussDB databases based on a foreign table.
- You are advised to configure LVS. If it is not configured, you are advised to use multiple CNs as the server addresses. Do not write the CN addresses of multiple clusters together.
- Ensure that the two databases have the same encoding. Otherwise, an error may occur or the received data may be garbled characters.
- If statistics have been collected on the remote table, run **ANALYZE** on the foreign table to obtain a better execution plan.
- Only 8.0.0 and later versions are supported.

## Procedure

**Step 1** Create a server.

```
CREATE SERVER server_remote FOREIGN DATA WRAPPER GC_FDW OPTIONS
   (address '10.180.157.231:8000,10.180.157.130:8000' ,
  dbname 'gaussdb',
  username 'xyz',
  password 'xxxxxx'
);
```

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NOTE

- **server_remote** is the server name used for the foreign table.
- **address** indicates the IP addresses and port numbers of CNs in the remote cluster. If LVS is configured, you are advised to enter only one LVS address. Otherwise, you are advised to set multiple CNs as server addresses.
- **dbname** is the database name of the remote cluster.
- **username** is the username used for connecting to the remote cluster. This user cannot be a system administrator.
- **password** is the password used for logging in to the remote cluster.

**Step 2** Create a foreign table.

```
 CREATE FOREIGN TABLE region
(
    R_REGIONKEY INT4,
    R_NAME TEXT,
    R_COMMENT TEXT
)
SERVER
    server_remote
OPTIONS
(
    schema_name 'test',
    table_name 'region',
    encoding 'gbk'
);
```

NOTE

- Foreign table columns cannot contain any constraints.
- The column names types of the foreign table must be the same as those of its corresponding remote table.
- **schema_name** specifies the schema of the foreign table corresponding to the remote cluster. If this parameter is not specified, the default schema is used.
- **table_name** specifies the name of the foreign table corresponding to the remote cluster. If this parameter is not specified, the default foreign table name is used.
- **encoding** specifies the encoding format of the remote cluster. If this parameter is not specified, the default encoding format is used.

**Step 3** View the foreign table.

```
\d+ region

                        Foreign table "public.region"
  Column    |  Type   | Modifiers | FDW Options | Storage  | Stats target | Description
------------+---------+-----------+-------------+----------+--------------+-------------
 r_regionkey | integer |           |             | plain    |              |
 r_name      | text    |           |             | extended |              |
 r_comment   | text    |           |             | extended |              |
Server: server_remote
FDW Options: (schema_name 'test', table_name 'region', encoding 'gbk')
FDW permition: read only
Has OIDs: no
Distribute By: ROUND ROBIN
Location Nodes: ALL DATANODES
```

**Step 4** Check the created server.

```
\des+ server_remote
                                                
```

```
-----------------------------------------------------------------------------------------------------------------------
+-------------
 server_remote | dbadmin | gc_fdw               |                  |      |        | (address
'10.180.157.231:8000,10.180.157.130:8000', dbname 'gaussdb'
, username 'xyz', password 'xxxxxx') |
(1 row)
```

**Step 5** Use the foreign table to import data or perform associated queries.

- Import data.

```
CREATE TABLE local_region
(
    R_REGIONKEY INT4,
    R_NAME TEXT,
    R_COMMENT TEXT
);
INSERT INTO local_region SELECT * FROM region;
```

  NOTE

  - If a connection failure is reported, check the server information and ensure that the specified clusters are connected.
  - If an error is reported, indicating that the table does not exist, check whether the **option** information of the foreign table is correct.
  - If a column mismatch error is reported, check whether the column information of the foreign table is consistent with that of the corresponding table in the remote cluster.
  - If a version inconsistency error is reported, upgrade the cluster and try again.
  - If garbled characters are displayed, check the encoding format of the source data, re-create a foreign table, and specify the correct coding format.

- Perform an associated query.

```
SELECT * FROM region, local_region WHERE local_region.R_NAME = region.R_NAME;
```

  NOTE

  - A foreign table can be used as a local table to perform complex jobs.
  - If statistics have been collected on the remote cluster, run **ANALYZE** on the foreign table to obtain a better execution plan.
  - If there are fewer DNs in the local cluster than in the remote cluster, the local cluster needs to use SMP for better performance.

**Step 6** Delete the foreign table.

```
DROP FOREIGN TABLE region;
```

**----End**

# 3.2.5 Using the gsql Meta-Command \COPY to Import Data

The **gsql** tool of GaussDB(DWS) provides the **\copy** meta-command to import data.

## \copy Command

For details about the **\copy** command, see **Table 3-12**.

**Table 3-12** \copy meta-command

| Syntax | Description |
| --- | --- |
| \copy { table [ ( column_list ) ] \| ( query ) } { from \| to } { filename \| stdin \| stdout \| pstdin \| pstdout } [ with ] [ binary ] [ oids ] [ delimiter [ as ] 'character' ] [ null [ as ] 'string' ] [ csv [ header ] [ quote [ as ] 'character' ] [ escape [ as ] 'character' ] [ force quote column_list \| * ] [ force not null column_list ] ] | You can run this command to import or export data after logging in to the database on any gsql client. Different from the **COPY** statement in SQL, this command performs read/write operations on local files rather than files on database servers. The accessibility and permissions of the local files are restricted to local users.<br>**NOTE**<br>**\copy** only applies to small-batch data import with uniform formats but poor error tolerance capability. GDS or **COPY** is preferred for data import. |

## Parameter Description

- table

  Specifies the name (possibly schema-qualified) of an existing table.

  Value range: an existing table name

- column_list

  Specifies an optional list of columns to be copied.

  Value range: any field in the table. If the column list is not specified, all columns in the table will be copied.

- query

  Specifies that the results will be copied.

  Valid value: a **SELECT** or **VALUES** command in parentheses.

- filename

  Specifies the absolute path of a file. To run the **\copy** command, the user must have the write permission for this path.

- stdin

  Specifies that input comes from the client application.

- stdout

  Specifies that output goes to the client application.

- pstdin

  Specifies that input comes from the gsql client.

- pstout
- Specifies that output goes to the gsql client.
- binary

  Specifies that data is stored and read in binary mode instead of text mode. In binary mode, you cannot declare **DELIMITER**, **NULL**, or **CSV**. After specifying BINARY, CSV, FIXED and TEXT cannot be specified through **option** or **copy_option**.

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- oid

  Specifies the internal OID to be copied for each row.

  NOTE

  An error is raised if OIDs are specified for a table that does not have OIDs, or in the case of copying a query.

  Valid value: **true**, **on**, **false**, and **off**.

  Default value: **false**

- delimiter [ as ] 'character'

  Specifies the character that separates columns within each row (line) of the file.

  NOTE

  - A delimiter cannot be **\r** or **\n**.
  - A delimiter cannot be the same as the **null** value. The delimiter of CSV data cannot be same as the **quote** value.
  - The delimiter of TEXT data cannot contain any of the following characters: \.abcdefghijklmnopqrstuvwxyz0123456789
  - The data length of a single row should be less than 1 GB. A row that has many columns using long delimiters cannot contain much valid data.
  - You are advised to use multi-characters and invisible characters for delimiters. For example, you can use the multiple-character delimiter "$^&" and invisible delimiters, such as E'\x07', E'\x08', and E'\x1b'.

  Value range: a multi-character delimiter within 10 bytes.

  Default value:

  – A tab character in TEXT format
  – A comma (,) in CSV format
  – No delimiter in FIXED format

- null [ as ] 'string'

  Specifies that a string represents a null value in a data file.

  Value range:

  – A null value cannot be **\r** or **\n**. The maximum length is 100 characters.
  – A null value cannot be the same as the **delimiter** or **quote** value.

  Default value:

  – An empty string without quotation marks in CSV format
  – **\N** in TEXT format

- header

  Specifies whether a data file contains a table header. **header** is available only for CSV and FIXED files.

  In data import scenarios, if **header** is **on**, the first row of the data file will be identified as the header and ignored. If **header** is **off**, the first row will be identified as a data row.

  If header is **on**, **fileheader** must be specified. **fileheader** specifies the content in the header. If header is **off**, the exported file does not contain a header.

  Valid value: **true**, **on**, **false**, and **off**.

  Default value: **false**

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- quote [ as ] 'character'

  Specifies the quote character for a CSV file.

  Default value: double quotation mark ("").

  NOTE

  - The **quote** value cannot be the same as the **delimiter** or **null** value.
  - The **quote** value must be a single-byte character.
  - You are advised to use invisible characters as quotes, for example, E'\x07', E'\x08', and E'\x1b'.

- escape [ as ] 'character'

  This option is allowed only when using CSV format. This must be a single one-byte character.

  Default value: double quotation mark ("). If the value is the same as the **quote** value, it will be replaced with **\0**.

- force quote column_list | *

  In CSV COPY TO mode, forces quoting to be used for all not-null values in each specified column. NULL will not be quoted.

  Value range: an existing column.

- force not null column_list

  In CSV COPY FROM mode, processes each specified column as though it were quoted and hence not a null value.

  Value range: an existing column.

## Examples

1. Create a target table, **a**.

```
CREATE TABLE a(a int);
```

2. Import data.

   a. Copy data from **stdin** to table **a**.

```
\copy a from stdin;
```

   When the **>>** characters are displayed, enter data. Enter a backslash and a period (\.) to end your input.

```
Enter data to be copied followed by a newline.
End with a backslash and a period on a line by itself.
>> 1
>> 2
>> \.
```

   Query data imported to table **a**.

```
SELECT * FROM a;
 a
---
 1
 2
(2 rows)
```

   b. Copy data from a local file to table **a**. Assume that the local file is **/home/omm/2.csv**.

      - Commas (,) are used as delimiters.

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- If the number of columns defined in the source data file is greater than that in a foreign table, extra columns will be ignored during import.

```
\copy a FROM '/home/omm/2.csv' WITH (delimiter',',IGNORE_EXTRA_DATA 'on');
```

# 3.2.6 Running the COPY FROM STDIN Statement to Import Data

## 3.2.6.1 Data Import Using COPY FROM STDIN

This method is applicable to low-concurrency scenarios where a small volume of data is to be imported.

Use either of the following methods to write data to GaussDB(DWS) using the **COPY FROM STDIN** statement:

- Write data into GaussDB(DWS) by typing.
- Import data from a file or database to GaussDB(DWS) through the CopyManager interface driven by JDBC. You can use any parameters in the **COPY** syntax.

## 3.2.6.2 Introduction to the CopyManager Class

CopyManager is an API interface class provided by the JDBC driver in GaussDB(DWS). It is used to import data to GaussDB(DWS) in batches.

## Inheritance Relationship of CopyManager

The CopyManager class is in the **org.postgresql.copy** package class and is inherited from the java.lang.Object class. The declaration of the class is as follows:

```
public class CopyManager
extends Object
```

## Constructor Method

public CopyManager(BaseConnection connection)

throws SQLException

## Basic Methods

**Table 3-13** Basic methods of CopyManager

| Return Value | Method | Description | Throws |
| --- | --- | --- | --- |
| CopyIn | copyIn(String sql) | - | SQLException |


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| Return Value | Method | Description | Throws |
| --- | --- | --- | --- |
| long | copyIn(String sql, InputStream from) | Uses **COPY FROM STDIN** to quickly import data to tables in a database from InputStream. | SQLException,IOException |
| long | copyIn(String sql, InputStream from, int bufferSize) | Uses **COPY FROM STDIN** to quickly import data to tables in a database from InputStream. | SQLException,IOException |
| long | copyIn(String sql, Reader from) | Uses **COPY FROM STDIN** to quickly import data to tables in a database from Reader. | SQLException,IOException |
| long | copyIn(String sql, Reader from, int bufferSize) | Uses **COPY FROM STDIN** to quickly import data to tables in a database from Reader. | SQLException,IOException |
| CopyOut | copyOut(String sql) | - | SQLException |
| long | copyOut(String sql, OutputStream to) | Sends the result set of **COPY TO STDOUT** from a database to the OutputStream class. | SQLException,IOException |
| long | copyOut(String sql, Writer to) | Sends the result set of **COPY TO STDOUT** from a database to the Writer class. | SQLException,IOException |

### 3.2.6.3 Example: Importing and Exporting Data Through Local Files

When the JAVA language is used for secondary development based on GaussDB(DWS), you can use the CopyManager interface to export data from the database to a local file or import a local file to the database by streaming. The file can be in CSV or TEXT format.

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The sample program is as follows. Load the GaussDB(DWS) JDBC driver before running it.

```
//gsjdbc4.jar is used as an example. If gsjdbc200.jar is used, replace the class name org.postgresql with com.huawei.gauss200.jdbc and replace the URL prefix jdbc:postgresql with jdbc:gaussdb.
import java.sql.Connection;
import java.sql.DriverManager;
import java.io.IOException;
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.sql.SQLException;
import org.postgresql.copy.CopyManager;
import org.postgresql.core.BaseConnection;

public class Copy{

    public static void main(String[] args)
    {
     String urls = new String("jdbc:postgresql://10.180.155.74:8000/gaussdb"); //Database URL
     String username = new String("jack");            //Username
     String password = new String("********");       // Password
     String tablename = new String("migration_table"); //Define table information.
     String tablename1 = new String("migration_table_1"); //Define table information.
     String driver = "org.postgresql.Driver";
     Connection conn = null;

     try {
           Class.forName(driver);
           conn = DriverManager.getConnection(urls, username, password);
         } catch (ClassNotFoundException e) {
             e.printStackTrace(System.out);
         } catch (SQLException e) {
             e.printStackTrace(System.out);
         }

     //Export the query result of SELECT * FROM migration_table to the local file d:/data.txt.
     try {
    copyToFile(conn, "d:/data.txt", "(SELECT * FROM migration_table)");
  } catch (SQLException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
  } catch (IOException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
  }
     //Import data from the d:/data.txt file to the migration_table_1 table.
     try {
     copyFromFile(conn, "d:/data.txt", tablename1);
  } catch (SQLException e) {
 // TODO Auto-generated catch block
        e.printStackTrace();
} catch (IOException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
}

     //Export the data from the migration_table_1 table to the d:/data1.txt file.
     try {
     copyToFile(conn, "d:/data1.txt", tablename1);
  } catch (SQLException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
  } catch (IOException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
}
    }

 public static void copyFromFile(Connection connection, String filePath, String tableName)
```

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```
        throws SQLException, IOException {

    FileInputStream fileInputStream = null;

    try {
        CopyManager copyManager = new CopyManager((BaseConnection)connection);
        fileInputStream = new FileInputStream(filePath);
        copyManager.copyIn("COPY " + tableName + " FROM STDIN", fileInputStream);
    } finally {
        if (fileInputStream != null) {
            try {
                fileInputStream.close();
            } catch (IOException e) {
                e.printStackTrace();
            }
        }
    }
}

 public static void copyToFile(Connection connection, String filePath, String tableOrQuery)
        throws SQLException, IOException {

     FileOutputStream fileOutputStream = null;

     try {
        CopyManager copyManager = new CopyManager((BaseConnection)connection);
        fileOutputStream = new FileOutputStream(filePath);
        copyManager.copyOut("COPY " + tableOrQuery + " TO STDOUT", fileOutputStream);
     } finally {
        if (fileOutputStream != null) {
            try {
                fileOutputStream.close();
            } catch (IOException e) {
                e.printStackTrace();
            }
        }
     }
 }
}
```

## 3.2.6.4 Example: Migrating Data from MySQL to GaussDB(DWS)

The following example shows how to use CopyManager to migrate data from MySQL to GaussDB(DWS).

```
//gsjdbc4.jar is used as an example. If gsjdbc200.jar is used, replace the driver class name org.postgresql with com.huawei.gauss200.jdbc and replace the URL prefix jdbc:postgresql with jdbc:gaussdb.
import java.io.StringReader;
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;

import org.postgresql.copy.CopyManager;
import org.postgresql.core.BaseConnection;

public class Migration{

    public static void main(String[] args) {
        String url = new String("jdbc:postgresql://10.180.155.74:8000/gaussdb"); //Database URL
        String user = new String("jack");            //Database username
        String pass = new String("********");            //Database password
        String tablename = new String("migration_table"); //Define table information.
        String delimiter = new String("|");              //Define a delimiter.
        String encoding = new String("UTF8");            //Define a character set.
        String driver = "org.postgresql.Driver";
        StringBuffer buffer = new StringBuffer();       //Define the buffer to store formatted data.
```

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```
        try {
            //Obtain the query result set of the source database.
            ResultSet rs = getDataSet();

            //Traverse the result set and obtain records row by row.
            //The values of columns in each record are separated by the specified delimiter and end with a
newline character to form strings.
            ////Add the strings to the buffer.
            while (rs.next()) {
                buffer.append(rs.getString(1) + delimiter
                        + rs.getString(2) + delimiter
                        + rs.getString(3) + delimiter
                        + rs.getString(4)
                        + "\n");
            }
            rs.close();

            try {
                //Connect to the target database.
                Class.forName(driver);
                Connection conn = DriverManager.getConnection(url, user, pass);
                BaseConnection baseConn = (BaseConnection) conn;
                baseConn.setAutoCommit(false);

                //Initialize table information.
                String sql = "Copy " + tablename + " from STDIN DELIMITER " + "'" + delimiter + "'" + "
ENCODING " + "'" + encoding + "'";

                //Submit data in the buffer.
                CopyManager cp = new CopyManager(baseConn);
                StringReader reader = new StringReader(buffer.toString());
                cp.copyIn(sql, reader);
                baseConn.commit();
                reader.close();
                baseConn.close();
            } catch (ClassNotFoundException e) {
                e.printStackTrace(System.out);
            } catch (SQLException e) {
                e.printStackTrace(System.out);
            }

        } catch (Exception e) {
            e.printStackTrace();
        }
    }

    //**********************************
    //Return the query result set from the source database.
    //**********************************
    private static ResultSet getDataSet() {
        ResultSet rs = null;
        try {
            Class.forName("com.mysql.jdbc.Driver").newInstance();
            Connection conn = DriverManager.getConnection("jdbc:mysql://10.119.179.227:3306/jack?
useSSL=false&allowPublicKeyRetrieval=true", "jack", "********");
            Statement stmt = conn.createStatement();
            rs = stmt.executeQuery("select * from migration_table");
        } catch (SQLException e) {
            e.printStackTrace();
        } catch (Exception e) {
            e.printStackTrace();
        }
        return rs;
    }
}
```

# 3.3 Full Database Migration

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# 3.3.1 Using CDM to Migrate Data to GaussDB(DWS)

You can use CDM to migrate data from other data sources (for example, MySQL) to the databases in clusters on GaussDB(DWS).

For details about scenarios where CDM is used to migrate data to GaussDB(DWS), see the following sections of *Cloud Data Migration User Guide*:

- **Getting Started**: describes how to use CDM to migrate local MySQL databases to GaussDB(DWS).

# 3.3.2 Using DSC to Migrate SQL Scripts

The DSC is a CLI tool running on the Linux or Windows OS. It is dedicated to providing customers with simple, fast, and reliable application SQL script migration services. It parses the SQL scripts of source database applications using the built-in syntax migration logic, and converts them to SQL scripts applicable to GaussDB(DWS) databases. You do not need to connect the DSC to a database. It can migrate data in offline mode without service interruption. In GaussDB(DWS), you can run the migrated SQL scripts to restore the database, thereby easily migrating offline databases to the cloud.

The DSC can migrate SQL scripts of Teradata, Oracle, Netezza, MySQL, and DB2 databases.

## Downloading the DSC SQL Migration Tool

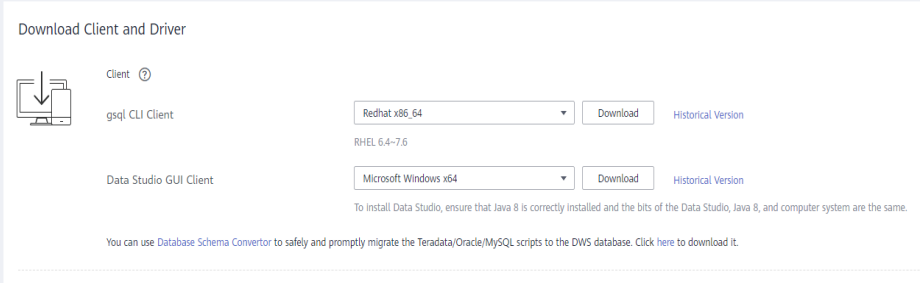
**Step 1** Log in to the GaussDB(DWS) management console.

**Step 2** In the navigation tree on the left, click **Connection Management**.

**Step 3** In the **Download Client and Driver** area, click **here** to download the DSC migration tool.

If you have clusters of different versions, the system displays a dialog box, prompting you to select the cluster version and download the client corresponding to the cluster version. In the cluster list on the **Cluster Management** page, click the name of the specified cluster and click the **Basic Information** tab to view the cluster version.

**Figure 3-7** Downloading the tool




**Step 4** After downloading the DSC tool to the local PC, use WinSCP to upload it to a Linux host.

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The user who uploads the tool must have the full control permission on the target directory of the Linux host.

**----End**

### Operation Guide for the DSC SQL Syntax Migration Tool

For details, see "DSC - SQL Syntax Migration Tool" in the *Data Warehouse Service Tool Guide*.

# 3.4 Metadata Migration

## 3.4.1 Using gs_dump and gs_dumpall to Export Metadata

### 3.4.1.1 Overview

GaussDB(DWS) provides gs_dump and gs_dumpall to export required database objects and related information. To migrate database information, you can use a tool to import the exported metadata to a target database. gs_dump exports a single database or its objects. gs_dumpall exports all databases or global objects in a cluster. For details, see **Table 3-14**.

**Table 3-14** Application scenarios

| Application Scenario | Export Granularity | Export Format | Import Method |
| --- | --- | --- | --- |
| Exporting a single database | **Database-level export**<br>• Export full information of a database.<br>You can use the exported information to create a same database containing the same data as the current one.<br>• Export all object definitions of a database, including the definitions of the database, functions, schemas, tables, indexes, and stored procedures.<br>You can use the exported object definitions to quickly create a same database as the current one, without data.<br>• Export data of a database. | • Plain text<br>• Custom<br>• Directory<br>• .tar | • For details about how to import data files in text format, see **Using the gsql Meta-Command \COPY to Import Data**.<br>• For details about how to import data files in .tar, directory, or custom format, see **Using gs_restore to Import Data**. |


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| Application Scenario | Export Granularity | Export Format | Import Method |
| --- | --- | --- | --- |
| | **Schema-level export**<br>• Export full information of a schema.<br>• Export data of a schema.<br>• Export all object definitions of a schema, including the definitions of tables, stored procedures, and indexes. | | |
| | **Table-level export**<br>• Export full information of a table.<br>• Export data of a table.<br>• Export the definition of a table. | | |
| Exporting all databases in a cluster | **Database-level export**<br>• Export full information of a cluster.<br>You can use the exported information to create a same cluster containing the same databases, global objects, and data as the current one.<br>• Export all object definitions of a cluster, including the definitions of tablespaces, databases, functions, schemas, tables, indexes, and stored procedures.<br>You can use the exported object definitions to quickly create a same cluster as the current one, containing the same databases and tablespaces but without data.<br>• Export data of a cluster. | Plain text | For details about how to import data files, see **Using the gsql Meta-Command \COPY to Import Data**. |
| | **Global object export**<br>• Export tablespaces.<br>• Export roles.<br>• Export tablespaces and roles. | | |


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gs_dump and gs_dumpall use **-U** to specify the user that performs the export. If the specified user does not have the required permission, data cannot be exported. In this case, you can set **--role** in the export command to the role that has the permission. Then, gs_dump or gs_dumpall uses the specified role to export data. See **Table 3-14** for application scenarios and **Data Export By a User Without Required Permissions** for operation details.

gs_dump and gs_dumpall encrypt the exported data files. These files are decrypted before being imported to prevent data disclosure for higher database security.

When gs_dump or gs_dumpall is used to export data from a cluster, other users can still access (read data from and write data to) databases in the cluster.

gs_dump and gs_dumpall can export complete, consistent data. For example, if gs_dump is used to export database A or gs_dumpall is used to export all databases from a cluster at T1, data of database A or all databases in the cluster at that time point will be exported, and modifications on the databases after that time point will not be exported.

Obtain gs_dump and gs_dumpall by decompressing the **gsql CLI client** package.

## Precautions

- Do not modify an exported file or its content. Otherwise, restoration may fail.
- For data consistency and integrity, gs_dump and gs_dumpall set a share lock for a table to be dumped. If a share lock has been set for the table in other transactions, gs_dump and gs_dumpall lock the table after the lock is released. If the table cannot be locked within the specified time, the dump fails. You can customize the timeout duration to wait for lock release by specifying the **--lock-wait-timeout** parameter.
- During an export, gs_dumpall reads all tables in a database. Therefore, you need to connect to the database as a cluster administrator to export a complete file. When you use gsql to import scripts, cluster administrator permissions are also required to add users and user groups, and create databases.
- By default, the definitions of all views in the GaussDB(DWS) database contain the prefix of table names or aliases (in **tab.col** format). Therefore, the definitions may be inconsistent with the original ones. As a result, the base table corresponding to the rebuilt view column is incorrect and an error is reported. However, this rarely happens. To prevent this problem, you are advised to set the GUC parameter **behavior_compat_options** to **compat_display_ref_table** when exporting view definitions, so the exported definitions are consistent with the original statements.

## 3.4.1.2 Exporting a Single Database

### 3.4.1.2.1 Exporting a Database

You can use gs_dump to export data and all object definitions of a database from GaussDB(DWS). You can specify the information to be exported as follows:

- Export full information of a database, including its data and all object definitions.

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You can use the exported information to create a same database containing the same data as the current one.

- Export all object definitions of a database, including the definitions of the database, functions, schemas, tables, indexes, and stored procedures.

  You can use the exported object definitions to quickly create a same database as the current one, without data.

- Export data of a database.

## Procedure

**Step 1** Prepare an ECS as the gsql client host. For details, see "Preparing an ECS as the gsql Client Host" in the *Data Warehouse Service (DWS) User Guide*.

**Step 2** Download the gsql client and use an SSH transfer tool (such as WinSCP) to upload it to the Linux server where gsql is to be installed. For details, see "Downloading the Client" in *Data Warehouse Service User Guide*.

The user who uploads the client must have the full control permission on the target directory on the host to which the client is uploaded.

**Step 3** Run the following commands to decompress the client:

```
cd <Path_for_storing_the_client>
unzip dws_client_8.1.x_redhat_x64.zip
```

Where,

- <*Path_for_storing_the_client*>: Replace it with the actual path.
- *dws_client_8.1.x_redhat_x86.zip*: This is the client tool package of **RedHat x86**. Replace it with the actual one.

**Step 4** Run the following command to configure the GaussDB(DWS) client:

```
source gsql_env.sh
```

If the following information is displayed, the GaussDB(DWS) client is successfully configured:

```
All things done.
```

**Step 5** Use gs_dump to export data of the database **gaussdb**.

```
gs_dump -W password -U jack -f /home//backup/postgres_backup.tar -p 8000 gaussdb  -h 10.10.10.100 -F t
```

**Table 3-15** Common parameters

| Parameter | Description | Example Value |
| --- | --- | --- |
| -U | Username for connecting to the database. If this parameter is not configured, the username of the connected database is used. | -U jack |

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| Parameter | Description | Example Value |
| --- | --- | --- |
| -W | User password for database connection.<br>● This parameter is not required for database administrators if the trust policy is used for authentication.<br>● If you connect to the database without specifying this parameter and you are not a database administrator, you will be prompted to enter the password. | -W *Password* |
| -f | Folder to store exported files. If this parameter is not specified, the exported files are stored in the standard output. | -f /home//backup/ *postgres*_backup.tar |
| -p | Name extension of the TCP port on which the server is listening or the local Unix domain socket. This parameter is configured to ensure connections. | -p 8000 |
| -h | *Cluster address*: If a public network address is used for connection, set this parameter to **Public Network Address** or **Public Network Domain Name**. If a private network address is used for connection, set this parameter to **Private Network Address** or **Private Network Domain Name**. | -h 10.10.10.100 |
| dbname | Name of the database to be exported. | gaussdb |
| -F | Format of exported files. The values of **-F** are as follows:<br>● **p**: plain text<br>● **c**: custom<br>● **d**: directory<br>● **t**: .tar | -F t |

For details about other parameters, see "gs_dump" in the *Tool Guide*.

**----End**

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## Examples

Example 1: Use gs_dump to run the following command to export full information of the database **gaussdb** and compress the exported files in SQL format.

```
gs_dump -W password -U jack -f /home//backup/postgres_backup.sql -p 8000  -h 10.10.10.100 gaussdb -Z
8 -F p
gs_dump[port='']['gaussdb'][2017-07-21 15:36:13]: dump database gaussdb successfully
gs_dump[port='']['gaussdb'][2017-07-21 15:36:13]: total time: 3793  ms
```

Example 2: Use gs_dump to run the following command to export data of the database **gaussdb**, excluding object definitions. The exported files are in a custom format.

```
gs_dump -W Password -U jack -f /home//backup/postgres_data_backup.dmp -p 8000 -h 10.10.10.100
gaussdb -a -F c
gs_dump[port='']['gaussdb'][2017-07-21 15:36:13]: dump database gaussdb successfully
gs_dump[port='']['gaussdb'][2017-07-21 15:36:13]: total time: 3793  ms
```

Example 3: Use gs_dump to run the following command to export object definitions of the database **gaussdb**. The exported files are in SQL format.

```
--Before the export, the nation table contains data.
select n_nationkey,n_name,n_regionkey from nation limit 3;
 n_nationkey |          n_name           | n_regionkey
-------------+---------------------------+-------------
           0 | ALGERIA                   |           0
           3 | CANADA                    |           1
          11 | IRAQ                      |           4
(3 rows)

gs_dump -W password -U jack -f /home//backup/postgres_def_backup.sql -p 8000 -h 10.10.10.100 gaussdb -
s -F p
gs_dump[port='']['gaussdb'][2017-07-20 15:04:14]: dump database gaussdb successfully
gs_dump[port='']['gaussdb'][2017-07-20 15:04:14]: total time: 472 ms
```

Example 4: Use gs_dump to run the following command to export object definitions of the database **gaussdb**. The exported files are in text format and are encrypted.

```
gs_dump -W password -U jack -f /home//backup/postgres_def_backup.sql -p 8000 -h 10.10.10.100 gaussdb
--with-encryption AES128 --with-key 1234567812345678 -s -F p
gs_dump[port='']['gaussdb'][2018-11-14 11:25:18]: dump database gaussdb successfully
gs_dump[port='']['gaussdb'][2018-11-14 11:25:18]: total time: 1161  ms
```

### 3.4.1.2.2 Exporting a Schema

You can use gs_dump to export data and all object definitions of a schema from GaussDB(DWS). You can export one or more specified schemas as needed. You can specify the information to be exported as follows:

- Export full information of a schema, including its data and object definitions.
- Export data of a schema, excluding its object definitions.
- Export the object definitions of a schema, including the definitions of tables, stored procedures, and indexes.

## Procedure

**Step 1** Prepare an ECS as the gsql client host. For details, see "Preparing an ECS as the gsql Client Host" in the *Data Warehouse Service (DWS) User Guide*.

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**Step 2** Download the gsql client and use an SSH transfer tool (such as WinSCP) to upload it to the Linux server where gsql is to be installed. For details, see "Downloading the Client" in *Data Warehouse Service User Guide*.

The user who uploads the client must have the full control permission on the target directory on the host to which the client is uploaded.

**Step 3** Run the following commands to decompress the client:

```
cd <Path_for_storing_the_client>
unzip dws_client_8.1.x_redhat_x64.zip
```

Where,

- <*Path_for_storing_the_client*>: Replace it with the actual path.
- *dws_client_8.1.x_redhat_x86.zip*: This is the client tool package of **RedHat x86**. Replace it with the actual one.

**Step 4** Run the following command to configure the GaussDB(DWS) client:

```
source gsql_env.sh
```

If the following information is displayed, the GaussDB(DWS) client is successfully configured:

```
All things done.
```

**Step 5** Use gs_dump to run the following command to export the **hr** and **public** schemas.

```
gs_dump -W Password -U jack -f /home//backup/MPPDB_schema_backup -p 8000 -h 10.10.10.100 human_resource -n hr -F d
```

**Table 3-16** Common parameters

| Parameter | Description | Example Value |
| --- | --- | --- |
| -U | Username for connecting to the database. If this parameter is not configured, the username of the connected database is used. | -U jack |
| -W | User password for database connection.<br>• This parameter is not required for database administrators if the trust policy is used for authentication.<br>• If you connect to the database without specifying this parameter and you are not a database administrator, you will be prompted to enter the password. | -W *Password* |
| -f | Folder to store exported files. If this parameter is not specified, the exported files are stored in the standard output. | -f /home//backup/MPPDB_schema_backup |

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| Parameter | Description | Example Value |
| --- | --- | --- |
| -p | Name extension of the TCP port on which the server is listening or the local Unix domain socket. This parameter is configured to ensure connections. | -p 8000 |
| -h | *Cluster address*: If a public network address is used for connection, set this parameter to **Public Network Address** or **Public Network Domain Name**. If a private network address is used for connection, set this parameter to **Private Network Address** or **Private Network Domain Name**. | -h 10.10.10.100 |
| dbname | Name of the database to be exported. | human_resource |
| -n | Names of schemas to be exported. Data of the specified schemas will also be exported.<br>• Single schema: Enter **-n** *schemaname*.<br>• Multiple schemas: Enter **-n** *schemaname* for each schema. | • Single schema: **-n hr**<br>• Multiple schemas: **-n hr -n public** |
| -F | Format of exported files. The values of **-F** are as follows:<br>• **p**: plain text<br>• **c**: custom<br>• **d**: directory<br>• **t**: .tar | -F d |

For details about other parameters, see "gs_dump" in the *Tool Guide*.

**----End**

## Examples

Example 1: Use gs_dump to run the following command to export full information of the **hr** schema. The exported files are compressed and stored in text format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_schema_backup.sql -p 8000 -h 10.10.10.100
human_resource -n hr -Z 6 -F p
gs_dump[port='']['human_resource'][2017-07-21 16:05:55]: dump database human_resource successfully
gs_dump[port='']['human_resource'][2017-07-21 16:05:55]: total time: 2425  ms
```

Example 2: Use gs_dump to run the following command to export data of the **hr** schema. The exported files are in .tar format.

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```
gs_dump -W password -U jack -f /home//backup/MPPDB_schema_data_backup.tar -p 8000 -h 10.10.10.100
human_resource -n hr -a -F t
gs_dump[port='']human_resource][2018-11-14 15:07:16]: dump database human_resource successfully
gs_dump[port='']human_resource][2018-11-14 15:07:16]: total time: 1865  ms
```

Example 3: Use gs_dump to run the following command to export the definition of the **hr** schema. The exported files are stored in a directory.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_schema_def_backup -p 8000 -h 10.10.10.100
human_resource -n hr -s -F d
gs_dump[port='']human_resource][2018-11-14 15:11:34]: dump database human_resource successfully
gs_dump[port='']human_resource][2018-11-14 15:11:34]: total time: 1652  ms
```

Example 4: Use gs_dump to run the following command to export the **human_resource** database excluding the **hr** schema. The exported files are in a custom format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_schema_backup.dmp -p 8000 -h 10.10.10.100
human_resource -N hr -F c
gs_dump[port='']human_resource][2017-07-21 16:06:31]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 16:06:31]: total time: 2522  ms
```

Example 5: Use gs_dump to run the following command to export the object definitions of the **hr** and **public** schemas, encrypt the exported files, and store them in .tar format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_schema_backup1.tar -p 8000 -h 10.10.10.100
human_resource -n hr -n public -s --with-encryption AES128 --with-key 1234567812345678 -F t
gs_dump[port='']human_resource][2017-07-21 16:07:16]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 16:07:16]: total time: 2132  ms
```

Example 6: Use gs_dump to run the following command to export the **human_resource** database excluding the **hr** and **public** schemas. The exported files are in a custom format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_schema_backup2.dmp -p 8000 -h 10.10.10.100
human_resource -N hr -N public -F c
gs_dump[port='']human_resource][2017-07-21 16:07:55]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 16:07:55]: total time: 2296  ms
```

Example 7: Use gs_dump to run the following command to export all tables, including views, sequences, and foreign tables, in the **public** schema, and the **staffs** table in the **hr** schema, including data and table definition. The exported files are in a custom format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_backup3.dmp -p 8000 -h 10.10.10.100
human_resource -t public.* -t hr.staffs -F c
gs_dump[port='']human_resource][2018-12-13 09:40:24]: dump database human_resource successfully
gs_dump[port='']human_resource][2018-12-13 09:40:24]: total time: 896  ms
```

### 3.4.1.2.3 Exporting a Table

You can use gs_dump to export data and all object definitions of a table-level object from GaussDB(DWS). Views, sequences, and foreign tables are special tables. You can export one or more specified tables as needed. You can specify the information to be exported as follows:

- Export full information of a table, including its data and definition.
- Export data of a table.
- Export the definition of a table.

## Procedure

**Step 1** Prepare an ECS as the gsql client host. For details, see "Preparing an ECS as the gsql Client Host" in the *Data Warehouse Service (DWS) User Guide*.

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**Step 2** Download the gsql client and use an SSH transfer tool (such as WinSCP) to upload it to the Linux server where gsql is to be installed. For details, see "Downloading the Client" in *Data Warehouse Service User Guide*.

The user who uploads the client must have the full control permission on the target directory on the host to which the client is uploaded.

**Step 3** Run the following commands to decompress the client:

```
cd <Path_for_storing_the_client>
unzip dws_client_8.1.x_redhat_x64.zip
```

Where,

- <*Path_for_storing_the_client*>: Replace it with the actual path.
- *dws_client_8.1.x_redhat_x86.zip*: This is the client tool package of **RedHat x86**. Replace it with the actual one.

**Step 4** Run the following command to configure the GaussDB(DWS) client:

```
source gsql_env.sh
```

If the following information is displayed, the GaussDB(DWS) client is successfully configured:

```
All things done.
```

**Step 5** Use gs_dump to run the following command to export the **hr.staffs** and **hr.employments** tables.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup -p 8000 -h 10.10.10.100
human_resource -t hr.staffs -F d
```

**Table 3-17** Common parameters

| Parameter | Description | Example Value |
| --- | --- | --- |
| -U | Username for connecting to the database. If this parameter is not configured, the username of the connected database is used. | -U jack |
| -W | User password for database connection.<br>• This parameter is not required for database administrators if the trust policy is used for authentication.<br>• If you connect to the database without specifying this parameter and you are not a database administrator, you will be prompted to enter the password. | -W *password* |
| -f | Folder to store exported files. If this parameter is not specified, the exported files are stored in the standard output. | -f /home//backup/MPPDB_table_backup |


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| Parameter | Description | Example Value |
| --- | --- | --- |
| -p | Name extension of the TCP port on which the server is listening or the local Unix domain socket. This parameter is configured to ensure connections. | -p 8000 |
| -h | *Cluster address*: If a public network address is used for connection, set this parameter to **Public Network Address** or **Public Network Domain Name**. If a private network address is used for connection, set this parameter to **Private Network Address** or **Private Network Domain Name**. | -h 10.10.10.100 |
| dbname | Name of the database to be exported. | human_resource |
| -t | Table (or view, sequence, foreign table) to be exported. You can specify multiple tables by listing them or using wildcard characters. When you use wildcard characters, quote wildcard patterns with single quotation marks ('') to prevent the shell from expanding the wildcard characters.<br>• Single table: Enter **-t** *schema.table*.<br>• Multiple tables: Enter **-t** *schema.table* for each table. | • Single table: **-t hr.staffs**<br>• Multiple tables: **-t hr.staffs -t hr.employments** |
| -F | Format of exported files. The values of **-F** are as follows:<br>• **p**: plain text<br>• **c**: custom<br>• **d**: directory<br>• **t**: .tar | -F d |

For details about other parameters, see "gs_dump" in the *Tool Guide*.

**----End**

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## Examples

Example 1: Use gs_dump to run the following command to export full information of the **hr.staffs** table. The exported files are in text format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup.sql -p 8000 -h 10.10.10.100
human_resource -t hr.staffs -Z 6 -F p
gs_dump[port='']human_resource][2017-07-21 17:05:10]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 17:05:10]: total time: 3116  ms
```

Example 2: Use gs_dump to run the following command to export data of the **hr.staffs** table. The exported files are in .tar format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_data_backup.tar -p 8000 -h 10.10.10.100
human_resource -t hr.staffs -a -F t
gs_dump[port='']human_resource][2017-07-21 17:04:26]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 17:04:26]: total time: 2570  ms
```

Example 3: Use gs_dump to run the following command to export the definition of the **hr.staffs** table. The exported files are stored in a directory.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_def_backup -p 8000 -h 10.10.10.100
human_resource -t hr.staffs -s -F d
gs_dump[port='']human_resource][2017-07-21 17:03:09]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 17:03:09]: total time: 2297  ms
```

Example 4: Use gs_dump to run the following command to export the **human_resource** database excluding the **hr.staffs** table. The exported files are in a custom format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup4.dmp -p 8000 -h 10.10.10.100
human_resource -T hr.staffs -F c
gs_dump[port='']human_resource][2017-07-21 17:14:11]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 17:14:11]: total time: 2450  ms
```

Example 5: Use gs_dump to run the following command to export the **hr.staffs** and **hr.employments** tables. The exported files are in text format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup1.sql -p 8000 -h 10.10.10.100
human_resource -t hr.staffs -t hr.employments -F p
gs_dump[port='']human_resource][2017-07-21 17:19:42]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 17:19:42]: total time: 2414  ms
```

Example 6: Use gs_dump to run the following command to export the **human_resource** database excluding the **hr.staffs** and **hr.employments** tables. The exported files are in text format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup2.sql -p 8000 -h 10.10.10.100
human_resource -T hr.staffs -T hr.employments -F p
gs_dump[port='']human_resource][2017-07-21 17:21:02]: dump database human_resource successfully
gs_dump[port='']human_resource][2017-07-21 17:21:02]: total time: 3165  ms
```

Example 7: Use gs_dump to run the following command to export data and definition of the **hr.staffs** table, and the definition of the **hr.employments** table. The exported files are in .tar format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup3.tar -p 8000 -h 10.10.10.100
human_resource -t hr.staffs -t hr.employments --exclude-table-data hr.employments -F t
gs_dump[port='']human_resource][2018-11-14 11:32:02]: dump database human_resource successfully
gs_dump[port='']human_resource][2018-11-14 11:32:02]: total time: 1645  ms
```

Example 8: Use gs_dump to run the following command to export data and definition of the **hr.staffs** table, encrypt the exported files, and store them in text format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup4.sql -p 8000 -h 10.10.10.100
human_resource -t hr.staffs --with-encryption AES128 --with-key 1212121212121212 -F p
gs_dump[port='']human_resource][2018-11-14 11:35:30]: dump database human_resource successfully
gs_dump[port='']human_resource][2018-11-14 11:35:30]: total time: 6708  ms
```

Example 9: Use gs_dump to run the following command to export all tables, including views, sequences, and foreign tables, in the **public** schema, and the

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**staffs** table in the **hr** schema, including data and table definition. The exported files are in a custom format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_table_backup5.dmp -p 8000 -h 10.10.10.100
human_resource -t public.* -t hr.staffs -F c
gs_dump[port='']human_resource][2018-12-13 09:40:24]: dump database human_resource successfully
gs_dump[port='']human_resource][2018-12-13 09:40:24]: total time: 896  ms
```

Example 10: Use gs_dump to run the following command to export the definition of the view referencing to the **test1** table in the **t1** schema. The exported files are in a custom format.

```
gs_dump -W password -U jack -f /home//backup/MPPDB_view_backup6 -p 8000 -h 10.10.10.100
human_resource -t t1.test1 --include-depend-objs --exclude-self -F d
gs_dump[port='']jack][2018-11-14 17:21:18]: dump database human_resource successfully
gs_dump[port='']jack][2018-11-14 17:21:23]: total time: 4239  ms
```

## 3.4.1.3 Exporting All Databases

### 3.4.1.3.1 Exporting All Databases

You can use gs_dumpall to export full information of all databases in a cluster from GaussDB(DWS), including information about each database and global objects in the cluster. You can specify the information to be exported as follows:

- Export full information of all databases, including information about each database and global objects (such as roles and tablespaces) in the cluster.

  You can use the exported information to create a same cluster containing the same databases, global objects, and data as the current one.
- Export data of all databases, excluding all object definitions and global objects.
- Export all object definitions of all databases, including the definitions of tablespaces, databases, functions, schemas, tables, indexes, and stored procedures.

  You can use the exported object definitions to quickly create a same cluster as the current one, containing the same databases and tablespaces but without data.

## Procedure

**Step 1** Prepare an ECS as the gsql client host. For details, see "Preparing an ECS as the gsql Client Host" in the *Data Warehouse Service (DWS) User Guide*.

**Step 2** Download the gsql client and use an SSH transfer tool (such as WinSCP) to upload it to the Linux server where gsql is to be installed. For details, see "Downloading the Client" in *Data Warehouse Service User Guide*.

The user who uploads the client must have the full control permission on the target directory on the host to which the client is uploaded.

**Step 3** Run the following commands to decompress the client:

```
cd <Path_for_storing_the_client>
unzip dws_client_8.1.x_redhat_x64.zip
```

Where,

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- <*Path_for_storing_the_client*>: Replace it with the actual path.
- *dws_client_8.1.x_redhat_x86.zip*: This is the client tool package of **RedHat x86**. Replace it with the actual one.

**Step 4** Run the following command to configure the GaussDB(DWS) client:

```
source gsql_env.sh
```

If the following information is displayed, the GaussDB(DWS) client is successfully configured:

```
All things done.
```

**Step 5** Use gs_dumpall to run the following command to export information of all databases.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_backup.sql -p 8000 -h 10.10.10.100
```

**Table 3-18** Common parameters

| Parameter | Description | Example Value |
| --- | --- | --- |
| -U | Username for database connection. The user must be a cluster administrator. | -U dbadmin |
| -W | User password for database connection.<br>● This parameter is not required for database administrators if the trust policy is used for authentication.<br>● If you connect to the database without specifying this parameter and you are not a database administrator, you will be prompted to enter the password. | -W *Password* |
| -f | Folder to store exported files. If this parameter is not specified, the exported files are stored in the standard output. | -f /home/dbadmin/backup/MPPDB_backup.sql |
| -p | Name extension of the TCP port on which the server is listening or the local Unix domain socket. This parameter is configured to ensure connections. | -p 8000 |

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| Parameter | Description | Example Value |
| --- | --- | --- |
| -h | *Cluster address*: If a public network address is used for connection, set this parameter to **Public Network Address** or **Public Network Domain Name**. If a private network address is used for connection, set this parameter to **Private Network Address** or **Private Network Domain Name**. | -h 10.10.10.100 |

For details about other parameters, see "gs_dumpall" in the *Tool Guide*.

**----End**

## Examples

Example 1: Use **gs_dumpall** to run the following command as the cluster administrator **dbadmin** to export information of all databases in a cluster. The exported files are in text format. After the command is executed, a large amount of output information will be displayed. **total time** will be displayed at the end of the information, indicating that the export is successful. In this example, only related output information is included.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_backup.sql -p 8000 -h
10.10.10.100
gs_dumpall[port='']['2017-07-21 15:57:31']: dumpall operation successful
gs_dumpall[port='']['2017-07-21 15:57:31']: total time: 9627  ms
```

Example 2: Use **gs_dumpall** to run the following command as the cluster administrator **dbadmin** to export definitions of all databases in a cluster. The exported files are in text format. After the command is executed, a large amount of output information will be displayed. **total time** will be displayed at the end of the information, indicating that the export is successful. In this example, only related output information is included.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_backup.sql -p 8000 -h
10.10.10.100 -s
gs_dumpall[port='']['2018-11-14 11:28:14']: dumpall operation successful
gs_dumpall[port='']['2018-11-14 11:28:14']: total time: 4147  ms
```

Example 3: Use gs_dumpall to run the following command export data of all databases in a cluster, encrypt the exported files, and store them in text format. After the command is executed, a large amount of output information will be displayed. **total time** will be displayed at the end of the information, indicating that the export is successful. In this example, only related output information is included.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_backup.sql -p 8000 -h
10.10.10.100 -a --with-encryption AES128 --with-key 1234567812345678
gs_dumpall[port='']['2018-11-14 11:32:26']: dumpall operation successful
gs_dumpall[port='']['2018-11-14 11:23:26']: total time: 4147  ms
```

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### 3.4.1.3.2 Exporting Global Objects

You can use gs_dumpall to export global objects from GaussDB(DWS), including database users, user groups, tablespaces, and attributes (for example, global access permissions).

## Procedure

**Step 1** Prepare an ECS as the gsql client host. For details, see "Preparing an ECS as the gsql Client Host" in the *Data Warehouse Service (DWS) User Guide*.

**Step 2** Download the gsql client and use an SSH transfer tool (such as WinSCP) to upload it to the Linux server where gsql is to be installed. For details, see "Downloading the Client" in *Data Warehouse Service User Guide*.

The user who uploads the client must have the full control permission on the target directory on the host to which the client is uploaded.

**Step 3** Run the following commands to decompress the client:

```
cd <Path_for_storing_the_client>
unzip dws_client_8.1.x_redhat_x64.zip
```

Where,

- <*Path_for_storing_the_client*>: Replace it with the actual path.
- *dws_client_8.1.x_redhat_x86.zip*: This is the client tool package of **RedHat x86**. Replace it with the actual one.

**Step 4** Run the following command to configure the GaussDB(DWS) client:

```
source gsql_env.sh
```

If the following information is displayed, the GaussDB(DWS) client is successfully configured:

```
All things done.
```

**Step 5** Use gs_dumpall to run the following command to export tablespace objects.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_tablespace.sql -p 8000 -h 10.10.10.100 -t
```

**Table 3-19** Common parameters

| Parameter | Description | Example Value |
| --- | --- | --- |
| -U | Username for database connection. The user must be a cluster administrator. | -U dbadmin |

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| Parameter | Description | Example Value |
| --- | --- | --- |
| -W | User password for database connection.<br>● This parameter is not required for database administrators if the trust policy is used for authentication.<br>● If you connect to the database without specifying this parameter and you are not a database administrator, you will be prompted to enter the password. | -W *Password* |
| -f | Folder to store exported files. If this parameter is not specified, the exported files are stored in the standard output. | -f /home//backup/*MPPDB_tablespace*.sql |
| -p | Name extension of the TCP port on which the server is listening or the local Unix domain socket. This parameter is configured to ensure connections. | -p 8000 |
| -h | *Cluster address*: If a public network address is used for connection, set this parameter to **Public Network Address** or **Public Network Domain Name**. If a private network address is used for connection, set this parameter to **Private Network Address** or **Private Network Domain Name**. | -h 10.10.10.100 |
| -t | Dumps only tablespaces. You can also use **--tablespaces-only** alternatively. | - |

For details about other parameters, see "gs_dumpall" in the *Tool Guide*.

**----End**

## Examples

Example 1: Use **gs_dumpall** to run the following command as the cluster administrator **dbadmin** to export information of global tablespaces and users in a cluster. The exported files are in text format.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_globals.sql -p 8000 -h 10.10.10.100 -g
```

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```
gs_dumpall[port='']2018-11-14 19:06:24]: dumpall operation successful
gs_dumpall[port='']2018-11-14 19:06:24]: total time: 1150  ms
```

Example 2: Use **gs_dumpall** to run the following command as the cluster administrator **dbadmin** to export global tablespaces in a cluster, encrypt the exported files, and store them in text format.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_tablespace.sql -p 8000 -h
10.10.10.100 -t --with-encryption AES128 --with-key 1212121212121212
gs_dumpall[port='']2018-11-14 19:00:58]: dumpall operation successful
gs_dumpall[port='']2018-11-14 19:00:58]: total time: 186  ms
```

Example 3: Use **gs_dumpall** to run the following command as the cluster administrator **dbadmin** to export information of global users in a cluster. The exported files are in text format.

```
gs_dumpall -W password -U dbadmin -f /home/dbadmin/backup/MPPDB_user.sql -p 8000 -h 10.10.10.100 -
r
gs_dumpall[port='']2018-11-14 19:03:18]: dumpall operation successful
gs_dumpall[port='']2018-11-14 19:03:18]: total time: 162  ms
```

### 3.4.1.4 Data Export By a User Without Required Permissions

gs_dump and gs_dumpall use **-U** to specify the user that performs the export. If the specified user does not have the required permission, data cannot be exported. In this case, you can set **--role** in the export command to the role that has the permission. Then, gs_dump or gs_dumpall uses the specified role to export data.

## Procedure

**Step 1** Prepare an ECS as the gsql client host. For details, see "Preparing an ECS as the gsql Client Host" in the *Data Warehouse Service (DWS) User Guide*.

**Step 2** Download the gsql client and use an SSH transfer tool (such as WinSCP) to upload it to the Linux server where gsql is to be installed. For details, see "Downloading the Client" in *Data Warehouse Service User Guide*.

The user who uploads the client must have the full control permission on the target directory on the host to which the client is uploaded.

**Step 3** Run the following commands to decompress the client:

```
cd <Path_for_storing_the_client>
unzip dws_client_8.1.x_redhat_x64.zip
```

Where,

- *<Path_for_storing_the_client>*: Replace it with the actual path.
- *dws_client_8.1.x_redhat_x86.zip*: This is the client tool package of **RedHat x86**. Replace it with the actual one.

**Step 4** Run the following command to configure the GaussDB(DWS) client:

```
source gsql_env.sh
```

If the following information is displayed, the GaussDB(DWS) client is successfully configured:

```
All things done.
```

**Step 5** Use gs_dump to export data of the **human_resource** database.

User **jack** does not have the permission for exporting data of the **human_resource** database and the role **role1** has this permission. To export data

of the **human_resource** database, you can set **--role** to **role1** in the export command. The exported files are in .tar format.

```
gs_dump -U jack -W password -f /home//backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100
human_resource --role role1 --rolepassword password -F t
```

**Table 3-20** Common parameters

| Parameter | Description | Example Value (dbadmin) |
| --- | --- | --- |
| -U | Username for database connection. | -U jack |
| -W | User password for database connection.<br>• This parameter is not required for database administrators if the trust policy is used for authentication.<br>• If you connect to the database without specifying this parameter and you are not a database administrator, you will be prompted to enter the password. | -W *Password* |
| -f | Folder to store exported files. If this parameter is not specified, the exported files are stored in the standard output. | -f /home//backup/MPPDB_backup.tar |
| -p | Name extension of the TCP port on which the server is listening or the local Unix domain socket. This parameter is configured to ensure connections. | -p 8000 |
| -h | *Cluster address*: If a public network address is used for connection, set this parameter to **Public Network Address** or **Public Network Domain Name**. If a private network address is used for connection, set this parameter to **Private Network Address** or **Private Network Domain Name**. | -h 10.10.10.100 |
| dbname | Name of the database to be exported. | human_resource |

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| Parameter | Description | Example Value (dbadmin) |
| --- | --- | --- |
| --role | Role name for the export operation. After this parameter is set and gs_dump or gs_dumpall connects to the database, the **SET ROLE** command will be issued. When the user specified by **-U** does not have the permissions required by gs_dump or gs_dumpall, this parameter allows the user to switch to a role with the required permissions. | -r role1 |
| --rolepassword | Role password. | --rolepassword password |
| -F | Format of exported files. The values of **-F** are as follows:<br>• **p**: plain text<br>• **c**: custom<br>• **d**: directory<br>• **t**: .tar | -F t |

For details about other parameters, see "gs_dump" or "gs_dumpall" in the *Tool Guide*.

**----End**

## Examples

Example 1: User **jack** does not have the permission for exporting data of the **human_resource** database and the role **role1** has this permission. To export data of the **human_resource** database, you can set **--role** to **role1** in the export command. The exported files are in .tar format.

```
human_resource=# CREATE USER jack IDENTIFIED BY "password";

gs_dump -U jack -W password -f /home//backup/MPPDB_backup11.tar -p 8000 -h 10.10.10.100
human_resource --role role1 --rolepassword password -F t
gs_dump[port='8000'][human_resource][2017-07-21 16:21:10]: dump database human_resource successfully
gs_dump[port='8000'][human_resource][2017-07-21 16:21:10]: total time: 4239  ms
```

Example 2: User **jack** does not have the permission for exporting the **public** schema and the role **role1** has this permission. To export the **public** schema, you can set **--role** to **role1** in the export command. The exported files are in .tar format.

```
human_resource=# CREATE USER jack IDENTIFIED BY "1234@abc";

gs_dump -U jack -W password -f /home//backup/MPPDB_backup12.tar -p 8000 -h 10.10.10.100
human_resource -n public --role role1 --rolepassword password -F t
gs_dump[port='8000'][human_resource][2017-07-21 16:21:10]: dump database human_resource successfully
gs_dump[port='8000'][human_resource][2017-07-21 16:21:10]: total time: 3278  ms
```

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Example 3: User **jack** does not have the permission for exporting all databases in a cluster and the role **role1** (cluster administrator) has this permission. To export all databases, you can set **--role** to **role1** in the export command. The exported files are in text format.

```
human_resource=# CREATE USER jack IDENTIFIED BY "password";

gs_dumpall -U jack -W password -f /home//backup/MPPDB_backup.sql -p 8000 -h 10.10.10.100 --role role1
--rolepassword password
gs_dumpall[port='8000'][human_resource][2018-11-14 17:26:18]: dumpall operation successful
gs_dumpall[port='8000'][human_resource][2018-11-14 17:26:18]: total time: 6437  ms
```

## 3.4.2 Using gs_restore to Import Data

### Scenarios

gs_restore is an import tool provided by GaussDB(DWS). You can use gs_restore to import the files exported by gs_dump to a database. gs_restore can import the files in .tar, custom, or directory format.

gs_restore can:

- Import data to a database.

  If a database is specified, data is imported to the database. If multiple databases are specified, the password for connecting to each database also needs to be specified.
- Import data to a script.

  If no database is specified, a script containing the SQL statement to recreate the database is created and written to a file or standard output. This script output is equivalent to the plain text output of gs_dump.

You can specify and sort the data to be imported.

### Procedure

**NOTE**

gs_restore incrementally imports data by default. To prevent data exception caused by consecutive imports, use the **-e** and **-c** parameters for each import. In this way, existing data is deleted from the target database before each import; the system exists the import task with an error (error message is displayed after the import process is complete) and proceeds with the next.

**Step 1** Log in to the server as the **root** user and run the following command to go to the data storage path:

```
cd /opt/bin
```

**Step 2** Use **gs_restore** to import all object definitions from the exported file of the whole **postgres** database to the **gaussdb** database.

```
gs_restore -W password -U jack /home//backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100 -d backupdb -
s -e -c
```

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**Table 3-21** Common parameters

| Parameter | Description | Example Value |
| --- | --- | --- |
| -U | Username for database connection. | -U jack |
| -W | User password for database connection.<br>• This parameter is not required for database administrators if the trust policy is used for authentication.<br>• If you connect to the database without specifying this parameter and you are not a database administrator, you will be prompted to enter the password. | -W *Password* |
| -d | Database to which data will be imported. | -d backupdb |
| -p | Name extension of the TCP port on which the server is listening or the local Unix domain socket. This parameter is configured to ensure connections. | -p 8000 |
| -h | *Cluster address*: If a public network address is used for connection, set this parameter to **Public Network Address** or **Public Network Domain Name**. If a private network address is used for connection, set this parameter to **Private Network Address** or **Private Network Domain Name**. | -h 10.10.10.100 |
| -e | Exits the current import task and performs the next if an error occurs when you send a SQL statement in the current import task. Error messages are displayed after the import process is complete. | - |
| -c | Cleans existing objects from the target database before the import. | - |


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| Parameter | Description | Example Value |
| --- | --- | --- |
| -s | Imports only object definitions in schemas and does not import data. Sequence values will also not be imported. | - |

For details about other parameters, see "Server Tools > gs_restore" in the *Tool Reference*.

**----End**

## Examples

Example 1: Use **gs_restore** to run the following command to import data and all object definitions of the **gaussdb** database from the **MPPDB_backup.dmp** file (custom format).

```
gs_restore -W password backup/MPPDB_backup.dmp -p 8000 -h 10.10.10.100 -d backupdb
gs_restore[2017-07-21 19:16:26]: restore operation successfu
gs_restore: total time: 13053  ms
```

Example 2: Use **gs_restore** to run the following command to import data and all object definitions of the **gaussdb** database from the **MPPDB_backup.tar** file.

```
gs_restore backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100 -d backupdb
gs_restore[2017-07-21 19:21:32]: restore operation successful
gs_restore[2017-07-21 19:21:32]: total time: 21203  ms
```

Example 3: Use **gs_restore** to run the following command to import data and all object definitions of the **gaussdb** database from the **MPPDB_backup** directory.

```
gs_restore backup/MPPDB_backup -p 8000 -h 10.10.10.100 -d backupdb
gs_restore[2017-07-21 19:26:46]: restore operation successful
gs_restore[2017-07-21 19:26:46]: total time: 21003  ms
```

Example 4: Use **gs_restore** to run the following command to import all object definitions of the **gaussdb** database to the **backupdb** database. Before the import, there are complete definitions in the **gaussdb** database. After the import, all object definitions exist in the **backupdb** database and there is no data in tables.

```
gs_restore -W password /home//backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100 -d backupdb -s -e -c
gs_restore[2017-07-21 19:46:27]: restore operation successful
gs_restore[2017-07-21 19:46:27]: total time: 32993  ms
```

Example 5: Use gs_restore to run the following command to import data and all definitions in the **PUBLIC** schema from the **MPPDB_backup.dmp** file. Existing objects are deleted from the target database before the import. If an existing object references to an object in another schema, you need to manually delete the referenced object first.

```
gs_restore backup/MPPDB_backup.dmp -p 8000 -h 10.10.10.100 -d backupdb -e -c -n PUBLIC
gs_restore: [archiver (db)] Error while PROCESSING TOC:
gs_restore: [archiver (db)] Error from TOC entry 313; 1259 337399 TABLE table1 gaussdba
gs_restore: [archiver (db)] could not execute query: ERROR:  cannot drop table table1 because other objects depend on it
DETAIL:  view t1.v1 depends on table table1
HINT:  Use DROP ... CASCADE to drop the dependent objects too.
Command was: DROP TABLE public.table1;
```

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Manually delete the referenced object and create it again after the import is complete.

```
gs_restore backup/MPPDB_backup.dmp -p 8000 -h 10.10.10.100 -d backupdb -e -c -n PUBLIC
gs_restore[2017-07-21 19:52:26]: restore operation successful
gs_restore[2017-07-21 19:52:26]: total time: 2203  ms
```

Example 6: Use gs_restore to run the following command to import the definition of the **hr.staffs** table in the **PUBLIC** schema from the **MPPDB_backup.dmp** file. Before the import, the **hr.staffs** table does not exist.

```
gs_restore backup/MPPDB_backup.dmp -p 8000 -h 10.10.10.100 -d backupdb -e -c -s -n PUBLIC -t hr.staffs
gs_restore[2017-07-21 19:56:29]: restore operation successful
gs_restore[2017-07-21 19:56:29]: total time: 21000  ms
```

Example 7: Use gs_restore to run the following command to import data of the **hr.staffs** table in the **PUBLIC** schema from the **MPPDB_backup.dmp** file. Before the import, the **hr.staffs** table is empty.

```
gs_restore backup/MPPDB_backup.dmp -p 8000 -h 10.10.10.100 -d backupdb -e -a -n PUBLIC -t hr.staffs
gs_restore[2017-07-21 20:12:32]: restore operation successful
gs_restore[2017-07-21 20:12:32]: total time: 20203  ms
```

Example 8: Use gs_restore to run the following command to import the definition of the **hr.staffs** table. Before the import, the **hr.staffs** table contains data.

```
human_resource=# select * from hr.staffs;
 staff_id | first_name  |  last_name  |  email   |    phone_number    |      hire_date      | employment_id |
salary  | commission_pct | manager_id | section_id
----------+-------------+-------------+----------+--------------------+---------------------+---------------+----------
+----------------+------------+------------
      200 | Jennifer    | Whalen      | JWHALEN  | 515.123.4444       | 1987-09-17 00:00:00 | AD_ASST       |
4400.00 |                |        101 |         10
      201 | Michael     | Hartstein   | MHARTSTE | 515.123.5555       | 1996-02-17 00:00:00 | MK_MAN        |
13000.00 |                |        100 |         20

gsql -d human_resource -p 8000
gsql ((GaussDB 8.1.1 build af002019) compiled at 2020-01-10 05:43:20 commit 6995 last mr 11566 )
Non-SSL connection (SSL connection is recommended when requiring high-security)
Type "help" for help.

human_resource=# drop table hr.staffs CASCADE;
NOTICE:  drop cascades to view hr.staff_details_view
DROP TABLE

gs_restore -W password /home//backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100 -d human_resource -n
hr -t staffs -s -e
restore operation successful
total time: 904  ms

human_resource=# select * from hr.staffs;
 staff_id | first_name | last_name | email | phone_number | hire_date | employment_id | salary |
commission_pct | manager_id | section_id
----------+------------+-----------+-------+--------------+-----------+---------------+--------+----------------
+------------+------------
(0 rows)
```

Example 9: Use gs_restore to run the following command to import data and definitions of the **staffs** and **areas** tables. Before the import, the **staffs** and **areas** tables do not exist.

```
human_resource=# \d
                        List of relations
 Schema |        Name        | Type  |  Owner   |             Storage
--------+--------------------+-------+----------+---------------------------------
 hr     | employment_history | table |  | {orientation=row,compression=no}
 hr     | employments        | table |  | {orientation=row,compression=no}
 hr     | places             | table |  | {orientation=row,compression=no}
 hr     | sections           | table |  | {orientation=row,compression=no}
```

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```
 hr     | states              | table |  | {orientation=row,compression=no}
(5 rows)

gs_restore -W password /home/mppdb/backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100 -d
human_resource -n hr -t staffs -n hr -t areas
restore operation successful
total time: 724  ms

human_resource=# \d
                          List of relations
 Schema |        Name         | Type  |  Owner   |             Storage
--------+---------------------+-------+----------+---------------------------------
 hr     | areas               | table |  | {orientation=row,compression=no}
 hr     | employment_history | table |  | {orientation=row,compression=no}
 hr     | employments         | table |  | {orientation=row,compression=no}
 hr     | places              | table |  | {orientation=row,compression=no}
 hr     | sections            | table |  | {orientation=row,compression=no}
 hr     | staffs              | table |  | {orientation=row,compression=no}
 hr     | states              | table |  | {orientation=row,compression=no}
(7 rows)

human_resource=# select * from hr.areas;
 area_id |       area_name
---------+------------------------
       4 | Iron
       1 | Wood
       2 | Lake
       3 | Desert
(4 rows)
```

Example 10: Use gs_restore to run the following command to import data and all object definitions in the **hr** schema.

```
gs_restore -W password  /home//backup/MPPDB_backup1.sql -p 8000 -h 10.10.10.100 -d backupdb -n hr -e
-c
restore operation successful
total time: 702  ms
```

Example 11: Use gs_restore to run the following command to import all object definitions in the **hr** and **hr1** schemas to the **backupdb** database.

```
gs_restore -W password /home//backup/MPPDB_backup2.dmp -p 8000 -h 10.10.10.100 -d backupdb -n hr -
n hr1 -s
restore operation successful
total time: 665  ms
```

Example 12: Use gs_restore to run the following command to decrypt the files exported from the **human_resource** database and import them to the **backupdb** database.

```
create database backupdb;
CREATE DATABASE

gs_restore /home//backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100 -d backupdb --with-
key=1234567812345678
restore operation successful
total time: 23472  ms

gsql -d backupdb -p 8000 -r
gsql ((GaussDB 8.1.1 build af002019) compiled at 2020-01-10 05:43:20 commit 6995 last mr 11566 )
Non-SSL connection (SSL connection is recommended when requiring high-security)
Type "help" for help.

backupdb=# select * from hr.areas;
 area_id |       area_name
---------+------------------------
       4 | Iron
       1 | Wood
       2 | Lake
       3 | Desert
(4 rows)
```

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Example 13: **user1** does not have the permission for importing data from an exported file to the **backupdb** database and **role1** has this permission. To import the exported data to the **backupdb** database, you can set **--role** to **role1** in the export command.

```
human_resource=# CREATE USER user1 IDENTIFIED BY 'password';

gs_restore -U user1 -W password /home//backup/MPPDB_backup.tar -p 8000 -h 10.10.10.100 -d backupdb
--role role1 --rolepassword password
restore operation successful
total time: 554  ms

gsql -d backupdb -p 8000 -r
gsql ((GaussDB 8.1.1 build af002019) compiled at 2020-01-10 05:43:20 commit 6995 last mr 11566 )
Non-SSL connection (SSL connection is recommended when requiring high-security)
Type "help" for help.

backupdb=# select * from hr.areas;
 area_id |       area_name
---------+------------------------
       4 | Iron
       1 | Wood
       2 | Lake
       3 | Desert
(4 rows)
```

# 3.5 Data Export

## 3.5.1 Exporting Data to OBS

### 3.5.1.1 Parallel OBS Data Export

### Overview

GaussDB(DWS) databases allow you to export data in parallel using OBS foreign tables, in which the export mode and the exported data format are specified. Data is exported in parallel through multiple DNs from GaussDB(DWS) to the OBS server, improving the overall export performance.

- The CN only plans data export tasks and delivers the tasks to DNs. In this case, the CN is released to process external requests.
- The computing capability and bandwidth of all the DNs are fully leveraged to export data.
- You can concurrently export data using multiple OBS services, but the bucket and object paths specified for the export tasks must be different and cannot be null.
- The OBS server connects to GaussDB(DWS) cluster nodes. The export rate is affected by the network bandwidth.
- The TEXT and CSV data file formats are supported. The size of data in a single row must be less than 1 GB.
- Data in ORC format is supported only by 8.1.0 or later.

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## Related Concepts

- **Source data file**: a TEXT or CSV file that stores data.
- **OBS**: a cloud storage service used to store unstructured data, such as documents, images, and videos. Data objects concurrently exported from GaussDB(DWS) are stored on the OBS server.
- **Bucket**: a container storing objects on OBS.
  - Object storage is a flat storage mode. Layered file system structures are not needed because all objects in buckets are at the same logical layer.
  - In OBS, each bucket name must be unique and cannot be changed. A default access control list (ACL) is created with a bucket. Each item in the ACL contains permissions granted to certain users, such as **READ**, **WRITE**, and **FULL_CONTROL**. Only authorized users can perform bucket operations, such as creating, deleting, viewing, and setting ACLs for buckets.
  - A user can create a maximum of 100 buckets. The total data size and the number of objects and files in each bucket are not limited.
- **Object**: a basic data storage unit in OBS. Data uploaded by users is stored in OBS buckets as objects. Object attributes include **Key**, **Metadata**, and **Data**.

  Generally, objects are managed as files. However, OBS has no file system–related concepts, such as files and folders. To let users easily manage data, OBS allows them to simulate folders. Users can add a slash (/) in the object name, for example, **tpcds1000/stock.csv**. In this name, **tpcds1000** is regarded as the folder name and **stock.csv** the file name. The value of **key** (object name) is still **tpcds1000/stock.csv**, and the content of the object is the content of the **stock.csv** file.
- **Key**: name of an object. It is a UTF-8 character sequence containing 1 to 1024 characters. A key value must be unique in a bucket. Users can name the objects they stored or obtained as *Bucket name*+*Object name*.
- **Metadata**: object metadata, which contains information about the object. There are system metadata and user metadata. The metadata is uploaded to OBS as key-value pairs together with HTTP headers.
  - System metadata is generated by OBS and used for processing object data. System metadata includes **Date**, **Content-length**, **last-modify**, and **Content-MD5**.
  - User metadata contains object descriptions specified by users for uploading objects.
- **Data**: object content, which is regarded by OBS as stateless binary data.
- **Foreign table**: A foreign table is used to identify data in a source data file. It stores information, such as the location, format, destination location, encoding format, and data delimiter of a source data file.

## Principles

The following describes the principles of exporting data from a cluster to OBS by using a distributed hash table or a replication table.

- Distributed hash table: the table for which **DISTRIBUTE BY HASH (Column_Name)** is specified in the table creation statement.

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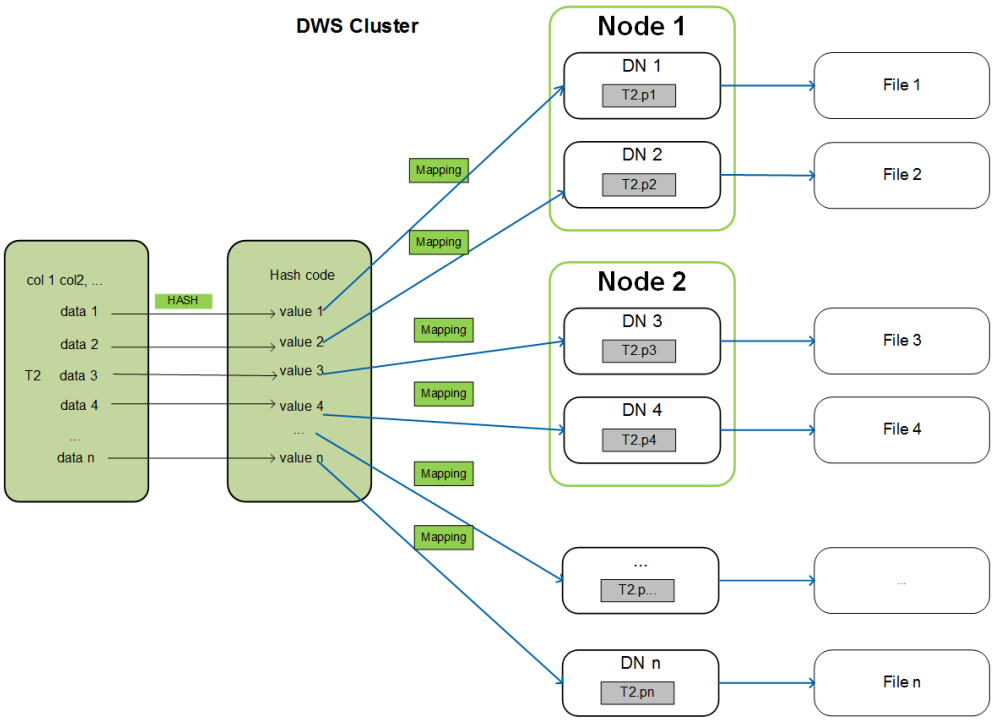
A distributed hash table stores data in hash mode. **Figure 3-8** shows how to export data from table (**T2**) to OBS as an example.

During table data storage, the **col2** hash column in table **T2** is hashed, and a hash value is generated. The tuple is distributed to corresponding DNs for storage according to the mapping between the DNs and the hash value.

When data is exported to OBS, DNs that store the exported data of **T2** directly export their data files to OBS. Original data on multiple nodes will be exported in parallel.

**Figure 3-8** Hash distribution principle




- Replication table: the table for which **DISTRIBUTE BY REPLICATION** is specified in the table creation statement.

  A replication table stores a package of complete table data on each GaussDB(DWS) node. When exporting data to OBS, GaussDB(DWS) randomly selects a DN for export.

## Naming Rules of Exported Files

Rules for naming the files exported from GaussDB(DWS) to OBS are as follows:

- Data exported from DNs is stored on OBS in segment format. The file is named as *Table name*_*Node name*_**segment.***n*. *n* is a natural number starting from 0, for example, 0, 1, 2, 3.

  For example, the data of table **t1** on **datanode3** will be exported as **t1_datanode3_segment.0**, **t1_datanode3_segment.1**, and so on.

  You are advised to export data from different clusters or databases to different OBS buckets or different paths of the same OBS bucket.
- Each segment can store a maximum of 1 GB data, with no tuples sliced. If data stored in a segment exceeds 1 GB, the excess data will be stored in the second segment.

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For example:

A segment has already stored 100 pieces of tuples (1023 MB) when **datanode3** exports data from **t1** to OBS. If a 5 MB tuple is inserted to the segment, the data size becomes 1028 MB. In this case, file **t1_datanode3_segment.0** (1023 MB) is generated and stored on OBS, and the new tuple is stored on OBS as file **t1_datanode3_segment.1**.

- When data is exported from a distributed hash table, the number of segments generated on each DN depends on the data volume stored on a DN, not on the number of DNs in the cluster. Data stored in hash mode may not be evenly distributed on each DN.

  For example, a cluster has **DataNode1**, **DataNode2**, **DataNode3**, **DataNode4**, **DataNode5**, and **DataNode6**, which store 1.5 GB, 0.7 GB, 0.6 GB, 0.8 GB, 0.4 GB, and 0.5 GB data, respectively. Seven OBS segment files will be generated during data export because **DataNode1** will generate two segment files, which store 1 GB and 0.5 GB data, respectively.

## Data Export Process

**Figure 3-9** Concurrent data export

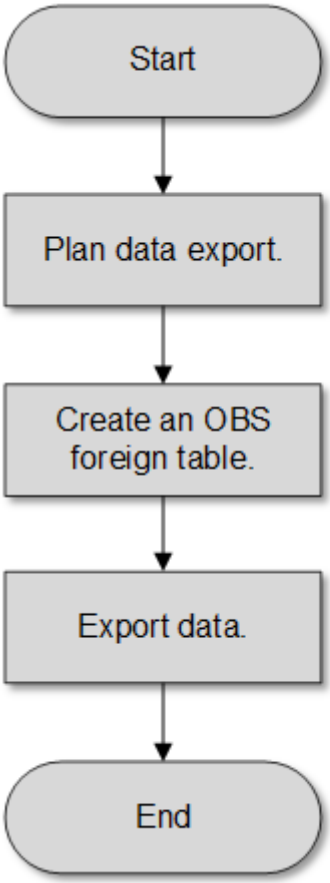



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**Table 3-22** Process description

| Procedure | Description | Subtask |
| --- | --- | --- |
| Plan data export. | Create an OBS bucket and a folder in the OBS bucket as the directory for storing exported data files.<br>For details, see **Planning Data Export**. | - |
| Create an OBS foreign table. | Create a foreign table to help OBS specify information about data files to be exported. The foreign table stores information, such as the destination location, format, encoding, and data delimiter of a source data file.<br>For details, see **Creating an OBS Foreign Table**. | - |
| Export data. | After the foreign table is created, run the **INSERT** statement to efficiently export data to data files.<br>For details, see **Exporting Data**. | - |

## 3.5.1.2 Exporting CSV/TXT Data to OBS

### 3.5.1.2.1 Planning Data Export

## Scenarios

Plan the storage location of exported data in OBS.

## Planning OBS Save Path and File

You need to specify the OBS path (to directory) for storing data that you want to export. The exported data can be saved to a file in CSV format. The system also supports TEXT so that you can import the exported data to various applications.

The target directory cannot contain any files.

## Planning OBS Bucket Permissions

The user used to export data must:

- Have OBS enabled.

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- Have the write permission on the OBS bucket where the data export path is located.

  You can configure ACL permissions for the OBS bucket to grant the write permission to a specific user.

  For details, see **Granting Write Permission to OBS Storage Location and OBS Bucket as Planned**.

## Planning Data to Be Exported and Foreign Tables

You must prepare data to be exported in the database table, and the data volume per row must be less than 1 GB. Based on the data to be exported, plan foreign tables whose attributes such as columns, column types, and length match those of user data.

## Granting Write Permission to OBS Storage Location and OBS Bucket as Planned

**Step 1** Create an OBS bucket and a folder in the OBS bucket as the directory for storing exported data.

1. Log in to the OBS management console.

   Click **Service List** and choose **Object Storage Service** to open the OBS management console.

2. Create a bucket.

   For details about how to create an OBS bucket, see "OBS Console Operation Guide > Managing Buckets > Creating a Bucket" in the *Object Storage Service User Guide*..

   For example, create a bucket named **mybucket**.

3. Create a folder.

   In the OBS bucket, create a folder for storing exported data.

   For details, see "OBS Console Operation Guide > Managing Objects > Creating a Folder" in the .

   For example, create a folder named **output_data** in the created **mybucket** OBS bucket.

**Step 2** Determine the path of the created OBS folder.

Specify the OBS path for storing exported data files. This path is the value of the **location** parameter used for creating a foreign table.

The OBS folder path in the **location** parameter consists of **obs://**, a bucket name, and a file path.

In this example, the OBS folder path is as follows:

```
obs://mybucket/output_data/
```

**NOTE**

The OBS directory to be used for storing data files must be empty.

**Step 3** Grant the OBS bucket write permission to the user who wants to export data.

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When exporting data, a user must have the write permission on the OBS bucket where the data export path is located. You can configure ACL permissions for the OBS bucket to grant the write permission to a specific user.

For details, see "OBS Console Operation Guide > Permission Control > Configuring a Bucket ACL" in the *Object Storage Service User Guide*.

**----End**

### 3.5.1.2.2 Creating an OBS Foreign Table

## Procedure

**Step 1** Based on the path planned in **Planning Data Export**, determine the value of the **location** parameter used for creating a foreign table.

**Step 2** Obtain the access keys (AK and SK) to access OBS.

To obtain access keys, log in to the management console, click the username in the upper right corner, and select **My Credential** from the menu. Then choose **Access Keys** in the navigation tree on the left. On the **Access Keys** page, you can view the existing AKs or click **Add Access Key** to create and download access keys.

**Step 3** Examine the formats of data to be exported and determine the values of data format parameters used for creating a foreign table. For details, see data format parameters.

**Step 4** Create an OBS table based on the parameter settings in the preceding steps. For details about how to create a foreign table, see CREATE FOREIGN TABLE (for GDS Import and Export).

**----End**

## Examples

Create a foreign table in the GaussDB(DWS) database. Set parameters as follows:

- **location**

  The OBS path of the source data file has been obtained in **Obtain the OBS path for storing source data files** in **Planning Data Export**.

  For example, set **location** as follows:

  ```
  location 'obs://mybucket/output_data/',
  ```

- **Access keys (AK and SK)**
  - Set **access_key** to the AK you have obtained.
  - Set **secret_access_key** to the SK you have obtained.

  NOTE

  **access_key** and **secret_access_key** have been obtained during user creation. Replace the italic part with the actual keys.

- **Data format parameters**
  - Set **format** to **CSV**.
  - Set **encoding** to **UTF-8**.

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- Configure **encrypt**. Its default value is **off**.
- Set **delimiter** to **,**.
- Set **header** (whether the exported data file contains the header row).

  Specifies whether a file contains a header with the names of each column in the file.

  When exporting data from OBS, this parameter cannot be set to **true**. Use the default value **false**, indicating that the first row of the exported data file is not the header.

Based on the preceding settings, the foreign table is created using the following statements:

```
DROP FOREIGN TABLE IF EXISTS product_info_output_ext;
CREATE FOREIGN TABLE product_info_output_ext
(
    product_price               integer       not null,
    product_id                  char(30)      not null,
    product_time                date          ,
    product_level               char(10)      ,
    product_name                varchar(200)  ,
    product_type1               varchar(20)   ,
    product_type2               char(10)      ,
    product_monthly_sales_cnt   integer       ,
    product_comment_time        date          ,
    product_comment_num         integer       ,
    product_comment_content     varchar(200)
)
SERVER gsmpp_server
OPTIONS(
location 'obs://mybucket/output_data/',
FORMAT 'CSV' ,
DELIMITER ',',
encoding 'utf8',
header 'false',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced'
)
WRITE ONLY ;
```

If the following information is displayed, the foreign table has been created:

```
CREATE FOREIGN TABLE
```

### 3.5.1.2.3 Exporting Data

## Procedure

**Step 1** Export data.

```
INSERT INTO [Foreign table name] SELECT * FROM [Source table name];
```

**NOTE**

- Only a single internal table can be exported at a time. Multi-table join is not supported during export. Results of the aggregation, sort, subquery, and limit operations on a single table also cannot be exported.

**----End**

## Examples

- **Example 1**: Export data from table **product_info_output** to a data file through the **product_info_output_ext** foreign table.

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```
INSERT INTO product_info_output_ext SELECT * FROM product_info_output;
```

If information similar to the following is displayed, the data has been exported.

```
INSERT 0 10
```

- **Example 2**: Export part of the data to a data file by specifying the filter condition **WHERE** *product_price>500*.

```
INSERT INTO product_info_output_ext SELECT * FROM product_info_output WHERE product_price>500;
```

NOTE

- The directory to be used for data storage must be empty, or the export will fail.
- Data of a special type, such as RAW, is exported as a binary file, which cannot be recognized by the import tool. You need to use the RAWTOHEX() function to convert it to the hexadecimal format before export.

### 3.5.1.2.4 Examples

## Exporting a Table

Create two foreign tables and use them to export tables from a database to two buckets in OBS.

**Step 1** Log in to the OBS data server through the management console. On the OBS server, create the buckets **/input-data1** and **/input-data2** for storing data files, and create data directories **/input-data1/data** and **/input-data2/data**, respectively, in the two buckets.

**Step 2** On the GaussDB(DWS) database, create the foreign tables **tpcds.customer_address_ext1** and **tpcds.customer_address_ext2** for the OBS data server to receive data exported from the database.

OBS and the database are in the same region. The example GaussDB(DWS) table to be exported is **tpcds.customer_address**.

Export information is set as follows:

- The source data file directories are **/input-data1/data/** and **/input-data2/data/**, so **location** of **tpcds.customer_address_ext1** and **tpcds.customer_address_ext2** is set to **obs://input-data1/data/** and **obs://input-data2/data/**, respectively.

Information about data formats is set based on the detailed data format parameters specified during data export from a database. The parameter settings are as follows:

- **format** is set to **CSV**.
- **encoding** is set to **UTF-8**.
- **delimiter** is set to **E'\x08'**.
- Configure **encrypt**. Its default value is **off**.
- **access_key** is set to the AK you have obtained. (mandatory)
- **secret_access_key** is set to the SK you have obtained. (mandatory)

NOTE

**access_key** and **secret_access_key** have been obtained during user creation. Replace the italic part with the actual keys.

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Based on the preceding settings, the foreign table is created using the following statements:

```
CREATE FOREIGN TABLE tpcds.customer_address_ext1
(
ca_address_sk             integer                       ,
ca_address_id             char(16)                      ,
ca_street_number          char(10)                      ,
ca_street_name            varchar(60)                   ,
ca_street_type            char(15)                      ,
ca_suite_number           char(10)                      ,
ca_city                   varchar(60)                   ,
ca_county                 varchar(30)                   ,
ca_state                  char(2)                       ,
ca_zip                    char(10)                      ,
ca_country                varchar(20)                   ,
ca_gmt_offset             decimal(5,2)                  ,
ca_location_type          char(20)
)
SERVER gsmpp_server
OPTIONS(LOCATION 'obs://input-data1/data/',
FORMAT 'CSV',
ENCODING 'utf8',
DELIMITER E'\x08',
ENCRYPT 'off',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced'
)Write Only;
CREATE FOREIGN TABLE tpcds.customer_address_ext2
(
ca_address_sk             integer                       ,
ca_address_id             char(16)                      ,
ca_street_number          char(10)                      ,
ca_street_name            varchar(60)                   ,
ca_street_type            char(15)                      ,
ca_suite_number           char(10)                      ,
ca_city                   varchar(60)                   ,
ca_county                 varchar(30)                   ,
ca_state                  char(2)                       ,
ca_zip                    char(10)                      ,
ca_country                varchar(20)                   ,
ca_gmt_offset             decimal(5,2)                  ,
ca_location_type          char(20)
)
SERVER gsmpp_server
OPTIONS(LOCATION 'obs://input-data2/data/',
FORMAT 'CSV',
ENCODING 'utf8',
DELIMITER E'\x08',
ENCRYPT 'off',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced'
)Write Only;
```

**Step 3** In GaussDB(DWS), export the data table **tpcds.customer_address** to the foreign tables **tpcds.customer_address_ext1** and **tpcds.customer_address_ext2** concurrently.

```
INSERT INTO tpcds.customer_address_ext1 SELECT * FROM tpcds.customer_address;
INSERT INTO tpcds.customer_address_ext2 SELECT * FROM tpcds.customer_address;
```

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NOTE

The design of OBS foreign tables does not allow exporting files to a non-empty path. However, in concurrent export scenarios, multiple files are exported to the same path, causing an error.

Assume that a user concurrently exports data from the same table to the same OBS foreign table, and that one SQL statement is executed to export data when another SQL statement is being executed and has not generated any file on the OBS server. In this case, certain data is overwritten although both SQL statements are successfully executed. Therefore, you are advised not to concurrently export data to the same OBS foreign table.

**----End**

## Concurrently Exporting Tables

Use the two foreign tables to export tables from the database to two buckets in OBS.

**Step 1** Log in to the OBS data server through the management console. On the OBS server, create the buckets **/input-data1** and **/input-data2** for storing data files, and create data directories **/input-data1/data** and **/input-data2/data**, respectively, in the two buckets.

**Step 2** In GaussDB(DWS), create foreign tables **tpcds.customer_address_ext1** and **tpcds.customer_address_ext2** for the OBS server to receive exported data.

OBS and the database are in the same region. Tables to be exported are **tpcds.customer_address** and **tpcds.customer_demographics**.

Export information is set as follows:

- The source data file directories are **/input-data1/data/** and **/input-data2/data/**, so **location** of **tpcds.customer_address_ext1** and **tpcds.customer_address_ext2** is set to **obs://input-data1/data/** and **obs://input-data2/data/**, respectively.

Information about data formats is set based on the detailed data format parameters specified during data export from GaussDB(DWS). The parameter settings are as follows:

- **format** is set to **CSV**.
- **encoding** is set to **UTF-8**.
- **delimiter** is set to **E'\x08'**.
- Configure **encrypt**. Its default value is **off**.
- **access_key** is set to the AK you have obtained. (mandatory)
- **secret_access_key** is set to the SK you have obtained. (mandatory)

NOTE

**access_key** and **secret_access_key** have been obtained during user creation. Replace the italic part with the actual keys.

Based on the preceding settings, the foreign table is created using the following statements:

```
CREATE FOREIGN TABLE tpcds.customer_address_ext1
(
ca_address_sk             integer               ,
```

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```
ca_address_id             char(16)              ,
ca_street_number          char(10)                ,
ca_street_name            varchar(60)               ,
ca_street_type            char(15)                ,
ca_suite_number           char(10)                ,
ca_city                   varchar(60)             ,
ca_county                 varchar(30)               ,
ca_state                  char(2)                 ,
ca_zip                    char(10)                ,
ca_country                varchar(20)               ,
ca_gmt_offset             decimal(5,2)              ,
ca_location_type          char(20)
)
SERVER gsmpp_server
OPTIONS(LOCATION 'obs://input-data1/data/',
FORMAT 'CSV',
ENCODING 'utf8',
DELIMITER E'\x08',
ENCRYPT 'off',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced'
)Write Only;
CREATE FOREIGN TABLE tpcds.customer_address_ext2
(
ca_address_sk             integer               ,
ca_address_id             char(16)              ,
ca_address_name           varchar(20)           ,
ca_address_code           integer               ,
ca_street_number          char(10)                ,
ca_street_name            varchar(60)               ,
ca_street_type            char(15)                ,
ca_suite_number           char(10)                ,
ca_city                   varchar(60)             ,
ca_county                 varchar(30)               ,
ca_state                  char(2)                 ,
ca_zip                    char(10)                ,
ca_country                varchar(20)               ,
ca_gmt_offset             decimal(5,2)
)
SERVER gsmpp_server
OPTIONS(LOCATION 'obs://input_data2/data/',
FORMAT 'CSV',
ENCODING 'utf8',
DELIMITER E'\x08',
QUOTE E'\x1b',
ENCRYPT 'off',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced'
)Write Only;
```

**Step 3** In GaussDB(DWS), export the data tables **tpcds.customer_address** and **tpcds.warehouse** in parallel to the foreign tables **tpcds.customer_address_ext1** and **tpcds.customer_address_ext2**, respectively.

```
INSERT INTO tpcds.customer_address_ext1 SELECT * FROM tpcds.customer_address;
INSERT INTO tpcds.customer_address_ext2 SELECT * FROM tpcds.warehouse;
```

**----End**

## 3.5.1.3 Exporting ORC Data to OBS

### 3.5.1.3.1 Planning Data Export

For details about exporting data to OBS, see **Planning Data Export**.

For details about the data types that can be exported to OBS, see **Table 3-6**.

For details about HDFS data export or MRS configuration, see the *MapReduce Service User Guide*.

#### 3.5.1.3.2 Creating a Foreign Server

For details about creating a foreign server on OBS, see **Creating a Foreign Server**.

For details about creating a foreign server in HDFS, see **Manually Creating a Foreign Server**.

#### 3.5.1.3.3 Creating a Foreign Table

After operations in **Creating a Foreign Server** are complete, create an OBS/HDFS write-only foreign table in the GaussDB(DWS) database to access data stored in OBS/HDFS. The foreign table is write-only and can be used only for data export.

The syntax for creating a foreign table is as follows. For details, see the syntax **CREATE FOREIGN TABLE (SQL on Hadoop or OBS)**.

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name
( [ { column_name type_name
   [ { [CONSTRAINT constraint_name] NULL |
   [CONSTRAINT constraint_name] NOT NULL |
     column_constraint [...]} ] |
     table_constraint [, ...]} [, ...] ] )
   SERVER dfs_server
   OPTIONS ( { option_name ' value ' } [, ...] )
   [ {WRITE ONLY }]
   DISTRIBUTE BY {ROUNDROBIN | REPLICATION}
   [ PARTITION BY ( column_name ) [ AUTOMAPPED ] ] ;
```

For example, when creating a foreign table named *product_info_ext_obs*, set parameters in the syntax as follows:

- **table_name**

  Specifies the name of the foreign table to be created.

- **Table column definitions**
  - **column_name**: specifies the name of a column in the foreign table.
  - **type_name**: specifies the data type of the column.

  Multiple columns are separate by commas (,).

- **SERVER dfs_server**

  Specifies the foreign server name of the foreign table. This server must exist. The foreign table connects to OBS/HDFS to read data through the foreign server.

  Set this parameter to the name of the foreign server created in **9.2.3 Creating a Foreign Server**.

- **OPTIONS parameters**

  These are parameters associated with the foreign table. The key parameters are as follows:
  - **format**: specifies the format of the exported data file. The ORC format is supported.
  - **foldername**: (mandatory) specifies the data source file directory in the foreign table. **OBS**: specifies the OBS path of the source data file. You only need to enter */Bucket name/Folder directory level/*, which does not contain the endpoint of OBS. HDFS: specifies the path in the HDFS file system. This parameter is mandatory for the write-only foreign table.

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  - **encoding**: specifies the encoding of the data source file in the foreign table. The default value is **utf8**.
  - filesize

    (Optional) Specifies the file size of a write-only foreign table. If this parameter is not specified, the file size in the distributed file system configuration is used by default. This syntax is available only for the write-only foreign table.

    Value range: an integer ranging from 1 to 1024

    NOTE

    The **filesize** parameter is valid only for the ORC-formatted write-only HDFS foreign table.
  - compression

    (Optional) Specifies the compression mode of ORC files. This syntax is available only for the write-only foreign table.

    Value range: **zlib**, **snappy**, and **lz4** The default value is **snappy**.
  - version

    (Optional) Specifies the ORC version number. This syntax is available only for the write-only foreign table.

    Value range: Only **0.12** is supported. The default value is **0.12**.
  - dataencoding

    (Optional) Specifies the data code of the data table to be exported when the database code is different from the data code of the data table. For example, the database code is Latin-1, but the data in the exported data table is in UTF-8 format. If this parameter is not specified, the database encoding format is used by default. This syntax is valid only for the write-only HDFS foreign table.

    Value range: data code types supported by the database encoding

    NOTE

    The **dataencoding** parameter is valid only for the ORC-formatted write-only HDFS foreign table.

- **Other parameters in the syntax**

  Other parameters are optional. You can set them as required. In this example, you do not need to set these parameters.

  Based on the preceding settings, the command for creating the foreign table is as follows:

```
DROP FOREIGN TABLE IF EXISTS product_info_ext_obs;

-- Create an OBS foreign table that does not contain partition columns. The foreign server associated with the table is obs_server, the file format on OBS corresponding to the table is ORC, and the data storage path on OBS is/mybucket/data/.

CREATE FOREIGN TABLE product_info_ext_obs
(
    product_price                integer        ,
    product_id                   char(30)       ,
    product_time                 date           ,
    product_level                char(10)       ,
    product_name                 varchar(200)   ,
    product_type1                varchar(20)    ,
    product_type2                char(10)       ,
```

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```
  product_monthly_sales_cnt    integer        ,
  product_comment_time         date           ,
  product_comment_num          integer        ,
  product_comment_content      varchar(200)
) SERVER obs_server
OPTIONS (
format 'orc',
foldername '/mybucket/demo.db/product_info_orc/',
  compression 'snappy',
  version '0.12'
) Write Only;
```

#### 3.5.1.3.4 Exporting Data

### Procedure

**Step 1** Export data.

```
INSERT INTO [Foreign table name] SELECT * FROM [Source table name];
```

NOTE

- Only a single internal table can be exported at a time. Multiple tables cannot be joined during export. Results of the aggregation, sort, subquery, and limit operations on a single table also cannot be exported.

**----End**

### Examples

- **Example 1**: Export data from table **product_info_output** to a data file using the **product_info_output_ext** foreign table.

  ```
  INSERT INTO product_info_output_ext SELECT * FROM product_info_output;
  ```

  If information similar to the following is displayed, the data has been exported.

  ```
  INSERT 0 10
  ```

- **Example 2**: Export part of the data to a data file by specifying the filter condition **WHERE** *product_price>500*.

  ```
  INSERT INTO product_info_output_ext SELECT * FROM product_info_output WHERE product_price>500;
  ```

NOTE

Data of a special type, such as RAW, is exported as a binary file, which cannot be recognized by the import tool. As a result, you need to use the **RAWTOHEX()** function to convert it to the hexadecimal format before export.

## 3.5.2 Exporting ORC Data to MRS

### 3.5.2.1 Overview

GaussDB(DWS) allows you to export ORC data to MRS using an HDFS foreign table. You can specify the export mode and export data format in the foreign table. Data is exported from GaussDB(DWS) in parallel using multiple DNs and stored in HDFS. In this way, the overall export performance is improved.

- The CN only plans data export tasks and delivers the tasks to DNs. In this case, the CN is released to process external requests.
- The computing capability and bandwidth of all the DNs are fully leveraged to export data.

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- Multiple HDFS servers can export data concurrently. The export path can be empty. The naming rule of the path must be the same as that of the exported file.
- MRS connects to GaussDB(DWS) cluster nodes. The export rate is affected by the network bandwidth.
- Data files in the ORC format are supported.

## Naming Rules of Exported Files

The rules for naming ORC data files exported from GaussDB(DWS) are as follows:

1. Data exported to MRS (HDFS): When data is exported from a DN, the data is stored in HDFS in the segment format. The file is named in the format of **mpp**_*Database name*_*Schema name*_*Table name*_*Node name*_*n*.**orc**. *n* is a natural number starting from 0 in ascending order, for example, 0, 1, 2, 3.
2. You are advised to export data from different clusters or databases to different paths. The maximum size of an ORC file is 128 MB, and that of a stripe file is 64 MB.
3. After the export is complete, the **_SUCCESS** file is generated.

## 3.5.2.2 Planning Data Export

For details about the data types that can be exported to MRS, see **Table 3-6**.

For details about HDFS data export or MRS configuration, see the *MapReduce Service User Guide*.

## 3.5.2.3 Creating a Foreign Server

For details about creating a foreign server on HDFS, see **Manually Creating a Foreign Server**.

## 3.5.2.4 Creating a Foreign Table

After operations in **Creating a Foreign Server** are complete, create an HDFS write-only foreign table in the GaussDB(DWS) database to access data stored in HDFS. The foreign table is write-only and can be used only for data export.

The syntax for creating a foreign table is as follows. For details, see **CREATE FOREIGN TABLE (SQL on Hadoop or OBS)**.

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name
( [ { column_name type_name
   [ { [CONSTRAINT constraint_name] NULL |
   [CONSTRAINT constraint_name] NOT NULL |
     column_constraint [...]} ] |
     table_constraint [, ...]} [, ...] ] )
   SERVER dfs_server
   OPTIONS ( { option_name ' value ' } [, ...] )
   [ {WRITE ONLY }]
   DISTRIBUTE BY {ROUNDROBIN | REPLICATION}
   [ PARTITION BY ( column_name ) [ AUTOMAPPED ] ] ;
```

For example, when creating a foreign table *product_info_ext_obs*, configure the parameters in the syntax as follows.

- **table_name**

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Specifies the name of the foreign table.

- **Table column definitions**
  - **column_name**: specifies the name of a column in the foreign table.
  - **type_name**: specifies the data type of the column.

  Multiple columns are separate by commas (,).
- **SERVER dfs_server**

  Specifies the foreign server name of the foreign table. This server must exist. The foreign table connects to OBS/HDFS to read data through the foreign server.

  Enter the name of the foreign server created in **Creating a Foreign Server**.
- **OPTIONS parameters**

  These parameters are associated with the foreign table. The key parameters are as follows:
  - **format**: specifies the format of the exported data file. The ORC format is supported.
  - **foldername**: specifies the directory of the data source file in the foreign table, that is, the corresponding file directory in HDFS. This parameter is mandatory for write-only foreign tables and optional for read-only foreign tables.
  - **encoding**: specifies the encoding format of the data source file in the foreign table. The default value is **utf8**.
  - filesize

    (Optional) Specifies the file size of a write-only foreign table. If this parameter is not specified, the file size in the distributed file system is used by default. This syntax is available only for the write-only foreign table.

    Value range: an integer ranging from 1 to 1024

    NOTE

    The **filesize** parameter is valid only for the write-only HDFS foreign table in ORC format.
  - compression

    (Optional) Specifies the compression mode of ORC files. This syntax is available only for the write-only foreign table.

    Value range: **zlib**, **snappy**, and **lz4**. The default value is **snappy**.
  - version

    (Optional) Specifies the ORC version number. This syntax is available only for the write-only foreign table.

    Value range: Only **0.12** is supported. The default value is **0.12**.
  - dataencoding

    (Optional) Specifies the data encoding of the data table to be exported when the database encoding is different from the data encoding of the data table. For example, the database encoding is Latin-1, but the data encoding of the exported data table is in UTF-8 format. If this parameter is not specified, the database encoding is used by default. This syntax is valid only for the write-only HDFS foreign table.

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Value range: data encoding types supported by the database encoding

NOTE

The **dataencoding** parameter is valid only for the write-only HDFS foreign table in ORC format.

- **Other parameters in the syntax**

  Other parameters are optional. You can configure them as required. In this example, you do not need to configure these parameters. For details, see **CREATE FOREIGN TABLE (SQL on Hadoop or OBS)**.

  Based on the preceding settings, the command for creating the foreign table is as follows:

```
DROP FOREIGN TABLE IF EXISTS product_info_ext_obs;

-- Create an OBS foreign table that does not contain partition columns. The foreign server associated with the table is hdfs_server, the format of the file on HDFS corresponding to the table is ORC, and the data storage path on OBS is /user/hive/warehouse/product_info_orc/.

CREATE FOREIGN TABLE product_info_ext_obs
(
    product_price                integer        ,
    product_id                   char(30)       ,
    product_time                 date           ,
    product_level                char(10)       ,
    product_name                 varchar(200)   ,
    product_type1                varchar(20)    ,
    product_type2                char(10)       ,
    product_monthly_sales_cnt    integer        ,
    product_comment_time         date           ,
    product_comment_num          integer        ,
    product_comment_content      varchar(200)
) SERVER hdfs_server
OPTIONS (
format 'orc',
foldername  '/user/hive/warehouse/product_info_orc/',
   compression 'snappy',
    version '0.12'
) Write Only;
```

## 3.5.2.5 Exporting Data

## Procedure

**Step 1** Export data.

```
INSERT INTO [Foreign table name] SELECT * FROM [Source table name];
```

NOTE

- Only a single internal table can be exported at a time. Multiple tables cannot be joined during export. Results of the aggregation, sort, subquery, and limit operations on a single table also cannot be exported.

**----End**

## Examples

- **Example 1**: Export data from table **product_info_output** to a data file using the **product_info_output_ext** foreign table.

```
INSERT INTO product_info_output_ext SELECT * FROM product_info_output;
```

  If information similar to the following is displayed, the data has been exported.

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```
INSERT 0 10
```

- **Example 2**: Export part of the data to a data file by specifying the filter condition **WHERE** *product_price>500*.
  INSERT INTO *product_info_output_ext* SELECT * FROM *product_info_output* WHERE *product_price>500*;

NOTE

Data of a special type, such as RAW, is exported as a binary file, which cannot be recognized by the import tool. As a result, you need to use the **RAWTOHEX()** function to convert it to the hexadecimal format before export.

# 3.5.3 Using GDS to Export Data to a Remote Server

## 3.5.3.1 Exporting Data In Parallel Using GDS

In high-concurrency scenarios, you can use GDS to export data from a database to a common file system.

In the current GDS version, data can be exported from a database to a pipe file.

- If the local disk space of the GDS user is insufficient:
  - The data exported from GDS is compressed using the pipe to occupy less disk space.
  - The exported data is transferred through the pipe to the HDFS server for storage.
- If you need to cleanse data before exporting data:
  - You can compile programs as needed and read streaming data from pipes in real time.

NOTE

- The current version does not support data export through GDS in SSL mode. Do not use GDS in SSL mode.
- All pipe files mentioned in this section refer to named pipes on Linux.

## Overview

**Using foreign tables**: A GDS foreign table specifies the exported file format and export mode. Data is exported in parallel through multiple DNs from the database to data files, which improves the overall data export performance. The data files cannot be directly exported to HDFS.

- The CN only plans data export tasks and delivers the tasks to DNs. In this case, the CN is released to process other tasks.
- In this way, the computing capabilities and bandwidths of all the DNs are fully leveraged to export data.

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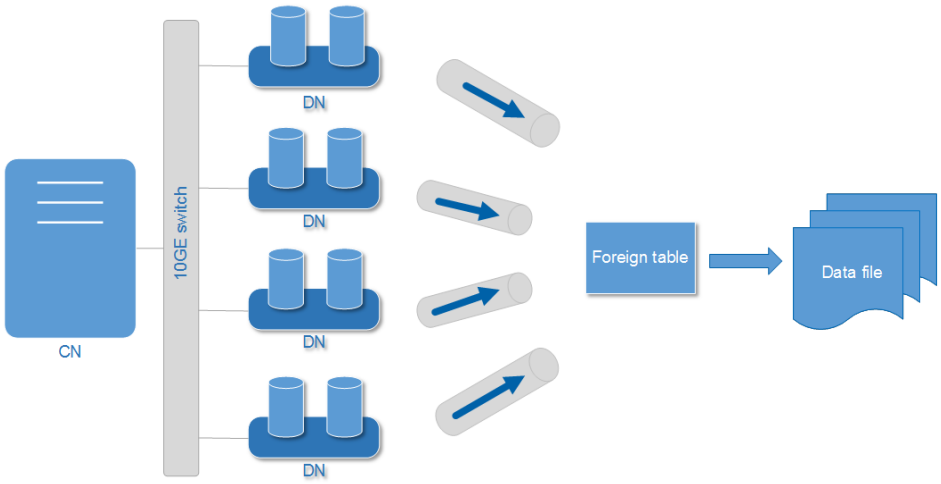
**Figure 3-10** Exporting data using foreign tables




## Related Concepts

- **Data file**: A TEXT, CSV, or FIXED file that stores data exported from the GaussDB(DWS) database.
- **Foreign table**: A table that stores information, such as the format, location, and encoding format of a data file.
- **GDS**: A data service tool. To export data, deploy it on the server where data files are stored.
- **Table**: Tables in the database, including row-store tables and column-store tables. Data in the data files is exported from these tables.
- **Remote mode**: Service data in a cluster is exported to hosts outside the cluster.

## Exporting a Schema

Data can be exported to GaussDB(DWS) in **Remote** mode.

- **Remote mode**: Service data in a cluster is exported to hosts outside the cluster.
  - In this mode, multiple GDSs are used to concurrently export data. One GDS can export data for only one cluster at a time.
  - The data export rate of a GDS that resides on the same intranet as cluster nodes is limited by the network bandwidth. A 10GE configuration is recommended.
  - Data files in TEXT or CSV format are supported. The size of data in a single row must be less than 1 GB.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## Data Export Process

**Figure 3-11** Concurrent data export

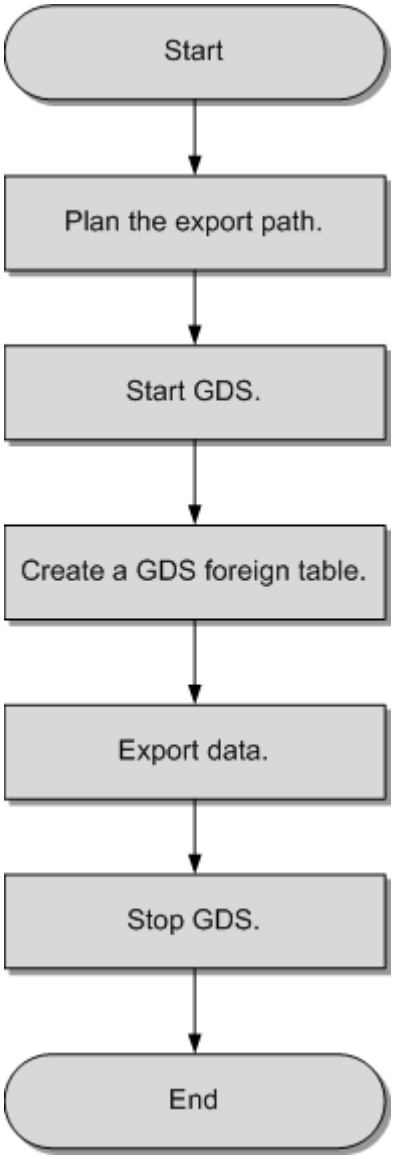


**Table 3-23** Process description

| Process | Description | Subtask |
| --- | --- | --- |
| Plan data export. | Prepare data to be exported and plan the export path for the mode to be selected.<br>For details, see **Planning Data Export**. | - |


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| Process | Description | Subtask |
| --- | --- | --- |
| Start GDS. | If the **Remote** mode is selected, install, configure, and start GDS on data servers.<br>For details, see **Installing, Configuring, and Starting GDS**. | - |
| Create a foreign table, | Create a foreign table to help GDS specify information about a data file. The foreign table stores information, such as the location, format, encoding, and inter-data delimiter of a data file.<br>For details, see **Creating a GDS Foreign Table**. | - |
| Export data. | After the foreign table is created, run the **INSERT** statement to efficiently export data to data files.<br>For details, see **Exporting Data**. | - |
| Stop GDS. | Stop GDS after data is exported.<br>For details, see **Stopping GDS**. | - |

### 3.5.3.2 Planning Data Export

## Scenarios

Before you use GDS to export data from a cluster, prepare data to be exported and plan the export path.

## Planning an Export Path

- **Remote** mode

**Step 1** Log in to the GDS data server as user **root** and create the **/output_data** directory for storing data files.

```
mkdir -p /output_data
```

**Step 2** (Optional) Create a user and the user group to which it belongs. This user is used to start GDS and must have the write permission on the directory for storing data files.

```
groupadd gdsgrp
useradd -g gdsgrp gdsuser
```

If the following information is displayed, the user and user group already exist. Skip this step.

```
useradd: Account 'gdsuser' already exists.
groupadd: Group 'gdsgrp' already exists.
```

**Step 3** Change the directory owner to **gdsuser**.


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```
chown -R gdsuser:gdsgrp /output_data
```

**----End**

### 3.5.3.3 Installing, Configuring, and Starting GDS

GDS is a data service tool provided by GaussDB(DWS). Using the foreign table mechanism, this tool helps export data at a high speed.

For details, see **Installing, Configuring, and Starting GDS**.

### 3.5.3.4 Creating a GDS Foreign Table

## Procedure

**Step 1** Set the **location** parameter for the foreign table based on the path planned in **Planning Data Export**.

- **Remote** mode

  Set the **location** parameter to the URL of the directory that stores the data files.

  You do not need to specify any file.

  For example:

  The IP address of the GDS data server is 192.168.0.90. The listening port number set during GDS startup is 5000. The directory for storing data files is **/output_data**.

  In this case, set the **location** parameter to **gsfs://192.168.0.90:5000/**.

  NOTE

  - **location** can be set to a subdirectory, for example, **gsfs://192.168.0.90:5000/2019/11/**, so that the same table can be exported to different directories by date.
  - In the current version, when an **export** task is executed, the system checks whether the **/output_data/2019/11** directory exists. If the directory does not exist, the system creates it. During the export, files are written to this directory. In this way, you do not need to manually run the **mkdir -p /output_data/2019/11** command after creating or modifying a foreign table.

**Step 2** Set data format parameters in the foreign table based on the planned data file formats. For details about format parameters, see data format parameters.

**Step 3** Create a GDS foreign table based on the parameter settings in the preceding steps. For details about how to create a foreign table, see CREATE FOREIGN TABLE (for GDS Import and Export).

**----End**

## Example

- **Example**: Create the GDS foreign table **foreign_tpcds_reasons** for the source data. Data is to be exported as CSV files.

  Data export mode settings are as follows:

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The data server resides on the same intranet as the cluster. The IP address of the data server is 192.168.0.90. Data is to be exported as CSV files. The **Remote** mode is selected for parallel data export.

Assume that the directory for storing data files is **/output_data/** and the GDS listening port is 5000 when GDS is started. Therefore, the **location** parameter is set to **gsfs://192.168.0.90:5000/**.

Data format parameter settings are as follows:

- **format** is set to **CSV**.
- **encoding** is set to **UTF-8**.
- **delimiter** is set to **E'\x08'**.
- **quote** is set to **E'\x1b'**.
- **null** is set to an empty string without quotation marks.
- **escape** is set to the same value as that of **quote** by default.
- **header** is set to **false**, indicating that the first row is identified as a data row in an exported file.
- **EOL** is set to **0X0A**.

The foreign table is created using the following statement:

```
CREATE FOREIGN TABLE foreign_tpcds_reasons
(
  r_reason_sk    integer         not null,
  r_reason_id    char(16)        not null,
  r_reason_desc  char(100)
)
SERVER gsmpp_server
OPTIONS (LOCATION 'gsfs://192.168.0.90:5000/',
FORMAT 'CSV',
DELIMITER E'\x08',
QUOTE E'\x1b',
NULL '',
EOL '0x0a'
)
WRITE ONLY;
```

## 3.5.3.5 Exporting Data

## Prerequisites

Ensure that the IP addresses and ports of servers where CNs and DNs are deployed can connect to those of the GDS server.

## Procedure

**Step 1** Export data.

```
INSERT INTO [Foreign table name] SELECT * FROM [Source table name];
```

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NOTE

- Create batch processing scripts to export data in parallel. The degree of parallelism depends on the server resource usage. You can test several tables and monitor resource usage to determine whether to increase or reduce the amount. Common resource monitoring commands include **top** for memory and CPU usage, **iostat** for I/O usage, and **sar** for networks. For details about application cases, see **Exporting Data Using Multiple Threads**.
- Only a single internal table can be exported at a time. Multiple tables cannot be joined during export. Results of the aggregation, sort, subquery, and limit operations on a single table also cannot be exported.

**----End**

## 3.5.3.6 Stopping GDS

GDS is a data service tool provided by GaussDB(DWS). Using the foreign table mechanism, this tool helps export data at a high speed.

For details, see **Stopping GDS**.

## 3.5.3.7 Examples of Exporting Data Using GDS

## Exporting Data in Remote Mode

The data server and the cluster reside on the same intranet, the IP address of the data server is **192.168.0.90**, and data source files are in CSV format. In this scenario, data is exported in parallel in **Remote** mode.

To export data in parallel in **Remote** mode, perform the following operations:

1. Log in to the GDS data server as user **root**, create the **/output_data** directory for storing data files, and create user **gds_user** and its user group.
   ```
   mkdir -p /output_data
   ```
2. (Optional) Create a user and the user group it belongs to. The user is used to start GDS. If the user and user group exist, skip this step.
   ```
   groupadd gdsgrp
   useradd -g gdsgrp gds_user
   ```
3. Change the owner of the **/output_data** directory on the data server to **gds_user**.
   ```
   chown -R gds_user:gdsgrp /output_data
   ```
4. Log in to the data server as user **gds_user** and start GDS.

   The GDS installation path is **/opt/bin/dws/gds**. Exported data files are stored in **/output_data/**. The IP address of the data server is **192.168.0.90**. The GDS listening port is **5000**. GDS runs in daemon mode.
   ```
   /opt/bin/dws/gds/bin/gds -d /output_data -p 192.168.0.90:5000 -H 10.10.0.1/24 -D
   ```
5. In the database, create the foreign table **foreign_tpcds_reasons** for receiving data from the data server.

   Data export mode settings are as follows:

   - The directory for storing exported files is **/output_data/** and the GDS listening port is **5000** when GDS is started. The directory created for storing exported files is **/output_data/**. Therefore, the **location** parameter is set to **gsfs://192.168.0.90:5000/**.

   Data format parameter settings are as follows:

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- **format** is set to **CSV**.
- **encoding** is set to **UTF-8**.
- **delimiter** is set to **E'\x0a'**.
- **quote** is set to **E'\x1b'**.
- **null** is set to an empty string without quotation marks.
- **escape** defaults to the value of **quote**.
- **header** is set to **false**, indicating that the first row is identified as a data row in an exported file.

Based on the above settings, the foreign table is created using the following statement:

```
CREATE FOREIGN TABLE foreign_tpcds_reasons
(
  r_reason_sk    integer        not null,
  r_reason_id    char(16)       not null,
  r_reason_desc  char(100)
) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://192.168.0.90:5000/', FORMAT 'CSV',ENCODING
'utf8',DELIMITER E'\x08', QUOTE E'\x1b', NULL '') WRITE ONLY;
```

6. In the database, export data to data files through the foreign table **foreign_tpcds_reasons**.

   ```
   INSERT INTO foreign_tpcds_reasons SELECT * FROM tpcds.reason;
   ```

7. After data export is complete, log in to the data server as user **gds_user** and stop GDS.

   The GDS process ID is **128954**.

   ```
   ps -ef|grep gds
   gds_user 128954      1  0 15:03 ?        00:00:00 gds -d /output_data -p 192.168.0.90:5000 -D
   gds_user 129003 118723  0 15:04 pts/0    00:00:00 grep gds
   kill -9 128954
   ```

## Exporting Data Using Multiple Threads

The data server and the cluster reside on the same intranet, the IP address of the data server is **192.168.0.90**, and data source files are in CSV format. In this scenario, data is concurrently exported to two target tables using multiple threads in **Remote** mode.

To concurrently export data using multiple threads in **Remote** mode, perform the following operations:

1. Log in to the GDS data server as user **root**, create the **/output_data** directory for storing data files, and create the database user and its user group.

   ```
   mkdir -p /output_data
   groupadd gdsgrp
   useradd -g gdsgrp gds_user
   ```

2. Change the owner of the **/output_data** directory on the data server to **gds_user**.

   ```
   chown -R gds_user:gdsgrp /output_data
   ```

3. Log in to the data server as user **gds_user** and start GDS.

   The GDS installation path is **/opt/bin/dws/gds**. Exported data files are stored in **/output_data/**. The IP address of the data server is **192.168.0.90**. The GDS listening port is **5000**. GDS runs in daemon mode. The degree of parallelism is 2.

   ```
   /opt/bin/dws/gds/bin/gds -d /output_data -p 192.168.0.90:5000 -H 10.10.0.1/24 -D -t 2
   ```

4. In GaussDB(DWS), create the foreign tables **foreign_tpcds_reasons1** and **foreign_tpcds_reasons2** for receiving data from the data server.

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- Data export mode settings are as follows:
  - The directory for storing exported files is **/output_data/** and the GDS listening port is **5000** when GDS is started. The directory created for storing exported files is **/output_data/**. Therefore, the **location** parameter is set to **gsfs://192.168.0.90:5000/**.
- Data format parameter settings are as follows:
  - **format** is set to **CSV**.
  - **encoding** is set to **UTF-8**.
  - **delimiter** is set to **E'\x08'**.
  - **quote** is set to **E'\x1b'**.
  - **null** is set to an empty string without quotation marks.
  - **escape** defaults to the value of **quote**.
  - **header** is set to **false**, indicating that the first row is identified as a data row in an exported file.

Based on the preceding settings, the foreign table **foreign_tpcds_reasons1** is created using the following statement:

```
CREATE FOREIGN TABLE foreign_tpcds_reasons1
(
  r_reason_sk    integer     not null,
  r_reason_id    char(16)    not null,
  r_reason_desc  char(100)
) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://192.168.0.90:5000/', FORMAT 'CSV',ENCODING
'utf8', DELIMITER E'\x08', QUOTE E'\x1b', NULL '') WRITE ONLY;
```

Based on the preceding settings, the foreign table **foreign_tpcds_reasons2** is created using the following statement:

```
CREATE FOREIGN TABLE foreign_tpcds_reasons2
(
  r_reason_sk    integer     not null,
  r_reason_id    char(16)    not null,
  r_reason_desc  char(100)
) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://192.168.0.90:5000/', FORMAT 'CSV', DELIMITER
E'\x08', QUOTE E'\x1b', NULL '') WRITE ONLY;
```

5. In the database, export data from table **reasons1** through the foreign table **foreign_tpcds_reasons1** and from table **reasons2** through the foreign table **foreign_tpcds_reasons2** to **/output_data**.

   ```
   INSERT INTO foreign_tpcds_reasons1 SELECT * FROM tpcds.reason;
   INSERT INTO foreign_tpcds_reasons2 SELECT * FROM tpcds.reason;
   ```

6. After data export is complete, log in to the data server as user **gds_user** and stop GDS.

   The GDS process ID is **128954**.

   ```
   ps -ef|grep gds
   gds_user 128954      1  0 15:03 ?        00:00:00 gds -d /output_data -p 192.168.0.90:5000 -D -t 2
   gds_user 129003 118723  0 15:04 pts/0    00:00:00 grep gds
   kill -9 128954
   ```

## Exporting Data Through a Pipe

**Step 1** Start GDS.

```
gds -d /***/gds_data/ -D -p 192.168.0.1:7789 -l /***/gds_log/aa.log -H 0/0 -t 10 -D
```

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If you need to set the timeout interval of a pipe, use the **--pipe-timeout** parameter.

**Step 2** Export data.

1. Log in to the database, create an internal table, and write data to the table.
```
CREATE TABLE test_pipe( id integer not null, sex text not null, name text ) ;

INSERT INTO test_pipe values(1,2,'11111111111111');
INSERT INTO test_pipe values(2,2,'11111111111111');
INSERT INTO test_pipe values(3,2,'11111111111111');
INSERT INTO test_pipe values(4,2,'11111111111111');
```
2. Create a write-only foreign table.
```
CREATE FOREIGN TABLE foreign_test_pipe_tw( id integer not null, age text not null, name  text )
SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://192.168.0.1:7789/', FORMAT 'text', DELIMITER ',',
NULL '', EOL '0x0a' ,file_type 'pipe', auto_create_pipe 'false') WRITE ONLY;
```
3. Execute the export statement. The statement will be blocked.
```
INSERT INTO foreign_test_pipe_tw select * from test_pipe;
```

**Step 3** Export data through the GDS pipe.

1. Log in to GDS and go to the GDS data directory.
```
cd /***/gds_data/
```
2. Create a pipe. If **auto_create_pipe** is set to **true**, skip this step.
```
mkfifo postgres_public_foreign_test_pipe_tw.pipe
```

   **NOTE**

   A pipe will be automatically cleared after an operation is complete. To perform another operation, create a pipe again.

3. Read data from the pipe and write it to a new file.
```
cat postgres_public_foreign_test_pipe_tw.pipe > postgres_public_foreign_test_pipe_tw.txt
```
4. To compress the exported files, run the following command:
```
gzip -9 -c < postgres_public_foreign_test_pipe_tw.pipe  > out.gz
```
5. To export the content from the pipe to the HDFS server, run the following command:
```
cat postgres_public_foreign_test_pipe_tw.pipe  | hdfs dfs -put -  /user/hive/***/test_pipe.txt
```

**Step 4** Verify the exported data.

1. Check whether the exported file is correct.
```
cat postgres_public_foreign_test_pipe_tw.txt
3,2,11111111111111
1,2,11111111111111
2,2,11111111111111
4,2,11111111111111
```
2. Check the compressed file.
```
vim out.gz
3,2,11111111111111
1,2,11111111111111
2,2,11111111111111
4,2,11111111111111
```
3. Check the data exported to the HDFS server.
```
hdfs dfs -cat /user/hive/***/test_pipe.txt
3,2,11111111111111
1,2,11111111111111
2,2,11111111111111
4,2,11111111111111
```

**----End**

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### Exporting Data Through Multi-Process Pipes

GDS also supports importing and exporting data through multi-process pipes. That is, one foreign table corresponds to multiple GDSs.

The following takes exporting a local file as an example.

**Step 1** Start multiple GDSs.

```
gds -d /***/gds_data/ -D -p 192.168.0.1:7789 -l /***/gds_log/aa.log -H 0/0 -t 10 -D
gds -d /***/gds_data_1/ -D -p 192.168.0.1:7790 -l /***/gds_log/aa.log -H 0/0 -t 10 -D
```

If you need to set the timeout interval of a pipe, use the **--pipe-timeout** parameter.

**Step 2** Export data.

1. Log in to the database and create an internal table.
   ```
   CREATE TABLE test_pipe (id integer not null, sex text not null, name  text);
   ```
2. Write data.
   ```
   INSERT INTO test_pipe values(1,2,'11111111111111');
   INSERT INTO test_pipe values(2,2,'11111111111111');
   INSERT INTO test_pipe values(3,2,'11111111111111');
   INSERT INTO test_pipe values(4,2,'11111111111111');
   ```
3. Create a write-only foreign table.
   ```
   CREATE FOREIGN TABLE foreign_test_pipe_tw( id integer not null, age text not null, name  text )
   SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://192.168.0.1:7789/|gsfs://192.168.0.1:7790/',
   FORMAT 'text', DELIMITER ',',  NULL '', EOL '0x0a' ,file_type 'pipe', auto_create_pipe 'false') WRITE
   ONLY;
   ```
4. Execute the export statement. The statement will be blocked.
   ```
   INSERT INTO foreign_test_pipe_tw select * from test_pipe;
   ```

**Step 3** Export data through the GDS pipes.

1. Log in to GDS and go to each GDS data directory.
   ```
   cd /***/gds_data/
   cd /***/gds_data_1/
   ```
2. Create a pipe. If **auto_create_pipe** is set to **true**, skip this step.
   ```
   mkfifo postgres_public_foreign_test_pipe_tw.pipe
   ```
3. Read each pipe and write the new file to the pipes.
   ```
   cat postgres_public_foreign_test_pipe_tw.pipe > postgres_public_foreign_test_pipe_tw.txt
   ```

**Step 4** Verify the exported data.

```
cat /***/gds_data/postgres_public_foreign_test_pipe_tw.txt
3,2,11111111111111
cat /***/gds_data_1/postgres_public_foreign_test_pipe_tw.txt
1,2,11111111111111
2,2,11111111111111
4,2,11111111111111
```

**----End**

# 3.6 Other Operations

## 3.6.1 GDS Pipe FAQs

### Precautions

- GDS supports concurrent import and export. The **gds -t** parameter is used to set the size of the thread pool and control the maximum number of

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concurrent working threads. But it does not accelerate a single SQL task. The default value of **gds -t** is **8**, and the upper limit is **200**. When using the pipe function to import and export data, ensure that the value of **-t** is greater than or equal to the number of concurrent services. In the dual-cluster interconnection scenario, the value of **-t** must be greater than or equal to twice the number of concurrent services.

- Data in pipes is deleted once read. Therefore, ensure that no other program except GDS reads data in the pipe during import or export. Otherwise, data may be lost, task errors may occur, or the exported files may be disordered.
- Concurrent import and export of foreign tables with the same location are not supported. That is, multiple threads of GDS cannot read or write pipe files at the same time.
- A single import or export task of GDS identifies only one pipe. Therefore, do not carry wildcard characters ({}[]?) in the location address set for the GDS foreign table. Example:

  ```
  CREATE FOREIGN TABLE foreign_test_pipe_tr( like test_pipe ) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://192.168.0.0.1:7789/foreign_test_*', FORMAT 'text', DELIMITER ',',  NULL '', EOL '0x0a' ,file_type 'pipe',auto_create_pipe 'false');
  ```

- When the **-r** recursion parameter is enabled for GDS, only one pipe can be identified. That is, GDS identifies only one pipe in the current data directory and does not recursively search for it. Therefore, the **-r** parameter does not take effect in the pipe import and export scenarios.
- CN retry is not supported during the import and export through a pipe, because GDS cannot control the operations performed by peer users and programs on pipes.
- During the import, if the peer program does not write data into the pipe for more than one hour, the import task times out and an error is reported.
- During the export, if the peer program does not read data from the pipe for more than one hour by default, the export task times out and an error is reported.
- Ensure that the GDS version and kernel version support the function of importing and exporting data through pipes.
- If the **auto_create_pipe parameter** of the foreign table is set to **true**, a delay may occur when GDS automatically creates a pipe. Before any operation on a pipe, check whether the automatically created pipe exists and whether it is a pipe file.
- Once an import or export task through a GDS pipe is complete, the pipe is automatically deleted. However, the pipe deletion is delayed, if you manually terminate an import or export task. In this situation, the pipe is deleted after the timeout interval expires.

## Common Troubleshooting Methods:

- Issue 1: **"/***/postgres_public_foreign_test_pipe_tr.pipe" must be named pipe.**

  Locating method: The type of the GDS foreign table **file_type** is pipe, but the operated file is a common file. Check whether the **postgres_public_foreign_test_pipe_tr.pipe** file is a pipe file.
- Issue 2: **could not open pipe "/***/ postgres_public_foreign_test_pipe_tw.pipe" cause by Permission denied**.

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Locating method: GDS does not have the permission to open the pipe file.

- Issue 3: **could not open source file /*****/ postgres_public_foreign_test_pipe_tw.pipe because timeout 300s for WRITING**.

  Locating method: Opening the pipe times out when GDS is used to export data. This is because the pipe is not created within 300 seconds after **auto_create_pipe** is set to **false**, or the pipe is created but is not read by any program within 300 seconds.

- Issue 4: **could not open source file /*****/ postgres_public_foreign_test_pipe_tw.pipe because timeout 300s for READING**.

  Locating method: Opening the pipe times out when GDS is used to export data. This is because the pipe is not created within 300 seconds after **auto_create_pipe** is set to **false**, or the pipe is created but is not written by any program within 300 seconds.

- Issue 5: **could not poll writing source pipe file "/****/ postgres_public_foreign_test_pipe_tw.pipe" timeout 300s.**

  Locating method: If the GDS does not receive any write event on the pipe within 300 seconds during data export, the pipe is not read for more than 300 seconds.

- Issue 6: **could not poll reading source pipe file "/****/ postgres_public_foreign_test_pipe_tw.pipe" timeout 300s.**

  Locating method: If the GDS does not receive any read event on the pipe within 300 seconds during data import, the pipe is not written for more than 300 seconds.

- Issue 7: **could not open pipe file "/***/ postgres_public_foreign_test_pipe_tw.pipe" for "WRITING" with error No such device or address**.

  Locating method: It indicates that the **/***/ postgres_public_foreign_test_pipe_tw.pipe** file is not read by any program. As a result, GDS cannot open the pipe file by writing.

# 3.6.2 Checking for Data Skew

## Scenarios

Data skew causes the query performance to deteriorate. Before importing all the data from a table consisting of over 10 million records, you are advised to import some of the data and check whether data skew occurs and whether the distribution keys need to be changed. Troubleshoot the problems if any. It is costly to address data skew and change the distribution keys after a large amount of data has been imported.

## Background

GaussDB(DWS) uses a massively parallel processing (MPP) system of the shared-nothing architecture. The MPP performs horizontal partitioning to store tuples in service data tables on all DNs using proper distribution policies.

The following user table distribution policies are supported:

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- Replication: stores a full table on each DN. You are advised to use the replication mode for tables containing a small volume of data.
- Hash: A distribution key must be specified for a user table. When a record is inserted, the system hashes it based on the distribution key and then stores it on the corresponding DN. You are advised to use the hash distribution policy for tables with a large volume of data.

If an inappropriate distribution key is used, data skew may occur when you use the hash policy. Check for data skew when you use the hash distribution policy so that data can be evenly distributed to each DN. You are advised to use the column with few replicated values as the distribution key.

## Procedure

**Step 1** Analyze data source features and select candidate distribution columns that have more distinct values and evenly distributed data.

**Step 2** Select a candidate column from **Step 1** to create a target table.

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE [ IF NOT EXISTS ] table_name
    ({ column_name data_type [ compress_mode ] [ COLLATE collation ] [ column_constraint [ ... ] ]
    | table_constraint    | LIKE source_table [ like_option [...] ] }
    [, ... ])    [ WITH ( {storage_parameter = value} [, ... ] ) ]
    [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
    [ COMPRESS | NOCOMPRESS ]    [ TABLESPACE tablespace_name ]
    [ DISTRIBUTE BY { REPLICATION

                    | { HASH ( column_name [,...] ) } } ];
```

**Step 3** Import a small batch of data to the target table.

When importing a single data file, you can evenly split this file and import a part of it to check for the data skew in the target table.

**Step 4** Check for data skew. (Replace *table_name* with the actual table name.)

```
SELECT a.count,b.node_name FROM (SELECT count(*) AS count,xc_node_id FROM table_name GROUP BY xc_node_id) a, pgxc_node b WHERE a.xc_node_id=b.node_id ORDER BY a.count desc;
```

**Step 5** If the data distribution deviation is less than 10% across DNs, data is evenly distributed and an appropriate distribution key has been selected. Delete the small batch of imported data and import full data to complete data migration.

If data distribution deviation across DNs is greater than or equal to 10%, data skew occurs. Remove this distribution key from the candidates in **Step 1**, delete the target table, and repeat **Step 2** through **Step 5**.

NOTE

The data distribution deviation indicates the difference between the actual data volume on DNs and the average data volume on DNs.

**Step 6** (Optional) If you fail to select an appropriate distribution key after performing the preceding steps, select multiple columns from the candidates as distribution keys.

**----End**

## Examples

Assume you want to select an appropriate distribution key for the **staffs** table.

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1. Analyze the source data for the **staffs** table and select the **staff_ID**, **FIRST_NAME**, and **LAST_NAME** columns as candidate distribution keys.
2. Select the **staff_ID** column as the distribution key and create the target table **staffs**.

```
CREATE TABLE staffs
(
  staff_ID       NUMBER(6) not null,
  FIRST_NAME     VARCHAR2(20),
  LAST_NAME      VARCHAR2(25),
  EMAIL          VARCHAR2(25),
  PHONE_NUMBER   VARCHAR2(20),
  HIRE_DATE      DATE,
  employment_ID  VARCHAR2(10),
  SALARY         NUMBER(8,2),
  COMMISSION_PCT NUMBER(2,2),
  MANAGER_ID     NUMBER(6),
  section_ID     NUMBER(4)
)
DISTRIBUTE BY hash(staff_ID);
```

3. Import a small batch of data to the target table **staffs**.

   There are eight DNs in the cluster based on the following query, and you are advised to import 80,000 records.

```
SELECT count(*) FROM pgxc_node where node_type='D';
 count
-------
     8
(1 row)
```

4. Verify the data skew of the target table **staffs** whose distribution key is **staff_ID**:

```
SELECT a.count,b.node_name FROM (select count(*) as count,xc_node_id FROM staffs GROUP BY
xc_node_id) a, pgxc_node b WHERE a.xc_node_id=b.node_id ORDER BY a.count desc;
count | node_name
------+-----------
11010 | datanode4
10000 | datanode3
12001 | datanode2
 8995 | datanode1
10000 | datanode5
 7999 | datanode6
 9995 | datanode7
10000 | datanode8
(8 rows)
```

5. The preceding query result indicates that the distribution deviation across DNs is greater than 10%. The data skew occurs. Therefore, delete **staff_ID** from the distribution key candidates and delete the **staffs** table.

```
DROP TABLE staffs;
```

6. Use **staff_ID**, **FIRST_NAME**, and **LAST_NAME** as distribution keys and create the target table **staffs**.

```
CREATE TABLE staffs
(
  staff_ID       NUMBER(6) not null,
  FIRST_NAME     VARCHAR2(20),
  LAST_NAME      VARCHAR2(25),
  EMAIL          VARCHAR2(25),
  PHONE_NUMBER   VARCHAR2(20),
  HIRE_DATE      DATE,
  employment_ID  VARCHAR2(10),
  SALARY         NUMBER(8,2),
  COMMISSION_PCT NUMBER(2,2),
  MANAGER_ID     NUMBER(6),
  section_ID     NUMBER(4)
)
DISTRIBUTE BY hash(staff_ID,FIRST_NAME,LAST_NAME);
```

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7. Verify the data skew of the target table **staffs** whose distribution keys are **staff_ID**, **FIRST_NAME**, and **LAST_NAME**.

```
SELECT a.count,b.node_name FROM (select count(*) as count,xc_node_id FROM staffs GROUP BY xc_node_id) a, pgxc_node b WHERE a.xc_node_id=b.node_id ORDER BY a.count desc;
count | node_name
------+-----------
10010 | datanode4
10000 | datanode3
10001 | datanode2
 9995 | datanode1
10000 | datanode5
 9999 | datanode6
 9995 | datanode7
10000 | datanode8
(8 rows)
```

8. The preceding query result indicates that the data deviation across DNs is less than 10%. The data is evenly distributed and the appropriate distribution keys have been selected.
9. Delete the imported small-batch data.

```
TRUNCATE TABLE staffs;
```

10. Import the full data to complete data migration.

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# 4 Syntax Compatibility Differences Among Oracle, Teradata, and MySQL

GaussDB(DWS) is compatible with Oracle, Teradata and MySQL syntax, of which the syntax behavior is different.

**Table 4-1** Compatibility differences

| Compatibility Item | Oracle | Teradata | MySQL |
| --- | --- | --- | --- |
| Empty string | An empty string is treated as **NULL**. | An empty string is distinguished from **NULL**. | An empty string is distinguished from **NULL**. |
| Conversion of an empty string to a number | NULL | 0 | 0 |
| Automatic truncation of overlong characters | Not supported | Supported (set GUC parameter **td_compatible_truncation** to **ON**) | Not supported |
| NULL concatenation | Returns a non-NULL object after combining a non-NULL object with NULL.<br>For example, **'abc'\|\|NULL** returns **'abc'**. | The **strict_text_concat_td** option is added to the GUC parameter **behavior_compat_options** to be compatible with the Teradata behavior. After the NULL type is concatenated, **NULL** is returned.<br>For example, **'abc'\|\| NULL** returns **NULL**. | Is compatible with MySQL behavior. After the NULL type is concatenated, **NULL** is returned.<br>For example, **'abc'\|\| NULL** returns **NULL**. |

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| Compatibility Item | Oracle | Teradata | MySQL |
| --- | --- | --- | --- |
| Concatenation of the char(n) type | Removes spaces and placeholders on the right when the char(n) type is concatenated.<br>For example, **cast('a' as char(3))\|\|'b'** returns **'ab'**. | After the **bpchar_text_without_rtrim** option is added to the GUC parameter **behavior_compat_options**, when the char(n) type is concatenated, spaces are reserved and supplemented to the specified length *n*.<br>Currently, ignoring spaces at the end of a string for comparison is not supported. If the concatenated string contains spaces at the end, the comparison is space-sensitive.<br>For example, **cast('a' as char(3))\|\|'b'** returns **'a b'**. | Removes spaces and placeholders on the right. |
| concat(str1,str2) | Returns the concatenation of all non-NULL strings. | Returns the concatenation of all non-NULL strings. | If an input parameter is **NULL**, **NULL** is returned. |
| left and right processing of negative values | Returns all characters except the first and last \|n\| characters. | Returns all characters except the first and last \|n\| characters. | Returns an empty string. |

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| Compatibility Item | Oracle | Teradata | MySQL |
| --- | --- | --- | --- |
| lpad(string text, length int [, fill text])<br>rpad(string text, length int [, fill text]) | Fills up the string to the specified **length** by appending the **fill** characters (a space by default). If the string is already longer than **length** then it is truncated (on the right). If **fill** is an empty string or **length** is a negative number, **null** is returned. | If **fill** is an empty string and the string length is less than the specified **length**, the original string is returned. If **length** is a negative number, an empty string is returned. | If **fill** is an empty string and the string length is less than the specified **length**, an empty string is returned. If **length** is a negative number, **null** is returned. |
| log(x) | Returns the logarithm with 10 as the base. | Returns the logarithm with 10 as the base. | Returns the natural logarithm. |
| mod(x, 0) | Returns x if the divisor is 0. | Returns x if the divisor is 0. | Reports an error if the divisor is 0. |
| Data type **DATE** | Converts the **DATE** data type to the **TIMESTAMP** data type which stores year, month, day, hour, minute, and second values. | Stores year and month values. | Stores year and month values. |

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| Compatibility Item | Oracle | Teradata | MySQL |
| --- | --- | --- | --- |
| to_char(date) | The maximum value of the input parameter can only be the maximum value of the timestamp type. The maximum value of the date type is not supported. The return value is of the timestamp type. | The maximum value of the input parameter can only be the maximum value of the timestamp type. The maximum value of the date type is not supported. The return value is of the date type in YYYY/MM/DD format. (The GUC parameter **convert_empty_str_to_null_td** is enabled.) | The maximum value of the input parameter can only be the maximum value of the timestamp type. The maximum value of the date type is not supported. The return value is of the date type. |
| to_date, to_timestamp, and to_number processing of empty strings | Returns **NULL**. | Returns **NULL**. (The **convert_empty_str_to_null_td** parameter is enabled.) | **to_date** and **to_timestamp** returns **NULL**. If the parameter passed to **to_number** is an empty string, **0** is returned. |
| Return value types of last_day and next_day | Returns values of the timestamp type. | Returns values of the timestamp type. | Returns values of the date type. |
| Return value type of add_months | Returns values of the timestamp type. | Returns values of the timestamp type. | If the input parameter is of the date type, the return value is of the date type.<br>If the input parameter is of the timestamp type, the return value is of the timestamp type.<br>If the input parameter is of the timestamptz type, the return value is of the timestamptz type. |

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| Compatibility Item | Oracle | Teradata | MySQL |
| --- | --- | --- | --- |
| CURRENT_TIME<br>CURRENT_TIME(p) | Obtains the time of the current transaction. The return value type is timetz. | Obtains the time of the current transaction. The return value type is timetz. | Obtains the execution time of the current statement. The return value type is time. |
| CURRENT_TIMESTAMP<br>CURRENT_TIMESTAMP(p) | Obtains the execution time of the current statement. The return value type is timestamptz. | Obtains the execution time of the current statement. The return value type is timestamptz. | Obtains the execution time of the current statement. The return value type is timestamp. |
| LOCALTIME<br>LOCALTIME(p) | Obtains the time of the current transaction. The return value type is time. | Obtains the time of the current transaction. The return value type is time. | Obtains the execution time of the current statement. The return value type is time. |
| LOCALTIMESTAMP<br>LOCALTIMESTAMP(p) | Obtains the time of the current transaction. The return value type is timestamp. | Obtains the time of the current transaction. The return value type is timestamp. | Obtains the execution time of the current statement. The return value type is timestamp. |
| SYSDATE<br>SYSDATE(p) | Obtains the execution time of the current statement. The return value type is timestamp(0). | Obtains the execution time of the current statement. The return value type is timestamp(0). | Obtains the current system time. The return value type is timestamp(0). |
| NOW() | Obtains the time of the current transaction. The return value type is timestamptz. | Obtains the time of the current transaction. The return value type is timestamptz. | Obtains the statement execution time. The return value type is timestamptz. |
| Operator ^ | Performs exponentiation. | Performs exponentiation. | Performs the exclusive OR operation. |

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| Compatibility Item | Oracle | Teradata | MySQL |
| --- | --- | --- | --- |
| Different input parameter types of CASE, COALESCE, IF, and IFNULL expressions | Reports error. | Is compatible with behavior of Teradata and supports type conversion between digits and strings. For example, if input parameters for COALESCE are of INT and VARCHAR types, the parameters are resolved as VARCHAR type. | Is compatible with behavior of MySQL and supports type conversion between strings and other types. For example, if input parameters for COALESCE are of DATE, INT, and VARCHAR types, the parameters are resolved as VARCHAR type. |

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# 5 Database Security Management

## 5.1 Managing Users and Their Permissions

### 5.1.1 Default Permission Mechanism

A user who creates an object is the owner of this object. By default, **Separation of Permissions** is disabled after cluster installation. A database system administrator has the same permissions as object owners. After an object is created, only the object owner or system administrator can query, modify, and delete the object, and grant permissions for the object to other users through **GRANT** by default.

To enable another user to use the object, grant required permissions to the user or the role that contains the user.

GaussDB(DWS) supports the following permissions: **SELECT**, **INSERT**, **UPDATE**, **DELETE**, **TRUNCATE**, **REFERENCES**, **CREATE**, **CONNECT**, **EXECUTE**, **USAGE** and **ANALYZE|ANALYSE**. Permission types are associated with object types. For permission details, see GRANT.

To remove permissions, use **REVOKE**. Object owner permissions such as **ALTER**, **DROP**, **GRANT**, and **REVOKE** are implicit and cannot be granted or revoked. That is, you have the implicit permissions for an object if you are the owner of the object. Object owners can remove their own common permissions, for example, making tables read-only to themselves or others.

System catalogs and views are visible to either system administrators or all users. System catalogs and views that require system administrator permissions can be queried only by system administrators. For details, see **System Catalogs and System Views**.

The database provides the object isolation feature. If this feature is enabled, users can view only the objects (tables, views, columns, and functions) that they have the permission to access. System administrators are not affected by this feature. For details, see ALTER DATABASE.

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## 5.1.2 System Administrator

A system administrator is an account with the **SYSADMIN** permission. After a cluster is installed, a system administrator has the permissions of all object owners by default.

The user **dbadmin** created upon GaussDB(DWS) startup is a system administrator.

To create a database administrator, connect to the database as an administrator and run the **CREATE USER** or **ALTER** statement with **SYSADMIN** specified.

```
CREATE USER sysadmin WITH SYSADMIN password 'password';
```

Alternatively, you can run the following statement:

```
ALTER USER joe SYSADMIN;
```

To run the **ALTER USER** statement, the user must exist.

## 5.1.3 Separation of Permissions

Descriptions in **Default Permission Mechanism** and **System Administrator** are about the initial situation after a cluster is created. By default, a system administrator with the **SYSADMIN** attribute has the highest-level permissions.

To avoid risks caused by centralized permissions, you can enable the separation of permissions to delegate system administrator permissions to security administrators and audit administrators.

After the separation of permissions is enabled, a system administrator does not have the **CREATEROLE** attribute (security administrator) and **AUDITADMIN** attribute (audit administrator). That is, you do not have the permissions for creating roles and users and the permissions for viewing and maintaining database audit logs. For details about the **CREATEROLE** and **AUDITADMIN** attributes, see CREATE ROLE.

After the separation of permissions is enabled, system administrators have the permissions only for the objects owned by them.

For details, see .

For details about permission changes before and after enabling the separation of permissions, see **Table 5-1** and **Table 5-2**.

**Table 5-1** Default user permissions

| Object | System Administrator | Security Administrator | Audit Administrator | Common User |
| --- | --- | --- | --- | --- |
| Tablespace | Can create, modify, delete, access, and allocate tablespaces. | Cannot create, modify, delete, or allocate tablespaces, with authorization required for accessing tablespaces. | | |
| Table | Has permissions for all tables. | Has permissions for its own tables, but does not have permissions for other users' tables. | | |


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| Object | System Administrator | Security Administrator | Audit Administrator | Common User |
| --- | --- | --- | --- | --- |
| Index | Can create indexes on all tables. | Can create indexes on their own tables. | | |
| Schema | Has permissions for all schemas. | Has all permissions for its own schemas, but does not have permissions for other users' schemas. | | |
| Function | Has permissions for all functions. | Has permissions for its own functions, has the call permission for other users' functions in the **public** schema, but does not have permissions for other users' functions in other schemas. | | |
| Customized view | Has permissions for all views. | Has permissions for its own views, but does not have permissions for other users' views. | | |
| System catalog and system view | Has permissions for querying all system catalogs and views. | Has permissions for querying only some system catalogs and views. For details, see **System Catalogs and System Views**. | | |

**Table 5-2** Changes in permissions after the separation of permissions

| Object | System Administrator | Security Administrator | Audit Administrator | Common User |
| --- | --- | --- | --- | --- |
| Tablespace | No change | No change | | |
| Table | Permissions reduced<br>Has all permissions for its own tables, but does not have permissions for other users' tables in their schemas. | No change | | |
| Index | Permissions reduced<br>Can create indexes on its own tables. | No change | | |
| Schema | Permissions reduced<br>Has all permissions for its own schemas, but does not have permissions for other users' schemas. | No change | | |

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| Object | System Administrator | Security Administrator | Audit Administrator | Common User |
| --- | --- | --- | --- | --- |
| Function | Permissions reduced<br>Has all permissions for its own functions, but does not have permissions for other users' functions in their schemas. | No change | | |
| Customized view | Permissions reduced<br>Has all permissions for its own views and other users' views in the **public** schema, but does not have permissions for other users' views in their schemas. | No change | | |
| System catalog and system view | No change | No change | No change | Has no permission for viewing any system catalogs or views. |

## 5.1.4 Users

You can use **CREATE USER** and **ALTER USER** to create and manage database users, respectively. The database cluster has one or more named databases. Users and roles are shared within the entire cluster, but their data is not shared. That is, a user can connect to any database, but after the connection is successful, any user can access only the database declared in the connection request.

In non-**separation-of-duty** scenarios, a GaussDB(DWS) user account can be created and deleted only by a system administrator or a security administrator with the **CREATEROLE** attribute. In separation-of-duty scenarios, a user account can be created only by a security administrator.

When a user logs in, GaussDB(DWS) authenticates the user. A user can own databases and database objects (such as tables), and grant permissions of these objects to other users and roles. In addition to system administrators, users with the **CREATEDB** attribute can create databases and grant permissions to these databases.

### Adding, Modifying, and Deleting Users

- To create a user, use the SQL CREATE USER statement.

  For example, create a user **joe** and set the **CREATEDB** attribute for the user.

  ```
  CREATE USER joe WITH CREATEDB PASSWORD 'password';
  ```

- To create a system administrator, use the CREATE USER statement with the **SYSADMIN** parameter.

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- To delete an existing user, use the DROP USER statement.
- To change a user account (for example, rename the user or change the password), use the ALTER USER statement.
- To view a user list, query the **PG_USER** view.
  ```
  SELECT * FROM pg_user;
  ```
- To view user attributes, query the system catalog **PG_AUTHID**.
  ```
  SELECT * FROM pg_authid;
  ```

### Private Users

If multiple service departments use different database user accounts to perform service operations and a database maintenance department at the same level uses database administrator accounts to perform maintenance operations, service departments may require that database administrators, without specific authorization, can manage (**DROP**, **ALTER**, and **TRUNCATE**) their data but cannot access (**INSERT**, **DELETE**, **UPDATE**, **SELECT**, and **COPY**) the data. That is, the management permissions of database administrators for tables need to be isolated from their access permissions to improve the data security of common users.

In **Separation of Permissions** mode, a database administrator does not have permissions for the tables in schemas of other users. In this case, database administrators have neither management permissions nor access permissions, which does not meet the requirements of the service departments mentioned above. Therefore, GaussDB(DWS) provides private users to solve the problem. That is, create private users with the **INDEPENDENT** attribute in non-separation-of-duties mode.

```
CREATE USER user_independent WITH INDEPENDENT IDENTIFIED BY "password";
```

Database administrators can manage (**DROP**, **ALTER**, and **TRUNCATE**) objects of private users but cannot access (**INSERT**, **DELETE**, **SELECT**, **UPDATE**, **COPY**, **GRANT**, **REVOKE**, and **ALTER OWNER** the objects before being authorized.

## 5.1.5 Roles

A role is a set of permissions. After a role is granted to a user through **GRANT**, the user will have all the permissions of the role. It is recommended that roles be used to efficiently grant permissions. For example, you can create different roles of design, development, and maintenance personnel, grant the roles to users, and then grant specific data permissions required by different users. When permissions are granted or revoked at the role level, these changes take effect on all members of the role.

GaussDB(DWS) provides an implicitly defined group **PUBLIC** that contains all roles. By default, all new users and roles have the permissions of **PUBLIC**. For details about the default permissions of **PUBLIC**, see GRANT. To revoke permissions of **PUBLIC** from a user or role, or re-grant these permissions to them, add the **PUBLIC** keyword in the **REVOKE** or **GRANT** statement.

To view all roles, query the system catalog **PG_ROLES**.

```
SELECT * FROM PG_ROLES;
```

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### Adding, Modifying, and Deleting Roles

In non-**separation-of-duty** scenarios, a role can be created, modified, and deleted only by a system administrator or a user with the **CREATEROLE** attribute. In separation-of-duty scenarios, a role can be created, modified, and deleted only by a user with the **CREATEROLE** attribute.

- To create a role, use **CREATE ROLE**.
- To add or delete users in an existing role, use **ALTER ROLE**.
- To delete a role, use **DROP ROLE**. **DROP ROLE** deletes only a role, rather than member users in the role.

## 5.1.6 Schema

Schemas function as models. Schema management allows multiple users to use the same database without mutual impacts, to organize database objects as manageable logical groups, and to add third-party applications to the same schema without causing conflicts.

Each database has one or more schemas. Each schema contains tables and other types of objects. When a database is created, a schema named **public** is created by default, and all users have permissions for this schema. You can group database objects by schema. A schema is similar to an OS directory but cannot be nested.

The same database object name can be used in different schemas of the same database without causing conflicts. For example, both **a_schema** and **b_schema** can contain a table named **mytable**. Users with required permissions can access objects across multiple schemas of the same database.

If a user is created, a schema named after the user will also be created in the current database.

Database objects are generally created in the first schema in a database search path. For details about the first schema and how to change the schema order, see **Search Path**.

### Creating, Modifying, and Deleting Schemas

- To create a schema, use **CREATE SCHEMA**. Any user can create a schema.
- To change the name or owner of a schema, use **ALTER SCHEMA**. Only the schema owner can do so.
- To delete a schema and its objects, use **DROP SCHEMA**. Only the schema owner can do so.
- To create a table in a schema, use the *schema_name*.*table_name* format to specify the table. If *schema_name* is not specified, the table will be created in the first schema in **Search Path**.
- To view the owner of a schema, perform the following join query on the system catalogs **PG_NAMESPACE** and **PG_USER**. Replace *schema_name* in the statement with the name of the schema to be queried.

  ```
  SELECT s.nspname,u.usename AS nspowner FROM pg_namespace s, pg_user u WHERE nspname='schema_name' AND s.nspowner = u.usesysid;
  ```

- To view a list of all schemas, query the system catalog **PG_NAMESPACE**.

  ```
  SELECT * FROM pg_namespace;
  ```

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- To view a list of tables in a schema, query the system catalog **PG_TABLES**. For example, the following query will return a table list from **PG_CATALOG** in the schema.

```
SELECT distinct(tablename),schemaname from pg_tables where schemaname = 'pg_catalog';
```

### Search Path

A search path is defined in the **search_path** parameter. The parameter value is a list of schema names separated by commas (,). If no target schema is specified during object creation, the object will be added to the first schema listed in the search path. If there are objects with the same name across different schemas and no schema is specified for an object query, the object will be returned from the first schema containing the object in the search path.

- To view the current search path, use **SHOW**.

```
SHOW SEARCH_PATH;
 search_path
----------------
 "$user",public
(1 row)
```

  The default value of **search_path** is **"$user",public**. **$user** indicates the name of the schema with the same name as the current session user. If the schema does not exist, **$user** will be ignored. By default, after a user connects to a database that has schemas with the same name, objects will be added to all the schemas. If there are no such schemas, objects will be added to only to the **public** schema.

- To change the default schema of the current session, run the **SET** statement.

  Run the following command to set **search_path** to **myschema** and **public** (**myschema** will be searched first):

```
SET SEARCH_PATH TO myschema, public;
SET
```

## 5.1.7 User Permission Setting

- To grant the permission for an object directly to a user, use **GRANT**.

  When permissions for a table or view in a schema are granted to a user or role, the **USAGE** permission of the schema must be granted together. Otherwise, the user or role can only see the names of the objects but cannot actually access them.

  In the following example, permissions for the schema **tpcds** are first granted to the user **joe**, and then the **SELECT** permission for the **tpcds.web_returns** table is also granted.

```
GRANT USAGE ON SCHEMA tpcds TO joe;
GRANT SELECT ON TABLE tpcds.web_returns to joe;
```

- Granting a role to a user allows the user to inherit the object permissions of the role.

  a. Create a role.

     Create a role **lily** and grant the system permission **CREATEDB** to the role.

```
CREATE ROLE lily WITH CREATEDB PASSWORD 'password';
```

  b. To grant object permissions to a role, use **GRANT**.

     For example, first grant permissions for the schema **tpcds** to the role **lily**, and then grant the **SELECT** permission of the **tpcds.web_returns** table to **lily**.

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```
GRANT USAGE ON SCHEMA tpcds TO lily;
GRANT SELECT ON TABLE tpcds.web_returns to lily;
```

c. Grant the role permissions to a user.

```
GRANT lily to joe;
```

NOTE

When the permissions of a role are granted to a user, the attributes of the role are not transferred together.

- To revoke user permissions, use **REVOKE**.

## 5.1.8 Row-Level Access Control

The row-level access control feature enables database access control to be accurate to each row of data tables. In this way, the same SQL query may return different results for different users.

You can create a row-level access control policy for a data table. The policy defines an expression that takes effect only for specific database users and SQL operations. When a database user accesses the data table, if a SQL statement meets the specified row-level access control policies of the data table, the expressions that meet the specified condition will be combined by using **AND** or **OR** based on the attribute type (**PERMISSIVE** | **RESTRICTIVE**) and applied to the execution plan in the query optimization phase.

Row-level access control is used to control the visibility of row-level data in tables. By predefining filters for data tables, the expressions that meet the specified condition can be applied to execution plans in the query optimization phase, which will affect the final execution result. Currently, the SQL statements that can be affected include **SELECT**, **UPDATE**, and **DELETE**.

Scenario 1: A table summarizes the data of different users. Users can view only their own data.

```
-- Create users alice, bob, and peter.
CREATE ROLE alice PASSWORD 'password';
CREATE ROLE bob PASSWORD 'password';
CREATE ROLE peter PASSWORD 'password';

-- Create the public.all_data table that contains user information.
CREATE TABLE public.all_data(id int, role varchar(100), data varchar(100));

-- Insert data into the data table.
INSERT INTO all_data VALUES(1, 'alice', 'alice data');
INSERT INTO all_data VALUES(2, 'bob', 'bob data');
INSERT INTO all_data VALUES(3, 'peter', 'peter data');

-- Grant the read permission for the all_data table to users alice, bob, and peter.
GRANT SELECT ON all_data TO alice, bob, peter;

-- Enable row-level access control.
ALTER TABLE all_data ENABLE ROW LEVEL SECURITY;

-- Create a row-level access control policy to specify that the current user can view only their own data.
CREATE ROW LEVEL SECURITY POLICY all_data_rls ON all_data USING(role = CURRENT_USER);

-- View table details.
\d+ all_data
                        Table "public.all_data"
 Column |          Type          | Modifiers | Storage  | Stats target | Description
--------+------------------------+-----------+----------+--------------+-------------
 id     | integer                |           | plain    |              |
 role   | character varying(100) |           | extended |              |
```

```
 data   | character varying(100) |           | extended |              |
Row Level Security Policies:
    POLICY "all_data_rls"
      USING (((role)::name = "current_user"()))
Has OIDs: no
Distribute By: HASH(id)
Location Nodes: ALL DATANODES
Options: orientation=row, compression=no, enable_rowsecurity=true

-- Switch to user alice and run SELECT * FROM all_data.
SET ROLE alice PASSWORD 'password';
SELECT * FROM all_data;
 id | role  |    data
----+-------+------------
  1 | alice | alice data
(1 row)

EXPLAIN(COSTS OFF) SELECT * FROM all_data;
                        QUERY PLAN
-----------------------------------------------------------------
  id |          operation
 ----+-------------------------------
   1 | ->  Streaming (type: GATHER)
   2 |    ->  Seq Scan on all_data

         Predicate Information (identified by plan id)
 ---------------------------------------------------------------
   2 --Seq Scan on all_data
         Filter: ((role)::name = 'alice'::name)
 Notice: This query is influenced by row level security feature
(10 rows)

-- Switch to user peter and run SELECT * FROM .all_data.
SET ROLE peter PASSWORD 'password';
SELECT * FROM all_data;
 id | role  |    data
----+-------+------------
  3 | peter | peter data
(1 row)

EXPLAIN(COSTS OFF) SELECT * FROM all_data;
                        QUERY PLAN
-----------------------------------------------------------------
  id |          operation
 ----+-------------------------------
   1 | ->  Streaming (type: GATHER)
   2 |    ->  Seq Scan on all_data

         Predicate Information (identified by plan id)
 ---------------------------------------------------------------
   2 --Seq Scan on all_data
         Filter: ((role)::name = 'peter'::name)
 Notice: This query is influenced by row level security feature
(10 rows)
```

## 5.1.9 Data Redaction

GaussDB(DWS) provides the column-level dynamic data masking (DDM) function. For sensitive data, such as the ID card number, mobile number, and bank card number, the DDM function is used to redact the original data to protect data security and user privacy.

- You can create a redaction policy for a specified table object and set the effective scope of the policy. For details, see "CREATE REDACTION POLICY" in the *SQL Syntax*.

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- You can modify a redaction policy using the provided syntax, including modifying expressions for the policy to take effect, renaming the policy, and adding, modifying, and deleting redacted columns. For details, see "ALTER REDACTION POLICY" in *SQL Syntax*.
- You can delete a redaction policy by deleting data redaction function information of the policy from all columns of a table. For details, see "DROP REDACTION POLICY" in *SQL Syntax*.
- You can use the built-in masking functions **MASK_NONE**, **MASK_FULL**, and **MASK_PARTIAL**, or create your own masking functions by using PL/pgSQL. For details, see section "Data Redaction Functions" in *SQL Syntax Reference*.
- Redaction policy information is stored in the system catalog **PG_REDACTION_POLICY**, and redacted column information is stored in the system catalog **PG_REDACTION_COLUMN**.
- You can view information about the redaction policy and redacted columns in the system views **REDACTION_POLICIES** and **REDACTION_COLUMNS**.

NOTE

- Generally, you can execute a **SELECT** statement to view the data redaction result. If the statement has the following features, sensitive data may be deliberately obtained. In this case, an error will be reported during statement execution.
  - The **GROUP BY** clause references a **Target Entry** that contains redacted columns as the target column.
  - The **DISTINCT** clause is executed on the output redacted columns.
  - The statement contains **CTE**.
  - Set operations are involved.
  - The target columns of a subquery are not redacted columns of the base table, but are the expressions or function calls for the redacted columns of the base table.
- You can use **COPY TO** or GDS to export the redacted data. As the redacted data is irreversible, any secondary operation on the redacted data is meaningless.
- The target columns of **UPDATE**, **MERGE INTO**, and **DELETE** statements cannot contain redacted columns.
- The **UPSERT** statement allows you to update data using **EXCLUDED**. If data in the base table is updated by referencing redacted columns, the data may be modified by mistake. As a result, an error will be reported during the execution.

## Examples

The following uses the employee table **emp**, administrator **alice**, and common users **matu** and **july** as examples to describe the data redaction process. The user **alice** is the owner of the **emp** table. The **emp** table contains private data such as the employee name, mobile number, email address, bank card number, and salary.

1. Create users **alice**, **matu**, and **july**:
   ```
   CREATE ROLE alice PASSWORD 'password';
   CREATE ROLE matu PASSWORD 'password';
   CREATE ROLE july PASSWORD 'password';
   ```
2. Create the **emp** table as user **alice**, and insert three employee records into the table.
   ```
   CREATE TABLE emp(id int, name varchar(20), phone_no varchar(11), card_no number, card_string varchar(19), email text, salary numeric(100, 4), birthday date);
   INSERT INTO emp VALUES(1, 'anny', '13420002340', 1234123412341234, '1234-1234-1234-1234', 'smithWu@163.com', 10000.00, '1999-10-02');
   INSERT INTO emp VALUES(2, 'bob', '18299023211', 3456345634563456, '3456-3456-3456-3456', '66allen_mm@qq.com', 9999.99, '1989-12-12');
   ```

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```
INSERT INTO emp VALUES(3, 'cici', '15512231233', NULL, NULL, 'jonesishere@sina.com', NULL,
'1992-11-06');
```

3. User **alice** grants the **emp** table read permission to users **matu** and **july**.

```
GRANT SELECT ON emp TO matu, july;
```

4. Only user **alice** can view all employee information. Users **matu** and **july** cannot view bank card numbers and salary data of the employees. Create a redaction policy for the **emp** table and bind the redaction function to **card_no**, **card_string**, and **salary** columns, respectively.

```
CREATE REDACTION POLICY mask_emp ON emp WHEN (current_user IN ('matu', 'july'))
ADD COLUMN card_no WITH mask_full(card_no),
ADD COLUMN card_string WITH mask_partial(card_string, 'VVVVFVVVVFVVVVFVVVV','VVVV-VVVV-
VVVV-VVVV','#',1,12),
ADD COLUMN salary WITH mask_partial(salary, '9', 1, length(salary) - 2);
```

5. Switch to users **matu** and **july** and view the **emp** table, respectively.

```
SET ROLE matu PASSWORD 'password';
SELECT * FROM emp;
 id | name |  phone_no   | card_no |     card_string     |       email         |   salary   |     birthday
----+------+-------------+---------+---------------------+---------------------+------------+---------------------
  1 | anny | 13420002340 |       0 | ####-####-####-1234 | smithWu@163.com     | 99999.9990 |
1999-10-02 00:00:00
  2 | bob  | 18299023211 |       0 | ####-####-####-3456 | 66allen_mm@qq.com   |  9999.9990 |
1989-12-12 00:00:00
  3 | cici | 15512231233 |         |                     | jonesishere@sina.com |            | 1992-11-06 00:00:00
(3 rows)
SET ROLE july PASSWORD 'password';
SELECT * FROM emp;
 id | name |  phone_no   | card_no |     card_string     |       email         |   salary   |     birthday
----+------+-------------+---------+---------------------+---------------------+------------+---------------------
  1 | anny | 13420002340 |       0 | ####-####-####-1234 | smithWu@163.com     | 99999.9990 |
1999-10-02 00:00:00
  2 | bob  | 18299023211 |       0 | ####-####-####-3456 | 66allen_mm@qq.com   |  9999.9990 |
1989-12-12 00:00:00
  3 | cici | 15512231233 |         |                     | jonesishere@sina.com |            | 1992-11-06 00:00:00
(3 rows)
```

6. User **matu** also has the permission for viewing all employee information, but user **july** does not. Modify the effective scope of the redaction policy.

```
ALTER REDACTION POLICY mask_emp ON emp WHEN(current_user = 'july');
```

7. Switch to users **matu** and **july** and view the **emp** table again, respectively.

```
SET ROLE matu PASSWORD 'password';
SELECT * FROM emp;
 id | name |  phone_no   |     card_no      |     card_string     |       email         |   salary   |
birthday
----+------+-------------+------------------+---------------------+---------------------+------------
+---------------------
  1 | anny | 13420002340 | 1234123412341234 | 1234-1234-1234-1234 | smithWu@163.com     |
10000.0000 | 1999-10-02 00:00:00
  2 | bob  | 18299023211 | 3456345634563456 | 3456-3456-3456-3456 | 66allen_mm@qq.com   |
9999.9900 | 1989-12-12 00:00:00
  3 | cici | 15512231233 |                  |                     | jonesishere@sina.com |            | 1992-11-06
00:00:00
(3 rows)
SET ROLE july PASSWORD 'password';
SELECT * FROM emp;
 id | name |  phone_no   | card_no |     card_string     |       email         |   salary   |     birthday
----+------+-------------+---------+---------------------+---------------------+------------+---------------------
  1 | anny | 13420002340 |       0 | ####-####-####-1234 | smithWu@163.com     | 99999.9990 |
1999-10-02 00:00:00
  2 | bob  | 18299023211 |       0 | ####-####-####-3456 | 66allen_mm@qq.com   |  9999.9990 |
1989-12-12 00:00:00
  3 | cici | 15512231233 |         |                     | jonesishere@sina.com |            | 1992-11-06 00:00:00
(3 rows)
```

8. The information in the **phone_no**, **email**, and **birthday** columns is private data. Update the redaction policy **mask_emp** and add three redacted columns.

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```
ALTER REDACTION POLICY mask_emp ON emp ADD COLUMN phone_no WITH
mask_partial(phone_no, '*', 4);
ALTER REDACTION POLICY mask_emp ON emp ADD COLUMN email WITH mask_partial(email, '*', 1,
position('@' in email));
ALTER REDACTION POLICY mask_emp ON emp ADD COLUMN birthday WITH mask_full(birthday);
```

9. Switch to user **july** and view the **emp** table data.

```
SET ROLE july PASSWORD 'password';
SELECT * FROM emp;
 id | name |  phone_no   | card_no |     card_string     |        email         |   salary   |      birthday
----+------+-------------+---------+---------------------+----------------------+------------+---------------------
  1 | anny | 134******** |       0 | ####-####-####-1234 | ********163.com      | 99999.9990 | 1970-01-01
00:00:00
  2 | bob  | 182******** |       0 | ####-####-####-3456 | **********qq.com     |  9999.9990 | 1970-01-01
00:00:00
  3 | cici | 155******** |         |                     | ***********sina.com |            | 1970-01-01 00:00:00
(3 rows)
```

10. Query **redaction_policies** and **redaction_columns** to view details about the current redaction policy **mask_emp**.

```
SELECT * FROM redaction_policies;
 object_schema | object_owner | object_name | policy_name |            expression             | enable |
policy_description
---------------+--------------+-------------+-------------+-----------------------------------+--------
+--------------------
 public        | alice        | emp         | mask_emp    | ("current_user"() = 'july'::name) | t      |
(1 row)
SELECT object_name, column_name, function_info FROM redaction_columns;
 object_name | column_name |
function_info
-------------+-------------
+-----------------------------------------------------------------------------------------------------
 emp         | card_no     | mask_full(card_no)
 emp         | card_string | mask_partial(card_string, 'VVVVFVVVVFVVVVFVVVV'::text, 'VVVV-VVVV-
VVVV-VVVV'::text, '#'::text, 1, 12)
 emp         | email       | mask_partial(email, '*'::text, 1, "position"(email, '@'::text))
 emp         | salary      | mask_partial(salary, '9'::text, 1, (length((salary)::text) - 2))
 emp         | birthday    | mask_full(birthday)
 emp         | phone_no    | mask_partial(phone_no, '*'::text, 4)
(6 rows)
```

11. Add the **salary_info** column. To replace the salary information in text format with *.*, you can create a user-defined redaction function. In this step, you can use the PL/pgSQL to define the redaction function **mask_regexp_salary**. To create a redaction column, you simply need to customize the function name and parameter list. For details, see **User-Defined Functions**.

```
ALTER TABLE emp ADD COLUMN salary_info TEXT;
UPDATE emp SET salary_info = salary::text;
CREATE FUNCTION mask_regexp_salary(salary_info text) RETURNS text AS
$$
 SELECT regexp_replace($1, '[0-9]+','*','g');
$$
LANGUAGE SQL
STRICT SHIPPABLE;
ALTER REDACTION POLICY mask_emp ON emp ADD COLUMN salary_info WITH
mask_regexp_salary(salary_info);
SET ROLE july PASSWORD 'password';
SELECT id, name, salary_info FROM emp;
 id | name | salary_info
----+------+-------------
  1 | anny | *.*
  2 | bob  | *.*
  3 | cici |
(3 rows)
```

12. If there is no need to set a redaction policy for the **emp** table, delete the redaction policy **mask_emp**.

```
DROP REDACTION POLICY mask_emp ON emp;
```

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# 5.2 Setting Security Policies

## 5.2.1 Setting Account Security Policies

### Background

For data security purposes, GaussDB(DWS) provides a series of security measures, such as automatically locking and unlocking accounts, manually locking and unlocking abnormal accounts, and deleting accounts that are no longer used.

### Automatically Locking and Unlocking Accounts

- If a user fails to enter the correct password for over 10 times during database connection, the system automatically locks the account.
- An account is automatically unlocked one day after it was locked.

### Manually Locking and Unlocking Accounts

If administrators detect an abnormal account that may be stolen or illegally accesses the database, they can manually lock the account.

The administrator can also manually unlock the account if the account becomes normal again.

For details about how to create a user, see **Users**. To manually lock and unlock user **joe**, run commands in the following format:

- To manually lock the user:
  ```
  ALTER USER joe ACCOUNT LOCK;
  ```
- To manually unlock the user:
  ```
  ALTER USER joe ACCOUNT UNLOCK;
  ```

### Deleting Accounts that Are No Longer Used

An administrator can delete an account that is no longer used. This operation cannot be rolled back.

When an account to be deleted is in the active state, it is deleted after the session is disconnected.

For example, if you want to delete account **joe**, run the command in the following format:

```
DROP USER joe CASCADE;
```

## 5.2.2 Setting the Validity Period of an Account

### Precautions

When creating a user, you need to specify the validity period of the user, including the start time and end time.

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To enable a user not within the validity period to use its account, set a new validity period.

## Procedure

**Step 1** Run the following command to create a user and specify the start time and end time.

```
CREATE USER joe WITH PASSWORD 'password' VALID BEGIN '2015-10-10 08:00:00' VALID UNTIL '2016-10-10 08:00:00';
```

**Step 2** If the user is not within the specified validity period, run the following command to set the start time and end time of a new validity period.

```
ALTER USER joe WITH VALID BEGIN '2016-11-10 08:00:00' VALID UNTIL '2017-11-10 08:00:00';
```

**----End**

NOTE

If **VALID BEGIN** is not specified in the **CREATE ROLE** or **ALTER ROLE** statement, the start time of the validity period is not limited. If **VALID UNTIL** is not specified, the end time of the validity period is not limited. If both of the parameters are not specified, the user is always valid.

# 5.2.3 Setting a User Password

User passwords are stored in the system catalog **pg_authid**. To prevent password leakage, GaussDB(DWS) encrypts and stores the user passwords.

- Password complexity

  The password complexity requirements are as follows:

  - The number of uppercase letters (A–Z) ranges from 0 to 999, the number of lowercase letters (a–z) ranges from 0 to 999, the number of digits ranges from 0 to 999, and the number of special characters ranges from 0 to 999. For details about the special characters, see **Table 5-3**.

    NOTE

    A password must contain at least three types of the preceding characters (uppercase letters, lowercase letters, digits, and special characters).
  - A password must contain at least 6 characters, and the default length is 8 characters.
  - A password can contain a maximum of 999 characters, and the default length is 32 characters.
  - A password must differ from the username or the username in reverse order.
  - A new password must be different from the current password or the current password in reverse order.
- Password reuse

  When a user changes the password, the user can reuse a password only if it has not been used for over 60 days.
- Password validity period

  A validity period (90 days by default) is set for each database user password. If the password is about to expire (in seven days), the system displays a message reminding the user to change it upon login.

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NOTE

Considering the usage and service continuity of a database, the database still allows a user to log in after the password expires. A password change notification is displayed every time the user logs in to the database until the password is changed.

- Password change
  - During database installation, an OS user named the same as the initial user is created. The password of the OS user needs to be changed periodically to ensure account security.

    If the password of the user **user1** needs to be changed, run the following command:

    ```
    passwd user1
    ```

    Change the password as prompted.
  - Both system administrators and common users need to periodically change their passwords to prevent the accounts from being stolen.

    For example, to change the password of the user **user1**, connect to the database as the administrator and run the following command:

    ```
    ALTER USER user1 IDENTIFIED BY "1234@abc" REPLACE "5678@def";
    ```

    NOTE

    **1234@abc** and **5678@def** represent the new password and the original password of the user **user1**, respectively. The new password must conform to the complexity rules. Otherwise, the new password is invalid.
  - An administrator can change its own password and other accounts' passwords. With the permission for changing other accounts' passwords, the administrator can resolve a login failure when a user forgets its password.

    To change the password of the user **joe**, run the following command:

    ```
    ALTER USER joe IDENTIFIED BY 'password';
    ```

    NOTE

    - System administrators are not allowed to change passwords for each other.
    - When a system administrator changes the password of a common user, the original password is not required.
    - However, when a system administrator changes its own password, the original password is required.
- Password verification

  Password verification is required when you set the user or role in the current session. If the entered password is inconsistent with the stored password of the user, an error is reported.

  To set the password of the user **joe**, run the following command:

  ```
  SET ROLE joe PASSWORD 'password';
  ```

**Table 5-3** Special characters

| No. | Character | No. | Character | No. | Character | No. | Character |
|---|---|---|---|---|---|---|---|
| 1 | ~ | 9 | * | 17 | \| | 25 | < |

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| No. | Character | No. | Character | No. | Character | No. | Character |
|---|---|---|---|---|---|---|---|
| 2 | ! | 10 | ( | 18 | [ | 26 | . |
| 3 | @ | 11 | ) | 19 | { | 27 | > |
| 4 | # | 12 | - | 20 | } | 28 | / |
| 5 | $ | 13 | _ | 21 | ] | 29 | ? |
| 6 | % | 14 | = | 22 | ; | - | - |
| 7 | ^ | 15 | + | 23 | : | - | - |
| 8 | & | 16 | \ | 24 | , | - | - |

# 5.3 Querying Audit Results

## Prerequisites

- Audit of required items has been enabled. For details about how to enable audit items, see the "Setting Operation Audit" section.
- The database is running properly and a series of addition, modification, deletion, and query operations have been executed in the database. Otherwise, no audit result is generated.
- Audit logs are separately recorded on the database nodes. If an LVS is used to manage the audit logs, you need to locate the specific node where the audit logs are recorded and connect the node to query the corresponding audit logs.

## Context

- Only users with the **AUDITADMIN** permission can view audit records. For details about database users and how to create users, see **Users**.
- The SQL function **pg_query_audit** provided by the database functions as the audit query command:

  **pg_query_audit(timestamptz** *startime*,**timestamptz** *endtime*,*audit_log*)

  **startime** and **endtime** indicate the start time and end time of the audit record, respectively. **audit_log** indicates the physical file path of the queried audit logs. If **audit_log** is not specified, the audit log information of the current instance is queried.

  You can run the SQL function **pgxc_query_audit** to query audit logs of all CN nodes. The prototype is as follows:

  **pgxc_query_audit(timestamptz** *startime*,**timestamptz** *endtime*)

  NOTE

  The difference between the values of the **startime** and **endtime** parameters indicates the query period, which can be any value ranging from 00:00:00 of the **startime** parameter to 23:59:59 of the **endtime** parameter. Therefore, the **startime** and **endtime** parameters must be properly set to ensure that the required audit information is displayed.

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## Procedure

**Step 1** Use a SQL client to connect to the database.

**Step 2** Run the following command to query the audit record:

```
SELECT * FROM pg_query_audit('2021-02-23 21:49:00','2021-02-23 21:50:00');
```

The query result is as follows.

```
         begintime         |         endtime          | operation_type | audit_type | result |  username  | database |
client_conninfo | object_name | command_text |                        detail_info                         |
transaction_xid | query_id |  node_name   |           thread_id           | local_port | remote_port
---------------------------+--------------------------+----------------+------------+--------+------------+----------
+-----------------+-------------+-----------------+--------------------------------------------------------------------------
+-----------------+----------+--------------+-----------------------------+------------+-------------q
 2021-02-23 21:49:57.76+08 | 2021-02-23 21:49:57.82+08 | login_logout   | user_login | ok     | dbadmin |
gaussdb | gsql@[local]    | gaussdb    | login db     | login db(gaussdb) successfully, the current user is:
dbadmin | 0               | 0          | coordinator1 | 140324035360512@667403397820909 | 27777      |
```

This record indicates that user **dbadmin** logged in to the **gaussdb** database at 2021-02-23 21:49:57.82+08. After the host specified by **log_hostname** is started and a client is connected to its IP address, the host name found by reverse DNS resolution is displayed following the at sign (@) in the value of **client_conninfo**.

**Step 3** Run the following command to query the audit records of all CN nodes:

```
SELECT * FROM pgxc_query_audit('2021-02-23 22:05:00','2021-02-23 22:07:00') where audit_type =
'user_login' and username = 'user1';
```

The query result is as follows:

```
         begintime         |         endtime          | operation_type | audit_type | result | username | database |
client_conninfo | object_name | command_text |                        detail_info                         |
transaction_xid | query_id |  node_name   |           thread_id           | local_port | remote_port
---------------------------+--------------------------+----------------+------------+--------+----------+----------
+-----------------+-------------+-----------------+--------------------------------------------------------------------------
+-----------------+----------+--------------+-----------------------------+------------+------------
 2021-02-23 22:06:22.219+08 | 2021-02-23 22:06:22.271+08 | login_lgout    | user_login | ok     | user1    |
gaussdb | gsql@[local]    | gaussdb    | login db     | login db(gaussdb) successfully, the current user is: user1
| 0               | 0          | coordinator2 | 140689577342720@667404382271356 | 27782      |
 2021-02-23 22:05:51.697+08 | 2021-02-23 22:05:51.749+08 | login_lgout    | user_login | ok     | user1    |
gaussdb | gsql@[local]    | gaussdb    | login db     | login db(gaussdb) successfully, the current user is: user1
| 0               | 0          | coordinator1 | 140525048424192@667404351749143 | 27777      |
```

The query result shows the successful login records of **user1** in to CN1 and CN2.

**----End**

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# 6 Development and Design Proposal

## 6.1 Development and Design Proposal

This chapter describes the design specifications for database modeling and application development. Modeling compliant with these specifications fits the distributed processing architecture of GaussDB(DWS) and provides efficient SQL code.

The meaning of "Proposal" and "Notice" in this chapter is as follows:

- **Proposal**: Design rules. Services compliant with the rules can run efficiently, and those violating the rules may have low performance or logic errors.
- **Notice**: Details requiring attention during service development. This term identifies SQL behavior that complies with SQL standards but users may have misconceptions about, and default behavior that users may be unaware of in a program.

## 6.2 Database Object Naming Conventions

The name of a database object must contain 1 to 63 characters, start with a letter or underscore (_), and can contain letters, digits, underscores (_), dollar signs ($), and number signs (#).

- [Proposal] Do not use reserved or non-reserved keywords to name database objects.

  NOTE

  To query the keywords of GaussDB(DWS), run **select * from pg_get_keywords()** or refer to section "Keyword."

- [Proposal] Do not use a string enclosed in double quotation marks ("") to define the database object name, unless you need to specify its capitalization. Case sensitivity of database object names makes problem location difficult.
- [Proposal] Use the same naming format for database objects.
  - In a system undergoing incremental development or service migration, you are advised to comply with its historical naming conventions.

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  - A database object name consists of letters, digits, and underscores (_); and cannot start with a digit. You are advised to use multiple words separated with hyphens (-).
  - You are advised to use intelligible names and common acronyms or abbreviations for database objects. Acronyms or abbreviations that are generally understood are recommended. For example, you can use English words indicating actual business terms. The naming format should be consistent within a cluster.
  - A variable name must be descriptive and meaningful. It must have a prefix indicating its type.
- [Proposal] The name of a table object should indicate its main characteristics, for example, whether it is an ordinary, temporary, or unlogged table.
  - An ordinary table name should indicate the business relevant to a data set.
  - Temporary tables are named in the format of **tmp**_*Suffix*.
  - Unlogged tables are named in the format of **ul**_*Suffix*.
  - Foreign tables are named in the format of **f**_*Suffix*.

# 6.3 Database Object Design

## 6.3.1 Database and Schema Design

In GaussDB(DWS), services can be isolated by databases and schemas. Databases share little resources and cannot directly access each other. Connections to and permissions on them are also isolated. Schemas share more resources than databases do. User permissions on schemas and subordinate objects can be controlled using the **GRANT** and **REVOKE** syntax.

- You are advised to use schemas to isolate services for convenience and resource sharing.
- It is recommended that system administrators create schemas and databases and then assign required permissions to users.

### Database Design Suggestions

- Create databases as required. Do not use the default **gaussdb** database of a cluster.
- Create a maximum of three user-defined databases in a cluster.
- To make your database encoding compatible with most characters, you are advised to use the UTF-8 encoding when creating a database.
- Exercise caution when you set **ENCODING** and **DBCOMPATIBILITY** configuration items during database creation. In GaussDB(DWS), **DBCOMPATIBILITY** can be set to **TD**, **Oracle**, or **MySQL** to be compatible with Teradata, Oracle, or MySQL syntax, respectively. Syntax behavior may vary with the three modes. For details, see **Syntax Compatibility Differences Among Oracle, Teradata, and MySQL**.
- By default, a database owner has all permissions for all objects in the database, including the deletion permission. Exercise caution when using the deletion permission.

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### Schema Design Suggestions

- To let a user access an object in a schema, grant the **usage** permission and the permissions for the object to the user, unless the user has the **sysadmin** permission or is the schema owner.
- To let a user create an object in the schema, grant the **create** permission for the schema to the user.
- By default, a schema owner has all permissions for all objects in the schema, including the deletion permission. Exercise caution when using the deletion permission.

## 6.3.2 Table Design

GaussDB(DWS) uses a distributed architecture. Data is distributed on DNs. Comply with the following principles to properly design a table:

- [Notice] Evenly distribute data on each DN to prevent data skew. If most data is stored on several DNs, the effective capacity of a cluster decreases. Select a proper distribution column to avoid data skew.
- [Notice] Evenly scan each DN when querying tables. Otherwise, DNs most frequently scanned will become the performance bottleneck. For example, when you use equivalent filter conditions on a fact table, the nodes are not evenly scanned.
- [Notice] Reduce the amount of data to be scanned. You can use the pruning mechanism of a partitioned table.
- [Notice] Minimize random I/O. By clustering or local clustering, you can sequentially store hot data, converting random I/O to sequential I/O to reduce the cost of I/O scanning.
- [Notice] Try to avoid data shuffling. To shuffle data is to physically transfer it from one node to another. This unnecessarily occupies many network resources. To reduce network pressure, locally process data, and to improve cluster performance and concurrency, you can minimize data shuffling by using proper association and grouping conditions.

### Selecting a Storage Mode

[Proposal] Selecting a storage mode is the first step in defining a table. The storage mode mainly depends on the customer's service type. For details, see **Table 6-1**.

**Table 6-1** Table storage modes and scenarios

| Storage Mode | Application Scenarios |
| --- | --- |
| Row storage | • Point queries (simple index-based queries that only return a few records)<br>• Scenarios requiring frequent addition, deletion, and modification |

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| Storage Mode | Application Scenarios |
| --- | --- |
| Column storage | • Statistical analysis queries (requiring a large number of association and grouping operations)<br>• Ad hoc queries (using uncertain query conditions and unable to utilize indexes to scan row-store tables) |

## Selecting a Distribution Mode

[Proposal] Comply with the following rules to distribute table data.

**Table 6-2** Table distribution modes and scenarios

| Distribution Mode | Description | Application Scenarios |
| --- | --- | --- |
| Hash | Table data is distributed on all DNs in a cluster by hash. | Fact tables containing a large amount of data |
| Replication | Full data in a table is stored on every DN in a cluster. | Dimension tables and fact tables containing a small amount of data |

## Selecting a Partitioning Mode

Comply with the following rules to partition a table containing a large amount of data:

- [Proposal] Create partitions on columns that indicate certain ranges, such as dates and regions.
- [Proposal] A partition name should show the data characteristics of a partition. For example, its format can be Keyword+Range characteristics.
- [Proposal] Set the upper limit of a partition to **MAXVALUE** to prevent data overflow.

The example of a partitioned table definition is as follows:

```
CREATE TABLE staffS_p1
(
  staff_ID       NUMBER(6) not null,
  FIRST_NAME     VARCHAR2(20),
  LAST_NAME      VARCHAR2(25),
  EMAIL          VARCHAR2(25),
  PHONE_NUMBER   VARCHAR2(20),
  HIRE_DATE      DATE,
  employment_ID  VARCHAR2(10),
  SALARY         NUMBER(8,2),
  COMMISSION_PCT NUMBER(4,2),
  MANAGER_ID     NUMBER(6),
  section_ID     NUMBER(4)
)
PARTITION BY RANGE (HIRE_DATE)
(
```

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```
  PARTITION HIRE_19950501 VALUES LESS THAN ('1995-05-01 00:00:00'),
  PARTITION HIRE_19950502 VALUES LESS THAN ('1995-05-02 00:00:00'),
  PARTITION HIRE_maxvalue VALUES LESS THAN (MAXVALUE)
);
```

### Selecting a Distribution Key

Selecting a distribution key is important for a hash table. An improper distribution key may cause data skew. As a result, the I/O load is heavy on several DNs, affecting the overall query performance. After you select a distribution policy for a hash table, check for data skew to ensure that data is evenly distributed. Comply with the following rules to select a distribution key:

- [Proposal] Select a column containing discrete data as the distribution key, so that data can be evenly distributed on each DN. If a single column is not discrete enough, consider using multiple columns as distribution keys. You can select the primary key of a table as the distribution key. For example, in an employee information table, select the certificate number column as the distribution key.
- [Proposal] If the first rule is met, do not select a column having constant filter conditions as the distribution key. For example, in a query on the **dwcjk** table, if the **zqdh** column contains the constant filter condition **zqdh='000001'**, avoid selecting the **zqdh** column as the distribution key.
- [Proposal] If the first and second rules are met, select the join conditions in a query as distribution keys. If a join condition is used as a distribution key, the data involved in a join task is locally distributed on DNs, which greatly reduces the data flow cost among DNs.

## 6.3.3 Column Design

### Selecting a Data Type

Comply with the following rules to improve query efficiency when you design columns:

- [Proposal] Use the most efficient data types allowed.

  If all of the following number types provide the required service precision, they are recommended in descending order of priority: integer, floating point, and numeric.
- [Proposal] In tables that are logically related, columns having the same meaning should use the same data type.
- [Proposal] For string data, you are advised to use variable-length strings and specify the maximum length. To avoid truncation, ensure that the specified maximum length is greater than the maximum number of characters to be stored. You are not advised to use CHAR(n), BPCHAR(n), NCHAR(n), or CHARACTER(n), unless you know that the string length is fixed.

  For details about string types, see **Common String Types**.

### Common String Types

Every column requires a data type suitable for its data characteristics. The following table lists common string types in GaussDB(DWS).

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**Table 6-3** Common string types

| Parameter | Description | Max. Storage Capacity |
| --- | --- | --- |
| CHAR(n) | Fixed-length string, where *n* indicates the stored bytes. If the length of an input string is smaller than *n*, the string is automatically padded to *n* bytes using NULL characters. | 10 MB |
| CHARACTER(n) | Fixed-length string, where *n* indicates the stored bytes. If the length of an input string is smaller than *n*, the string is automatically padded to *n* bytes using NULL characters. | 10 MB |
| NCHAR(n) | Fixed-length string, where *n* indicates the stored bytes. If the length of an input string is smaller than *n*, the string is automatically padded to *n* bytes using NULL characters. | 10 MB |
| BPCHAR(n) | Fixed-length string, where *n* indicates the stored bytes. If the length of an input string is smaller than *n*, the string is automatically padded to *n* bytes using NULL characters. | 10 MB |
| VARCHAR(n) | Variable-length string, where *n* indicates the maximum number of bytes that can be stored. | 10 MB |
| CHARACTER VARYING(n) | Variable-length string, where *n* indicates the maximum number of bytes that can be stored. This data type and VARCHAR(n) are different representations of the same data type. | 10 MB |
| VARCHAR2(n) | Variable-length string, where *n* indicates the maximum number of bytes that can be stored. This data type is added to be compatible with the Oracle database, and its behavior is the same as that of VARCHAR(n). | 10 MB |
| NVARCHAR2(n) | Variable-length string, where *n* indicates the maximum number of bytes that can be stored. | 10 MB |

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| Parameter | Description | Max. Storage Capacity |
| --- | --- | --- |
| TEXT | Variable-length string. Its maximum length is 8203 bytes less than 1 GB. | 8203 bytes less than 1 GB |

## 6.3.4 Constraint Design

### DEFAULT and NULL Constraints

- [Proposal] If all the column values can be obtained from services, you are not advised to use the **DEFAULT** constraint, because doing so will generate unexpected results during data loading.
- [Proposal] Add **NOT NULL** constraints to columns that never have NULL values. The optimizer automatically optimizes the columns in certain scenarios.
- [Proposal] Explicitly name all constraints excluding **NOT NULL** and **DEFAULT**.

### Partial Cluster Key

A partial cluster key (PCK) is a local clustering technology used for column-store tables. After creating a PCK, you can quickly filter and scan fact tables using min or max sparse indexes in GaussDB(DWS). Comply with the following rules to create a PCK:

- [Notice] Only one PCK can be created in a table. A PCK can contain multiple columns, preferably no more than two columns.
- [Proposal] Create a PCK on simple expression filter conditions in a query. Such filter conditions are usually in the form of **col op const**, where **col** specifies a column name, **op** specifies an operator (such as =, >, >=, <=, and <), and **const** specifies a constant.
- [Proposal] If the preceding conditions are met, create a PCK on the column having the least distinct values.

### Unique Constraint

- [Notice] Both row-store and column-store tables support unique constraints.
- [Proposal] The constraint name should indicate that it is a unique constraint, for example, **UNI***Included columns*.

### Primary Key Constraint

- [Notice] Both row-store and column-store tables support the primary key constraint.
- [Proposal] The constraint name should indicate that it is a primary key constraint, for example, **PK***Included columns*.

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### Check Constraint

- [Notice] Check constraints can be used in row-store tables but not in column-store tables.
- [Proposal] The constraint name should indicate that it is a check constraint, for example, **CK***Included columns*.

## 6.3.5 View and Joined Table Design

### View Design

- [Proposal] Do not nest views unless they have strong dependency on each other.
- [Proposal] Try to avoid sort operations in a view definition.

### Joined Table Design

- [Proposal] Minimize joined columns across tables.
- [Proposal] Joined columns should use the same data type.
- [Proposal] The names of joined columns should indicate their relationship. For example, they can use the same name.

# 6.4 JDBC Configuration

Currently, third-party tools are connected to GaussDB(DWS) trough JDBC. This section describes the precautions for configuring the tools.

### Connection Parameters

- [Notice] When a third-party tool connects to GaussDB(DWS) through JDBC, JDBC sends a connection request to GaussDB(DWS). By default, the following parameters are added. For details, see the implementation of the ConnectionFactoryImpl JDBC code.

```
params = {
{ "user", user },
{ "database", database },
{ "client_encoding", "UTF8" },
{ "DateStyle", "ISO" },
{ "extra_float_digits", "2" },
{ "TimeZone",  createPostgresTimeZone() },
};
```

  These parameters may cause the JDBC and gsql clients to display inconsistent data, for example, date data display mode, floating point precision representation, and timezone.

  If the result is not as expected, you are advised to explicitly set these parameters in the Java connection setting.

- [Proposal] When connecting to the database through JDBC, ensure that the following two time zones are the same:
  - Time zone of the host where the JDBC client is located
  - Time zone of the host where the GaussDB(DWS) server is located

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### fetchsize

[Notice] To use **fetchsize** in applications, disable the **autocommit** switch. Enabling the **autocommit** switch makes the **fetchsize** configuration invalid.

### autocommit

[Proposal] It is recommended that you enable the **autocommit** switch in the code for connecting to GaussDB(DWS) by the JDBC. If **autocommit** needs to be disabled to improve performance or for other purposes, applications need to ensure their transactions are committed. For example, explicitly commit translations after specifying service SQL statements. Particularly, ensure that all transactions are committed before the client exits.

### Connection Releasing

[Proposal] You are advised to use connection pools to limit the number of connections from applications. Do not connect to a database every time you run an SQL statement.

[Proposal] After an application completes its tasks, disconnect its connection to GaussDB(DWS) to release occupied resources. You are advised to set the session timeout interval in the task.

[Proposal] Reset the session environment before releasing connections to the JDBC connection tool. Otherwise, historical session information may cause object conflicts.

- If GUC parameters are set in the connection, before you return the connection to the connection pool, run **SET SESSION AUTHORIZATION DEFAULT;RESET ALL;** to clear the connection status.
- If a temporary table is used, delete it before you return the connection to the connection pool.

### CopyManager

[Proposal] In the scenario where the ETL tool is not used and real-time data import is required, it is recommended that you use the CopyManger interface driven by the GaussDB(DWS) JDBC to import data in batches during application development. For details about how to use **CopyManager**, see **CopyManager**.

## 6.5 SQL Compilation

### DDL

- [Proposal] In GaussDB(DWS), you are advised to execute DDL operations, such as creating table or making comments, separately from batch processing jobs to avoid performance deterioration caused by many concurrent transactions.
- [Proposal] Execute data truncation after unlogged tables are used because GaussDB(DWS) cannot ensure the security of unlogged tables in abnormal scenarios.

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- [Proposal] Suggestions on the storage mode of temporary and unlogged tables are the same as those on base tables. Create temporary tables in the same storage mode as the base tables to avoid high computing costs caused by hybrid row and column correlation.
- [Proposal] The total length of an index column cannot exceed 50 bytes. Otherwise, the index size will increase greatly, resulting in large storage cost and low index performance.
- [Proposal] Do not delete objects using **DROP...CASCADE**, unless the dependency between objects is specified. Otherwise, the objects may be deleted by mistake.

## Data Loading and Uninstalling

- [Proposal] Provide the inserted column list in the insert statement. Example:
  ```
  INSERT INTO task(name,id,comment) VALUES ('task1','100','100th task');
  ```
- [Proposal] After data is imported to the database in batches or the data increment reaches the threshold, you are advised to analyze tables to prevent the execution plan from being degraded due to inaccurate statistics.
- [Proposal] To clear all data in a table, you are advised to use **TRUNCATE TABLE** instead of **DELETE TABLE**. **DELETE TABLE** is not efficient and cannot release disk space occupied by the deleted data.

## Type conversion

- [Proposal] Perform type coercion to convert data types. If you perform implicit conversion, the result may differ from expected.
- [Proposal] During data query, explicitly specify the data type for constants, and do not attempt to perform any implicit data type conversion.
- [Notice] In Oracle compatibility mode, null strings will be automatically converted to NULL during data import. If a null string needs to be reserved, you need to create a database that is compatible with Teradata.

## Query Operation

- [Proposal] Do not return a large number of result sets to a client except the ETL program. If a large result set is returned, consider modifying your service design.
- [Proposal] Perform DDL and DML operations encapsulated in transactions. Operations like table truncation, update, deletion, and dropping, cannot be rolled back once committed. You are advised to encapsulate such operations in transactions so that you can roll back the operations if necessary.
- [Proposal] During query compilation, you are advised to list all columns to be queried and avoid using *****. Doing so reduces output lines, improves query performance, and avoids the impact of adding or deleting columns on front-end service compatibility.
- [Proposal] During table object access, add the schema prefix to the table object to avoid accessing an unexpected table due to schema switchover.
- [Proposal] The cost of joining more than three tables or views, especially full joins, is difficult to be estimated. You are advised to use the **WITH TABLE AS** statement to create interim tables to improve the readability of SQL statements.

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- [Proposal] Do not use Cartesian products or full joins. Cartesian products and full joins will result in a sharp expansion of result sets and poor performance.
- [Notice] Only **IS NULL** and **IS NOT NULL** can be used to determine NULL value comparison results. If any other method is used, NULL is returned. For example, **NULL** instead of expected Boolean values is returned for **NULL<>NULL**, **NULL=NULL**, and **NULL<>1**.
- [Notice] Do not use count(col) instead of count(*) to count the total number of records in a table. count(*) counts the NULL value (actual rows) while count (col) does not.
- [Notice] While executing count(col), the number of NULL record rows is counted as 0. While executing sum(col), NULL is returned if all records are NULL. If not all the records are NULL, the number of NULL record rows is counted as 0.
- [Notice] To count multiple columns using count(), column names must be enclosed with parentheses. For example, count ((col1, col2, col3)). Note: When multiple columns are used to count the number of NULL record rows, a row is counted even if all the selected columns are NULL. The result is the same as that when count(*) is executed.
- [Notice] Null records are not counted when count(distinct col) is used to calculate the number of non-null columns that are not repeated.
- [Notice] If all statistical columns are NULL when count(distinct (col1,col2,...)) is used to count the number of unique values in multiple columns, Null records are also counted, and the records are considered the same.
- [Notice] When constants are used to filter data, the system searches for functions used for calculating these two data types based on the data types of the constants and matched columns. If no function is found, the system converts the data type implicitly. Then, the system searches for a function used for calculating the converted data type.

  ```
  SELECT * FROM test WHERE timestamp_col = 20000101;
  ```

  In the preceding example, if **timestamp_col** is the timestamp type, the system first searches for the function that supports the "equal" operation of the timestamp and int types (constant numbers are considered as the int type). If no such function is found, the **timestamp_col** data and constant numbers are implicitly converted into the text type for calculation.
- [Proposal] Do not use scalar subquery statements. A scalar subquery appears in the output list of a **SELECT** statement. In the following example, the part enclosed in parentheses is a scalar subquery statement:

  ```
  SELECT id, (SELECT COUNT(*) FROM films f WHERE f.did = s.id) FROM staffs_p1 s;
  ```

  Scalar subqueries often result in query performance deterioration. During application development, scalar subqueries need to be converted into equivalent table associations based on the service logic.
- [Proposal] In **WHERE** clauses, the filtering conditions should be sorted. The condition that few records are selected for reading (the number of filtered records is small) is listed at the beginning.
- [Proposal] Filtering conditions in **WHERE** clauses should comply with unilateral rules. That is, when the column name is placed on one side of a comparison operator, the optimizer automatically performs pruning optimization in some scenarios. Filtering conditions in a **WHERE** clause will be displayed in **col op expression** format, where **col** indicates a table column, **op**

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indicates a comparison operator, such as = and >, and **expression** indicates an expression that does not contain a column name. For example:

```
SELECT id, from_image_id, from_person_id, from_video_id FROM face_data WHERE
current_timestamp(6) - time < '1 days'::interval;
```

The modification is as follows:

```
SELECT id, from_image_id, from_person_id, from_video_id FROM face_data where time >
current_timestamp(6) - '1 days'::interval;
```

- [Proposal] Do not perform unnecessary sorting operations. Sorting requires a large amount of memory and CPU. If service logic permits, **ORDER BY** and **LIMIT** can be combined to reduce resource overhead. By default, data in GaussDB(DWS) is sorted by ASC & NULL LAST.
- [Proposal] When the **ORDER BY** clause is used for sorting, specify sorting modes (ASC or DESC), and use NULL FIRST or NULL LAST for NULL record sorting.
- [proposal] Do not rely on only the **LIMIT** clause to return the result set displayed in a specific sequence. Combine **ORDER BY** and **LIMIT** clauses for some specific result sets and use offset to skip specific results if necessary.
- [Proposal] If the service logic is accurate, you are advised to use **UNION ALL** instead of **UNION**.
- [Proposal] If a filtering condition contains only an **OR** expression, convert the **OR** expression to **UNION ALL** to improve performance. SQL statements that use **OR** expressions cannot be optimized, resulting in slow execution. Example:

  ```
  SELECT * FROM scdc.pub_menu
  WHERE (cdp= 300 AND inline=301) OR (cdp= 301 AND inline=302) OR (cdp= 302 AND inline=301);
  ```

  Convert the statement to the following:

  ```
  SELECT * FROM scdc.pub_menu
  WHERE (cdp= 300 AND inline=301)
  union all
  SELECT * FROM scdc.pub_menu
  WHERE (cdp= 301 AND inline=302)
  union all
  SELECT * FROM tablename
  WHERE (cdp= 302 AND inline=301);
  ```

- [Proposal] If an **in(val1, val2, va...)** expression contains a large number of columns, you are advised to replace it with the **in (values (va11), (val2), (val3...)** statement. The optimizer will automatically convert the **IN** constraint into a non-correlated subquery to improve the query performance.
- [Proposal] Replace **(not) in** with **(not) exist** when associated columns do not contain **NULL** values. For example, in the following query statement, if the T1.C1 column does not contain any NULL value, add the NOT NULL constraint to the T1.C1 column, and then rewrite the statements.

  ```
  SELECT * FROM T1 WHERE T1.C1 NOT IN (SELECT T2.C2 FROM T2);
  ```

  Rewrite the statement as follows:

  ```
  SELECT * FROM T1 WHERE NOT EXISTS (SELECT  * FROM T1,T2 WHERE T1.C1=T2.C2);
  ```

  **NOTE**

  - If the value of the T1.C1 column will possibly be NULL, the preceding rewriting cannot be performed.
  - If T1.C1 is the output of a subquery, check whether the output is NOT NULL based on the service logic.
- [Proposal] Use cursors instead of the **LIMIT OFFSET** syntax to perform pagination queries to avoid resource overheads caused by multiple executions.

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A cursor must be used in a transaction, and you must disable it and commit transaction once the query is finished.

# 6.6 PL/Java Usage

- [Notice] Java UDFs can perform some Java logic calculation. Do not encapsulate services in Java UDFs.
- [Notice] Do not connect to a database in any way (for example, by using JDBC) in Java functions.
- [Notice] Only the data types listed in the following table can be used. User-defined types and complex data types (Java Array and derived classes) are not supported.
- [Notice] User-defined aggregation functions (UDAFs) and user-defined table-generating functions (UDTFs) are not supported.

**Table 6-4** PL/Java mapping for default data types

| GaussDB(DWS) | Java |
| --- | --- |
| BOOLEAN | boolean |
| "char" | byte |
| bytea | byte[] |
| SMALLINT | short |
| INTEGER | int |
| BIGINT | long |
| FLOAT4 | float |
| FLOAT8 | double |
| CHAR | java.lang.String |
| VARCHAR | java.lang.String |
| TEXT | java.lang.String |
| name | java.lang.String |
| DATE | java.sql.Timestamp |
| TIME | java.sql.Time (stored value treated as local time) |
| TIMETZ | java.sql.Time |
| TIMESTAMP | java.sql.Timestamp |
| TIMESTAMPTZ | java.sql.Timestamp |

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# 6.7 PL/pgSQL Usage

## General Principles

1. Development shall strictly comply with design documents.
2. Program modules shall be highly cohesive and loosely coupled.
3. Proper, comprehensive troubleshooting measures shall be developed.
4. Code shall be reasonable and clear.
5. Program names shall comply with a unified naming rule.
6. Fully consider the program efficiency, including the program execution efficiency and database query and storage efficiency. Use efficient and effective processing methods.
7. Program comments shall be detailed, correct, and standard.
8. The commit or rollback operation shall be performed at the end of a stored procedure, unless otherwise required by applications.
9. Programs shall support 24/7 processing. In the case of an interruption, the applications shall provide secure, easy-to-use resuming features.
10. Application output shall be standard and simple. The output shall show the progress, error description, and execution results for application maintenance personnel, and provide clear and intuitive reports and documents for business personnel.

## Programming Principles

1. Use bound variables in SQL statements in the PL/pgSQL.
2. **RETURNING** is recommended for SQL statements in PL/pgSQL.
3. Principles for using stored procedures:
   a. Do not use more than 50 output parameters of the Varchar or Varchar2 type in a stored procedure.
   b. Do not use the LONG type for input or output parameters.
   c. Use the CLOB type for output strings that exceed 10 MB.
4. Variable declaration principles:
   a. Use **%TYPE** to declare a variable that has the same meaning as that of a column or variable in an application table.
   b. Use **%ROWTYPE** to declare a record that has the same meaning as that of a row in an application table.
   c. Each line of a variable declaration shall contain only one statement.
   d. Do not declare variables of the LONG type.
5. Principles for using cursors:
   a. Explicit cursors shall be closed after being used.
   b. A cursor variable shall be closed after being used. If the cursor variable needs to transfer data to an invoked application, the cursor shall be closed in the application. If the cursor variable is used only in a stored procedure, the cursor shall be closed explicitly.

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c. Before using **DBMS_SQL.CLOSE_CURSOR** to close a cursor, use **DBMS_SQL.IS_OPEN** to check whether the cursor is open.

6. Principles for collections:
   a. You are advised to use the **FOR ALL** statement instead of the **FOR** loop statement to reference elements in a collection.
7. Principles for using dynamic statements:
   a. Dynamic SQL shall not be used in the transaction programs of online systems.
   b. Dynamic SQL statements can be used to implement DDL statements and system control commands in PL/pgSQL.
   c. Variable binding is recommended.
8. Principles for assembling SQL statements:
   a. You are advised to use bound variables to assemble SQL statements.
   b. If the conditions for assembling SQL statements contain external input sources, the characters in the input conditions shall be checked to prevent attacks.
   c. In a PL/pgSQL script, the length of a single line of code cannot exceed 2499 characters.
9. Principles for using triggers:
   a. Triggers can be used to implement availability design in scenarios where differential data logs are irrelevant to service processing.
   b. Do not use triggers to implement service processing functions.

## Exception Handling Principles

Any error that occurs in a PL/pgSQL function aborts the execution of the function and related transactions. You can use a **BEGIN** block with an **EXCEPTION** clause to catch and fix errors.

1. In a PL/pgSQL block, if an SQL statement cannot return a definite result, you are advised to handle exceptions (if any) in **EXCEPTION**. Otherwise, unhandled errors may be transferred to the external block and cause program logic errors.
2. You can directly use the exceptions that have been defined in the system. DWS does not support custom exceptions.
3. A block containing an **EXCEPTION** clause is more expensive to enter and exit than a block without one. Therefore, do not use **EXCEPTION** without need.

## Writing Standard

1. Variable naming rules:
   a. The input parameter format of a procedure or function is **IN**_*Parameter_name*. The parameter name shall be in uppercase.
   b. The output parameter format of a procedure or function is **OUT**_*Parameter_name*. The parameter name shall be in uppercase.
   c. The input and output parameter format of a procedure or function is **IO**_*Parameter_name*. The parameter name shall be in uppercase.

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d. Variables used in procedures and functions shall be composed of **v**_*Variable_name*. The variable name shall be in lower case.

e. In query concatenation, the concatenation variable name of the **WHERE** statement shall be **v_where**, and the concatenation variable name of the **SELECT** statement shall be **v_select**.

f. The record type (TYPE) name shall consist of **T** and a variable name. The name shall be in uppercase.

g. A cursor name shall consist of **CUR** and a variable name. The name shall be in uppercase.

h. The name of a reference cursor (REF CURSOR) shall consist of **REF** and a variable name. The name shall be in uppercase.

2. Rules for defining variable types:

   a. Use **%TYPE** to declare the type of a variable that has the same meaning as that of a column in an application table.

   b. Use **%ROWTYPE** to declare the type of a record that has the same meaning as that of a row in an application table.

3. Rules for writing comments:

   a. Comments shall be meaningful and shall not just repeat the code content.

   b. Comments shall be concise and easy to understand.

   c. Comments shall be provided at the beginning of each stored procedure or function. The comments shall contain a brief function description, author, compilation date, program version number, and program change history. The format of the comments at the beginning of stored procedures shall be the same.

   d. Comments shall be provided next to the input and output parameters to describe the meaning of variables.

   e. Comments shall be provided at the beginning of each block or large branch to briefly describe the function of the block. If an algorithm is used, comments shall be provided to describe the purpose and result of the algorithm.

4. Variable declaration format:

   Each line shall contain only one statement. To assign initial values, write them in the same line.

5. Letter case:

   Use uppercase letters except for variable names.

6. Indentation:

   In the statements used for creating a stored procedure, the keywords **CREATE**, **AS/IS**, **BEGIN**, and **END** at the same level shall have the same indent.

7. Statement rules:

   a. For statements that define variables, Each line shall contain only one statement.

   b. The keywords **IF**, **ELSE IF**, **ELSE**, and **END** at the same level shall have the same indent.

   c. The keywords **CASE** and **END** shall have the same indent. The keywords **WHEN** and **ELSE** shall be indented.

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d. The keywords **LOOP** and **END LOOP** at the same level shall have the same indent. Nested statements or statements at lower levels shall have more indent.

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# 7 Guide: JDBC- or ODBC-Based Development

## 7.1 Development Specifications

If the connection pool mechanism is used during application development, comply with the following specifications:

- If GUC parameters are set in the connection, before you return the connection to the connection pool, run **SET SESSION AUTHORIZATION DEFAULT;RESET ALL;** to clear the connection status.
- If a temporary table is used, delete it before you return the connection to the connection pool.

If you do not do so, the status of connections in the connection pool will remain, which affects subsequent operations using the connection pool.

## 7.2 Downloading Drivers

For details, see section "Downloading the JDBC or ODBC Driver" in the *Data Warehouse Service User Guide*.

## 7.3 JDBC-Based Development

Java Database Connectivity (JDBC) is a Java API for executing SQL statements, providing a unified access interface for different relational databases, based on which applications process data. GaussDB(DWS) supports JDBC 4.0 and requires JDK 1.6 or later for code compiling. It does not support JDBC-ODBC Bridge.

### 7.3.1 JDBC Package and Driver Class

#### JDBC Package

Obtain a JDBC package from the release package. The package name is **dws_8.1.x_jdbc_driver.zip**.

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After the decompression, you will obtain the following JDBC packages in .jar format:

- **gsjdbc4.jar**: Driver package compatible with PostgreSQL. The class name and class structure in the driver are the same as those in the PostgreSQL driver. All the applications running on PostgreSQL can be smoothly transferred to the current system.
- **gsjdbc200.jar**: This driver package is used when both PostgreSQL and GaussDB(DWS) are accessed in a JVM process. The main class name is **com.huawei.gauss200.jdbc.Driver** and the prefix of the URL for database connection is **jdbc:gaussdb**. Other information of this driver package is the same as that of **gsjdbc4.jar**.

## Driver Class

Before creating a database connection, you need to load the database driver class **org.postgresql.Driver** (decompressed from **gsjdbc4.jar**) or **com.huawei.gauss200.jdbc.Driver** (decompressed from **gsjdbc200.jar**).

NOTE

GaussDB(DWS) is compatible with PostgreSQL in the use of JDBC. Therefore, when two JDBC drivers are used in the same process, class names may conflict.

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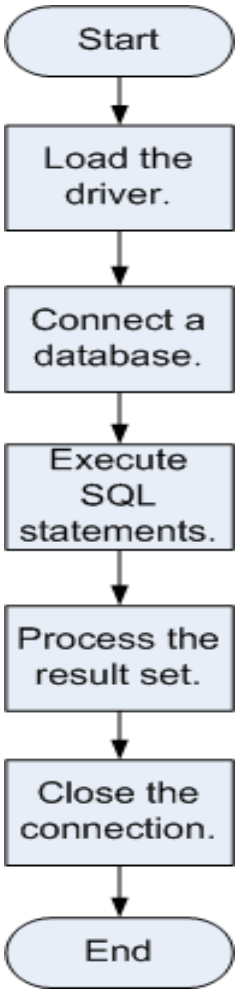
## 7.3.2 Development Process

**Figure 7-1** JDBC-based application development process




## 7.3.3 Loading a Driver

Load the database driver before creating a database connection.

You can load the driver in the following ways:

- Implicitly loading the driver before creating a connection in the code: **Class.forName ("org.postgresql.Driver")**
- Transferring a parameter during the JVM startup: **java -Djdbc.drivers=org.postgresql.Driver jdbctest**

  NOTE

  - **jdbctest** is the name of a test application.
  - If **gsjdbc200.jar** is used, change the driver class name to **"com.huawei.gauss200.jdbc.Driver"**.

## 7.3.4 Connecting to a Database

After a database is connected, you can execute SQL statements in the database.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**NOTE**

If you use an open-source Java Database Connectivity (JDBC) driver, ensure that the database parameter **password_encryption_type** is set to **1**. If the value is not 1, the connection may fail. A typical error message is "none of the server's SASL authentication mechanisms are supported." To avoid such problems, perform the following operations:

1. Set **password_encryption_type** to **1**. For details, see "Modifying Database Parameters" in *User Guide*.
2. Create a new database user for connection or reset the password of the existing database user.
   - If you use an administrator account, reset the password. For details, see "Password Reset" in *User Guide*.
   - If you are a common user, use another client tool (such as Data Studio) to connect to the database and run the **ALTER USER** statement to change your password.
3. Connect to the database.

Here are the reasons why you need to perform these operations:

- MD5 algorithms may by vulnerable to collision attacks and cannot be used for password verification. Currently, GaussDB(DWS) uses the default security design. By default, MD5 password verification is disabled, but MD5 is required by the open-source libpq communication protocol of PostgreSQL. For connectivity purposes, you need to adjust the cryptographic algorithm parameter **password_encryption_type** and enable the MD5 algorithm.
- The database stores the hash digest of passwords instead of password text. During password verification, the system compares the hash digest with the password digest sent from the client (salt operations are involved). If you change your cryptographic algorithm policy, the database cannot generate a new MD5 hash digest for your existing password. For connectivity purposes, you must manually change your password or create a new user. The new password will be encrypted using the hash algorithm and stored for authentication in the next connection.

## Function Prototype

JDBC provides the following three database connection methods:

- DriverManager.getConnection(String url);
- DriverManager.getConnection(String url, Properties info);
- DriverManager.getConnection(String url, String user, String password);

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## Parameter

**Table 7-1** Database connection parameters

| Parameter | Description |
| --- | --- |
| url | **gsjdbc4.jar** database connection descriptor. The descriptor format can be:<br>• jdbc:postgresql:database<br>• jdbc:postgresql://host/database<br>• jdbc:postgresql://host:port/database<br>• jdbc:postgresql://host:port[,host:port][...]/database<br>**NOTE**<br>If **gsjdbc200.jar** is used, replace **jdbc:postgresql** with **jdbc:gaussdb**.<br>• **database**: indicates the name of the database to be connected.<br>• **host**: indicates the name or IP address of the database server.<br>Specify the IP address for connecting to the GaussDB(DWS) cluster on GaussDB(DWS) management console. If the connected host and the GaussDB(DWS) cluster are in the same network, select the private IP address. Otherwise, select the public IP address.<br>For security purposes, the CN forbids access from other nodes in the cluster without authentication. To access the CN from inside the cluster, deploy the JDBC program on the host where the CN is located and set **host** to **127.0.0.1**. Otherwise, the error message **FATAL: Forbid remote connection with trust method!** may be displayed.<br>It is recommended that the service system be deployed outside the cluster. Otherwise, the database performance may be affected.<br>• **port**: indicates the port number of a database server. By default, the database on port **8000** of the local host is connected.<br>• Multiple IP addresses and ports can be configured. JDBC balances load by random access and failover, and will automatically ignore unreachable IP addresses.<br>IP addresses are separated using commas. Example: **jdbc:postgresql://10.10.0.13:8000,10.10.0.14:8000/database** |

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| Parameter | Description |
| --- | --- |
| info | Database connection properties. Common properties include:<br>• **user**: string type. It indicates the database user who creates the connection.<br>• **password**: string type. It indicates the password of a database user.<br>• **ssl**: boolean type. It indicates whether the Secure Socket Layer (SSL) is used.<br>• **loggerLevel**: string type. It indicates the amount of information that the driver logs and prints to the LogStream or LogWriter specified in the DriverManager. Currently, **OFF**, **DEBUG**, and **TRACE** are supported. **DEBUG** indicates that only logs of the **DEBUG** or higher level are printed, generating little log information. **TRACE** indicates that logs of the **DEBUG** and **TRACE** levels are printed, generating detailed log information. The default value is **OFF**, indicating that no information will be logged.<br>• **prepareThreshold**: integer type. It indicates the number of **PreparedStatement** executions required before requests are converted to prepared statements in servers. The default value is **5**.<br>• **batchMode**: boolean type. It indicates whether to connect the database in batch mode.<br>• **fetchsize**: integer type. It indicates the default fetch size for statements in the created connection.<br>• **ApplicationName**: string type. It indicates an application name. The default value is **PostgreSQL JDBC Driver**.<br>• **allowReadOnly**: boolean type. It indicates whether to enable the read-only mode for connection. The default value is **false**. If the value is not changed to **true**, the execution of **connection.setReadOnly** does not take effect.<br>• **blobMode**: string type. It is used to set the setBinaryStream method to assign values to different data types. The value **on** indicates that values are assigned to the BLOB data type and **off** indicates that values are assigned to the BYTEA data type. The default value is **on**.<br>• **connectionExtraInfo**: boolean type. It indicates whether the JDBC driver reports the driver deployment path and process owner to the database.<br>**NOTE**<br>The value can be **true** or **false**. The default value is **false**. If **connectionExtraInfo** is set to **true**, the JDBC driver reports the driver deployment path and process owner to the database and displays the information in the **connection_info** parameter (see **connection_info**). In this case, you can query the information from **PG_STAT_ACTIVITY** or **PGXC_STAT_ACTIVITY**. |
| user | Indicates a database user. |


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| Parameter | Description |
| --- | --- |
| password | Indicates the password of a database user. |

## Examples

```
//gsjdbc4.jar is used as an example. If gsjdbc200.jar is used, replace the class name org.postgresql with com.huawei.gauss200.jdbc and replace the URL prefix jdbc:postgresql with jdbc:gaussdb.
//The following code encapsulates database connection operations into an interface. The database can then be connected using an authorized username and password.

public static Connection GetConnection(String username, String passwd)
  {
      //Set the driver class.
      String driver = "org.postgresql.Driver";
      //Set the database connection descriptor.
      String sourceURL = "jdbc:postgresql://10.10.0.13:8000/postgres?currentSchema=test";
      Connection conn = null;

      try
      {
          //Load the driver.
          Class.forName(driver);
      }
      catch( Exception e )
      {
          e.printStackTrace();
          return null;
      }

      try
      {
           //Create a connection.
          conn = DriverManager.getConnection(sourceURL, username, passwd);
          System.out.println("Connection succeed!");
      }
      catch(Exception e)
      {
          e.printStackTrace();
          return null;
      }

      return conn;
  };
```

# 7.3.5 Executing SQL Statements

## Executing an Ordinary SQL Statement

The application performs data (parameter statements do not need to be transferred) in the database by running SQL statements, and you need to perform the following steps:

**Step 1** Create a statement object by triggering the createStatement method in Connection.

```
Statement stmt = con.createStatement();
```

**Step 2** Execute the SQL statement by triggering the executeUpdate method in Statement.

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```
int rc = stmt.executeUpdate("CREATE TABLE customer_t1(c_customer_sk INTEGER, c_customer_name
VARCHAR(32));");
```

**NOTE**

If an execution request (not in a transaction block) received in the database contains multiple statements, the request is packed into a transaction. **VACUUM** is not supported in a transaction block. If one of the statements fails, the entire request will be rolled back.

**Step 3** Close the statement object.

```
stmt.close();
```

**----End**

## Executing a Prepared SQL Statement

Pre-compiled statements were once complied and optimized and can have additional parameters for different usage. For the statements have been pre-compiled, the execution efficiency is greatly improved. If you want to execute a statement for several times, use a precompiled statement. Perform the following procedure:

**Step 1** Create a prepared statement object by calling the prepareStatement method in Connection.

```
PreparedStatement pstmt = con.prepareStatement("UPDATE customer_t1 SET c_customer_name = ?
WHERE c_customer_sk = 1");
```

**Step 2** Set parameters by triggering the setShort method in PreparedStatement.

```
pstmt.setShort(1, (short)2);
```

**Step 3** Execute the precompiled SQL statement by triggering the executeUpdate method in PreparedStatement.

```
int rowcount = pstmt.executeUpdate();
```

**Step 4** Close the precompiled statement object by calling the close method in PreparedStatement.

```
pstmt.close();
```

**----End**

## Calling a Stored Procedure

Perform the following steps to call existing stored procedures through the JDBC interface in GaussDB(DWS):

**Step 1** Create a call statement object by calling the prepareCall method in Connection.

```
CallableStatement cstmt = myConn.prepareCall("{? = CALL TESTPROC(?,?,?)}");
```

**Step 2** Set parameters by calling the setInt method in CallableStatement.

```
cstmt.setInt(2, 50);
cstmt.setInt(1, 20);
cstmt.setInt(3, 90);
```

**Step 3** Register with an output parameter by calling the registerOutParameter method in CallableStatement.

```
cstmt.registerOutParameter(4, Types.INTEGER);  //Register an OUT parameter as an integer.
```

**Step 4** Call the stored procedure by calling the execute method in CallableStatement.

```
cstmt.execute();
```

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**Step 5** Obtain the output parameter by calling the getInt method in CallableStatement.

```
int out = cstmt.getInt(4);  //Obtain the OUT parameter.
```

For example:

```
//The following stored procedure has been created with the OUT parameter:
create or replace procedure testproc
(
    psv_in1 in integer,
    psv_in2 in integer,
    psv_inout in out integer
)
as
begin
    psv_inout := psv_in1 + psv_in2 + psv_inout;
end;
/
```

**Step 6** Close the call statement by calling the close method in CallableStatement.

```
cstmt.close();
```

NOTE

- Many database classes such as Connection, Statement, and ResultSet have a close() method. Close these classes after using their objects. Close these actions after using their objects. Closing Connection will close all the related Statements, and closing a Statement will close its ResultSet.
- Some JDBC drivers support named parameters, which can be used to set parameters by name rather than sequence. If a parameter has a default value, you do not need to specify any parameter value but can use the default value directly. Even though the parameter sequence changes during a stored procedure, the application does not need to be modified. Currently, the GaussDB(DWS) JDBC driver does not support this method.
- GaussDB(DWS) does not support functions containing OUT parameters, or default values of stored procedures and function parameters.

**----End**

NOTICE

- If JDBC is used to call a stored procedure whose returned value is a cursor, the returned cursor cannot be used.
- A stored procedure and an SQL statement must be executed separately.

## Batch Processing

When a prepared statement batch processes multiple pieces of similar data, the database creates only one execution plan. This improves the compilation and optimization efficiency. Perform the following procedure:

**Step 1** Create a prepared statement object by calling the prepareStatement method in Connection.

```
PreparedStatement pstmt = con.prepareStatement("INSERT INTO customer_t1 VALUES (?)");
```

**Step 2** Call the setShort parameter for each piece of data, and call addBatch to confirm that the setting is complete.

```
pstmt.setShort(1, (short)2);
pstmt.addBatch();
```

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**Step 3** Execute batch processing by calling the executeBatch method in PreparedStatement.

```
int[] rowcount = pstmt.executeBatch();
```

**Step 4** Close the precompiled statement object by calling the close method in PreparedStatement.

```
pstmt.close();
```

NOTE

Do not terminate a batch processing action when it is ongoing; otherwise, the database performance will deteriorate. Therefore, disable the automatic submission function during batch processing, and manually submit every several lines. The statement for disabling automatic submission is **conn.setAutoCommit(false)**.

**----End**

# 7.3.6 Processing Data in a Result Set

## Setting a Result Set Type

Different types of result sets are applicable to different application scenarios. Applications select proper types of result sets based on requirements. Before executing an SQL statement, you must create a statement object. Some methods of creating statement objects can set the type of a result set. **Table 7-2** lists result set parameters. The related Connection methods are as follows:

```
//Create a Statement object. This object will generate a ResultSet object with a specified type and concurrency.
createStatement(int resultSetType, int resultSetConcurrency);

//Create a PreparedStatement object. This object will generate a ResultSet object with a specified type and concurrency.
prepareStatement(String sql, int resultSetType, int resultSetConcurrency);

//Create a CallableStatement object. This object will generate a ResultSet object with a specified type and concurrency.
prepareCall(String sql, int resultSetType, int resultSetConcurrency);
```


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**Table 7-2** Result set types

| Parameter | Description |
| --- | --- |
| resultSetType | Indicates the type of a result set. There are three types of result sets:<br>• **ResultSet.TYPE_FORWARD_ONLY**: The ResultSet object can only be navigated forward. It is the default value.<br>• **ResultSet.TYPE_SCROLL_SENSITIVE**: You can view the modified result by scrolling to the modified row.<br>• **ResultSet.TYPE_SCROLL_INSENSITIVE**: The ResultSet object is insensitive to changes in the underlying data source.<br>**NOTE**<br>After a result set has obtained data from the database, the result set is insensitive to data changes made by other transactions, even if the result set type is **ResultSet.TYPE_SCROLL_SENSITIVE**. To obtain up-to-date data of the record pointed by the cursor from the database, call the refreshRow() method in a ResultSet object. |
| resultSetConcurrency | Indicates the concurrency type of a result set. There are two types of concurrency.<br>• **ResultSet.CONCUR_READ_ONLY**: The data in a result set cannot be updated except that an updated statement has been created in the result set data.<br>• **ResultSet.CONCUR_UPDATEABLE**: changeable result set. The concurrency type for a result set object can be updated if the result set is scrollable. |

## Positioning a Cursor in a Result Set

ResultSet objects include a cursor pointing to the current data row. The cursor is initially positioned before the first row. The next method moves the cursor to the next row from its current position. When a ResultSet object does not have a next row, a call to the next method returns **false**. Therefore, this method is used in the while loop for result set iteration. However, the JDBC driver provides more cursor positioning methods for scrollable result sets, which allows positioning cursor in the specified row. **Table 7-3** lists these methods.

**Table 7-3** Methods for positioning a cursor in a result set

| Method | Description |
| --- | --- |
| next() | Moves cursor to the next row from its current position. |
| previous() | Moves cursor to the previous row from its current position. |

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| Method | Description |
| --- | --- |
| beforeFirst() | Places cursor before the first row. |
| afterLast() | Places cursor after the last row. |
| first() | Places cursor to the first row. |
| last() | Places cursor to the last row. |
| absolute(int) | Places cursor to a specified row. |
| relative(int) | Moves cursor forward or backward a specified number of rows. |

## Obtaining the cursor position from a result set

This cursor positioning method will be used to change the cursor position for a scrollable result set. JDBC driver provides a method to obtain the cursor position in a result set. **Table 7-4** lists the method.

**Table 7-4** Method for obtaining the cursor position in a result set

| Method | Description |
| --- | --- |
| isFirst() | Checks whether the cursor is in the first row. |
| isLast() | Checks whether the cursor is in the last row. |
| isBeforeFirst() | Checks whether the cursor is before the first row. |
| isAfterLast() | Checks whether the cursor is after the last row. |
| getRow() | Gets the current row number of the cursor. |

## Obtaining data from a result set

ResultSet objects provide a variety of methods to obtain data from a result set. **Table 7-5** lists the common methods for obtaining data. If you want to know more about other methods, see JDK official documents.

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**Table 7-5** Common methods for obtaining data from a result set

| Method | Description |
| --- | --- |
| int getInt(int columnIndex) | Retrieves the value of the column designated by a column index in the current row as an int. |
| int getInt(String columnLabel) | Retrieves the value of the column designated by a column label in the current row as an int. |
| String getString(int columnIndex) | Retrieves the value of the column designated by a column index in the current row as a String. |
| String getString(String columnLabel) | Retrieves the value of the column designated by a column label in the current row as a String. |
| Date getDate(int columnIndex) | Retrieves the value of the column designated by a column index in the current row as a Date. |
| Date getDate(String columnLabel) | Retrieves the value of the column designated by a column name in the current row as a Date. |

## 7.3.7 Closing the Connection

After you complete required data operations in the database, close the database connection.

Call the close method to close the connection, such as, **conn. close()**.

## 7.3.8 Example: Common Operations

### Example 1

Before completing the following example, you need to create a stored procedure.

```
create or replace procedure testproc
(
    psv_in1 in integer,
    psv_in2 in integer,
    psv_inout in out integer
)
as
begin
    psv_inout := psv_in1 + psv_in2 + psv_inout;
end;
/
```

This example illustrates how to develop applications based on the GaussDB(DWS) JDBC interface.

```
//DBtest.java
//gsjdbc4.jar is used as an example. If gsjdbc200.jar is used, replace the class name org.postgresql with
```

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**com.huawei.gauss200.jdbc** and replace the URL prefix **jdbc:postgresql** with **jdbc:gaussdb**.

```
// This example illustrates the main processes of JDBC-based development, covering database connection creation, table creation, and data insertion.

import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.PreparedStatement;
import java.sql.SQLException;
import java.sql.Statement;
import java.sql.CallableStatement;

public class DBTest {

  //Establish a connection to the database.
  public static Connection GetConnection(String username, String passwd) {
    String driver = "org.postgresql.Driver";
    String sourceURL = "jdbc:postgresql://localhost:8000/gaussdb";
    Connection conn = null;
    try {
      //Load the database driver.
      Class.forName(driver).newInstance();
    } catch (Exception e) {
      e.printStackTrace();
      return null;
    }

    try {
      //Establish a connection to the database.
      conn = DriverManager.getConnection(sourceURL, username, passwd);
      System.out.println("Connection succeed!");
    } catch (Exception e) {
      e.printStackTrace();
      return null;
    }

    return conn;
  };

  //Run an ordinary SQL statement. Create a customer_t1 table.
  public static void CreateTable(Connection conn) {
    Statement stmt = null;
    try {
      stmt = conn.createStatement();

      //Run an ordinary SQL statement.
      int rc = stmt
          .executeUpdate("CREATE TABLE customer_t1(c_customer_sk INTEGER, c_customer_name
VARCHAR(32));");

      stmt.close();
    } catch (SQLException e) {
      if (stmt != null) {
        try {
          stmt.close();
        } catch (SQLException e1) {
          e1.printStackTrace();
        }
      }
      e.printStackTrace();
    }
  }

  //Run the preprocessing statement to insert data in batches.
  public static void BatchInsertData(Connection conn) {
    PreparedStatement pst = null;

    try {
      //Generate a prepared statement.
      pst = conn.prepareStatement("INSERT INTO customer_t1 VALUES (?,?)");
```

```
    for (int i = 0; i < 3; i++) {
      //Add parameters.
      pst.setInt(1, i);
      pst.setString(2, "data " + i);
      pst.addBatch();
    }
    //Run batch processing.
    pst.executeBatch();
    pst.close();
  } catch (SQLException e) {
    if (pst != null) {
      try {
        pst.close();
      } catch (SQLException e1) {
      e1.printStackTrace();
      }
    }
    e.printStackTrace();
  }
}

 //Run the precompilation statement to update data.
 public static void ExecPreparedSQL(Connection conn) {
   PreparedStatement pstmt = null;
   try {
     pstmt = conn
         .prepareStatement("UPDATE customer_t1 SET c_customer_name = ? WHERE c_customer_sk = 1");
     pstmt.setString(1, "new Data");
     int rowcount = pstmt.executeUpdate();
     pstmt.close();
   } catch (SQLException e) {
     if (pstmt != null) {
       try {
         pstmt.close();
       } catch (SQLException e1) {
         e1.printStackTrace();
       }
     }
     e.printStackTrace();
   }
 }


//Run a stored procedure.
 public static void ExecCallableSQL(Connection conn) {
   CallableStatement cstmt = null;
   try {

     cstmt=conn.prepareCall("{? = CALL TESTPROC(?,?,?)}");
     cstmt.setInt(2, 50);
     cstmt.setInt(1, 20);
     cstmt.setInt(3, 90);
      cstmt.registerOutParameter(4, Types.INTEGER);  //Register an OUT parameter as an integer.
     cstmt.execute();
     int out = cstmt.getInt(4);  //Obtain the out parameter value.
     System.out.println("The CallableStatment TESTPROC returns:"+out);
     cstmt.close();
   } catch (SQLException e) {
     if (cstmt != null) {
       try {
         cstmt.close();
       } catch (SQLException e1) {
         e1.printStackTrace();
       }
     }
     e.printStackTrace();
   }
 }
```

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```
 /**
  * Main process. Call static methods one by one.
  * @param args
 */
 public static void main(String[] args) {
   //Establish a connection to the database.
   Connection conn = GetConnection("tester", "password");

   //Create a table.
   CreateTable(conn);

   //Insert data in batches.
   BatchInsertData(conn);

  //Run the precompilation statement to update data.
   ExecPreparedSQL(conn);

   //Run a stored procedure.
   ExecCallableSQL(conn);

   //Close the connection to the database.
   try {
     conn.close();
   } catch (SQLException e) {
     e.printStackTrace();
   }

 }

}
```

## Example 2: High Client Memory Usage

In this example, **setFetchSize** adjusts the memory usage of the client by using the database cursor to obtain server data in batches. It may increase network interaction and damage some performance.

The cursor is valid within a transaction. Therefore, you need to disable the autocommit function.

```
// Disable the autocommit function.
conn.setAutoCommit(false);
Statement st = conn.createStatement();

// Open the cursor and obtain 50 lines of data each time.
st.setFetchSize(50);
ResultSet rs = st.executeQuery("SELECT * FROM mytable");
while (rs.next())
{
    System.out.print("a row was returned.");
}
rs.close();

// Disable the server cursor.
st.setFetchSize(0);
rs = st.executeQuery("SELECT * FROM mytable");
while (rs.next())
{
    System.out.print("many rows were returned.");
}
rs.close();

// Close the statement.
st.close();
```

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# 7.3.9 Example: Retrying SQL Queries for Applications

If the primary DN is faulty and cannot be restored within 40s, its standby is automatically promoted to primary to ensure the normal running of the cluster. Jobs running during the failover will fail and those started after the failover will not be affected. To protect upper-layer services from being affected by the failover, refer to the following example to construct a SQL retry mechanism at the service layer.

```
//gsjdbc4.jar is used as an example. If gsjdbc200.jar is used, replace the class name org.postgresql with com.huawei.gauss200.jdbc and replace the URL prefix jdbc:postgresql with jdbc:gaussdb.
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;

/**
 *
 *
 */

class ExitHandler extends Thread {
    private Statement cancel_stmt = null;

    public ExitHandler(Statement stmt) {
        super("Exit Handler");
        this.cancel_stmt = stmt;
    }
    public void run() {
        System.out.println("exit handle");
        try {
            this.cancel_stmt.cancel();
        } catch (SQLException e) {
            System.out.println("cancel query failed.");
            e.printStackTrace();
        }
    }
}

public class SQLRetry {
  //Establish a connection to the database.
    public static Connection GetConnection(String username, String passwd) {
      String driver = "org.postgresql.Driver";
      String sourceURL = "jdbc:postgresql://10.131.72.136:8000/gaussdb";
      Connection conn = null;
      try {
       //Load the database driver.
        Class.forName(driver).newInstance();
      } catch (Exception e) {
        e.printStackTrace();
        return null;
      }

      try {
       //Establish a connection to the database.
        conn = DriverManager.getConnection(sourceURL, username, passwd);
        System.out.println("Connection succeed!");
      } catch (Exception e) {
        e.printStackTrace();
        return null;
      }

      return conn;
}
```

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```
//Run an ordinary SQL statement. Create a jdbc_test1 table.
 public static void CreateTable(Connection conn) {
   Statement stmt = null;
   try {
     stmt = conn.createStatement();

     // add ctrl+c handler
     Runtime.getRuntime().addShutdownHook(new ExitHandler(stmt));

    // Run an ordinary SQL statement.
     int rc2 = stmt
        .executeUpdate("DROP TABLE if exists jdbc_test1;");

     int rc1 = stmt
        .executeUpdate("CREATE TABLE jdbc_test1(col1 INTEGER, col2 VARCHAR(10));");

     stmt.close();
   } catch (SQLException e) {
     if (stmt != null) {
       try {
         stmt.close();
       } catch (SQLException e1) {
         e1.printStackTrace();
       }
     }
     e.printStackTrace();
   }
 }

//Run the preprocessing statement to insert data in batches.
 public static void BatchInsertData(Connection conn) {
   PreparedStatement pst = null;

   try {
    //Generate a prepared statement.
     pst = conn.prepareStatement("INSERT INTO jdbc_test1 VALUES (?,?)");
     for (int i = 0; i < 100; i++) {
      //Add parameters.
       pst.setInt(1, i);
       pst.setString(2, "data " + i);
       pst.addBatch();
     }
    //Perform batch processing.
     pst.executeBatch();
     pst.close();
   } catch (SQLException e) {
     if (pst != null) {
       try {
         pst.close();
       } catch (SQLException e1) {
       e1.printStackTrace();
       }
     }
     e.printStackTrace();
   }
 }

//Run the precompilation statement to update data.
 private static boolean QueryRedo(Connection conn){
   PreparedStatement pstmt = null;
   boolean retValue = false;
   try {
     pstmt = conn
         .prepareStatement("SELECT col1 FROM jdbc_test1 WHERE col2 = ?");

         pstmt.setString(1, "data 10");
         ResultSet rs = pstmt.executeQuery();

         while (rs.next()) {
```

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```
            System.out.println("col1 = " + rs.getString("col1"));
        }
        rs.close();

     pstmt.close();
      retValue = true;
    } catch (SQLException e) {
     System.out.println("catch..... retValue " + retValue);
     if (pstmt != null) {
       try {
        pstmt.close();
      } catch (SQLException e1) {
        e1.printStackTrace();
       }
     }
     e.printStackTrace();
   }

    System.out.println("finesh.....");
   return retValue;
 }

//Run a query statement and retry upon a failure. The number of retry times can be configured.
  public static void ExecPreparedSQL(Connection conn) throws InterruptedException {
       int maxRetryTime = 50;
       int time = 0;
       String result = null;
       do {
           time++;
           try {
 System.out.println("time:" + time);
 boolean ret = QueryRedo(conn);
 if(ret == false){
  System.out.println("retry, time:" + time);
  Thread.sleep(10000);
  QueryRedo(conn);
 }
           } catch (Exception e) {
               e.printStackTrace();
           }
       } while (null == result && time < maxRetryTime);

  }

  /**
  * Main process. Call static methods one by one.
   * @param args
 * @throws InterruptedException
  */
  public static void main(String[] args) throws InterruptedException {
   //Establish a connection to the database.
    Connection conn = GetConnection("testuser", "test@123");

   //Create a table.
    CreateTable(conn);

   //Insert data in batches.
    BatchInsertData(conn);

   //Run the precompilation statement to update data.
    ExecPreparedSQL(conn);

   //Disconnect from the database.
    try {
      conn.close();
    } catch (SQLException e) {
      e.printStackTrace();
    }
```

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```
  }

}
```

## 7.3.10 Example: Importing and Exporting Data Through Local Files

When the JAVA language is used for secondary development based on GaussDB(DWS), you can use the CopyManager interface to export data from the database to a local file or import a local file to the database by streaming. The file can be in CSV or TEXT format.

The sample program is as follows. Load the GaussDB(DWS) JDBC driver before running it.

```
//gsjdbc4.jar is used as an example. If gsjdbc200.jar is used, replace the class name org.postgresql with com.huawei.gauss200.jdbc and replace the URL prefix jdbc:postgresql with jdbc:gaussdb.
import java.sql.Connection;
import java.sql.DriverManager;
import java.io.IOException;
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.sql.SQLException;
import org.postgresql.copy.CopyManager;
import org.postgresql.core.BaseConnection;

public class Copy{

    public static void main(String[] args)
    {
     String urls = new String("jdbc:postgresql://10.180.155.74:8000/gaussdb"); //Database URL
     String username = new String("jack");            //Username
     String password = new String("********");       // Password
     String tablename = new String("migration_table"); //Define table information.
     String tablename1 = new String("migration_table_1"); //Define table information.
     String driver = "org.postgresql.Driver";
     Connection conn = null;

     try {
           Class.forName(driver);
           conn = DriverManager.getConnection(urls, username, password);
         } catch (ClassNotFoundException e) {
             e.printStackTrace(System.out);
         } catch (SQLException e) {
             e.printStackTrace(System.out);
         }

     //Export the query result of SELECT * FROM migration_table to the local file d:/data.txt.
     try {
    copyToFile(conn, "d:/data.txt", "(SELECT * FROM migration_table)");
  } catch (SQLException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
  } catch (IOException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
  }
     //Import data from the d:/data.txt file to the migration_table_1 table.
     try {
     copyFromFile(conn, "d:/data.txt", tablename1);
  } catch (SQLException e) {
 // TODO Auto-generated catch block
        e.printStackTrace();
} catch (IOException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
}
```

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```
    //Export the data from the migration_table_1 table to the d:/data1.txt file.
    try {
    copyToFile(conn, "d:/data1.txt", tablename1);
  } catch (SQLException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
  } catch (IOException e) {
 // TODO Auto-generated catch block
 e.printStackTrace();
}
   }

 public static void copyFromFile(Connection connection, String filePath, String tableName)
       throws SQLException, IOException {

   FileInputStream fileInputStream = null;

   try {
      CopyManager copyManager = new CopyManager((BaseConnection)connection);
      fileInputStream = new FileInputStream(filePath);
      copyManager.copyIn("COPY " + tableName + " FROM STDIN", fileInputStream);
   } finally {
      if (fileInputStream != null) {
         try {
            fileInputStream.close();
         } catch (IOException e) {
            e.printStackTrace();
         }
      }
   }
}

 public static void copyToFile(Connection connection, String filePath, String tableOrQuery)
       throws SQLException, IOException {

    FileOutputStream fileOutputStream = null;

    try {
       CopyManager copyManager = new CopyManager((BaseConnection)connection);
       fileOutputStream = new FileOutputStream(filePath);
       copyManager.copyOut("COPY " + tableOrQuery + " TO STDOUT", fileOutputStream);
    } finally {
       if (fileOutputStream != null) {
          try {
             fileOutputStream.close();
          } catch (IOException e) {
             e.printStackTrace();
          }
       }
    }
 }
}
```

# 7.3.11 Example: Migrating Data from MySQL to GaussDB(DWS)

The following example shows how to use CopyManager to migrate data from MySQL to GaussDB(DWS).

```
//gsjdbc4.jar is used as an example. If gsjdbc200.jar is used, replace the driver class name org.postgresql with com.huawei.gauss200.jdbc and replace the URL prefix jdbc:postgresql with jdbc:gaussdb.
import java.io.StringReader;
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;
```

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```
import org.postgresql.copy.CopyManager;
import org.postgresql.core.BaseConnection;

public class Migration{

    public static void main(String[] args) {
        String url = new String("jdbc:postgresql://10.180.155.74:8000/gaussdb"); //Database URL
        String user = new String("jack");             //Database username
        String pass = new String("********");             //Database password
        String tablename = new String("migration_table"); //Define table information.
        String delimiter = new String("|");              //Define a delimiter.
        String encoding = new String("UTF8");            //Define a character set.
        String driver = "org.postgresql.Driver";
        StringBuffer buffer = new StringBuffer();       //Define the buffer to store formatted data.

        try {
            //Obtain the query result set of the source database.
            ResultSet rs = getDataSet();

            //Traverse the result set and obtain records row by row.
            //The values of columns in each record are separated by the specified delimiter and end with a
newline character to form strings.
            ////Add the strings to the buffer.
            while (rs.next()) {
                buffer.append(rs.getString(1) + delimiter
                        + rs.getString(2) + delimiter
                        + rs.getString(3) + delimiter
                        + rs.getString(4)
                        + "\n");
            }
            rs.close();

            try {
                //Connect to the target database.
                Class.forName(driver);
                Connection conn = DriverManager.getConnection(url, user, pass);
                BaseConnection baseConn = (BaseConnection) conn;
                baseConn.setAutoCommit(false);

                //Initialize table information.
                String sql = "Copy " + tablename + " from STDIN DELIMITER " + "'" + delimiter + "'" + "
ENCODING " + "'" + encoding + "'";

                //Submit data in the buffer.
                CopyManager cp = new CopyManager(baseConn);
                StringReader reader = new StringReader(buffer.toString());
                cp.copyIn(sql, reader);
                baseConn.commit();
                reader.close();
                baseConn.close();
            } catch (ClassNotFoundException e) {
                e.printStackTrace(System.out);
            } catch (SQLException e) {
                e.printStackTrace(System.out);
            }

        } catch (Exception e) {
            e.printStackTrace();
        }
    }

    //**********************************
    //Return the query result set from the source database.
    //**********************************
    private static ResultSet getDataSet() {
        ResultSet rs = null;
        try {
            Class.forName("com.mysql.jdbc.Driver").newInstance();
```

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```
            Connection conn = DriverManager.getConnection("jdbc:mysql://10.119.179.227:3306/jack?
useSSL=false&allowPublicKeyRetrieval=true", "jack", "********");
            Statement stmt = conn.createStatement();
            rs = stmt.executeQuery("select * from migration_table");
        } catch (SQLException e) {
            e.printStackTrace();
        } catch (Exception e) {
            e.printStackTrace();
        }
        return rs;
    }
}
```

# 7.3.12 JDBC Interface Reference

JDBC interface is a set of API methods for users. This section describes some common interfaces. For other interfaces, see information in JDK1.6 (software package) and JDBC4.0.

## 7.3.12.1 java.sql.Connection

This section describes **java.sql.Connection**, the interface for connecting to a database.

**Table 7-6** Support status for java.sql.Connection

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| close() | void | Yes |
| commit() | void | Yes |
| createStatement() | Statement | Yes |
| getAutoCommit() | boolean | Yes |
| getClientInfo() | Properties | Yes |
| getClientInfo(String name) | String | Yes |
| getTransactionIsolation() | int | Yes |
| isClosed() | boolean | Yes |
| isReadOnly() | boolean | Yes |
| prepareStatement(String sql) | PreparedStatement | Yes |
| rollback() | void | Yes |
| setAutoCommit(boolean autoCommit) | void | Yes |
| setClientInfo(Properties properties) | void | Yes |
| setClientInfo(String name,String value) | void | Yes |

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NOTICE

The AutoCommit mode is used by default within the interface. If you disable it running **setAutoCommit(false)**, all the statements executed later will be packaged in explicit transactions, and you cannot execute statements that cannot be executed within transactions.

## 7.3.12.2 java.sql.CallableStatement

This section describes **java.sql.CallableStatement**, the stored procedure execution interface.

**Table 7-7** Support status for java.sql.CallableStatement

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| registerOutParameter(int parameterIndex, int type) | void | Yes |
| wasNull() | boolean | Yes |
| getString(int parameterIndex) | String | Yes |
| getBoolean(int parameterIndex) | boolean | Yes |
| getByte(int parameterIndex) | byte | Yes |
| getShort(int parameterIndex) | short | Yes |
| getInt(int parameterIndex) | int | Yes |
| getLong(int parameterIndex) | long | Yes |
| getFloat(int parameterIndex) | float | Yes |
| getDouble(int parameterIndex) | double | Yes |
| getBigDecimal(int parameterIndex) | BigDecimal | Yes |
| getBytes(int parameterIndex) | byte[] | Yes |
| getDate(int parameterIndex) | Date | Yes |
| getTime(int parameterIndex) | Time | Yes |
| getTimestamp(int parameterIndex) | Timestamp | Yes |
| getObject(int parameterIndex) | Object | Yes |


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NOTE

- The batch operation of statements containing OUT parameter is not allowed.
- The following methods are inherited from java.sql.Statement: close, execute, executeQuery, executeUpdate, getConnection, getResultSet, getUpdateCount, isClosed, setMaxRows, and setFetchSize.
- The following methods are inherited from java.sql.PreparedStatement: addBatch, clearParameters, execute, executeQuery, executeUpdate, getMetaData, setBigDecimal, setBoolean, setByte, setBytes, setDate, setDouble, setFloat, setInt, setLong, setNull, setObject, setString, setTime, and setTimestamp.

## 7.3.12.3 java.sql.DatabaseMetaData

This section describes **java.sql.DatabaseMetaData**, the interface for defining database objects.

**Table 7-8** Support status for java.sql.DatabaseMetaData

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getTables(String catalog, String schemaPattern, String tableNamePattern, String[] types) | ResultSet | Yes |
| getColumns(String catalog, String schemaPattern, String tableNamePattern, String columnNamePattern) | ResultSet | Yes |
| getTableTypes() | ResultSet | Yes |
| getUserName() | String | Yes |
| isReadOnly() | boolean | Yes |
| nullsAreSortedHigh() | boolean | Yes |
| nullsAreSortedLow() | boolean | Yes |
| nullsAreSortedAtStart() | boolean | Yes |
| nullsAreSortedAtEnd() | boolean | Yes |
| getDatabaseProductName() | String | Yes |
| getDatabaseProductVersion() | String | Yes |
| getDriverName() | String | Yes |
| getDriverVersion() | String | Yes |
| getDriverMajorVersion() | int | Yes |
| getDriverMinorVersion() | int | Yes |

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| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| usesLocalFiles() | boolean | Yes |
| usesLocalFilePerTable() | boolean | Yes |
| supportsMixedCaseIdentifiers() | boolean | Yes |
| storesUpperCaseIdentifiers() | boolean | Yes |
| storesLowerCaseIdentifiers() | boolean | Yes |
| supportsMixedCaseQuotedIdentifiers() | boolean | Yes |
| storesUpperCaseQuotedIdentifiers() | boolean | Yes |
| storesLowerCaseQuotedIdentifiers() | boolean | Yes |
| storesMixedCaseQuotedIdentifiers() | boolean | Yes |
| supportsAlterTableWithAddColumn() | boolean | Yes |
| supportsAlterTableWithDropColumn() | boolean | Yes |
| supportsColumnAliasing() | boolean | Yes |
| nullPlusNonNullIsNull() | boolean | Yes |
| supportsConvert() | boolean | Yes |
| supportsConvert(int fromType, int toType) | boolean | Yes |
| supportsTableCorrelationNames() | boolean | Yes |
| supportsDifferentTableCorrelationNames() | boolean | Yes |
| supportsExpressionsInOrderBy() | boolean | Yes |
| supportsOrderByUnrelated() | boolean | Yes |
| supportsGroupBy() | boolean | Yes |
| supportsGroupByUnrelated() | boolean | Yes |
| supportsGroupByBeyondSelect() | boolean | Yes |
| supportsLikeEscapeClause() | boolean | Yes |

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| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| supportsMultipleResultSets() | boolean | Yes |
| supportsMultipleTransactions() | boolean | Yes |
| supportsNonNullableColumns() | boolean | Yes |
| supportsMinimumSQLGrammar() | boolean | Yes |
| supportsCoreSQLGrammar() | boolean | Yes |
| supportsExtendedSQLGrammar() | boolean | Yes |
| supportsANSI92EntryLevelSQL() | boolean | Yes |
| supportsANSI92IntermediateSQL() | boolean | Yes |
| supportsANSI92FullSQL() | boolean | Yes |
| supportsIntegrityEnhancementFacility() | boolean | Yes |
| supportsOuterJoins() | boolean | Yes |
| supportsFullOuterJoins() | boolean | Yes |
| supportsLimitedOuterJoins() | boolean | Yes |
| isCatalogAtStart() | boolean | Yes |
| supportsSchemasInDataManipulation() | boolean | Yes |
| supportsSavepoints() | boolean | Yes |
| supportsResultSetHoldability(int holdability) | boolean | Yes |
| getResultSetHoldability() | int | Yes |
| getDatabaseMajorVersion() | int | Yes |
| getDatabaseMinorVersion() | int | Yes |
| getJDBCMajorVersion() | int | Yes |
| getJDBCMinorVersion() | int | Yes |

### 7.3.12.4 java.sql.Driver

This section describes **java.sql.Driver**, the database driver interface.

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**Table 7-9** Support status for java.sql.Driver

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| acceptsURL(String url) | boolean | Yes |
| connect(String url, Properties info) | Connection | Yes |
| jdbcCompliant() | boolean | Yes |
| getMajorVersion() | int | Yes |
| getMinorVersion() | int | Yes |

### 7.3.12.5 java.sql.PreparedStatement

This section describes **java.sql.PreparedStatement**, the interface for preparing statements.

**Table 7-10** Support status for java.sql.PreparedStatement

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| clearParameters() | void | Yes |
| execute() | boolean | Yes |
| executeQuery() | ResultSet | Yes |
| excuteUpdate() | int | Yes |
| getMetaData() | ResultSetMetaData | Yes |
| setBoolean(int parameterIndex, boolean x) | void | Yes |
| setBigDecimal(int parameterIndex, BigDecimal x) | void | Yes |
| setByte(int parameterIndex, byte x) | void | Yes |
| setBytes(int parameterIndex, byte[] x) | void | Yes |
| setDate(int parameterIndex, Date x) | void | Yes |
| setDouble(int parameterIndex, double x) | void | Yes |

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| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| setFloat(int parameterIndex, float x) | void | Yes |
| setInt(int parameterIndex, int x) | void | Yes |
| setLong(int parameterIndex, long x) | void | Yes |
| setNString(int parameterIndex, String value) | void | Yes |
| setShort(int parameterIndex, short x) | void | Yes |
| setString(int parameterIndex, String x) | void | Yes |
| addBatch() | void | Yes |
| executeBatch() | int[] | Yes |
| clearBatch() | void | Yes |

NOTE

- Execute addBatch() and execute() only after running clearBatch().
- Batch is not cleared by calling executeBatch(). Clear batch by explicitly calling clearBatch().
- After bounded variables of a batch are added, if you want to reuse these values (add a batch again), set*() is not necessary.
- The following methods are inherited from java.sql.Statement: close, execute, executeQuery, executeUpdate, getConnection, getResultSet, getUpdateCount, isClosed, setMaxRows, and setFetchSize.

## 7.3.12.6 java.sql.ResultSet

This section describes **java.sql.ResultSet**, the interface for execution result sets.

**Table 7-11** Support status for java.sql.ResultSet

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| findColumn(String columnLabel) | int | Yes |
| getBigDecimal(int columnIndex) | BigDecimal | Yes |

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| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getBigDecimal(String columnLabel) | BigDecimal | Yes |
| getBoolean(int columnIndex) | boolean | Yes |
| getBoolean(String columnLabel) | boolean | Yes |
| getByte(int columnIndex) | byte | Yes |
| getBytes(int columnIndex) | byte[] | Yes |
| getByte(String columnLabel) | byte | Yes |
| getBytes(String columnLabel) | byte[] | Yes |
| getDate(int columnIndex) | Date | Yes |
| getDate(String columnLabel) | Date | Yes |
| getDouble(int columnIndex) | double | Yes |
| getDouble(String columnLabel) | double | Yes |
| getFloat(int columnIndex) | float | Yes |
| getFloat(String columnLabel) | float | Yes |
| getInt(int columnIndex) | int | Yes |
| getInt(String columnLabel) | int | Yes |
| getLong(int columnIndex) | long | Yes |
| getLong(String columnLabel) | long | Yes |
| getShort(int columnIndex) | short | Yes |
| getShort(String columnLabel) | short | Yes |
| getString(int columnIndex) | String | Yes |
| getString(String columnLabel) | String | Yes |

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| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getTime(int columnIndex) | Time | Yes |
| getTime(String columnLabel) | Time | Yes |
| getTimestamp(int columnIndex) | Timestamp | Yes |
| getTimestamp(String columnLabel) | Timestamp | Yes |
| isAfterLast() | boolean | Yes |
| isBeforeFirst() | boolean | Yes |
| isFirst() | boolean | Yes |
| next() | boolean | Yes |

NOTE

- One Statement cannot have multiple open ResultSets.
- The cursor that is used for traversing the ResultSet cannot be open after committed.

## 7.3.12.7 java.sql.ResultSetMetaData

This section describes **java.sql.ResultSetMetaData**, which provides details about ResultSet object information.

**Table 7-12** Support status for java.sql.ResultSetMetaData

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getColumnCount() | int | Yes |
| getColumnName(int column) | String | Yes |
| getColumnType(int column) | int | Yes |
| getColumnTypeName(int column) | String | Yes |

## 7.3.12.8 java.sql.Statement

This section describes **java.sql.Statement**, the interface for executing SQL statements.

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**Table 7-13** Support status for java.sql.Statement

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| close() | void | Yes |
| execute(String sql) | boolean | Yes |
| executeQuery(String sql) | ResultSet | Yes |
| executeUpdate(String sql) | int | Yes |
| getConnection() | Connection | Yes |
| getResultSet() | ResultSet | Yes |
| getQueryTimeout() | int | Yes |
| getUpdateCount() | int | Yes |
| isClosed() | boolean | Yes |
| setQueryTimeout(int seconds) | void | Yes |
| setFetchSize(int rows) | void | Yes |
| cancel() | void | Yes |

NOTE

Using setFetchSize can reduce the memory occupied by result sets on the client. Result sets are packaged into cursors and segmented for processing, which will increase the communication traffic between the database and the client, affecting performance.

Database cursors are valid only within their transaction. If **setFetchSize** is set, set **setAutoCommit(false)** and commit transactions on the connection to flush service data to a database.

## 7.3.12.9 javax.sql.ConnectionPoolDataSource

This section describes **javax.sql.ConnectionPoolDataSource**, the interface for data source connection pools.

**Table 7-14** Support status for javax.sql.ConnectionPoolDataSource

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getLoginTimeout() | int | Yes |
| getLogWriter() | PrintWriter | Yes |
| getPooledConnection() | PooledConnection | Yes |


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| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getPooledConnection(String user,String password) | PooledConnection | Yes |
| setLoginTimeout(int seconds) | void | Yes |
| setLogWriter(PrintWriter out) | void | Yes |

## 7.3.12.10 javax.sql.DataSource

This section describes **javax.sql.DataSource**, the interface for data sources.

**Table 7-15** Support status for javax.sql.DataSource

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getConneciton() | Connection | Yes |
| getConnection(String username,String password) | Connection | Yes |
| getLoginTimeout() | int | Yes |
| getLogWriter() | PrintWriter | Yes |
| setLoginTimeout(int seconds) | void | Yes |
| setLogWriter(PrintWriter out) | void | Yes |

## 7.3.12.11 javax.sql.PooledConnection

This section describes **javax.sql.PooledConnection**, the connection interface created by a connection pool.

**Table 7-16** Support status for javax.sql.PooledConnection

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| addConnectionEventListener (ConnectionEventListener listener) | void | Yes |
| close() | void | Yes |
| getConnection() | Connection | Yes |
| removeConnectionEventListener (ConnectionEventListener listener) | void | Yes |

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| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| addStatementEventListener (StatementEventListener listener) | void | Yes |
| removeStatementEventListener (StatementEventListener listener) | void | Yes |

## 7.3.12.12 javax.naming.Context

This section describes **javax.naming.Context**, the context interface for connection configuration.

**Table 7-17** Support status for javax.naming.Context

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| bind(Name name, Object obj) | void | Yes |
| bind(String name, Object obj) | void | Yes |
| lookup(Name name) | Object | Yes |
| lookup(String name) | Object | Yes |
| rebind(Name name, Object obj) | void | Yes |
| rebind(String name, Object obj) | void | Yes |
| rename(Name oldName, Name newName) | void | Yes |
| rename(String oldName, String newName) | void | Yes |
| unbind(Name name) | void | Yes |
| unbind(String name) | void | Yes |

## 7.3.12.13 javax.naming.spi.InitialContextFactory

This section describes **javax.naming.spi.InitialContextFactory**, the initial context factory interface.

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**Table 7-18** Support status for javax.naming.spi.InitialContextFactory

| Method Name | Return Type | Support JDBC 4 |
| --- | --- | --- |
| getInitialContext(Hashtable<?,?> environment) | Context | Yes |

## 7.3.12.14 CopyManager

CopyManager is an API interface class provided by the JDBC driver in GaussDB(DWS). It is used to import data to GaussDB(DWS) in batches.

## Inheritance Relationship of CopyManager

The CopyManager class is in the **org.postgresql.copy** package class and inherits the java.lang.Object class. The declaration of the class is as follows:

```
public class CopyManager
extends Object
```

## Construction Method

public CopyManager(BaseConnection connection)

throws SQLException

## Basic Methods

**Table 7-19** Common methods of CopyManager

| Return Value | Method | Description | throws |
| --- | --- | --- | --- |
| CopyIn | copyIn(String sql) | - | SQLException |
| long | copyIn(String sql, InputStream from) | Uses **COPY FROM STDIN** to quickly load data to tables in the database from InputStream. | SQLException,IOException |
| long | copyIn(String sql, InputStream from, int bufferSize) | Uses **COPY FROM STDIN** to quickly load data to tables in the database from InputStream. | SQLException,IOException |

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| Return Value | Method | Description | throws |
| --- | --- | --- | --- |
| long | copyIn(String sql, Reader from) | Uses **COPY FROM STDIN** to quickly load data to tables in the database from Reader. | SQLException,IOException |
| long | copyIn(String sql, Reader from, int bufferSize) | Uses **COPY FROM STDIN** to quickly load data to tables in the database from Reader. | SQLException,IOException |
| CopyOut | copyOut(String sql) | - | SQLException |
| long | copyOut(String sql, OutputStream to) | Sends the result set of **COPY TO STDOUT** from the database to the OutputStream class. | SQLException,IOException |
| long | copyOut(String sql, Writer to) | Sends the result set of **COPY TO STDOUT** from the database to the Writer class. | SQLException,IOException |

# 7.4 ODBC-Based Development

Open Database Connectivity (ODBC) is a Microsoft API for accessing databases based on the X/OPEN CLI. The ODBC API alleviates applications from directly operating in databases, and enhances the database portability, extensibility, and maintainability.

**Figure 7-2** shows the system structure of ODBC.

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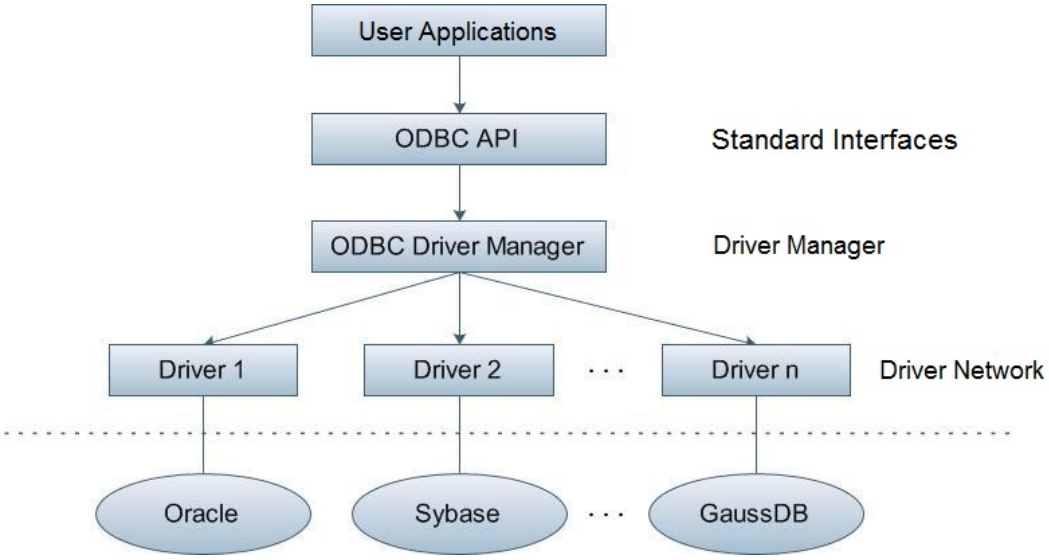
**Figure 7-2** ODBC system structure




GaussDB(DWS) supports ODBC 3.5 in the following environments.

**Table 7-20** OSs Supported by ODBC

| OS | Platform |
| --- | --- |
| SUSE Linux Enterprise Server 11 SP1/SP2/SP3/SP4<br>SUSE Linux Enterprise Server 12 and SP1/SP2/SP3/SP5 | x86_64 |
| Red Hat Enterprise Linux 6.4/6.5/6.6/6.7/6.8/6.9/7.0/7.1/7.2/7.3/7.4/7.5 | x86_64 |
| Red Hat Enterprise Linux 7.5 | ARM64 |
| CentOS 6.4/6.5/6.6/6.7/6.8/6.9/7.0/7.1/7.2/7.3/7.4 | x86_64 |
| CentOS 7.6 | ARM64 |
| EulerOS 2.0 SP2/SP3 | x86_64 |
| EulerOS 2.0 SP8 | ARM64 |
| NeoKylin 7.5/7.6 | ARM64 |
| Oracle Linux R7U4 | x86_64 |
| Windows 7 | 32-bit |
| Windows 7 | 64-bit |
| Windows Server 2008 | 32-bit |
| Windows Server 2008 | 64-bit |

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The operating systems listed above refer to the operating systems on which the ODBC program runs. They can be different from the operating systems where databases are deployed.

The ODBC Driver Manager running on UNIX or Linux can be unixODBC or iODBC. Select unixODBC-2.3.0 here as the component for connecting the database.

Windows has a native ODBC Driver Manager. You can locate **Data Sources (ODBC)** by choosing **Control Panel > Administrative Tools**.

NOTE

The current database ODBC driver is based on an open source version and may be incompatible with vendor-unique data types, such as tinyint, smalldatetime, and nvarchar2.

# 7.4.1 ODBC Package and Its Dependent Libraries and Header Files

## ODBC Package for the Linux OS

Obtain the **dws_8.1.*x*_odbc_driver_for**_*xxx_xxx*.**zip** package from the release package. In the Linux OS, header files (including **sql.h** and **sqlext.h**) and library (**libodbc.so**) are required in application development. These header files and libraries can be obtained from the unixODBC-2.3.0 installation package.

## ODBC Package for the Windows OS

Obtain the **dws_8.1.*x*_odbc_driver_for_windows.zip** package from the release package. In the Windows OS, the required header files and library files are system-resident.

# 7.4.2 Configuring a Data Source in the Linux OS

The ODBC DRIVER (psqlodbcw.so) provided by GaussDB(DWS) can be used after it has been configured in the data source. To configure data sources, users must configure the **odbc.ini** and **odbcinst.ini** files on the server. The two files are generated during the unixODBC compilation and installation, and are saved in the **/usr/local/etc** directory by default.

## Procedure

**Step 1** Obtain the source code package of unixODBC at:

https://sourceforge.net/projects/unixodbc/files/unixODBC/2.3.0/unixODBC-2.3.0.tar.gz/download

**Step 2** Currently, unixODBC-2.2.1 is not supported. Assume you are to install unixODBC-2.3.0. Run the following commands. unixODBC is installed in the **/usr/local** directory by default. The data source file is generated in the **/usr/local/etc** directory, and the library file is generated in the **/usr/local/lib** directory.

```
tar zxvf unixODBC-2.3.0.tar.gz
cd unixODBC-2.3.0
# Open the configure file. If it does not exist, open the configure.ac file. Find LIB_VERSION.
# Change the value of LIB_VERSION to 1:0:0 to compile a *.so.1 dynamic library with the same dependency on psqlodbcw.so.
```

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```
vim configure

./configure --enable-gui=no # To perform the compilation on a TaiShan server, add the configure parameter --build=aarch64-unknown-linux-gnu.
make
# The installation may require root permissions.
make install
```

Install unixODBC. If another version of unixODBC has been installed, it will be overwritten after installation.

**Step 3** Replace the GaussDB(DWS) client driver.

Decompress the **dws_8.1.*x*_odbc_driver_for_*xxx_xxx*.zip** package.

- Obtain the **psqlodbcw.la** and **psqlodbcw.so** files in the **/dws_8.1.*x*_odbc_driver_for_*xxx_xxx*/odbc/lib** directory.
- The lib file is generated in the **/dws_8.1.*x*_odbc_driver_for_*xxx_xxx*/lib** directory.

**Step 4** Configure the data source.

1. Configure the ODBC driver file.

   Add the following content to the end of the **/usr/local/etc/odbcinst.ini** file:

   ```
   [GaussMPP]
   Driver64=/usr/local/lib/psqlodbcw.so
   setup=/usr/local/lib/psqlodbcw.so
   ```

   For descriptions of the parameters in the **odbcinst.ini** file, see **Table 7-21**.

   **Table 7-21** odbcinst.ini configuration parameters

   | Parameter | Description | Example |
   | --- | --- | --- |
   | [DriverName] | Driver name, corresponding to Driver in DSN. | [DRIVER_N] |
   | Driver64 | Path of the dynamic driver library | Driver64=/xxx/odbc/lib/psqlodbcw.so |
   | setup | Driver installation path, which is the same as the dynamic library path in Driver64. | setup=/xxx/odbc/lib/psqlodbcw.so |

2. Configure the data source file.

   Add the following content to the end of the **/usr/local/etc/odbc.ini** file:

   ```
   [MPPODBC]
   Driver=GaussMPP
   Servername=10.10.0.13 (database server IP address)
   Database=gaussdb (database name)
   Username=dbadmin (database username)
   Password= (database user password)
   Port=8000 (database listening port)
   Sslmode=allow
   ```

   For descriptions of the parameters in the **odbc.ini** file, see **Table 7-22**.

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**Table 7-22** odbc.ini configuration parameters

| Parameter | Description | Example |
| --- | --- | --- |
| [DSN] | Data source name | [MPPODBC] |
| Driver | Driver name, corresponding to DriverName in **odbcinst.ini** | Driver=DRIVER_N |
| Servername | IP address of the server | Servername=10.145.130.26 |
| Database | Name of the database to connect to | Database=gaussdb |
| Username | Name of the database user | Username=dbadmin |
| Password | Password of the database user | Password=<br>**NOTE**<br>After a user established a connection, the ODBC driver automatically clears their password stored in memory.<br>However, if this parameter is configured, unixODBC will cache data source files, which may cause the password to be stored in the memory for a long time.<br>When you connect to an application, you are advised to send your password through an API instead of writing it in a data source configuration file. After the connection has been established, immediately clear the memory segment where your password is stored. |
| Port | Port ID of the server | Port=8000 |
| Sslmode | Whether to enable the SSL mode | Sslmode=allow |
| UseServerSidePrepare | Whether to enable the extended query protocol for the database.<br>The value can be **0** or **1**. The default value is **1**, indicating that the extended query protocol is enabled. | UseServerSidePrepare=1 |


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| Parameter | Description | Example |
| --- | --- | --- |
| UseBatchProtocol | Whether to enable the batch query protocol. If it is enabled, the DML performance can be improved. The value can be **0** or **1**. The default value is **1**.<br>If this parameter is set to **0**, the batch query protocol is disabled (mainly for communication with earlier database versions).<br>If this parameter is set to **1** and the **support_batch_bind** parameter is set to **on**, the batch query protocol is enabled. | UseBatchProtocol=1 |
| ConnectionExtraInfo | Whether to display the driver deployment path and process owner in the **connection_info** parameter mentioned in **connection_info** | ConnectionExtraInfo=1<br>**NOTE**<br>The default value is **0**. If this parameter is set to **1**, the ODBC driver reports the driver deployment path and process owner to the database and displays the information in the **connection_info** parameter (see **connection_info**). In this case, you can query the information from **PG_STAT_ACTIVITY** or **PGXC_STAT_ACTIVITY**. |

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| Parameter | Description | Example |
| --- | --- | --- |
| ForExtensionConnector | ETL tool performance optimization parameter. It can be used to optimize the memory and reduce the memory usage by the peer CN, to avoid system instability caused by excessive CN memory usage.<br>The value can be **0** or **1**. The default value is **0**, indicating that the optimization item is disabled.<br>Do not set this parameter for other services outside the database system. Otherwise, the service correctness may be affected. | ForExtensionConnector=1 |
| KeepDisallowPremature | Specifies whether the cursor in the SQL statement has the **with hold** attribute when the following conditions are met: **UseDeclareFetch** is set to **1**, and the application invokes **SQLNumResultCols**, **SQLDescribeCol**, or **SQLColAttribute** after invoking **SQLPrepare** to obtain the column information of the result set.<br>The value can be **0** or **1**. **0** indicates that the **with hold** attribute is supported, and **1** indicates that the **with hold** attribute is not supported. The default value is **0**. | KeepDisallowPremature=1<br>**NOTE**<br>– When **UseServerSidePrepare** is set to **1**, the **KeepDisallowPremature** parameter does not take effect. To use this parameter, set **UseServerSidePrepare** to **0**. For example, set **UseDeclareFetch** to **1**. KeepDisallowPremature=1<br>UseServerSidePrepare=0 |

The valid values of **sslmode** are as follows:

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**Table 7-23** sslmode options

| sslmode | Whether SSL Encryption Is Enabled | Description |
| --- | --- | --- |
| disable | No | The SSL secure connection is not used. |
| allow | Probably | The SSL secure encrypted connection is used if required by the database server, but does not check the authenticity of the server. |
| prefer | Probably | The SSL secure encrypted connection is used as a preferred mode if supported by the database, but does not check the authenticity of the server. |
| require | Yes | The SSL secure connection must be used, but it only encrypts data and does not check the authenticity of the server. |
| verify-ca | Yes | The SSL secure connection must be used, and it checks whether the database has certificates issued by a trusted CA. |
| verify-full | Yes | The SSL secure connection must be used. In addition to the check scope specified by **verify-ca**, it checks whether the name of the host where the database resides is the same as that on the certificate. This mode is not supported. |

**Step 5** Enable the SSL mode.

To use SSL certificates for connection, decompress the certificate package contained in the GaussDB(DWS) installation package, and run the **source sslcert_env.sh** file in a shell environment to deploy certificates in the default location of the current session.

Or manually declare the following environment variables and ensure that the permission for the client.key* series files is set to 600.

```
export PGSSLCERT= "/YOUR/PATH/OF/client.crt" # Change the path to the absolute path of client.crt.
export PGSSLKEY= "/YOUR/PATH/OF/client.key" # Change the path to the absolute path of client.key.
```

In addition, change the value of **Sslmode** in the data source to **verify-ca**.

**Step 6** In the security group rules of GaussDB(DWS), add the IP address segment of the servers with the client deployed to ensure that the servers can communicate with GaussDB(DWS).

**Step 7** Configure environment variables.

```
vim ~/.bashrc
```

Add the following content to the end of the configuration file:

```
export LD_LIBRARY_PATH=/usr/local/lib/:$LD_LIBRARY_PATH
export ODBCSYSINI=/usr/local/etc
export ODBCINI=/usr/local/etc/odbc.ini
```

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**Step 8** Run the following commands to validate the settings:

```
source ~/.bashrc
```

**----End**

## Testing Data Source Configuration

Run the **isql -v** *GaussODBC* command (*GaussODBC* is the data source name).

- If the following information is displayed, the configuration is correct and the connection succeeds.

```
+---------------------------------------+
| Connected!                            |
|                                       |
| sql-statement                         |
| help [tablename]                      |
| quit                                  |
|                                       |
+---------------------------------------+
SQL>
```

- If error information is displayed, the configuration is incorrect. Check the configuration.

## Troubleshooting

- [UnixODBC][Driver Manager]Can't open lib 'xxx/xxx/psqlodbcw.so' : file not found.

  Possible causes:

  – The path configured in the **odbcinst.ini** file is incorrect.

  Run **ls** to check the path in the error information, ensuring that the **psqlodbcw.so** file exists and you have execution permissions on it.

  – The dependent library of **psqlodbcw.so** does not exist or is not in system environment variables.

  Run **ldd** to check the path in the error information. If **libodbc.so.1** or other unixODBC libraries are lacking, configure unixODBC again following the procedure provided in this section, and add the **lib** directory under its installation directory to **LD_LIBRARY_PATH**. If other libraries are lacking, add the **lib** directory under the ODBC driver package to **LD_LIBRARY_PATH**.

- [UnixODBC]connect to server failed: no such file or directory

  Possible causes:

  – An incorrect or unreachable database IP address or port was configured.

  Check the **Servername** and **Port** configuration items in data sources.

  – Server monitoring is improper.

  If **Servername** and **Port** are correctly configured, ensure the proper network adapter and port are monitored based on database server configurations in the procedure in this section.

  – Firewall and network gatekeeper settings are improper.

  Check firewall settings, ensuring that the database communication port is trusted.

  Check to ensure network gatekeeper settings are proper (if any).

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- [unixODBC]The password-stored method is not supported.

  Possible causes:

  The **sslmode** configuration item is not configured in the data sources.

  Solution:

  Set it to **allow** or a higher level. For more details, see **Table 7-23**.

- Server common name "xxxx" does not match host name "xxxxx"

  Possible causes:

  When **verify-full** is used for SSL encryption, the driver checks whether the host name in certificates is the same as the actual one.

  Solution:

  To solve this problem, use **verify-ca** to stop checking host names, or generate a set of CA certificates containing the actual host names.

- Driver's SQLAllocHandle on SQL_HANDLE_DBC failed

  Possible causes:

  The executable file (such as the **isql** tool of unixODBC) and the database driver (**psqlodbcw.so**) depend on different library versions of ODBC, such as **libodbc.so.1** and **libodbc.so.2**. You can verify this problem by using the following method:

  ```
  ldd `which isql` | grep odbc
  ldd psqlodbcw.so | grep odbc
  ```

  If the suffix digits of the outputs **libodbc.so** are different or indicate different physical disk files, this problem exists. Both **isql** and **psqlodbcw.so** load **libodbc.so**. If different physical files are loaded, different ODBC libraries with the same function list conflict with each other in a visible domain. As a result, the database driver cannot be loaded.

  Solution:

  Uninstall the unnecessary unixODBC, such as libodbc.so.2, and create a soft link with the same name and the .so.2 suffix for the remaining libodbc.so.1 library.

- FATAL: Forbid remote connection with trust method!

  For security purposes, the CN forbids access from other nodes in the cluster without authentication.

  To access the CN from inside the cluster, deploy the ODBC program on the machine where the CN is located and use 127.0.0.1 as the server address. It is recommended that the service system be deployed outside the cluster. If it is deployed inside, the database performance may be affected.

- [unixODBC][Driver Manager]Invalid attribute value

  This problem occurs when you use SQL on other GaussDB. The possible cause is that the unixODBC version is not the recommended one. You are advised to run the **odbcinst --version** command to check the unixODBC version.

- authentication method 10 not supported.

  If this error occurs on an open source client, the cause may be:

  The database stores only the SHA-256 hash of the password, but the open source client supports only MD5 hashes.

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NOTE

- The database stores the hashes of user passwords instead of actual passwords.
- In versions earlier than V100R002C80SPC300, the database stores only SHA-256 hashes and no MD5 hashes. Therefore, MD5 cannot be used for user password authentication.
- In V100R002C80SPC300 and later, if a password is updated or a user is created, both types of hashes will be stored, compatible with open-source authentication protocols.
- An MD5 hash can only be generated using the original password, but the password cannot be obtained by reversing its SHA-256 hash. If your database is upgraded from a version earlier than V100R002C80SPC300, passwords in the old version will only have SHA-256 hashes and not support MD5 authentication.

To solve this problem, you can update the user password. For details, see "ALTER USER" in the *SQL Syntax*. Alternatively, create a user (see "CREATE USER" in the *SQL Syntax*), assign the same permissions to the user, and use the new user to connect to the database.

- unsupported frontend protocol 3.51: server supports 1.0 to 3.0

  The database version is too early or the database is an open-source database. Use the driver of the required version to connect to the database.

# 7.4.3 Configuring a Data Source in the Windows OS

Configure the ODBC data source using the ODBC data source manager preinstalled in the Windows OS.

## Procedure

**Step 1** Replace the GaussDB(DWS) client driver.

Decompress **GaussDB-8.1.1-Windows-Odbc.tar.gz** and install **psqlodbc.msi** (for 32-bit OS) or **psqlodbc_x64.msi** (for 64-bit OS).

**Step 2** Open Driver Manager.

Use the Driver Manager suitable for your OS to configure the data source. (Assume the Windows system drive is drive C.)

- If you develop 32-bit programs in the 64-bit Windows OS, open the 32-bit Driver Manager at **C:\Windows\SysWOW64\odbcad32.exe** after you install the 32-bit driver.

  Do not open Driver Manager by choosing **Control Panel**, clicking **Administrative Tools**, and clicking **Data Sources (ODBC)**.

  NOTE

  WoW64 is the acronym for "Windows 32-bit on Windows 64-bit". **C:\Windows\SysWOW64** stores the 32-bit environment on a 64-bit system. **C:\Windows\System32** stores the environment consistent with the current OS. For technical details, see Windows technical documents.

- If you develop 64-bit programs in the 64-bit Windows OS, open the 64-bit Driver Manager at **C:\Windows\System32\odbcad32.exe** after you install the 64-bit driver.

  Do not open **Driver Manager** by choosing **Control Panel**, clicking **Administrative Tools**, and clicking **Data Sources (ODBC)**.

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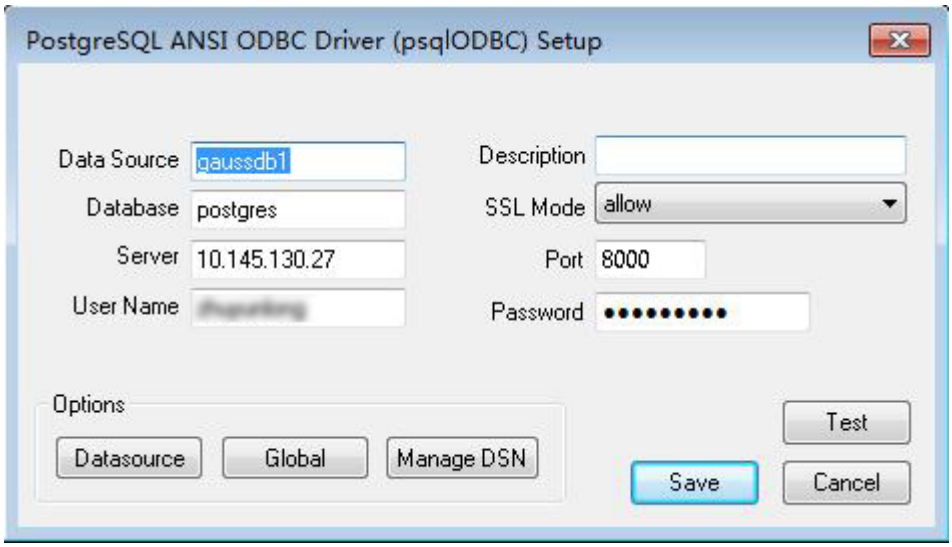
- In a 32-bit Windows OS, open **C:\Windows\System32\odbcad32.exe**.

  In the Windows OS, click **Computer**, and choose **Control Panel**. Click **Administrative Tools** and click **Data Sources (ODBC)**.

**Step 3** Configure the data source.

On the **User DSN** tab, click **Add**, and choose **PostgreSQL Unicode** for setup. (An identifier will be displayed for the 64-bit OS.)




**NOTICE**

The entered username and password will be recorded in the Windows registry and you do not need to enter them again when connecting to the database next time. For security purposes, you are advised to delete sensitive information before clicking **Save** and enter the required username and password again when using ODBC APIs to connect to the database.

**Step 4** Enable the SSL mode.

To use SSL certificates for connection, decompress the certificate package contained in the GaussDB(DWS) installation package, and double-click the **sslcert_env.bat** file to deploy certificates in the default location.

**NOTICE**

The **sslcert_env.bat** file ensures the purity of the certificate environment. When the **%APPDATA%\postgresql** directory exists, a message will be prompted asking you whether you want to remove related directories. If you want to remove related directories, back up files in the directory.

Alternatively, you can copy the **client.crt**, **client.key**, **client.key.cipher**, and **client.key.rand** files in the certificate file folder to the manually created **%APPDATA%\postgresql** directory. Change **client** in the file names to **postgres**,

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for example, change **client.key** to **postgres.key**. Copy the **cacert.pem** file to the **%APPDATA%\postgresql** directory and change its name to **root.crt**.

Change the value of **SSL Mode** in step 2 to **verify-ca**.

**Table 7-24** sslmode options

| sslmode | Whether SSL Encryption Is Enabled | Description |
| --- | --- | --- |
| disable | No | The SSL secure connection is not used. |
| allow | Probably | The SSL secure encrypted connection is used if required by the database server, but does not check the authenticity of the server. |
| prefer | Probably | The SSL secure encrypted connection is used as a preferred mode if supported by the database, but does not check the authenticity of the server. |
| require | Yes | The SSL secure connection must be used, but it only encrypts data and does not check the authenticity of the server. |
| verify-ca | Yes | The SSL secure connection must be used, and it checks whether the database has certificates issued by a trusted CA. |
| verify-full | Yes | The SSL secure connection must be used. In addition to the check scope specified by **verify-ca**, it checks whether the name of the host where the database resides is the same as that on the certificate.<br>**NOTE**<br>This mode cannot be used. |

**Step 5** Add the IP address segment of the host where the client is located to the security group rules of GaussDB(DWS) to ensure that the host can communicate with GaussDB(DWS).

**----End**

## Testing Data Source Configuration

Click **Test**.

- If the following information is displayed, the configuration is correct and the connection succeeds.

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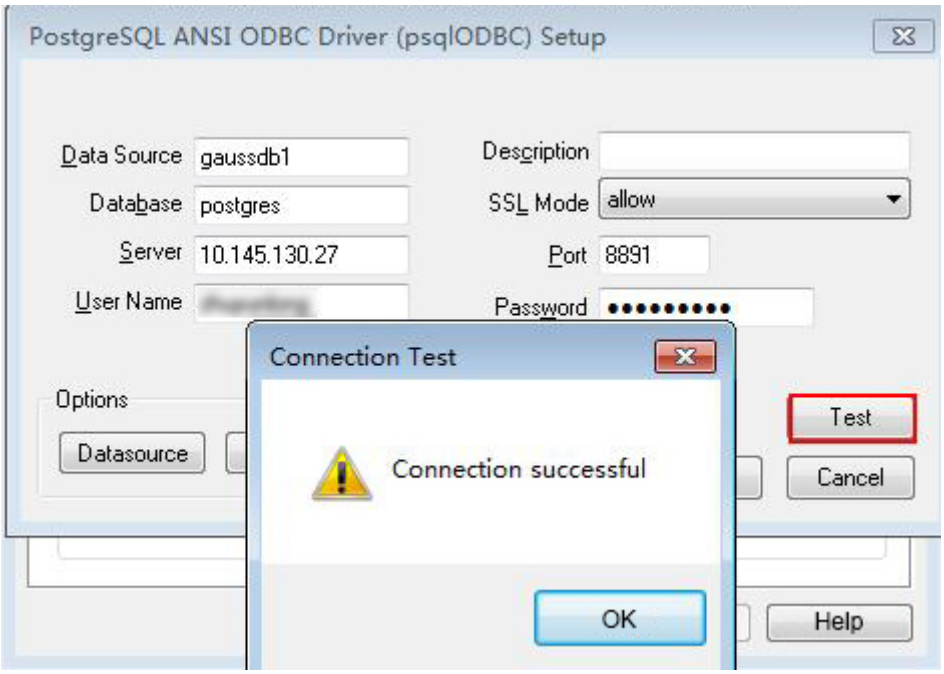


- If error information is displayed, the configuration is incorrect. Check the configuration.

## Troubleshooting

- Server common name "xxxx" does not match host name "xxxxx"

  This problem occurs because when **verify-full** is used for SSL encryption, the driver checks whether the host name in certificates is the same as the actual one. To solve this problem, use **verify-ca** to stop checking host names, or generate a set of CA certificates containing the actual host names.

- connect to server failed: no such file or directory

  Possible causes:

  – An incorrect or unreachable database IP address or port was configured.

    Check the **Servername** and **Port** configuration items in data sources.

  – Server monitoring is improper.

    If **Servername** and **Port** are correctly configured, ensure the proper network adapter and port are monitored based on database server configurations in the procedure in this section.

  – Firewall and network gatekeeper settings are improper.

    Check firewall settings, ensuring that the database communication port is trusted.

    Check to ensure network gatekeeper settings are proper (if any).

- In the specified DSN, the system structures of the drive do not match those of the application.

  Possible cause: The bit versions of the drive and program are different.

  **C:\Windows\SysWOW64\odbcad32.exe** is a 32-bit ODBC Drive Manager.

  **C:\Windows\System32\odbcad32.exe** is a 64-bit ODBC Drive Manager.

- The password-stored method is not supported.

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Possible causes:

**sslmode** is not configured for the data source. Set this configuration item to **allow** or a higher level to enable SSL connections. For details about **sslmode**, see **Table 7-24**.

- authentication method 10 not supported.

  If this error occurs on an open source client, the cause may be:

  The database stores only the SHA-256 hash of the password, but the open source client supports only MD5 hashes.

  NOTE

  - The database stores the hashes of user passwords instead of actual passwords.
  - In versions earlier than V100R002C80SPC300, the database stores only SHA-256 hashes and no MD5 hashes. Therefore, MD5 cannot be used for user password authentication.
  - In V100R002C80SPC300 and later, if a password is updated or a user is created, both types of hashes will be stored, compatible with open-source authentication protocols.
  - An MD5 hash can only be generated using the original password, but the password cannot be obtained by reversing its SHA-256 hash. If your database is upgraded from a version earlier than V100R002C80SPC300, passwords in the old version will only have SHA-256 hashes and not support MD5 authentication.

  To solve this problem, you can update the user password. For details, see "ALTER USER" in the *SQL Syntax*. Alternatively, create a user (see "CREATE USER" in the *SQL Syntax*), assign the same permissions to the user, and use the new user to connect to the database.

- unsupported frontend protocol 3.51: server supports 1.0 to 3.0

  The database version is too early or the database is an open-source database. Use the driver of the required version to connect to the database.

# 7.4.4 ODBC Development Example

## Code for Common Functions

```
// The following example shows how to obtain data from GaussDB(DWS) through the ODBC interface.
// DBtest.c (compile with: libodbc.so)
#include <stdlib.h>
#include <stdio.h>
#include <sqlext.h>
#ifdef WIN32
#include <windows.h>
#endif
SQLHENV       V_OD_Env;        // Handle ODBC environment
SQLHSTMT      V_OD_hstmt;      // Handle statement
SQLHDBC       V_OD_hdbc;       // Handle connection
char          typename[100];
SQLINTEGER    value = 100;
SQLINTEGER    V_OD_erg,V_OD_buffer,V_OD_err,V_OD_id;
SQLLEN        V_StrLen_or_IndPtr;
int main(int argc,char *argv[])
{
    // 1. Apply for an environment handle.
    V_OD_erg = SQLAllocHandle(SQL_HANDLE_ENV,SQL_NULL_HANDLE,&V_OD_Env);
    if ((V_OD_erg != SQL_SUCCESS) && (V_OD_erg != SQL_SUCCESS_WITH_INFO))
    {
        printf("Error AllocHandle\n");
        exit(0);
    }
```


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```
    // 2. Set environment attributes (version information)
    SQLSetEnvAttr(V_OD_Env, SQL_ATTR_ODBC_VERSION, (void*)SQL_OV_ODBC3, 0);
    // 3. Apply for a connection handle.
    V_OD_erg = SQLAllocHandle(SQL_HANDLE_DBC, V_OD_Env, &V_OD_hdbc);
    if ((V_OD_erg != SQL_SUCCESS) && (V_OD_erg != SQL_SUCCESS_WITH_INFO))
    {
        SQLFreeHandle(SQL_HANDLE_ENV, V_OD_Env);
        exit(0);
    }
    // 4. Set connection attributes.
    SQLSetConnectAttr(V_OD_hdbc, SQL_ATTR_AUTOCOMMIT, SQL_AUTOCOMMIT_ON, 0);
// 5. Connect to the data source. userName and password indicate the username and password for connecting to the database. Set them as needed.
// If the username and password have been set in the odbc.ini file, you do not need to set userName or password here, retaining "" for them. However, you are not advised to do so because the username and password will be disclosed if the permission for odbc.ini is abused.
    V_OD_erg = SQLConnect(V_OD_hdbc, (SQLCHAR*) "gaussdb", SQL_NTS,
                          (SQLCHAR*) "userName", SQL_NTS,  (SQLCHAR*) "password", SQL_NTS);
    if ((V_OD_erg != SQL_SUCCESS) && (V_OD_erg != SQL_SUCCESS_WITH_INFO))
    {
        printf("Error SQLConnect %d\n",V_OD_erg);
        SQLFreeHandle(SQL_HANDLE_ENV, V_OD_Env);
        exit(0);
    }
    printf("Connected !\n");
    // 6. Set statement attributes
    SQLSetStmtAttr(V_OD_hstmt,SQL_ATTR_QUERY_TIMEOUT,(SQLPOINTER *)3,0);
    // 7. Apply for a statement handle
    SQLAllocHandle(SQL_HANDLE_STMT, V_OD_hdbc, &V_OD_hstmt);
    // 8. Executes an SQL statement directly
    SQLExecDirect(V_OD_hstmt,"drop table IF EXISTS customer_t1",SQL_NTS);
    SQLExecDirect(V_OD_hstmt,"CREATE TABLE customer_t1(c_customer_sk INTEGER, c_customer_name VARCHAR(32));",SQL_NTS);
    SQLExecDirect(V_OD_hstmt,"insert into customer_t1 values(25,'li')",SQL_NTS);
    // 9. Prepare for execution
    SQLPrepare(V_OD_hstmt,"insert into customer_t1 values(?)",SQL_NTS);
    // 10. Bind parameters
    SQLBindParameter(V_OD_hstmt,1,SQL_PARAM_INPUT,SQL_C_SLONG,SQL_INTEGER,0,0,
                     &value,0,NULL);
    // 11. Execute the ready statement
    SQLExecute(V_OD_hstmt);
    SQLExecDirect(V_OD_hstmt,"select id from testtable",SQL_NTS);
    // 12. Obtain the attributes of a certain column in the result set
    SQLColAttribute(V_OD_hstmt,
1,SQL_DESC_TYPE_NAME,typename,sizeof(typename),NULL,NULL);
    printf("SQLColAtrribute %s\n",typename);
    // 13. Bind the result set
    SQLBindCol(V_OD_hstmt,1,SQL_C_SLONG, (SQLPOINTER)&V_OD_buffer,150,
            (SQLLEN *)&V_StrLen_or_IndPtr);
    // 14. Collect data using SQLFetch
    V_OD_erg=SQLFetch(V_OD_hstmt);
    // 15. Obtain and return data using SQLGetData
    while(V_OD_erg != SQL_NO_DATA)
    {
        SQLGetData(V_OD_hstmt,1,SQL_C_SLONG,(SQLPOINTER)&V_OD_id,0,NULL);
        printf("SQLGetData ----ID = %d\n",V_OD_id);
        V_OD_erg=SQLFetch(V_OD_hstmt);
    };
    printf("Done !\n");
    // 16. Disconnect from the data source and release handles
    SQLFreeHandle(SQL_HANDLE_STMT,V_OD_hstmt);
    SQLDisconnect(V_OD_hdbc);
    SQLFreeHandle(SQL_HANDLE_DBC,V_OD_hdbc);
    SQLFreeHandle(SQL_HANDLE_ENV, V_OD_Env);
    return(0);
}
```

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## Code for Batch Processing

```
/**************************************************************************
* Set UseBatchProtocol to 1 in the data source and set the database parameter support_batch_bind
* to on.
* The CHECK_ERROR command is used to check and print error information.
* This example is used to interactively obtain the DSN, data volume to be processed, and volume of ignored
data from users, and insert required data into the test_odbc_batch_insert table.
**************************************************************************/
#include <stdio.h>
#include <stdlib.h>
#include <sql.h>
#include <sqlext.h>
#include <string.h>

#include "util.c"

void Exec(SQLHDBC hdbc, SQLCHAR* sql)
{
    SQLRETURN retcode;                  // Return status
    SQLHSTMT hstmt = SQL_NULL_HSTMT;    // Statement handle
    SQLCHAR     loginfo[2048];

    // Allocate Statement Handle
    retcode = SQLAllocHandle(SQL_HANDLE_STMT, hdbc, &hstmt);
    CHECK_ERROR(retcode, "SQLAllocHandle(SQL_HANDLE_STMT)",
                hstmt, SQL_HANDLE_STMT);

    // Prepare Statement
    retcode = SQLPrepare(hstmt, (SQLCHAR*) sql, SQL_NTS);
    sprintf((char*)loginfo, "SQLPrepare log: %s", (char*)sql);
    CHECK_ERROR(retcode, loginfo, hstmt, SQL_HANDLE_STMT);

    retcode = SQLExecute(hstmt);
    sprintf((char*)loginfo, "SQLExecute stmt log: %s", (char*)sql);
    CHECK_ERROR(retcode, loginfo, hstmt, SQL_HANDLE_STMT);

    retcode = SQLFreeHandle(SQL_HANDLE_STMT, hstmt);
    sprintf((char*)loginfo, "SQLFreeHandle stmt log: %s", (char*)sql);
    CHECK_ERROR(retcode, loginfo, hstmt, SQL_HANDLE_STMT);
}

int main ()
{
    SQLHENV  henv  = SQL_NULL_HENV;
    SQLHDBC  hdbc  = SQL_NULL_HDBC;
    int      batchCount = 1000;
    SQLLEN   rowsCount = 0;
    int      ignoreCount = 0;

    SQLRETURN   retcode;
    SQLCHAR     dsn[1024] = {'\0'};
    SQLCHAR     loginfo[2048];

// Interactively obtain data source names.
    getStr("Please input your DSN", (char*)dsn, sizeof(dsn), 'N');
// Interactively obtain the amount of data to be batch processed.
    getInt("batchCount", &batchCount, 'N', 1);
    do
    {
// Interactively obtain the amount of batch processing data that is not inserted into the database.
        getInt("ignoreCount", &ignoreCount, 'N', 1);
        if (ignoreCount > batchCount)
        {
            printf("ignoreCount(%d) should be less than batchCount(%d)\n", ignoreCount, batchCount);
        }
    }while(ignoreCount > batchCount);

    retcode = SQLAllocHandle(SQL_HANDLE_ENV, SQL_NULL_HANDLE, &henv);
    CHECK_ERROR(retcode, "SQLAllocHandle(SQL_HANDLE_ENV)",
```

```
            henv, SQL_HANDLE_ENV);

    // Set ODBC Verion
    retcode = SQLSetEnvAttr(henv, SQL_ATTR_ODBC_VERSION,
                            (SQLPOINTER*)SQL_OV_ODBC3, 0);
    CHECK_ERROR(retcode, "SQLSetEnvAttr(SQL_ATTR_ODBC_VERSION)",
            henv, SQL_HANDLE_ENV);

    // Allocate Connection
    retcode = SQLAllocHandle(SQL_HANDLE_DBC, henv, &hdbc);
    CHECK_ERROR(retcode, "SQLAllocHandle(SQL_HANDLE_DBC)",
            henv, SQL_HANDLE_DBC);

    // Set Login Timeout
    retcode = SQLSetConnectAttr(hdbc, SQL_LOGIN_TIMEOUT, (SQLPOINTER)5, 0);
    CHECK_ERROR(retcode, "SQLSetConnectAttr(SQL_LOGIN_TIMEOUT)",
            hdbc, SQL_HANDLE_DBC);

    // Set Auto Commit
    retcode = SQLSetConnectAttr(hdbc, SQL_ATTR_AUTOCOMMIT,
                            (SQLPOINTER)(1), 0);
    CHECK_ERROR(retcode, "SQLSetConnectAttr(SQL_ATTR_AUTOCOMMIT)",
            hdbc, SQL_HANDLE_DBC);

    // Connect to DSN
    sprintf(loginfo, "SQLConnect(DSN:%s)", dsn);
    retcode = SQLConnect(hdbc, (SQLCHAR*) dsn, SQL_NTS,
                         (SQLCHAR*) NULL, 0, NULL, 0);
    CHECK_ERROR(retcode, loginfo, hdbc, SQL_HANDLE_DBC);

    // init table info.
    Exec(hdbc, "drop table if exists test_odbc_batch_insert");
    Exec(hdbc, "create table test_odbc_batch_insert(id int primary key, col varchar2(50))");

// The following code constructs the data to be inserted based on the data volume entered by users:
    {
        SQLRETURN retcode;
        SQLHSTMT hstmtinesrt = SQL_NULL_HSTMT;
        int          i;
        SQLCHAR      *sql = NULL;
        SQLINTEGER   *ids  = NULL;
        SQLCHAR      *cols = NULL;
        SQLLEN       *bufLenIds = NULL;
        SQLLEN       *bufLenCols = NULL;
        SQLUSMALLINT *operptr = NULL;
        SQLUSMALLINT *statusptr = NULL;
        SQLULEN      process = 0;

// Data is constructed by column. Each column is stored continuously.
        ids = (SQLINTEGER*)malloc(sizeof(ids[0]) * batchCount);
        cols = (SQLCHAR*)malloc(sizeof(cols[0]) * batchCount * 50);
// Data size in each row for a column
        bufLenIds = (SQLLEN*)malloc(sizeof(bufLenIds[0]) * batchCount);
        bufLenCols = (SQLLEN*)malloc(sizeof(bufLenCols[0]) * batchCount);
// Whether this row needs to be processed. The value is SQL_PARAM_IGNORE or SQL_PARAM_PROCEED.
        operptr = (SQLUSMALLINT*)malloc(sizeof(operptr[0]) * batchCount);
        memset(operptr, 0, sizeof(operptr[0]) * batchCount);
// Processing result of the row
// Note: In the database, a statement belongs to one transaction. Therefore, data is processed as a unit.
That is, either all data is inserted successfully or all data fails to be inserted.
        statusptr = (SQLUSMALLINT*)malloc(sizeof(statusptr[0]) * batchCount);
        memset(statusptr, 88, sizeof(statusptr[0]) * batchCount);

        if (NULL == ids || NULL == cols || NULL == bufLenCols || NULL == bufLenIds)
        {
            fprintf(stderr, "FAILED:\tmalloc data memory failed\n");
            goto exit;
        }
```

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```
    for (int i = 0; i < batchCount; i++)
    {
        ids[i] = i;
        sprintf(cols + 50 * i, "column test value %d", i);
        bufLenIds[i] = sizeof(ids[i]);
        bufLenCols[i] = strlen(cols + 50 * i);
        operptr[i] = (i < ignoreCount) ? SQL_PARAM_IGNORE : SQL_PARAM_PROCEED;
    }

    // Allocate Statement Handle
    retcode = SQLAllocHandle(SQL_HANDLE_STMT, hdbc, &hstmtinesrt);
    CHECK_ERROR(retcode, "SQLAllocHandle(SQL_HANDLE_STMT)",
                hstmtinesrt, SQL_HANDLE_STMT);

    // Prepare Statement
    sql = (SQLCHAR*)"insert into test_odbc_batch_insert values(?, ?)";
    retcode = SQLPrepare(hstmtinesrt, (SQLCHAR*) sql, SQL_NTS);
    sprintf((char*)loginfo, "SQLPrepare log: %s", (char*)sql);
    CHECK_ERROR(retcode, loginfo, hstmtinesrt, SQL_HANDLE_STMT);

    retcode = SQLSetStmtAttr(hstmtinesrt, SQL_ATTR_PARAMSET_SIZE, (SQLPOINTER)batchCount,
sizeof(batchCount));
    CHECK_ERROR(retcode, "SQLSetStmtAttr", hstmtinesrt, SQL_HANDLE_STMT);

    retcode = SQLBindParameter(hstmtinesrt, 1, SQL_PARAM_INPUT, SQL_C_SLONG, SQL_INTEGER,
sizeof(ids[0]), 0,&(ids[0]), 0, bufLenIds);
    CHECK_ERROR(retcode, "SQLBindParameter for id", hstmtinesrt, SQL_HANDLE_STMT);

    retcode = SQLBindParameter(hstmtinesrt, 2, SQL_PARAM_INPUT, SQL_C_CHAR, SQL_CHAR, 50, 50,
cols, 50, bufLenCols);
    CHECK_ERROR(retcode, "SQLBindParameter for cols", hstmtinesrt, SQL_HANDLE_STMT);

    retcode = SQLSetStmtAttr(hstmtinesrt, SQL_ATTR_PARAMS_PROCESSED_PTR, (SQLPOINTER)&process,
sizeof(process));
    CHECK_ERROR(retcode, "SQLSetStmtAttr for SQL_ATTR_PARAMS_PROCESSED_PTR", hstmtinesrt,
SQL_HANDLE_STMT);

    retcode = SQLSetStmtAttr(hstmtinesrt, SQL_ATTR_PARAM_STATUS_PTR, (SQLPOINTER)statusptr,
sizeof(statusptr[0]) * batchCount);
    CHECK_ERROR(retcode, "SQLSetStmtAttr for SQL_ATTR_PARAM_STATUS_PTR", hstmtinesrt,
SQL_HANDLE_STMT);

    retcode = SQLSetStmtAttr(hstmtinesrt, SQL_ATTR_PARAM_OPERATION_PTR, (SQLPOINTER)operptr,
sizeof(operptr[0]) * batchCount);
    CHECK_ERROR(retcode, "SQLSetStmtAttr for SQL_ATTR_PARAM_OPERATION_PTR", hstmtinesrt,
SQL_HANDLE_STMT);

    retcode = SQLExecute(hstmtinesrt);
    sprintf((char*)loginfo, "SQLExecute stmt log: %s", (char*)sql);
    CHECK_ERROR(retcode, loginfo, hstmtinesrt, SQL_HANDLE_STMT);

    retcode = SQLRowCount(hstmtinesrt, &rowsCount);
    CHECK_ERROR(retcode, "SQLRowCount execution", hstmtinesrt, SQL_HANDLE_STMT);

    if (rowsCount != (batchCount - ignoreCount))
    {
        sprintf(loginfo, "(batchCount - ignoreCount)(%d) != rowsCount(%d)", (batchCount - ignoreCount),
rowsCount);
        CHECK_ERROR(SQL_ERROR, loginfo, NULL, SQL_HANDLE_STMT);
    }
    else
    {
        sprintf(loginfo, "(batchCount - ignoreCount)(%d) == rowsCount(%d)", (batchCount - ignoreCount),
rowsCount);
        CHECK_ERROR(SQL_SUCCESS, loginfo, NULL, SQL_HANDLE_STMT);
    }

    if (rowsCount != process)
    {
```

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```
            sprintf(loginfo, "process(%d) != rowsCount(%d)", process, rowsCount);
            CHECK_ERROR(SQL_ERROR, loginfo, NULL, SQL_HANDLE_STMT);
        }
        else
        {
            sprintf(loginfo, "process(%d) == rowsCount(%d)", process, rowsCount);
            CHECK_ERROR(SQL_SUCCESS, loginfo, NULL, SQL_HANDLE_STMT);
        }

        for (int i = 0; i < batchCount; i++)
        {
            if (i < ignoreCount)
            {
                if (statusptr[i] != SQL_PARAM_UNUSED)
                {
                    sprintf(loginfo, "statusptr[%d](%d) != SQL_PARAM_UNUSED", i, statusptr[i]);
                    CHECK_ERROR(SQL_ERROR, loginfo, NULL, SQL_HANDLE_STMT);
                }
            }
            else if (statusptr[i] != SQL_PARAM_SUCCESS)
            {
                sprintf(loginfo, "statusptr[%d](%d) != SQL_PARAM_SUCCESS", i, statusptr[i]);
                CHECK_ERROR(SQL_ERROR, loginfo, NULL, SQL_HANDLE_STMT);
            }
        }

        retcode = SQLFreeHandle(SQL_HANDLE_STMT, hstmtinesrt);
        sprintf((char*)loginfo, "SQLFreeHandle hstmtinesrt");
        CHECK_ERROR(retcode, loginfo, hstmtinesrt, SQL_HANDLE_STMT);
    }


exit:
    printf ("\nComplete.\n");

    // Connection
    if (hdbc != SQL_NULL_HDBC) {
        SQLDisconnect(hdbc);
        SQLFreeHandle(SQL_HANDLE_DBC, hdbc);
    }

    // Environment
    if (henv != SQL_NULL_HENV)
        SQLFreeHandle(SQL_HANDLE_ENV, henv);

    return 0;
}
```

# 7.4.5 ODBC Interfaces

The ODBC interface is a set of API functions provided to users. This chapter describes its common interfaces. For details on other interfaces, see "ODBC Programmer's Reference" at MSDN (https://msdn.microsoft.com/en-us/library/windows/desktop/ms714177(v=vs.85).aspx).

## 7.4.5.1 SQLAllocEnv

In ODBC 3.x, **SQLAllocEnv** (an ODBC 2.x function) was deprecated and replaced with **SQLAllocHandle**. For details, see **SQLAllocHandle**.

## 7.4.5.2 SQLAllocConnect

In ODBC 3.x, **SQLAllocConnect** (an ODBC 2.x function) was deprecated and replaced with **SQLAllocHandle**. For details, see **SQLAllocHandle**.


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### 7.4.5.3 SQLAllocHandle

## Function

**SQLAllocHandle** allocates environment, connection, or statement handles. This function is a generic function for allocating handles that replaces the deprecated ODBC 2.x functions **SQLAllocEnv**, **SQLAllocConnect**, and **SQLAllocStmt**.

## Prototype

```
SQLRETURN SQLAllocHandle(SQLSMALLINT   HandleType,
                         SQLHANDLE     InputHandle,
                         SQLHANDLE     *OutputHandlePtr);
```

## Parameter

**Table 7-25** SQLAllocHandle parameters

| Keyword | Description |
| --- | --- |
| HandleType | The type of handle to be allocated by SQLAllocHandle. The value must be one of the following:<br>● SQL_HANDLE_ENV (environment handle)<br>● SQL_HANDLE_DBC (connection handle)<br>● SQL_HANDLE_STMT (statement handle)<br>● SQL_HANDLE_DESC (description handle)<br>The handle application sequence is: **SQL_HANDLE_ENV** > **SQL_HANDLE_DBC** > **SQL_HANDLE_STMT**. The handle applied later depends on the handle applied prior to it. |
| InputHandle | Existing handle to use as a context for the new handle being allocated.<br>● If **HandleType** is **SQL_HANDLE_ENV**, this is SQL_NULL_HANDLE.<br>● If **HandleType** is **SQL_HANDLE_DBC**, this must be an environment handle.<br>● If **HandleType** is **SQL_HANDLE_STMT** or **SQL_HANDLE_DESC**, it must be a connection handle. |
| OutputHandlePtr | **Output parameter**: Pointer to a buffer in which to return the handle to the newly allocated data structure. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

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## Precautions

When allocating a non-environment handle, if **SQLAllocHandle** returns **SQL_ERROR**, it sets **OutputHandlePtr** to **SQL_NULL_HENV**, **SQL_NULL_HDBC**, **SQL_NULL_HSTMT**, or **SQL_NULL_HDESC**. The application can then call **SQLGetDiagRec**, with **HandleType** and **Handle** set to **IntputHandle**, to obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

### 7.4.5.4 SQLAllocStmt

In ODBC 3.x, **SQLAllocStmt** was deprecated and replaced with **SQLAllocHandle**. For details, see **SQLAllocHandle**.

### 7.4.5.5 SQLBindCol

## Function

**SQLBindCol** is used to associate (bind) columns in a result set to an application data buffer.

## Prototype

```
SQLRETURN SQLBindCol(SQLHSTMT       StatementHandle,
                     SQLUSMALLINT   ColumnNumber,
                     SQLSMALLINT    TargetType,
                     SQLPOINTER     TargetValuePtr,
                     SQLLEN         BufferLength,
                     SQLLEN         *StrLen_or_IndPtr);
```

## Parameter

**Table 7-26** SQLBindCol parameters

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle. |
| ColumnNumber | Number of the column to be bound. The column number starts with 0 and increases in ascending order. Column 0 is the bookmark column. If no bookmark column is set, column numbers start at 1. |
| TargetType | The C data type in the buffer. |
| TargetValuePtr | **Output parameter**: pointer to the buffer bound with the column. The SQLFetch function returns data in the buffer. If **TargetValuePtr** is null, **StrLen_or_IndPtr** is a valid value. |


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| Keyword | Description |
| --- | --- |
| BufferLength | Size of the **TargetValuePtr** buffer in bytes available to store the column data. |
| StrLen_or_IndPtr | **Output parameter**: pointer to the length or indicator of the buffer. If **StrLen_or_IndPtr** is null, no length or indicator is used. |

## Return Values

- SQL_SUCCESS indicates that the call succeeded.
- SQL_SUCCESS_WITH_INFO indicates some warning information is displayed.
- SQL_ERROR indicates major errors, such as memory allocation and connection failures.
- SQL_INVALID_HANDLE indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

## Precautions

If **SQLBindCol** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, with **HandleType** and **Handle** set to **SQL_HANDLE_STMT** and **StatementHandle**, respectively, to obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

# 7.4.5.6 SQLBindParameter

## Function

**SQLBindParameter** is used to associate (bind) parameter markers in an SQL statement to a buffer.

## Prototype

```
SQLRETURN SQLBindParameter(SQLHSTMT       StatementHandle,
                           SQLUSMALLINT   ParameterNumber,
                           SQLSMALLINT    InputOutputType,
                           SQLSMALLINT    ValuetType,
                           SQLSMALLINT    ParameterType,
                           SQLULEN        ColumnSize,
                           SQLSMALLINT    DecimalDigits,
                           SQLPOINTER     ParameterValuePtr,
                           SQLLEN         BufferLength,
                           SQLLEN         *StrLen_or_IndPtr);
```

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## Parameter

**Table 7-27** SQLBindParameter

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle. |
| ParameterNumber | Parameter marker number, starting at 1 and increasing in an ascending order. |
| InputOutputType | Input/output type of the parameter. |
| ValueType | C data type of the parameter. |
| ParameterType | SQL data type of the parameter. |
| ColumnSize | Size of the column or expression of the corresponding parameter marker. |
| DecimalDigits | Digital number of the column or the expression of the corresponding parameter marker. |
| ParameterValuePtr | Pointer to the storage parameter buffer. |
| BufferLength | Size of the ParameterValuePtr buffer in bytes. |
| StrLen_or_IndPtr | Pointer to the length or indicator of the buffer. If StrLen_or_IndPtr is null, no length or indicator is used. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

## Precautions

If **SQLBindCol** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, with **HandleType** and **Handle** set to **SQL_HANDLE_STMT** and **StatementHandle**, respectively, to obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.


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## 7.4.5.7 SQLColAttribute

### Function

**SQLColAttribute** returns the descriptor information about a column in the result set.

### Prototype

```
SQLRETURN SQLColAttribute(SQLHSTMT        StatementHandle,
                          SQLUSMALLINT    ColumnNumber,
                          SQLUSMALLINT    FieldIdentifier,
                          SQLPOINTER      CharacterAtrributePtr,
                          SQLSMALLINT     BufferLength,
                          SQLSMALLINT     *StringLengthPtr,
                          SQLPOINTER      NumericAttributePtr);
```

### Parameter

**Table 7-28** SQLColAttribute parameter

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle. |
| ColumnNumber | Column number of the field to be queried, starting at 1 and increasing in an ascending order. |
| FieldIdentifier | Field identifier of **ColumnNumber** in IRD. |
| CharacterAttributePtr | **Output parameter**: pointer to the buffer that returns FieldIdentifier field value. |
| BufferLength | • **FieldIdentifier** indicates the length of the buffer if **FieldIdentifier** is an ODBC-defined field and **CharacterAttributePtr** points to a character string or a binary buffer.<br>• Ignore this parameter if **FieldIdentifier** is an ODBC-defined field and **CharacterAttributePtr** points to an integer. |
| StringLengthPtr | **Output parameter**: pointer to a buffer in which the total number of valid bytes (for string data) is stored in ***CharacterAttributePtr**. Ignore the value of **BufferLength** if the data is not a string. |
| NumericAttributePtr | **Output parameter**: pointer to an integer buffer in which the value of the **FieldIdentifier** field in the **ColumnNumber** row of the IRD is returned. |

### Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.

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- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

## Precautions

If **SQLColAttribute** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_STMT** and **StatementHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

# 7.4.5.8 SQLConnect

## Function

**SQLConnect** establishes a connection between a driver and a data source. After the connection, the connection handle can be used to access all information about the data source, including its application operating status, transaction processing status, and error information.

## Prototype

```
SQLRETURN  SQLConnect(SQLHDBC        ConnectionHandle,
                      SQLCHAR        *ServerName,
                      SQLSMALLINT    NameLength1,
                      SQLCHAR        *UserName,
                      SQLSMALLINT    NameLength2,
                      SQLCHAR        *Authentication,
                      SQLSMALLINT    NameLength3);
```

## Parameter

**Table 7-29** SQLConnect parameters

| Keyword | Description |
| --- | --- |
| ConnectionHandle | Connection handle, obtained from **SQLAllocHandle**. |
| ServerName | Name of the data source to connect to. |
| NameLength1 | Length of **ServerName**. |
| UserName | User name of the database in the data source. |
| NameLength2 | Length of **UserName**. |
| Authentication | User password of the database in the data source. |
| NameLength3 | Length of **Authentication**. |

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## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.
- **SQL_STILL_EXECUTING** indicates that the statement is being executed.

## Precautions

If **SQLConnect** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_DBC** and **ConnectionHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

# 7.4.5.9 SQLDisconnect

## Function

**SQLDisconnect** closes the connection associated with the database connection handle.

## Prototype

```
SQLRETURN SQLDisconnect(SQLHDBC     ConnectionHandle);
```

## Parameter

**Table 7-30** SQLDisconnect parameters

| Keyword | Description |
| --- | --- |
| ConnectionHandle | Connection handle, obtained from **SQLAllocHandle**. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.


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## Precautions

If **SQLDisconnect** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_DBC** and **ConnectionHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

## 7.4.5.10 SQLExecDirect

## Function

**SQLExecDirect** executes a prepared SQL statement specified in this parameter. This is the fastest execution method for executing only one SQL statement at a time.

## Prototype

```
SQLRETURN SQLExecDirect(SQLHSTMT         StatementHandle,
                        SQLCHAR          *StatementText,
                        SQLINTEGER       TextLength);
```

## Parameter

**Table 7-31** SQLExecDirect parameters

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle, obtained from **SQLAllocHandle**. |
| StatementText | SQL statement to be executed. One SQL statement can be executed at a time. |
| TextLength | Length of **StatementText**. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_NEED_DATA** indicates insufficient parameters provided before executing the SQL statement.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.
- **SQL_STILL_EXECUTING** indicates that the statement is being executed.


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- **SQL_NO_DATA** indicates that the SQL statement does not return a result set.

## Precautions

If **SQLExecDirect** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_STMT** and **StatementHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

# 7.4.5.11 SQLExecute

## Function

The **SQLExecute** function executes a prepared SQL statement using **SQLPrepare**. The statement is executed using the current value of any application variables that were bound to parameter markers by **SQLBindParameter**.

## Prototype

```
SQLRETURN SQLExecute(SQLHSTMT    StatementHandle);
```

## Parameter

**Table 7-32** SQLExecute parameters

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle to be executed. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_NEED_DATA** indicates insufficient parameters provided before executing the SQL statement.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_NO_DATA** indicates that the SQL statement does not return a result set.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.
- **SQL_STILL_EXECUTING** indicates that the statement is being executed.

## Precautions

If **SQLExecute** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to


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**SQL_HANDLE_STMT** and **StatementHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

## 7.4.5.12 SQLFetch

## Function

**SQLFetch** advances the cursor to the next row of the result set and retrieves any bound columns.

## Prototype

```
SQLRETURN SQLFetch(SQLHSTMT    StatementHandle);
```

## Parameter

**Table 7-33** SQLFetch parameters

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle, obtained from **SQLAllocHandle**. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_NO_DATA** indicates that the SQL statement does not return a result set.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.
- **SQL_STILL_EXECUTING** indicates that the statement is being executed.

## Precautions

If **SQLFetch** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_STMT** and **StatementHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.


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### 7.4.5.13 SQLFreeStmt

In ODBC 3.x, **SQLFreeStmt** (an ODBC 2.x function) was deprecated and replaced with **SQLFreeHandle**. For details, see **SQLFreeHandle**.

### 7.4.5.14 SQLFreeConnect

In ODBC 3.x, **SQLFreeConnect** (an ODBC 2.x function) was deprecated and replaced with **SQLFreeHandle**. For details, see **SQLFreeHandle**.

### 7.4.5.15 SQLFreeHandle

#### Function

**SQLFreeHandle** releases resources associated with a specific environment, connection, or statement handle. It replaces the ODBC 2.x functions: **SQLFreeEnv**, **SQLFreeConnect**, and **SQLFreeStmt**.

#### Prototype

```
SQLRETURN SQLFreeHandle(SQLSMALLINT   HandleType,
                        SQLHANDLE     Handle);
```

#### Parameter

**Table 7-34** SQLFreeHandle parameters

| Keyword | Description |
| --- | --- |
| HandleType | The type of handle to be freed by SQLFreeHandle. The value must be one of the following:<br>• SQL_HANDLE_ENV<br>• SQL_HANDLE_DBC<br>• SQL_HANDLE_STMT<br>• SQL_HANDLE_DESC<br>If **HandleType** is not one of the preceding values, **SQLFreeHandle** returns **SQL_INVALID_HANDLE**. |
| Handle | The name of the handle to be freed. |

#### Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.


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## Precautions

If **SQLFreeHandle** returns **SQL_ERROR**, the handle is still valid.

## Examples

See **Examples**.

## 7.4.5.16 SQLFreeEnv

In ODBC 3.x, **SQLFreeEnv** (an ODBC 2.x function) was deprecated and replaced with **SQLFreeHandle**. For details, see **SQLFreeHandle**.

## 7.4.5.17 SQLPrepare

## Function

**SQLPrepare** prepares an SQL statement to be executed.

## Prototype

```
SQLRETURN SQLPrepare(SQLHSTMT      StatementHandle,
                     SQLCHAR       *StatementText,
                     SQLINTEGER    TextLength);
```

## Parameter

**Table 7-35** SQLPrepare parameters

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle. |
| StatementText | SQL text string. |
| TextLength | Length of **StatementText**. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.
- **SQL_STILL_EXECUTING** indicates that the statement is being executed.

## Precautions

If **SQLPrepare** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to


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**SQL_HANDLE_STMT** and **StatementHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

## 7.4.5.18 SQLGetData

## Function

**SQLGetData** retrieves data for a single column in the current row of the result set. It can be called for many times to retrieve data of variable lengths.

## Prototype

```
SQLRETURN SQLGetData(SQLHSTMT        StatementHandle,
                     SQLUSMALLINT    Col_or_Param_Num,
                     SQLSMALLINT     TargetType,
                     SQLPOINTER      TargetValuePtr,
                     SQLLEN          BufferLength,
                     SQLLEN          *StrLen_or_IndPtr);
```

## Parameter

**Table 7-36** SQLGetData parameters

| Keyword | Description |
| --- | --- |
| StatementHandle | Statement handle, obtained from **SQLAllocHandle**. |
| Col_or_Param_Num | Column number for which the data retrieval is requested. The column number starts with 1 and increases in ascending order. The number of the bookmark column is 0. |
| TargetType | C data type in the TargetValuePtr buffer. If **TargetType** is **SQL_ARD_TYPE**, the driver uses the data type of the **SQL_DESC_CONCISE_TYPE** field in ARD. If **TargetType** is **SQL_C_DEFAULT**, the driver selects a default data type according to the source SQL data type. |
| TargetValuePtr | **Output parameter**: pointer to the pointer that points to the buffer where the data is located. |
| BufferLength | Size of the buffer pointed to by **TargetValuePtr**. |
| StrLen_or_IndPtr | **Output parameter**: pointer to the buffer where the length or identifier value is returned. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.


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- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_NO_DATA** indicates that the SQL statement does not return a result set.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.
- **SQL_STILL_EXECUTING** indicates that the statement is being executed.

## Precautions

If **SQLFetch** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_STMT** and **StatementHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

# 7.4.5.19 SQLGetDiagRec

## Function

**SQLGetDiagRec** returns the current values of multiple fields of a diagnostic record that contains error, warning, and status information.

## Prototype

```
SQLRETURN  SQLGetDiagRec(SQLSMALLINT    HandleType
                         SQLHANDLE      Handle,
                         SQLSMALLINT    RecNumber,
                         SQLCHAR        *SQLState,
                         SQLINTEGER     *NativeErrorPtr,
                         SQLCHAR        *MessageText,
                         SQLSMALLINT    BufferLength
                         SQLSMALLINT    *TextLengthPtr);
```

## Parameter

**Table 7-37** SQLGetDiagRec parameters

| Keyword | Description |
| --- | --- |
| HandleType | A handle-type identifier that describes the type of handle for which diagnostics are desired. The value must be one of the following:<br>• SQL_HANDLE_ENV<br>• SQL_HANDLE_DBC<br>• SQL_HANDLE_STMT<br>• SQL_HANDLE_DESC |

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| Keyword | Description |
| --- | --- |
| Handle | A handle for the diagnostic data structure. Its type is indicated by HandleType. If **HandleType** is **SQL_HANDLE_ENV**, **Handle** may be shared or non-shared environment handle. |
| RecNumber | Indicates the status record from which the application seeks information. RecNumber starts with 1. |
| SQLState | **Output parameter**: pointer to a buffer that saves the 5-character **SQLSTATE** code pertaining to **RecNumber**. |
| NativeErrorPtr | **Output parameter**: pointer to a buffer that saves the native error code. |
| MessageText | Pointer to a buffer that saves text strings of diagnostic information. |
| BufferLength | Length of MessageText. |
| TextLengthPtr | **Output parameter**: pointer to the buffer, the total number of bytes in the returned **MessageText**. If the number of bytes available to return is greater than **BufferLength**, then the diagnostics information text in **MessageText** is truncated to **BufferLength** minus the length of the null termination character. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

## Precautions

**SQLGetDiagRec** does not release diagnostic records for itself. It uses the following returned values to report execution results:

- **SQL_SUCCESS**: The function successfully returns diagnostic information.
- **SQL_SUCCESS_WITH_INFO**: The ***MessageText** buffer is too small to hold the requested diagnostic message. No diagnostic records are generated.
- **SQL_INVALID_HANDLE**: The handle indicated by **HandType** and **Handle** is not a valid handle.
- **SQL_ERROR**: **RecNumber** is smaller than or equal to zero, or **BufferLength** is smaller than zero.

If an ODBC function returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec** and obtain the **SQLSTATE** value. The possible **SQLSTATE** values are listed as follows:

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**Table 7-38** SQLSTATE values

| SQLSATATE | Error | Description |
| --- | --- | --- |
| HY000 | General error | An error occurred for which there is no specific SQLSTATE. |
| HY001 | Memory allocation error | The driver is unable to allocate memory required to support execution or completion of the function. |
| HY008 | Operation canceled | SQLCancel is called to terminate the statement execution, but the StatementHandle function is still called. |
| HY010 | Function sequence error | The function is called prior to sending data to data parameters or columns being executed. |
| HY013 | Memory management error | The function fails to be called. The error may be caused by low memory conditions. |
| HYT01 | Connection timed out | The timeout period expired before the application was able to connect to the data source. |
| IM001 | Function not supported by the driver | The called function is not supported by the StatementHandle driver. |

## Examples

See **Examples**.

## 7.4.5.20 SQLSetConnectAttr

## Function

**SQLSetConnectAttr** sets connection attributes.

## Prototype

```
SQLRETURN SQLSetConnectAttr(SQLHDBC      ConnectionHandle
                            SQLINTEGER   Attribute,
                            SQLPOINTER   ValuePtr,
                            SQLINTEGER   StringLength);
```


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## Parameter

**Table 7-39** SQLSetConnectAttr parameters

| Keyword | Description |
| --- | --- |
| StatementttHandle | Connection handle. |
| Attribute | Attribute to set. |
| ValuePtr | Pointer to the Attribute value. **ValuePtr** depends on the Attribute value, and can be a 32-bit unsigned integer value or a null-terminated string. If **ValuePtr** parameter is driver-specific value, it may be signed integer. |
| StringLength | If **ValuePtr** points to a string or a binary buffer, this parameter should be the length of ***ValuePtr**. If **ValuePtr** points to an integer, **StringLength** is ignored. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

## Precautions

If **SQLSetConnectAttr** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_DBC** and **ConnectionHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

## 7.4.5.21 SQLSetEnvAttr

## Function

**SQLSetEnvAttr** sets environment attributes.

## Prototype

```
SQLRETURN SQLSetEnvAttr(SQLHENV      EnvironmentHandle
                        SQLINTEGER   Attribute,
                        SQLPOINTER   ValuePtr,
                        SQLINTEGER   StringLength);
```


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## Parameters

**Table 7-40** SQLSetEnvAttr parameters

| Keyword | Description |
| --- | --- |
| EnviromentHandle | Environment handle. |
| Attribute | Environment attribute to be set. Its value must be one of the following:<br>• **SQL_ATTR_ODBC_VERSION**: ODBC version<br>• **SQL_CONNECTION_POOLING**: connection pool attribute<br>• **SQL_OUTPUT_NTS**: string type returned by the driver |
| ValuePtr | Pointer to the Attribute value. **ValuePtr** depends on the Attribute value, and can be a 32-bit integer value or a null-terminated string. |
| StringLength | If **ValuePtr** points to a string or a binary buffer, this parameter should be the length of ***ValuePtr**. If **ValuePtr** points to an integer, **StringLength** is ignored. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

## Precautions

If **SQLSetEnvAttr** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_ENV** and **EnvironmentHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

## 7.4.5.22 SQLSetStmtAttr

## Function

**SQLSetStmtAttr** sets attributes related to a statement.


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## Prototype

```
SQLRETURN SQLSetStmtAttr(SQLHSTMT      StatementHandle
                         SQLINTEGER    Attribute,
                         SQLPOINTER    ValuePtr,
                         SQLINTEGER    StringLength);
```

## Parameter

**Table 7-41** SQLSetStmtAttr parameters

| Keyword | Description |
| --- | --- |
| StatementtHandle | Statement handle. |
| Attribute | Attribute to set. |
| ValuePtr | Pointer to the Attribute value. **ValuePtr** depends on the Attribute value, and can be a 32-bit unsigned integer value or a pointer to a null-terminated string, a binary buffer, and a driver-specified value. If **ValuePtr** parameter is driver-specific value, it may be signed integer. |
| StringLength | If **ValuePtr** points to a string or a binary buffer, this parameter should be the length of ***ValuePtr**. If **ValuePtr** points to an integer, **StringLength** is ignored. |

## Return Values

- **SQL_SUCCESS** indicates that the call succeeded.
- **SQL_SUCCESS_WITH_INFO** indicates some warning information is displayed.
- **SQL_ERROR** indicates major errors, such as memory allocation and connection failures.
- **SQL_INVALID_HANDLE** indicates that invalid handles were called. Values returned by other APIs are similar to the preceding values.

## Precautions

If **SQLSetStmtAttr** returns **SQL_ERROR** or **SQL_SUCCESS_WITH_INFO**, the application can then call **SQLGetDiagRec**, set **HandleType** and **Handle** to **SQL_HANDLE_STMT** and **StatementHandle**, and obtain the **SQLSTATE** value. The **SQLSTATE** value provides the detailed function calling information.

## Examples

See **Examples**.

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# 8 PostGIS Extension

## 8.1 PostGIS

NOTE

- The third-party software that the PostGIS Extension depends on needs to be installed separately. If you need to use PostGIS, submit a service ticket or contact technical support to submit an application.
- If the error message "ERROR: EXTENSION is not yet supported." is displayed, the PostGIS software package is not installed. Contact technical support.

GaussDB(DWS) provides PostGIS Extension (PostGIS-2.4.2). PostGIS Extension is a spatial database extender for PostgreSQL. It provides the following spatial information services: spatial objects, spatial indexes, spatial functions, and spatial operators. PostGIS Extension complies with the OpenGIS specifications.

In GaussDB(DWS), PostGIS Extension depends on the listed third-party open-source software.

- Geos 3.6.2
- Proj 4.9.2
- Json 0.12.1
- Libxml2 2.7.1
- Gdal 1.11.0

## 8.2 Using PostGIS

NOTE

- The third-party software that the PostGIS Extension depends on needs to be installed separately. If you need to use PostGIS, submit a service ticket or contact technical support to submit an application.
- If the error message "ERROR: EXTENSION is not yet supported." is displayed, the PostGIS software package is not installed. Contact technical support.

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## Creating PostGIS Extension

Run the **CREATE EXTENSION** command to create PostGIS Extension.

```
CREATE EXTENSION postgis;
```

After PostGIS Extension is created, you can run the following command to enable the grid function in PostGIS if needed:

```
CREATE EXTENSION postgis_raster;
```

## Using PostGIS Extension

Use the following function to invoke a PostGIS Extension:

```
SELECT GisFunction (Param1, Param2,.....);
```

**GisFunction** is the function, and **Param1** and **Param2** are function parameters. The following SQL statements are a simple illustration for PostGIS use. For details about related functions, see ***PostGIS 2.4.2 Manual***.

Example 1: Create a geometry table.

```
CREATE TABLE cities ( id integer, city_name varchar(50) );
SELECT AddGeometryColumn('cities', 'position', 4326, 'POINT', 2);
```

Example 2: Insert geometry data.

```
INSERT INTO cities (id, position, city_name) VALUES (1,ST_GeomFromText('POINT(-9.5 23)',4326),'CityA');
INSERT INTO cities (id, position, city_name) VALUES (2,ST_GeomFromText('POINT(-10.6 40.3)',4326),'CityB');
INSERT INTO cities (id, position, city_name) VALUES (3,ST_GeomFromText('POINT(20.8 30.3)',4326), 'CityC');
```

Example 3: Calculate the distance between any two cities among three cities.

```
SELECT p1.city_name,p2.city_name,ST_Distance(p1.position,p2.position) FROM cities AS p1, cities AS p2
WHERE p1.id > p2.id;
```

## Deleting PostGIS Extension

Run the following command to delete PostGIS Extension from GaussDB(DWS):

```
DROP EXTENSION postgis [CASCADE];
```

**NOTE**

If PostGIS Extension is the dependee of other objects (for example, geometry tables), you need to add the **CASCADE** keyword to delete all these objects.

# 8.3 PostGIS Support and Constraints

## Supported Data Types

In GaussDB(DWS), PostGIS Extension support the following data types:

- box2d
- box3d
- geometry_dump
- geometry

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- geography
- raster

NOTE

- The grid-related GUC parameters **postgis.gdal_datapath**, **postgis.gdal_enabled_drivers**, and **postgis.enable_outdb_rasters** have been enabled. You do not need to manually set them.
- If PostGIS is used by a user other than the creator of the PostGIS, set the following GUC parameters:
  ```
  SET behavior_compat_options = 'bind_procedure_searchpath';
  ```

## Supported Operators and Functions

**Table 8-1 Operators and functions supported by PostGIS**

| Category | Function |
| --- | --- |
| Management functions | AddGeometryColumn, DropGeometryColumn, DropGeometryTable, PostGIS_Full_Version, PostGIS_GEOS_Version, PostGIS_Liblwgeom_Version, PostGIS_Lib_Build_Date, PostGIS_Lib_Version, PostGIS_PROJ_Version, PostGIS_Scripts_Build_Date, PostGIS_Scripts_Installed, PostGIS_Version, PostGIS_LibXML_Version, PostGIS_Scripts_Released, Populate_Geometry_Columns, UpdateGeometrySRID |
| Geometry constructors | ST_BdPolyFromText, ST_BdMPolyFromText, ST_Box2dFromGeoHash, ST_GeogFromText, ST_GeographyFromText, ST_GeogFromWKB, ST_GeomCollFromText, ST_GeomFromEWKB, ST_GeomFromEWKT, ST_GeometryFromText, ST_GeomFromGeoHash, ST_GeomFromGML, ST_GeomFromGeoJSON, ST_GeomFromKML, ST_GMLToSQL, ST_GeomFromText, ST_GeomFromWKB, ST_LineFromMultiPoint, ST_LineFromText, ST_LineFromWKB, ST_LinestringFromWKB, ST_MakeBox2D, ST_3DMakeBox, ST_MakeEnvelope, ST_MakePolygon, ST_MakePoint, ST_MakePointM, ST_MLineFromText, ST_MPointFromText, ST_MPolyFromText, ST_Point, ST_PointFromGeoHash, ST_PointFromText, ST_PointFromWKB, ST_Polygon, ST_PolygonFromText, ST_WKBToSQL, ST_WKTToSQL |
| Geometry accessors | GeometryType, ST_Boundary, ST_CoordDim, ST_Dimension, ST_EndPoint, ST_Envelope, ST_ExteriorRing, ST_GeometryN, ST_GeometryType, ST_InteriorRingN, ST_IsClosed, ST_IsCollection, ST_IsEmpty, ST_IsRing, ST_IsSimple, ST_IsValid, ST_IsValidReason, ST_IsValidDetail, ST_M, ST_NDims, ST_NPoints, ST_NRings, ST_NumGeometries, ST_NumInteriorRings, ST_NumInteriorRing, ST_NumPatches, ST_NumPoints, ST_PatchN, ST_PointN, ST_SRID, ST_StartPoint, ST_Summary, ST_X, ST_XMax, ST_XMin, ST_Y, ST_YMax, ST_YMin, ST_Z, ST_ZMax, ST_Zmflag, ST_ZMin |

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| Category | Function |
| --- | --- |
| Geometry editors | ST_AddPoint, ST_Affine, ST_Force2D, ST_Force3D, ST_Force3DZ, ST_Force3DM, ST_Force4D, ST_ForceCollection, ST_ForceSFS, ST_ForceRHR, ST_LineMerge, ST_CollectionExtract, ST_CollectionHomogenize, ST_Multi, ST_RemovePoint, ST_Reverse, ST_Rotate, ST_RotateX, ST_RotateY, ST_RotateZ, ST_Scale, ST_Segmentize, ST_SetPoint, ST_SetSRID, ST_SnapToGrid, ST_Snap, ST_Transform, ST_Translate, ST_TransScale |
| Geometry outputs | ST_AsBinary, ST_AsEWKB, ST_AsEWKT, ST_AsGeoJSON, ST_AsGML, ST_AsHEXEWKB, ST_AsKML, ST_AsLatLonText, ST_AsSVG, ST_AsText, ST_AsX3D, ST_GeoHash |
| Operators | &&, &&&, &<, &<\|, &>, <<, <<\|, =, >>, @, \|&>, \|>>, ~, ~=, <->, <#> |
| Spatial relationships and measurements | ST_3DClosestPoint, ST_3DDistance, ST_3DDWithin, ST_3DDFullyWithin, ST_3DIntersects, ST_3DLongestLine, ST_3DMaxDistance, ST_3DShortestLine, ST_Area, ST_Azimuth, ST_Centroid, ST_ClosestPoint, ST_Contains, ST_ContainsProperly, ST_Covers, ST_CoveredBy, ST_Crosses, ST_LineCrossingDirection, ST_Disjoint, ST_Distance, ST_HausdorffDistance, ST_MaxDistance, ST_DistanceSphere, ST_DistanceSpheroid, ST_DFullyWithin, ST_DWithin, ST_Equals, ST_HasArc, ST_Intersects, ST_Length, ST_Length2D, ST_3DLength, ST_Length_Spheroid, ST_Length2D_Spheroid, ST_3DLength_Spheroid, ST_LongestLine, ST_OrderingEquals, ST_Overlaps, ST_Perimeter, ST_Perimeter2D, ST_3DPerimeter, ST_PointOnSurface, ST_Project, ST_Relate, ST_RelateMatch, ST_ShortestLine, ST_Touches, ST_Within |
| Geometry processing | ST_Buffer, ST_BuildArea, ST_Collect, ST_ConcaveHull, ST_ConvexHull, ST_CurveToLine, ST_DelaunayTriangles, ST_Difference, ST_Dump, ST_DumpPoints, ST_DumpRings, ST_FlipCoordinates, ST_Intersection, ST_LineToCurve, ST_MakeValid, ST_MemUnion, ST_MinimumBoundingCircle, ST_Polygonize, ST_Node, ST_OffsetCurve, ST_RemoveRepeatedPoints, ST_SharedPaths, ST_Shift_Longitude, ST_Simplify, ST_SimplifyPreserveTopology, ST_Split, ST_SymDifference, ST_Union, ST_UnaryUnion |
| Linear referencing | ST_LineInterpolatePoint, ST_LineLocatePoint, ST_LineSubstring, ST_LocateAlong, ST_LocateBetween, ST_LocateBetweenElevations, ST_InterpolatePoint, ST_AddMeasure |
| Miscellaneous functions | ST_Accum, Box2D, Box3D, ST_Expand, ST_Extent, ST_3Dextent, Find_SRID, ST_MemSize |
| Exceptional functions | PostGIS_AddBBox, PostGIS_DropBBox, PostGIS_HasBBox |

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| Category | Function |
| --- | --- |
| Raster Management Functions | AddRasterConstraints, DropRasterConstraints, AddOverviewConstraints, DropOverviewConstraints, PostGIS_GDAL_Version, PostGIS_Raster_Lib_Build_Date, PostGIS_Raster_Lib_Version, and ST_GDALDrivers, and UpdateRasterSRID |
| Raster Constructors | ST_AddBand, ST_AsRaster, ST_Band, ST_MakeEmptyRaster, ST_Tile, and ST_FromGDALRaster |
| Raster Accessors | ST_GeoReference, ST_Height, ST_IsEmpty, ST_MetaData, ST_NumBands, ST_PixelHeight, ST_PixelWidth, ST_ScaleX, ST_ScaleY, ST_RasterToWorldCoord, ST_RasterToWorldCoordX, ST_RasterToWorldCoordY, ST_Rotation, ST_SkewX, ST_SkewY, ST_SRID, ST_Summary, ST_UpperLeftX, ST_UpperLeftY, ST_Width, ST_WorldToRasterCoord, ST_WorldToRasterCoordX, ST_WorldToRasterCoordY |
| Raster Band Accessors | ST_BandMetaData, ST_BandNoDataValue, ST_BandIsNoData, ST_BandPath, ST_BandPixelType, and ST_HasNoBand |
| Raster Pixel Accessors and Setters | ST_PixelAsPolygon, ST_PixelAsPolygons, ST_PixelAsPoint, ST_PixelAsPoints, ST_PixelAsCentroid, ST_PixelAsCentroids, ST_Value, ST_NearestValue, ST_Neighborhood, ST_SetValue, ST_SetValues, ST_DumpValues, and ST_PixelOfValue |
| Raster Editors | ST_SetGeoReference, ST_SetRotation, ST_SetScale, ST_SetSkew, ST_SetSRID, ST_SetUpperLeft, ST_Resample, ST_Rescale, ST_Reskew, and ST_SnapToGrid, ST_Resize, and ST_Transform |
| Raster Band Editors | ST_SetBandNoDataValue and ST_SetBandIsNoData |
| Raster Band Statistics and Analytics | ST_Count, ST_CountAgg, ST_Histogram, ST_Quantile, ST_SummaryStats, ST_SummaryStatsAgg, and ST_ValueCount |
| Raster Outputs | ST_AsBinary, ST_AsGDALRaster, ST_AsJPEG, ST_AsPNG, and ST_AsTIFF |
| Raster Processing | ST_Clip, ST_ColorMap, ST_Intersection, ST_MapAlgebra, ST_Reclass, and ST_Union ST_Distinct4ma, ST_InvDistWeight4ma, ST_Max4ma, ST_Mean4ma, ST_Min4ma, ST_MinDist4ma, ST_Range4ma, ST_StdDev4ma, and ST _Sum4ma, ST_Aspect, ST_HillShade, ST_Roughness, ST_Slope, ST_TPI, ST_TRI, Box3D, ST_ConvexHull, ST_DumpAsPolygons, and ST_ Envelope, ST_MinConvexHull, ST_Polygon, ST_Contains, ST_ContainsProperly, ST_Covers, ST_CoveredBy, ST_Disjoint, ST_Intersects, and ST_Overlaps, ST_Touches, ST_SameAlignment, ST_NotSameAlignmentReason, ST_Within, ST_DWithin, and ST_DFullyWithin |

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| Category | Function |
| --- | --- |
| Raster Operators | &&, &<, &>, =, @, ~=, and ~ |

## Spatial Indexes

In GaussDB(DWS), PostGIS Extension supports Generalized Search Tree (GIST) spatial indexes. This index type is inapplicable to partitioned tables. Different from B-tree indexes, GIS indexes are adaptable to all kinds of irregular data structures, which can effectively improve the retrieval efficiency for geometry and geographic data.

Run the following command to create a GiST index:

```
CREATE INDEX indexname ON tablename USING GIST ( geometryfield );
```

## Extension Constraints

- Only row-store tables are supported.
- Only Oracle-compatible databases are supported.
- The topology object management module, Topology, is not supported.
- BRIN indexes are not supported.
- The **spatial_ref_sys** table can only be queried during scale-out.

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# 9 Resource Load Management

## 9.1 Overview

Resources influencing cluster performance include the memory, CPU, disk I/O, and storage space.

During service operation, system resources may not be fully utilized, and some nodes in a cluster or some resources in the system may become the cluster performance bottleneck. GaussDB(DWS) provides resource management methods to balance system resource usage among tasks.

CPU and memory are computing resources of a server. Centralized control over them prevents resource conflicts of jobs, performs high-priority jobs (such as generating key reports) before others, and isolates user resources.

Storage space management is an important feature in the multi-tenant scenario. It limits the storage space quotas for users. GaussDB(DWS) provides a simple syntax interface used for specifying the size of the storage space when you create a user, collecting statistics on and controlling the storage space based on internal logics.

**Figure 9-1** shows an example. Where,

- CPU and I/O resources are managed using a resource pool.
- Memory can be controlled at node and job levels. Memory is managed using database system parameters, GUC parameters, and resource pools.
- Data storage space is specified when you create a user.

  NOTE

  The resource pool is a basic unit of load management in GaussDB(DWS). It manages system resources (including CPU, I/O, and memory) required by service operations and controls SQL concurrency.

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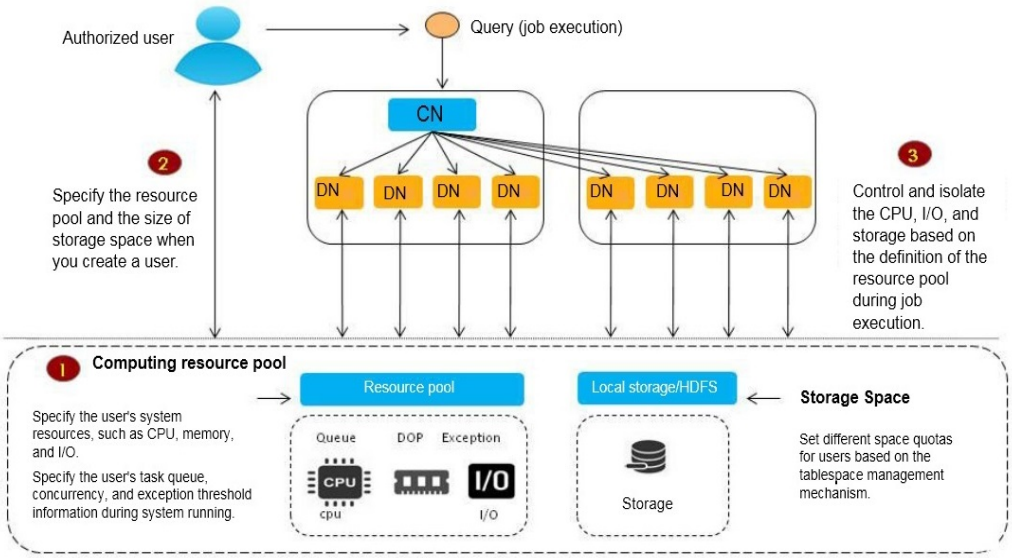
**Figure 9-1** Resource load management overview




# 9.2 Query Band Load Identification

## Context

GaussDB(DWS) implements load identification and intra-queue priority control based on query_band. It provides more flexible load identification methods and identifies load queues based on job types, application names, and script names. Users can flexibly configure query_band identification queues based on service scenarios. In addition, priority control of job delivery in the queue is implemented. In the future, priority control of resources in the queue will be gradually implemented.

Administrators can configure the queue associated with query_band and estimate the memory limit based on service scenarios and job types to implement more flexible load control and resource management and control. If query_band is not configured for the service or the user does not associate query_band with an action, the user is associated with the queue and the priority in the queue is used by default.

## Prerequisites

use_workload_manager has been set to **on**, indicating that load management control is enabled.

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## Procedure

**Step 1** Set the associated resource pool to **p1**, priority to **rush**, and order to **1** for query_band **JobName to abc**.

```
SELECT * FROM gs_wlm_set_queryband_action('JobName=abc','respool=p1;priority=rush',1);
gs_wlm_set_queryband_action
----------------------------
 t
(1 row)
```

**Step 2** Change the associated resource pool to **p2** for query_band **JobName=abc**.

```
SELECT * FROM gs_wlm_set_queryband_action('JobName=abc','respool=p2');
gs_wlm_set_queryband_action
----------------------------
 t
(1 row)
```

**Step 3** Change the priority to **high** for query_band **JobName=abc**.

```
SELECT * FROM gs_wlm_set_queryband_action('JobName=abc','priority=high');
gs_wlm_set_queryband_action
----------------------------
 t
(1 row)
```

**Step 4** Change the order to **3** for query_band **JobName=abc**.

```
SELECT * FROM gs_wlm_set_queryband_order('JobName=abc',3);
gs_wlm_set_queryband_order
----------------------------
 t
(1 row)
```

**----End**

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NOTE

- The pg_workload_action cross-database system catalog is used to store the query_band action and order. For details, see **PG_WORKLOAD_ACTION**.
- As an identifier, **query_band** indicates only load identification. To limit the system catalog size, the default actions (for example, default resource pool or medium priority) are not stored in the system catalog. You can query the specific action of **query_band** through the **pg_queryband_action** view.
- The **gs_wlm_set_queryband_action** function is used to configure query_band actions. The maximum length of the first parameter, that is, the query_band key value pair, is 63 characters. For the second parameter, it is case-insensitive and multiple actions are separated by semicolons (;). **order** is the default parameter and its default value is **-1**. **query_band** supports the following associated actions: resource pool and intra-queue priority. For details, see **gs_wlm_set_queryband_action** in the resource management function.
- The **gs_wlm_set_queryband_order** function sets the **query_band** sequence. The maximum length of the first parameter, that is, the **queryband** key value pair, is 63 characters. The value of **query_band** must be greater than or equal to **–1**. Except the default value **–1**, the value of **query_band** must be unique. If query_bands have the same order during order configuration, increase the original query_band order by 1. For details, see **gs_wlm_set_queryband_order** in the resource management function.
- The **gs_wlm_get_queryband_action** function queries the **query_band** action. For details, see **gs_wlm_set_queryband_action** in the resource management function.
- pg_queryband_action is used to query all query_band actions in the system view. For details, see **PG_QUERYBAND_ACTION**.
- query_band associated with resource pool: query_band can be associated with queues. During job execution, if a queue is specified by query_band, the queue associated with query_band is used. Otherwise, the queue associated with the user is used.
  - When query_band is associated with a resource pool, an error is reported if the resource pool does not exist, and the association fails.
  - When query_band is associated with a resource pool, the dependency between query_band and the resource pool is recorded.
  - When the resource pool associated with query_band is deleted, a message is displayed indicating that the resource pool fails to be deleted because of the dependency between query_band and the resource pool.
- Intra-queue priority of query_band: query_band can be associated with job priorities, including high, medium, and low. Rush is provided as a special priority (green channel). The default priority is medium. In practice, most jobs use the medium priority, low-priority jobs use the low priority, and privileged jobs use the high priority. It is not recommended that a large number of jobs use the high priority. The rush priority is used only in special scenarios and is not recommended in normal cases.

  The intra-queue priority is used to implement the queuing priority.
  - In the static load management scenario, when the CN concurrency is insufficient, CN global queuing is triggered. The CN global queue is a priority queue.
  - In the dynamic load management scenario, if the DN memory is insufficient, CCN global queuing is triggered. The CCN global queue is a priority queue.
  - When the resource pool concurrency or memory is insufficient, resource pool queuing is triggered. The resource pool queue is a priority queue.

  The preceding priority queues comply with the following scheduling rules:
  - Jobs with a higher priority are scheduled first.
  - After all jobs with a high priority are scheduled, jobs with a low priority are scheduled.
  - In dynamic load management scenarios, the CN global queue does not support the query_band priority.

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- The query_band priority is displayed as an integer in the load management view. The mapping between numbers and priorities is as follows:
  - 0: not controlled by load management
  - 1: low
  - 2: medium
  - 4: high
  - 8: rush
- The default action and order are not stored in the **pg_workload_action** system catalog. If a non-default action is set for query_band, the default action is also displayed when actions are queried. The message <query_band information not found> is displayed when the action and order to be queried are the default query_band action.
- query_band is set in key-value pair mode, that is, 'key=value'. Multiple query_band key-value pairs can be set in a session. Multiple key-value pairs are separated by semicolons (;). The maximum length of both the **query_band** key-value pair and parameter value is 1024 characters.
- The query_band key-value pair supports the following valid characters: digits 0 to 9, uppercase letters A to Z, lowercase letters a to z, '.', '-', '_', and '#'.
- When multiple query_band key-value pairs are set in a session, the query_band key-value pair with a smaller order number is used as query_band for load identification. The minimum order number is **0**, and the default order number **–1** is the maximum order number. When the orders are the default order, query_band that is set ahead is used as query_band for load identification. For example, in set query_band='b=1;a=3;c=1'; b=1, indicating the order -1, a=3, indicating the order 4; c=1, indicating the order 1. In this case, c=1 is used as query_band for load identification. This design enables the load administrator to adjust load scheduling.
- Permission control: Except initial users, other users have the permission to set and query query_band only when they are authorized.
- When all running jobs are canceled in batches or the maximum number of concurrent jobs in a queue is 1 and only one queue is running jobs, the CN may be triggered to automatically wake up jobs. As a result, jobs are not delivered by priority.

## Query Band Actions

Table 9-1 lists the actions supported by query_band.

**Table 9-1** Actions supported by query_band

| Type | Action | Action Description |
| --- | --- | --- |
| Workload | Resource pool (respool) | query_band associated with a resource pool |
| Workload | Priority | Priority in the queue |
| Order | Queue (respool)<br>Currently, this field is invalid and is used for future extension. | query_band query order |

Run the following command to query the query_band action:

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```
SELECT * FROM pg_queryband_action;
 qband | respool_id | respool | priority | qborder
-------+------------+---------+----------+---------
 a=2   |          0 | NULL    | high     |       2
 a=3   |      16388 | p1      | rush     |       1
 a=1   |      16388 | p1      | Medium   |      -1
(3 rows)
```

# 9.3 Schema Space Control

## Context

The GaussDB(DWS) storage resource management manages and controls schema space. On one hand, the space of a single instance can be managed and controlled, preventing the database from being read-only and the disk from being full. On the other hand, space management and control are decoupled from users and queues, enabling users without permissions to manage and control space easier.

You can specify the storage space during schema creation to manage storage. This feature is only applicable to the storage of permanent tables (PERM SPACE). Schema storage space management supports storage management of table data. When a schema has a space limit, if the total table data in the schema exceeds the space limit during service execution, a service error occurs.

## Prerequisites

- enable_perm_space has been set to **on**, indicating that storage space control is enabled.
- use_workload_manager has been set to **on**, indicating that load management control is enabled.

## Procedure

**Step 1** Create a schema named **schema1** and set the permanent tablespace limit to **100 GB**:

```
CREATE SCHEMA schema1 WITH PERM SPACE '100G';
```

**Step 2** Change the permanent tablespace limit of **schema1** to **unlimited**:

```
ALTER SCHEMA schema1 WITH PERM SPACE 'unlimited';
```

**Step 3** Check whether the permanent tablespace limit has been set for **schema1**:

```
SELECT * FROM PG_NAMESPACE WHERE NSPNAME = 'schema1';
 nspname | nspowner | nsptimeline | nspacl | permspace | usedspace
---------+----------+-------------+--------+-----------+-----------
 schema1 |       10 |           0 |        |        -1 |         0
(1 row)
```

**----End**

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NOTE

- The schema space information is the storage space information of a single instance. The CN and DN instances are calculated separately and do not affect each other. In this way, job skew can be prevented.
- If the space used by a job exceeds the schema space limit, the job will be canceled and the information "out of schema's perm space limit" will be recorded in the log file in the **pg_log** directory.
- When the **max_query_retry_times** value of unlogged table is greater than **0**, that is, the SQL retry function is enabled, the table is considered as a common table and the used space is recorded in the permanent tablespace of the schema (PERM SPACE). When the value of **max_query_retry_times** is **0**, that is, the SQL retry function is disabled, the table is considered as a temporary table and the used space is not recorded in the schema permanent tablespace. If **max_query_retry_times** is switched during the use of an unlogged table, the result of determining whether the unlogged table is a temporary or common table will be different before and after the switchover. In addition, when data is added to or deleted from the corresponding table, the permanent data space in the corresponding schema changes abnormally, and the value is different from the actual physical space. If a primary/standby switchover occurs during the use of an unlogged table, data in the unlogged table will be lost. As a result, the amount of lost data in the corresponding schema space is different from that in the actual physical space.
- In the **PG_TOTAL_SCHEMA_INFO** view, there may be a deviation (about ±5%) between the used schema space and the actually used disk space. You can run the **select pgxc_wlm_readjust_schema_space()** function to correct the deviation. The correction function cannot be re-entered. Otherwise, the result is incorrect. If data is inserted into the table during the function correction, the statistics result may be incorrect.
- **CUDESC**, **CUDESC_INDEX**, **DELTA**, **CUDESC_PART** and **CUDESC_PART_INDEX** in column-based tables are auxiliary tables. The space of these auxiliary tables is recorded in the **CSTORE** schema space. The storage size of the **CBTREE** index in the column-based table is recorded to the schema in the primary table queue. But the storage size of the **PSORT** index is still recorded to the **CSTORE** schema space. The storage sizes of **TOAST** table and **TOAST** are recorded in the **PG_TOAST** schema space.
- The storage size of the table in tablespace is recorded in the schema where the table is located.
- Schema space control ignores **template0** and **template1** and does not control schemas in these two template libraries.
- In the scale-in or scale-out scenario, after data re-distribution, the schema space statistics will be inaccurate. You need to invoke the calibration function to recalibrate them.
- In the scenario where the distribution column of a table is modified, the schema space statistics will be inaccurate. You need to invoke the calibration function to recalibrate them.
- When VACUUM FULL or REINDEX is executed on the table, if a primary/standby switchover occurs due to a primary DN fault, the schema space statistics will be inaccurate. In this case, the calibration function needs to be invoked to calibrate the table again.
- A temporary schema is created during temporary table creation. The name of the temporary schema is similar to **pg_temp_*** and **pg_toast_temp_***. The space of the temporary schema is not limited, and the temporary schema information is not displayed in the view of **PG_TOTAL_SCHEMA_INFO**.
- For an upgrade from a version earlier than GaussDB(DWS) 8.1.0.3 to 8.1.0.3 or later, the perm space information collected in **PG_TOTAL_SCHEMA_INFO** does not include the space used before the upgrade. After the upgrade, you can run the select **pgxc_wlm_readjust_schema_space()** function to collect statistics on the space.
- GaussDB(DWS) provides the **PGXC_TOTAL_SCHEMA_INFO** and **PGXC_TOTAL_SCHEMA_INFO_ANALYZE** views for querying the schema space

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information of the cluster. The **PGXC_TOTAL_SCHEMA_INFO** view provides the schema space information of all instances in the cluster. The **PGXC_TOTAL_SCHEMA_INFO_ANALYZE** view summarizes and analyzes the schema space information of all instances in the cluster, and provides the total value, average value, skew ratio, maximum value, minimum value, maximum instance name, and minimum instance name of the cluster. In a logical cluster, the preceding two views provide the schema space information and analysis results of all logical clusters. If you focus only on a specific logical cluster, you can use the **PGXC_WLM_GET_SCHEMA_SPACE('lccluster1')** and **PGXC_WLM_ANALYZE_SCHEMA_SPACE('lccluster1')** functions provided by GaussDB(DWS) to obtain the schema space information of the logical cluster **lccluster1**.

## Viewing Schema Space Information

```
select * from pg_namespace;
 nspname           | nspowner | nsptimeline |         nspacl          | permspace | usedspace
--------------------+----------+-------------+-------------------------+-----------+-----------
 public            |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 dbms_redact       |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 schema1           |       10 |           0 |                         |        -1 |         0
 dbms_random       |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 pg_toast          |       10 |           0 |                         |        -1 |   2326528
 testt             |    28726 |           0 |                         |        -1 |      8192
 dbms_om           |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 dbms_job          |       10 |           0 | {lys1=UC/lys1,=UC/lys1} |        -1 |         0
 sys               |       10 |           0 |                         |        -1 |         0
 information_schema |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |    294912
 utl_file          |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 utl_raw           |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 dbms_output       |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 dbms_sql          |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 dbms_lob          |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |         0
 cstore            |       10 |           0 |                         |        -1 |    696320
 user1             |    16390 |           0 |                         |  22405120 |      8192
 pg_catalog        |       10 |           0 | {lys1=UC/lys1,=U/lys1}  |        -1 |  24903680
(18 rows)

select * from pg_total_schema_info;
 schemaid |     schemaname     | databaseid | databasename | usedspace | permspace
----------+--------------------+------------+--------------+-----------+-----------
       11 | pg_catalog         |      16389 | test         |         0 |        -1
       99 | pg_toast           |      16389 | test         |         0 |        -1
      100 | cstore             |      16389 | test         |         0 |        -1
     2200 | public             |      15095 | gaussdb      |         0 |        -1
     2200 | public             |      16389 | test         |         0 |        -1
     4230 | dbms_redact        |      15095 | gaussdb      |         0 |        -1
     3987 | dbms_om            |      15095 | gaussdb      |         0 |        -1
     3988 | dbms_job           |      15095 | gaussdb      |         0 |        -1
     3987 | dbms_om            |      16389 | test         |         0 |        -1
     3988 | dbms_job           |      16389 | test         |         0 |        -1
     4230 | dbms_redact        |      16389 | test         |         0 |        -1
    11693 | sys                |      15095 | gaussdb      |         0 |        -1
    28714 | test1              |      15095 | gaussdb      |         0 |        -1
    28715 | test3              |      15095 | gaussdb      |         0 |        -1
    28728 | redisuser          |      15095 | gaussdb      |         0 |        -1
    28730 | testt              |      15095 | gaussdb      |      8192 |        -1
    28766 | redisuser1         |      15095 | gaussdb      |         0 |        -1
    28798 | schema1            |      15095 | gaussdb      |         0 |        -1
    11693 | sys                |      16389 | test         |         0 |        -1
    14147 | information_schema |      15095 | gaussdb      |    294912 |        -1
    14490 | utl_file           |      15095 | gaussdb      |         0 |        -1
    14515 | utl_raw            |      15095 | gaussdb      |         0 |        -1
    14508 | dbms_output        |      15095 | gaussdb      |         0 |        -1
    14512 | dbms_random        |      15095 | gaussdb      |         0 |        -1
    14520 | dbms_sql           |      15095 | gaussdb      |         0 |        -1
    14547 | dbms_lob           |      15095 | gaussdb      |         0 |        -1
    14147 | information_schema |      16389 | test         |         0 |        -1
    14490 | utl_file           |      16389 | test         |         0 |        -1
```

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```
  14508 | dbms_output        |      16389 | test          |         0 |        -1
  14515 | utl_raw            |      16389 | test          |         0 |        -1
  14512 | dbms_random        |      16389 | test          |         0 |        -1
  14520 | dbms_sql           |      16389 | test          |         0 |        -1
  14547 | dbms_lob           |      16389 | test          |         0 |        -1
     11 | pg_catalog         |      15095 | gaussdb       |  22405120 |  22405120
     99 | pg_toast           |      15095 | gaussdb       |   2326528 |        -1
    100 | cstore             |      15095 | gaussdb       |    696320 |        -1
  16392 | user1              |      15095 | gaussdb       |      8192 |        -1
(37 rows)

select * from  pgxc_total_schema_info;
    schemaname     | schemaid | databasename | databaseid |   nodename   |  nodegroup   | usedspace |
permspace
--------------------+----------+--------------+------------+--------------+--------------+-----------+-----------
 pg_catalog         |       11 | test1        |      16384 | datanode1    | installation |   9469952 |        -1
 public             |     2200 | gaussdb      |      15253 | datanode1    | installation |  25280512 |        -1
 pg_toast           |       99 | test1        |      16384 | datanode1    | installation |   1859584 |        -1
 cstore             |      100 | test1        |      16384 | datanode1    | installation |         0 |        -1
 data_redis         |    18106 | gaussdb      |      15253 | datanode1    | installation |    655360 |        -1
 data_redis         |    18116 | test1        |      16384 | datanode1    | installation |         0 |        -1
 public             |     2200 | test1        |      16384 | datanode1    | installation |     16384 |        -1
 dbms_om            |     3987 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 dbms_job           |     3988 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 dbms_om            |     3987 | test1        |      16384 | datanode1    | installation |         0 |        -1
 dbms_job           |     3988 | test1        |      16384 | datanode1    | installation |         0 |        -1
 sys                |    11693 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 sys                |    11693 | test1        |      16384 | datanode1    | installation |         0 |        -1
 utl_file           |    14644 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 utl_raw            |    14669 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 dbms_sql           |    14674 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 dbms_output        |    14662 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 dbms_random        |    14666 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 dbms_lob           |    14701 | gaussdb      |      15253 | datanode1    | installation |         0 |        -1
 information_schema |    14300 | gaussdb      |      15253 | datanode1    | installation |    294912 |        -1
 information_schema |    14300 | test1        |      16384 | datanode1    | installation |    294912 |        -1
 utl_file           |    14644 | test1        |      16384 | datanode1    | installation |         0 |        -1
 dbms_output        |    14662 | test1        |      16384 | datanode1    | installation |         0 |        -1
 dbms_random        |    14666 | test1        |      16384 | datanode1    | installation |         0 |        -1
 utl_raw            |    14669 | test1        |      16384 | datanode1    | installation |         0 |        -1
 dbms_sql           |    14674 | test1        |      16384 | datanode1    | installation |         0 |        -1
 dbms_lob           |    14701 | test1        |      16384 | datanode1    | installation |         0 |        -1
 pg_catalog         |       11 | gaussdb      |      15253 | datanode1    | installation |  13017088 |        -1
 redisuser          |    16387 | gaussdb      |      15253 | datanode1    | installation |    630784 |        -1
 pg_toast           |       99 | gaussdb      |      15253 | datanode1    | installation |   3080192 |        -1
 cstore             |      100 | gaussdb      |      15253 | datanode1    | installation |   2408448 |        -1
 pg_catalog         |       11 | test1        |      16384 | datanode2    | installation |   9469952 |        -1
 public             |     2200 | gaussdb      |      15253 | datanode2    | installation |  25214976 |        -1
 pg_toast           |       99 | test1        |      16384 | datanode2    | installation |   1859584 |        -1
 cstore             |      100 | test1        |      16384 | datanode2    | installation |         0 |        -1
 data_redis         |    18106 | gaussdb      |      15253 | datanode2    | installation |    655360 |        -1
 data_redis         |    18116 | test1        |      16384 | datanode2    | installation |         0 |        -1
 public             |     2200 | test1        |      16384 | datanode2    | installation |     16384 |        -1
 dbms_om            |     3987 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 dbms_job           |     3988 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 dbms_om            |     3987 | test1        |      16384 | datanode2    | installation |         0 |        -1
 dbms_job           |     3988 | test1        |      16384 | datanode2    | installation |         0 |        -1
 sys                |    11693 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 sys                |    11693 | test1        |      16384 | datanode2    | installation |         0 |        -1
 utl_file           |    14644 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 utl_raw            |    14669 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 dbms_sql           |    14674 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 dbms_output        |    14662 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 dbms_random        |    14666 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 dbms_lob           |    14701 | gaussdb      |      15253 | datanode2    | installation |         0 |        -1
 information_schema |    14300 | gaussdb      |      15253 | datanode2    | installation |    294912 |        -1
 information_schema |    14300 | test1        |      16384 | datanode2    | installation |    294912 |        -1
 utl_file           |    14644 | test1        |      16384 | datanode2    | installation |         0 |        -1
 dbms_output        |    14662 | test1        |      16384 | datanode2    | installation |         0 |        -1
```

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```
 dbms_random        |    14666 | test1        |      16384 | datanode2     | installation |         0 |        -1

select * from  pgxc_total_schema_info_analyze;
     schemaname     | databasename |  nodegroup   | total_value | avg_value | skew_percent |
extend_info
--------------------+--------------+--------------+-------------+-----------+--------------
+-----------------------------------------------
 pg_catalog         | test1        | installation |    56819712 |   9469952 |            0 | min:9469952
datanode1,max:9469952 datanode1
 public             | gaussdb      | installation |   150495232 |  25082538 |            0 | min:24903680
datanode6,max:25280512 datanode1
 pg_toast           | test1        | installation |    11157504 |   1859584 |            0 | min:1859584 datanode1,max:
1859584 datanode1
 cstore             | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 data_redis         | gaussdb      | installation |     1966080 |    327680 |           50 | min:0 datanode4,max:
655360 datanode1
 data_redis         | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 public             | test1        | installation |       98304 |     16384 |            0 | min:16384 datanode1,max:
16384 datanode1
 dbms_om            | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0
datanode1
 dbms_job           | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 dbms_om            | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 dbms_job           | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 sys                | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 sys                | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 utl_file           | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 utl_raw            | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 dbms_sql           | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 dbms_output        | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0
datanode1
 dbms_random        | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0
datanode1
 dbms_lob           | gaussdb      | installation |           0 |         0 |            0 | min:0 datanode1,max:0
datanode1
 information_schema | gaussdb      | installation |     1769472 |    294912 |            0 | min:294912
datanode1,max:294912 datanode1
 information_schema | test1        | installation |     1769472 |    294912 |            0 | min:294912
datanode1,max:294912 datanode1
 utl_file           | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 dbms_output        | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0
datanode1
 dbms_random        | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0
datanode1
 utl_raw            | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 dbms_sql           | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 dbms_lob           | test1        | installation |           0 |         0 |            0 | min:0 datanode1,max:0 datanode1
 pg_catalog         | gaussdb      | installation |    75210752 |  12535125 |            3 | min:12091392
datanode4,max:13017088 datanode1
 redisuser          | gaussdb      | installation |     1884160 |    314026 |           50 | min:16384 datanode4,max:
630784 datanode1
 pg_toast           | gaussdb      | installation |    17154048 |   2859008 |            7 | min:2637824
datanode4,max:3080192 datanode1
 cstore             | gaussdb      | installation |    15294464 |   2549077 |            5 | min:2408448 datanode1,max:
2703360 datanode6
(31 rows)
```

# 9.4 Memory Management

## 9.4.1 Overview

### Overview

Sufficient memory is important for GaussDB(DWS) running. Effective utilization of the memory helps improve service query performance.

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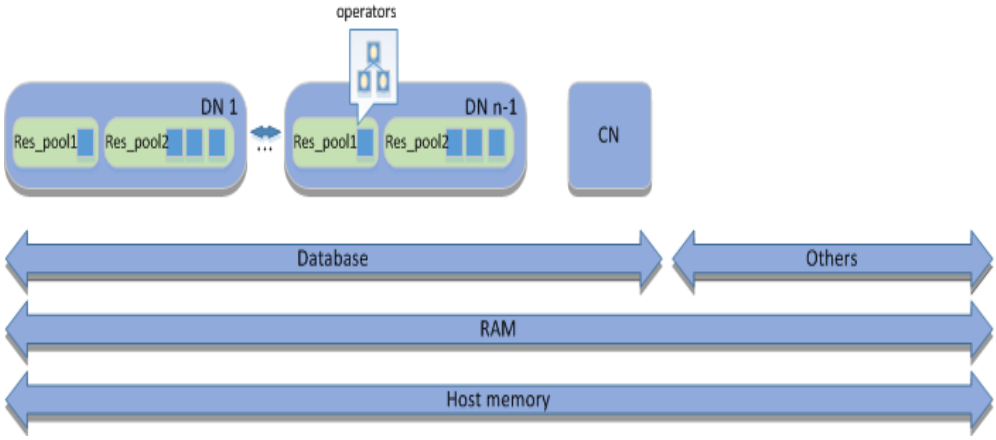
The resource pool is a collection of system resources managed by GaussDB(DWS), responsible for distributing and managing task resources running in it.

## Host Memory

On a GaussDB(DWS) node, the memory on the host is shared among all running processes, including the OS processes, GaussDB(DWS) instance processes, and other application processes. The administrator must monitor the memory shared between GaussDB(DWS) and non-GaussDB(DWS) processes.

**Figure 9-2** Memory usage on a GaussDB(DWS) node




- "Host memory" represents the total memory, that is the physical memory RAM on the server. (On a Linux server, the host memory includes the swap cache as well. As GaussDB(DWS) uses precise memory management, here only the physical memory RAM is included in the host memory.) The physical memory RAM is shared by GaussDB(DWS) processes and all other processes running on the host. Some programs may occupy a large volume of resources. You can resolve the problem by adjusting the number of DNs on each node or increasing the physical memory.
- If the node is deployed with a CN, the CN and DNs share the memory occupied by GaussDB(DWS).
- On each DN, the memory occupied by the DN is shared in a resource pool.
- Concurrent SQL statements (represented by small blue blocks in the figure) running in the resource pools share the memory occupied by the resource pool.
- The query optimizer generates an execution plan containing a series of tasks (or operators, as shown in the figure). Task operators, such as table scanning or joining operators, process data records and generate an interim result set. All operators in a query share the memory occupied by the query statement.

## Configuring Host Memory

Host memory is the memory shared by all programs on a server. You can increase the physical memory by adding RAM to the server.

Generally, the physical memory and OS configuration are managed by system administrators.

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## 9.4.2 Job-Level Memory Control

### Context

GaussDB(DWS) can control memory at job level. This helps you more efficiently utilize memory resources than **work_mem** does.

### Prerequisites

The cluster has been installed and works properly.

### Memory Parameters

You can set **query_mem** for a session to control memory available for jobs.

### Procedure

The database administrator can manage the logical memory of the database by taking the following steps:

**Step 1** Set **query_mem** to **500MB**.

```
set query_mem='500MB';
SET
```

**Step 2** Execute the job.

**----End**

**NOTICE**

If **query_mem** exceeds the upper limit of memory available in the resource pool or is less than 256 MB, **query_mem** will not take effect. Available memory for jobs is still controlled by **work_mem**.

# 9.5 Basic Framework for Resource Load Management

## 9.5.1 Resource Pools

### Context

The core element of resource load management in GaussDB(DWS) is the resource pool, which provides attributes to control memory, I/O, and CPU resources at the bottom layer and to manage and allocate resources based on the priority-based task scheduling mechanism, managing resource load for user services.

Resource pool-oriented load management includes concurrence management and priority-based task scheduling.

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## Overview

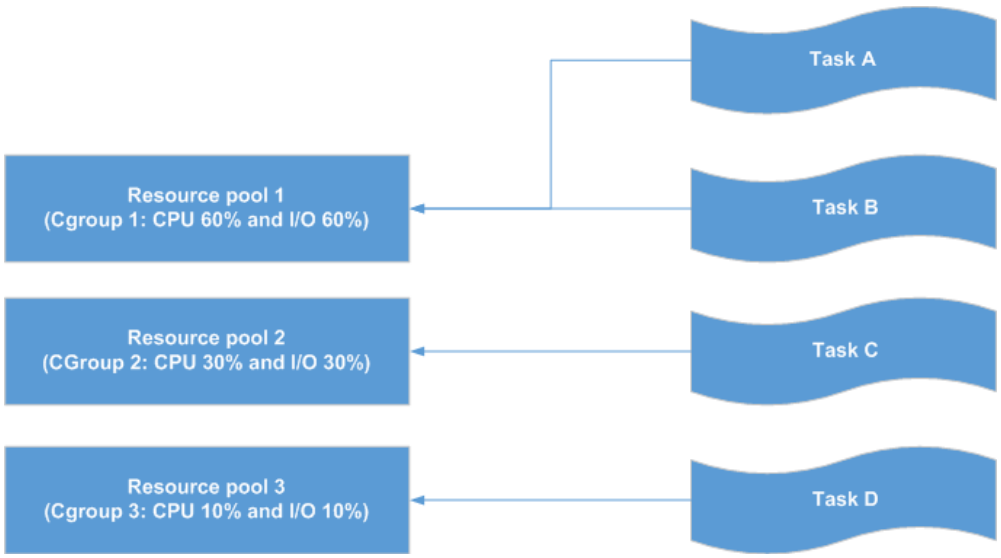
The resource pool is a resource configuration mechanism for allocating host resources. You can specify resources and concurrency queue attributes for a resource pool, and then configure the available resources for a job by binding it to the resource pool.

The database administrator binds the resource pool to its corresponding Cgroup based on different service types.

## Resource Pool-Oriented Load Management

**Figure 9-3** illustrates how resource loads are managed.

**Figure 9-3** Load management




A resource pool allocates resources through its binding Cgroup. The task priority depends on the resource volume allocated to the binding resource pool. Generally, the more resources a resource pool has, the higher priority a binding task possesses, as the task will have more resources for execution.

In this figure:

- The priority of task A is higher than that of task C and task D, because the resource pool that task A is bound to has the largest volume of resources.
- Task A and Task B possess the same priority and share system resources allocated to resource pool 1 in equal during competition because the two are in the same resource pool.

To adjust the priority of a task, you can simply change its binding resource pool.

## Initialization Process

**Figure 9-4** and **Table 9-2** illustrates the details of the operation process in resource load management.

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**Figure 9-4** Load management workflow

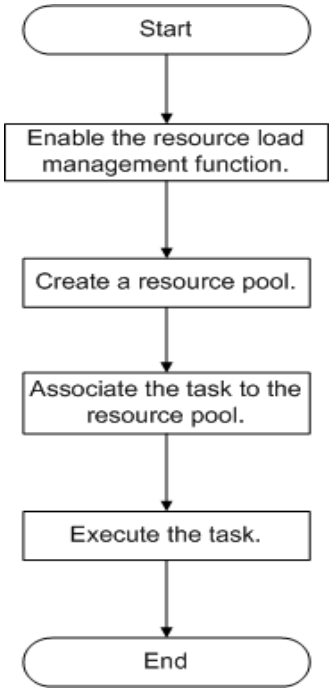


**Table 9-2** Load management tasks

| Task | Description |
| --- | --- |
| **Resource Pools** | Create a resource pool using the DDL statements provided in GaussDB(DWS), or modify or remove a resource pool using corresponding DDL statements. |
| **Associated Jobs** | Associate a user to a resource pool to bind the tasks to a specified resource pool before executing the task. |
| Executing the task | - |

## default_pool

After the resource load management function is enabled, **default_pool** is automatically created by the system. A session or user not associated with a resource pool is associated with **default_pool**. By default, **default_pool** is bound with the DefaultClass:Medium Cgroup and does not limit the number of concurrent services.

For detailed **default_pool** attributes, see **Table 9-3**.

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**Table 9-3** default_pool attributes

| Attribute | Value | Description |
| --- | --- | --- |
| respool_name | default_pool | Specifies the name of the resource pool. |
| mem_percent | 100 | Specifies the maximum memory usage. |
| cpu_affinity | -1 | Specifies the CPU affinity (reserved). |
| control_group | DefaultClass:Medium | Specifies the Cgroup associated with the resource pool. |
| active_statements | -1 | Specifies the maximum number of concurrent queries allowed by the resource pool. The value **-1** indicates that the number of concurrent queries is not limited. |
| max_dop | 1 | Concurrency level of execution operators after the SMP is enabled (reserved). |
| memory_limit | 8 GB | Specifies the upper memory usage limit (reserved). |
| parentid | 0 | Specifies the OID of the parent resource pool. |
| io_limits | 0 | Specifies the upper limit of I/Os per second. It is counted by ones in a column-store table and by ten thousands in a row-store table. **0** indicates that the upper limit of I/Os per second is not controlled. |
| io_priority | None | I/O priority set for jobs that consume many I/O resources. It takes effect when I/O usage reaches 90%. Its values **Low**, **Medium**, and **High** correspond to 25%, 50%, and 80% of the IOPS used by each job when it was triggered, respectively. **None** indicates the priority is not controlled. |

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NOTICE

- **default_pool** cannot be modified in GaussDB(DWS).
- For the services associated with **default_pool**, the number of concurrent queries is limited by the **max_active_statements** parameter. **max_active_statements** specifies the maximum number of queries that can be performed on a CN.

## Procedure

Creating a resource pool

After resource load management is enabled, the default resource pool is insufficient to address the resource load management requirements of services. Therefore, new resource pools must be used to reallocate system resources to address the requirements.

After connecting to the database as user or a user with database administrator permissions, you can run SQL statements to create and manage resource pools. For details about the syntax, see CREATE RESOURCE POOL, ALTER RESOURCE POOL, and DROP RESOURCE POOL.

- Create a resource pool associated with the default Cgroup. If you do not specify an associated Cgroup when creating a resource pool, the resource pool will be associated with the default Cgroup, which is the Timeshare Cgroup **Medium** under the **DefaultClass** Cgroup.
  ```
  CREATE RESOURCE POOL respool1;
  ```
  If the following information is displayed, the resource pool has been created.
  ```
  CREATE RESOURCE POOL
  ```
- Create a resource pool associated with the **Rush** timeshare Cgroup.
  ```
  CREATE RESOURCE POOL respool2 WITH (control_group='Rush');
  ```
  If the following information is displayed, the resource pool has been created.
  ```
  CREATE RESOURCE POOL
  ```

  NOTE

  - The value of **control_group** is case-sensitive and must be contained in quotation marks (').
  - Only strings indicating Timeshare Cgroups (**Rush**, **High**, **Medium**, or **Low**) can be specified. For example, set **control_group** to **High**. The resource pool is specified to the Timeshare Cgroup whose **control_group** is **High** under DefaultClass.
- Create a resource pool that limits the number of concurrent queries. When creating a resource pool, you can set **active_statements** to specify the maximum number of concurrent tasks associated with the resource pool. If the limit is exceeded, a task queue is implemented to control the number of concurrent tasks.
  ```
  CREATE RESOURCE POOL respool3 WITH (active_statements=5);
  ```
  If the following information is displayed, the resource pool has been created.
  ```
  CREATE RESOURCE POOL
  ```

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NOTE

1. The default value of **active_statements** is **10**, indicating that there are a maximum of 10 concurrent tasks on a resource pool.
2. The value range of **active_statements** is from **-1** to **INT_MAX**, where **-1** indicates that the number of concurrent tasks is not limited.

- Create a resource pool that limits available memory. While creating a resource pool, you can set **MEM_PERCENT** to specify the maximum memory available to the resource pool. **MEM_PERCENT** is an integer ranging from 0 to 100.
  ```
  CREATE RESOURCE POOL respool4 WITH (MEM_PERCENT=20);
  ```
  If the following information is displayed, the resource pool has been created.
  ```
  CREATE RESOURCE POOL
  ```

  NOTE

  Set the size of the memory used by the resource pool to 20% of the available memory size.

Managing resource pools

After creating resource pools, an administrator often needs to manage resource pools as required, such as adjusting resource pool configurations or deleting obsolete resource pools.

Resource pool management includes:

- Modifying resource pool attributes
  - Modifying Cgroups associated with resource pools
    ```
    ALTER RESOURCE POOL respool1 WITH (control_group="Rush");
    ```
    If the following information is displayed, the Cgroup has been modified.
    ```
    ALTER RESOURCE POOL
    ```
  - Modifying the number of concurrent tasks of resource pools
    ```
    ALTER RESOURCE POOL respool1 WITH (ACTIVE_STATEMENTS=15);
    ```
    If the following information is displayed, the number of concurrent tasks has been modified.
    ```
    ALTER RESOURCE POOL
    ```
  - Modifying the upper limit on the available memory of resource pools
    ```
    ALTER RESOURCE POOL respool1 WITH (MEM_PERCENT=20);
    ```
    If the following information is displayed, the upper limit of the available resource pool memory has been modified.
    ```
    ALTER RESOURCE POOL
    ```

  For more usage, see ALTER RESOURCE POOL.
- **DROP RESOURCE POOL** deletes a resource pool.
  ```
  DROP RESOURCE POOL respool1;
  DROP RESOURCE POOL
  ```

## Managing Local Concurrent Tasks

The local number of concurrent tasks indicates the maximum number of tasks that can be concurrently executed on one resource pool. The number is specified by **ACTIVE_STATEMENTS**.

Generally, the global number of concurrent tasks must be greater than the sum of local number of concurrent tasks. If the global concurrency is less than the sum of

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local concurrency, the actual number of concurrent jobs will not exceed the configured global concurrency.

You can specify the number of concurrent tasks of a resource pool either when creating a resource pool or change the number after creating the resource pool.

- To specify the number when creating a resource pool:
  **CREATE RESOURCE POOL** *pool1* **WITH** (**ACTIVE_STATEMENTS**=5);
- To change the number after creating a resource pool:
  **ALTER RESOURCE POOL** *pool1* **WITH** (**ACTIVE_STATEMENTS**=3);

  The resource pool uses the method of calculating the concurrent points to calculate the number of concurrent tasks, and the formula is:

  Number of points used during task execution: active_points = (query_mem/respool_mem) x active_statements x 100

  Total number of points of a resource pool: total_points = active_statements x 100

  Unit points: 100

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NOTE

- The points are used when **query_mem** is not used during task execution.
- After all the points of a resource pool are used up, the jobs will enter a first in first out (FIFO) queue.
- **MAX_DOP** limits the number of concurrent fast lanes. The value ranges from **1** to **INT_MAX**. The default value is **-1**, indicating that the number of concurrent fast lanes is not limited.
- The value range of **ACTIVE_STATEMENTS** is from **-1** to **INT_MAX**. The default value is **10**, which is recommended. The values **0** and **-1** mean that slow lane concurrency is not subject to the value of **ACTIVE_STATEMENTS**.
- The value of **MEM_PERCENT** ranges from **0** to **100**. When the value is set to **0**, the slow lane concurrency is not subject to the value of **MEM_PERCENT**.
- The slow lane concurrency is restricted by **ACTIVE_STATEMENTS** and **MEM_PERCENT**. The point control mode is used. The total number of points is determined by **ACTIVE_STATEMENTS**.
  - When **ACTIVE_STATEMENTS** is set to **-1** or **0**, the value of **total_points** is **90**.
  - Job points are classified into memory points and concurrent points. The number of memory points is determined by the estimated memory of a job. The number of concurrent points is fixed at 100. The number of memory points and that of concurrent points are controlled separately. After the limit is exceeded, the slow lane query triggers queuing, and the queue complies with the FIFO rule.
- Generally, the global concurrency must be greater than or equal to the sum of local concurrency. If the global concurrency is less than the sum of local concurrency, the actual number of concurrent jobs will not exceed the configured global concurrency.
- In non-adaptive-load scenarios, a complex statement is a statement whose execution cost is greater than or equal to the value of the GUC parameter parctl_min_cost. Among common statements, the DDL statements and **SET** statements, which come with low execution costs, are not restricted to local concurrency.
- In adaptive load scenarios, a complex statement is a statement whose estimated memory usage is greater than a specified threshold (32 MB currently).
- If **enable_transaction_parctl** is set to **off**, stored procedures and transactions are not restricted by local concurrency control.
- If **enable_transaction_parctl** is set to **on**, **transaction_pending_time** is set to a value greater than **0**, and the number of transaction block statements and stored procedure statements waiting in a queue exceeds the specified value, the statements will be forcibly executed regardless of the current resource status.
- Statements triggered by internal logics, such as the internal logics of system views and the execution logics of **gs_clean** and CM tools, are not restricted to local concurrency.
- You can manage memory and concurrency separately or jointly. Under joint management and control, jobs can be executed only when both the memory and concurrency meet the delivery conditions.

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## Viewing the Current Resource Pool

**NOTICE**

- Do not use **insert**, **update**, **delete**, or **truncate** in the system catalog **pg_resource_pool** for resource load management. Otherwise, the contents of **pg_resource_pool** queried through different CNs may be inconsistent.
- Do not modify the **cpu_affinity** attribute of a resource pool.

- View the resource pool associated with a user.

```
SELECT rolrespool FROM PG_AUTHID WHERE rolname = 'rolename';
 rolrespool
-------------
 default_pool
(1 row)
```

- View all the resource pool information of the current cluster.

```
SELECT * FROM PG_RESOURCE_POOL;
 respool_name | mem_percent | cpu_affinity |     control_group     | active_statements | max_dop |
memory_limit | parentid | io_limits | io_priority
--------------+-------------+--------------+-----------------------+-------------------+---------+--------------
+----------+-----------+-------------
 default_pool |         100 |           -1 | DefaultClass:Medium |                -1 |       1 | 8GB          |        0
|         0 | None
(1 row)
```

## Viewing the Cgroup Information Associated with a Resource Pool

View the Cgroup information associated with a resource pool. In the following example, **resource_pool_a1** is the name of the resource pool.

```
SELECT * FROM gs_control_group_info('resource_pool_a1');
        name         |  class  |  workload   | type  | gid | shares | limits | rate | cpucores
---------------------+---------+-------------+-------+-----+--------+--------+------+----------
 class_a:workload_a1 | class_a | workload_a1 | DEFWD |  87 |     30 |      0 |    0 | 0-3
(1 row)
```

**Table 9-4** gs_control_group_info attributes

| Attribute | Value | Description |
| --- | --- | --- |
| name | class_a:workload_a1 | Class name and workload name |
| class | class_a | Class Cgroup name |
| workload | workload_a1 | Workload Cgroup name |
| type | DEFWD | Cgroup type (Top, CLASS, BAKWD, DEFWD, and TSWD) |
| gid | 87 | Cgroup ID |
| shares | 30 | Percentage of CPU resources to those on the parent node |
| limits | 0 | Percentage of CPU cores to those on the parent node |
| rate | 0 | Allocation ratio in Timeshare |

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| Attribute | Value | Description |
| --- | --- | --- |
| cpucores | 0-3 | CPU core count |

## 9.5.2 Associated Jobs

### Context

After allocating system resources using resource pools, you must associate tasks with resource pools for service load management.

After a resource pool is associated with a user, all the tasks of the user are automatically associated with the resource pool.

### Procedure

**Step 1** Create a resource pool **respool** associated with the default Cgroup.

```
CREATE RESOURCE POOL respool;
CREATE RESOURCE POOL
```

NOTE

You can associate the resource pool with a user-defined Cgroup as required. For details, see **Resource Pools**.

**Step 2** Create user **user1** and associate the user with the **respool** resource pool.

```
CREATE USER user1 WITH RESOURCE POOL 'respool' password 'password';
```

**Step 3** Run **job.sql** as user **user1**.

```
gsql -U user1 -W password -d gaussdb -p 8000 -f job.sql
```

Alternatively, connect to the related database as user **user1** and run the task.

```
gsql -U user1 -W password -d gaussdb -p 8000
```

**----End**

# 9.6 Priority-based Scheduling

## 9.6.1 CPU

Priority scheduling can be based on CPU or I/O usage. The former puts new tasks in a resource pool based on the priority of associated Cgroups, and the latter suspends I/O requests in the database. This section mainly describes CPU priority scheduling.

### Prerequisites

Resource load management has been enabled.

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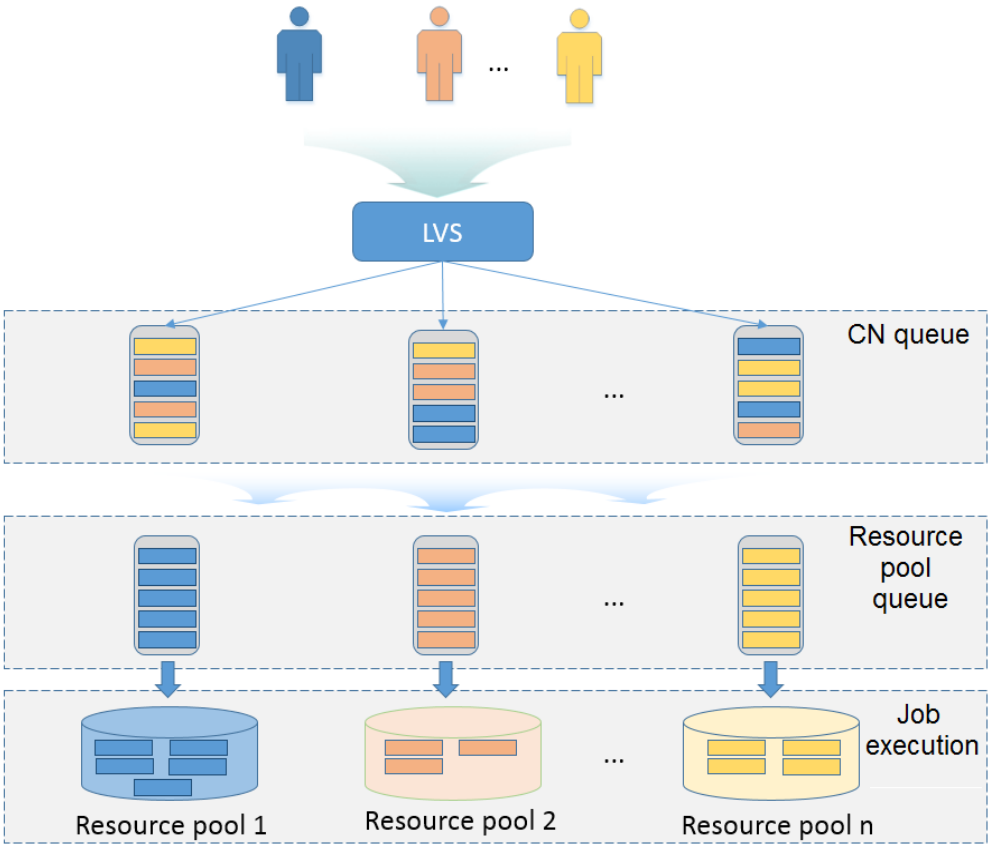
## Context

After the number of concurrent tasks of a resource pool reaches the upper limit, new tasks enter the waiting queue of the resource pool.

**Figure 9-5** shows the queue mechanism in resource load management.

**Figure 9-5** Queue mechanism for load management




Users' tasks enter queues of CNs, queues of resource pools, and then resource pools for execution. The process is described as follows:

1. Users' tasks are distributed by the Linux Virtual Server (LVS) to queues of CNs. Alternatively, tasks are directly distributed by users to the queues. On any CN, tasks are processed in the first-in-first-out (FIFO) principle, which means that a task entering the queue of a CN earlier than another task enters the following step before the other task.
2. In the queue of any CN, a task is distributed to the queue of the resource pool corresponding to the task according to the following rules: based on the following rules:
   - The tasks in the queue of a CN are distributed in the FIFO principle.
   - A task is distributed to the queue of the resource pool bound with the user who initiates the task. If no resource pool is bound with the user, the task is distributed to the queue of the default resource pool **default_pool**.

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3. The tasks in the queue of a resource pool are executed in the FIFO principle. If the idle resources in a resource pool meet the requirement of the first task (counted from bottom to top) in the queue of the resource pool, the task enters the resource pool for execution.

## Procedure

- Adjust resource pool priorities.

  If the resource proportion of a resource pool changes, change the priority of the resource pool accordingly. You can change the priority by modifying attributes in the resource pool.

  ```
  ALTER RESOURCE POOL respool2 WITH(CONTROL_GROUP = "Rush");
  ```

  NOTE

  The preceding statement changes the attribute of the Cgroup associated with a resource pool to **Rush**.

- Adjust the priority of the current user. You can change the priority of a user by changing the resource pool it binds to. For example:

  ```
  ALTER USER user1 WITH RESOURCE POOL 'respool2';
  ```

  Where **user1** is the user whose priority is to be changed, and **respool2** is the resource pool it is to be bound to. You need the sysadmin permission to adjust priorities.

- Adjust the priority of the current session.

  You can change the Cgroup bound with the current session to adjust the priorities of the tasks in the session. For example:

  ```
  SET CGROUP_NAME="Rush";
  ```

  Query for the Cgroup associated with the current session.

  ```
  SHOW CGROUP_NAME;
  ```

- Manually changing the positions of tasks in queues.

  If the priority of a task must be increased or a task must be executed at an earlier time, an administrator can change the position of the task in the queue.

  a. Query for the PID of the task in the queue of a CN.

  ```
  SELECT * FROM pg_session_wlmstat where status = 'pending';
  ```

  b. Move the task to the first position of the queue.

  ```
  SELECT pg_wlm_jump_queue(threadid);
  ```

  c. Change the priority of the task to **High** during the task execution. You can query the **pg_session_wlmstat** view for the thread ID of the task.

  ```
  SELECT gs_wlm_switch_cgroup(threadid, 'High');
  ```

  NOTE

  Only the administrator can adjust the priorities of tasks being executed.

# 9.6.2 I/O

## Context

Control I/O resources for data import or complex queries.

I/O resources can be managed based on priority or upper limits at session- or user-level.

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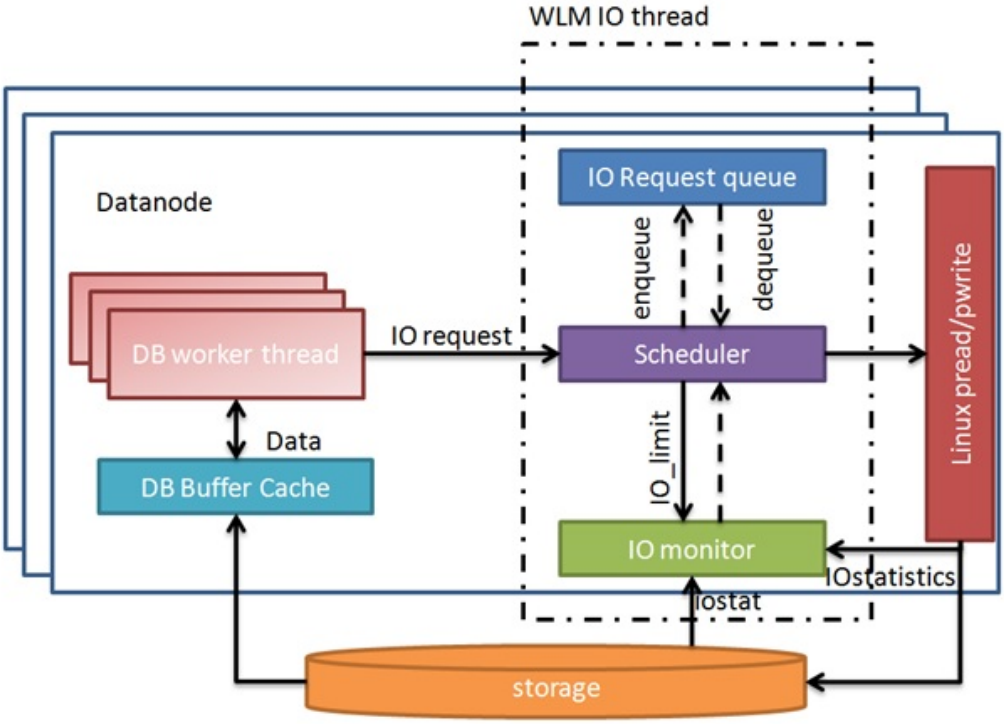
**Figure 9-6** illustrates how I/O resources are managed.

**Figure 9-6** Managing I/O resources




I/O resource management complies with the following rules:

- Not all statement I/O is controlled. The write I/O of only **INSERT INTO SELECT**, **COPY FROM**, and **CREATE TABLE AS** statements can be controlled. Read I/O will be controlled if the amount of data to be scanned on a single DN exceeds 500 MB. The data volume is estimated by the optimizer. **VACUUM FULL**, **CREATE INDEX**, **CLUSTER TABLE USING INDEX**, **ANALYZE**, and **MERGE INTO** are read/write operations and will possibly trigger I/O control under certain conditions.
- You need to manually set GUC parameter or resource pool settings to enable I/O control.
- The GUC parameters **io_priority** and **io_limits** can control I/O based on priority and upper limit, respectively, at session level.
- You can set **io_limits** or **io_priority**, and associate a user with a resource pool to implement control I/O at user level.
- **io_limits** controls the maximum number of I/O requests that can be triggered per second. The default value is **0**, indicating no control. The number of requests is counted by ones for column storage and by thousands for row storage.
- When the disk usage reaches 90%, the I/O control specified by **io_priority** is triggered. The priority can be **High**, **Medium**, or **Low**, which indicate that 80%, 50%, or 20% of I/O triggered by jobs are controlled. The default value is **None**, indicating no control.

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NOTE

- According to the buffer policy, read/write I/O requests are controlled for row storage during buffer read/write instead of disk read/write. The unit of **io_limits** is ten thousand times per second. The value can be set to around **100**. You are advised to use **io_priority** for row storage, so that I/O resources can be fully utilized when they are sufficient.
- The mechanisms for querying and importing data in column-store storage are different from those in row storage. The value of **io_limits** can be set to around **100**. Values much larger may fail to control I/O.

### Querying I/O Resource Management Views

- **pg_session_iostat** monitors I/O resources at the session level.
  ```
  select * from pg_session_iostat;
  ```
- **pg_user_iostat** monitors I/O resources at the user level.
  ```
  select * from pg_user_iostat('username');
  ```

## 9.7 Storage Space Management

### Scenarios

Users using too much storage space may result in service blocking. To prevent this problem, you need to enhance the control over the storage space.

### Storage Space Management

- User space limit

### Procedure

Assume that you need to set the maximum space of user **user1** to 100 GB.

**Step 1** Create user **user1**.

```
CREATE USER user1 PASSWORD 'password' PERM SPACE '100G';
```

**Step 2** Insert data as user **user1**.

**----End**

NOTE

1. The CN periodically obtains and checks space information from a DN. The interval is 10s.

2. When detecting that the required space exceeds the current available space, the CN cancels all data inserting jobs and records the following information in the log file in the **pg_log** directory: "cancel thread <threadid> for space limit exceed."

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# 10 Resource Monitoring

GaussDB(DWS) provides multiple dimensional resource monitoring views to show the real-time and historical resource usage of tasks.

## 10.1 User Resource Query

### Context

In the multi-tenant management framework, you can query the real-time or historical usage of all user resources (including memory, CPU cores, storage space, temporary space, and I/Os).

NOTE

- User real-time resource views/functions: **PG_TOTAL_USER_RESOURCE_INFO** and GS_WLM_USER_RESOURCE_INFO; user historical resource table: **GS_WLM_USER_RESOURCE_HISTORY**.
- In the preceding views and tables, the value of **used_cpu** indicates the CPU usage of a user's resource pool. The resource pool records only the CPU usage of long queries.
- In the preceding views and tables, I/O-related resource statistics only record I/O read and write data of long queries executed by users.
- When there are a large number of users and a large cluster, querying such real-time views will cause network latency due to the real-time communication overhead between CNs and DNs.
- User memory and CPU monitoring does not apply to short queries or administrator jobs.

### Procedure

- Query all users' resource quotas and real-time resource usage.

```
SELECT * FROM PG_TOTAL_USER_RESOURCE_INFO;
```

The result view is as follows:

```
username       | used_memory | total_memory | used_cpu | total_cpu | used_space | total_space |
used_temp_space | total_temp_space | used_spill_space | total_spill_space | read_kbytes | write_kbytes |
read_counts | write_counts | read_speed | write_speed
----------------------+-------------+--------------+----------+-----------+------------+-------------
+-----------------+------------------+------------------+-------------------+-------------+--------------
+-------------+--------------+------------+-------------
perfadm             |           0 |        17250 |        0 |         0 |          0 |          -1 |            0 |
-1 |             0 |             -1 |           0 |           0 |           0 |           0 |          0 |           0
usern               |           0 |        17250 |        0 |        48 |          0 |          -1 |            0 |            -1
```

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```
|             0 |             -1 |          0 |          0 |          0 |          0 |          0 |          0
userg           |         34 |       15525 |    23.53 |       48 |         0 |         -1 |           0 |
-1 |       814955731 |            -1 |     6111952 |     1145864 |     763994 |      143233 |     42678
|       8001
user1           |         34 |       13972 |    23.53 |       48 |         0 |         -1 |           0 |
-1 |       814972419 |            -1 |     6111952 |     1145864 |     763994 |      143233 |     42710
|       8007
(4 rows)
```

The I/O resource monitoring fields (**read_kbytes**, **write_kbytes**, **read_counts**, **write_counts**, **read_speed**, and **write_speed**) can be available only when the GUC parameter enable_user_metric_persistent is enabled.

For details about each column, see **PG_TOTAL_USER_RESOURCE_INFO**.

- Query a user's resource quota and real-time resource usage.

```
SELECT * FROM GS_WLM_USER_RESOURCE_INFO('username');
```

The query result is as follows:

```
userid | used_memory | total_memory | used_cpu | total_cpu | used_space | total_space |
used_temp_space | total_temp_space | used_spill_space | total_spill_space | read_kbytes | write_kbytes |
read_counts | write_counts | read_speed | write_speed
--------+-------------+--------------+----------+-----------+------------+-------------+-----------------
+------------------+------------------+------------------+-------------+--------------+-------------+--------------
+------------+-------------
16407 |          18 |       1655 |       6 |         19 |         13787176 |         -1 |             0 |             -1
|             0 |             -1 |          0 |          0 |          0 |          0 |          0 |          0
(1 row)
```

- Query all users' resource quotas and historical resource usage.

```
SELECT * FROM GS_WLM_USER_RESOURCE_HISTORY;
```

The query result is as follows:

```
username        |           timestamp           | used_memory | total_memory | used_cpu | total_cpu |
used_space | total_space | used_temp_space | total_temp_space | used_spill_space | total_spill_space |
read_kbytes | write_kbytes | read_counts | write_counts | read_speed  | write_speed
----------------------+-------------------------------+-------------+--------------+----------+-----------
+------------+-------------+-----------------+------------------+------------------+-------------------
+-------------+--------------+-------------+--------------+-------------+-------------
usern               | 2020-01-08 22:56:06.456855+08 |          0 |       17250 |       0 |       48 |          0
|         -1 |             0 |             -1 |         88349078 |             -1 |       45680 |         34 |       5710
|          8 |        320 |          0
userg               | 2020-01-08 22:56:06.458659+08 |          0 |       15525 |    33.48 |       48 |          0
|         -1 |             0 |             -1 |        110169581 |             -1 |       17648 |         23 |
2206 |          5 |        123 |          0
user1               | 2020-01-08 22:56:06.460252+08 |          0 |       13972 |    33.48 |       48 |          0
|         -1 |             0 |             -1 |        136106277 |             -1 |       17648 |         23 |
2206 |          5 |        123 |          0
```

For the system catalog in **GS_WLM_USER_RESOURCE_HISTORY**, data in the **PG_TOTAL_USER_RESOURCE_INFO** view is periodically saved to historical tables only when the GUC parameter enable_user_metric_persistent is enabled.

For details about each column, see **GS_WLM_USER_RESOURCE_HISTORY**.

- Query the real-time I/O control resource usage of a specific user. (The value in the view indicates the I/O control resource usage instead of the actual I/O read/write data.)

```
SELECT * FROM pg_user_iostat('username');
```

The query result is as follows:

```
 userid | min_curr_iops | max_curr_iops | min_peak_iops | max_peak_iops | io_limits | io_priority
 -------+---------------+---------------+---------------+---------------+-----------+-------------
     10 |             0 |             0 |             0 |             0 |         0 | None
(1 row)
```

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# 10.2 Monitoring Memory Resources

## Monitoring the Memory

GaussDB(DWS) provides a view for monitoring the memory usage of the entire cluster.

Query the pgxc_total_memory_detail view as a user with sysadmin permissions.

```
SELECT * FROM pgxc_total_memory_detail;
```

If the following error message is returned during the query, enable the memory management function.

```
SELECT * FROM pgxc_total_memory_detail;
ERROR:  unsupported view for memory protection feature is disabled.
CONTEXT:  PL/pgSQL function pgxc_total_memory_detail() line 12 at FOR over EXECUTE statement
Monitoring the Memory
GaussDB(DWS) provides a view for monitoring the memory usage of the entire cluster.
SELECT * FROM pgxc_total_memory_detail;
If the following error message is returned during the query, enable the memory management function.
SELECT * FROM pgxc_total_memory_detail;
ERROR:  unsupported view for memory protection feature is disabled.
CONTEXT:  PL/pgSQL function pgxc_total_memory_detail() line 12 at FOR over EXECUTE statement
```

## Monitoring the Shared Memory

You can query the context information about the shared memory on the pg_shared_memory_detail view.

```
SELECT * FROM pg_shared_memory_detail;
          contextname          | level |            parent              | totalsize | freesize | usedsize
-------------------------------+-------+--------------------------------+-----------+----------+----------
 ProcessMemory                 |     0 |                                |     24576 |     9840 |    14736
 Workload manager memory context |     1 | ProcessMemory                |   2105400 |     7304 |  2098096
 wlm collector hash table      |     2 | Workload manager memory context |      8192 |     3736 |     4456
 Resource pool hash table      |     2 | Workload manager memory context |     24576 |    15968 |     8608
 wlm cgroup hash table         |     2 | Workload manager memory context |     24576 |    15968 |     8608
(5 rows)
```

This view lists the context name of the memory, level, the upper-layer memory context, and the total size of the shared memory.

In the database, GUC parameter **memory_tracking_mode** is used to configure the memory statistics collecting mode, including the following options:

- **none:** The memory statistics collecting function is not enabled.
- **normal:** Only memory statistics is collected in real time and no file is generated.
- **executor:** The statistics file is generated, containing the context information about all allocated memory used on the execution layer.

  When the parameter is set to **executor**, cvs files are generated under the **pg_log** directory of the DN process. The file names are in the format of **memory_track**_*<DN name>*_**query**_*<queryid>*.**csv**. The information about the operators executed by the postgres thread of the executor and all stream threads are input in this file during task execution.

  The instance is built with a file content similar to the following:

  ```
  0, 0, ExecutorState, 0, PortalHeapMemory, 0, 40K, 602K, 23
  1, 3, CStoreScan_29360131_25, 0, ExecutorState, 1, 265K, 554K, 23
  ```

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```
2, 128, cstore scan per scan memory context, 1, CStoreScan_29360131_25, 2, 24K, 24K, 23
3, 127, cstore scan memory context, 1, CStoreScan_29360131_25, 2, 264K, 264K, 23
4, 7, InitPartitionMapTmpMemoryContext, 1, CStoreScan_29360131_25, 2, 31K, 31K, 23
5, 2, VecPartIterator_29360131_24, 0, ExecutorState, 1, 16K, 16K, 23
0, 0, ExecutorState, 0, PortalHeapMemory, 0, 24K, 1163K, 20
1, 3, CStoreScan_29360131_22, 0, ExecutorState, 1, 390K, 1122K, 20
2, 20, cstore scan per scan memory context, 1, CStoreScan_29360131_22, 2, 476K, 476K, 20
3, 19, cstore scan memory context, 1, CStoreScan_29360131_22, 2, 264K, 264K, 20
4, 7, InitPartitionMapTmpMemoryContext, 1, CStoreScan_29360131_22, 2, 23K, 23K, 20
5, 2, VecPartIterator_29360131_21, 0, ExecutorState, 1, 16K, 16K, 20
```

The fields include the output SN, SN of the memory allocation context within the thread, name of the current memory context, output SN of the parent memory context, name of the parent memory context, tree layer No. of the memory context, peak memory used by the current memory context, peak memory used by the current memory context and all its child memory contexts, and plan node ID of the query where the thread is executed.

In this example, the record "1, 3, CStoreScan_29360131_22, 0, ExecutorState, 1, 390K, 1122K, 20" represents the following information about Explain Analyze:

- **CstoreScan_29360131_22** indicates the CstoreScan operator.
- **1122K** indicates the peak memory used by the CstoreScan operator.

- **fullexec:** The generated file includes the information about all memory contexts requested by the execution layer.

  If the parameter is set to **fullexec**, the output information will be similar to that for **executor**, except that some memory context allocation information may be returned because the information about all memory applications (no matter succeeded or not) is printed. As only the memory application information is recorded, the peak memory used by the memory context is recorded as **0**.

# 10.3 Instance Resource Monitoring

GaussDB(DWS) provides system catalogs for monitoring the resource usage of CNs and DNs (including memory, CPU usage, disk I/O, process physical I/O, and process logical I/O), and system catalogs for monitoring the resource usage of the entire cluster.

For details about the system catalog **GS_WLM_INSTANCE_HISTORY**, see **GS_WLM_INSTANCE_HISTORY**.

NOTE

Data in the system catalog**GS_WLM_INSTANCE_HISTORY** is distributed in corresponding instances. CN monitoring data is stored in the CN instance, and DN monitoring data is stored in the DN instance. The DN has a standby node. When the primary DN is abnormal, the monitoring data of the DN can be restored from the standby node. However, a CN has no standby node. When a CN is abnormal and then restored, the monitoring data of the CN will be lost.

## Procedure

- Query the latest resource usage of the current instance.

```
SELECT * FROM GS_WLM_INSTANCE_HISTORY ORDER BY TIMESTAMP DESC;
```

  The query result is as follows:

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```
instancename |          timestamp          | used_cpu | free_mem | used_mem | io_await | io_util  |
disk_read | disk_write | process_read | process_write | logical_read | logical_write | read_counts |
write_counts
--------------+-------------------------------+----------+----------+----------+----------+----------+-----------
+------------+--------------+---------------+--------------+--------------+-------------+--------------
dn_6015_6016 | 2020-01-10 17:29:17.329495+08 |        0 |    14570 |     8982 |  662.923 |  99.9601 |
697666 |    93655.5 |       183104 |         30082 |       285659 |         30079 |      357717 |        37667
dn_6015_6016 | 2020-01-10 17:29:07.312049+08 |        0 |    14578 |     8974 |  883.102 |  99.9801 |
756228 |    81417.4 |       189722 |         30786 |       285681 |         30780 |      358103 |        38584
dn_6015_6016 | 2020-01-10 17:28:57.284472+08 |        0 |    14583 |     8969 |  727.135 |  99.9801 |
648581 |    88799.6 |       177120 |         31176 |       252161 |         31175 |      316085 |        39079
dn_6015_6016 | 2020-01-10 17:28:47.256613+08 |        0 |    14591 |     8961 |  679.534 |   100.08 |
655360 |     169962 |       179404 |         30424 |       242002 |         30422 |      303351 |        38136
```

- Query the resource usage of the current instance during a specified period.

  ```
  SELECT * FROM GS_WLM_INSTANCE_HISTORY WHERE TIMESTAMP > '2020-01-10' AND TIMESTAMP
  < '2020-01-11' ORDER BY TIMESTAMP DESC;
  ```

  The query result is as follows:

  ```
  instancename |          timestamp          | used_cpu | free_mem | used_mem | io_await | io_util  |
  disk_read | disk_write | process_read | process_write | logical_read | logical_write | read_counts |
  write_counts
  --------------+-------------------------------+----------+----------+----------+----------+----------+-----------
  +------------+--------------+---------------+--------------+--------------+-------------+--------------
  dn_6015_6016 | 2020-01-10 17:29:17.329495+08 |        0 |    14570 |     8982 |  662.923 |  99.9601 |
  697666 |    93655.5 |       183104 |         30082 |       285659 |         30079 |      357717 |        37667
  dn_6015_6016 | 2020-01-10 17:29:07.312049+08 |        0 |    14578 |     8974 |  883.102 |  99.9801 |
  756228 |    81417.4 |       189722 |         30786 |       285681 |         30780 |      358103 |        38584
  dn_6015_6016 | 2020-01-10 17:28:57.284472+08 |        0 |    14583 |     8969 |  727.135 |  99.9801 |
  648581 |    88799.6 |       177120 |         31176 |       252161 |         31175 |      316085 |        39079
  dn_6015_6016 | 2020-01-10 17:28:47.256613+08 |        0 |    14591 |     8961 |  679.534 |   100.08 |
  655360 |     169962 |       179404 |         30424 |       242002 |         30422 |      303351 |        38136
  ```

- To query the latest resource usage of a cluster, you can invoke the **pgxc_get_wlm_current_instance_info** stored procedure on the CN.

  ```
  SELECT * FROM pgxc_get_wlm_current_instance_info('ALL');
  ```

  The query result is as follows:

  ```
  instancename |          timestamp          | used_cpu | free_mem | used_mem | io_await | io_util |
  disk_read | disk_write | process_read | process_write | logical_read | logical_write | read_counts |
  write_counts
  --------------+-------------------------------+----------+----------+----------+----------+---------+-----------
  +------------+--------------+---------------+--------------+--------------+-------------+--------------
  coordinator2 | 2020-01-14 21:58:29.290894+08 |        0 |    12010 |      278 |  16.0445 | 7.19561 |
  184.431 |    27959.3 |            0 |            10 |            0 |            0 |          0 |            0
  coordinator3 | 2020-01-14 21:58:27.567655+08 |        0 |    12000 |      288 |  .964557 | 3.40659 |
  332.468 |    3375.02 |           26 |            13 |            0 |            0 |          0 |            0
  datanode1    | 2020-01-14 21:58:23.900321+08 |        0 |    11899 |      389 |  1.17296 |    3.25 |
  329.6 |     2870.4 |           28 |             8 |           13 |            3 |         18 |            6
  datanode2    | 2020-01-14 21:58:32.832989+08 |        0 |    11904 |      384 |   17.948 | 8.52148 |
  214.186 |    25894.1 |           28 |            10 |           13 |            3 |         18 |            6
  datanode3    | 2020-01-14 21:58:24.826694+08 |        0 |    11894 |      394 |  1.16088 |    3.15 |       328
  |     2868.8 |           25 |            10 |            13 |            3 |         18 |            6
  coordinator1 | 2020-01-14 21:58:33.367649+08 |        0 |    11988 |      300 |  9.53286 |   10.05 |
  43.2 |      55232 |            0 |             0 |            0 |            0 |          0 |            0
  coordinator1 | 2020-01-14 21:58:23.216645+08 |        0 |    11988 |      300 |  1.17085 | 3.21182 |
  324.729 |    2831.13 |            8 |            13 |            0 |            0 |          0 |            0
  (7 rows)
  ```

- To query historical resource usage of a cluster, you can invoke the **pgxc_get_wlm_current_instance_info** stored procedure on the CN.

  ```
  SELECT * FROM pgxc_get_wlm_history_instance_info('ALL', '2020-01-14 21:00:00', '2020-01-14
  22:00:00', 3);
  ```

  The query result is as follows:

  ```
  instancename |          timestamp          | used_cpu | free_mem | used_mem | io_await |  io_util  |
  disk_read | disk_write | process_read | process_write | logical_read | logical_write | read_counts |
  write_counts
  --------------+-------------------------------+----------+----------+----------+----------+-----------+-----------
  ```

```
+------------+--------------+---------------+--------------+---------------+-------------+--------------
coordinator2 | 2020-01-14 21:50:49.778902+08 |       0 |    12020 |     268 |  .127371 |   .789211 |
15.984 |    3994.41 |           0 |           0 |          0 |           0 |         0 |           0
coordinator2 | 2020-01-14 21:53:49.043646+08 |       0 |    12018 |     270 |  30.2902 |   8.65404 |
276.77 |    16741.8 |           3 |           1 |          0 |           0 |         0 |           0
coordinator2 | 2020-01-14 21:57:09.202654+08 |       0 |    12018 |     270 |   .16051 |   .979021 |
59.9401 |       5596 |           0 |           0 |          0 |           0 |         0 |           0
coordinator3 | 2020-01-14 21:38:48.948646+08 |       0 |    12012 |     276 | .0769231 | .00999001
|         0 |    35.1648 |           0 |           1 |          0 |           0 |         0 |           0
coordinator3 | 2020-01-14 21:40:29.061178+08 |       0 |    12012 |     276 |  .118421 |  .0199601
|         0 |    970.858 |           0 |           0 |          0 |           0 |         0 |           0
coordinator3 | 2020-01-14 21:50:19.612777+08 |       0 |    12010 |     278 |   24.411 |   11.7665 |
8.78244 |    44641.1 |           0 |           0 |          0 |           0 |         0 |           0
datanode1    | 2020-01-14 21:49:42.758649+08 |       0 |    11909 |     379 |  .798776 |      8.02 |
51.2 |    20924.8 |           0 |           0 |          0 |           0 |         0 |           0
datanode1    | 2020-01-14 21:49:52.760188+08 |       0 |    11909 |     379 |  23.8972 |      14.1 |
0 |      74760 |           0 |           0 |          0 |           0 |         0 |           0
datanode1    | 2020-01-14 21:50:22.769226+08 |       0 |    11909 |     379 |  39.5868 |       7.4 |         0
|    19760.8 |           0 |           0 |          0 |           0 |         0 |           0
datanode2    | 2020-01-14 21:58:02.826185+08 |       0 |    11905 |     383 |  .351648 |       .32 |
20.8 |      504.8 |           0 |           0 |          0 |           0 |         0 |           0
datanode2    | 2020-01-14 21:56:42.80793+08  |       0 |    11906 |     382 |  .559748 |       .04 |         0
|      326.4 |           0 |           0 |          0 |           0 |         0 |           0
datanode2    | 2020-01-14 21:45:21.632407+08 |       0 |    11901 |     387 |  12.1313 |   4.55544 |
3.1968 |    45177.2 |           0 |           0 |          0 |           0 |         0 |           0
datanode3    | 2020-01-14 21:58:14.823317+08 |       0 |    11898 |     390 |  .378205 |       .99 |
48 |    23353.6 |           0 |           0 |          0 |           0 |         0 |           0
datanode3    | 2020-01-14 21:47:50.665028+08 |       0 |    11901 |     387 |  1.07494 |       1.19 |
0 |    15506.4 |           0 |           0 |          0 |           0 |         0 |           0
datanode3    | 2020-01-14 21:51:21.720117+08 |       0 |    11903 |     385 |  10.2795 |       3.11 |
0 |    11031.2 |           0 |           0 |          0 |           0 |         0 |           0
coordinator1 | 2020-01-14 21:42:59.121945+08 |       0 |    12020 |     268 | .0857143 |  .0699301
|         0 |    6579.02 |           0 |           0 |          0 |           0 |         0 |           0
coordinator1 | 2020-01-14 21:41:49.042646+08 |       0 |    12020 |     268 |  20.9039 |   11.3786 |
6042.76 |    57903.7 |           0 |           0 |          0 |           0 |         0 |           0
coordinator1 | 2020-01-14 21:41:09.007652+08 |       0 |    12020 |     268 | .0446429 |   .03996 |
0 |    1109.29 |           0 |           0 |          0 |           0 |         0 |           0
(18 rows)
```

# 10.4 Real-time TopSQL

You can query real-time Top SQL in real-time resource monitoring views at different levels. The real-time resource monitoring view records the resource usage (including memory, disk, CPU time, and I/O) and performance alarm information during job running.

The following table describes the external interfaces of the real-time views.

**Table 10-1** Real-time resource monitoring views

| Level | Monitored Node | View |
| --- | --- | --- |
| Query level/perf level | Current CN | GS_WLM_SESSION_STATISTICS |
| | All CNs | PGXC_WLM_SESSION_STATISTICS |
| Operator level | Current CN | GS_WLM_OPERATOR_STATISTICS |
| | All CNs | PGXC_WLM_OPERATOR_STATISTICS |

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NOTE

- The view level is determined by the resource monitoring level, that is, the **resource_track_level** configuration.
- The perf and operator levels affect the values of the **query_plan** and **warning** columns in **GS_WLM_SESSION_STATISTICS**/**PGXC_WLM_SESSION_INFO**. For details, see **SQL Self-Diagnosis**.
- Prefixes **gs** and **pgxc** indicate views showing single CN information and those showing cluster information, respectively. Common users can log in to a CN in the cluster to query only views with the **gs** prefix.
- When you query this type of views, there will be network latency, because the views obtain resource usage in real time.
- If instance fault occurs, some SQL statement information may fail to be recorded in real-time resource monitoring views.
- SQL statements are recorded in real-time resource monitoring views as follows:
  - DDL statements are not recorded, such as the execution of **CREATE**, **ALTER**, **DROP**, **GRANT**, **REVOKE**, and **VACUUM** statements.
  - DML statements are recorded, including:
    - the execution of **SELECT**, **INSERT**, **UPDATE**, and **DELETE**
    - the execution of **EXPLAIN ANALYZE** and **EXPLAIN PERFORMANCE**
    - the use of a query-level/perf-level view, which also supports the **CREATE TABLE AS** syntax.
  - Statements in functions and stored procedures and statements used for calling functions and stored procedures are recorded. Statements in loop bodies (if any) of functions and stored procedures are not recorded.
  - Statements in anonymous blocks are not recorded.
  - Statements in transaction blocks are recorded. Statements in loop bodies (if any) of transaction blocks are not recorded.
  - Cursor statements are recorded.
  - Jobs in a redistribution process are not monitored.

## Prerequisites

- The GUC parameter enable_resource_track is set to **on**. The default value is **on**.
- The GUC parameter **resource_track_level** is set to **query**, **perf**, or **operator**. The default value is **query**.
- Job monitoring rules are as follows:
  - Jobs whose execution cost estimated by the optimizer is greater than or equal to **resource_track_cost**.
  - Long query jobs
- If the Cgroups function is properly loaded, you can run the **gs_cgroup -P** command to view information about Cgroups.

In the preceding prerequisites, enable_resource_track is a system-level parameter that specifies whether to enable resource monitoring. **resource_track_level** is a session-level parameter. You can set the resource monitoring level of a session as needed. The following table describes the values of the two parameters.

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**Table 10-2** Setting the resource monitoring level to collect statistics

| enable_resource_track | resource_track_level | Query-Level Information | Operator-Level Information |
| --- | --- | --- | --- |
| on(default) | none | Not collected | Not collected |
| | query(default) | Collected | Not collected |
| | perf | Collected | Not collected |
| | operator | Collected | Collected |
| off | none/query/operator | Not collected | Not collected |

## Procedure

**Step 1** Query for the real-time CPU information in the **gs_session_cpu_statistics** view.

```
SELECT * FROM gs_session_cpu_statistics;
```

**Step 2** Query for the real-time memory information in the **gs_session_memory_statistics** view.

```
SELECT * FROM gs_session_memory_statistics;
```

**Step 3** Query for the real-time resource information about the current CN in the **gs_wlm_session_statistics** view.

```
SELECT * FROM gs_wlm_session_statistics;
```

**Step 4** Query for the real-time resource information about all CNs in the **pgxc_wlm_session_statistics** view.

```
SELECT * FROM pgxc_wlm_session_statistics;
```

**Step 5** Query for the real-time resource information about job operators on the current CN in the **gs_wlm_operator_statistics** view.

```
SELECT * FROM gs_wlm_operator_statistics;
```

**Step 6** Query for the real-time resource information about job operators on all CNs in the **pgxc_wlm_operator_statistics** view.

```
SELECT * FROM pgxc_wlm_operator_statistics;
```

**Step 7** Query for the load management information about the jobs executed by the current user in the **PG_SESSION_WLMSTAT** view.

```
SELECT * FROM pg_session_wlmstat;
```

**Step 8** Query the job execution status of the current user on each CN in the **pgxc_wlm_workload_records** view (this view is available when the dynamic load function is enabled, that is, **enable_dynamic_workload** is set to **on**).

```
SELECT * FROM pgxc_wlm_workload_records;
```

**----End**

# 10.5 Historical TopSQL

You can query historical Top SQL in historical resource monitoring views. The historical resource monitoring view records the resource usage (of memory, disk,

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CPU time, and I/O), running status (including errors, termination, and exceptions), and performance alarm information during job running. For queries that abnormally terminate due to FATAL or PANIC errors, their status is displayed as **aborted** and no detailed information is recorded. Status information about query parsing in the optimization phase cannot be monitored.

The following table describes the external interfaces of the historical views.

| Level | Monitored Node | View | |
|---|---|---|---|
| Query level/perf level | Current CN | History (Database Manager interface) | GS_WLM_SESSION_HISTORY |
| | | History (internal dump interface) | GS_WLM_SESSION_INFO |
| | All CNs | History (Database Manager interface) | PGXC_WLM_SESSION_HISTORY |
| | | History (internal dump interface) | PGXC_WLM_SESSION_INFO |
| Operator | Current CN | History (Database Manager interface) | GS_WLM_OPERATOR_HISTORY |
| | | History (internal dump interface) | GS_WLM_OPERAROR_INFO |
| | All CNs | History (Database Manager interface) | PGXC_WLM_OPERATOR_HISTORY |
| | | History (internal dump interface) | PGXC_WLM_OPERATOR_INFO |

NOTE

- The view level is determined by the resource monitoring level, that is, the **resource_track_level** configuration.
- The perf and operator levels affect the values of the **query_plan** and **warning** columns in **GS_WLM_SESSION_STATISTICS**/**PGXC_WLM_SESSION_INFO**. For details, see **SQL Self-Diagnosis**.
- Prefixes **gs** and **pgxc** indicate views showing single CN information and those showing cluster information, respectively. Common users can log in to a CN in the cluster to query only views with the **gs** prefix.
- You can query the **gs_wlm_session_info**, **gs_wlm_operator_info**, **pgxc_wlm_session_info**, and **pgxc_wlm_operator_info** views only after connecting to the **gaussdb** database.
- If instance fault occurs, some SQL statement information may fail to be recorded in historical resource monitoring views.
- In some abnormal cases, the status information column in the historical TopSQL may be displayed as **unknown**. The recorded monitoring information may be inaccurate.
- The SQL statements that can be recorded in historical resource monitoring views are the same as those recorded in real-time resource monitoring views. For details, see **SQL statements recorded in real-time resource monitoring views**.

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## Prerequisites

- The GUC parameter enable_resource_track is set to **on**. The default value is **on**.
- The GUC parameter **resource_track_level** is set to **query**, **perf**, or **operator**. The default value is **query**. For details, see **Table 10-2**.
- The GUC parameter enable_resource_record is set to **on**. The default value is **off**.
- The value of the **resource_track_duration** parameter (**60s** by default) is less than the job execution time.
- Job monitoring rules are as follows:
  - Jobs whose execution time recorded in the real-time resource monitoring view (see **Table 10-1**) is greater than or equal to **resource_track_duration**.
- If the Cgroups function is properly loaded, you can run the **gs_cgroup -P** command to view information about Cgroups.
- This function will cause storage space expansion and slightly affect system performance. You are not advised to set it as a default system function.

## Procedure

**Step 1** Query the load records of the current CN after its latest job is complete in the **gs_wlm_session_history** view.

```
SELECT * FROM gs_wlm_session_history;
```

**Step 2** Query the load records of all the CNs after their latest job are complete in the **pgxc_wlm_session_history** view.

```
SELECT * FROM pgxc_wlm_session_history;
```

**Step 3** Query the load records of the current CN through the **gs_wlm_session_info** table after the task is complete. To query the historical records successfully, set enable_resource_record to **on**.

```
SELECT * FROM gs_wlm_session_info;
```

- Top 10 queries that consume the most memory (You can specify a query period.)

```
SELECT * FROM gs_wlm_session_info order by max_peak_memory desc limit 10;
SELECT * FROM gs_wlm_session_info WHERE start_time >= '2022-05-15 21:00:00' and finish_time
<='2022-05-15 23:30:00'order by max_peak_memory desc limit 10;
```

- Top 10 queries that consume the most CPU (You can specify a query period.)

```
SELECT * FROM gs_wlm_session_info order by total_cpu_time desc limit 10;
SELECT * FROM gs_wlm_session_info WHERE start_time >= '2022-05-15 21:00:00' and finish_time
<='2022-05-15 23:30:00'order by total_cpu_time desc limit 10;
```

**Step 4** Query for the load records of all the CNs after their jobs are complete in the **pgxc_wlm_session_info** view. To query the historical records successfully, set enable_resource_record to **on**.

```
SELECT * FROM pgxc_wlm_session_info;
```

- Query the top 10 queries that take up the most CN processing time (You can specify a query period.)

```
SELECT * FROM pgxc_wlm_session_info order by duration desc limit 10;
SELECT * FROM pgxc_wlm_session_info WHERE start_time >= '2022-05-15 21:00:00' and finish_time
<='2022-05-15 23:30:00'order by nodename,max_peak_memory desc limit 10;
```

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**Step 5** Use the **pgxc_get_wlm_session_info_bytime** function to filter and query the **pgxc_wlm_session_info** view. To query the historical records successfully, set enable_resource_record to **on**. You are advised to use this function if the view contains a large number of records.

NOTE

A GaussDB(DWS) cluster uses the UTC time by default, which has an 8-hour time difference with the system time. Before queries, ensure that the database time is the same as the system time.

- Return the queries started between **2019-09-10 15:30:00** and **2019-09-10 15:35:00** on all CNs. For each CN, a maximum of 10 queries will be returned.

```
SELECT * FROM pgxc_get_wlm_session_info_bytime('start_time', '2019-09-10 15:30:00', '2019-09-10 15:35:00', 10);
```

- Return the queries ended between **2019-09-10 15:30:00** and **2019-09-10 15:35:00** on all CNs. For each CN, a maximum of 10 queries will be returned.

```
SELECT * FROM pgxc_get_wlm_session_info_bytime('finish_time', '2019-09-10 15:30:00', '2019-09-10 15:35:00', 10);
```

**Step 6** Query the recent resource information of the job operators on the current CN in the **gs_wlm_operator_history** view. Ensure that **resource_track_level** is set to **operator**.

```
SELECT * FROM gs_wlm_operator_history;
```

**Step 7** Query the recent resource information of the job operators on all the CNs in the **pgxc_wlm_operator_history** view. Ensure that **resource_track_level** is set to **operator**.

```
SELECT * FROM pgxc_wlm_operator_history;
```

**Step 8** Query the recent resource information of the job operators on the current CN in the **gs_wlm_operator_info** view. Ensure that **resource_track_level** is set to **operator** and enable_resource_record to **on**.

```
SELECT * FROM gs_wlm_operator_info;
```

**Step 9** Query for the historical resource information of job operators on all the CNs in the **pgxc_wlm_operator_info** view. Ensure that **resource_track_level** is set to **operator** and enable_resource_record to **on**.

```
SELECT * FROM pgxc_wlm_operator_info;
```

**----End**

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NOTE

- The number of data records that can be retained in the memory is limited, because certain memory is reserved. After a real-time query is complete, its information is imported to historical views and will be deleted when the information has been stored in the hash table in the memory for 3 minutes. The upper limit of records varies by view. For a query-level view, whether a record can be stored depends on the upper limit of records allowed by the memory at that time point. On each CN, the maximum number of real-time query-level records that can be stored in memory (default: **5MB**) is **max_session_realt_num** (set to **12850** by default). The maximum number of historical records that can be stored in memory (default: **100MB**) is **max_session_hist_num** (set to **137970** by default). The average execution time of queries in a service system is greater than **run_time** (in the unit of s). The maximum number of concurrent jobs allowed by real-time views on each CN is: **num_realt_active** = **max_session_realt_num**. The maximum number of concurrent jobs allowed by historical views on each CN is: **num_hist_active** = **max_session_hist_num**/(**180**/**run_time**).
- For operator-level views, whether a record can be stored depends on the upper limit allowed by the memory at that time point. If the number of plan nodes plus the number of records in the memory exceeds the upper limit, the record cannot be stored. On each CN, the maximum numbers of real-time and historical operator-level records that can be stored in the memory are **max_oper_realt_num** (set to **56987** by default) and **max_oper_hist_num** (set to **113975** by default), respectively. The average number of plan nodes of a query is **num_plan_node**. Maximum number of concurrent tasks allowed by real-time views on each CN is: **num_realt_active** = **max_oper_realt_num**/**num_plan_node**. Maximum number of concurrent tasks allowed by historical views on each CN is: **num_hist_active** = **max_oper_hist_num**/(**180**/**run_time**)/**num_plan_node**.
- In high concurrency, ensure that the number of queries to be recorded does not exceed the maximum values set for query- and operator-level queries. You can modify the memory of the real-time query view by setting **session_statistics_memory** and the memory of the historical query view by setting **session_history_memory**. The memory size increases in direct proportion to the maximum number of queries that can be recorded.

# 10.6 TopSQL Query Example

In this section, TPC-DS sample data is used as an example to describe how to query **Real-time TopSQL** and **Historical TopSQL**.

## Configuring Cluster Parameters

To query for historical or archived resource monitoring information about jobs of top SQLs, you need to set related GUC parameters first. The procedure is as follows:

1. Log in to the GaussDB(DWS) management console.
2. On the **Cluster Management** page, locate the required cluster and click the cluster name. The cluster details page is displayed.
3. Click the **Parameter Modifications** tab to view the values of cluster parameters.
4. Set an appropriate value for parameter **resource_track_duration** and click **Save**.

   NOTE

   If **enable_resource_record** is set to **on**, storage space expansion may occur and thereby slightly affects the performance. Therefore, set is to **off** if record archiving is unnecessary.

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5. Go back to the **Cluster Management** page, click the refresh button in the upper right corner, and wait until the cluster parameter settings are applied.

## Example for Querying for Top SQLs

The TPC-DS sample data is used as an example.

**Step 1** Open the SQL client tool and connect to your database.

**Step 2** Run the **EXPLAIN** statement to query for the estimated cost of the SQL statement to be executed to determine whether resources of the SQL statement will be monitored.

By default, only resources of a query whose execution cost is greater than the value (default: **100000**) of **resource_track_cost** are monitored and can be queried by users.

For example, run the following statements to query for the estimated execution cost of the SQL statement:

```
SET CURRENT_SCHEMA = tpcds;
EXPLAIN WITH customer_total_return AS
( SELECT sr_customer_sk as ctr_customer_sk,
sr_store_sk as ctr_store_sk,
sum(SR_FEE) as ctr_total_return
FROM store_returns, date_dim
WHERE sr_returned_date_sk = d_date_sk AND d_year =2000
GROUP BY sr_customer_sk, sr_store_sk )
SELECT  c_customer_id
FROM customer_total_return ctr1, store, customer
WHERE ctr1.ctr_total_return > (select avg(ctr_total_return)*1.2
FROM customer_total_return ctr2
WHERE ctr1.ctr_store_sk = ctr2.ctr_store_sk)
AND s_store_sk = ctr1.ctr_store_sk
AND s_state = 'TN'
AND ctr1.ctr_customer_sk = c_customer_sk
ORDER BY c_customer_id
limit 100;
```

In the following query result, the value in the first row of the **E-costs** column is the estimated cost of the SQL statement.

**Figure 10-1** EXPLAIN result

```
 id |                                operation                                | E-rows | E-width | E-costs
----+-------------------------------------------------------------------------+--------+---------+---------
  1 | ->  Row Adapter                                                         |      6 |      20 | 153.06
  2 |    ->  Vector Limit                                                     |      6 |      20 | 153.06
  3 |       ->  Vector Streaming (type: GATHER)                               |      6 |      20 | 153.06
  4 |          ->  Vector Limit                                               |      6 |      20 | 152.84
  5 |             ->  Vector Sort                                             |      6 |      20 | 152.84
  6 |                ->  Vector Hash Join (7,26)                              |      6 |      20 | 152.83
  7 |                   ->  Vector Streaming(type: REDISTRIBUTE)              |      6 |       4 | 134.57
  8 |                      ->  Vector Hash Join (9,18)                        |      6 |       4 | 134.46
  9 |                         ->  Vector Hash Join (10,11)                    |      1 |      44 | 97.33
 10 |                            ->  CStore Scan on store                     |      1 |       4 | 60.23
 11 |                            ->  Vector Subquery Scan on ctr1             |      6 |      40 | 37.07
 12 |                               ->  Vector Hash Aggregate                 |      6 |      54 | 37.06
 13 |                                  ->  Vector Streaming(type: REDISTRIBUTE)|      6 |      22 | 37.04
 14 |                                     ->  Vector Hash Join (15,17)        |      6 |      22 | 37.00
 15 |                                        ->  Vector Streaming(type: BROADCAST)|      6 |       4 | 18.74
 16 |                                           ->  CStore Scan on date_dim   |      1 |       4 | 18.06
 17 |                                        ->  CStore Scan on store_returns |     60 |      26 | 18.02
 18 |                         ->  Vector Hash Aggregate                       |      6 |      68 | 37.09
 19 |                            ->  Vector Subquery Scan on ctr2             |      6 |      36 | 37.07
 20 |                               ->  Vector Hash Aggregate                 |      6 |      54 | 37.06
 21 |                                  ->  Vector Streaming(type: REDISTRIBUTE)|      6 |      22 | 37.04
 22 |                                     ->  Vector Hash Join (23,25)        |      6 |      22 | 37.00
 23 |                                        ->  Vector Streaming(type: BROADCAST)|      6 |       4 | 18.74
 24 |                                           ->  CStore Scan on date_dim   |      1 |       4 | 18.06
 25 |                                        ->  CStore Scan on store_returns |     60 |      26 | 18.02
 26 |                   ->  CStore Scan on customer                           |     60 |      24 | 18.02
(26 rows)
```

In this example, to demonstrate the resource monitoring function of top SQLs, you need to set **resource_track_cost** to a value smaller than the estimated cost in the

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**EXPLAIN** result, for example, **100**. For details about the parameter setting, see **resource_track_cost**.

NOTE

After completing this example, you still need to reset **resource_track_cost** to its default value **100000** or a proper value. An overly small parameter value will compromise the database performance.

**Step 3** Run SQL statements.

```
SET CURRENT_SCHEMA = tpcds;
WITH customer_total_return AS
(SELECT sr_customer_sk as ctr_customer_sk,
sr_store_sk as ctr_store_sk,
sum(SR_FEE) as ctr_total_return
FROM store_returns,date_dim
WHERE sr_returned_date_sk = d_date_sk
AND d_year =2000
GROUP BY sr_customer_sk ,sr_store_sk)
SELECT  c_customer_id
FROM customer_total_return ctr1, store, customer
WHERE ctr1.ctr_total_return > (select avg(ctr_total_return)*1.2
FROM customer_total_return ctr2
WHERE ctr1.ctr_store_sk = ctr2.ctr_store_sk)
AND s_store_sk = ctr1.ctr_store_sk
AND s_state = 'TN'
AND ctr1.ctr_customer_sk = c_customer_sk
ORDER BY c_customer_id
limit 100;
```

**Step 4** During statement execution, query for the real-time memory peak information about the SQL statement on the current CN.

```
SELECT query,max_peak_memory,average_peak_memory,memory_skew_percent FROM
gs_wlm_session_statistics ORDER BY start_time DESC;
```

The preceding command queries for the real-time peak information at the query-level. The peak information includes the maximum memory peak among all DNs per second, average memory peak among all DNs per second, and memory usage skew across DNs.

For more examples of querying for the real-time resource monitoring information of top SQLs, see **Real-time TopSQL**.

**Step 5** Wait until the SQL statement execution in **Step 3** is complete, and then query for the historical resource monitoring information of the statement.

```
select query,start_time,finish_time,duration,status from gs_wlm_session_history order by start_time desc;
```

The preceding command queries for the historical information at the query-level. The peak information includes the execution start time, execution duration (unit: ms), and execution status. The time unit is ms.

For more examples of querying for the historical resource monitoring information of top SQLs, see **Historical TopSQL**.

**Step 6** Wait for 3 minutes after the execution of the SQL statement in **Step 3** is complete, query for the historical resource monitoring information of the statement in the **info** view.

If **enable_resource_record** is set to **on** and the execution time of the SQL statement in **Step 3** is no less than the value of **resource_track_duration**, historical information about the SQL statement will be archived to the

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**gs_wlm_session_info** view 3 minutes after the execution of the SQL statement is complete.

The **info** view can be queried only when the **gaussdb** database is connected. Therefore, switch to the **gaussdb** database before running the following statement:

```
select query,start_time,finish_time,duration,status from gs_wlm_session_info order by start_time desc;
```

**----End**

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# 11 Query Performance Optimization

## 11.1 Overview of Query Performance Optimization

The aim of SQL optimization is to maximize the utilization of resources, including CPU, memory, disk I/O, and network I/O. To maximize resource utilization is to run SQL statements as efficiently as possible to achieve the highest performance at a lower cost. For example, when performing a typical point query, you can use the seqscan and filter (that is, read every tuple and query conditions for match). You can also use an index scan, which can be implemented at a lower cost but achieve the same effect.

This chapter describes how to analyze and improve query performance, and provides common cases and troubleshooting methods.

## 11.2 Query Analysis

### 11.2.1 Query Execution Process

The process from receiving SQL statements to the statement execution by the SQL engine is shown in **Figure 11-1** and **Table 11-1**. The texts in red are steps where database administrators can optimize queries.

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**Figure 11-1** Execution process of query-related SQL statements by the SQL engine

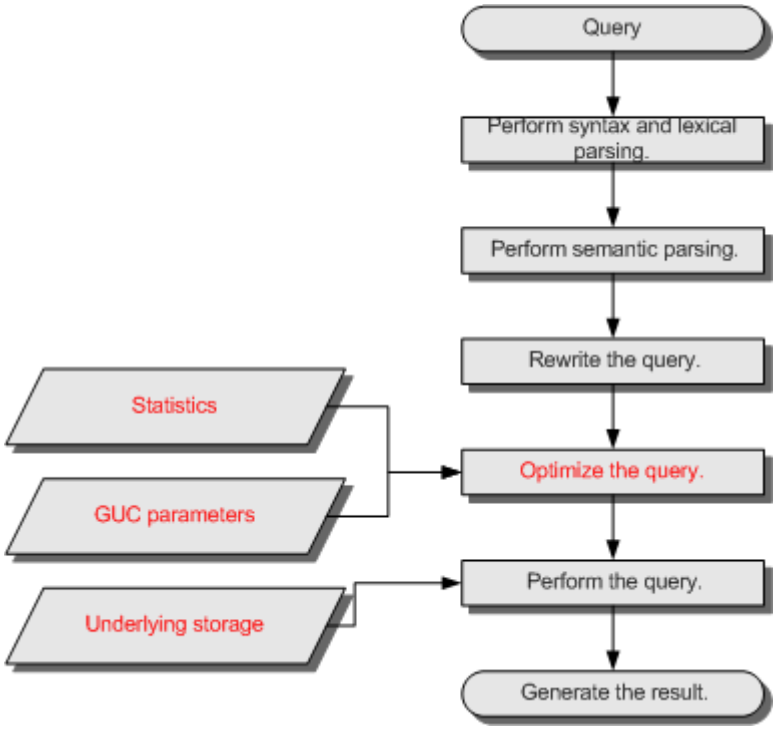


**Table 11-1** Execution process of query-related SQL statements by the SQL engine

| Procedure | Description |
| --- | --- |
| 1. Perform syntax and lexical parsing. | Converts the input SQL statements from the string data type to the formatted structure stmt based on the specified SQL statement rules. |
| 2. Perform semantic parsing. | Converts the formatted structure obtained from the previous step into objects that can be recognized by the database. |
| 3. Rewrite the query statements. | Converts the output of the last step into the structure that optimizes the query execution. |
| 4. Optimize the query. | Determines the execution mode of SQL statements (the execution plan) based on the result obtained from the last step and the internal database statistics. For details about the impact of statistics and GUC parameters on query optimization (execution plan), see **Optimizing Queries Using Statistics** and **Optimizing Queries Using GUC parameters**. |
| 5. Perform the query. | Executes the SQL statements based on the execution path specified in the last step. Selecting a proper underlying storage mode improves the query execution efficiency. For details, see **Optimizing Queries Using the Underlying Storage**. |

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## Optimizing Queries Using Statistics

The GaussDB(DWS) optimizer is a typical Cost-based Optimization (CBO). By using CBO, the database calculates the number of tuples and the execution cost for each execution step under each execution plan based on the number of table tuples, column width, NULL record ratio, and characteristic values, such as distinct, MCV, and HB values, and certain cost calculation methods. The database then selects the execution plan that takes the lowest cost for the overall execution or for the return of the first tuple. These characteristic values are the statistics, which is the core for optimizing a query. Accurate statistics helps the planner select the most appropriate query plan. Generally, you can collect statistics of a table or that of some columns in a table using **ANALYZE**. You are advised to periodically execute **ANALYZE** or execute it immediately after you modified most contents in a table.

## Optimizing Queries Using GUC parameters

Optimizing queries aims to select an efficient execution mode.

Take the following statement as an example:

```
select count(1)
from customer inner join store_sales on (ss_customer_sk = c_customer_sk);
```

During execution of **customer inner join store_sales**, GaussDB(DWS) supports nested loop, merge join, and hash join. The optimizer estimates the result set value and the execution cost under each join mode based on the statistics of the **customer** and **store_sales** tables and selects the execution plan that takes the lowest execution cost.

As described in the preceding content, the execution cost is calculated based on certain methods and statistics. If the actual execution cost cannot be accurately estimated, you need to optimize the execution plan by setting the GUC parameters.

## Optimizing Queries Using the Underlying Storage

GaussDB(DWS) supports row- and column-based tables. The selection of an underlying storage mode strongly depends on specific customer business scenarios. You are advised to use column-store tables for computing service scenarios (mainly involving association and aggregation operations) and row-store tables for service scenarios, such as point queries and massive **UPDATE** or **DELETE** executions.

Optimization methods of each storage mode will be described in details in the performance optimization chapter.

## Optimizing Queries by Rewriting SQL Statements

Besides the preceding methods that improve the performance of the execution plan generated by the SQL engine, database administrators can also enhance SQL statement performance by rewriting SQL statements while retaining the original service logic based on the execution mechanism of the database and abundant practical experience.

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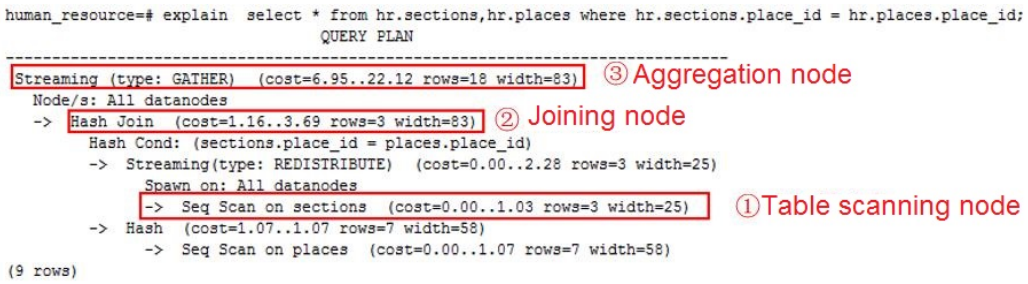
This requires that the system administrators know the customer business well and have professional knowledge of SQL statements.

## 11.2.2 Overview of the SQL Execution Plan

The SQL execution plan is a node tree, which displays detailed procedure when GaussDB(DWS) runs an SQL statement. A database operator indicates one step.

You can run the **EXPLAIN** command to view the execution plan generated for each query by an optimizer. Explain outputs a row of information for each execution node, showing the basic node type and the expense estimate that the optimizer makes for executing the node. See **Figure 11-2**.

**Figure 11-2** SQL execution plan example




- Nodes at the bottom level are scan nodes. They scan tables and return raw rows. The types of scan nodes (sequential scans and index scans) vary depending on the table access methods. Objects scanned by the bottom layer nodes may not be row-store data (not directly read from a table), such as VALUES clauses and functions that return rows, which have their own types of scan nodes.
- If the query requires join, aggregation, sorting, or other operations on the raw rows, there will be other nodes above the scan nodes to perform these operations. In addition, there is more than one possible way to perform these operations, so different execution node types may be displayed here.
- The first row (the upper-layer node) estimates the total execution cost of the execution plan. This value indicates the value that the optimizer tries to minimize.

### Execution Plan Display Format

GaussDB(DWS) provides four display formats: **normal**, **pretty**, **summary**, and **run**.

- **normal** indicates that the default printing format is used. **Figure 11-2** shows the display format.
- **pretty** indicates that the optimized display mode of GaussDB(DWS) is used. A new format contains a plan node ID, directly and effectively analyzing performance. as shown in **Figure 11-3**.
- **summary** indicates that the analysis result based on such information is printed in addition to the printed information in the format specified by **pretty**.
- **run** indicates that in addition to the printed information specified by **summary**, the database exports the information as a CSV file.

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**Figure 11-3** Example of an execution plan using the pretty format

```
postgres=# explain select cjxh, count(1) from dwcjk group by cjxh;
 id |               operation               | E-rows | E-memory | E-width | E-costs
----+---------------------------------------+--------+----------+---------+---------
  1 | ->  Row Adapter                       |      1 |          |      52 | 58.42
  2 |    ->  Vector Streaming (type: GATHER) |      1 |          |      52 | 58.42
  3 |       ->  Vector Hash Aggregate       |      1 | 16MB     |      52 | 58.02
  4 |          ->  CStore Scan on dwcjk     |      1 | 1MB      |      44 | 58.00
(4 rows)
```

You can change the display format of execution plans by setting **explain_perf_mode**. Later examples use the pretty format by default.

### Execution Plan Information

In addition to setting different display formats for an execution plan, you can use different **EXPLAIN** syntax to display execution plan information in details. The following lists the common **EXPLAIN** syntax. For details, see EXPLAIN.

- EXPLAIN *statement*: only generates an execution plan and does not execute. The *statement* indicates SQL statements.
- EXPLAIN ANALYZE *statement*: generates and executes an execution plan, and displays the execution summary. Then actual execution time statistics are added to the display, including the total elapsed time expended within each plan node (in milliseconds) and the total number of rows it actually returned.
- EXPLAIN PERFORMANCE *statement*: generates and executes the execution plan, and displays all execution information.

To measure the run time cost of each node in the execution plan, the current execution of **EXPLAIN ANALYZE** or **EXPLAIN PERFORMANCE** adds profiling overhead to query execution. Running **EXPLAIN ANALYZE** or **PERFORMANCE** on a query sometimes takes longer time than executing the query normally. The amount of overhead depends on the nature of the query, as well as the platform being used.

Therefore, if an SQL statement is not finished after being running for a long time, run the **EXPLAIN** statement to view the execution plan and then locate the fault. If the SQL statement has been properly executed, run the **EXPLAIN ANALYZE** or **EXPLAIN PERFORMANCE** statement to check the execution plan and information to locate the fault.

The **EXPLAIN PERFORMANCE** lightweight execution is consistent with **EXPLAIN PERFORMANCE** but greatly reduces the time spent on performance analysis.

## 11.2.3 Deep Dive on the SQL Execution Plan

As described in **Overview of the SQL Execution Plan**, **EXPLAIN** displays the execution plan, but will not actually run SQL statements. **EXPLAIN ANALYZE** and **EXPLAIN PERFORMANCE** both will actually run SQL statements and return the execution information. In this section, detailed execution plan and execution information are described.

### Execution Plan

The following SQL statement is used as an example:

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```
select
   cjxh,
   count(1)
from dwcjk
group by cjxh;
```

Run the **EXPLAIN** command and the output is as follows:

```
postgres=# explain select cjxh, count(1) from dwcjk group by cjxh;
 id |               operation               | E-rows | E-memory | E-width | E-costs
----+---------------------------------------+--------+----------+---------+---------
  1 | ->  Row Adapter                       |      1 |          |      52 | 58.42
  2 |    ->  Vector Streaming (type: GATHER) |      1 |          |      52 | 58.42
  3 |       ->  Vector Hash Aggregate       |      1 | 16MB     |      52 | 58.02
  4 |          ->  CStore Scan on dwcjk     |      1 | 1MB      |      44 | 58.00
(4 rows)
```

**Interpretation of the execution plan column (horizontal)**:

- Id: execution operator node ID
- operation: execution node operator name

  The operator of the Vector prefix refers to a vectorized execution engine operator, which exists in a query containing a column-store table.

  Streaming is a special operator. It implements the core data shuffle function of the distributed architecture. Streaming has three types, which correspond to different data shuffle functions in the distributed architecture:

  - Streaming (type: GATHER): The CN collects data from DNs.
  - Streaming(type: REDISTRIBUTE): Data is redistributed to all the DNs based on selected columns.
  - Streaming(type: BROADCAST): Data on the current DN is broadcast to other DNs.
- E-rows: indicates the number of rows estimated by each operator.
- E-memory: indicates the estimated memory used by each operator on a DN. Only operators executed on DNs are displayed. In certain scenarios, the memory upper limit enclosed in parentheses will be displayed following the estimated memory usage.
- E-width: indicates the estimated width of tuples provided by each operator.
- E-costs: indicates the execution cost estimated by each operator.
  - E-costs are defined by the optimizer based on cost parameters, habitually grasping disk page as a unit. Other overhead parameters are set by referring to E-costs.
  - The cost of each node (the E-costs value) includes the cost of all of its child nodes.
  - Overhead reflects only what the optimizer is concerned about, but does not consider the time that the result row passed to the client. Although the time may play a very important role in the actual total time, it is ignored by the optimizer, because it cannot be changed by modifying the plan.

**Interpretation of the execution plan level (vertical)**:

1. Layer 1: CStore Scan on dwcjk

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The table scan operator scans the table **dwcjk** using Cstore Scan. The function of this layer is to read data in the table dwcjk from the buffer or disks, or transfers it to the upper-layer node to participate in the calculation.

2. Layer 2: Vector Hash Aggregate

   Aggregation operators are used to perform aggregation operations (group by) on operators calculated from the lower layer.

3. Layer 3: Vector Streaming (type: GATHER)

   The GATHER-typed Shuffle operator aggregates data from DNs to the CN.

4. Layer 4: Row Adapter

   Storage format conversion operator is used to convert data in columns of the memory to data in rows for client display.

It should be noted that when operators in the top layer are Data Node Scan, you need to set **enable_fast_query_shipping** to **off** to view detailed execution plan as follows:

```
postgres=# set enable_fast_query_shipping=on;
SET
postgres=# set explain_perf_mode=pretty;
SET
postgres=# explain select cjxh, count(1) from dwcjk group by cjxh;
                                  QUERY PLAN
------------------------------------------------------------------------------------
  id |                  operation                   | E-rows | E-width | E-costs
 ----+----------------------------------------------+--------+---------+---------
   1 | ->  Data Node Scan on "__REMOTE_FQS_QUERY__" |      0 |       0 | 0.00
(3 rows)
```

After **enable_fast_query_shipping** is set, the execution plan is displayed as follows:

```
postgres=# set enable_fast_query_shipping=off;
SET
postgres=# explain select cjxh, count(1) from dwcjk group by cjxh;
                                QUERY PLAN
---------------------------------------------------------------------------
  id |              operation                | E-rows | E-width | E-costs
 ----+---------------------------------------+--------+---------+---------
   1 | ->  Row Adapter                       |     20 |      12 | 19.18
   2 |    ->  Vector Streaming (type: GATHER) |     20 |      12 | 19.18
   3 |       ->  Vector Sonic Hash Aggregate |     20 |      12 | 13.18
   4 |          ->  CStore Scan on dwcjk     |     20 |       4 | 13.01
(6 rows)
```

**Keywords in the execution plan**:

1. Table access modes
   - Seq Scan

     Scans all rows of the table in sequence.
   - Index Scan

     The optimizer uses a two-step plan: the child plan node visits an index to find the locations of rows matching the index condition, and then the upper plan node actually fetches those rows from the table itself. Fetching rows separately is much more expensive than reading them sequentially, but because not all pages of the table have to be visited, this is still cheaper than a sequential scan. The upper-layer planning node first sort the location of index identifier rows based on physical locations before reading them. This minimizes the independent capturing overhead.

     If there are separate indexes on multiple columns referenced in **WHERE**, the optimizer might choose to use an **AND** or **OR** combination of the

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indexes. However, this requires the visiting of both indexes, so it is not necessarily a win compared to using just one index and treating the other condition as a filter.

The following Index scans featured with different sorting mechanisms are involved:

- Bitmap Index Scan

  Fetches data pages using a bitmap.

- Index Scan using index_name

  Fetches table rows in index order, which makes them even more expensive to read. However, there are so few rows that the extra cost of sorting the row locations is unnecessary. This plan type is used mainly for queries fetching just a single row and queries having an **ORDER BY** condition that matches the index order, because no extra sorting step is needed to satisfy **ORDER BY**.

2. Table connection modes
   - Nested Loop

     Nested-loop is used for queries that have a smaller data set connected. In a Nested-loop join, the foreign table drives the internal table and each row returned from the foreign table should have a matching row in the internal table. The returned result set of all queries should be less than 10,000. The table that returns a smaller subset will work as a foreign table, and indexes are recommended for connection fields of the internal table.
   - (Sonic) Hash Join

     A Hash join is used for large tables. The optimizer uses a hash join, in which rows of one table are entered into an in-memory hash table, after which the other table is scanned and the hash table is probed for matches to each row. Sonic and non-Sonic hash joins differ in their hash table structures, which do not affect the execution result set.
   - Merge Join

     In a merge join, data in the two joined tables is sorted by join columns. Then, data is extracted from the two tables to a sorted table for matching.

     Merge join requires more resources for sorting and its performance is lower than that of hash join. If the source data has been sorted, it does not need to be sorted again when merge join is performed. In this case, the performance of merge join is better than that of hash join.
3. Operators
   - sort

     Sorts the result set.
   - filter

     The **EXPLAIN** output shows the **WHERE** clause being applied as a **Filter** condition attached to the **Seq Scan** plan node. This means that the plan node checks the condition for each row it scans, and returns only the ones that meet the condition. The estimated number of output rows has been reduced because of the **WHERE** clause. However, the scan will still have to visit all 10000 rows. As a result, the cost is not decreased. It

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increases a bit (by 10000 x **cpu_operator_cost**) to reflect the extra CPU time spent on checking the **WHERE** condition.

– LIMIT

**LIMIT** limits the number of output execution results. If a **LIMIT** condition is added, not all rows are retrieved.

## Task Execution

You can use **EXPLAIN ANALYZE** or **EXPLAIN PERFORMANCE** to check the SQL statement execution information and compare the actual execution and the optimizer's estimation to find what to optimize. **EXPLAIN PERFORMANCE** provides the execution information on each DN, whereas **EXPLAIN ANALYZE** does not.

The following SQL statement is used as an example:

```
select count(1) from tb1;
```

The output of running **EXPLAIN PERFORMANCE** is as follows:

```
postgres=# explain performance select count(1) from tb1;
                                                                QUERY PLAN
-------------------------------------------------------------------------------------------------------------------------------
 id |              operation              |    A-time     | A-rows | E-rows | E-distinct | Peak Memory  | A-width | E-width | E-costs
----+-------------------------------------+---------------+--------+--------+------------+--------------+---------+---------+---------
  1 | ->  Aggregate                       | 6.274         |      1 |      1 |            | 7KB          |         |       8 | 19.17
  2 |    ->  Streaming (type: GATHER)     | 6.156         |      2 |      2 |            | 76KB         |         |       8 | 19.17
  3 |       ->  Aggregate                 | [0.022,0.025] |      2 |      2 |            | [7KB, 7KB]   |         |       8 | 13.17
  4 |          ->  Seq Scan on public.tb1 | [0.003,0.003] |      0 |     20 |            | [11KB, 11KB] |         |       0 | 13.13

             Memory Information (identified by plan id)
-----------------------------------------------------------------------
Coordinator Query Peak Memory:
        Query Peak Memory: 0MB
DataNode Query Peak Memory
        datanode1 Query Peak Memory: 0MB
        datanode2 Query Peak Memory: 0MB
  1 --Aggregate
        Peak Memory: 7KB, Estimate Memory: 64MB
  2 --Streaming (type: GATHER)
        Peak Memory: 76KB, Estimate Memory: 64MB
  3 --Aggregate
        datanode1 Peak Memory: 7KB, Estimate Memory: 64MB
        datanode2 Peak Memory: 7KB, Estimate Memory: 64MB
        datanode1 Stream Send time: 0.000; Data Serialize time: 0.005
        datanode2 Stream Send time: 0.000; Data Serialize time: 0.005
  4 --Seq Scan on public.tb1
        datanode1 Peak Memory: 11KB, Estimate Memory: 64MB
        datanode2 Peak Memory: 11KB, Estimate Memory: 64MB


Targetlist Information (identified by plan id)
----------------------------------------------
  1 --Aggregate
        Output: count((count(1)))
  2 --Streaming (type: GATHER)
        Output: (count(1))
        Node/s: All datanodes
  3 --Aggregate
        Output: count(1)
  4 --Seq Scan on public.tb1
        Output: a, b
        Distribute Key: a


               Datanode Information (identified by plan id)
-------------------------------------------------------------------------------
  1 --Aggregate
        (actual time=4.489..4.490 rows=1 loops=1)
        (Buffers: 0)
        (CPU: ex c/r=66607, ex row=2, ex cyc=133214, inc cyc=13465336)
  2 --Streaming (type: GATHER)
        (actual time=3.966..4.445 rows=2 loops=1)
        (Buffers: 0)
        (CPU: ex c/r=6666061, ex row=2, ex cyc=13332122, inc cyc=13332122)
  3 --Aggregate
        datanode1 (actual time=0.008..0.008 rows=1 loops=1)
        datanode2 (actual time=0.010..0.010 rows=1 loops=1)
        datanode1 (Buffers: 0)
        datanode2 (Buffers: 0)
        datanode1 (CPU: ex c/r=0, ex row=0, ex cyc=12404, inc cyc=18038)
        datanode2 (CPU: ex c/r=0, ex row=0, ex cyc=16528, inc cyc=25024)
  4 --Seq Scan on public.tb1
        datanode1 (actual time=0.002..0.002 rows=0 loops=1)
        datanode2 (actual time=0.002..0.002 rows=0 loops=1)
        datanode1 (Buffers: 0)
        datanode2 (Buffers: 0)
        datanode1 (CPU: ex c/r=0, ex row=0, ex cyc=5634, inc cyc=5634)
        datanode2 (CPU: ex c/r=0, ex row=0, ex cyc=8496, inc cyc=8496)
```

```
                    User Define Profiling
---------------------------------------------------------------
Plan Node id: 2  Track name: coordinator get datanode connection
       coordinator1: (time=1.884 total_calls=1 loops=1)

                      ====== Query Summary =====
---------------------------------------------------------------------------
Datanode executor start time [datanode2, datanode1]: [0.287 ms,0.373 ms]
Datanode executor end time [datanode2, datanode1]: [0.097 ms,0.105 ms]
Remote query poll time: 1.658 ms, Deserialze time: 0.000 ms
Coordinator executor start time: 0.357 ms
Coordinator executor run time: 4.498 ms
Coordinator executor end time: 0.329 ms
Planner runtime: 0.341 ms
Query Id: 723390690146407 37
Total runtime: 5.275 ms
(81 rows)
```

This figure shows that the execution information can be classified into the following 7 aspects.

1. The plan is displayed as a table, which contains 11 columns: **id**, **operation**, **A-time**, **A-rows**, **E-rows**, **E-distinct**, **Peak Memory**, **E-memory**, **A-width**, **E-width**, and **E-costs**. The definition of the plan-type columns (columns started with id, operation, or some started with E) is the same as that of running **EXPLAIN**. For details, see **Execution Plan** (execution plan) in the section. The definition of A-time, A-rows, E-distinct, Peak Memory, and A-width are described as follows:
   - A-time: indicates the execution completion time of the current operator. Generally, the A-time of the operator executed on the DN is two values enclosed by square brackets ([]), indicating the shortest time and longest time for completing the operator on all DNs, respectively.
   - A-rows: indicates the number of tuples provided by the current operator
   - E-distinct: indicates the estimated distinct value of the hashjoin operator.
   - Peak Memory: indicates the peak memory usage of an operator on each DN.
   - A-width: indicates that the current operator tuple actual width of each line. This parameter is valid only for the heavy memory operator is displayed, including: (Vec)HashJoin, (Vec)HashAgg, (Vec) HashSetOp, (Vec)Sort, and (Vec)Materialize operator. The (Vec)HashJoin calculation of width is the width of the right subtree operator, it will be displayed in the right subtree.
2. Predicate Information (identified by plan id):

   This part displays the static information that does not change during the plan execution process, such as some join conditions and filter information.
3. Memory Information (identified by plan id):

   This part displays the memory usage information printed by certain operators (mainly Hash and Sort), including **peak memory**, **control memory**, **operator memory**, **width**, **auto spread num**, and **early spilled**; and spill details, including **spill Time(s)**, **inner/outer partition spill num**, **temp file num**, split data volume, and **written disk IO [***min, max***]**. The Sort operator does not display the number of files written to disks, and displays disks only when displaying sorting methods.
4. Targetlist Information (identified by plan id)

   This part displays the target columns provided by each operator.
5. DataNode Information (identified by plan id):

   This part displays the execution time of each operator (including the execution time of filtering and projection, if any), CPU usage, and buffer usage.

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6. User Define Profiling

   This part displays CNs and DNs, DN and DN connection time, and some execution information in the storage layer.

7. ====== Query Summary =====:

   The total execution time and network traffic, including the maximum and minimum execution time in the initialization and end phases on each DN, initialization, execution, and time in the end phase on each CN, and the system available memory during the current statement execution, and statement estimation memory information.

**NOTICE**

- The difference between A-rows and E-rows shows the deviation between the optimizer estimation and actual execution. Generally, if the deviation is large, the plan generated by the optimizer is untrusted, and you need to modify the deviation value.
- If the difference of the A-time values is large, it indicates that the operator computing skew (difference between execution time on DNs) is large and that manual performance tuning is required. Generally, for two adjacent operators, the execution time of the upper-layer operator includes that of the lower-layer operator. However, if the upper-layer operator is a stream operator, its execution time may be less than that of the lower-layer operator, as there is no driving relationship between threads.
- **Max Query Peak Memory** is often used to estimate the consumed memory of SQL statements, and is also used as an important basis for setting a memory parameter during SQL statement optimization. Generally, the output from **EXPLAIN ANALYZE** or **EXPLAIN PERFORMANCE** is provided for the input for further optimization.

## 11.2.4 Querying SQL Statements That Affect Performance Most

This section describes how to query SQL statements whose execution takes a long time, leading to poor system performance.

### Procedure

**Step 1** Query the statements that are run for a long time in the database.

```
SELECT current_timestamp - query_start AS runtime, datname, username, query FROM pg_stat_activity
where state != 'idle' ORDER BY 1 desc;
```

After the query, query statements are returned as a list, ranked by execution time in descending order. The first result is the query statement that has the longest execution time in the system. The returned result contains the SQL statement invoked by the system and the SQL statement run by users. Find the statements that were run by users and took a long time.

Alternatively, you can set **current_timestamp - query_start** to be greater than a threshold to identify query statements that are executed for a duration longer than this threshold.

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```
SELECT query FROM pg_stat_activity WHERE current_timestamp - query_start > interval '1 days';
```

**Step 2** Set the parameter **track_activities** to **on**.

```
SET track_activities = on;
```

The database collects the running information about active queries only if the parameter is set to **on**.

**Step 3** View the running query statements.

Viewing **pg_stat_activity** is used as an example here.

```
SELECT datname, usename, state FROM pg_stat_activity;
 datname  | usename | state  |
----------+---------+--------+
 postgres |   omm   | idle   |
 postgres |   omm   | active |
(2 rows)
```

If the **state** column is idle, the connection is idle and requires a user to enter a command.

To identify only active query statements, run the following command:

```
SELECT datname, usename, state FROM pg_stat_activity WHERE state != 'idle';
```

**Step 4** Analyze the status of the query statements that were run for a long time.

- If the query statement is normal, wait until the execution is complete.
- If a query statement is blocked, run the following command to view this query statement:

  ```
  SELECT datname, usename, state, query FROM pg_stat_activity WHERE waiting = true;
  ```

  The command output lists a query statement in the block state. The lock resource requested by this query statement is occupied by another session, so this query statement is waiting for the session to release the lock resource.

  NOTE

  Only when the query is blocked by internal lock resources, the **waiting** field is **true**. In most cases, block happens when query statements are waiting for lock resources to be released. However, query statements may be blocked because they are waiting to write in files or for timers. Such blocked queries are not displayed in the **pg_stat_activity** view.

**----End**

# 11.2.5 Checking Blocked Statements

During database running, query statements are blocked in some service scenarios and run for an excessively long time. In this case, you can forcibly terminate the faulty session.

## Procedure

**Step 1** View blocked query statements and information about the tables and schemas that block the query statements.

```
SELECT w.query as waiting_query,
w.pid as w_pid,
w.usename as w_user,
l.query as locking_query,
l.pid as l_pid,
```

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```
l.usename as l_user,
t.schemaname || '.' || t.relname as tablename
from pg_stat_activity w join pg_locks l1 on w.pid = l1.pid
and not l1.granted join pg_locks l2 on l1.relation = l2.relation
and l2.granted join pg_stat_activity l on l2.pid = l.pid join pg_stat_user_tables t on l1.relation = t.relid
where w.waiting;
```

The thread ID, user information, query status, as well as information about the tables and schemas that block the query statements are returned.

**Step 2** Run the following command to terminate the required session, where **139834762094352** is the thread ID:

```
SELECT PG_TERMINATE_BACKEND(139834762094352);
```

If information similar to the following is displayed, the session is successfully terminated:

```
 PG_TERMINATE_BACKEND
----------------------
 t
(1 row)
```

If a command output similar to the following is displayed, a user is attempting to terminate the session, and the session will be reconnected rather than being terminated.

```
FATAL:  terminating connection due to administrator command
FATAL:  terminating connection due to administrator command
The connection to the server was lost. Attempting reset: Succeeded.
```

NOTE

If the **PG_TERMINATE_BACKEND** function is used to terminate the background threads of the session, the gsql client will be reconnected rather than be logged out.

**----End**

# 11.3 Query Improvement

## 11.3.1 Optimization Process

You can analyze slow SQL statements to optimize them.

### Procedure

**Step 1** Collect all table statistics associated with the SQL statements. In a database, statistics indicate the source data of a plan generated by a planner. If statistics are unavailable or out of date, the execution plan may seriously deteriorate, leading to low performance. According to past experience, about 10% performance problem occurred because no statistics are collected. For details, see **Updating Statistics**.

**Step 2** View the execution plan to find out the cause. If the SQL statements have been running for a long period of time and not ended, run the **EXPLAIN** command to view the execution plan and then locate the fault. If the SQL statement has been executed, run the **EXPLAIN ANALYZE** or **EXPLAIN PERFORMANCE** command to check the execution plan and actual running situation and then accurately locate the fault.

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**Step 3** **Review and modify the table definition.**

**Step 4** For details about **EXPLAIN** or **EXPLAIN PERFORMANCE**, the reason why SQL statements are slowly located, and how to solve this problem, see **Typical SQL Optimization Methods**.

**Step 5** Generally, some SQL statements can be converted to its equivalent statements in all or certain scenarios by rewriting queries. SQL statements are simpler after they are rewritten. Some execution steps can be simplified to improve the performance. The query rewriting method is universal in all databases. **Experience in Rewriting SQL Statements** describes several optimization methods by rewriting SQL statements.

**Step 6** Specify a join order; join, stream, or scan operations; number of rows in a result; or redistribution skew information to optimize an execution plan, improving query performance. For details, see **Hint-based Tuning**.

**Step 7** To maintain high database performance, you are advised to perform **Routinely Maintaining Tables** and **Routinely Recreating an Index**.

**Step 8** (Optional) Improve performance by using operators if resources are sufficient in GaussDB(DWS). For details, see **SMP Manual Optimization Suggestions**.

**----End**

## 11.3.2 Updating Statistics

In a database, statistics indicate the source data of a plan generated by a planner. If no collection statistics are available or out of date, the execution plan may seriously deteriorate, leading to low performance.

### Context

The **ANALYZE** statement collects statistic about table contents in databases, which will be stored in the system table **PG_STATISTIC**. Then, the query optimizer uses the statistics to work out the most efficient execution plan.

After executing batch insertion and deletions, you are advised to run the **ANALYZE** statement on the table or the entire library to update statistics. By default, 30,000 rows of statistics are sampled. That is, the default value of the GUC parameter **default_statistics_target** is **100**. If the total number of rows in the table exceeds 1,600,000, you are advised to set **default_statistics_target** to **-2**, indicating that 2% of the statistics are collected.

For an intermediate table generated during the execution of a batch script or stored procedure, you also need to run the **ANALYZE** statement.

If there are multiple inter-related columns in a table and the conditions or grouping operations based on these columns are involved in the query, collect statistics about these columns so that the query optimizer can accurately estimate the number of rows and generate an effective execution plan.

### Procedure

Run the following commands to update the statistics about a table or the entire database:

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```
ANALYZE tablename;                    --Update statistics about a table.
ANALYZE;                              ---Update statistics about the entire database.
```

Run the following statements to perform statistics-related operations on multiple columns:

```
ANALYZE tablename ((column_1, column_2));                    --Collect statistics about column_1 and column_2 of tablename.

ALTER TABLE tablename ADD STATISTICS ((column_1, column_2));    --Declare statistics about column_1 and column_2 of tablename.
ANALYZE tablename;                                           --Collect statistics about one or more columns.

ALTER TABLE tablename DELETE STATISTICS ((column_1, column_2)); --Delete statistics about column_1 and column_2 of tablename or their statistics declaration.
```

**NOTICE**

After the statistics are declared for multiple columns by running the **ALTER TABLE** *tablename* **ADD STATISTICS** statement, the system collects the statistics about these columns next time **ANALYZE** is performed on the table or the entire database.

To collect the statistics, run the **ANALYZE** statement.

**NOTE**

Use **EXPLAIN** to show the execution plan of each SQL statement. If **rows=10** (the default value, probably indicating the table has not been analyzed) is displayed in the **SEQ SCAN** output of a table, run the **ANALYZE** statement for this table.

# 11.3.3 Reviewing and Modifying a Table Definition

## 11.3.3.1 Reviewing and Modifying a Table Definition

In a distributed framework, data is distributed on DNs. Data on one or more DNs is stored on a physical storage device. To properly define a table, you must:

1. **Evenly distribute data on each DN** to avoid the available capacity decrease of a cluster caused by insufficient storage space of the storage device associated with a DN. Specifically, select a proper distribution key to avoid data skew.
2. **Evenly assign table scanning tasks on each DN** to avoid that a DN is overloaded by the table scanning tasks. Specifically, do not select columns in the equivalent filter of a base table as the distribution key.
3. **Reduce the data volume scanned** by using the partition pruning mechanism.
4. **Avoid the use of random I/O** by using clustering or partial clustering.
5. **Avoid data shuffle** to reduce the network pressure by selecting the **join-condition** column or **group by** column as the distribution column.

The distribution column is the core for defining a table. The following figure shows the procedure of defining a table. The table definition is created during the database design and is reviewed and modified during the SQL statement optimization.

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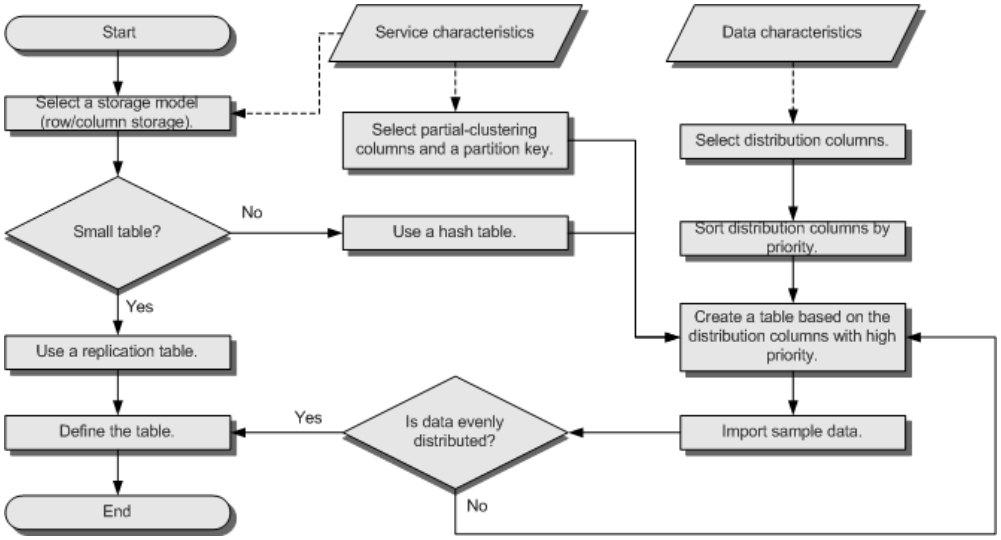
**Figure 11-4** Procedure of defining a table




## 11.3.3.2 Selecting a Storage Model

During database design, some key factors about table design will greatly affect the subsequent query performance of the database. Table design affects data storage as well. Scientific table design reduces I/O operations and minimizes memory usage, improving the query performance.

Selecting a model for table storage is the first step of table definition. Select a proper storage model for your service based on the following table.

| Storage Model | Application Scenario |
| --- | --- |
| Row storage | Point query (simple index–based query that returns only a few records).<br>Query involving many **INSERT**, **UPDATE**, and **DELETE** operations. |
| Column storage | Statistics analysis query, in which operations, such as group and join, are performed many times. |

## 11.3.3.3 Selecting a Distribution Mode

In replication mode, full data in a table is copied to each DN in the cluster. This mode is used for tables containing a small volume of data. Full data in a table stored on each DN avoids data redistribution during the **JOIN** operation. This reduces network costs and plan segments (each with a thread), but generates much redundant data. Generally, replication is only used for small dimension tables.

In hash mode, hash values are generated for one or more columns. You can obtain the storage location of a tuple based on the mapping between DNs and the hash values. In a hash table, I/O resources on each node can be used for data read/write, which greatly accelerates the read/write of a table. Generally, a table containing a large amount of data is defined as a hash table.

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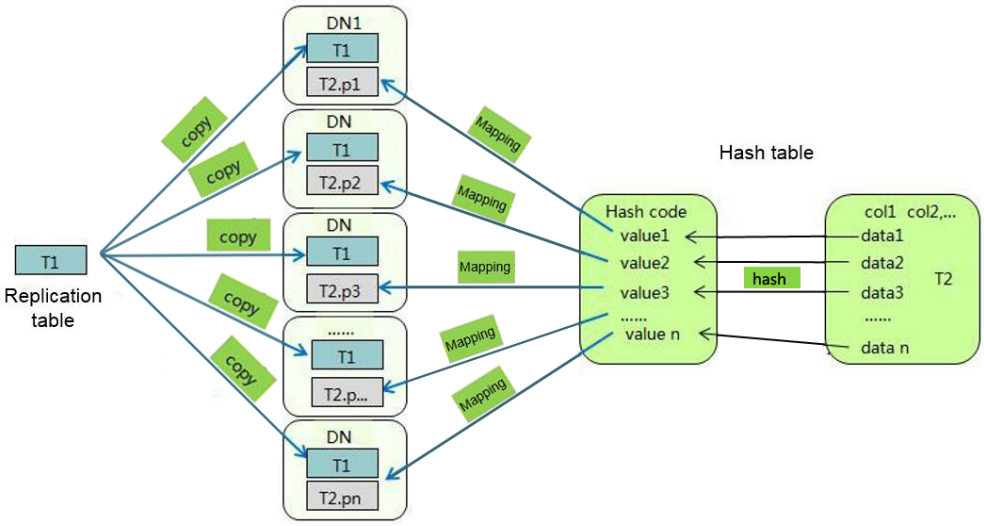
| Policy | Description | Scenario |
| --- | --- | --- |
| Hash | Table data is distributed on all DNs in the cluster. | Fact tables containing a large amount of data |
| Replication | Full data in a table is stored on each DN in the cluster. | Small tables and dimension tables |

As shown in **Figure 11-5**, **T1** is a replication table and **T2** is a hash table.

**Figure 11-5** Replication table and hash table




## 11.3.3.4 Selecting a Distribution Column

The distribution column in a hash table must meet the following requirements, which are ranked by priority in descending order:

1. **The value of the distribution column should be discrete so that data can be evenly distributed on each DN.** For example, you are advised to select the primary key of a table as the distribution column, and the ID card number as the distribution column in a personnel information table.
2. **Do not select the column where a constant filter exists.** For example, if a constant constraint (for example, zqdh= '000001') exists on the **zqdh** column in some queries on the **dwcjk** table, you are not advised to use **zqdh** as the distribution column.
3. **Select the join condition as the distribution column**, so that join tasks can be pushed down to DNs to execute, reducing the amount of data transferred between the DNs.

   For a hash table, an improper distribution key may cause data skew or poor I/O performance on certain DNs. Therefore, you need to check the table to ensure that data is evenly distributed on each DN. You can run the following SQL statements to check data skew:

   ```
   select
   xc_node_id, count(1)
   from tablename
   ```

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```
group by xc_node_id
order by xc_node_id desc;
```

**xc_node_id** corresponds to a DN. Generally, **over 5% difference between the amount of data on different DNs is regarded as data skew. If the difference is over 10%, choose another distribution column.**

4. You are not advised to add a column as a distribution column, especially add a new column and use the SEQUENCE value to fill the column. This is because SEQUENCE may cause performance bottlenecks and unnecessary maintenance costs.

Multiple distribution columns can be selected in GaussDB(DWS) to evenly distribute data.

## 11.3.3.5 Using Partial Clustering

Partial Cluster Key is the column-based technology. It can minimize or maximize sparse indexes to quickly filter base tables. Partial cluster key can specify multiple columns, but you are advised to specify no more than two columns. Use the following principles to specify columns:

1. The selected columns must be restricted by simple expressions in base tables. Such constraints are usually represented by Col, Op, and Const. Col specifies the column name, Op specifies operators, (including =, >, >=, <=, and <) Const specifies constants.
2. Select columns that are frequently selected (to filter much more undesired data) in simple expressions.
3. List the less frequently selected columns on the top.
4. List the columns of the enumerated type at the top.

## 11.3.3.6 Using Partitioned Tables

Partitioning refers to splitting what is logically one large table into smaller physical pieces based on specific schemes. The table based on the logic is called a partitioned table, and a physical piece is called a partition. Data is stored on these smaller physical pieces, namely, partitions, instead of the larger logical partitioned table. A partitioned table has the following advantages over an ordinary table:

1. High query performance: The system queries only the concerned partitions rather than the whole table, improving the query efficiency.
2. High availability: If a partition is faulty, data in the other partitions is still available.
3. Easy maintenance: You only need to fix the faulty partition.

GaussDB(DWS) supports range-partitioned tables.

Range-partitioned table: Data within a specific range is mapped onto each partition. The range is determined by the partition key specified during the partitioned table creation. The partition key is usually a date. For example, sales data is partitioned by month.

## 11.3.3.7 Selecting a Data Type

Use the following principles to obtain efficient data types:

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1. **Using the data type that can be efficiently executed**

   Generally, calculation of integers (including common comparison calculations, such as =, >, <, ≥, ≤, and ≠ and group by) is more efficient than that of strings and floating point numbers. For example, if you need to filter data in a column containing numeric data for a column-store table where point query is performed, the execution takes over 10s. However, the execution time is reduced to 1.8s when you change the data type from NUMERIC to INT.

2. **Using the data type of short length column**

   Using the data type with a shorter length reduces both the data file size and the memory used for computing, improving the I/O and computing performance. For example, use SMALLINT instead of INT, and INT instead of BIGINT.

3. **Using the same data type for associated columns**

   Use the same data type for associated columns. If columns having different data types are associated, the database must dynamically convert the different data types into the same ones for comparison. The conversion results in performance overheads.

## 11.3.4 Typical SQL Optimization Methods

SQL optimization involves continuous analysis and adjustment. You need to test-run a query, locate and fix its performance issues (if any) based on its execution plan, and run it again, until the execution performance meet your requirements.

### 11.3.4.1 SQL Self-Diagnosis

Performance issues may occur when you query data or run the **INSERT**, **DELETE**, **UPDATE**, or **CREATE TABLE AS** statement. You can query the **warning** column in the **GS_WLM_SESSION_STATISTICS**, **GS_WLM_SESSION_HISTORY**, and **GS_WLM_SESSION_INFO** views to obtain performance diagnosis information for tuning.

Alarms that can trigger SQL self-diagnosis depend on the settings of **resource_track_level**. If **resource_track_level** is set to **query** or **perf**, you can diagnose alarms indicating that statistics of multiple columns or a single column are not collected or SQL statements are not pushed down. If **resource_track_level** is set to **operator**, all alarm scenarios can be diagnosed.

Whether a SQL plan will be diagnosed depends on the settings of **resource_track_cost**. A SQL plan will be diagnosed only if its execution cost is greater than **resource_track_cost**. You can use the **EXPLAIN** keyword to check the plan execution cost.

### Alarms

Currently, the following performance alarms will be reported:

- Some column statistics are not collected.

  If statistics of a single column or multiple columns are not collected, an alarm is reported. For details about the optimization, see **Updating Statistics** and **Optimizing Statistics**.

  If no statistics are collected for the OBS foreign table and HDFS foreign table in the query statement, an alarm indicating that statistics are not collected

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will be reported. Because the **ANALYZE** performance of the OBS foreign table and HDFS foreign table is poor, you are not advised to perform **ANALYZE** on these tables. Instead, you are advised to use the **ALTER FOREIGN TABLE** syntax to modify the **totalrows** attribute of the foreign table to correct the estimated number of rows.

Example alarms:

No statistics about a table are not collected.

```
Statistic Not Collect:
    schema_test.t1
```

The statistics about a single column are not collected.

```
Statistic Not Collect:
    schema_test.t2(c1)
```

The statistics about multiple columns are not collected.

```
Statistic Not Collect:
    schema_test.t3((c1,c2))
```

The statistics about a single column and multiple columns are not collected.

```
Statistic Not Collect:
    schema_test.t4(c1)    schema_test.t5((c1,c2))
```

- SQL statements are not pushed down.

  The cause details are displayed in the alarms. For details about the optimization, see **Optimizing Statement Pushdown**.

  - If the pushdown failure is caused by functions, the function names are displayed in the alarm.
  - If the pushdown failure is caused by syntax, the alarm indicates that the syntax does not support pushdown. For example, the syntax containing the **With Recursive**, **Distinct On**, or **Row** expression, and syntax whose return value is of record type do not support pushdown.

  Example alarms:

  ```
  SQL is not plan-shipping, reason : ""enable_stream_operator" is off"
  SQL is not plan-shipping, reason : ""Distinct On" can not be shipped"
  SQL is not plan-shipping, reason : ""v_test_unshipping_log" is VIEW that will be treated as Record type can't be shipped"
  ```

- In a hash join, the larger table is used as the inner table.

  An alarm will be reported if the number of rows in the inner table reaches or exceeds 10 times of that in the foreign table, more than 100,000 inner-table rows are processed on each DN in average, and data has been flushed to disks. You can view the **query_plan** column in **GS_WLM_SESSION_HISTORY** to check whether hash joins are used. In this scenario, you need to adjust the sequence of the HashJoin internal and foreign tables. For details, see **Join Order Hints**.

  Example alarm:

  ```
  PlanNode[7] Large Table is INNER in HashJoin "Vector Hash Aggregate"
  ```

  In the preceding command, **7** indicates the operator whose ID is **7** in the **query_plan** column.

- **nestloop** is used in a large-table equivalent join.

  An alarm will be reported if nested loop is used in an equivalent join where more than 100,000 larger-table rows are processed on each DN in average. You can view the **query_plan** column of **GS_WLM_SESSION_HISTORY** to check whether nested loop is used. In this scenario, you need to adjust the

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table join mode and disable the NestLoop join mode between the current internal and foreign tables. For details, see **Join Operation Hints**.

Example alarm:

```
PlanNode[5] Large Table with Equal-Condition use Nestloop"Nested Loop"
```

- A large table is broadcasted.

  An alarm will be reported if more than 100 thousand of rows are broadcasted on each DN in average. In this scenario, the broadcast operation of the BroadCast lower-layer operator needs to be disabled. For details about the optimization, see **Stream Operation Hints**.

  Example alarm:

  ```
  PlanNode[5] Large Table in Broadcast "Streaming(type: BROADCAST dop: 1/2)"
  ```

- Data skew occurs.

  An alarm will be reported if the number of rows processed on any DN exceeds 100 thousand, and the number of rows processed on a DN reaches or exceeds 10 times of that processed on another DN. Generally, this alarm is generated due to storage layer skew or computing layer skew. For details about the optimization, see **Optimizing Data Skew**.

  Example alarm:

  ```
  PlanNode[6] DataSkew:"Seq Scan", min_dn_tuples:0, max_dn_tuples:524288
  ```

- The index is improper.

  During base table scanning, an alarm is reported if the following conditions are met:

  - For row-store tables:
    - When the index scanning is used, the ratio of the number of output lines to the number of scanned lines is greater than 1/1000 and the number of output lines is greater than 10,000.
    - When sequential scanning is used, the number of output lines to the number of scanned lines is less than 1/1000, the number of output lines is less than or equal to 10,000, and the number of scanned lines is greater than 10,000.
  - For column-store tables:
    - When the index scanning is used, the ratio of the number of output lines to the number of scanned lines is greater than 1/10000 and the number of output lines is greater than 100.
    - When sequential scanning is used, the number of output lines to the number of scanned lines is less than 1/10,000, the number of output lines is less than or equal to 100, and the number of scanned lines is greater than 10,000.

  For details about the optimization, see **Optimizing Operators**. You can also refer to **Case: Creating an Appropriate Index** and **Case: Setting Partial Cluster Keys**.

  Example alarms:

  ```
  PlanNode[4] Indexscan is not properly used:"Index Only Scan", output:524288, filtered:0, rate:1.00000
  PlanNode[5] Indexscan is ought to be used:"Seq Scan", output:1, filtered:524288, rate:0.00000
  ```

- Estimation is inaccurate.

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An alarm will be reported if the maximum number or the estimated maximum number of rows processed on a DN is over 100,000, and the larger number reaches or exceeds 10 times of the smaller one. In this scenario, you can refer to **Rows Hints** to correct the estimation on the number of rows, so that the optimizer can re-design the execution plan based on the correct number.

Example alarm:

```
PlanNode[5] Inaccurate Estimation-Rows: "Hash Join" A-Rows:0, E-Rows:52488
```

## Restrictions

1. An alarm contains a maximum of 2048 characters. If the length of an alarm exceeds this value (for example, a large number of long table names and column names are displayed in the alarm when their statistics are not collected), a warning instead of an alarm will be reported.
   ```
   WARNING, "Planner issue report is truncated, the rest of planner issues will be skipped"
   ```
2. If a query statement contains the **Limit** operator, alarms of operators lower than **Limit** will not be reported.
3. For alarms about data skew and inaccurate estimation, only alarms on the lower-layer nodes in a plan tree will be reported. This is because the same alarms on the upper-level nodes may be triggered by problems on the lower-layer nodes. For example, if data skew occurs on the **Scan** node, data skew may also occur in operators (for example, **Hashagg**) at the upper layer.

## 11.3.4.2 Optimizing Statement Pushdown

## Statement Pushdown

Currently, the GaussDB(DWS) optimizer can use three methods to develop statement execution policies in the distributed framework: generating a statement pushdown plan, a distributed execution plan, or a distributed execution plan for sending statements.

- A statement pushdown plan pushes query statements from a CN down to DNs for execution and returns the execution results to the CN.
- In a distributed execution plan, a CN compiles and optimizes query statements, generates a plan tree, and then sends the plan tree to DNs for execution. After the statements have been executed, execution results will be returned to the CN.
- A distributed execution plan for sending statements pushes queries that can be pushed down (mostly base table scanning statements) to DNs for execution. Then, the plan obtains the intermediate results and sends them to the CN, on which the remaining queries are to be executed.

The third policy sends many intermediate results from the DNs to a CN for further execution. In this case, the CN performance bottleneck (in bandwidth, storage, and computing) is caused by statements that cannot be pushed down to DNs. Therefore, you are not advised to use the query statements that only the third policy is applicable to.

Statements cannot be pushed down to DNs if they have **Functions That Do Not Support Pushdown** or **Syntax That Does Not Support Pushdown**. Generally, you can rewrite the execution statements to solve the problem.

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## Viewing Whether the Execution Plan Has Been Pushed Down to DNs

Perform the following procedure to quickly determine whether the execution plan can be pushed down to DNs:

**Step 1** Set the GUC parameter **enable_fast_query_shipping** to **off** to use the distributed framework policy for the query optimizer.

```
SET enable_fast_query_shipping = off;
```

**Step 2** View the execution plan.

If the execution plan contains Data Node Scan, the SQL statements cannot be pushed down to DNs. If the execution plan contains Streaming, the SQL statements can be pushed down to DNs.

For example:

```
select
count(ss.ss_sold_date_sk order by ss.ss_sold_date_sk)c1
from store_sales ss, store_returns sr
where
sr.sr_customer_sk = ss.ss_customer_sk;
```

The execution plan is as follows, which indicates that the SQL statement cannot be pushed down.

```
                            QUERY PLAN
------------------------------------------------------------------------------
Aggregate
->  Hash Join
Hash Cond: (ss.ss_customer_sk = sr.sr_customer_sk)
->  Data Node Scan on store_sales "_REMOTE_TABLE_QUERY_"
Node/s: All datanodes
->  Hash
->  Data Node Scan on store_returns "_REMOTE_TABLE_QUERY_"
Node/s: All datanodes
(8 rows)
```

**----End**

## Syntax That Does Not Support Pushdown

SQL syntax that does not support pushdown is described using the following table definition examples:

```
CREATE TABLE CUSTOMER1
(
    C_CUSTKEY     BIGINT NOT NULL
  , C_NAME        VARCHAR(25) NOT NULL
  , C_ADDRESS     VARCHAR(40) NOT NULL
  , C_NATIONKEY   INT NOT NULL
  , C_PHONE       CHAR(15) NOT NULL
  , C_ACCTBAL     DECIMAL(15,2)   NOT NULL
  , C_MKTSEGMENT  CHAR(10) NOT NULL
  , C_COMMENT     VARCHAR(117) NOT NULL
)
DISTRIBUTE BY hash(C_CUSTKEY);
CREATE TABLE test_stream(a int, b float);--float does not support redistribution.
CREATE TABLE sal_emp ( c1 integer[] ) DISTRIBUTE BY replication;
```

- The **returning** statement cannot be pushed down.

  ```
  explain update customer1 set C_NAME = 'a' returning c_name;
                              QUERY PLAN
  ------------------------------------------------------------------
   Update on customer1  (cost=0.00..0.00 rows=30 width=187)
  ```

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```
  Node/s: All datanodes
  Node expr: c_custkey
  ->  Data Node Scan on customer1 "_REMOTE_TABLE_QUERY_"  (cost=0.00..0.00 rows=30 width=187)
        Node/s: All datanodes
(5 rows)
```

- If columns in **count(distinct expr)** do not support redistribution, they do not support pushdown.

```
explain verbose select count(distinct b) from test_stream;
                                QUERY PLAN
---------------------------------------------------------------------- Aggregate  (cost=2.50..2.51 rows=1 width=8)
  Output: count(DISTINCT test_stream.b)
  ->  Data Node Scan on test_stream "_REMOTE_TABLE_QUERY_"  (cost=0.00..0.00 rows=30 width=8)
        Output: test_stream.b
        Node/s: All datanodes
        Remote query: SELECT b FROM ONLY public.test_stream WHERE true
(6 rows)
```

- Statements using **distinct on** cannot be pushed down.

```
explain verbose select distinct on (c_custkey) c_custkey from customer1 order by c_custkey;
                                  QUERY PLAN
---------------------------------------------------------------------- Unique  (cost=49.83..54.83 rows=30 width=8)
  Output: customer1.c_custkey
  ->  Sort  (cost=49.83..52.33 rows=30 width=8)
        Output: customer1.c_custkey
        Sort Key: customer1.c_custkey
        ->  Data Node Scan on customer1 "_REMOTE_TABLE_QUERY_"  (cost=0.00..0.00 rows=30
width=8)
              Output: customer1.c_custkey
              Node/s: All datanodes
              Remote query: SELECT c_custkey FROM ONLY public.customer1 WHERE true
(9 rows)
```

- In a statement using **FULL JOIN**, if the column specified using **JOIN** does not support redistribution, the statement does not support pushdown.

```
explain select * from test_stream t1 full join test_stream t2 on t1.a=t2.b;
                                  QUERY PLAN
---------------------------------------------------------------------- Hash Full Join  (cost=0.38..0.82 rows=30
width=24)
  Hash Cond: ((t1.a)::double precision = t2.b)
  ->  Data Node Scan on test_stream "_REMOTE_TABLE_QUERY_"  (cost=0.00..0.00 rows=30 width=12)
        Node/s: All datanodes
  ->  Hash  (cost=0.00..0.00 rows=30 width=12)
        ->  Data Node Scan on test_stream "_REMOTE_TABLE_QUERY_"  (cost=0.00..0.00 rows=30
width=12)
              Node/s: All datanodes
(7 rows)
```

- Does not support array expression pushdown.

```
explain verbose select array[c_custkey,1] from customer1 order by c_custkey;

                        QUERY PLAN
---------------------------------------------------------------------- Sort  (cost=49.83..52.33 rows=30 width=8)
  Output: (ARRAY[customer1.c_custkey, 1::bigint]), customer1.c_custkey
  Sort Key: customer1.c_custkey
  ->  Data Node Scan on "__REMOTE_SORT_QUERY__"  (cost=0.00..0.00 rows=30 width=8)
        Output: (ARRAY[customer1.c_custkey, 1::bigint]), customer1.c_custkey
        Node/s: All datanodes
        Remote query: SELECT ARRAY[c_custkey, 1::bigint], c_custkey FROM ONLY public.customer1
WHERE true ORDER BY 2
(7 rows)
```

- The following table describes the scenarios where a statement containing **WITH RECURSIVE** cannot be pushed down in the current version, as well as the causes.

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| No. | Scenario | Cause of Not Supporting Pushdown |
| --- | --- | --- |
| 1 | The query contains foreign tables or HDFS tables. | LOG: SQL can't be shipped, reason: RecursiveUnion contains HDFS Table or ForeignScan is not shippable (In this table, **LOG** describes the cause of not supporting pushdown.)<br>In the current version, queries containing foreign tables or HDFS tables do not support pushdown. |
| 2 | Multiple Node Groups | LOG: SQL can't be shipped, reason: With-Recursive under multi-nodegroup scenario is not shippable<br>In the current version, pushdown is supported only when all base tables are stored and computed in the same Node Group. |
| 3 | WITH recursive t_result AS (<br>SELECT dm,sj_dm,name,1 as level<br>FROM test_rec_part<br>WHERE sj_dm > 10<br>UNION<br>SELECT t2.dm,t2.sj_dm,t2.name\|\|' > '\|\|<br>t1.name,t1.level+1<br>FROM t_result t1<br>JOIN test_rec_part t2 ON t2.sj_dm = t1.dm<br>)<br>SELECT * FROM t_result t; | LOG: SQL can't be shipped, reason: With-Recursive does not contain "ALL" to bind recursive & none-recursive branches<br>**ALL** is not used for **UNION**. In this case, the return result is deduplicated. |
| 4 | WITH RECURSIVE x(id) AS<br>(<br>select count(1) from pg_class where<br>oid=1247<br>UNION ALL<br>SELECT id+1 FROM x WHERE id < 5<br>), y(id) AS<br>(<br>select count(1) from pg_class where<br>oid=1247<br>UNION ALL<br>SELECT id+1 FROM x WHERE id < 10<br>)<br>SELECT y.*, x.* FROM y LEFT JOIN x<br>USING (id) ORDER BY 1; | LOG: SQL can't be shipped, reason: With-Recursive contains system table is not shippable<br>A base table contains the system catalog. |

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| No. | Scenario | Cause of Not Supporting Pushdown |
| --- | --- | --- |
| 5 | WITH RECURSIVE t(n) AS (<br>VALUES (1)<br>UNION ALL<br>SELECT n+1 FROM t WHERE n < 100<br>)<br>SELECT sum(n) FROM t; | LOG: SQL can't be shipped, reason: With-Recursive contains only values rte is not shippable<br>Only **VALUES** is used for scanning base tables. In this case, the statement can be executed on the CN, and DNs are unnecessary. |
| 6 | select  a.ID,a.Name,<br>(<br>with recursive cte as (<br>select ID, PID, NAME from b where b.ID = 1<br>union all<br>select parent.ID,parent.PID,parent.NAME from cte as child join b as parent on child.pid=parent.id<br>where child.ID = a.ID<br>)<br>select NAME from cte limit 1<br>) cName<br>from<br>(<br>select id, name, count(*) as cnt<br>from a group by id,name<br>) a order by 1,2; | LOG: SQL can't be shipped, reason: With-Recursive recursive term correlated only is not shippable<br>The correlation conditions of correlated subqueries are only in the recursion part, and the non-recursion part has no correlation condition. |
| 7 | WITH recursive t_result AS (<br>select * from(<br>SELECT dm,sj_dm,name,1 as level<br>FROM test_rec_part<br>WHERE sj_dm < 10 order by dm limit 6 offset 2)<br>UNION all<br>SELECT t2.dm,t2.sj_dm,t2.name\|\|' > '\|\| t1.name,t1.level+1<br>FROM t_result t1<br>JOIN test_rec_part t2 ON t2.sj_dm = t1.dm<br>)<br>SELECT * FROM t_result t; | LOG: SQL can't be shipped, reason: With-Recursive contains conflict distribution in none-recursive(Replicate) recursive(Hash)<br>The **replicate** plan is used for **limit** in the non-recursion part but the **hash** plan is used in the recursion part, resulting in conflicts. |

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| No. | Scenario | Cause of Not Supporting Pushdown |
| --- | --- | --- |
| 8 | with recursive cte as<br>(<br>select * from rec_tb4 where id<4<br>union all<br>select h.id,h.parentID,h.name from<br>(<br>with recursive cte as<br>(<br>select * from rec_tb4 where id<4<br>union all<br>select h.id,h.parentID,h.name from<br>rec_tb4 h inner join cte c on<br>h.id=c.parentID<br>)<br>SELECT id ,parentID,name from cte order<br>by parentID<br>) h<br>inner join cte c on h.id=c.parentID<br>)<br>SELECT id ,parentID,name from cte order<br>by parentID,1,2,3; | LOG: SQL can't be shipped, reason: Recursive CTE references recursive CTE "cte"<br>**recursive** of multiple-layers are nested. That is, a **recursive** is nested in the recursion part of another **recursive**. |

## Functions That Do Not Support Pushdown

This module describes the variability of functions. The function variability in GaussDB(DWS) is as follows:

- **IMMUTABLE**

  Indicates that the function always returns the same result if the parameter values are the same.

- **STABLE**

  Indicates that the function cannot modify the database, and that within a single table scan it will consistently return the same result for the same parameter values, but that its result varies by SQL statements.

- **VOLATILE**

  Indicates that the function value can change even within a single table scan, so no optimizations can be made.

The volatility of a function can be obtained by querying its **provolatile** column in **pg_proc**. The value **i** indicates immutable, **s** indicates stable, and **v** indicates volatile. The valid values of the **proshippable** column in **pg_proc** are **t**, **f**, and **NULL**. This column and the **provolatile** column together describe whether a function is pushed down.

- If the **provolatile** of a function is **i**, the function can be pushed down regardless of the value of **proshippable**.
- If the **provolatile** of a function is **s** or **v**, the function can be pushed only if the value of **proshippable** is **t**.
- CTEs containing random are not pushed down, because pushdown may lead to incorrect results.

For a UDF, you can specify the values of **provolatile** and **proshippable** during its creation. For details, see CREATE FUNCTION.

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In scenarios where a function does not support pushdown, perform one of the following as required:

- If it is a system function, replace it with a functionally equivalent one.
- If it is a UDF function, check whether its **provolatile** and **proshippable** are correctly defined.

## Example: UDF

Define a user-defined function that generates fixed output for a certain input as the **immutable** type.

Take the sales information of TPCDS as an example. If you want to write a function to calculate the discount data of a product, you can define the function as follows:

```
CREATE FUNCTION func_percent_2 (NUMERIC, NUMERIC) RETURNS NUMERIC
AS 'SELECT $1 / $2 WHERE $2 > 0.01'
LANGUAGE SQL
VOLATILE;
```

Run the following statement:

```
SELECT func_percent_2(ss_sales_price, ss_list_price)
FROM store_sales;
```

The execution plan is as follows:

```
 Data Node Scan on store_sales "_REMOTE_TABLE_QUERY_"
   Output: func_percent_2(store_sales.ss_sales_price, store_sales.ss_list_price)
   Remote query: SELECT ss_sales_price, ss_list_price FROM ONLY store_sales WHERE true
(3 rows)
```

**func_percent_2** is not pushed down, and **ss_sales_price** and **ss_list_price** are executed on a CN. In this case, a large amount of resources on the CN is consumed, and the performance deteriorates as a result.

In this example, the function returns certain output when certain input is entered. Therefore, we can modify the function to the following one:

```
CREATE FUNCTION func_percent_1 (NUMERIC, NUMERIC) RETURNS NUMERIC
AS 'SELECT $1 / $2 WHERE $2 > 0.01'
LANGUAGE SQL
IMMUTABLE;
```

Run the following statement:

```
SELECT func_percent_1(ss_sales_price, ss_list_price)
FROM store_sales;
```

The execution plan is as follows:

```
 Data Node Scan on "__REMOTE_FQS_QUERY__"  (cost=0.00..0.00 rows=0 width=0)
   Output: (func_percent_1(store_sales.ss_sales_price, store_sales.ss_list_price))
   Node/s: All datanodes
   Remote query: SELECT public.func_percent_1(ss_sales_price, ss_list_price) AS func_percent_1 FROM public.store_sales
(4 rows)
```

**func_percent_1** is pushed down to DNs for quicker execution. (In TPCDS 1000X, where three CNs and 18 DNs are used, the query efficiency is improved by over 100 times).

## Example 2: Pushing Down the Sorting Operation

For details, see **Case: Pushing Down Sort Operations to DNs**.

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## 11.3.4.3 Optimizing Subqueries

## What Is a Subquery

When an application runs a SQL statement to operate the database, a large number of subqueries are used because they are more clear than table join. Especially in complicated query statements, subqueries have more complete and independent semantics, which makes SQL statements clearer and easy to understand. Therefore, subqueries are widely used.

In GaussDB(DWS), subqueries can also be called sublinks based on the location of subqueries in SQL statements.

- Subquery: corresponds to a scope table (RangeTblEntry) in the query parse tree. That is, a subquery is a **SELECT** statement following immediately after the **FROM** keyword.
- Sublink: corresponds to an expression in the query parsing tree. That is, a sublink is a statement in the **WHERE** or **ON** clause or in the target list.

  In conclusion, a subquery is a scope table and a sublink is an expression in the query parsing tree. A sublink can be found in constraint conditions and expressions. In GaussDB(DWS), sublinks can be classified into the following types:

  - exist_sublink: corresponding to the **EXIST** and **NOT EXIST** statements.
  - any_sublink: corresponding to the **OP ANY(SELEC...)** statement. **OP** can be the **IN**, **<**, **>**, or **=** operator.
  - all_sublink: corresponding to the **OP ALL(SELEC...)** statement. **OP** can be the **IN**, **<**, **>**, or **=** operator.
  - rowcompare_sublink: corresponding to the **RECORD OP (SELECT...)** statement.
  - expr_sublink: corresponding to the **(SELECT** with a single target list item**)** statement.
  - array_sublink: corresponding to the **ARRAY(SELECT...)** statement.
  - cte_sublink: corresponding to the **WITH(...)** statement.

  The sublinks commonly used in OLAP and HTAP are exist_sublink and any_sublink. The sublinks are pulled up by the optimization engine of GaussDB(DWS). Because of the flexible use of subqueries in SQL statements, complex subqueries may affect query performance. Subqueries are classified into non-correlated subqueries and correlated subqueries.

  - **Non-correlated subquery**

    The execution of a subquery is independent from any attribute of outer queries. In this way, a subquery can be executed before outer queries.

    Example:

```
select t1.c1,t1.c2
from t1
where t1.c1 in (
    select c2
    from t2
    where t2.c2 IN (2,3,4)
);
                        QUERY PLAN
------------------------------------------------------------
Streaming (type: GATHER)
```

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```
  Node/s: All datanodes
  ->  Hash Right Semi Join
        Hash Cond: (t2.c2 = t1.c1)
        ->  Streaming(type: REDISTRIBUTE)
              Spawn on: All datanodes
              ->  Seq Scan on t2
                    Filter: (c2 = ANY ('{2,3,4}'::integer[]))
        ->  Hash
              ->  Seq Scan on t1
(10 rows)
```

- **Correlated subquery**

  The execution of a subquery depends on some attributes of outer queries which are used as **AND** conditions of the subquery. In the following example, **t1.c1** in the **t2.c1 = t1.c1** condition is a dependent attribute. Such a subquery depends on outer queries and needs to be executed once for each outer query.

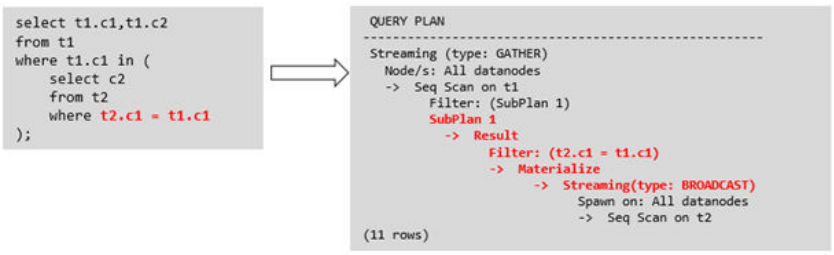
  Example:

```
select t1.c1,t1.c2
from t1
where t1.c1 in (
   select c2
   from t2
   where t2.c1 = t1.c1 AND t2.c2 in (2,3,4)
);
                              QUERY PLAN
-----------------------------------------------------------------------
Streaming (type: GATHER)
  Node/s: All datanodes
  ->  Seq Scan on t1
        Filter: (SubPlan 1)
        SubPlan 1
          ->  Result
                Filter: (t2.c1 = t1.c1)
                ->  Materialize
                      ->  Streaming(type: BROADCAST)
                            Spawn on: All datanodes
                  ->  Seq Scan on t2
                              Filter: (c2 = ANY ('{2,3,4}'::integer[]))
(12 rows)
```

## GaussDB(DWS) SubLink Optimization

A subquery is pulled up to join with tables in outer queries, preventing the subquery from being converted into the combination of a subplan and broadcast. You can run the **EXPLAIN** statement to check whether a subquery is converted into the combination of a subplan and broadcast.

Example:




- Sublink-release supported by GaussDB(DWS)

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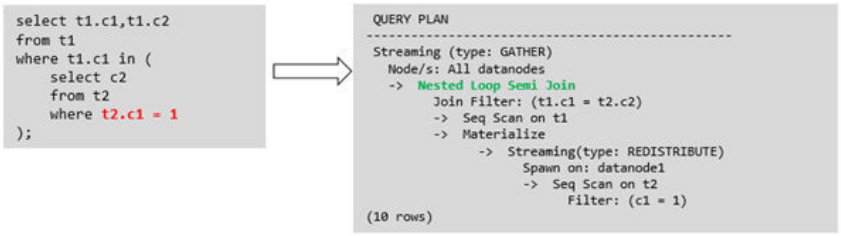
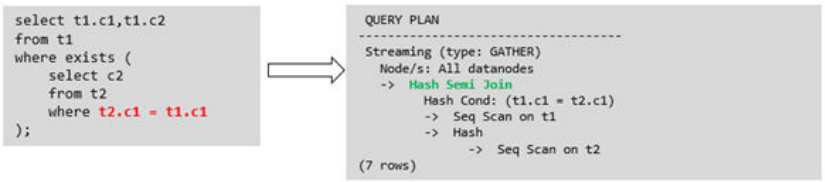
- Pulling up the **IN** sublink
  - The subquery cannot contain columns in the outer query (columns in more outer queries are allowed).
  - The subquery cannot contain volatile functions.




- Pulling up the **EXISTS** sublink

  The **WHERE** clause must contain a column in the outer query. Other parts of the subquery cannot contain the column. Other restrictions are as follows:
  - The subquery must contain the **FROM** clause.
  - The subquery cannot contain the **WITH** clause.
  - The subquery cannot contain aggregate functions.
  - The subquery cannot contain a **SET**, **SORT**, **LIMIT**, **WindowAgg**, or **HAVING** operation.
  - The subquery cannot contain volatile functions.




- Pulling up an equivalent query containing aggregation functions

  The **WHERE** condition of the subquery must contain a column from the outer query. Equivalence comparison must be performed between this column and related columns in tables of the subquery. These conditions must be connected using **AND**. Other parts of the subquery cannot contain the column. Other restrictions are as follows:
  - The expression in the **WHERE** condition of the subquery must be table columns.
  - After the **SELECT** keyword of the subquery, there must be only one output column. The output column must be an aggregation function (for example, **MAX**), and the parameter (for example, **t2.c2**) of the aggregate function cannot be columns of a table (for example, **t1**) in outer quires. The aggregate function cannot be **COUNT**.

    For example, the following subquery can be pulled up:

```
select * from t1 where c1 >(
      select max(t2.c1) from t2 where t2.c1=t1.c1
);
```

The following subquery cannot be pulled up because the subquery has no aggregation function.

```
select * from t1 where c1 >(
      select  t2.c1 from t2 where t2.c1=t1.c1
);
```

The following subquery cannot be pulled up because the subquery has two output columns:

```
select * from t1 where (c1,c2) >(
      select  max(t2.c1),min(t2.c2) from t2 where t2.c1=t1.c1
);
```

- The subquery must be a **FROM** clause.
- The subquery cannot contain a **GROUP BY**, **HAVING**, or **SET** operation.
- The subquery can only be inner join.

  For example, the following subquery can be pulled up:

  ```
  select * from t1 where c1 >(
        select max(t2.c1) from t2 full join t3 on (t2.c2=t3.c2) where t2.c1=t1.c1
  );
  ```

- The target list of the subquery cannot contain the function that returns a set.
- The **WHERE** condition of the subquery must contain a column from the outer query. Equivalence comparison must be performed between this column and related columns in tables of the subquery. These conditions must be connected using **AND**. Other parts of the subquery cannot contain the columns from the outer query. For example, the following subquery can be pulled up:

  ```
  select * from t3 where t3.c1=(
        select t1.c1
        from t1 where c1 >(
              select max(t2.c1) from t2 where t2.c1=t1.c1
  ));
  ```

  If another condition is added to the subquery in the previous example, the subquery cannot be pulled up because the subquery references to the column in the outer query. Example:

  ```
  select * from t3 where t3.c1=(
        select t1.c1
        from t1 where c1 >(
              select max(t2.c1) from t2 where t2.c1=t1.c1 and t3.c1>t2.c2

  ));
  ```

– Pulling up a sublink in the **OR** clause

  If the **WHERE** condition contains a **EXIST**-related sublink connected by **OR**,

  for example,

  ```
  select a, c from t1
  where t1.a = (select avg(a) from t3 where t1.b = t3.b) or
  exists (select * from t4 where t1.c = t4.c);
  ```

  the process of pulling up such a sublink is as follows:

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i. Extract **opExpr** from the **OR** clause in the **WHERE** condition. The value is **t1.a = (select avg(a) from t3 where t1.b = t3.b)**.

ii. The **opExpr** contains a subquery. If the subquery can be pulled up, the subquery is rewritten as **elect avg(a), t3.b from t3 group by t3.b**, generating the **NOT NULL** condition **t3.b is not null**. The **opExpr** is replaced with this **NOT NULL** condition. In this case, the SQL statement changes to:

```
select a, c
from t1 left join (select avg(a) avg, t3.b from t3 group by t3.b)  as t3 on (t1.a = avg and t1.b = t3.b)
where t3.b is not null or exists (select * from t4 where t1.c = t4.c);
```

iii. Extract the **EXISTS** sublink **exists (select * from t4 where t1.c = t4.c)** from the **OR** clause to check whether the sublink can be pulled up. If it can be pulled up, it is converted into **select t4.c from t4 group by t4.c**, generating the **NOT NULL** condition **t4.c is not null**. In this case, the SQL statement changes to:

```
select a, c
from t1 left join (select avg(a) avg, t3.b from t3 group by t3.b)  as t3 on (t1.a = avg and t1.b = t3.b)
left join (select t4.c from t4 group by t4.c) where t3.b is not null or t4.c is not null;
```

```
select * from t1
where exists (
    select t2.c1 from t2
    where t2.c1 = t1.c1
) OR
exists (
    select t3.c1 from t3
    where t3.c1 = t1.c1
);
```

```
QUERY PLAN
------------------------------------------------------------------
Streaming (type: GATHER)
  Node/s: All datanodes
  ->  Hash Left Join
        Hash Cond: (t1.c1 = t3.c1)
        Filter: ((t2.c1 IS NOT NULL) OR (t3.c1 IS NOT NULL))
        ->  Hash Left Join
              Hash Cond: (t1.c1 = t2.c1)
              ->  Seq Scan on t1
              ->  Hash
                    ->  HashAggregate
                          Group By Key: t2.c1
                          ->  Seq Scan on t2
        ->  Hash
              ->  HashAggregate
                    Group By Key: t3.c1
                    ->  Seq Scan on t3
(16 rows)
```

- Sublink-release not supported by GaussDB(DWS)

  Except the sublinks described above, all the other sublinks cannot be pulled up. In this case, a join subquery is planned as the combination of a subplan and broadcast. As a result, if tables in the subquery have a large amount of data, query performance may be poor.

  If a correlated subquery joins with two tables in outer queries, the subquery cannot be pulled up. You need to change the parent query into a **WITH** clause and then perform the join.

  Example:

  ```
  select distinct t1.a, t2.a
  from t1 left join t2 on t1.a=t2.a and not exists (select a,b from test1 where test1.a=t1.a and test1.b=t2.a);
  ```

  The parent query is changed into:

  ```
  with temp as
  (
        select * from (select t1.a as a, t2.a as b from t1 left join t2 on t1.a=t2.a)

  )
  select distinct a,b
  from temp
  where not exists (select a,b from test1 where temp.a=test1.a and temp.b=test1.b);
  ```

  – The subquery (without **COUNT**) in the target list cannot be pulled up.

    Example:

    ```
    explain (costs off)
    select (select c2 from t2 where t1.c1 = t2.c1) ssq, t1.c2
    ```

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```
from t1
where t1.c2 > 10;
```

The execution plan is as follows:

```
explain (costs off)
select (select c2 from t2 where t1.c1 = t2.c1) ssq, t1.c2
from t1
where t1.c2 > 10;
                    QUERY PLAN
-----------------------------------------------------
 Streaming (type: GATHER)
   Node/s: All datanodes
   ->  Seq Scan on t1
         Filter: (c2 > 10)
         SubPlan 1
           ->  Result
                 Filter: (t1.c1 = t2.c1)
                 ->  Materialize
                       ->  Streaming(type: BROADCAST)
                             Spawn on: All datanodes
                             ->  Seq Scan on t2
(11 rows)
```

The correlated subquery is displayed in the target list (query return list). Values need to be returned even if the condition **t1.c1=t2.c1** is not met. Therefore, use left outer join to join **T1** and **T2** so that SSQ can return padding values when the condition **t1.c1=t2.c1** is not met.

NOTE

ScalarSubQuery (SSQ) and Correlated-ScalarSubQuery (CSSQ) are described as follows:

- SSQ: a sublink that returns only a single row and column scalar value
- CSSQ: an SSQ containing conditions

The preceding SQL statement can be changed into:

```
with ssq as
(
   select t2.c2 from t2
)
select ssq.c2, t1.c2
from t1 left join ssq on t1.c1 = ssq.c2
where t1.c2 > 10;
```

The execution plan after the change is as follows:

```
               QUERY PLAN
-------------------------------------------
 Streaming (type: GATHER)
   Node/s: All datanodes
   ->  Hash Right Join
         Hash Cond: (t2.c2 = t1.c1)
         ->  Streaming(type: REDISTRIBUTE)
               Spawn on: All datanodes
               ->  Seq Scan on t2
         ->  Hash
               ->  Seq Scan on t1
                     Filter: (c2 > 10)
(10 rows)
```

In the preceding example, the SSQ is pulled up to right join, preventing poor performance caused by the combination of a subplan and broadcast when the table (**T2**) in the subquery is too large.

- The subquery (with **COUNT**) in the target list cannot be pulled up.

  Example:

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```
select (select count(*) from t2 where t2.c1=t1.c1) cnt, t1.c1, t3.c1
from t1,t3
where t1.c1=t3.c1 order by cnt, t1.c1;
```

The execution plan is as follows:

```
                        QUERY PLAN
------------------------------------------------------------------
 Streaming (type: GATHER)
   Node/s: All datanodes
   ->  Sort
         Sort Key: ((SubPlan 1)), t1.c1
         ->  Hash Join
               Hash Cond: (t1.c1 = t3.c1)
               ->  Seq Scan on t1
               ->  Hash
                     ->  Seq Scan on t3
               SubPlan 1
                 ->  Aggregate
                       ->  Result
                             Filter: (t2.c1 = t1.c1)
                             ->  Materialize
                                   ->  Streaming(type: BROADCAST)
                                         Spawn on: All datanodes
                                         ->  Seq Scan on t2
(17 rows)
```

The correlated subquery is displayed in the target list (query return list). Values need to be returned even if the condition **t1.c1=t2.c1** is not met. Therefore, use left outer join to join **T1** and **T2** so that SSQ can return padding values when the condition **t1.c1=t2.c1** is not met. However, **COUNT** is used to ensure that **0** is returned when the condition is note met. Therefore, **case-when NULL then 0 else count(*)** can be used.

The preceding SQL statement can be changed into:

```
with ssq as
(
   select count(*) cnt, c1 from t2 group by c1
)
select case when
          ssq.cnt is null then 0
          else ssq.cnt
      end cnt, t1.c1, t3.c1
from t1 left join ssq on ssq.c1 = t1.c1,t3
where t1.c1 = t3.c1
order by ssq.cnt, t1.c1;
```

The execution plan after the change is as follows:

```
 QUERY PLAN
-----------------------------------------------------
 Streaming (type: GATHER)
   Node/s: All datanodes
   ->  Sort
         Sort Key: (count(*)), t1.c1
         ->  Hash Join
               Hash Cond: (t1.c1 = t3.c1)
               ->  Hash Left Join
                     Hash Cond: (t1.c1 = t2.c1)
                     ->  Seq Scan on t1
                     ->  Hash
                           ->  HashAggregate
                                 Group By Key: t2.c1
                                 ->  Seq Scan on t2
               ->  Hash
                     ->  Seq Scan on t3
(15 rows)
```

- Pulling up nonequivalent subqueries

  Example:

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```
select t1.c1, t1.c2
from t1
where t1.c1 = (select agg() from t2.c2 > t1.c2);
```

Nonequivalent subqueries cannot be pulled up. You can perform join twice (one CorrelationKey and one rownum self-join) to rewrite the statement.

You can rewrite the statement in either of the following ways:

- Subquery rewriting

```
select t1.c1, t1.c2
from t1, (
    select t1.rowid, agg() aggref
    from t1,t2
    where t1.c2 > t2.c2 group by t1.rowid
) dt /* derived table */
where t1.rowid = dt.rowid AND t1.c1 = dt.aggref;
```

- CTE rewriting

```
WITH dt as
(
    select t1.rowid, agg() aggref
    from t1,t2
    where t1.c2 > t2.c2 group by t1.rowid
)
select t1.c1, t1.c2
from t1, derived_table
where t1.rowid = derived_table.rowid AND
t1.c1 = derived_table.aggref;
```

**NOTICE**

- Currently, GaussDB(DWS) does not have an effective way to provide globally unique row IDs for tables and intermediate result sets. Therefore, the rewriting is difficult. It is recommended that this issue is avoided at the service layer or by using **t1.xc_node_id + t1.ctid** to associate row IDs. However, the high repetition rate of **xc_node_id** leads to low association efficiency, and **xc_node_id+ctid** cannot be used as the join condition of hash join.
- If the AGG type is **COUNT(*)**, **0** is used for data padding if **CASE-WHEN** is not matched. If the type is not **COUNT(*)**, **NULL** is used.
- CTE rewriting works better by using share scan.

## More Optimization Examples

1. Change the base table to a replication table and create an index on the filter column.

```
create table master_table (a int);
create table sub_table(a int, b int);
select a from master_table group by a having a in (select a from sub_table);
```

In this example, a correlated subquery is contained. To improve the query performance, you can change **sub_table** to a replication table and create an index on the **a** column.

2. Modify the **SELECT** statement, change the subquery to a **JOIN** relationship between the primary table and the parent query, or modify the subquery to

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improve the query performance. Ensure that the subquery to be used is semantically correct.

```
explain (costs off)select * from master_table as t1 where t1.a in (select t2.a from sub_table as t2 where t1.a
= t2.b);
                     QUERY PLAN
------------------------------------------------------------
 Streaming (type: GATHER)
   Node/s: All datanodes
   ->  Seq Scan on master_table t1
         Filter: (SubPlan 1)
         SubPlan 1
           ->  Result
                 Filter: (t1.a = t2.b)
                 ->  Materialize
                       ->  Streaming(type: BROADCAST)
                             Spawn on: All datanodes
                             ->  Seq Scan on sub_table t2
(11 rows)
```

In the preceding example, a subplan is used. To remove the subplan, you can modify the statement as follows:

```
explain(costs off) select * from master_table as t1 where exists (select t2.a from sub_table as t2 where t1.a
= t2.b and t1.a = t2.a);
                  QUERY PLAN
-----------------------------------------------------
 Streaming (type: GATHER)
   Node/s: All datanodes
   ->  Hash Semi Join
         Hash Cond: (t1.a = t2.b)
         ->  Seq Scan on master_table t1
         ->  Hash
               ->  Streaming(type: REDISTRIBUTE)
                     Spawn on: All datanodes
                     ->  Seq Scan on sub_table t2
(9 rows)
```

In this way, the subplan is replaced by the semi-join between the two tables, greatly improving the execution efficiency.

## 11.3.4.4 Optimizing Statistics

## What Is Statistic Optimization

GaussDB(DWS) generates optimal execution plans based on the cost estimation. Optimizers need to estimate the number of data rows and the cost based on statistics collected using **ANALYZE**. Therefore, the statistics is vital for the estimation of the number of rows and cost. Global statistics are collected using **ANALYZE**: **relpages** and **reltuples** in the **pg_class** table; **stadistinct**, **stanullfrac**, **stanumbersN**, **stavaluesN**, and **histogram_bounds** in the **pg_statistic** table.

## Example 1: Poor Query Performance Due to the Lack of Statistics

In most cases, the lack of statistics in tables or columns involved in the query greatly affects the query performance.

The table structure is as follows:

```
CREATE TABLE LINEITEM
(
L_ORDERKEY        BIGINT        NOT NULL
, L_PARTKEY       BIGINT        NOT NULL
```

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```
, L_SUPPKEY        BIGINT        NOT NULL3
, L_LINENUMBER     BIGINT        NOT NULL
, L_QUANTITY       DECIMAL(15,2) NOT NULL
, L_EXTENDEDPRICE  DECIMAL(15,2) NOT NULL
, L_DISCOUNT       DECIMAL(15,2) NOT NULL
, L_TAX            DECIMAL(15,2) NOT NULL
, L_RETURNFLAG     CHAR(1)       NOT NULL
, L_LINESTATUS     CHAR(1)       NOT NULL
, L_SHIPDATE       DATE          NOT NULL
, L_COMMITDATE     DATE          NOT NULL
, L_RECEIPTDATE    DATE          NOT NULL
, L_SHIPINSTRUCT   CHAR(25)      NOT NULL
, L_SHIPMODE       CHAR(10)      NOT NULL
, L_COMMENT        VARCHAR(44)   NOT NULL
) with (orientation = column, COMPRESSION = MIDDLE) distribute by hash(L_ORDERKEY);

CREATE TABLE ORDERS
(
O_ORDERKEY        BIGINT        NOT NULL
, O_CUSTKEY       BIGINT        NOT NULL
, O_ORDERSTATUS   CHAR(1)       NOT NULL
, O_TOTALPRICE    DECIMAL(15,2) NOT NULL
, O_ORDERDATE     DATE NOT NULL
, O_ORDERPRIORITY CHAR(15)      NOT NULL
, O_CLERK         CHAR(15)      NOT NULL
, O_SHIPPRIORITY  BIGINT        NOT NULL
, O_COMMENT       VARCHAR(79)   NOT NULL
)with (orientation = column, COMPRESSION = MIDDLE) distribute by hash(O_ORDERKEY);
```

The query statements are as follows:

```
explain verbose select
count(*) as numwait
from
lineitem l1,
orders
where
o_orderkey = l1.l_orderkey
and o_orderstatus = 'F'
and l1.l_receiptdate > l1.l_commitdate
and not exists (
select
*
from
lineitem l3
where
l3.l_orderkey = l1.l_orderkey
and l3.l_suppkey <> l1.l_suppkey
and l3.l_receiptdate > l3.l_commitdate
)
order by
numwait desc;
```

If such an issue occurs, you can use the following methods to check whether statistics in tables or columns has been collected using **ANALYZE**.

1. Execute **EXPLAIN VERBOSE** to analyze the execution plan and check the warning information:

   ```
   WARNING:Statistics in some tables or columns(public.lineitem.l_receiptdate,
   public.lineitem.l_commitdate, public.lineitem.l_orderkey, public.lineitem.l_suppkey,
   public.orders.o_orderstatus, public.orders.o_orderkey) are not collected.
   HINT:Do analyze for them in order to generate optimized plan.
   ```

2. Check whether the following information exists in the log file in the **pg_log** directory. If it does, the poor query performance was caused by the lack of statistics in some tables or columns.

   ```
   2017-06-14 17:28:30.336 CST 140644024579856 20971684 [BACKEND] LOG:Statistics in some tables
   or columns(public.lineitem.l_receiptdate, public.lineitem.l_commitdate, public.lineitem.l_orderkey,
   public.linei
   ```

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```
tem.l_suppkey, public.orders.o_orderstatus, public.orders.o_orderkey) are not collected.
2017-06-14 17:28:30.336 CST 140644024579856 20971684 [BACKEND] HINT:Do analyze for them in order to generate optimized plan.
```

By using any of the preceding methods, you can identify tables or columns whose statistics have not been collected using **ANALYZE**. You can execute **ANALYZE** to warnings or tables and columns recorded in logs to resolve the problem.

## Example 2: Setting cost_param to Optimize Query Performance

For details, see **Case: Configuring cost_param for Better Query Performance**.

## Example 3: Optimization is Not Accurate When Intermediate Results Exist in the Query Where JOIN Is Used for Multiple Tables

**Symptom**: Query the personnel who have checked in an Internet cafe within 15 minutes before and after the check-in of a specified person.

```
SELECT
C.WBM,
C.DZQH,
C.DZ,
B.ZJHM,
B.SWKSSJ,
B.XWSJ
FROM
b_zyk_wbswxx A,
b_zyk_wbswxx B,
b_zyk_wbcs C
WHERE
A.ZJHM = '522522******3824'
AND A.WBDM = B.WBDM
AND A.WBDM = C.WBDM
AND abs(to_date(A.SWKSSJ,'yyyymmddHH24MISS') - to_date(B.SWKSSJ,'yyyymmddHH24MISS')) <
INTERVAL '15 MINUTES'
ORDER BY
B.SWKSSJ,
B.ZJHM
limit 10 offset 0
;
```

**Figure 11-6** shows the execution plan. This query takes about 12s.

**Figure 11-6** Using an unlogged table (1)

```
                                                
```

**Optimization analysis:**

1. In the execution plan, index scan is used for node scanning, the **Join Filter** calculation in the external **NEST LOOP IN** statement consumes most of the query time, and the calculation uses the string addition and subtraction, and unequal-value comparison.
2. Use an unlogged table to record the Internet access time of the specified person. The start time and end time are processed during data insertion, and this reduces subsequent addition and subtraction operations.

```
//Create a temporary unlogged table.
CREATE UNLOGGED TABLE temp_tsw
(
ZJHM         NVARCHAR2(18),
WBDM         NVARCHAR2(14),
SWKSSJ_START NVARCHAR2(14),
SWKSSJ_END   NVARCHAR2(14),
WBM          NVARCHAR2(70),
DZQH         NVARCHAR2(6),
DZ           NVARCHAR2(70),
IPDZ         NVARCHAR2(39)
)
;
//Insert the Internet access record of the specified person, and process the start time and end time.
INSERT INTO
temp_tsw
SELECT
A.ZJHM,
A.WBDM,
to_char((to_date(A.SWKSSJ,'yyyymmddHH24MISS') - INTERVAL '15
MINUTES'),'yyyymmddHH24MISS'),
to_char((to_date(A.SWKSSJ,'yyyymmddHH24MISS') + INTERVAL '15
MINUTES'),'yyyymmddHH24MISS'),
B.WBM,B.DZQH,B.DZ,B.IPDZ
FROM
b_zyk_wbswxx A,
b_zyk_wbcs B
WHERE
A.ZJHM='522522******3824' AND A.WBDM = B.WBDM
;

//Query the personnel who have check in an Internet cafe before and after 15 minutes of the check-in
of the specified person. Convert their ID card number format to int8 in comparison.
SELECT
A.WBM,
A.DZQH,
A.DZ,
A.IPDZ,
B.ZJHM,
B.XM,
to_date(B.SWKSSJ,'yyyymmddHH24MISS') as SWKSSJ,
to_date(B.XWSJ,'yyyymmddHH24MISS') as XWSJ,
B.SWZDH
FROM temp_tsw A,
b_zyk_wbswxx B
WHERE
A.ZJHM <> B.ZJHM
AND A.WBDM = B.WBDM
AND (B.SWKSSJ)::int8 > (A.swkssj_start)::int8
AND (B.SWKSSJ)::int8 < (A.swkssj_end)::int8
order by
B.SWKSSJ,
B.ZJHM
limit 10 offset 0
;
```

The query takes about 7s. **Figure 11-7** shows the execution plan.

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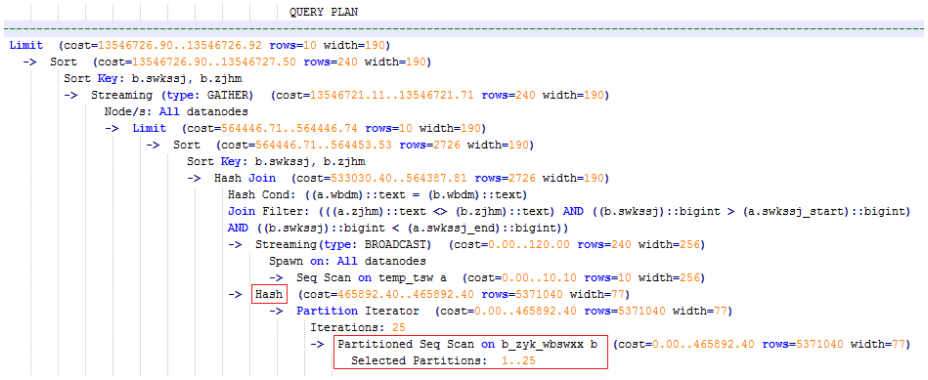
**Figure 11-7** Using an unlogged table (2)




3. In the previous plan, **Hash Join** has been executed, and a Hash table has been created for the large table **b_zyk_wbswxx**. The table contains large amounts of data, so the creation takes long time.

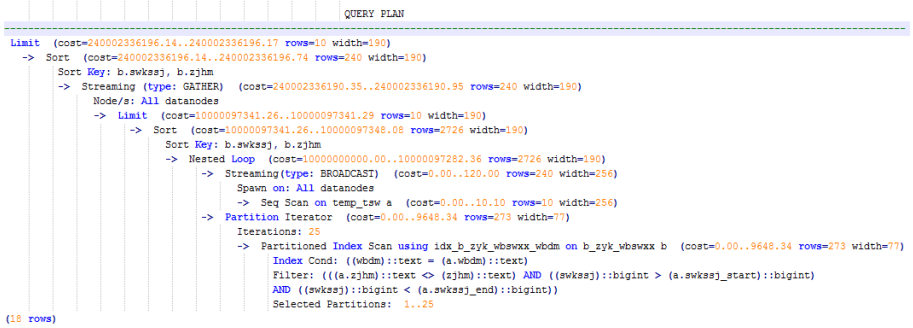
   **temp_tsw** contains only hundreds of records, and an equal-value connection is created between **temp_tsw** and **b_zyk_wbswxx** using wbdm (the Internet cafe code). Therefore, if **JOIN** is changed to **NEST LOOP JOIN**, index scan can be used for node scanning, and the performance will be boosted.

4. Execute the following statement to change **JOIN** to **NEST LOOP JOIN**.

   ```
   SET enable_hashjoin = off;
   ```

   **Figure 11-8** shows the execution plan. The query takes about 3s.

**Figure 11-8** Using an unlogged table (3)




5. Save the query result set in the unlogged table for paging display.

   If paging display needs to be achieved on the upper-layer application page, change the **offset** value to determine the result set on the target page. In this way, the previous query statement will be executed every time after a page turning operation, which causes long response latency.

   To resolve this problem, you are advised to use the unlogged table to save the result set.

   ```
   //Create an unlogged table to save the result set.
   CREATE UNLOGGED TABLE temp_result
   (
   WBM      NVARCHAR2(70),
   DZQH     NVARCHAR2(6),
   DZ       NVARCHAR2(70),
   IPDZ     NVARCHAR2(39),
   ZJHM     NVARCHAR2(18),
   XM       NVARCHAR2(30),
   SWKSSJ   date,
   XWSJ     date,
   ```

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```
SWZDH    NVARCHAR2(32)
);

//Insert the result set to the unlogged table. The insertion takes about 3s.
INSERT INTO
temp_result
SELECT
A.WBM,
A.DZQH,
A.DZ,
A.IPDZ,
B.ZJHM,
B.XM,
to_date(B.SWKSSJ,'yyyymmddHH24MISS') as SWKSSJ,
to_date(B.XWSJ,'yyyymmddHH24MISS') as XWSJ,
B.SWZDH
FROM temp_tsw A,
b_zyk_wbswxx B
WHERE
A.ZJHM <> B.ZJHM
AND A.WBDM = B.WBDM
AND (B.SWKSSJ)::int8 > (A.swkssj_start)::int8
AND (B.SWKSSJ)::int8 < (A.swkssj_end)::int8
;

//Perform paging query on the result set. The paging query takes about 10 ms.
SELECT
*
FROM
temp_result
ORDER BY
SWKSSJ,
ZJHM
LIMIT 10 OFFSET 0;
```

**CAUTION**

Collecting global statistics using ANALYZE improves query performance.

If a performance problem occurs, you can use plan hint to adjust the query plan to the previous one. For details, see **Hint-based Tuning**.

## 11.3.4.5 Optimizing Operators

### What Is Operator Optimization

A query statement needs to go through multiple operator procedures to generate the final result. Sometimes, the overall query performance deteriorates due to long execution time of certain operators, which are regarded as bottleneck operators. In this case, you need to execute the **EXPLAIN ANALYZE/ PERFORMANCE** command to view the bottleneck operators, and then perform optimization.

For example, in the following execution process, the execution time of the **Hashagg** operator accounts for about 66% [(51016-13535)/56476 ≈ 66%] of the total execution time. Therefore, the **Hashagg** operator is the bottleneck operator for this query. Optimize this operator first.

| id | operation | A-time | A-rows | E-rows | Peak Memory | E-memory | A-width | E-width | E-costs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -> Row Adapter | 56476.397 | 10000000 | 237060 | 19KB | | | 20 | 20933222.75 |
| 2 | -> Vector Streaming (type: GATHER) | 55664.220 | 10000000 | 237060 | 243KB | | | 20 | 20933222.75 |
| 3 | -> Vector Hash Aggregate | [55124.685,55132.180] | 10000000 | 237060 | [29349KB, 29441KB] | 16MB | [20,20] | 20 | 20918406.50 |
| 4 | -> Vector Streaming(type: REDISTRIBUTE) | [52519.781,53709.779] | 339364604 | 4856184 | [1219KB, 1219KB] | 1MB | | 20 | 10461210.85 |
| 5 | -> Vector Hash Aggregate | [35675.636,51016.424] | 339364604 | 4856184 | [732850KB, 746894KB] | 16MB | [20,20] | 20 | 10457195.65 |
| 6 | -> Vector Partition Iterator | [9035.202,13565.884] | 970000000 | 935838097 | [9KB, 9KB] | 1MB | | 20 | 10195891.68 |
| 7 | -> Partitioned CStore Scan on xuji.e_mp_day_energy_csv_1 | [9015.645,13535.346] | 970000000 | 935838097 | [845KB, 845KB] | 1MB | | 20 | 10195891.68 |

(7 rows)


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## Operator Optimization Example

1. Scan the base table. For queries requiring large volume of data filtering, such as point queries or queries that need range scanning, a full table scan using SeqScan will take a long time. To facilitate scanning, you can create indexes on the condition column and select IndexScan for index scanning.

```
explain (analyze on, costs off) select * from store_sales where ss_sold_date_sk = 2450944;
 id |            operation          |       A-time        | A-rows | Peak Memory  | A-width
----+-------------------------------+---------------------+--------+--------------+---------
  1 | ->  Streaming (type: GATHER)  | 3666.020            |   3360 | 195KB        |
  2 |    ->  Seq Scan on store_sales | [3594.611,3594.611] |   3360 | [34KB, 34KB] |

 Predicate Information (identified by plan id)
-----------------------------------------------
   2 --Seq Scan on store_sales
         Filter: (ss_sold_date_sk = 2450944)
         Rows Removed by Filter: 4968936
 create index idx on store_sales_row(ss_sold_date_sk);
CREATE INDEX
 explain (analyze on, costs off) select * from store_sales_row where ss_sold_date_sk = 2450944;
 id |                   operation                   |      A-time      | A-rows | Peak Memory  | A-width
----+-----------------------------------------------+------------------+--------+--------------+----------
  1 | ->  Streaming (type: GATHER)                  | 81.524           |   3360 | 195KB        |
  2 |    ->  Index Scan using idx on store_sales_row | [13.352,13.352] |   3360 | [34KB, 34KB] |
```

In this example, the full table scan filters much data and returns 3360 records. After an index has been created on the **ss_sold_date_sk** column, the scanning efficiency is significantly boosted from 3.6s to 13 ms by using **IndexScan**.

2: If NestLoop is used for joining tables with a large number of rows, the join may take a long time. In the following example, NestLoop takes 181s. If **enable_mergejoin=off** is set to disable merge join and **enable_nestloop=off** is set to disable NestLoop so that the optimizer selects hash join, the join takes more than 200 ms.

```
postgres=#  explain analyze select count(*) from store_sales ss, item i where ss.ss_item_sk = i.i_item_sk;
 id |                   operation                   |          A-time          |  A-rows   | E-rows  |  Peak Memory   | E-memory | A-width | E-width |   E-costs
----+-----------------------------------------------+--------------------------+-----------+---------+----------------+----------+---------+---------+-------------
  1 | ->  Row Adapter                               | 184300.301               |         1 |       1 | 11KB           |          |         |       0 | 48629179.77
  2 |    ->  Vector Aggregate                       | 184300.280               |         1 |       1 | 181KB          |          |         |       0 | 48629179.77
  3 |       ->  Vector Streaming (type: GATHER)     | 184300.186               |         4 |       4 | 188KB          |          |         |       0 | 48629179.77
  4 |          ->  Vector Aggregate                 | [165575.384,184252.368]  |         4 |       4 | [140KB, 140KB] | 1MB      |         |       0 | 48629179.61
  5 |             ->  Vector Nest Loop (6,7)        | [162918.848,181438.162]  |   2880404 | 2880404 | [74KB, 74KB]   | 1MB      |         |       0 | 48627379.35
  6 |                ->  CStore Scan on store_sales ss | [15.660,16.229]      |   2880404 | 2880404 | [490KB, 490KB] | 1MB      |         |       4 | 16683.10
  7 |                ->  Vector Materialize         | [118314.521,132478.454]  | 12968211302 |   18000 | [869KB, 900KB] | 16MB     | [8,8]   |       4 | 3890.00
  8 |                   ->  CStore Scan on item i   | [0.234,0.243]            |     18000 |   18000 | [476KB, 476KB] | 1MB      |         |       4 | 3867.50
(8 rows)



 postgres=#  set enable_nestloop=off;
 SET
 postgres=#  set enable_mergejoin=off;
 SET
 ppostgres=# explain analyze select count(*) fpostgres=# ales ss, item i where ss.ss_item_sk = i.i_item_sk;
  id |                   operation                   |          A-time          | A-rows  | E-rows  |  Peak Memory   | E-memory | A-width | E-width | E-costs
 ----+-----------------------------------------------+--------------------------+---------+---------+----------------+----------+---------+---------+----------
   1 | ->  Row Adapter                               | 291.066                  |       1 |       1 | 11KB           |          |         |       0 | 32308.66
   2 |    ->  Vector Aggregate                       | 291.052                  |       1 |       1 | 181KB          |          |         |       0 | 32308.66
   3 |       ->  Vector Streaming (type: GATHER)     | 290.973                  |       4 |       4 | 188KB          |          |         |       0 | 32308.66
   4 |          ->  Vector Aggregate                 | [220.792,234.532]        |       4 |       4 | [140KB, 140KB] | 1MB      |         |       0 | 32308.50
   5 |             ->  Vector Hash Join (6,7)        | [209.987,223.345]        | 2880404 | 2880404 | [236KB, 241KB] | 16MB     | [8,8]   |       0 | 30508.24
   6 |                ->  CStore Scan on store_sales ss | [13.132,13.717]      | 2880404 | 2880404 | [490KB, 490KB] | 1MB      |         |       4 | 16683.10
   7 |                ->  CStore Scan on item i      | [0.214,0.246]            |   18000 |   18000 | [477KB, 477KB] | 1MB      |         |       4 | 3867.50
 (7 rows)
```

3. Generally, query performance can be improved by selecting **HashAgg**. If **Sort** and **GroupAgg** are used for a large result set, you need to set **enable_sort** to **off**. **HashAgg** consumes less time than **Sort** and **GroupAgg**.

```
postgres=#  explain analyze select count(*) from store_sales group by ss_item_sk;
 id |                   operation                   |          A-time          | A-rows  | E-rows  |      Peak Memory      | E-memory | A-width | E-width | E-costs
----+-----------------------------------------------+--------------------------+---------+---------+-----------------------+----------+---------+---------+----------
  1 | ->  Row Adapter                               | 1977.385                 |   18000 |   17644 | 20KB                  |          |         |       4 | 92875.24
  2 |    ->  Vector Streaming (type: GATHER)        | 1973.617                 |   18000 |   17644 | 1946KB                |          |         |       4 | 92875.24
  3 |       ->  Vector Sort Aggregate               | [1784.800,1883.243]      |   18000 |   17644 | [273KB, 273KB]        | 1MB      |         |       4 | 92186.02
  4 |          ->  Vector Sort                      | [1752.270,1848.357]      | 2880404 | 2880404 | [128466KB, 135135KB]  | 16MB     | [8,8]   |       4 | 88541.40
  5 |             ->  CStore Scan on store_sales    | [12.483,13.548]          | 2880404 | 2880404 | [490KB, 490KB]        | 1MB      |         |       4 | 16683.10
 (5 rows)



postgres=#  set enable_sort=off;
SET
postgres=#  explain analyze select count(*) from store_sales group by ss_item_sk;
 id |                   operation                   |          A-time          | A-rows  | E-rows  |      Peak Memory      | E-memory | A-width | E-width | E-costs
----+-----------------------------------------------+--------------------------+---------+---------+-----------------------+----------+---------+---------+----------
  1 | ->  Row Adapter                               | 838.218                  |   18000 |   17644 | 20KB                  |          |         |       4 | 21016.93
  2 |    ->  Vector Streaming (type: GATHER)        | 834.264                  |   18000 |   17644 | 228KB                 |          |         |       4 | 21016.93
  3 |       ->  Vector Hash Aggregate               | [585.017,758.204]        |   18000 |   17644 | [262552KB, 262564KB]  | 16MB     | [8,8]   |       4 | 20327.72
  4 |          ->  CStore Scan on store_sales       | [12.540,13.941]          | 2880404 | 2880404 | [490KB, 490KB]        | 1MB      |         |       4 | 16683.10
(4 rows)
```

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## 11.3.4.6 Optimizing Data Skew

Data skew breaks the balance among nodes in the distributed MPP architecture. If the amount of data stored or processed by a node is much greater than that by other nodes, the following problems may occur:

- Storage skew severely limits the system capacity. The skew on a single node hinders system storage utilization.
- Computing skew severely affects performance. The data to be processed on the skew node is much more than that on other nodes, deteriorating overall system performance.
- Data skew severely affects the scalability of the MPP architecture. During storage or computing, data with the same values is often placed on the same node. Therefore, even if we add nodes after a data skew occurs, the skew data (data with the same values) is still placed on the node and affects the system capacity or performance bottleneck.

GaussDB(DWS) provides a complete solution for data skew, including storage and computing skew.

## Data Skew in the Storage Layer

In the GaussDB(DWS) database, data is distributed and stored on each DN. You can improve the query efficiency by using distributed execution. However, if data skew occurs, bottlenecks exist on some DNs during distribution execution, affecting the query performance. This is because the distribution column is not properly selected. This can be solved by adjusting the distribution column.

For example:

```
explain performance select count(*) from inventory;
5 --CStore Scan on lmz.inventory
        dn_6001_6002 (actual time=0.444..83.127 rows=42000000 loops=1)
        dn_6003_6004 (actual time=0.512..63.554 rows=27000000 loops=1)
        dn_6005_6006 (actual time=0.722..99.033 rows=45000000 loops=1)
        dn_6007_6008 (actual time=0.529..100.379 rows=51000000 loops=1)
        dn_6009_6010 (actual time=0.382..71.341 rows=36000000 loops=1)
        dn_6011_6012 (actual time=0.547..100.274 rows=51000000 loops=1)
        dn_6013_6014 (actual time=0.596..118.289 rows=60000000 loops=1)
        dn_6015_6016 (actual time=1.057..132.346 rows=63000000 loops=1)
        dn_6017_6018 (actual time=0.940..110.310 rows=54000000 loops=1)
        dn_6019_6020 (actual time=0.231..41.198 rows=21000000 loops=1)
        dn_6021_6022 (actual time=0.927..114.538 rows=54000000 loops=1)
        dn_6023_6024 (actual time=0.637..118.385 rows=60000000 loops=1)
        dn_6025_6026 (actual time=0.288..32.240 rows=15000000 loops=1)
        dn_6027_6028 (actual time=0.566..118.096 rows=60000000 loops=1)
        dn_6029_6030 (actual time=0.423..82.913 rows=42000000 loops=1)
        dn_6031_6032 (actual time=0.395..78.103 rows=39000000 loops=1)
        dn_6033_6034 (actual time=0.376..51.052 rows=24000000 loops=1)
        dn_6035_6036 (actual time=0.569..79.463 rows=39000000 loops=1)
```

In the performance information, you can view the number of scan rows of each DN in the inventory table. The number of rows of each DN differs a lot, the biggest is 63000000 and the smallest value is 15000000. This value difference on the performance of data scan is acceptable, but if the join operator exists in the upper-layer, the impact on the performance cannot be ignored.

Generally, the data table is hash distributed on each DN; therefore, it is important to choose a proper distribution column. Run table_skewness() to view data skew of each DN in the inventory table. The query result is as follows:

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```
select table_skewness('inventory');
              table_skewness
-------------------------------------------
 ("dn_6015_6016         ",63000000,8.046%)
 ("dn_6013_6014         ",60000000,7.663%)
 ("dn_6023_6024         ",60000000,7.663%)
 ("dn_6027_6028         ",60000000,7.663%)
 ("dn_6017_6018         ",54000000,6.897%)
 ("dn_6021_6022         ",54000000,6.897%)
 ("dn_6007_6008         ",51000000,6.513%)
 ("dn_6011_6012         ",51000000,6.513%)
 ("dn_6005_6006         ",45000000,5.747%)
 ("dn_6001_6002         ",42000000,5.364%)
 ("dn_6029_6030         ",42000000,5.364%)
 ("dn_6031_6032         ",39000000,4.981%)
 ("dn_6035_6036         ",39000000,4.981%)
 ("dn_6009_6010         ",36000000,4.598%)
 ("dn_6003_6004         ",27000000,3.448%)
 ("dn_6033_6034         ",24000000,3.065%)
 ("dn_6019_6020         ",21000000,2.682%)
 ("dn_6025_6026         ",15000000,1.916%)
(18 rows)
```

The table definition indicates that the table uses the **inv_date_sk** column as the distribution column, which causes a data skew. Based on the data distribution of each column, change the distribution column to **inv_item_sk**. The skew status is as follows:

```
select table_skewness('inventory');
              table_skewness
-------------------------------------------
 ("dn_6001_6002         ",43934200,5.611%)
 ("dn_6007_6008         ",43829420,5.598%)
 ("dn_6003_6004         ",43781960,5.592%)
 ("dn_6031_6032         ",43773880,5.591%)
 ("dn_6033_6034         ",43763280,5.589%)
 ("dn_6011_6012         ",43683600,5.579%)
 ("dn_6013_6014         ",43551660,5.562%)
 ("dn_6027_6028         ",43546340,5.561%)
 ("dn_6009_6010         ",43508700,5.557%)
 ("dn_6023_6024         ",43484540,5.554%)
 ("dn_6019_6020         ",43466800,5.551%)
 ("dn_6021_6022         ",43458500,5.550%)
 ("dn_6017_6018         ",43448040,5.549%)
 ("dn_6015_6016         ",43247700,5.523%)
 ("dn_6005_6006         ",43200240,5.517%)
 ("dn_6029_6030         ",43181360,5.515%)
 ("dn_6025_6026         ",43179700,5.515%)
 ("dn_6035_6036         ",42960080,5.487%)
(18 rows)
```

Data skew is solved.

In addition to the **table_skewness()** view, you can use the **table_distribution** function and the **PGXC_GET_TABLE_SKEWNESS** view to efficiently query the data skew of each table.

## Data Skew in the Computing Layer

Even if data is balanced across nodes after you change the distribution key of a table, data skew may still occur during a query. If data skew occurs in the result set of an operator on a DN, skew will also occur during the computing that involves the operator. Generally, this is caused by data redistribution during the execution.

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During a query, JOIN keys and GROUP BY keys are not used as distribution columns. Data is redistributed among DNs based on the hash values of data on the keys. The redistribution is implemented using the Redistribute operator in an execution plan. Data skew in redistribution columns can lead to data skew during system operation. After the redistribution, some nodes will have much more data, process more data, and will have much lower performance than others.

In the following example, the **s** and **t** tables are joined, and **s.x** and **t.x** columns in the join condition are not their distribution keys. Table data is redistributed using the **REDISTRIBUTE** operator. Data skew occurs in the **s.x** column and not in the **t.x** column. The result set of the **Streaming** operator (**id** being **6**) on datanode2 has data three times that of other DNs and causes a skew.

```
select * from skew s,test t where s.x = t.x order by s.a limit 1;
 id |                    operation                     |        A-time
----+--------------------------------------------------+----------------------
  1 | ->  Limit                                        | 52622.382
  2 |    ->  Streaming (type: GATHER)                  | 52622.374
  3 |       ->  Limit                                  | [30138.494,52598.994]
  4 |         ->  Sort                                 | [30138.486,52598.986]
  5 |           ->  Hash Join (6,8)                    | [30127.013,41483.275]
  6 |             ->  Streaming(type: REDISTRIBUTE)    | [11365.110,22024.845]
  7 |               ->  Seq Scan on public.skew s      | [2019.168,2175.369]
  8 |             ->  Hash                             | [2460.108,2499.850]
  9 |               ->  Streaming(type: REDISTRIBUTE)  | [1056.214,1121.887]
 10 |                 ->  Seq Scan on public.test t    | [310.848,325.569]

6 --Streaming(type: REDISTRIBUTE)
       datanode1 (rows=5050368)
       datanode2 (rows=15276032)
       datanode3 (rows=5174272)
       datanode4 (rows=5219328)
```

It is more difficult to detect skew in computing than in storage. To solve skew in computing, GaussDB provides the Runtime Load Balance Technology (RLBT) solution controlled by the **skew_option** parameter. The RLBT solution addresses how to detect and solve data skew.

1. Detect data skew.

   The solution first checks whether skew data exists in redistribution columns used for computing. RLBT can detect data skew based on statistics, specified hints, or rules.

   - Detection based on statistics

     Run the **ANALYZE** statement to collect statistics on tables. The optimizer will automatically identify skew data on redistribution keys based on the statistics and generate optimization plans for queries having potential skew. When the redistribution key has multiple columns, statistics information can be used for identification only when all columns belong to the same base table.

     The statistics information can only provide the skew of the base table. When a column in the base table is skewed, other columns have filtering conditions, or after the join of other tables, we cannot determine whether the skewed data still exists on the skewed column. If **skew_option** is set to **normal**, it indicates that data skew persists and the base tables will be optimized to solve the skew. If **skew_option** is set to **lazy**, it indicates that data skew is solved and the optimization will stop.

   - Detection based on specified hints

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The intermediate results of complex queries are difficult to estimate based on statistics. In this case, you can specify hints provide the skew information, based on which the optimizer optimize queries. For details about the syntax of hints, see **Skew Hints**.

- Detection based on rules

  In a business intelligence (BI) system, a large number of SQL statements having outer joins (including left joins, right joins, and full joins) are generated, and many NULL values will be generated in empty columns that have no match for outer joins. If JOIN or GROUP BY operations are performed on the columns, data skew will occur. RLBT can automatically identify this scenario and generate an optimization plan for NULL value skew.

2. Solve computing skew.

   **Join** and **Aggregate** operators are optimized to solve skew.

   - **Join** optimization

   Skew and non-skew data is separately processed. Details are as follows:

   a. When redistribution is required on both sides of a join:

      Use **PART_REDISTRIBUTE_PART_ROUNDROBIN** on the side with skew. Specifically, perform round-robin on skew data and redistribution on non-skew data.

      Use **PART_REDISTRIBUTE_PART_BROADCAST** on the side with no skew. Specifically, perform broadcast on skew data and redistribution on non-skew data.

   b. When redistribution is required on only one side of a join:

      Use **PART_REDISTRIBUTE_PART_ROUNDROBIN** on the side where redistribution is required.

      Use **PART_LOCAL_PART_BROADCAST** on the side where redistribution is not required. Specifically, perform broadcast on skew data and retain other data locally.

   c. When a table has **NULL** values padded:

      Use **PART_REDISTRIBUTE_PART_LOCAL** on the table. Specifically, retain the **NULL** values locally and perform redistribution on other data.

   In the example query, the **s.x** column contains skewed data and its value is **0**. The optimizer identifies the skew data in statistics and generates the following optimization plan:

```
 id |                              operation                               |        A-time
----+----------------------------------------------------------------------+----------------------
  1 | ->  Limit                                                           | 23642.049
  2 |    ->  Streaming (type: GATHER)                                     | 23642.041
  3 |       ->  Limit                                                     | [23310.768,23618.021]
  4 |          ->  Sort                                                   | [23310.761,23618.012]
  5 |             ->  Hash Join (6,8)                                     | [20898.341,21115.272]
  6 |                ->  Streaming(type: PART REDISTRIBUTE PART ROUNDROBIN)   |
[7125.834,7472.111]
  7 |                   ->  Seq Scan on public.skew s                     | [1837.079,1911.025]
  8 |                ->  Hash                                             | [2612.484,2640.572]
  9 |                   ->  Streaming(type: PART REDISTRIBUTE PART BROADCAST) | [1193.548,1297.894]
 10 |                      ->  Seq Scan on public.test t                  | [314.343,328.707]

  5 --Vector Hash Join (6,8)
      Hash Cond: s.x = t.x
      Skew Join Optimizated by Statistic
```

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```
 6 --Streaming(type: PART REDISTRIBUTE PART ROUNDROBIN)
      datanode1 (rows=7635968)
      datanode2 (rows=7517184)
      datanode3 (rows=7748608)
      datanode4 (rows=7818240)
```

In the preceding execution plan, **Skew Join Optimized by Statistic** indicates that this is an optimized plan used for handling data skew. The **Statistic** keyword indicates that the plan optimization is based on statistics; **Hint** indicates that the optimization is based on hints; **Rule** indicates that the optimization is based on rules. In this plan, skew and non-skew data is separately processed. Non-skew data in the **s** table is redistributed based on its hash values, and skew data (whose value is **0**) is evenly distributed on all nodes in round-robin mode. In this way, data skew is solved.

To ensure result correctness, the **t** table also needs to be processed. In the **t** table, the data whose value is **0** (skew value in the **s.x** table) is broadcast and other data is redistributed based on its hash values.

In this way, data skew in JOIN operations is solved. The above result shows that the output of the **Streaming** operator (**id** being **6**) is balanced and the end-to-end performance of the query is doubled.

If the stream operator type in the execution plan is **HYBRID**, the stream mode varies depending on the skew data. The following plan is an example:

```
EXPLAIN (nodes OFF, costs OFF) SELECT COUNT(*) FROM skew_scol s, skew_scol1 s1 WHERE s.b =
s1.c;
QUERY PLAN
-------------------------------------------------------------------------------------------------------------------------------
-------------------------------------------
id |                                                                    operation
----
+-------------------------------------------------------------------------------------------------------------------------------
-------------------------------------
1 | ->  Aggregate
2 |    ->  Streaming (type: GATHER)
3 |       ->  Aggregate
4 |          ->  Hash Join (5,7)
5 |             ->  Streaming(type: HYBRID)
6 |                ->  Seq Scan on skew_scol s
7 |             ->  Hash
8 |                ->  Streaming(type: HYBRID)
9 |                   ->  Seq Scan on skew_scol1 s1

Predicate Information (identified by plan id)
-------------------------------------------------------------------------------------------------------------------------------
--------------------
4 --Hash Join (5,7)
Hash Cond: (s.b = s1.c)
Skew Join Optimized by Statistic
5 --Streaming(type: HYBRID)
Skew Filter: (b = 1)
Skew Filter: (b = 0)
8 --Streaming(type: HYBRID)
Skew Filter: (c = 0)
Skew Filter: (c = 1)
```

Data 1 has skew in the **skew_scol** table. Perform **ROUNDROBIN** on skew data and **REDISTRIBUTE** on non-skew data.

Data 0 is the side with no skew in the **skew_scol** table. Perform **BROADCAST** on skew data and **REDISTRIBUTE** on non-skew data.

As shown in the preceding figure, the two stream types are **PART REDISTRIBUTE PART ROUNDROBIN** and **PART REDISTRIBUTE PART BROADCAST**. In this example, the stream type is **HYBRID**.

– **Aggregate** optimization

For aggregation, data on each DN is deduplicated based on the **GROUP BY** key and then redistributed. After the deduplication on DNs, the global occurrences of each value will not be greater than the number of DNs. Therefore, no serious data skew will occur. Take the following query as an example:

```
select c1, c2, c3, c4, c5, c6, c7, c8, c9, count(*) from t group by c1, c2, c3, c4, c5, c6, c7, c8, c9 limit 10;
```

The command output is as follows:

```
 id |                operation                 |         A-time         | A-rows
----+------------------------------------------+------------------------+----------
  1 | ->  Streaming (type: GATHER)             | 130621.783             |      12
  2 |   ->  GroupAggregate                     | [85499.711,130432.341] |      12
  3 |     ->  Sort                             | [85499.509,103145.632] | 36679237
  4 |       ->  Streaming(type: REDISTRIBUTE)  | [25668.897,85499.050]  | 36679237
  5 |         ->  Seq Scan on public.t         | [9835.069,10416.388]   | 36679237

 4 --Streaming(type: REDISTRIBUTE)
     datanode1 (rows=36678837)
     datanode2 (rows=100)
     datanode3 (rows=100)
     datanode4 (rows=200)
```

A large amount of skew data exists. As a result, after data is redistributed based on its **GROUP BY** key, the data volume of datanode1 is hundreds of thousands of times that of others. After optimization, a GROUP BY operation is performed on the DN to deduplicate data. After redistribution, no data skew occurs.

```
 id |                operation                 |         A-time
----+------------------------------------------+------------------------
  1 | ->  Streaming (type: GATHER)             | 10961.337
  2 |   ->  HashAggregate                      | [10953.014,10953.705]
  3 |     ->  HashAggregate                    | [10952.957,10953.632]
  4 |       ->  Streaming(type: REDISTRIBUTE)  | [10952.859,10953.502]
  5 |         ->  HashAggregate                | [10084.280,10947.139]
  6 |           ->  Seq Scan on public.t       | [4757.031,5201.168]

 Predicate Information (identified by plan id)
-----------------------------------------------
  3 --HashAggregate
     Skew Agg Optimized by Statistic

  4 --Streaming(type: REDISTRIBUTE)
     datanode1 (rows=17)
     datanode2 (rows=8)
     datanode3 (rows=8)
     datanode4 (rows=14)
```

Applicable scope

– **Join** operator

  - **nest loop**, **merge join**, and **hash join** can be optimized.
  - If skew data is on the left to the join, **inner join**, **left join**, **semi join**, and **anti join** are supported. If skew data is on the right to the join, **inner join**, **right join**, **right semi join**, and **right anti join** are supported.
  - For an optimization plan generated based on statistics, the optimizer checks whether it is optimal by estimating its cost. Optimization plans based on hints or rules are forcibly generated.

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- **Aggregate** operator
  - **array_agg**, **string_agg**, and **subplan in agg qual** cannot be optimized.
  - A plan generated based on statistics is affected by its cost, the **plan_mode_seed** parameter, and the **best_agg_plan** parameter. A plan generated based on hints or rules are not affected by them.

## 11.3.5 Experience in Rewriting SQL Statements

Based on the database SQL execution mechanism and a large number of practices, summarize finds that: using rules of a certain SQL statement, on the basis of the so that the correct test result, which can improve the SQL execution efficiency. You can comply with these rules to greatly improve service query efficiency.

- Replacing **UNION** with **UNION ALL**

  **UNION** eliminates duplicate rows while merging two result sets but **UNION ALL** merges the two result sets without deduplication. Therefore, replace **UNION** with **UNION ALL** if you are sure that the two result sets do not contain duplicate rows based on the service logic.

- **Adding NOT NULL to the join column**

  If there are many **NULL** values in the **JOIN** columns, you can add the filter criterion **IS NOT NULL** to filter data in advance to improve the **JOIN** efficiency.

- Converting **NOT IN** to **NOT EXISTS**

  **nestloop anti join** must be used to implement **NOT IN**, and **Hash anti join** is required for **NOT EXISTS**. If no **NULL** value exists in the **JOIN** column, **NOT IN** is equivalent to **NOT EXISTS**. Therefore, if you are sure that no **NULL** value exists, you can convert **NOT IN** to **NOT EXISTS** to generate **hash joins** and to improve the query performance.

  As shown in the following figure, the **t2.d2** column does not contain null values (it is set to **NOT NULL**) and **NOT EXISTS** is used for the query.

  ```
  SELECT * FROM t1 WHERE  NOT EXISTS (SELECT * FROM t2 WHERE t1.c1=t2.d2);
  ```

  The generated execution plan is as follows:

  **Figure 11-9 NOT EXISTS** execution plan

  ```
   id |                 operation
  ----+-------------------------------------------
    1 | ->  Streaming (type: GATHER)
    2 |     ->  Hash Right Anti Join (3, 5)
    3 |        ->  Streaming(type: REDISTRIBUTE)
    4 |           ->  Seq Scan on t2
    5 |        ->  Hash
    6 |           ->  Seq Scan on t1

  Predicate Information (identified by plan id)
  -----------------------------------------------
    2 --Hash Right Anti Join (3, 5)
          Hash Cond: (t2.d2 = t1.c1)
  (13 rows)
  ```

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- Use **hashagg**.

  If a plan involving groupAgg and SORT operations generated by the **GROUP BY** statement is poor in performance, you can set **work_mem** to a larger value to generate a **hashagg** plan, which does not require sorting and improves the performance.

- Replace functions with **CASE** statements

  The GaussDB(DWS) performance greatly deteriorates if a large number of functions are called. In this case, you can modify the pushdown functions to **CASE** statements.

- **Do not use functions or expressions for indexes.**

  Using functions or expressions for indexes stops indexing. Instead, it enables scanning on the full table.

- Do not use **!=** or **<>** operators, **NULL**, **OR**, or implicit parameter conversion in **WHERE** clauses.

- **Split complex SQL statements.**

  You can split an SQL statement into several ones and save the execution result to a temporary table if the SQL statement is too complex to be tuned using the solutions above, including but not limited to the following scenarios:

  - The same subquery is involved in multiple SQL statements of a task and the subquery contains large amounts of data.
  - Incorrect **Plan cost** causes a small hash bucket of subquery. For example, the actual number of rows is 10 million, but only 1000 rows are in hash bucket.
  - Functions such as **substr** and **to_number** cause incorrect measures for subqueries containing large amounts of data.
  - **BROADCAST** subqueries are performed on large tables in multi-DN environment.

## 11.3.6 Adjusting Key Parameters During SQL Tuning

This section describes the key CN parameters that affect GaussDB(DWS) SQL tuning performance. For details about how to configure these parameters, see **Configuring GUC Parameters**.

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**Table 11-2** CN parameters

| Parameter/ Reference Value | Description |
| --- | --- |
| enable_nestloop=on | Specifies how the optimizer uses **Nest Loop Join**. If this parameter is set to **on**, the optimizer preferentially uses **Nest Loop Join**. If it is set to **off**, the optimizer preferentially uses other methods, if any.<br>**NOTE**<br>To temporarily change the value of this parameter in the current database connection (that is, the current session), run the following SQL statement:<br>`SET enable_nestloop to off;`<br>By default, this parameter is set to **on**. Change the value as required. Generally, nested loop join has the poorest performance among the three **JOIN** methods (nested loop join, merge join, and hash join). You are advised to set this parameter to **off**. |
| enable_bitmapscan=on | Specifies whether the optimizer uses bitmap scanning. If the value is **on**, bitmap scanning is used. If the value is **off**, it is not used.<br>**NOTE**<br>If you only want to temporarily change the value of this parameter during the current database connection (that is, the current session), run the following SQL statements:<br>`SET enable_bitmapscan to off;`<br>The bitmap scanning applies only in the query condition where **a > 1 and b > 1** and indexes are created on columns **a** and **b**. During performance tuning, if the query performance is poor and bitmapscan operators are in the execution plan, set this parameter to **off** and check whether the performance is improved. |
| enable_fast_query_shipping=on | Specifies whether the optimizer uses a distribution framework. If the value is **on**, the execution plan is generated on both CNs and DNs. If the value is **off**, the distribution framework is used, that is, the execution plan is generated on the CNs and then sent to DNs for execution.<br>**NOTE**<br>To temporarily change the value of this parameter in the current database connection (that is, the current session), run the following SQL statement:<br>`SET enable_fast_query_shipping to off;` |
| enable_hashagg=on | Specifies whether to enable the optimizer's use of Hash-aggregation plan types. |
| enable_hashjoin=on | Specifies whether to enable the optimizer's use of Hash-join plan types. |
| enable_mergejoin=on | Specifies whether to enable the optimizer's use of Hash-merge plan types. |

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| Parameter/ Reference Value | Description |
| --- | --- |
| enable_indexscan=on | Specifies whether to enable the optimizer's use of index-scan plan types. |
| enable_indexonlyscan=on | Specifies whether to enable the optimizer's use of index-only-scan plan types. |
| enable_seqscan=on | Specifies whether the optimizer uses bitmap scanning. It is impossible to suppress sequential scans entirely, but setting this variable to **off** allows the optimizer to preferentially choose other methods if available. |
| enable_sort=on | Specifies the optimizer sorts. It is impossible to fully suppress explicit sorts, but setting this variable to **off** allows the optimizer to preferentially choose other methods if available. |
| enable_broadcast=on | Specifies whether enable the optimizer's use of data broadcast. In data broadcast, a large amount of data is transferred on the network. When the number of transmission nodes (stream) is large and the estimation is inaccurate, set this parameter to **off** and check whether the performance is improved. |
| rewrite_rule | Specifies whether the optimizer enables the LAZY_AGG and MAGIC_SET rewriting rules. |

# 11.3.7 Hint-based Tuning

## 11.3.7.1 Plan Hint Optimization

In plan hints, you can specify a join order, join, stream, and scan operations, the number of rows in a result, and redistribution skew information to tune an execution plan, improving query performance.

## Function

The hint syntax must follow immediately after a **SELECT** keyword and is written in the following format:

```
/*+ <plan hint>*/
```

You can specify multiple hints for a query plan and separate them by spaces. A hint specified for a query plan does not apply to its subquery plans. To specify a hint for a subquery, add the hint following the **SELECT** of this subquery.

For example:

```
select /*+ <plan_hint1> <plan_hint2> */ * from t1, (select /*+ <plan_hint3> */ from t2) where 1=1;
```

In the preceding command, <*plan_hint1*> and <*plan_hint2*> are the hints of a query, and <*plan_hint3*> is the hint of its subquery.

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NOTICE

If a hint is specified in the **CREATE VIEW** statement, the hint will be applied each time this view is used.

If the random plan function is enabled (**plan_mode_seed** is set to a value other than 0), the specified hint will not be used.

## Supported Hints

Currently, the following hints are supported:

- Join order hints (**leading**)
- Join operation hints, excluding the **semi join**, **anti join**, and **unique plan** hints
- Rows hints
- Stream operation hints
- Scan operation hints, supporting only **tablescan**, **indexscan**, and **indexonlyscan**
- Sublink name hints
- Skew hints, supporting only the skew in the redistribution involving Join or HashAgg
- Configuration parameter hints, supporting the parameters described in **Configuration Parameter Hints**

## Precautions

- Hints do not support **Agg**, **Sort**, **Setop**, or **Subplan**.
- Hints do not support SMP or Node Groups.

## Examples

The following is the original plan and is used for comparing with the optimized ones:

```
explain
select i_product_name product_name
,i_item_sk item_sk
,s_store_name store_name
,s_zip store_zip
,ad2.ca_street_number c_street_number
,ad2.ca_street_name c_street_name
,ad2.ca_city c_city
,ad2.ca_zip c_zip
,count(*) cnt
,sum(ss_wholesale_cost) s1
,sum(ss_list_price) s2
,sum(ss_coupon_amt) s3
FROM   store_sales
,store_returns
,store
,customer
,promotion
,customer_address ad2
,item
WHERE  ss_store_sk = s_store_sk AND
ss_customer_sk = c_customer_sk AND
```

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```
ss_item_sk = i_item_sk and
ss_item_sk = sr_item_sk and
ss_ticket_number = sr_ticket_number and
c_current_addr_sk = ad2.ca_address_sk and
ss_promo_sk = p_promo_sk and
i_color in ('maroon','burnished','dim','steel','navajo','chocolate') and
i_current_price between 35 and 35 + 10 and
i_current_price between 35 + 1 and 35 + 15
group by i_product_name
,i_item_sk
,s_store_name
,s_zip
,ad2.ca_street_number
,ad2.ca_street_name
,ad2.ca_city
,ad2.ca_zip
;
```

```
 id |                                operation                                 |   E-rows   | E-memory | E-width |  E-costs
----+--------------------------------------------------------------------------+------------+----------+---------+------------
  1 | ->  Row Adapter                                                          |          6 |          |     273 | 3401632.49
  2 |    ->  Vector Streaming (type: GATHER)                                   |          6 |          |     273 | 3401632.49
  3 |       ->  Vector Hash Aggregate                                          |          6 | 16MB     |     273 | 3401630.82
  4 |          ->  Vector Streaming(type: REDISTRIBUTE)                        |          6 | 1MB      |     169 | 3401630.78
  5 |             ->  Vector Hash Join (6,21)                                  |          6 | 16MB     |     169 | 3401630.42
  6 |                ->  Vector Hash Join (7,20)                               |          7 | 43MB     |     173 | 3400343.15
  7 |                   ->  Vector Streaming(type: REDISTRIBUTE)               |          7 | 1MB      |     123 | 3395775.64
  8 |                      ->  Vector Hash Join (9,19)                         |          7 | 27MB     |     123 | 3395775.48
  9 |                         ->  Vector Streaming(type: REDISTRIBUTE)         |          7 | 1MB      |     123 | 3386294.72
 10 |                            ->  Vector Hash Join (11,18)                  |          7 | 16MB     |     123 | 3386294.56
 11 |                               ->  Vector Hash Join (12,14)               |          7 | 19MB     |     112 | 3384018.02
 12 |                                  ->  Vector Partition Iterator           |  287999764 | 1MB      |      12 | 227383.99
 13 |                                     ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |      12 | 227383.99
 14 |                                  ->  Vector Hash Join (15,17)            |    1516824 | 16MB     |     124 | 3065686.08
 15 |                                     ->  Vector Partition Iterator        | 2879987999 | 1MB      |      66 | 2756066.50
 16 |                                        ->  Partitioned CStore Scan on store_sales | 2879987999 | 1MB |      66 | 2756066.50
 17 |                                     ->  CStore Scan on item              |        158 | 1MB      |      58 | 4051.25
 18 |                               ->  CStore Scan on store                   |      24048 | 1MB      |      19 | 2264.00
 19 |                            ->  CStore Scan on customer                   |   12000000 | 1MB      |       8 | 12923.00
 20 |                      ->  CStore Scan on customer_address ad2             |    6000000 | 1MB      |      58 | 5770.00
 21 |                ->  CStore Scan on promotion                              |      36000 | 1MB      |       4 | 1268.50
(21 rows)
```

## 11.3.7.2 Join Order Hints

## Function

Theses hints specify the join order and outer/inner tables.

## Syntax

- Specify only the join order.

```
leading(join_table_list)
```

- Specify the join order and outer/inner tables. The outer/inner tables are specified by the outermost parentheses.

```
leading((join_table_list))
```

## Parameter Description

*join_table_list* specifies the tables to be joined. The values can be table names or table aliases. If a subquery is pulled up, the value can also be the subquery alias. Separate the values with spaces. You can add parentheses to specify the join priorities of tables.

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**NOTICE**

A table name or alias can only be a string without a schema name.

An alias (if any) is used to represent a table.

To prevent semantic errors, tables in the list must meet the following requirements:

- The tables must exist in the query or its subquery to be pulled up.
- The table names must be unique in the query or subquery to be pulled up. If they are not, their aliases must be unique.
- A table appears only once in the list.
- An alias (if any) is used to represent a table.

For example:

**leading(t1 t2 t3 t4 t5)**: **t1**, **t2**, **t3**, **t4**, and **t5** are joined. The join order and outer/inner tables are not specified.

**leading(t1 t2 t3 t4 t5)**: **t1**, **t2**, **t3**, **t4**, and **t5** are joined in sequence. The table on the right is used as the inner table in each join.

**leading(t1 (t2 t3 t4) t5)**: First, **t2**, **t3**, and **t4** are joined and the outer/inner tables are not specified. Then, the result is joined with **t1** and **t5**, and the outer/inner tables are not specified.

**leading(t1 (t2 t3 t4) t5)**: First, **t2**, **t3**, and **t4** are joined and the outer/inner tables are not specified. Then, the result is joined with **t1**, and **(t2 t3 t4)** is used as the inner table. Finally, the result is joined with **t5**, and **t5** is used as the inner table.

**leading((t1 (t2 t3) t4 t5)) leading((t3 t2))**: First, **t2** and **t3** are joined and **t2** is used as the inner table. Then, the result is joined with **t1**, and **(t2 t3)** is used as the inner table. Finally, the result is joined with **t4** and then **t5**, and the table on the right in each join is used as the inner table.

## Examples

Hint the query plan in **Examples** as follows:

```
explain
select /*+ leading((((((store_sales store) promotion) item) customer) ad2) store_returns) leading((store store_sales))*/ i_product_name product_name ...
```

First, **store_sales** and **store** are joined and **store_sales** is the inner table. Then, The result is joined with **promotion**, **item**, **customer**, **ad2**, and **store_returns** in sequence. The optimized plan is as follows:

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```
WARNING:  Duplicated or conflict hint: Leading(store_sales store), will be discarded.
 id |                                  operation                                  |   E-rows   | E-memory | E-width |   E-costs
----+-----------------------------------------------------------------------------+------------+----------+---------+-------------
  1 | ->  Row Adapter                                                             |          6 |          |     273 | 16308094.34
  2 |    ->  Vector Streaming (type: GATHER)                                      |          6 |          |     273 | 16308094.34
  3 |       ->  Vector Hash Aggregate                                             |          6 | 16MB     |     273 | 16308092.67
  4 |          ->  Vector Hash Join (5,20)                                        |          6 | 585MB    |     169 | 16308092.63
  5 |             ->  Vector Streaming(type: REDISTRIBUTE)                        |    1320811 | 1MB      |     181 | 16069870.93
  6 |                ->  Vector Hash Join (7,19)                                  |    1320811 | 43MB     |     181 | 16061891.00
  7 |                   ->  Vector Streaming(type: REDISTRIBUTE)                  |    1320811 | 1MB      |     131 | 16056566.78
  8 |                      ->  Vector Hash Join (9,18)                            |    1320811 | 27MB     |     131 | 16048586.85
  9 |                         ->  Vector Streaming(type: REDISTRIBUTE)            |    1383248 | 1MB      |     131 | 16038321.62
 10 |                            ->  Vector Hash Join (11,17)                     |    1383248 | 16MB     |     131 | 16029664.50
 11 |                               ->  Vector Hash Join (12,16)                  | 2626366951 | 16MB     |      73 | 15751384.88
 12 |                                  ->  Vector Hash Join (13,14)               | 2750085660 | 2156MB   |      77 | 14226077.19
 13 |                                     ->  CStore Scan on store                |      24048 | 1MB      |      19 | 2264.00
 14 |                                     ->  Vector Partition Iterator           | 2879987999 | 1MB      |      66 | 2756066.50
 15 |                                        ->  Partitioned CStore Scan on store_sales | 2879987999 | 1MB      |      66 | 2756066.50
 16 |                                  ->  CStore Scan on promotion               |      36000 | 1MB      |       4 | 1268.50
 17 |                               ->  CStore Scan on item                       |        158 | 1MB      |      58 | 4051.25
 18 |                         ->  CStore Scan on customer                         |   12000000 | 1MB      |       8 | 12923.00
 19 |                      ->  CStore Scan on customer_address ad2                |    6000000 | 1MB      |      58 | 5770.00
 20 |               ->  Vector Partition Iterator                                 |  287999764 | 1MB      |      12 | 227383.99
 21 |                  ->  Partitioned CStore Scan on store_returns               |  287999764 | 1MB      |      12 | 227383.99
(21 rows)
```

For details about the warning at the top of the plan, see **Hint Errors, Conflicts, and Other Warnings**.

## 11.3.7.3 Join Operation Hints

### Function

Specifies the join method. It can be nested loop join, hash join, or merge join.

### Syntax

```
[no] nestloop|hashjoin|mergejoin(table_list)
```

### Parameter Description

- **no** indicates that the specified hint will not be used for a join.
- *table_list* specifies the tables to be joined. The values are the same as those of **join_table_list** but contain no parentheses.

For example:

**no nestloop(t1 t2 t3)**: **nestloop** is not used for joining **t1**, **t2**, and **t3**. The three tables may be joined in either of the two ways: Join **t2** and **t3**, and then **t1**; join **t1** and **t2**, and then **t3**. This hint takes effect only for the last join. If necessary, you can hint other joins. For example, you can add **no nestloop(t2 t3)** to join **t2** and **t3** first and to forbid the use of **nestloop**.

### Examples

Hint the query plan in **Examples** as follows:

```
explain
select /*+ nestloop(store_sales store_returns item) */ i_product_name product_name ...
```

**nestloop** is used for the last join between **store_sales**, **store_returns**, and **item**. The optimized plan is as follows:

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```
 id |                                operation                                 |   E-rows   | E-memory | E-width |     E-costs
----+--------------------------------------------------------------------------+------------+----------+---------+-----------------
  1 | ->  Row Adapter                                                          |          6 |          |     273 | 100061693161.06
  2 |    ->  Vector Streaming (type: GATHER)                                   |          6 |          |     273 | 100061693161.06
  3 |       ->  Vector Hash Aggregate                                          |          6 | 16MB     |     273 | 100061693159.40
  4 |          ->  Vector Streaming(type: REDISTRIBUTE)                        |          6 | 1MB      |     169 | 100061693159.36
  5 |             ->  Vector Hash Join (6,22)                                  |          6 | 43MB     |     169 | 100061693158.99
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                  |          6 | 1MB      |     119 | 100061688591.48
  7 |                   ->  Vector Hash Join (8,21)                            |          6 | 16MB     |     119 | 100061688591.30
  8 |                      ->  Vector Hash Join (9,20)                         |          7 | 27MB     |     123 | 100061687304.04
  9 |                         ->  Vector Streaming(type: REDISTRIBUTE)         |          7 | 1MB      |     123 | 100061677823.27
 10 |                            ->  Vector Hash Join (11,19)                  |          7 | 16MB     |     123 | 100061677823.12
 11 |                               ->  Vector Nest Loop (12,17)               |          7 | 1MB      |     112 | 100061675546.57
 12 |                                  ->  Vector Hash Join (13,15)            |      13670 | 585MB    |      62 | 6163443.54
 13 |                                     ->  Vector Partition Iterator        | 2879987999 | 1MB      |      66 | 2756066.50
 14 |                                        ->  Partitioned CStore Scan on store_sales | 2879987999 | 1MB |  66 | 2756066.50
 15 |                                     ->  Vector Partition Iterator        |  287999764 | 1MB      |      12 | 227383.99
 16 |                                        ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |  12 | 227383.99
 17 |                                  ->  Vector Materialize                  |        158 | 16MB     |      58 | 4051.28
 18 |                                     ->  CStore Scan on item              |        158 | 1MB      |      58 | 4051.25
 19 |                               ->  CStore Scan on store                   |      24048 | 1MB      |      19 | 2264.00
 20 |                            ->  CStore Scan on customer                   |   12000000 | 1MB      |       8 | 12923.00
 21 |                         ->  CStore Scan on promotion                     |      36000 | 1MB      |       4 | 1268.50
 22 |                      ->  CStore Scan on customer_address ad2             |    6000000 | 1MB      |      58 | 5770.00
(22 rows)
```

## 11.3.7.4 Rows Hints

### Function

These hints specify the number of rows in an intermediate result set. Both absolute values and relative values are supported.

### Syntax

```
rows(table_list #|+|-|* const)
```

### Parameter Description

- **#**,**+**,**-**, and ***** are operators used for hinting the estimation. **#** indicates that the original estimation is used without any calculation. **+**,**-**, and ***** indicate that the original estimation is calculated using these operators. The minimum calculation result is 1. *table_list* specifies the tables to be joined. The values are the same as those of **table_list** in **Join Operation Hints**.
- *const* can be any non-negative number and supports scientific notation.

For example:

**rows(t1 #5)**: The result set of **t1** is five rows.

**rows(t1 t2 t3 *1000)**: Multiply the result set of joined **t1**, **t2**, and **t3** by 1000.

### Suggestion

- The hint using ***** for two tables is recommended, because this hint will take effect for a join as long as the two tables appear on both sides of this join. For example, if the hint is **rows(t1 t2 * 3)**, the join result of **(t1 t3 t4)** and **(t2 t5 t6)** will be multiplied by 3 because **t1** and **t2** appear on both sides of the join.
- **rows** hints can be specified for the result sets of a single table, multiple tables, function tables, and subquery scan tables.

### Examples

Hint the query plan in **Examples** as follows:

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```
explain
select /*+ rows(store_sales store_returns *50) */ i_product_name product_name ...
```

Multiply the result set of joined **store_sales** and **store_returns** by 50. The optimized plan is as follows:

```
 id |                                operation                                |   E-rows   | E-memory | E-width |  E-costs
----+-------------------------------------------------------------------------+------------+----------+---------+------------
  1 | ->  Row Adapter                                                         |        312 |          |     273 | 3401656.58
  2 |    ->  Vector Streaming (type: GATHER)                                  |        312 |          |     273 | 3401656.58
  3 |       ->  Vector Hash Aggregate                                         |        312 | 16MB     |     273 | 3401634.91
  4 |          ->  Vector Streaming(type: REDISTRIBUTE)                       |        313 | 1MB      |     169 | 3401634.39
  5 |             ->  Vector Hash Join (6,21)                                 |        313 | 43MB     |     169 | 3401633.06
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                 |        313 | 1MB      |     119 | 3397065.38
  7 |                   ->  Vector Hash Join (8,20)                           |        313 | 27MB     |     119 | 3397064.31
  8 |                      ->  Vector Streaming(type: REDISTRIBUTE)           |        328 | 1MB      |     119 | 3387583.37
  9 |                         ->  Vector Hash Join (10,19)                    |        328 | 16MB     |     119 | 3387582.18
 10 |                            ->  Vector Hash Join (11,18)                 |        344 | 16MB     |     123 | 3386294.74
 11 |                               ->  Vector Hash Join (12,14)              |        360 | 19MB     |     112 | 3384018.02
 12 |                                  ->  Vector Partition Iterator          |  287999764 | 1MB      |      12 | 227383.99
 13 |                                     ->  Partitioned CStore Scan on store_returns |  287999764 | 1MB      |      12 | 227383.99
 14 |                                  ->  Vector Hash Join (15,17)           |    1516824 | 16MB     |     124 | 3065686.08
 15 |                                     ->  Vector Partition Iterator       | 2879987999 | 1MB      |      66 | 2756066.50
 16 |                                        ->  Partitioned CStore Scan on store_sales | 2879987999 | 1MB      |      66 | 2756066.50
 17 |                                     ->  CStore Scan on item             |        158 | 1MB      |      58 | 4051.25
 18 |                                  ->  CStore Scan on store               |      24048 | 1MB      |      19 | 2264.00
 19 |                               ->  CStore Scan on promotion              |      36000 | 1MB      |       4 | 1268.50
 20 |                            ->  CStore Scan on customer                  |   12000000 | 1MB      |       8 | 12923.00
 21 |                         ->  CStore Scan on customer_address ad2         |    6000000 | 1MB      |      58 | 5770.00
(21 rows)
```

The estimation value after the hint in row 11 is **360**, and the original value is rounded off to 7.

## 11.3.7.5 Stream Operation Hints

### Function

These hints specify a stream operation, which can be **broadcast** or **redistribute**.

### Syntax

```
[no] broadcast|redistribute(table_list)
```

### Parameter Description

- **no** indicates that the specified hint will not be used for a join.
- *table_list* specifies the tables to be joined. For details, see **Parameter Description**.

### Examples

Hint the query plan in **Examples** as follows:

```
explain
select /*+ no redistribute(store_sales store_returns item store) leading(((store_sales store_returns item
store) customer)) */ i_product_name product_name ...
```

In the original plan, the join result of **store_sales**, **store_returns**, **item**, and **store** is redistributed before it is joined with **customer**. After the hinting, the redistribution is disabled and the join order is retained. The optimized plan is as follows:

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```
 id |                                operation                                 |   E-rows   | E-memory | E-width |  E-costs
----+--------------------------------------------------------------------------+------------+----------+---------+------------
  1 | ->  Row Adapter                                                          |          6 |          |     273 | 5718448.94
  2 |    ->  Vector Streaming (type: GATHER)                                   |          6 |          |     273 | 5718448.94
  3 |       ->  Vector Hash Aggregate                                          |          6 | 16MB     |     273 | 5718447.27
  4 |          ->  Vector Streaming(type: REDISTRIBUTE)                        |          6 | 1MB      |     169 | 5718447.23
  5 |             ->  Vector Hash Join (6,21)                                  |          6 | 16MB     |     169 | 5718446.86
  6 |                ->  Vector Hash Join (7,20)                               |          7 | 43MB     |     173 | 5717159.60
  7 |                   ->  Vector Streaming(type: REDISTRIBUTE)               |          7 | 1MB      |     123 | 5712592.09
  8 |                      ->  Vector Hash Join (9,18)                         |          7 | 585MB    |     123 | 5712591.93
  9 |                         ->  Vector Hash Join (10,17)                     |          7 | 16MB     |     123 | 3386294.56
 10 |                            ->  Vector Hash Join (11,13)                  |          7 | 19MB     |     112 | 3384018.02
 11 |                               ->  Vector Partition Iterator              |  287999764 | 1MB      |      12 | 227383.99
 12 |                                  ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |      12 | 227383.99
 13 |                               ->  Vector Hash Join (14,16)               |    1516824 | 16MB     |     124 | 3065686.08
 14 |                                  ->  Vector Partition Iterator           | 2879987999 | 1MB      |      66 | 2756066.50
 15 |                                     ->  Partitioned CStore Scan on store_sales | 2879987999 | 1MB |      66 | 2756066.50
 16 |                                  ->  CStore Scan on item                 |        158 | 1MB      |      58 | 4051.25
 17 |                            ->  CStore Scan on store                      |      24048 | 1MB      |      19 | 2264.00
 18 |                         ->  Vector Streaming(type: BROADCAST)            |  288000000 | 1MB      |       8 | 2176297.36
 19 |                            ->  CStore Scan on customer                   |   12000000 | 1MB      |       8 | 12923.00
 20 |                      ->  CStore Scan on customer_address ad2             |    6000000 | 1MB      |      58 | 5770.00
 21 |                   ->  CStore Scan on promotion                           |      36000 | 1MB      |       4 | 1268.50
(21 rows)
```

## 11.3.7.6 Scan Operation Hints

### Function

These hints specify a scan operation, which can be **tablescan**, **indexscan**, or **indexonlyscan**.

### Syntax

```
[no] tablescan|indexscan|indexonlyscan(table [index])
```

### Parameter Description

- **no** indicates that the specified hint will not be used for a join.
- *table* specifies the table to be scanned. You can specify only one table. Use a table alias (if any) instead of a table name.
- *index* indicates the index for **indexscan** or **indexonlyscan**. You can specify only one index.

NOTE

**indexscan** and **indexonlyscan** hints can be used only when the specified index belongs to the table.

Scan operation hints can be used for row-store tables, column-store tables, HDFS tables, HDFS foreign tables, OBS tables, and subquery tables. HDFS tables include primary tables and delta tables. The delta tables are invisible to users. Therefore, scan operation hints are used only for primary tables.

### Examples

To specify an index-based hint for a scan, create an index named **i** on the **i_item_sk** column of the **item** table.

```
create index i on item(i_item_sk);
```

Hint the query plan in **Examples** as follows:

```
explain
select /*+ indexscan(item i) */ i_product_name product_name ...
```

**item** is scanned based on an index. The optimized plan is as follows:

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```
 id |                                operation                                 |   E-rows   | E-memory | E-width |     E-costs
----+--------------------------------------------------------------------------+------------+----------+---------+-----------------
  1 | ->  Row Adapter                                                          |          6 |          |     273 | 100061674938.26
  2 |    ->  Vector Streaming (type: GATHER)                                   |          6 |          |     273 | 100061674938.26
  3 |       ->  Vector Hash Aggregate                                          |          6 | 16MB     |     273 | 100061674936.59
  4 |          ->  Vector Streaming(type: REDISTRIBUTE)                        |          6 | 1MB      |     169 | 100061674936.55
  5 |             ->  Vector Hash Join (6,21)                                  |          6 | 43MB     |     169 | 100061674936.19
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                  |          6 | 1MB      |     119 | 100061670368.67
  7 |                   ->  Vector Hash Join (8,20)                            |          6 | 16MB     |     119 | 100061670368.50
  8 |                      ->  Vector Hash Join (9,19)                         |          7 | 27MB     |     123 | 100061669081.23
  9 |                         ->  Vector Streaming(type: REDISTRIBUTE)         |          7 | 1MB      |     123 | 100061659600.47
 10 |                            ->  Vector Hash Join (11,18)                  |          7 | 16MB     |     123 | 100061659600.31
 11 |                               ->  Vector Nest Loop (12,17)               |          7 | 1MB      |     112 | 100061657323.77
 12 |                                  ->  Vector Hash Join (13,15)            |      13670 | 585MB    |      62 | 6163443.54
 13 |                                     ->  Vector Partition Iterator        | 2879987999 | 1MB      |      66 | 2756066.50
 14 |                                        ->  Partitioned CStore Scan on store_sales | 2879987999 | 1MB |  66 | 2756066.50
 15 |                                     ->  Vector Partition Iterator        |  287999764 | 1MB      |      12 | 227383.99
 16 |                                        ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |  12 | 227383.99
 17 |                                  ->  CStore Index Scan using i on item   |          1 | 1MB      |      58 | 4.01
 18 |                               ->  CStore Scan on store                   |      24048 | 1MB      |      19 | 2264.00
 19 |                            ->  CStore Scan on customer                   |   12000000 | 1MB      |       8 | 12923.00
 20 |                         ->  CStore Scan on promotion                     |      36000 | 1MB      |       4 | 1268.50
 21 |                   ->  CStore Scan on customer_address ad2                |    6000000 | 1MB      |      58 | 5770.00
(21 rows)
```

## 11.3.7.7 Sublink Name Hints

## Function

These hints specify the name of a sublink block.

## Syntax

```
blockname (table)
```

## Parameter Description

- *table* indicates the name you have specified for a sublink block.

NOTE

- This hint is used by an outer query only when a sublink is pulled up. Currently, only the **Agg** equivalent join, **IN**, and **EXISTS** sublinks can be pulled up. This hint is usually used together with the hints described in the previous sections.
- The subquery after the **FROM** keyword is hinted by using the subquery alias. In this case, **blockname** becomes invalid.
- If a sublink contains multiple tables, the tables will be joined with the outer-query tables in a random sequence after the sublink is pulled up. In this case, **blockname** also becomes invalid.

## Examples

```
explain select /*+nestloop(store_sales tt) */ * from store_sales where ss_item_sk in (select /*
+blockname(tt)*/ i_item_sk from item group by 1);
```

**tt** indicates the sublink block name. After being pulled up, the sublink is joined with the outer-query table **store_sales** by using **nestloop**. The optimized plan is as follows:

```
 id |                    operation                    |   E-rows   | E-memory | E-width |     E-costs
----+-------------------------------------------------+------------+----------+---------+-----------------
  1 | ->  Row Adapter                                 | 1439994000 |          |     216 | 325105765847.91
  2 |    ->  Vector Streaming (type: GATHER)          | 1439994000 |          |     216 | 325105765847.91
  3 |       ->  Vector Nest Loop Semi Join (4, 6)     | 1439994000 | 1MB      |     216 | 325026664615.00
  4 |          ->  Vector Partition Iterator          | 2879987999 | 1MB      |     216 | 2756066.50
  5 |             ->  Partitioned CStore Scan on store_sales | 2879987999 | 1MB |  216 | 2756066.50
  6 |          ->  Vector Materialize                 |     300000 | 16MB     |       4 | 4176.25
  7 |             ->  Vector Hash Aggregate           |     300000 | 16MB     |       4 | 3988.75
  8 |                ->  CStore Scan on item          |     300000 | 1MB      |       4 | 3832.50
(8 rows)
```

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## 11.3.7.8 Skew Hints

### Function

Theses hints specify redistribution keys containing skew data and skew values, and are used to optimize redistribution involving Join or HashAgg.

### Syntax

- Specify single-table skew.
  ```
  skew(table (column) [(value)])
  ```
- Specify intermediate result skew.
  ```
  skew((join_rel) (column) [(value)])
  ```

### Parameter Description

- **table** specifies the table where skew occurs.
- **join_rel** specifies two or more joined tables. For example, **(t1 t2)** indicates that the result of joining **t1** and **t2** tables contains skew data.
- **column** specifies one or more columns where skew occurs.
- **value** specifies one or more skew values.

NOTE

- Skew hints are used only if redistribution is required and the specified skew information matches the redistribution information.
- Skew hints are controlled by the GUC parameter **skew_option**. If the parameter is disabled, skew hints cannot be used for solving skew.
- Currently, skew hints support only the table relationships of the ordinary table and subquery types. Hints can be specified for base tables, subqueries, and **WITH ... AS** clauses. Unlike other hints, a subquery can be used in skew hints regardless of whether it is pulled up.
- Use an alias (if any) to specify a table where data skew occurs.
- You can use a name or an alias to specify a skew column as long as it is not ambiguous. The columns in skew hints cannot be expressions. If data skew occurs in the redistribution that uses an expression as a redistribution key, set the redistribution key as a new column and specify the column in skew hints.
- The number of skew values must be an integer multiple of the number of columns. Skew values must be grouped based on the column sequence, with each group containing a maximum of 10 values. You can specify duplicate values to group skew columns having different number of skew values. For example, the **c1** and **c2** columns of the **t1** table contains skew data. The skew value of the **c1** column is **a1**, and the skew values of the **c2** column are **b1** and **b2**. In this case, the skew hint is **skew(t1 (c1 c2) ((a1 b1)(a1 b2)))**. **(a1 b1)** is a value group, where **NULL** is allowed as a skew value. Each hint can contain a maximum of 10 groups and the number of groups should be an integer multiple of the number of columns.
- In the redistribution optimization of Join, a skew value must be specified for skew hints. The skew value can be left empty for HashAgg.
- If multiple tables, columns, or values are specified, separate items of the same type with spaces.
- The type of skew values cannot be forcibly converted in hints. To specify a string, enclose it with single quotation marks (' ').

Example:

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- Specify single-table skew.

  Each skew hint describes the skew information of one table relationship. To describe the skews of multiple table relationships in a query, specify multiple skew hints.

  Skew hints have the following formats:

  - One skew value in one column: **skew(t (c1) (v1))**

    Description: The **v1** value in the **c1** column of the **t** table relationship causes skew in query execution.
  - Multiple skew values in one column: **skew(t (c1) (v1 v2 v3 ...))**

    Description: Values including **v1, v2**, and **v3** in the **c1** column of the **t** table relationship cause skew in query execution.
  - Multiple columns, each having one skew value: **skew(t (c1 c2) (v1 v2))**

    Description: The **v1** value in the **c1** column and the **v2** value in the **c2** column of the **t** table relationship cause skew in query execution.
  - Multiple columns, each having multiple skew values: **skew(t (c1 c2) ((v1 v2) (v3 v4) (v5 v6) ...))**

    Description: Values including **v1, v3**, and **v5** in the **c1** column and values including **v2, v4**, and **v6** in the **c2** column of the **t** table relationship cause skew in query execution.

    **NOTICE**

    In the last format, parentheses for skew value groups can be omitted, for example, **skew(t (c1 c2) (v1 v2 v3 v4 v5 v6 ...))**. In a skew hint, either use parentheses for all skew value groups or for none of them.

    Otherwise, a syntax error will be generated. For example, **skew(t (c1 c2) (v1 v2 v3 v4 (v5 v6) ...))** will generate an error.

- Specify intermediate result skew.

  If data skew does not occur in base tables but in an intermediate result during query execution, specify skew hints of the intermediate result to solve the skew. The format is **skew((t1 t2) (c1) (v1))**.

  Description: Data skew occurs after the table relationships **t1** and **t2** are joined. The **c1** column of the **t1** table contains skew data and its skew value is **v1**.

  **c1** can exist only in a table relationship of **join_rel**. If there is another column having the same name, use aliases to avoid ambiguity.

## Suggestion

- For a multi-level query, write the hint on the layer where data skew occurs.
- For a listed subquery, you can specify the subquery name in a hint. If you know data skew occurs on which base table, directly specify the table.
- Aliases are preferred when you specify a table or column in a hint.

## Examples

Specify single-table skew.

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- Specify hints in the original query.

  For example, the original query is as follows:

```
explain
with customer_total_return as
(select sr_customer_sk as ctr_customer_sk
,sr_store_sk as ctr_store_sk
,sum(SR_FEE) as ctr_total_return
from store_returns
,date_dim
where sr_returned_date_sk = d_date_sk
and d_year =2000
group by sr_customer_sk
,sr_store_sk)
 select  c_customer_id
from customer_total_return ctr1
,store
,customer
where ctr1.ctr_total_return > (select avg(ctr_total_return)*1.2
from customer_total_return ctr2
where ctr1.ctr_store_sk = ctr2.ctr_store_sk)
and s_store_sk = ctr1.ctr_store_sk
and s_state = 'NM'
and ctr1.ctr_customer_sk = c_customer_sk
order by c_customer_id
limit 100;
```

```
 id |                                  operation                                  |  E-rows   |    E-memory    | E-width |  E-costs
----+-----------------------------------------------------------------------------+-----------+----------------+---------+-----------
  1 | ->  Row Adapter                                                             |       100 |                |      20 | 911254.47
  2 |    ->  Vector Limit                                                         |       100 |                |      20 | 911254.47
  3 |       ->  Vector Streaming (type: GATHER)                                   |      2400 |                |      20 | 911325.75
  4 |          ->  Vector Limit                                                   |      2400 | 1MB            |      20 | 911247.62
  5 |             ->  Vector Sort                                                 |   3684816 | 16MB           |      20 | 911631.21
  6 |                ->  Vector Hash Join (7,29)                                  |   3684817 | 41MB(12374MB)  |      20 | 905379.41
  7 |                   ->  Vector Streaming(type: REDISTRIBUTE)                  |   3684817 | 384KB          |       4 | 883010.31
  8 |                      ->  Vector Hash Join (9,19)                            |   3684817 | 16MB           |       4 | 861302.05
  9 |                         ->  Vector Hash Join (10,18)                        |  11054450 | 16MB           |      44 | 427109.71
 10 |                            ->  Vector Hash Aggregate                        |  50247501 | 397MB(12671MB) |      54 | 395302.57
 11 |                               ->  Vector Streaming(type: REDISTRIBUTE)      |  50247501 | 384KB          |      22 | 358663.76
 12 |                                  ->  Vector Hash Join (13,15)               |  50247501 | 16MB           |      22 | 294300.51
 13 |                                     ->  Vector Partition Iterator           | 287999764 | 1MB            |      26 | 227383.99
 14 |                                        ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |      26 | 227383.99
 15 |                                     ->  Vector Streaming(type: BROADCAST)   |      8712 | 384KB          |       4 | 975.56
 16 |                                        ->  Vector Partition Iterator        |       363 | 1MB            |       4 | 910.65
 17 |                                           ->  Partitioned CStore Scan on date_dim |       363 | 1MB |       4 | 910.65
 18 |                            ->  CStore Scan on store                         |        44 | 1MB            |       4 | 1006.39
 19 |                         ->  Vector Hash Aggregate                           |       192 | 16MB           |      68 | 426707.38
 20 |                            ->  Vector Subquery Scan on ctr2                 |  50247501 | 1MB            |      36 | 416239.03
 21 |                               ->  Vector Hash Aggregate                     |  50247501 | 397MB(12671MB) |      54 | 395302.57
 22 |                                  ->  Vector Streaming(type: REDISTRIBUTE)   |  50247501 | 384KB          |      22 | 358663.76
 23 |                                     ->  Vector Hash Join (24,26)            |  50247501 | 16MB           |      22 | 294300.51
 24 |                                        ->  Vector Partition Iterator        | 287999764 | 1MB            |      26 | 227383.99
 25 |                                           ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |      26 | 227383.99
 26 |                                        ->  Vector Streaming(type: BROADCAST)|      8712 | 384KB          |       4 | 975.56
 27 |                                           ->  Vector Partition Iterator     |       363 | 1MB            |       4 | 910.65
 28 |                                              ->  Partitioned CStore Scan on date_dim |       363 | 1MB |       4 | 910.65
 29 |                   ->  CStore Scan on customer                               |  12000000 | 1MB            |      24 | 12923.00
(29 rows)
```

  Specify the hints of HashAgg in the inner **with** clause and of the outer Hash Join. The query containing hints is as follows:

```
explain
with customer_total_return as
(select /*+ skew(store_returns(sr_store_sk sr_customer_sk)) */sr_customer_sk as ctr_customer_sk
,sr_store_sk as ctr_store_sk
,sum(SR_FEE) as ctr_total_return
from store_returns
,date_dim
where sr_returned_date_sk = d_date_sk
and d_year =2000
group by sr_customer_sk
,sr_store_sk)
 select  /*+ skew(ctr1(ctr_customer_sk)(11))*/  c_customer_id
from customer_total_return ctr1
,store
,customer
where ctr1.ctr_total_return > (select avg(ctr_total_return)*1.2
from customer_total_return ctr2
where ctr1.ctr_store_sk = ctr2.ctr_store_sk)
and s_store_sk = ctr1.ctr_store_sk
and s_state = 'NM'
and ctr1.ctr_customer_sk = c_customer_sk
```

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```
order by c_customer_id
limit 100;
```

The hints indicate that the **group by** in the inner **with** clause contains skew data during redistribution by HashAgg, corresponding to the original Hash Agg operators 10 and 21; and that the **ctr_customer_sk** column in the outer **ctr1** table contains skew data during redistribution by Hash Join, corresponding to operator 6 in the original plan. The optimized plan is as follows:

```
 id |                                operation                                 |  E-rows  |   E-memory    | E-width |  E-costs
----+--------------------------------------------------------------------------+----------+---------------+---------+-----------
  1 | ->  Row Adapter                                                          |      100 |               |      20 | 1061778.14
  2 |    ->  Vector Limit                                                      |      100 |               |      20 | 1061778.14
  3 |       ->  Vector Streaming (type: GATHER)                                |     2400 |               |      20 | 1061849.41
  4 |          ->  Vector Limit                                                |     2400 | 1MB           |      20 | 1061771.29
  5 |             ->  Vector Sort                                              |  3684816 | 16MB          |      20 | 1062154.87
  6 |                ->  Vector Hash Join (7,31)                               |  3684817 | 41MB(12344MB) |      20 | 1055903.08
  7 |                   ->  Vector Streaming(type: PART REDISTRIBUTE PART ROUNDROBIN) |  3684817 | 384KB |       4 | 1013056.49
  8 |                      ->  Vector Hash Join (9,20)                         |  3684817 | 16MB          |       4 | 1000006.10
  9 |                         ->  Vector Hash Join (10,19)                     | 11054450 | 16MB          |      44 | 496461.73
 10 |                            ->  Vector Hash Aggregate                     | 50247501 | 397MB(12010MB) |      54 | 464654.59
 11 |                               ->  Vector Streaming(type: REDISTRIBUTE)   | 50247501 | 384KB         |      54 | 428015.79
 12 |                                  ->  Vector Hash Aggregate               | 50247501 | 397MB(12010MB) |      54 | 330939.31
 13 |                                     ->  Vector Hash Join (14,16)         | 50247501 | 16MB          |      22 | 294300.51
 14 |                                        ->  Vector Partition Iterator     | 287999764 | 1MB          |      26 | 227383.99
 15 |                                           ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |  26 | 227383.99
 16 |                                        ->  Vector Streaming(type: BROADCAST) |    8712 | 384KB         |       4 | 975.56
 17 |                                           ->  Vector Partition Iterator  |      363 | 1MB           |       4 | 910.65
 18 |                                              ->  Partitioned CStore Scan on date_dim |  363 | 1MB |  4 | 910.65
 19 |                            ->  CStore Scan on store                      |       44 | 1MB           |       4 | 1006.39
 20 |                         ->  Vector Hash Aggregate                        |      192 | 16MB          |      68 | 496059.40
 21 |                            ->  Vector Subquery Scan on ctr2              | 50247501 | 1MB           |      36 | 485591.05
 22 |                               ->  Vector Hash Aggregate                  | 50247501 | 397MB(12010MB) |      54 | 464654.59
 23 |                                  ->  Vector Streaming(type: REDISTRIBUTE) | 50247501 | 384KB         |      54 | 428015.79
 24 |                                     ->  Vector Hash Aggregate            | 50247501 | 397MB(12010MB) |      54 | 330939.31
 25 |                                        ->  Vector Hash Join (26,28)      | 50247501 | 16MB          |      22 | 294300.51
 26 |                                           ->  Vector Partition Iterator  | 287999764 | 1MB          |      26 | 227383.99
 27 |                                              ->  Partitioned CStore Scan on store_returns | 287999764 | 1MB |  26 | 227383.99
 28 |                                           ->  Vector Streaming(type: BROADCAST) |    8712 | 384KB         |       4 | 975.56
 29 |                                              ->  Vector Partition Iterator |      363 | 1MB           |       4 | 910.65
 30 |                                                 ->  Partitioned CStore Scan on date_dim |  363 | 1MB |  4 | 910.65
 31 |                   ->  Vector Streaming(type: PART LOCAL PART BROADCAST)  | 12000000 | 384KB         |      24 | 34485.50
 32 |                      ->  CStore Scan on customer                         | 12000000 | 1MB           |      24 | 12923.00
(32 rows)
```

To solve data skew in the redistribution, Hash Agg is changed to double-level Agg operators and the redistribution operators used by Hash Join are changed in the optimized plan.

- Modify the query and then specify hints.

  For example, the original query and its plan are as follows:

  ```
  explain select count(*) from store_sales_1 group by round(ss_list_price);
  ```

  ```
  ----+-----------------------------------------------------------------------+---------+----------+---------+----------
    1 | ->  Row Adapter                                                       |   16672 |          |      14 | 62261.28
    2 |    ->  Vector Streaming (type: GATHER)                                |   16672 |          |      14 | 62261.28
    3 |       ->  Vector Streaming(type: LOCAL GATHER dop: 1/2)               |   16672 | 32KB     |      14 | 61479.78
    4 |          ->  Vector Hash Aggregate                                    |   16672 | 16MB     |      14 | 61452.00
    5 |             ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 2/2)   | 3112836 | 128KB    |       6 | 57498.43
    6 |                ->  CStore Scan on store_sales_1                       | 3112836 | 1MB      |       6 | 21810.25
  (6 rows)
  ```

  Columns in hints do not support expressions. To specify hints, rewrite the query as several subqueries. The rewritten query and its plan are as follows:

  ```
  explain
  select count(*)
  from (select round(ss_list_price),ss_hdemo_sk
  from store_sales_1)tmp(a,ss_hdemo_sk)
  group by a;
  ```

  ```
  ----+-----------------------------------------------------------------------+---------+----------+---------+----------
    1 | ->  Row Adapter                                                       |   16672 |          |      14 | 62261.28
    2 |    ->  Vector Streaming (type: GATHER)                                |   16672 |          |      14 | 62261.28
    3 |       ->  Vector Streaming(type: LOCAL GATHER dop: 1/2)               |   16672 | 32KB     |      14 | 61479.78
    4 |          ->  Vector Hash Aggregate                                    |   16672 | 16MB     |      14 | 61452.00
    5 |             ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 2/2)   | 3112836 | 128KB    |       6 | 57498.43
    6 |                ->  CStore Scan on store_sales_1                       | 3112836 | 1MB      |       6 | 21810.25
  (6 rows)
  ```

  Ensure that the service logic is not changed during the rewriting.

  Specify hints in the rewritten query as follows:

  ```
  explain
  select /*+ skew(tmp(a)) */ count(*)
  from (select round(ss_list_price),ss_hdemo_sk
  from store_sales_1)tmp(a,ss_hdemo_sk)
  group by a;
  ```

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```
 id |                              operation                              | E-rows  | E-memory | E-width | E-costs
----+---------------------------------------------------------------------+---------+----------+---------+----------
  1 | ->  Row Adapter                                                     |   16672 |          |      14 | 27771.82
  2 |    ->  Vector Streaming (type: GATHER)                              |   16672 |          |      14 | 27771.82
  3 |       ->  Vector Streaming(type: LOCAL GATHER dop: 1/2)             |   16672 | 32KB     |      14 | 26990.32
  4 |          ->  Vector Hash Aggregate                                  |   16671 | 16MB     |      14 | 26962.54
  5 |             ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 2/2) |   66216 | 128KB    |      14 | 26838.09
  6 |                ->  Vector Hash Aggregate                            |   66216 | 16MB     |      14 | 25949.61
  7 |                   ->  CStore Scan on store_sales_1                  | 3112836 | 1MB      |       6 | 21810.25
(7 rows)
```

The plan shows that after Hash Agg is changed to double-layer Agg operators, redistributed data is greatly reduced and redistribution time shortened.

You can specify hints in columns in a subquery, for example:

```
explain
select /*+ skew(tmp(b)) */ count(*)
from (select round(ss_list_price) b,ss_hdemo_sk
from store_sales_1)tmp(a,ss_hdemo_sk)
group by a;
```

## 11.3.7.9 Configuration Parameter Hints

### Function

A hint, or a GUC hint, specifies a configuration parameter value when a plan is generated. Currently, only the following parameters are supported:

- agg_redistribute_enhancement
- best_agg_plan
- enable_fast_query_shipping
- enable_hashagg
- enable_hashjoin
- enable_indexscan
- enable_nestloop
- enable_nodegroup_debug
- expected_computing_nodegroup
- qrw_inlist2join_optmode
- query_dop
- rewrite_rule
- skew_option

### Syntax

```
set [global](guc_name guc_value)
```

### Parameters

- **global** indicates that the parameter set by hint takes effect at the statement level. If **global** is not specified, the parameter takes effect only in the subquery where the hint is located.
- **guc_name** indicates the name of the configuration parameter specified by hint.
- **guc_value** indicates the value of a configuration parameter specified by hint.

NOTE

- If a parameter set by hint takes effect at the statement level, the hint must be written to the top-level query instead of the subquery. For **UNION**, **INTERSECT**, **EXCEPT**, and **MINUS** statements, you can write the GUC hint at the statement level to any **SELECT** clause that participates in the set operation. The configuration parameters set by the GUC hint take effect on each **SELECT** clause that participates in the set operation.
- When a subquery is pulled up, all GUC hints on the subquery are discarded.
- The **enable_fast_query_shipping**, **enable_nodegroup_debug**, **expected_computing_nodegroup**, **query_dop**, and **rewrite_rule** parameters can be set only at the statement level.
- If a parameter is set by both the statement-level GUC hint and the subquery-level GUC hint, the subquery-level GUC hint takes effect in the corresponding subquery, and the statement-level GUC hint takes effect in other subqueries of the statement.

## Example

Hint the query plan in **Examples** as follows:

```
explain
select /*+ set global(query_dop 0) */ i_product_name product_name
...
```

This hint indicates that the **query_dop** parameter is set to **0** when the plan for a statement is generated, which means the SMP adaptation function is enabled. The generated plan is as follows:

```
 id |                                        operation                                        | E-rows  | E-memory | E-width | E-costs
----+-----------------------------------------------------------------------------------------+---------+----------+---------+----------
  1 | ->  Row Adapter                                                                         |       1 |          |     230 | 19595.89
  2 |    ->  Vector Sonic Hash Aggregate                                                      |       1 |          |     230 | 19595.89
  3 |       ->  Vector Streaming (type: GATHER)                                               |       3 |          |     230 | 19595.89
  4 |          ->  Vector Sonic Hash Aggregate                                                |       3 | 16MB     |     230 | 19595.66
  5 |             ->  Vector Nest Loop (6,28)                                                 |       3 | 1MB      |     126 | 19595.62
  6 |                ->  Vector Nest Loop (7,27)                                              |       3 | 1MB      |     130 | 19291.57
  7 |                   ->  Vector Streaming(type: LOCAL GATHER dop: 1/2)                     |       3 | 4MB      |     118 | 19279.41
  8 |                      ->  Vector Nest Loop (9,24)                                        |       3 | 1MB      |     118 | 19279.38
  9 |                         ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 2/2)         |       3 | 4MB      |      82 | 18117.66
 10 |                            ->  Vector Nest Loop (11,21)                                 |       3 | 1MB      |      82 | 18117.61
 11 |                               ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 2/2)   |       3 | 4MB      |      82 | 16195.20
 12 |                                  ->  Vector Sonic Hash Join (13,15)                     |       3 | 16MB     |      82 | 16195.15
 13 |                                     ->  Vector Partition Iterator                       |  287514 | 1MB      |      12 | 1110.42
 14 |                                        ->  Partitioned CStore Scan on store_returns     |  287514 | 1MB      |      12 | 1110.42
 15 |                                     ->  Vector Streaming(type: LOCAL BROADCAST dop: 2/2) |    2764 | 4MB      |      94 | 14718.42
 16 |                                        ->  Vector Sonic Hash Join (17,19)               |    1382 | 16MB     |      94 | 14699.69
 17 |                                           ->  Vector Partition Iterator                 | 2880404 | 1MB      |      39 | 11541.07
 18 |                                              ->  Partitioned CStore Scan on store_sales | 2880404 | 1MB      |      39 | 11541.07
 19 |                                           ->  Vector Streaming(type: LOCAL BROADCAST dop: 2/2) |      16 | 4MB      |      55 | 1947.12
 20 |                                              ->  CStore Scan on item                    |       8 | 1MB      |      55 | 1947.00
 21 |                                  ->  Vector Materialize                                 |  100000 | 16MB     |       8 | 1797.41
 22 |                                     ->  Vector Streaming(type: LOCAL REDISTRIBUTE dop: 2/2) |  100000 | 4MB      |       8 | 1714.07
 23 |                                        ->  CStore Scan on customer                      |  100000 | 1MB      |       8 | 703.67
 24 |                            ->  Vector Materialize                                       |   50000 | 16MB     |      44 | 1099.22
 25 |                               ->  Vector Streaming(type: LOCAL REDISTRIBUTE dop: 2/2)   |   50000 | 4MB      |      44 | 1057.55
 26 |                                  ->  CStore Scan on customer_address ad2               |   50000 | 1MB      |      44 | 552.33
 27 |                      ->  CStore Scan on store                                           |      36 | 1MB      |      20 | 12.01
 28 |                   ->  CStore Scan on promotion                                          |     900 | 1MB      |       4 | 300.30
(28 rows)
```

## 11.3.7.10 Hint Errors, Conflicts, and Other Warnings

Plan hints change an execution plan. You can run **EXPLAIN** to view the changes.

Hints containing errors are invalid and do not affect statement execution. The errors will be displayed in different ways based on statement types. Hint errors in an **EXPLAIN** statement are displayed as a warning on the interface. Hint errors in other statements will be recorded in debug1-level logs containing the **PLANHINT** keyword.

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## Hint Error Types

- Syntax errors.

  An error will be reported if the syntax tree fails to be reduced. The No. of the row generating an error is displayed in the error details.

  For example, the hint keyword is incorrect, no table or only one table is specified in the **leading** or **join** hint, or no tables are specified in other hints. The parsing of a hint is terminated immediately after a syntax error is detected. Only the hints that have been parsed successfully are valid.

  For example:

  ```
  leading((t1 t2)) nestloop(t1) rows(t1 t2 #10)
  ```

  The syntax of **nestloop(t1)** is wrong and its parsing is terminated. Only **leading(t1 t2)** that has been successfully parsed before **nestloop(t1)** is valid.

- Semantic errors.
  - An error will be reported if the specified tables do not exist, multiple tables are found based on the hint setting, or a table is used more than once in the **leading** or **join** hint.
  - An error will be reported if the index specified in a scan hint does not exist.
  - If multiple tables with the same name exist after a subquery is pulled up and some of them need to be hinted, add aliases for them to avoid name duplication.

- Duplicated or conflicted hints.

  If hint duplication or conflicts occur, only the first hint takes effect. A message will be displayed to describe the situation.
  - Hint duplication indicates that a hint is used more than once in the same query, for example, **nestloop(t1 t2) nestloop(t1 t2)**.
  - A hint conflict indicates that the functions of two hints with the same table list conflict with each other.

    For example, if **nestloop (t1 t2) hashjoin (t1 t2)** is used, **hashjoin (t1 t2)** becomes invalid. **nestloop(t1 t2)** does not conflict with **no mergejoin(t1 t2)**.

    **NOTICE**

    The table list in the **leading** hint is disassembled. For example, **leading (t1 t2 t3)** will be disassembled as **leading(t1 t2) leading((t1 t2) t3)**, which will conflict with **leading(t2 t1)** (if any). In this case, the latter **leading(t2 t1)** becomes invalid. If two hints use duplicated table lists and only one of them has the specified outer/inner table, the one without a specified outer/inner table becomes invalid.

- A hint becomes invalid after a sublink is pulled up.

  In this case, a message will be displayed. Generally, such invalidation occurs if a sublink contains multiple tables to be joined, because the table list in the sublink becomes invalid after the sublink is pulled up.

- Unsupported column types.

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  - Skew hints are specified to optimize redistribution. They will be invalid if their corresponding columns do not support redistribution.
- Specified hints are not used.
  - If **hashjoin** or **mergejoin** is specified for non-equivalent joins, it will not be used.
  - If **indexscan** or **indexonlyscan** is specified for a table that does not have an index, it will not be used.
  - If **indexscan hint** or **indexonlyscan** is specified for a full-table scan or for a scan whose filtering conditions are not set on index columns, it will not be used.
  - The specified **indexonlyscan** hint is used only when the output column contains only indexes.
  - In equivalent joins, only the joins containing equivalence conditions are valid. Therefore, the **leading**, **join**, and **rows** hints specified for the joins without an equivalence condition will not be used. For example, **t1**, **t2**, and **t3** are to be joined, and the join between **t1** and **t3** does not contain an equivalence condition. In this case, **leading(t1 t3)** will not be used.
  - To generate a streaming plan, if the distribution key of a table is the same as its join key, **redistribute** specified for this table will not be used. If the distribution key and join key are different for this table but the same for the other table in the join, **redistribute** specified for this table will be used but **broadcast** will not.
  - If no sublink is pulled up, the specified **blockname** hint will not be used.
  - Skew hints are not used possibly because:
    - The plan does not require redistribution.
    - The columns specified by hints contain distribution keys.
    - Skew information specified in hints is incorrect or incomplete, for example, no value is specified for join optimization.
    - Skew optimization is disabled by GUC parameters.
  - GUC hints are not used possibly because:
    - The configuration parameter does not exist.
    - The configuration parameter is not supported by GUC hints.
    - The configuration parameter value is invalid.
    - The statement-level GUC hint is not written in the top-level query.
    - The configuration parameter set by the GUC hint at the subquery level cannot be set at the subquery level.
    - The subquery where the GUC hint is located is pulled up.

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### 11.3.7.11 Plan Hint Cases

This section takes the statements in TPC-DS (Q24) as an example to describe how to optimize an execution plan by using hints in 1000X+24DN environments. For example:

```
select avg(netpaid) from
(select c_last_name
,c_first_name
,s_store_name
,ca_state
,s_state
,i_color
,i_current_price
,i_manager_id
,i_units
,i_size
,sum(ss_sales_price) netpaid
from store_sales
,store_returns
,store
,item
,customer
,customer_address
where ss_ticket_number = sr_ticket_number
and ss_item_sk = sr_item_sk
and ss_customer_sk = c_customer_sk
and ss_item_sk = i_item_sk
and ss_store_sk = s_store_sk
and c_birth_country = upper(ca_country)
and s_zip = ca_zip
and s_market_id=7
group by c_last_name
,c_first_name
,s_store_name
,ca_state
,s_state
,i_color
,i_current_price
,i_manager_id
,i_units
,i_size);
```

1. The original plan of this statement is as follows and the statement execution takes 110s:

```
 id |                                        operation                                        |        A-time          |  A-rows   |  E-rows   |
----+-----------------------------------------------------------------------------------------+------------------------+-----------+-----------+
  1 | ->  Row Adapter                                                                         | 110324.107             |         1 |         1 |
  2 |    ->  Vector Aggregate                                                                 | 110324.093             |         1 |         1 |
  3 |       ->  Vector Streaming (type: GATHER)                                               | 110323.958             |        24 |        24 |
  4 |          ->  Vector Aggregate                                                           | [110179.302,110309.653] |        24 |        24 |
  5 |             ->  Vector Hash Aggregate                                                   | [110178.388,110308.515] |    647824 |     16656 |
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                                 | [77616.177,96478.771]  |  666834733 |     16664 |
  7 |                   ->  Vector Hash Join (8,22)                                           | [81727.257,84728.519]  |  666834733 |     16664 |
  8 |                      ->  Vector Streaming(type: REDISTRIBUTE)                           | [78770.520,82021.087]  |  666834733 |     16664 |
  9 |                         ->  Vector Hash Join (10,21)                                    | [88066.755,90701.860]  |  666834733 |     16664 |
 10 |                            ->  Vector Streaming(type: BROADCAST)                        | [7940.962,21430.725]   |  591882336 |     51360 |
 11 |                               ->  Vector Hash Join (12,20)                              | [2419.995,5319.606]    |   24661764 |      2140 |
 12 |                                  ->  Vector Streaming(type: REDISTRIBUTE)               | [1750.448,4659.581]    |   25258268 |      2241 |
 13 |                                     ->  Vector Hash Join (14,18)                        | [15240.666,17159.616]  |   25258268 |      2241 |
 14 |                                        ->  Vector Hash Join (15,17)                     | [12112.913,13563.366]  |  252564412 |  472070592 |
 15 |                                           ->  Vector Partition Iterator                 | [11148.731,12473.230]  | 2879987999 | 2879987999 |
 16 |                                              ->  Partitioned CStore Scan on public.store_sales | [11097.921,12412.596]  | 2879987999 | 2879987999 |
 17 |                                           ->  CStore Scan on public.store               | [0.447,0.689]          |      2064 |      2064 |
 18 |                                        ->  Vector Partition Iterator                    | [296.805,319.014]      |  287999764 |  287999764 |
 19 |                                           ->  Partitioned CStore Scan on public.store_returns | [292.938,314.787]      |  287999764 |  287999764 |
 20 |                                  ->  CStore Scan on public.customer                     | [114.358,144.462]      |   12000000 |   12000000 |
 21 |                            ->  CStore Scan on public.customer_address                   | [38.426,56.753]        |    6000000 |    6000000 |
 22 |                      ->  CStore Scan on public.item                                     | [3.160,5.026]          |     300000 |     300000 |
(22 rows)
```

In this plan, the performance of the layer-10 **broadcast** is poor because the estimation result generated at layer 11 is 2140 rows, which is much less than the actual number of rows. The inaccurate estimation is mainly caused by the underestimated number of rows in layer-13 hash join. In this layer, **store_sales**

and **store_returns** are joined (based on the **ss_ticket_number** and **ss_item_sk** columns in **store_sales** and the **sr_ticket_number** and **sr_item_sk** columns in **store_returns**) but the multi-column correlation is not considered.

2. After the **rows** hint is used for optimization, the plan is as follows and the statement execution takes 318s:

```
select avg(netpaid) from
(select /*+rows(store_sales store_returns * 11270)*/ c_last_name ...
```

```
 id |                                                operation                                                |          A-time          |  A-rows   |  E-rows
----+---------------------------------------------------------------------------------------------------------+--------------------------+-----------+-----------
  1 | ->  Row Adapter                                                                                         | 318585.246               |         1 |         1
  2 |    ->  Vector Aggregate                                                                                 | 318585.232               |         1 |         1
  3 |       ->  Vector Streaming (type: GATHER)                                                               | 318585.082               |        24 |        24
  4 |          ->  Vector Aggregate                                                                           | [318323.324,318499.290]  |        24 |        24
  5 |             ->  Vector Hash Aggregate                                                                   | [318320.813,318497.054]  |    647824 |  187770504
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                                                 | [288074.860,305601.698]  |  666834733 |  187770507
  7 |                   ->  Vector Hash Join (8,22)                                                           | [253642.468,315808.664]  |  666834733 |  187770507
  8 |                      ->  Vector Hash Join (9,18)                                                        | [250904.317,315684.018]  |  666834733 |  187770507
  9 |                         ->  Vector Streaming(type: REDISTRIBUTE)                                        | [4552.500,310602.307]    |  275042158 |  147106999
 10 |                            ->  Vector Hash Join (11,17)                                                 | [7658.951,14053.823]     |  275042158 |  147106999
 11 |                               ->  Vector Streaming(type: REDISTRIBUTE)                                  | [3953.255,10264.943]     |  287999764 |  154060900
 12 |                                  ->  Vector Hash Join (13,15)                                           | [28196.188,32838.794]    |  287999764 |  154060900
 13 |                                     ->  Vector Partition Iterator                                       | [11477.673,12324.583]    | 2879987999 | 2879987999
 14 |                                        ->  Partitioned CStore Scan on public.store_sales                | [11411.382,12250.209]    | 2879987999 | 2879987999
 15 |                                     ->  Vector Partition Iterator                                       | [304.188,403.205]        |  287999764 |  287999764
 16 |                                        ->  Partitioned CStore Scan on public.store_returns              | [299.838,398.255]        |  287999764 |  287999764
 17 |                               ->  CStore Scan on public.customer                                        | [122.246,170.128]        |   12000000 |   12000000
 18 |                         ->  Vector Streaming(type: REDISTRIBUTE)                                        | [57.558,117.461]         |     492915 |     146467
 19 |                            ->  Vector Hash Join (20,21)                                                 | [45.554,96.238]          |     492915 |     146467
 20 |                               ->  CStore Scan on public.customer_address                                | [39.738,89.412]          |    6000000 |    6000000
 21 |                               ->  CStore Scan on public.store                                           | [0.361,1.095]            |       2064 |       2064
 22 |                      ->  Vector Streaming(type: BROADCAST)                                              | [48.986,91.170]          |    7200000 |    7200000
 23 |                         ->  CStore Scan on public.item                                                  | [4.506,6.602]            |     300000 |     300000
(23 rows)
```

The execution takes a longer time because layer-9 **redistribute** is slow. Considering that data skew does not occur at layer-9 **redistribute**, the slow redistribution is caused by the slow layer-8 **hashjoin** due to data skew at layer-18 **redistribute**.

3. Data skew occurs at layer-18 **redistribute** because **customer_address** has a few different values in its two join keys. Therefore, plan **customer_address** as the last one to be joined. After the hint is used for optimization, the plan is as follows and the statement execution takes 116s:

```
select avg(netpaid) from
(select /*+rows(store_sales store_returns *11270)
leading((store_sales store_returns store item customer) customer_address)*/
c_last_name ...
```

```
 id |                                                operation                                                |          A-time          |  A-rows   |  E-rows
----+---------------------------------------------------------------------------------------------------------+--------------------------+-----------+-----------
  1 | ->  Row Adapter                                                                                         | 116326.597               |         1 |         1
  2 |    ->  Vector Aggregate                                                                                 | 116326.590               |         1 |         1
  3 |       ->  Vector Streaming (type: GATHER)                                                               | 116326.473               |        24 |        24
  4 |          ->  Vector Aggregate                                                                           | [116157.161,116236.494]  |        24 |        24
  5 |             ->  Vector Hash Aggregate                                                                   | [116155.328,116233.946]  |    647824 |  187770504
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                                                 | [84103.951,102052.326]   |  666834733 |  187770507
  7 |                   ->  Vector Hash Join (8,10)                                                           | [23229.469,47484.697]    |  666834733 |  187770507
  8 |                      ->  Vector Streaming(type: REDISTRIBUTE)                                           | [38.367,74.930]          |    6000000 |    6000000
  9 |                         ->  CStore Scan on public.customer_address                                      | [69.877,121.460]         |    6000000 |    6000000
 10 |                      ->  Vector Streaming(type: REDISTRIBUTE)                                           | [17404.744,17567.550]    |   24661764 |   24112909
 11 |                         ->  Vector Hash Join (12,22)                                                    | [16123.627,16397.246]    |   24661764 |   24112909
 12 |                            ->  Vector Streaming(type: REDISTRIBUTE)                                     | [15320.663,15741.646]    |   25258268 |   25252751
 13 |                               ->  Vector Hash Join (14,21)                                              | [14962.342,16375.458]    |   25258268 |   25252751
 14 |                                  ->  Vector Hash Join (15,19)                                           | [14449.031,15825.949]    |   25258268 |   25252751
 15 |                                     ->  Vector Hash Join (16,18)                                        | [11439.959,12510.065]    |  252564412 |  472070592
 16 |                                        ->  Vector Partition Iterator                                    | [10531.986,11536.213]    | 2879987999 | 2879987999
 17 |                                           ->  Partitioned CStore Scan on public.store_sales             | [10483.634,11474.944]    | 2879987999 | 2879987999
 18 |                                        ->  CStore Scan on public.store                                  | [0.347,0.463]            |       2064 |       2064
 19 |                                     ->  Vector Partition Iterator                                       | [293.977,365.021]        |  287999764 |  287999764
 20 |                                        ->  Partitioned CStore Scan on public.store_returns              | [289.936,360.808]        |  287999764 |  287999764
 21 |                                  ->  CStore Scan on public.item                                         | [3.109,5.245]            |     300000 |     300000
 22 |                               ->  CStore Scan on public.customer                                        | [113.871,141.791]        |   12000000 |   12000000
(22 rows)
```

Most of the time is spent on layer-6 **redistribute**. The plan needs to be further optimized.

4. Most of the time is spent on layer-6 **redistribute** because of data skew. To avoid the data skew, plan the **item** table as the last one to be joined because the

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number of rows is not reduced after **item** is joined. After the hint is used for optimization, the plan is as follows and the statement execution takes 120s:

```
select avg(netpaid) from
(select /*+rows(store_sales store_returns *11270)
leading((customer_address (store_sales store_returns store customer) item))
c_last_name ...
```

```
 id |                                operation                                |        A-time         | A-rows  | E-rows
----+-------------------------------------------------------------------------+-----------------------+---------+---------
  1 | ->  Row Adapter                                                         | 120377.258            |       1 |       1
  2 |    ->  Vector Aggregate                                                 | 120377.245            |       1 |       1
  3 |       ->  Vector Streaming (type: GATHER)                               | 120377.091            |      24 |      24
  4 |          ->  Vector Aggregate                                           | [120184.884,120301.704] |      24 |      24
  5 |             ->  Vector Hash Aggregate                                   | [120183.119,120297.845] |  647824 |  187770504
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                 | [87775.682,106070.878] |  666834733 |  187770507
  7 |                   ->  Vector Hash Join (8,22)                           | [22323.764,49878.523] |  666834733 |  187770507
  8 |                      ->  Vector Hash Join (9,11)                        | [21129.236,45208.255] |  666834733 |  187770507
  9 |                         ->  Vector Streaming(type: REDISTRIBUTE)        | [37.859,75.412]       |    6000000 |    6000000
 10 |                            ->  CStore Scan on public.customer_address   | [74.798,114.449]      |    6000000 |    6000000
 11 |                         ->  Vector Streaming(type: REDISTRIBUTE)        | [15714.458,15824.928] |   24661764 |   24112909
 12 |                            ->  Vector Hash Join (13,21)                 | [14637.516,14955.464] |   24661764 |   24112909
 13 |                               ->  Vector Streaming(type: REDISTRIBUTE)  | [13898.593,14333.200] |   25258268 |   25252751
 14 |                                  ->  Vector Hash Join (15,19)           | [14166.917,15378.244] |   25258268 |   25252751
 15 |                                     ->  Vector Hash Join (16,18)        | [11272.239,12052.532] |  252564412 |  472070592
 16 |                                        ->  Vector Partition Iterator    | [10409.566,11127.981] | 2879987999 | 2879987999
 17 |                                           ->  Partitioned CStore Scan on public.store_sales | [10365.838,11077.601] | 2879987999 | 2879987999
 18 |                                        ->  CStore Scan on public.store  | [0.431,0.609]         |    2064 |    2064
 19 |                                     ->  Vector Partition Iterator       | [343.780,408.254]     |  287999764 |  287999764
 20 |                                        ->  Partitioned CStore Scan on public.store_returns | [339.844,403.923] |  287999764 |  287999764
 21 |                                  ->  CStore Scan on public.customer     | [117.234,163.598]     |   12000000 |   12000000
 22 |                            ->  Vector Streaming(type: BROADCAST)        | [44.571,130.129]      |    7200000 |    7200000
 23 |                               ->  CStore Scan on public.item            | [4.169,6.347]         |     300000 |     300000
(23 rows)
```

Data skew occurs after the join of **item** and **customer_address** because **item** is broadcasted at layer-22. As a result, layer-6 **redistribute** is still slow.

5. Add a hint to disable **broadcast** for **item** or add a **redistribute** hint for the join result of **item** and **customer_address**. After the hint is used for optimization, the plan is as follows and the statement execution takes 105s:

```
select avg(netpaid) from
(select /*+rows(store_sales store_returns *11270)
leading((customer_address (store_sales store_returns store customer) item))
no broadcast(item)*/
c_last_name ...
```

```
 id |                                operation                                |        A-time         | A-rows  | E-rows
----+-------------------------------------------------------------------------+-----------------------+---------+---------
  1 | ->  Row Adapter                                                         | 105854.957            |       1 |       1
  2 |    ->  Vector Aggregate                                                 | 105854.948            |       1 |       1
  3 |       ->  Vector Streaming (type: GATHER)                               | 105854.825            |      24 |      24
  4 |          ->  Vector Aggregate                                           | [105706.709,105776.135] |      24 |      24
  5 |             ->  Vector Hash Aggregate                                   | [105705.061,105773.013] |  647824 |  187770504
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                 | [70701.966,89973.672] |  666834733 |  187770507
  7 |                   ->  Vector Hash Join (8,23)                           | [71759.500,79018.433] |  666834733 |  187770507
  8 |                      ->  Vector Streaming(type: REDISTRIBUTE)           | [69794.307,77269.178] |  666834733 |  187770507
  9 |                         ->  Vector Hash Join (10,12)                    | [21443.307,46714.378] |  666834733 |  187770507
 10 |                            ->  Vector Streaming(type: REDISTRIBUTE)     | [41.295,83.419]       |    6000000 |    6000000
 11 |                               ->  CStore Scan on public.customer_address | [70.405,166.072]      |    6000000 |    6000000
 12 |                            ->  Vector Streaming(type: REDISTRIBUTE)     | [15689.053,15788.475] |   24661764 |   24112909
 13 |                               ->  Vector Hash Join (14,22)              | [14517.847,14712.929] |   24661764 |   24112909
 14 |                                  ->  Vector Streaming(type: REDISTRIBUTE) | [13806.733,14089.770] |   25258268 |   25252751
 15 |                                     ->  Vector Hash Join (16,20)        | [13709.384,15095.449] |   25258268 |   25252751
 16 |                                        ->  Vector Hash Join (17,19)     | [10944.796,11827.285] |  252564412 |  472070592
 17 |                                           ->  Vector Partition Iterator | [10070.316,10884.728] | 2879987999 | 2879987999
 18 |                                              ->  Partitioned CStore Scan on public.store_sales | [10018.966,10828.990] | 2879987999 | 2879987999
 19 |                                           ->  CStore Scan on public.store | [0.447,0.568]         |    2064 |    2064
 20 |                                        ->  Vector Partition Iterator    | [293.042,329.056]     |  287999764 |  287999764
 21 |                                           ->  Partitioned CStore Scan on public.store_returns | [288.631,324.782] |  287999764 |  287999764
 22 |                                  ->  CStore Scan on public.customer     | [113.735,138.235]     |   12000000 |   12000000
 23 |                      ->  CStore Scan on public.item                     | [3.127,5.357]         |     300000 |     300000
(23 rows)
```

6. The last layer uses single-layer **Agg** and the number of rows is greatly reduced. Set **best_agg_plan** to **3** and change the single-layer **Agg** to a double-layer **Agg**. The plan is as follows and the statement execution takes 94s. The optimization ends.

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```
 id |                                operation                                 |        A-time         |  A-rows  |  E-rows
----+--------------------------------------------------------------------------+-----------------------+----------+-----------
  1 | ->  Row Adapter                                                          | 94004.670             |        1 |         1
  2 |    ->  Vector Aggregate                                                  | 94004.655             |        1 |         1
  3 |       ->  Vector Streaming (type: GATHER)                                | 94004.504             |       24 |        24
  4 |          ->  Vector Aggregate                                            | [93833.832,93928.052] |       24 |        24
  5 |             ->  Vector Hash Aggregate                                    | [93832.460,93926.412] |   647824 | 187770507
  6 |                ->  Vector Streaming(type: REDISTRIBUTE)                  | [93640.866,93787.939] |   647824 | 183912384
  7 |                   ->  Vector Hash Aggregate                              | [93687.544,93791.242] |   647824 | 183912384
  8 |                      ->  Vector Hash Join (9,24)                         | [70025.469,72773.161] |   666834733 | 187770507
  9 |                         ->  Vector Streaming(type: REDISTRIBUTE)         | [68242.223,71275.972] |   666834733 | 187770507
 10 |                            ->  Vector Hash Join (11,13)                  | [21421.136,44830.306] |   666834733 | 187770507
 11 |                               ->  Vector Streaming(type: REDISTRIBUTE)   | [35.444,71.328]       |   6000000 |   6000000
 12 |                                  ->  CStore Scan on public.customer_address | [67.246,119.224]    |   6000000 |   6000000
 13 |                               ->  Vector Streaming(type: REDISTRIBUTE)   | [16089.853,16212.570] |   24661764 |  24112909
 14 |                                  ->  Vector Hash Join (15,23)            | [14822.972,15188.942] |   24661764 |  24112909
 15 |                                     ->  Vector Streaming(type: REDISTRIBUTE) | [14061.867,14604.162] |   25258268 |  25252751
 16 |                                        ->  Vector Hash Join (17,21)      | [13949.756,15492.311] |   25258268 |  25252751
 17 |                                           ->  Vector Hash Join (18,20)   | [10935.742,12160.719] |   252564412 | 472070592
 18 |                                              ->  Vector Partition Iterator | [10052.958,11194.962] | 2879987999 | 2879987999
 19 |                                                 ->  Partitioned CStore Scan on public.store_sales | [10008.415,11143.984] | 2879987999 | 2879987999
 20 |                                              ->  CStore Scan on public.store | [0.452,0.839]       |   2064 |   2064
 21 |                                           ->  Vector Partition Iterator  | [298.235,332.736]     |   287999764 | 287999764
 22 |                                              ->  Partitioned CStore Scan on public.store_returns | [294.067,327.629] |   287999764 | 287999764
 23 |                                     ->  CStore Scan on public.customer   | [114.377,145.156]     |   12000000 |  12000000
 24 |                               ->  CStore Scan on public.item             | [3.150,3.530]         |   300000 |   300000
(24 rows)
```

If the query performance deteriorates due to statistics changes, you can use hints to optimize the query plan. Take TPCH-Q17 as an example. The query performance deteriorates after the value of **default_statistics_target** is changed from the default one to **–2** for statistics collection.

1. If **default_statistics_target** is set to the default value **100**, the plan is as follows:

```
 id |                                operation                                 |          A-time
----+--------------------------------------------------------------------------+---------------------------
  1 | ->  Row Adapter                                                          | 265006.779
  2 |    ->  Vector Aggregate                                                  | 265006.764
  3 |       ->  Vector Streaming (type: GATHER)                                | 265006.071
  4 |          ->  Vector Aggregate                                            | [263699.512,264503.084]
  5 |             ->  Vector Hash Join (6,17)                                  | [263676.665,264477.932]
  6 |                ->  Vector Streaming(type: LOCAL GATHER dop: 1/4)         | [1.998,7.594]
  7 |                   ->  Vector Hash Aggregate                              | [201775.393,202432.672]
  8 |                      ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 4/4) | [201567.130,202231.524]
  9 |                         ->  Vector Hash Join (10,12)                     | [170675.231,199908.410]
 10 |                            ->  Vector Partition Iterator                 | [34847.797,51968.266]
 11 |                               ->  Partitioned CStore Scan on tpch10wx_col.lineitem | [33805.013,51137.657]
 12 |                            ->  Vector Hash Aggregate                     | [23283.387,25359.493]
 13 |                               ->  Vector Streaming(type: SPLIT BROADCAST dop: 4/4) | [12850.624,14608.515]
 14 |                                  ->  Vector Hash Aggregate              | [2690.439,3616.623]
 15 |                                     ->  Vector Partition Iterator       | [2659.700,3579.390]
 16 |                                        ->  Partitioned CStore Scan on tpch10wx_col.part | [2642.213,3559.093]
 17 |                   ->  Vector Streaming(type: REDISTRIBUTE dop: 1/4)      | [262300.732,262961.078]
 18 |                      ->  Vector Hash Join (19,21)                        | [225749.727,260990.322]
 19 |                         ->  Vector Partition Iterator                    | [40046.078,56220.694]
 20 |                            ->  Partitioned CStore Scan on tpch10wx_col.lineitem | [39204.414,55328.448]
 21 |                         ->  Vector Streaming(type: SPLIT BROADCAST dop: 4/4) | [55748.177,61987.136]
 22 |                            ->  Vector Partition Iterator                 | [3042.864,3873.942]
 23 |                               ->  Partitioned CStore Scan on tpch10wx_col.part | [3027.023,3848.159]
(23 rows)
```

2. If **default_statistics_target** is set to **–2**, the plan is as follows:

```
 id |                                operation                                 |          A-time
----+--------------------------------------------------------------------------+---------------------------
  1 | ->  Row Adapter                                                          | 1440492.994
  2 |    ->  Vector Aggregate                                                  | 1440492.982
  3 |       ->  Vector Streaming (type: GATHER)                                | 1440491.021
  4 |          ->  Vector Streaming(type: LOCAL GATHER dop: 1/6)               | [1439737.284,1440008.568]
  5 |             ->  Vector Aggregate                                         | [1439008.369,1439854.148]
  6 |                ->  Vector Hash Join (7,18)                               | [1439006.016,1439851.619]
  7 |                   ->  Vector Streaming(type: LOCAL BROADCAST dop: 6/6)   | [2.932,139.405]
  8 |                      ->  Vector Hash Aggregate                           | [190452.312,195910.748]
  9 |                         ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 6/6) | [190171.929,195653.119]
 10 |                            ->  Vector Hash Join (11,13)                  | [161076.195,178831.123]
 11 |                               ->  Vector Partition Iterator              | [27306.318,45564.565]
 12 |                                  ->  Partitioned CStore Scan on tpch10wx_col.lineitem | [26752.444,44912.020]
 13 |                               ->  Vector Hash Aggregate                  | [35601.624,39812.058]
 14 |                                  ->  Vector Streaming(type: SPLIT BROADCAST dop: 6/6) | [23096.460,27057.137]
 15 |                                     ->  Vector Hash Aggregate           | [2372.587,3052.445]
 16 |                                        ->  Vector Partition Iterator    | [2345.381,3012.732]
 17 |                                           ->  Partitioned CStore Scan on tpch10wx_col.part | [2329.874,2989.393]
 18 |                   ->  Vector Hash Join (19,22)                           | [1437388.414,1438470.781]
 19 |                      ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 6/6) | [1392693.529,1408571.859]
 20 |                         ->  Vector Partition Iterator                    | [29065.204,41264.514]
 21 |                            ->  Partitioned CStore Scan on tpch10wx_col.lineitem | [28212.219,40133.491]
 22 |                      ->  Vector Streaming(type: LOCAL REDISTRIBUTE dop: 6/6) | [2570.841,3438.567]
 23 |                         ->  Vector Partition Iterator                    | [2447.569,3276.369]
 24 |                            ->  Partitioned CStore Scan on tpch10wx_col.part | [2432.124,3263.641]
(24 rows)
```

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3. After the analysis, the cause is that the stream type is changed from **BroadCast** to **Redistribute** during the join of the **lineitem** and **part** tables. You can use a hint to change the stream type back to **BroadCast**. For example:

```
select /*+ no redistribute(part lineitem) */
    sum(l_extendedprice) / 7.0 as avg_yearly
from
    lineitem,
    part
where
    p_partkey = l_partkey
    and p_brand = 'Brand#23'
    and p_container = 'MED BOX'
    and l_quantity < (
        select
            0.2 * avg(l_quantity)
        from
            lineitem
        where
            l_partkey = p_partkey
    );
```

## 11.3.8 Routinely Maintaining Tables

To ensure proper database running, after INSERT and DELETE operations, you need to routinely do **VACUUM FULL** and **ANALYZE** as appropriate for customer scenarios and update statistics to obtain better performance.

### Related Concepts

You need to routinely run **VACUUM**, **VACUUM FULL**, and **ANALYZE** to maintain tables, because:

- **VACUUM FULL** reclaims disk space occupied by updated or deleted data and combines small-size data files.
- **VACUUM** maintains a visualized mapping to track pages that contain arrays visible to other active transactions. A common index scan uses the mapping to obtain the corresponding array and check whether pages are visible to the current transaction. If the array cannot be obtained, the visibility is checked by fetching stack arrays. Therefore, updating the visible mapping of a table can accelerate unique index scans.
- **VACUUM** can avoid old data loss caused by duplicate transaction IDs when the number of executed transactions exceeds the database threshold.
- **ANALYZE** collects statistics on tables in databases. The statistics are stored in the PG_STATISTIC system catalog. Then, the query optimizer uses the statistics to work out the most efficient execution plan.

### Procedure

**Step 1** Run the **VACUUM** or **VACUUM FULL** command to reclaim disk space.

- **VACUUM**:

  Do **VACUUM** to the table:

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```
VACUUM customer;
VACUUM
```

This command can be concurrently executed with database operation commands, including **SELECT**, **INSERT**, **UPDATE**, and **DELETE**; excluding **ALTER TABLE**.

Do **VACUUM** to the partitioned table:

```
VACUUM customer_par PARTITION ( P1 );
VACUUM
```

- VACUUM FULL:

```
VACUUM FULL customer;
VACUUM
```

**VACUUM FULL** needs to add exclusive locks on tables it operates on and requires that all other database operations be suspended.

When reclaiming disk space, you can query for the session corresponding to the earliest transactions in the cluster, and then end the earliest long transactions as needed to make full use of the disk space.

a. Run the following command to query for oldestxmin on the GTM:

```
select * from pgxc_gtm_snapshot_status();
```

b. Run the following command to query for the PID of the corresponding session on the CN. *xmin* is the oldestxmin obtained in the previous step.

```
select * from pgxc_running_xacts() where xmin=1400202010;
```

**Step 2** Do **ANALYZE** to update statistical information.

```
ANALYZE customer;
ANALYZE
```

Do **ANALYZE VERBOSE** to update statistics and display table information.

```
ANALYZE VERBOSE customer;
ANALYZE
```

You can use **VACUUM ANALYZE** at the same time to optimize the query.

```
VACUUM ANALYZE customer;
VACUUM
```

NOTE

**VACUUM** and **ANALYZE** cause a substantial increase in I/O traffic, which may cause poor performance of other active sessions. Therefore, you are advised to set by specifying the **vacuum_cost_delay** parameter.

**Step 3** Delete a table

```
DROP TABLE customer;
DROP TABLE customer_par;
DROP TABLE part;
```

If the following output is displayed, the index has been deleted.

```
DROP TABLE
```

**----End**

## Maintenance Suggestion

- Routinely do **VACUUM FULL** to large tables. If the database performance deteriorates, do **VACUUM FULL** to the entire database. If the database performance is stable, you are advised to monthly do **VACUUM FULL**.

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- Routinely do **VACUUM FULL** to system catalogs, mainly **PG_ATTRIBUTE**.
- The automatic vacuum process (**AUTOVACUUM**) in the system automatically runs the **VACUUM** and **ANALYZE** statements to reclaim the record space marked as the deleted state and to update statistics related to the table.

# 11.3.9 Routinely Recreating an Index

## Context

When data deletion is repeatedly performed in the database, index keys will be deleted from the index page, resulting in index distention. Recreating an index routinely improves query efficiency.

The database supports B-tree, GIN, and psort indexes.

- Recreating a B-tree index helps improve query efficiency.
  - If massive data is deleted, index keys on the index page will be deleted. As a result, the number of index pages reduces and index bloat occurs. Recreating an index helps reclaim wasted space.
  - In the created index, pages adjacent in its logical structure are adjacent in its physical structure. Therefore, a created index achieves higher access speed than an index that has been updated for multiple times.
- You are advised not to recreate a non-B-tree index.

## Rebuilding an Index

Use either of the following two methods to recreate an index:

- Run the **DROP INDEX** statement to delete an index and run the **CREATE INDEX** statement to create an index.

  When you delete an index, a temporary exclusive lock is added in the parent table to block related read/write operations. When you create an index, the write operation is locked but the read operation is not. The data is read and scanned by order.
- Run the **REINDEX** statement to recreate an index:
  - When you run the **REINDEX TABLE** statement to recreate an index, an exclusive lock is added to block related read/write operations.
  - When you run the **REINDEX INTERNAL TABLE** statement to recreate an index for a **desc** table (), an exclusive lock is added to block read/write operations on the table.

## Procedure

Assume the ordinary index areaS_idx exists in the **area_id** column of the imported table **areaS**. Use either of the following two methods to recreate an index:

- Run the **DROP INDEX** statement to delete the index and run the **CREATE INDEX** statement to create an index.

  a. Delete an index.

  ```
  DROP INDEX areaS_idx;
  DROP INDEX
  ```

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b. Create an index.
```
CREATE INDEX areaS_idx ON areaS (area_id);
CREATE INDEX
```

- Run the **REINDEX** statement to recreate an index.
  - Run the **REINDEX TABLE** statement to recreate an index.
    ```
    REINDEX TABLE areaS;
    REINDEX
    ```
  - Run the **REINDEX INTERNAL TABLE** statement to recreate an index for a **desc** table ().
    ```
    REINDEX INTERNAL TABLE areaS;
    REINDEX
    ```

# 11.3.10 Configuring the SMP

This section describes the usage restrictions, application scenarios, and configuration guide of symmetric multiprocessing (SMP).

## 11.3.10.1 Application Scenarios and Restrictions

### Context

The SMP feature improves the performance through operator parallelism and occupies more system resources, including CPU, memory, network, and I/O. Actually, SMP is a method consuming resources to save time. It improves system performance in appropriate scenarios and when resources are sufficient, but may deteriorate performance otherwise. In addition, compared with the serial processing, SMP generates more candidate plans, which is more time-consuming and may deteriorate performance.

### Applicable Scenarios

- Operators supporting parallel processing are used.

  The execution plan contains the following operators:

  a. Scan: Row Storage common table and a line memory partition table sequential scanning, column-oriented storage ordinary table and column-oriented storage partition table sequential scanning, HDFS internal and external table sequence scanning. Surface scanning GDS data can be imported at the same time. All of the above does not support replication tables.

  b. Join: HashJoin, NestLoop

  c. Agg: HashAgg, SortAgg, PlainAgg, and WindowAgg, which supports only **partition by**, and does not support **order by**.

  d. Stream: Redistribute, Broadcast

  e. Other: Result, Subqueryscan, Unique, Material, Setop, Append, VectoRow, RowToVec

- SMP-unique operators

  To execute queries in parallel, Stream operators are added for data exchange of the SMP feature. These new operators can be considered as the subtypes of Stream operators.

  a. Local Gather aggregates data of parallel threads within a DN

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b. Local Redistribute redistributes data based on the distributed key across threads within a DN
c. Local Broadcast broadcasts data to each thread within a DN.
d. Local RoundRobin distributes data in polling mode across threads within a DN.
e. Split Redistribute redistributes data across parallel threads on different DNs.
f. Split Broadcast broadcasts data to all parallel DN threads in the cluster.

Among these operators, Local operators exchange data between parallel threads within a DN, and non-Local operators exchange data across DNs.

- Example

  The TPCH Q1 parallel plan is used as an example.

```
 id |                                operation                                 |
----+--------------------------------------------------------------------------+
  1 | ->  Row Adapter                                                          |
  2 |    ->  Vector Streaming (type: GATHER)                                   |
  3 |       ->  Vector Sort                                                    |
  4 |          ->  Vector Streaming(type: LOCAL GATHER dop: 1/4)               |
  5 |             ->  Vector Hash Aggregate                                    |
  6 |                ->  Vector Streaming(type: SPLIT REDISTRIBUTE dop: 4/4)   |
  7 |                   ->  Vector Hash Aggregate                              |
  8 |                      ->  Vector Append(9, 10)                            |
  9 |                         ->  Dfs Scan on lineitem                         |
 10 |                         ->  Vector Adapter                               |
 11 |                            ->  Seq Scan on pg_delta_1423863972 lineitem  |
(11 rows)
```

  In this plan, implement the Hdfs Scan and HashAgg operator parallel, and adds the Local Gather and Split Redistribute data exchange operator.

  In this example, the sixth operator is Split Redistribute, and **dop: 4/4** next to the operator indicates that the degree of parallelism of the sender and receiver is 4. 4 No operator is Local Gather, marked dop: 1/4 above, this operator sender thread parallel degree is 4, while the receiving end thread parallelism degree to 1, that is, lower-layer 5 number Hash Aggregate operators according to the 4 parallel degree, while the working mode of the port on the upper-layer 1 to 3 number operator according to the executed one by one, 4 number operator is used to achieve intra-DN concurrent threads data aggregation.

  You can view the parallelism situation of each operator in the dop information.

## Non-applicable Scenarios

1. Short query operations are performed, where the plan generation is time-consuming.
2. Operators are processed on CNs.
3. Statements that cannot be pushed down are executed.
4. The **subplan** of a query and operators containing a subquery are executed.

## 11.3.10.2 Resource Impact on SMP Performance

The SMP architecture uses abundant resources to obtain time. After the plan parallelism is executed, the resource consumption is added, including the CPU,

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memory, I/O, and network bandwidth resources. As the parallelism degree is expanded, the resource consumption increases. If these resources become a bottleneck, the SMP cannot improve the performance and the overall cluster performance may be deteriorated. Adaptive SMP is provided to dynamically select the optimal parallel degree for each query based on the resource usage and query requirements. The following information describes the situations that the SMP affects theses resources:

- **CPU resources**

  In a general customer scenario, the system CPU usage rate is not high. Using the SMP parallelism architecture will fully use the CPU resource to improve the system performance. If the number of CPU kernels of the database server is too small and the CPU usage is already high, enabling the SMP parallelism may deteriorate the system performance due to resource compete between multiple threads.

- **Memory resources**

  The query parallel causes memory usage growth, but the memory upper limit used by each operator is still restricted by **work_mem**. Assume that **work_mem** is 4 GB, and the degree of parallelism is 2, then the memory upper limit of each concurrent thread is 2 GB. When **work_mem** is small or the system memory is sufficient, running SMP parallelism may push data down to disks. As a result, the query performance deteriorates.

- **Network bandwidth resources**

  To execute a query in parallel, data exchange operators are added. Local Stream operators exchange data between threads within a DN. Data is exchanged in memory and network performance is not affected. Non-Local operators exchange data over the network and increase network load. If the capacity of a network resource becomes a bottleneck, parallelism may also increase the network load.

- **I/O resources**

  A parallel scan increases I/O resource consumption. It can improve performance only when I/O resources are sufficient.

## 11.3.10.3 Other Factors Affecting SMP Performance

Besides resource factors, there are other factors that impact the SMP parallelism performance, such as unevenly data distributed in a partitioned table and system parallelism degree.

- **Impact of data skew on SMP performance**

  Serious data skew deteriorates parallel execution performance. For example, if the data volume of a value in the join column is much more than that of other values, the data volume of a parallel thread will be much more than that of others after Hash-based data redistribution, resulting in the long-tail issue and poor parallelism performance.

- **Impact on the SMP performance due to system parallelism degree**

  The SMP feature uses more resources, and unused resources are decreasing in a high concurrency scenario. Therefore, enabling the SMP parallelism will result in serious resource compete among queries. Once resource competes occur, no matter the CPU, I/O, memory, or network resources, all of them will result in entire performance deterioration. In the high concurrency scenario,

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enabling the SMP will not improve the performance effect and even may cause performance deterioration.

### 11.3.10.4 Suggestions for SMP Parameter Settings

Starting from this version, SMP auto adaptation is enabled. For newly deployed clusters, the default value of **query_dop** is **0**, and SMP parameters have been adjusted. To ensure forward compatibility, the value of **query_dop** should remain unchanged after an existing cluster is upgraded.

For an upgraded cluster, if you want to set **query_dop** to **0** and enable SMP parallel processing, modify the following parameters to obtain better dop options:

- comm_usable_memory

  If the system memory is large, the value of **max_process_memory** is large. In this case, you are advised to set the value of this parameter to 5% of **max_process_memory**, that is, 4 GB by default.

- comm_max_stream

  The recommended value for this parameter is calculated as follows: comm_max_stream = Min(dop_limit x dop_limit x 20 x 2, max_process_memory (bytes) x 0.005/Number of DNs/260). The value must be within the value range of **comm_max_stream**.

- max_connections

  The recommended value for this parameter is calculated as follows: max_connections = dop_limit x 20 x 6 + 24. The value must be within the value range of **max_connections**.

**CAUTION**

In the preceding formulas, **dop_limit** indicates the number of CPUs corresponding to each DN in the cluster. It is calculated as follows: **dop_limit** = Number of logical CPU cores of a single server/Number of DNs of a single server.

### 11.3.10.5 SMP Manual Optimization Suggestions

To manually optimize SMP, you need to be familiar with **Suggestions for SMP Parameter Settings**. This section describes how to optimize SMP.

## Constraints

The CPU, memory, I/O, and network bandwidth resources are sufficient. The SMP architecture uses abundant resources to save time. After the plan parallelism is executed, resource consumption increases. When these resources become a bottleneck, SMP may deteriorate, rather than improve performance. In addition, it takes a longer time to generate SMP plans than serial plans. Therefore, in TP services that mainly involve short queries or in case resources are insufficient, you are advised to disable SMP by setting **query_dop** to **1**.

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### Procedure

1. Observe the current system load situation. If the resource is sufficient (the resource usage ratio is smaller than 50%), perform step 2. Otherwise, exit this system.
2. Set **query_dop** to **1** (default value). Use **explain** to generate an execution plan and check whether the plan can be used in scenarios in **Application Scenarios and Restrictions**. If the plan can be used, go to the next step.
3. Set **query_dop=–***value*. The value range of the parallelism degree is [1, *value*].
4. Set **query_dop=***value*. The parallelism degree is 1 or *value*.
5. Before the query statement is executed, set **query_dop** to an appropriate value. After the statement is executed, set **query_dop** to **off**. For example:

```
SET query_dop = 0;
SELECT COUNT(*) FROM t1 GROUP BY a;
......
SET query_dop = 1;
```

NOTE

- If resources are enough, the higher the parallelism degree is, the better the performance improvement effect is.
- The SMP parallelism degree supports a session level setting and you are advised to enable the SMP before executing the query that meets the requirements. After the execution is complete, disable the SMP. Otherwise, SMP may affect services in peak hours.
- SMP adaptation (**query_dop** ≤ 0) depends on resource management. If resource management is disabled (use_workload_manager is **off**), plans with parallelism degree of only 1 or 2 are generated.

# 11.4 Optimization Cases

## 11.4.1 Case: Selecting an Appropriate Distribution Column

### Symptom

Tables are defined as follows:

```
CREATE TABLE t1 (a int, b int);
CREATE TABLE t2 (a int, b int);
```

The following query is executed:

```
SELECT * FROM t1, t2 WHERE t1.a = t2.b;
```

### Optimization Analysis

If **a** is the distribution column of **t1** and **t2**:

```
CREATE TABLE t1 (a int, b int) DISTRIBUTE BY HASH (a);
CREATE TABLE t2 (a int, b int) DISTRIBUTE BY HASH (a);
```

Then **Streaming** exists in the execution plan and the data volume is heavy among DNs, as shown in **Figure 11-10**.

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**Figure 11-10** Selecting an appropriate distribution column (1)

```
postgres=> explain select * from t1, t2 where t1.a = t2.b;
                                  QUERY PLAN
------------------------------------------------------------------------------
 Streaming (type: GATHER)  (cost=245.40..582.15 rows=240 width=16)
   Node/s: All datanodes
   ->  Hash Join  (cost=10.22..24.26 rows=10 width=16)
         Hash Cond: (t1.a = t2.b)
         ->  Seq Scan on t1  (cost=0.00..10.10 rows=10 width=8)
         ->  Hash  (cost=3.79..3.79 rows=10 width=8)
               ->  Streaming(type: REDISTRIBUTE)  (cost=0.00..3.79 rows=10 width=8)
                     Spawn on: All datanodes
                     ->  Seq Scan on t2  (cost=0.00..10.10 rows=10 width=8)
(9 rows)
```

If **a** is the distribution column of **t1** and **b** is the distribution column of **t2**:

```
CREATE TABLE t1 (a int, b int) DISTRIBUTE BY HASH (a);
CREATE TABLE t2 (a int, b int) DISTRIBUTE BY HASH (b);
```

Then **Streaming** does not exist in the execution plan, and the data volume among DNs is decreasing and the query performance is increasing, as shown in **Figure 11-11**.

**Figure 11-11** Selecting an appropriate distribution column (2)

```
postgres=> explain select * from t1, t2 where t1.a = t2.b;
                                QUERY PLAN
---------------------------------------------------------------------------
 Streaming (type: GATHER)  (cost=245.40..491.10 rows=240 width=16)
   Node/s: All datanodes
   ->  Hash Join  (cost=10.22..20.46 rows=10 width=16)
         Hash Cond: (t1.a = t2.b)
         ->  Seq Scan on t1  (cost=0.00..10.10 rows=10 width=8)
         ->  Hash  (cost=10.10..10.10 rows=10 width=8)
               ->  Seq Scan on t2  (cost=0.00..10.10 rows=10 width=8)
(7 rows)
```

## 11.4.2 Case: Creating an Appropriate Index

### Symptom

Query the information about all personnel in the sales department.

```
SELECT staff_id,first_name,last_name,employment_id,state_name,city
FROM staffs,sections,states,places
WHERE sections.section_name='Sales'
AND staffs.section_id = sections.section_id
AND sections.place_id = places.place_id
AND places.state_id = states.state_id
ORDER BY staff_id;
```

### Optimization Analysis

The original execution plan is as follows before creating the **places.place_id** and **states.state_id** indexes:

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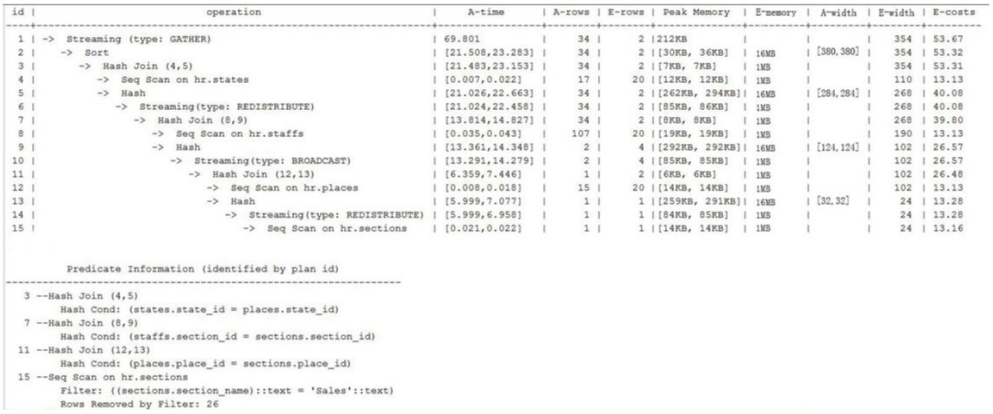
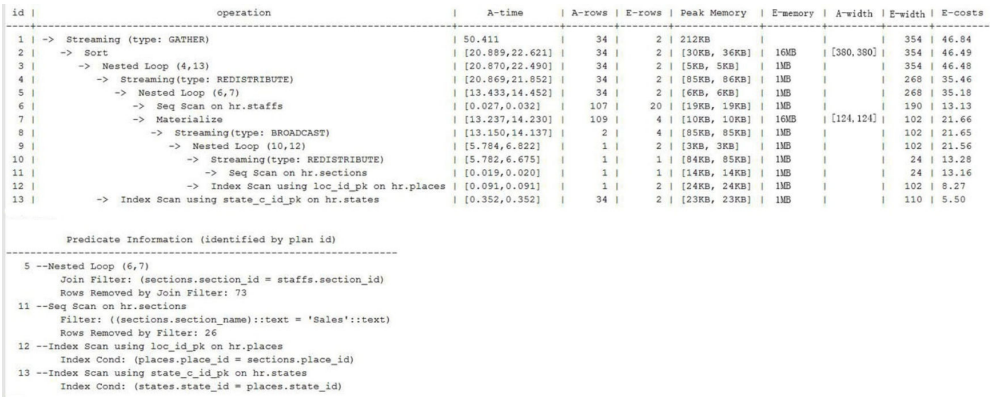


```
 id |                        operation                        |      A-time      | A-rows | E-rows | Peak Memory  | E-memory | A-width | E-width | E-costs
----+---------------------------------------------------------+------------------+--------+--------+--------------+----------+---------+---------+---------
  1 | ->  Streaming (type: GATHER)                            | 69.801           |     34 |      2 |212KB         |          |         |     354 | 53.67
  2 |    ->  Sort                                             | [21.508,23.283]  |     34 |      2 |[30KB, 36KB]  | 16MB     |[380,380]|     354 | 53.32
  3 |       ->  Hash Join (4,5)                               | [21.483,23.153]  |     34 |      2 |[7KB, 7KB]    | 1MB      |         |     354 | 53.31
  4 |          ->  Seq Scan on hr.states                      | [0.007,0.022]    |     17 |     20 |[12KB, 12KB]  | 1MB      |         |     110 | 13.13
  5 |          ->  Hash                                       | [21.026,22.663]  |     34 |      2 |[262KB, 294KB]| 16MB     |[284,284]|     268 | 40.08
  6 |             ->  Streaming(type: REDISTRIBUTE)           | [21.024,22.458]  |     34 |      2 |[85KB, 86KB]  | 1MB      |         |     268 | 40.08
  7 |                ->  Hash Join (8,9)                      | [13.814,14.827]  |     34 |      2 |[8KB, 8KB]    | 1MB      |         |     268 | 39.80
  8 |                   ->  Seq Scan on hr.staffs             | [0.035,0.043]    |    107 |     20 |[19KB, 19KB]  | 1MB      |         |     190 | 13.13
  9 |                   ->  Hash                              | [13.361,14.348]  |      2 |      4 |[292KB, 292KB]| 16MB     |[124,124]|     102 | 26.57
 10 |                      ->  Streaming(type: BROADCAST)     | [13.291,14.279]  |      2 |      4 |[85KB, 85KB]  | 1MB      |         |     102 | 26.57
 11 |                         ->  Hash Join (12,13)           | [6.359,7.446]    |      1 |      2 |[6KB, 6KB]    | 1MB      |         |     102 | 26.48
 12 |                            ->  Seq Scan on hr.places    | [0.008,0.018]    |     15 |     20 |[14KB, 14KB]  | 1MB      |         |     102 | 13.13
 13 |                            ->  Hash                     | [5.999,7.077]    |      1 |      1 |[259KB, 291KB]| 16MB     |[32,32]  |      24 | 13.28
 14 |                               ->  Streaming(type: REDISTRIBUTE) | [5.999,6.958]    |      1 |      1 |[84KB, 85KB]  | 1MB      |         |      24 | 13.28
 15 |                                  ->  Seq Scan on hr.sections | [0.021,0.022]    |      1 |      1 |[14KB, 14KB]  | 1MB      |         |      24 | 13.16


        Predicate Information (identified by plan id)
-------------------------------------------------------------
  3 --Hash Join (4,5)
       Hash Cond: (states.state_id = places.state_id)
  7 --Hash Join (8,9)
       Hash Cond: (staffs.section_id = sections.section_id)
 11 --Hash Join (12,13)
       Hash Cond: (places.place_id = sections.place_id)
 15 --Seq Scan on hr.sections
       Filter: ((sections.section_name)::text = 'Sales'::text)
       Rows Removed by Filter: 26
```

The optimized execution plan is as follows (two indexes have been created on the **places.place_id** and **states.state_id** columns):



```
 id |                        operation                        |      A-time      | A-rows | E-rows | Peak Memory  | E-memory | A-width | E-width | E-costs
----+---------------------------------------------------------+------------------+--------+--------+--------------+----------+---------+---------+---------
  1 | ->  Streaming (type: GATHER)                            | 50.411           |     34 |      2 | 212KB        |          |         |     354 | 46.84
  2 |    ->  Sort                                             | [20.889,22.621]  |     34 |      2 | [30KB, 36KB] | 16MB     |[380,380]|     354 | 46.49
  3 |       ->  Nested Loop (4,13)                            | [20.870,22.490]  |     34 |      2 | [5KB, 5KB]   | 1MB      |         |     354 | 46.48
  4 |          ->  Streaming(type: REDISTRIBUTE)              | [20.869,21.852]  |     34 |      2 | [85KB, 86KB] | 1MB      |         |     268 | 35.46
  5 |             ->  Nested Loop (6,7)                       | [13.433,14.452]  |     34 |      2 | [6KB, 6KB]   | 1MB      |         |     268 | 35.18
  6 |                ->  Seq Scan on hr.staffs                | [0.027,0.032]    |    107 |     20 | [19KB, 19KB] | 1MB      |         |     190 | 13.13
  7 |                ->  Materialize                          | [13.237,14.230]  |    109 |      4 | [10KB, 10KB] | 16MB     |[124,124]|     102 | 21.66
  8 |                   ->  Streaming(type: BROADCAST)        | [13.150,14.137]  |      2 |      4 | [85KB, 85KB] | 1MB      |         |     102 | 21.65
  9 |                      ->  Nested Loop (10,12)            | [5.784,6.822]    |      1 |      2 | [3KB, 3KB]   | 1MB      |         |     102 | 21.56
 10 |                         ->  Streaming(type: REDISTRIBUTE) | [5.782,6.675]    |      1 |      1 | [84KB, 85KB] | 1MB      |         |      24 | 13.28
 11 |                            ->  Seq Scan on hr.sections  | [0.019,0.020]    |      1 |      1 | [14KB, 14KB] | 1MB      |         |      24 | 13.16
 12 |                         ->  Index Scan using loc_id_pk on hr.places | [0.091,0.091]    |      1 |      2 | [24KB, 24KB] | 1MB      |         |     102 | 8.27
 13 |          ->  Index Scan using state_c_id_pk on hr.states | [0.352,0.352]    |     34 |      2 | [23KB, 23KB] | 1MB      |         |     110 | 5.50


        Predicate Information (identified by plan id)
-------------------------------------------------------------
  5 --Nested Loop (6,7)
       Join Filter: (sections.section_id = staffs.section_id)
       Rows Removed by Join Filter: 73
 11 --Seq Scan on hr.sections
       Filter: ((sections.section_name)::text = 'Sales'::text)
       Rows Removed by Filter: 26
 12 --Index Scan using loc_id_pk on hr.places
       Index Cond: (places.place_id = sections.place_id)
 13 --Index Scan using state_c_id_pk on hr.states
       Index Cond: (states.state_id = places.state_id)
```

# 11.4.3 Case: Adding NOT NULL for JOIN Columns

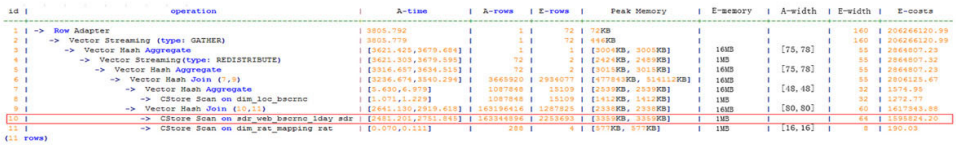
## Symptom

```
SELECT
 *
FROM
( ( SELECT
  STARTTIME STTIME,
  SUM(NVL(PAGE_DELAY_MSEL,0)) PAGE_DELAY_MSEL,
  SUM(NVL(PAGE_SUCCEED_TIMES,0)) PAGE_SUCCEED_TIMES,
  SUM(NVL(FST_PAGE_REQ_NUM,0)) FST_PAGE_REQ_NUM,
  SUM(NVL(PAGE_AVG_SIZE,0)) PAGE_AVG_SIZE,
  SUM(NVL(FST_PAGE_ACK_NUM,0)) FST_PAGE_ACK_NUM,
  SUM(NVL(DATATRANS_DW_DURATION,0)) DATATRANS_DW_DURATION,
  SUM(NVL(PAGE_SR_DELAY_MSEL,0)) PAGE_SR_DELAY_MSEL
 FROM
  PS.SDR_WEB_BSCRNC_1DAY SDR
  INNER JOIN (SELECT
      BSCRNC_ID,
      BSCRNC_NAME,
      ACCESS_TYPE,
      ACCESS_TYPE_ID
     FROM
      nethouse.DIM_LOC_BSCRNC
     GROUP BY
      BSCRNC_ID,
      BSCRNC_NAME,
      ACCESS_TYPE,
      ACCESS_TYPE_ID) DIM
  ON SDR.BSCRNC_ID = DIM.BSCRNC_ID
```

```
 AND DIM.ACCESS_TYPE_ID IN (0,1,2)
 INNER JOIN nethouse.DIM_RAT_MAPPING RAT
 ON (RAT.RAT = SDR.RAT)
WHERE
 ( (STARTTIME >= 1461340800
 AND STARTTIME < 1461427200) )
 AND RAT.ACCESS_TYPE_ID IN (0,1,2)
 --and SDR.BSCRNC_ID is not null
GROUP BY
 STTIME ) ) ;
```

**Figure 11-12** shows the execution plan.

**Figure 11-12** Adding NOT NULL for JOIN columns (1)




## Optimization Analysis

1. As shown in **Figure 11-12**, the sequential scan phase is time consuming.
2. The JOIN performance is poor because a large number of null values exist in the JOIN column **BSCRNC_ID** of the PS.SDR_WEB_BSCRNC_1DAY table.

   Therefore, you are advised to manually add **NOT NULL** for **JOIN** columns in the statement, as shown below:

```
SELECT
 *
FROM
( ( SELECT
  STARTTIME STTIME,
  SUM(NVL(PAGE_DELAY_MSEL,0)) PAGE_DELAY_MSEL,
  SUM(NVL(PAGE_SUCCEED_TIMES,0)) PAGE_SUCCEED_TIMES,
  SUM(NVL(FST_PAGE_REQ_NUM,0)) FST_PAGE_REQ_NUM,
  SUM(NVL(PAGE_AVG_SIZE,0)) PAGE_AVG_SIZE,
  SUM(NVL(FST_PAGE_ACK_NUM,0)) FST_PAGE_ACK_NUM,
  SUM(NVL(DATATRANS_DW_DURATION,0)) DATATRANS_DW_DURATION,
  SUM(NVL(PAGE_SR_DELAY_MSEL,0)) PAGE_SR_DELAY_MSEL
 FROM
  PS.SDR_WEB_BSCRNC_1DAY SDR
  INNER JOIN (SELECT
      BSCRNC_ID,
      BSCRNC_NAME,
      ACCESS_TYPE,
      ACCESS_TYPE_ID
     FROM
      nethouse.DIM_LOC_BSCRNC
     GROUP BY
      BSCRNC_ID,
      BSCRNC_NAME,
      ACCESS_TYPE,
      ACCESS_TYPE_ID) DIM
  ON SDR.BSCRNC_ID = DIM.BSCRNC_ID
  AND DIM.ACCESS_TYPE_ID IN (0,1,2)
  INNER JOIN nethouse.DIM_RAT_MAPPING RAT
  ON (RAT.RAT = SDR.RAT)
 WHERE
  ( (STARTTIME >= 1461340800
  AND STARTTIME < 1461427200) )
  AND RAT.ACCESS_TYPE_ID IN (0,1,2)
  and SDR.BSCRNC_ID is not null
 GROUP BY
  STTIME ) ) A;
```

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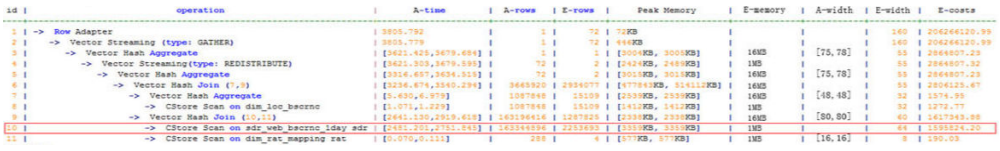
**Figure 11-13** shows the execution plan.

**Figure 11-13** Adding NOT NULL for JOIN columns (2)



## 11.4.4 Case: Pushing Down Sort Operations to DNs

### Symptom

In an execution plan, more than 95% of the execution time is spent on **window agg** performed on the CN. In this case, **sum** is performed for the two columns separately, and then another **sum** is performed for the separate sum results of the two columns. After this, trunc and sorting are performed in sequence.

The table structure is as follows:

```
CREATE TABLE public.test(imsi int,L4_DW_THROUGHPUT int,L4_UL_THROUGHPUT int)
with (orientation = column) DISTRIBUTE BY hash(imsi);
```

The query statements are as follows:

```
SELECT COUNT(1) over() AS DATACNT,
IMSI AS IMSI_IMSI,
CAST(TRUNC(((SUM(L4_UL_THROUGHPUT) + SUM(L4_DW_THROUGHPUT))), 0) AS
DECIMAL(20)) AS TOTAL_VOLOME_KPIID
FROM public.test AS test
GROUP BY IMSI
order by TOTAL_VOLOME_KPIID DESC;
```

The execution plan is as follows:

```
Row Adapter  (cost=10.70..10.70 rows=10 width=12)
  ->  Vector Sort  (cost=10.68..10.70 rows=10 width=12)
       Sort Key: ((trunc((((sum(l4_ul_throughput)) + (sum(l4_dw_throughput))))::numeric,
0))::numeric(20,0))
       ->  Vector WindowAgg  (cost=10.09..10.51 rows=10 width=12)
            ->  Vector Streaming (type: GATHER)  (cost=242.04..246.84 rows=240 width=12)
                 Node/s: All datanodes
                 ->  Vector Hash Aggregate  (cost=10.09..10.29 rows=10 width=12)
                      Group By Key: imsi
                      ->  CStore Scan on test  (cost=0.00..10.01 rows=10 width=12)
```

As we can see, both **window agg** and **sort** are performed on the CN, which is time consuming.

### Optimization Analysis

Modify the statement to a subquery statement, as shown below:

```
SELECT COUNT(1) over() AS DATACNT, IMSI_IMSI, TOTAL_VOLOME_KPIID
FROM (SELECT IMSI AS IMSI_IMSI,
CAST(TRUNC(((SUM(L4_UL_THROUGHPUT) + SUM(L4_DW_THROUGHPUT))),
0) AS DECIMAL(20)) AS TOTAL_VOLOME_KPIID
FROM public.test AS test
GROUP BY IMSI
ORDER BY TOTAL_VOLOME_KPIID DESC);
```

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Perform **sum** on the **trunc** results of the two columns, take it as a subquery, and then perform **window agg** for the subquery to push down the sorting operation to DNs, as shown below:

```
Row Adapter  (cost=10.70..10.70 rows=10 width=24)
  ->  Vector WindowAgg  (cost=10.45..10.70 rows=10 width=24)
        ->  Vector Streaming (type: GATHER)  (cost=250.83..253.83 rows=240 width=24)
              Node/s: All datanodes
              ->  Vector Sort  (cost=10.45..10.48 rows=10 width=12)
                    Sort Key: ((trunc(((sum(test.l4_ul_throughput) + sum(test.l4_dw_throughput)))::numeric,
0))::numeric(20,0))
                    ->  Vector Hash Aggregate  (cost=10.09..10.29 rows=10 width=12)
                          Group By Key: test.imsi
                          ->  CStore Scan on test  (cost=0.00..10.01 rows=10 width=12)
```

The optimized SQL statement greatly improves the performance by reducing the execution time from 120s to 7s.

# 11.4.5 Case: Configuring cost_param for Better Query Performance

## Symptom

If **bit0** of **cost_param** is set to **1**, an improved mechanism is used for estimating the selection rate of non-equi-joins. This method is more accurate for estimating the selection rate of joins between two identical tables. The following example describes the optimization scenario when **bit0** of **cost_param** is set to **1**. In V300R002C00 and later, **cost_param & 1=0** is not used. That is, an optimized formula is selected for calculation.

**Note**: The selection rate indicates the percentage for which the number of rows meeting the join conditions account of the **JOIN** results when the **JOIN** relationship is established between two tables.

The table structure is as follows:

```
CREATE TABLE LINEITEM
(
L_ORDERKEY BIGINT NOT NULL
, L_PARTKEY BIGINT NOT NULL
, L_SUPPKEY BIGINT NOT NULL
, L_LINENUMBER BIGINT NOT NULL
, L_QUANTITY DECIMAL(15,2) NOT NULL
, L_EXTENDEDPRICE DECIMAL(15,2) NOT NULL
, L_DISCOUNT DECIMAL(15,2) NOT NULL
, L_TAX DECIMAL(15,2) NOT NULL
, L_RETURNFLAG CHAR(1) NOT NULL
, L_LINESTATUS CHAR(1) NOT NULL
, L_SHIPDATE DATE NOT NULL
, L_COMMITDATE DATE NOT NULL
, L_RECEIPTDATE DATE NOT NULL
, L_SHIPINSTRUCT CHAR(25) NOT NULL
, L_SHIPMODE CHAR(10) NOT NULL
, L_COMMENT VARCHAR(44) NOT NULL
) with (orientation = column, COMPRESSION = MIDDLE) distribute by hash(L_ORDERKEY);

CREATE TABLE ORDERS
(
O_ORDERKEY BIGINT NOT NULL
, O_CUSTKEY BIGINT NOT NULL
, O_ORDERSTATUS CHAR(1) NOT NULL
, O_TOTALPRICE DECIMAL(15,2) NOT NULL
, O_ORDERDATE DATE NOT NULL
```

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```
, O_ORDERPRIORITY CHAR(15) NOT NULL
, O_CLERK CHAR(15) NOT NULL
, O_SHIPPRIORITY BIGINT NOT NULL
, O_COMMENT VARCHAR(79) NOT NULL
)with (orientation = column, COMPRESSION = MIDDLE) distribute by hash(O_ORDERKEY);
```

The query statements are as follows:

```
explain verbose select
count(*) as numwait
from
lineitem l1,
orders
where
o_orderkey = l1.l_orderkey
and o_orderstatus = 'F'
and l1.l_receiptdate > l1.l_commitdate
and not exists (
select
*
from
lineitem l3
where
l3.l_orderkey = l1.l_orderkey
and l3.l_suppkey <> l1.l_suppkey
and l3.l_receiptdate > l3.l_commitdate
)
order by
numwait desc;
```

The following figure shows the execution plan. (When **verbose** is used, **distinct** is added for column selection which is controlled by **cost off/on**. The hash join rows show the estimated number of distinct values and the other rows do not.)

```
 id |                       operation                       | E-rows | E-distinct | E-width | E-costs
----+-------------------------------------------------------+--------+------------+---------+---------
  1 | ->  Row Adapter                                       |      1 |            |       8 | 39.36
  2 |    ->  Vector Sort                                    |      1 |            |       8 | 39.36
  3 |       ->  Vector Aggregate                            |      1 |            |       8 | 39.34
  4 |          ->  Vector Streaming (type: GATHER)          |      2 |            |       8 | 39.34
  5 |             ->  Vector Aggregate                      |      2 |            |       8 | 39.25
  6 |                ->  Vector Hash Anti Join (7, 10)      |      2 | 4, 5       |       0 | 39.24
  7 |                   ->  Vector Hash Join (8,9)          |      2 | 200, 1     |      16 | 26.12
  8 |                      ->  CStore Scan on public.lineitem l1 |      7 |            |      16 | 13.05
  9 |                      ->  CStore Scan on public.orders |      1 |            |       8 | 13.05
 10 |                   ->  CStore Scan on public.lineitem l3 |      7 |            |      16 | 13.05
```

## Optimization Analysis 1

These queries are from Anti Join connected in the lineitem table. When **cost_param & bit0** is **1**, the estimated number of Anti Join rows greatly differ from that of the actual number of rows so that the query performance deteriorates. You can estimate the number of Anti Join rows more accurately by setting **cost_param & bit0** to **1** to improve the query performance. The optimized execution plan is as follows:

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| id | operation | E-rows | E-memory | E-width | E-costs |
|---|---|---|---|---|---|
| 1 | -> Row Adapter | 1 | | 0 | 9104892.37 9 |
| 2 | -> Vector Sort | 1 | | 0 | 9104892.37 9 |
| 3 | -> Vector Aggregate | 1 | | 0 | 9104892.35 8 |
| 4 | -> Vector Streaming (type: GATHER) | 48 | | 0 | 9104892.35 8 |
| 5 | -> Vector Aggregate | 48 | 1MB | 0 | 9104890.82 5 |
| 6 | -> Vector Hash Join (7.12) | 2526630903 | 929MB | 0 | 8973295.45 4 |
| 7 | -> Vector Hash Anti Join (8. 10) | 1999996587 | 3178MB | 8 | 7198231.14 |
| 8 | -> Vector Partition Iterator | 1999996587 | 1MB | 16 | 3000158.25 |
| 9 | -> Partitioned CStore Scan on public.lineitem 11 | 1999996587 | 1MB | 16 | 3000158.25 1 |
| 10 | -> Vector Partition Iterator | 1999996587 | 1MB | 16 | 3000158.25 |
| 11 | -> Partitioned CStore Scan on public.lineitem 13 | 1999996587 | 1MB | 16 | 3000158.25 |
| 12 | -> Vector Partition Iterator | 730839014 | 1MB | 8 | 589611.00 |
| 13 | -> Partitioned CStore Scan on public.orders | 730839014 | 1MB | 8 | 589611.00 |

## Symptom 2

If **bit1** is set to **1** (**set cost_param=2**), the selection rate is estimated based on multiple filter criteria. The lowest selection rate among all filter criteria, but not the product of the selection rates for two tables under a specific filter criterion, is used as the total selection rate. This method is more accurate when a close correlation exists between the columns to be filtered. The following example describes the optimization scenario when **cost_param & bit1** is **1**.

The table structure is as follows:

```
CREATE TABLE NATION
(
N_NATIONKEYINT NOT NULL
, N_NAMECHAR(25) NOT NULL
, N_REGIONKEYINT NOT NULL
, N_COMMENTVARCHAR(152)
) distribute by replication;
CREATE TABLE SUPPLIER
(
S_SUPPKEYBIGINT NOT NULL
, S_NAMECHAR(25) NOT NULL
, S_ADDRESSVARCHAR(40) NOT NULL
, S_NATIONKEYINT NOT NULL
, S_PHONECHAR(15) NOT NULL
, S_ACCTBALDECIMAL(15,2) NOT NULL
, S_COMMENTVARCHAR(101) NOT NULL
) distribute by hash(S_SUPPKEY);
CREATE TABLE PARTSUPP
(
PS_PARTKEYBIGINT NOT NULL
, PS_SUPPKEYBIGINT NOT NULL
, PS_AVAILQTYBIGINT NOT NULL
, PS_SUPPLYCOSTDECIMAL(15,2)NOT NULL
, PS_COMMENTVARCHAR(199) NOT NULL
)distribute by hash(PS_PARTKEY);
```

The query statements are as follows:

```
set cost_param=2;
explain verbose select
nation,
sum(amount) as sum_profit
from
(
select
n_name as nation,
l_extendedprice * (1 - l_discount) - ps_supplycost * l_quantity as amount
from
supplier,
lineitem,
```

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```
partsupp,
nation
where
s_suppkey = l_suppkey
and ps_suppkey = l_suppkey
and ps_partkey = l_partkey
and s_nationkey = n_nationkey
) as profit
group by nation
order by nation;
```

When **bit1** of **cost_param** is **0**, the execution plan is shown as follows:

```
 id |                           operation                           | E-rows | E-distinct | E-width | E-costs
----+---------------------------------------------------------------+--------+------------+---------+---------
  1 | ->  Sort                                                      |      1 |            |     208 | 61.52
  2 |    ->  HashAggregate                                          |      1 |            |     208 | 61.51
  3 |       ->  Streaming (type: GATHER)                            |      2 |            |     208 | 61.51
  4 |          ->  HashAggregate                                    |      2 |            |     208 | 61.36
  5 |             ->  Hash Join (6,7)                               |      2 | 20, 15     |     176 | 61.33
  6 |                ->  Seq Scan on public.nation                  |     40 |            |     108 | 20.20
  7 |                ->  Hash                                       |      2 |            |      76 | 41.04
  8 |                   ->  Hash Join (9,16)                        |      2 | 10, 13     |      76 | 41.04
  9 |                      ->  Streaming(type: REDISTRIBUTE)        |      2 |            |      88 | 27.73
 10 |                         ->  Hash Join (11,14)                 |      2 | 10, 13     |      88 | 27.62
 11 |                            ->  Streaming(type: REDISTRIBUTE)  |     20 |            |      70 | 14.19
 12 |                               ->  Row Adapter                 |     21 |            |      70 | 13.01
 13 |                                  ->  CStore Scan on public.lineitem |     20 |            |      70 | 13.01
 14 |                            ->  Hash                           |     21 |            |      34 | 13.13
 15 |                               ->  Seq Scan on public.partsupp |     20 |            |      34 | 13.13
 16 |                      ->  Hash                                 |     21 |            |      12 | 13.13
 17 |                         ->  Seq Scan on public.supplier       |     20 |            |      12 | 13.13
```

## Optimization Analysis 2

In the preceding queries, the hash join criteria of the supplier, lineitem, and partsupp tables are setting **lineitem.l_suppkey** to **supplier.s_suppkey** and **lineitem.l_partkey** to **partsupp.ps_partkey**. Two filter criteria exist in the hash join conditions. **lineitem.l_suppkey** in the first filter criteria and **lineitem.l_partkey** in the second filter criteria are two columns with strong relationship of the lineitem table. In this situation, when you estimate the rate of the hash join conditions, if **cost_param & bit1** is **0**, the selection rate is estimated based on multiple filter criteria. The lowest selection rate among all filter criteria, but not the product of the selection rates for two tables under a specific filter criterion, is used as the total selection rate. This method is more accurate when a close correlation exists between the columns to be filtered. The plan after optimization is shown as follows:

```
 id |                           operation                           | E-rows | E-distinct | E-width | E-costs
----+---------------------------------------------------------------+--------+------------+---------+---------
  1 | ->  Sort                                                      |     10 |            |     208 | 64.42
  2 |    ->  HashAggregate                                          |     10 |            |     208 | 64.23
  3 |       ->  Streaming (type: GATHER)                            |     20 |            |     208 | 64.23
  4 |          ->  HashAggregate                                    |     20 |            |     208 | 62.71
  5 |             ->  Hash Join (6,7)                               |     20 | 20, 10     |     176 | 62.46
  6 |                ->  Seq Scan on public.nation                  |     40 |            |     108 | 20.20
  7 |                ->  Hash                                       |     20 |            |      76 | 41.97
  8 |                   ->  Hash Join (9,16)                        |     20 | 10, 13     |      76 | 41.97
  9 |                      ->  Streaming(type: REDISTRIBUTE)        |     20 |            |      82 | 28.54
 10 |                         ->  Hash Join (11,14)                 |     20 | 10, 13     |      82 | 27.63
 11 |                            ->  Streaming(type: REDISTRIBUTE)  |     20 |            |      70 | 14.19
 12 |                               ->  Row Adapter                 |     21 |            |      70 | 13.01
 13 |                                  ->  CStore Scan on public.lineitem |     20 |            |      70 | 13.01
 14 |                            ->  Hash                           |     21 |            |      12 | 13.13
 15 |                               ->  Seq Scan on public.supplier |     20 |            |      12 | 13.13
 16 |                      ->  Hash                                 |     21 |            |      34 | 13.13
 17 |                         ->  Seq Scan on public.partsupp       |     20 |            |      34 | 13.13
```

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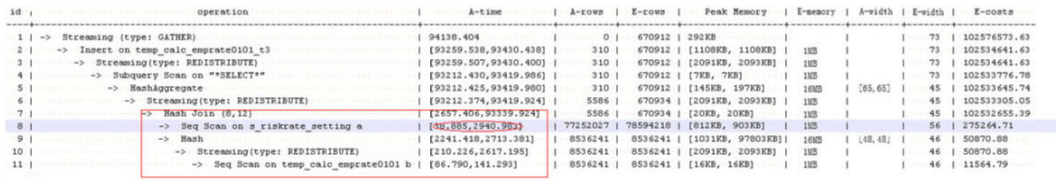
# 11.4.6 Case: Adjusting the Distribution Key

## Symptom

During a site test, the information is displayed after **EXPLAIN ANALYZE** is executed:



| id | operation | A-time | A-rows | E-rows | Peak Memory | E-memory | A-width | E-width | E-costs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -> Streaming (type: GATHER) | 94138.404 | 0 | 670912 | 292KB | | | 73 | 102576573.63 |
| 2 | -> Insert on temp_calc_emprate0101_t3 | [93259.538,93430.438] | 310 | 670912 | [1108KB, 1108KB] | 1MB | | 73 | 102534641.63 |
| 3 | -> Streaming(type: REDISTRIBUTE) | [93259.507,93430.400] | 310 | 670912 | [2091KB, 2093KB] | 1MB | | 73 | 102534641.63 |
| 4 | -> Subquery Scan on "*SELECT*" | [93212.430,93419.986] | 310 | 670912 | [7KB, 7KB] | 1MB | | 73 | 102533776.78 |
| 5 | -> HashAggregate | [93212.425,93419.980] | 310 | 670912 | [145KB, 197KB] | 16MB | [65,65] | 45 | 102533645.74 |
| 6 | -> Streaming(type: REDISTRIBUTE) | [93212.374,93419.924] | 5586 | 670934 | [2091KB, 2093KB] | 1MB | | 45 | 102533305.05 |
| 7 | -> Hash Join (8,12) | [2657.406,93339.924] | 5586 | 670934 | [20KB, 20KB] | 1MB | | 45 | 102532655.39 |
| 8 | -> Seq Scan on s_riskrate_setting a | [38.885,2940.983] | 77252027 | 78594218 | [812KB, 903KB] | 1MB | | 56 | 275264.71 |
| 9 | -> Hash | [2241.418,2713.381] | 8536241 | 8536241 | [1031KB, 97803KB] | 16MB | [48,48] | 46 | 50870.88 |
| 10 | -> Streaming(type: REDISTRIBUTE) | [210.226,2617.195] | 8536241 | 8536241 | [2091KB, 2093KB] | 1MB | | 46 | 50870.88 |
| 11 | -> Seq Scan on temp_calc_emprate0101 b | [86.790,141.293] | 8536241 | 8536241 | [16KB, 16KB] | 1MB | | 46 | 11564.79 |

According to the execution information, HashJoin becomes the performance bottleneck of the whole plan. Based on the execution time of HashJoin **[2657.406, 93339.924]**, it can be seen that severe skew occurs on different DNs during the HashJoin operation.

In the memory information (as shown in the following figure), it can be seen that the data skew occurs in the memory usage of each node.

```
                Memory Information (identified by plan id)
--------------------------------------------------------------------------------
Coordinator:
  Query Peak Memory: 4MB
Datanode:
  Max Query Peak Memory: 118MB
  Min Query Peak Memory: 24MB
12 --Hash
        Max Buckets: 131072  Max Batches: 1  Max Memory Usage: 91857kB
        Min Buckets: 131072  Min Batches: 1  Min Memory Usage: 0kB
```

## Optimization Analysis

The preceding two symptoms indicate that this SQL statement has serious computing skew. The further lower-layer analysis on the HashJoin operator shows that serious computing skew **[38.885,2940.983]** occurs in **Seq Scan on s_riskrate_setting**. Based on the description of the Scan, we can infer that the performance problems of this plan lie in data skew occurred in the **s_riskrate_setting** table. Later, it is proved that serious data skew occurred in the **s_riskrate_setting** table. After performance optimization, the execution time is reduced from 94s to 50s.

# 11.4.7 Case: Adjusting the Partial Clustering Key

## Symptom

Information on the EXPLAIN PERFORMANCE at a site is as follows: As shown in the red boxes, two performance bottlenecks are scan operations in a table.

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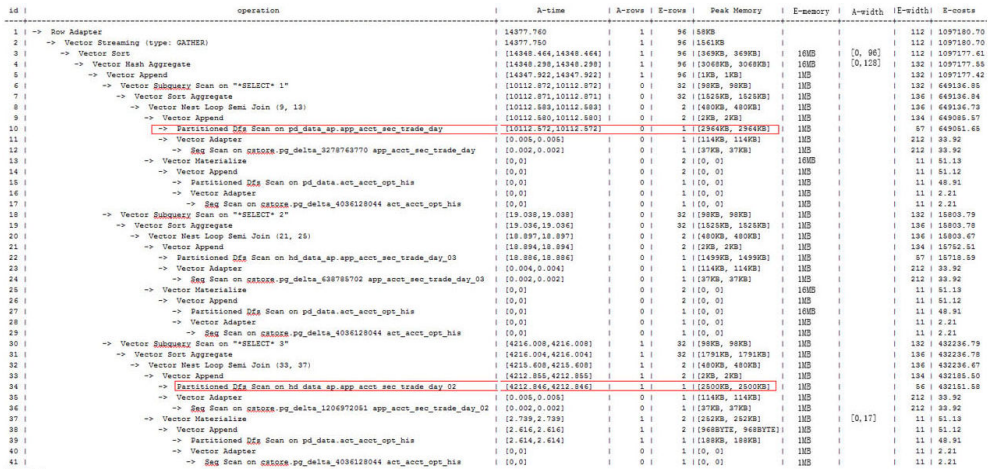
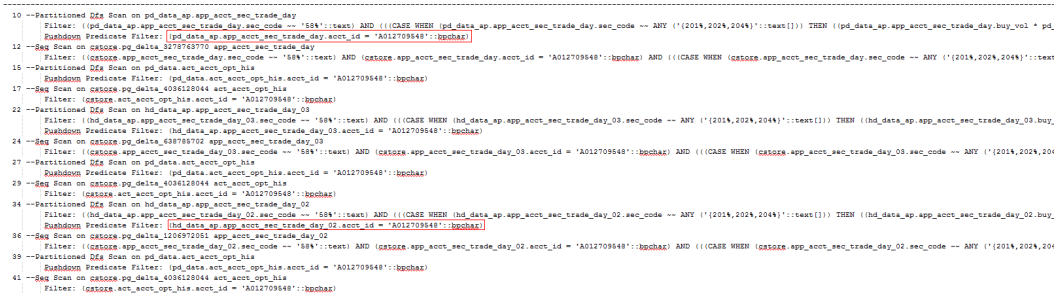


## Optimization Analysis

After further analysis, we found that the filter condition acct_id ='A012709548':: bpchar exists in the two tables.



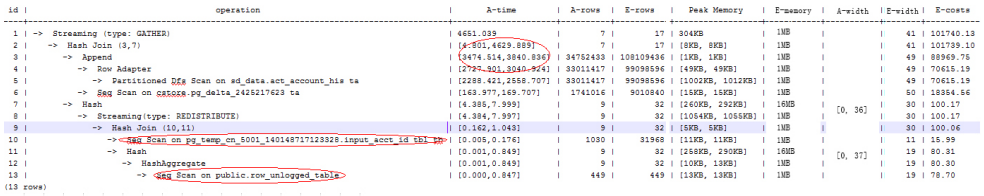
Try to add the partial clustering key in the acct_id column of the two tables, and run the **VACUUM FULL** statement to make the local clustering take effect. The table performance is improved.

# 11.4.8 Case: Adjusting the Table Storage Mode in a Medium Table

## Symptom

In the GaussDB(DWS) database, row-store tables use the row execution engine, and column-store tables use the column execution engine. If both row-store table and column-store tables exist in a SQL statement, the system will automatically select the row execution engine. The performance of a column execution engine (except for the indexscan related operators) is much better than that of a row execution engine. Therefore, a column-store table is recommended. This is important for some medium result set dumping tables, and you need to select a proper table storage type.

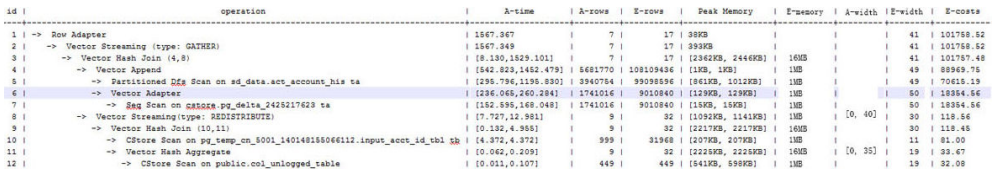
During the test at a site, if the following execution plan is performed, the customer expects that the performance can be improved and the result can be returned within 3s.



## Optimization Analysis

It is found that the row engine is used after analysis, because both the temporary plan table input_acct_id_tbl and the medium result dumping table row_unlogged_table use a row-store table.

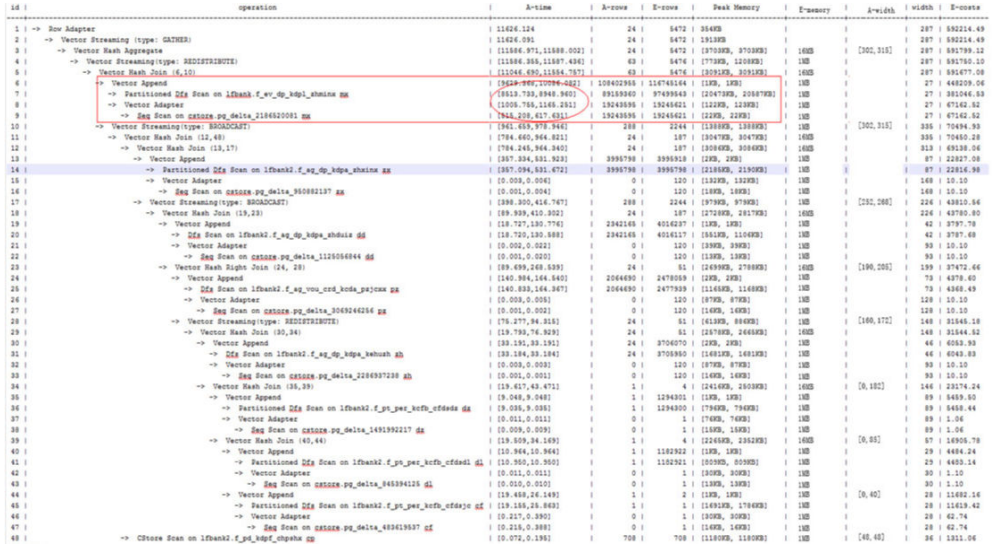
After the two tables are changed into column-store tables, the system performance is improved and the result is returned by 1.6s.



# 11.4.9 Case: Adjusting the Local Clustering Column

## Symptom

During the test at a site, if the following execution plan is performed, the customer expects that the performance can be improved and the result can be returned within 3s.



## Optimization Analysis

The analysis shows that the performance bottleneck of this plan is lfbank.f_ev_dp_kdpl_zhminx. The scan condition of this table is as follows:

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```
                                Predicate Information (identified by plan id)
--------------------------------------------------------------------------------------------------------------------------------
  5 --Vector Hash Join (6,10)
      Hash Cond: (((mx.zhanghao)::text = (dd.zhanghao)::text) AND ((mx.farendma)::text = (cf.farendma)::text))
  7 --Partitioned Dfs Scan on lfbank.f_ev_dp_kdpl_zhminx mx
      Pushdown Predicate Filter: ((mx.yezdminc)::text = 'DPLDGBAL'::text)
  9 --Seq Scan on cstore.pg_delta_21865ZUU81 mx
      Filter: ((mx.yezdminc)::text = 'DPLDGBAL'::text)
      Rows Removed by Filter: 489
```

Try to modify the lfbank. f_ev_dp_kdpl_zhmin table to a column-store table, and then create the PCK (local clustering) in the **yezdminc** column, and set **PARTIAL_CLUSTER_ROWS** to **100000000**. The execution plan after optimization is as follows:

```
 id |                                                operation                                                 |          A-time          | A-rows |  E-rows  |  Peak Memory   | E-memory | A-width | E-width | E-costs
----+----------------------------------------------------------------------------------------------------------+--------------------------+--------+----------+----------------+----------+---------+---------+----------
  1 | ->  Row Adapter                                                                                          | 2633.864                 |     24 |     5496 | 384KB          |          |         |     287 | 746338.94
  2 |   ->  Vector Streaming (type: GATHER)                                                                    | 2633.847                 |     24 |     5496 | 191KB          |          |         |     287 | 746338.94
  3 |     ->  Vector Hash Aggregate                                                                            | [2597.766,2599.012]      |     24 |     5496 | [3703KB, 3703KB] | 16MB     | [302,315] |     287 | 744921.75
  4 |       ->  Vector Streaming(type: REDISTRIBUTE)                                                           | [2597.346,2599.631]      |     63 |     5491 | [779KB, 1208KB]  | 1MB      |         |     287 | 744872.52
  5 |         ->  Vector Hash Join (6,7)                                                                       | [2317.652,2579.831]      |     63 |     5491 | [3003KB, 3003KB] | 16MB     |         |     287 | 744799.18
  6 |           ->  CStore Scan on lfbank.f_ev_dp_kdpl_zhminx_column mx                                         | [1164.465,1345.652]      | 116702564 | 117058649 | [1681KB, 1802KB] | 1MB      |         |      28 | 590396.39
  7 |           ->  Vector Streaming(type: BROADCAST)                                                          | [715.439,725.474]        |    288 |     2244 | [1388KB, 1388KB] | 1MB      | [419,425] |     337 | 81233.75
  8 |             ->  Vector Hash Join (9,42)                                                                  | [610.787,723.121]        |     24 |      187 | [3047KB, 3047KB] | 16MB     |         |     337 | 81189.11
  9 |               ->  Vector Hash Join (10,11)                                                               | [610.191,722.463]        |     24 |      187 | [2997KB, 2997KB] | 16MB     |         |     315 | 79876.88
 10 |                 ->  CStore Scan on lfbank.f_sg_dp_kdpa_zhxinx zx                                         | [146.165,248.865]        | 3995798 | 3995798 | [3800KB, 3915KB] | 1MB      |         |      89 | 33565.98
 11 |                 ->  Vector Streaming(type: BROADCAST)                                                    | [443.942,448.609]        |    288 |     2244 | [979KB, 979KB]   | 1MB      | [282,288] |     226 | 43810.56
 12 |                   ->  Vector Hash Join (13,17)                                                           | [90.644,440.831]         |     24 |      187 | [2726KB, 2817KB] | 16MB     |         |     226 | 43780.80
 13 |                     ->  Vector Append                                                                    | [20.159,146.517]         | 2342165 | 4016237 | [1KB, 1KB]       | 1MB      |         |      42 | 3797.78
 14 |                       ->  Dfs Scan on lfbank2.f_sg_dp_kdpa_shduix dd                                     | [20.151,146.359]         | 2342165 | 4016117 | [551KB, 1104KB]  | 1MB      |         |      42 | 3787.68
 15 |                       ->  Vector Adapter                                                                 | [0.002,0.006]            |      0 |      120 | [39KB, 39KB]     | 1MB      |         |      93 | 10.10
 16 |                         ->  Seq Scan on cstore.pg_delta_1125056844 dd                                    | [0.001,0.002]            |      0 |      120 | [13KB, 13KB]     | 1MB      |         |      93 | 10.10
 17 |                     ->  Vector Hash Right Join (18, 22)                                                  | [90.411,291.664]         |     24 |       51 | [2699KB, 2788KB] | 16MB     | [190,206] |     199 | 37472.66
 18 |                       ->  Vector Append                                                                  | [148.194,187.048]        | 2064690 | 2478099 | [2KB, 2KB]       | 1MB      |         |      73 | 4378.60
 19 |                         ->  Dfs Scan on lfbank2.f_sg_vou_crd_kcda_pzjcnx pz                              | [148.049,186.900]        | 2064690 | 2477939 | [1165KB, 1165KB] | 1MB      |         |      73 | 4368.49
 20 |                         ->  Vector Adapter                                                               | [0.003,0.018]            |      0 |      120 | [87KB, 87KB]     | 1MB      |         |     128 | 10.10
 21 |                           ->  Seq Scan on cstore.pg_delta_3069246256 pz                                  | [0.001,0.003]            |      0 |      120 | [16KB, 16KB]     | 1MB      |         |     128 | 10.10
 22 |                       ->  Vector Streaming(type: REDISTRIBUTE)                                           | [90.084,94.358]          |     24 |       51 | [413KB, 886KB]   | 1MB      | [160,172] |     148 | 31548.18
 23 |                         ->  Vector Hash Join (24,28)                                                     | [19.829,80.468]          |     24 |       51 | [2578KB, 2665KB] | 16MB     |         |     148 | 31544.52
 24 |                           ->  Vector Append                                                              | [35.109,35.109]          |     24 |     3706070 | [2KB, 2KB]   | 1MB      |         |      66 | 6063.93
 25 |                             ->  Dfs Scan on lfbank2.f_sg_dp_kdpa_kehuzh zh                               | [35.102,35.102]          |     24 |     3705950 | [1681KB, 1681KB] | 1MB      |         |      66 | 6043.83
 26 |                             ->  Vector Adapter                                                           | [0.003,0.003]            |      0 |      120 | [87KB, 87KB]     | 1MB      |         |      93 | 10.10
 27 |                               ->  Seq Scan on cstore.pg_delta_2286937238 zh                              | [0.002,0.002]            |      0 |      120 | [16KB, 16KB]     | 1MB      |         |      93 | 10.10
 28 |                           ->  Vector Hash Join (29,33)                                                   | [19.974,45.091]          |      1 |        4 | [2414KB, 2503KB] | 16MB     | [0,182] |     146 | 23174.24
 29 |                             ->  Vector Append                                                            | [8.778,8.778]            |      1 |  1294301 | [1KB, 1KB]       | 1MB      |         |      89 | 5459.60
 30 |                               ->  Partitioned Dfs Scan on lfbank2.f_ps_per_kcfb_cfdsda ds                | [8.769,8.769]            |      1 |  1294300 | [796KB, 796KB]   | 1MB      |         |      89 | 5458.44
 31 |                               ->  Vector Adapter                                                         | [0.009,0.009]            |      0 |        1 | [76KB, 76KB]     | 1MB      |         |      89 | 1.06
 32 |                                 ->  Seq Scan on cstore.pg_delta_1491992217 ds                            | [0.008,0.008]            |      0 |        1 | [16KB, 16KB]     | 1MB      |         |      89 | 1.06
 33 |                             ->  Vector Hash Join (34,38)                                                 | [19.310,36.096]          |      1 |        4 | [2265KB, 2362KB] | 16MB     | [0,85]  |      57 | 16905.78
 34 |                               ->  Vector Append                                                          | [11.000,11.000]          |      1 |  1182922 | [1KB, 1KB]       | 1MB      |         |      29 | 4484.24
 35 |                                 ->  Partitioned Dfs Scan on lfbank2.f_ps_per_kcfb_cfdsdl dl              | [10.988,10.988]          |      1 |  1182921 | [859KB, 859KB]   | 1MB      |         |      29 | 4483.14
 36 |                                 ->  Vector Adapter                                                       | [0.009,0.009]            |      0 |        1 | [30KB, 30KB]     | 1MB      |         |      30 | 1.10
 37 |                                   ->  Seq Scan on cstore.pg_delta_846394126 dl                           | [0.008,0.008]            |      0 |        1 | [13KB, 13KB]     | 1MB      |         |      30 | 1.10
 38 |                               ->  Vector Append                                                          | [19.286,28.756]          |      1 |        2 | [1KB, 1KB]       | 1MB      | [0,40]  |      28 | 11682.16
 39 |                                 ->  Partitioned Dfs Scan on lfbank2.f_ps_per_kcfb_cfdsjc cf              | [19.003,28.284]          |      1 |        1 | [1691KB, 1786KB] | 1MB      |         |      28 | 11619.42
 40 |                                 ->  Vector Adapter                                                       | [0.250,0.539]            |      0 |        1 | [30KB, 30KB]     | 1MB      |         |      28 | 62.74
 41 |                                   ->  Seq Scan on cstore.pg_delta_483619537 cf                           | [0.247,0.536]            |      0 |        1 | [16KB, 16KB]     | 1MB      |         |      28 | 62.74
 42 |                   ->  CStore Scan on lfbank2.f_pd_kdpf_chpshx cp                                         | [0.135,0.338]            |    708 |      708 | [1180KB, 1180KB] | 1MB      | [48,48] |      36 | 1311.06
```

**NOTE**

- This method actually sacrifices the performance during data import to improve the query performance.
- The number of local sorting tuples is increased, and you need to increase the value of **psort_work_mem** to improve the sorting efficiency.

# 11.4.10 Case: Reconstructing Partition Tables

## Symptom

In the following simple SQL statements, the performance bottlenecks exist in the scan operation of dwcjk.

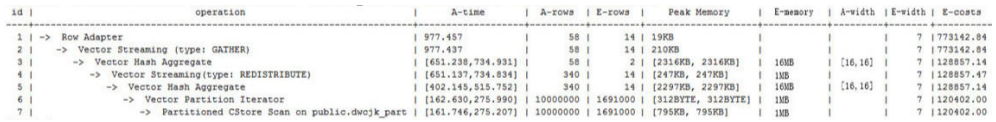
```
postgres=# explain performance select zqdh, count(1) from dwcjk where cjrq = '2015-05-02 00:00:00' group by zqdh;
```

```
 id |                  operation                  |        A-time        | A-rows | E-rows |  Peak Memory   | E-memory | A-width | E-width | E-costs
----+---------------------------------------------+----------------------+--------+--------+----------------+----------+---------+---------+----------
  1 | ->  Row Adapter                             | 1599.794             |     58 |     12 | 19KB           |          |         |       7 | 771106.83
  2 |   ->  Vector Streaming (type: GATHER)       | 1599.781             |     58 |     12 | 210KB          |          |         |       7 | 771106.83
  3 |     ->  Vector Hash Aggregate               | [1445.092,1446.332]  |     58 |      2 | [2315KB, 2315KB] | 16MB     | [16,16] |       7 | 128517.80
  4 |       ->  Vector Streaming(type: REDISTRIBUTE) | [1444.996,1446.259] |    340 |     12 | [247KB, 247KB] | 1MB      |         |       7 | 128518.09
  5 |         ->  Vector Hash Aggregate           | [573.150,1261.354]   |    340 |     12 | [2297KB, 2297KB] | 16MB     | [16,16] |       7 | 128517.80
  6 |           ->  CStore Scan on public.dwcjk   | [330.178,1021.695]   | 10000000 | 1623137 | [786KB, 786KB] | 1MB      |         |       7 | 120402.00
```

## Optimization Analysis

Obviously, there are date features in the cjrq field of table data in the service layer, and this meet the features of a partitioned table. Replan the table definition of the dwcjk table. Set the cjrq field as a partition key, and day as an interval unit. Define the partitioned table dwcjk_part. The modified result is as follows, and the performance is nearly doubled.

```
postgres=# explain performance select zqdh, count(1) from dwcjk_part where cjrq = '2015-05-02 00:00:00' group by zqdh;
```



| id | operation | A-time | A-rows | E-rows | Peak Memory | E-memory | A-width | E-width | E-costs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -> Row Adapter | 977.457 | 58 | 14 | 19KB | | | 7 | 773142.84 |
| 2 | -> Vector Streaming (type: GATHER) | 977.437 | 58 | 14 | 210KB | | | 7 | 773142.84 |
| 3 | -> Vector Hash Aggregate | [651.238,734.931] | 58 | 2 | [2316KB, 2316KB] | 16MB | [16,16] | 7 | 128857.14 |
| 4 | -> Vector Streaming(type: REDISTRIBUTE) | [651.137,734.834] | 340 | 14 | [247KB, 247KB] | 1MB | | 7 | 128857.47 |
| 5 | -> Vector Hash Aggregate | [402.145,515.752] | 340 | 14 | [2297KB, 2297KB] | 16MB | [16,16] | 7 | 128857.14 |
| 6 | -> Vector Partition Iterator | [162.630,275.990] | 10000000 | 1691000 | [312BYTE, 312BYTE] | 1MB | | 7 | 120402.00 |
| 7 | -> Partitioned CStore Scan on public.dwcjk_part | [161.746,275.207] | 10000000 | 1691000 | [795KB, 795KB] | 1MB | | 7 | 120402.00 |

# 11.4.11 Case: Adjusting the GUC Parameter best_agg_plan

## Symptom

The t1 table is defined as follows:

```
create table t1(a int, b int, c int) distribute by hash(a);
```

Assume that the distribution column of the result set provided by the agg lower-layer operator is setA, and the group by column of the agg operation is setB, the agg operations can be performed in two scenarios in the stream framework.

1. setA is a subset of setB.

   In this scenario, the aggregation result of the lower-layer result set is the correct result, which can be directly used by the upper-layer operator. For details, see the following figure:

   ```
   explain select a, count(1) from t1 group by a;
    id |          operation           | E-rows | E-width | E-costs
   ----+------------------------------+--------+---------+---------
     1 | ->  Streaming (type: GATHER) |     30 |       4 | 15.56
     2 |    ->  HashAggregate         |     30 |       4 | 14.31
     3 |       ->  Seq Scan on t1     |     30 |       4 | 14.14
   (3 rows)
   ```

2. setA is not a subset of setB.

   In this scenario, the Stream execution framework is classified into the following three plans:

   hashagg+gather(redistribute)+hashagg

   redistribute+hashagg(+gather)

   hashagg+redistribute+hashagg(+gather)

   GaussDB(DWS) provides the guc parameter **best_agg_plan** to intervene the execution plan, and forces the plan to generate the corresponding execution plan. This parameter can be set to **0**, **1**, **2**, and **3**.

   - When the value is set to **1**, the first plan is forcibly generated.
   - When the value is set to **2** and if the **group by** column can be redistributed, the second plan is forcibly generated. Otherwise, the first plan is generated.
   - When the value is set to **3** and if the **group by** column can be redistributed, the third plan is generated. Otherwise, the first plan is generated.
   - When the value is set to **0**, the query optimizer chooses the most optimal plan by the three preceding plans' evaluation cost.

   For details, see the following figure.

   ```
   set best_agg_plan to 1;
   SET
   explain select b,count(1) from t1 group by b;
    id |          operation           | E-rows | E-width | E-costs
   ----+------------------------------+--------+---------+---------
     1 | ->  HashAggregate            |      8 |       4 | 15.83
   ```

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```
 2 |   ->  Streaming (type: GATHER) |     25 |       4 | 15.83
 3 |      ->  HashAggregate         |     25 |       4 | 14.33
 4 |         ->  Seq Scan on t1     |     30 |       4 | 14.14
(4 rows)
set best_agg_plan to 2;
SET
explain select b,count(1) from t1 group by b;
 id |              operation               | E-rows | E-width | E-costs
----+--------------------------------------+--------+---------+---------
 1 | ->  Streaming (type: GATHER)           |     30 |       4 | 15.85
 2 |   ->  HashAggregate                    |     30 |       4 | 14.60
 3 |      ->  Streaming(type: REDISTRIBUTE) |     30 |       4 | 14.45
 4 |         ->  Seq Scan on t1             |     30 |       4 | 14.14
(4 rows)
set best_agg_plan to 3;
SET
explain select b,count(1) from t1 group by b;
 id |              operation               | E-rows | E-width | E-costs
----+--------------------------------------+--------+---------+---------
 1 | ->  Streaming (type: GATHER)           |     30 |       4 | 15.84
 2 |   ->  HashAggregate                    |     30 |       4 | 14.59
 3 |      ->  Streaming(type: REDISTRIBUTE) |     25 |       4 | 14.59
 4 |         ->  HashAggregate              |     25 |       4 | 14.33
 5 |           ->  Seq Scan on t1           |     30 |       4 | 14.14
(5 rows)
```

## Optimization

Generally, the optimizer chooses an optimal execution plan, but the cost estimation, especially that of the intermediate result set, has large deviations, which may result in large deviations in agg calculation. In this case, you need to use best_agg_plan to adjust the agg calculation model.

When the aggregation convergence ratio is very small, that is, the number of result sets does not become small obviously after the agg operation (5 times is a critical point), you can select the redistribute+hashagg or hashagg+redistribute +hashagg execution mode.

# 11.4.12 Case: Rewriting SQL and Deleting Subqueries (Case 1)

## Symptom

```
select
   1,
   (select count(*) from customer_address_001 a4 where a4.ca_address_sk = a.ca_address_sk) as GZCS
from customer_address_001 a;
```

This SQL performance is poor. SubPlan exists in the execution plan as follows:

```
postgres=# explain select 1,(select count(*)
postgres(#           from customer_address_001 a4
postgres(#          where a4.ca_address_sk = a.ca_address_sk
postgres(#         ) as GZCS from customer_address_001 a;
 id |                          operation                          | E-rows | E-width | E-costs
----+-------------------------------------------------------------+--------+---------+---------
  1 | ->  Streaming (type: GATHER)                                |    320 |       4 | 4529.27
  2 |    ->  Seq Scan on customer_address_001 a                   |    320 |       4 | 4496.27
  3 |       ->  Aggregate  [2, SubPlan 1]                         |     32 |       4 | 139.50
  4 |          ->  Result                                         |  10240 |       4 | 138.69
  5 |             ->  Materialize                                 |  10240 |       4 | 138.69
  6 |                ->  Streaming(type: BROADCAST)               |  10240 |       4 | 137.09
  7 |                   ->  Seq Scan on customer_address_001 a4   |    320 |       4 | 32.32
(7 rows)
```

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## Optimization

The core of this optimization is to eliminate subqueries. Based on the service scenario analysis, *a.ca_address_sk* is not null. In terms of SQL syntax, you can rewrite the SQL statement as follows:

```
select
count(*)
from customer_address_001 a4, customer_address_001 a
where a4.ca_address_sk = a.ca_address_sk
group by  a.ca_address_sk;
```

**NOTE**

To ensure that the modified statements have the same functions, *not null* is added to *customer_address_001. ca_address_sk*.

# 11.4.13 Case: Rewriting SQL and Deleting Subqueries (Case 2)

## Symptom

On a site, the customer gave the feedback saying that the execution time of the following SQL statements lasted over one day and did not end:

```
UPDATE calc_empfyc_c_cusr1 t1
SET ln_rec_count =
 (
   SELECT CASE WHEN current_date - ln_process_date + 1 <= 12 THEN 0 ELSE t2.ln_rec_count END
   FROM calc_empfyc_c1_policysend_tmp t2
   WHERE t1.ln_branch = t2.ln_branch AND t1.ls_policyno_cusr1 = t2.ls_policyno_cusr1
)
WHERE dsign = '1'
AND flag = '1'
AND EXISTS
   (SELECT 1
   FROM calc_empfyc_c1_policysend_tmp t2
   WHERE t1.ln_branch = t2.ln_branch AND t1.ls_policyno_cusr1 = t2.ls_policyno_cusr1
   );
```

The corresponding execution plan is as follows:

```
Streaming (type: GATHER)  (cost=44693.26..19548819558.34 rows=4058158 width=1061)
  Node/s: All datanodes
  ->  Update on channel.calc_empfyc_c_cusr1 t1  (cost=44689.26..19546717163.01 rows=4058158 width=1061)
        ->  Hash Join  (cost=44689.26..19546717163.01 rows=4058158 width=1061)
              Hash Cond: (((t1.ln_branch)::text = ((t2.ln_branch)::text)) AND ((t1.ls_policyno_cusr1)::text = ((t2.ls_policyno_cusr1)::text)))
              ->  Seq Scan on channel.calc_empfyc_c_cusr1 t1  (cost=0.00..28692.39 rows=7105667 width=1055)
                    Filter: ((t1.dsign = '1'::bpchar) AND (t1.flag = '1'::bpchar))
              ->  Hash  (cost=2112.16..2112.16 rows=108998016 width=37)
                    ->  Unique  (cost=2112.06..2112.16 rows=108998016 width=37)
                          ->  Sort  (cost=2112.06..2112.09 rows=775 width=37)
                                Sort Key: ((t2.ln_branch)::text), ((t2.ls_policyno_cusr1)::text)
                                ->  Streaming(type: BROADCAST)  (cost=2109.81..2111.85 rows=775 width=37)
                                      Spawn on: All datanodes
                                      ->  HashAggregate  (cost=2109.81..2109.82 rows=12 width=37)
                                            Group By Key: (t2.ln_branch)::text, (t2.ls_policyno_cusr1)::text
                                            ->  Seq Scan on channel.calc_empfyc_c1_policysend_tmp t2  (cost=0.00..1406.87 rows=1703094 width=37)
              SubPlan 1
                ->  Result  (cost=0.00..308262.89 rows=108998016 width=44)
                      Filter: (((t1.ln_branch)::text = (t2.ln_branch)::text) AND ((t1.ls_policyno_cusr1)::text = (t2.ls_policyno_cusr1)::text))
                      ->  Materialize  (cost=0.00..295489.68 rows=108998016 width=44)
                            ->  Streaming(type: BROADCAST)  (cost=0.00..286974.21 rows=108998016 width=44)
                                  Spawn on: All datanodes
                                  ->  Seq Scan on channel.calc_empfyc_c1_policysend_tmp t2  (cost=0.00..1406.87 rows=1703094 width=44)
```

## Optimization

SubPlan exists in the execution plan, and the calculation accounts for a large proportion in the SubPlan query. That is, SubPlan is a performance bottleneck.

Based on the SQL syntax, you can rewrite the SQL statements and delete SubPlan as follows:

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```
UPDATE calc_empfyc_c_cusr1 t1
SET ln_rec_count = CASE WHEN current_date - ln_process_date + 1 <= 12 THEN 0 ELSE t2.ln_rec_count END
FROM calc_empfyc_c1_policysend_tmp t2
WHERE
t1.dsign = '1' AND t1.flag = '1'
AND t1.ln_branch = t2.ln_branch AND t1.ls_policyno_cusr1 = t2.ls_policyno_cusr1;
```

The modified SQL statement task is complete within 50s.

# 11.4.14 Case: Rewriting SQL Statements and Eliminating Prune Interference

## Symptom

In a test at a site, **ddw_f10_op_cust_asset_mon** is a partitioned table and the partition key is **year_mth** whose value is a combined string of month and year values.

The following figure shows the tested SQL statements:

```
select
   count(1)
from t_ddw_f10_op_cust_asset_mon b1
where b1.year_mth between to_char(add_months(to_date(''20170222'','yyyymmdd'), -11),'yyyymm') and
substr(''20170222'',1 ,6 );
```

The test result shows the SQL Scan table takes 135s. This may be the performance bottleneck.

**NOTE**

add_months is a local adaptation function.

```
CREATE OR REPLACE FUNCTION ADD_MONTHS(date, integer) RETURNS date
  AS $$
  SELECT
  CASE
  WHEN (EXTRACT(day FROM $1) = EXTRACT(day FROM (date_trunc('month', $1) + INTERVAL '1
month - 1 day'))) THEN
      date_trunc('month', $1) + CAST($2 + 1 || ' month - 1 day' as interval)
  ELSE
      $1 + CAST($2 || ' month' as interval)
  END
  $$
  LANGUAGE SQL
  IMMUTABLE;
```

## Optimization

According to the statement execution plan, the base table filter is displayed as follows:

```
Filter: (((year_mth)::text <= '201702'::text) AND ((year_mth)::text >=
to_char(add_months(to_date('20170222'::text, 'YYYYMMDD'::text), (-11)), 'YYYYMM'::text)))
```

The query condition expression to_char(add_months(to_date(''20170222'','yyyymmdd'),-11),'yyyymm') exists in the filter condition, and this non-constant expression cannot be used for pruning. Therefore, all data of query statements in the partitioned tables is scanned.

to_date and to_char are stable functions as queried in the pg_proc. Based on the function behaviors described in Postgresql, this type of function cannot be

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converted into the Const value in the preprocessing phase, which is the root cause of preventing partition pruning.

Based on the preceding analysis, the optimization expression can be used for partition pruning, which is the key to performance optimization. The original SQL statements can be written to as follows:

```
select
   count(1)
from t_ddw_f10_op_cust_asset_mon b1
where b1.year_mth between(substr(ADD_MONTHS('20170222'::date, -11), 1, 4)||
substr(ADD_MONTHS('20170222'::date, -11), 6, 2)) and substr("20170222",1 ,6 );
```

The execution time of modified SQL statements is reduced from 135s to 18s.

# 11.4.15 Case: Rewriting SQL Statements and Deleting in-clause

## Symptom

in-clause/any-clause is a common SQL statement constraint. Sometimes, the clause following **in** or **any** is a constant. For example:

```
select
count(1)
from calc_empfyc_c1_result_tmp_t1
where ls_pid_cusr1 in ('20120405', '20130405');
```

or

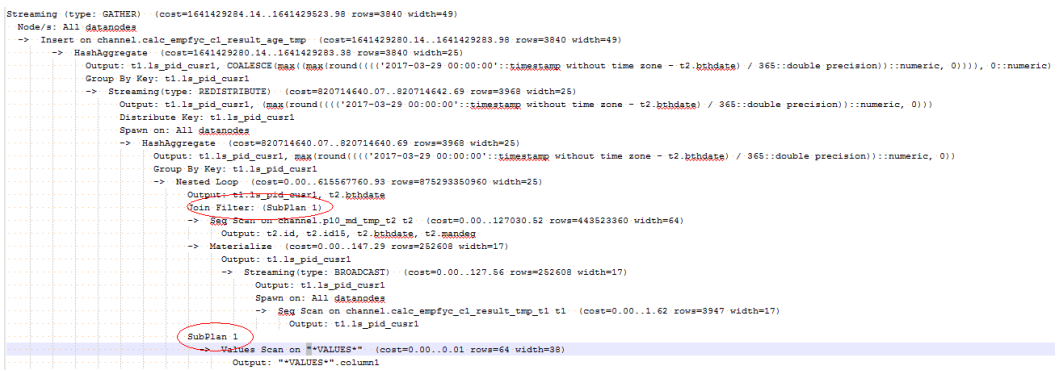
```
select
count(1)
from calc_empfyc_c1_result_tmp_t1
where ls_pid_cusr1 in any('20120405', '20130405');
```

Some special usages are as follows:

```
SELECT
ls_pid_cusr1,COALESCE(max(round((current_date-bthdate)/365)),0)
FROM calc_empfyc_c1_result_tmp_t1 t1,p10_md_tmp_t2 t2
WHERE t1.ls_pid_cusr1 = any(values(id),(id15))
GROUP BY ls_pid_cusr1;
```

Where **id** and **id15** are columns of p10_md_tmp_t2. ls_pid_cusr1 = any(values(id), (id15)) equals t1. ls_pid_cusr1 = id or t1. ls_pid_cusr1 = id15.

Therefore, join-condition is essentially an inequality, and nestloop must be used for this join operation. The execution plan is as follows:

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## Optimization

The test result shows that both result sets are too large. As a result, nestloop is time-consuming with more than one hour to return results. Therefore, the key to performance optimization is to eliminate nestloop, using more efficient hashjoin. From the perspective of semantic equivalence, the SQL statements can be written as follows:

```
select
ls_pid_cusr1,COALESCE(max(round(ym/365)),0)
from
(
    (
        SELECT
            ls_pid_cusr1,(current_date-bthdate) as ym
        FROM calc_empfyc_c1_result_tmp_t1 t1,p10_md_tmp_t2 t2
        WHERE t1.ls_pid_cusr1 = t2.id and t1.ls_pid_cusr1 != t2.id15
    )
    union all
    (
        SELECT
            ls_pid_cusr1,(current_date-bthdate) as ym
        FROM calc_empfyc_c1_result_tmp_t1 t1,p10_md_tmp_t2 t2
        WHERE t1.ls_pid_cusr1 = id15
    )
)
GROUP BY ls_pid_cusr1;
```

The optimized SQL queries consist of two equivalent join subqueries, and each subquery can be used for hashjoin in this scenario. The optimized execution plan is as follows:

```
 id |                                  operation                                  |       A-time        |  A-rows  |  E-rows  |   Peak Memory   |  E-memory  |  A-width
----+-----------------------------------------------------------------------------+---------------------+----------+----------+-----------------+------------+----------
  1 | ->  Streaming (type: GATHER)                                                | 6737.281            |        0 |      192 | 292KB           |            |
  2 |    ->  Insert on channel.calc_empfyc_c1_result_age_tmp                      | [4665.024,4990.666] |        0 |      192 | [1108KB, 1108KB] |  1MB      |
  3 |       ->  HashAggregate                                                     | [4664.996,4990.641] |        0 |      192 | [12KB, 12KB]     |  16MB     |
  4 |          ->  Streaming(type: REDISTRIBUTE)                                  | [4664.991,4990.637] |        0 |     3392 | [2090KB, 2090KB] |  1MB      |
  5 |             ->  HashAggregate                                               | [3416.939,4958.348] |        0 |     3392 | [14KB, 14KB]     |  16MB     |
  6 |                ->  Append                                                   | [3416.936,4958.340] |        0 |     4011 | [1KB, 1KB]       |  1MB      |
  7 |                   ->  Hash Join (8,9)                                       | [2011.226,3080.697] |        0 |     3947 | [6KB, 6KB]       |  1MB      |
  8 |                      ->  Seq Scan on channel.p10_md_tmp_t2 t2               | [803.782,1238.984]  | 443525717 | 443523360 | [12KB, 12KB]     |  1MB      |
  9 |                      ->  Hash                                               | [4.357,328.979]     |   252608 |   252608 | [482KB, 482KB]   |  16MB     |  [35,39]
 10 |                         ->  Streaming(type: BROADCAST)                      | [2.345,326.320]     |   252608 |   252608 | [2090KB, 2090KB] |  1MB      |
 11 |                            ->  Seq Scan on channel.calc_empfyc_c1_result_tmp_t1 t1 | [0.011,0.030]      |     3947 |     3947 | [11KB, 11KB]     |  1MB      |
 12 |                   ->  Hash Join (13,14)                                     | [1376.258,2066.110] |        0 |       64 | [5KB, 5KB]       |  1MB      |
 13 |                      ->  Seq Scan on channel.p10_md_tmp_t2 t2               | [777.552,1388.499]  | 443525717 | 443523360 | [12KB, 12KB]     |  1MB      |
 14 |                      ->  Hash                                               | [2.812,4.217]       |   252608 |   252608 | [482KB, 482KB]   |  16MB     |  [23,27]
 15 |                         ->  Streaming(type: BROADCAST)                      | [1.276,1.868]       |   252608 |   252608 | [2090KB, 2090KB] |  1MB      |
 16 |                            ->  Seq Scan on channel.calc_empfyc_c1_result_tmp_t1 t1 | [0.010,0.033]      |     3947 |     3947 | [11KB, 11KB]     |  1MB      |
(16 rows)
```

Before the optimization, no result is returned for more than 1 hour. After the optimization, the result is returned within 7s.

# 11.4.16 Case: Setting Partial Cluster Keys

You can add **PARTIAL CLUSTER KEY**(*column_name*[,...]) to the definition of a column-store table to set one or more columns of this table as partial cluster keys. In this way, each 70 CUs (4.2 million rows) will be sorted based on the cluster keys by default during data import and the value range is narrowed down for each of the new 70 CUs. If the **where** condition in the query statement contains these columns, the filtering performance will be improved.

1. Use partial cluster keys.

```
CREATE TABLE lineitem
(
L_ORDERKEY    BIGINT NOT NULL
, L_PARTKEY     BIGINT NOT NULL
, L_SUPPKEY     BIGINT NOT NULL
, L_LINENUMBER  BIGINT NOT NULL
, L_QUANTITY    DECIMAL(15,2) NOT NULL
, L_EXTENDEDPRICE  DECIMAL(15,2) NOT NULL
```

```
, L_DISCOUNT    DECIMAL(15,2) NOT NULL
, L_TAX         DECIMAL(15,2) NOT NULL
, L_RETURNFLAG  CHAR(1) NOT NULL
, L_LINESTATUS  CHAR(1) NOT NULL
, L_SHIPDATE    DATE NOT NULL
, L_COMMITDATE  DATE NOT NULL
, L_RECEIPTDATE DATE NOT NULL
, L_SHIPINSTRUCT CHAR(25) NOT NULL
, L_SHIPMODE     CHAR(10) NOT NULL
, L_COMMENT      VARCHAR(44) NOT NULL
)
with (orientation = column)
distribute by hash(L_ORDERKEY);

select
sum(l_extendedprice * l_discount) as revenue
from
lineitem
where
l_shipdate >= '1994-01-01'::date
and l_shipdate < '1994-01-01'::date + interval '1 year'
and l_discount between 0.06 - 0.01 and 0.06 + 0.01
and l_quantity < 24;
```

In the **where** condition, both the **l_shipdate** and **l_quantity** columns have a few distinct values, and their values can be used for min/max filtering. Therefore, modify the table definition as follows:

```
CREATE TABLE lineitem
(
L_ORDERKEY    BIGINT NOT NULL
, L_PARTKEY     BIGINT NOT NULL
, L_SUPPKEY     BIGINT NOT NULL
, L_LINENUMBER  BIGINT NOT NULL
, L_QUANTITY    DECIMAL(15,2) NOT NULL
, L_EXTENDEDPRICE  DECIMAL(15,2) NOT NULL
, L_DISCOUNT    DECIMAL(15,2) NOT NULL
, L_TAX         DECIMAL(15,2) NOT NULL
, L_RETURNFLAG  CHAR(1) NOT NULL
, L_LINESTATUS  CHAR(1) NOT NULL
, L_SHIPDATE    DATE NOT NULL
, L_COMMITDATE  DATE NOT NULL
, L_RECEIPTDATE DATE NOT NULL
, L_SHIPINSTRUCT CHAR(25) NOT NULL
, L_SHIPMODE     CHAR(10) NOT NULL
, L_COMMENT      VARCHAR(44) NOT NULL
, partial cluster key(l_shipdate, l_quantity)
)
with (orientation = column)
distribute by hash(L_ORDERKEY);
```

Import the data again and run the query statement. Then, compare the execution time before and after partial cluster keys are used.

**Figure 11-14** Partial cluster keys not used

```
 id |                 operation                 |       A-time       | A-rows | E-rows |  Peak Memory   | A-width | E-width |  E-costs
----+-------------------------------------------+--------------------+--------+--------+----------------+---------+---------+----------
  1 | ->  Row Adapter                           | 1653.156           |      1 |      1 | 12KB           |         |      44 | 205803.90
  2 |    ->  Vector Aggregate                   | 1653.146           |      1 |      1 | 184KB          |         |      44 | 205803.90
  3 |       ->  Vector Streaming (type: GATHER) | 1653.070           |      1 |      1 | 174KB          |         |      44 | 205803.90
  4 |          ->  Vector Aggregate             | [1481.497,1481.497] |      1 |      1 | [225KB, 225KB] |         |      44 | 205803.84
  5 |             ->  CStore Scan on public.lineitem | [1405.004,1405.004] | 114160 | 111485 | [792KB, 792KB] |         |      12 | 205246.40
(5 rows)
```

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**Figure 11-15** CU loading without partial cluster keys

```
 5 --CStore Scan on public.lineitem
       datanode1 (actual time=40.623..1405.004 rows=114160 loops=1)
       datanode1 (RoughCheck CU: CUNone: 0, CUSome: 101)
       datanode1 (LLVM Optimized)
       datanode1 (Buffers: shared hit=18385 read=23)
       datanode1 (CPU: ex c/r=31917, ex cyc=3643646206, inc cyc=3643646206)
```

**Figure 11-16** Partial cluster keys used

```
id |                operation                |      A-time       | A-rows | E-rows |  Peak Memory   | A-width | E-width |  E-costs
---+-----------------------------------------+-------------------+--------+--------+----------------+---------+---------+----------
 1 | ->  Row Adapter                         | 459.539           |      1 |      1 | 12KB           |         |      44 | 205693.85
 2 |    ->  Vector Aggregate                 | 459.528           |      1 |      1 | 184KB          |         |      44 | 205693.85
 3 |       ->  Vector Streaming (type: GATHER) | 459.452         |      1 |      1 | 174KB          |         |      44 | 205693.85
 4 |          ->  Vector Aggregate           | [285.177,285.177] |      1 |      1 | [225KB, 225KB] |         |      44 | 205693.79
 5 |             ->  CStore Scan on public.lineitem | [249.757,249.757] | 114160 |  89475 | [792KB, 792KB] |         |      12 | 205246.40
(5 rows)
```

**Figure 11-17** CU loading with partial cluster keys

```
 5 --CStore Scan on public.lineitem
       datanode1 (actual time=23.017..249.757 rows=114160 loops=1)
       datanode1 (RoughCheck CU: CUNone: 84, CUSome: 17)
       datanode1 (LLVM Optimized)
       datanode1 (Buffers: shared hit=2853 read=23)
       datanode1 (CPU: ex c/r=5673, ex cyc=647656146, inc cyc=647656146)
```

After partial cluster keys are used, the execution time of **5-- CStore Scan on public.lineitem** decreases by 1.2s because 84 CUs are filtered out.

2. Select partial cluster keys.
   - The following data types support cluster keys: character varying(n), varchar(n), character(n), char(n), text, nvarchar2, timestamp with time zone, timestamp without time zone, date, time without time zone, and time with time zone.
   - Smaller number of distinct values in a partial cluster key generates higher filtering performance.
   - Columns that can filter out larger amount of data is preferentially selected as partial cluster keys.
   - If multiple columns are selected as partial cluster keys, the columns are used in sequence to sort data. You are advised to select a maximum of three columns.
3. Modify parameters to reduce the impact of partial cluster keys on the import performance.

   After partial cluster keys are used, data will be sorted when they are imported, affecting the import performance. If all the data can be sorted in the memory, the keys have little impact on import. If some data cannot be sorted in the memory and is written into a temporary file for sorting, the import performance will be greatly affected.

   The memory used for sorting is specified by the **psort_work_mem** parameter. You can set it to a larger value so that the sorting has less impact on the import performance.

   The volume of data to be sorted is specified by the **PARTIAL_CLUSTER_ROWS** parameter of the table. Decreasing the value of this parameter reduces the amount of data to be sorted at a time. **PARTIAL_CLUSTER_ROWS** is usually used along with the **MAX_BATCHROW** parameter. The value of

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**PARTIAL_CLUSTER_ROWS** must be an integer multiple of the **MAX_BATCHROW** value. **MAX_BATCHROW** specifies the maximum number of rows in a CU.

# 11.5 SQL Execution Troubleshooting

## 11.5.1 Low Query Efficiency

A query task that used to take a few milliseconds to complete is now requiring several seconds, and that used to take several seconds is now requiring even half an hour. This section describes how to analyze and rectify such low efficiency issues.

### Procedure

Perform the following procedure to locate the cause of this fault.

**Step 1** Run the **analyze** command to analyze the database.

The **analyze** command updates data statistics information, such as data sizes and attributes in all tables. This is a lightweight command and can be executed frequently. If the query efficiency is improved or restored after the command execution, the autovacuum process does not function well and requires further analysis.

**Step 2** Check whether the query statement returns unnecessary information.

For example, if we only need the first 10 records in a table but the query statement searches all records in the table, the query efficiency is fine for a table containing only 50 records but very low for a table containing 50,000 records.

If an application requires only a part of data information but the query statement returns all information, add a LIMIT clause to the query statement to restrict the number of returned records. In this way, the database optimizer can optimize space and improve query efficiency.

**Step 3** Check whether the query statement still has a low response even when it is solely executed.

Run the query statement when there are no or only a few other query requests in the database, and observe the query efficiency. If the efficiency is high, the previous issue is possibly caused by a heavily loaded host in the database system or an inefficient execution plan.

**Step 4** Check the same query statement repeatedly to check the query efficiency.

One major cause that will reduce query efficiency is that the required information is not cached in the memory or is replaced by other query requests because of insufficient memory resources.

Run the same query statement repeatedly. If the query efficiency increases gradually, the previous issue might be caused by this reason.

**----End**

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## 11.5.2 DROP TABLE Fails to Be Executed

### Problem

**DROP TABLE** fails to be executed in the following scenarios:

- A user runs the **\dt+** command using **gsql** and finds that the *table_name* table does not exist. When the user runs the **CREATE TABLE table_name** command, an error message indicating that the *table_name* table exists is displayed. When the user runs the **DROP TABLE** *table_name* command, an error message indicating that the *table_name* table does not exist is displayed. In this case, the *table_name* table cannot be recreated.
- A user runs the **\dt+** command using **gsql** and finds that the *table_name* table exists in the database. When the user runs the **DROP TABLE** *table_name* command, an error message indicating that the *table_name* table does not exist is displayed. In this case, the *table_name* table cannot be recreated.

### Possible Causes

The table_name table exists on some nodes only.

### Troubleshooting Method

In the preceding scenarios, if **DROP TABLE** *table_name* fails to be executed, run **DROP TABLE IF EXISTS** *table_name* to successfully drop *table_name*.

## 11.5.3 Different Data Is Displayed for the Same Table Queried By Multiple Users

### Problem

Two users log in to the same database human_resource and run the **select count(*) from areas** statement separately to query the areas table, but obtain different results.

### Possible Causes

Check whether the two users really query the same table. In a relational database, a table is identified by three elements: **database**, **schema**, and **table**. In this issue, **database** is **human_resource** and **table** is **areas**. Then, check **schema**. Log in as users **dbadmin** and **user01** separately. It is found that **search_path** is **public** for **dbadmin** and *$user* for **user01**. By default, a schema having the same name as user **dbadmin**, the cluster administrator, is not created. That is, all tables will be created in **public** if no schema is specified. However, when a common user, such as **user01**, is created, the same-name schema (**user01**) is created by default. That is, all tables are created in **user01** if the schema is not specified. In conclusion, both the two users are operating the table, causing that the same-name table is not really the same table.

### Troubleshooting Method

Use *schema*.**table** to determine a table for query.

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## 11.5.4 An Error Occurs During the Integer Conversion

### Problem

The following error is reported during the integer conversion:

```
Invalid input syntax for integer: "13."
```

### Possible Causes

Some data types cannot be converted to the target data type.

### Troubleshooting

Gradually narrow down the range of SQL statements to locate the fault.

## 11.5.5 Automatic Retry upon SQL Statement Execution Errors

With automatic retry (referred to as CN retry), GaussDB(DWS) retries an SQL statement when the execution of this statement fails. If an SQL statement sent from the **gsql** client, JDBC driver, or ODBC driver fails to be executed, the CN can automatically identify the error reported during execution and re-deliver the task to retry.

The restrictions of this function are as follows:

- Functionality restrictions:
  - CN retry increases execution success rate but does not guarantee success.
  - CN retry is enabled by default. In this case, the system records logs about temporary tables. If it is disabled, the system will not record the logs. Therefore, do not repeatedly enable and disable CN retry when temporary tables are used. Otherwise, data inconsistency may occur after a CN retry following a primary/standby switchover.
  - CN retry is enabled by default. In this case, the **unlogged** keyword is ignored in the statement for creating unlogged tables and thereby ordinary tables will be created by using this statement. If CN retry is disabled, the system records logs about unlogged tables. Therefore, do not repeatedly enable and disable CN retry when unlogged tables are used. Otherwise, data inconsistency may occur after a CN retry following a primary/standby switchover.
  - When GDS is used to export data, CN retry is supported. The existing mechanism checks for duplicate files and deletes duplicate files during data export. Therefore, you are advised not to repeatedly export data for the same foreign table unless you are sure that files with the same name in the data directory need to be deleted.
- Error type restrictions:

  Only the error types in **Table 11-3** are supported.
- Statement type restrictions:

  Support single-statement CN retry, stored procedures, functions, and anonymous blocks. Statements in transaction blocks are not supported.
- Statement restrictions of a stored procedure:

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  - If an error occurs during the execution of a stored procedure containing **EXCEPTION** (including statement block execution and statement execution in EXCEPTION), the stored procedure can be retried. If an internal error occurs, the stored procedure will retry first, but if the error is captured by **EXCEPTION**, the stored procedure cannot be retried.
  - Packages that use global variables are not supported.
  - **DBMS_JO** is not supported.
  - **UTL_FILE** is not supported.
  - If the stored procedure has printed information (such as **dbms_output.put_line** or **raise info**), the printed information will be output repeatedly when retry occurs, and "Notice: Retry triggered, some message may be duplicated. " will be output before the repeated information.
- Cluster status restrictions:
  - Only DNs or GTMs are faulty.
  - The cluster can be recovered before the number of CN retries reaches the allowed maximum (controlled by **max_query_retry_times**). Otherwise, CN retry may fail.
  - CN retry is not supported during scale-out.
- Data import restrictions:
  - The **COPY FROM STDIN** statement is not supported.
  - The **gsql \copy from** metacommand is not supported.
  - **JDBC CopyManager copyIn** is not supported.

Table 11-3 lists the error types supported by CN retry and the corresponding error codes. You can use the GUC parameter **retry_ecode_list** to set the list of error types supported by CN retry. You are not advised to modify this parameter. To modify it, contact the technical support.

**Table 11-3** Error types supported by CN retry

| Error Type | Error Code | Remarks |
| --- | --- | --- |
| CONNECTION_RESET_BY_PEER | YY001 | TCP communication errors: Connection reset by peer (communication between the CN and DNs) |
| STREAM_CONNECTION_RESET_BY_PEER | YY002 | TCP communication errors: Stream connection reset by peer (communication between DNs) |
| LOCK_WAIT_TIMEOUT | YY003 | Lock wait timeout |
| CONNECTION_TIMED_OUT | YY004 | TCP communication errors: Connection timed out |

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| Error Type | Error Code | Remarks |
| --- | --- | --- |
| SET_QUERY_ERROR | YY005 | Failed to deliver the **SET** command: Set query |
| OUT_OF_LOGICAL_MEMORY | YY006 | Failed to apply for memory: Out of logical memory |
| SCTP_MEMORY_ALLOC | YY007 | SCTP communication errors: Memory allocate error |
| SCTP_NO_DATA_IN_BUFFER | YY008 | SCTP communication errors: SCTP no data in buffer |
| SCTP_RELEASE_MEMORY_CLOSE | YY009 | SCTP communication errors: Release memory close |
| SCTP_TCP_DISCONNECT | YY010 | SCTP communication errors: TCP disconnect |
| SCTP_DISCONNECT | YY011 | SCTP communication errors: SCTP disconnect |
| SCTP_REMOTE_CLOSE | YY012 | SCTP communication errors: Stream closed by remote |
| SCTP_WAIT_POLL_UNKNOW | YY013 | Waiting for an unknown poll: SCTP wait poll unknown |
| SNAPSHOT_INVALID | YY014 | Snapshot invalid |
| ERRCODE_CONNECTION_RECEIVE_WRONG | YY015 | Connection receive wrong |
| OUT_OF_MEMORY | 53200 | Out of memory |
| CONNECTION_FAILURE | 08006 | GTM errors: Connection failure |
| CONNECTION_EXCEPTION | 08000 | Failed to communicate with DNs due to connection errors: Connection exception |
| ADMIN_SHUTDOWN | 57P01 | System shutdown by administrators: Admin shutdown |
| STREAM_REMOTE_CLOSE_SOCKET | XX003 | Remote socket disabled: Stream remote close socket |
| ERRCODE_STREAM_DUPLICATE_QUERY_ID | XX009 | Duplicate query id |

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| Error Type | Error Code | Remarks |
| --- | --- | --- |
| ERRCODE_STREAM_CONCURRENT_UPDATE | YY016 | Stream concurrent update |
| ERRCODE_LLVM_BAD_ALLOC_ERROR | CG003 | Memory allocation error: Allocate error |
| ERRCODE_LLVM_FATAL_ERROR | CG004 | Fatal error |
| HashJoin Temporary File Read Error(ERRCODE_HASHJOIN_TEMP_FILE_ERROR) | F0011 | Temporary file read error, File error |

To enable CN retry, set the following GUC parameters:

- Mandatory GUC parameters (required by both CNs and DNs)

  max_query_retry_times

  **CAUTION**

  If CN retry is enabled, temporary table data is logged. For data consistency, do not switch the enabled/disabled status for CN retry when the temporary tables are being used by sessions.

# 11.6 Common Performance Parameter Optimization Design

To improve the cluster performance, you can use multiple methods to optimize the database, including hardware configuration, software driver upgrade, and internal parameter adjustment of the database. This section describes some common parameters and recommended configurations.

1. **query_dop**: user-defined query degree of parallelism (DOP)

   The SMP architecture uses abundant resources to obtain time. After the plan parallelism is executed, more resources are consumed, including the CPU, memory, I/O, and network bandwidth. As the DOP grows, the resource consumption increases.

   - When resources become a bottleneck, the SMP cannot improve the performance and may even deteriorate the performance. In the case of a resource bottleneck, you are advised to disable the SMP.
   - If resources are sufficient, the higher the DOP, the more the performance is improved.

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The SMP DOP can be configured at a session level and you are advised to enable the SMP before executing the query that meets the requirements. After the execution is complete, disable the SMP. Otherwise, SMP may affect services in peak hours.

The default value of **query_dop** is **1**. You can set **query_dop** to **10** to enable the SMP in a session.

2. **enable_dynamic_workload**: dynamic load management

   Dynamic load management refers to the automatic queue control of complex queries based on user loads in a database. This fine-tunes system parameters without manual adjustment.

   This parameter is enabled by default. Notes:

   - A CN in the cluster is used as the Central Coordinator (CCN) for collecting and scheduling job execution. To query this CN, run **gs_om -t status --detail**. Its status will be displayed in **Central Coordinator State**. If there is no CCN, jobs will not be controlled by dynamic load management.
   - Simple query jobs (which are estimated to require less than 32 MB memory) and non-DML statements (statements other than **INSERT**, **UPDATE**, **DELETE**, and **SELECT**) have no adaptive load restrictions. Control the upper memory limits for them on a single CN using **max_active_statements**.
   - The default value of **work_mem** is **64 MB**. In adaptive load scenarios, the value cannot be increased. If you increase it, memory cannot be controlled for certain statements, such as statements that have not been analyzed.
   - Reduce concurrency in the following scenarios, because high concurrency may lead to uncontrollable memory usage.

     - A single tuple occupies excessive memory, for example, a base table contains a column more than 1 MB wide.
     - A query is fully pushed down.
     - A statement occupies a large amount of memory on the CN, for example, a statement that cannot be pushed down or a cursor withholding statement.
     - An execution plan creates a hash table based on the hash join operator, and the table has many duplicate values and occupies a large amount of memory.
     - UDFs are used and occupy a large amount of memory.

   When configuring this parameter, you can set **query_dop** to **0** (adaptive). In this case, the system dynamically selects the optimal DOP between 1 and 8 for each query based on resource usage and plan characteristics. The **enable_dynamic_workload** parameter supports the dynamic memory allocation.

3. **max_active_statements**

   Specifies the maximum number of concurrent jobs. This parameter applies to all the jobs on one CN.

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Set the value of this parameter based on system resources, such as CPU, I/O, and memory resources, to ensure that the system resources can be fully utilized and the system will not be crashed due to excessive concurrent jobs.

- If this parameter is set to **-1** or **0**, the number of global concurrent jobs is not limited.
- In the point query scenario, you are advised to set this parameter to **100**.
- In an analytical query scenario, set this parameter to the number of CPU cores divided by the number of DNs. Generally, its value ranges from 5 to 8.

4. **session_timeout**

   By default, if a client is in idle state after connecting to a database, the client automatically disconnects from the database after the duration specified by the parameter.

   You are advised to set this parameter to 0, indicating that the timeout setting is disabled to prevent disconnection due to timeout.

5. The five parameters that affect the database memory are as follows:

   **max_process_memory**, **shared_buffers**, **cstore_buffers**, **work_mem**, and **maintenance_work_mem**

   - **max_process_memory**

     **max_process_memory** is a logical memory management parameter. It is used to control the maximum available memory on a single CN or DN.

     Formula: **max_process_memory** = Physical memory x 0.665/ (1 + Number of primary DNs)

   - **shared_buffers**

     Specifies the size of the shared memory used by GaussDB(DWS). If the value of this parameter is increased, GaussDB(DWS) requires more System V shared memory than the default system setting.

     You are advised to set **shared_buffers** to a value less than 40% of the memory. It is used to scan row-store tables. Formula: **shared_buffers** = (Memory of a single server/Number of DNs on a single server) x 0.4 x 0.25

   - **cstore_buffers**

     Specifies the size of the shared buffer used by column-store tables and column-store tables (ORC, Parquet, and CarbonData) of OBS and HDFS foreign tables.

     For details about the calculation formula, see the formula in **shared_buffers**.

   - **work_mem**

     Specifies the size of the memory used by internal sequential operations and the Hash table before data is written into temporary disk files.

     Sort operations are required for **ORDER BY**, **DISTINCT**, and merge joins. Hash tables are used in hash joins, hash-based aggregation, and hash-based processing of **IN** subqueries.

     In a complex query, several sort or hash operations may run in parallel. Each operation will be allowed to use as much memory as this parameter specifies. If the memory is insufficient, data will be written into temporary files. In addition, several running sessions may be performing such

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operations concurrently. Therefore, the total memory used may be many times the value of **work_mem**.

The formulas are as follows:

For non-concurrent complex serial queries, each query requires five to ten associated operations. Configure **work_mem** using the following formula: **work_mem** = 50% of the memory/10.

For non-concurrent simple serial queries, each query requires two to five associated operations. Configure **work_mem** using the following formula: **work_mem** = 50% of the memory/5.

For concurrent queries, configure **work_mem** using the following formula: **work_mem** = **work_mem** for serial queries/Number of concurrent SQL statements.

- **maintenance_work_mem**

  **maintenance_work_mem** specifies the maximum size of memory used for maintenance operations, involving **VACUUM**, **CREATE INDEX**, and **ALTER TABLE ADD FOREIGN KEY**.

  Setting suggestions:

  If you set this parameter to a value greater than that of **work_mem**, database dump files can be cleaned up and restored more efficiently. In a database session, only one maintenance operation can be performed at a time. Maintenance is usually performed when there are not many sessions.

  When the automatic cleanup process is running, up to **autovacuum_max_workers** times of the memory will be allocated. In this case, set **maintenance_work_mem** to a value greater than or equal to that of **work_mem**.

6. **bulk_write_ring_size**

   Specifies the size of a ring buffer used for parallel data import.

   This parameter affects the database import performance. You are advised to increase the value of this parameter on DNs when a large amount of data is to be imported.

7. Two connection parameters:

   **max_connections** and **max_prepared_transactions**

   - **max_connections**

     Specifies the maximum number of concurrent connections to the database. This parameter affects the concurrent processing capability of the cluster.

     Setting suggestions:

     Retain the default value of this parameter on CNs. Set this parameter on DNs to a value calculated using this formula: Number of CNs x Value of this parameter on a CN.

     If the value of this parameter is increased, GaussDB(DWS) may require more System V shared memory or semaphore, which may exceed the default maximum value of the OS. In this case, modify the value as needed.

   - **max_prepared_transactions**

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Specifies the maximum number of transactions that can stay in the **prepared** state simultaneously. If the value of this parameter is increased, GaussDB(DWS) requires more System V shared memory than the default system setting.

**NOTICE**

The value of **max_connections** is related to **max_prepared_transactions**. Before configuring **max_connections**, ensure that the value of **max_prepared_transactions** is greater than or equal to that of **max_connections**. In this way, each session has a prepared transaction in the waiting state.

8. **checkpoint_completion_target**

   Specifies the target for which the checkpoint is completed.

   Each checkpoint must be completed within 50% of the checkpoint interval.

   The default value is **0.5**. To improve the performance, you can change the value to 0.9.

9. **data_replicate_buffer_size**

   Specifies the memory used by queues when the sender sends data pages to the receiver. The value of this parameter affects the buffer size used for the replication from the primary server to the standby server.

   The default value is **128 MB**. If the server memory is 256 GB, you can increase the value to 512 MB.

10. **wal_receiver_buffer_size**

    Specifies the memory buffer size for the standby and secondary servers to store the received XLOG files.

    The default value is **64 MB**. If the server memory is 256 GB, you can increase the value to 128 MB.

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# 12 User-Defined Functions

## 12.1 PL/Java Functions

With the GaussDB(DWS) PL/Java functions, you can choose your favorite Java IDE to write Java methods and install the JAR files containing these methods into the GaussDB(DWS) database before invoking them. GaussDB(DWS) PL/Java is developed based on open-source PL/Java 1.5.5 and uses JDK 1.8.0_292.

### Constraints

Java UDF can be used for some Java logical computing. You are not advised to encapsulate services in Java UDF.

- You are not advised to connect to a database in any way (for example, JDBC) in Java functions.
- Currently, only data types listed in **Table 12-1** are supported. Other data types, such as user-defined data types and complex data types (for example, Java array and its derived types) are not supported.
- Currently, UDAF and UDTF are not supported.

### Examples

Before using PL/Java, you need to pack the implementation of Java methods into a JAR package and deploy it into the database. Then, create functions as a database administrator. For compatibility purposes, use JDK 1.8.0_262 for compilation.

**Step 1** Compile a JAR package.

Java method implementation and JAR package archiving can be achieved in an integrated development environment (IDE). The following is a simple example of compilation and archiving through command lines. You can create a JAR package that contains a single method in the similar way.

First, prepare an **Example.java** file that contains a method for converting substrings to uppercase. In the following example, **Example** is the class name and **upperString** is the method name:

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```
public class Example
{
    public static String upperString (String text, int beginIndex, int endIndex)
    {
        return text.substring(beginIndex, endIndex).toUpperCase();
    }
}
```

Then, create a **manifest.txt** file containing the following content:

```
Manifest-Version: 1.0
Main-Class: Example
Specification-Title: "Example"
Specification-Version: "1.0"
Created-By: 1.6.0_35-b10-428-11M3811
Build-Date: 08/14/2018 10:09 AM
```

**Manifest-Version** specifies the version of the **manifest** file. **Main-Class** specifies the main class used by the .jar file. **Specification-Title** and **Specification-Version** are the extended attributes of the package. **Specification-Title** specifies the title of the extended specification and **Specification-Version** specifies the version of the extended specification. **Created-By** specifies the person who created the file. **Build-Date** specifies the date when the file was created.

Finally, archive the .java file and package it into **javaudf-example.jar**.

```
javac Example.java
jar cfm javaudf-example.jar manifest.txt Example.class
```

**NOTICE**

JAR package names must comply with JDK rules. If a name contains invalid characters, an error occurs when a function is deployed or used.

**Step 2** Deploy the JAR package.

First store the JAR package on an OBS server. For details, see "Uploading a File" in *Object Storage Service Console Operation Guide*. Then, create the access key AK/SK. For details about how to create access keys, see "Creating an Access Key (AK and SK)" in *Data Warehouse Service User Guide*. After that, log in to the database, run the gs_extend_library function, and import the package to GaussDB(DWS).

```
SELECT gs_extend_library('addjar', 'obs://bucket/path/javaudf-example.jar
accesskey=access_key_value_to_be_replaced  secretkey=secret_access_key_value_to_be_replaced
region=region_name libraryname=example');
```

For details about how to use the gs_extend_library function, see **Manage JAR packages and files**. Change the values of AK and SK as needed. Replace *region_name* with an actual region name.

**Step 3** Use a PL/Java function.

Log in to the database as a user who has the **sysadmin** permission (for example, dbadmin) and create the **java_upperstring** function:

```
CREATE FUNCTION java_upperstring(VARCHAR, INTEGER, INTEGER)
    RETURNS VARCHAR
    AS 'Example.upperString'
LANGUAGE JAVA;
```

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**NOTE**

- The data type defined in the java_upperstring function should be a type in GaussDB(DWS) and match the data type defined in **Step 1** in the upperString method in Java. For details about the mapping between GaussDB(DWS) and Java data types, see **Table 12-1**.
- The AS clause specifies the class name and static method name of the Java method invoked by the function. The format is *Class name*.*Method name*. The class name and method name must match the Java class and method defined in **Step 1**. In this example, no packages are specified. If a package has been specified, specify the complete class name when using **CREATE FUNCTION**.
- To use PL/Java functions, set **LANGUAGE** to **JAVA**.
- For details about CREATE FUNCTION, see **Create functions**.

Execute the java_upperstring function.

```
SELECT java_upperstring('test', 0, 1);
```

The expected result is as follows:

```
 java_upperstring
--------------------
 T
(1 row)
```

**Step 4** Authorize a common user to use the PL/Java function.

Create a common user named **udf_user**.

```
CREATE USER udf_user PASSWORD 'password';
```

This command grants user **udf_user** the permission for the java_upperstring function. Note that the user can use this function only if it also has the permission for using the schema of the function.

```
GRANT ALL PRIVILEGES ON SCHEMA public TO udf_user;
GRANT ALL PRIVILEGES ON FUNCTION java_upperstring(VARCHAR, INTEGER, INTEGER) TO udf_user;
```

Log in to the database as user **udf_user**.

```
SET SESSION SESSION AUTHORIZATION udf_user PASSWORD 'password';
```

Execute the java_upperstring function.

```
SELECT public.java_upperstring('test', 0, 1);
```

The expected result is as follows:

```
 java_upperstring
--------------------
 T
(1 row)
```

**Step 5** Delete the function.

If you no longer need this function, delete it.

```
DROP FUNCTION java_upperstring;
```

**Step 6** Uninstall the JAR package.

Use the gs_extend_library function to uninstall the JAR package.

```
SELECT gs_extend_library('rmjar', 'libraryname=example');
```

**----End**

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## SQL Definition and Usage

- **Manage JAR packages and files.**

  A database user having the **sysadmin** permission can use the gs_extend_library function to deploy, view, and delete JAR packages in the database. The syntax of the function is as follows:

  ```
  SELECT gs_extend_library('[action]', '[operation]');
  ```

  NOTE

  - **action**: operation action. The options are as follows:
    - **ls**: Displays JAR packages in the database and checks the MD5 value consistency of files on each node.
    - **addjar**: deploys a JAR package on the OBS server in the database.
    - **rmjar**: Deletes JAR packages from the database.
  - **operation**: operation string. The format can be either of the following:

    obs://[bucket]/[source_filepath] accesskey=[accesskey] secretkey=[secretkey] region=[region] libraryname=[libraryname]
    - **bucket**: name of the bucket to which the OBS file belongs. It is mandatory.
    - **source_filepath**: file path on the OBS server. Only .jar files are supported.
    - **accesskey**: key obtained for accessing the OBS service. It is mandatory.
    - **secret_key**: secret key obtained for the OBS service. It is mandatory.
    - **region**: region where the OBS bucket stored in the JAR package of a user-defined function belongs to. This parameter is mandatory.
    - **libraryname**: user-defined library name, which is used to invoke JAR files in GaussDB(DWS). If **action** is set to **addjar** or **rmjar**, **libraryname** must be specified. If **action** is set to **ls**, **libraryname** is optional. Note that a user-defined library name cannot contain the following characters: /|;&$<>\'{}"() []~*?!

- Create functions.

  PL/Java functions can be created using the **CREATE FUNCTION** syntax and are defined as **LANGUAGE JAVA**, including the **RETURNS** and **AS** clauses.

  - To use **CREATE FUNCTION**, specify the name and parameter type for the function to be created.
  - The **RETURNS** clause specifies the return type for the function.
  - The **AS** clause specifies the class name and static method name of the Java method to be invoked. If the **NULL** value needs to be transferred to the Java method as an input parameter, specify the name of the Java encapsulation class corresponding to the parameter type. For details, see **NULL Handling**.
  - For details about the syntax, see CREATE FUNCTION.

    ```
    CREATE [ OR REPLACE ] FUNCTION function_name
    ( [ { argname [ argmode ] argtype [ { DEFAULT | := | = } expression ]} [, ...] ])
    [ RETURNS rettype [ DETERMINISTIC ] ]
    LANGAUGE JAVA
    [
       { IMMUTABLE | STATBLE | VOLATILE }
       | [ NOT ] LEAKPROOF
       | WINDOW
       | { CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT |STRICT }
       | {[ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER | AUTHID DEFINER |
    AUTHID CURRENT_USER}
       | { FENCED }
       | COST execution_cost
       | ROWS result_rows
    ```

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```
    | SET configuration_parameter { {TO |=} value | FROM CURRENT}
] [...]
{
    AS 'class_name.method_name' ( { argtype } [, ...] )
}
```

- Use functions.

  During execution, PL/Java searches for the Java class specified by a function among all the deployed JAR packages, which are ranked by name in alphabetical order, invokes the Java method in the first found class, and returns results.

- Delete functions.

  PL/Java functions can be deleted by using the **DROP FUNCTION** syntax. For details about the syntax, see DROP FUNCTION.

  ```
  DROP FUNCTION [ IF EXISTS ] function_name [ ( [ {[ argmode ] [ argname ] argtype} [, ...] ] )
  [ CASCADE | RESTRICT ] ];
  ```

  To delete an overloaded function (for details, see **Overloaded Functions**), specify **argtype** in the function. To delete other functions, simply specify **function_name**.

- Authorize permissions for functions.

  Only user **sysadmin** can create PL/Java functions. It can also grant other users the permission to use the PL/Java functions. For details about the syntax, see GRANT.

  ```
  GRANT { EXECUTE | ALL [ PRIVILEGES ] }
    ON { FUNCTION {function_name ( [ {[ argmode ] [ arg_name ] arg_type} [, ...] ] )} [, ...]
      | ALL FUNCTIONS IN SCHEMA schema_name [, ...] }
    TO { [ GROUP ] role_name | PUBLIC } [, ...]
    [ WITH GRANT OPTION ];
  ```

## Mapping for Basic Data Types

**Table 12-1** PL/Java mapping for default data types

| GaussDB(DWS) | Java |
| --- | --- |
| BOOLEAN | boolean |
| "char" | byte |
| bytea | byte[] |
| SMALLINT | short |
| INTEGER | int |
| BIGINT | long |
| FLOAT4 | float |
| FLOAT8 | double |
| CHAR | java.lang.String |
| VARCHAR | java.lang.String |
| TEXT | java.lang.String |

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| GaussDB(DWS) | Java |
| --- | --- |
| name | java.lang.String |
| DATE | java.sql.Timestamp |
| TIME | java.sql.Time (stored value treated as local time) |
| TIMETZ | java.sql.Time |
| TIMESTAMP | java.sql.Timestamp |
| TIMESTAMPTZ | java.sql.Timestamp |

## Array Type Processing

GaussDB(DWS) can convert basic array types. You only need to append a pair of square brackets ([]) to the data type when creating a function.

```
CREATE FUNCTION java_arrayLength(INTEGER[])
  RETURNS INTEGER
  AS 'Example.getArrayLength'
LANGUAGE JAVA;
```

Java code is similar to the following:

```
public class Example
{
  public static int getArrayLength(Integer[] intArray)
  {
    return intArray.length;
  }
}
```

Invoke the following statement:

```
SELECT java_arrayLength(ARRAY[1, 2, 3]);
```

The expected result is as follows:

```
java_arrayLength
----------------------
3
(1 row)
```

## NULL Handling

NULL values cannot be handled for GaussDB(DWS) data types that are mapped and can be converted to simple Java types by default. If you use a Java function to obtain and process the **NULL** value transferred from GaussDB(DWS), specify the Java encapsulation class in the **AS** clause as follows:

```
CREATE FUNCTION java_countnulls(INTEGER[])
  RETURNS INTEGER
  AS 'Example.countNulls(java.lang.Integer[])'
LANGUAGE JAVA;
```

Java code is similar to the following:

```
public class Example
{
```

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```
    public static int countNulls(Integer[] intArray)
    {
        int nullCount = 0;
        for (int idx = 0; idx < intArray.length; ++idx)
        {
            if (intArray[idx] == null)
            nullCount++;
        }
        return nullCount;
    }
}
```

Invoke the following statement:

```
SELECT java_countNulls(ARRAY[null, 1, null, 2, null]);
```

The expected result is as follows:

```
java_countNulls
--------------------
3
(1 row)
```

## Overloaded Functions

PL/Java supports overloaded functions. You can create functions with the same name or invoke overloaded functions from Java code. The procedure is as follows:

**Step 1** Create overloaded functions.

For example, create two Java methods with the same name, and specify the methods dummy(int) and dummy(String) with different parameter types.

```
public class Example
{
    public static int dummy(int value)
    {
        return value*2;
    }
    public static String dummy(String value)
    {
        return value;
    }
}
```

In addition, create two functions with the same names as the above two functions in GaussDB(DWS).

```
CREATE FUNCTION java_dummy(INTEGER)
    RETURNS INTEGER
    AS 'Example.dummy'
LANGUAGE JAVA;

CREATE FUNCTION java_dummy(VARCHAR)
    RETURNS VARCHAR
    AS 'Example.dummy'
LANGUAGE JAVA;
```

**Step 2** Invoke the overloaded functions.

GaussDB(DWS) invokes the functions that match the specified parameter type. The results of invoking the above two functions are as follows:

```
SELECT java_dummy(5);
 java_dummy
-----------------
          10
```

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```
(1 row)

SELECT java_dummy('5');
 java_dummy
---------------
5
(1 row)
```

Note that GaussDB(DWS) may implicitly convert data types. Therefore, you are advised to specify the parameter type when invoking an overloaded function.

```
SELECT java_dummy(5::varchar);
 java_dummy
----------------
5
(1 row)
```

In this case, the specified parameter type is preferentially used for matching. If there is no Java method matching the specified parameter type, the system implicitly converts the parameter and searches for Java methods based on the conversion result.

```
SELECT java_dummy(5::INTEGER);
 java_dummy
-----------------
10
(1 row)

DROP FUNCTION java_dummy(INTEGER);

SELECT java_dummy(5::INTEGER);
 java_dummy
----------------
5
(1 row)
```

**NOTICE**

Data types supporting implicit conversion are as follows:

- **SMALLINT**: It can be converted to the **INTEGER** type by default.
- **SMALLINT** and **INTEGER**: They can be converted to the **BIGINT** type by default.
- **TINYINT**, **SMALLINT**, **INTEGER**, and **BIGINT**: They can be converted to the **BOOL** type by default.
- **CHAR**, **NAME**, **BIGINT**, **INTEGER**, **SMALLINT**, **TINYINT**, **RAW**, **FLOAT4**, **FLOAT8**, **BPCHAR**, **VARCHAR**, **NVARCHAR2**, **DATE**, **TIMESTAMP**, **TIMESTAMPTZ**, **NUMERIC**, and **SMALLDATETIME**: They can be converted to the **TEXT** type by default.
- **TEXT**, **CHAR**, **BIGINT**, **INTEGER**, **SMALLINT**, **TINYINT**, **RAW**, **FLOAT4**, **FLOAT8**, **BPCHAR**, **DATE**, **NVARCHAR2**, **TIMESTAMP**, **NUMERIC**, and **SMALLDATETIME**: They can be converted to the **VARCHAR** type by default.

**Step 3** Delete the overloaded functions.

To delete an overloaded function, specify the parameter type for the function. Otherwise, the function cannot be deleted.

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```
DROP FUNCTION java_dummy(INTEGER);
```

**----End**

## GUC Parameters

- **pljava_vmoptions**

  A session-level GUC parameter. It is used to set JVM startup parameters.

  ```
  SET pljava_vmoptions='-Xmx64m –Xms2m –XX:MaxMetaspaceSize=8m';
  ```

  **pljava_vmoptions** supports:

  – JDK8 JVM startup parameters.

  – JDK8 JVM system attributes (starting with **–D**, for example, **–Djava.ext.dirs**).

  **NOTICE**

  You are not advised to set any parameters that contain directories because such setting may lead to unpredictable behavior.

  – User-defined parameters (starting with **–D**, for example, **–Duser.defined.option**).

  **NOTICE**

  If a user sets **pljava_vmoptions** to a value beyond the value range, an error will be reported during function revoking.

  ```
  SET pljava_vmoptions=' illegal.option';
  SET
  SELECT java_dummy(5::int);
  ERROR:  UDF Error:cannot use PL/Java before successfully completing its setup.Please check if your pljava_vmoption is set correctly,since we do not ignore illegal parameters.Or check the log for more messages.
  ```

- **FencedUDFMemoryLimit**

  A session-level GUC parameter. It is used to specify the maximum virtual memory used by a single Fenced UDF Worker process initiated by a session.

  ```
  SET FencedUDFMemoryLimit='512MB';
  ```

  The value range of this parameter is (**150 MB**, **1G**]. If the value is greater than **1G**, an error will be reported immediately. If the value is less than or equal to **150 MB**, an error will be reported during function invoking.

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NOTICE

- If **FencedUDFMemoryLimit** is set to **0**, the virtual memory for a Fenced UDF Worker process will not be limited.
- You are advised to use **udf_memory_limit** to control the physical memory used by Fenced UDF Worker processes. You are not advised to use **FencedUDFMemoryLimit**, especially when Java UDFs are used. If you are clear about the impact of this parameter, set it based on the following information:
  - After a C Fenced UDF Worker process is started, it will occupy about 200 MB virtual memory, and about 16 MB physical memory.
  - After a Java Fenced UDF Worker process is started, it will occupy about 2.5 GB virtual memory, and about 50 MB physical memory.

## Exception Handling

If there is an exception in a JVM, PL/Java will export JVM stack information during the exception to a client.

## Logging

PL/Java uses the standard Java Logger. Therefore, you can record logs as follows:

```
Logger.getAnonymousLogger().config( "Time is " + new
Date(System.currentTimeMillis()));
```

An initialized Java Logger class is set to the **CONFIG** level by default, corresponding to the **LOG** level in GaussDB(DWS). In this case, log messages generated by Java Logger are all redirected to the GaussDB(DWS) backend. Then, the log messages are written into server logs or displayed on the user interface. MPPDB server logs record information at the **LOG**, **WARNING**, and **ERROR** levels. The SQL user interface displays logs at the **WARNING** and **ERROR** levels. The following table lists mapping between Java Logger levels and GaussDB(DWS) log levels.

**Table 12-2** PL/Java log levels

| java.util.logging.Level | GaussDB(DWS) Log Level |
| --- | --- |
| **SERVER** | ERROR |
| **WARINING** | WARNING |
| **CONFIG** | LOG |
| **INFO** | INFO |
| **FINE** | DEBUG1 |
| **FINER** | DEBUG2 |
| **FINEST** | DEBUG3 |

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You can change Java Logger levels. For example, if the Java Logger level is changed to **SEVERE** by the following Java code, log messages (**msg**) will not be recorded in GaussDB(DWS) logs during **WARNING** logging.

```
Logger log = Logger.getAnonymousLogger();
Log.setLevel(Level.SEVERE);
log.log(Level.WARNING, msg);
```

### Security Issues

In GaussDB(DWS), PL/Java is an untrusted language. Only user **sysadmin** can create PL/Java functions. The user can grant other users the permission for using the PL/Java functions. For details, see **Authorize permissions for functions**.

In addition, PL/Java controls user access to file systems, forbidding users from reading most system files, or writing, deleting, or executing any system files in Java methods.

## 12.2 PL/pgSQL Functions

PL/pgSQL is similar to PL/SQL of Oracle. It is a loadable procedural language.

The functions created using PL/pgSQL can be used in any place where you can use built-in functions. For example, you can create calculation functions with complex conditions and use them to define operators or use them for index expressions.

SQL is used by most databases as a query language. It is portable and easy to learn. Each SQL statement must be executed independently by a database server.

In this case, when a client application sends a query to the server, it must wait for it to be processed, receive and process the results, and then perform some calculation before sending more queries to the server. If the client and server are not on the same machine, all these operations will cause inter-process communication and increase network loads.

PL/pgSQL enables a whole computing part and a series of queries to be grouped inside a database server. This makes procedural language available and SQL easier to use. In addition, the client/server communication cost is reduced.

- Extra round-trip communication between clients and servers is eliminated.
- Intermediate results that are not required by clients do not need to be sorted or transmitted between the clients and servers.
- Parsing can be skipped in multiple rounds of queries.

PL/pgSQL can use all data types, operators, and functions in SQL.

For details about the PL/pgSQL syntax for creating functions, see **CREATE FUNCTION**. As mentioned earlier, PL/pgSQL is similar to PL/SQL of Oracle and is a loadable procedural language. Its application method is similar to that of **Stored Procedures**. There is only one difference. Stored procedures have no return values but the functions have.

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# 13 Stored Procedures

## 13.1 Stored Procedure

In GaussDB(DWS), business rules and logics are saved as stored procedures.

A stored procedure is a combination of SQL, PL/SQL, and Java statements, enabling business rule code to be moved from applications to databases and used by multiple programs at a time.

For details about how to create and invoke a stored procedure, see section "CREATE PROCEDURE" in *SQL Syntax*.

The functions and stored procedures created by using PL/pgSQL in **PL/pgSQL Functions** are applicable to all the following sections.

## 13.2 Data Types

A data type refers to a value set and an operation set defined on the value set. A GaussDB(DWS) database consists of tables, each of which is defined by its own columns. Each column corresponds to a data type. GaussDB(DWS) uses corresponding functions to perform operations on data based on data types. For example, GaussDB(DWS) can perform addition, subtraction, multiplication, and division operations on data of numeric values.

## 13.3 Data Type Conversion

Certain data types in the database support implicit data type conversions, such as assignments and parameters invoked by functions. For other data types, you can use the type conversion functions provided by GaussDB(DWS), such as the CAST function, to forcibly convert them.

**Table 13-1** lists common implicit data type conversions in GaussDB(DWS).

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NOTICE

The valid value range of DATE supported by GaussDB(DWS) is from 4713 B.C. to 294276 A.D.

**Table 13-1** Implicit data type conversions

| Raw Data Type | Target Data Type | Remarks |
| --- | --- | --- |
| CHAR | VARCHAR2 | - |
| CHAR | NUMBER | Raw data must consist of digits. |
| CHAR | DATE | Raw data cannot exceed the valid date range. |
| CHAR | RAW | - |
| CHAR | CLOB | - |
| VARCHAR2 | CHAR | - |
| VARCHAR2 | NUMBER | Raw data must consist of digits. |
| VARCHAR2 | DATE | Raw data cannot exceed the valid date range. |
| VARCHAR2 | CLOB | - |
| NUMBER | CHAR | - |
| NUMBER | VARCHAR2 | - |
| DATE | CHAR | - |
| DATE | VARCHAR2 | - |
| RAW | CHAR | - |
| RAW | VARCHAR2 | - |
| CLOB | CHAR | - |
| CLOB | VARCHAR2 | - |
| CLOB | NUMBER | Raw data must consist of digits. |
| INT4 | CHAR | - |

# 13.4 Arrays and Records

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# 13.4.1 Arrays

## Use of Array Types

Before the use of arrays, an array type needs to be defined:

Define an array type immediately after the **AS** keyword in a stored procedure. Run the following statement:

```
TYPE array_type IS VARRAY(size) OF data_type [NOT NULL];
```

Its parameters are as follows:

- **array_type**: indicates the name of the array type to be defined.
- **VARRAY**: indicates the array type to be defined.
- **size**: indicates the maximum number of members in the array type to be defined. The value is a positive integer.
- **data_type**: indicates the types of members in the array type to be created.
- **NOT NULL**: an optional constraint. It can be used to ensure that none of the elements in the array is **NULL**.

NOTE

- In GaussDB(DWS), an array automatically increases. If an access violation occurs, a null value will be returned, and no error message will be reported. If out-of-bounds write occurs in an array, the message **Subscript outside of limit** is displayed.
- The scope of an array type defined in a stored procedure takes effect only in this storage process.
- It is recommended that you use one of the preceding methods to define an array type. If both methods are used to define the same array type, GaussDB(DWS) prefers the array type defined in a stored procedure to declare array variables.

In GaussDB(DWS) 8.1.0 and earlier versions, the system does not verify the length of array elements and out-of-bounds write because the array can automatically increase. This version adds related constraints to be compatible with Oracle databases. If out-of-bounds write exists, you can configure **varray_verification** in the parameter **behavior_compat_options** to be compatible with previously unverified operations.

Example:

```
-- Declare an array in a stored procedure.
CREATE OR REPLACE PROCEDURE array_proc
AS
    TYPE ARRAY_INTEGER IS VARRAY(1024) OF INTEGER;--Define the array type.
    TYPE ARRAY_INTEGER_NOT_NULL IS VARRAY(1024) OF INTEGER NOT NULL;-- Defines non-null array
types.
    ARRINT ARRAY_INTEGER: = ARRAY_INTEGER();  --Declare the variable of the array type.
BEGIN
    ARRINT.extend(10);
    FOR I IN 1..10 LOOP
        ARRINT(I) := I;
    END LOOP;
    DBMS_OUTPUT.PUT_LINE(ARRINT.COUNT);
    DBMS_OUTPUT.PUT_LINE(ARRINT(1));
    DBMS_OUTPUT.PUT_LINE(ARRINT(10));
    DBMS_OUTPUT.PUT_LINE(ARRINT(ARRINT.FIRST));
    DBMS_OUTPUT.PUT_LINE(ARRINT(ARRINT.last));
END;
/
```

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```
-- Invoke the stored procedure.
CALL array_proc();
10
1
10
1
10

-- Delete the stored procedure.
DROP PROCEDURE array_proc;
```

## Declaration and Use of Rowtype Arrays

In addition to the declaration and use of common arrays and non-null arrays in the preceding example, the array also supports the declaration and use of rowtype arrays.

Example:

```
-- Use the COUNT function on an array in a stored procedure.
CREATE TABLE tbl (a int, b int);
INSERT INTO tbl VALUES(1, 2),(2, 3),(3, 4);
CREATE OR REPLACE PROCEDURE array_proc
AS
    CURSOR all_tbl IS SELECT * FROM tbl ORDER BY a;
    TYPE tbl_array_type IS varray(50) OF tbl%rowtype; -- Defines the array of the rowtype type. tbl indicates
any table.
    tbl_array tbl_array_type;
    tbl_item tbl%rowtype;
    inx1 int;
BEGIN
    tbl_array := tbl_array_type();
    inx1 := 0;
    FOR tbl_item IN all_tbl LOOP
        inx1 := inx1 + 1;
        tbl_array(inx1) := tbl_item;
    END LOOP;
    WHILE inx1 IS NOT NULL LOOP
        DBMS_OUTPUT.PUT_LINE('tbl_array(inx1).a=' || tbl_array(inx1).a || ' tbl_array(inx1).b=' ||
tbl_array(inx1).b);
        inx1 := tbl_array.PRIOR(inx1);
    END LOOP;
END;
/
```

The execution output is as follows:

```
call array_proc();
tbl_array(inx1).a=3 tbl_array(inx1).b=4
tbl_array(inx1).a=2 tbl_array(inx1).b=3
tbl_array(inx1).a=1 tbl_array(inx1).b=2
```

## Array Related Functions

GaussDB(DWS) supports Oracle-related array functions. You can use the following functions to obtain array attributes or perform operations on the array content.

## COUNT

Returns the number of elements in the current array. Only the initialized elements or the elements extended by the EXTEND function are counted.

Use:

*varray*.**COUNT** or *varray*.**COUNT()**

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Example:

```
-- Use the COUNT function on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
AS
    TYPE varray_type IS VARRAY(20) OF INT;
    v_varray varray_type;
BEGIN
    v_varray := varray_type(1, 2, 3);
    DBMS_OUTPUT.PUT_LINE('v_varray.count=' || v_varray.count);
    v_varray.extend;
    DBMS_OUTPUT.PUT_LINE('v_varray.count=' || v_varray.count);
END;
/
```

The execution output is as follows:

```
call test_varray();
v_varray.count=3
v_varray.count=4
```

## FIRST and LAST

The FIRST function can return the subscript of the first element. The LAST function can return the subscript of the last element.

Use:

*varray*.**FIRST** or *varray*.**FIRST()**

*varray*.**LAST** or *varray*.**LAST()**

Example:

```
-- Use the FIRST and LAST functions on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
AS
    TYPE varray_type IS VARRAY(20) OF INT;
    v_varray varray_type;
BEGIN
    v_varray := varray_type(1, 2, 3);
    DBMS_OUTPUT.PUT_LINE('v_varray.first=' || v_varray.first);
    DBMS_OUTPUT.PUT_LINE('v_varray.last=' || v_varray.last);
END;
/
```

The execution output is as follows:

```
call test_varray();
v_varray.first=1
v_varray.last=3
```

## EXTEND

**NOTE**

The EXTEND function is used to be compatible with two Oracle database operations. In GaussDB(DWS), an array automatically grows, and the EXTEND function is not necessary. For a newly written stored procedure, you do not need to use the EXTEND function.

The EXTEND function can extend arrays. The EXTEND function can be invoked in either of the following ways:

- Method 1:

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EXTEND contains an integer input parameter, indicating that the array size is extended by the specified length. After executing the EXTEND function, the values of the COUNT and LAST functions change accordingly.

Use:

*varray*.EXTEND(size)

By default, one bit is added to the end of *varray*.**EXTEND**, which is equivalent to *varray*.**EXTEND(1)**.

- Method 2:

  EXTEND contains two integer input parameters. The first parameter indicates the length of the extended size. The second parameter indicates that the value of the extended array element is the same as that of the element with the **index** subscript.

  Use:

  *varray*.EXTEND(size, index)

Example:

```
-- Use the EXTEND function on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
AS
   TYPE varray_type IS VARRAY(20) OF INT;
   v_varray varray_type;
BEGIN
   v_varray := varray_type(1, 2, 3);
   v_varray.extend(3);
   DBMS_OUTPUT.PUT_LINE('v_varray.count=' || v_varray.count);
   v_varray.extend(2,3);
   DBMS_OUTPUT.PUT_LINE('v_varray.count=' || v_varray.count);
   DBMS_OUTPUT.PUT_LINE('v_varray(7)=' || v_varray(7));
   DBMS_OUTPUT.PUT_LINE('v_varray(8)=' || v_varray(7));
END;
/
```

The execution output is as follows:

```
call test_varray();
v_varray.count=6
v_varray.count=8
v_varray(7)=3
v_varray(8)=3
```

## NEXT and PRIOR

The NEXT and PRIOR functions are used for cyclic array traversal. The NEXT function returns the subscript of the next array element based on the input parameter **index**. If the subscript reaches the maximum value, **NULL** is returned. The PRIOR function returns the subscript of the previous array element based on the input parameter **index**. If the minimum value of the array subscript is reached, **NULL** is returned.

Use:

*varray*.NEXT(index)

*varray*.PRIOR(index)

Example:

```
-- Use the NEXT and PRIOR functions on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
```

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```
AS
    TYPE varray_type IS VARRAY(20) OF INT;
    v_varray varray_type;
    i int;
BEGIN
    v_varray := varray_type(1, 2, 3);

    i := v_varray.COUNT;
    WHILE i IS NOT NULL LOOP
        DBMS_OUTPUT.PUT_LINE('test prior v_varray('||i||')=' || v_varray(i));
        i := v_varray.PRIOR(i);
    END LOOP;

    i := 1;
    WHILE i IS NOT NULL LOOP
        DBMS_OUTPUT.PUT_LINE('test next v_varray('||i||')=' || v_varray(i));
        i := v_varray.NEXT(i);
    END LOOP;
END;
/
```

The execution output is as follows:

```
call test_varray();
test prior v_varray(3)=3
test prior v_varray(2)=2
test prior v_varray(1)=1
test next v_varray(1)=1
test next v_varray(2)=2
test next v_varray(3)=3
```

## EXISTS

Determines whether an array subscript exists.

Use:

*varray*.EXISTS(index)

Example:

```
-- Use the EXISTS function on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
AS
    TYPE varray_type IS VARRAY(20) OF INT;
    v_varray varray_type;
BEGIN
    v_varray := varray_type(1, 2, 3);
    IF v_varray.EXISTS(1) THEN
        DBMS_OUTPUT.PUT_LINE('v_varray.EXISTS(1)');
    END IF;
    IF NOT v_varray.EXISTS(10) THEN
        DBMS_OUTPUT.PUT_LINE('NOT v_varray.EXISTS(10)');
    END IF;
END;
/
```

The execution output is as follows:

```
call test_varray();
v_varray.EXISTS(1)
NOT v_varray.EXISTS(10)
```

## TRIM

Deletes a specified number of elements from the end of an array.

Use:

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*varray*.TRIM(size)

*varray*.**TRIM** is equivalent to *varray*.**TRIM(1)**, because the default input parameter is **1**.

Example:

```
-- Use the TRIM function on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
AS
    TYPE varray_type IS VARRAY(20) OF INT;
    v_varray varray_type;
BEGIN
    v_varray := varray_type(1, 2, 3, 4, 5);
    v_varray.trim(3);
    DBMS_OUTPUT.PUT_LINE('v_varray.count' || v_varray.count);
    v_varray.trim;
    DBMS_OUTPUT.PUT_LINE('v_varray.count:' || v_varray.count);
END;
/
```

The execution output is as follows:

```
call test_varray();
v_varray.count:2
v_varray.count:1
```

## DELETE

Deletes all elements from an array.

Use:

*varray*.**DELETE** or *varray*.**DELETE()**

Example:

```
-- Use the DELETE function on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
AS
    TYPE varray_type IS VARRAY(20) OF INT;
    v_varray varray_type;
BEGIN
    v_varray := varray_type(1, 2, 3, 4, 5);
    v_varray.delete;
    DBMS_OUTPUT.PUT_LINE('v_varray.count:' || v_varray.count);
END;
/
```

The execution output is as follows:

```
call test_varray();
v_varray.count:0
```

## LIMIT

Returns the allowed maximum length of an array.

Use:

*varray*.**LIMIT** or *varray*.**LIMIT()**

Example:

```
-- Use the LIMIT function on an array in a stored procedure.
CREATE OR REPLACE PROCEDURE test_varray
```

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```
AS
    TYPE varray_type IS VARRAY(20) OF INT;
    v_varray varray_type;
BEGIN
    v_varray := varray_type(1, 2, 3, 4, 5);
    DBMS_OUTPUT.PUT_LINE('v_varray.limit:' || v_varray.limit);
END;
/
```

The execution output is as follows:

```
call test_varray();
v_varray.limit:20
```

# 13.4.2 record

## record Variables

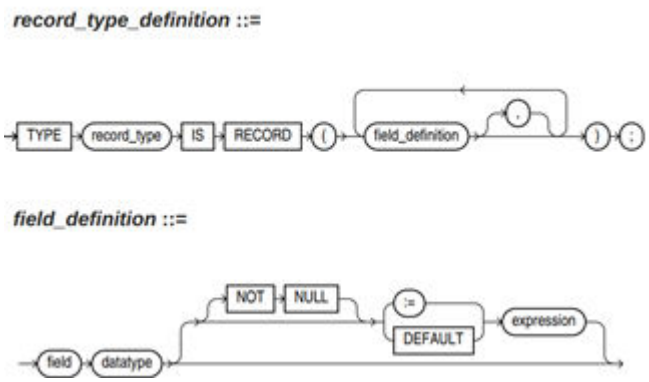
Perform the following operations to create a record variable:

Define a record type and use this type to declare a variable.

## Syntax

For the syntax of the record type, see **Figure 13-1**.

**Figure 13-1** Syntax of the record type




The syntax is described as follows:

- **record_type**: record name
- **field**: record columns
- **datatype**: record data type
- **expression**: expression for setting a default value

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**NOTE**

In GaussDB(DWS):

- When assigning values to record variables, you can:
  - Declare a record type and define member variables of this type when you declare a function or stored procedure.
  - Assign the value of a record variable to another record variable.
  - Use **SELECT INTO** or **FETCH** to assign values to a record type.
  - Assign the **NULL** value to a record variable.
- The **INSERT** and **UPDATE** statements cannot use a record variable to insert or update data.
- Just like a variable, a record column of the compound type does not have a default value in the declaration.

## Examples

```
The table used in the following stored procedure is defined as follows:
CREATE TABLE emp_rec
(
    empno            numeric(4,0),
    ename            character varying(10),
    job              character varying(9),
    mgr              numeric(4,0),
    hiredate         timestamp(0) without time zone,
    sal              numeric(7,2),
    comm             numeric(7,2),
    deptno           numeric(2,0)
)
with (orientation = column,compression=middle)
distribute by hash (sal);
\d emp_rec
                Table "public.emp_rec"
  Column  |              Type              | Modifiers
----------+--------------------------------+-----------
 empno    | numeric(4,0)                   |
 ename    | character varying(10)          |
 job      | character varying(9)           |
 mgr      | numeric(4,0)                   |
 hiredate | timestamp(0) without time zone |
 sal      | numeric(7,2)                   |
 comm     | numeric(7,2)                   |
 deptno   | numeric(2,0)                   |

-- Perform array operations in the stored procedure.
CREATE OR REPLACE FUNCTION regress_record(p_w VARCHAR2)
RETURNS
VARCHAR2  AS $$
DECLARE

  -- Declare a record type.
  type rec_type is record (name  varchar2(100), epno int);
  employer rec_type;

  -- Use %type to declare the record type.
  type rec_type1 is record (name  emp_rec.ename%type, epno int not null :=10);
  employer1 rec_type1;

  -- Declare a record type with a default value.
  type rec_type2 is record (
       name varchar2 not null := 'SCOTT',
       epno int not null :=10);
   employer2 rec_type2;
   CURSOR C1 IS  select ename,empno from emp_rec order by 1 limit 1;
```

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```
BEGIN
     -- Assign a value to a member record variable.
    employer.name := 'WARD';
    employer.epno = 18;
    raise info 'employer name: % , epno:%', employer.name, employer.epno;

     -- Assign the value of a record variable to another variable.
    employer1 := employer;
    raise info 'employer1 name: % , epno: %',employer1.name, employer1.epno;

     -- Assign the NULL value to a record variable.
    employer1 := NULL;
    raise info 'employer1 name: % , epno: %',employer1.name, employer1.epno;

     -- Obtain the default value of a record variable.
    raise info 'employer2 name: % ,epno: %', employer2.name, employer2.epno;

     -- Use a record variable in the FOR loop.
     for employer in select ename,empno from emp_rec order by 1  limit 1
        loop
            raise info 'employer name: % , epno: %', employer.name, employer.epno;
        end loop;

     -- Use a record variable in the SELECT INTO statement.
     select ename,empno  into employer2 from emp_rec order by 1 limit 1;
     raise info 'employer name: % , epno: %', employer2.name, employer2.epno;

     -- Use a record variable in a cursor.
     OPEN C1;
     FETCH C1 INTO employer2;
     raise info 'employer name: % , epno: %', employer2.name, employer2.epno;
     CLOSE C1;
     RETURN employer.name;
END;
$$
LANGUAGE plpgsql;

-- Invoke the stored procedure.
CALL regress_record('abc');
INFO:  employer name: WARD , epno:18
INFO:  employer1 name: WARD , epno: 18
INFO:  employer1 name: <NULL> , epno: <NULL>
INFO:  employer2 name: SCOTT ,epno: 10

-- Delete the stored procedure.
DROP PROCEDURE regress_record;
```

# 13.5 Syntax

## 13.5.1 Basic Structure

### Structure

A PL/SQL block can contain a sub-block which can be placed in any section. The following describes the architecture of a PL/SQL block:

- **DECLARE**: declares variables, types, cursors, and regional stored procedures and functions used in the PL/SQL block.
  ```
  DECLARE
  ```

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NOTE

This part is optional if no variable needs to be declared.

- An anonymous block may omit the **DECLARE** keyword if no variable needs to be declared.
- For a stored procedure, **AS** is used, which is equivalent to **DECLARE**. The **AS** keyword must be reserved even if there is no variable declaration part.

- **EXECUTION**: specifies procedure and SQL statements. It is the main part of a program. Mandatory
  ```
  BEGIN
  ```
- **EXCEPTION**: processes errors. Optional
  ```
  EXCEPTION
  ```
- **END**
  ```
  END;
  /
  ```

NOTICE

You are not allowed to use consecutive tabs in the PL/SQL block, because they may result in an exception when the parameter **-r** is executed using the **gsql** tool.

### Type

PL/SQL blocks are classified into the following types:

- Anonymous block: a dynamic block that can be executed only for once. For details about the syntax, see **Figure 13-2**.
- Subprogram: a stored procedure, function, operator, or packages stored in a database. A subprogram created in a database can be called by other programs.

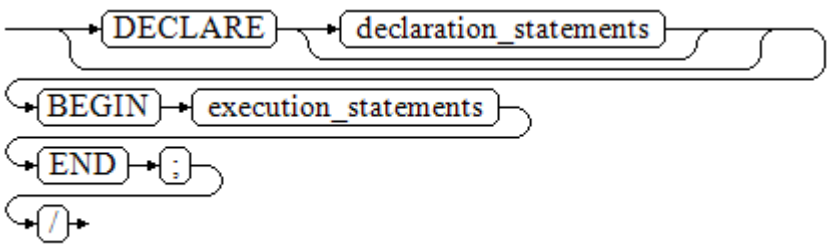
## 13.5.2 Anonymous Block

An anonymous block applies to a script infrequently executed or a one-off activity. An anonymous block is executed in a session and is not stored.

### Syntax

**Figure 13-2** shows the syntax diagrams for an anonymous block.

**Figure 13-2** anonymous_block::=

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Details about the syntax diagram are as follows:

- The execute part of an anonymous block starts with a **BEGIN** statement, has a break with an **END** statement, and ends with a semicolon (;). Type a slash (/) and press **Enter** to execute the statement.

  **NOTICE**

  The terminator "/" must be written in an independent row.

- The declaration section includes the variable definition, type, and cursor definition.
- A simplest anonymous block does not execute any commands. At least one statement, even a null statement, must be presented in any implementation blocks.

### Examples

The following lists basic anonymous block programs:

```
-- Null statement block:
BEGIN
    NULL;
END;
/

-- Print information to the console:
BEGIN
    dbms_output.put_line('hello world!');
END;
/

-- Print variable contents to the console:
DECLARE
    my_var VARCHAR2(30);
BEGIN
    my_var :='world';
    dbms_output.put_line('hello'||my_var);
END;
/
```

## 13.5.3 Subprogram

A subprogram stores stored procedures, functions, operators, and advanced packages. A subprogram created in a database can be called by other programs.

# 13.6 Basic Statements

## 13.6.1 Variable Definition Statement

This section describes the declaration of variables in the PL/SQL and the scope of this variable in codes.

### Variable Declaration

For details about the variable declaration syntax, see **Figure 13-3**.

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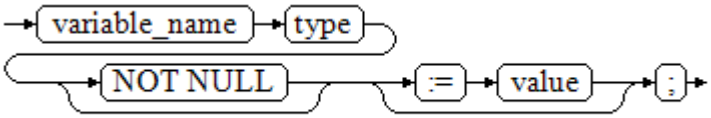
**Figure 13-3** declare_variable::=




The above syntax diagram is explained as follows:

- **variable_name** indicates the name of a variable.
- **type** indicates the type of a variable.
- **value** indicates the initial value of the variable. (If the initial value is not given, NULL is taken as the initial value.) **value** can also be an expression.

Example:

```
DECLARE
    emp_id  INTEGER := 7788; -- Define a variable and assign a value to it.
BEGIN
    emp_id := 5*7784; -- Assign a value to the variable.
END;
/
```

In addition to the declaration of basic variable types, %TYPE and %ROWTYPE can be used to declare variables related to table columns or table structures.

## %TYPE Attribute

%TYPE declares a variable to be of the same data type as a previously declared variable (for example, a column in a table). For example, if you want to define a **my_name** variable whose data type is the same as the data type of the **firstname** column in the **employee** table, you can define the variable as follows:

```
my_name employee.firstname%TYPE
```

In this way, you can declare **my_name** without the need of knowing the data type of **firstname** in **employee**, and the data type of **my_name** can be automatically updated when the data type of **firstname** changes.

## %ROWTYPE Attribute

%ROWTYPE declares data types of a set of data. It stores a row of table data or results fetched from a cursor. For example, if you want to define a set of data with the same column names and column data types as the **employee** table, you can define the data as follows:

```
my_employee employee%ROWTYPE
```

**NOTICE**

If multiple CNs are used, the %ROWTYPE and %TYPE attributes of temporary tables cannot be declared in a stored procedure, because a temporary table is valid only in the current session and is invisible to other CNs in the compilation phase. In this case, a message is displayed indicating that the temporary table does not exist.

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### Scope of a Variable

The scope of a variable indicates the accessibility and availability of a variable in code block. In other words, a variable takes effect only within its scope.

- To define a function scope, a variable must declare and create a **BEGIN-END** block in the declaration section. The necessity of such declaration is also determined by block structure, which requires that a variable has different scopes and lifetime during a process.
- A variable can be defined multiple times in different scopes, and inner definition can cover outer one.
- A variable defined in an outer block can also be used in a nested block. However, the outer block cannot access variables in the nested block.

Example:

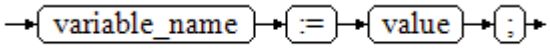
```
DECLARE
    emp_id  INTEGER :=7788; -- Define a variable and assign a value to it.
    outer_var  INTEGER :=6688; -- Define a variable and assign a value to it.
BEGIN
    DECLARE
        emp_id INTEGER :=7799; -- Define a variable and assign a value to it.
        inner_var  INTEGER :=6688; -- Define a variable and assign a value to it.
    BEGIN
        dbms_output.put_line('inner emp_id ='||emp_id); -- Display the value as 7799.
        dbms_output.put_line('outer_var ='||outer_var); -- Cite variables of an outer block.
    END;
    dbms_output.put_line('outer emp_id ='||emp_id); -- Display the value as 7788.
END;
/
```

## 13.6.2 Assignment Statement

### Syntax

Figure 13-4 shows the syntax diagram for assigning a value to a variable.

**Figure 13-4** assignment_value::=




The above syntax diagram is explained as follows:

- **variable_name** indicates the name of a variable.
- **value** can be a value or an expression. The type of **value** must be compatible with the type of **variable_name**.

### Examples

```
DECLARE
    emp_id  INTEGER := 7788; --Assignment
BEGIN
    emp_id := 5; --Assignment
    emp_id := 5*7784;
END;
/
```

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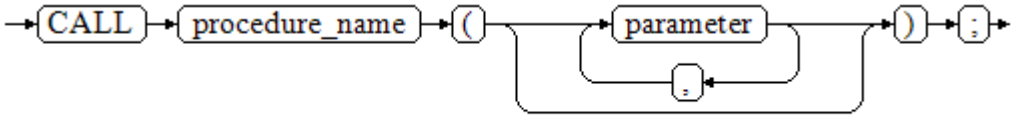
# 13.6.3 Call Statement

## Syntax

Figure 13-5 shows the syntax diagram for calling a clause.

**Figure 13-5** call_clause::=




The above syntax diagram is explained as follows:

- **procedure_name** specifies the name of a stored procedure.
- **parameter** specifies the parameters for the stored procedure. You can set no parameter or multiple parameters.

## Examples

```
-- Create the stored procedure proc_staffs:
CREATE OR REPLACE PROCEDURE proc_staffs
(
section     NUMBER(6),
salary_sum out NUMBER(8,2),
staffs_count out INTEGER
)
IS
BEGIN
SELECT sum(salary), count(*) INTO salary_sum, staffs_count FROM staffs where section_id = section;
END;
/

-- Create the stored procedure proc_return:
CREATE OR REPLACE PROCEDURE proc_return
AS
v_num NUMBER(8,2);
v_sum INTEGER;
BEGIN
proc_staffs(30, v_sum, v_num);  --Invoke a statement
dbms_output.put_line(v_sum||'#'||v_num);
RETURN;   --Return a statement
END;
/

-- Invoke a stored procedure proc_return:
CALL proc_return();

-- Delete a stored procedure:
DROP PROCEDURE proc_staffs;
DROP PROCEDURE proc_return;

--Create the function func_return.
CREATE OR REPLACE FUNCTION func_return returns void
language plpgsql
AS $$
DECLARE
v_num INTEGER := 1;
BEGIN
dbms_output.put_line(v_num);
```

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```
RETURN;   --Return a statement
END $$;


-- Invoke the function func_return.
 CALL func_return();
1

-- Delete the function:
 DROP FUNCTION func_return;
```

# 13.7 Dynamic Statements

## 13.7.1 Executing Dynamic Query Statements

You can perform dynamic queries using **EXECUTE IMMEDIATE** or **OPEN FOR** in GaussDB(DWS). **EXECUTE IMMEDIATE** dynamically executes **SELECT** statements and **OPEN FOR** combines use of cursors. If you need to store query results in a data set, use **OPEN FOR**.

### EXECUTE IMMEDIATE

**Figure 13-6** shows the syntax diagram.

**Figure 13-6** EXECUTE IMMEDIATE dynamic_select_clause::=

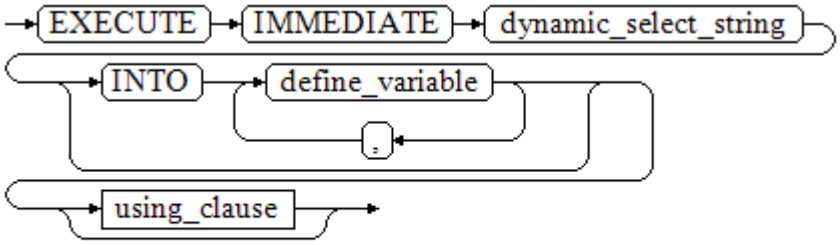
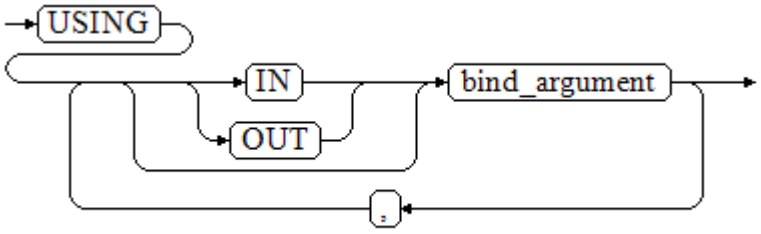



**Figure 13-7** shows the syntax diagram for **using_clause**.

**Figure 13-7** using_clause-1




The above syntax diagram is explained as follows:

- **define_variable**: specifies variables to store single-line query results.

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- **USING IN bind_argument**: specifies where the variable passed to the dynamic SQL value is stored, that is, in the dynamic placeholder of **dynamic_select_string**.
- **USING OUT bind_argument**: specifies where the dynamic SQL returns the value of the variable.

**NOTICE**

- In query statements, **INTO** and **OUT** cannot coexist.
- A placeholder name starts with a colon (:) followed by digits, characters, or strings, corresponding to *bind_argument* in the **USING** clause.
- *bind_argument* can only be a value, variable, or expression. It cannot be a database object such as a table name, column name, and data type. That is, *bind_argument* cannot be used to transfer schema objects for dynamic SQL statements. If a stored procedure needs to transfer database objects through *bind_argument* to construct dynamic SQL statements (generally, DDL statements), you are advised to use double vertical bars (||) to concatenate *dynamic_select_clause* with a database object.
- A dynamic PL/SQL block allows duplicate placeholders. That is, a placeholder can correspond to only one *bind_argument* in the **USING** clause.

**Example**

```
--Retrieve values from dynamic statements (INTO clause).
DECLARE
  staff_count  VARCHAR2(20);
BEGIN
  EXECUTE IMMEDIATE 'select count(*) from staffs'
    INTO staff_count;
  dbms_output.put_line(staff_count);
END;
/

--Pass and retrieve values (the INTO clause is used before the USING clause).
CREATE OR REPLACE PROCEDURE dynamic_proc
AS
  staff_id     NUMBER(6) := 200;
  first_name   VARCHAR2(20);
  salary       NUMBER(8,2);
BEGIN
  EXECUTE IMMEDIATE 'select first_name, salary from staffs where staff_id = :1'
     INTO first_name, salary
     USING IN staff_id;
  dbms_output.put_line(first_name || ' ' || salary);
END;
/

-- Invoke the stored procedure.
CALL dynamic_proc();

-- Delete the stored procedure.
DROP PROCEDURE dynamic_proc;
```

## OPEN FOR

Dynamic query statements can be executed by using **OPEN FOR** to open dynamic cursors.

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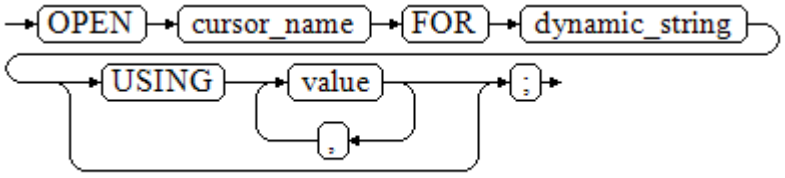
For details about the syntax, see **Figure 13-8**.

**Figure 13-8** open_for::=




Parameter description:

- **cursor_name**: specifies the name of the cursor to be opened.
- **dynamic_string**: specifies the dynamic query statement.
- **USING** *value*: applies when a placeholder exists in dynamic_string.

For use of cursors, see **Cursors**.

**Example**

```
DECLARE
    name           VARCHAR2(20);
    phone_number   VARCHAR2(20);
    salary         NUMBER(8,2);
    sqlstr         VARCHAR2(1024);

    TYPE app_ref_cur_type IS REF CURSOR; -- Define the cursor type.
    my_cur app_ref_cur_type; -- Define the cursor variable.

BEGIN
    sqlstr := 'select first_name,phone_number,salary from staffs
        where section_id = :1';
    OPEN my_cur FOR sqlstr USING '30'; -- Open the cursor. using is optional.
    FETCH my_cur INTO name, phone_number, salary; -- Retrieve the data.
    WHILE my_cur%FOUND LOOP
        dbms_output.put_line(name||'#'||phone_number||'#'||salary);
        FETCH my_cur INTO name, phone_number, salary;
    END LOOP;
    CLOSE my_cur; -- Close the cursor.
END;
/
```

## 13.7.2 Executing Dynamic Non-query Statements

### Syntax

**Figure 13-9** shows the syntax diagram.

**Figure 13-9** noselect::=

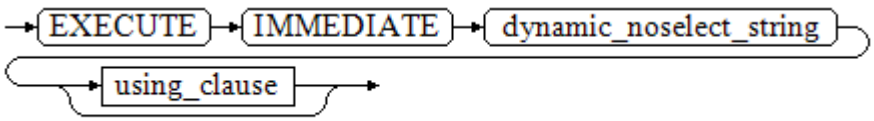



**Figure 13-10** shows the syntax diagram for **using_clause**.

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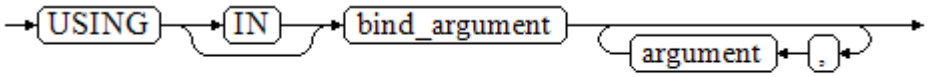
**Figure 13-10** using_clause-2




The above syntax diagram is explained as follows:

**USING IN bind_argument** is used to specify the variable that transfers values to dynamic SQL statements. It is used when a placeholder exists in **dynamic_noselect_string**. That is, a placeholder is replaced by the corresponding *bind_argument* when a dynamic SQL statement is executed. Note that *bind_argument* can only be a value, variable, or expression, and cannot be a database object such as a table name, column name, and data type. If a stored procedure needs to transfer database objects through *bind_argument* to construct dynamic SQL statements (generally, DDL statements), you are advised to use double vertical bars (||) to concatenate *dynamic_select_clause* with a database object. In addition, a dynamic PL/SQL block allows duplicate placeholders. That is, a placeholder can correspond to only one *bind_argument*.

## Examples

```
-- Create a table:
CREATE TABLE sections_t1
(
  section       NUMBER(4) ,
  section_name  VARCHAR2(30),
  manager_id    NUMBER(6),
  place_id      NUMBER(4)
)
DISTRIBUTE BY hash(manager_id);

--Declare a variable:
DECLARE
  section       NUMBER(4) := 280;
  section_name  VARCHAR2(30) := 'Info support';
  manager_id    NUMBER(6) := 103;
  place_id      NUMBER(4) := 1400;
  new_colname   VARCHAR2(10) := 'sec_name';
BEGIN
-- Execute the query:
    EXECUTE IMMEDIATE 'insert into sections_t1 values(:1, :2, :3, :4)'
      USING section, section_name, manager_id,place_id;
-- Execute the query (duplicate placeholders):
    EXECUTE IMMEDIATE 'insert into sections_t1 values(:1, :2, :3, :1)'
      USING section, section_name, manager_id;
-- Run the ALTER statement. (You are advised to use double vertical bars (||) to concatenate the dynamic
DDL statement with a database object.)
    EXECUTE IMMEDIATE 'alter table sections_t1 rename section_name to ' || new_colname;
END;
/

-- Query data:
SELECT * FROM sections_t1;

--Delete the table.
DROP TABLE sections_t1;
```

# 13.7.3 Dynamically Calling Stored Procedures

This section describes how to dynamically call store procedures. You must use anonymous statement blocks to package stored procedures or statement blocks

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and append **IN** and **OUT** behind the **EXECUTE IMMEDIATE...USING** statement to input and output parameters.

## Syntax

**Figure 13-11** shows the syntax diagram.

**Figure 13-11** call_procedure::=

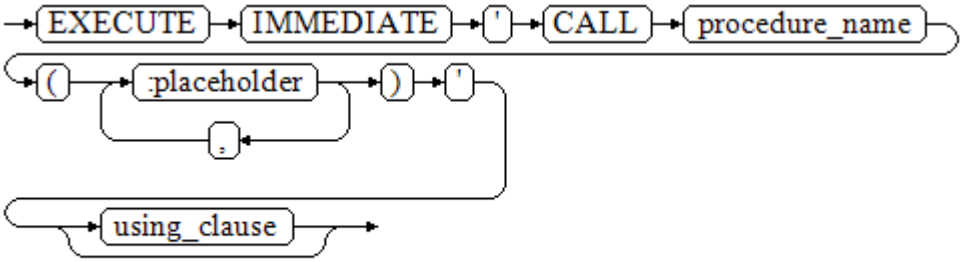
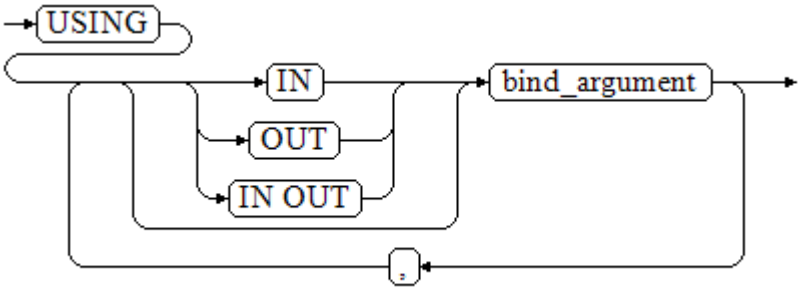



**Figure 13-12** shows the syntax diagram for **using_clause**.

**Figure 13-12** using_clause-3




The above syntax diagram is explained as follows:

- **CALL procedure_name**: calls the stored procedure.
- **[:placeholder1,:placeholder2,...]**: specifies the placeholder list of the stored procedure parameters. The numbers of the placeholders and the parameters are the same.
- **USING [IN|OUT|IN OUT]bind_argument**: specifies where the variable passed to the stored procedure parameter value is stored. The modifiers in front of **bind_argument** and of the corresponding parameter are the same.

## Examples

```
--Create the stored procedure proc_add:
CREATE OR REPLACE PROCEDURE proc_add
(
    param1    in   INTEGER,
    param2    out  INTEGER,
    param3    in   INTEGER
)
AS
```

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```
BEGIN
   param2:= param1 + param3;
END;
/

DECLARE
    input1 INTEGER:=1;
    input2 INTEGER:=2;
    statement  VARCHAR2(200);
    param2     INTEGER;
BEGIN
   --Declare the call statement:
    statement := 'call proc_add(:col_1, :col_2, :col_3)';
   --Execute the statement:
    EXECUTE IMMEDIATE statement
        USING IN input1, OUT param2, IN input2;
    dbms_output.put_line('result is: '||to_char(param2));
END;
/

-- Delete the stored procedure.
DROP PROCEDURE proc_add;
```

## 13.7.4 Dynamically Calling Anonymous Blocks

This section describes how to execute anonymous blocks in dynamic statements. Append **IN** and **OUT** behind the **EXECUTE IMMEDIATE...USING** statement to input and output parameters.

### Syntax

**Figure 13-13** shows the syntax diagram.

**Figure 13-13** call_anonymous_block::=

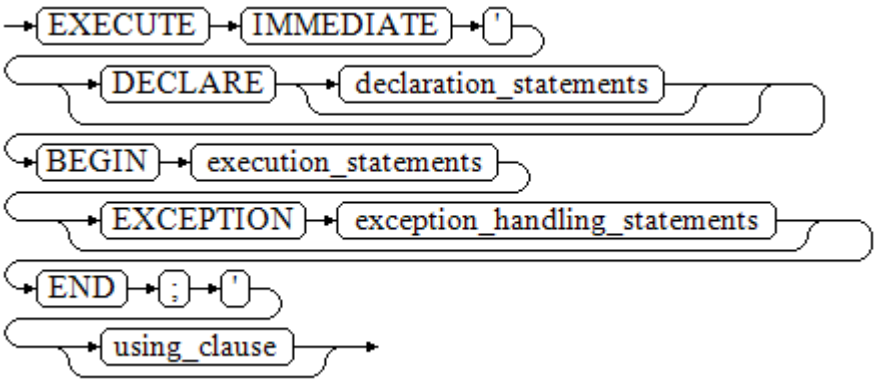


**Figure 13-14** shows the syntax diagram for **using_clause**.

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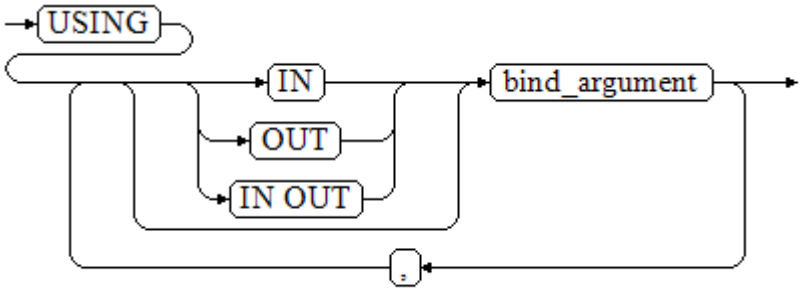
**Figure 13-14** using_clause-4




The above syntax diagram is explained as follows:

- The execute part of an anonymous block starts with a **BEGIN** statement, has a break with an **END** statement, and ends with a semicolon (;).
- **USING [IN|OUT|IN OUT]bind_argument**: specifies where the variable passed to the stored procedure parameter value is stored. The modifiers in front of **bind_argument** and of the corresponding parameter are the same.
- The input and output parameters in the middle of an anonymous block are designated by placeholders. The numbers of the placeholders and the parameters are the same. The sequences of the parameters corresponding to the placeholders and the USING parameters are the same.
- Currently in GaussDB(DWS), when dynamic statements call anonymous blocks, placeholders cannot be used to pass input and output parameters in an **EXCEPTION** statement.

## Example

```
--Create the stored procedure dynamic_proc.
CREATE OR REPLACE PROCEDURE dynamic_proc
AS
   staff_id     NUMBER(6) := 200;
   first_name   VARCHAR2(20);
   salary       NUMBER(8,2);
BEGIN
--Execute the anonymous block.
    EXECUTE IMMEDIATE 'begin select first_name, salary into :first_name, :salary from staffs where
staff_id= :dno; end;'
       USING OUT first_name, OUT salary, IN staff_id;
   dbms_output.put_line(first_name|| ' ' || salary);
END;
/

-- Invoke the stored procedure.
CALL dynamic_proc();

-- Delete the stored procedure.
DROP PROCEDURE dynamic_proc;
```

# 13.8 Control Statements

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# 13.8.1 RETURN Statements

In GaussDB(DWS), data can be returned in either of the following ways: **RETURN**, **RETURN NEXT**, or **RETURN QUERY**. **RETURN NEXT** and **RETURN QUERY** are used only for functions and cannot be used for stored procedures.

## 13.8.1.1 RETURN

### Syntax

**Figure 13-15** shows the syntax diagram for a return statement.

**Figure 13-15** return_clause::=

The syntax details are as follows:

This statement returns control from a stored procedure or function to a caller.

### Examples

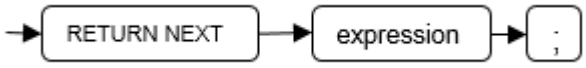
See **Examples** for call statement examples.

## 13.8.1.2 RETURN NEXT and RETURN QUERY

### Syntax

When creating a function, specify **SETOF datatype** for the return values.

return_next_clause::=




return_query_clause::=

The syntax details are as follows:

If a function needs to return a result set, use **RETURN NEXT** or **RETURN QUERY** to add results to the result set, and then continue to execute the next statement of the function. As the **RETURN NEXT** or **RETURN QUERY** statement is executed repeatedly, more and more results will be added to the result set. After the function is executed, all results are returned.

**RETURN NEXT** can be used for scalar and compound data types.

**RETURN QUERY** has a variant **RETURN QUERY EXECUTE**. You can add dynamic queries and add parameters to the queries by using **USING**.

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## Examples

```
CREATE TABLE t1(a int);
INSERT INTO t1 VALUES(1),(10);

--RETURN NEXT
CREATE OR REPLACE FUNCTION fun_for_return_next() RETURNS SETOF t1 AS $$
DECLARE
  r t1%ROWTYPE;
BEGIN
  FOR r IN select * from t1
  LOOP
    RETURN NEXT r;
  END LOOP;
  RETURN;
END;
$$ LANGUAGE PLPGSQL;
call fun_for_return_next();
 a
---
 1
 10
(2 rows)

-- RETURN QUERY
CREATE OR REPLACE FUNCTION fun_for_return_query() RETURNS SETOF t1 AS $$
DECLARE
  r t1%ROWTYPE;
BEGIN
  RETURN QUERY select * from t1;
END;
$$
language plpgsql;
call fun_for_return_next();
 a
---
 1
 10
(2 rows)
```

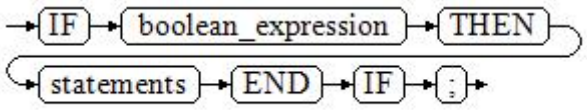
# 13.8.2 Conditional Statements

Conditional statements are used to decide whether given conditions are met. Operations are executed based on the decisions made.

GaussDB(DWS) supports five usages of **IF**:

- IF_THEN

  **Figure 13-16** IF_THEN::=

  **IF_THEN** is the simplest form of **IF**. If the condition is true, statements are executed. If it is false, they are skipped.

  **Example**

  ```
  IF v_user_id <> 0 THEN
      UPDATE users SET email = v_email WHERE user_id = v_user_id;
  END IF;
  ```

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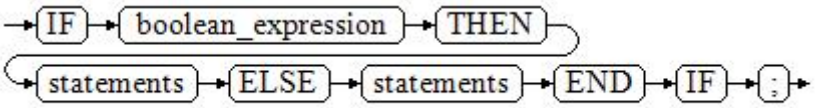
- IF_THEN_ELSE

  **Figure 13-17** IF_THEN_ELSE::=

  **IF-THEN-ELSE** statements add **ELSE** branches and can be executed if the condition is **false**.

  **Example**

  ```
  IF parentid IS NULL OR parentid = ''
  THEN
      RETURN;
  ELSE
      hp_true_filename(parentid); -- Call the stored procedure.
  END IF;
  ```

- IF_THEN_ELSE IF

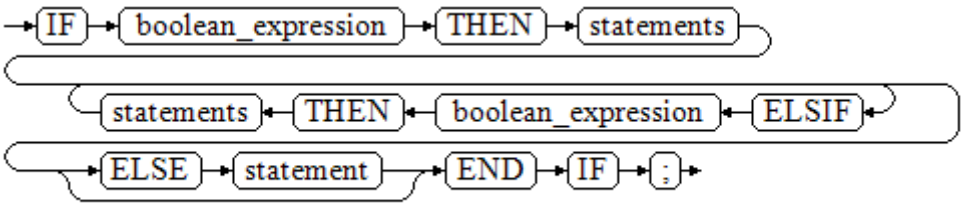
  **IF** statements can be nested in the following way:

  ```
  IF sex = 'm' THEN
      pretty_sex := 'man';
  ELSE
      IF sex = 'f' THEN
          pretty_sex := 'woman';
      END IF;
  END IF;
  ```

  Actually, this is a way of an **IF** statement nesting in the **ELSE** part of another **IF** statement. Therefore, an **END IF** statement is required for each nesting **IF** statement and another **END IF** statement to end the parent **IF-ELSE** statement. To set multiple options, use the following form:

- IF_THEN_ELSIF_ELSE

  **Figure 13-18** IF_THEN_ELSIF_ELSE::=

  **Example**

  ```
  IF number_tmp = 0 THEN
      result := 'zero';
  ELSIF number_tmp > 0 THEN
      result := 'positive';
  ELSIF number_tmp < 0 THEN
      result := 'negative';
  ELSE
      result := 'NULL';
  END IF;
  ```

- IF_THEN_ELSEIF_ELSE

  **ELSEIF** is an alias of **ELSIF**.

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**Example**

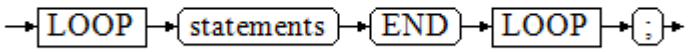
```
CREATE OR REPLACE PROCEDURE proc_control_structure(i in integer)
AS
   BEGIN
      IF i > 0 THEN
         raise info 'i:% is greater than 0. ',i;
      ELSIF i < 0 THEN
         raise info 'i:% is smaller than 0. ',i;
      ELSE
         raise info 'i:% is equal to 0. ',i;
      END IF;
      RETURN;
   END;
/

CALL proc_control_structure(3);

-- Delete the stored procedure:
DROP PROCEDURE proc_control_structure;
```

# 13.8.3 Loop Statements

## Simple LOOP Statements

The syntax diagram is as follows.

**Figure 13-19** loop::=




Example:

```
CREATE OR REPLACE PROCEDURE proc_loop(i in integer, count out integer)
AS
   BEGIN
      count:=0;
      LOOP
      IF count > i THEN
         raise info 'count is %. ', count;
         EXIT;
      ELSE
         count:=count+1;
      END IF;
      END LOOP;
   END;
/

CALL proc_loop(10,5);
```

**NOTICE**

The loop must be exploited together with **EXIT**; otherwise, a dead loop occurs.

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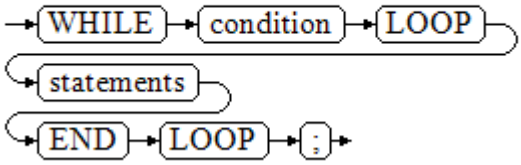
## WHILE-LOOP Statements

The syntax diagram is as follows.

**Figure 13-20** while_loop::=




If the conditional expression is true, a series of statements in the WHILE statement are repeatedly executed and the condition is decided each time the loop body is executed.

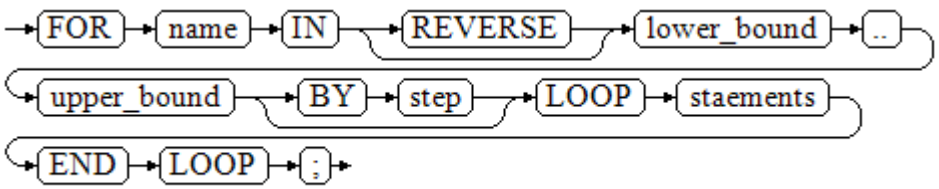
Examples

```
CREATE TABLE integertable(c1 integer) DISTRIBUTE BY hash(c1);
CREATE OR REPLACE PROCEDURE proc_while_loop(maxval in integer)
AS
    DECLARE
    i int :=1;
    BEGIN
        WHILE i < maxval LOOP
            INSERT INTO integertable VALUES(i);
            i:=i+1;
        END LOOP;
    END;
/

-- Invoke a function:
CALL proc_while_loop(10);

-- Delete the stored procedure and table:
DROP PROCEDURE proc_while_loop;
DROP TABLE integertable;
```

## FOR_LOOP (*Integer variable*) *Statement*

The syntax diagram is as follows.

**Figure 13-21** for_loop::=

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**NOTE**

- The variable **name** is automatically defined as the **integer** type and exists only in this loop. The variable name falls between lower_bound and upper_bound.
- When the keyword **REVERSE** is used, the lower bound must be greater than or equal to the upper bound; otherwise, the loop body is not executed.

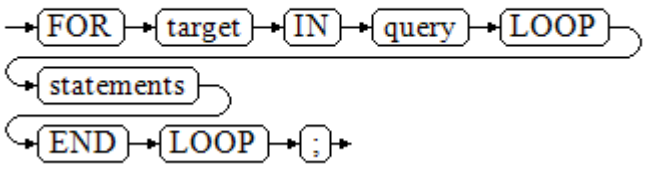
Example:

```
-- Loop from 0 to 5:
CREATE OR REPLACE PROCEDURE proc_for_loop()
AS
   BEGIN
   FOR I IN 0..5 LOOP
      DBMS_OUTPUT.PUT_LINE('It is '||to_char(I) || ' time;') ;
   END LOOP;
END;
/

-- Invoke a function:
CALL proc_for_loop();

-- Delete the stored procedure:
DROP PROCEDURE proc_for_loop;
```

## FOR_LOOP Query Statements

The syntax diagram is as follows.

**Figure 13-22** for_loop_query::=




**NOTE**

The variable **target** is automatically defined, its type is the same as that in the **query** result, and it is valid only in this loop. The target value is the query result.

Example:

```
-- Display the query result from the loop:
CREATE OR REPLACE PROCEDURE proc_for_loop_query()
AS
   record VARCHAR2(50);
BEGIN
   FOR record IN SELECT spcname FROM pg_tablespace LOOP
   dbms_output.put_line(record);
   END LOOP;
END;
/

-- Invoke a function.
CALL proc_for_loop_query();

-- Delete the stored procedure.
DROP PROCEDURE proc_for_loop_query;
```

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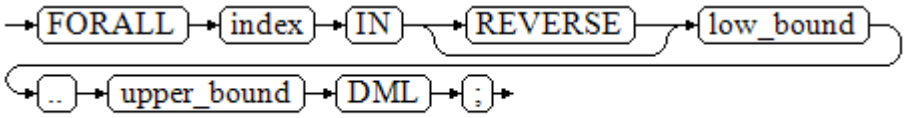
### FORALL Batch Query Statements

The syntax diagram is as follows.

**Figure 13-23** forall::=




NOTE

The variable **index** is automatically defined as the **integer** type and exists only in this loop. The index value falls between low_bound and upper_bound.

Example:

```
CREATE TABLE hdfs_t1 (
  title NUMBER(6),
  did VARCHAR2(20),
  data_peroid VARCHAR2(25),
  kind VARCHAR2(25),
  interval VARCHAR2(20),
  time DATE,
  isModified VARCHAR2(10)
)
DISTRIBUTE BY hash(did);

INSERT INTO hdfs_t1 VALUES( 8, 'Donald', 'OConnell', 'DOCONNEL', '650.507.9833', to_date('21-06-1999',
'dd-mm-yyyy'), 'SH_CLERK' );

CREATE OR REPLACE PROCEDURE proc_forall()
AS
BEGIN
    FORALL i IN 100..120
        insert into hdfs_t1(title) values(i);
END;
/

-- Invoke a function:
CALL proc_forall();

-- Query the invocation result of the stored procedure:
SELECT * FROM hdfs_t1 WHERE title BETWEEN 100 AND 120;

-- Delete the stored procedure and table:
DROP PROCEDURE proc_forall;
DROP TABLE hdfs_t1;
```

## 13.8.4 Branch Statements

### Syntax

**Figure 13-24** shows the syntax diagram.

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**Figure 13-24** case_when::=

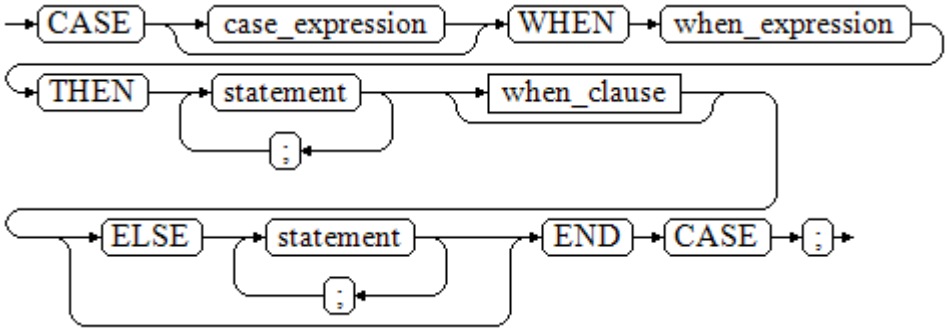
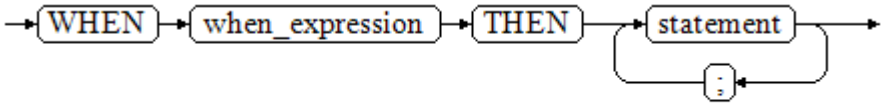



Figure 13-25 shows the syntax diagram for **when_clause**.

**Figure 13-25** when_clause::=




Parameter description:

- **case_expression**: specifies the variable or expression.
- **when_expression**: specifies the constant or conditional expression.
- **statement**: specifies the statement to execute.

## Examples

```
CREATE OR REPLACE PROCEDURE proc_case_branch(pi_result in integer, pi_return out integer)
AS
   BEGIN
      CASE pi_result
         WHEN 1 THEN
            pi_return := 111;
         WHEN 2 THEN
            pi_return := 222;
         WHEN 3 THEN
            pi_return := 333;
         WHEN 6 THEN
            pi_return := 444;
         WHEN 7 THEN
            pi_return := 555;
         WHEN 8 THEN
            pi_return := 666;
         WHEN 9 THEN
            pi_return := 777;
         WHEN 10 THEN
            pi_return := 888;
         ELSE
            pi_return := 999;
      END CASE;
      raise info 'pi_return : %',pi_return ;
END;
/

CALL proc_case_branch(3,0);
```

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```
-- Delete the stored procedure:
DROP PROCEDURE proc_case_branch;
```

# 13.8.5 NULL Statements

In PL/SQL programs, **NULL** statements are used to indicate "nothing should be done", equal to placeholders. They grant meanings to some statements and improve program readability.

## Syntax

The following shows example use of NULL statements.

```
DECLARE
   ...
BEGIN
   ...
   IF v_num IS NULL THEN
      NULL; --No data needs to be processed.
   END IF;
END;
/
```

# 13.8.6 Error Trapping Statements

By default, any error occurring in a PL/SQL function aborts execution of the function, and indeed of the surrounding transaction as well. You can trap errors and restore from them by using a **BEGIN** block with an **EXCEPTION** clause. The syntax is an extension of the normal syntax for a **BEGIN** block:

```
[<<label>>]
[DECLARE
   declarations]
BEGIN
   statements
EXCEPTION
   WHEN condition [OR condition ...] THEN
      handler_statements
   [WHEN condition [OR condition ...] THEN
      handler_statements
   ...]
END;
```

If no error occurs, this form of block simply executes all the statements, and then control passes to the next statement after **END**. But if an error occurs within the statements, further processing of the statements is abandoned, and control passes to the **EXCEPTION** list. The list is searched for the first condition matching the error that occurred. If a match is found, the corresponding **handler_statements** are executed, and then control passes to the next statement after **END**. If no match is found, the error propagates out as though the **EXCEPTION** clause were not there at all:

The error can be caught by an enclosing block with **EXCEPTION**, or if there is none it aborts processing of the function.

The condition names can be any of those shown in *GaussDB(DWS) Error Code Reference*. The special condition name **OTHERS** matches every error type except **QUERY_CANCELED**.

If a new error occurs within the selected **handler_statements**, it cannot be caught by this **EXCEPTION** clause, but is propagated out. A surrounding **EXCEPTION** clause could catch it.

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When an error is caught by an **EXCEPTION** clause, the local variables of the PL/SQL function remain as they were when the error occurred, but all changes to persistent database state within the block are rolled back.

Example:

```
CREATE TABLE mytab(id INT,firstname VARCHAR(20),lastname VARCHAR(20)) DISTRIBUTE BY hash(id);

INSERT INTO mytab(firstname, lastname) VALUES('Tom', 'Jones');

CREATE FUNCTION fun_exp() RETURNS INT
AS $$
DECLARE
   x INT :=0;
   y INT;
BEGIN
   UPDATE mytab SET firstname = 'Joe' WHERE lastname = 'Jones';
   x := x + 1;
   y := x / 0;
EXCEPTION
   WHEN division_by_zero THEN
      RAISE NOTICE 'caught division_by_zero';
      RETURN x;
END;$$
LANGUAGE plpgsql;

call fun_exp();
NOTICE:  caught division_by_zero
 fun_exp
---------
       1
(1 row)

select * from mytab;
 id | firstname | lastname
----+-----------+----------
    | Tom       | Jones
(1 row)

DROP FUNCTION fun_exp();
DROP TABLE mytab;
```

When control reaches the assignment to **y**, it will fail with a **division_by_zero** error. This will be caught by the **EXCEPTION** clause. The value returned in the **RETURN** statement will be the incremented value of **x**.

**NOTE**

A block containing an **EXCEPTION** clause is more expensive to enter and exit than a block without one. Therefore, do not use **EXCEPTION** without need.

In the following scenario, an exception cannot be caught, and the entire transaction rolls back. The threads of the nodes participating the stored procedure exit abnormally due to node failure and network fault, or the source data is inconsistent with that of the table structure of the target table during the COPY FROM operation.

Example: Exceptions with **UPDATE**/**INSERT**

This example uses exception handling to perform either **UPDATE** or **INSERT**, as appropriate:

```
CREATE TABLE db (a INT, b TEXT);

CREATE FUNCTION merge_db(key INT, data TEXT) RETURNS VOID AS
$$
BEGIN
   LOOP
```

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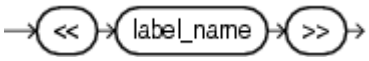
```
-- Try updating the key:
       UPDATE db SET b = data WHERE a = key;
       IF found THEN
          RETURN;
       END IF;
-- Not there, so try to insert the key. If someone else inserts the same key concurrently, we could get a
unique-key failure.
       BEGIN
          INSERT INTO db(a,b) VALUES (key, data);
          RETURN;
       EXCEPTION WHEN unique_violation THEN
       -- Loop to try the UPDATE again:
       END;
    END LOOP;
END;
$$
LANGUAGE plpgsql;

SELECT merge_db(1, 'david');
SELECT merge_db(1, 'dennis');

-- Delete FUNCTION and TABLE:
DROP FUNCTION merge_db;
DROP TABLE db ;
```

# 13.8.7 GOTO Statements

The **GOTO** statement unconditionally transfers the control from the current statement to a labeled statement. The **GOTO** statement changes the execution logic. Therefore, use this statement only when necessary. Alternatively, you can use the **EXCEPTION** statement to handle issues in special scenarios. To run the **GOTO** statement, the labeled statement must be unique.

## Syntax

label declaration ::=




goto statement ::=

## Examples

```
CREATE OR REPLACE PROCEDURE GOTO_test()
AS
DECLARE
   v1  int;
BEGIN
   v1  := 0;
       LOOP
       EXIT WHEN v1 > 100;
              v1 := v1 + 2;
              if v1 > 25 THEN
                     GOTO pos1;
              END IF;
       END LOOP;
<<pos1>>
v1 := v1 + 10;
raise info 'v1 is %. ', v1;
END;
```

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```
/

call GOTO_test();
DROP PROCEDURE GOTO_test();
```

## Constraints

The **GOTO** statement has the following constraints:

- The **GOTO** statement does not allow multiple labeled statements even if they are in different blocks.

```
BEGIN
 GOTO pos1;
 <<pos1>>
 SELECT * FROM ...
 <<pos1>>
 UPDATE t1 SET ...
END;
```

- The **GOTO** statement cannot transfer control to the **IF**, **CASE**, or **LOOP** statement.

```
BEGIN
  GOTO pos1;
  IF valid THEN
    <<pos1>>
    SELECT * FROM ...
  END IF;
 END;
```

- The **GOTO** statement cannot transfer control from one **IF** clause to another, or from one **WHEN** clause in the **CASE** statement to another.

```
BEGIN
  IF valid THEN
    GOTO pos1;
    SELECT * FROM ...
  ELSE
    <<pos1>>
    UPDATE t1 SET ...
  END IF;
 END;
```

- The **GOTO** statement cannot transfer control from an outer block to an inner **BEGIN-END** block.

```
BEGIN
  GOTO pos1;
  BEGIN
    <<pos1>>
    UPDATE t1 SET ...
  END;
 END;
```

- The **GOTO** statement cannot transfer control from an **EXCEPTION** block to the current **BEGIN-END** block but can transfer to an outer **BEGIN-END** block.

```
BEGIN
  <<pos1>>
  UPDATE t1 SET ...
  EXCEPTION
    WHEN condition THEN
      GOTO pos1;
 END;
```

- If the labeled statement in the **GOTO** statement does not exist, you need to add the **NULL** statement.

```
DECLARE
  done  BOOLEAN;
BEGIN
  FOR i IN 1..50 LOOP
    IF done THEN
```

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```
        GOTO end_loop;
    END IF;
    <<end_loop>>  -- not allowed unless an executable statement follows
    NULL; -- add NULL statement to avoid error
  END LOOP;  -- raises an error without the previous NULL
END;
/
```

# 13.9 Other Statements

## 13.9.1 Lock Operations

GaussDB(DWS) provides multiple lock modes to control concurrent accesses to table data. These modes are used when Multi-Version Concurrency Control (MVCC) cannot give expected behaviors. Alike, most GaussDB(DWS) commands automatically apply appropriate locks to ensure that called tables are not deleted or modified in an incompatible manner during command execution. For example, when concurrent operations exist, **ALTER TABLE** cannot be executed on the same table.

## 13.9.2 Cursor Operations

GaussDB(DWS) provides cursors as a data buffer for users to store execution results of SQL statements. Each cursor region has a name. Users can use SQL statements to obtain records one by one from cursors and grant them to master variables, then being processed further by host languages.

Cursor operations include cursor definition, open, fetch, and close operations.

For the complete example of cursor operations, see **Explicit Cursor**.

# 13.10 Cursors

## 13.10.1 Overview

To process SQL statements, the stored procedure process assigns a memory segment to store context association. Cursors are handles or pointers to context areas. With cursors, stored procedures can control alterations in context areas.

**NOTICE**

If JDBC is used to call a stored procedure whose returned value is a cursor, the returned cursor is not available.

Cursors are classified into explicit cursors and implicit cursors. **Table 13-2** shows the usage conditions of explicit and implicit cursors for different SQL statements.

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**Table 13-2** Cursor usage conditions

| SQL Statement | Cursor |
| --- | --- |
| Non-query statements | Implicit |
| Query statements with single-line results | Implicit or explicit |
| Query statements with multi-line results | Explicit |

## 13.10.2 Explicit Cursor

An explicit cursor is used to process query statements, particularly when the query results contain multiple records.

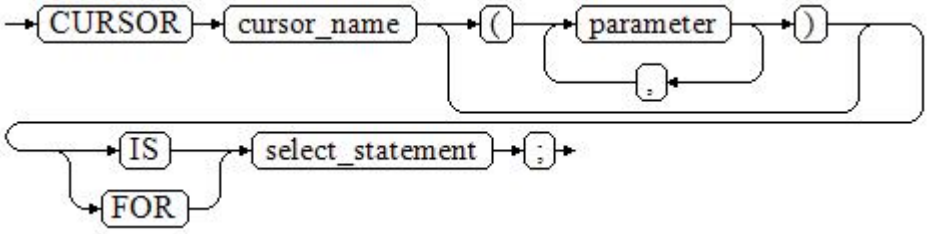
### Procedure

An explicit cursor performs the following six PL/SQL steps to process query statements:

**Step 1** **Define a static cursor:** Define a cursor name and its corresponding **SELECT** statement.

Figure 13-26 shows the syntax diagram for defining a static cursor.

**Figure 13-26** static_cursor_define::=




Parameter description:

- **cursor_name**: defines a cursor name.
- **parameter**: specifies cursor parameters. Only input parameters are allowed in the following format:
  ```
  parameter_name datatype
  ```
- **select_statement**: specifies a query statement.

NOTE

The system automatically determines whether the cursor can be used for backward fetches based on the execution plan.

**Define a dynamic cursor:** Define a **ref** cursor, which means that the cursor can be opened dynamically by a set of static SQL statements. Define the type of the **ref** cursor first and then the cursor variable of this cursor type. Dynamically bind a **SELECT** statement through **OPEN FOR** when the cursor is opened.

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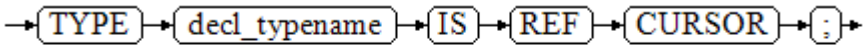
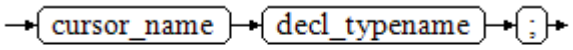
Figure 13-27 and Figure 13-28 show the syntax diagrams for defining a dynamic cursor.

**Figure 13-27** cursor_typename::=




GaussDB(DWS) supports the dynamic cursor type **sys_refcursor**. A function or stored procedure can use the **sys_refcursor** parameter to pass on or pass out the cursor result set. A function can return **sys_refcursor** to return the cursor result set.

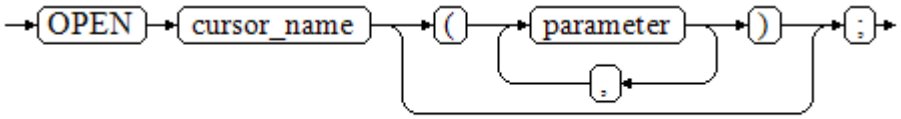
**Figure 13-28** dynamic_cursor_define::=




**Step 2** **Open the static cursor:** Execute the **SELECT** statement corresponding to the cursor. The query result is placed in the work area and the pointer directs to the head of the work area to identify the cursor result set. If the cursor query statement contains the **FOR UPDATE** option, the **OPEN** statement locks the data row corresponding to the cursor result set in the database table.

Figure 13-29 shows the syntax diagram for opening a static cursor.

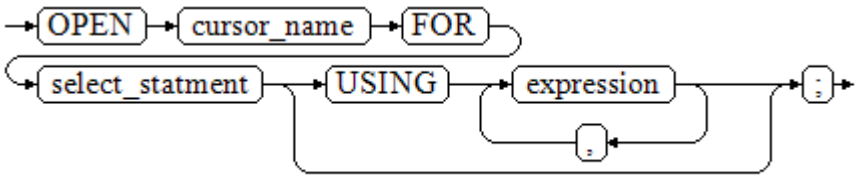
**Figure 13-29** open_static_cursor::=




**Open the dynamic cursor:** Use the **OPEN FOR** statement to open the dynamic cursor and the SQL statement is dynamically bound.

Figure 13-30 shows the syntax diagram for opening a dynamic cursor.

**Figure 13-30** open_dynamic_cursor::=




A PL/SQL program cannot use the **OPEN** statement to repeatedly open a cursor.

**Step 3** **Fetch cursor data**: Retrieve data rows in the result set and place them in specified output variables.

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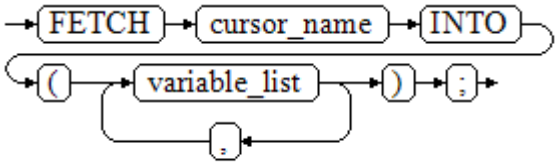
Figure 13-31 shows the syntax diagram for fetching cursor data.

**Figure 13-31** fetch_cursor::=



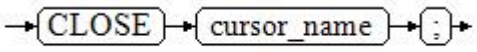

**Step 4** Process the record.

**Step 5** Continue to process until the active set has no record.

**Step 6** **Close the cursor**: When fetching and finishing the data in the cursor result set, close the cursor immediately to release system resources used by the cursor and invalidate the work area of the cursor so that the **FETCH** statement cannot be used to fetch data any more. A closed cursor can be reopened using the **OPEN** statement.

Figure 13-32 shows the syntax diagram for closing a cursor.

**Figure 13-32** close_cursor::=




**----End**

## Attributes

Cursor attributes are used to control program procedures or learn about program status. When a DML statement is executed, the PL/SQL opens a built-in cursor and processes its result. A cursor is a memory segment for maintaining query results. It is opened when a DML statement is executed and closed when the execution is finished. An explicit cursor has the following attributes:

- **%FOUND**: Boolean attribute, which returns **TRUE** if the last fetch returns a row.
- **%NOTFOUND**: Boolean attribute, which works opposite to the **%FOUND** attribute.
- **%ISOPEN**: Boolean attribute, which returns **TRUE** if the cursor has been opened.
- **%ROWCOUNT**: numeric attribute, which returns the number of records fetched from the cursor.

## Examples

```
-- Specify the method for passing cursor parameters:
CREATE OR REPLACE PROCEDURE cursor_proc1()
AS
DECLARE
   DEPT_NAME VARCHAR(100);
   DEPT_LOC NUMBER(4);
   -- Define a cursor:
```

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```
    CURSOR C1 IS
        SELECT section_name, place_id FROM sections WHERE section_id <= 50;
    CURSOR C2(sect_id INTEGER) IS
        SELECT section_name, place_id FROM sections WHERE section_id <= sect_id;
    TYPE CURSOR_TYPE IS REF CURSOR;
    C3 CURSOR_TYPE;
    SQL_STR VARCHAR(100);
BEGIN
    OPEN C1;-- Open the cursor:
    LOOP
        -- Fetch data from the cursor:
        FETCH C1 INTO DEPT_NAME, DEPT_LOC;
        EXIT WHEN C1%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE(DEPT_NAME||'---'||DEPT_LOC);
    END LOOP;
    CLOSE C1;-- Close the cursor.

    OPEN C2(10);
    LOOP
        FETCH C2 INTO DEPT_NAME, DEPT_LOC;
        EXIT WHEN C2%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE(DEPT_NAME||'---'||DEPT_LOC);
    END LOOP;
    CLOSE C2;

    SQL_STR := 'SELECT section_name, place_id FROM sections WHERE section_id <= :DEPT_NO;';
    OPEN C3 FOR SQL_STR USING 50;
    LOOP
        FETCH C3 INTO DEPT_NAME, DEPT_LOC;
        EXIT WHEN C3%NOTFOUND;
        DBMS_OUTPUT.PUT_LINE(DEPT_NAME||'---'||DEPT_LOC);
    END LOOP;
    CLOSE C3;
END;
/

CALL cursor_proc1();

DROP PROCEDURE cursor_proc1;
-- Increase the salary of employees whose salary is lower than CNY3000 by CNY500:
CREATE TABLE staffs_t1 AS TABLE staffs;

CREATE OR REPLACE PROCEDURE cursor_proc2()
AS
DECLARE
  V_EMPNO  NUMBER(6);
  V_SAL    NUMBER(8,2);
  CURSOR C IS SELECT staff_id, salary FROM staffs_t1;
BEGIN
  OPEN C;
  LOOP
    FETCH C INTO V_EMPNO, V_SAL;
    EXIT WHEN C%NOTFOUND;
    IF V_SAL<=3000 THEN
         UPDATE staffs_t1 SET salary =salary + 500 WHERE staff_id = V_EMPNO;
    END IF;
  END LOOP;
  CLOSE C;
END;
/

CALL cursor_proc2();

-- Drop the stored procedure:
DROP PROCEDURE cursor_proc2;
DROP TABLE staffs_t1;
-- Use function parameters of the SYS_REFCURSOR type:
CREATE OR REPLACE PROCEDURE proc_sys_ref(O OUT SYS_REFCURSOR)
IS
```

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```
C1 SYS_REFCURSOR;
BEGIN
OPEN C1 FOR SELECT section_ID FROM sections ORDER BY section_ID;
O := C1;
END;
/

DECLARE
C1 SYS_REFCURSOR;
TEMP NUMBER(4);
BEGIN
proc_sys_ref(C1);
LOOP
  FETCH C1 INTO TEMP;
  DBMS_OUTPUT.PUT_LINE(C1%ROWCOUNT);
  EXIT WHEN C1%NOTFOUND;
END LOOP;
END;
/

-- Drop the stored procedure:
DROP PROCEDURE proc_sys_ref;
```

## 13.10.3 Implicit Cursor

The system automatically sets implicit cursors for non-query statements, such as **ALTER** and **DROP**, and creates work areas for these statements. These implicit cursors are named SQL, which is defined by the system.

### Overview

Implicit cursor operations, such as definition, opening, value-grant, and closing, are automatically performed by the system. Users can use only the attributes of implicit cursors to complete operations. The data stored in the work area of an implicit cursor is the latest SQL statement, and is not related to the user-defined explicit cursors.

**Format call**: SQL%

NOTE

**INSERT**, **UPDATE**, **DROP**, and **SELECT** statements do not require defined cursors.

### Attributes

An implicit cursor has the following attributes:

- **SQL%FOUND**: Boolean attribute, which returns **TRUE** if the last fetch returns a row.
- **SQL%NOTFOUND**: Boolean attribute, which works opposite to the **SQL %FOUND** attribute.
- **SQL%ROWCOUNT**: numeric attribute, which returns the number of records fetched from the cursor.
- **SQL%ISOPEN**: Boolean attribute, whose value is always **FALSE**. Close implicit cursors immediately after an SQL statement is executed.

### Examples

```
-- Delete all employees in a department from the EMP table. If the department has no employees, delete the department from the DEPT table.
```

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```
CREATE TABLE staffs_t1 AS TABLE staffs;
CREATE TABLE sections_t1 AS TABLE sections;

CREATE OR REPLACE PROCEDURE proc_cursor3()
AS
   DECLARE
   V_DEPTNO NUMBER(4) := 100;
   BEGIN
      DELETE FROM staffs WHERE section_ID = V_DEPTNO;
      -- Proceed based on cursor status:
      IF SQL%NOTFOUND THEN
      DELETE FROM sections_t1 WHERE section_ID = V_DEPTNO;
      END IF;
   END;
/

CALL proc_cursor3();

-- Drop the stored procedure and the temporary table:
DROP PROCEDURE proc_cursor3;
DROP TABLE staffs_t1;
DROP TABLE sections_t1;
```

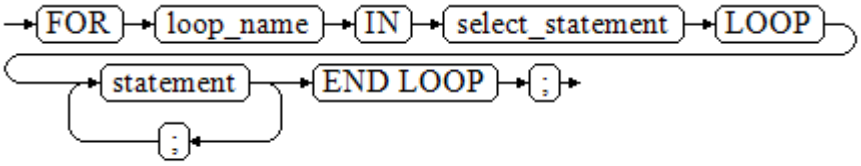
## 13.10.4 Cursor Loop

The use of cursors in **WHILE** and **LOOP** statements is called a cursor loop. Generally, **OPEN**, **FETCH**, and **CLOSE** statements are needed in cursor loop. The following describes a loop that is applicable to a static cursor loop without executing the four steps of a static cursor.

### Syntax

**Figure 13-33** shows the syntax diagram for the **FOR AS** loop.

**Figure 13-33** FOR_AS_loop::=




### Precautions

- The **UPDATE** operation for the queried table is not allowed in the loop statement.
- The variable *loop_name* is automatically defined and is valid only in this loop. The type and value of *loop_name* are the same as those of the query result of *select_statement*.
- The **%FOUND**, **%NOTFOUND**, and **%ROWCOUNT** attributes access the same internal variable in GaussDB(DWS). Transactions and anonymous blocks cannot be accessed by multiple cursors at the same time.

### Examples

```
BEGIN
FOR ROW_TRANS IN
      SELECT first_name FROM staffs
```

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```
    LOOP
        DBMS_OUTPUT.PUT_LINE (ROW_TRANS.first_name );
    END LOOP;
END;
/

-- Create a table:
CREATE TABLE integerTable1( A INTEGER) DISTRIBUTE BY hash(A);
CREATE TABLE integerTable2( B INTEGER) DISTRIBUTE BY hash(B);
INSERT INTO integerTable2 VALUES(2);

-- Multiple cursors share the parameters of cursor attributes:
DECLARE
   CURSOR C1 IS SELECT A FROM integerTable1;--Declare the cursor.
   CURSOR C2 IS SELECT B FROM integerTable2;
   PI_A INTEGER;
   PI_B INTEGER;
BEGIN
    OPEN C1;-- Open the cursor.
   OPEN C2;
   FETCH C1 INTO PI_A; ----  The value of C1%FOUND and C2%FOUND is FALSE.
   FETCH C2 INTO PI_B; ----  The value of C1%FOUND and C2%FOUND is TRUE.
-- Determine the cursor status:
   IF C1%FOUND THEN
      IF C2%FOUND THEN
        DBMS_OUTPUT.PUT_LINE('Dual cursor share paremeter.');
      END IF;
   END IF;
    CLOSE C1;-- Close the cursor.
   CLOSE C2;
END;
/

-- Drop the temporary table:
DROP TABLE integerTable1;
DROP TABLE integerTable2;
```

# 13.11 Advanced Packages

## 13.11.1 DBMS_LOB

### Related Interfaces

Table 13-3 provides all interfaces supported by the **DBMS_LOB** package.

**Table 13-3** DBMS_LOB

| API | Description |
| --- | --- |
| DBMS_LOB.GETLENGTH | Obtains and returns the specified length of a LOB object. |
| DBMS_LOB.OPEN | Opens a LOB and returns a LOB descriptor. |
| DBMS_LOB.READ | Loads a part of LOB contents to BUFFER area according to the specified length and initial position offset. |
| DBMS_LOB.WRITE | Copies contents in BUFFER area to LOB according to the specified length and initial position offset. |

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| API | Description |
| --- | --- |
| DBMS_LOB.WRITEAPPEND | Copies contents in BUFFER area to the end part of LOB according to the specified length. |
| DBMS_LOB.COPY | Copies contents in BLOB to another BLOB according to the specified length and initial position offset. |
| DBMS_LOB.ERASE | Deletes contents in BLOB according to the specified length and initial position offset. |
| DBMS_LOB.CLOSE | Closes a LOB descriptor. |
| DBMS_LOB.INSTR | Returns the position of the Nth occurrence of a character string in LOB. |
| DBMS_LOB.COMPARE | Compares two LOBs or a certain part of two LOBs. |
| DBMS_LOB.SUBSTR | Reads the substring of a LOB and returns the number of read bytes or the number of characters. |
| DBMS_LOB.TRIM | Truncates the LOB of a specified length. After the execution is complete, the length of the LOB is set to the length specified by the **newlen** parameter. |
| DBMS_LOB.CREATETEMPORARY | Creates a temporary BLOB or CLOB. |
| DBMS_LOB.APPEND | Adds the content of a LOB to another LOB. |

- DBMS_LOB.GETLENGTH

  Specifies the length of a LOB type object obtained and returned by the stored procedure **GETLENGTH**.

  The function prototype of **DBMS_LOB.GETLENGTH** is:

```
DBMS_LOB.GETLENGTH (
lob_loc    IN   BLOB)
RETURN INTEGER;

DBMS_LOB.GETLENGTH (
lob_loc    IN   CLOB)
RETURN INTEGER;
```

  **Table 13-4** DBMS_LOB.GETLENGTH interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | LOB type object whose length is to be obtained |

- DBMS_LOB.OPEN

  A stored procedure opens a LOB and returns a LOB descriptor. This process is used only for compatibility.

  The function prototype of **DBMS_LOB.OPEN** is:

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```
DBMS_LOB.LOB (
lob_loc INOUT BLOB,
open_mode IN BINARY_INTEGER);

DBMS_LOB.LOB (
lob_loc INOUT CLOB,
open_mode IN BINARY_INTEGER);
```

**Table 13-5** DBMS_LOB.OPEN interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | BLOB or CLOB descriptor that is opened |
| open_mode IN BINARY_INTEGER | Open mode (currently, DBMS_LOB.LOB_READWRITE is supported) |

- DBMS_LOB.READ

  The stored procedure **READ** loads a part of LOB contents to BUFFER according to the specified length and initial position offset.

  The function prototype of **DBMS_LOB.READ** is:

```
DBMS_LOB.READ (
lob_loc     IN          BLOB,
amount      IN          INTEGER,
offset      IN          INTEGER,
buffer      OUT         RAW);

DBMS_LOB.READ (
lob_loc    IN           CLOB,
amount     IN OUT       INTEGER,
offset     IN           INTEGER,
buffer     OUT          VARCHAR2);
```

**Table 13-6** DBMS_LOB.READ interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | LOB type object to be loaded |
| amount | Load data length<br>**NOTE**<br>If the read length is negative, the error message "ERROR: argument 2 is null, invalid, or out of range." is displayed. |
| offset | Indicates where to start reading the LOB contents, that is, the offset bytes to initial position of LOB contents. |
| buffer | Target buffer to store the loaded LOB contents |

- DBMS_LOB.WRITE

  The stored procedure **WRITE** copies contents in BUFFER to LOB variables according to the specified length and initial position offset.

  The function prototype of **DBMS_LOB.WRITE** is:

```
DBMS_LOB.WRITE (
lob_loc    IN OUT     BLOB,
```

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```
amount     IN         INTEGER,
offset     IN         INTEGER,
buffer     IN         RAW);

DBMS_LOB.WRITE (
lob_loc   IN OUT      CLOB,
amount    IN          INTEGER,
offset    IN          INTEGER,
buffer    IN          VARCHAR2);
```

**Table 13-7** DBMS_LOB.WRITE interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | LOB type object to be written |
| amount | Write data length<br>**NOTE**<br>If the write data is shorter than 1 or longer than the contents to be written, an error is reported. |
| offset | Indicates where to start writing the LOB contents, that is, the offset bytes to initial position of LOB contents.<br>**NOTE**<br>If the offset is shorter than 1 or longer than the maximum length of LOB type contents, an error is reported. |
| buffer | Content to be written |

- DBMS_LOB.WRITEAPPEND

  The stored procedure **WRITEAPPEND** copies contents in BUFFER to the end part of LOB according to the specified length.

  The function prototype of **DBMS_LOB.WRITEAPPEND** is:

```
DBMS_LOB.WRITEAPPEND (
lob_loc     IN OUT     BLOB,
amount      IN         INTEGER,
buffer      IN         RAW);

DBMS_LOB.WRITEAPPEND (
lob_loc     IN OUT     CLOB,
amount      IN         INTEGER,
buffer      IN         VARCHAR2);
```

**Table 13-8** DBMS_LOB.WRITEAPPEND interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | LOB type object to be written |
| amount | Write data length<br>**NOTE**<br>If the write data is shorter than 1 or longer than the contents to be written, an error is reported. |
| buffer | Content to be written |

- DBMS_LOB.COPY

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The stored procedure **COPY** copies contents in BLOB to another BLOB according to the specified length and initial position offset.

The function prototype of **DBMS_LOB.COPY** is:

```
DBMS_LOB.COPY (
dest_lob      IN OUT     BLOB,
src_lob       IN         BLOB,
amount        IN         INTEGER,
dest_offset   IN         INTEGER  DEFAULT 1,
src_offset    IN         INTEGER  DEFAULT 1);
```

**Table 13-9** DBMS_LOB.COPY interface parameters

| Parameter | Description |
| --- | --- |
| dest_lob | BLOB type object to be pasted |
| src_lob | BLOB type object to be copied |
| amount | Length of the copied data<br>**NOTE**<br>If the copied data is shorter than 1 or longer than the maximum length of BLOB type contents, an error is reported. |
| dest_offset | Indicates where to start pasting the BLOB contents, that is, the offset bytes to initial position of BLOB contents.<br>**NOTE**<br>If the offset is shorter than 1 or longer than the maximum length of BLOB type contents, an error is reported. |
| src_offset | Indicates where to start copying the BLOB contents, that is, the offset bytes to initial position of BLOB contents.<br>**NOTE**<br>If the offset is shorter than 1 or longer than the length of source BLOB, an error is reported. |

- DBMS_LOB.ERASE

  The stored procedure **ERASE** deletes contents in BLOB according to the specified length and initial position offset.

  The function prototype of **DBMS_LOB.ERASE** is:

  ```
  DBMS_LOB.ERASE (
  lob_loc         IN OUT   BLOB,
  amount          IN OUT   INTEGER,
  offset          IN       INTEGER DEFAULT 1);
  ```

  **Table 13-10** DBMS_LOB.ERASE interface parameters

  | Parameter | Description |
  | --- | --- |
  | lob_loc | BLOB type object whose contents are to be deleted |
  | amount | Length of contents to be deleted<br>**NOTE**<br>If the deleted data is shorter than 1 or longer than the maximum length of BLOB type contents, an error is reported. |

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| Parameter | Description |
| --- | --- |
| offset | Indicates where to start deleting the BLOB contents, that is, the offset bytes to initial position of BLOB contents.<br>**NOTE**<br>If the offset is shorter than 1 or longer than the maximum length of BLOB type contents, an error is reported. |

- DBMS_LOB.CLOSE

  The procedure **CLOSE** disables the enabled contents of LOB according to the specified length and initial position offset.

  The function prototype of **DBMS_LOB.CLOSE** is:

```
DBMS_LOB.CLOSE(
src_lob       IN              BLOB);

DBMS_LOB.CLOSE (
src_lob      IN              CLOB);
```

  **Table 13-11** DBMS_LOB.CLOSE interface parameters

| Parameter | Description |
| --- | --- |
| src_loc | LOB type object to be disabled |

- DBMS_LOB.INSTR

  This function returns the Nth occurrence position in LOB. If invalid values are entered, **NULL** is returned. The invalid values include offset < 1 or offset > LOBMAXSIZE, nth < 1, and nth > LOBMAXSIZE.

  The function prototype of **DBMS_LOB.INSTR** is:

```
DBMS_LOB.INSTR (
lob_loc     IN      BLOB,
pattern     IN      RAW,
offset      IN      INTEGER := 1,
nth         IN      INTEGER := 1)
RETURN INTEGER;

DBMS_LOB.INSTR (
lob_loc     IN      CLOB,
pattern     IN      VARCHAR2 ,
offset      IN      INTEGER := 1,
nth         IN      INTEGER := 1)
RETURN INTEGER;
```

  **Table 13-12** DBMS_LOB.INSTR interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | LOB descriptor to be searched for |
| pattern | Matched pattern. It is RAW for BLOB and TEXT for CLOB. |
| offset | For BLOB, the absolute offset is in the unit of byte. For CLOB, the offset is in the unit of character. The matching start position is 1. |

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| Parameter | Description |
| --- | --- |
| nth | Number of pattern matching times. The minimum value is 1. |

- DBMS_LOB.COMPARE

  This function compares two LOBs or a certain part of two LOBs.

  – If the two parts are equal, **0** is returned. Otherwise, a non-zero value is returned.

  – If the first CLOB is smaller than the second, **-1** is returned. If the first CLOB is larger than the second, **1** is returned.

  – If any of the **amount**, **offset_1**, and **offset_2** parameters is invalid, **NULL** is returned. The valid offset range is 1 to LOBMAXSIZE.

  The function prototype of **DBMS_LOB.READ** is:

```
DBMS_LOB.COMPARE (
lob_1     IN     BLOB,
lob_2     IN     BLOB,
amount    IN     INTEGER := DBMS_LOB.LOBMAXSIZE,
offset_1  IN     INTEGER := 1,
offset_2  IN     INTEGER := 1)
RETURN INTEGER;

DBMS_LOB.COMPARE (
lob_1     IN     CLOB,
lob_2     IN     CLOB,
amount    IN     INTEGER := DBMS_LOB.LOBMAXSIZE,
offset_1  IN     INTEGER := 1,
offset_2  IN     INTEGER := 1)
RETURN INTEGER;
```

**Table 13-13** DBMS_LOB.COMPARE interface parameters

| Parameter | Description |
| --- | --- |
| lob_1 | First LOB descriptor to be compared |
| lob_2 | Second LOB descriptor to be compared |
| amount | Number of characters or bytes to be compared. The maximum value is DBMS_LOB.LOBMAXSIZE. |
| offset_1 | Offset of the first LOB descriptor. The initial position is 1. |
| offset_2 | Offset of the second LOB descriptor. The initial position is 1. |

- DBMS_LOB.SUBSTR

  This function reads the substring of a LOB and returns the number of read bytes or the number of characters. If amount > 1, amount < 32767, offset < 1, or offset > LOBMAXSIZE, **NULL** is returned.

  The function prototype of **DBMS_LOB.SUBSTR** is:

```
DBMS_LOB.SUBSTR (
lob_loc     IN     BLOB,
amount      IN     INTEGER := 32767,
```

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```
offset      IN     INTEGER := 1)
RETURN RAW;

DBMS_LOB.SUBSTR (
lob_loc    IN     CLOB,
amount     IN     INTEGER := 32767,
offset     IN     INTEGER := 1)
RETURN VARCHAR2;
```

**Table 13-14** DBMS_LOB.SUBSTR interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | LOB descriptor of the substring to be read. For BLOB, the return value is the number of read bytes. For CLOB, the return value is the number of characters. |
| offset | Number of bytes or characters to be read. |
| buffer | Number of characters or bytes offset from the start position. |

- DBMS_LOB.TRIM

  This stored procedure truncates the LOB of a specified length. After this stored procedure is executed, the length of the LOB is set to the length specified by the **newlen** parameter. If an empty LOB is truncated, no execution result is displayed. If the specified length is longer than the length of LOB, an exception occurs.

  The function prototype of **DBMS_LOB.TRIM** is:

  ```
  DBMS_LOB.TRIM (
  lob_loc     IN OUT     BLOB,
  newlen      IN         INTEGER);

  DBMS_LOB.TRIM (
  lob_loc    IN          OUT CLOB,
  newlen     IN          INTEGER);
  ```

  **Table 13-15** DBMS_LOB.TRIM interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | BLOB type object to be read |
| newlen | After truncation, the new LOB length for BLOB is in the unit of byte and that for CLOB is in the unit of character. |

- DBMS_LOB.CREATETEMPORARY

  This stored procedure creates a temporary BLOB or CLOB and is used only for syntax compatibility.

  The function prototype of **DBMS_LOB.CREATETEMPORARY** is:

  ```
  DBMS_LOB.CREATETEMPORARY (
  lob_loc    IN OUT      BLOB,
  cache      IN          BOOLEAN,
  dur        IN          INTEGER);
  ```

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```
DBMS_LOB.CREATETEMPORARY (
lob_loc    IN OUT     CLOB,
cache      IN         BOOLEAN,
dur        IN         INTEGER);
```

**Table 13-16** DBMS_LOB.CREATETEMPORARY interface parameters

| Parameter | Description |
| --- | --- |
| lob_loc | LOB descriptor |
| cache | This parameter is used only for syntax compatibility. |
| dur | This parameter is used only for syntax compatibility. |

- DBMS_LOB.APPEND

  The stored procedure **READ** loads a part of BLOB contents to BUFFER according to the specified length and initial position offset.

  The function prototype of **DBMS_LOB.APPEND** is:

```
DBMS_LOB.APPEND (
dest_lob    IN OUT      BLOB,
src_lob     IN          BLOB);

DBMS_LOB.APPEND (
dest_lob    IN OUT      CLOB,
src_lob     IN          CLOB);
```

**Table 13-17** DBMS_LOB.APPEND interface parameters

| Parameter | Description |
| --- | --- |
| dest_lob | LOB descriptor to be written |
| src_lob | LOB descriptor to be read |

## Examples

```
-- Obtain the length of the character string.
SELECT DBMS_LOB.GETLENGTH('12345678');

DECLARE
myraw  RAW(100);
amount INTEGER :=2;
buffer INTEGER :=1;
begin
DBMS_LOB.READ('123456789012345',amount,buffer,myraw);
dbms_output.put_line(myraw);
end;
/

CREATE TABLE blob_Table (t1 blob) DISTRIBUTE BY REPLICATION;
CREATE TABLE blob_Table_bak (t2 blob) DISTRIBUTE BY REPLICATION;
INSERT INTO blob_Table VALUES('abcdef');
INSERT INTO blob_Table_bak VALUES('22222');

DECLARE
str varchar2(100) := 'abcdef';
source raw(100);
dest blob;
copyto blob;
```

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```
amount int;
PSV_SQL varchar2(100);
PSV_SQL1 varchar2(100);
a int :=1;
len int;
BEGIN
source := utl_raw.cast_to_raw(str);
amount := utl_raw.length(source);

PSV_SQL :='select * from blob_Table for update';
PSV_SQL1 := 'select * from blob_Table_bak for update';

EXECUTE IMMEDIATE PSV_SQL into dest;
EXECUTE IMMEDIATE PSV_SQL1 into copyto;

DBMS_LOB.WRITE(dest, amount, 1, source);
DBMS_LOB.WRITEAPPEND(dest, amount, source);

DBMS_LOB.ERASE(dest, a, 1);
DBMS_OUTPUT.PUT_LINE(a);
DBMS_LOB.COPY(copyto, dest, amount, 10, 1);
DBMS_LOB.CLOSE(dest);
RETURN;
END;
/

--Delete the table.
DROP TABLE blob_Table;
DROP TABLE blob_Table_bak;
```

# 13.11.2 DBMS_RANDOM

## Related Interfaces

**Table 13-18** provides all interfaces supported by the **DBMS_RANDOM** package.

**Table 13-18** DBMS_RANDOM interface parameters

| API | Description |
| --- | --- |
| **DBMS_RANDOM.SEED** | Sets a seed for a random number. |
| **DBMS_RANDOM.VALUE** | Generates a random number between a specified low and a specified high. |

- DBMS_RANDOM.SEED

  The stored procedure SEED is used to set a seed for a random number. The DBMS_RANDOM.SEED function prototype is:

  ```
  DBMS_RANDOM.SEED (seed  IN  INTEGER);
  ```

  **Table 13-19** DBMS_RANDOM.SEED interface parameters

  | Parameter | Description |
  | --- | --- |
  | seed | Generates a seed for a random number. |

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- DBMS_RANDOM.VALUE

  The stored procedure VALUE generates a random number between a specified low and a specified high. The DBMS_RANDOM.VALUE function prototype is:

```
DBMS_RANDOM.VALUE(
low  IN  NUMBER,
high IN  NUMBER)
RETURN NUMBER;
```

**Table 13-20** DBMS_RANDOM.VALUE interface parameters

| Parameter | Description |
| --- | --- |
| low | Sets the low bound for a random number. The generated random number is greater than or equal to the low. |
| high | Sets the high bound for a random number. The generated random number is less than the high. |

NOTE

The only requirement is that the parameter type is **NUMERIC** regardless of the right and left bound values.

## Examples

```
-- Generate a random number between 0 and 1:
SELECT DBMS_RANDOM.VALUE(0,1);

-- Add the low and high parameters to an integer within the specified range and intercept smaller values from the result. (The maximum value cannot be a possible value.) Therefore, use the following code for an integer between 0 and 99:
SELECT TRUNC(DBMS_RANDOM.VALUE(0,100));
```

# 13.11.3 DBMS_OUTPUT

## Related Interfaces

Table 13-21 provides all interfaces supported by the **DBMS_OUTPUT** package.

**Table 13-21** DBMS_OUTPUT

| API | Description |
| --- | --- |
| DBMS_OUTPUT.PUT_LINE | Outputs the specified text. The text length cannot exceed 32,767 bytes. |
| DBMS_OUTPUT.PUT | Outputs the specified text to the front of the specified text without adding a line break. The text length cannot exceed 32,767 bytes. |

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| API | Description |
| --- | --- |
| DBMS_OUTPUT.ENABLE | Sets the buffer area size. If this interface is not specified, the maximum buffer size is 20,000 bytes and the minimum buffer size is 2000 bytes. If the specified buffer size is less than 2000 bytes, the default minimum buffer size is applied. |

- DBMS_OUTPUT.PUT_LINE

The PUT_LINE procedure writes a row of text carrying a line end symbol in the buffer. The DBMS_OUTPUT.PUT_LINE function prototype is:

```
DBMS_OUTPUT.PUT_LINE (
item IN VARCHAR2);
```

**Table 13-22** DBMS_OUTPUT.PUT_LINE interface parameters

| Parameter | Description |
| --- | --- |
| item | Specifies the text that was written to the buffer. |

- DBMS_OUTPUT.PUT

The stored procedure **PUT** outputs the specified text to the front of the specified text without adding a linefeed. The DBMS_OUTPUT.PUT function prototype is:

```
DBMS_OUTPUT.PUT (
item IN VARCHAR2);
```

**Table 13-23** DBMS_OUTPUT.PUT interface parameters

| Parameter | Description |
| --- | --- |
| item | Specifies the text that was written to the specified text. |

- DBMS_OUTPUT.ENABLE

The stored procedure **ENABLE** sets the output buffer size. If the size is not specified, it contains a maximum of 20,000 bytes. The DBMS_OUTPUT.ENABLE function prototype is:

```
DBMS_OUTPUT.ENABLE (
buf IN INTEGER);
```

**Table 13-24** DBMS_OUTPUT.ENABLE interface parameters

| Parameter | Description |
| --- | --- |
| buf | Sets the buffer area size. |

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## Examples

```
BEGIN
   DBMS_OUTPUT.ENABLE(50);
   DBMS_OUTPUT.PUT ('hello, ');
   DBMS_OUTPUT.PUT_LINE('database!');-- Displaying "hello, database!"
END;
/
```

# 13.11.4 UTL_RAW

## Related Interfaces

Table 13-25 provides all interfaces supported by the **UTL_RAW** package.

**Table 13-25** UTL_RAW

| API | Description |
| --- | --- |
| UTL_RAW.CAST_FROM_BINARY_INTEGER | Converts an INTEGER type value to a binary representation (RAW type). |
| UTL_RAW.CAST_TO_BINARY_INTEGER | Converts a binary representation (RAW type) to an INTEGER type value. |
| UTL_RAW.LENGTH | Obtains the length of the RAW type object. |
| UTL_RAW.CAST_TO_RAW | Converts a VARCHAR2 type value to a binary expression (RAW type). |

**NOTICE**

The external representation of the RAW type data is hexadecimal and its internal storage form is binary. For example, the representation of the **RAW** type data **11001011** is 'CB'. The input of the actual type conversion is 'CB'.

- UTL_RAW.CAST_FROM_BINARY_INTEGER

  The stored procedure **CAST_FROM_BINARY_INTEGER** converts an **INTEGER** type value to a binary representation (**RAW** type).

  The **UTL_RAW.CAST_FROM_BINARY_INTEGER** function prototype is:

  ```
  UTL_RAW.CAST_FROM_BINARY_INTEGER (
  n           IN  INTEGER,
  endianess   IN  INTEGER)
  RETURN RAW;
  ```

  **Table 13-26** UTL_RAW.CAST_FROM_BINARY_INTEGER interface parameters

  | Parameter | Description |
  | --- | --- |
  | n | Specifies the INTEGER type value to be converted to the RAW type. |

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| Parameter | Description |
| --- | --- |
| endianess | Specifies the **INTEGER** type value **1** or **2** of the byte sequence. (**1** indicates **BIG_ENDIAN** and **2** indicates **LITTLE-ENDIAN**.) |

- UTL_RAW.CAST_TO_BINARY_INTEGER

  The stored procedure CAST_TO_BINARY_INTEGER converts an INTEGER type value in a binary representation (RAW type) to the INTEGER type.

  The UTL_RAW.CAST_TO_BINARY_INTEGER function prototype is:

```
UTL_RAW.CAST_TO_BINARY_INTEGER (
r          IN  RAW,
endianess  IN  INTEGER)
RETURN BINARY_INTEGER;
```

  **Table 13-27** UTL_RAW.CAST_TO_BINARY_INTEGER interface parameters

| Parameter | Description |
| --- | --- |
| r | Specifies an INTEGER type value in a binary representation (RAW type). |
| endianess | Specifies the **INTEGER** type value **1** or **2** of the byte sequence. (**1** indicates **BIG_ENDIAN** and **2** indicates **LITTLE-ENDIAN**.) |

- UTL_RAW.LENGTH

  The stored procedure LENGTH returns the length of a RAW type object.

  The UTL_RAW.LENGTH function prototype is:

```
UTL_RAW.LENGTH(
r      IN RAW)
RETURN INTEGER;
```

  **Table 13-28** UTL_RAW.LENGTH interface parameters

| Parameter | Description |
| --- | --- |
| r | Specifies a RAW type object. |

- UTL_RAW.CAST_TO_RAW

  The stored procedure CAST_TO_RAW converts a VARCHAR2 type object to the RAW type.

  The UTL_RAW.CAST_TO_RAW function prototype is:

```
UTL_RAW.CAST_TO_RAW(
c      IN VARCHAR2)
RETURN RAW;
```

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**Table 13-29** UTL_RAW.CAST_TO_RAW interface parameters

| Parameter | Description |
| --- | --- |
| c | Specifies a VARCHAR2 type object to be converted. |

## Examples

```
-- Perform operations on RAW data in a stored procedure.
CREATE OR REPLACE PROCEDURE proc_raw
AS
str varchar2(100) := 'abcdef';
source raw(100);
amount integer;
BEGIN
source := utl_raw.cast_to_raw(str);--Convert the type.
amount := utl_raw.length(source);--Obtain the length.
dbms_output.put_line(amount);
END;
/

-- Invoke the stored procedure.
CALL proc_raw();

-- Delete the stored procedure.
DROP PROCEDURE proc_raw;
```

# 13.11.5 DBMS_JOB

## Related Interfaces

Table 13-30 lists all interfaces supported by the **DBMS_JOB** package.

**Table 13-30** DBMS_JOB

| Interface | Description |
| --- | --- |
| DBMS_JOB.SUBMIT | Submits a job to the job queue. The job number is automatically generated by the system. |
| DBMS_JOB.ISUBMIT | Submits a job to the job queue. The job number is specified by the user. |
| DBMS_JOB.REMOVE | Removes a job from the job queue by job number. |
| DBMS_JOB.BROKEN | Disables or enables job execution. |
| DBMS_JOB.CHANGE | Modifies user-definable attributes of a job, including the job description, next execution time, and execution interval. |
| DBMS_JOB.WHAT | Modifies the job description of a job. |
| DBMS_JOB.NEXT_DATE | Modifies the next execution time of a job. |

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| Interface | Description |
| --- | --- |
| DBMS_JOB.INTERVAL | Modifies the execution interval of a job. |
| DBMS_JOB.CHANGE_OWNER | Modifies the owner of a job. |

- DBMS_JOB.SUBMIT

  The stored procedure **SUBMIT** submits a job provided by the system.

  A prototype of the DBMS_JOB.SUBMIT function is as follows:

```
DMBS_JOB.SUBMIT(
what         IN   TEXT,
next_date    IN   TIMESTAMP DEFAULT sysdate,
job_interval IN   TEXT  DEFAULT 'null',
job          OUT  INTEGER);
```

  **NOTE**

  When a job is created (using DBMS_JOB), the system binds the current database and the username to the job by default. This function can be invoked by using **call** or **select**. If you invoke this function by using **select**, there is no need to specify output parameters. To invoke this function within a stored procedure, use **perform**.

  **Table 13-31** DBMS_JOB.SUBMIT interface parameters

| Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| what | text | IN | No | SQL statement to be executed. One or multiple DMLs, anonymous blocks, and SQL statements that invoke stored procedures, or all three combined are supported. |
| next_date | timestamp | IN | No | Specifies the next time the job will be executed. The default value is the current system time (sysdate). If the specified time has past, the job is executed at the time it is submitted. |
| interval | text | IN | Yes | Calculates the next time to execute the job. It can be an interval expression, or sysdate followed by a numeric value, for example, **sysdate+1.0/24**. If this parameter is left blank or set to **null**, the job will be executed only once, and the job status will change to **'d'** afterward. |

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| Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| job | integer | OUT | No | Specifies the job number. The value ranges from 1 to 32767. When **dbms.submit** is invoked using **select**, this parameter can be skipped. |

For example:

```
select DBMS_JOB.SUBMIT('call pro_xxx();', to_date('20180101','yyyymmdd'),'sysdate+1');

select DBMS_JOB.SUBMIT('call pro_xxx();', to_date('20180101','yyyymmdd'),'sysdate+1.0/24');

CALL DBMS_JOB.SUBMIT('INSERT INTO T_JOB  VALUES(1);  call pro_1(); call pro_2();',
add_months(to_date('201701','yyyymm'),1), 'date_trunc(''day'',SYSDATE) + 1 +(8*60+30.0)/
(24*60)' ,:jobid);
```

- DBMS_JOB.ISUBMIT

  **ISUBMIT** has the same syntax function as **SUBMIT**, but the first parameter of **ISUBMIT** is an input parameter, that is, a specified job number. In contrast, that last parameter of **SUBMIT** is an output parameter, indicating the job number automatically generated by the system.

  For example:

  ```
  CALL dbms_job.isubmit(101, 'insert_msg_statistic1;', sysdate, 'sysdate+3.0/24');
  ```

- DBMS_JOB.REMOVE

  The stored procedure **REMOVE** deletes a specified job.

  A prototype of the DBMS_JOB.REMOVE function is as follows:

  ```
  REMOVE(job  IN  INTEGER);
  ```

  **Table 13-32** DBMS_JOB.REMOVE interface parameters

  | Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
  | --- | --- | --- | --- | --- |
  | job | integer | IN | No | Specifies the job number. |

  For example:

  ```
  CALL dbms_job.remove(101);
  ```

- DBMS_JOB.BROKEN

  The stored procedure **BROKEN** sets the broken flag of a job.

  A prototype of the DBMS_JOB.BROKEN function is as follows:

  ```
  DMBS_JOB.BROKEN(
  job         IN   INTEGER,
  ```

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```
broken       IN   BOOLEAN,
next_date    IN   TIMESTAMP  DEFAULT  sysdate);
```

**Table 13-33** DBMS_JOB.BROKEN interface parameters

| Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| job | integer | IN | No | Specifies the job number. |
| broken | boolean | IN | No | Specifies the status flag, **true** for broken and **false** for not broken. Setting this parameter to **true** or **false** updates the current job. If the parameter is left blank, the job status remains unchanged. |
| next_date | timestamp | IN | Yes | Specifies the next execution time. The default is the current system time. If **broken** is set to **true**, **next_date** is updated to **'4000-1-1'**. If **broken** is **false** and **next_date** is not empty, **next_date** is updated for the job. If **next_date** is empty, it will not be updated. This parameter can be omitted, and its default value will be used in this case. |

For example:

```
CALL dbms_job.broken(101, true);
CALL dbms_job.broken(101, false, sysdate);
```

- DBMS_JOB.CHANGE

  The stored procedure **CHANGE** modifies user-definable attributes of a job, including the job content, next-execution time, and execution interval.

  A prototype of the DBMS_JOB.CHANGE function is as follows:

```
DMBS_JOB.CHANGE(
job          IN   INTEGER,
what         IN   TEXT,
next_date    IN   TIMESTAMP,
interval     IN   TEXT);
```

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**Table 13-34** DBMS_JOB.CHANGE interface parameters

| Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| job | integer | IN | No | Specifies the job number. |
| what | text | IN | Yes | Specifies the name of the stored procedure or SQL statement block that is executed. If this parameter is left blank, the system does not update the **what** parameter for the specified job. Otherwise, the system updates the **what** parameter for the specified job. |
| next_date | timestamp | IN | Yes | Specifies the next execution time. If this parameter is left blank, the system does not update the **next_date** parameter for the specified job. Otherwise, the system updates the **next_date** parameter for the specified job. |
| interval | text | IN | Yes | Specifies the time expression for calculating the next time the job will be executed. If this parameter is left blank, the system does not update the **interval** parameter for the specified job. Otherwise, the system updates the **interval** parameter for the specified job after necessary validity check. If this parameter is set to **null**, the job will be executed only once, and the job status will change to '**d**' afterward. |

For example:

```
CALL dbms_job.change(101, 'call userproc();', sysdate, 'sysdate + 1.0/1440');
CALL dbms_job.change(101, 'insert into tbl_a values(sysdate);', sysdate, 'sysdate + 1.0/1440');
```

- DBMS_JOB.WHAT

  The stored procedure **WHAT** modifies the procedures to be executed by a specified job.

  A prototype of the DBMS_JOB.WHAT function is as follows:

```
DMBS_JOB.WHAT(
job             IN     INTEGER,
what            IN     TEXT);
```

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**Table 13-35** DBMS_JOB.WHAT interface parameters

| Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| job | integer | IN | No | Specifies the job number. |
| what | text | IN | No | Specifies the name of the stored procedure or SQL statement block that is executed. |

NOTE

- If the value specified by the **what** parameter is one or multiple executable SQL statements, program blocks, or stored procedures, this procedure can be executed successfully; otherwise, it will fail to be executed.
- If the **what** parameter is a simple statement such as insert and update, a schema name must be added in front of the table name.

For example:

```
CALL dbms_job.what(101, 'call userproc();');
CALL dbms_job.what(101, 'insert into tbl_a values(sysdate);');
```

- DBMS_JOB.NEXT_DATE

  The stored procedure **NEXT_DATE** modifies the next-execution time attribute of a job.

  A prototype of the DBMS_JOB.NEXT_DATE function is as follows:

```
DMBS_JOB.NEXT_DATE(
job         IN    INTEGER,
next_date   IN    TIMESTAMP);
```

**Table 13-36** DBMS_JOB.NEXT_DATE interface parameters

| Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| job | integer | IN | No | Specifies the job number. |
| next_date | timestamp | IN | No | Specifies the next execution time. |

NOTE

If the specified **next_date** value is earlier than the current date, the job is executed once immediately.

For example:

```
CALL dbms_job.next_date(101, sysdate);
```

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- DBMS_JOB.INTERVAL

  The stored procedure **INTERVAL** modifies the execution interval attribute of a job.

  A prototype of the DBMS_JOB.INTERVAL function is as follows:

```
DMBS_JOB.INTERVAL(
job             IN   INTEGER,
interval        IN   TEXT);
```

  **Table 13-37** DBMS_JOB.INTERVAL interface parameters

| Parameter | Type | Input / Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| job | integer | IN | No | Specifies the job number. |
| interval | text | IN | Yes | Specifies the time expression for calculating the next time the job will be executed. If this parameter is left blank or set to **null**, the job will be executed only once, and the job status will change to **'d'** afterward. **interval** must be a valid time or interval type. |

  For example:

```
CALL dbms_job.interval(101, 'sysdate + 1.0/1440');
```

  NOTE

  For a job that is currently running (that is, **job_status** is **'r'**), it is not allowed to use **remove**, **change**, **next_date**, **what**, or **interval** to delete or modify job parameters.

- DBMS_JOB.CHANGE_OWNER

  The stored procedure **CHANGE_OWNER** modifies the owner of a job.

  A prototype of the DBMS_JOB.CHANGE_OWNER function is as follows:

```
DMBS_JOB.CHANGE_OWNER(
job             IN     INTEGER,
new_owner       IN     NAME);
```

  **Table 13-38** DBMS_JOB.CHANGE_OWNER interface parameters

| Parameter | Type | Input/ Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| job | integer | IN | No | Specifies the job number. |

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| Parameter | Type | Input/Output Parameter | Can Be Empty | Description |
| --- | --- | --- | --- | --- |
| new_owner | name | IN | No | Specifies the new username. |

For example:

```
CALL dbms_job.change_owner(101, 'alice');
```

## Constraints

1. After a new job is created, this job belongs to the current coordinator only, that is, this job can be scheduled and executed only on the current coordinator. Other coordinators will not schedule or execute this job. All coordinators can query, modify, and delete jobs created on other CNs.
2. Create, update, and delete jobs only using the procedures provided by the **DBMS_JOB** package. These procedures synchronize job information between different CNs and associate primary keys between the **pg_jobs** tables. If you use DML statements to add, delete, or modify records in the **pg_jobs** table, job information will become inconsistent between CNs and system catalogs may fail to be associated, compromising internal job management.
3. Each user-created task is bound to a CN. If the automatic migration function is not enabled, task statuses cannot be updated in real time when the CN is faulty during task execution. When a CN fails, all jobs on this CN cannot be scheduled or executed until the CN is restored manually. Enable the automatic migration function on CNs, so that jobs on the faulty CN will be migrated to other CNs for scheduling.
4. For each job, the hosting CN updates the real-time job information (including the job status, last execution start time, last execution end time, next execution start time, the number of execution failures if any) to the **pg_jobs** table, and synchronizes the information to other CNs, ensuring consistent job information between different CNs. In the case of CN failures, job information synchronization is reattempted by the hosting CNs, which increases job execution time. Although job information fails to be synchronized between CNs, job information can still be properly updated in the **pg_jobs** table on the hosting CNs, and jobs can be executed successfully. After a CN recovers, job information such as job execution time and status in its **pg_jobs** table may be incorrect and will be updated only after the jobs are executed again on related CNs.
5. For each job, a thread is established to execute it. If multiple jobs are triggered concurrently as scheduled, the system will need some time to start the required threads, resulting in a latency of 0.1 ms in job execution.

# 13.11.6 DBMS_SQL

## Related Interfaces

**Table 13-39** lists interfaces supported by the **DBMS_SQL** package.

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**Table 13-39** DBMS_SQL

| API | Description |
| --- | --- |
| DBMS_SQL.OPEN_CURSOR | Opens a cursor. |
| DBMS_SQL.CLOSE_CURSOR | Closes an open cursor. |
| DBMS_SQL.PARSE | Transmits a group of SQL statements to a cursor. Currently, only the **SELECT** statement is supported. |
| DBMS_SQL.EXECUTE | Performs a set of dynamically defined operations on the cursor. |
| DBMS_SQL.FETCHE_ROWS | Reads a row of cursor data. |
| DBMS_SQL.DEFINE_COLUMN | Dynamically defines a column. |
| DBMS_SQL.DEFINE_COLUMN_CHAR | Dynamically defines a column of the CHAR type. |
| DBMS_SQL.DEFINE_COLUMN_INT | Dynamically defines a column of the INT type. |
| DBMS_SQL.DEFINE_COLUMN_LONG | Dynamically defines a column of the LONG type. |
| DBMS_SQL.DEFINE_COLUMN_RAW | Dynamically defines a column of the RAW type. |
| DBMS_SQL.DEFINE_COLUMN_TEXT | Dynamically defines a column of the TEXT type. |
| DBMS_SQL.DEFINE_COLUMN_UNKNOWN | Dynamically defines a column of an unknown type. |
| DBMS_SQL.COLUMN_VALUE | Reads a dynamically defined column value. |
| DBMS_SQL.COLUMN_VALUE_CHAR | Reads a dynamically defined column value of the CHAR type. |
| DBMS_SQL.COLUMN_VALUE_INT | Reads a dynamically defined column value of the INT type. |
| DBMS_SQL.COLUMN_VALUE_LONG | Reads a dynamically defined column value of the LONG type. |
| DBMS_SQL.COLUMN_VALUE_RAW | Reads a dynamically defined column value of the RAW type. |
| DBMS_SQL.COLUMN_VALUE_TEXT | Reads a dynamically defined column value of the TEXT type. |
| DBMS_SQL.COLUMN_VALUE_UNKNOWN | Reads a dynamically defined column value of an unknown type. |

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| API | Description |
| --- | --- |
| DBMS_SQL.IS_OPEN | Checks whether a cursor is opened. |

NOTE

- You are advised to use **dbms_sql.define_column** and **dbms_sql.column_value** to define columns.
- If the size of the result set is greater than the value of **work_mem**, the result set will be flushed to disk. The value of **work_mem** must be no greater than 512 MB.

- DBMS_SQL.OPEN_CURSOR

  This function opens a cursor and is the prerequisite for the subsequent dbms_sql operations. This function does not transfer any parameter. It automatically generates cursor IDs in an ascending order and returns values to integer variables.

  The function prototype of **DBMS_SQL.OPEN_CURSOR** is:

  ```
  DBMS_SQL.OPEN_CURSOR (
  )
  RETURN INTEGER;
  ```

- DBMS_SQL.CLOSE_CURSOR

  This function closes a cursor. It is the end of each dbms_sql operation. If this function is not invoked when the stored procedure ends, the memory is still occupied by the cursor. Therefore, remember to close a cursor when you do not need to use it. If an exception occurs, the stored procedure exits but the cursor is not closed. Therefore, you are advised to include this interface in the exception handling of the stored procedure.

  The function prototype of **DBMS_SQL.CLOSE_CURSOR** is:

  ```
  DBMS_SQL.CLOSE_CURSOR (
  cursorid     IN INTEGER
  )
  RETURN INTEGER;
  ```

  **Table 13-40** DBMS_SQL.CLOSE_CURSOR interface parameters

  | Parameter Name | Description |
  | --- | --- |
  | cursorid | ID of the cursor to be closed |

- DBMS_SQL.PARSE

  This function parses the query statement of a given cursor. The input query statement is executed immediately. Currently, only the **SELECT** query statement can be parsed. The statement parameters can be transferred only through the TEXT type. The length cannot exceed 1 GB.

  The function prototype of **DBMS_SQL.PARSE** is:

  ```
  DBMS_SQL.PARSE (
  cursorid     IN INTEGER,
  query_string IN TEXT,
  label        IN INTEGER
  )
  RETURN BOOLEAN;
  ```

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**Table 13-41** DBMS_SQL.PARSE interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor whose query statement is parsed |
| query_string | Query statements to be parsed |
| language_flag | Version language number. Currently, only **1** is supported. |

- DBMS_SQL.EXECUTE

  This function executes a given cursor. This function receives a cursor ID. The obtained data after is used for subsequent operations. Currently, only the **SELECT** query statement can be executed.

  The function prototype of **DBMS_SQL.EXECUTE** is:

```
DBMS_SQL.EXECUTE(
cursorid     IN INTEGER,
)
RETURN INTEGER;
```

**Table 13-42** DBMS_SQL.EXECUTE interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor whose query statement is parsed |

- DBMS_SQL.FETCHE_ROWS

  This function returns the number of data rows that meet query conditions. Each time the interface is executed, the system obtains a set of new rows until all data is read.

  The function prototype of **DBMS_SQL.FETCHE_ROWS** is:

```
DBMS_SQL.FETCHE_ROWS(
cursorid     IN INTEGER,
)
RETURN INTEGER;
```

**Table 13-43** DBMS_SQL.FETCH_ROWS interface parameters

| Parameter Name | Description |
| --- | --- |
| curosorid | ID of the cursor to be executed |

- DBMS_SQL.DEFINE_COLUMN

  This function defines columns returned from a given cursor and can be used only for the cursors defined by **SELECT**. The defined columns are identified by the relative positions in the query list. The data type of the input variable determines the column type.

  The function prototype of **DBMS_SQL.DEFINE_COLUMN** is:

```
DBMS_SQL.DEFINE_COLUMN(
cursorid     IN INTEGER,
```

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```
position     IN INTEGER,
column_ref   IN ANYELEMENT,
column_size      IN INTEGER default 1024
)
RETURN INTEGER;
```

**Table 13-44** DBMS_SQL.DEFINE_COLUMN interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| column_ref | Variable of any type. You can select an appropriate interface to dynamically define columns based on variable types. |
| column_size | Length of a defined column |

- DBMS_SQL.DEFINE_COLUMN_CHAR

  This function defines columns of the CHAR type returned from a given cursor and can be used only for the cursors defined by **SELECT**. The defined columns are identified by the relative positions in the query list. The data type of the input variable determines the column type.

  The function prototype of **DBMS_SQL.DEFINE_COLUMN_CHAR** is:

```
DBMS_SQL.DEFINE_COLUMN_CHAR(
cursorid     IN INTEGER,
position     IN INTEGER,
column       IN TEXT,
column_size      IN INTEGER
)
RETURN INTEGER;
```

**Table 13-45** DBMS_SQL.DEFINE_COLUMN_CHAR interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| column | Parameter to be defined |
| column_size | Length of a dynamically defined column |

- DBMS_SQL.DEFINE_COLUMN_INT

  This function defines columns of the INT type returned from a given cursor and can be used only for the cursors defined by **SELECT**. The defined columns are identified by the relative positions in the query list. The data type of the input variable determines the column type.

  The function prototype of **DBMS_SQL.DEFINE_COLUMN_INT** is:

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```
DBMS_SQL.DEFINE_COLUMN_INT(
cursorid     IN INTEGER,
position     IN INTEGER
)
RETURN INTEGER;
```

**Table 13-46** DBMS_SQL.DEFINE_COLUMN_INT interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |

- DBMS_SQL.DEFINE_COLUMN_LONG

  This function defines columns of a long type (not LONG) returned from a given cursor and can be used only for the cursors defined by **SELECT**. The defined columns are identified by the relative positions in the query list. The data type of the input variable determines the column type. The maximum size of a long column is 1 GB.

  The function prototype of **DBMS_SQL.DEFINE_COLUMN_LONG** is:

```
DBMS_SQL.DEFINE_COLUMN_LONG(
cursorid     IN INTEGER,
position     IN INTEGER
)
RETURN INTEGER;
```

**Table 13-47** DBMS_SQL.DEFINE_COLUMN_LONG interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |

- DBMS_SQL.DEFINE_COLUMN_RAW

  This function defines columns of the RAW type returned from a given cursor and can be used only for the cursors defined by **SELECT**. The defined columns are identified by the relative positions in the query list. The data type of the input variable determines the column type.

  The function prototype of **DBMS_SQL.DEFINE_COLUMN_RAW** is:

```
DBMS_SQL.DEFINE_COLUMN_RAW(
cursorid     IN INTEGER,
position     IN INTEGER,
column       IN BYTEA,
column_size     IN INTEGER
)
RETURN INTEGER;
```

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**Table 13-48** DBMS_SQL.DEFINE_COLUMN_RAW interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| column | Parameter of the RAW type |
| column_size | Column length |

- DBMS_SQL.DEFINE_COLUMN_TEXT

  This function defines columns of the TEXT type returned from a given cursor and can be used only for the cursors defined by **SELECT**. The defined columns are identified by the relative positions in the query list. The data type of the input variable determines the column type.

  The function prototype of **DBMS_SQL.DEFINE_COLUMN_TEXT** is:

```
DBMS_SQL.DEFINE_COLUMN_CHAR(
cursorid     IN INTEGER,
position     IN INTEGER,
max_size     IN INTEGER
)
RETURN INTEGER;
```

**Table 13-49** DBMS_SQL.DEFINE_COLUMN_TEXT interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| max_size | Maximum length of the defined TEXT type |

- DBMS_SQL.DEFINE_COLUMN_UNKNOWN

  This function processes columns of unknown data types returned from a given cursor and is used only for the system to report an error and exist when the type cannot be identified.

  The function prototype of **DBMS_SQL.DEFINE_COLUMN_UNKNOWN** is:

```
DBMS_SQL.DEFINE_COLUMN_CHAR(
cursorid     IN INTEGER,
position     IN INTEGER,
column       IN TEXT
)
RETURN INTEGER;
```

**Table 13-50** DBMS_SQL.DEFINE_COLUMN_UNKNOWN interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |

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| Parameter Name | Description |
| --- | --- |
| position | Position of a dynamically defined column in the query |
| column | Dynamically defined parameter |

- DBMS_SQL.COLUMN_VALUE

  This function returns the cursor element value specified by a cursor and accesses the data obtained by DBMS_SQL.FETCH_ROWS.

  The function prototype of **DBMS_SQL.COLUMN_VALUE** is:

```
DBMS_SQL.COLUMN_VALUE(
cursorid              IN    INTEGER,
position              IN    INTEGER,
column_value             INOUT ANYELEMENT
)
RETURN ANYELEMENT;
```

  **Table 13-51** DBMS_SQL.COLUMN_VALUE interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| column_value | Return value of a defined column |

- DBMS_SQL.COLUMN_VALUE_CHAR

  This function returns the value of the CHAR type in a specified position of a cursor and accesses the data obtained by DBMS_SQL.FETCH_ROWS.

  The function prototype of **DBMS_SQL.COLUMN_VALUE_CHAR** is:

```
DBMS_SQL.COLUMN_VALUE_CHAR(
cursorid              IN    INTEGER,
position              IN    INTEGER,
column_value             INOUT CHARACTER,
err_num                INOUT NUMERIC default 0,
actual_length           INOUT INTEGER default 1024
)
RETURN RECORD;
```

  **Table 13-52** DBMS_SQL.COLUMN_VALUE_CHAR interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| column_value | Return value |

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| Parameter Name | Description |
| --- | --- |
| err_num | Error No. It is an output parameter and the argument must be a variable. Currently, the output value is **–1** regardless of the argument. |
| actual_length | Length of a return value |

- DBMS_SQL.COLUMN_VALUE_INT

  This function returns the value of the INT type in a specified position of a cursor and accesses the data obtained by DBMS_SQL.FETCH_ROWS. The function prototype of **DBMS_SQL.COLUMN_VALUE_INT** is:

```
DBMS_SQL.COLUMN_VALUE_INT(
cursorid              IN    INTEGER,
position              IN    INTEGER
)
RETURN INTEGER;
```

  **Table 13-53** DBMS_SQL.COLUMN_VALUE_INT interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |

- DBMS_SQL.COLUMN_VALUE_LONG

  This function returns the value of a long type (not LONG or BIGINT) in a specified position of a cursor and accesses the data obtained by DBMS_SQL.FETCH_ROWS.

  The function prototype of **DBMS_SQL.COLUMN_VALUE_LONG** is:

```
DBMS_SQL.COLUMN_VALUE_LONG(
cursorid              IN    INTEGER,
position              IN    INTEGER,
length                IN    INTEGER,
off_set               IN    INTEGER,
column_value              INOUT TEXT,
actual_length             INOUT INTEGER default 1024
)
RETURN RECORD;
```

  **Table 13-54** DBMS_SQL.COLUMN_VALUE_LONG interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| length | Length of a return value |
| off_set | Start position of a return value |

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| Parameter Name | Description |
| --- | --- |
| column_value | Return value |
| actual_length | Length of a return value |

- DBMS_SQL.COLUMN_VALUE_RAW

  This function returns the value of the RAW type in a specified position of a cursor and accesses the data obtained by DBMS_SQL.FETCH_ROWS.

  The function prototype of **DBMS_SQL.COLUMN_VALUE_RAW** is:

```
DBMS_SQL.COLUMN_VALUE_RAW(
cursorid              IN    INTEGER,
position              IN    INTEGER,
column_value            INOUT BYTEA,
err_num               INOUT NUMERIC default 0,
actual_length           INOUT INTEGER default 1024
)
RETURN RECORD;
```

**Table 13-55** DBMS_SQL.COLUMN_VALUE_RAW interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| column_value | Returned column value |
| err_num | Error No. It is an output parameter and the argument must be a variable. Currently, the output value is **–1** regardless of the argument. |
| actual_length | Length of a return value. The value longer than this length will be truncated. |

- DBMS_SQL.COLUMN_VALUE_TEXT

  This function returns the value of the TEXT type in a specified position of a cursor and accesses the data obtained by DBMS_SQL.FETCH_ROWS.

  The function prototype of **DBMS_SQL.COLUMN_VALUE_TEXT** is:

```
DBMS_SQL.COLUMN_VALUE_TEXT(
cursorid              IN    INTEGER,
position              IN    INTEGER
)
RETURN TEXT;
```

**Table 13-56** DBMS_SQL.COLUMN_VALUE_TEXT interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |

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| Parameter Name | Description |
| --- | --- |
| position | Position of a dynamically defined column in the query |

- DBMS_SQL.COLUMN_VALUE_UNKNOWN

  This function returns the value of an unknown type in a specified position of a cursor. This is an error handling interface when the type is not unknown.

  The function prototype of **DBMS_SQL.COLUMN_VALUE_UNKNOWN** is:

```
DBMS_SQL.COLUMN_VALUE_UNKNOWN(
cursorid              IN    INTEGER,
position              IN    INTEGER,
COLUMN_TYPE             IN    TEXT
)
RETURN TEXT;
```

  **Table 13-57** DBMS_SQL.COLUMN_VALUE_UNKNOWN interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be executed |
| position | Position of a dynamically defined column in the query |
| column_type | Returned parameter type |

- DBMS_SQL.IS_OPEN

This function returns the status of a cursor: **open**, **parse**, **execute**, or **define**. The value is **TRUE**. If the status is unknown, an error is reported. In other cases, the value is **FALSE**.

The function prototype of **DBMS_SQL.IS_OPEN** is:

```
DBMS_SQL.IS_OPEN(
cursorid              IN    INTEGER
)
RETURN BOOLEAN;
```

**Table 13-58** DBMS_SQL.IS_OPEN interface parameters

| Parameter Name | Description |
| --- | --- |
| cursorid | ID of the cursor to be queried |

## Examples

```
-- Perform operations on RAW data in a stored procedure.
create or replace procedure pro_dbms_sql_all_02(in_raw raw,v_in int,v_offset int)
as
cursorid int;
v_id int;
v_info bytea :=1;
query varchar(2000);
execute_ret int;
```

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```
define_column_ret_raw bytea :='1';
define_column_ret int;
begin
drop table if exists pro_dbms_sql_all_tb1_02 ;
create table pro_dbms_sql_all_tb1_02(a int ,b blob);
insert into pro_dbms_sql_all_tb1_02 values(1,HEXTORAW('DEADBEEE'));
insert into pro_dbms_sql_all_tb1_02 values(2,in_raw);
query := 'select * from pro_dbms_sql_all_tb1_02 order by 1';
-- Open a cursor.
cursorid := dbms_sql.open_cursor();
-- Compile the cursor.
dbms_sql.parse(cursorid, query, 1);
-- Define a column.
define_column_ret:= dbms_sql.define_column(cursorid,1,v_id);
define_column_ret_raw:= dbms_sql.define_column_raw(cursorid,2,v_info,10);
-- Execute the cursor.
execute_ret := dbms_sql.execute(cursorid);
loop
exit when (dbms_sql.fetch_rows(cursorid) <= 0);
-- Obtain values.
dbms_sql.column_value(cursorid,1,v_id);
dbms_sql.column_value_raw(cursorid,2,v_info,v_in,v_offset);
-- Output the result.
dbms_output.put_line('id:'|| v_id || ' info:' || v_info);
end loop;
-- Close the cursor.
dbms_sql.close_cursor(cursorid);
end;
/
-- Invoke the stored procedure.
call pro_dbms_sql_all_02(HEXTORAW('DEADBEEF'),0,1);

-- Delete the stored procedure.
DROP PROCEDURE pro_dbms_sql_all_02;
```

# 13.12 Debugging

## Syntax

RAISE has the following five syntax formats:

**Figure 13-34** raise_format::=

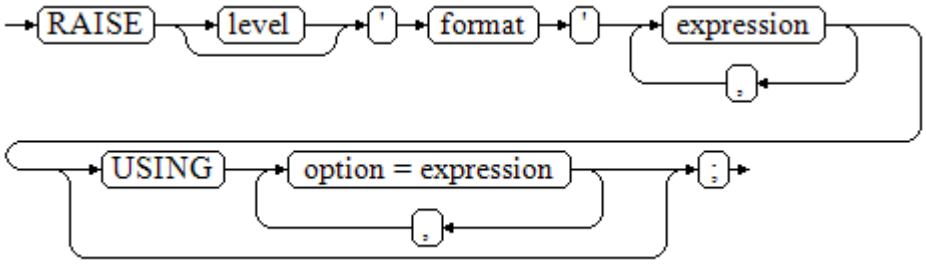


**Figure 13-35** raise_condition::=

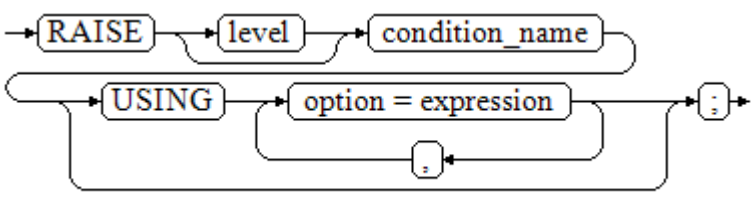


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**Figure 13-36** raise_sqlstate::=

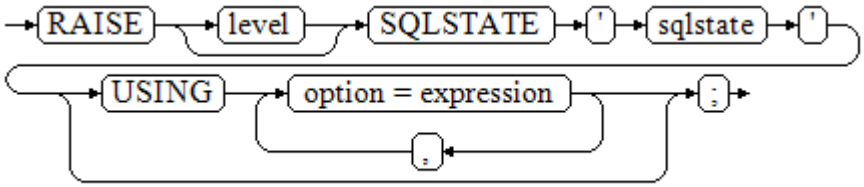



**Figure 13-37** raise_option::=

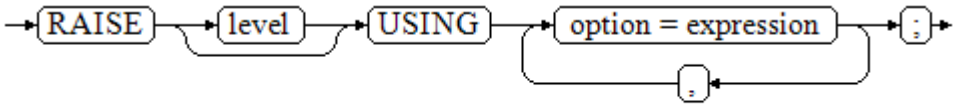
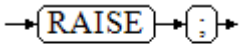



**Figure 13-38** raise::=




Parameter description:

- The level option is used to specify the error level, that is, **DEBUG**, **LOG**, **INFO**, **NOTICE**, **WARNING**, or **EXCEPTION** (default). **EXCEPTION** throws an error that normally terminates the current transaction and the others only generate information at their levels. The **log_min_messages** and **client_min_messages** parameters control whether the error messages of specific levels are reported to the client and are written to the server log.
- **format**: specifies the error message text to be reported, a format character string. The format character string can be appended with an expression for insertion to the message text. In a format character string, **%** is replaced by the parameter value attached to format and **%%** is used to print **%**. For example:

```
--v_job_id replaces % in the character string.
RAISE NOTICE 'Calling cs_create_job(%)',v_job_id;
```

- option = expression: inserts additional information to an error report. The keyword option can be **MESSAGE**, **DETAIL**, **HINT**, or **ERRCODE**, and each expression can be any character string.
  - MESSAGE: specifies the error message text. This option cannot be used in a RAISE statement that contains a format character string in front of USING.
  - DETAIL: specifies detailed information of an error.
  - HINT: prints hint information.
  - **ERRCODE**: designates an error code (SQLSTATE) to a report. A condition name or a five-character SQLSTATE error code can be used.
- condition_name: specifies the condition name corresponding to the error code.
- sqlstate: specifies the error code.

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If neither a condition name nor an **SQLSTATE** is designated in a **RAISE EXCEPTION** command, the **RAISE EXCEPTION (P0001)** is used by default. If no message text is designated, the condition name or SQLSTATE is used as the message text by default.

**NOTICE**

If the **SQLSTATE** designates an error code, the error code is not limited to a defined error code. It can be any error code containing five digits or ASCII uppercase rather than **00000**. Do not use an error code ended with three zeros because this kind of error codes are type codes and can be captured by the whole category.

**NOTE**

The syntax described in **Figure 13-38** does not append any parameter. This form is used only for the **EXCEPTION** statement in a **BEGIN** block so that the error can be re-processed.

## Examples

Display error and hint information when a transaction terminates:

```
CREATE OR REPLACE PROCEDURE proc_raise1(user_id in integer)
AS
BEGIN
RAISE EXCEPTION 'Noexistence ID --> %',user_id USING HINT = 'Please check your user ID';
END;
/

call proc_raise1(300011);

-- Execution result:
ERROR:  Noexistence ID --> 300011
HINT:  Please check your user ID
```

Two methods are available for setting **SQLSTATE**:

```
CREATE OR REPLACE PROCEDURE proc_raise2(user_id in integer)
AS
BEGIN
RAISE 'Duplicate user ID: %',user_id USING ERRCODE = 'unique_violation';
END;
/

\set VERBOSITY verbose
call proc_raise2(300011);

-- Execution result:
ERROR:  Duplicate user ID: 300011
SQLSTATE: 23505
LOCATION:  exec_stmt_raise, pl_exec.cpp:3482
```

If the main parameter is a condition name or **SQLSTATE**, the following applies:

RAISE division_by_zero;

RAISE SQLSTATE '22012';

For example:

```
CREATE OR REPLACE PROCEDURE division(div in integer, dividend in integer)
AS
DECLARE
```

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```
res int;
    BEGIN
    IF dividend=0 THEN
        RAISE division_by_zero;
        RETURN;
    ELSE
        res := div/dividend;
        RAISE INFO 'division result: %', res;
        RETURN;
    END IF;
    END;
/
call division(3,0);

-- Execution result:
ERROR:  division_by_zero
```

Alternatively:

```
RAISE unique_violation USING MESSAGE = 'Duplicate user ID: ' || user_id;
```

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# 14 System Catalogs and System Views

## 14.1 Overview of System Catalogs and System Views

System catalogs store structured metadata of GaussDB(DWS). They are the source of information used by GaussDB(DWS) to control system running and are a core component of the database system.

System views provide ways to query system catalogs and internal database status.

In separation of duty, non-administrators have no permission to view system catalogs and views. In other scenarios, system catalogs and views are either visible only to administrators or visible to all users. Some of the following system catalogs and views have marked the need of administrator permissions. They are accessible only to administrators.

You can delete and recreate the catalogs, add columns to them, and insert and update values in them, but doing so may make system information inconsistent and cause system faults. Generally, users should not modify system catalogs and system views, or rename the corresponding schemas. They are automatically maintained by the system.

**NOTICE**

Do not add, delete, or modify system catalogs because doing so will result in exceptions or even cluster unavailability.

## 14.2 System Catalogs

### 14.2.1 GS_OBSSCANINFO

**GS_OBSSCANINFO** defines the OBS runtime information scanned in cluster acceleration scenarios. Each record corresponds to a piece of runtime information of a foreign table on OBS in a query.

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**Table 14-1** GS_OBSSCANINFO columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| query_id | bigint | - | Specifies a query ID. |
| user_id | text | - | Specifies a database user who performs queries. |
| table_name | text | - | Specifies the name of a foreign table on OBS. |
| file_type | text | - | Specifies the format of files storing the underlying data. |
| time_stamp | time_stam | - | Specifies the scanning start time. |
| actual_time | double | - | Specifies the scanning execution time in seconds. |
| file_scanned | bigint | - | Specifies the number of files scanned. |
| data_size | double | - | Specifies the size of data scanned in bytes. |
| billing_info | text | - | Specifies the reserved fields. |

## 14.2.2 GS_WLM_INSTANCE_HISTORY

The **GS_WLM_INSTANCE_HISTORY** system catalog stores information about resource usage related to CN or DN instances. Each record in the system table indicates the resource usage of an instance at a specific time point, including the memory, number of CPU cores, disk I/O, physical I/O of the process, and logical I/O of the process.

**Table 14-2 GS_WLM_INSTANCE_HISTORY** column

| Name | Type | Description |
| --- | --- | --- |
| instancena me | text | Instance name |
| timestamp | timestamp with time zone | Timestamp |
| used_cpu | int | CPU usage of an instance |
| free_mem | int | Unused memory of an instance (unit: MB) |
| used_mem | int | Used memory of an instance (unit: MB) |

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| Name | Type | Description |
| --- | --- | --- |
| io_await | real | Specifies the **io_wait** value (average value within 10 seconds) of the disk used by an instance. |
| io_util | real | Specifies the **io_util** value (average value within 10 seconds) of the disk used by an instance. |
| disk_read | real | Specifies the disk read rate (average value within 10 seconds) of an instance (unit: KB/s). |
| disk_write | real | The disk write rate (average value within 10 seconds) of an instance (unit: KB/s). |
| process_read | bigint | Specifies the read rate (excluding the number of bytes read from the disk pagecache) of the corresponding instance process that reads data from a disk. (Unit: KB/s) |
| process_write | bigint | Specifies the write rate (excluding the number of bytes written to the disk pagecache) of the corresponding instance process that writes data to a disk within 10 seconds. (Unit: KB/s) |
| logical_read | bigint | CN instance: N/A<br>DN instance: Specifies the logical read byte rate of the instance in the statistical interval (10 seconds). (Unit: KB/s) |
| logical_write | bigint | CN instance: N/A<br>DN instance: Specifies the logical write byte rate of the instance within the statistical interval (10 seconds). (Unit: KB/s) |
| read_counts | bigint | CN instance: N/A<br>DN instance: Specifies the total number of logical read operations of the instance in the statistical interval (10 seconds). |
| write_counts | bigint | CN instance: N/A<br>DN instance: Specifies the total number of logical write operations of the instance in the statistical interval (10 seconds). |

## 14.2.3 GS_WLM_OPERATOR_INFO

**GS_WLM_OPERATOR_INFO** records operators of completed jobs. The data is dumped from the kernel to a system catalog.

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NOTE

- This system catalog's schema is **dbms_om**.
- This system catalog has a distribution column, the gaussdb column, in PostgreSQL databases only, not other databases.
- The **pg_catalog** has the **GS_WLM_OPERATOR_INFO** view.

**Table 14-3** GS_WLM_OPERATOR_INFO columns

| Name | Type | Description |
| --- | --- | --- |
| nodename | text | Name of the CN where the statement is executed |
| queryid | bigint | Internal query_id used for statement execution |
| pid | bigint | Thread ID of the backend |
| plan_node_id | integer | plan_node_id of the execution plan of a query |
| plan_node_name | text | Name of the operator corresponding to plan_node_id |
| start_time | timestamp with time zone | Time when an operator starts to process the first data record |
| duration | bigint | Total execution time of an operator. The unit is ms. |
| query_dop | integer | Degree of parallelism (DOP) of the current operator |
| estimated_rows | bigint | Number of rows estimated by the optimizer |
| tuple_processed | bigint | Number of elements returned by the current operator |
| min_peak_memory | integer | Minimum peak memory used by the current operator on all DNs. The unit is MB. |
| max_peak_memory | integer | Maximum peak memory used by the current operator on all DNs. The unit is MB. |
| average_peak_memory | integer | Average peak memory used by the current operator on all DNs. The unit is MB. |
| memory_skew_percent | integer | Memory usage skew of the current operator among DNs |
| min_spill_size | integer | Minimum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |

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| Name | Type | Description |
| --- | --- | --- |
| max_spill_size | integer | Maximum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| average_spill_size | integer | Average spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| spill_skew_percent | integer | DN spill skew when a spill occurs |
| min_cpu_time | bigint | Minimum execution time of the operator on all DNs. The unit is ms. |
| max_cpu_time | bigint | Maximum execution time of the operator on all DNs. The unit is ms. |
| total_cpu_time | bigint | Total execution time of the operator on all DNs. The unit is ms. |
| cpu_skew_percent | integer | Skew of the execution time among DNs. |
| warning | text | Warning. The following warnings are displayed:<br>1. Sort/SetOp/HashAgg/HashJoin spill<br>2. Spill file size large than 256MB<br>3. Broadcast size large than 100MB<br>4. Early spill<br>5. Spill times is greater than 3<br>6. Spill on memory adaptive<br>7. Hash table conflict |

## 14.2.4 GS_WLM_SESSION_INFO

**GS_WLM_SESSION_INFO** records load management information about a completed job executed on all CNs. The data is dumped from the kernel to a system catalog.

NOTE

- This system catalog's schema is **dbms_om**.
- This system catalog has a distribution column, the gaussdb column, in PostgreSQL databases only, not other databases.
- The **pg_catalog** has the **GS_WLM_SESSION_INFO** view.

## 14.2.5 GS_WLM_USER_RESOURCE_HISTORY

The **GS_WLM_USER_RESOURCE_HISTORY** system table stores information about resources used by users and is valid only on CNs. Each record in the system table

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indicates the resource usage of a user at a time point, including the memory, number of CPU cores, storage space, temporary space, operator flushing space, logical I/O traffic, number of logical I/O times, and logical I/O rate. The memory, CPU, and I/O monitoring items record only the resource usage of complex jobs.

Data in the **GS_WLM_USER_RESOURCE_HISTORY** system table comes from the **PG_TOTAL_USER_RESOURCE_INFO** view.

**Table 14-4 GS_WLM_USER_RESOURCE_HISTORY** column

| Name | Type | Description |
| --- | --- | --- |
| username | text | Username |
| timestamp | timestamp with time zone | Timestamp |
| used_memory | int | Specifies the used memory (unit: MB) |
| total_memory | int | Available memory (unit: MB). **0** indicates that the available memory is not limited and depends on the maximum memory available in the database. |
| used_cpu | real | Number of CPU cores in use |
| total_cpu | int | Total number of CPU cores of the Cgroup associated with a user on the node |
| used_space | bigint | Used storage space (unit: KB) |
| total_space | bigint | Available storage space (unit: KB). **-1** indicates that the storage space is not limited. |
| used_temp_space | bigint | Used temporary storage space (unit: KB) |
| total_temp_space | bigint | Available temporary storage space (unit: KB). **-1** indicates that the maximum temporary storage space is not limited. |
| used_spill_space | bigint | Used space of operator flushing (unit: KB) |
| total_spill_space | bigint | Available storage space for operator flushing (unit: KB). The value **-1** indicates that the maximum operator flushing space is not limited. |
| read_kbytes | bigint | Byte traffic of read operations in a monitoring period (unit: KB) |
| write_kbytes | bigint | Byte traffic of write operations in a monitoring period (unit: KB) |

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| Name | Type | Description |
| --- | --- | --- |
| read_counts | bigint | Number of read operations in a monitoring period. |
| write_counts | bigint | Number of write operations in a monitoring period. |
| read_speed | real | Byte rate of read operations in a monitoring period (unit: KB) |
| write_speed | real | Byte rate of write operations in a monitoring period (unit: KB) |

## 14.2.6 PG_AGGREGATE

**pg_aggregate** records information about aggregation functions. Each entry in **pg_aggregate** is an extension of an entry in **pg_proc**. The **pg_proc** entry carries the aggregate's name, input and output data types, and other information that is similar to ordinary functions.

**Table 14-5** PG_AGGREGATE columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| aggfnoid | regproc | PG_PROC.oid | PG_PROC OID of the aggregate function |
| aggtransfn | regproc | PG_PROC.oid | Transition function |
| aggcollectfn | regproc | PG_PROC.oid | Aggregate function |
| aggfinalfn | regproc | PG_PROC.oid | Final function (zero if none) |
| aggsortop | oid | PG_OPERATOR.oid | Associated sort operator (zero if none) |
| aggtranstype | oid | PG_TYPE.oid | Data type of the aggregate function's internal transition (state) data |
| agginitval | text | - | Initial value of the transition state. This is a text column containing the initial value in its external string representation. If this column is null, the transition state value starts out null. |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| agginitcollect | text | - | Initial value of the collection state. This is a text column containing the initial value in its external string representation. If this column is null, the collection state value starts out null. |

## 14.2.7 PG_AM

**PG_AM** records information about index access methods. There is one row for each index access method supported by the system.

**Table 14-6** PG_AM columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| amname | name | - | Name of the access method |
| amstrategies | smallint | - | Number of operator strategies for this access method, or zero if access method does not have a fixed set of operator strategies |
| amsupport | smallint | - | Number of support routines for this access method |
| amcanorder | boolean | - | Whether the access method supports ordered scans sorted by the indexed column's value |
| amcanorderbyop | boolean | - | Whether the access method supports ordered scans sorted by the result of an operator on the indexed column |
| amcanbackward | boolean | - | Whether the access method supports backward scanning |
| amcanunique | boolean | - | Whether the access method supports unique indexes |
| amcanmulticol | boolean | - | Whether the access method supports multi-column indexes |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| amoptionalkey | boolean | - | Whether the access method supports a scan without any constraint for the first index column |
| amsearcharray | boolean | - | Whether the access method supports **ScalarArrayOpExpr** searches |
| amsearchnulls | boolean | - | Whether the access method supports **IS NULL/NOT NULL** searches |
| amstorage | boolean | - | Whether an index storage data type can differ from a column data type |
| amclusterable | boolean | - | Whether an index of this type can be clustered on |
| ampredlocks | boolean | - | Whether an index of this type manages fine-grained predicate locks |
| amkeytype | oid | **PG_TYPE**.oid | Type of data stored in index, or zero if not a fixed type |
| aminsert | regproc | **PG_PROC**.oid | "Insert this tuple" function |
| ambeginscan | regproc | **PG_PROC**.oid | "Prepare for index scan" function |
| amgettuple | regproc | **PG_PROC**.oid | "Next valid tuple" function, or zero if none |
| amgetbitmap | regproc | **PG_PROC**.oid | "Fetch all valid tuples" function, or zero if none |
| amrescan | regproc | **PG_PROC**.oid | "(Re)start index scan" function |
| amendscan | regproc | **PG_PROC**.oid | "Clean up after index scan" function |
| ammarkpos | regproc | **PG_PROC**.oid | "Mark current scan position" function |
| amrestrpos | regproc | **PG_PROC**.oid | "Restore marked scan position" function |
| ammerge | regproc | **PG_PROC**.oid | "Merge multiple indexes" function |
| ambuild | regproc | **PG_PROC**.oid | "Build new index" function |
| ambuildempty | regproc | **PG_PROC**.oid | "Build empty index" function |
| ambulkdelete | regproc | **PG_PROC**.oid | Bulk-delete function |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| amvacuumcleanup | regproc | PG_PROC.oid | Post-**VACUUM** cleanup function |
| amcanreturn | regproc | PG_PROC.oid | Function to check whether index supports index-only scans, or zero if none |
| amcostestimate | regproc | PG_PROC.oid | Function to estimate cost of an index scan |
| amoptions | regproc | PG_PROC.oid | Function to parse and validate **reloptions** for an index |

## 14.2.8 PG_AMOP

**PG_AMOP** records information about operators associated with access method operator families. There is one row for each operator that is a member of an operator family. A family member can be either a search operator or an ordering operator. An operator can appear in more than one family, but cannot appear in more than one search position nor more than one ordering position within a family.

**Table 14-7** PG_AMOP columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| amopfamily | oid | PG_OPFAMILY.oid | Operator family this entry is for |
| amoplefttype | oid | PG_TYPE.oid | Left-hand input data type of operator |
| amoprighttype | oid | PG_TYPE.oid | Right-hand input data type of operator |
| amopstrategy | smallint | - | Number of operator strategies |
| amoppurpose | "char" | - | Operator purpose, either **s** for search or **o** for ordering |
| amopopr | oid | PG_OPERATOR.oid | OID of the operator |
| amopmethod | oid | PG_AM.oid | Index access method the operator family is for |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| amopsortfamily | oid | PG_OPFAMILY.oid | The btree operator family this entry sorts according to, if an ordering operator; zero if a search operator |

A "search" operator entry indicates that an index of this operator family can be searched to find all rows satisfying **WHERE indexed_column operator constant**. Obviously, such an operator must return a Boolean value, and its left-hand input type must match the index's column data type.

An "ordering" operator entry indicates that an index of this operator family can be scanned to return rows in the order represented by **ORDER BY indexed_column operator constant**. Such an operator could return any sortable data type, though again its left-hand input type must match the index's column data type. The exact semantics of the **ORDER BY** are specified by the **amopsortfamily** column, which must reference a btree operator family for the operator's result type.

## 14.2.9 PG_AMPROC

**PG_AMPROC** records information about the support procedures associated with the access method operator families. There is one row for each support procedure belonging to an operator family.

**Table 14-8** PG_AMPROC columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| amprocfamily | oid | PG_OPFAMILY.oid | Operator family this entry is for |
| amproclefttype | oid | PG_TYPE.oid | Left-hand input data type of associated operator |
| amprocrighttype | oid | PG_TYPE.oid | Right-hand input data type of associated operator |
| amprocnum | smallint | - | Support procedure number |
| amproc | regproc | PG_PROC.oid | OID of the procedure |

The usual interpretation of the **amproclefttype** and **amprocrighttype** columns is that they identify the left and right input types of the operator(s) that a particular support procedure supports. For some access methods these match the input data type(s) of the support procedure itself, for others not. There is a notion of

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"default" support procedures for an index, which are those with **amproclefttype** and **amprocrighttype** both equal to the index opclass's **opcintype**.

## 14.2.10 PG_ATTRDEF

**PG_ATTRDEF** stores default values of columns.

**Table 14-9** PG_ATTRDEF columns

| Name | Type | Description |
| --- | --- | --- |
| adrelid | oid | Table to which the column belongs |
| adnum | smallint | Number of the column |
| adbin | pg_node_tree | Internal representation of the default value of the column |
| adsrc | text | Internal representation of the readable default value |

## 14.2.11 PG_ATTRIBUTE

**PG_ATTRIBUTE** records information about table columns.

**Table 14-10** PG_ATTRIBUTE columns

| Name | Type | Description |
| --- | --- | --- |
| attrelid | oid | Table to which the column belongs |
| attname | name | Column name |
| atttypid | oid | Column type |
| attstattarget | integer | Controls the level of details of statistics collected for this column by **ANALYZE**.<br>• A zero value indicates that no statistics should be collected.<br>• A negative value says to use the system default statistics target.<br>• The exact meaning of positive values is data type-dependent.<br>For scalar data types, **attstattarget** is both the target number of "most common values" to collect, and the target number of histogram bins to create. |
| attlen | smallint | Copy of **pg_type.typlen** of the column's type |
| attnum | smallint | Number of a column. |

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| Name | Type | Description |
| --- | --- | --- |
| attndims | integer | Number of dimensions if the column is an array; otherwise, the value is 0. |
| attcacheoff | integer | This column is always -1 on disk. When it is loaded into a row descriptor in the memory, it may be updated to cache the offset of the columns in the row. |
| atttypmod | integer | Type-specific data supplied at table creation time (for example, the maximum length of a **varchar** column). This column is used as the third parameter when passing to type-specific input functions and length coercion functions. The value will generally be -1 for types that do not need ATTTYPMOD. |
| attbyval | boolean | Copy of **pg_type.typbyval** of the column's type |
| attstorage | "char" | Copy of **pg_type.typstorage** of this column's type |
| attalign | "char" | Copy of **pg_type.typalign** of the column's type |
| attnotnull | boolean | A not-null constraint. It is possible to change this column to enable or disable the constraint. |
| atthasdef | boolean | Indicates that this column has a default value, in which case there will be a corresponding entry in the **pg_attrdef** table that actually defines the value. |
| attisdropped | boolean | Whether the column has been dropped and is no longer valid. A dropped column is still physically present in the table but is ignored by the analyzer, so it cannot be accessed through SQL. |
| attislocal | boolean | Whether the column is defined locally in the relation. Note that a column can be locally defined and inherited simultaneously. |
| attcmprmode | tinyint | Compressed modes for a specific column The compressed mode includes:<br>● ATT_CMPR_NOCOMPRESS<br>● ATT_CMPR_DELTA<br>● ATT_CMPR_DICTIONARY<br>● ATT_CMPR_PREFIX<br>● ATT_CMPR_NUMSTR |

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| Name | Type | Description |
| --- | --- | --- |
| attinhcount | integer | Number of direct ancestors this column has. A column with an ancestor cannot be dropped nor renamed. |
| attcollation | oid | Defined collation of a column |
| attacl | aclitem[] | Permissions for column-level access |
| attoptions | text[] | Property-level options |
| attfdwoptions | text[] | Property-level external data options |
| attinitdefval | bytea | **attinitdefval** stores the default value expression. **ADD COLUMN** in a row-store table must use this column. |

## 14.2.12 PG_AUTHID

**PG_AUTHID** records information about the database authentication identifiers (roles). The concept of users is contained in that of roles. A user is actually a role whose rolcanlogin has been set. Any role, whether the rolcanlogin is set or not, can use other roles as members.

For a cluster, only one **pg_authid** exists which is not available for every database. It is accessible only to users with system administrator rights.

**Table 14-11** PG_AUTHID columns

| Column | Type | Description |
| --- | --- | --- |
| oid | oid | Row identifier (hidden attribute; must be explicitly selected) |
| rolname | name | Role name |
| rolsuper | boolean | Whether the role is the initial system administrator with the highest permission |
| rolinherit | boolean | Whether the role automatically inherits permissions of roles it is a member of |
| rolcreaterole | boolean | Whether the role can create more roles |
| rolcreatedb | boolean | Whether the role can create databases |
| rolcatupdate | boolean | Whether the role can directly update system catalogs. Only the initial system administrator whose usesysid is 10 has this permission. It is not available for other users. |

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| Column | Type | Description |
| --- | --- | --- |
| rolcanlogin | boolean | Whether a role can log in, that is, whether a role can be given as the initial session authorization identifier. |
| rolreplication | boolean | Indicates that the role is a replicated one (an adaptation syntax and no actual meaning). |
| rolauditadmin | boolean | Indicates that the role is an audit user. |
| rolsystemadmin | boolean | Indicates that the role is an administrator. |
| rolconnlimit | integer | For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit. |
| rolpassword | text | Password (possibly encrypted); **NULL** if no password. |
| rolvalidbegin | timestamp with time zone | Account validity start time; **NULL** if no start time |
| rolvaliduntil | timestamp with time zone | Password expiry time; **NULL** if no expiration |
| rolrespool | name | Resource pool that a user can use |
| roluseft | boolean | Whether the role can perform operations on foreign tables |
| rolparentid | oid | OID of a group user to which the user belongs |
| roltabspace | Text | Storage space of the user permanent table |
| rolkind | char | Special type of user, including private users, logical cluster administrators, and common users. |
| rolnodegroup | oid | OID of a node group associated with a user. The node group must be a logical cluster. |
| roltempspace | Text | Storage space of the user temporary table |
| rolspillspace | Text | Operator disk spill space of the user |
| rolexcpdata | text | Reserved column |
| rolauthinfo | text | Additional information when LDAP authentication is used. If other authentication modes are used, the value is **NULL**. |

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| Column | Type | Description |
| --- | --- | --- |
| rolpwdexpire | integer | Password expiration time. Users can change their password before it expires. After the password expires, only the administrator can change the password. The value **-1** indicates that the password never expires. |
| rolpwdtime | timestamp with time zone | Time when a password is created |

## 14.2.13 PG_AUTH_HISTORY

**PG_AUTH_HISTORY** records the authentication history of the role. It is accessible only to users with system administrator rights.

**Table 14-12** PG_AUTH_HISTORY columns

| Name | Type | Description |
| --- | --- | --- |
| roloid | oid | ID of the role |
| passwordtime | timestamp with time zone | Time of password creation and change |
| rolpassword | text | Role password that is encrypted using MD5 or SHA256, or that is not encrypted |

## 14.2.14 PG_AUTH_MEMBERS

**PG_AUTH_MEMBERS** records the membership relations between roles.

**Table 14-13** PG_AUTH_MEMBERS columns

| Name | Type | Description |
| --- | --- | --- |
| roleid | oid | ID of a role that has a member |
| member | oid | ID of a role that is a member of ROLEID |
| grantor | oid | ID of a role that grants this membership |
| admin_option | boolean | Whether a member can grant membership in ROLEID to others |

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## 14.2.15 PG_CAST

**PG_CAST** records conversion relationships between data types.

**Table 14-14** PG_CAST columns

| Name | Type | Description |
| --- | --- | --- |
| castsource | oid | OID of the source data type |
| casttarget | oid | OID of the target data type |
| castfunc | oid | OID of the conversion function. If the value is **0**, no conversion function is required. |
| castcontext | "char" | Conversion mode between the source and target data types<br>• **e** indicates that only explicit conversion can be performed (using the CAST or :: syntax).<br>• **i** indicates that only implicit conversion can be performed.<br>• **a** indicates that both explicit and implicit conversion can be performed between data types. |
| castmethod | "char" | Conversion method<br>• **f** indicates that conversion is performed using the specified function in the **castfunc** column.<br>• **b** indicates that binary forcible conversion rather than the specified function in the **castfunc** column is performed between data types. |

## 14.2.16 PG_CLASS

**PG_CLASS** records database objects and their relations.

**Table 14-15** PG_CLASS columns

| Name | Type | Description |
| --- | --- | --- |
| oid | oid | Row identifier (hidden attribute; must be explicitly selected) |
| relname | name | Name of an object, such as a table, index, or view |
| relnamespace | oid | OID of the namespace that contains the relationship |

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| Name | Type | Description |
| --- | --- | --- |
| reltype | oid | Data type that corresponds to this table's row type (the index is 0 because the index does not have **pg_type** record) |
| reloftype | oid | OID is of composite type. **0** indicates other types. |
| relowner | oid | Owner of the relationship |
| relam | oid | Specifies the access method used, such as B-tree and hash, if this is an index |
| relfilenode | oid | Name of the on-disk file of this relationship. If such file does not exist, the value is **0**. |
| reltablespace | oid | Tablespace in which this relationship is stored. If its value is **0**, the default tablespace in this database is used. This column is meaningless if the relationship has no on-disk file. |
| relpages | double precision | Size of the on-disk representation of this table in pages (of size BLCKSZ). This is only an estimate used by the optimizer. |
| reltuples | double precision | Number of rows in the table. This is only an estimate used by the optimizer. |
| relallvisible | integer | Number of pages marked as all visible in the table. This column is used by the optimizer for optimizing SQL execution. It is updated by **VACUUM**, **ANALYZE**, and a few DDL statements such as **CREATE INDEX**. |
| reltoastrelid | oid | OID of the TOAST table associated with this table. The OID is 0 if no TOAST table exists.<br>The TOAST table stores large columns "offline" in a secondary table. |
| reltoastidxid | oid | OID of the index for a TOAST table. The OID is 0 for a table other than a TOAST table. |
| reldeltarelid | oid | OID of a Delta table<br>Delta tables belong to column-store tables. They store long tail data generated during data import. |
| reldeltaidx | oid | OID of the index for a Delta table |
| relcudescrelid | oid | OID of a CU description table<br>CU description tables (Desc tables) belong to column-store tables. They control whether storage data in the HDFS table directory is visible. |
| relcudescidx | oid | OID of the index for a CU description table |

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| Name | Type | Description |
| --- | --- | --- |
| relhasindex | boolean | Its value is **true** if this column is a table and has (or recently had) at least one index.<br>It is set by **CREATE INDEX** but is not immediately cleared by **DROP INDEX**. If the **VACUUM** process detects that a table has no index, it clears the **relhasindex** column and sets the value to **false**. |
| relisshared | boolean | Its value is **true** if the table is shared across all databases in the cluster. Only certain system catalogs (such as **pg_database**) are shared. |
| relpersistence | "char" | • **p** indicates a permanent table.<br>• **u** indicates a non-log table.<br>• **t** indicates a temporary table. |
| relkind | "char" | • **r** indicates an ordinary table.<br>• **i** indicates an index.<br>• **S** indicates a sequence.<br>• **v** indicates a view.<br>• **c** indicates the composite type.<br>• **t** indicates a TOAST table.<br>• **f** indicates a foreign table. |
| relnatts | smallint | Number of user columns in the relationship (excluding system columns) **pg_attribute** has the same number of rows corresponding to the user columns. |
| relchecks | smallint | Number of constraints on a table. For details, see **PG_CONSTRAINT**. |
| relhasoids | boolean | Its value is **true** if an OID is generated for each row of the relationship. |
| relhaspkey | boolean | Its value is **true** if the table has (or once had) a primary key. |
| relhasrules | boolean | Its value is **true** if the table has rules. See table **PG_REWRITE** to check whether it has rules. |
| relhastriggers | boolean | Its value is **true** if the table has (or once had) triggers. See **PG_TRIGGER**. |
| relhassubclass | boolean | Its value is **true** if the table has (or once had) any inheritance child table. |

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| Name | Type | Description |
| --- | --- | --- |
| relcmprs | tinyint | Whether the compression feature is enabled for the table. Note that only batch insertion triggers compression so ordinary CRUD does not trigger compression.<br>• **0** indicates other tables that do not support compression (primarily system tables, on which the compression attribute cannot be modified).<br>• **1** indicates that the compression feature of the table data is NOCOMPRESS or has no specified keyword.<br>• **2** indicates that the compression feature of the table data is COMPRESS. |
| relhasclusterkey | boolean | Whether the local cluster storage is used |
| relrowmovement | boolean | Whether the row migration is allowed when the partitioned table is updated<br>• **true** indicates that the row migration is allowed.<br>• **false** indicates that the row migration is not allowed. |
| parttype | "char" | Whether the table or index has the property of a partitioned table<br>• **p** indicates that the table or index has the property of a partitioned table.<br>• **n** indicates that the table or index does not have the property of a partitioned table.<br>• **v** indicates that the table is the value partitioned table in the HDFS. |
| relfrozenxid | xid32 | All transaction IDs before this one have been replaced with a permanent ("frozen") transaction ID in this table. This column is used to track whether the table needs to be vacuumed in order to prevent transaction ID wraparound (or to allow **pg_clog** to be shrunk). The value is 0 (**InvalidTransactionId**) if the relationship is not a table.<br>To ensure forward compatibility, this column is reserved. The **relfrozenxid64** column is added to record the information. |

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| Name | Type | Description |
| --- | --- | --- |
| relacl | aclitem[] | Access permissions<br>The command output of the query is as follows:<br>rolename=xxxx/yyyy --Assigning privileges to a role<br>=xxxx/yyyy --Assigning the permission to public<br>*xxxx* indicates the assigned privileges, and *yyyy* indicates the roles that are assigned to the privileges. For details about permission descriptions, see **Table 14-16**. |
| reloptions | text[] | Access-method-specific options, as "keyword=value" strings |
| relfrozenxid64 | xid | All transaction IDs before this one have been replaced with a permanent ("frozen") transaction ID in this table. This column is used to track whether the table needs to be vacuumed in order to prevent transaction ID wraparound (or to allow **pg_clog** to be shrunk). The value is 0 (**InvalidTransactionId**) if the relationship is not a table. |

**Table 14-16** Description of privileges

| Parameter | Description |
| --- | --- |
| r | SELECT (read) |
| w | UPDATE (write) |
| a | INSERT (insert) |
| d | DELETE |
| D | TRUNCATE |
| x | REFERENCES |
| t | TRIGGER |
| X | EXECUTE |
| U | USAGE |
| C | CREATE |
| c | CONNECT |
| T | TEMPORARY |
| A | ANALYZE\|ANALYSE |
| arwdDxtA | ALL PRIVILEGES (used for tables) |
| * | Authorization options for preceding permissions |

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### Examples

View the OID and relfilenode of a table.

```
select oid,relname,relfilenode from pg_class where relname = 'table_name';
```

Count row-store tables.

```
select 'row count:'||count(1) as point from pg_class where relkind = 'r' and oid > 16384 and reloptions::text not like '%column%' and reloptions::text not like '%internal_mask%';
```

Count column-store tables.

```
select 'column count:'||count(1) as point from pg_class where relkind = 'r' and oid > 16384 and reloptions::text like '%column%';
```

## 14.2.17 PG_COLLATION

**PG_COLLATION** records the available collations, which are essentially mappings from an SQL name to operating system locale categories.

**Table 14-17** PG_COLLATION columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| collname | name | - | Collation name (unique per namespace and encoding) |
| collnamespace | oid | PG_NAMESPACE.oid | OID of the namespace that contains this collation |
| collowner | oid | PG_AUTHID.oid | Owner of the collation |
| collencoding | integer | - | Encoding in which the collation is applicable, or **-1** if it works for any encoding |
| collcollate | name | - | **LC_COLLATE** for this collation object |
| collctype | name | - | **LC_CTYPE** for this collation object |

## 14.2.18 PG_CONSTRAINT

**PG_CONSTRAINT** records check, primary key, unique, and foreign key constraints on the tables.

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**Table 14-18** PG_CONSTRAINT columns

| Name | Type | Description |
| --- | --- | --- |
| conname | name | Constraint name (not necessarily unique) |
| connamespace | oid | OID of the namespace that contains the constraint |
| contype | "char" | • **c** indicates check constraints.<br>• **f** indicates foreign key constraints.<br>• **p** indicates primary key constraints.<br>• **u** indicates unique constraints.<br>• **t** indicates trigger constraints. |
| condeferrable | boolean | Whether the constraint can be deferrable |
| condeferred | boolean | Whether the constraint can be deferrable by default |
| convalidated | boolean | Whether the constraint is valid Currently, only foreign key and check constraints can be set to false. |
| conrelid | oid | Table containing this constraint. The value is **0** if it is not a table constraint. |
| contypid | oid | Domain containing this constraint. The value is **0** if it is not a domain constraint. |
| conindid | oid | ID of the index associated with the constraint |
| confrelid | oid | Referenced table if this constraint is a foreign key; otherwise, the value is **0**. |
| confupdtype | "char" | Foreign key update action code<br>• **a** indicates no action.<br>• **r** indicates restriction.<br>• **c** indicates cascading.<br>• **n** indicates that the parameter is set to null.<br>• **d** indicates that the default value is used. |
| confdeltype | "char" | Foreign key deletion action code<br>• **a** indicates no action.<br>• **r** indicates restriction.<br>• **c** indicates cascading.<br>• **n** indicates that the parameter is set to null.<br>• **d** indicates that the default value is used. |

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| Name | Type | Description |
| --- | --- | --- |
| confmatchtype | "char" | Foreign key match type<br>• **f** indicates full match.<br>• **p** indicates partial match.<br>• **u** indicates simple match (not specified). |
| conislocal | boolean | Whether the local constraint is defined for the relationship |
| coninhcount | integer | Number of direct inheritance parent tables this constraint has. When the number is not **0**, the constraint cannot be deleted or renamed. |
| connoinherit | boolean | Whether the constraint can be inherited |
| consoft | boolean | Whether the column indicates an informational constraint. |
| conopt | boolean | Whether you can use Informational Constraint to optimize the execution plan. |
| conkey | smallint[] | Column list of the constrained control if this column is a table constraint |
| confkey | smallint[] | List of referenced columns if this column is a foreign key |
| conpfeqop | oid[] | ID list of the equality operators for PK = FK comparisons if this column is a foreign key |
| conppeqop | oid[] | ID list of the equality operators for PK = PK comparisons if this column is a foreign key |
| conffeqop | oid[] | ID list of the equality operators for FK = FK comparisons if this column is a foreign key |
| conexclop | oid[] | ID list of the per-column exclusion operators if this column is an exclusion constraint |
| conbin | pg_node_tree | Internal representation of the expression if this column is a check constraint |
| consrc | text | Human-readable representation of the expression if this column is a check constraint |

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NOTICE

- **consrc** is not updated when referenced objects change; for example, it will not track renaming of columns. Rather than relying on this field, it's best to use **pg_get_constraintdef()** to extract the definition of a check constraint.
- **pg_class.relchecks** must be consistent with the number of check-constraint entries in this table for each relationship.

## 14.2.19 PG_CONVERSION

**PG_CONVERSION** records encoding conversion information.

**Table 14-19** PG_CONVERSION columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| conname | name | - | Conversion name (unique in a namespace) |
| connamespace | oid | PG_NAMESPACE.oid | OID of the namespace that contains this conversion |
| conowner | oid | PG_AUTHID.oid | Owner of the conversion |
| conforencoding | integer | - | Source encoding ID |
| contoencoding | integer | - | Destination encoding ID |
| conproc | regproc | PG_PROC.oid | Conversion procedure |
| condefault | boolean | - | Its value is **true** if this is the default conversion. |

## 14.2.20 PG_DATABASE

**PG_DATABASE** records information about the available databases.

**Table 14-20** PG_DATABASE columns

| Name | Type | Description |
| --- | --- | --- |
| datname | name | Database name |
| datdba | oid | Owner of the database, usually the user who created it |

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| Name | Type | Description |
| --- | --- | --- |
| encoding | integer | Database encoding.<br>You can use pg_encoding_to_char() to convert this number to the encoding name. |
| datcollate | name | Sequence used by the database |
| datctype | name | Character type used by the database |
| datistemplate | boolean | Whether this column can serve as a template database |
| datallowconn | boolean | If false then no one can connect to this database. This column is used to protect the **template0** database from being altered. |
| datconnlimit | integer | Maximum number of concurrent connections allowed on this database. **-1** indicates no limit. |
| datlastsysoid | oid | Last system OID in the database |
| datfrozenxid | xid32 | Tracks whether the database needs to be vacuumed in order to prevent transaction ID wraparound.<br>To ensure forward compatibility, this column is reserved. The **datfrozenxid64** column is added to record the information. |
| dattablespace | oid | Default tablespace of the database |
| datcompatibility | name | Database compatibility mode |
| datacl | aclitem[] | Access permissions |
| datfrozenxid64 | xid | Tracks whether the database needs to be vacuumed in order to prevent transaction ID wraparound. |

## 14.2.21 PG_DB_ROLE_SETTING

**PG_DB_ROLE_SETTING** records the default values of configuration items bonded to each role and database when the database is running.

**Table 14-21** PG_DB_ROLE_SETTING columns

| Name | Type | Description |
| --- | --- | --- |
| setdatabase | oid | Database corresponding to the configuration items; the value is **0** if the database is not specified |

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| Name | Type | Description |
| --- | --- | --- |
| setrole | oid | Role corresponding to the configuration items; the value is **0** if the role is not specified |
| setconfig | text[] | Default value of configuration items when the database is running |

## 14.2.22 PG_DEFAULT_ACL

**PG_DEFAULT_ACL** records the initial privileges assigned to the newly created objects.

**Table 14-22** PG_DEFAULT_ACL columns

| Name | Type | Description |
| --- | --- | --- |
| defaclrole | oid | ID of the role associated with the permission |
| defaclnamespace | oid | Namespace associated with the permission; the value is **0** if no ID |
| defaclobjtype | "char" | Object type of the permission:<br>• **r** indicates a table or view.<br>• **S** indicates a sequence.<br>• **f** indicates a function.<br>• **T** indicates a type. |
| defaclacl | aclitem[] | Access permissions that this type of object should have on creation |

## 14.2.23 PG_DEPEND

**PG_DEPEND** records the dependency relationships between database objects. This information allows **DROP** commands to find which other objects must be dropped by **DROP CASCADE** or prevent dropping in the **DROP RESTRICT** case.

See also **PG_SHDEPEND**, which provides a similar function for dependencies involving objects that are shared across a database cluster.

**Table 14-23** PG_DEPEND columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| classid | oid | **PG_CLASS**.oid | OID of the system catalog the dependent object is in |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| objid | oid | Any OID column | OID of the specific dependent object |
| objsubid | integer | - | For a table column, this is the column number (the objid and classid refer to the table itself). For all other object types, this column is **0**. |
| refclassid | oid | **PG_CLASS**.oid | OID of the system catalog the referenced object is in |
| refobjid | oid | Any OID column | OID of the specific referenced object |
| refobjsubid | integer | - | For a table column, this is the column number (the refobjid and refclassid refer to the table itself). For all other object types, this column is **0**. |
| deptype | "char" | - | A code defining the specific semantics of this dependency relationship |

In all cases, a **pg_depend** entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors defined by **deptype**:

- DEPENDENCY_NORMAL (n): A normal relationship between separately-created objects. The dependent object can be dropped without affecting the referenced object. The referenced object can only be dropped by specifying **CASCADE**, in which case the dependent object is dropped, too. Example: a table column has a normal dependency on its data type.
- DEPENDENCY_AUTO (a): The dependent object can be dropped separately from the referenced object, and should be automatically dropped (regardless of RESTRICT or CASCADE mode) if the referenced object is dropped. Example: a named constraint on a table is made autodependent on the table, so that it will go away if the table is dropped.
- DEPENDENCY_INTERNAL (i): The dependent object was created as part of creation of the referenced object, and is only a part of its internal implementation. A DROP of the dependent object will be disallowed outright (We'll tell the user to issue a DROP against the referenced object, instead). A DROP of the referenced object will be propagated through to drop the dependent object whether CASCADE is specified or not. Example: A trigger created to enforce a foreign-key constraint is made internally dependent on the constraint's **PG_CONSTRAINT** entry.
- DEPENDENCY_EXTENSION (e): dependent objects depended object extension of a member. For details, see **PG_EXTENSION**). The dependent object can be dropped via **DROP EXTENSION** on the referenced object. Functionally this dependency type acts the same as an internal dependency, but it is kept separate for clarity and to simplify **gs_dump**.

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- DEPENDENCY_PIN (p): There is no dependent object. This type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by **initdb**. The columns for the dependent object contain zeroes.

## 14.2.24 PG_DESCRIPTION

**PG_DESCRIPTION** records optional descriptions (comments) for each database object. Descriptions of many built-in system objects are provided in the initial contents of **PG_DESCRIPTION**.

See also **PG_SHDESCRIPTION**, which performs a similar function for descriptions involving objects that are shared across a database cluster.

**Table 14-24** PG_DESCRIPTION columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| objoid | oid | Any OID column | OID of the object this description pertains to |
| classoid | oid | **PG_CLASS**oid | OID of the system catalog this object appears in |
| objsubid | integer | - | For a comment on a table column, this is the column number (the **objoid** and **classoid** refer to the table itself). For all other object types, this column is **0**. |
| description | text | - | Arbitrary text that serves as the description of this object |

## 14.2.25 PG_ENUM

**PG_ENUM** records entries showing the values and labels for each enum type. The internal representation of a given enum value is actually the OID of its associated row in **pg_enum**.

**Table 14-25** PG_ENUM columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| enumtypid | oid | **PG_TYPE**.oid | OID of the **pg_type** entry that contains this enum value |
| enumsortorder | real | - | Sort position of this enum value within its enum type |
| enumlabel | name | - | Textual label for this enum value |

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The OIDs for **PG_ENUM** rows follow a special rule: even-numbered OIDs are guaranteed to be ordered in the same way as the sort ordering of their enum type. That is, if two even OIDs belong to the same enum type, the smaller OID must have the smaller **enumsortorder** value. Odd-numbered OID values need bear no relationship to the sort order. This rule allows the enum comparison routines to avoid catalog lookups in many common cases. The routines that create and alter enum types attempt to assign even OIDs to enum values whenever possible.

When an enum type is created, its members are assigned sort-order positions from 1 to *n*. But members added later might be given negative or fractional values of **enumsortorder**. The only requirement on these values is that they be correctly ordered and unique within each enum type.

## 14.2.26 PG_EXTENSION

**PG_EXTENSION** records information about the installed extensions. By default, GaussDB(DWS) has 12 extensions, that is, PLPGSQL, DIST_FDW, FILE_FDW, HDFS_FDW, HSTORE, PLDBGAPI, DIMSEARCH, PACKAGES, GC_FDW, UUID-OSSP, LOG_FDW, and ROACH_API.

**Table 14-26** PG_EXTENSION

| Name | Type | Description |
| --- | --- | --- |
| extname | name | Extension name |
| extowner | oid | Owner of the extension |
| extnamespace | oid | Namespace containing the extension's exported objects |
| extrelocatable | boolean | Its value is **true** if the extension can be relocated to another schema. |
| extversion | text | Version number of the extension |
| extconfig | oid[] | Configuration information about the extension |
| extcondition | text[] | Filter conditions for the extension's configuration information |

## 14.2.27 PG_EXTENSION_DATA_SOURCE

**PG_EXTENSION_DATA_SOURCE** records information about external data source. An external data source contains information about an external database, such as its password encoding. It is mainy used with Extension Connector.

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**Table 14-27** PG_EXTENSION_DATA_SOURCE columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| srcname | name | - | Name of an external data source |
| srcowner | oid | PG_AUTHID.oid | Owner of an external data source |
| srctype | text | - | Type of an external data source. It is NULL by default. |
| srcversion | text | - | Type of an external data source. It is NULL by default. |
| srcacl | aclitem[] | - | Access permissions |
| srcoptions | text[] | - | Option used for foreign data sources. It is a keyword=value string. |

## 14.2.28 PG_FOREIGN_DATA_WRAPPER

**PG_FOREIGN_DATA_WRAPPER** records foreign-data wrapper definitions. A foreign-data wrapper is the mechanism by which external data, residing on foreign servers, is accessed.

**Table 14-28** PG_FOREIGN_DATA_WRAPPER columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| fdwname | name | - | Name of the foreign-data wrapper |
| fdwowner | oid | PG_AUTHID.oid | Owner of the foreign-data wrapper |
| fdwhandler | oid | PG_PROC.oid | References a handler function that is responsible for supplying execution routines for the foreign-data wrapper. Its value is **0** if no handler is provided. |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| fdwvalidator | oid | PG_PROC.oid | References a validator function that is responsible for checking the validity of the options given to the foreign-data wrapper, as well as options for foreign servers and user mappings using the foreign-data wrapper. Its value is **0** if no validator is provided. |
| fdwacl | aclitem[] | - | Access permissions |
| fdwoptions | text[] | - | Option used for foreign data wrappers. It is a keyword=value string. |

## 14.2.29 PG_FOREIGN_SERVER

**PG_FOREIGN_SERVER** records the foreign server definitions. A foreign server describes a source of external data, such as a remote server. Foreign servers are accessed via foreign-data wrappers.

**Table 14-29** PG_FOREIGN_SERVER columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| srvname | name | - | Name of the foreign server |
| srvowner | oid | PG_AUTHID.oid | Owner of the foreign server |
| srvfdw | oid | PG_FOREIGN_DATA_WRAPPER.oid | OID of the foreign-data wrapper of this foreign server |
| srvtype | text | - | Type of the server (optional) |
| srvversion | text | - | Version of the server (optional) |
| srvacl | aclitem[] | - | Access permissions |
| srvoptions | text[] | - | Option used for foreign servers. It is a keyword=value string. |

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## 14.2.30 PG_FOREIGN_TABLE

**PG_FOREIGN_TABLE** records auxiliary information about foreign tables.

**Table 14-30** PG_FOREIGN_TABLE columns

| Name | Type | Description |
| --- | --- | --- |
| ftrelid | oid | OID of the foreign table |
| ftserver | oid | OID of the server where the foreign table is located |
| ftwriteonly | boolean | Whether data can be written in the foreign table |
| ftoptions | text[] | Foreign table options |

## 14.2.31 PG_INDEX

**PG_INDEX** records part of the information about indexes. The rest is mostly in **PG_CLASS**.

**Table 14-31** PG_INDEX columns

| Name | Type | Description |
| --- | --- | --- |
| indexrelid | oid | OID of the **pg_class** entry for this index |
| indrelid | oid | OID of the **pg_class** entry for the table this index is for |
| indnatts | smallint | Number of columns in an index |
| indisunique | boolean | This index is a unique index if the value is **true**. |
| indisprimary | boolean | This index represents the primary key of the table if the value is **true**. If this value is **true**, the value of **indisunique** is true. |
| indisexclusion | boolean | This index supports exclusion constraints if the value is **true**. |
| indimmediate | boolean | A uniqueness check is performed upon data insertion if the value is **true**. |
| indisclustered | boolean | The table was last clustered on this index if the value is **true**. |
| indisusable | boolean | This index supports insert/select if the value is **true**. |

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| Name | Type | Description |
| --- | --- | --- |
| indisvalid | boolean | This index is valid for queries if the value is **true**. If this column is **false**, this index is possibly incomplete and must still be modified by **INSERT/UPDATE** operations, but it cannot safely be used for queries. If it is a unique index, the uniqueness property is also not true. |
| indcheckxmin | boolean | If the value is **true**, queries must not use the index until the xmin of this row in **pg_index** is below their **TransactionXmin** event horizon, because the table may contain broken HOT chains with incompatible rows that they can see. |
| indisready | boolean | If the value is **true**, this index is ready for inserts. If the value is **false**, this index is ignored when data is inserted or modified. |
| indkey | int2vector | This is an array of **indnatts** values that indicate which table columns this index creates. For example, a value of **1 3** means that the first and the third columns make up the index key. **0** in this array indicates that the corresponding index attribute is an expression over the table columns, rather than a simple column reference. |
| indcollation | oidvector | ID of each column used by the index |
| indclass | oidvector | For each column in the index key, this column contains the OID of the operator class to use. For details, see **PG_OPCLASS**. |
| indoption | int2vector | Array of values that store per-column flag bits. The meaning of the bits is defined by the index's access method. |
| indexprs | pg_node_tree | Expression trees (in **nodeToString()** representation) for index attributes that are not simple column references. It is a list with one element for each zero entry in **INDKEY**. NULL if all index attributes are simple references. |
| indpred | pg_node_tree | Expression tree (in **nodeToString()** representation) for partial index predicate. If the index is not a partial index, the value is null. |

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## 14.2.32 PG_INHERITS

**PG_INHERITS** records information about table inheritance hierarchies. There is one entry for each direct child table in the database. Indirect inheritance can be determined by following chains of entries.

**Table 14-32** PG_INHERITS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| inhrelid | oid | PG_CLASS.oid | OID of the child table |
| inhparent | oid | PG_CLASS.oid | OID of the parent table |
| inhseqno | integer | - | If there is more than one direct parent for a child table (multiple inheritances), this number tells the order in which the inherited columns are to be arranged. The count starts at 1. |

## 14.2.33 PG_JOBS

**PG_JOBS** records detailed information about jobs created by users. Dedicated threads poll the **pg_jobs** table and trigger jobs based on scheduled job execution time. This table belongs to the Shared Relation category. All job records are visible to all databases.

**Table 14-33** PG_JOBS columns

| Name | Type | Description |
| --- | --- | --- |
| job_id | integer | Job ID, primary key, unique (with a unique index) |
| what | text | Job content |
| log_user | oid | Username of the job creator |
| priv_user | oid | User ID of the job executor |
| job_db | oid | OID of the database where the job is executed |
| job_nsp | oid | OID of the namespace where a job is running |
| job_node | oid | CN node on which the job will be created and executed |

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| Name | Type | Description |
| --- | --- | --- |
| is_broken | boolean | Job invalid or not. If a job fails to be executed for 16 consecutive times, **is_broken** is automatically set to **true** and the job will not be executed later. |
| start_date | timestamp without time zone | Start time of the first job execution, accurate to millisecond |
| next_run_date | timestamp without time zone | Scheduled time of the next job execution, accurate to millisecond |
| failure_count | smallint | Number of times the job has started and failed. If a job fails to be executed for 16 consecutive times, no more attempt will be made on it. |
| interval | text | Job execution interval |
| last_start_date | timestamp without time zone | Start time of the last job execution, accurate to millisecond |
| last_end_date | timestamp without time zone | End time of the last job execution, accurate to millisecond |
| last_suc_date | timestamp without time zone | Start time of the last successful job execution, accurate to millisecond |
| this_run_date | timestamp without time zone | Start time of the ongoing job execution, accurate to millisecond |

## 14.2.34 PG_LANGUAGE

**PG_LANGUAGE** records programming languages. You can use them and interfaces to write functions or stored procedures.

**Table 14-34** PG_LANGUAGE columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| lanname | name | - | Name of the language |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| lanowner | oid | PG_AUTHID.oid | Owner of the language |
| lanispl | boolean | - | The value is **false** for internal languages (such as SQL) and **true** for user-defined languages. Currently, **gs_dump** still uses this to determine which languages need to be dumped, but this might be replaced by a different mechanism in the future. |
| lanpltrusted | boolean | - | Its value is **true** if this is a trusted language, which means that it is believed not to grant access to anything outside the normal SQL execution environment. Only the initial user can create functions in untrusted languages. |
| lanplcallfoid | oid | PG_PROC.oid | For external languages, this references the language handler, which is a special function that is responsible for executing all functions that are written in the particular language. |
| laninline | oid | PG_PROC.oid | This references a function that is responsible for executing "inline" anonymous code blocks (DO blocks). The value is **0** if inline blocks are not supported. |
| lanvalidator | oid | PG_PROC.oid | This references a language validator function that is responsible for checking the syntax and validity of new functions when they are created. The value is **0** if no validator is provided. |
| lanacl | aclitem[] | - | Access permissions |

## 14.2.35 PG_LARGEOBJECT

**PG_LARGEOBJECT** records the data making up large objects A large object is identified by an OID assigned when it is created. Each large object is broken into segments or "pages" small enough to be conveniently stored as rows in **pg_largeobject**. The amount of data per page is defined to be LOBLKSIZE (which is currently BLCKSZ/4, or typically 2 kB).

It is accessible only to users with system administrator rights.

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**Table 14-35** PG_LARGEOBJECT columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| loid | oid | PG_LARGEOBJECT_METADATA.oid | Identifier of the large object that includes this page |
| pageno | integer | - | Page number of this page within its large object (counting from zero) |
| data | bytea | - | Actual data stored in the large object. This will never be more than **LOBLKSIZE** bytes and might be less. |

Each row of **pg_largeobject** holds data for one page of a large object, beginning at byte offset (**pageno * LOBLKSIZE**) within the object. The implementation allows sparse storage: pages might be missing, and might be shorter than **LOBLKSIZE** bytes even if they are not the last page of the object. Missing regions within a large object are read as zeroes.

## 14.2.36 PG_LARGEOBJECT_METADATA

**PG_LARGEOBJECT_METADATA** records metadata associated with large objects. The actual large object data is stored in **PG_LARGEOBJECT**.

**Table 14-36** PG_LARGEOBJECT_METADATA columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| lomowner | oid | PG_AUTHID.oid | Owner of the large object |
| lomacl | aclitem[] | - | Access permissions |

## 14.2.37 PG_NAMESPACE

**PG_NAMESPACE** records the namespaces, that is, schema-related information.

**Table 14-37** PG_NAMESPACE columns

| Name | Type | Description |
| --- | --- | --- |
| nspname | name | Name of the namespace |
| nspowner | oid | Owner of the namespace |

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| Name | Type | Description |
| --- | --- | --- |
| nsptimeline | bigint | Timeline when the namespace is created on the DN This column is for internal use and valid only on the DN. |
| nspacl | aclitem[] | Access permissions For details, see GRANT and REVOKE. |
| permspace | bigint | Quota of a schema's permanent tablespace |
| usedspace | bigint | Used size of a schema's permanent tablespace |

## 14.2.38 PG_OBJECT

**PG_OBJECT** records the user creation, creation time, last modification time, and last analyzing time of objects of specified types (types existing in **object_type**).

**Table 14-38** PG_OBJECT columns

| Name | Type | Description |
| --- | --- | --- |
| object_oid | oid | Object identifier. |
| object_type | "char" | Object type:<br>• **r** indicates a table, which can be an ordinary table or a temporary table.<br>• **i** indicates an index.<br>• **s** indicates a sequence.<br>• **v** indicates a view.<br>• **p** indicates a stored procedure and function. |
| creator | oid | ID of the creator. |
| ctime | timestamp with time zone | Object creation time. |
| mtime | timestamp with time zone | Time when the object was last modified. By default, the **ALTER**, **COMMENT**, **GRANT**, **REVOKE**, and **TRUNCATE** operations are recorded.<br>If **light_object_mtime** is configured for **behavior_compat_options**, the **GRANT**, **REVOKE**, and **TRUNCATE** operations are not recorded. |
| last_analyze_time | timestamp with time zone | Time when an object is analyzed for the last time. |

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NOTICE

- Only normal user operations are recorded. Operations before the object upgrade and during the **initdb** process cannot be recorded.
- **ctime** and **mtime** are the start time of the transaction.
- The time of object modification due to capacity expansion is also recorded.

## 14.2.39 PG_OBSSCANINFO

**PG_OBSSCANINFO** defines the OBS runtime information scanned in cluster acceleration scenarios. Each record corresponds to a piece of runtime information of a foreign table on OBS in a query.

**Table 14-39** PG_OBSSCANINFO columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| query_id | bigint | - | Query ID |
| user_id | text | - | Database user who performs queries |
| table_name | text | - | Name of a foreign table on OBS |
| file_type | text | - | Format of files storing the underlying data |
| time_stamp | time_stam | - | Scanning start time |
| actual_time | double | - | Scanning execution time, in seconds |
| file_scanned | bigint | - | Number of files scanned |
| data_size | double | - | Size of data scanned, in bytes |
| billing_info | text | - | Reserved columns |

## 14.2.40 PG_OPCLASS

**PG_OPCLASS** defines index access method operator classes.

Each operator class defines semantics for index columns of a particular data type and a particular index access method. An operator class essentially specifies that a particular operator family is applicable to a particular indexable column data type. The set of operators from the family that are actually usable with the indexed column are whichever ones accept the column's data type as their lefthand input.

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**Table 14-40** PG_OPCLASS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| opcmethod | oid | PG_AM.oid | Index access method the operator class is for |
| opcname | name | - | Name of the operator class |
| opcnamespace | oid | PG_NAMESPACE.oid | Namespace to which the operator class belongs |
| opcowner | oid | PG_AUTHID.oid | Owner of the operator class |
| opcfamily | oid | PG_OPFAMILY.oid | Operator family containing the operator class |
| opcintype | oid | PG_TYPE.oid | Data type that the operator class indexes |
| opcdefault | boolean | - | Whether the operator class is the default for **opcintype**. If it is, its value is **true**. |
| opckeytype | oid | PG_TYPE.oid | Type of data stored in index, or zero if same as **opcintype** |

An operator class's **opcmethod** must match the **opfmethod** of its containing operator family. Also, there must be no more than one **pg_opclass** row having **opcdefault** true for any given combination of **opcmethod** and **opcintype**.

## 14.2.41 PG_OPERATOR

**PG_OPERATOR** records information about operators.

**Table 14-41** PG_OPERATOR columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| oprname | name | - | Name of the operator |
| oprnamespace | oid | PG_NAMESPACE.oid | OID of the namespace that contains this operator |
| oprowner | oid | PG_AUTHID.oid | Owner of the operator |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oprkind | "char" | - | • **b**: infix ("both")<br>• **l**: prefix ("left")<br>• **r**: postfix ("right") |
| oprcanmerge | boolean | - | Whether the operator supports merge joins |
| oprcanhash | boolean | - | Whether the operator supports hash joins |
| oprleft | oid | **PG_TYPE**.oid | Type of the left operand |
| oprright | oid | **PG_TYPE**.oid | Type of the right operand |
| oprresult | oid | **PG_TYPE**.oid | Type of the result |
| oprcom | oid | **PG_OPERATOR**.oid | Commutator of this operator, if any |
| oprnegate | oid | **PG_OPERATOR**.oid | Negator of this operator, if any |
| oprcode | regproc | **PG_PROC**.oid | Function that implements this operator |
| oprrest | regproc | **PG_PROC**.oid | Restriction selectivity estimation function for this operator |
| oprjoin | regproc | **PG_PROC**.oid | Join selectivity estimation function for this operator |

## 14.2.42 PG_OPFAMILY

**PG_OPFAMILY** defines operator families.

Each operator family is a collection of operators and associated support routines that implement the semantics specified for a particular index access method. Furthermore, the operators in a family are all "compatible", in a way that is specified by the access method. The operator family concept allows cross-data-type operators to be used with indexes and to be reasoned about using knowledge of access method semantics.

**Table 14-42** PG_OPFAMILY columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| opfmethod | oid | PG_AM.oid | Index access method the operator family is for |
| opfname | name | - | Name of the operator family |
| opfnamespace | oid | PG_NAMESPACE.oid | Namespace of the operator family |
| opfowner | oid | PG_AUTHID.oid | Owner of the operator family |

The majority of the information defining an operator family is not in **PG_OPFAMILY**, but in the associated **PG_AMOP**, **PG_AMPROC**, and **PG_OPCLASS**.

## 14.2.43 PG_PARTITION

**PG_PARTITION** records all partitioned tables, table partitions, toast tables on table partitions, and index partitions in the database. Partitioned index information is not stored in the **PG_PARTITION** system catalog.

**Table 14-43** PG_PARTITION columns

| Name | Type | Description |
| --- | --- | --- |
| relname | name | Names of the partitioned tables, table partitions, TOAST tables on table partitions, and index partitions |
| parttype | "char" | Object type<br>• **r** indicates a partitioned table.<br>• **p** indicates a table partition.<br>• **x** indicates an index partition.<br>• **t** indicates a TOAST table. |
| parentid | oid | OID of the partitioned table in **PG_CLASS** when the object is a partitioned table or table partition<br>OID of the partitioned index when the object is an index partition |
| rangenum | integer | Reserved field. |
| intervalnum | integer | Reserved field. |
| partstrategy | "char" | Partition policy of the partitioned table. The following policies are supported:<br>**r** indicates the range partition.<br>**v** indicates the numeric partition |

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| Name | Type | Description |
| --- | --- | --- |
| relfilenode | oid | Physical storage locations of the table partition, index partition, and TOAST table on the table partition. |
| reltablespace | oid | OID of the tablespace containing the table partition, index partition, TOAST table on the table partition |
| relpages | double precision | Statistics: numbers of data pages of the table partition and index partition |
| reltuples | double precision | Statistics: numbers of tuples of the table partition and index partition. |
| relallvisible | integer | Statistics: number of visible data pages of the table partition and index partition. |
| reltoastrelid | oid | OID of the TOAST table corresponding to the table partition |
| reltoastidxid | oid | OID of the TOAST table index corresponding to the table partition |
| indextblid | oid | OID of the table partition corresponding to the index partition |
| indisusable | boolean | Whether the index partition is available |
| reldeltarelid | oid | OID of a Delta table |
| reldeltaidx | oid | OID of the index for a Delta table |
| relcudescrelid | oid | OID of a CU description table |
| relcudescidx | oid | OID of the index for a CU description table |
| relfrozenxid | xid32 | Frozen transaction ID<br>To ensure forward compatibility, this column is reserved. The **relfrozenxid64** column is added to record the information. |
| intspnum | integer | Number of tablespaces that the interval partition belongs to |
| partkey | int2vector | Column number of the partition key |
| intervaltablespace | oidvector | Tablespace that the interval partition belongs to. Interval partitions fall in the tablespaces in the round-robin manner |
| interval | text[] | Interval value of the interval partition |
| boundaries | text[] | Upper boundary of the range partition and interval partition |
| transit | text[] | Transit of the interval partition |

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| Name | Type | Description |
| --- | --- | --- |
| reloptions | text[] | Storage property of a partition used for collecting online scale-out information. Same as **pg_class.reloptions**, it is a keyword=value string. |
| relfrozenxid64 | xid | Frozen transaction ID |

## 14.2.44 PG_PLTEMPLATE

**PG_PLTEMPLATE** records template information for procedural languages.

**Table 14-44** PG_PLTEMPLATE columns

| Name | Type | Description |
| --- | --- | --- |
| tmplname | name | Name of the language for which this template is used |
| tmpltrusted | boolean | The value is **true** if the language is considered trusted. |
| tmpldbacreate | boolean | The value is **true** if the language is created by the owner of the database. |
| tmplhandler | text | Name of the call handler function |
| tmplinline | text | Name of the anonymous block handler. If no name of the block handler exists, the value is null. |
| tmplvalidator | text | Name of the verification function. If no verification function is available, the value is null. |
| tmpllibrary | text | Path of the shared library that implements languages |
| tmplacl | aclitem[] | Access permissions for template (not yet used) |

## 14.2.45 PG_PROC

**PG_PROC** records information about functions or procedures.

**Table 14-45** PG_PROC columns

| Name | Type | Description |
| --- | --- | --- |
| proname | name | Name of the function |

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| Name | Type | Description |
| --- | --- | --- |
| pronamespace | oid | OID of the namespace that contains the function |
| proowner | oid | Owner of the function |
| prolang | oid | Implementation language or call interface of the function |
| procost | real | Estimated execution cost |
| prorows | real | Estimate number of result rows |
| provariadic | oid | Data type of parameter element |
| protransform | regproc | Simplified call method for this function |
| proisagg | boolean | Whether this function is an aggregate function |
| proiswindow | boolean | Whether this function is a window function |
| prosecdef | boolean | Whether this function is a security definer (such as a "setuid" function) |
| proleakproof | boolean | Whether this function has side effects. If no leakproof treatment is provided for parameters, the function throws errors. |
| proisstrict | boolean | The function returns null if any call parameter is null. In that case the function does not actually be called at all. Functions that are not "strict" must be prepared to process null inputs. |
| proretset | boolean | The function returns a set, that is, multiple values of the specified data type. |
| provolatile | "char" | Whether the function's result depends only on its input parameters, or is affected by outside factors<br>● It is **i** for "immutable" functions, which always deliver the same result for the same inputs.<br>● It is **s** for "stable" functions, whose results (for fixed inputs) do not change within a scan.<br>● It is **v** for "volatile" functions, whose results may change at any time. |
| pronargs | smallint | Number of parameters |
| pronargdefaults | smallint | Number of parameters that have default values |
| prorettype | oid | OID of the returned parameter type |

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| Name | Type | Description |
| --- | --- | --- |
| proargtypes | oidvector | Array with the data types of the function parameters. This array includes only input parameters (including **INOUT** parameters) and thus represents the call signature of the function. |
| proallargtypes | oid[] | Array with the data types of the function parameters. This array includes all parameter types (including **OUT** and **INOUT** parameters); however, if all the parameters are **IN** parameters, this column is null. Note that array subscripting is 1-based, whereas for historical reasons, and **proargtypes** is subscripted from 0. |
| proargmodes | "char"[] | Array with the modes of the function parameters.<br>● **i** indicates **IN** parameters.<br>● **o** indicates **OUT** parameters.<br>● **b** indicates **INOUT** parameters.<br>If all the parameters are **IN** parameters, this column is null. Note that subscripts of this array correspond to positions of **proallargtypes** not **proargtypes**. |
| proargnames | text[] | Array that stores the names of the function parameters. Parameters without a name are set to empty strings in the array. If none of the parameters have a name, this column is null. Note that subscripts correspond to positions of **proallargtypes** not **proargtypes**. |
| proargdefaults | pg_node_tree | Expression tree of the default value. This is the list of PRONARGDEFAULTS elements. |
| prosrc | text | A definition that describes a function or stored procedure. In an interpreting language, it is the function source code, a link symbol, a file name, or any body content specified when a function or stored procedure is created, depending on how a language or calling is used. |
| probin | text | Additional information about how to call the function. Again, the interpretation is language-specific. |
| proconfig | text[] | Function's local settings for run-time configuration variables. |
| proacl | aclitem[] | Access permissions For details, see GRANT and REVOKE. |

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| Name | Type | Description |
| --- | --- | --- |
| prodefaultargpos | int2vector | Locations of the function default values. Not only the last few parameters have default values. |
| fencedmode | boolean | Execution mode of a function, indicating whether a function is executed in fence or not fence mode. If the execution mode is fence, the function is executed in the fork process that is reworked. The default value is **fence**. |
| proshippable | boolean | Whether a function can be pushed down to DNs. The default value is **false**.<br>• Functions of the IMMUTABLE type can always be pushed down to the DNs.<br>• Functions of the STABLE or VOLATILE type can be pushed down to DNs only if their attribute is **SHIPPABLE**. |
| propackage | boolean | Indicates whether the function supports overloading, which is mainly used for the Oracle style function. The default value is **false**. |

## 14.2.46 PG_RANGE

**PG_RANGE** records information about range types.

This is in addition to the types' entries in **PG_TYPE**.

**Table 14-46** PG_RANGE columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| rngtypid | oid | **PG_TYPE**.oid | OID of the range type |
| rngsubtype | oid | **PG_TYPE**.oid | OID of the element type (subtype) of this range type |
| rngcollation | oid | **PG_COLLATION**.oid | OID of the collation used for range comparisons, or 0 if none |
| rngsubopc | oid | **PG_OPCLASS**.oid | OID of the subtype's operator class used for range comparisons |
| rngcanonical | regproc | **PG_PROC**.oid | OID of the function to convert a range value into canonical form, or 0 if none |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| rngsubdiff | regproc | PG_PROC.oid | OID of the function to return the difference between two element values as **double precision**, or 0 if none |

**rngsubopc** (plus **rngcollation**, if the element type is collatable) determines the sort ordering used by the range type. **rngcanonical** is used when the element type is discrete.

## 14.2.47 PG_REDACTION_COLUMN

**PG_REDACTION_COLUMN** records the information about the redacted columns.

**Table 14-47** PG_REDACTION_COLUMN columns

| Name | Type | Description |
| --- | --- | --- |
| object_oid | oid | OID of the object to be redacted. |
| column_attrno | smallint | **attrno** of the redacted column. |
| function_type | integer | Redaction type.<br>**NOTE**<br>This column is reserved. It is used only for forward compatibility of redacted column information in earlier versions. The value can be **0** (NONE) or **1** (FULL). |
| function_parameters | text | Parameters used when the redaction type is **partial** (reserved). |
| regexp_pattern | text | Pattern string when the redaction type is **regexp** (reserved). |
| regexp_replace_string | text | Replacement string when the redaction type is **regexp** (reserved). |
| regexp_position | integer | Start and end replacement positions when the redaction type is **regexp** (reserved). |

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| Name | Type | Description |
| --- | --- | --- |
| regexp_occurrence | integer | Replacement times when the redaction type is **regexp** (reserved). |
| regexp_match_parameter | text | Regular control parameter used when the redaction type is **regexp** (reserved). |
| column_description | text | Description of the redacted column. |
| function_expr | pg_node_tree | Internal representation of the redaction function. |

## 14.2.48 PG_REDACTION_POLICY

**PG_REDACTION_POLICY** records information about the object to be redacted.

**Table 14-48** PG_REDACTION_POLICY columns

| Name | Type | Description |
| --- | --- | --- |
| object_oid | oid | OID of the object to be redacted. |
| policy_name | name | Name of the redact policy. |
| enable | boolean | Policy status (enabled or disabled).<br>**NOTE**<br>The value can be:<br>• **true**: enabled.<br>• **false**: disabled. |
| expression | pg_node_tree | Policy effective expression (for users). |
| policy_description | text | Description of a policy. |

## 14.2.49 PG_RLSPOLICY

**PG_RLSPOLICY** displays the information about row-level access control policies.

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**Table 14-49** PG_RLSPOLICY columns

| Name | Type | Description |
| --- | --- | --- |
| polname | name | Name of a row-level access control policy |
| polrelid | oid | Table OID of a row-level access control policy |
| polcmd | char | SQL operations affected by a row-level access control policy. The options are ***(ALL)**, **r(SELECT)**, **w(UPDATE)**, and **d(DELETE)**. |
| polpermissive | boolean | Type of a row-level access control policy<br>**NOTE**<br>Values of **polpermissive**:<br>• **true**: The row-level access control policy is a permissive policy.<br>• **false**: The row-level access control policy is a restrictive policy. |
| polroles | oid[] | OID of database user affected by a row-level access control policy |
| polqual | pg_node_tree | SQL condition expression of a row-level access control policy |

## 14.2.50 PG_RESOURCE_POOL

**PG_RESOURCE_POOL** records the information about database resource pool.

**Table 14-50** PG_RESOURCE_POOL columns

| Name | Type | Description |
| --- | --- | --- |
| respool_name | name | Name of the resource pool |
| mem_percent | integer | Percentage of the memory configuration |
| cpu_affinity | bigint | Value of cores bound to the CPU |
| control_group | name | Name of the Cgroup where the resource pool is located |
| active_statements | integer | Maximum number of concurrent statements in the resource pool |
| max_dop | integer | Maximum concurrency. This is a reserved parameter. |
| memory_limit | name | Maximum memory of resource pool |
| parentid | oid | OID of the parent resource pool |

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| Name | Type | Description |
| --- | --- | --- |
| io_limits | integer | Upper limit of IOPS. It is counted by ones for column storage and by 10 thousands for row storage. |
| io_priority | text | I/O priority set for jobs that consume many I/O resources. It takes effect when the I/O usage reaches 90%. |
| is_foreign | boolean | Indicates whether the resource pool can be used for users outside the logical cluster. If it is set to **true**, the resource pool controls the resources of common users who do not belong to the current resource pool. |

## 14.2.51 PG_REWRITE

**PG_REWRITE** records rewrite rules defined for tables and views.

**Table 14-51** PG_REWRITE columns

| Name | Type | Description |
| --- | --- | --- |
| rulename | name | Rule name |
| ev_class | oid | Name of the table that uses the rule |
| ev_attr | smallint | Column this rule is for (always **0** to indicate the entire table) |
| ev_type | "char" | Event type for this rule:<br>• 1 = SELECT<br>• 2 = UPDATE<br>• 3 = INSERT<br>• 4 = DELETE |
| ev_enabled | "char" | Controls in which mode the rule fires<br>• **O**: The rule fires in "origin" and "local" modes.<br>• **D**: The rule is disabled.<br>• **R**: The rule fires in "replica" mode.<br>• **A**: The rule always fires. |
| is_instead | boolean | Its value is **true** if the rule is an **INSTEAD** rule. |

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| Name | Type | Description |
| --- | --- | --- |
| ev_qual | pg_node_tree | Expression tree (in the form of a **nodeToString()** representation) for the rule's qualifying condition |
| ev_action | pg_node_tree | Query tree (in the form of a **nodeToString()** representation) for the rule's action |

## 14.2.52 PG_SECLABEL

**PG_SECLABEL** records security labels on database objects.

See also **PG_SHSECLABEL**, which performs a similar function for security labels of database objects that are shared across a database cluster.

**Table 14-52** PG_SECLABEL columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| objoid | oid | Any OID column | OID of the object this security label pertains to |
| classoid | oid | **PG_CLASS**.oid | OID of the system catalog that contains the object |
| objsubid | integer | - | For a security label on a table column, this is the column number. |
| provider | text | - | Label provider associated with this label |
| label | text | - | Security label applied to this object |

## 14.2.53 PG_SHDEPEND

**PG_SHDEPEND** records the dependency relationships between database objects and shared objects, such as roles. This information allows GaussDB(DWS) to ensure that those objects are unreferenced before attempting to delete them.

See also **PG_DEPEND**, which performs a similar function for dependencies involving objects within a single database.

Unlike most system catalogs, **PG_SHDEPEND** is shared across all databases of a cluster: there is only one copy of **PG_SHDEPEND** per cluster, not one per database.

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**Table 14-53** PG_SHDEPEND columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| dbid | oid | PG_DATABASE.oid | OID of the database the dependent object is in. The value is **0** for a shared object. |
| classid | oid | PG_CLASS.oid | OID of the system catalog the dependent object is in. |
| objid | oid | Any OID column | OID of the specific dependent object |
| objsubid | integer | - | For a table column, this is the column number (the **objid** and **classid** refer to the table itself). For all other object types, this column is **0**. |
| refclassid | oid | PG_CLASS.oid | OID of the system catalog the referenced object is in (must be a shared catalog) |
| refobjid | oid | Any OID column | OID of the specific referenced object |
| deptype | "char" | - | Code segment defining the specific semantics of this dependency relationship. See the following text for details. |
| objfile | text | - | Path of the user-defined C function library file. |

In all cases, a **pg_shdepend** entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors defined by **deptype**:

- SHARED_DEPENDENCY_OWNER (o)

  The referenced object (which must be a role) is the owner of the dependent object.

- SHARED_DEPENDENCY_ACL (a)

  The referenced object (which must be a role) is mentioned in the ACL (access control list, i.e., privileges list) of the dependent object. (A **SHARED_DEPENDENCY_ACL** entry is not made for the owner of the object, since the owner will have a **SHARED_DEPENDENCY_OWNER** entry anyway.)

- SHARED_DEPENDENCY_PIN (p)

  There is no dependent object. This type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by **initdb**. The columns for the dependent object contain zeroes.

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## 14.2.54 PG_SHDESCRIPTION

**PG_SHDESCRIPTION** records optional comments for shared database objects. Descriptions can be manipulated with the **COMMENT** command and viewed with psql's **\d** commands.

See also **PG_DESCRIPTION**, which performs a similar function for descriptions involving objects within a single database.

Unlike most system catalogs, **PG_SHDESCRIPTION** is shared across all databases of a cluster. There is only one copy of **PG_SHDESCRIPTION** per cluster, not one per database.

**Table 14-54** PG_SHDESCRIPTION columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| objoid | oid | Any OID column | OID of the object this description pertains to |
| classoid | oid | PG_CLASS.oid | OID of the system catalog where the object resides |
| description | text | - | Arbitrary text that serves as the description of this object |

## 14.2.55 PG_SHSECLABEL

**PG_SHSECLABEL** records security labels on shared database objects. Security labels can be manipulated with the **SECURITY LABEL** command.

For an easier way to view security labels, see **PG_SECLABELS**.

See also **PG_SECLABEL**, which performs a similar function for security labels involving objects within a single database.

Unlike most system catalogs, **PG_SHSECLABEL** is shared across all databases of a cluster. There is only one copy of **PG_SHSECLABEL** per cluster, not one per database.

**Table 14-55** PG_SHSECLABEL columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| objoid | oid | Any OID column | OID of the object this security label pertains to |
| classoid | oid | PG_CLASS.oid | OID of the system catalog where the object resides |
| provider | text | - | Label provider associated with this label |
| label | text | - | Security label applied to this object |

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# 14.2.56 PG_STATISTIC

**PG_STATISTIC** records statistics about tables and index columns in a database. It is accessible only to users with system administrator rights.

**Table 14-56** PG_STATISTIC columns

| Name | Type | Description |
| --- | --- | --- |
| starelid | oid | Table or index which the described column belongs to |
| starelkind | "char" | Type of an object |
| staattnum | smallint | Number of the described column in the table, starting from 1 |
| stainherit | boolean | Whether to collect statistics for objects that have inheritance relationship |
| stanullfrac | real | Percentage of column entries that are null |
| stawidth | integer | Average stored width, in bytes, of non-null entries |
| stadistinct | real | Number of distinct, not-null data values in the column for all DNs<br>● A value greater than zero is the actual number of distinct values.<br>● A value less than zero is the negative of a multiplier for the number of rows in the table. (For example, **stadistinct=-0.5** indicates that values in a column appear twice on average.)<br>● **0** indicates that the number of distinct values is unknown. |
| stakindN | smallint | Code number stating that the type of statistics is stored in Slot N of the **pg_statistic** row.<br>Value range: 1 to 5 |
| staopN | oid | Operator used to generate the statistics stored in Slot N. For example, a histogram slot shows the < operator that defines the sort order of the data.<br>Value range: 1 to 5 |
| stanumbersN | real[] | Numerical statistics of the appropriate type for Slot N. The value is null if the slot kind does not involve numerical values.<br>Value range: 1 to 5 |

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| Name | Type | Description |
| --- | --- | --- |
| stavaluesN | anyarray | Column data values of the appropriate type for Slot N. The value is null if the slot type does not store any data values. Each array's element values are actually of the specific column's data type so there is no way to define these columns' type more specifically than anyarray.<br>Value range: 1 to 5 |
| stadndistinct | real | Number of unique non-null data values in the **dn1** column<br>● A value greater than zero is the actual number of distinct values.<br>● A value less than zero is the negative of a multiplier for the number of rows in the table. (For example, **stadistinct=-0.5** indicates that values in a column appear twice on average.)<br>● **0** indicates that the number of distinct values is unknown. |
| staextinfo | text | Information about extension statistics (reserved) |

## 14.2.57 PG_STATISTIC_EXT

**PG_STATISTIC_EXT** records the extended statistics of tables in a database, such as statistics of multiple columns. Statistics of expressions will be supported later. You can specify the extended statistics to be collected. It is accessible only to users with system administrator rights.

**Table 14-57** PG_STATISTIC_EXT columns

| Parameter | Type | Description |
| --- | --- | --- |
| starelid | oid | Table or index which the described column belongs to |
| starelkind | "char" | Type of an object |
| stainherit | boolean | Whether to collect statistics for objects that have inheritance relationship |
| stanullfrac | real | Percentage of column entries that are null |
| stawidth | integer | Average stored width, in bytes, of non-null entries |

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| Parameter | Type | Description |
| --- | --- | --- |
| stadistinct | real | Number of distinct, not-null data values in the column for all DNs<br>● A value greater than zero is the actual number of distinct values.<br>● A value less than zero is the negative of a multiplier for the number of rows in the table. (For example, **stadistinct=-0.5** indicates that values in a column appear twice on average.)<br>● **0** indicates that the number of distinct values is unknown. |
| stadndistinct | real | Number of unique non-null data values in the **dn1** column<br>● A value greater than zero is the actual number of distinct values.<br>● A value less than zero is the negative of a multiplier for the number of rows in the table. (For example, **stadistinct=-0.5** indicates that values in a column appear twice on average.)<br>● **0** indicates that the number of distinct values is unknown. |
| stakindN | smallint | Code number stating that the type of statistics is stored in Slot N of the **pg_statistic** row.<br>Value range: 1 to 5 |
| staopN | oid | Operator used to generate the statistics stored in Slot N. For example, a histogram slot shows the < operator that defines the sort order of the data.<br>Value range: 1 to 5 |
| stakey | int2vector | Array of a column ID |
| stanumbersN | real[] | Numerical statistics of the appropriate type for Slot N. The value is null if the slot kind does not involve numerical values.<br>Value range: 1 to 5 |
| stavaluesN | anyarray | Column data values of the appropriate type for Slot N. The value is null if the slot type does not store any data values. Each array's element values are actually of the specific column's data type so there is no way to define these columns' type more specifically than anyarray.<br>Value range: 1 to 5 |
| staexprs | pg_node_tree | Expression corresponding to the extended statistics information. |

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## 14.2.58 PG_SYNONYM

**PG_SYNONYM** records the mapping between synonym object names and other database object names.

**Table 14-58 PG_SYNONYM** columns

| Name | Type | Description |
| --- | --- | --- |
| synname | name | Synonym name. |
| synnamespace | oid | OID of the namespace where the synonym is located. |
| synowner | oid | Owner of a synonym, usually the OID of the user who created it. |
| synobjschema | name | Schema name specified by the associated object. |
| synobjname | name | Name of the associated object. |

## 14.2.59 PG_TABLESPACE

**PG_TABLESPACE** records tablespace information.

**Table 14-59** PG_TABLESPACE columns

| Name | Type | Description |
| --- | --- | --- |
| spcname | name | Name of the tablespace |
| spcowner | oid | Owner of the tablespace, usually the user who created it |
| spcacl | aclitem[] | Access permissions For details, see GRANT and REVOKE. |
| spcoptions | text[] | Specifies options of the tablespace. |
| spcmaxsize | text | Maximum size of the available disk space, in bytes |

## 14.2.60 PG_TRIGGER

**PG_TRIGGER** records the trigger information.

| Name | Type | Description |
| --- | --- | --- |
| tgrelid | oid | OID of the table where the trigger is located. |

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| Name | Type | Description |
| --- | --- | --- |
| tgname | name | Trigger name. |
| tgfoid | oid | Trigger OID. |
| tgtype | smallint | Trigger type |
| tgenabled | "char" | **O**: The trigger fires in "origin" or "local" mode.<br>**D**: The trigger is disabled.<br>**R**: The trigger fires in "replica" mode.<br>**A**: The trigger always fires. |
| tgisinternal | boolean | Internal trigger ID. If the value is true, it indicates an internal trigger. |
| tgconstrrelid | oid | The table referenced by the integrity constraint |
| tgconstrindid | oid | Index of the integrity constraint |
| tgconstraint | oid | OID of the constraint trigger in the **pg_constraint** |
| tgdeferrable | boolean | The constraint trigger is of the DEFERRABLE type. |
| tginitdeferred | boolean | whether the trigger is of the INITIALLY DEFERRED type |
| tgnargs | smallint | Input parameters number of the trigger function |
| tgattr | int2vector | Column ID specified by the trigger. If no column is specified, an empty array is used. |
| tgargs | bytea | Parameter transferred to the trigger |
| tgqual | pg_node_tree | Indicates the WHEN condition of the trigger. If the WHEN condition does not exist, the value is null. |

## 14.2.61 PG_TS_CONFIG

**PG_TS_CONFIG** records entries representing text search configurations. A configuration specifies a particular text search parser and a list of dictionaries to use for each of the parser's output token types.

The parser is shown in the **PG_TS_CONFIG** entry, but the token-to-dictionary mapping is defined by subsidiary entries in **PG_TS_CONFIG_MAP**.

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**Table 14-60** PG_TS_CONFIG columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| cfgname | name | - | Text search configuration name |
| cfgnamespace | oid | PG_NAMESPACE.oid | OID of the namespace where the configuration resides |
| cfgowner | oid | PG_AUTHID.oid | Owner of the configuration |
| cfgparser | oid | PG_TS_PARSER.oid | OID of the text search parser for this configuration |
| cfoptions | text[] | - | Configuration options |

## 14.2.62 PG_TS_CONFIG_MAP

**PG_TS_CONFIG_MAP** records entries showing which text search dictionaries should be consulted, and in what order, for each output token type of each text search configuration's parser.

**Table 14-61** PG_TS_CONFIG_MAP columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| mapcfg | oid | PG_TS_CONFIG.oid | OID of the PG_TS_CONFIG entry owning this map entry |
| maptokentype | integer | - | A token type emitted by the configuration's parser |
| mapseqno | integer | - | Order in which to consult this entry |
| mapdict | oid | PG_TS_DICT.oid | OID of the text search dictionary to consult |

## 14.2.63 PG_TS_DICT

**PG_TS_DICT** records entries that define text search dictionaries. A dictionary depends on a text search template, which specifies all the implementation functions needed. The dictionary itself provides values for the user-settable parameters supported by the template.

This division of labor allows dictionaries to be created by unprivileged users. The parameters are specified by a text string **dictinitoption**, whose format and meaning vary depending on the template.

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**Table 14-62** PG_TS_DICT columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| dictname | name | - | Text search dictionary name |
| dictnamespace | oid | PG_NAMESPACE.oid | OID of the namespace that contains the dictionary |
| dictowner | oid | PG_AUTHID.oid | Owner of the dictionary |
| dicttemplate | oid | PG_TS_TEMPLATE.oid | OID of the text search template for this dictionary |
| dictinitoption | text | - | Initialization option string for the template |

## 14.2.64 PG_TS_PARSER

**PG_TS_PARSER** records entries defining text search parsers. A parser splits input text into lexemes and assigns a token type to each lexeme. Since a parser must be implemented by C functions, parsers can be created only by database administrators.

**Table 14-63** PG_TS_PARSER columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| prsname | name | - | Text search parser name |
| prsnamespace | oid | PG_NAMESPACE.oid | OID of the namespace that contains the parser |
| prsstart | regproc | PG_PROC.oid | OID of the parser's startup function |
| prstoken | regproc | PG_PROC.oid | OID of the parser's next-token function |
| prsend | regproc | PG_PROC.oid | OID of the parser's shutdown function |
| prsheadline | regproc | PG_PROC.oid | OID of the parser's headline function |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| prslextype | regproc | PG_PROC.oid | OID of the parser's lextype function |

## 14.2.65 PG_TS_TEMPLATE

**PG_TS_TEMPLATE** records entries defining text search templates. A template provides a framework for text search dictionaries. Since a template must be implemented by C functions, templates can be created only by database administrators.

**Table 14-64** PG_TS_TEMPLATE columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| tmplname | name | - | Text search template name |
| tmplnamespace | oid | PG_NAMESPACE.oid | OID of the namespace that contains the template |
| tmplinit | regproc | PG_PROC.oid | OID of the template's initialization function |
| tmpllexize | regproc | PG_PROC.oid | OID of the template's lexize function |

## 14.2.66 PG_TYPE

**PG_TYPE** records the information about data types.

**Table 14-65** PG_TYPE columns

| Name | Type | Description |
| --- | --- | --- |
| typname | name | Data type name |
| typnamespace | oid | OID of the namespace that contains this type |
| typowner | oid | Owner of this type |

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| Name | Type | Description |
| --- | --- | --- |
| typlen | smallint | Number of bytes in the internal representation of the type for a fixed-size type. But for a variable-length type, **typlen** is negative.<br>● **-1** indicates a "varlena" type (one that has a length word).<br>● **-2** indicates a null-terminated C string. |
| typbyval | boolean | Whether the value of this type is passed by parameter or reference of this column. **TYPBYVAL** is false if the type of **TYPLEN** is not 1, 2, 4, or 8, because values of this type are always passed by reference of this column. **TYPBYVAL** can be false even the **TYPLEN** is passed by parameter of this column. |
| typtype | char | ● **b** indicates a basic type.<br>● **c** indicates a composite type, for example, a table's row type.<br>● **e** indicates an enumeration type.<br>● **p** indicates a pseudo type.<br>For details, see **typrelid** and **typbasetype**. |
| typcategory | char | **typcategory** is an arbitrary classification of data types that is used by the parser to determine which implicit casts should be "preferred". |
| typispreferred | boolean | Whether data is converted. It is **true** if conversion is performed when data meets the conversion rules specified by **TYPCATEGORY**. |
| typisdefined | boolean | The value is **true** if the type is defined. The value is **false** if this is a placeholder entry for a not-yet-defined type. When it is **false**, type name, namespace, and OID are the only dependable objects. |
| typdelim | char | Character that separates two values of this type when parsing array input. Note that the delimiter is associated with the array element data type, not the array data type. |
| typrelid | oid | If this is a composite type (see **typtype**), then this column points to the **pg_class** entry that defines the corresponding table. For a free-standing composite type, the **pg_class** entry does not represent a table, but it is required for the type's **pg_attribute** entries to link to. The value is **0** for non-composite types. |

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| Name | Type | Description |
| --- | --- | --- |
| typelem | oid | If **typelem** is not 0 then it identifies another row in **pg_type**. The current type can be subscripted like an array yielding values of type **typelem**. The current type can then be subscripted like an array yielding values of type **typelem**. A "true" array type is variable length (**typlen** = -1), but some fixed-length (**typlen** > 0) types also have nonzero **typelem**, for example **name** and **point**. If a fixed-length type has a **typelem**, its internal representation must be some number of values of the **typelem** data type with no other data. Variable-length array types have a header defined by the array subroutines. |
| typarray | oid | Indicates that the corresponding type record is available in **pg_type** if the value is not **0**. |
| typinput | regproc | Input conversion function (text format) |
| typoutput | regproc | Output conversion function (text format) |
| typreceive | regproc | Input conversion function (binary format). If no input conversion function, the value is **0**. |
| typsend | regproc | output conversion function (binary format). If no output conversion function, the value is **0**. |
| typmodin | regproc | Type modifier input function. The value is **0** if the type does not support modifiers. |
| typmodout | regproc | Type modifier output function. The value is **0** if the type does not support modifiers. |
| typanalyze | regproc | Custom **ANALYZE** function. The value is **0** if the standard function is used. |

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| Name | Type | Description |
| --- | --- | --- |
| typalign | char | Alignment required when storing a value of this type. It applies to storage on disk as well as most representations of the value inside PostgreSQL. When multiple values are stored consecutively, such as in the representation of a complete row on disk, padding is inserted before a data of this type so that it begins on the specified boundary. The alignment reference is the beginning of the first datum in the sequence. Possible values are:<br>• **c**: char alignment, that is, no alignment needed<br>• **s**: short alignment (2 bytes on most machines)<br>• **i**: **int** alignment (4 bytes on most machines).<br>• **d**: **double** alignment (8 bytes on many machines, but by no means all)<br>**NOTICE**<br>For types used in system catalogs, the size and alignment defined in **pg_type** must agree with the way that the compiler lays out the column in a structure representing a table row. |
| typstorage | char | **typstorage** tells for varlena types (those with **typlen = -1**) if the type is prepared for toasting and what the default strategy for attributes of this type should be. Possible values are:<br>• **p** indicates that values are always stored plain.<br>• **e**: Value can be stored in a "secondary" relationship (if the relation has one, see **pg_class.reltoastrelid**).<br>• **m**: Values can be stored compressed inline.<br>• **x**: Values can be stored compressed inline or stored in secondary storage.<br>**NOTICE**<br>**m** domains can also be moved out to secondary storage, but only as a last resort (**e** and **x** domains are moved first). |
| typenotnull | boolean | Represents a **NOTNULL** constraint on a type. Currently, it is used for domains only. |
| typbasetype | oid | If this is a domain (see **typtype**), then **typbasetype** identifies the type that this one is based on. The value is **0** if this type is not a derived type. |
| typtypmod | integer | Records the **typtypmod** to be applied to domains' base types by domains (the value is **-1** if the base type does not use **typmod**). The value is **-1** if this type is not a domain. |

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| Name | Type | Description |
| --- | --- | --- |
| typndims | integer | Number of array dimensions for a domain that is an array (that is, **typbasetype** is an array type; the domain's **typelem** matches the base type's **typelem**). The value is **0** for types other than domains over array types. |
| typcollation | oid | Sequence rule for specified types. Sequencing is not supported if the value is 0. |
| typdefaultbin | pg_node_tree | **nodeToString()** representation of a default expression for the type if the value is non-null. Currently, this column is only used for domains. |
| typdefault | text | The value is null if a type has no associated default value. If **typdefaultbin** is not null, **typdefault** must contain a human-readable version of the default expression represented by **typdefaultbin**. If **typdefaultbin** is null and **typdefault** is not, then **typdefault** is the external representation of the type's default value, which can be fed to the type's input converter to produce a constant. |
| typacl | aclitem[] | Access permissions |

## 14.2.67 PG_USER_MAPPING

**PG_USER_MAPPING** records the mappings from local users to remote.

It is accessible only to users with system administrator rights. You can use view **PG_USER_MAPPINGS** to query common users.

**Table 14-66** PG_USER_MAPPING columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| oid | oid | - | Row identifier (hidden attribute; must be explicitly selected) |
| umuser | oid | **PG_AUTHID**.oid | OID of the local role being mapped, 0 if the user mapping is public |
| umserver | oid | **PG_FOREIGN_SERVER**.oid | OID of the foreign server that contains this mapping |
| umoptions | text[] | - | Option used for user mapping. It is a keyword=value string. |

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## 14.2.68 PG_USER_STATUS

**PG_USER_STATUS** records the states of users that access to the database. It is accessible only to users with system administrator rights.

**Table 14-67** PG_USER_STATUS columns

| Name | Type | Description |
| --- | --- | --- |
| roloid | oid | ID of the role |
| failcount | integer | Specifies the number of failed attempts. |
| locktime | timestamp with time zone | Time at which the role is locked |
| rolstatus | smallint | Role state<br>• **0**: normal<br>• **1** indicates that the role is locked for some time because the failed login attempts exceed the threshold<br>• **2** indicates that the role is locked by the administrator. |
| permspace | bigint | Size of the permanent table storage space used by a role in the current instance. |
| tempspace | bigint | Size of the temporary table storage space used by a role in the current instance. |

## 14.2.69 PG_WORKLOAD_ACTION

**PG_WORKLOAD_ACTION** records information about **query_band**.

**Table 14-68** PG_WORKLOAD_ACTION columns

| Name | Type | Description |
| --- | --- | --- |
| qband | name | **query_band** key-value pairs |
| class | name | Class of the object associated with **query_band** |
| object | name | Object associated with **query_band** |
| action | name | Action of the object associated with **query_band** |

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## 14.2.70 PGXC_CLASS

**PGXC_CLASS** records the replicated or distributed information for each table.

**Table 14-69** PGXC_CLASS columns

| Name | Type | Description |
| --- | --- | --- |
| pcrelid | oid | Table OID |
| pclocatortype | "char" | Locator type<br>• **H**: hash<br>• **M**: Modulo<br>• **N**: Round Robin<br>• **R**: Replicate |
| pchashalgorithm | smallint | Distributed tuple using the hash algorithm |
| pchashbuckets | smallint | Value of a harsh container |
| pgroup | name | Name of the node group |
| redistributed | "char" | The table has been redistributed. |
| redis_order | integer | Redistribution sequence |
| pcattnum | int2vector | Column number used as a distribution key |
| nodeoids | oidvector_extend | List of distributed table node OIDs |
| options | text | Extension status information. This is a reserved column in the system. |

## 14.2.71 PGXC_GROUP

**PGXC_GROUP** records information about node groups.

**Table 14-70** PGXC_GROUP columns

| Name | Type | Description |
| --- | --- | --- |
| group_name | name | Name of the node group |
| in_redistribution | "char" | Whether redistribution is required<br>• **n** indicates that the Node Group is not redistributed.<br>• **y** indicates the source Node Group in redistribution.<br>• **t** indicates the destination Node Group in redistribution. |

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| Name | Type | Description |
| --- | --- | --- |
| group_members | oidvector_extend | Node OID list of the node group |
| group_buckets | text | Distributed data bucket group |
| is_installation | boolean | Whether to install a sub-cluster |
| group_acl | aclitem[] | Access permissions |
| group_kind | "char" | Node Group type<br>• **i** indicates an installation Node Group.<br>• **n** indicates a Node Group in a common, non-logical cluster.<br>• **v** indicates a Node Group in a logical cluster.<br>• **e** indicates an elastic cluster. |

## 14.2.72 PGXC_NODE

**PGXC_NODE** records information about cluster nodes.

**Table 14-71** PGXC_NODE columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | name | Node name |
| node_type | "char" | Node type<br>**C**: CN<br>**D**: DN |
| node_port | integer | Port ID of the node |
| node_host | name | Host name or IP address of a node. (If a virtual IP address is configured, its value is a virtual IP address.) |
| node_port1 | integer | Port number of a replication node |
| node_host1 | name | Host name or IP address of a replication node. (If a virtual IP address is configured, its value is a virtual IP address.) |
| hostis_primary | boolean | Whether a switchover occurs between the primary and the standby server on the current node |

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| Name | Type | Description |
| --- | --- | --- |
| nodeis_primary | boolean | Whether the current node is preferred to execute non-query operations in the **replication** table |
| nodeis_preferred | boolean | Whether the current node is preferred to execute queries in the **replication** table |
| node_id | integer | Node identifier |
| sctp_port | integer | Specifies the port used by the TCP proxy communication library or SCTP communication library of the primary node to listen to the data channel. |
| control_port | integer | Specifies the port used by the TCP proxy communication library or SCTP communication library of the primary node to listen to the control channel. |
| sctp_port1 | integer | Specifies the port used by the TCP proxy communication library or SCTP communication library of the standby node to listen to the data channel. |
| control_port1 | integer | Specifies the port used by the TCP proxy communication library or SCTP communication library of the standby node to listen to the control channel. |
| nodeis_central | boolean | Indicates that the current node is the central node. |

# 14.3 System Views

## 14.3.1 ALL_ALL_TABLES

**ALL_ALL_TABLES** displays the tables or views accessible to the current user.

**Table 14-72** ALL_ALL_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | name | Owner of the table or the view |
| table_name | name | Name of the table or the view |
| tablespace_name | name | Tablespace where the table or view is located |

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## 14.3.2 ALL_CONSTRAINTS

**ALL_CONSTRAINTS** displays information about constraints accessible to the current user.

**Table 14-73** ALL_CONSTRAINTS columns

| Name | Type | Description |
| --- | --- | --- |
| constraint_name | vcharacter varying(64) | Constraint name |
| constraint_type | text | Constraint type<br>• C: Check constraint.<br>• F: Foreign key constraint<br>• P: Primary key constraint<br>• U: Unique constraint. |
| table_name | character varying(64) | Name of constraint-related table |
| index_owner | character varying(64) | Owner of constraint-related index (only for the unique constraint and primary key constraint) |
| index_name | character varying(64) | Name of constraint-related index (only for the unique constraint and primary key constraint) |

## 14.3.3 ALL_CONS_COLUMNS

**ALL_CONS_COLUMNS** displays information about constraint columns accessible to the current user.

**Table 14-74** ALL_CONS_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| table_name | character varying(64) | Name of constraint-related table |
| column_name | character varying(64) | Name of constraint-related column |
| constraint_name | character varying(64) | Constraint name |
| position | smallint | Position of the column in the table |

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## 14.3.4 ALL_COL_COMMENTS

**ALL_COL_COMMENTS** displays the comment information about table columns accessible to the current user.

**Table 14-75** ALL_COL_COMMENTS columns

| Name | Type | Description |
| --- | --- | --- |
| column_name | character varying(64) | Column name |
| table_name | character varying(64) | Table name |
| owner | character varying(64) | Table owner |
| comments | text | Comments |

## 14.3.5 ALL_DEPENDENCIES

**ALL_DEPENDENCIES** displays dependencies between functions and advanced packages accessible to the current user.

NOTICE

Currently in GaussDB(DWS), this table is empty without any record due to information constraints.

**Table 14-76** ALL_DEPENDENCIES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(30) | Owner of the object |
| name | character varying(30) | Object name |
| type | character varying(17) | Type of the object |
| referenced_owner | character varying(30) | Owner of the referenced object |
| referenced_name | character varying(64) | Name of the referenced object |
| referenced_type | character varying(17) | Type of the referenced object |
| referenced_link_name | character varying(128) | Name of the link to the referenced object |
| schemaid | numeric | ID of the current schema |

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| Name | Type | Description |
| --- | --- | --- |
| dependency_type | character varying(4) | Dependency type (REF or HARD) |

## 14.3.6 ALL_IND_COLUMNS

**ALL_IND_COLUMNS** displays all index columns accessible to the current user.

**Table 14-77** ALL_IND_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_name | name | Column name |
| column_position | smallint | Position of column in the index |

## 14.3.7 ALL_IND_EXPRESSIONS

**ALL_IND_EXPRESSIONS** displays information about the expression indexes accessible to the current user.

**Table 14-78** ALL_IND_EXPRESSIONS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_expression | text | Function-based index expression of a specified column |
| column_position | smallint | Position of a column in the index |

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## 14.3.8 ALL_INDEXES

**ALL_INDEXES** displays information about indexes accessible to the current user.

**Table 14-79** ALL_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_name | character varying(64) | Name of the table corresponding to the index. |
| uniqueness | text | Whether the index is a unique index |
| generated | character varying(1) | Whether the index name is generated by the system |
| partitioned | character(3) | Whether the index has the property of the partition table |

## 14.3.9 ALL_OBJECTS

**ALL_OBJECTS** displays all database objects accessible to the current user.

**Table 14-80** ALL_OBJECTS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | name | Owner of the object |
| object_name | name | Object name |
| object_id | oid | OID of the object |
| object_type | name | Type of the object |
| namespace | oid | ID of the namespace where the object resides |
| created | timestamp with time zone | Object creation time |
| last_ddl_time | timestamp with time zone | The last time when an object was modified. |

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NOTICE

For details about the value ranges of **last_ddl_time** and **last_ddl_time**, see **PG_OBJECT**.

## 14.3.10 ALL_PROCEDURES

**ALL_PROCEDURES** displays information about all stored procedures or functions accessible to the current user.

**Table 14-81** ALL_PROCEDURES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | name | Owner of the object |
| object_name | name | Object name |

## 14.3.11 ALL_SEQUENCES

**ALL_SEQUENCES** displays all sequences accessible to the current user.

**Table 14-82** ALL_SEQUENCES columns

| Name | Type | Description |
| --- | --- | --- |
| sequence_owner | name | Owner of the sequence |
| sequence_name | name | Name of the sequence |
| min_value | bigint | Minimum value of the sequence |
| max_value | bigint | Maximum value of the sequence |
| increment_by | bigint | Value by which the sequence is incremented |
| cycle_flag | character(1) | Whether the sequence is a cycle sequence. The value can be **Y** or **N**.<br>• **Y** indicates that it is a cycle sequence.<br>• **N** indicates that it is not a cycle sequence. |

## 14.3.12 ALL_SOURCE

**ALL_SOURCE** displays information about stored procedures or functions accessible to the current user, and provides the columns defined by the stored procedures and functions.

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**Table 14-83** ALL_SOURCE columns

| Name | Type | Description |
| --- | --- | --- |
| owner | name | Owner of the object |
| name | name | Object name |
| type | name | Type of the object |
| text | text | Definition of the object |

## 14.3.13 ALL_SYNONYMS

**ALL_SYNONYMS** displays all synonyms accessible to the current user.

**Table 14-84 ALL_SYNONYMS** columns

| Name | Type | Description |
| --- | --- | --- |
| owner | text | Owner of a synonym. |
| schema_name | text | Name of the schema to which the synonym belongs. |
| synonym_name | text | Synonym name. |
| table_owner | text | Owner of the associated object. |
| table_schema_name | text | Schema name of the associated object. |
| table_name | text | Name of the associated object. |

## 14.3.14 ALL_TAB_COLUMNS

**ALL_TAB_COLUMNS** displays description information about columns of the tables accessible to the current user.

**Table 14-85** ALL_TAB_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the table |
| table_name | character varying(64) | Table name |
| column_name | character varying(64) | Column name |

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| Name | Type | Description |
| --- | --- | --- |
| data_type | character varying(128) | Data type of the column |
| column_id | integer | Column ID generated when the object is created or column is added |
| data_length | integer | Length of the column in the unit of bytes |
| avg_col_len | numeric | Average length of a column in the unit of bytes |
| nullable | bpchar | Whether the column can be empty. For the primary key constraint and non-null constraint, the value is n. |
| data_precision | integer | Indicates the precision of the data type. This parameter is valid for the numeric data type and NULL for other types. |
| data_scale | integer | Number of decimal places. This parameter is valid for the numeric data type. For other data types, the value of this parameter is 0. |
| char_length | numeric | Column length in the unit of bytes. This parameter is valid only for the varchar, nvarchar2, bpchar, and char types. |

## 14.3.15 ALL_TAB_COMMENTS

**ALL_TAB_COMMENTS** displays comments about all tables and views accessible to the current user.

**Table 14-86** ALL_TAB_COMMENTS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the table or the view |
| table_name | character varying(64) | Name of the table or the view |
| comments | text | Comments |

## 14.3.16 ALL_TABLES

**ALL_TABLES** displays all the tables accessible to the current user.

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**Table 14-87** ALL_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| tablespace_name | character varying(64) | Name of the tablespace that contains the table |
| status | character varying(8) | Whether the current record is valid |
| temporary | character(1) | Whether the table is a temporary table<br>• **Y** indicates that it is a temporary table.<br>• **N** indicates that it is not a temporary table. |
| dropped | character varying | Whether the current record is deleted<br>• **YES** indicates that it is deleted.<br>• **NO** indicates that it is not deleted. |
| num_rows | numeric | The estimated number of rows in the table |

## 14.3.17 ALL_USERS

**ALL_USERS** displays all users of the database visible to the current user, however, it does not describe the users.

**Table 14-88** ALL_USERS columns

| Name | Type | Description |
| --- | --- | --- |
| username | name | User name |
| user_id | oid | OID of the user |

## 14.3.18 ALL_VIEWS

**ALL_VIEWS** displays the description about all views accessible to the current user.

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**Table 14-89** ALL_VIEWS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | name | Owner of the view |
| view_name | name | Name of the view |
| text_length | integer | Text length of the view |
| text | text | Text in the view |

## 14.3.19 DBA_DATA_FILES

**DBA_DATA_FILES** displays the description of database files. It is accessible only to users with system administrator rights.

**Table 14-90** DBA_DATA_FILES columns

| Name | Type | Description |
| --- | --- | --- |
| tablespace_name | name | Name of the tablespace to which the file belongs |
| bytes | double precision | Length of the file in bytes |

## 14.3.20 DBA_USERS

**DBA_USERS** displays all user names in the database. It is accessible only to users with system administrator rights.

**Table 14-91** DBA_USERS columns

| Name | Type | Description |
| --- | --- | --- |
| username | character varying(64) | User name |

## 14.3.21 DBA_COL_COMMENTS

**DBA_COL_COMMENTS** displays information about table colum comments in the database. It is accessible only to users with system administrator rights.

**Table 14-92** DBA_COL_COMMENTS columns

| Name | Type | Description |
| --- | --- | --- |
| column_name | character varying(64) | Column name |
| table_name | character varying(64) | Table name |

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| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Table owner |
| comments | text | Comments |

## 14.3.22 DBA_CONSTRAINTS

**DBA_CONSTRAINTS** displays information about table constraints in database. It is accessible only to users with system administrator rights.

**Table 14-93** DBA_CONSTRAINTS columns

| Name | Type | Description |
| --- | --- | --- |
| constraint_name | vcharacter varying(64) | Constraint name |
| constraint_type | text | Constraint type<br>• C: Check constraint.<br>• F: Foreign key constraint<br>• P: Primary key constraint<br>• U: Unique constraint. |
| table_name | character varying(64) | Name of constraint-related table |
| index_owner | character varying(64) | Owner of constraint-related index (only for the unique constraint and primary key constraint) |
| index_name | character varying(64) | Name of constraint-related index (only for the unique constraint and primary key constraint) |

## 14.3.23 DBA_CONS_COLUMNS

**DBA_CONS_COLUMNS** displays information about constraint columns in database tables. It is accessible only to users with system administrator rights.

**Table 14-94** DBA_CONS_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| table_name | character varying(64) | Name of constraint-related table |
| column_name | character varying(64) | Name of constraint-related column |

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| Name | Type | Description |
| --- | --- | --- |
| constraint_name | character varying(64) | Constraint name |
| position | smallint | Position of the column in the table |

## 14.3.24 DBA_IND_COLUMNS

**DBA_IND_COLUMNS** displays column information about all indexes in the database. It is accessible only to users with system administrator rights.

**Table 14-95** DBA_IND_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_name | name | Column name |
| column_position | smallint | Position of column in the index |

## 14.3.25 DBA_IND_EXPRESSIONS

**DBA_IND_EXPRESSIONS** displays the information about expression indexes in the database. It is accessible only to users with system administrator rights.

**Table 14-96** DBA_IND_EXPRESSIONS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_expression | text | The function-based index expression of a specified column |
| column_position | smallint | Position of column in the index |

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## 14.3.26 DBA_IND_PARTITIONS

**DBA_IND_PARTITIONS** displays information about all index partitions in the database. Each index partition of a partitioned table in the database, if present, has a row of records in **DBA_IND_PARTITIONS**. It is accessible only to users with system administrator rights.

**Table 14-97** DBA_IND_PARTITIONS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Name of the owner of the partitioned index to which the index partition belongs |
| schema | character varying(64) | Schema of the partitioned index to which the index partition belongs |
| index_name | character varying(64) | Index name of the partitioned table to which the index partition belongs |
| partition_name | character varying(64) | Name of the index partition |
| index_partition_usable | boolean | Whether the index partition is available |
| high_value | text | Upper boundary of the partition corresponding to the index partition |
| def_tablespace_name | name | Tablespace name of the index partition |

## 14.3.27 DBA_INDEXES

**DBA_INDEXES** displays all indexes in the database. It is accessible only to users with system administrator rights.

**Table 14-98** DBA_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the index |
| index_name | character varying(64) | Index name |
| table_name | character varying(64) | Name of the table corresponding to the index |

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| Name | Type | Description |
| --- | --- | --- |
| uniqueness | text | Whether the index is a unique index |
| generated | character varying(1) | Whether the index name is generated by the system |
| partitioned | character(3) | Whether the index has the property of the partition table |

## 14.3.28 DBA_OBJECTS

**DBA_OBJECTS** displays all database objects in the database. It is accessible only to users with system administrator rights.

**Table 14-99 DBA_OBJECTS** columns

| Name | Type | Description |
| --- | --- | --- |
| owner | name | Owner of the object |
| object_name | name | Object name |
| object_id | oid | OID of the object |
| object_type | name | Type of the object |
| namespace | oid | Namespace containing the object |
| created | timestamp with time zone | Object creation time |
| last_ddl_time | timestamp with time zone | The last time when an object was modified. |

NOTICE

For details about the value ranges of **last_ddl_time** and **last_ddl_time**, see **PG_OBJECT**.

## 14.3.29 DBA_PART_INDEXES

**DBA_PART_INDEXES** displays information about all partitioned table indexes in the database. It is accessible only to users with system administrator rights.

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**Table 14-100** DBA_PART_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Name of the owner of the partitioned table index |
| schema | character varying(64) | Schema of the partitioned table index |
| index_name | character varying(64) | Name of the partitioned table index |
| table_name | character varying(64) | Name of the partitioned table to which the partitioned table index belongs |
| partitioning_type | text | Partition policy of the partitioned table<br>**NOTE**<br>Currently, only range partitioning is supported. |
| partition_count | bigint | Number of index partitions of the partitioned table index |
| def_tablespace_name | name | Tablespace name of the partitioned table index |
| partitioning_key_count | integer | Number of partition keys of the partitioned table |

## 14.3.30 DBA_PART_TABLES

**DBA_PART_TABLES** displays information about all partitioned tables in the database. It is accessible only to users with system administrator rights.

**Table 14-101** DBA_PART_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| table_owner | character varying(64) | Name of the owner of the partitioned table |
| schema | character varying(64) | Schema of the partitioned table |
| table_name | character varying(64) | Name of the partitioned table |

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| Name | Type | Description |
| --- | --- | --- |
| partitioning_type | text | Partition policy of the partitioned table<br>**NOTE**<br>Currently, only range partitioning is supported. |
| partition_count | bigint | Number of partitions of the partitioned table |
| def_tablespace_name | name | Tablespace name of the partitioned table |
| partitioning_key_count | integer | Number of partition keys of the partitioned table |

## 14.3.31 DBA_PROCEDURES

**DBA_PROCEDURES** displays information about all stored procedures and functions in the database. It is accessible only to users with system administrator rights.

**Table 14-102** DBA_PROCEDURES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the stored procedure or the function |
| object_name | character varying(64) | Name of the stored procedure or the function |
| argument_number | smallint | Number of the input parameters in the stored procedure |

## 14.3.32 DBA_SEQUENCES

**DBA_SEQUENCES** displays information about all sequences in the database. It is accessible only to users with system administrator rights.

**Table 14-103** DBA_SEQUENCES columns

| Name | Type | Description |
| --- | --- | --- |
| sequence_owner | character varying(64) | Owner of the sequence |
| sequence_name | character varying(64) | Name of the sequence |

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## 14.3.33 DBA_SOURCE

**DBA_SOURCE** displays all stored procedures or functions in the database, and it provides the columns defined by the stored procedures or functions. It is accessible only to users with system administrator rights.

**Table 14-104** DBA_SOURCE columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the stored procedure or the function |
| name | character varying(64) | Name of the stored procedure or the function |
| text | text | Definition of the stored procedure or the function |

## 14.3.34 DBA_SYNONYMS

**DBA_SYNONYMS** displays all synonyms in the database. It is accessible only to users with system administrator rights.

**Table 14-105 DBA_SYNONYMS** columns

| Name | Type | Description |
| --- | --- | --- |
| owner | text | Owner of a synonym. |
| schema_name | text | Name of the schema to which the synonym belongs. |
| synonym_name | text | Synonym name. |
| table_owner | text | Owner of the associated object. |
| table_schema_name | text | Schema name of the associated object. |
| table_name | text | Name of the associated object. |

## 14.3.35 DBA_TAB_COLUMNS

**DBA_TAB_COLUMNS** displays the columns of tables. Each column of a table in the database has a row in **DBA_TAB_COLUMNS**. It is accessible only to users with system administrator rights.

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**Table 14-106** DBA_TAB_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_name | character varying(64) | Column name |
| data_type | character varying(128) | Data type of the column |
| column_id | integer | Sequence number of the column when the table is created |
| data_length | integer | Length of the column in the unit of bytes |
| comments | text | Comments |
| avg_col_len | numeric | Average length of a column in the unit of bytes |
| nullable | bpchar | Whether the column can be empty. For the primary key constraint and non-null constraint, the value is n. |
| data_precision | integer | Indicates the precision of the data type. This parameter is valid for the numeric data type, however its value is NULL for other types. |
| data_scale | integer | Number of decimal places. This parameter is valid for the numeric data type. For other data types, the value of this parameter is 0. |
| char_length | numeric | Column length (in the unit of bytes) which is valid only for varchar, nvarchar2, bpchar, and char types. |

## 14.3.36 DBA_TAB_COMMENTS

**DBA_TAB_COMMENTS** displays comments about all tables and views in the database. It is accessible only to users with system administrator rights.

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**Table 14-107** DBA_TAB_COMMENTS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the table or the view |
| table_name | character varying(64) | Name of the table or the view |
| comments | text | Comments |

## 14.3.37 DBA_TAB_PARTITIONS

**DBA_TAB_PARTITIONS** displays information about all partitions in the database.

**Table 14-108** DBA_TAB_PARTITIONS columns

| Name | Type | Description |
| --- | --- | --- |
| table_owner | character varying(64) | Owner of the table that contains the partition |
| schema | character varying(64) | Schema of the partitioned table |
| table_name | character varying(64) | Table name |
| partition_name | character varying(64) | Name of the partition |
| high_value | text | Upper boundary of the range partition and interval partition |
| tablespace_name | name | Name of the tablespace that contains the partition |

## 14.3.38 DBA_TABLES

**DBA_TABLES** displays all tables in the database. It is accessible only to users with system administrator rights.

**Table 14-109** DBA_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| tablespace_name | character varying(64) | Name of the tablespace that contains the table |
| status | character varying(8) | Whether the current record is valid |

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| Name | Type | Description |
| --- | --- | --- |
| temporary | character(1) | Whether the table is a temporary table<br>• **Y** indicates that it is a temporary table.<br>• **N** indicates that it is not a temporary table. |
| dropped | character varying | Whether the current record is deleted<br>• **YES** indicates that it is deleted.<br>• **NO** indicates that it is not deleted. |
| num_rows | numeric | The estimated number of rows in the table |

## 14.3.39 DBA_TABLESPACES

**DBA_TABLESPACES** displays information about available tablespaces. It is accessible only to users with system administrator rights.

**Table 14-110** DBA_TABLESPACES columns

| Name | Type | Description |
| --- | --- | --- |
| tablespace_name | character varying(64) | Name of the tablespace |

## 14.3.40 DBA_TRIGGERS

**DBA_TRIGGERS** displays information about triggers in the database. It is accessible only to users with system administrator rights.

**Table 14-111** DBA_TRIGGERS columns

| Name | Type | Description |
| --- | --- | --- |
| trigger_name | character varying(64) | Trigger name |
| table_name | character varying(64) | Name of the table that defines the trigger |
| table_owner | character varying(64) | Owner of the table that defines the trigger |

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## 14.3.41 DBA_VIEWS

**DBA_VIEWS** displays views in the database. It is accessible only to users with system administrator rights.

**Table 14-112** DBA_VIEWS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the view |
| view_name | character varying(64) | View name |

## 14.3.42 DUAL

**DUAL** is automatically created by the database based on the data dictionary. It has only one text column in only one row for storing expression calculation results. It is accessible to all users.

**Table 14-113** DUAL columns

| Name | Type | Description |
| --- | --- | --- |
| dummy | text | Expression calculation result |

## 14.3.43 GLOBAL_REDO_STAT

**GLOBAL_REDO_STAT** displays the total statistics of XLOG redo operations on all nodes in a cluster. Except the **avgiotim** column (indicating the average redo write time of all nodes), the names of the other columns in this view are the same as those in the **PV_REDO_STAT** view. The respective meanings of the other columns are the sum of the values of the same columns in the **PV_REDO_STAT** view on each node.

This view is accessible only to users with system administrator rights.

## 14.3.44 GLOBAL_REL_IOSTAT

**GLOBAL_REL_IOSTAT** displays the total disk I/O statistics of all nodes in a cluster. The name of each column in this view is the same as that in the **GS_REL_IOSTAT** view, but the column meaning is the sum of the value of the same column in the **GS_REL_IOSTAT** view on each node. This view is accessible only to users with system administrator rights.

## 14.3.45 GLOBAL_STAT_DATABASE

**GLOBAL_STAT_DATABASE** displays the status and statistics of databases on all nodes in a cluster.

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- When you query the **GLOBAL_STAT_DATABASE** view on a CN, the respective values of all columns returned, except **stats_reset** (indicating the status reset time on the current CN), are the sum of values on related nodes in the cluster. Note that the sum range varies depending on the logical meaning of each column in the **GLOBAL_STAT_DATABASE** view.
- When you query the **GLOBAL_STAT_DATABASE** view on a DN, the query result is the same as that in **Table 14-114**.

**Table 14-114** GLOBAL_STAT_DATABASE columns

| Name | Type | Description | Sum Range |
| --- | --- | --- | --- |
| datid | oid | Database OID | - |
| datname | name | Database name | - |
| numbackends | integer | Number of backends currently connected to this database on the current node. This is the only column in this view that reflects the current state value. All columns return the accumulated value since the last reset. | CN |
| xact_commit | bigint | Number of transactions in this database that have been committed on the current node | CN |
| xact_rollback | bigint | Number of transactions in this database that have been rolled back on the current node | CN |
| blks_read | bigint | Number of disk blocks read in this database on the current node | DN |
| blks_hit | bigint | Number of disk blocks found in the buffer cache on the current node, that is, the number of blocks hit in the cache. (This only includes hits in the GaussDB(DWS) buffer cache, not in the file system cache.) | DN |
| tup_returned | bigint | Number of rows returned by queries in this database on the current node | DN |
| tup_fetched | bigint | Number of rows fetched by queries in this database on the current node | DN |
| tup_inserted | bigint | Number of rows inserted in this database on the current node | DN |

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| Name | Type | Description | Sum Range |
| --- | --- | --- | --- |
| tup_updated | bigint | Number of rows updated in this database on the current node | DN |
| tup_deleted | bigint | Number of rows deleted from this database on the current node | DN |
| conflicts | bigint | Number of queries canceled due to database recovery conflicts on the current node (conflicts occurring only on the standby server). For details, see **PG_STAT_DATABASE_CONFLICTS**. | CN and DN |
| temp_files | bigint | Number of temporary files created by this database on the current node. All temporary files are counted, regardless of why the temporary file was created (for example, sorting or hashing), and regardless of the **log_temp_files** setting. | DN |
| temp_bytes | bigint | Size of temporary files written to this database on the current node. All temporary files are counted, regardless of why the temporary file was created, and regardless of the **log_temp_files** setting. | DN |
| deadlocks | bigint | Number of deadlocks in this database on the current node | CN and DN |
| blk_read_time | double precision | Time spent reading data file blocks by backends in this database on the current node, in milliseconds | DN |
| blk_write_time | double precision | Time spent writing into data file blocks by backends in this database on the current node, in milliseconds | DN |
| stats_reset | timestamp with time zone | Time when the database statistics are reset on the current node | - |

## 14.3.46 GLOBAL_WORKLOAD_SQL_COUNT

**GLOBAL_WORKLOAD_SQL_COUNT** displays statistics on the number of SQL statements executed in all workload Cgroups in a cluster, including the number of

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**SELECT**, **UPDATE**, **INSERT**, and **DELETE** statements and the number of DDL, DML, and DCL statements.

**Table 14-115 GLOBAL_WORKLOAD_SQL_COUNT** columns

| Name | Type | Description |
| --- | --- | --- |
| workload | name | Workload Cgroup name |
| select_count | bigint | Number of **SELECT** statements |
| update_count | bigint | Number of **UPDATE** statements |
| insert_count | bigint | Number of **INSERT** statements |
| delete_count | bigint | Number of **DELETE** statements |
| ddl_count | bigint | Number of **DDL** statements |
| dml_count | bigint | Number of **DML** statements |
| dcl_count | bigint | Number of **DCL** statements |

## 14.3.47 GLOBAL_WORKLOAD_SQL_ELAPSE_TIME

**GLOBAL_WORKLOAD_SQL_ELAPSE_TIME** displays statistics on the response time of SQL statements in all workload Cgroups in a cluster, including the maximum, minimum, average, and total response time of **SELECT**, **UPDATE**, **INSERT**, and **DELETE** statements. The unit is microsecond.

**Table 14-116 GLOBAL_WORKLOAD_SQL_ELAPSE_TIME** columns

| Name | Type | Description |
| --- | --- | --- |
| workload | name | Workload Cgroup name |
| total_select_elapse | bigint | Total response time of **SELECT** |
| max_select_elapse | bigint | Maximum response time of **SELECT** |
| min_select_elapse | bigint | Minimum response time of **SELECT** |
| avg_select_elapse | bigint | Average response time of **SELECT** |

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| Name | Type | Description |
| --- | --- | --- |
| total_update_elapse | bigint | Total response time of **UPDATE** |
| max_update_elapse | bigint | Maximum response time of **UPDATE** |
| min_update_elapse | bigint | Minimum response time of **UPDATE** |
| avg_update_elapse | bigint | Average response time of **UPDATE** |
| total_insert_elapse | bigint | Total response time of **INSERT** |
| max_insert_elapse | bigint | Maximum response time of **INSERT** |
| min_insert_elapse | bigint | Minimum response time of **INSERT** |
| avg_insert_elapse | bigint | Average response time of **INSERT** |
| total_delete_elapse | bigint | Total response time of **DELETE** |
| max_delete_elapse | bigint | Maximum response time of **DELETE** |
| min_delete_elapse | bigint | Minimum response time of **DELETE** |
| avg_delete_elapse | bigint | Average response time of **DELETE** |

## 14.3.48 GLOBAL_WORKLOAD_TRANSACTION

**GLOBAL_WORKLOAD_TRANSACTION** provides the total transaction information about workload Cgroups on all CNs in the cluster. This view is accessible only to users with system administrator rights. It is valid only when the real-time resource monitoring function is enabled, that is, **enable_resource_track** is **on**.

**Table 14-117** GLOBAL_WORKLOAD_TRANSACTION columns

| Name | Type | Description |
| --- | --- | --- |
| workload | name | Workload Cgroup name |
| commit_counter | bigint | Total number of submission times on each CN |
| rollback_counter | bigint | Total number of rollback times on each CN |

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| Name | Type | Description |
| --- | --- | --- |
| resp_min | bigint | Minimum response time of the cluster |
| resp_max | bigint | Maximum response time of the cluster |
| resp_avg | bigint | Average response time on each CN |
| resp_total | bigint | Total response time on each CN |

## 14.3.49 GS_ALL_CONTROL_GROUP_INFO

**GS_ALL_CONTROL_GROUP_INFO** displays all Cgroup information in a database.

**Table 14-118** GS_ALL_CONTROL_GROUP_INFO columns

| Name | Type | Description |
| --- | --- | --- |
| name | text | Name of the Cgroup |
| type | text | Type of the Cgroup |
| gid | bigint | Cgroup ID |
| classgid | bigint | ID of the Class Cgroup to which a Workload belongs |
| class | text | Class Cgroup |
| workload | text | Workload Cgroup |
| shares | bigint | CPU quota allocated to a Cgroup |
| limits | bigint | Limit of CPUs allocated to a Cgroup |
| wdlevel | bigint | Workload Cgroup level |
| cpucores | text | Usage of CPU cores in a Cgroup |

## 14.3.50 GS_CLUSTER_RESOURCE_INFO

**GS_CLUSTER_RESOURCE_INFO** displays a DN resource summary.

**Table 14-119** GS_CLUSTER_RESOURCE_INFO columns

| Name | Type | Description |
| --- | --- | --- |
| min_mem_util | integer | Minimum memory usage of a DN |
| max_mem_util | integer | Maximum memory usage of a DN |
| min_cpu_util | integer | Minimum CPU usage of a DN |

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| Name | Type | Description |
| --- | --- | --- |
| max_cpu_util | integer | Maximum CPU usage of a DN |
| min_io_util | integer | Minimum I/O usage of a DN |
| max_io_util | integer | Maximum I/O usage of a DN |
| used_mem_rate | integer | Maximum physical memory usage |

# 14.3.51 GS_INSTR_UNIQUE_SQL

## Unique SQL Definition

The database parses each received SQL text string and generates an internal parsing tree. The database traverses the parsing tree and ignores constant values in the parsing tree. In this case, an integer value is calculated using a certain algorithm. This integer is used as the Unique SQL ID to uniquely identify this type of SQL. SQLs with the same Unique SQL ID are called Unique SQLs.

## Examples

Assume that the user enters the following SQL statements in sequence:

```
select * from t1 where id = 1;
select * from t1 where id = 2;
```

The statistics of the two SQL statements are aggregated to the same Unique SQL statement.

```
select * from t1 where id = ?;
```

## GS_INSTR_UNIQUE_SQL View

The **GS_INSTR_UNIQUE_SQL** view displays the execution information about the Unique SQL statements collected by the current node, including:

- Unique SQL ID and normalized SQL text string. The normalized SQL text is described in **Examples**.
- Number of execution times (number of successful execution times) and response time (SQL execution time in the database, including the maximum, minimum, and total time)
- Cache/IO information, including the number of physical reads and logical reads of a block. Only information about successfully executed SQL statements on each DN is collected. The statistical value is related to factors such as the amount of data processed during query execution, used memory, whether the query is executed for multiple times, memory management policy, and whether there are other concurrent queries. The statistical value reflects the number of physical reads and logical reads of the buffer block in the entire query execution process. The statistical value may vary according to the execution time.
- Row activities, such as the number of returned rows, updated rows, inserted rows, deleted rows, sequentially scanned rows, and randomly scanned rows in

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the result set of the **SELECT** statement. Except that the number of rows returned by the result set is the same as the number of rows in the result set of the **SELECT** statement and is recorded only on the CN, the activity information of other rows is recorded on the DN. The statistical value reflects the row activities during the entire query execution process, including scanning and modifying related system catalogs, metadata tables, and data tables. The value of this parameter is related to the data volume and related parameter settings. That is, the statistical value is greater than or equal to the scanning and modification times of actual data tables.

- Time distribution, including DB_TIME/CPU_TIME/EXECUTION_TIME/PARSE_TIME/PLAN_TIME/REWRITE_TIME/PL_EXECUTION_TIME/PL_COMPILATION_TIME/NET_SEND_TIME/DATA_IO_TIME. For details, see **Table 14-120**. The information is collected on both CNs and DNs and is displayed during view query.
- Number of soft and hard parsing times, such as the number of soft parsing times (cache plan) and hard parsing times (generation plan). If the cache plan is executed this time, the number of soft parsing times increases by 1. If the generation plan is regenerated this time, the number of hard parsing times increases by 1. This number is counted on both CNs and DNs and is displayed during view query.

The Unique SQL statistics function has the following restrictions:

- Detailed statistics are displayed only for successfully executed SQL statements. Otherwise, only query, node, and user information are recorded.
- Based on the Unique SQL ID generation algorithm, different IDs may be generated when the same SQL statement is executed on different nodes.
- If the Unique SQL statistics function is enabled, the CN collects statistics on all received queries, including tool and user queries.
- If an SQL statement contains multiple SQL statements or similar stored procedures, a Unique SQL statement is generated for the outermost SQL statement. The statistics of all sub-SQL statements are summarized to the Unique SQL record.
- The response time statistics of Unique SQL does not include the time of the **NET_SEND_TIME** phase. Therefore, there is no comparison between **EXECUTION_TIME** and **elapse_time**.
- **parse_time** of clauses cannot be calculated for **begin;...;commit** and similar transaction blocks.

When a common user accesses the **GS_INSTR_UNIQUE_SQL** view, only the Unique SQL information about the user is displayed. When an administrator accesses the **GS_INSTR_UNIQUE_SQL** view, all Unique SQL information about the current node is displayed. The **GS_INSTR_UNIQUE_SQL** view can be queried on both CNs and DNs. The DN displays the Unique SQL statistics of the local node, and the CN displays the complete Unique SQL statistics of the local node. That is, the CN collects the Unique SQL execution information of the CN from other CNs and DNs and displays the information. You can query the **GS_INSTR_UNIQUE_SQL** view to locate the top SQL statements that consume different resources, providing a basis for cluster performance optimization and maintenance.

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**Table 14-120 GS_INSTR_UNIQUE_SQL** columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | name | Name of the CN that receives SQL statements |
| node_id | integer | Node ID, which is the same as the value of **node_id** in the **pgxc_node** table |
| user_name | name | Username |
| user_id | oid | User ID |
| unique_sql_id | bigint | Normalized Unique SQL ID |
| query | text | Normalized SQL text. The maximum length is equal to the value of the GUC parameter **track_activity_query_size**. |
| n_calls | bigint | Number of successful execution times |
| min_elapse_time | bigint | Minimum running time of the SQL statement in the database (unit: μs) |
| max_elapse_time | bigint | Maximum running time of SQL statements in the database (unit: μs) |
| total_elapse_time | bigint | Total running time of SQL statements in the database (unit: μs) |
| n_returned_rows | bigint | Row activity - Number of rows in the result set returned by the **SELECT** statement |
| n_tuples_fetched | bigint | Row activity - Randomly scan rows (column-store tables/foreign tables are not counted.) |
| n_tuples_returned | bigint | Row activity - Sequential scan rows (Column-store tables/foreign tables are not counted.) |

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| Name | Type | Description |
| --- | --- | --- |
| n_tuples_inserted | bigint | Row activity - Inserted rows |
| n_tuples_updated | bigint | Row activity - Updated rows |
| n_tuples_deleted | bigint | Row activity - Deleted rows |
| n_blocks_fetched | bigint | Block access times of the buffer, that is, physical read/I/O |
| n_blocks_hit | bigint | Block hits of the buffer, that is, logical read/ cache |
| n_soft_parse | bigint | Number of soft parsing times (cache plan) |
| n_hard_parse | bigint | Number of hard parsing times (generation plan) |
| db_time | bigint | Valid DB execution time, including the waiting time and network sending time. If multiple threads are involved in query execution, the value of **DB_TIME** is the sum of **DB_TIME** of multiple threads (unit: μs). |
| cpu_time | bigint | CPU execution time, excluding the sleep time (unit: μs) |
| execution_time | bigint | SQL execution time in the query executor, DDL statements, and statements (such as Copy statements) that are not executed by the executor are not counted (unit: μs). |
| parse_time | bigint | SQL parsing time (unit: μs) |
| plan_time | bigint | SQL generation plan time (unit: μs) |

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| Name | Type | Description |
| --- | --- | --- |
| rewrite_time | bigint | SQL rewriting time (unit: μs) |
| pl_execution_time | bigint | Execution time of the plpgsql procedural language function (unit: μs) |
| pl_compilation_time | bigint | Compilation time of the plpgsql procedural language function (unit: μs) |
| net_send_time | bigint | Network time, including the time spent by the CN in sending data to the client and the time spent by the DN in sending data to the CN (unit: μs) |
| data_io_time | bigint | File I/O time (unit: μs) |

## 14.3.52 GS_REL_IOSTAT

**GS_REL_IOSTAT** displays disk I/O statistics on the current node. In the current version, only one page is read or written in each read or write operation. Therefore, the number of read/write times is the same as the number of pages.

**Table 14-121** GS_REL_IOSTAT columns

| Name | Type | Description |
| --- | --- | --- |
| phyrds | bigint | Number of disk reads |
| phywrts | bigint | Number of disk writes |
| phyblkrd | bigint | Number of read pages |
| phyblkwrt | bigint | Number of written pages |

## 14.3.53 GS_NODE_STAT_RESET_TIME

The GS_NODE_STAT_RESET_TIME view provides the reset time of statistics on the current node and returns the timestamp with the time zone. For details, see the **get_node_stat_reset_time()** function in "Functions and Operators > System Administration Functions > Other Functions" in *SQL Syntax.*

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## 14.3.54 GS_SESSION_CPU_STATISTICS

**GS_SESSION_CPU_STATISTICS** displays load management information about CPU usage of ongoing complex jobs executed by the current user.

**Table 14-122** GS_SESSION_CPU_STATISTICS columns

| Name | Type | Description |
| --- | --- | --- |
| datid | oid | OID of the database this backend is connected to |
| usename | name | Name of the user logging in to the backend |
| pid | bigint | ID of a backend process |
| start_time | timestamp with time zone | Time when the statement starts to be executed |
| min_cpu_time | bigint | Minimum CPU time of the statement across all DNs. The unit is ms. |
| max_cpu_time | bigint | Maximum CPU time of the statement across all DNs. The unit is ms. |
| total_cpu_time | bigint | Total CPU time of the statement across all DNs. The unit is ms. |
| query | text | Statement that is being executed |
| node_group | text | Logical cluster of the user running the statement |

## 14.3.55 GS_SESSION_MEMORY_STATISTICS

**GS_SESSION_MEMORY_STATISTICS** displays load management information about memory usage of ongoing complex jobs executed by the current user.

**Table 14-123** GS_SESSION_MEMORY_STATISTICS columns

| Name | Type | Description |
| --- | --- | --- |
| datid | oid | OID of the database this backend is connected to |
| usename | name | Name of the user logging in to the backend |
| pid | bigint | ID of a backend process |
| start_time | timestamp with time zone | Time when the statement starts to be executed |

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| Name | Type | Description |
| --- | --- | --- |
| min_peak_memory | integer | Minimum memory peak of a statement across all DNs, in MB |
| max_peak_memory | integer | Maximum memory peak of a statement across all DNs, in MB |
| spill_info | text | Information about statement flushing into disks on DNs<br>**None** indicates that the statement has not been flushed to disks on any DNs.<br>**All** indicates that the statement has been flushed to disks on every DN.<br>**[*a*:*b*]** indicates that the statement has been flushed to disks on *a* of *b* DNs. |
| query | text | Statement that is being executed |
| node_group | text | Logical cluster of the user running the statement |

## 14.3.56 GS_SQL_COUNT

**GS_SQL_COUNT** displays statistics about the five types of statements (**SELECT**, **INSERT**, **UPDATE**, **DELETE**, and **MERGE INTO**) executed on the current node of the database, including the number of execution times, response time (the maximum, minimum, average, and total response time of the other four types of statements except the **MERGE INTO** statement, in microseconds), and the number of execution times of **DDL**, **DML**, and **DCL statements**.

The classification of **DDL**, **DML**, and **DCL** statements in the **GS_SQL_COUNT** view is slightly different from that of the SQL syntaxt. The details are as follows:

- User-related statements, such as **CREATE**/**ALTER**/**DROP USER** and **CREATE**/**ALTER**/**DROP ROLE**, are of the DCL type.
- Transaction-related statements such as **BEGIN**/**COMMIT**/**SET CONSTRAINTS**/**ROLLBACK**/**SAVEPOINT**/**START** are of the DCL type.
- **ALTER SYSTEM KILL SESSION** is equivalent to the **SELECT pg_terminate_backend()** statement and is of the DML type.

The classification of other statements is similar to the definition in the SQL syntax.

When a common user queries the **GS_SQL_COUNT** view, only the statistics of this user in the current node can be viewed. When a user with the administrator permissions queries the **GS_SQL_COUNT** view, the statistics of all users in the current node can be viewed. When the cluster or the node is restarted, the statistics are cleared and the counting restarts. The counting is based on the number of queries received by the node, including the queries performed inside the cluster. Statistics about the **GS_SQL_COUNT** view are collected only on CNs, and SQL statements sent from other CNs are not collected. No result is returned when you query the view on a DN.

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**Table 14-124** GS_SQL_COUNT columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | name | Node name |
| user_name | name | User name |
| select_count | bigint | Number of **SELECT** statements |
| update_count | bigint | Number of **UPDATE** statements |
| insert_count | bigint | Number of **INSERT** statements |
| delete_count | bigint | Number of **DELETE** statements |
| mergeinto_count | bigint | Number of **MERGE INTO** statements |
| ddl_count | bigint | Number of **DDL** statements |
| dml_count | bigint | Number of **DML** statements |
| dcl_count | bigint | Number of **DCL** statements |
| total_select_elapse | bigint | Total response time of **SELECT** statements |
| avg_select_elapse | bigint | Average response time of **SELECT** statements |
| max_select_elapse | bigint | Maximum response time of **SELECT** statements |
| min_select_elapse | bigint | Minimum response time of **SELECT** statements |
| total_update_elapse | bigint | Total response time of **UPDATE** statements |
| avg_update_elapse | bigint | Average response time of **UPDATE** statements |
| max_update_elapse | bigint | Maximum response time of **UPDATE** statements |
| min_update_elapse | bigint | Minimum response time of **UPDATE** statements |
| total_delete_elapse | bigint | Total response time of **DELETE** statements |
| avg_delete_elapse | bigint | Average response time of **DELETE** statements |
| max_delete_elapse | bigint | Maximum response time of **DELETE** statements |
| min_delete_elapse | bigint | Minimum response time of **DELETE** statements |

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| Name | Type | Description |
| --- | --- | --- |
| total_insert_elapse | bigint | Total response time of **INSERT** statements |
| avg_insert_elapse | bigint | Average response time of **INSERT** statements |
| max_insert_elapse | bigint | Maximum response time of **INSERT** statements |
| min_insert_elapse | bigint | Minimum response time of **INSERT** statements |

## 14.3.57 GS_WAIT_EVENTS

**GS_WAIT_EVENTS** displays statistics about waiting status and events on the current node.

The values of statistical columns in this view are accumulated only when the **enable_track_wait_event** GUC parameter is set to **on**. If **enable_track_wait_event** is set to **off** during statistics measurement, the statistics will no longer be accumulated, but the existing values are not affected. If **enable_track_wait_event** is **off**, 0 row is returned when this view is queried.

**Table 14-125** GS_WAIT_EVENTS columns

| Name | Type | Description |
| --- | --- | --- |
| nodename | name | Node name |
| type | text | Event type, which can be **STATUS**, **LOCK_EVENT**, **LWLOCK_EVENT**, or **IO_EVENT** |
| event | text | Event name. For details, see **PG_THREAD_WAIT_STATUS**. |
| wait | bigint | Number of times an event occurs. This column and all the columns below are values accumulated during process running. |
| failed_wait | bigint | Number of waiting failures. In the current version, this column is used only for counting timeout errors and waiting failures of locks such as **LOCK** and **LWLOCK**. |
| total_wait_time | bigint | Total duration of the event |
| avg_wait_time | bigint | Average duration of the event |
| max_wait_time | bigint | Maximum wait time of the event |

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| Name | Type | Description |
| --- | --- | --- |
| min_wait_time | bigint | Minimum wait time of the event |

In the current version, for events whose **type** is **LOCK_EVENT**, **LWLOCK_EVENT**, or **IO_EVENT**, the display scope of **GS_WAIT_EVENTS** is the same as that of the corresponding events in the **PG_THREAD_WAIT_STATUS** view.

For events whose **type** is **STATUS**, **GS_WAIT_EVENTS** displays the following waiting status columns. For details, see the **PG_THREAD_WAIT_STATUS** view.

- acquire lwlock
- acquire lock
- wait io
- wait pooler get conn
- wait pooler abort conn
- wait pooler clean conn
- wait transaction sync
- wait wal sync
- wait data sync
- wait producer ready
- create index
- analyze
- vacuum
- vacuum full
- gtm connect
- gtm begin trans
- gtm commit trans
- gtm rollback trans
- gtm create sequence
- gtm alter sequence
- gtm get sequence val
- gtm set sequence val
- gtm drop sequence
- gtm rename sequence

## 14.3.58 GS_WLM_OPERARAOR_INFO

This view displays the execution information about operators in the query statements that have been executed on the current CN. The information comes from the system catalog **dbms_om**. **gs_wlm_operator_info**.

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## 14.3.59 GS_WLM_OPERATOR_HISTORY

This view displays the records of operators in jobs that have been executed by the current user on the current CN.

This view is used by Database Manager to query data from the kernel. Data in the kernel is cleared every 3 minutes.

## 14.3.60 GS_WLM_OPERATOR_STATISTICS

**GS_WLM_OPERATOR_STATISTICS** displays the operators of the jobs that are being executed by the current user.

**Table 14-126** GS_WLM_OPERATOR_STATISTICS columns

| Name | Type | Description |
| --- | --- | --- |
| queryid | bigint | Internal query_id used for statement execution |
| pid | bigint | ID of the backend thread |
| plan_node_id | integer | plan_node_id of the execution plan of a query |
| plan_node_name | text | Name of the operator corresponding to plan_node_id |
| start_time | timestamp with time zone | Time when an operator starts to process the first data record |
| duration | bigint | Total execution time of an operator. The unit is ms. |
| status | text | Execution status of the current operator. Its value can be **finished** or **running**. |
| query_dop | integer | DOP of the current operator |
| estimated_rows | bigint | Number of rows estimated by the optimizer |
| tuple_processed | bigint | Number of elements returned by the current operator |
| min_peak_memory | integer | Minimum peak memory used by the current operator on all DNs. The unit is MB. |
| max_peak_memory | integer | Maximum peak memory used by the current operator on all DNs. The unit is MB. |
| average_peak_memory | integer | Average peak memory used by the current operator on all DNs. The unit is MB. |
| memory_skew_percent | integer | Memory usage skew of the current operator among DNs |

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| Name | Type | Description |
| --- | --- | --- |
| min_spill_size | integer | Minimum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| max_spill_size | integer | Maximum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| average_spill_size | integer | Average spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| spill_skew_percent | integer | DN spill skew when a spill occurs |
| min_cpu_time | bigint | Minimum execution time of the operator on all DNs. The unit is ms. |
| max_cpu_time | bigint | Maximum execution time of the operator on all DNs. The unit is ms. |
| total_cpu_time | bigint | Total execution time of the operator on all DNs. The unit is ms. |
| cpu_skew_percent | integer | Skew of the execution time among DNs. |
| warning | text | Warning. The following warnings are displayed:<br>1. Sort/SetOp/HashAgg/HashJoin spill<br>2. Spill file size large than 256MB<br>3. Broadcast size large than 100MB<br>4. Early spill<br>5. Spill times is greater than 3<br>6. Spill on memory adaptive<br>7. Hash table conflict |

## 14.3.61 GS_WLM_SESSION_INFO

This view displays the execution information about the query statements that have been executed on the current CN. The information comes from the system catalog **dbms_om**. **gs_wlm_session_info**.

## 14.3.62 GS_WLM_SESSION_HISTORY

**GS_WLM_SESSION_HISTORY** displays load management information about a completed job executed by the current user on the current CN. This view is used by Database Manager to query data from GaussDB(DWS). Data in the GaussDB(DWS) is cleared every 3 minutes.

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**Table 14-127** GS_WLM_SESSION_HISTORY columns

| Name | Type | Description |
| --- | --- | --- |
| datid | oid | OID of the database this backend is connected to |
| dbname | text | Name of the database the backend is connected to |
| schemaname | text | Schema name |
| nodename | text | Name of the CN where the statement is run |
| username | text | User name used for connecting to the backend |
| application_name | text | Name of the application that is connected to the backend |
| client_addr | inet | IP address of the client connected to this backend. If this column is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum. |
| client_hostname | text | Host name of the connected client, as reported by a reverse DNS lookup of **client_addr**. This column will only be non-null for IP connections, and only when **log_hostname** is enabled. |
| client_port | integer | TCP port number that the client uses for communication with this backend, or **-1** if a Unix socket is used |
| query_band | text | Job type, which is specified by the **query_band** parameter. The default value is a null string. |
| block_time | bigint | Duration that a statement is blocked before being executed, including the statement parsing and optimization duration. The unit is ms. |
| start_time | timestamp with time zone | Time when the statement starts to be run |
| finish_time | timestamp with time zone | Time when the statement execution ends |
| duration | bigint | Execution time of a statement. The unit is ms. |
| estimate_total_time | bigint | Estimated execution time of a statement. The unit is ms. |
| status | text | Final statement execution status. Its value can be **finished** (normal) or **aborted** (abnormal). |

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| Name | Type | Description |
| --- | --- | --- |
| abort_info | text | Exception information displayed if the final statement execution status is **aborted**. |
| resource_pool | text | Resource pool used by the user |
| control_group | text | Cgroup used by the statement |
| min_peak_memory | integer | Minimum memory peak of a statement across all DNs. The unit is MB. |
| max_peak_memory | integer | Maximum memory peak of a statement across all DNs. The unit is MB. |
| average_peak_memory | integer | Average memory usage during statement execution. The unit is MB. |
| memory_skew_percent | integer | Memory usage skew of a statement among DNs. |
| spill_info | text | Statement spill information on all DNs.<br>**None** indicates that the statement has not been flushed to disks on any DNs.<br>**All** indicates that the statement has been flushed to disks on every DN.<br>**[***a***:***b***]** indicates that the statement has been flushed to disks on *a* of *b* DNs. |
| min_spill_size | integer | Minimum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| max_spill_size | integer | Maximum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| average_spill_size | integer | Average spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| spill_skew_percent | integer | DN spill skew when a spill occurs |
| min_dn_time | bigint | Minimum execution time of a statement across all DNs. The unit is ms. |
| max_dn_time | bigint | Maximum execution time of a statement across all DNs. The unit is ms. |
| average_dn_time | bigint | Average execution time of a statement across all DNs. The unit is ms. |
| dntime_skew_percent | integer | Execution time skew of a statement among DNs. |

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| Name | Type | Description |
| --- | --- | --- |
| min_cpu_time | bigint | Minimum CPU time of a statement across all DNs. The unit is ms. |
| max_cpu_time | bigint | Maximum CPU time of a statement across all DNs. The unit is ms. |
| total_cpu_time | bigint | Total CPU time of a statement across all DNs. The unit is ms. |
| cpu_skew_percent | integer | CPU time skew of a statement among DNs. |
| min_peak_iops | integer | Minimum IOPS peak of a statement across all DNs. It is counted by ones in a column-store table and by ten thousands in a row-store table. |
| max_peak_iops | integer | Maximum IOPS peak of a statement across all DNs. It is counted by ones in a column-store table and by ten thousands in a row-store table. |
| average_peak_iops | integer | Average IOPS peak of a statement across all DNs. It is counted by ones in a column-store table and by ten thousands in a row-store table. |
| iops_skew_percent | integer | I/O skew across DNs. |
| warning | text | Warning. The following warnings and warnings related to SQL self-diagnosis tuning are displayed:<br>1. Spill file size large than 256MB<br>2. Broadcast size large than 100MB<br>3. Early spill<br>4. Spill times is greater than 3<br>5. Spill on memory adaptive<br>6. Hash table conflict |
| queryid | bigint | Internal query ID used for statement execution |
| query | text | Statement executed |
| query_plan | text | Execution plan of a statement |
| node_group | text | Logical cluster of the user running the statement |

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# 14.3.63 GS_WLM_SESSION_STATISTICS

**GS_WLM_SESSION_STATISTICS** displays load management information about jobs being executed by the current user on the current CN.

**Table 14-128** GS_WLM_SESSION_STATISTICS columns

| Name | Type | Description |
| --- | --- | --- |
| datid | oid | OID of the database this backend is connected to |
| dbname | name | Name of the database the backend is connected to |
| schemaname | text | Schema name |
| nodename | text | Name of the CN where the statement is executed |
| username | name | User name used for connecting to the backend |
| application_name | text | Name of the application that is connected to the backend |
| client_addr | inet | IP address of the client connected to this backend. If this column is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum. |
| client_hostname | text | Host name of the connected client, as reported by a reverse DNS lookup of **client_addr**. This column will only be non-null for IP connections, and only when **log_hostname** is enabled. |
| client_port | integer | TCP port number that the client uses for communication with this backend, or **-1** if a Unix socket is used |
| query_band | text | Job type, which is specified by the GUC parameter **query_band** parameter. The default value is a null string. |
| pid | bigint | Process ID of the backend |
| block_time | bigint | Block time before the statement is executed. The unit is ms. |
| start_time | timestamp with time zone | Time when the statement starts to be executed |
| duration | bigint | For how long a statement has been executing. The unit is ms. |

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| Name | Type | Description |
| --- | --- | --- |
| estimate_total_time | bigint | Estimated execution time of a statement. The unit is ms. |
| estimate_left_time | bigint | Estimated remaining time of statement execution. The unit is ms. |
| enqueue | text | Workload management resource status |
| resource_pool | name | Resource pool used by the user |
| control_group | text | Cgroup used by the statement |
| estimate_memory | integer | Estimated memory used by the statement. The unit is MB. |
| min_peak_memory | integer | Minimum memory peak of a statement across all DNs. The unit is MB. |
| max_peak_memory | integer | Maximum memory peak of a statement across all DNs. The unit is MB. |
| average_peak_memory | integer | Average memory usage during statement execution. The unit is MB. |
| memory_skew_percent | integer | Memory usage skew of a statement among DNs. |
| spill_info | text | Statement spill information on all DNs.<br>**None** indicates that the statement has not been flushed to disks on any DNs.<br>**All** indicates that the statement has been flushed to disks on every DN.<br>**[*a*:*b*]** indicates that the statement has been flushed to disks on *a* of *b* DNs. |
| min_spill_size | integer | Minimum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| max_spill_size | integer | Maximum spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| average_spill_size | integer | Average spilled data among all DNs when a spill occurs. The unit is MB. The default value is **0**. |
| spill_skew_percent | integer | DN spill skew when a spill occurs |
| min_dn_time | bigint | Minimum execution time of a statement across all DNs. The unit is ms. |

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| Name | Type | Description |
| --- | --- | --- |
| max_dn_time | bigint | Maximum execution time of a statement across all DNs. The unit is ms. |
| average_dn_time | bigint | Average execution time of a statement across all DNs. The unit is ms. |
| dntime_skew_percent | bigint | Execution time skew of a statement among DNs. |
| min_cpu_time | bigint | Minimum CPU time of a statement across all DNs. The unit is ms. |
| max_cpu_time | bigint | Maximum CPU time of a statement across all DNs. The unit is ms. |
| total_cpu_time | bigint | Total CPU time of a statement across all DNs. The unit is ms. |
| cpu_skew_percent | integer | CPU time skew of a statement among DNs. |
| min_peak_iops | integer | Minimum IOPS peak of a statement across all DNs. It is counted by ones in a column-store table and by ten thousands in a row-store table. |
| max_peak_iops | integer | Maximum IOPS peak of a statement across all DNs. It is counted by ones in a column-store table and by ten thousands in a row-store table. |
| average_peak_iops | integer | Average IOPS peak of a statement across all DNs. It is counted by ones in a column-store table and by ten thousands in a row-store table. |
| iops_skew_percent | integer | I/O skew across DNs. |
| warning | text | Warning. The following warnings and warnings related to SQL self-diagnosis tuning are displayed:<br>1. Spill file size large than 256MB<br>2. Broadcast size large than 100MB<br>3. Early spill<br>4. Spill times is greater than 3<br>5. Spill on memory adaptive<br>6. Hash table conflict |
| queryid | bigint | Internal query ID used for statement execution |
| query | text | Statement that is being executed |

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| Name | Type | Description |
| --- | --- | --- |
| query_plan | text | Execution plan of a statement |
| node_group | text | Logical cluster of the user running the statement |

## 14.3.64 GS_WLM_SQL_ALLOW

**GS_WLM_SQL_ALLOW** displays the configured resource management SQL whitelist, including the default SQL whitelist and the SQL whitelist configured using the GUC parameter **wlm_sql_allow_list**.

## 14.3.65 GS_WORKLOAD_SQL_COUNT

**GS_WORKLOAD_SQL_COUNT** displays statistics on the number of SQL statements executed in workload Cgroups on the current node, including the number of **SELECT**, **UPDATE**, **INSERT**, and **DELETE** statements and the number of DDL, DML, and DCL statements.

**Table 14-129 GS_WORKLOAD_SQL_COUNT** columns

| Name | Type | Description |
| --- | --- | --- |
| workload | name | Workload Cgroup name |
| select_count | bigint | Number of **SELECT** statements |
| update_count | bigint | Number of **UPDATE** statements |
| insert_count | bigint | Number of **INSERT** statements |
| delete_count | bigint | Number of **DELETE** statements |
| ddl_count | bigint | Number of **DDL** statements |
| dml_count | bigint | Number of **DML** statements |
| dcl_count | bigint | Number of **DCL** statements |

## 14.3.66 GS_WORKLOAD_SQL_ELAPSE_TIME

**GS_WORKLOAD_SQL_ELAPSE_TIME** displays statistics on the response time of SQL statements in workload Cgroups on the current node, including the

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maximum, minimum, average, and total response time of **SELECT**, **UPDATE**, **INSERT**, and **DELETE** statements. The unit is microsecond.

**Table 14-130 GS_WORKLOAD_SQL_ELAPSE_TIME** columns

| Name | Type | Description |
| --- | --- | --- |
| workload | name | Workload Cgroup name |
| total_select_elapse | bigint | Total response time of **SELECT** statements |
| max_select_elapse | bigint | Maximum response time of **SELECT** statements |
| min_select_elapse | bigint | Minimum response time of **SELECT** statements |
| avg_select_elapse | bigint | Average response time of **SELECT** statements |
| total_update_elapse | bigint | Total response time of **UPDATE** statements |
| max_update_elapse | bigint | Maximum response time of **UPDATE** statements |
| min_update_elapse | bigint | Minimum response time of **UPDATE** statements |
| avg_update_elapse | bigint | Average response time of **UPDATE** statements |
| total_insert_elapse | bigint | Total response time of **INSERT** statements |
| max_insert_elapse | bigint | Maximum response time of **INSERT** statements |
| min_insert_elapse | bigint | Minimum response time of **INSERT** statements |
| avg_insert_elapse | bigint | Average response time of **INSERT** statements |
| total_delete_elapse | bigint | Total response time of **DELETE** statements |
| max_delete_elapse | bigint | Maximum response time of **DELETE** statements |
| min_delete_elapse | bigint | Minimum response time of **DELETE** statements |
| avg_delete_elapse | bigint | Average response time of **DELETE** statements |

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## 14.3.67 GS_WORKLOAD_TRANSACTION

GS_WORKLOAD_TRANSACTION provides transaction information about workload cgroups on a single CN. The database records the number of times that each workload Cgroup commits and rolls back transactions and the response time of transaction commitment and rollback, in microseconds.

**Table 14-131** GS_WORKLOAD_TRANSACTION columns

| Name | Type | Description |
| --- | --- | --- |
| workload | name | Workload Cgroup name |
| commit_counter | bigint | Number of the commit times |
| rollback_counter | bigint | Number of rollbacks |
| resp_min | bigint | Minimum response time |
| resp_max | bigint | Maximum response time |
| resp_avg | bigint | Average response time |
| resp_total | bigint | Total response time |

## 14.3.68 GS_STAT_DB_CU

**GS_STAT_DB_CU** displsys CU hits in a database and in each node in a cluster. You can clear it using **gs_stat_reset()**.

**Table 14-132** GS_STAT_DB_CU columns

| Name | Type | Description |
| --- | --- | --- |
| node_name1 | text | Node name |
| db_name | text | Database name |
| mem_hit | integer | Number of memory hits |
| hdd_sync_read | integer | Number of hard disk synchronous reads |
| hdd_asyn_read | integer | Number of hard disk asynchronous reads |

## 14.3.69 GS_STAT_SESSION_CU

**GS_STAT_SESSION_CU** displays the CU hit rate of running sessions on each node in a cluster. This data about a session is cleared when you exit this session or restart the cluster.

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**Table 14-133** GS_STAT_SESSION_CU columns

| Name | Type | Description |
| --- | --- | --- |
| node_name1 | text | Node name |
| mem_hit | integer | Number of memory hits |
| hdd_sync_read | integer | Number of hard disk synchronous reads |
| hdd_asyn_read | integer | Number of hard disk asynchronous reads |

## 14.3.70 GS_TOTAL_NODEGROUP_MEMORY_DETAIL

**GS_TOTAL_NODEGROUP_MEMORY_DETAIL** displays statistics about memory usage of the logical cluster that the current database belongs to in the unit of MB.

**Table 14-134** GS_TOTAL_NODEGROUP_MEMORY_DETAIL columns

| Name | Type | Description |
| --- | --- | --- |
| ngname | text | Name of a logical cluster |
| memorytype | text | Memory type. Its value can be:<br>• **ng_total_memory**: total memory of the logical cluster<br>• **ng_used_memory**: memory usage of the logical cluster<br>• **ng_estimate_memory**: estimated memory usage of the logical cluster<br>• **ng_foreignrp_memsize**: total memory of the external resource pool of the logical cluster<br>• **ng_foreignrp_memsize**: memory usage of the external resource pool of the logical cluster<br>• **ng_foreignrp_peaksize**: peak memory usage of the external resource pool of the logical cluster<br>• **ng_foreignrp_mempct**: percentage of the external resource pool of the logical cluster to the total memory of the logical cluster<br>• **ng_foreignrp_estmsize**: estimated memory usage of the external resource pool of the logical cluster |
| memorymbytes | integer | Size of allocated memory-typed memory |

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## 14.3.71 GS_USER_TRANSACTION

**GS_USER_TRANSACTION** provides transaction information about users on a single CN. The database records the number of times that each user commits and rolls back transactions and the response time of transaction commitment and rollback, in microseconds.

**Table 14-135 GS_USER_TRANSACTION** columns

| Name | Type | Description |
| --- | --- | --- |
| usename | name | Username |
| commit_counter | bigint | Number of the commit times |
| rollback_counter | bigint | Number of rollbacks |
| resp_min | bigint | Minimum response time |
| resp_max | bigint | Maximum response time |
| resp_avg | bigint | Average response time |
| resp_total | bigint | Total response time |

## 14.3.72 GS_VIEW_DEPENDENCY

**GS_VIEW_DEPENDENCY** allows you to query the direct dependencies of all views visible to the current user.

**Table 14-136** GS_VIEW_DEPENDENCY columns

| Column | Type | Description |
| --- | --- | --- |
| objschema | name | View space name |
| objname | name | View name |
| refobjschema | name | Name of the space where the dependent object resides |
| refobjname | name | Name of a dependent object |
| relobjkind | char | Type of a dependent object<br>• r: table<br>• v: view |

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## 14.3.73 GS_VIEW_DEPENDENCY_PATH

**GS_VIEW_DEPENDENCY_PATH** allows you to query the direct dependencies of all views visible to the current user. If the base table on which the view depends exists and the dependency between views at different levels is normal, you can use this view to query the dependency between views at different levels starting from the base table.

**Table 14-137** GS_VIEW_DEPENDENCY_PATH columns

| Column | Type | Description |
| --- | --- | --- |
| objschema | name | View space name |
| objname | name | View name |
| refobjschema | name | Name of the space where the dependent object resides |
| refobjname | name | Name of a dependent object |
| path | text | Dependency path |

## 14.3.74 GS_VIEW_INVALID

**GS_VIEW_INVALID** queries all unavailable views visible to the current user. If the base table, function, or synonym that the view depends on is abnormal, the **validtype** column of the view is displayed as "invalid".

**Table 14-138** GS_VIEW_INVALID columns

| Column | Type | Description |
| --- | --- | --- |
| oid | oid | OID of the view |
| schemaname | name | View space name |
| viewname | name | Name of the view |
| viewowner | name | Owner of the view |
| definition | text | Definition of the view |
| validtype | text | View validity flag |

## 14.3.75 PG_AVAILABLE_EXTENSION_VERSIONS

**PG_AVAILABLE_EXTENSION_VERSIONS** displays the extension versions of certain database features.

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**Table 14-139** PG_AVAILABLE_EXTENSION_VERSIONS columns

| Name | Type | Description |
| --- | --- | --- |
| name | name | Extension name |
| version | text | Version name |
| installed | boolean | The value is **true** if the version of this extension is currently installed. |
| superuser | boolean | The value is **true** if only system administrators are allowed to install this extension. |
| relocatable | boolean | The value is **true** if an extension can be relocated to another schema. |
| schema | name | Name of the schema that the extension must be installed into. The value is null if the extension is partially or fully relocatable. |
| requires | name[] | Names of prerequisite extensions. The value is null if there are no prerequisite extensions. |
| comment | text | Comment string from the extension's control file |

## 14.3.76 PG_AVAILABLE_EXTENSIONS

**PG_AVAILABLE_EXTENSIONS** displays the extended information about certain database features.

**Table 14-140** PG_AVAILABLE_EXTENSIONS columns

| Name | Type | Description |
| --- | --- | --- |
| name | name | Extension name |
| default_version | text | Name of default version. The value is **NULL** if none is specified. |
| installed_version | text | Currently installed version of the extension. The value is **NULL** if no version is installed. |
| comment | text | Comment string from the extension's control file |

## 14.3.77 PG_BULKLOAD_STATISTICS

On any normal node in a cluster, **PG_BULKLOAD_STATISTICS** displays the execution status of the import and export services. Each import or export service

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corresponds to a record. This view is accessible only to users with system administrators rights.

**Table 14-141** PG_BULKLOAD_STATISTICS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| db_name | text | Database name |
| query_id | bigint | Query ID. It is equivalent to **debug_query_id**. |
| tid | bigint | ID of the current thread |
| lwtid | integer | Lightweight thread ID |
| session_id | bigint | GDS session ID |
| direction | text | Service type. The options are **gds to file**, **gds from file**, **gds to pipe**, **gds from pipe**, **copy from**, and **copy to**. |
| query | text | Query statement |
| address | text | Location of the foreign table used for data import and export |
| query_start | timestamp with time zone | Start time of data import or export |
| total_bytes | bigint | Total size of data to be processed<br>This parameter is specified only when a GDS common file is to be imported and the record in the row comes from a CN. Otherwise, left this parameter unspecified. |
| phase | text | Execution phase of the current service import and export. The options are **INITIALIZING**, **TRANSFER_DATA**, and **RELEASE_RESOURCE**. |
| done_lines | bigint | Number of lines that have been transferred |
| done_bytes | bigint | Number of bytes that have been transferred |

## 14.3.78 PG_COMM_CLIENT_INFO

**PG_COMM_CLIENT_INFO** stores the client connection information of a single node. (You can query this view on a DN to view the information about the connection between the CN and DN.)

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**Table 14-142 PG_COMM_CLIENT_INFO** columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Current node name. |
| app | text | Client application name |
| tid | bigint | Thread ID of the current thread. |
| lwtid | integer | Lightweight thread ID of the current thread. |
| query_id | bigint | Query ID. It is equivalent to **debug_query_id**. |
| socket | integer | It is displayed if the connection is a physical connection. |
| remote_ip | text | Peer node IP address. |
| remote_port | text | Peer node port. |
| logic_id | integer | If the connection is a logical connection, **sid** is displayed. If **-1** is displayed, the current connection is a physical connection. |

## 14.3.79 PG_COMM_DELAY

**PG_COMM_DELAY** displays the communication library delay status for a single DN.

**Table 14-143** PG_COMM_DELAY columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| remote_name | text | Name of the peer node |
| remote_host | text | IP address of the peer |
| stream_num | integer | Number of logical stream connections used by the current physical connection |
| min_delay | integer | Minimum delay of the current physical connection within 1 minute. Its unit is microsecond.<br>**NOTE**<br>A negative result is invalid. Wait until the delay status is updated and query again. |
| average | integer | Average delay of the current physical connection within 1 minute. The unit is microsecond. |

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| Name | Type | Description |
| --- | --- | --- |
| max_delay | integer | Maximum delay of the current physical connection within 1 minute. The unit is microsecond. |

## 14.3.80 PG_COMM_STATUS

**PG_COMM_STATUS** displays the communication library status for a single DN.

**Table 14-144** PG_COMM_STATUS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Specifies the node name. |
| rxpck/s | integer | Receiving rate of the communication library on a node. The unit is byte/s. |
| txpck/s | integer | Sending rate of the communication library on a node. The unit is byte/s. |
| rxkB/s | bigint | Receiving rate of the communication library on a node. The unit is KB/s. |
| txkB/s | bigint | Sending rate of the communication library on a node. The unit is KB/s. |
| buffer | bigint | Size of the buffer of the Cmailbox. |
| memKB(libcomm) | bigint | Communication memory size of the **libcomm** process, in KB. |
| memKB(libpq) | bigint | Communication memory size of the **libpq** process, in KB. |
| %USED(PM) | integer | Real-time usage of the postmaster thread. |
| %USED (sflow) | integer | Real-time usage of the **gs_sender_flow_controller** thread. |
| %USED (rflow) | integer | Real-time usage of the **gs_receiver_flow_controller** thread. |
| %USED (rloop) | integer | Highest real-time usage among multiple **gs_receivers_loop** threads. |
| stream | integer | Total number of used logical connections. |

## 14.3.81 PG_COMM_RECV_STREAM

**PG_COMM_RECV_STREAM** displays the receiving stream status of all the communication libraries for a single DN.

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**Table 14-145** PG_COMM_RECV_STREAM columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| local_tid | bigint | ID of the thread using this stream |
| remote_name | text | Name of the peer node |
| remote_tid | bigint | Peer thread ID |
| idx | integer | Peer DN ID in the local DN |
| sid | integer | Stream ID in the physical connection |
| tcp_sock | integer | TCP socket used in the stream |
| state | text | Current status of the stream |
| query_id | bigint | **debug_query_id** corresponding to the stream |
| pn_id | integer | **plan_node_id** of the query executed by the stream |
| send_smp | integer | **smpid** of the sender of the query executed by the stream |
| recv_smp | integer | **smpid** of the receiver of the query executed by the stream |
| recv_bytes | bigint | Total data volume received from the stream. The unit is byte. |
| time | bigint | Current life cycle service duration of the stream. The unit is ms. |
| speed | bigint | Average receiving rate of the stream. The unit is byte/s. |
| quota | bigint | Current communication quota value of the stream. The unit is byte. |
| buff_usize | bigint | Current size of the data cache of the stream. The unit is byte. |

## 14.3.82 PG_COMM_SEND_STREAM

**PG_COMM_SEND_STREAM** displays the sending stream status of all the communication libraries for a single DN.

**Table 14-146** PG_COMM_SEND_STREAM columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |

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| Name | Type | Description |
| --- | --- | --- |
| local_tid | bigint | ID of the thread using this stream |
| remote_name | text | Name of the peer node |
| remote_tid | bigint | Peer thread ID |
| idx | integer | Peer DN ID in the local DN |
| sid | integer | Stream ID in the physical connection |
| tcp_sock | integer | TCP socket used in the stream |
| state | text | Current status of the stream |
| query_id | bigint | **debug_query_id** corresponding to the stream |
| pn_id | integer | **plan_node_id** of the query executed by the stream |
| send_smp | integer | **smpid** of the sender of the query executed by the stream |
| recv_smp | integer | **smpid** of the receiver of the query executed by the stream |
| send_bytes | bigint | Total data volume sent by the stream. The unit is Byte. |
| time | bigint | Current life cycle service duration of the stream. The unit is ms. |
| speed | bigint | Average sending rate of the stream. The unit is Byte/s. |
| quota | bigint | Current communication quota value of the stream. The unit is Byte. |
| wait_quota | bigint | Extra time generated when the stream waits the quota value. The unit is ms. |

## 14.3.83 PG_CONTROL_GROUP_CONFIG

**PG_CONTROL_GROUP_CONFIG** displays the Cgroup configuration information in the system.

**Table 14-147** PG_CONTROL_GROUP_CONFIG columns

| Name | Type | Description |
| --- | --- | --- |
| pg_control_group_config | text | Configuration information of the cgroup |

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## 14.3.84 PG_CURSORS

**PG_CURSORS** displays the cursors that are currently available.

**Table 14-148** PG_CURSORS columns

| Name | Type | Description |
| --- | --- | --- |
| name | text | Cursor name |
| statement | text | Query statement when the cursor is declared to change |
| is_holdable | boolean | Whether the cursor is holdable (that is, it can be accessed after the transaction that declared the cursor has committed). If it is, its value is **true**. |
| is_binary | boolean | Whether the cursor was declared BINARY. If it was, its value is **true**. |
| is_scrollable | boolean | Whether the cursor is scrollable (that is, it allows rows to be retrieved in a nonsequential manner). If it is, its value is **true**. |
| creation_time | timestamp with time zone | Timestamp at which the cursor is declared |

## 14.3.85 PG_EXT_STATS

**PG_EXT_STATS** displays extension statistics stored in the **PG_STATISTIC_EXT** table. The extension statistics means multiple columns of statistics.

**Table 14-149** PG_EXT_STATS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| schemaname | name | **PG_NAMESPACE**.nspname | Name of the schema that contains a table |
| tablename | name | **PG_CLASS**.relname | Name of a table |
| attname | int2vector | **PG_STATISTIC_EXT**.stakey | Indicates the columns to be combined for collecting statistics. |
| inherited | boolean | - | Includes inherited sub-columns if the value is **true**; otherwise, indicates the column in a specified table. |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| null_frac | real | - | Percentage of column combinations that are null to all records |
| avg_width | integer | - | Average width of column combinations. The unit is byte. |
| n_distinct | real | - | • Estimated number of distinct values in a column combination if the value is greater than 0<br>• Negative of the number of distinct values divided by the number of rows if the value is less than 0<br>The negated form is used when **ANALYZE** believes that the number of distinct values is likely to increase as the table grows.<br>The positive form is used when the column seems to have a fixed number of possible values. For example, **-1** indicates that the number of distinct values is the same as the number of rows for a column combination.<br>• The number of distinct values is unknown if the value is **0**. |
| n_dndistinct | real | - | Number of unique not-null data values in the **dn1** column combination<br>• Exact number of distinct values if the value is greater than 0<br>• Negative of the number of distinct values divided by the number of rows if the value is less than 0 For example, if a value in a column combination appears twice in average, **n_dndistinct** equals **-0.5**.<br>• The number of distinct values is unknown if the value is **0**. |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| most_common_vals | anyarray | - | List of the most common values in a column combination. If this combination does not have the most common values, **most_common_vals_null** will be **NULL**. None of the most common values in **most_common_vals** is **NULL**. |
| most_common_freqs | real[] | - | List of the frequencies of the most common values, that is, the number of occurrences of each value divided by the total number of rows. (NULL if **most_common_vals** is **NULL**) |
| most_common_vals_null | anyarray | - | List of the most common values in a column combination. If this combination does not have the most common values, **most_common_vals_null** will be **NULL**. At least one of the common values in **most_common_vals_null** is **NULL**. |
| most_common_freqs_null | real[] | - | List of the frequencies of the most common values, that is, the number of occurrences of each value divided by the total number of rows. (**NULL** if **most_common_vals_null** is **NULL**) |

## 14.3.86 PG_GET_INVALID_BACKENDS

**PG_GET_INVALID_BACKENDS** displays the information about backend threads on the CN that are connected to the current standby DN.

**Table 14-150** PG_GET_INVALID_BACKENDS columns

| Name | Type | Description |
| --- | --- | --- |
| pid | bigint | Thread ID |
| node_name | text | Node information connected to the backend thread |
| dbname | name | Name of the connected database |

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| Name | Type | Description |
| --- | --- | --- |
| backend_start | timestamp with time zone | Backend thread startup time |
| query | text | Query statement performed by the backend thread |

## 14.3.87 PG_GET_SENDERS_CATCHUP_TIME

**PG_GET_SENDERS_CATCHUP_TIME** displays the catchup information of the currently active primary/standby instance sending thread on a single DN.

**Table 14-151** PG_GET_SENDERS_CATCHUP_TIME columns

| Name | Type | Description |
| --- | --- | --- |
| pid | bigint | Current sender thread ID |
| lwpid | integer | Current sender lwpid |
| local_role | text | Local role |
| peer_role | text | Peer role |
| state | text | Current sender's replication status |
| type | text | Current sender type |
| catchup_start | timestamp with time zone | Startup time of a catchup task |
| catchup_end | timestamp with time zone | End time of a catchup task |
| catchup_type | text | Catchup task type, full or incremental |
| catchup_bcm_filename | text | BCM file executed by the current catchup task |
| catchup_bcm_finished | integer | Number of BCM files completed by a catchup task |
| catchup_bcm_total | integer | Total number of BCM files to be operated by a catchup task |
| catchup_percent | text | Completion percentage of a catchup task |
| catchup_remaining_time | text | Estimated remaining time of a catchup task |

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## 14.3.88 PG_GROUP

**PG_GROUP** displays the database role authentication and the relationship between roles.

**Table 14-152** PG_GROUP columns

| Name | Type | Description |
| --- | --- | --- |
| groname | name | Group name |
| grosysid | oid | Group ID |
| grolist | oid[] | An array, including all the role IDs in this group |

## 14.3.89 PG_INDEXES

**PG_INDEXES** displays access to useful information about each index in the database.

**Table 14-153** PG_INDEXES columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| schemaname | name | **PG_NAMESPACE**.nspname | Name of the schema that contains tables and indexes |
| tablename | name | **PG_CLASS**.relname | Name of the table for which the index serves |
| indexname | name | **PG_CLASS**.relname | Index name |
| tablespace | name | **PG_TABLESPACE**.spcname | Name of the tablespace that contains the index |
| indexdef | text | - | Index definition (a reconstructed **CREATE INDEX** command) |

## 14.3.90 PG_JOB

The **PG_JOB** view replaces the **PG_JOB** system catalog in earlier versions and provides forward compatibility with earlier versions. The original **PG_JOB** system catalog is changed to the **PG_JOBS** system catalog. For details about **PG_JOBS**, see **PG_JOBS**.

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**Table 14-154** PG_JOB columns

| Name | Type | Description |
| --- | --- | --- |
| job_id | bigint | Job ID |
| current_postgres_pid | bigint | If the current job has been executed, the PostgreSQL thread ID of this job is recorded. The default value is **-1**, indicating that the job has not yet been executed. |
| log_user | name | User name of the job creator |
| priv_user | name | User name of the job executor |
| dbname | name | Name of the database where the job is executed |
| node_name | name | CN node on which the job will be created and executed |
| job_status | text | Status of the current job. The value range is **r**, **s**, **f**, or **d**. The default value is **s**. The indications are as follows:<br>● r=running<br>● s=successfully finished<br>● f=job failed<br>● d=disable<br>If a job fails to be executed for 16 consecutive times, **job_status** is automatically set to **d**, and no more attempt will be made on this job.<br>**NOTE**<br>● Note: When you disable a scheduled task (by setting **job_queue_processes** to **0**), the thread monitor the job execution is not started, and the **job_status** will not be updated. You can ignore the **job_status**.<br>● Only when the scheduled task function is enabled (that is, when **job_queue_processes** is not **0**), the system updates the value of **job_status** based on the real-time job status. |
| start_date | timestamp without time zone | Start time of the first job execution, precise to millisecond |
| next_run_date | timestamp without time zone | Scheduled time of the next job execution, accurate to millisecond |
| failure_count | smallint | Number of times the job has started and failed. If a job fails to be executed for 16 consecutive times, no more attempt will be made on it. |

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| Name | Type | Description |
| --- | --- | --- |
| interval | text | Job execution interval |
| last_start_date | timestamp without time zone | Start time of the last job execution, accurate to millisecond |
| last_end_date | timestamp without time zone | End time of the last job execution, accurate to millisecond |
| last_suc_date | timestamp without time zone | Start time of the last successful job execution, accurate to millisecond |
| this_run_date | timestamp without time zone | Start time of the ongoing job execution, accurate to millisecond |
| nspname | name | Name of the namespace where a job is running |
| what | text | Job content |

## 14.3.91 PG_JOB_PROC

The **PG_JOB_PROC** view replaces the **PG_JOB_PROC** system catalog in earlier versions and provides forward compatibility with earlier versions. The original **PG_JOB_PROC** and **PG_JOB** system catalogs are merged into the **PG_JOBS** system catalog in the current version. For details about the **PG_JOBS** system catalog, see **PG_JOBS**.

**Table 14-155** PG_JOB_PROC columns

| Name | Type | Description |
| --- | --- | --- |
| job_id | bigint | Job ID |
| what | text | Job content |

## 14.3.92 PG_JOB_SINGLE

PG_JOB_SINGLE displays job information about the current node.

**Table 14-156** PG_JOB_SINGLE columns

| Name | Type | Description |
| --- | --- | --- |
| job_id | bigint | Job ID |

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| Name | Type | Description |
| --- | --- | --- |
| current_postgres_pid | bigint | If the current job has been executed, the PostgreSQL thread ID of this job is recorded. The default value is **-1**, indicating that the job has not yet been executed. |
| log_user | name | User name of the job creator |
| priv_user | name | User name of the job executor |
| dbname | name | Name of the database where the job is executed |
| node_name | name | CN node on which the job will be created and executed |
| job_status | text | Status of the current job. The value range is **r**, **s**, **f**, or **d**. The default value is **s**. The indications are as follows:<br>● r=running<br>● s=successfully finished<br>● f=job failed<br>● d=disable<br>If a job fails to be executed for 16 consecutive times, **job_status** is automatically set to **d**, and no more attempt will be made on this job.<br>**NOTE**<br>● Note: When you disable a scheduled task (by setting **job_queue_processes** to **0**), the thread monitor the job execution is not started, and the **job_status** will not be updated. You can ignore the **job_status**.<br>● Only when the scheduled task function is enabled (that is, when **job_queue_processes** is not **0**), the system updates the value of **job_status** based on the real-time job status. |
| start_date | timestamp without time zone | Start time of the first job execution, precise to millisecond |
| next_run_date | timestamp without time zone | Scheduled time of the next job execution, accurate to millisecond |
| failure_count | smallint | Number of times the job has started and failed. If a job fails to be executed for 16 consecutive times, no more attempt will be made on it. |
| interval | text | Job execution interval |

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| Name | Type | Description |
| --- | --- | --- |
| last_start_date | timestamp without time zone | Start time of the last job execution, accurate to millisecond |
| last_end_date | timestamp without time zone | End time of the last job execution, accurate to millisecond |
| last_suc_date | timestamp without time zone | Start time of the last successful job execution, accurate to millisecond |
| this_run_date | timestamp without time zone | Start time of the ongoing job execution, accurate to millisecond |
| nspname | name | Name of the namespace where a job is running |
| what | text | Job content |

## 14.3.93 PG_LIFECYCLE_DATA_DISTRIBUTE

**PG_LIFECYCLE_DATA_DISTRIBUTE** displays the distribution of cold and hot data in a multi-temperature table of OBS.

**Table 14-157** PG_LIFECYCLE_DATA_DISTRIBUTE columns

| Name | Type | Description |
| --- | --- | --- |
| schemaname | name | Schema name |
| tablename | name | Current table name |
| nodename | name | Node name |
| hotpartition | text | Hot partition on the DN |
| coldpartition | text | Cold partition on the DN |
| switchable partition | text | Switchable partition on the DN |
| hotdatasize | text | Data size of the hot partition on the DN |
| colddatasize | text | Data size of the cold partition on the DN |

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| Name | Type | Description |
| --- | --- | --- |
| switchable datasize | text | Data size of the switchable partition on the DN |

## 14.3.94 PG_LOCKS

**PG_LOCKS** displays information about the locks held by open transactions.

**Table 14-158** PG_LOCKS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| locktype | text | - | Type of the locked object: relation, extend, page, tuple, transactionid, virtualxid, object, userlock, and advisory |
| database | oid | PG_DATABASE.oid | OID of the database in which the locked target exists<br>• The OID is **0** if the target is a shared object.<br>• The OID is **NULL** if the locked target is a transaction. |
| relation | oid | PG_CLASS.oid | OID of the relationship targeted by the lock. The value is **NULL** if the object is neither a relationship nor part of a relationship. |
| page | integer | - | Page number targeted by the lock within the relationship. If the object is neither a relation page nor row page, the value is **NULL**. |
| tuple | smallint | - | Row number targeted by the lock within the page. If the object is not a row, the value is **NULL**. |
| virtualxid | text | - | Virtual ID of the transaction targeted by the lock. If the object is not a virtual transaction ID, the value is **NULL**. |
| transactionid | xid | - | ID of the transaction targeted by the lock. If the object is not a transaction ID, the value is **NULL**. |
| classid | oid | PG_CLASS.oid | OID of the system table that contains the object. If the object is not a general database object, the value is **NULL**. |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| objid | oid | - | OID of the lock target within its system table. If the target is not a general database object, the value is **NULL**. |
| objsubid | smallint | - | Column number for a column in the table. The value is **0** if the target is some other object type. If the object is not a general database object, the value is **NULL**. |
| virtualtransaction | text | - | Virtual ID of the transaction holding or awaiting this lock |
| pid | bigint | - | Logical ID of the server thread holding or awaiting this lock. This is **NULL** if the lock is held by a prepared transaction. |
| mode | text | - | Lock mode held or desired by this thread For more information about lock modes, see "LOCK" in *GaussDB(DWS) SQL Syntax Reference*. |
| granted | boolean | - | • The value is **true** if the lock is a held lock.<br>• The value is **false** if the lock is an awaited lock. |
| fastpath | boolean | - | Whether the lock is obtained through **fast-path** (**true**) or main lock table (**false**) |

## 14.3.95 PG_NODE_ENV

**PG_NODE_ENVO** displays the environmental variable information about the current node.

**Table 14-159** PG_NODE_ENV columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Name of the current node |
| host | text | Host name of the current node |
| process | integer | Process ID of the current node |
| port | integer | Port ID of the current node |

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| Name | Type | Description |
| --- | --- | --- |
| installpath | text | Installation directory of current node |
| datapath | text | Data directory of the current node |
| log_directory | text | Log directory of the current node |

## 14.3.96 PG_OS_THREADS

**PG_OS_THREADS** displays the status information about all the threads under the current node.

**Table 14-160** PG_OS_THREADS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Name of the current node |
| pid | bigint | Thread number running under the current node process |
| lwpid | integer | Lightweight thread ID corresponding to the PID |
| thread_name | text | Thread name corresponding to the PID |
| creation_time | timestamp with time zone | Thread creation time corresponding to the PID |

## 14.3.97 PG_POOLER_STATUS

**PG_POOLER_STATUS** displays the cache connection status in the pooler. **PG_POOLER_STATUS** can only query on the CN, and displays the connection cache information about the pooler module.

**Table 14-161** PG_POOLER_STATUS columns

| Name | Type | Description |
| --- | --- | --- |
| database | text | Database name |
| user_name | text | User name |
| tid | bigint | ID of a thread connected to the CN |
| node_oid | bigint | OID of the node connected |
| node_name | name | Name of the node connected |

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| Name | Type | Description |
| --- | --- | --- |
| in_use | boolean | Whether the connection is in use<br>• **t** (true): indicates that the connection is in use.<br>• **f** (false): indicates that the connection is not in use. |
| fdsock | bigint | Peer socket. |
| remote_pid | bigint | Peer thread ID. |
| session_params | text | GUC session parameter delivered by the connection. |

## 14.3.98 PG_PREPARED_STATEMENTS

**PG_PREPARED_STATEMENTS** displays all prepared statements that are available in the current session.

**Table 14-162** PG_PREPARED_STATEMENTS columns

| Name | Type | Description |
| --- | --- | --- |
| name | text | Identifier of the prepared statement |
| statement | text | Query string for creating this prepared statement For prepared statements created through SQL, this is the PREPARE statement submitted by the client. For prepared statements created through the frontend/backend protocol, this is the text of the prepared statement itself. |
| prepare_time | timestamp with time zone | Timestamp when the prepared statement is created |
| parameter_types | regtype[] | Expected parameter types for the prepared statement in the form of an array of **regtype**. The OID corresponding to an element of this array can be obtained by casting the regtype value to oid. |
| from_sql | boolean | How a prepared statement was created<br>• **true**: The prepared statement was created through the PREPARE statement.<br>• **false** The statement was prepared through the frontend/backend protocol. |

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## 14.3.99 PG_PREPARED_XACTS

**PG_PREPARED_XACTS** displays information about transactions that are currently prepared for two-phase commit.

**Table 14-163** PG_PREPARED_XACTS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| transaction | xid | - | Numeric transaction identifier of the prepared transaction |
| gid | text | - | Global transaction identifier that was assigned to the transaction |
| prepared | timestamp with time zone | - | Time at which the transaction is prepared for commit |
| owner | name | PG_AUTHID.rolname | Name of the user that executes the transaction |
| database | name | PG_DATABASE.datname | Name of the database in which the transaction is executed |

## 14.3.100 PG_QUERYBAND_ACTION

**PG_QUERYBAND_ACTION** displays information about the object associated with **query_band** and the **query_band** query order.

**Table 14-164** PG_QUERYBAND_ACTION columns

| Name | Type | Description |
| --- | --- | --- |
| qband | text | **query_band** key-value pairs |
| respool_id | oid | OID of the resource pool associated with **query_band** |
| respool | text | Name of the resource pool associated with **query_band** |
| priority | text | Intra-queue priority associated with **query_band** |
| qborder | integer | **query_band** query order |

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## 14.3.101 PG_REPLICATION_SLOTS

**PG_REPLICATION_SLOTS** displays the replication node information.

**Table 14-165** PG_REPLICATION_SLOTS columns

| Name | Type | Description |
| --- | --- | --- |
| slot_name | text | Name of a replication node |
| plugin | name | Name of the output plug-in of the logical replication slot |
| slot_type | text | Type of a replication node |
| datoid | oid | OID of the database on the replication node |
| database | name | Name of the database on the replication node |
| active | boolean | Whether the replication node is active |
| xmin | xid | Transaction ID of the replication node |
| catalog_xmin | text | ID of the earliest-decoded transaction corresponding to the logical replication slot |
| restart_lsn | text | Xlog file information on the replication node |
| dummy_standby | boolean | Whether the replication node is the dummy standby node |

## 14.3.102 PG_ROLES

**PG_ROLES** displays information about database roles.

**Table 14-166** PG_ROLES columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| rolname | name | - | Role name |
| rolsuper | boolean | - | Whether the role is the initial system administrator with the highest permission |
| rolinherit | boolean | - | Whether the role inherits permissions for this type of roles |
| rolcreaterole | boolean | - | Whether the role can create other roles |
| rolcreatedb | boolean | - | Whether the role can create databases |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| rolcatupdate | boolean | - | Whether the role can update system tables directly. Only the initial system administrator whose usesysid is 10 has this permission. It is not available for other users. |
| rolcanlogin | boolean | - | Whether the role can log in to the database |
| rolreplication | boolean | - | Whether the role can be replicated |
| rolauditadmin | boolean | - | Whether the role is an audit system administrator |
| rolsystemadmin | boolean | - | Whether the role is a system administrator |
| rolconnlimit | integer | - | Sets the maximum number of concurrent connections this role can make if this role can log in. -1 indicates no limit. |
| rolpassword | text | - | Not the password (always reads as ********) |
| rolvalidbegin | timestamp with time zone | - | Account validity start time; null if no start time |
| rolvaliduntil | timestamp with time zone | - | Password expiry time; null if no expiration |
| rolrespool | name | - | Resource pool that a user can use |
| rolparentid | oid | PG_AUTHID.rolparentid | OID of a group user to which the user belongs |
| roltabspace | text | - | The storage space of the user permanent table. |
| roltempspace | text | - | The storage space of the user temporary table. |
| rolspillspace | text | - | The operator disk flushing space of the user. |
| rolconfig | text[] | - | Session defaults for runtime configuration variables |
| oid | oid | PG_AUTHID.oid | ID of the role |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| roluseft | boolean | PG_AUTHID.roluseft | Whether the role can perform operations on foreign tables |
| nodegroup | name | - | Name of the logical cluster associated with the role. If no logical cluster is associated, this column is left empty. |

## 14.3.103 PG_RULES

**PG_RULES** displays information about rewrite rules.

**Table 14-167** PG_RULES columns

| Name | Type | Description |
| --- | --- | --- |
| schemaname | name | Name of the schema that contains the table |
| tablename | name | Name of the table the rule is for |
| rulename | name | Rule name |
| definition | text | Rule definition (a reconstructed creation command) |

## 14.3.104 PG_RUNNING_XACTS

**PG_RUNNING_XACTS** displays the running transaction information on the current node.

**Table 14-168** PG_RUNNING_XACTS columns

| Name | Type | Description |
| --- | --- | --- |
| handle | integer | Handle corresponding to the transaction in GTM |
| gxid | xid | Transaction ID |
| state | tinyint | Transaction status (**3**: prepared; **0**: starting) |
| node | text | Node name |
| xmin | xid | Minimum transaction ID **xmin** on the node |
| vacuum | boolean | Whether the current transaction is lazy vacuum |
| timeline | bigint | Number of database restarts |

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| Name | Type | Description |
| --- | --- | --- |
| prepare_xid | xid | Transaction ID in the **prepared** status. If the status is not **prepared**, the value is **0**. |
| pid | bigint | Thread ID corresponding to the transaction |
| next_xid | xid | Transaction ID sent from a CN to a DN |

## 14.3.105 PG_SECLABELS

**PG_SECLABELS** displays information about security labels.

**Table 14-169** PG_SECLABEL columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| objoid | oid | Any OID column | OID of the object this security label pertains to |
| classoid | oid | **PG_CLASS**.oid | OID of the system table that contains the object |
| objsubid | integer | - | For a security label on a table column, this is the column number (the **objoid** and **classoid** refer to the table itself). For all other object types, this column is **0**. |
| objtype | text | - | Type of the object to which this label applies |
| objnamespace | oid | **PG_NAMESPACE**.oid | OID of the namespace for this object, if applicable; otherwise NULL. |
| objname | text | - | Name of the object to which the label applies |
| provider | text | **PG_SECLABEL**.provider | Label provider associated with this label |
| label | text | **PG_SECLABEL**.label | Security label applied to this object |

## 14.3.106 PG_SESSION_WLMSTAT

**PG_SESSION_WLMSTAT** displays the corresponding load management information about the task currently executed by the user.

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**Table 14-170** PG_SESSION_WLMSTAT columns

| Column | Type | Description |
| --- | --- | --- |
| datid | oid | OID of the database this backend is connected to |
| datname | name | Name of the database the backend is connected to |
| threadid | bigint | ID of the backend thread |
| processid | integer | Thread PID of the backend |
| usesysid | oid | OID of the user who logged into the backend |
| appname | text | Name of the application that is connected to the backend |
| usename | name | Name of the user logged in to the backend |
| priority | bigint | Priority of Cgroup where the statement is located |
| attribute | text | Statement attributes<br>• **Ordinary**: default attribute of a statement before it is parsed by the database<br>• **Simple**: simple statements<br>• **Complicated**: complicated statements<br>• **Internal**: internal statement of the database |
| block_time | bigint | Pending duration of the statements by now (unit: s) |
| elapsed_time | bigint | Actual execution duration of the statements by now (unit: s) |
| total_cpu_time | bigint | Total CPU usage duration of the statement on the DN in the last period (unit: s) |
| cpu_skew_percent | integer | CPU usage inclination ratio of the statement on the DN in the last period |
| statement_mem | integer | Estimated memory required for statement execution. This column is reserved. |
| active_points | integer | Number of concurrently active points occupied by the statement in the resource pool |
| dop_value | integer | DOP value obtained by the statement from the resource pool |
| control_group | text | Cgroup currently used by the statement |

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| Column | Type | Description |
| --- | --- | --- |
| status | text | Status of a statement, including:<br>• **pending**<br>• **running**<br>• **finished** (If **enqueue** is set to **StoredProc** or **Transaction**, this state indicates that only a part of jobs in the statement have been executed. This state persists until the finish of this statement.)<br>• **aborted**: terminated unexpectedly<br>• **active**: normal status except for those above<br>• **unknown**: unknown status |
| enqueue | text | Current queuing status of the statements, including:<br>• **Global**: queuing in the global queue<br>• **Respool**: queuing in the resource pool queue<br>• **CentralQueue**: queuing on the CCN<br>• **Transaction**: being in a transaction block<br>• **StoredProc**: being in a stored procedure<br>• **None**: not in a queue<br>• **Forced None**: being forcibly executed (transaction block statement or stored procedure statement are) because the statement waiting time exceeds the specified value |
| resource_pool | name | Current resource pool where the statements are located. |
| query | text | Text of this backend's most recent query If **state** is **active**, this column shows the executing query. In all other states, it shows the last query that was executed. |
| isplana | bool | In logical cluster mode, indicates whether a statement occupies the resources of other logical clusters. The default value is **f** (does not occupy). |
| node_group | text | Logical cluster of the user running the statement |
| lane | text | Fast or slow lane for statement queries.<br>• fast: fast lane<br>• slow: slow lane<br>• none: not controlled |

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## 14.3.107 PG_SESSION_IOSTAT

**PG_SESSION_IOSTAT** displays the I/O load management information about the task currently executed by the user.

IOPS is counted by ones for column storage and by thousands for row storage.

**Table 14-171** PG_SESSION_IOSTAT columns

| Name | Type | Description |
| --- | --- | --- |
| query_id | bigint | Job ID |
| mincurriops | integer | Minimum I/O of the current job across DNs |
| maxcurriops | integer | Maximum I/O of the current job across DNs |
| minpeakiops | integer | Minimum peak I/O of the current job across DNs |
| maxpeakiops | integer | Maximum peak I/O of the current job across DNs |
| io_limits | integer | **io_limits** set for the job |
| io_priority | text | **io_priority** set for the job |
| query | text | Job |
| node_group | text | Logical cluster of the user running the job |

## 14.3.108 PG_SETTINGS

**PG_SETTINGS** displays information about parameters of the running database.

**Table 14-172** PG_SETTINGS columns

| Name | Type | Description |
| --- | --- | --- |
| name | text | Parameter name |
| setting | text | Current value of the parameter |
| unit | text | Implicit unit of the parameter |
| category | text | Logical group of the parameter |
| short_desc | text | Brief description of the parameter |
| extra_desc | text | Detailed description of the parameter |
| context | text | Context of parameter values including internal, backend, superuser, and user |
| vartype | text | Parameter type. It can be **bool**, **enum**, **integer**, **real**, or **string**. |

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| Name | Type | Description |
| --- | --- | --- |
| source | text | Method of assigning the parameter value |
| min_val | text | Minimum value of the parameter. If the parameter type is not numeric data, the value of this column is null. |
| max_val | text | Maximum value of the parameter. If the parameter type is not numeric data, the value of this column is null. |
| enumvals | text[] | Valid values of an enum-typed parameter. If the parameter type is not enum, the value of this column is null. |
| boot_val | text | Default parameter value used upon the database startup |
| reset_val | text | Default parameter value used upon the database reset |
| sourcefile | text | Configuration file used to set parameter values. If parameter values are not configured using the configuration file, the value of this column is null. |
| sourceline | integer | Row number of the configuration file for setting parameter values. If parameter values are not configured using the configuration file, the value of this column is null. |

## 14.3.109 PG_SHADOW

**PG_SHADOW** displays properties of all roles that are marked as **rolcanlogin** in **PG_AUTHID**.

The name stems from the fact that this table should not be readable by the public since it contains passwords. **PG_USER** is a publicly readable view on **PG_SHADOW** that blanks out the password column.

**Table 14-173** PG_SHADOW columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| usename | name | **PG_AUTHID**.rolname e | User name |
| usesysid | oid | **PG_AUTHID**.oid | ID of a user |
| usecreated b | boolea n | - | Indicates that the user can create databases. |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| usesuper | boolean | - | Indicates that the user is an administrator. |
| usecatupd | boolean | - | Indicates that the user can update system catalogs. Even the system administrator cannot do this unless this column is **true**. |
| userepl | boolean | - | User can initiate streaming replication and put the system in and out of backup mode. |
| passwd | text | - | Password (possibly encrypted); null if none. See **PG_AUTHID** for details about how encrypted passwords are stored. |
| valbegin | timestamp with time zone | - | Account validity start time; null if no start time |
| valuntil | timestamp with time zone | - | Password expiry time; null if no expiration |
| respool | name | - | Resource pool used by the user |
| parent | oid | - | Parent resource pool |
| spacelimit | text | - | The storage space of the permanent table. |
| tempspacelimit | text | - | The storage space of the temporary table. |
| spillspacelimit | text | - | The operator disk flushing space. |
| useconfig | text[ ] | - | Session defaults for runtime configuration variables |

## 14.3.110 PG_SHARED_MEMORY_DETAIL

**PG_SHARED_MEMORY_DETAIL** displays usage information about all the shared memory contexts.

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**Table 14-174** PG_SHARED_MEMORY_DETAIL columns

| Name | Type | Description |
| --- | --- | --- |
| contextname | text | Name of the context in the memory |
| level | smallint | Hierarchy of the memory context |
| parent | text | Context of the parent memory |
| totalsize | bigint | Total size of the shared memory, in bytes |
| freesize | bigint | Remaining size of the shared memory, in bytes |
| usedsize | bigint | Used size of the shared memory, in bytes |

## 14.3.111 PG_STATS

**PG_STATS** displays the single-column statistics stored in the **pg_statistic** table.

**Table 14-175** PG_STATS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| schemaname | name | **PG_NAMESPACE**.nspname | Name of the schema that contains the table |
| tablename | name | **PG_CLASS**.relname | Name of the table |
| attname | name | **PG_ATTRIBUTE**.attname | Column name |
| inherited | boolean | - | Includes inherited sub-columns if the value is **true**; otherwise, indicates the column in a specified table. |
| null_frac | real | - | Percentage of column entries that are null |
| avg_width | integer | - | Average width in bytes of column's entries |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| n_distinct | real | - | • Estimated number of distinct values in the column if the value is greater than 0<br>• Negative of the number of distinct values divided by the number of rows if the value is less than 0<br>The negated form is used when ANALYZE believes that the number of distinct values is likely to increase as the table grows.<br>The positive form is used when the column seems to have a fixed number of possible values. For example, **-1** indicates a unique column in which the number of distinct values is the same as the number of rows. |
| n_dndistinct | real | - | Number of unique non-null data values in the **dn1** column<br>• Exact number of distinct values if the value is greater than 0<br>• Negative of the number of distinct values divided by the number of rows if the value is less than 0 (For example, if the value of a column appears twice in average, set **n_dndistinct=-0.5**.)<br>• The number of distinct values is unknown if the value is **0**. |
| most_common_vals | anyarray | - | List of the most common values in a column. If this combination does not have the most common values, it will be **NULL**. |
| most_common_freqs | real[] | - | List of the frequencies of the most common values, that is, the number of occurrences of each value divided by the total number of rows. (NULL if **most_common_vals** is **NULL**) |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| histogram_bounds | anyarray | - | List of values that divide the column's values into groups of equal proportion. The values in **most_common_vals**, if present, are omitted from this histogram calculation. This field is null if the field data type does not have a **<** operator or if the **most_common_vals** list accounts for the entire population. |
| correlation | real | - | Statistical correlation between physical row ordering and logical ordering of the column values. It ranges from -1 to +1. When the value is near to -1 or +1, an index scan on the column is estimated to be cheaper than when it is near to zero, due to reduction of random access to the disk. This column is null if the column data type does not have a < operator. |
| most_common_elems | anyarray | - | Specifies a list of non-null element values most often appearing. |
| most_common_elem_freqs | real[] | - | Specifies a list of the frequencies of the most common element values. |
| elem_count_histogram | real[] | - | Specifies a histogram of the counts of distinct non-null element values. |

## 14.3.112 PG_STAT_ACTIVITY

**PG_STAT_ACTIVITY** displays information about the current user's queries.

**Table 14-176** PG_STAT_ACTIVITY columns

| Name | Type | Description |
| --- | --- | --- |
| datid | oid | OID of the database that the user session connects to in the backend |
| datname | name | Name of the database that the user session connects to in the backend |
| pid | bigint | Process ID of the backend |

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| Name | Type | Description |
| --- | --- | --- |
| usesysid | oid | OID of the user logging in to the backend |
| usename | name | OID of the user logging in to the backend |
| application_name | text | Name of the application connected to the backend |
| client_addr | inet | IP address of the client connected to the backend If this column is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum. |
| client_hostname | text | Host name of the connected client, as reported by a reverse DNS lookup of **client_addr**. This column will only be non-null for IP connections, and only when **log_hostname** is enabled. |
| client_port | integer | TCP port number that the client uses for communication with this backend, or **-1** if a Unix socket is used |
| backend_start | timestamp with time zone | Startup time of the backend process, that is, the time when the client connects to the server. |
| xact_start | timestamp with time zone | Time when the current transaction was started, or **NULL** if no transaction is active. If the current query is the first of its transaction, this column is equal to the **query_start** column. |
| query_start | timestamp with time zone | Time when the currently active query was started, or if **state** is not **active**, when the last query was started |
| state_change | timestamp with time zone | Time for the last status change |
| waiting | boolean | Whether the backend is currently waiting on a lock. If it is, its value is **true**. |

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| Name | Type | Description |
| --- | --- | --- |
| enqueue | text | Queuing status of a statement. Its value can be:<br>• **waiting in queue**: The statement is in the queue.<br>• **waiting in global queue**: The statement is in the global queue.<br>• **waiting in respool queue**: The statement is in the resource pool queue.<br>• **waiting in ccn queue**: The job is in the CCN queue.<br>• **Empty**: The statement is running. |

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| Name | Type | Description |
| --- | --- | --- |
| state | text | Current overall state of this backend. Its value can be:<br>• **active**: The backend is executing queries.<br>• **idle**: The backend is waiting for new client commands.<br>• **idle in transaction**: The backend is in a transaction, but there is no statement being executed in the transaction.<br>• **idle in transaction** (aborted): The backend is in a transaction, but there are statements failed in the transaction.<br>• **fastpath function call**: The backend is executing a fast-path function.<br>• **disabled**: This state is reported if **track_activities** is disabled in this backend.<br>**NOTE**<br>Common users can view only their own session status. The state information of other accounts is empty. For example, after user **judy** is connected to the database, the state information of user **joe** and the initial user **omm** in **pg_stat_activity** is empty.<br>SELECT datname, usename, usesysid, state,pid FROM pg_stat_activity;<br>datname \| usename \| usesysid \| state \| pid<br>----------+---------+----------+--------+-----------------<br>gaussdb \| dbadmin \| 10 \| \| 139968752121616<br>gaussdb \| dbadmin \| 10 \| \| 139968903116560<br>db_tpcds \| judy \| 16398 \| active \| 139968391403280<br>gaussdb \| dbadmin \| 10 \| \| 139968643069712<br>gaussdb \| dbadmin \| 10 \| \| 139968680818448<br>gaussdb \| joe \| 16390 \| \| 139968563377936<br>(6 rows) |
| resource_pool | name | Resource pool used by the user |
| query_id | bigint | ID of a query |

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| Name | Type | Description |
| --- | --- | --- |
| query | text | Text of this backend's most recent query If **state** is **active**, this column shows the executing query. In all other states, it shows the last query that was executed. |
| connection_info | text | A string in JSON format recording the driver type, driver version, driver deployment path, and process owner of the connected database (for details, see **connection_info**) |

## 14.3.113 PG_STAT_ALL_INDEXES

**PG_STAT_ALL_INDEXES** displays access informaton about all indexes in the database, with information about each index displayed in a row.

Indexes can be used via either simple index scans or "bitmap" index scans. In a bitmap scan the output of several indexes can be combined via AND or OR rules, so it is difficult to associate individual heap row fetches with specific indexes when a bitmap scan is used. Therefore, a bitmap scan increments the **pg_stat_all_indexes.idx_tup_read** count(s) for the index(es) it uses, and it increments the **pg_stat_all_tables.idx_tup_fetch** count for the table, but it does not affect **pg_stat_all_indexes.idx_tup_fetch**.

**Table 14-177** PG_STAT_ALL_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | OID of the table for this index |
| indexrelid | oid | OID of this index |
| schemaname | name | Name of the schema this index is in |
| relname | name | Name of the table for this index |
| indexrelname | name | Name of this index |
| idx_scan | bigint | Number of index scans initiated on this index |
| idx_tup_read | bigint | Number of index entries returned by scans on this index |
| idx_tup_fetch | bigint | Number of live table rows fetched by simple index scans using this index |

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# 14.3.114 PG_STAT_ALL_TABLES

**PG_STAT_ALL_TABLES** displays access information about all rows in all tables (including TOAST tables) in the database.

**Table 14-178** PG_STAT_ALL_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Name of the table |
| seq_scan | bigint | Number of sequential scans started on the table |
| seq_tup_read | bigint | Number of rows that have live data fetched by sequential scans |
| idx_scan | bigint | Number of index scans |
| idx_tup_fetch | bigint | Number of rows that have live data fetched by index scans |
| n_tup_ins | bigint | Number of rows inserted |
| n_tup_upd | bigint | Number of rows updated |
| n_tup_del | bigint | Number of rows deleted |
| n_tup_hot_upd | bigint | Number of rows updated by **HOT** (no separate index update is required) |
| n_live_tup | bigint | Estimated number of live rows |
| n_dead_tup | bigint | Estimated number of dead rows |
| last_vacuum | timestamp with time zone | Last time at which this table was manually vacuumed (excluding **VACUUM FULL**) |
| last_autovacuum | timestamp with time zone | Last time at which this table was automatically vacuumed |
| last_analyze | timestamp with time zone | Last time at which this table was analyzed |
| last_autoanalyze | timestamp with time zone | Last time at which this table was automatically vacuumed |
| vacuum_count | bigint | Number of vacuum operations (excluding **VACUUM FULL**) |

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| Name | Type | Description |
| --- | --- | --- |
| autovacuum_count | bigint | Number of autovacuum operations |
| analyze_count | bigint | Number of analyze operations |
| autoanalyze_count | bigint | Number of autoanalyze operations |
| last_data_changed | timestamp with time zone | Last time at which this table was updated (by **INSERT**/**UPDATE**/**DELETE** or **EXCHANGE**/**TRUNCATE**/**DROP** *partition*). This column is recorded only on the local CN. |

## 14.3.115 PG_STAT_BAD_BLOCK

**PG_STAT_BAD_BLOCK** displays statistics about page or CU verification failures after a node is started.

**Table 14-179** PG_STAT_BAD_BLOCK columns

| Name | Type | Description |
| --- | --- | --- |
| nodename | text | Node name |
| databaseid | integer | Database OID |
| tablespaceid | integer | Tablespace OID |
| relfilenode | integer | File object ID |
| forknum | integer | File type |
| error_count | integer | Number of verification failures |
| first_time | timestamp with time zone | Time of the first occurrence |
| last_time | timestamp with time zone | Time of the latest occurrence |

## 14.3.116 PG_STAT_BGWRITER

**PG_STAT_BGWRITER** displays statistics about the background writer process's activity.

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**Table 14-180** PG_STAT_BGWRITER columns

| Name | Type | Description |
| --- | --- | --- |
| checkpoints_timed | bigint | Number of scheduled checkpoints that have been performed |
| checkpoints_req | bigint | Number of requested checkpoints that have been performed |
| checkpoint_write_time | double precision | Total amount of time that has been spent in the portion of checkpoint processing where files are written to disk, in milliseconds |
| checkpoint_sync_time | double precision | Total amount of time that has been spent in the portion of checkpoint processing where files are synchronized to disk, in milliseconds |
| buffers_checkpoint | bigint | Number of buffers written during checkpoints |
| buffers_clean | bigint | Number of buffers written by the background writer |
| maxwritten_clean | bigint | Number of times the background writer stopped a cleaning scan because it had written too many buffers |
| buffers_backend | bigint | Number of buffers written directly by a backend |
| buffers_backend_fsync | bigint | Number of times that a backend has to execute **fsync** |
| buffers_alloc | bigint | Number of buffers allocated |
| stats_reset | timestamp with time zone | Time at which these statistics were reset |

## 14.3.117 PG_STAT_DATABASE

**PG_STAT_DATABASE** displays the status and statistics of each database on the current node.

**Table 14-181** PG_STAT_DATABASE columns

| Name | Type | Description |
| --- | --- | --- |
| datid | oid | Database OID |
| datname | name | Database name |

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| Name | Type | Description |
| --- | --- | --- |
| numbackends | integer | Number of backends currently connected to this database on the current node. This is the only column in this view that reflects the current state value. All columns return the accumulated value since the last reset. |
| xact_commit | bigint | Number of transactions in this database that have been committed on the current node |
| xact_rollback | bigint | Number of transactions in this database that have been rolled back on the current node |
| blks_read | bigint | Number of disk blocks read in this database on the current node |
| blks_hit | bigint | Number of disk blocks found in the buffer cache on the current node, that is, the number of blocks hit in the cache. (This only includes hits in the GaussDB(DWS) buffer cache, not in the file system cache.) |
| tup_returned | bigint | Number of rows returned by queries in this database on the current node |
| tup_fetched | bigint | Number of rows fetched by queries in this database on the current node |
| tup_inserted | bigint | Number of rows inserted in this database on the current node |
| tup_updated | bigint | Number of rows updated in this database on the current node |
| tup_deleted | bigint | Number of rows deleted from this database on the current node |
| conflicts | bigint | Number of queries canceled due to database recovery conflicts on the current node (conflicts occurring only on the standby server). For details, see **PG_STAT_DATABASE_CONFLICTS**. |
| temp_files | bigint | Number of temporary files created by this database on the current node. All temporary files are counted, regardless of why the temporary file was created (for example, sorting or hashing), and regardless of the **log_temp_files** setting. |
| temp_bytes | bigint | Size of temporary files written to this database on the current node. All temporary files are counted, regardless of why the temporary file was created, and regardless of the **log_temp_files** setting. |

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| Name | Type | Description |
| --- | --- | --- |
| deadlocks | bigint | Number of deadlocks in this database on the current node |
| blk_read_time | double precision | Time spent reading data file blocks by backends in this database on the current node, in milliseconds |
| blk_write_time | double precision | Time spent writing into data file blocks by backends in this database on the current node, in milliseconds |
| stats_reset | timestamp with time zone | Time when the database statistics are reset on the current node |

## 14.3.118 PG_STAT_DATABASE_CONFLICTS

**PG_STAT_DATABASE_CONFLICTS** displays statistics about database conflicts.

**Table 14-182** PG_STAT_DATABASE_CONFLICTS columns

| Name | Type | Description |
| --- | --- | --- |
| datid | oid | Database OID |
| datname | name | Database name |
| confl_tablespace | bigint | Number of conflicting tablespaces |
| confl_lock | bigint | Number of conflicting locks |
| confl_snapshot | bigint | Number conflicting snapshots |
| confl_bufferpin | bigint | Number of conflicting buffers |
| confl_deadlock | bigint | Number of conflicting deadlocks |

## 14.3.119 PG_STAT_GET_MEM_MBYTES_RESERVED

**PG_STAT_GET_MEM_MBYTES_RESERVED** displays the current activity information of a thread stored in memory. You need to specify the thread ID (pid in **PG_STAT_ACTIVITY**) for query. If the thread ID is set to **0**, the current thread ID is used. For example:

```
SELECT pg_stat_get_mem_mbytes_reserved(0);
```

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**Table 14-183** PG_STAT_GET_MEM_MBYTES_RESERVED columns

| Parameter | Description |
| --- | --- |
| ConnectInfo | Connection information |
| ParctlManager | Concurrency management information |
| GeneralParams | Basic parameter information |
| GeneralParams RPDATA | Basic resource pool information |
| ExceptionManager | Exception management information |
| CollectInfo | Collection information |
| GeneralInfo | Basic information |
| ParctlState | Concurrency status information |
| CPU INFO | CPU information |
| ControlGroup | Cgroup information |
| IOSTATE | I/O status information |

## 14.3.120 PG_STAT_USER_FUNCTIONS

**PG_STAT_USER_FUNCTIONS** displays user-defined function status information in the namespace. (The language of the function is non-internal language.)

**Table 14-184** PG_STAT_USER_FUNCTIONS columns

| Name | Type | Description |
| --- | --- | --- |
| funcid | oid | Function OID |
| schemaname | name | Schema name |
| funcname | name | Function name |
| calls | bigint | Number of times this function has been called |
| total_time | double precision | Total time spent in this function and all other functions called by it |
| self_time | double precision | Total time spent in this function itself, excluding other functions called by it |

## 14.3.121 PG_STAT_USER_INDEXES

**PG_STAT_USER_INDEXES** displays information about the index status of user-defined ordinary tables and TOAST tables.

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**Table 14-185** PG_STAT_USER_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID for the index |
| indexrelid | oid | Index OID |
| schemaname | name | Schema name for the index |
| relname | name | Table name for the index |
| indexrelname | name | Index name |
| idx_scan | bigint | Number of index scans |
| idx_tup_read | bigint | Number of index entries returned by scans on this index |
| idx_tup_fetch | bigint | Number of rows that have live data fetched by index scans |

## 14.3.122 PG_STAT_USER_TABLES

**PG_STAT_USER_TABLES** displays status information about user-defined ordinary tables and TOAST tables in all namespaces.

**Table 14-186** PG_STAT_USER_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| seq_scan | bigint | Number of sequential scans started on the table |
| seq_tup_read | bigint | Number of rows that have live data fetched by sequential scans |
| idx_scan | bigint | Number of index scans |
| idx_tup_fetch | bigint | Number of rows that have live data fetched by index scans |
| n_tup_ins | bigint | Number of rows inserted |
| n_tup_upd | bigint | Number of rows updated |
| n_tup_del | bigint | Number of rows deleted |
| n_tup_hot_upd | bigint | Number of rows updated by **HOT** (no separate index update is required) |

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| Name | Type | Description |
| --- | --- | --- |
| n_live_tup | bigint | Estimated number of live rows |
| n_dead_tup | bigint | Estimated number of dead rows |
| last_vacuum | timestamp with time zone | Last time at which this table was manually vacuumed (excluding **VACUUM FULL**) |
| last_autovacuum | timestamp with time zone | Last time at which this table was automatically vacuumed |
| last_analyze | timestamp with time zone | Last time at which this table was analyzed |
| last_autoanalyze | timestamp with time zone | Last time at which this table was automatically analyzed |
| vacuum_count | bigint | Number of vacuum operations (excluding **VACUUM FULL**) |
| autovacuum_count | bigint | Number of autovacuum operations |
| analyze_count | bigint | Number of analyze operations |
| autoanalyze_count | bigint | Number of autoanalyze operations |

## 14.3.123 PG_STAT_REPLICATION

**PG_STAT_REPLICATION** displays information about log synchronization status, such as the locations of the sender sending logs and the receiver receiving logs.

**Table 14-187** PG_STAT_REPLICATION columns

| Name | Type | Description |
| --- | --- | --- |
| pid | bigint | PID of the thread |
| usesysid | oid | User system ID |
| usename | name | Username |
| application_name | text | Application name |
| client_addr | inet | Client address |
| client_hostname | text | Client name |

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| Name | Type | Description |
| --- | --- | --- |
| client_port | integer | Client port number |
| backend_start | timestamp with time zone | Start time of the program |
| state | text | Log replication state (catch-up or consistent streaming) |
| sender_sent_location | text | Location where the sender sends logs |
| receiver_write_location | text | Location where the receiver writes logs |
| receiver_flush_location | text | Location where the receiver flushes logs |
| receiver_replay_location | text | Location where the receiver replays logs |
| sync_priority | integer | Priority of synchronous duplication (**0** indicates asynchronization) |
| sync_state | text | Synchronization state (asynchronous duplication, synchronous duplication, or potential synchronization) |

## 14.3.124 PG_STAT_SYS_INDEXES

**PG_STAT_SYS_INDEXES** displays the index status information about all the system catalogs in the **pg_catalog** and **information_schema** schemas.

**Table 14-188** PG_STAT_SYS_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID for the index |
| indexrelid | oid | Index OID |
| schemaname | name | Schema name for the index |
| relname | name | Table name for the index |
| indexrelname | name | Index name |
| idx_scan | bigint | Number of index scans |
| idx_tup_read | bigint | Number of index entries returned by scans on this index |

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| Name | Type | Description |
| --- | --- | --- |
| idx_tup_fetch | bigint | Number of rows that have live data fetched by index scans |

## 14.3.125 PG_STAT_SYS_TABLES

**PG_STAT_SYS_TABLES** displays the statistics about the system catalogs of all the namespaces in **pg_catalog** and **information_schema** schemas.

**Table 14-189** PG_STAT_SYS_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| seq_scan | bigint | Number of sequential scans started on the table |
| seq_tup_read | bigint | Number of rows that have live data fetched by sequential scans |
| idx_scan | bigint | Number of index scans |
| idx_tup_fetch | bigint | Number of rows that have live data fetched by index scans |
| n_tup_ins | bigint | Number of rows inserted |
| n_tup_upd | bigint | Number of rows updated |
| n_tup_del | bigint | Number of rows deleted |
| n_tup_hot_upd | bigint | Number of rows HOT updated (that is, with no separate index update required) |
| n_live_tup | bigint | Estimated number of live rows |
| n_dead_tup | bigint | Estimated number of dead rows |
| last_vacuum | timestamp with time zone | Last time at which this table was manually vacuumed (excluding **VACUUM FULL**) |
| last_autovacuum | timestamp with time zone | Last time at which this table was automatically vacuumed |
| last_analyze | timestamp with time zone | Last time at which this table was analyzed |

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| Name | Type | Description |
| --- | --- | --- |
| last_autoanalyze | timestamp with time zone | Last time at which this table was automatically analyzed |
| vacuum_count | bigint | Number of vacuum operations (excluding **VACUUM FULL**) |
| autovacuum_count | bigint | Number of autovacuum operations |
| analyze_count | bigint | Number of analyze operations |
| autoanalyze_count | bigint | Number of autoanalyze operations |

## 14.3.126 PG_STAT_XACT_ALL_TABLES

**PG_STAT_XACT_ALL_TABLES** displays the transaction status information about all ordinary tables and TOAST tables in the namespaces.

**Table 14-190** PG_STAT_XACT_ALL_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| seq_scan | bigint | Number of sequential scans started on the table |
| seq_tup_read | bigint | Number of live rows fetched by sequential scans |
| idx_scan | bigint | Number of index scans started on the table |
| idx_tup_fetch | bigint | Number of live rows fetched by index scans |
| n_tup_ins | bigint | Number of rows inserted |
| n_tup_upd | bigint | Number of rows updated |
| n_tup_del | bigint | Number of rows deleted |
| n_tup_hot_upd | bigint | Number of rows HOT updated (that is, with no separate index update required) |

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## 14.3.127 PG_STAT_XACT_SYS_TABLES

**PG_STAT_XACT_SYS_TABLES** displays the transaction status information of the system catalog in the namespace.

**Table 14-191** PG_STAT_XACT_SYS_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| seq_scan | bigint | Number of sequential scans started on the table |
| seq_tup_read | bigint | Number of live rows fetched by sequential scans |
| idx_scan | bigint | Number of index scans started on the table |
| idx_tup_fetch | bigint | Number of live rows fetched by index scans |
| n_tup_ins | bigint | Number of rows inserted |
| n_tup_upd | bigint | Number of rows updated |
| n_tup_del | bigint | Number of rows deleted |
| n_tup_hot_upd | bigint | Number of rows HOT updated (that is, with no separate index update required) |

## 14.3.128 PG_STAT_XACT_USER_FUNCTIONS

**PG_STAT_XACT_USER_FUNCTIONS** displays statistics about function executions, with statistics about each execution displayed in a row.

**Table 14-192** PG_STAT_XACT_USER_FUNCTIONS columns

| Name | Type | Description |
| --- | --- | --- |
| funcid | oid | Function OID |
| schemaname | name | Schema name |
| funcname | name | Function name |
| calls | bigint | Number of times this function has been called |
| total_time | double precision | Total time spent in this function and all other functions called by it |

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| Name | Type | Description |
| --- | --- | --- |
| self_time | double precision | Total time spent in this function itself, excluding other functions called by it |

## 14.3.129 PG_STAT_XACT_USER_TABLES

**PG_STAT_XACT_USER_TABLES** displays the transaction status information of the user table in the namespace.

**Table 14-193** PG_STAT_XACT_USER_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| seq_scan | bigint | Number of sequential scans started on the table |
| seq_tup_read | bigint | Number of live rows fetched by sequential scans |
| idx_scan | bigint | Number of index scans started on the table |
| idx_tup_fetch | bigint | Number of live rows fetched by index scans |
| n_tup_ins | bigint | Number of rows inserted |
| n_tup_upd | bigint | Number of rows updated |
| n_tup_del | bigint | Number of rows deleted |
| n_tup_hot_upd | bigint | Number of rows HOT updated (that is, with no separate index update required) |

## 14.3.130 PG_STATIO_ALL_INDEXES

**PG_STATIO_ALL_INDEXES** contains each row of each index in the current database, showing I/O statistics about accesses to that specific index.

**Table 14-194** PG_STATIO_ALL_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID for the index |
| indexrelid | oid | Index OID |

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| Name | Type | Description |
| --- | --- | --- |
| schemaname | name | Schema name for the index |
| relname | name | Table name for the index |
| indexrelname | name | Index name |
| idx_blks_read | bigint | Number of disk blocks read from this index |
| idx_blks_hit | bigint | Number of buffer hits in this index |

## 14.3.131 PG_STATIO_ALL_SEQUENCES

**PG_STATIO_ALL_SEQUENCES** contains each row of each sequence in the current database, showing I/O statistics about accesses to that specific sequence.

**Table 14-195** PG_STATIO_ALL_SEQUENCES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | OID of this sequence |
| schemaname | name | Name of the schema this sequence is in |
| relname | name | Name of the sequence |
| blks_read | bigint | Number of disk blocks read from this sequence |
| blks_hit | bigint | Number of buffer hits in this sequence |

## 14.3.132 PG_STATIO_ALL_TABLES

**PG_STATIO_ALL_TABLES** contains one row for each table in the current database (including TOAST tables), showing I/O statistics about accesses to that specific table.

**Table 14-196** PG_STATIO_ALL_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| heap_blks_read | bigint | Number of disk blocks read from this table |
| heap_blks_hit | bigint | Number of buffer hits in this table |

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| Name | Type | Description |
| --- | --- | --- |
| idx_blks_read | bigint | Number of disk blocks read from the index in this table |
| idx_blks_hit | bigint | Number of buffer hits in all indexes on this table |
| toast_blks_read | bigint | Number of disk blocks read from the TOAST table (if any) in this table |
| toast_blks_hit | bigint | Number of buffer hits in the TOAST table (if any) in this table |
| tidx_blks_read | bigint | Number of disk blocks read from the TOAST table index (if any) in this table |
| tidx_blks_hit | bigint | Number of buffer hits in the TOAST table index (if any) in this table |

## 14.3.133 PG_STATIO_SYS_INDEXES

**PG_STATIO_SYS_INDEXES** displays the I/O status information about all system catalog indexes in the namespace.

**Table 14-197** PG_STATIO_SYS_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID for the index |
| indexrelid | oid | Index OID |
| schemaname | name | Schema name for the index |
| relname | name | Table name for the index |
| indexrelname | name | Index name |
| idx_blks_read | bigint | Number of disk blocks read from this index |
| idx_blks_hit | bigint | Number of buffer hits in this index |

## 14.3.134 PG_STATIO_SYS_SEQUENCES

**PG_STATIO_SYS_SEQUENCES** displays the I/O status information about all the system sequences in the namespace.

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**Table 14-198** PG_STATIO_SYS_SEQUENCES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | OID of this sequence |
| schemaname | name | Name of the schema this sequence is in |
| relname | name | Name of the sequence |
| blks_read | bigint | Number of disk blocks read from this sequence |
| blks_hit | bigint | Number of buffer hits in this sequence |

## 14.3.135 PG_STATIO_SYS_TABLES

**PG_STATIO_SYS_TABLES** displays the I/O status information about all the system catalogs in the namespace.

**Table 14-199** PG_STATIO_SYS_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| heap_blks_read | bigint | Number of disk blocks read from this table |
| heap_blks_hit | bigint | Number of buffer hits in this table |
| idx_blks_read | bigint | Number of disk blocks read from all indexes in this table |
| idx_blks_hit | bigint | Number of buffer hits in all indexes on this table |
| toast_blks_read | bigint | Number of disk blocks read from the TOAST table (if any) in this table |
| toast_blks_hit | bigint | Number of buffer hits in the TOAST table (if any) in this table |
| tidx_blks_read | bigint | Number of disk blocks read from the TOAST table index (if any) in this table |
| tidx_blks_hit | bigint | Number of buffer hits in the TOAST table index (if any) in this table |

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## 14.3.136 PG_STATIO_USER_INDEXES

**PG_STATIO_USER_INDEXES** displays the I/O status information about all the user relationship table indexes in the namespace.

**Table 14-200** PG_STATIO_USER_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID for the index |
| indexrelid | oid | Index OID |
| schemaname | name | Schema name for the index |
| relname | name | Table name for the index |
| indexrelname | name | Index name |
| idx_blks_read | bigint | Number of disk blocks read from this index |
| idx_blks_hit | bigint | Number of buffer hits in this index |

## 14.3.137 PG_STATIO_USER_SEQUENCES

**PG_STATIO_USER_SEQUENCES** displays the I/O status information about all the user relation table sequences in the namespace.

**Table 14-201** PG_STATIO_USER_SEQUENCES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | OID of this sequence |
| schemaname | name | Name of the schema this sequence is in |
| relname | name | Name of this sequence |
| blks_read | bigint | Number of disk blocks read from this sequence |
| blks_hit | bigint | Number of cache hits in this sequence |

## 14.3.138 PG_STATIO_USER_TABLES

**PG_STATIO_USER_TABLES** displays the I/O status information about all the user relation tables in the namespace.

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**Table 14-202** PG_STATIO_USER_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| schemaname | name | Schema name of the table |
| relname | name | Table name |
| heap_blks_read | bigint | Number of disk blocks read from this table |
| heap_blks_hit | bigint | Number of buffer hits in this table |
| idx_blks_read | bigint | Number of disk blocks read from the index in this table |
| idx_blks_hit | bigint | Number of buffer hits in all indexes on this table |
| toast_blks_read | bigint | Number of disk blocks read from the TOAST table (if any) in this table |
| toast_blks_hit | bigint | Number of buffer hits in the TOAST table (if any) in this table |
| tidx_blks_read | bigint | Number of disk blocks read from the TOAST table index (if any) in this table |
| tidx_blks_hit | bigint | Number of buffer hits in the TOAST table index (if any) in this table |

## 14.3.139 PG_THREAD_WAIT_STATUS

**PG_THREAD_WAIT_STATUS** allows you to test the block waiting status about the backend thread and auxiliary thread of the current instance.

**Table 14-203** PG_THREAD_WAIT_STATUS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Current node name |
| db_name | text | Database name |
| thread_name | text | Thread name |
| query_id | bigint | Query ID. It is equivalent to **debug_query_id**. |
| tid | bigint | Thread ID of the current thread |
| lwtid | integer | Lightweight thread ID of the current thread |
| ptid | integer | Parent thread of the streaming thread |
| tlevel | integer | Level of the streaming thread |

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| Name | Type | Description |
| --- | --- | --- |
| smpid | integer | Concurrent thread ID |
| wait_status | text | Waiting status of the current thread. For details about the waiting status, see **Table 14-204**. |
| wait_event | text | If **wait_status** is **acquire lock**, **acquire lwlock**, or **wait io**, this column describes the lock, lightweight lock, and I/O information, respectively. If **wait_status** is not any of the three values, this column is empty. |

The waiting statuses in the **wait_status** column are as follows:

**Table 14-204** Waiting status list

| Value | Description |
| --- | --- |
| none | Waiting for no event |
| acquire lock | Waiting for locking until the locking succeeds or times out |
| acquire lwlock | Waiting for a lightweight lock |
| wait io | Waiting for I/O completion |
| wait cmd | Waiting for network communication packet read to complete |
| wait pooler get conn | Waiting for pooler to obtain the connection |
| wait pooler abort conn | Waiting for pooler to terminate the connection |
| wait pooler clean conn | Waiting for pooler to clear connections |
| pooler create conn: [nodename], total N | Waiting for the pooler to set up a connection. The connection is being established with the node specified by *nodename*, and there are *N* connections waiting to be set up. |
| get conn | Obtaining the connection to other nodes |
| set cmd: [nodename] | Waiting for running the **SET**, **RESET**, **TRANSACTION BLOCK LEVEL PARA SET**, or **SESSION LEVEL PARA SET** statement on the connection. The statement is being executed on the node specified by *nodename*. |
| cancel query | Canceling the SQL statement that is being executed through the connection |

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| Value | Description |
| --- | --- |
| stop query | Stopping the query that is being executed through the connection |
| wait node: [nodename](plevel), total N, [phase] | Waiting for receiving the data from a connected node. The thread is waiting for the data from the plevel thread of the node specified by *nodename*. The data of *N* connections is waiting to be returned. If *phase* is included, the possible phases are as follows:<br>• **begin**: The transaction is being started.<br>• **commit**: The transaction is being committed.<br>• **rollback**: The transaction is being rolled back. |
| wait transaction sync: xid | Waiting for synchronizing the transaction specified by *xid* |
| wait wal sync | Waiting for the completion of wal log of synchronization from the specified LSN to the standby instance |
| wait data sync | Waiting for the completion of data page synchronization to the standby instance |
| wait data sync queue | Waiting for putting the data pages that are in the row storage or the CU in the column storage into the synchronization queue |
| flush data: [nodename](plevel), [phase] | Waiting for sending data to the plevel thread of the node specified by *nodename*. If *phase* is included, the possible phase is **wait quota**, indicating that the current communication flow is waiting for the quota value. |
| stream get conn: [nodename], total N | Waiting for connecting to the consumer object of the node specified by *nodename* when the stream flow is initialized. There are *N* consumers waiting to be connected. |
| wait producer ready: [nodename](plevel), total N | Waiting for each producer to be ready when the stream flow is initialized. The thread is waiting for the procedure of the plevel thread on the *nodename* node to be ready. There are *N* producers waiting to be ready. |
| synchronize quit | Waiting for the threads in the stream thread group to quit when the steam plan ends |
| nodegroup destroy | Waiting for destroying the stream node group when the steam plan ends |

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| Value | Description |
| --- | --- |
| wait active statement | Waiting for job execution under resource and load control. |
| wait global queue | Waiting for job execution. The job is queuing in the global queue. |
| wait respool queue | Waiting for job execution. The job is queuing in the resource pool. |
| wait ccn queue | Waiting for job execution. The job is queuing on the central coordinator node (CCN). |
| gtm connect | Waiting for connecting to GTM. |
| gtm get gxid | Wait for obtaining xids from GTM. |
| gtm get snapshot | Wait for obtaining transaction snapshots from GTM. |
| gtm begin trans | Waiting for GTM to start a transaction. |
| gtm commit trans | Waiting for GTM to commit a transaction. |
| gtm rollback trans | Waiting for GTM to roll back a transaction. |
| gtm create sequence | Waiting for GTM to create a sequence. |
| gtm alter sequence | Waiting for GTM to modify a sequence. |
| gtm get sequence val | Waiting for obtaining the next value of a sequence from GTM. |
| gtm set sequence val | Waiting for GTM to set a sequence value. |
| gtm drop sequence | Waiting for GTM to delete a sequence. |
| gtm rename sequece | Waiting for GTM to rename a sequence. |
| analyze: [relname], [phase] | The thread is doing **ANALYZE** to the *relname* table. If *phase* is included, the possible phase is **autovacuum**, indicating that the database automatically enables the AutoVacuum thread to execute **ANALYZE**. |
| vacuum: [relname], [phase] | The thread is doing **VACUUM** to the *relname* table. If *phase* is included, the possible phase is **autovacuum**, indicating that the database automatically enables the AutoVacuum thread to execute **VACUUM**. |
| vacuum full: [relname] | The thread is doing **VACUUM FULL** to the *relname* table. |
| create index | An index is being created. |

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| Value | Description |
| --- | --- |
| HashJoin - [ build hash \| write file ] | The **HashJoin** operator is being executed. In this phase, you need to pay attention to the execution time-consuming.<br>● **build hash**: The **HashJoin** operator is creating a hash table.<br>● **write file**: The **HashJoin** operator is writing data to disks. |
| HashAgg - [ build hash \| write file ] | The **HashAgg** operator is being executed. In this phase, you need to pay attention to the execution time-consuming.<br>● **build hash**: The **HashAgg** operator is creating a hash table.<br>● **write file**: The **HashAgg** operator is writing data to disks. |
| HashSetop - [build hash \| write file ] | The **HashSetop** operator is being executed. In this phase, you need to pay attention to the execution time-consuming.<br>● **build hash**: The **HashSetop** operator is creating a hash table.<br>● **write file**: The **HashSetop** operator is writing data to disks. |
| Sort \| Sort - write file | The **Sort** operator is being executed. **write file** indicates that the **Sort** operator is writing data to disks. |
| Material \| Material - write file | The **Material** operator is being executed. **write file** indicates that the **Material** operator is writing data to disks. |
| wait sync consumer next step | The consumer (receive end) synchronously waits for the next iteration. |
| wait sync producer next step | The producer (transmit end) synchronously waits for the next iteration. |

If **wait_status** is **acquire lwlock**, **acquire lock**, or **wait io**, there is an event performing I/O operations or waiting for obtaining the corresponding lightweight lock or transaction lock.

The following table describes the corresponding wait events when **wait_status** is **acquire lwlock**. (If **wait_event** is **extension**, the lightweight lock is dynamically allocated and is not monitored.)

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**Table 14-205** List of wait events corresponding to lightweight locks

| wait_event | Description |
| --- | --- |
| ShmemIndexLock | Used to protect the primary index table, a hash table, in shared memory |
| OidGenLock | Used to prevent different threads from generating the same OID |
| XidGenLock | Used to prevent two transactions from obtaining the same XID |
| ProcArrayLock | Used to prevent concurrent access to or concurrent modification on the ProcArray shared array |
| SInvalReadLock | Used to prevent concurrent execution with invalid message deletion |
| SInvalWriteLock | Used to prevent concurrent execution with invalid message write and deletion |
| WALInsertLock | Used to prevent concurrent execution with WAL insertion |
| WALWriteLock | Used to prevent concurrent write from a WAL buffer to a disk |
| ControlFileLock | Used to prevent concurrent read/write or concurrent write/write on the **pg_control** file |
| CheckpointLock | Used to prevent multi-checkpoint concurrent execution |
| CLogControlLock | Used to prevent concurrent access to or concurrent modification on the Clog control data structure |
| MultiXactGenLock | Used to allocate a unique MultiXact ID in serial mode |
| MultiXactOffsetControl-Lock | Used to prevent concurrent read/write or concurrent write/write on **pg_multixact/offset** |
| MultiXactMemberControl-Lock | Used to prevent concurrent read/write or concurrent write/write on **pg_multixact/members** |
| RelCacheInitLock | Used to add a lock before any operations are performed on the **init** file when messages are invalid |
| CheckpointerCommLock | Used to send file flush requests to a checkpointer. The request structure needs to be inserted to a request queue in serial mode. |
| TwoPhaseStateLock | Used to prevent concurrent access to or modification on two-phase information sharing arrays |

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| wait_event | Description |
| --- | --- |
| TablespaceCreateLock | Used to check whether a tablespace already exists |
| BtreeVacuumLock | Used to prevent **VACUUM** from clearing pages that are being used by B-tree indexes |
| AutovacuumLock | Used to access the autovacuum worker array in serial mode |
| AutovacuumScheduleLock | Used to distribute tables requiring **VACUUM** in serial mode |
| SyncScanLock | Used to determine the start position of a relfilenode during heap scanning |
| NodeTableLock | Used to protect a shared structure that stores CN and DN information |
| PoolerLock | Used to prevent two threads from simultaneously obtaining the same connection from a connection pool |
| RelationMappingLock | Used to wait for the mapping file between system catalogs and storage locations to be updated |
| AsyncCtlLock | Used to prevent concurrent access to or concurrent modification on the sharing notification status |
| AsyncQueueLock | Used to prevent concurrent access to or concurrent modification on the sharing notification queue |
| SerializableXactHashLock | Used to prevent concurrent read/write or concurrent write/write on a sharing structure for serializable transactions |
| SerializableFinishedList-Lock | Used to prevent concurrent read/write or concurrent write/write on a shared linked list for completed serial transactions |
| SerializablePredicateLock-ListLock | Used to protect a linked list of serializable transactions that have locks |
| OldSerXidLock | Used to protect a structure that records serializable transactions that have conflicts |
| FileStatLock | Used to protect a data structure that stores statistics file information |
| SyncRepLock | Used to protect Xlog synchronization information during primary-standby replication |
| DataSyncRepLock | Used to protect data page synchronization information during primary-standby replication |
| CStoreColspaceCacheLock | Used to add a lock when CU space is allocated for a column-store table |

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| wait_event | Description |
| --- | --- |
| CStoreCUCacheSweep-Lock | Used to add a lock when CU caches used by a column-store table are cyclically washed out |
| MetaCacheSweepLock | Used to add a lock when metadata is cyclically washed out |
| DfsConnectorCacheLock | Used to protect a global hash table where HDFS connection handles are cached |
| dummyServerInfoCache-Lock | Used to protect a global hash table where the information about computing Node Group connections is cached |
| ExtensionConnectorLi-bLock | Used to add a lock when a specific dynamic library is loaded or uninstalled in ODBC connection initialization scenarios |
| SearchServerLibLock | Used to add a lock on the file read operation when a specific dynamic library is initially loaded in GPU-accelerated scenarios |
| DfsUserLoginLock | Used to protect a global linked table where HDFS user information is stored |
| DfsSpaceCacheLock | Used to ensure that the IDs of files to be imported to an HDFS table increase monotonically |
| LsnXlogChkFileLock | Used to serially update the Xlog flush points for primary and standby servers recorded in a specific structure |
| GTMHostInfoLock | Used to prevent concurrent access to or concurrent modification on GTM host information |
| ReplicationSlotAllocation-Lock | Used to add a lock when a primary server allocates stream replication slots during primary-standby replication |
| ReplicationSlotControl-Lock | Used to prevent concurrent update of replication slot status during primary-standby replication |
| ResourcePoolHashLock | Used to prevent concurrent access to or concurrent modification on a resource pool table, a hash table |
| WorkloadStatHashLock | Used to prevent concurrent access to or concurrent modification on a hash table that contains SQL requests from the CN side |
| WorkloadIoStatHashLock | Used to prevent concurrent access to or concurrent modification on a hash table that contains the I/O information of the current DN |
| WorkloadCGroupHash-Lock | Used to prevent concurrent access to or concurrent modification on a hash table that contains Cgroup information |

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| wait_event | Description |
| --- | --- |
| OBSGetPathLock | Used to prevent concurrent read/write or concurrent write/write on an OBS path |
| WorkloadUserInfoLock | Used to prevent concurrent access to or concurrent modification on a hash table that contains user information about load management |
| WorkloadRecordLock | Used to prevent concurrent access to or concurrent modification on a hash table that contains requests received by CNs during adaptive memory management |
| WorkloadIOUtilLock | Used to protect a structure that records **iostat** and CPU load information |
| WorkloadNodeGroupLock | Used to prevent concurrent access to or concurrent modification on a hash table that contains Node Group information in memory |
| JobShmemLock | Used to protect global variables in the shared memory that is periodically read during a scheduled task where MPP is compatible with Oracle |
| OBSRuntimeLock | Used to obtain environment variables, for example, GASSHOME |
| LLVMDumpIRLock | Used to export the assembly language for dynamically generating functions |
| LLVMParseIRLock | Used to compile and parse a finished IR function from the IR file at the start position of a query |
| RPNumberLock | Used by a DN on a computing Node Group to count the number of threads for a task where plans are being executed |
| ClusterRPLock | Used to control concurrent access on cluster load data maintained in a CCN of the cluster |
| CriticalCacheBuildLock | Used to load caches from a shared or local cache initialization file |
| WaitCountHashLock | Used to protect a shared structure in user statement counting scenarios |
| BufMappingLock | Used to protect operations on a table mapped to shared buffer |
| LockMgrLock | It is used to protect a common lock structure. |
| PredicateLockMgrLock | Used to protect a lock structure that has serializable transactions |

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| wait_event | Description |
| --- | --- |
| OperatorRealTLock | Used to prevent concurrent access to or concurrent modification on a global structure that contains real-time data at the operator level |
| OperatorHistLock | Used to prevent concurrent access to or concurrent modification on a global structure that contains historical data at the operator level |
| SessionRealTLock | Used to prevent concurrent access to or concurrent modification on a global structure that contains real-time data at the query level |
| SessionHistLock | Used to prevent concurrent access to or concurrent modification on a global structure that contains historical data at the query level |
| CacheSlotMappingLock | Used to protect global CU cache information |
| BarrierLock | Used to ensure that only one thread is creating a barrier at a time |

The following table describes the corresponding wait events when **wait_status** is **wait io**.

**Table 14-206** List of wait events corresponding to I/Os

| wait_event | Description |
| --- | --- |
| BufFileRead | Reads data from a temporary file to a specified buffer. |
| BufFileWrite | Writes the content of a specified buffer to a temporary file. |
| ControlFileRead | Reads the **pg_control** file, mainly during database startup, checkpoint execution, and primary/standby verification. |
| ControlFileSync | Flushes the **pg_control** file to a disk, mainly during database initialization. |
| ControlFileSyncUpdate | Flushes the **pg_control** file to a disk, mainly during database startup, checkpoint execution, and primary/standby verification. |
| ControlFileWrite | Writes to the **pg_control** file, mainly during database initialization. |
| ControlFileWriteUpdate | Updates the **pg_control** file, mainly during database startup, checkpoint execution, and primary/standby verification. |

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| wait_event | Description |
| --- | --- |
| CopyFileRead | Reads a file during file copying. |
| CopyFileWrite | Writes a file during file copying. |
| DataFileExtend | Writes a file during file extension. |
| DataFileFlush | Flushes a table data file to a disk. |
| DataFileImmediateSync | Flushes a table data file to a disk immediately. |
| DataFilePrefetch | Reads a table data file asynchronously. |
| DataFileRead | Reads a table data file synchronously. |
| DataFileSync | Flushes table data file modifications to a disk. |
| DataFileTruncate | Truncates a table data file. |
| DataFileWrite | Writes a table data file. |
| LockFileAddToDataDir-Read | Reads the **postmaster.pid** file. |
| LockFileAddToDataDir-Sync | Flushes the **postmaster.pid** file to a disk. |
| LockFileAddToDataDir-Write | Writes the PID information into the **postmaster.pid** file. |
| LockFileCreateRead | Read the LockFile file **%s.lock**. |
| LockFileCreateSync | Flushes the LockFile file **%s.lock** to a disk. |
| LockFileCreateWRITE | Writes the PID information into the LockFile file **%s.lock**. |
| RelationMapRead | Reads the mapping file between system catalogs and storage locations. |
| RelationMapSync | Flushes the mapping file between system catalogs and storage locations to a disk. |
| RelationMapWrite | Writes the mapping file between system catalogs and storage locations. |
| ReplicationSlotRead | Reads a stream replication slot file during a restart. |
| ReplicationSlotRestore-Sync | Flushes a stream replication slot file to a disk during a restart. |
| ReplicationSlotSync | Flushes a temporary stream replication slot file to a disk during checkpoint execution. |
| ReplicationSlotWrite | Writes a temporary stream replication slot file during checkpoint execution. |

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| wait_event | Description |
| --- | --- |
| SLRUFlushSync | Flushes the **pg_clog**, **pg_subtrans**, and **pg_multixact** files to a disk, mainly during checkpoint execution and database shutdown. |
| SLRURead | Reads the **pg_clog**, **pg_subtrans**, and **pg_multixact** files. |
| SLRUSync | Writes dirty pages into the **pg_clog**, **pg_subtrans**, and **pg_multixact** files, and flushes the files to a disk, mainly during checkpoint execution and database shutdown. |
| SLRUWrite | Writes the **pg_clog**, **pg_subtrans**, and **pg_multixact** files. |
| TimelineHistoryRead | Reads the timeline history file during database startup. |
| TimelineHistorySync | Flushes the timeline history file to a disk during database startup. |
| TimelineHistoryWrite | Writes to the timeline history file during database startup. |
| TwophaseFileRead | Reads the **pg_twophase** file, mainly during two-phase transaction submission and restoration. |
| TwophaseFileSync | Flushes the **pg_twophase** file to a disk, mainly during two-phase transaction submission and restoration. |
| TwophaseFileWrite | Writes the **pg_twophase** file, mainly during two-phase transaction submission and restoration. |
| WALBootstrapSync | Flushes an initialized WAL file to a disk during database initialization. |
| WALBootstrapWrite | Writes an initialized WAL file during database initialization. |
| WALCopyRead | Read operation generated when an existing WAL file is read for replication after archiving and restoration. |
| WALCopySync | Flushes a replicated WAL file to a disk after archiving and restoration. |
| WALCopyWrite | Write operation generated when an existing WAL file is read for replication after archiving and restoration. |
| WALInitSync | Flushes a newly initialized WAL file to a disk during log reclaiming or writing. |

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| wait_event | Description |
| --- | --- |
| WALInitWrite | Initializes a newly created WAL file to 0 during log reclaiming or writing. |
| WALRead | Reads data from Xlogs during redo operations on two-phase files. |
| WALSyncMethodAssign | Flushes all open WAL files to a disk. |
| WALWrite | Writes a WAL file. |

The following table describes the corresponding wait events when **wait_status** is **acquire lock**.

**Table 14-207** List of wait events corresponding to transaction locks

| wait_event | Description |
| --- | --- |
| relation | Adds a lock to a table. |
| extend | Adds a lock to a table being scaled out. |
| partition | Adds a lock to a partitioned table. |
| partition_seq | Adds a lock to a partition of a partitioned table. |
| page | Adds a lock to a table page. |
| tuple | Adds a lock to a tuple on a page. |
| transactionid | Adds a lock to a transaction ID. |
| virtualxid | Adds a lock to a virtual transaction ID. |
| object | Adds a lock to an object. |
| cstore_freespace | Adds a lock to idle column-store space. |
| userlock | Adds a lock to a user. |
| advisory | Adds an advisory lock. |

## 14.3.140 PG_TABLES

**PG_TABLES** displays access to each table in the database.

**Table 14-208** PG_TABLES columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| schemaname | name | PG_NAMESPACE.nspname | Name of the schema that contains the table |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| tablename | name | PG_CLASS.relname | Name of the table |
| tableowner | name | pg_get_userbyid(PG_CLASS.relowner) | Owner of the table |
| tablespace | name | PG_TABLESPACE.spcname | Tablespace that contains the table. The default value is null |
| hasindexes | boolean | PG_CLASS.relhasindex | Whether the table has (or recently had) an index. If it does, its value is **true**. Otherwise, its value is **false**. |
| hasrules | boolean | PG_CLASS.relhasruls | Whether the table has rules. If it does, its value is **true**. Otherwise, its value is **false**. |
| hastriggers | boolean | PG_CLASS.RELHASTRIGGERS | Whether the table has triggers. If it does, its value is **true**. Otherwise, its value is **false**. |
| tablecreator | name | pg_get_userbyid(PG_OBJECT.creator) | Table creator. If the creator has been deleted, no value is returned. |
| created | timestamp with time zone | PG_OBJECT.ctime | Time when the table was created. |
| last_ddl_time | timestamp with time zone | PG_OBJECT.mtime | Last time when the cluster was modified. |

## 14.3.141 PG_TDE_INFO

**PG_TDE_INFO** displays the encryption information about the current cluster.

**Table 14-209** PG_TDE_INFO columns

| Name | Type | Description |
| --- | --- | --- |
| is_encrypt | text | Whether the cluster is an encryption cluster<br>• **f**: Non-encryption cluster<br>• **t**: Encryption cluster |

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| Name | Type | Description |
| --- | --- | --- |
| g_tde_algo | text | Encryption algorithm<br>• SM4-CTR-128<br>• AES-CTR-128 |
| remain | text | Reserved |

## Examples

Check whether the current cluster is encrypted, and check the encryption algorithm (if any) used by the current cluster.

```
SELECT * FROM PG_TDE_INFO;
 is_encrypt | g_tde_algo  | remain
------------+-------------+--------
 f          | AES-CTR-128 | remain
(1 row)
```

# 14.3.142 PG_TIMEZONE_ABBREVS

**PG_TIMEZONE_ABBREVS** displays all time zone abbreviations that can be recognized by the input routines.

**Table 14-210** PG_TIMEZONE_ABBREVS columns

| Name | Type | Description |
| --- | --- | --- |
| abbrev | text | Time zone abbreviation |
| utc_offset | interval | Offset from UTC |
| is_dst | boolean | Whether the abbreviation indicates a daylight saving time (DST) zone. If it does, its value is **true**. Otherwise, its value is **false**. |

# 14.3.143 PG_TIMEZONE_NAMES

**PG_TIMEZONE_NAMES** displays all time zone names that can be recognized by **SET TIMEZONE**, along with their associated abbreviations, UTC offsets, and daylight saving time statuses.

**Table 14-211** PG_TIMEZONE_NAMES columns

| Name | Type | Description |
| --- | --- | --- |
| name | text | Name of the time zone |
| abbrev | text | Time zone name abbreviation |

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| Name | Type | Description |
| --- | --- | --- |
| utc_offset | interval | Offset from UTC |
| is_dst | boolean | Whether DST is used. If it is, its value is **true**. Otherwise, its value is **false**. |

## 14.3.144 PG_TOTAL_MEMORY_DETAIL

**PG_TOTAL_MEMORY_DETAIL** displays the memory usage of a certain node in the database.

**Table 14-212** PG_TOTAL_MEMORY_DETAIL columns

| Name | Type | Description |
| --- | --- | --- |
| nodename | text | Node name |

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| Name | Type | Description |
| --- | --- | --- |
| memorytype | text | It can be set to any of the following values:<br>• **max_process_memory**: memory used by a GaussDB(DWS) cluster instance<br>• **process_used_memory**: memory used by a GaussDB(DWS) process<br>• **max_dynamic_memory**: maximum dynamic memory<br>• **dynamic_used_memory**: used dynamic memory<br>• **dynamic_peak_memory**: dynamic peak value of the memory<br>• **dynamic_used_shrctx**: maximum dynamic shared memory context<br>• **dynamic_peak_shrctx**: dynamic peak value of the shared memory context<br>• **max_shared_memory**: maximum shared memory<br>• **shared_used_memory**: used shared memory<br>• **max_cstore_memory**: maximum memory allowed for column store<br>• **cstore_used_memory**: memory used for column store<br>• **max_sctpcomm_memory**: maximum memory allowed for the communication library<br>• **sctpcomm_used_memory**: memory used for the communication library<br>• **sctpcomm_peak_memory**: memory peak of the communication library<br>• **other_used_memory**: other used memory<br>• **gpu_max_dynamic_memory**: maximum GPU memory<br>• **gpu_dynamic_used_memory**: sum of the available GPU memory and temporary GPU memory<br>• **gpu_dynamic_peak_memory**: maximum memory used for GPU<br>• **pooler_conn_memory**: memory used for pooler connections<br>• **pooler_freeconn_memory**: memory used for idle pooler connections |

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| Name | Type | Description |
| --- | --- | --- |
| | | • **storage_compress_memory**: memory used for column-store compression and decompression<br>• **udf_reserved_memory**: memory reserved for the **UDF Worker** process<br>• **mmap_used_memory**: memory used for **mmap** |
| memorymbytes | integer | Size of the used memory (MB) |

## 14.3.145 PG_TOTAL_SCHEMA_INFO

PG_TOTAL_SCHEMA_INFO displays the storage usage of all schemas in each database. This view is valid only if use_workload_manager is set to **on**.

| Column | Type | Description |
| --- | --- | --- |
| schemaid | oid | Schema OID |
| schemaname | text | Schema name |
| databaseid | oid | Database OID |
| databasename | name | Database name |
| usedspace | bigint | Size of the permanent table storage space used by the schema, in bytes. |
| permspace | bigint | Upper limit of the permanent table storage space of the schema, in bytes. |

## 14.3.146 PG_TOTAL_USER_RESOURCE_INFO

**PG_TOTAL_USER_RESOURCE_INFO** displays the resource usage of all users. Only administrators can query this view. This view is valid only if use_workload_manager is set to **on**.

**Table 14-213 PG_TOTAL_USER_RESOURCE_INFO** columns

| Name | Type | Description |
| --- | --- | --- |
| username | name | Username |
| used_memory | integer | Used memory (unit: MB) |

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| Name | Type | Description |
| --- | --- | --- |
| total_memory | integer | Available memory (unit: MB). **0** indicates that the available memory is not limited and depends on the maximum memory available in the database. |
| used_cpu | double precision | Number of CPU cores in use. Only the CPU usage of complex jobs in the non-default resource pool is collected, and the value is the CPU usage of the related cgroup. |
| total_cpu | integer | Total number of CPU cores of the cgroup associated with a user on the node |
| used_space | bigint | Used permanent table storage space (unit: KB) |
| total_space | bigint | Available storage space (unit: KB). **-1** indicates that the storage space is not limited. |
| used_temp_space | bigint | Used temporary table storage space (unit: KB) |
| total_temp_space | bigint | Available temporary table storage space (unit: KB). **-1** indicates that the storage space is not limited. |
| used_spill_space | bigint | Size of the used operator flushing space, in KB |
| total_spill_space | bigint | Size of the available operator flushing space, in KB. The value **-1** indicates that the operator flushing space is not limited. |
| read_kbytes | bigint | CN: total number of bytes read by a user's complex jobs on all DNs in the last 5 seconds. The unit is KB.<br>DN: total number of bytes read by a user's complex jobs from the instance startup time to the current time. The unit is KB. |
| write_kbytes | bigint | CN: total number of bytes written by a user's complex jobs on all DNs in the last 5 seconds. The unit is KB.<br>DN: total number of bytes written by a user's complex jobs from the instance startup time to the current time. The unit is KB. |
| read_counts | bigint | CN: total number of read times of a user's complex jobs on all DNs in the last 5 seconds. Unit: count.<br>DN: total number of read times of a user's complex jobs from the instance startup time to the current time. Unit: count. |

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| Name | Type | Description |
| --- | --- | --- |
| write_counts | bigint | CN: total number of write times of a user's complex jobs on all DNs in the last 5 seconds. Unit: count.<br>DN: total number of write times of a user's complex jobs from the instance startup time to the current time. Unit: count. |
| read_speed | double precision | CN: average read rate of a user's complex jobs on a single DN in the last 5 seconds. (Unit: KB/s)<br>DN: indicates the average read rate of a user's complex jobs on a single DN in the last 5 seconds. (Unit: KB/s) |
| write_speed | double precision | CN: average write rate of a user's complex jobs on a single DN in the last 5 seconds. (Unit: KB/s)<br>DN: average write rate of a user's complex jobs on a single DN in the last 5 seconds. (Unit: KB/s) |

## 14.3.147 PG_USER

**PG_USER** displays information about users who can access the database.

**Table 14-214** PG_USER columns

| Name | Type | Description |
| --- | --- | --- |
| usename | name | User name |
| usesysid | oid | ID of this user |
| usecreatedb | boolean | Whether the user has the permission to create databases |
| usesuper | boolean | whether the user is the initial system administrator with the highest rights. |
| usecatupd | boolean | whether the user can directly update system tables. Only the initial system administrator whose usesysid is 10 has this permission. It is not available for other users. |
| userepl | boolean | Whether the user has the permission to duplicate data streams |
| passwd | text | Encrypted user password. The value is displayed as ********. |

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| Name | Type | Description |
| --- | --- | --- |
| valbegin | timestamp with time zone | Account validity start time; null if no start time |
| valuntil | timestamp with time zone | Password expiry time; null if no expiration |
| respool | name | Resource pool where the user is in |
| parentid | oid | Parent user OID |
| spacelimit | text | The storage space of the permanent table. |
| tempspacelimit | text | The storage space of the temporary table. |
| spillspacelimit | text | The operator disk flushing space. |
| useconfig | text[] | Session defaults for run-time configuration variables |
| nodegroup | name | Name of the logical cluster associated with the user. If no logical cluster is associated, this column is left blank. |

## 14.3.148 PG_USER_MAPPINGS

**PG_USER_MAPPINGS** displays information about user mappings.

This is essentially a publicly readable view of **PG_USER_MAPPING** that leaves out the options column if the user has no rights to use it.

**Table 14-215** PG_USER_MAPPINGS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| umid | oid | **PG_USER_MAPPING**.oid | OID of the user mapping |
| srvid | oid | **PG_FOREIGN_SERVER**.oid | OID of the foreign server that contains this mapping |
| srvname | name | **PG_FOREIGN_SERVER**.srvname | Name of the foreign server |
| umuser | oid | **PG_AUTHID**.oid | OID of the local role being mapped, 0 if the user mapping is public |
| usename | name | - | Name of the local user to be mapped |

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| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| umoptions | text[] | - | User mapping specific options. If the current user is the owner of the foreign server, its value is keyword=value strings. Otherwise, its value is null. |

## 14.3.149 PG_VIEWS

**PG_VIEWS** displays basic information about each view in the database.

**Table 14-216** PG_VIEWS columns

| Name | Type | Reference | Description |
| --- | --- | --- | --- |
| schemaname | name | PG_NAMESPACE.nspname | Name of the schema that contains the view |
| viewname | name | PG_CLASS.relname | View name |
| viewowner | name | PG_AUTHID.Erolname | Owner of the view |
| definition | text | - | Definition of the view |

## 14.3.150 PG_WLM_STATISTICS

**PG_WLM_STATISTICS** displays information about workload management after the task is complete or the exception has been handled.

**Table 14-217** PG_WLM_STATISTICS columns

| Name | Type | Description |
| --- | --- | --- |
| statement | text | Statement executed for exception handling |
| block_time | bigint | Block time before the statement is executed |
| elapsed_time | bigint | Elapsed time when the statement is executed |
| total_cpu_time | bigint | Total time used by the CPU on the DN when the statement is executed for exception handling |
| qualification_time | bigint | Period when the statement checks the inclination ratio |
| cpu_skew_percent | integer | CPU usage skew on the DN when the statement is executed for exception handling |

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| Name | Type | Description |
| --- | --- | --- |
| control_group | text | Cgroup used when the statement is executed for exception handling |
| status | text | Statement status after it is executed for exception handling<br>• **pending**: The statement is waiting to be executed.<br>• **running**: The statement is being executed.<br>• **finished**: The execution is finished normally.<br>• **abort**: The execution is unexpectedly terminated. |
| action | text | Actions when statements are executed for exception handling<br>• **abort** indicates terminating the operation.<br>• **adjust** indicates executing the Cgroup adjustment operations. Currently, you can only perform the demotion operation.<br>• **finish** indicates that the operation is normally finished. |
| queryid | bigint | Internal query ID used for statement execution |
| threadid | bigint | ID of the backend thread |

## 14.3.151 PGXC_BULKLOAD_PROGRESS

**PGXC_BULKLOAD_PROGRESS** displays the progress of the service import. Only GDS common files can be imported. This view is accessible only to users with system administrators rights.

**Table 14-218** PGXC_BULKLOAD_PROGRESS columns

| Name | Type | Description |
| --- | --- | --- |
| session_id | bigint | GDS session ID |
| query_id | bigint | Query ID. It is equivalent to **debug_query_id**. |
| query | text | Query statement |
| progress | text | Progress percentage |

## 14.3.152 PGXC_BULKLOAD_STATISTICS

**PGXC_BULKLOAD_STATISTICS** displays real-time statistics about service execution, such as GDS, COPY, and \COPY, on a CN. This view summarizes the

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real-time execution status of import and export services that are being executed on each node in the current cluster. In this way, you can monitor the real-time progress of import and export services and locate performance problems.

Columns in **PGXC_BULKLOAD_STATISTICS** are the same as those in **PG_BULKLOAD_STATISTICS**. This is because **PGXC_BULKLOAD_STATISTICS** is essentially the summary result of querying **PG_BULKLOAD_STATISTICS** on each node in the cluster.

This view is accessible only to users with system administrators rights.

**Table 14-219** PGXC_BULKLOAD_STATISTICS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| db_name | text | Database name |
| query_id | bigint | Query ID. It is equivalent to **debug_query_id**. |
| tid | bigint | ID of the current thread |
| lwtid | integer | Lightweight thread ID |
| session_id | bigint | GDS session ID |
| direction | text | Service type. The options are **gds to file**, **gds from file**, **gds to pipe**, **gds from pipe**, **copy from**, and **copy to**. |
| query | text | Query statement |
| address | text | Location of the foreign table used for data import and export |
| query_start | timestamp with time zone | Start time of data import or export |
| total_bytes | bigint | Total size of data to be processed<br>This parameter is specified only when a GDS common file is to be imported and the record in the row comes from a CN. Otherwise, left this parameter unspecified. |
| phase | text | Current phase. The options are **INITIALIZING**, **TRANSFER_DATA**, and **RELEASE_RESOURCE**. |
| done_lines | bigint | Number of lines that have been transferred |
| done_bytes | bigint | Number of bytes that have been transferred |

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## 14.3.153 PGXC_COMM_CLIENT_INFO

**PGXC_COMM_CLIENT_INFO** stores the client connection information of all nodes. (You can query this view on a DN to view the information about the connection between the CN and DN.)

**Table 14-220 PGXC_COMM_CLIENT_INFO** columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Current node name. |
| app | text | Client application name |
| tid | bigint | Thread ID of the current thread. |
| lwtid | integer | Lightweight thread ID of the current thread. |
| query_id | bigint | Query ID. It is equivalent to **debug_query_id**. |
| socket | integer | It is displayed if the connection is a physical connection. |
| remote_ip | text | Peer node IP address. |
| remote_port | text | Peer node port. |
| logic_id | integer | If the connection is a logical connection, **sid** is displayed. If **-1** is displayed, the current connection is a physical connection. |

## 14.3.154 PGXC_COMM_DELAY

**PGXC_COMM_STATUS** displays the communication library delay status for all the DNs.

**Table 14-221** PGXC_COMM_DELAY columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| remote_name | text | Name of the peer node |
| remote_host | text | IP address of the peer |
| stream_num | integer | Number of logical stream connections used by the current physical connection |

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| Name | Type | Description |
| --- | --- | --- |
| min_delay | integer | Minimum delay of the current physical connection within 1 minute. Its unit is microsecond.<br>**NOTE**<br>A negative result is invalid. Wait until the delay status is updated and query again. |
| average | integer | Average delay of the current physical connection within 1 minute. Its unit is microsecond. |
| max_delay | integer | Maximum delay of the current physical connection within 1 minute. Its unit is microsecond. |

## 14.3.155 PGXC_COMM_RECV_STREAM

**PG_COMM_RECV_STREAM** displays the receiving stream status of the communication libraries for all the DNs.

**Table 14-222** PGXC_COMM_RECV_STREAM columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| local_tid | bigint | ID of the thread using this stream |
| remote_name | text | Name of the peer node |
| remote_tid | bigint | Peer thread ID |
| idx | integer | Peer DN ID in the local DN |
| sid | integer | Stream ID in the physical connection |
| tcp_sock | integer | TCP socket used in the stream |
| state | text | Current status of the stream |
| query_id | bigint | **debug_query_id** corresponding to the stream |
| pn_id | integer | **plan_node_id** of the query executed by the stream |
| send_smp | integer | **smpid** of the sender of the query executed by the stream |
| recv_smp | integer | **smpid** of the receiver of the query executed by the stream |
| recv_bytes | bigint | Total data volume received from the stream. The unit is byte. |

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| Name | Type | Description |
| --- | --- | --- |
| time | bigint | Current life cycle service duration of the stream. The unit is ms. |
| speed | bigint | Average receiving rate of the stream. The unit is byte/s. |
| quota | bigint | Current communication quota value of the stream. The unit is byte. |
| buff_usize | bigint | Current size of the data cache of the stream. The unit is byte. |

## 14.3.156 PGXC_COMM_SEND_STREAM

**PGXC_COMM_SEND_STREAM** displays the sending stream status of the communication libraries for all the DNs.

**Table 14-223** PGXC_COMM_SEND_STREAM columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| local_tid | bigint | ID of the thread using this stream |
| remote_name | text | Name of the peer node |
| remote_tid | bigint | Peer thread ID |
| idx | integer | Peer DN ID in the local DN |
| sid | integer | Stream ID in the physical connection |
| tcp_sock | integer | TCP socket used in the stream |
| state | text | Current status of the stream |
| query_id | bigint | **debug_query_id** corresponding to the stream |
| pn_id | integer | **plan_node_id** of the query executed by the stream |
| send_smp | integer | **smpid** of the sender of the query executed by the stream |
| recv_smp | integer | **smpid** of the receiver of the query executed by the stream |
| send_bytes | bigint | Total data volume sent by the stream. The unit is Byte. |
| time | bigint | Current life cycle service duration of the stream. The unit is ms. |

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| Name | Type | Description |
| --- | --- | --- |
| speed | bigint | Average sending rate of the stream. The unit is Byte/s. |
| quota | bigint | Current communication quota value of the stream. The unit is Byte. |
| wait_quota | bigint | Extra time generated when the stream waits the quota value. The unit is ms. |

## 14.3.157 PGXC_COMM_STATUS

**PGXC_COMM_STATUS** displays the communication library status for all the DNs.

**Table 14-224** PGXC_COMM_STATUS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| rxpck/s | integer | Receiving rate of the communication library on a node. The unit is byte/s. |
| txpck/s | integer | Sending rate of the communication library on a node. The unit is byte/s. |
| rxkB/s | bigint | Receiving rate of the communication library on a node. The unit is KB/s. |
| txkB/s | bigint | Sending rate of the communication library on a node. The unit is KB/s. |
| buffer | bigint | Size of the buffer of the Cmailbox. |
| memKB(libcomm) | bigint | Communication memory size of the **libcomm** process, in KB. |
| memKB(libpq) | bigint | Communication memory size of the **libpq** process, in KB. |
| %USED(PM) | integer | Real-time usage of the postmaster thread. |
| %USED (sflow) | integer | Real-time usage of the **gs_sender_flow_controller** thread. |
| %USED (rflow) | integer | Real-time usage of the **gs_receiver_flow_controller** thread. |
| %USED (rloop) | integer | Highest real-time usage among multiple **gs_receivers_loop** threads. |
| stream | integer | Total number of used logical connections. |

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# 14.3.158 PGXC_DEADLOCK

**PGXC_DEADLOCK** displays lock wait information generated due to distributed deadlocks.

Currently, **PGXC_DEADLOCK** collects only lock wait information about locks whose **locktype** is **relation**, **partition**, **page**, **tuple**, or **transactionid**.

**Table 14-225** PGXC_DEADLOCK columns

| Name | Type | Description |
| --- | --- | --- |
| locktype | text | Type of the locked object |
| nodename | name | Name of the node where the locked object resides |
| dbname | name | Name of the database where the locked object resides. The value is **NULL** if the locked object is a transaction. |
| nspname | name | Name of the namespace of the locked object |
| relname | name | Name of the relation targeted by the lock. The value is **NULL** if the object is not a relation or part of a relation. |
| partname | name | Name of the partition targeted by the lock. The value is **NULL** if the locked object is not a partition. |
| page | integer | Number of the page targeted by the lock. The value is **NULL** if the locked object is neither a page nor a tuple. |
| tuple | smallint | Number of the tuple targeted by the lock. The value is **NULL** if the locked object is not a tuple. |
| transactionid | xid | ID of the transaction targeted by the lock. The value is **NULL** if the locked object is not a transaction. |
| waitusername | name | Name of the user who waits for the lock |
| waitgxid | xid | ID of the transaction that waits for the lock |
| waitxactstart | timestamp with time zone | Start time of the transaction that waits for the lock |
| waitqueryid | bigint | Latest query ID of the thread that waits for the lock |
| waitquery | text | Latest query statement of the thread that waits for the lock |

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| Name | Type | Description |
| --- | --- | --- |
| waitpid | bigint | ID of the thread that waits for the lock |
| waitmode | text | Mode of the waited lock |
| holdusername | name | Name of the user who holds the lock |
| holdgxid | xid | ID of the transaction that holds the lock |
| holdxactstart | timestamp with time zone | Start time of the transaction that holds the lock |
| holdqueryid | bigint | Latest query ID of the thread that holds the lock |
| holdquery | text | Latest query statement of the thread that holds the lock |
| holdpid | bigint | ID of the thread that holds the lock |
| holdmode | text | Mode of the held lock |

## 14.3.159 PGXC_GET_STAT_ALL_TABLES

**PGXC_GET_STAT_ALL_TABLES** displays information about insertion, update, and deletion operations on tables and the dirty page rate of tables.

Before running **VACUUM FULL** to a system catalog with a high dirty page rate, ensure that no user is performing operations it.

You are advised to run **VACUUM FULL** to tables (excluding system catalogs) whose dirty page rate exceeds 30% or run it based on service scenarios.

**Table 14-226** PGXC_GET_STAT_ALL_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| relname | name | Table name |
| schemaname | name | Schema name of the table |
| n_tup_ins | numeric | Number of inserted tuples |
| n_tup_upd | numeric | Number of updated tuples |
| n_tup_del | numeric | Number of deleted tuples |
| n_live_tup | numeric | Number of live tuples |
| n_dead_tup | numeric | Number of dead tuples |

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| Name | Type | Description |
| --- | --- | --- |
| page_dirty_rate | numeric(5,2) | Dirty page rate (%) of a table |

GaussDB(DWS) also provides the **pgxc_get_stat_dirty_tables(int dirty_percent, int n_tuples)** and **pgxc_get_stat_dirty_tables(int dirty_percent, int n_tuples, text schema)** functions to quickly filter out tables whose dirty page rate is greater than **dirty_percent**, number of dead tuples is greater than **n_tuples**, and schema name is **schema**. For details, see "Functions and Operators > System Administration Functions > Other Functions" in the *SQL Syntax*.

## 14.3.160 PGXC_GET_STAT_ALL_PARTITIONS

**PGXC_GET_STAT_ALL_PARTITIONS** displays information about insertion, update, and deletion operations on partitions of partitioned tables and the dirty page rate of tables.

The statistics of this view depend on the **ANALYZE** operation. To obtain the most accurate information, perform the **ANALYZE** operation on the partitioned table first.

**Table 14-227** PGXC_GET_STAT_ALL_PARTITIONS columns

| Column | Type | Description |
| --- | --- | --- |
| relid | oid | Table OID |
| partid | oid | Partition OID |
| schename | name | Schema name of a table |
| relname | name | Table name |
| partname | name | Partition name |
| n_tup_ins | numeric | Number of inserted tuples |
| n_tup_upd | numeric | Number of updated tuples |
| n_tup_del | numeric | Number of deleted tuples |
| n_live_tup | numeric | Number of live tuples |
| n_dead_tup | numeric | Number of dead tuples |
| page_dirty_rate | numeric(5,2) | Dirty page rate (%) of a table |

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## 14.3.161 PGXC_GET_TABLE_SKEWNESS

**PGXC_GET_TABLE_SKEWNESS** displays the data skew on tables in the current database.

**Table 14-228** PGXC_GET_TABLE_SKEWNESS columns

| Name | Type | Description |
| --- | --- | --- |
| schemaname | name | Schema name of a table |
| tablename | name | Name of a table |
| totalsize | numeric | Total size of a table, in bytes |
| avgsize | numeric(1000, 0) | Average table size (total table size divided by the number of DNs), which is the ideal size of tables distributed on each DN |
| maxratio | numeric(4,3) | Ratio of the maximum table size on a single DN to the total table size |
| minratio | numeric(4,3) | Ratio of the minimum table size on a single DN to the total table size |
| skewsize | bigint | Table skew rate (the maximum table size on a single DN minus the minimum table size on a single DN) |
| skewratio | numeric(4,3) | Table skew rate (skew size divided by total table size) |
| skewstddev | numeric(1000, 0) | Standard deviation of table distribution (For two tables of the same size, a larger deviation indicates a more severe skew.) |

## 14.3.162 PGXC_GTM_SNAPSHOT_STATUS

**PGXC_GTM_SNAPSHOT_STATUS** displays transaction information on the current GTM.

**Table 14-229** PGXC_GTM_SNAPSHOT_STATUS columns

| Name | Type | Description |
| --- | --- | --- |
| xmin | xid | Minimum ID of the running transactions |
| xmax | xid | ID of the transaction next to the executed transaction with the maximum ID |

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| Name | Type | Description |
| --- | --- | --- |
| csn | integer | Sequence number of the transaction to be committed |
| oldestxmin | xid | Minimum ID of the executed transactions |
| xcnt | integer | Number of the running transactions |
| running_xids | text | IDs of the running transactions |

## 14.3.163 PGXC_INSTANCE_TIME

**PGXC_INSTANCE_TIME** displays the running time of processes on each node in the cluster and the time consumed in each execution phase. Except the **node_name** column, the other columns are the same as those in the **PV_INSTANCE_TIME** view. This view is accessible only to users with system administrator rights.

## 14.3.164 PGXC_INSTR_UNIQUE_SQL

**PGXC_INSTR_UNIQUE_SQL** displays the complete Unique SQL statistics of all CN nodes in the cluster.

Only the system administrator can access this view. For details about the field, see **GS_INSTR_UNIQUE_SQL**.

## 14.3.165 PGXC_LOCK_CONFLICTS

**PGXC_LOCK_CONFLICTS** displays information about conflicting locks in the cluster.

When a lock is waiting for another lock or another lock is waiting for this one, a lock conflict occurs.

Currently, **PGXC_LOCK_CONFLICTS** collects only information about locks whose **locktype** is **relation**, **partition**, **page**, **tuple**, or **transactionid**.

**Table 14-230** PGXC_LOCK_CONFLICTS columns

| Name | Type | Description |
| --- | --- | --- |
| locktype | text | Type of the locked object |
| nodename | name | Name of the node where the locked object resides |
| dbname | name | Name of the database where the locked object resides. The value is **NULL** if the locked object is a transaction. |
| nspname | name | Name of the namespace of the locked object |

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| Name | Type | Description |
| --- | --- | --- |
| relname | name | Name of the relation targeted by the lock. The value is **NULL** if the object is not a relation or part of a relation. |
| partname | name | Name of the partition targeted by the lock. The value is **NULL** if the locked object is not a partition. |
| page | integer | Number of the page targeted by the lock. The value is **NULL** if the locked object is neither a page nor a tuple. |
| tuple | smallint | Number of the tuple targeted by the lock. The value is **NULL** if the locked object is not a tuple. |
| transactionid | xid | ID of the transaction targeted by the lock. The value is **NULL** if the locked object is not a transaction. |
| username | name | Name of the user who applies for the lock |
| gxid | xid | ID of the transaction that applies for the lock |
| xactstart | timestamp with time zone | Start time of the transaction that applies for the lock |
| queryid | bigint | Latest query ID of the thread that applies for the lock |
| query | text | Latest query statement of the thread that applies for the lock |
| pid | bigint | ID of the thread that applies for the lock |
| mode | text | Lock mode |
| granted | boolean | • **TRUE** if the lock has been held<br>• **FALSE** if the lock is still waiting for another lock |

## 14.3.166 PGXC_NODE_ENV

**PGXC_NODE_ENV** displays the environmental variables information about all nodes in a cluster.

**Table 14-231** PGXC_NODE_ENV columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Names of all nodes in the cluster |

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| Name | Type | Description |
| --- | --- | --- |
| host | text | Host names of all nodes in the cluster |
| process | integer | Process IDs of all nodes in the cluster |
| port | integer | Port numbers of all nodes in the cluster |
| installpath | text | Installation directory of all nodes in the cluster |
| datapath | text | Data directory of all nodes in the cluster |
| log_directory | text | Log directory of all nodes in the cluster |

## 14.3.167 PGXC_NODE_STAT_RESET_TIME

**PGXC_NODE_STAT_RESET_TIME** displays the time when statistics of each node in the cluster are reset. All columns except **node_name** are the same as those in the **GS_NODE_STAT_RESET_TIME** view. This view is accessible only to users with system administrators rights.

## 14.3.168 PGXC_OS_RUN_INFO

**PGXC_OS_RUN_INFO** displays the OS running status of each node in the cluster. All columns except **node_name** are the same as those in the **PV_OS_RUN_INFO** view. This view is accessible only to users with system administrators rights.

## 14.3.169 PGXC_OS_THREADS

**PGXC_OS_THREADS** displays thread status information under all normal nodes in the current cluster.

**Table 14-232** PGXC_OS_THREADS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | All normal node names in the cluster |
| pid | bigint | IDs of running threads among all normal node processes in the current cluster |
| lwpid | integer | Lightweight thread ID corresponding to the PID |
| thread_name | text | Thread name corresponding to the PID |
| creation_time | timestamp with time zone | Thread creation time corresponding to the PID |

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## 14.3.170 PGXC_PREPARED_XACTS

**PGXC_PREPARED_XACTS** displays the two-phase transactions in the **prepared** phase.

**Table 14-233** PGXC_PREPARED_XACTS columns

| Name | Type | Description |
| --- | --- | --- |
| pgxc_prepared_xact | text | Two-phase transactions in **prepared** phase |

## 14.3.171 PGXC_REDO_STAT

**PGXC_REDO_STAT** displays statistics on redoing Xlogs of each node in the cluster. All columns except **node_name** are the same as those in the **PV_REDO_STAT** view. This view is accessible only to users with system administrators rights.

## 14.3.172 PGXC_REL_IOSTAT

**PGXC_REL_IOSTAT** displays statistics on disk read and write of each node in the cluster. All columns except **node_name** are the same as those in the **GS_REL_IOSTAT** view. This view is accessible only to users with system administrators rights.

## 14.3.173 PGXC_REPLICATION_SLOTS

**PGXC_REPLICATION_SLOTS** displays the replication information of DNs in the cluster. All columns except **node_name** are the same as those in the **PG_REPLICATION_SLOTS** view. This view is accessible only to users with system administrators rights.

## 14.3.174 PGXC_RUNNING_XACTS

**PGXC_RUNNING_XACTS** displays information about running transactions on each node in the cluster. The content is the same as that displayed in **PG_RUNNING_XACTS**.

**Table 14-234** PGXC_RUNNING_XACTS columns

| Name | Type | Description |
| --- | --- | --- |
| handle | integer | Handle corresponding to the transaction in GTM |
| gxid | xid | Transaction ID |
| state | tinyint | Transaction status (**3**: prepared or **0**: starting) |
| node | text | Node name |
| xmin | xid | Minimum transaction ID **xmin** on the node |


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| Name | Type | Description |
| --- | --- | --- |
| vacuum | boolean | Whether the current transaction is lazy vacuum |
| timeline | bigint | Number of database restart |
| prepare_xid | xid | Transaction ID in **prepared** state. If the status is not **prepared**, the value is **0**. |
| pid | bigint | Thread ID corresponding to the transaction |
| next_xid | xid | Transaction ID sent from a CN to a DN |

## 14.3.175 PGXC_SETTINGS

**PGXC_SETTINGS** displays the database running status of each node in the cluster. All columns except **node_name** are the same as those in the **PG_SETTINGS** view. This view is accessible only to users with system administrators rights.

## 14.3.176 PGXC_STAT_ACTIVITY

**PGXC_STAT_ACTIVITY** displays information about the query performed by the current user on all the CNs in the current cluster.

**Table 14-235** PGXC_STAT_ACTIVITY columns

| Name | Type | Description |
| --- | --- | --- |
| coorname | text | Name of the CN in the current cluster |
| datid | oid | OID of the database that the user session connects to in the backend |
| datname | name | Name of the database that the user session connects to in the backend |
| pid | bigint | ID of the backend thread |
| usesysid | oid | OID of the user logging in to the backend |
| usename | name | Name of the user logging in to the backend |
| application_name | text | Name of the application connected to the backend |
| client_addr | inet | IP address of the client connected to the backend. If this column is **null**, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum. |

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| Name | Type | Description |
| --- | --- | --- |
| client_hostname | text | Host name of the connected client, as reported by a reverse DNS lookup of **client_addr**. This column will only be non-null for IP connections, and only when **log_hostname** is enabled. |
| client_port | integer | TCP port number that the client uses for communication with this backend, or **-1** if a Unix socket is used |
| backend_start | timestamp with time zone | Startup time of the backend process, that is, the time when the client connects to the server |
| xact_start | timestamp with time zone | Time when the current transaction was started, or **NULL** if no transaction is active. If the current query is the first of its transaction, this column is equal to the **query_start** column. |
| query_start | timestamp with time zone | Time when the currently active query was started, or time when the last query was started if **state** is not **active** |
| state_change | timestamp with time zone | Time for the last status change |
| waiting | boolean | If backend is currently waiting for a lock, the value is **true**. |
| enqueue | text | Queuing status of a statement. Its value can be:<br>• **waiting in global queue**: The statement is in the global queue.<br>• **waiting in respool queue**: The statement is in the resource pool queue.<br>• **waiting in ccn queue**: The job is in the CCN queue.<br>• Empty or **no waiting queue**: The statement is running. |

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| Name | Type | Description |
| --- | --- | --- |
| state | text | Overall state of the backend. Its value can be:<br>• **active**: The backend is executing a query.<br>• **idle**: The backend is waiting for a new client command.<br>• **idle in transaction**: The backend is in a transaction, but there is no statement being executed in the transaction.<br>• **idle in transaction (aborted)**: The backend is in a transaction, but there are statements failed in the transaction.<br>• **fastpath function call**: The backend is executing a **fast-path** function.<br>• **disabled**: This state is reported if **track_activities** is disabled in this backend.<br>**NOTE**<br>Only system administrators can view the session status of their accounts. The state information of other accounts is empty. For example, after user **judy** is connected to the database, the state information of user **joe** and the initial user **dbadmin** in **pgxc_stat_activity** is empty.<br>SELECT datname, username, usesysid, state,pid FROM pgxc_stat_activity;<br>datname \| username \| usesysid \| state \| pid<br>----------+----------+----------+--------<br>+-----------------<br>gaussdb \| dbadmin \| 10 \| \| 139968752121616<br>gaussdb \| dbadmin \| 10 \| \| 139968903116560<br>db_tpcds \| judy \| 16398 \| active \| 139968391403280<br>gaussdb \| dbadmin \| 10 \| \| 139968643069712<br>gaussdb \| dbadmin \| 10 \| \| 139968680818448<br>gaussdb \| joe \| 16390 \| \| 139968563377936<br>(6 rows) |
| resource_pool | name | Resource pool used by the user |
| query_id | bigint | ID of a query |
| query | text | Text of this backend's most recent query If **state** is **active**, this column shows the running query. In all other states, it shows the last query that was executed. |

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| Name | Type | Description |
| --- | --- | --- |
| connection_info | text | A string in JSON format recording the driver type, driver version, driver deployment path, and process owner of the connected database (for details, see **connection_info**) |

## 14.3.177 PGXC_STAT_BAD_BLOCK

**PGXC_STAT_BAD_BLOCK** displays statistics about page or CU verification failures after all nodes in a cluster are started.

**Table 14-236** PGXC_STAT_BAD_BLOCK columns

| Name | Type | Description |
| --- | --- | --- |
| nodename | text | Node name |
| databaseid | integer | Database OID |
| tablespaceid | integer | Tablespace OID |
| relfilenode | integer | File object ID |
| forknum | integer | File type |
| error_count | integer | Number of verification failures |
| first_time | timestamp with time zone | Time of the first occurrence |
| last_time | timestamp with time zone | Time of the latest occurrence |

## 14.3.178 PGXC_STAT_BGWRITER

**PGXC_STAT_BGWRITER** displays statistics on the background writer of each node in the cluster. All columns except **node_name** are the same as those in the **PG_STAT_BGWRITER** view. This view is accessible only to users with system administrators rights.

## 14.3.179 PGXC_STAT_DATABASE

**PGXC_STAT_DATABASE** displays the database status and statistics of each node in the cluster. All columns except **node_name** are the same as those in the **PG_STAT_DATABASE** view. This view is accessible only to users with system administrators rights.

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## 14.3.180 PGXC_STAT_REPLICATION

**PGXC_STAT_REPLICATION** displays the log synchronization status of each node in the cluster. All columns except **node_name** are the same as those in the **PG_STAT_REPLICATION** view. This view is accessible only to users with system administrators rights.

## 14.3.181 PGXC_SQL_COUNT

**PGXC_SQL_COUNT** displays the node-level and user-level statistics for the SQL statements of **SELECT**, **INSERT**, **UPDATE**, **DELETE**, and **MERGE INTO** and DDL, DML, and DCL statements of each CN in a cluster in real time, identifies query types with heavy load, and measures the capability of a cluster or a node to perform a specific type of query. You can calculate QPS based on the quantities and response time of the preceding types of SQL statements at certain time points. For example, **USER1 SELECT** is counted as **X1** at T1 and as **X2** at T2. The **SELECT** QPS of the user can be calculated as follows: (X2 – X1)/(T2 – T1). In this way, the system can draw cluster-user-level QPS curve graphs and determine cluster throughput, monitoring changes in the service load of each user. If there are drastic changes, the system can locate the specific statement type (such as **SELECT**, **INSERT**, **UPDATE**, **DELETE**, and **MERGE INTO**). You can also observe QPS curves to determine the time points when problems occur and then locate the problems using other tools. The curves provide a basis for optimizing cluster performance and locating problems.

Columns in the **PGXC_SQL_COUNT** view are the same as those in the **GS_SQL_COUNT** view. For details, see **Table 14-124**.

NOTE

If a **MERGE INTO** statement can be pushed down and a DN receives it, the statement will be counted on the DN and the value of the **mergeinto_count** column will increment by 1. If the pushdown is not allowed, the DN will receive an **UPDATE** or **INSERT** statement. In this case, the **update_count** or **insert_count** column will increment by 1.

## 14.3.182 PGXC_THREAD_WAIT_STATUS

**PGXC_THREAD_WAIT_STATUS** displays all the call layer hierarchy relationship between threads of the SQL statements on all the nodes in a cluster, and the waiting status of the block for each thread, so that you can easily locate the causes of process response failures and similar phenomena.

The definitions of **PGXC_THREAD_WAIT_STATUS** view and **PG_THREAD_WAIT_STATUS** view are the same, because the essence of the **PGXC_THREAD_WAIT_STATUS** view is the query summary result of the **PG_THREAD_WAIT_STATUS** view on each node in the cluster.

**Table 14-237** PGXC_THREAD_WAIT_STATUS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Current node name |
| db_name | text | Database name |

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| Name | Type | Description |
| --- | --- | --- |
| thread_name | text | Thread name |
| query_id | bigint | Query ID. It is equivalent to **debug_query_id**. |
| tid | bigint | Thread ID of the current thread |
| lwtid | integer | Lightweight thread ID of the current thread |
| ptid | integer | Parent thread of the streaming thread |
| tlevel | integer | Level of the streaming thread |
| smpid | integer | Concurrent thread ID |
| wait_status | text | Waiting status of the current thread. For details about the waiting status, see **Table 14-204**. |
| wait_event | text | If **wait_status** is **acquire lock**, **acquire lwlock**, or **wait io**, this column describes the lock, lightweight lock, and I/O information, respectively. If **wait_status** is not any of the three values, this column is empty. |

Example:

Assume you run a statement on coordinator1, and no response is returned after a long period of time. In this case, establish another connection to coordinator1 to check the thread status on it.

```
 select * from pg_thread_wait_status where query_id > 0;
  node_name   | db_name  | thread_name  | query_id |       tid       | lwtid | ptid  | tlevel | smpid |
wait_status   |   wait_event
--------------+----------+--------------+----------+-----------------+-------+-------+--------+-------
+----------------------
 coordinator1 | gaussdb | gsql         | 20971544 | 140274089064208 | 22579 |       |      0 |     0 | wait node:
datanode4 |
(1 rows)
```

Furthermore, you can view the statement working status on each node in the entire cluster. In the following example, no DNs have threads blocked, and there is a huge amount of data to be read, causing slow execution.

```
select * from pgxc_thread_wait_status where query_id=20971544;
  node_name   | db_name  | thread_name  | query_id |       tid       | lwtid | ptid  | tlevel | smpid |
wait_status   |   wait_event
--------------+----------+--------------+----------+-----------------+-------+-------+--------+-------
+----------------------
 datanode1    | gaussdb | coordinator1 | 20971544 | 139902867994384 | 22735 |       |      0 |     0 | wait
node: datanode3 |
 datanode1    | gaussdb | coordinator1 | 20971544 | 139902838634256 | 22970 | 22735 |      5 |     0 |
synchronize quit     |
 datanode1    | gaussdb | coordinator1 | 20971544 | 139902607947536 | 22972 | 22735 |      5 |     1 |
synchronize quit     |
 datanode2    | gaussdb | coordinator1 | 20971544 | 140632156796688 | 22736 |       |      0 |     0 | wait
node: datanode3 |
 datanode2    | gaussdb | coordinator1 | 20971544 | 140632030967568 | 22974 | 22736 |      5 |     0 |
synchronize quit     |
 datanode2    | gaussdb | coordinator1 | 20971544 | 140632081299216 | 22975 | 22736 |      5 |     1 |
```

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```
synchronize quit     |
 datanode3    | gaussdb | coordinator1 | 20971544 | 140323627988752 | 22737 |       |      0 |     0 | wait
node: datanode3 |
 datanode3    | gaussdb | coordinator1 | 20971544 | 140323523131152 | 22976 | 22737 |      5 |     0 | net
flush data       |
 datanode3    | gaussdb | coordinator1 | 20971544 | 140323548296976 | 22978 | 22737 |      5 |     1 | net
flush data
 datanode4    | gaussdb | coordinator1 | 20971544 | 140103024375568 | 22738 |       |      0 |     0 | wait
node: datanode3
 datanode4    | gaussdb | coordinator1 | 20971544 | 140102919517968 | 22979 | 22738 |      5 |     0 |
synchronize quit     |
 datanode4    | gaussdb | coordinator1 | 20971544 | 140102969849616 | 22980 | 22738 |      5 |     1 |
synchronize quit     |
 coordinator1 | gaussdb | gsql         | 20971544 | 140274089064208 | 22579 |       |      0 |     0 | wait node:
datanode4  |
(13 rows)
```

# 14.3.183 PGXC_TOTAL_MEMORY_DETAIL

**PGXC_TOTAL_MEMORY_DETAIL** displays the memory usage in the cluster.

**Table 14-238** PGXC_TOTAL_MEMORY_DETAIL columns

| Name | Type | Description |
| --- | --- | --- |
| nodename | text | Node name |

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| Name | Type | Description |
| --- | --- | --- |
| memorytype | text | Memory name, which can be set to any of the following values:<br>• **max_process_memory**: memory used by a GaussDB(DWS) cluster instance<br>• **process_used_memory**: memory used by a GaussDB(DWS) process<br>• **max_dynamic_memory**: maximum dynamic memory<br>• **dynamic_used_memory**: used dynamic memory<br>• **dynamic_peak_memory**: dynamic peak value of the memory<br>• **dynamic_used_shrctx**: maximum dynamic shared memory context<br>• **dynamic_peak_shrctx**: dynamic peak value of the shared memory context<br>• **max_shared_memory**: maximum shared memory<br>• **shared_used_memory**: used shared memory<br>• **max_cstore_memory**: maximum memory allowed for column store<br>• **cstore_used_memory**: memory used for column store<br>• **max_sctpcomm_memory**: maximum memory allowed for the communication library<br>• **sctpcomm_used_memory**: memory used for the communication library<br>• **sctpcomm_peak_memory**: memory peak of the communication library<br>• **other_used_memory**: other used memory<br>• **gpu_max_dynamic_memory**: maximum GPU memory<br>• **gpu_dynamic_used_memory**: sum of the available GPU memory and temporary GPU memory<br>• **gpu_dynamic_peak_memory**: maximum memory used for GPU<br>• **pooler_conn_memory**: memory used for pooler connections<br>• **pooler_freeconn_memory**: memory used for idle pooler connections |

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| Name | Type | Description |
| --- | --- | --- |
| | | • **storage_compress_memory**: memory used for column-store compression and decompression<br>• **udf_reserved_memory**: memory reserved for the **UDF Worker** process<br>• **mmap_used_memory**: memory used for **mmap** |
| memorymbytes | integer | Size of the used memory (MB) |

## 14.3.184 PGXC_TOTAL_SCHEMA_INFO

**PGXC_TOTAL_SCHEMA_INFO** displays the schema space information of all instances in the cluster, providing visibility into the schema space usage of each instance. This view can be queried only on CNs.

**Table 14-239** PGXC_TOTAL_SCHEMA_INFO columns

| Name | Type | Description |
| --- | --- | --- |
| schemaname | text | Schema name |
| schemaid | oid | Schema OID |
| databasename | text | Database name |
| databaseid | oid | Database OID |
| nodename | text | Instance name |
| nodegroup | text | Name of the node group |
| usedspace | bigint | Size of used space |
| permspace | bigint | Upper limit of the space |

## 14.3.185 PGXC_TOTAL_SCHEMA_INFO_ANALYZE

**PGXC_TOTAL_SCHEMA_INFO_ANALYZE** displays the overall schema space information of the cluster, including the total cluster space, average space of instances, skew ratio, maximum space of a single instance, minimum space of a single instance, and names of the instances with the maximum space and minimum space. It provides visibility into the schema space usage of the entire cluster. This view can be queried only on CNs.

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**Table 14-240** PGXC_TOTAL_SCHEMA_INFO_ANALYZE columns

| Name | Type | Description |
| --- | --- | --- |
| schemaname | text | Schema name |
| databasename | text | Database name |
| nodegroup | text | Name of the node group |
| total_value | bigint | Total cluster space in the current schema |
| avg_value | bigint | Average space of instances in the current schema |
| skew_percent | integer | Skew ratio |
| extend_info | text | Extended information, including the maximum space of a single instance, minimum space of a single instance, and names of the instances with the maximum sapce and minimum space |

## 14.3.186 PGXC_USER_TRANSACTION

**PGXC_USER_TRANSACTION** provides transaction information about users on all CNs. It is accessible only to users with system administrator rights. This view is valid only when the real-time resource monitoring function is enabled, that is, when enable_resource_track is **on**.

**Table 14-241 PGXC_USER_TRANSACTION** columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | name | Node name |
| usename | name | Username |
| commit_counter | bigint | Number of the commit times |
| rollback_counter | bigint | Number of rollbacks |
| resp_min | bigint | Minimum response time |
| resp_max | bigint | Maximum response time |
| resp_avg | bigint | Average response time |
| resp_total | bigint | Total response time |

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## 14.3.187 PGXC_VARIABLE_INFO

**PGXC_VARIABLE_INFO** displays information about transaction IDs and OIDs of all nodes in a cluster.

**Table 14-242** PGXC_VARIABLE_INFO columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Node name |
| nextOid | oid | OID generated next time for a node |
| nextXid | xid | Transaction ID generated next time for a node |
| oldestXid | xid | Oldest transaction ID for a node |
| xidVacLimit | xid | Critical point that triggers forcible autovacuum |
| oldestXidDB | oid | OID of the database that has the minimum **datafrozenxid** on a node |
| lastExtendCSNLogpage | integer | Number of the last extended csnlog page |
| startExtendCSNLogpage | integer | Number of the page from which the csnlog extending starts |
| nextCommitSeqNo | integer | CSN generated next time for a node |
| latestCompletedXid | xid | Latest transaction ID on a node after the transaction commission or rollback |
| startupMaxXid | xid | Last transaction ID before a node is powered off |

## 14.3.188 PGXC_WAIT_EVENTS

**PGXC_WAIT_EVENTS** displays statistics on the waiting status and events of each node in the cluster. The content is the same as that displayed in **GS_WAIT_EVENTS**. This view is accessible only to users with system administrators rights.

## 14.3.189 PGXC_WLM_OPERATOR_HISTORY

**PGXC_WLM_OPERATOR_HISTORY** displays the operator information of completed jobs executed on all CNs. This view is used by Database Manager to query data from a database. Data in the database is cleared every 3 minutes.

This view is accessible only to users with system administrators rights. For details about columns in the view, see **Table 14-3**.


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## 14.3.190 PGXC_WLM_OPERATOR_INFO

**PGXC_WLM_OPERATOR_INFO** displays the operator information of completed jobs executed on CNs. The data in this view is obtained from **GS_WLM_OPERATOR_INFO**.

This view is accessible only to users with system administrators rights. For details about columns in the view, see **Table 14-3**.

## 14.3.191 PGXC_WLM_OPERATOR_STATISTICS

**PGXC_WLM_OPERATOR_STATISTICS** displays the operator information of jobs being executed on CNs.

This view is accessible only to users with system administrators rights. For details about columns in the view, see **GS_WLM_OPERATOR_STATISTICS columns**.

## 14.3.192 PGXC_WLM_SESSION_INFO

**PGXC_WLM_SESSION_INFO** displays load management information for completed jobs executed on all CNs. The data in this view is obtained from **GS_WLM_SESSION_INFO**.

This view is accessible only to users with system administrators rights. For details about columns in the view, see **Table 14-127**.

## 14.3.193 PGXC_WLM_SESSION_HISTORY

**PGXC_WLM_SESSION_HISTORY** displays load management information for completed jobs executed on all CNs. This view is used by Data Manager to query data from a database. Data in the database is cleared every 3 minutes. For details, see **GS_WLM_SESSION_HISTORY**.

This view is accessible only to users with system administrators rights. For details about columns in the view, see **Table 14-127**.

## 14.3.194 PGXC_WLM_SESSION_STATISTICS

**PGXC_WLM_SESSION_STATISTICS** displays load management information about jobs that are being executed on CNs.

This view is accessible only to users with system administrators rights. For details about columns in the view, see **Table 14-128**.

## 14.3.195 PGXC_WLM_WORKLOAD_RECORDS

**PGXC_WLM_WORKLOAD_RECORDS** displays the status of job executed by the current user on CNs. It is accessible only to users with system administrator rights. This view is available only when **enable_dynamic_workload** is set to **on**.

**Table 14-243** PGXC_WLM_WORKLOAD_RECORDS columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | text | Name of the CN where the job is executed |

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| Name | Type | Description |
| --- | --- | --- |
| thread_id | bigint | ID of the backend thread |
| processid | integer | lwpid of a thread |
| timestamp | bigint | Time when a statement starts to be executed |
| username | name | Name of the user logging in to the backend |
| memory | integer | Memory required by a statement |
| active_points | integer | Number of resources consumed by a statement in a resource pool |
| max_points | integer | Maximum number of resources in a resource pool |
| priority | integer | Priority of a job |
| resource_pool | text | Resource pool to which a job belongs |
| status | text | Job execution status. Its value can be:<br>**pending**<br>**running**<br>**finished**<br>**aborted**<br>**unknown** |
| control_group | text | Cgroups used by a job |
| enqueue | text | Queue that a job is in. Its value can be:<br>**GLOBAL**: global queue<br>**RESPOOL**: resource pool queue<br>**ACTIVE**: not in a queue |
| query | text | Statement that is being executed |

## 14.3.196 PGXC_WORKLOAD_SQL_COUNT

**PGXC_WORKLOAD_SQL_COUNT** displays statistics on the number of SQL statements executed in workload Cgroups on all CNs in a cluster, including the number of **SELECT**, **UPDATE**, **INSERT**, and **DELETE** statements and the number of DDL, DML, and DCL statements. It is accessible only to users with system administrator rights.

**Table 14-244 PGXC_WORKLOAD_SQL_COUNT** columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | name | Node name |

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| Name | Type | Description |
| --- | --- | --- |
| workload | name | Workload Cgroup name |
| select_count | bigint | Number of **SELECT** statements |
| update_count | bigint | Number of **UPDATE** statements |
| insert_count | bigint | Number of **INSERT** statements |
| delete_count | bigint | Number of **DELETE** statements |
| ddl_count | bigint | Number of **DDL** statements |
| dml_count | bigint | Number of **DML** statements |
| dcl_count | bigint | Number of **DCL** statements |

## 14.3.197 PGXC_WORKLOAD_SQL_ELAPSE_TIME

**PGXC_WORKLOAD_SQL_ELAPSE_TIME** displays statistics on the response time of SQL statements in workload Cgroups on all CNs in a cluster, including the maximum, minimum, average, and total response time of **SELECT**, **UPDATE**, **INSERT**, and **DELETE** statements. The unit is microsecond. It is accessible only to users with system administrator rights.

**Table 14-245 PGXC_WORKLOAD_SQL_ELAPSE_TIME** columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | name | Node name |
| workload | name | Workload Cgroup name |
| total_select_elapse | bigint | Total response time of **SELECT** statements |
| max_select_elapse | bigint | Maximum response time of **SELECT** statements |
| min_select_elapse | bigint | Minimum response time of **SELECT** statements |
| avg_select_elapse | bigint | Average response time of **SELECT** statements |

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| Name | Type | Description |
| --- | --- | --- |
| total_update_elapse | bigint | Total response time of **UPDATE** statements |
| max_update_elapse | bigint | Maximum response time of **UPDATE** statements |
| min_update_elapse | bigint | Minimum response time of **UPDATE** statements |
| avg_update_elapse | bigint | Average response time of **UPDATE** statements |
| total_insert_elapse | bigint | Total response time of **INSERT** statements |
| max_insert_elapse | bigint | Maximum response time of **INSERT** statements |
| min_insert_elapse | bigint | Minimum response time of **INSERT** statements |
| avg_insert_elapse | bigint | Average response time of **INSERT** statements |
| total_delete_elapse | bigint | Total response time of **DELETE** statements |
| max_delete_elapse | bigint | Maximum response time of **DELETE** statements |
| min_delete_elapse | bigint | Minimum response time of **DELETE** statements |
| avg_delete_elapse | bigint | Average response time of **DELETE** statements |

## 14.3.198 PGXC_WORKLOAD_TRANSACTION

**PGXC_WORKLOAD_TRANSACTION** provides transaction information about workload Cgroups on all CNs. It is accessible only to users with system administrator rights. This view is valid only when the real-time resource monitoring function is enabled, that is, when **enable_resource_track** is **on**.

**Table 14-246** PGXC_WORKLOAD_TRANSACTION columns

| Name | Type | Description |
| --- | --- | --- |
| node_name | name | Node name |
| workload | name | Workload Cgroup name |

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| Name | Type | Description |
| --- | --- | --- |
| commit_counter | bigint | Number of the commit times |
| rollback_counter | bigint | Number of rollbacks |
| resp_min | bigint | Minimum response time (unit: μs) |
| resp_max | bigint | Maximum response time (unit: μs) |
| resp_avg | bigint | Average response time (unit: μs) |
| resp_total | bigint | Total response time (unit: μs) |

## 14.3.199 PLAN_TABLE

**PLAN_TABLE** displays the plan information collected by **EXPLAIN PLAN**. Plan information is in a session-level life cycle. After the session exits, the data will be deleted. Data is isolated between sessions and between users.

**Table 14-247** PLAN_TABLE columns

| Name | Type | Description |
| --- | --- | --- |
| statement_id | varchar2(30) | Query tag specified by a user |
| plan_id | bigint | ID of a plan to be queried |
| id | int | ID of each operator in a generated plan |
| operation | varchar2(30) | Operation description of an operator in a plan |
| options | varchar2(255) | Operation parameters |
| object_name | name | Name of an operated object. It is defined by users, not the object alias used in the query. |
| object_type | varchar2(30) | Object type |
| object_owner | name | User-defined schema to which an object belongs |
| projection | varchar2(4000) | Returned column information |

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NOTE

- A valid **object_type** value consists of a relkind type defined in **PG_CLASS** (**TABLE** ordinary table, **INDEX**, **SEQUENCE**, **VIEW**, **FOREIGN TABLE**, **COMPOSITE TYPE**, or **TOASTVALUE TOAST** table) and the rtekind type used in the plan (**SUBQUERY**, **JOIN**, **FUNCTION**, **VALUES**, **CTE**, or **REMOTE_QUERY**).
- For RangeTableEntry (RTE), **object_owner** is the object description used in the plan. Non-user-defined objects do not have **object_owner**.
- Information in the **statement_id**, **object_name**, **object_owner**, and **projection** columns is stored in letter cases specified by users and information in other columns is stored in uppercase.
- **PLAN_TABLE** supports only **SELECT** and **DELETE** and does not support other DML operations.

## 14.3.200 PLAN_TABLE_DATA

**PLAN_TABLE_DATA** displays the plan information collected by **EXPLAIN PLAN**. Different from the **PLAN_TABLE** view, the system catalog **PLAN_TABLE_DATA** stores the plan information collected by all sessions and users.

**Table 14-248** PLAN_TABLE columns

| Name | Type | Description |
| --- | --- | --- |
| session_id | text | Session that inserts the data. Its value consists of a service thread start timestamp and a service thread ID. Values are constrained by **NOT NULL**. |
| user_id | oid | User who inserts the data. Values are constrained by **NOT NULL**. |
| statement_id | varchar2(30) | Query tag specified by a user |
| plan_id | bigint | ID of a plan to be queried |
| id | int | Node ID in a plan |
| operation | varchar2(30) | Operation description |
| options | varchar2(255) | Operation parameters |
| object_name | name | Name of an operated object. It is defined by users. |
| object_type | varchar2(30) | Object type |
| object_owner | name | User-defined schema to which an object belongs |
| projection | varchar2(4000) | Returned column information |

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NOTE

- **PLAN_TABLE_DATA** records data of all users and sessions on the current node. Only administrators can access all the data. Common users can view only their own data in the **PLAN_TABLE** view.
- Data of inactive (exited) sessions is cleaned from **PLAN_TABLE_DATA** by **gs_clean** after being stored in this system catalog for a certain period of time (5 minutes by default). You can also manually run **gs_clean -C** to delete inactive session data from the table..
- Data is automatically inserted into **PLAN_TABLE_DATA** after **EXPLAIN PLAN** is executed. Therefore, do not manually insert data into or update data in **PLAN_TABLE_DATA**. Otherwise, data in **PLAN_TABLE_DATA** may be disordered. To delete data from **PLAN_TABLE_DATA**, you are advised to use the **PLAN_TABLE** view.
- Information in the **statement_id**, **object_name**, **object_owner**, and **projection** columns is stored in letter cases specified by users and information in other columns is stored in uppercase.

## 14.3.201 PV_FILE_STAT

By collecting statistics about the data file I/Os, **PV_FILE_STAT** displays the I/O performance of the data to detect the performance problems, such as abnormal I/O operations.

**Table 14-249** PV_FILE_STAT columns

| Name | Type | Description |
| --- | --- | --- |
| filenum | oid | File ID |
| dbid | oid | Database ID |
| spcid | oid | Tablespace ID |
| phyrds | bigint | Number of times of reading physical files |
| phywrts | bigint | Number of times of writing into physical files |
| phyblkrd | bigint | Number of times of reading physical file blocks |
| phyblkwrt | bigint | Number of times of writing into physical file blocks |
| readtim | bigint | Total duration of reading files. The unit is microsecond. |
| writetim | bigint | Total duration of writing files. The unit is microsecond. |
| avgiotim | bigint | Average duration of reading and writing files. The unit is microsecond. |
| lstiotim | bigint | Duration of the last file reading. The unit is microsecond. |
| miniotim | bigint | Minimum duration of reading and writing files. The unit is microsecond. |

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| Name | Type | Description |
| --- | --- | --- |
| maxiowtm | bigint | Maximum duration of reading and writing files. The unit is microsecond. |

## 14.3.202 PV_INSTANCE_TIME

**PV_INSTANCE_TIME** collects statistics on the running time of processes and the time consumed in each execution phase, in microseconds.

**PV_INSTANCE_TIME** records time consumption information of the current node. The time consumption information is classified into the following types:

- **DB_TIME**: effective time spent by jobs in multi-core scenarios
- **CPU_TIME**: CPU time spent
- **EXECUTION_TIME**: time spent within executors
- **PARSE_TIME**: time spent on parsing SQL statements
- **PLAN_TIME**: time spent on generating plans
- **REWRITE_TIME**: time spent on rewriting SQL statements
- **PL_EXECUTION_TIME**: execution time of the PL/pgSQL stored procedure
- **PL_COMPILATION_TIME**: compilation time of the PL/pgSQL stored procedure
- **NET_SEND_TIME**: time spent on the network
- **DATA_IO_TIME**: I/O time spent

**Table 14-250** PV_INSTANCE_TIME columns

| Name | Type | Description |
| --- | --- | --- |
| stat_id | integer | Type ID |
| stat_name | text | Running time type name |
| value | bigint | Running time value |

## 14.3.203 PV_OS_RUN_INFO

**PV_OS_RUN_INFO** displays the running status of the current operating system.

**Table 14-251** PV_OS_RUN_INFO columns

| Name | Type | Description |
| --- | --- | --- |
| id | integer | ID |
| name | text | Name of the OS running status |
| value | numeric | Value of the OS running status |

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| Name | Type | Description |
| --- | --- | --- |
| comments | text | Remarks of the OS running status |
| cumulative | boolean | Whether the value of the OS running status is cumulative |

## 14.3.204 PV_SESSION_MEMORY

**PV_SESSION_MEMORY** displays statistics about memory usage at the session level in the unit of MB, including all the memory allocated to Postgres and Stream threads on DNs for jobs currently executed by users.

**Table 14-252** PV_SESSION_MEMORY columns

| Name | Type | Description |
| --- | --- | --- |
| sessid | text | Thread start time and ID |
| init_mem | integer | Memory allocated to the currently executed task before the task enters the executor, in MB |
| used_mem | integer | Memory allocated to the currently executed task, in MB |
| peak_mem | integer | Peak memory allocated to the currently executed task, in MB |

## 14.3.205 PV_SESSION_MEMORY_DETAIL

**PV_SESSION_MEMORY_DETAIL** displays statistics about thread memory usage by memory context.

The memory context TempSmallContextGroup collects information about all memory contexts whose value in the **totalsize** column is less than 8192 bytes in the current thread, and the number of the collected memory contexts is recorded in the **usedsize** column. Therefore, the **totalsize** and **freesize** columns for TempSmallContextGroup in the view display the corresponding information about all the memory contexts whose value in the **totalsize** column is less than 8192 bytes in the current thread, and the **usedsize** column displays the number of these memory contexts.

You can run the **SELECT * FROM pv_session_memctx_detail (***threadid***,'');** statement to record information about all memory contexts of a thread into the *threadid_timestamp***.log** file in the **/tmp/dumpmem** directory. *threadid* can be obtained from the following table.

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**Table 14-253** PV_SESSION_MEMORY_DETAIL columns

| Name | Type | Description |
| --- | --- | --- |
| sessid | text | Thread start time+thread ID (string: *timestamp.threadid*) |
| sesstype | text | Thread name |
| contextname | text | Name of the memory context |
| level | smallint | Hierarchy of the memory context |
| parent | text | Name of the parent memory context |
| totalsize | bigint | Total size of the memory context, in bytes |
| freesize | bigint | Total size of released memory in the memory context, in bytes |
| usedsize | bigint | Size of used memory in the memory context, in bytes. For TempSmallContextGroup, this parameter specifies the number of collected memory contexts. |

## 14.3.206 PV_SESSION_STAT

**PV_SESSION_STAT** displays session state statistics based on session threads or the **AutoVacuum** thread.

**Table 14-254** PV_SESSION_STAT columns

| Name | Type | Description |
| --- | --- | --- |
| sessid | text | Thread ID and start time |
| statid | integer | Statistics ID |
| statname | text | Name of the statistics session |
| statunit | text | Unit of the statistics session |
| value | bigint | Value of the statistics session |

## 14.3.207 PV_SESSION_TIME

**PV_SESSION_TIME** displays statistics about the running time of session threads and time consumed in each execution phase, in microseconds.

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**Table 14-255** PV_SESSION_TIME columns

| Name | Type | Description |
| --- | --- | --- |
| sessid | text | Thread ID and start time |
| stat_id | integer | Statistics ID |
| stat_name | text | Running time type name |
| value | bigint | Running time value |

## 14.3.208 PV_TOTAL_MEMORY_DETAIL

**PV_TOTAL_MEMORY_DETAIL** displays statistics about memory usage of the current database node in the unit of MB.

**Table 14-256** PV_TOTAL_MEMORY_DETAIL columns

| Name | Type | Description |
| --- | --- | --- |
| nodename | text | Node name |

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| Name | Type | Description |
| --- | --- | --- |
| memorytype | text | Memory type. Its value can be:<br>• **max_process_memory**: memory used by a GaussDB(DWS) cluster instance<br>• **process_used_memory**: memory used by a GaussDB(DWS) process<br>• **max_dynamic_memory**: maximum dynamic memory<br>• **dynamic_used_memory**: used dynamic memory<br>• **dynamic_peak_memory**: dynamic peak value of the memory<br>• **dynamic_used_shrctx**: maximum dynamic shared memory context<br>• **dynamic_peak_shrctx**: dynamic peak value of the shared memory context<br>• **max_shared_memory**: maximum shared memory<br>• **shared_used_memory**: used shared memory<br>• **max_cstore_memory**: maximum memory allowed for column store<br>• **cstore_used_memory**: memory used for column store<br>• **max_sctpcomm_memory**: maximum memory allowed for the communication library<br>• **sctpcomm_used_memory**: memory used for the communication library<br>• **sctpcomm_peak_memory**: memory peak of the communication library<br>• **other_used_memory**: other used memory<br>• **gpu_max_dynamic_memory**: maximum GPU memory<br>• **gpu_dynamic_used_memory**: sum of the available GPU memory and temporary GPU memory<br>• **gpu_dynamic_peak_memory**: maximum memory used for GPU<br>• **pooler_conn_memory**: memory used for pooler connections<br>• **pooler_freeconn_memory**: memory used for idle pooler connections<br>• **storage_compress_memory**: memory used for column-store compression and decompression<br>• **udf_reserved_memory**: memory reserved for the **UDF Worker** process |

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| Name | Type | Description |
| --- | --- | --- |
| | | • **mmap_used_memory**: memory used for **mmap** |
| memorymbytes | integer | Size of allocated memory-typed memory |

## 14.3.209 PV_REDO_STAT

**PV_REDO_STAT** displays statistics on redoing Xlogs on the current node.

**Table 14-257** PV_REDO_STAT columns

| Name | Type | Description |
| --- | --- | --- |
| phywrts | bigint | Number of physical writes |
| phyblkwrt | bigint | Number of physical write blocks |
| writetim | bigint | Time consumed by physical writes |
| avgiotim | bigint | Average time for each write |
| lstiotim | bigint | Last write time |
| miniotim | bigint | Minimum write time |
| maxiowtm | bigint | Maximum write time |

## 14.3.210 REDACTION_COLUMNS

**REDACTION_COLUMNS** displays information about all redaction columns in the current database.

**Table 14-258 REDACTION_COLUMNS** columns

| Name | Type | Description |
| --- | --- | --- |
| object_owner | name | Owner of the object to be redacted. |
| object_name | name | Redacted object name |
| column_name | name | Redacted column name |
| function_type | integer | Redaction type |
| function_parameters | text | Parameter used when the redaction type is **partial** (reserved) |

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| Name | Type | Description |
| --- | --- | --- |
| regexp_pattern | text | Pattern string when the redaction type is **regexp** (reserved) |
| regexp_replace_string | text | Replacement string when the redaction type is **regexp** (reserved) |
| regexp_position | integer | Start and end replacement positions when the redaction type is **regexp** (reserved) |
| regexp_occurrence | integer | Replacement times when the redaction type is **regexp** (reserved) |
| regexp_match_parameter | text | Regular control parameter used when the redaction type is **regexp** (reserved) |
| function_info | text | Redaction function information |
| column_description | text | Description of the redacted column |

## 14.3.211 REDACTION_POLICIES

**REDACTION_POLICIES** displays information about all redaction objects in the current database.

**Table 14-259 REDACTION_POLICIES** columns

| Name | Type | Description |
| --- | --- | --- |
| object_owner | name | Owner of the object to be redacted. |
| object_name | name | Redacted object name |
| policy_name | name | Name of the redact policy |
| expression | text | Policy effective expression (for users) |
| enable | boolean | Policy status (enabled or disabled) |
| policy_description | text | Description of a policy |

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## 14.3.212 USER_COL_COMMENTS

**USER_COL_COMMENTS** displays the column comments of the table accessible to the current user.

**Table 14-260** USER_COL_COMMENTS columns

| Name | Type | Description |
| --- | --- | --- |
| column_name | character varying(64) | Column name |
| table_name | character varying(64) | Table name |
| owner | character varying(64) | Table owner |
| comments | text | Comments |

## 14.3.213 USER_CONSTRAINTS

**USER_CONSTRAINTS** displays the table constraint information accessible to the current user.

**Table 14-261** USER_CONSTRAINTS columns

| Name | Type | Description |
| --- | --- | --- |
| constraint_name | vcharacter varying(64) | Constraint name |
| constraint_type | text | Constraint type<br>• **C**: Check constraint<br>• **F**: Foreign key constraint<br>• **P**: Primary key constraint<br>• **U**: Unique constraint |
| table_name | character varying(64) | Name of constraint-related table |
| index_owner | character varying(64) | Owner of constraint-related index (only for the unique constraint and primary key constraint) |
| index_name | character varying(64) | Name of constraint-related index (only for the unique constraint and primary key constraint) |

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## 14.3.214 USER_CONS_COLUMNS

**USER_CONSTRAINTS** displays the information about constraint columns of the tables accessible to the current user.

**Table 14-262** USER_CONS_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| table_name | character varying(64) | Name of constraint-related table |
| column_name | character varying(64) | Name of constraint-related column |
| constraint_name | character varying(64) | Constraint name |
| position | smallint | Position of the column in the table |

## 14.3.215 USER_INDEXES

**USER_INDEXES** displays index information in the current schema.

**Table 14-263** USER_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_name | character varying(64) | Table name for the index |
| uniqueness | text | Whether the index is a unique index |
| generated | character varying(1) | Whether the index name is generated by the system |
| partitioned | character(3) | Whether the index has the property of the partition table |

## 14.3.216 USER_IND_COLUMNS

**USER_IND_COLUMNS** displays column information about all indexes accessible to the current user.

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**Table 14-264** USER_IND_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_name | name | Column name |
| column_position | smallint | Position of column in the index |

## 14.3.217 USER_IND_EXPRESSIONS

**USER_IND_EXPRESSIONS** displays information about the function-based expression index accessible to the current user.

**Table 14-265** USER_IND_EXPRESSIONS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Index owner |
| index_name | character varying(64) | Index name |
| table_owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_expression | text | Function-based index expression of a specified column |
| column_position | smallint | Position of column in the index |

## 14.3.218 USER_IND_PARTITIONS

**USER_IND_PARTITIONS** displays information about index partitions accessible to the current user.

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**Table 14-266** USER_IND_PARTITIONS columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Name of the owner of the partitioned table index to which the index partition belongs |
| schema | character varying(64) | Schema of the partitioned table index to which the index partition belongs |
| index_name | character varying(64) | Name of the partitioned table index to which the index partition belongs |
| partition_name | character varying(64) | Name of the index partition |
| index_partition_usable | boolean | Whether the index partition is available |
| high_value | text | Upper limit of the partition corresponding to the index partition |
| def_tablespace_name | name | Name of the tablespace of the index partition |

## 14.3.219 USER_JOBS

**USER_JOBS** displays all jobs owned by the user.

**Table 14-267** USER_JOBS columns

| Name | Type | Description |
| --- | --- | --- |
| job | int4 | Job ID |
| log_user | name not null | User name of the job creator |
| priv_user | name not null | User name of the job executor |
| dbname | name not null | Database in which the job is created |
| start_date | timestamp without time zone | Job start time |
| start_suc | text | Start time of the successful job execution |

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| Name | Type | Description |
| --- | --- | --- |
| last_date | timestamp without time zone | Start time of the last job execution |
| last_suc | text | Start time of the last successful job execution |
| this_date | timestamp without time zone | Start time of the ongoing job execution |
| this suc | text | Same as **THIS_DATE** |
| next_date | timestamp without time zone | Schedule time of the next job execution |
| next suc | text | Same as **next_date** |
| broken | text | Task status<br>**Y**: the system does not try to execute the task.<br>**N**: the system attempts to execute the task. |
| status | char | Status of the current job. The value range is **'r', 's', 'f', 'd'**. The default value is **'s'**. The indications are as follows:<br>• **r**: running<br>• **s**: finished<br>• **f**: failed<br>• **d**: aborted |
| interval | text | Time expression used to calculate the next execution time. If this parameter is set to **null**, the job will be executed once only. |
| failures | smallint | Number of times the job has started and failed. If a job fails to be executed for 16 consecutive times, no more attempt will be made on it. |
| what | text | Body of the PL/SQL blocks or anonymous clock that the job executes |

## 14.3.220 USER_OBJECTS

**USER_OBJECTS** displays all database objects accessible to the current user.

**Table 14-268** USER_OBJECTS columns

| Name | Type | Description |
| --- | --- | --- |
| object_name | name | Object name |

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| Name | Type | Description |
| --- | --- | --- |
| object_id | oid | OID of the object |
| object_type | name | Type of the object (**TABLE**, **INDEX**, **SEQUENCE**, or **VIEW**) |
| namespace | oid | Namespace that the object belongs to |
| created | timestamp with time zone | Object creation time |
| last_ddl_time | timestamp with time zone | The last time when an object was modified. |

**NOTICE**

For details about the value ranges of **last_ddl_time** and **last_ddl_time**, see **PG_OBJECT**.

## 14.3.221 USER_PART_INDEXES

**USER_PART_INDEXES** displays information about partitioned table indexes accessible to the current user.

**Table 14-269** USER_PART_INDEXES columns

| Name | Type | Description |
| --- | --- | --- |
| index_owner | character varying(64) | Name of the owner of the partitioned table index |
| schema | character varying(64) | Schema of the partitioned table index |
| index_name | character varying(64) | Name of the partitioned table index |
| table_name | character varying(64) | Name of the partitioned table to which the partitioned table index belongs |
| partitioning_type | text | Partition policy of the partitioned table |
| partition_count | bigint | Number of index partitions of the partitioned table index |

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| Name | Type | Description |
| --- | --- | --- |
| def_tablespace_name | name | Name of the tablespace of the partitioned table index |
| partitioning_key_count | integer | Number of partition keys of the partitioned table |

## 14.3.222 USER_PART_TABLES

**USER_PART_TABLES** displays information about partitioned tables accessible to the current user.

**Table 14-270** USER_PART_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| table_owner | character varying(64) | Name of the owner of the partitioned table |
| schema | character varying(64) | Schema of the partitioned table |
| table_name | character varying(64) | Name of the partitioned table |
| partitioning_type | text | Partition policy of the partitioned table |
| partition_count | bigint | Number of partitions of the partitioned table |
| def_tablespace_name | name | Name of the tablespace of the partitioned table |
| partitioning_key_count | integer | Number of partition keys of the partitioned table |

## 14.3.223 USER_PROCEDURES

**USER_PROCEDURES** displays information about all stored procedures and functions in the current schema.

**Table 14-271** USER_PROCEDURES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the stored procedure or the function |
| object_name | character varying(64) | Name of the stored procedure or the function |

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| Name | Type | Description |
| --- | --- | --- |
| argument_number | smallint | Number of the input parameters in the stored procedure |

## 14.3.224 USER_SEQUENCES

**USER_SEQUENCES** displays sequence information in the current schema.

**Table 14-272** USER_SEQUENCES columns

| Name | Type | Description |
| --- | --- | --- |
| sequence_owner | character varying(64) | Owner of the sequence |
| sequence_name | character varying(64) | Name of the sequence |

## 14.3.225 USER_SOURCE

**USER_SOURCE** displays information about stored procedures or functions in this mode, and provides the columns defined by the stored procedures or the functions.

**Table 14-273** USER_SOURCE columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the stored procedure or the function |
| name | character varying(64) | Name of the stored procedure or the function |
| text | text | Definition of the stored procedure or the function |

## 14.3.226 USER_SYNONYMS

**USER_SYNONYMS** displays synonyms accessible to the current user.

**Table 14-274 USER_SYNONYMS** columns

| Name | Type | Description |
| --- | --- | --- |
| schema_name | text | Name of the schema to which the synonym belongs. |

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| Name | Type | Description |
| --- | --- | --- |
| synonym_name | text | Synonym name. |
| table_owner | text | Owner of the associated object. |
| table_schema_name | text | Schema name of the associated object. |
| table_name | text | Name of the associated object. |

## 14.3.227 USER_TAB_COLUMNS

**USER_TAB_COLUMNS** displays information about table columns accessible to the current user.

**Table 14-275** USER_TAB_COLUMNS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| column_name | character varying(64) | Column name |
| data_type | character varying(128) | Data type of the column |
| column_id | integer | Sequence number of the column when the table is created |
| data_length | integer | Length of the column in the unit of bytes |
| comments | text | Comments |
| avg_col_len | numeric | Average length of a column in the unit of bytes |
| nullable | bpchar | Whether the column can be empty. For the primary key constraint and non-null constraint, the value is **n**. |
| data_precision | integer | Precision of the data type. This parameter is valid for the numeric data type and **NULL** for other types. |

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| Name | Type | Description |
| --- | --- | --- |
| data_scale | integer | Number of decimal places. This parameter is valid for the numeric data type and **0** for other types. |
| char_length | numeric | Column length in the unit of bytes which is valid only for the varchar, nvarchar2, bpchar, and char types. |

## 14.3.228 USER_TAB_COMMENTS

**USER_TAB_COMMENTS** displays comments about all tables and views accessible to the current user.

**Table 14-276** USER_TAB_COMMENTS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the table or the view |
| table_name | character varying(64) | Name of the table or the view |
| comments | text | Comments |

## 14.3.229 USER_TAB_PARTITIONS

**USER_TAB_PARTITIONS** displays all table partitions accessible to the current user. Each partition of a partitioned table accessible to the current user has a piece of record in **USER_TAB_PARTITIONS**.

**Table 14-277** USER_TAB_PARTITIONS columns

| Name | Type | Description |
| --- | --- | --- |
| table_owner | character varying(64) | Name of the owner of the partitioned table |
| schema | character varying(64) | Schema of the partitioned table |
| table_name | character varying(64) | Name of the partitioned table |
| partition_name | character varying(64) | Name of the table partition |

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| Name | Type | Description |
| --- | --- | --- |
| high_value | text | Upper boundary of the table partition |
| tablespace_name | name | Name of the tablespace of the table partition |

## 14.3.230 USER_TABLES

**USER_TABLES** displays table information in the current schema.

**Table 14-278** USER_TABLES columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Table owner |
| table_name | character varying(64) | Table name |
| tablespace_name | character varying(64) | Name of the tablespace where the table is located |
| status | character varying(8) | Whether the current record is valid |
| temporary | character(1) | Whether the table is a temporary table<br>• **Y**: temporary table<br>• **N**: not a temporary table |
| dropped | character varying | Whether the current record is deleted<br>• **YES**: deleted<br>• **NO**: not deleted |
| num_rows | numeric | Estimated number of rows in the table |

## 14.3.231 USER_TRIGGERS

**USER_TRIGGERS** displays the information about triggers accessible to the current user.

**Table 14-279** USER_TRIGGERS columns

| Name | Type | Description |
| --- | --- | --- |
| trigger_name | character varying(64) | Trigger name |

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| Name | Type | Description |
| --- | --- | --- |
| table_name | character varying(64) | Name of the relationship table |
| table_owner | character varying(64) | Role name |

## 14.3.232 USER_VIEWS

**USER_VIEWS** displays information about all views in the current schema.

**Table 14-280** USER_VIEWS columns

| Name | Type | Description |
| --- | --- | --- |
| owner | character varying(64) | Owner of the view |
| view_name | character varying(64) | View name |

## 14.3.233 V$SESSION

**V$SESSION** displays all session information about the current session.

**Table 14-281** V$SESSION columns

| Name | Type | Description |
| --- | --- | --- |
| sid | bigint | OID of the background process of the current activity |
| serial# | integer | Sequence number of the active background process, which is **0** in GaussDB(DWS). |
| user# | oid | OID of the user that has logged in to the background process |
| username | name | Name of the user that has logged in to the background process |

## 14.3.234 V$SESSION_LONGOPS

**V$SESSION_LONGOPS** displays the progress of ongoing operations.

**Table 14-282** V$SESSION_LONGOPS columns

| Name | Type | Description |
| --- | --- | --- |
| sid | bigint | OID of the running background process |

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| Name | Type | Description |
| --- | --- | --- |
| serial# | integer | Sequence number of the running background process, which is **0** in GaussDB(DWS). |
| sofar | integer | Completed workload, which is empty in GaussDB(DWS). |
| totalwork | integer | Total workload, which is empty in GaussDB(DWS). |

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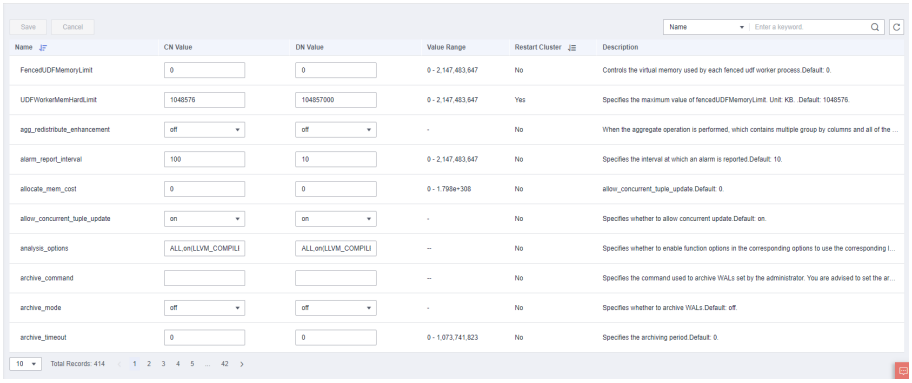
# 15 GUC Parameters

## 15.1 Viewing GUC Parameters

GaussDB(DWS) GUC parameters can control database system behaviors. You can check and adjust the GUC parameters based on your business scenario and data volume.

- After a cluster is installed, you can check common database parameters on the GaussDB(DWS) management console.




- You can also connect to a cluster and run SQL commands to check the GUC parameters.
  - Run the **SHOW** command.

    To view a certain parameter, run the following command:
    ```
    SHOW server_version;
    ```

    *server_version* indicates the database version.

    Run the following command to view all the parameters:
    ```
    SHOW ALL;
    ```
  - Use the **pg_settings** view.

    To view a certain parameter, run the following command:
    ```
    SELECT * FROM pg_settings WHERE NAME='server_version';
    ```

    Run the following command to view values of all parameters:
    ```
    SELECT * FROM pg_settings;
    ```

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# 15.2 Configuring GUC Parameters

## Context

You can configure the GUC parameters of databases, users, or sessions in GaussDB(DWS).

- Parameter names are case-insensitive.
- A parameter value can be an integer, floating point number, string, Boolean value, or enumerated value.
  - The Boolean values can be **on**/**off**, **true**/**false**, **yes**/**no**, or **1**/**0**, and are case-insensitive.
  - The enumerated value range is specified in the **enumvals** column of the **pg_settings** system catalog.
- For parameters using units, specify their units during the setting, or default units are used.
  - The default units are specified in the **unit** column of **pg_settings**.
  - The unit of memory can be KB, MB, or GB.
  - The unit of time can be ms, s, min, h, or d.
- You can set a parameter for CNs and DNs at the same time, but cannot do the same to other types of parameters.

## Setting GUC Parameters

You can configure GUC parameters in the following ways:

- Method 1: After a cluster is created, you can log in to the GaussDB(DWS) management console and modify the database parameters of the cluster. For details, see "Modifying Database Parameters" in *Data Warehouse Service (DWS) User Guide*.
- Method 2: Connect to a cluster and run SQL commands to configure the parameters of the SUSET or USERSET type.
  - SUSET parameters are database administrator parameters. They can be set by common users when or after the database is started. They can also be set by database administrators using SQL commands.
  - USERSET parameters are common user parameters. They can be configured by any user at any time.

  Configure parameters at database, user, or session levels.
  - Set a database-level parameter.
    **ALTER DATABASE** *dbname* **SET** *paraname* **TO** *value;*

    The setting takes effect in the next session.
  - Set a user-level parameter.
    **ALTER USER** *username* **SET** *paraname* **TO** *value;*

    The setting takes effect in the next session.
  - Set a session-level parameter.
    **SET** *paraname* **TO** *value;*

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Parameter value in the current session is changed. After you exit the session, the setting becomes invalid.

## Procedure

The following example shows how to set **explain_perf_mode**.

**Step 1** View the value of **explain_perf_mode**.

```
SHOW explain_perf_mode;
 explain_perf_mode
-------------------
 normal
(1 row)
```

**Step 2** Set **explain_perf_mode**.

Perform one of the following operations:

- Set a database-level parameter.
  ```
  ALTER DATABASE gaussdb SET explain_perf_mode TO pretty;
  ```
  If the following information is displayed, the setting has been modified.
  ```
  ALTER DATABASE
  ```
  The setting takes effect in the next session.
- Set a user-level parameter.
  ```
  ALTER USER dbadmin SET explain_perf_mode TO pretty;
  ```
  If the following information is displayed, the setting has been modified.
  ```
  ALTER USER
  ```
  The setting takes effect in the next session.
- Set a session-level parameter.
  ```
  SET explain_perf_mode TO pretty;
  ```
  If the following information is displayed, the setting has been modified.
  ```
  SET
  ```

**Step 3** Check whether the parameter is correctly set.

```
SHOW explain_perf_mode;
 explain_perf_mode
--------------
 pretty
(1 row)
```

**----End**

# 15.3 GUC Parameter Usage

The database provides many operation parameters. Configuration of these parameters affects the behavior of the database system. Before modifying these parameters, learn the impact of these parameters on the database. Otherwise, unexpected results may occur.

## Precautions

- If the value range of a parameter is a string, the string should comply with the naming conventions of the path and file name in the OS running the database.

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- If the allowed maximum value of a parameter is **INT_MAX**, it indicates the maximum parameter value varies by OS.
- If the allowed maximum value of a parameter is **DBL_MAX**, it indicates the maximum parameter value varies by OS.

# 15.4 Connection and Authentication

## 15.4.1 Connection Settings

This section describes parameters related to the connection mode between the client and server.

### max_connections

**Parameter description**: Specifies the maximum number of allowed parallel connections to the database. This parameter influences the concurrent processing capability of the cluster.

**Type**: POSTMASTER

**Value range**: an integer. For CNs, the ranges from 1 to 16384. For DNs, the value ranges from 1 to 262143. Because there are internal connections in the cluster, the maximum value is rarely reached. If **invalid value for parameter "max_connections"** is displayed in the log, you need to decrease the **max_connections** value for DNs.

**Default value**: **800** for CNs and **5000** for DNs. If the default value is greater than the maximum value supported by kernel (determined when the **gs_initdb** command is executed), an error message will be displayed.

**Setting suggestions**:

Retain the default value of this parameter on the CN. Set this parameter on the DN to the following calculation result: Number of CNs x Value of this parameter on the CN.

If the parameter is set to a large value, GaussDB(DWS) requires more SystemV shared memories or semaphores, which may exceed the maximum default configuration of the OS. In this case, modify the value as needed.

**NOTICE**

The value of **max_connections** is related to **max_prepared_transactions**. Before setting **max_connections**, ensure that the value of **max_prepared_transactions** is greater than or equal to that of **max_connections**. In this way, each session has a prepared transaction in the waiting state.

### sysadmin_reserved_connections

**Parameter description**: Specifies the minimum number of connections reserved for administrators.

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**Type**: POSTMASTER

**Value range**: an integer ranging from 0 to 262143

**Default value**: **3**

### application_name

**Parameter description**: Specifies the name of the client program connecting to the database.

**Type**: USERSET

**Value range**: a string

**Default value**: **gsql**

### connection_info

**Parameter description**: Specifies the database connection information, including the driver type, driver version, driver deployment path, and process owner. (This is an O&M parameter. Do not configure it by yourself.)

**Type**: USERSET

**Value range**: a string

**Default value**: an empty string

NOTE

- An empty string indicates that the driver connected to the database does not support automatic setting of the **connection_info** parameter or the parameter is not set by users in applications.
- The following is an example of the concatenated value of **connection_info**:
  ```
  {"driver_name":"ODBC","driver_version": "(GaussDB 8.1.1 build af002019) compiled at 2020-01-10 05:43:20 commit 6995 last mr 11566 debug","driver_path":"/usr/local/lib/psqlodbcw.so","os_user":"dbadmin"}
  ```
  **driver_name** and **driver_version** are displayed by default. Whether **driver_path** and **os_user** are displayed is determined by users.

## 15.4.2 Security and Authentication (postgresql.conf)

This section describes parameters about how to securely authenticate the client and server.

### authentication_timeout

**Parameter description**: Specifies the longest duration to wait before the client authentication times out. If a client is not authenticated by the server within the timeout period, the server automatically breaks the connection from the client so that the faulty client does not occupy connection resources.

**Type**: SIGHUP

**Value range**: an integer ranging from 1 to 600. The minimum unit is second (s).

**Default value**: **1min**

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## auth_iteration_count

**Parameter description**: Specifies the number of interactions during the generation of encryption information for authentication.

**Type**: SIGHUP

**Value range**: an integer ranging from 2048 to 134217728

**Default value**: **50000**

NOTICE

If this parameter is set to a large value, performance deteriorates in operations involving password encryption, such as authentication and user creation. Set this parameter to an appropriate value based on the hardware conditions.

## session_timeout

**Parameter description**: Specifies the longest duration with no operations after the connection to the server.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 86400. The minimum unit is second (s). **0** means to disable the timeout.

**Default value**: **10 min**

NOTICE

- The gsql client of GaussDB(DWS) has an automatic reconnection mechanism. If the initialized local connection of a user to the server times out, gsql disconnects from and reconnects to the server.
- Connections from the pooler connection pool to other CNs and DNs are not controlled by the **session_timeout** parameter.

## ssl

**Parameter description**: Specifies whether the SSL connection is enabled.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates that the SSL connection is enabled.
- **off** indicates that the SSL connection is not enabled.

NOTICE

GaussDB(DWS) supports the SSL connection when the client connects to CNs. It is recommended that the SSL connection be enabled only on CNs.

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**Default value**: **on**

## ssl_ciphers

**Parameter description**: Specifies the encryption algorithm list supported by the SSL.

**Type**: POSTMASTER

**Value range**: a string. Separate multiple encryption algorithms with semicolons (;).

**Default value**: **ALL**

## ssl_renegotiation_limit

**Parameter description**: Specifies the traffic volume over the SSL-encrypted channel before the session key is renegotiated. The renegotiation traffic limitation mechanism reduces the probability that attackers use the password analysis method to crack the key based on a huge amount of data but causes big performance losses. The traffic indicates the sum of sent and received traffic.

**Type**: USERSET

NOTE

You are advised to retain the default value, that is, disable the renegotiation mechanism. You are not advised to use the **gs_guc** tool or other methods to set the **ssl_renegotiation_limit** parameter in the **postgresql.conf** file. The setting does not take effect.

**Value range**: an integer ranging from 0 to **INT_MAX**. The unit is KB. **0** indicates that the renegotiation mechanism is disabled.

**Default value**: **0**

## password_policy

**Parameter description**: Specifies whether to check the password complexity when you run the **CREATE ROLE/USER** or **ALTER ROLE/USER** command to create or modify a GaussDB(DWS) account.

**Type**: SIGHUP

NOTICE

For security purposes, do not disable the password complexity policy.

**Value range**: an integer, **0** or **1**

- **0** indicates that no password complexity policy is enabled.
- **1** indicates that the default password complexity policy is disabled.

**Default value**: **1**

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## password_reuse_time

**Parameter description:** Specifies whether to check the reuse days of the new password when you run the **ALTER USER** or **ALTER ROLE** command to change a user password.

**Type**: SIGHUP

**NOTICE**

When you change the password, the system checks the values of **password_reuse_time** and **password_reuse_max**.

- If the values of **password_reuse_time** and **password_reuse_max** are both positive numbers, the password can be reused if either of the following conditions is met:
- If the value of **password_reuse_time** is **0**, the days of password reuse are not limited and only the times of password reuse are limited.
- If the value of **password_reuse_max** is **0**, the times of password reuse are not limited and only the days of password reuse are limited.
- If the values of **password_reuse_time** and **password_reuse_max** are both **0**, password reuse is not limited.

**Value range**: a floating number ranging from 0 to 3650. The unit is day.

- **0** indicates that the password reuse days are not checked.
- A positive number indicates that the new password cannot be the one that is used within the specified days.

**Default value**: **60**

## password_reuse_max

**Parameter description:** Specifies whether to check the reuse times of the new password when you run the **ALTER USER** or **ALTER ROLE** command to change a user password.

**Type**: SIGHUP

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NOTICE

When you change the password, the system checks the values of **password_reuse_time** and **password_reuse_max**.

- If the values of **password_reuse_time** and **password_reuse_max** are both positive numbers, the password can be reused if either of the following conditions is met:
- If the value of **password_reuse_time** is **0**, the days of password reuse are not limited and only the times of password reuse are limited.
- If the value of **password_reuse_max** is **0**, the times of password reuse are not limited and only the days of password reuse are limited.
- If the values of **password_reuse_time** and **password_reuse_max** are both **0**, password reuse is not limited.

**Value range**: an integer ranging from 0 to 1000

- **0** indicates that the password reuse times are not checked.
- A positive number indicates that the new password cannot be the one whose reuse times exceed the specified number.

**Default value**: **0**

## password_lock_time

**Parameter description**: Specifies the duration before an account is automatically unlocked.

**Type**: SIGHUP

NOTICE

The locking and unlocking functions take effect only when the values of **password_lock_time** and **failed_login_attempts** are positive numbers.

**Value range**: a floating number ranging from 0 to 365. The unit is day.

- **0** indicates that the automatic locking function does not take effect if the password verification fails.
- A positive number indicates the duration after which an account is automatically unlocked.

**Default value**: **1**

## failed_login_attempts

**Parameter description**: Specifies the maximum number of incorrect password attempts before an account is locked. The account will be automatically unlocked after the time specified in **password_lock_time**. For example, incorrect password attempts during login and password input failures when using the **ALTER USER** command

**Type**: SIGHUP

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**Value range**: an integer ranging from 0 to 1000

- **0** indicates that the automatic locking function does not take effect.
- A positive number indicates that an account is locked when the number of incorrect password attempts reaches the value of **failed_login_attempts**.

**Default value**: **10**

NOTICE

- The locking and unlocking functions take effect only when the values of **failed_login_attempts** and **password_lock_time** are positive numbers.
- **failed_login_attempts** works with the SSL connection mode of the client to identify the number of incorrect password attempts. If PGSSLMODE is set to **allow** or **prefer**, two connection requests are generated for a password connection request. One request attempts an SSL connection, and the other request attempts a non-SSL connection. In this case, the number of incorrect password attempts perceived by the user is the value of **failed_login_attempts** divided by 2.

## password_encryption_type

**Parameter description**: Specifies the encryption type of user passwords.

**Type**: SIGHUP

**Value range**: an integer, **0**, **1**, or **2**

- **0** indicates that passwords are encrypted in MD5 mode.
- **1** indicates that passwords are encrypted using SHA256, which is compatible with the MD5 user authentication method of the PostgreSQL client.
- **2** indicates that passwords are encrypted using SHA256.

NOTICE

- MD5 is not recommended because it is not a secure encryption algorithm.
- If the cluster is upgraded from 8.0.0 or an earlier version to the current version, the default value of this parameter is the same as that of the cluster of the earlier version. For example, the default value of **password_encryption_type** in 8.0.0 is **1**. After the cluster is upgraded from 8.0.0 to 8.1.1, the default value of **password_encryption_type** remains **1**.

**Default value**: **2**

## password_min_length

**Parameter description**: Specifies the minimum account password length.

**Type**: SIGHUP

**Value range**: an integer. A password can contain 6 to 999 characters.

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**Default value**: **8**

## password_max_length

**Parameter description**: Specifies the maximum account password length.

**Type**: SIGHUP

**Value range**: an integer. A password can contain 6 to 999 characters.

**Default value**: **32**

## password_min_uppercase

**Parameter description**: Specifies the minimum number of uppercase letters that an account password must contain.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 999.

- **0** means no limit.
- A positive integer indicates the minimum number of uppercase letters in the password specified for creating an account.

**Default value**: **0**

## password_min_lowercase

**Parameter description**: Specifies the minimum number of lowercase letters that an account password must contain.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 999.

- **0** means no limit.
- A positive integer indicates the minimum number of lowercase letters in the password specified for creating an account.

**Default value**: **0**

## password_min_digital

**Parameter description**: Specifies the minimum number of digits that an account password must contain.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 999.

- **0** means no limit.
- A positive integer indicates the minimum number of digits in the password specified for creating an account.

**Default value**: **0**

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### password_min_special

**Parameter description**: Specifies the minimum number of special characters that an account password must contain.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 999.

- **0** means no limit.
- A positive integer indicates the minimum number of special characters in the password specified for creating an account.

**Default value**: **0**

### password_effect_time

**Parameter description**: Specifies the validity period of an account password.

**Type**: SIGHUP

**Value range**: a floating number ranging from 0 to 999. The unit is day.

- **0** indicates the function of validity period restriction is disabled.
- A floating point number from 1 to 999 indicates the validity period of the password specified for creating an account. When the password is about to expire or has expired, the system prompts the user to change the password.

**Default value**: **90**

### password_notify_time

**Parameter description**: Specifies how many days in advance users are notified before the account password expires.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 999. The unit is day.

- **0** indicates the reminder is disabled.
- A positive integer indicates how long before expiry the reminder will appear.

**Default value**: **7**

## 15.4.3 Communication Library Parameters

This section describes parameter settings and value ranges for communication libraries.

### comm_tcp_mode

**Parameter description**: Specifies whether the communication library uses the TCP or SCTP protocol to set up a data channel. The modification of this parameter takes effect after the cluster is restarted.

**Type**: POSTMASTER

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**Value range**: Boolean. If this parameter is set to **on** for CNs, the CNs connect to DNs using TCP. If this parameter is set to **on** for DNs, the DNs communicate with each other using TCP.

**Default value**: **on**

## comm_sctp_port

**Parameter description**: Specifies the TCP or SCTP listening port used by the TCP proxy communication library or SCTP communication library, respectively.

**Type**: POSTMASTER

NOTICE

This port number is automatically allocated during cluster deployment. Do not change the parameter setting. If the port number is incorrectly set, the database communication fails.

**Value range**: an integer ranging from 0 to 65535

**Default value**: port + Number of primary DNs on the local host x 2 + Sequence number of the local DN on the local host

## comm_control_port

**Parameter description**: Specifies the TCP listening port used by the TCP proxy communication library or SCTP communication library, respectively.

**Type**: POSTMASTER

**Value range**: an integer ranging from 0 to 65535

**Default value**: port + Number of primary DNs on the local host x 2 + Sequence number of the local DN on the local host + 1

NOTICE

This port number is automatically allocated during cluster deployment. Do not change the parameter setting. If the port number is incorrectly set, the database communication fails.

## comm_max_datanode

**Parameter description**: Specifies the maximum number of DNs supported by the TCP proxy communication library or SCTP communication library.

**Type**: USERSET

**Value range**: an integer ranging from 1 to 8192

**Default value**: actual number of DNs

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## comm_max_stream

**Parameter description**: Specifies the maximum number of concurrent data streams supported by the TCP proxy communication library or SCTP communication library. The value of this parameter must be greater than: Number of concurrent data streams x Number of operators in each stream x Square of SMP.

**Type**: POSTMASTER

**Value range**: an integer ranging from 1 to 60000

**Default value**: calculated by the following formula: min (query_dop_limit x query_dop_limit x 2 x 20, max_process_memory (bytes) x 0.005/(Maximum number of CNs + Number of current DNs)/260. If the value is less than 1024, 1024 is used. query_dop_limit = Number of CPU cores of a single server/Number of DNs of a single server.

NOTE

- You are not advised to set this parameter to a large value because this will cause high memory usage (256 bytes x **comm_max_stream** x **comm_max_datanode**). If the number of concurrent data streams is large, the query is complex and the smp is large, resulting in insufficient memory.
- If the value of **comm_max_datanode** is small, the process memory is sufficient. In this case, you can increase the value of **comm_max_stream**.

## comm_max_receiver

**Parameter description**: Specifies the maximum number of receiving threads for the TCP proxy communication library or SCTP communication library.

**Type**: POSTMASTER

**Value range**: an integer ranging from 1 to 50

**Default value**: 4

## comm_quota_size

**Parameter description**: Specifies the maximum size of packets that can be consecutively sent by the TCP proxy communication library or SCTP communication library. When you use a 1GE NIC, a small value ranging from 20 KB to 40 KB is recommended.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 102400. The default unit is KB. The value **0** indicates that the quota mechanism is not used.

**Default value**: **1MB**

## comm_usable_memory

**Parameter description**: Specifies the maximum memory available for buffering on the TCP proxy communication library or SCTP communication library on a single DN.

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**Type**: POSTMASTER

**Value range**: an integer ranging from 102400 to **INT_MAX/2**. The default unit is KB. The minimum size cannot be less than 1 GB for installation.

**Default value**: **max_process_memory/8**

NOTICE

This parameter must be specifically set based on environment memory and the deployment method. If it is too large, there may be out-of-memory (OOM). If it is too small, the performance of the TCP proxy communication library or SCTP communication library may deteriorate.

## comm_memory_pool_percent

**Parameter description**: Specifies the percentage of the memory pool resources that can be used by the TCP proxy communication library or the SCTP communication library in a DN. This parameter is used to adaptively reserve memory used by the communication libraries.

**Type**: POSTMASTER

**Value range**: an integer ranging from 0 to 100

**Default value**: **0**

NOTICE

If the memory used by the communication library is small, set this parameter to a small value. Otherwise, set it to a large value.

## comm_client_bind

**Parameter description**: Specifies whether to bind the client of the communication library to a specified IP address when the client initiates a connection.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the client is bound to a specified IP address.
- **off** indicates that the client is not bound to any IP addresses.

NOTICE

If multiple IP addresses of a node in a cluster are on the same communication network segment, set this parameter to **on**. In this case, the client is bound to the IP address specified by **listen_addresses**. The concurrency performance of a cluster depends on the number of random ports because a port can be used only by one client at a time.

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**Default value**: **off**

## comm_no_delay

**Parameter description**: Specifies whether to use the **NO_DELAY** attribute of the communication library connection. Restart the cluster for the setting to take effect.

**Type**: USERSET

**Value range**: Boolean

**Default value: off**

NOTICE

If packet loss occurs because a large number of packets are received per second, set this parameter to **off** to reduce the total number of packets.

## comm_debug_mode

**Parameter description**: Specifies the debug mode of the TCP proxy communication library or SCTP communication library, that is, whether to print logs about the communication layer. The setting is effective at the session layer.

NOTICE

When the switch is set to **on**, the number of printed logs is huge, adding extra overhead and reducing database performance. Therefore, set the switch to **on** only in the debug mode.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the detailed debug log of the communication library is printed.
- **off** indicates the detailed debug log of the communication library is not printed.

**Default value**: **off**

## comm_ackchk_time

**Parameter description**: Specifies the duration after which the communication library server automatically triggers ACK when no data package is received.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 20000. The unit is millisecond (ms). **0** indicates that automatic ACK triggering is disabled.

**Default value**: **2000**

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## comm_timer_mode

**Parameter description**: Specifies the timer mode of the TCP proxy communication library or SCTP communication library, that is, whether to print timer logs in each phase of the communication layer. The setting is effective at the session layer.

NOTICE

When the switch is set to **on**, the number of printed logs is huge, adding extra overhead and reducing database performance. Therefore, set the switch to **on** only in the debug mode.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the detailed timer log of the communication library is printed.
- **off** indicates the detailed timer log of the communication library is not printed.

**Default value**: **off**

## comm_stat_mode

**Parameter description**: Specifies the statistics mode of the TCP proxy communication library or SCTP communication library, that is, whether to print statistics about the communication layer. The setting is effective at the session layer.

NOTICE

When the switch is set to **on**, the number of printed logs is huge, adding extra overhead and reducing database performance. Therefore, set the switch to **on** only in the debug mode.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the statistics log of the communication library is printed.
- **off** indicates the statistics log of the communication library is not printed.

**Default value: off**

## enable_stateless_pooler_reuse

**Parameter description**: Specifies whether to enable the pooler reuse mode. The setting takes effect after the cluster is restarted.

**Type**: POSTMASTER

**Value range**: Boolean

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- **on** or **true** indicates that the pooler reuse mode is enabled.
- **off** or **false** indicates that the pooler reuse mode is disabled.

NOTICE

Set this parameter to the same value for CNs and DNs. If **enable_stateless_pooler_reuse** is set to **off** for CNs and set to **on** for DNs, the cluster communication fails. Restart the cluster to make the setting take effect.

**Default value**: **off**

### comm_cn_dn_logic_conn

**Parameter description**: Specifies a switch for logical connections between CNs and DNs. The parameter setting takes effect only after the cluster is restarted.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** or **true** indicates that the connections between CNs and DNs are logical, with the libcomm component in use.
- **off** or **false** indicates that the connections between CNs and DNs are physical, with the libpq component in use.

NOTICE

If **comm_cn_dn_logic_conn** is set to **off** for CNs and set to **on** for DNs, cluster communication will fail. You are advised to set this parameter to the same value for all CNs and DNs. Restart the cluster to make the setting take effect.

**Default value: off**

## 15.5 Resource Consumption

### 15.5.1 Memory

This section describes memory parameters.

NOTICE

Parameters described in this section take effect only after the database service restarts.

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## enable_memory_limit

**Parameter description**: Specifies whether to enable the logical memory management module.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates the logic memory management module is enabled.
- **off** indicates the logic memory management module is disabled.

**Default value**: **on**

NOTICE

If the result of **max_process_memory** - **shared_buffer** - **cstore_buffers** is less than 2 GB, GaussDB(DWS) forcibly sets **enable_memory_limit** to **off**.

## max_process_memory

**Parameter description**: Specifies the maximum physical memory of a database node.

**Type**: POSTMASTER

**Value range**: an integer ranging from 2 x 1024 x 1024 to INT_MAX/2. The unit is KB.

**Default value**: The value is automatically adapted by non-secondary DNs. The formula is (Physical memory size) x 0.6/(1 + Number of primary DNs). If the result is less than 2 GB, 2 GB is used by default. The default size of the secondary DN is 12 GB.

**Setting suggestions:**

On DNs, the value of this parameter is determined based on the physical system memory and the number of DNs deployed on a single node. Parameter value = (Physical memory – **vm.min_free_kbytes**) x 0.7/(n + Number of primary DNs). This parameter aims to ensure system reliability, preventing node OOM caused by increasing memory usage. **vm.min_free_kbytes** indicates OS memory reserved for kernels to receive and send data. Its value is at least 5% of the total memory. That is, **max_process_memory** = Physical memory x 0.665/(n + Number of primary DNs). If the cluster scale (number of nodes in the cluster) is smaller than 256, n=1; if the cluster scale is larger than 256 and smaller than 512, n=2; if the cluster scale is larger than 512, n=3.

Set this parameter on CNs to the same value as that on DNs.

RAM is the maximum memory allocated to the cluster.

## shared_buffers

**Parameter description**: Specifies the size of shared memory used by GaussDB(DWS). If this parameter is set to a large value, GaussDB(DWS) may require more System V shared memory than the default setting.

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**Type**: POSTMASTER

**Value range**: an integer ranging from 128 to INT_MAX. The unit is 8 KB.

Changing the value of **BLCKSZ** will result in a change in the minimum value of the **shared_buffers**.

**Default value**: **512 MB** for CNs and **1 GB** for DNs. If the maximum value allowed by the OS is smaller than 32 MB, this parameter will be automatically changed to the maximum value allowed by the OS during database initialization.

**Setting suggestions:**

Set this parameter for DNs to a value greater than that for CNs, because GaussDB(DWS) pushes most of its queries down to DNs.

It is recommended that **shared_buffers** be set to a value less than 40% of the memory. Set it to a large value for row-store tables and a small value for column-store tables. For column-store tables: shared_buffers = (Memory of a single server/ Number of DNs on the single server) x 0.4 x 0.25

If you want to increase the value of **shared_buffers**, you also need to increase the value of **checkpoint_segments**, because a longer period of time is required to write a large amount of new or changed data.

## bulk_write_ring_size

**Parameter description**: Specifies the size of the ring buffer used for data parallel import.

**Type**: USERSET

**Value range**: an integer ranging from 16384 to INT_MAX. The unit is KB.

**Default value**: **2 GB**

**Setting suggestions**: Increase the value of this parameter on DNs if a large amount of data is to be imported.

## temp_buffers

**Parameter description**: Specifies the maximum size of local temporary buffers used by each database session.

**Type**: USERSET

**Value range**: an integer ranging from 800 to INT_MAX/2. The unit is KB.

**Default value**: **8 MB**

NOTE

- This parameter can be modified only before the first use of temporary tables within each session. Subsequent attempts to change the value of this parameter will not take effect on that session.
- Based on the value of **temp_buffers**, a session allocates temporary buffers as required. The cost of setting a large value in sessions that do not require many temporary buffers is only a buffer descriptor. If a buffer is used, 8192 bytes will be consumed for it.

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## max_prepared_transactions

**Parameter description**: Specifies the maximum number of transactions that can stay in the **prepared** state simultaneously. If this parameter is set to a large value, GaussDB(DWS) may require more System V shared memory than the default setting.

When GaussDB(DWS) is deployed as an HA system, set this parameter on the standby server to the same value or a value greater than that on the primary server. Otherwise, queries will fail on the standby server.

**Type**: POSTMASTER

**Value range**: an integer ranging from 0 to 536870911. **800** indicates that the prepared transaction feature is disabled.

**Default value**: **800**

NOTE

Set this parameter to a value greater than or equal to that of **max_connections** to avoid failures in preparation.

## work_mem

**Parameter description**: Specifies the memory used for internal sort operations and hash tables before data is written into temporary disk files. Sort operations are used for **ORDER BY**, **DISTINCT**, and merge joins. Hash tables are required for Hash joins as well as Hash-based aggregations and **IN** subqueries.

For a complex query, several sort or Hash operations may be running in parallel; each operation will be allowed to use as much memory as this value specifies. If the memory is insufficient, data is written into temporary files. In addition, several running sessions could be performing such operations concurrently. Therefore, the total memory used may be many times the value of **work_mem**.

**Type**: USERSET

**Value range**: an integer ranging from 64 to INT_MAX. The unit is KB.

**Default value**: **64 MB**

**Setting suggestions**:

If the physical memory specified by **work_mem** is insufficient, additional operator calculation data will be written into temporary tables based on query characteristics and the degree of parallelism. This reduces performance by five to ten times, and prolongs the query response time from seconds to minutes.

- In complex serial query scenarios, each query requires five to ten associated operations. Set **work_mem** using the following formula: **work_mem** = 50% of the memory/10.
- In simple serial query scenarios, each query requires two to five associated operations. Set **work_mem** using the following formula: **work_mem** = 50% of the memory/5.
- For concurrent queries, use the formula: **work_mem** = **work_mem** in serialized scenario/Number of concurrent SQL statements.

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## query_mem

**Parameter description**: Specifies the memory used by query. If the value of **query_mem** is greater than 0, the optimizer adjusts the estimated query memory to this value when generating an execution plan.

**Type**: USERSET

**Value range**: 0 or an integer greater than 32. The default unit is KB. If the value is set to a negative value or less than 32 MB, the default value **0** is used. In this case, the optimizer does not adjust the estimated query memory.

**Default value**: **0**

## query_max_mem

**Parameter description**: Specifies the maximum memory that can be used by query. If the value of **query_max_mem** is greater than 0, an error is reported when the query memory usage exceeds the value.

**Type**: USERSET

**Value range**: 0 or an integer greater than 32 MB. The default unit is KB. If the value is set to a negative value or less than 32 MB, the default value **0** is used. In this case, the optimizer does not limit the query memory.

**Default value**: **0**

## maintenance_work_mem

**Parameter description:** Specifies the maximum size of memory to be used for maintenance operations, such as **VACUUM**, **CREATE INDEX**, and **ALTER TABLE ADD FOREIGN KEY**. This parameter may affect the execution efficiency of **VACUUM**, **VACUUM FULL**, **CLUSTER**, and **CREATE INDEX**.

**Type**: USERSET

**Value range**: an integer ranging from 1024 to INT_MAX. The unit is KB.

**Default value**: **128 MB**

**Setting suggestions**:

- The value of this parameter must be greater than that of **work_mem** so database dump files can be more quickly cleared or restored. In a database session, only one maintenance operation can be performed at a time. Maintenance is usually performed when there are not much sessions.
- When the **Automatic Cleanup** process is running, up to **autovacuum_max_workers** times of this memory may be allocated. Set **maintenance_work_mem** to a value equal to or larger than the value of **work_mem**.
- If a large amount of data needs to be processed in the cluster, increase the value of this parameter in sessions.

## psort_work_mem

**Parameter description**: Specifies the memory used for internal sort operations on column-store tables before data is written into temporary disk files. This

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parameter can be used for inserting tables with a partial cluster key or index, creating a table index, and deleting or updating a table.

**Type**: USERSET

NOTICE

Multiple running sessions may perform partial sorting on a table at the same time. Therefore, the total memory usage may be several times of the **psort_work_mem** value.

**Value range**: an integer ranging from 64 to INT_MAX. The unit is KB.

**Default value**: **512 MB**

## max_loaded_cudesc

**Parameter description**: Specifies the number of loaded CuDescs per column when a column-store table is scanned. Increasing the value will improve the query performance and increase the memory usage, particularly when there are many columns in the column tables.

**Type**: USERSET

**Value range**: an integer ranging from 100 to INT_MAX/2

**Default value**: **1024**

NOTICE

When the value of **max_loaded_cudesc** is set to a large value, the memory may be insufficient.

## max_stack_depth

**Parameter description**: Specifies the maximum safe depth of GaussDB(DWS) execution stack. The safety margin is required because the stack depth is not checked in every routine in the server, but only in key potentially-recursive routines, such as expression evaluation.

**Type**: SUSET

**Configuration principles**:

- The ideal value of this parameter is the maximum stack size enforced by the kernel (value of **ulimit -s**).
- If this parameter is set to a value greater than the actual kernel limit, a running recursive function may crash an individual backend process. In an OS where GaussDB(DWS) can check the kernel limit, such as the SLES, GaussDB(DWS) will prevent this parameter from being set to a value greater than the kernel limit.
- Since not all the OSs provide this function, you are advised to set this parameter to a specific value.

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**Value range**: an integer ranging from 100 to INT_MAX. The unit is KB.

**Default value**: **2 MB**

NOTE

**2 MB** is a small value and will not incur system breakdown in general, but may lead to execution failures of complex functions.

## cstore_buffers

**Parameter description**: Specifies the size of the shared buffer used by ORC, Parquet, or CarbonData data of column-store tables and OBS or HDFS column-store foreign tables.

**Type**: POSTMASTER

**Value range**: an integer ranging from 16384 to INT_MAX. The unit is KB.

**Default value**: **32 MB**

**Setting suggestions**:

Column-store tables use the shared buffer specified by **cstore_buffers** instead of that specified by **shared_buffers**. When column-store tables are mainly used, reduce the value of **shared_buffers** and increase that of **cstore_buffers**.

Use **cstore_buffers** to specify the cache of ORC, Parquet, or CarbonData metadata and data for OBS or HDFS foreign tables. The metadata cache size should be 1/4 of **cstore_buffers** and not exceed 2 GB. The remaining cache is shared by column-store data and foreign table column-store data.

## enable_orc_cache

**Parameter description**: Specifies whether to reserve 1/4 of **cstore_buffers** for storing ORC metadata when the cstore buffer is initialized.

**Type**: POSTMASTER

**Value range**: Boolean

**Default value**: **on**

- **on** indicates that the ORC metadata is cached, which improves the query performance of the HDFS table but occupies the column-store buffer resources. As a result, the column-store performance is compromised.
- **off** indicates that the ORC metadata is not cached.

## schedule_splits_threshold

**Parameter description**: Specifies the maximum number of files that can be stored in memory when you schedule an HDFS foreign table. If the number is exceeded, all files in the list will be spilled to disk for scheduling.

**Type**: USERSET

**Value range**: an integer ranging from 1 to INT_MAX

**Default value**: **60000**

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### bulk_read_ring_size

**Parameter description**: Specifies the size of the ring buffer used for data parallel export.

**Type**: USERSET

**Value range**: an integer ranging from 256 to INT_MAX. The unit is KB.

**Default value**: **16 MB**

### check_cu_size_threshold

**Parameter description**: If the amount of data inserted to a CU is greater than the value of this parameter when data is inserted to a column-store table, the system starts row-level size verification to prevent the generation of a CU whose size is greater than 1 GB (non-compressed size).

**Type**: USERSET

**Value range**: an integer ranging from 0 to 1024. The unit is MB.

**Default value**: **1024 MB**

## 15.5.2 Disk Space

This section describes the disk space parameter, which is used to set a limit on the disk space for storing files flushed to the disk.

### sql_use_spacelimit

**Parameter description**: Specifies the space size for files to be flushed to disks when a single SQL statement is executed on a single DN. The managed space includes the space occupied by ordinary tables, temporary tables, and intermediate result sets to be flushed to disks.

**Type**: USERSET

**Value range**: an integer ranging from -1 to INT_MAX. The unit is KB. **–1** indicates no limit.

**Default value**: **–1**

### bi_page_reuse_factor

**Parameter description**: Specifies the percentage of idle space of old pages that can be reused when page replication is used for data synchronization between primary and standby DNs in the scenario where data is inserted into row-store tables in batches.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 100. The value is a percentage. Value **0** indicates that the old pages are not reused and new pages are requested.

**Default value**: **70**

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NOTICE

- In an upgrade, the default value of this parameter is the same as that in the cluster before the upgrade. In a newly installed 8.1.1.500 cluster, the default value of this parameter is **0**.
- You are not advised to set this parameter to a value less than **50** (except **0**). If the idle space of the reused page is small, too much old page data will be transmitted between the primary and standby DNs. As a result, the batch insertion performance deteriorates.
- You are not advised to set this parameter to a value greater than **90**. If this parameter is set to a value greater than **90**, idle pages will be frequently queried, but old pages cannot be reused.

### temp_file_limit

**Parameter description**: Specifies the size of a single file spilled to disk if splitting is triggered in a session. The temporary file can be the one used by sorting or hash tables, or cursors in a session.

This is a session-level setting.

**Type**: SUSET

**Value range**: an integer ranging from -1 to INT_MAX. The unit is KB. **–1** indicates no limit.

**Default value**: **–1**

NOTICE

This parameter does not apply to disk space occupied by temporary tablespaces used for executing SQL queries.

## 15.5.3 Kernel Resources

This section describes kernel resource parameters. Whether these parameters take effect depends on OS settings.

### max_files_per_process

**Parameter description**: Specifies the maximum number of simultaneously open files allowed by each server process. If the kernel is enforcing a proper limit, setting this parameter is not required.

But on some platforms, especially on most BSD systems, the kernel allows independent processes to open far more files than the system can really support. If the message "Too many open files" is displayed, try to reduce the setting. Generally, the number of file descriptors must be greater than or equal to the maximum number of concurrent tasks multiplied by the number of primary DNs on the current physical machine (*max_files_per_process*3).

**Type**: POSTMASTER

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**Value range**: an integer ranging from 25 to INT_MAX

**Default value**: **1000**

## 15.5.4 Cost-based Vacuum Delay

This feature allows administrators to reduce the I/O impact of the **VACUUM** and **ANALYZE** statements on concurrent database activities. It is often more important to prevent maintenance statements, such as **VACUUM** and **ANALYZE**, from affecting other database operations than to run them quickly. Cost-based vacuum delay provides a way for administrators to achieve this purpose.

NOTICE

Certain operations hold critical locks and should be complete as quickly as possible. In GaussDB(DWS), cost-based vacuum delays do not take effect during such operations. To avoid uselessly long delays in such cases, the actual delay is calculated as follows and is the maximum value of the following calculation results:

- vacuum_cost_delay*accumulated_balance/vacuum_cost_limit
- vacuum_cost_delay*4

### Context

During the execution of the ANALYZE | ANALYSE and VACUUM statements, the system maintains an internal counter that keeps track of the estimated cost of the various I/O operations that are performed. When the accumulated cost reaches a limit (specified by **vacuum_cost_limit**), the process performing the operation will sleep for a short period of time (specified by **vacuum_cost_delay**). Then, the counter resets and the operation continues.

By default, this feature is disabled. To enable this feature, set **vacuum_cost_delay** to a value other than 0.

### vacuum_cost_delay

**Parameter description**: Specifies the length of time that the process will sleep when **vacuum_cost_limit** has been exceeded.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 100. The unit is millisecond (ms). A positive number enables cost-based vacuum delay and **0** disables cost-based vacuum delay.

**Default value**: **0**

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NOTICE

- On many systems, the effective resolution of sleep length is 10 ms. Therefore, setting this parameter to a value that is not a multiple of 10 has the same effect as setting it to the next higher multiple of 10.
- This parameter is set to a small value, such as 10 or 20 milliseconds. Adjusting vacuum's resource consumption is best done by changing other parameters.

## vacuum_cost_page_hit

**Parameter description:** Specifies the estimated cost for vacuuming a buffer found in the shared buffer. It represents the cost to lock the buffer pool, look up the shared Hash table, and scan the page.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 10000. The unit is millisecond (ms).

**Default value**: **1**

## vacuum_cost_page_miss

**Parameter description:** Specifies the estimated cost for vacuuming a buffer read from the disk. It represents the cost to lock the buffer pool, look up the shared Hash table, read the desired block from the disk, and scan the block.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 10000. The unit is millisecond (ms).

**Default value**: **10**

## vacuum_cost_page_dirty

**Parameter description:** Specifies the estimated cost charged when vacuum modifies a block that was previously clean. It represents the I/Os required to flush the dirty block out to disk again.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 10000. The unit is millisecond (ms).

**Default value**: **20**

## vacuum_cost_limit

**Parameter description:** Specifies the cost limit. The cleanup process will sleep if this limit is exceeded.

**Type**: USERSET

**Value range**: an integer ranging from 1 to 10000. The unit is ms.

**Default value: 200**

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# 15.5.5 Asynchronous I/O Operations

## enable_adio_debug

**Parameter description**: Specifies whether O&M personnel are allowed to generate some ADIO logs to locate ADIO issues. This parameter is used only by developers. Common users are advised not to use it.

**Type**: SUSET

**Value range**: Boolean

- **on** or **true** indicates the log switch is enabled.
- **off** or **false** indicates the log switch is disabled.

**Default value**: **off**

## enable_fast_allocate

**Parameter description**: Specifies whether the quick allocation switch of the disk space is enabled. This switch can be enabled only in the XFS file system.

**Type**: SUSET

**Value range**: Boolean

- **on** or **true** indicates that this function is enabled.
- **off** or **false** indicates that the function is disabled.

**Default value**: **off**

## prefetch_quantity

**Parameter description**: Specifies the number of row-store prefetches using the ADIO.

**Type**: USERSET

**Value range**: an integer ranging from 1024 to 1048576. The unit is 8 KB.

**Default value**: **32 MB**

## backwrite_quantity

**Parameter description**: Specifies the number of row-store writes using the ADIO.

**Type**: USERSET

**Value range**: an integer ranging from 1024 to 1048576. The unit is 8 KB.

**Default value**: **8MB**

## cstore_prefetch_quantity

**Parameter description**: Specifies the number of column-store prefetches using the ADIO.

**Type**: USERSET

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**Value range**: an integer. The value range is from 1024 to 1048576 and the unit is KB.

**Default value**: **32 MB**

## cstore_backwrite_quantity

**Parameter description**: Specifies the number of column-store writes using the ADIO.

**Type**: USERSET

**Value range**: an integer. The value range is from 1024 to 1048576 and the unit is KB.

**Default value**: **8MB**

## cstore_backwrite_max_threshold

**Parameter description**: Specifies the maximum number of column-store writes buffered in the database using the ADIO.

**Type**: USERSET

**Value range**: An integer. The value range is from 4096 to INT_MAX/2 and the unit is KB.

**Default value**: **2 GB**

## fast_extend_file_size

**Parameter description**: Specifies the disk size that the row-store pre-scales using the ADIO.

**Type**: SUSET

**Value range**: an integer. The value range is from 1024 to 1048576 and the unit is KB.

**Default value**: **8MB**

## effective_io_concurrency

**Parameter description**: Specifies the number of requests that can be simultaneously processed by the disk subsystem. For the RAID array, the parameter value must be the number of disk drive spindles in the array.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 1000

**Default value**: **1**

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# 15.6 Parallel Data Import

GaussDB(DWS) provides a parallel data import function that enables a large amount of data to be imported in a fast and efficient manner. This section describes parameters for importing data in parallel in GaussDB(DWS).

## raise_errors_if_no_files

**Parameter description**: Specifies whether distinguish between the problems "the number of imported file records is empty" and "the imported file does not exist". If this parameter is set to **true** and the problem "the imported file does not exist" occurs, GaussDB(DWS) will report the error message "file does not exist".

**Type**: SUSET

**Value range**: Boolean

- **on** indicates the messages of "the number of imported file records is empty" and "the imported file does not exist" are distinguished when files are imported.
- **off** indicates the messages of "the number of imported file records is empty" and "the imported file does not exist" are not distinguished when files are imported.

**Default value**: **off**

## partition_mem_batch

**Parameter description**: To optimize the inserting of column-store partitioned tables in batches, data is cached during the inserting process and then written to the disk in batches. You can use **partition_mem_batch** to specify the number of buffers. If the value is too large, much memory will be consumed. If it is too small, the performance of inserting column-store partitioned tables in batches will deteriorate.

**Type**: USERSET

**Value range**: 1 to 65535

**Default value**: **256**

## partition_max_cache_size

**Parameter description**: To optimize the inserting of column-store partitioned tables in batches, data is cached during the inserting process and then written to the disk in batches. You can use **partition_max_cache_size** to specify the size of the data buffer. If the value is too large, much memory will be consumed. If it is too small, the performance of inserting column-store partitioned tables in batches will deteriorate.

**Type**: USERSET

**Value range**: 4096 to INT_MAX/2. The minimum unit is KB.

**Default value**: **2 GB**

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### gds_debug_mod

**Parameter description**: Specifies whether to enable the debug function of Gauss Data Service (GDS). This parameter is used to better locate and analyze GDS faults. After the debug function is enabled, types of packets received or sent by GDS, peer end of GDS during command interaction, and other interaction information about GDS are written into the logs of corresponding nodes. In this way, state switching on the GaussDB state machine and the current state are recorded. If this function is enabled, additional log I/O resources will be consumed, affecting log performance and validity. You are advised to enable this function only when locating GDS faults.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the GDS debug function is enabled.
- **off** indicates that the GDS debug function is disabled.

**Default value**: **off**

### enable_delta_store

**Parameter description**: This parameter has been discarded. You can set this parameter to **on** for forward compatibility, but the setting will not take effect.

For details about how to enable the delta table function of column-store tables, see the table-level parameter **enable_delta** in "CREATE TABLE" in the *SQL Syntax*.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates that the delta table function of column-store tables is enabled.
- **off** indicates that the delta table function of column-store tables is disabled.

**Default value**: **off**

# 15.7 Write Ahead Logs

## 15.7.1 Settings

### wal_level

**Parameter description:** Specifies the level of the information that is written to WALs.

**Type**: POSTMASTER

**Value range**: enumerated values

- minimal

  Advantages: Certain bulk operations (including creating tables and indexes, executing cluster operations, and copying tables) are safely skipped in logging, which can make those operations much faster.

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Disadvantages: WALs only contain basic information required for the recovery from a database server crash or an emergency shutdown. Archived WALs cannot be used to restore data.

- archive

  Adds logging required for WAL archiving, supporting the database restoration from archives.

- hot_standby
  - Further adds information required to run SQL queries on a standby server and takes effect after a server restart.
  - To enable read-only queries on a standby server, the **wal_level** parameter must be set to **hot_standby** on the primary server and the same value must be set on the standby server. There is little measurable difference in performance between using **hot_standby** and **archive** levels, so feedback is welcome if any production performance impacts are noticeable.

**Default value**: **hot_standby**

**NOTICE**

- To enable WAL archiving and data streaming replication between primary and standby servers, set this parameter to **archive** or **hot_standby**.
- If this parameter is set to **archive**, **hot_standby** must be set to **off**. Otherwise, the database startup fails.

## synchronous_commit

**Parameter description**: Specifies the synchronization mode of the current transaction.

**Type**: USERSET

**Value range**: enumerated values

- **on** indicates synchronization logs of a standby server are flushed to disks.
- **off** indicates asynchronous commit.
- **local** indicates local commit.
- **remote_write** indicates synchronization logs of a standby server are written to disks.
- **remote_receive** indicates synchronization logs of a standby server are required to receive data.

**Default value**: **on**

## wal_buffers

**Parameter description**: Specifies the number of XLOG_BLCKSZs used for storing WAL data. The size of each XLOG_BLCKSZ is 8 KB.

**Type**: POSTMASTER

**Value range**: -1 to $2^{18}$. The unit is 8 KB.

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- If this parameter is set to **-1**, the value of **wal_buffers** is automatically changed to 1/32 of **shared_buffers**. The minimum value is 8 x **XLOG_BLCKSZ**, and the maximum value is 2048 x **XLOG_BLCKSZ**.
- If it is set to a value smaller than **8**, the value **8** is used. If it is set to a value greater than 2048, the value **2048** is used.

**Default value**: **16 MB**

**Setting suggestions**: The content of WAL buffers is written to disks at each transaction commit, and setting this parameter to a large value does not significantly improve system performance. Setting this parameter to hundreds of megabytes can improve the disk writing performance on the server, to which a large number of transactions are committed. Based on experiences, the default value meets user requirements in most cases.

## commit_delay

**Parameter description**: Specifies the duration of committed data be stored in the WAL buffer.

**Type**: USERSET

**Value range**: an integer, ranging from 0 to 100000 (unit: μs). **0** indicates no delay.

**Default value**: **0**

NOTICE

- When this parameter is set to a value other than 0, the committed transaction is stored in the WAL buffer instead of being written to the WAL immediately. Then, the WALwriter process flushes the buffer out to disks periodically.
- If system load is high, other transactions are probably ready to be committed within the delay. If no transactions are waiting to be submitted, the delay is a waste of time.

## commit_siblings

**Parameter description**: Specifies a limit on the number of ongoing transactions. If the number of ongoing transactions is greater than the limit, a new transaction will wait for the period of time specified by **commit_delay** before it is submitted. If the number of ongoing transactions is less than the limit, the new transaction is immediately written into a WAL.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 1000

**Default value**: **5**

## enable_xlog_group_insert

**Parameter description**: Specifies whether to enable the group insertion mode for WALs. Only the Kunpeng architecture supports this parameter.

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**Type**: SIGHUP

**Value range**: Boolean

- **on**: enabled
- **off**: disabled

**Default value**: **on**

## wal_compression

**Parameter description**: Specifies whether to compress FPI pages.

**Type**: USERSET

**Value range**: Boolean

- **on**: enable the compression
- **off**: disable the compression

**Default value**: **off**

NOTICE

- Only zlib compression algorithm is supported.
- For clusters that are upgraded to the current version from an earlier version, this parameter is set to **off** by default. You can run the **gs_guc** command to enable the FPI compression function if needed.
- If the current version is a newly installed version, this parameter is set to **on** by default.
- If this parameter is manually enabled for a cluster upgraded from an earlier version, the cluster cannot be rolled back.

## wal_compression_level

**Parameter description**: Specifies the compression level of zlib compression algorithm when the **wal_compression** parameter is enabled.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 9.

- **0** indicates no compression.
- **1** indicates the lowest compression ratio.
- **9** indicates the highest compression ratio.

**Default value**: **9**

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# 15.7.2 Checkpoints

## checkpoint_segments

**Parameter description**: Specifies the minimum number of WAL segment files in the period specified by **checkpoint_timeout**. The size of each log file is 16 MB.

**Type**: SIGHUP

**Value range**: an integer. The minimum value is **1**.

**Default value**: **64**

NOTICE

Increasing the value of this parameter speeds up the export of big data. Set this parameter based on **checkpoint_timeout** and **shared_buffers**. This parameter affects the number of WAL log segment files that can be reused. Generally, the maximum number of reused files in the **pg_xlog** folder is twice the number of checkpoint segments. The reused files are not deleted and are renamed to the WAL log segment files which will be later used.

## checkpoint_timeout

**Parameter description**: Specifies the maximum time between automatic WAL checkpoints.

**Type**: SIGHUP

**Value range:** an integer ranging from 30 to 3600 (s)

**Default value**: **15min**

NOTICE

If the value of **checkpoint_segments** is increased, you need to increase the value of this parameter. The increase of them further requires the increase of **shared_buffers**. Consider all these parameters during setting.

## checkpoint_completion_target

**Parameter description**: Specifies the target of checkpoint completion, as a fraction of total time between checkpoints.

**Type**: SIGHUP

**Value range**: 0.0 to 1.0. The default value 0.5 indicates that each checkpoint must be completed within 50% of the checkpoint interval.

**Default value**: **0.5**

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### checkpoint_warning

**Parameter description**: Specifies a time in seconds. If the checkpoint interval is close to this time due to filling of checkpoint segment files, a message is sent to the server log to increase the value of **checkpoint_segments**.

**Type**: SIGHUP

**Value range**: an integer (unit: s). **0** indicates that warning is disabled.

**Default value**: **5min**

**Recommended value**: **5min**

### checkpoint_wait_timeout

**Parameter description**: Specifies the longest time that the checkpoint waits for the checkpointer thread to start.

**Type**: SIGHUP

**Value range**: an integer ranging from 2 to 3600 (s)

**Default value**: **1min**

## 15.7.3 Archiving

### archive_mode

**Parameter description**: When **archive_mode** is enabled, completed WAL segments are sent to archive storage by setting **archive_command**.

**Type**: SIGHUP

**Value range**: Boolean

- **on**: The archiving is enabled.
- **off**: The archiving is disabled.

**Default value**: **off**

NOTICE

When **wal_level** is set to **minimal**, **archive_mode** cannot be used.

### archive_command

**Parameter description**: Specifies the command used to archive WALs set by the administrator. You are advised to set the archive log path to an absolute path.

**Type**: SIGHUP

**Value range**: a string

**Default value**: **(disabled)**

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NOTICE

- Any **%p** in the string is replaced with the absolute path of the file to archive, and any **%f** is replaced with only the file name. (The relative path is relative to the data directory.) Use **%%** to embed an actual **%** character in the command.
- This command returns zero only if it succeeds. Example:

```
archive_command = 'cp --remove-destination %p /mnt/server/archivedir/%f'
archive_command = 'copy %p /mnt/server/archivedir/%f'  # Windows
```

- **--remove-destination** indicates that files will be overwritten during the archiving.
- When **archive_mode** is set to **on** or not specified, a **backup** folder will be created in the **pg_xlog** directory and WALs will be compressed and copied to the **pg_xlog/backup** directory.

## max_xlog_backup_size

**Parameter description**: Specifies the size of WAL logs backed up in the **pg_xlog/backup** directory.

**Type**: SIGHUP

**Value range**: an integer between **1048576** and **104857600**. The unit is KB.

**Default value**: 2097152

NOTICE

- The **max_xlog_backup_size** parameter setting takes effect only when **archive_mode** is enabled and **archive_command** is set to **NULL**.
- The system checks the size of backup WALs in the **pg_xlog/backup** directory every minute. If the size exceeds the value specified by **max_xlog_backup_size**, the system deletes the earliest backup WALs until the size is less than the **max_xlog_backup_size** value × 0.9.

## archive_timeout

**Parameter description**: Specifies the archiving period.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to INT_MAX. The unit is second. **0** indicates that archiving timeout is disabled.

**Default value**: **0**

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NOTICE

- The server is forced to switch to a new WAL segment file with the period specified by this parameter.
- Archived files that are closed early due to a forced switch are still of the same length as completely full files. Therefore, a very short **archive_timeout** will bloat the archive storage. You are advised to set **archive_timeout** to **60s**.

# 15.8 HA Replication

## 15.8.1 Sending Server

### wal_keep_segments

**Parameter description**: Specifies the number of Xlog file segments. Specifies the minimum number of transaction log files stored in the **pg_xlog** directory. The standby server obtains log files from the primary server for streaming replication.

**Type**: SIGHUP

**Value range**: an integer ranging from 2 to INT_MAX

**Default value**: **65**

**Setting suggestions**:

- During WAL archiving or recovery from a checkpoint on the server, the system retains more log files than the number specified by **wal_keep_segments**.
- If this parameter is set to a too small value, a transaction log may have been overwritten by a new transaction log before requested by the standby server. As a result, the request fails, and the relationship between the primary and standby servers is interrupted.
- If the HA system uses asynchronous transmission, increase the value of **wal_keep_segments** when data greater than 4 GB is continuously imported in COPY mode. Take T6000 board as an example. If the data to be imported reaches 50 GB, you are advised to set this parameter to **1000**. You can dynamically restore the setting of this parameter after data import is complete and the WAL synchronization is proper.

### wal_sender_timeout

**Parameter description:** Specifies the maximum duration that the sending server waits for the WAL reception in the receiver.

**Type**: SIGHUP

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NOTICE

- If the primary server contains a huge volume of data, increase the value of this parameter for database rebuilding.
- This parameter cannot be set to a value larger than the value of **wal_receiver_timeout** or the timeout parameter for database rebuilding.

**Value range**: an integer ranging from 0 to INT_MAX. The unit is millisecond (ms).

**Default value**: **15s**

## max_replication_slots

**Parameter description**: Specifies the number of log replication slots on the primary server.

**Type**: POSTMASTER

**Value range**: an integer ranging from 0 to 262143

**Default value**: **8**

A physical replication slot provides an automatic method to ensure that an Xlog is not removed from a primary DN before all the standby and secondary DNs receive it. Physical replication slots are used to support HA clusters. The number of physical replication slots required by a cluster is as follows: ratio of standby and secondary DNs to the primary DN in a ring of DNs. For example, if an HA cluster has 1 primary DN, 1 standby DN, and 1 secondary DN, the number of required physical replication slots will be 2.

Plan the number of logical replication slots as follows:

- A logical replication slot can carry changes of only one database for decoding. If multiple databases are involved, create multiple logical replication slots.
- If logical replication is needed by multiple target databases, create multiple logical replication slots in the source database. Each logical replication slot corresponds to one logical replication link.

## max_build_io_limit

**Parameter description:** Specifies the data volume that can be read from the disk per second when the primary server provides a build session to the standby server.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 1048576. The unit is KB. The value **0** indicates that the I/O flow is not restricted when the primary server provides a build session to the standby server.

**Default value**: **0**

**Setting suggestions:** Set this parameter based on the disk bandwidth and job model. If there is no flow restriction or job interference, for disks with good performance such as SSDs, a full build consumes a relatively small proportion of bandwidth and has little impact on service performance. In this case, you do not need to set the threshold. If the service performance of a common 10,000 rpm

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SAS disk deteriorates significantly during a build, you are advised to set the parameter to 20 MB.

This setting directly affects the build speed and completion time. Therefore, you are advised to set this parameter to a value larger than 10 MB. During off-peak hours, you are advised to remove the flow restriction to restore to the normal build speed.

NOTE

- This parameter is used during peak hours or when the disk I/O pressure of the primary server is high. It limits the build flow rate on the standby server to reduce the impact on primary server services. After the service peak hours, you can remove the restriction or reset the flow rate threshold.
- You are advised to set a proper threshold based on service scenarios and disk performance.

## 15.8.2 Primary Server

### vacuum_defer_cleanup_age

**Parameter description**: Specifies the number of transactions by which **VACUUM** will defer the cleanup of invalid row-store table records, so that **VACUUM** and **VACUUM FULL** do not clean up deleted tuples immediately.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 1000000. **0** means no delay.

**Default value**: **0**

### data_replicate_buffer_size

**Parameter description**: Specifies the size of memory used by queues when the sender sends data pages to the receiver. The value of this parameter affects the buffer size copied for the replication between the primary and standby servers.

**Type**: POSTMASTER

**Value range**: an integer ranging from 4 to 1023. The unit is MB.

**Default value**: **128 MB**

### enable_data_replicate

**Parameter description**: Specifies the data synchronization mode between the primary and standby servers when data is imported to row-store tables in a database.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that data pages are used for the data synchronization between the primary and standby servers when data is imported to row-store tables in a database. This parameter cannot be set to **on** if **replication_type** is set to **1**.
- **off** indicates that the primary and standby servers synchronize data using Xlogs while the data is imported to a row-store table.

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**Default value**: **on**

### enable_incremental_catchup

**Parameter description**: Specifies the data catchup mode between the primary and standby nodes.

**Type**: SIGHUP

**Value range:** Boolean

- **on** indicates that the standby node uses the incremental catchup mode. That is, the standby server scans local data files on the standby server to obtain the list of differential data files between the primary and standby nodes and then performs catchup between the primary and standby nodes.
- **off** indicates that the standby node uses the full catchup mode. That is, the standby node scans all local data files on the primary node to obtain the list of differential data files between the primary and standby nodes and performs catchup between the primary and standby nodes.

**Default value**: **on**

### wait_dummy_time

**Parameter description**: Specifies the maximum duration for the primary, standby, and secondary clusters to wait for the secondary cluster to start in sequence and the maximum duration for the secondary cluster to send the scanning list when incremental data catchup is enabled.

**Type**: SIGHUP

**Value range**: Integer, from 1 to **INT_MAX**, in seconds.

**Default value**: **300s**

**CAUTION**

The unit can only be second.

# 15.9 Query Planning

## 15.9.1 Optimizer Method Configuration

These configuration parameters provide a crude method of influencing the query plans chosen by the query optimizer. If the default plan chosen by the optimizer for a particular query is not optimal, a temporary solution is to use one of these configuration parameters to force the optimizer to choose a different plan. Better ways include adjusting the optimizer cost constants, manually running **ANALYZE**, increasing the value of the **default_statistics_target** configuration parameter, and adding the statistics collected in a specific column using **ALTER TABLE SET STATISTICS**.

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## enable_bitmapscan

**Parameter description**: Controls whether the query optimizer uses the bitmap-scan plan type.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_hashagg

**Parameter description**: Controls whether the query optimizer uses the Hash aggregation plan type.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_hashjoin

**Parameter description**: Controls whether the query optimizer uses the Hash-join plan type.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_indexscan

**Parameter description**: Controls whether the query optimizer uses the index-scan plan type.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

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## enable_indexonlyscan

**Parameter description**: Controls whether the query optimizer uses the index-only-scan plan type.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_material

**Parameter description**: Controls whether the query optimizer uses materialization. It is impossible to suppress materialization entirely, but setting this parameter to **off** prevents the optimizer from inserting materialized nodes.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_mergejoin

**Parameter description**: Controls whether the query optimizer uses the merge-join plan type.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **off**

## enable_nestloop

**Parameter description**: Controls whether the query optimizer uses the nested-loop join plan type to fully scan internal tables. It is impossible to suppress nested-loop joins entirely, but setting this parameter to **off** allows the optimizer to choose other methods if available.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **off**

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## enable_index_nestloop

**Parameter description**: Controls whether the query optimizer uses the nested-loop join plan type to scan the parameterized indexes of internal tables.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the query optimizer uses the nested-loop join plan type.
- **off** indicates the query optimizer does not use the nested-loop join plan type.

**Default value**: The default value for a newly installed cluster is **on**. If the cluster is upgraded from R8C10, the forward compatibility is retained. If the version is upgraded from R7C10 or an earlier version, the default value is **off**.

## enable_seqscan

**Parameter description**: Controls whether the query optimizer uses the sequential scan plan type. It is impossible to suppress sequential scans entirely, but setting this variable to **off** allows the optimizer to preferentially choose other methods if available.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_sort

**Parameter description**: Controls whether the query optimizer uses the sort method. It is impossible to suppress explicit sorts entirely, but setting this variable to **off** allows the optimizer to preferentially choose other methods if available.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_tidscan

**Parameter description**: Controls whether the query optimizer uses the Tuple ID (TID) scan plan type.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.

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- **off** indicates it is disabled.

**Default value**: **on**

## enable_kill_query

**Parameter description**: In CASCADE mode, when a user is deleted, all the objects belonging to the user are deleted. This parameter specifies whether the queries of the objects belonging to the user can be unlocked when the user is deleted.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates the unlocking is allowed.
- **off** indicates the unlocking is not allowed.

**Default value**: **off**

## enforce_oracle_behavior

**Parameter description**: Controls the rule matching modes of regular expressions.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the ORACLE matching rule is used.
- **off** indicates that the POSIX matching rule is used.

**Default value**: **on**

## enable_stream_concurrent_update

**Parameter description**: Controls the use of **stream** in concurrent updates. This parameter is restricted by the **enable_stream_operator** parameter.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the optimizer can generate stream plans for the **UPDATE** statement.
- **off** indicates that the optimizer can generate only non-stream plans for the **UPDATE** statement.

**Default value**: **on**

## enable_stream_operator

**Parameter description:** Controls whether the query optimizer uses streams.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.

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- **off** indicates it is disabled.

**Default value**: **on**

## enable_stream_recursive

**Parameter description**: Specifies whether to push **WITH RECURSIVE** join queries to DNs for processing.

**Type**: USERSET

**Value range**: Boolean

- **on**: **WITH RECURSIVE** join queries will be pushed down to DNs.
- **off**: **WITH RECURSIVE** join queries will not be pushed down to DNs.

**Default value**: **on**

## max_recursive_times

**Parameter description**: Specifies the maximum number of **WITH RECURSIVE** iterations.

**Type**: USERSET

**Value range**: an integer ranging from 0 to INT_MAX

**Default value**: **200**

## enable_vector_engine

**Parameter description**: Controls whether the query optimizer uses the vectorized executor.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## enable_broadcast

**Parameter description**: Controls whether the query optimizer uses the broadcast distribution method when it evaluates the cost of stream.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

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## enable_change_hjcost

**Parameter description**: Specifies whether the optimizer excludes internal table running costs when selecting the Hash Join cost path. If it is set to **on**, tables with a few records and high running costs are more possible to be selected.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **off**

## enable_fstream

**Parameter description**: Controls whether the query optimizer uses streams when it delivers statements. This parameter is only used for external HDFS tables.

This parameter has been discarded. To reserve forward compatibility, set this parameter to **on**, but the setting does not make a difference.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **off**

## best_agg_plan

**Parameter description**: The query optimizer generates three plans for the aggregate operation under the stream:

1. hashagg+gather(redistribute)+hashagg
2. redistribute+hashagg(+gather)
3. hashagg+redistribute+hashagg(+gather).

This parameter is used to control the query optimizer to generate which type of hashagg plans.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 3.

- When the value is set to **1**, the first plan is forcibly generated.
- When the value is set to **2** and if the **group by** column can be redistributed, the second plan is forcibly generated. Otherwise, the first plan is generated.
- When the value is set to **3** and if the **group by** column can be redistributed, the third plan is generated. Otherwise, the first plan is generated.
- When the value is set to **0**, the query optimizer chooses the most optimal plan based on the estimated costs of the three plans above.

**Default value**: **0**

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## agg_redistribute_enhancement

**Parameter description**: When the aggregate operation is performed, which contains multiple **group by** columns and all of the columns are not in the distribution column, you need to select one **group by** column for redistribution. This parameter controls the policy of selecting a redistribution column.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the column that can be redistributed and evaluates the most distinct value for redistribution.
- **off** indicates the first column that can be redistributed for redistribution.

**Default value**: **off**

## enable_valuepartition_pruning

**Parameter description**: Specifies whether the DFS partitioned table is dynamically or statically optimized.

**Type**: USERSET

**Value range:** Boolean

- **on** indicates that the DFS partitioned table is dynamically or statically optimized.
- **off** indicates that the DFS partitioned table is not dynamically or statically optimized.

**Default value**: **on**

## expected_computing_nodegroup

**Parameter description**: Specifies a computing Node Group or the way to choose such a group. The Node Group mechanism is now for internal use only. You do not need to set it.

During join or aggregation operations, a Node Group can be selected in four modes. In each mode, the specified candidate computing Node Groups are listed for the optimizer to select an appropriate one for the current operator.

**Type**: USERSET

**Value range**: a string

- **optimal**: The list of candidate computing Node Groups consists of the Node Group where the operator's operation objects are located and the DNs in the Node Groups on which the current user has the COMPUTE permission.
- **query**: The list of candidate computing Node Groups consists of the Node Group where the operator's operation objects are located and the DNs in the Node Groups where base tables involved in the query are located.
- **bind**: If the current session user is a logical cluster user, the candidate computing Node Group is the Node Group of the logical cluster associated with the current user. If the session user is not a logical cluster user, the

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candidate computing Node Group selection rule is the same as that when this parameter is set to **query**.

- Node Group name:
  - If **enable_nodegroup_debug** is set to **off**, the list of candidate computing Node Groups consists of the Node Group where the operator's operation objects are located and the specified Node Group.
  - If **enable_nodegroup_debug** is set to **on**, the specified Node Group is used as the candidate Node Group.

**Default value**: **bind**

## enable_nodegroup_debug

**Parameter description**: Specifies whether the optimizer assigns computing workloads to a specific Node Group when multiple Node Groups exist in an environment. The Node Group mechanism is now for internal use only. You do not need to set it.

This parameter takes effect only when **expected_computing_nodegroup** is set to a specific Node Group.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that computing workloads are assigned to the Node Group specified by **expected_computing_nodegroup**.
- **off** indicates no Node Group is specified to compute.

**Default value**: **off**

## stream_multiple

**Parameter description**: Specifies the weight used for optimizer to calculate the final cost of stream operators.

The base stream cost is multiplied by this weight to make the final cost.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to DBL_MAX

**Default value**: **1**

NOTICE

This parameter is applicable only to Redistribute and Broadcast streams.

## qrw_inlist2join_optmode

**Parameter description**: Specifies whether enable inlist-to-join (inlist2join) query rewriting.

**Type**: USERSET

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**Value range**: a string

- **disable**: inlist2join disabled
- **cost_base**: cost-based inlist2join query rewriting
- **rule_base**: forcible rule-based inlist2join query rewriting
- A positive integer: threshold of Inlist2join query rewriting. If the number of elements in the list is greater than the threshold, the rewriting is performed.

**Default value**: **cost_base**

### skew_option

**Parameter description**: Specifies whether an optimization policy is used

**Type**: USERSET

**Value range**: a string

- **off**: policy disabled
- **normal**: radical policy. All possible skews are optimized.
- **lazy**: conservative policy. Uncertain skews are ignored.

**Default value: normal**

## 15.9.2 Optimizer Cost Constants

This section describes the optimizer cost constants. The cost variables described in this section are measured on an arbitrary scale. Only their relative values matter, therefore scaling them all in or out by the same factor will result in no differences in the optimizer's choices. By default, these cost variables are based on the cost of sequential page fetches, that is, **seq_page_cost** is conventionally set to **1.0** and the other cost variables are set with reference to the parameter. However, you can use a different scale, such as actual execution time in milliseconds.

### seq_page_cost

**Parameter description**: Specifies the optimizer's estimated cost of a disk page fetch that is part of a series of sequential fetches.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to DBL_MAX

**Default value**: **1**

### random_page_cost

**Parameter description**: Specifies the optimizer's estimated cost of an out-of-sequence disk page fetch.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to DBL_MAX

**Default value**: **4**

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NOTE

- Although the server allows you to set the value of **random_page_cost** to less than that of **seq_page_cost**, it is not physically sensitive to do so. However, setting them equal makes sense if the database is entirely cached in RAM, because in that case there is no penalty for fetching pages out of sequence. Also, in a heavily-cached database you should lower both values relative to the CPU parameters, since the cost of fetching a page already in RAM is much smaller than it would normally be.
- This value can be overwritten for tables and indexes in a particular tablespace by setting the tablespace parameter of the same name.
- Comparing to **seq_page_cost**, reducing this value will cause the system to prefer index scans and raising it makes index scans relatively more expensive. You can increase or decrease both values at the same time to change the disk I/O cost relative to CPU cost.

## cpu_tuple_cost

**Parameter description**: Specifies the optimizer's estimated cost of processing each row during a query.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to DBL_MAX

**Default value**: **0.01**

## cpu_index_tuple_cost

**Parameter description**: Specifies the optimizer's estimated cost of processing each index entry during an index scan.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to DBL_MAX

**Default value: 0.005**

## cpu_operator_cost

**Parameter description**: Specifies the optimizer's estimated cost of processing each operator or function during a query.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to DBL_MAX

**Default value**: **0.0025**

## effective_cache_size

**Parameter description**: Specifies the optimizer's assumption about the effective size of the disk cache that is available to a single query.

When setting this parameter you should consider both GaussDB(DWS)'s shared buffer and the kernel's disk cache. Also, take into account the expected number of concurrent queries on different tables, since they will have to share the available space.

This parameter has no effect on the size of shared memory allocated by GaussDB(DWS). It is used only for estimation purposes and does not reserve

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kernel disk cache. The value is in the unit of disk page. Usually the size of each page is 8192 bytes.

**Type**: USERSET

**Value range**: an integer ranging is from 1 to INT_MAX. The unit is 8 KB.

A value greater than the default one may enable index scanning, and a value less than the default one may enable sequence scanning.

**Default value**: **128 MB**

### allocate_mem_cost

**Parameter description**: Specifies the query optimizer's estimated cost of creating a Hash table for memory space using Hash join. This parameter is used for optimization when the Hash join estimation is inaccurate.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to DBL_MAX

**Default value**: **0**

## 15.9.3 Genetic Query Optimizer

This section describes parameters related to genetic query optimizer. The genetic query optimizer (GEQO) is an algorithm that plans queries by using heuristic searching. This algorithm reduces planning time for complex queries and the cost of producing plans are sometimes inferior to those found by the normal exhaustive-search algorithm.

### geqo

**Parameter description**: Controls the use of genetic query optimization.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates GEQO is enabled.
- **off** indicates GEQO is disabled.

**Default value**: **on**

NOTICE

Generally, do not set this parameter to **off**. **geqo_threshold** provides more subtle control of GEQO.

### geqo_threshold

**Parameter description:** Specifies the number of **FROM** items. Genetic query optimization is used to plan queries when the number of statements executed is greater than this value.

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**Type**: USERSET

**Value range**: an integer ranging from 2 to INT_MAX

**Default value**: **12**

NOTICE

- For simpler queries it is best to use the regular, exhaustive-search planner, but for queries with many tables it is better to use GEQO to manage the queries.
- A **FULL OUTER JOIN** construct counts as only one **FROM** item.

## geqo_effort

**Parameter description**: Controls the trade-off between planning time and query plan quality in GEQO.

**Type**: USERSET

**Value range**: an integer ranging from 1 to 10

**Default value**: **5**

NOTICE

- Larger values increase the time spent in query planning, but also increase the probability that an efficient query plan is chosen.
- **geqo_effort** does not have direct effect. This parameter is only used to compute the default values for the other variables that influence GEQO behavior. You can manually set other parameters as required.

## geqo_pool_size

**Parameter description**: Specifies the pool size used by GEQO, that is, the number of individuals in the genetic population.

**Type**: USERSET

**Value range**: an integer ranging from 0 to INT_MAX

NOTICE

The value of this parameter must be at least **2**, and useful values are typically from **100** to **1000**. If this parameter is set to **0**, GaussDB(DWS) selects a proper value based on **geqo_effort** and the number of tables.

**Default value**: **0**

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### geqo_generations

**Parameter description**: Specifies the number parameter iterations of the algorithm used by GEQO.

**Type**: USERSET

**Value range**: an integer ranging from 0 to INT_MAX

NOTICE

The value of this parameter must be at least **1**, and useful values are typically from **100** to **1000**. If it is set to **0**, a suitable value is chosen based on **geqo_pool_size**.

**Default value**: **0**

### geqo_selection_bias

**Parameter description**: Specifies the selection bias used by GEQO. The selection bias is the selective pressure within the population.

**Type**: USERSET

**Value range**: a floating point number ranging from 1.5 to 2.0

**Default value**: **2**

### geqo_seed

**Parameter description**: Specifies the initial value of the random number generator used by GEQO to select random paths through the join order search space.

**Type**: USERSET

**Value range**: a floating point number ranging from 0.0 to 1.0

NOTICE

Varying the value changes the setting of join paths explored, and may result in a better or worse path being found.

**Default value**: **0**

## 15.9.4 Other Optimizer Options

### default_statistics_target

**Parameter description**: Specifies the default statistics target for table columns without a column-specific target set via **ALTER TABLE SET STATISTICS**. If this parameter is set to a positive number, it indicates the number of samples of statistics information. If this parameter is set to a negative number, percentage is

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used to set the statistic target. The negative number converts to its corresponding percentage, for example, -5 means 5%. During sampling, **default_statistics_target * 300** is used as the size of the random sampling. For example, if the default value is 100, 100 x 300 pages are read in a random sampling.

**Type**: USERSET

**Value range**: an integer ranging from -100 to 10000

NOTICE

- A larger positive number than the parameter value increases the time required to do **ANALYZE**, but might improve the quality of the optimizer's estimates.
- Changing settings of this parameter may result in performance deterioration. If query performance deteriorates, you can:
  1. Restore to the default statistics.
  2. Use hints to optimize the query plan.
- If this parameter is set to a negative value, the number of samples is greater than or equal to 2% of the total data volume, and the number of records in user tables is less than 1.6 million, the time taken by running **ANALYZE** will be longer than when this parameter uses its default value.
- If this parameter is set to a negative value, the autoanalyze function does not support percentage sampling. The sampling uses the default value of this parameter.
- If this parameter is set to a positive value, you must have the ANALYZE permission to execute ANALYZE.
- If this parameter is set to a negative value, that is, percentage sampling, you need to be granted the ANALYZE and SELECT permissions to execute ANALYZE.

**Default value**: **100**

## constraint_exclusion

**Parameter description**: Controls the query optimizer's use of table constraints to optimize queries.

**Type**: USERSET

**Value range**: enumerated values

- **on** indicates the constraints for all tables are examined.
- **off**: No constraints are examined.
- **partition** indicates that only constraints for inherited child tables and **UNION ALL** subqueries are examined.

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NOTICE

When **constraint_exclusion** is set to **on**, the optimizer compares query conditions with the table's **CHECK** constraints, and omits scanning tables for which the conditions contradict the constraints.

**Default value**: **partition**

NOTE

Currently, this parameter is set to **on** by default to partition tables. If this parameter is set to **on**, extra planning is imposed on simple queries, which has no benefits. If you have no partitioned tables, set it to **off**.

## cursor_tuple_fraction

**Parameter description**: Specifies the optimizer's estimated fraction of a cursor's rows that are retrieved.

**Type**: USERSET

**Value range**: a floating point number ranging from 0.0 to 1.0

NOTICE

Smaller values than the default value bias the optimizer towards using **fast start** plans for cursors, which will retrieve the first few rows quickly while perhaps taking a long time to fetch all rows. Larger values put more emphasis on the total estimated time. At the maximum setting of **1.0**, cursors are planned exactly like regular queries, considering only the total estimated time and how soon the first rows might be delivered.

**Default value**: **0.1**

## from_collapse_limit

**Parameter description**: Specifies whether the optimizer merges sub-queries into upper queries based on the resulting FROM list. The optimizer merges sub-queries into upper queries if the resulting FROM list would have no more than this many items.

**Type**: USERSET

**Value range**: an integer ranging from 1 to INT_MAX

NOTICE

Smaller values reduce planning time but may lead to inferior execution plans.

**Default value**: **8**

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## join_collapse_limit

**Parameter description**: Specifies whether the optimizer rewrites **JOIN** constructs (except **FULL JOIN**) into lists of **FROM** items based on the number of the items in the result list.

**Type**: USERSET

**Value range**: an integer ranging from 1 to INT_MAX

NOTICE

- Setting this parameter to **1** prevents join reordering. As a result, the join order specified in the query will be the actual order in which the relations are joined. The query optimizer does not always choose the optimal join order. Therefore, advanced users can temporarily set this variable to **1**, and then specify the join order they desire explicitly.
- Smaller values reduce planning time but lead to inferior execution plans.

**Default value**: **8**

## plan_mode_seed

**Parameter description**: This is a commissioning parameter. Currently, it supports only OPTIMIZE_PLAN and RANDOM_PLAN. **OPTIMIZE_PLAN** indicates the optimal plan, the cost of which is estimated using the dynamic planning algorithm, and its value is **0**. **RANDOM_PLAN** indicates the plan that is randomly generated. If **plan_mode_seed** is set to **-1**, you do not need to specify the value of the seed identifier. Instead, the optimizer generates a random integer ranging from **1** to **2147483647**, and then generates a random execution plan based on this random number. If **plan_mode_seed** is set to an integer ranging from **1** to **2147483647**, you need to specify the value of the seed identifier, and the optimizer generates a random execution plan based on the seed value.

**Type**: USERSET

**Value range**: an integer ranging from -1 to 2147483647

**Default value**: **0**

NOTICE

- If **plan_mode_seed** is set to **RANDOM_PLAN**, the optimizer generates different random execution plans, which may not be the optimal. Therefore, to guarantee the query performance, the default value **0** is recommended during upgrade, scale-out, scale-in, and O&M.
- If this parameter is not set to **0**, the specified hint will not be used.

## enable_hdfs_predicate_pushdown

**Parameter description**: Specifies whether the function of pushing down predicates the native data layer is enabled.

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**Type**: SUSET

**Value range**: Boolean

- **on** indicates this function is enabled.
- **off** indicates this function is disabled.

**Default value**: **on**

## enable_random_datanode

**Parameter description**: Specifies whether the function that random query about DNs in the replication table is enabled. A complete data table is stored on each DN for random retrieval to release the pressure on nodes.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates this function is enabled.
- **off** indicates this function is disabled.

**Default value**: **on**

## hashagg_table_size

**Parameter description**: Specifies the hash table size during the execution of the **HASH AGG** operation.

**Type**: USERSET

**Value range**: an integer ranging from 0 to INT_MAX/2

**Default value**: **0**

## enable_codegen

**Parameter description**: Specifies whether code optimization can be enabled. Currently, the code optimization uses the LLVM optimization.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates code optimization can be enabled.
- **off** indicates code optimization cannot be enabled.

**NOTICE**

Currently, the LLVM optimization only supports the vectorized executor and SQL on Hadoop features. You are advised to set this parameter to **off** in other cases.

**Default value**: **on**

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## codegen_strategy

**Parameter description**: Specifies the codegen optimization strategy that is used when an expression is converted to codegen-based.

**Type**: USERSET

**Value range**: enumerated values

- **partial** indicates that you can still call the LLVM dynamic optimization strategy using the codegen framework of an expression even if functions that are not codegen-based exist in the expression.
- **pure** indicates that the LLVM dynamic optimization strategy can be called only when all functions in an expression can be codegen-based.

**NOTICE**

In the scenario where query performance reduces after the codegen function is enabled, you can set this parameter to **pure**. In other scenarios, do not change the default value **partial** of this parameter.

**Default value**: **partial**

## enable_codegen_print

**Parameter description:** Specifies whether the LLVM IR function can be printed in logs.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the LLVM IR function can be printed in logs.
- **off** indicates that the LLVM IR function cannot be printed in logs.

**Default value**: **off**

## codegen_cost_threshold

**Parameter description**: The LLVM compilation takes some time to generate executable machine code. Therefore, LLVM compilation is beneficial only when the actual execution cost is more than the sum of the code required for generating machine code and the optimized execution cost. This parameter specifies a threshold. If the estimated execution cost exceeds the threshold, LLVM optimization is performed.

**Type**: USERSET

**Value range**: an integer ranging from **0** to **INT_MAX**

**Default value**: **10000**

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## enable_constraint_optimization

**Parameter description**: Specifies whether the informational constraint optimization execution plan can be used for an HDFS foreign table.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates the plan can be used.
- **off** indicates the plan cannot be used.

**Default value**: **on**

## enable_bloom_filter

**Parameter description**: Specifies whether the BloomFilter optimization is used.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the BloomFilter optimization can be used.
- **off** indicates the BloomFilter optimization cannot be used.

**Default value**: **on**

## enable_extrapolation_stats

**Parameter description**: Specifies whether the extrapolation logic is used for data of DATE type based on historical statistics. The logic can increase the accuracy of estimation for tables whose statistics are not collected in time, but will possibly provide an overlarge estimation due to incorrect extrapolation. Enable the logic only in scenarios where the data of DATE type is periodically inserted.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the extrapolation logic is used for data of DATE type based on historical statistics.
- **off** indicates that the extrapolation logic is not used for data of DATE type based on historical statistics.

**Default value**: **off**

## autoanalyze

**Parameter description**: Specifies whether to allow automatic statistics collection for tables that have statistics when generating a plan. Foreign tables nor temporary tables with the ON COMMIT [DELETE ROWS|DROP] option can trigger autoanalyze. To collect statistics, you need to manually perform the ANALYZE operation. If an exception occurs in the database during the execution of autoanalyze on a table, after the database is recovered, the system may still prompt you to collect the statistics of the table when you run the statement again. In this case, manually perform the ANALYZE operation on the table to synchronize statistics.

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**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the table statistics are automatically collected.
- **off** indicates that the table statistics are not automatically collected.

**Default value**: **on**

## query_dop

**Parameter description**: Specifies the user-defined degree of parallelism.

**Type**: USERSET

**Value range**: an integer ranging from -64 to 64.

[1, 64]: Fixed SMP is enabled, and the system will use the specified degree.

0: SMP adaptation function is enabled. The system dynamically selects the optimal parallelism degree [1,8] (x86 platforms) or [1,64] (Kunpeng platforms) for each query based on the resource usage and query plans.

[-64, -1]: SMP adaptation is enabled, and the system will dynamically select a degree from the limited range.

NOTE

- For TP services that mainly involve short queries, if services cannot be optimized through lightweight CNs or statement delivery, it will take a long time to generate an SMP plan. You are advised to set **query_dop** to **1**. For AP services with complex statements, you are advised to set **query_dop** to **0**.
- After enabling concurrent queries, ensure you have sufficient CPU, memory, network, and I/O resources to achieve the optimal performance.
- To prevent performance deterioration caused by an overly large value of **query_dop**, the system calculates the maximum number of available CPU cores for a DN and uses the number as the upper limit for this parameter. If the value of **query_dop** is greater than 4 and also the upper limit, the system resets **query_dop** to the upper limit.

**Default value**: **1**

## query_dop_ratio

**Parameter description**: Specifies the DOP multiple used to adjust the optimal DOP preset in the system when **query_dop** is set to **0**. That is, DOP = Preset DOP x query_dop_ratio (ranging from 1 to 64). If this parameter is set to **1**, the DOP cannot be adjusted.

**Type**: USERSET

**Value range**: a floating point number ranging from 0 to 64

**Default value**: **1**

## debug_group_dop

**Parameter description**: Specifies the unified DOP parallelism degree allocated to the groups that use the Stream operator as the vertex in the generated execution

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plan when the value of **query_dop** is **0**. This parameter is used to manually specify the DOP for specific groups for performance optimization. Its format is **G1,D1,G2,D2,...,**, where **G1** and **G2** indicate the group IDs that can be obtained from logs and **D1** and **D2** indicate the specified DOP values and can be any positive integers.

**Type**: USERSET

**Value range**: a string

**Default value**: empty

NOTICE

This parameter is used only for internal optimization and cannot be set. You are advised to use the default value.

## enable_analyze_check

**Parameter description:** Checks whether statistics were collected about tables whose **reltuples** and **relpages** are shown as **0** in **pg_class** during plan generation.

**Type**: SUSET

**Value range**: Boolean

- **on** enables the check.
- **off** disables the check.

**Default value**: **on**

## enable_sonic_hashagg

**Parameter description**: Specifies whether to use the Hash Agg operator for column-oriented hash table design when certain constraints are met.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the Hash Agg operator is used for column-oriented hash table design when certain constraints are met.
- **off** indicates that the Hash Agg operator is not used for column-oriented hash table design.

NOTE

- If **enable_sonic_hashagg** is enabled and certain constraints are met, the Hash Agg operator will be used for column-oriented hash table design, and the memory usage of the operator can be reduced. However, in scenarios where the code generation technology (enabled by **enable_codegen**) can significantly improve performance, the performance of the operator may deteriorate.
- If **enable_sonic_hashagg** is set to **on**, when certain constraints are met, the hash aggregation operator designed for column-oriented hash tables is used and its name is displayed as **Sonic Hash Aggregation** in the output of the Explain Analyze/Performance operation. When the constraints are not met, the operator name is displayed as **Hash Aggregation**.

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**Default value**: **on**

## enable_sonic_hashjoin

**Parameter description**: Specifies whether to use the Hash Join operator for column-oriented hash table design when certain constraints are met.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the Hash Join operator is used for column-oriented hash table design when certain constraints are met.
- **off** indicates that the Hash Join operator is not used for column-oriented hash table design.

NOTE

- Currently, the parameter can be used only for Inner Join.
- If **enable_sonic_hashjoin** is enabled, the memory usage of the Hash Inner operator can be reduced. However, in scenarios where the code generation technology can significantly improve performance, the performance of the operator may deteriorate.
- If **enable_sonic_hashjoin** is set to **on**, when certain constraints are met, the hash join operator designed for column-oriented hash tables is used and its name is displayed as **Sonic Hash Join** in the output of the Explain Analyze/Performance operation. When the constraints are not met, the operator name is displayed as **Hash Join**.

**Default value**: **on**

## enable_sonic_optspill

**Parameter description**: Specifies whether to optimize the number of Hash Join or Hash Agg files written to disks in the sonic scenario. This parameter takes effect only when **enable_sonic_hashjoin** or **enable_sonic_hashagg** is enabled.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the number of files written to disks is optimized.
- **off** indicates that the number of files written to disks is not optimized.

NOTE

For the Hash Join or Hash Agg operator that meets the sonic condition, if this parameter is set to **off**, one file is written to disks for each column. If this parameter is set to **on** and the data types of different columns are similar, only one file (a maximum of five files) will be written to disks.

**Default value**: **on**

## expand_hashtable_ratio

**Parameter description**: Specifies the expansion ratio used to resize the hash table during the execution of the Hash Agg and Hash Join operators.

**Type**: USERSET

**Value range**: a floating point number of 0 or ranging from 0.5 to 10

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NOTE

- Value **0** indicates that the hash table is adaptively expanded based on the current memory size.
- The value ranging from 0.5 to 10 indicates the multiple used to expand the hash table. Generally, a larger hash table delivers better performance but occupies more memory space. If the memory space is insufficient, data may be spilled to disks in advance, causing performance deterioration.

**Default value**: **0**

## plan_cache_mode

**Parameter description**: Specifies the policy for generating an execution plan in the **prepare** statement.

**Type**: USERSET

**Value range**: enumerated values

- **auto** indicates that the **custom plan** or **generic plan** is selected by default.
- **force_generic_plan** indicates that the **generic plan** is forcibly used.
- **force_custom_plan** indicates that the **custom plan** is forcibly used.

NOTE

- This parameter is valid only for the **prepare** statement. It is used when the parameterized field in the **prepare** statement has severe data skew.
- **custom plan** is a plan generated after you run a **prepare** statement where parameters in the execute statement is embedded in the **prepare** statement. The **custom plan** generates a plan based on specific parameters in the execute statement. This scheme generates a preferred plan based on specific parameters each time and has good execution performance. The disadvantage is that the plan needs to be regenerated before each execution, resulting in a large amount of repeated optimizer overhead.
- **generic plan** is a plan generated for the **prepare** statement. The plan policy binds parameters to the plan when you run the execute statement and execute the plan. The advantage of this solution is that repeated optimizer overheads can be avoided in each execution. The disadvantage is that the plan may not be optimal when data skew occurs for the bound parameter field. When some bound parameters are used, the plan execution performance is poor.

**Default value**: **auto**

## wlm_query_accelerate

**Parameter description**: Specifies whether the query needs to be accelerated when short query acceleration is enabled.

**Type**: USERSET

**Value range**: an integer ranging from **–1** to **1**

- **-1**: indicates that short queries are controlled by the fast lane, and the long queries are controlled by the slow lane.
- **0**: indicates that queries are not accelerated. Both short and long queries are controlled by the slow lane.
- **1**: indicates that queries are accelerated. Both short queries and long queries are controlled by the fast lane.

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**Default value**: **–1**

### show_unshippable_warning

**Parameter description**: Specifies whether to print the alarm for the statement pushdown failure to the client.

**Type**: USERSET

**Value range**: Boolean

- **on**: Records the reason why the statement cannot be pushed down in a WARNING log and prints the log to the client.
- **off**: Logs the reason why the statement cannot be pushed down only.

**Default value**: **off**

## 15.10 Error Reporting and Logging

## 15.10.1 Logging Destination

### log_truncate_on_rotation

**Parameter description**: Specifies the writing mode of the log files when **logging_collector** is set to **on**.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that GaussDB(DWS) overwrites the existing log file of the same name on the server.
- **off** indicates that GaussDB(DWS) appends the log messages to the existing log file of the same name on the server.

**Default value**: **off**

NOTE

Example:

Assume that you plan to keep logs in a period of 7 days, one log file is generated per day, log files generated on Monday are named **server_log.Mon** and named **server_log.Tue** on Tuesday (others are named in the same way), and log files generated on the same day in different weeks are overwritten. Implement the plan by performing the following operations: set **log_filename** to **server_log.%a**, **log_truncate_on_rotation** to **on**, and **log_rotation_age** to **1440** (indicating the valid duration of the log file is 24 hours).

### log_rotation_age

**Parameter description**: Specifies the interval for creating a log file when **logging_collector** is set to **on**. If the difference between the current time and the time when the previous audit log file is created is greater than the value of **log_rotation_age**, a new log file will be generated.

**Type**: SIGHUP

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**Value range**: an integer ranging from 0 to 24 days. The unit is min, h, or d. **0** indicates that the time-based creation of new log files is disabled.

**Default value**: **1d**

### log_rotation_size

**Parameter description**: Specifies the maximum size of a server log file when **logging_collector** is set to **on**. If the total size of messages in a server log exceeds the capacity of the server log file, a log file will be generated.

**Type**: SIGHUP

**Value range**: an integer ranging from INT_MAX to 1024. The unit is KB.

**0** indicates the capacity-based creation of new log files is disabled.

**Default value**: **20 MB**

### event_source

**Parameter description**: Specifies the identifier of the GaussDB(DWS) error messages in logs when **log_destination** is set to **eventlog**.

**Type**: POSTMASTER

**Value range**: a string

**Default value**: **PostgreSQL**

## 15.10.2 Logging Time

### client_min_messages

**Parameter description**: Specifies which level of messages are sent to the client. Each level covers all the levels following it. The lower the level is, the fewer messages are sent.

**Type**: USERSET

NOTICE

When the values of **client_min_messages** and **log_min_messages** are the same, the levels are different.

**Valid values**: Enumerated values. Valid values: **debug5**, **debug4**, **debug3**, **debug2**, **debug1**, **info**, **log**, **notice**, **warning**, **error** For details about the parameters, see **Table 15-1**.

**Default value: notice**

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## log_min_messages

**Parameter description**: Specifies which level of messages will be written into server logs. Each level covers all the levels following it. The lower the level is, the fewer messages will be written into the log.

**Type**: SUSET

NOTICE

When the values of **client_min_messages** and **log_min_messages** are the same, the levels are different.

**Value range**: enumerated type. Valid values: **debug5**, **debug4**, **debug3**, **debug2**, **debug1**, **info**, **log**, **notice**, **warning**, **error**, **fatal**, **panic** For details about the parameters, see **Table 15-1**.

**Default value**: **warning**

## log_min_error_statement

**Parameter description**: Specifies which SQL statements that cause errors condition will be recorded in the server log.

**Type**: SUSET

**Value range**: enumerated type. Valid values: **debug5**, **debug4**, **debug3**, **debug2**, **debug1**, **info**, **log**, **notice**, **warning**, **error**, **fatal**, **panic** For details about the parameters, see **Table 15-1**.

NOTE

- The default is **error**, indicating that statements causing errors, log messages, fatal errors, or panics will be logged.
- **panic**: This feature is disabled.

**Default value**: **error**

## log_min_duration_statement

**Parameter description**: Specifies the threshold for logging statement execution durations. The execution duration that is greater than the specified value will be logged.

This parameter helps track query statements that need to be optimized. For clients using extended query protocol, durations of the Parse, Bind, and Execute are logged independently.

**Type**: SUSET

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NOTICE

If this parameter and **log_statement** are used at the same time, statements recorded based on the value of **log_statement** will not be logged again after their execution duration exceeds the value of this parameter. If you are not using **syslog**, it is recommended that you log the process ID (PID) or session ID using log_line_prefix so that you can link the current statement message to the last logged duration.

**Value range**: an integer ranging from -1 to INT_MAX. The unit is millisecond.

- If this parameter is set to **250**, execution durations of SQL statements that run 250 ms or longer will be logged.
- **0**: Execution durations of all the statements are logged.
- **–1**: This feature is disabled.

**Default value**: **30min**

## backtrace_min_messages

**Parameter description**: Prints the function's stack information to the server's log file if the level of information generated is greater than or equal to this parameter level.

**Type**: SUSET

NOTICE

This parameter is used for locating customer on-site problems. Because frequent stack printing will affect the system's overhead and stability, therefore, when you locate the onsite problems, set the value of this parameter to ranks other than **fatal** and **panic**.

**Value range**: enumerated values

Valid values: **debug5**, **debug4**, **debug3**, **debug2**, **debug1**, **info**, **log**, **notice**, **warning**, **error**, **fatal**, **panic** For details about the parameters, see **Table 15-1**.

**Default value**: **panic**

**Table 15-1** explains the message security levels used in GaussDB(DWS). If logging output is sent to **syslog** or **eventlog**, severity is translated in GaussDB(DWS) as shown in the table.

**Table 15-1** Message Severity Levels

| Severity | Description | syslog | eventlog |
| --- | --- | --- | --- |
| debug[1-5] | Provides detailed debug information. | DEBUG | INFORMATION |

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| Severity | Description | syslog | eventlog |
| --- | --- | --- | --- |
| log | Reports information of interest to administrators, for example, checkpoint activity. | INFO | INFORMATION |
| info | Provides information implicitly requested by the user, for example, output from **VACUUM VERBOSE**. | INFO | INFORMATION |
| notice | Provides information that might be helpful to users, for example, notice of truncation of long identifiers and index created as part of the primary key. | NOTICE | INFORMATION |
| warning | Provides warnings of likely problems, for example, **COMMIT** outside a transaction block. | NOTICE | WARNING |
| error | Reports an error that causes a command to terminate. | WARNING | ERROR |
| fatal | Reports the reason that causes a session to terminate. | ERR | ERROR |
| panic | Reports an error that caused all database sessions to terminate. | CRIT | ERROR |

## plog_merge_age

**Parameter description**: Specifies the output interval of performance log data.

**Type**: SUSET

NOTICE

This parameter value is in milliseconds. You are advised to set this parameter to a value that is a multiple of 1000. That is, the value is in seconds. Name extension of the performance log files controlled by this parameter is .prf. These log files are stored in the **$GAUSSLOG/gs_profile/**<*node_name*> directory. *node_name* is the value of **pgxc_node_name** in the **postgres.conf** file. You are advised not to use this parameter externally.

**Value range**: an integer ranging from 0 to INT_MAX. The unit is millisecond (ms).

- **0** indicates that the current session will not output performance log data.

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- A value other than 0 indicates the output interval of performance log data. The smaller the value is, the more log data is output, resulting in more negative impact on the performance.

**Default value**: **3s**

# 15.10.3 Logging Content

## debug_print_parse

**Parameter description**: Specifies whether to print parsing tree results.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the printing result function is enabled.
- **off** indicates the printing result function is disabled.

**Default value**: **off**

## debug_print_rewritten

**Parameter description**: Specifies whether to print query rewriting results.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the printing result function is enabled.
- **off** indicates the printing result function is disabled.

**Default value**: **off**

## debug_print_plan

**Parameter description**: Specifies whether to print query execution results.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the printing result function is enabled.
- **off** indicates the printing result function is disabled.

**Default value**: **off**

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NOTICE

- Debugging information about **debug_print_parse**, **debug_print_rewritten**, and **debug_print_plan** are printed only when the log level is set to **log** or higher. When these parameters are set to **on**, their debugging information will be recorded in server logs and will not be sent to client logs. You can change the log level by setting **client_min_messages** and **log_min_messages**.
- Do not invoke the **gs_encrypt_aes128** and **gs_decrypt_aes128** functions when **debug_print_plan** is set to **on**, preventing the risk of sensitive information disclosure. You are advised to filter parameter information of the **gs_encrypt_aes128** and **gs_decrypt_aes128** functions in the log files generated when **debug_print_plan** is set to **on**, and then provide the information to external maintenance engineers for fault locating. After you finish using the logs, delete them as soon as possible.

## debug_pretty_print

**Parameter description**: Specifies the logs produced by **debug_print_parse**, **debug_print_rewritten**, and **debug_print_plan**. The output format is more readable but much longer than the output generated when this parameter is set to **off**.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the indentation is enabled.
- **off** indicates the indentation is disabled.

**Default value**: **on**

## log_checkpoints

**Parameter description**: Specifies whether the statistics on the checkpoints and restart points are recorded in the server logs. When this parameter is set to **on**, statistics on checkpoints and restart points are recorded in the log messages, including the number of buffers to be written and the time spent in writing them.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the statistics on the checkpoints and restart points are recorded in the server logs.
- **off** indicates the statistics on the checkpoints and restart points are not recorded in the server logs.

**Default value**: **off**

## log_connections

**Parameter description**: Specifies whether to record connection request information of the client.

**Type**: BACKEND

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NOTICE

- Session connection parameter. Users are not advised to configure this parameter.
- Some client programs, such as gsql, attempt to connect twice while determining if a password is required. In this case, duplicate **connection receive** messages do not necessarily indicate a problem.

**Value range**: Boolean

- **on** indicates the request information is recorded.
- **off** indicates the request information is not recorded.

**Default value**: **off**

## log_disconnections

**Parameter description**: Specifies whether to record end connection request information of the client.

**Type**: BACKEND

**Value range**: Boolean

- **on** indicates the request information is recorded.
- **off** indicates the request information is not recorded.

**Default value**: **off**

NOTE

Session connection parameter. Users are not advised to configure this parameter.

## log_duration

**Parameter description**: Specifies whether to record the duration of every completed SQL statement. For clients using extended query protocols, the time required for parsing, binding, and executing steps are logged independently.

**Type**: SUSET

**Value range**: Boolean

- If this parameter is set to **off**, the difference between setting this parameter and setting **log_min_duration_statement** is that exceeding **log_min_duration_statement** forces the text of the query to be logged, but this parameter does not.
- If this parameter is set to **on** and **log_min_duration_statement** has a positive value, all durations are logged but the query text is included only for statements exceeding the threshold. This behavior can be used for gathering statistics in high-load situation.

**Default value**: **on**

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## log_error_verbosity

**Parameter description**: Specifies the amount of detail written in the server log for each message that is logged.

**Type**: SUSET

**Value range**: enumerated values

- **terse** indicates that the output excludes the logging of DETAIL, HINT, QUERY, and CONTEXT error information.
- **verbose** indicates that the output includes the SQLSTATE error code, the source code file name, function name, and number of the line in which the error occurs.
- **default** indicates that the output includes the logging of DETAIL, HINT, QUERY, and CONTEXT error information, and excludes the SQLSTATE error code, the source code file name, function name, and number of the line in which the error occurs.

**Default value**: **default**

## log_hostname

**Parameter description**: By default, connection log messages only show the IP address of the connected host. The host name can be recorded when this parameter is set to **on**. It may take some time to parse the host name. Therefore, the database performance may be affected.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the host name can be simultaneously recorded.
- **off** indicates the host name cannot be simultaneously recorded.

**Default value**: **off**

## log_lock_waits

**Parameter description**: If the time that a session used to wait a lock is longer than the value of **deadlock_timeout**, this parameter specifies whether to record this message in the database. This is useful in determining if lock waits are causing poor performance.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates the information is recorded.
- **off** indicates the information is not recorded.

**Default value**: **off**

## log_statement

**Parameter description**: Specifies whether to record SQL statements. For clients using extended query protocols, logging occurs when an execute message is

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received, and values of the Bind parameters are included (with any embedded single quotation marks doubled).

**Type**: SUSET

NOTICE

Statements that contain simple syntax errors are not logged even if **log_statement** is set to **all**, because the log message is emitted only after basic parsing has been completed to determine the statement type. If the extended query protocol is used, this setting also does not log statements before the execution phase (during parse analysis or planning). Set **log_min_error_statement** to ERROR or lower to log such statements.

**Value range**: enumerated values

- **none** indicates that no statement is recorded.
- **ddl** indicates that all data definition statements, such as CREATE, ALTER, and DROP, are recorded.
- **mod** indicates that all DDL statements and data modification statements, such as INSERT, UPDATE, DELETE, TRUNCATE, and COPY FROM, are recorded.
- **all** indicates that all statements are recorded. The PREPARE, EXECUTE, and EXPLAIN ANALYZE statements are also recorded.

**Default value**: **none**

## log_temp_files

**Parameter description**: Specifies whether to record the delete information of temporary files. Temporary files can be created for sorting, hashing, and temporary querying results. A log entry is generated for each temporary file when it is deleted.

**Type**: SUSET

**Value range**: an integer ranging from -1 to INT_MAX. The unit is KB.

- A positive value indicates that the delete information of temporary files whose values are larger than that of **log_temp_files** is recorded.
- If the parameter is set to **0**, all the delete information of temporary files is recorded.
- If the parameter is set to **-1**, the delete information of no temporary files is recorded.

**Default value**: **–1**

## log_timezone

**Parameter description**: Specifies the time zone used for time stamps written in the server log. Different from **TimeZone**, this parameter takes effect for all sessions in the database.

**Type**: SIGHUP

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**Value range**: a string

**Default value**: **PRC**

NOTE

The value can be changed when **gs_initdb** is used to set system environments.

## logging_module

**Parameter description**: Specifies whether module logs can be output on the server. This parameter is a session-level parameter, and you are not advised to use the **gs_guc** tool to set it.

**Type**: USERSET

**Value range**: a string

**Default value**: **off**. All the module logs on the server can be viewed by running **show logging_module**.

**Setting method**: First, you can run **show logging_module** to view which module is controllable. For example, the query output result is as follows:

```
show logging_module;
logging_module
----------------------
```

```
-----------------------------------------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------------------------------------------
-----------------------------------------------------
ALL,on(),off(DFS,GUC,HDFS,ORC,SLRU,MEM_CTL,AUTOVAC,CACHE,ADIO,SSL,GDS,TBLSPC,WLM,OBS,EXECUT
OR,VEC_EXECUTOR,STREAM,LLVM,OPT,OPT_REWRITE,OPT_JOIN,OPT_AGG,OPT_SUBPLAN,OPT_SETOP,OPT_
C
ARD,OPT_SKEW,UDF,COOP_ANALYZE,WLMCP,ACCELERATE,PLANHINT,PARQUET,CARBONDATA,SNAPSHOT,X
ACT,HANDLE,CLOG,TQUAL,EC,REMOTE,CN_RETRY,PLSQL,TEXTSEARCH,SEQ,INSTR,COMM_IPC,COMM_PARA
M,CSTORE)
(1 row)

set logging_module='on(ALL)';
SET
show
logging_module;
        logging_module
-----------------------------------------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------------------------------------------
-----------------------------------------------------
ALL,on(DFS,GUC,HDFS,ORC,SLRU,MEM_CTL,AUTOVAC,CACHE,ADIO,SSL,GDS,TBLSPC,WLM,OBS,EXECUTOR,V
EC_EXECUTOR,STREAM,LLVM,OPT,OPT_REWRITE,OPT_JOIN,OPT_AGG,OPT_SUBPLAN,OPT_SETOP,OPT_CARD,
OP
T_SKEW,UDF,COOP_ANALYZE,WLMCP,ACCELERATE,PLANHINT,PARQUET,CARBONDATA,SNAPSHOT,XACT,H
ANDLE,CLOG,TQUAL,EC,REMOTE,CN_RETRY,PLSQL,TEXTSEARCH,SEQ,INSTR,COMM_IPC,COMM_PARAM,CST
ORE),off()
(1 row)
```

**Dependency relationship**: The value of this parameter depends on the settings of **log_min_messages**.

## enable_unshipping_log

**Parameter description**: Specifies whether to log statements that are not pushed down. The logs help locate performance issues that may be caused by statements not pushed down.

**Type**: SUSET

**Value range**: Boolean

- **on**: Statements not pushed down will be logged.
- **off**: Statements not pushed down will not be logged.

**Default value**: **on**

# 15.11 Alarm Detection

During cluster running, error scenarios can be detected in a timely manner to inform users as soon as possible.

## enable_alarm

**Parameter description**: Enables the alarm detection thread to detect the fault scenarios that may occur in the database.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates the alarm detection thread can be enabled.

- **off** indicates the alarm detection thread cannot be enabled.

**Default value**: **on**

### connection_alarm_rate

**Parameter description**: Specifies the ratio restriction that the maximum number of allowed parallel connections to the database. The maximum number of concurrent connections to the database is **max_connections** x **connection_alarm_rate**.

**Type**: SIGHUP

**Value range**: a floating point number ranging from 0.0 to 1.0

**Default value**: **0.9**

### alarm_report_interval

**Parameter description**: Specifies the interval at which an alarm is reported.

**Type**: SIGHUP

**Value range**: a non-negative integer. The unit is second.

**Default value**: **10**

## 15.12 Statistics During the Database Running

## 15.12.1 Query and Index Statistics Collector

The query and index statistics collector is used to collect statistics during database running. The statistics include the times of inserting and updating a table and an index, the number of disk blocks and tuples, and the time required for the last cleanup and analysis on each table. The statistics can be viewed by querying system view families pg_stats and pg_statistic. The following parameters are used to set the statistics collection feature in the server scope.

### track_activities

**Parameter description**: Collects statistics about the commands that are being executed in session.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the statistics collection function is enabled.
- **off** indicates that the statistics collection function is disabled.

**Default value**: **on**

### track_counts

**Parameter description**: Collects statistics about data activities.

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**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the statistics collection function is enabled.
- **off** indicates that the statistics collection function is disabled.

NOTE

When the database to be cleaned up is selected from the AutoVacuum automatic cleanup process, the database statistics are required. In this case, the default value is set to **on**.

**Default value**: **on**

## track_io_timing

**Parameter description**: Collects statistics about I/O invoking timing in the database. The I/O timing statistics can be queried by using the **pg_stat_database** parameter.

**Type**: SUSET

**Value range**: Boolean

- If this parameter is set to **on**, the collection function is enabled. In this case, the collector repeatedly queries the OS at the current time. As a result, large numbers of costs may occur on some platforms. Therefore, the default value is set to **off**.
- **off** indicates that the statistics collection function is disabled.

**Default value**: **off**

## track_functions

**Parameter description**: Collects statistics about invoking times and duration in a function.

**Type**: SUSET

NOTICE

When the SQL functions are set to inline functions queried by the invoking, these SQL functions cannot be traced no matter these functions are set or not.

**Value range**: enumerated values

- **pl** indicates that only procedural language functions are traced.
- **all** indicates that SQL and C language functions are traced.
- **none** indicates that the function tracing function is disabled.

**Default value**: none

## track_activity_query_size

**Parameter description**: Specifies byte counts of the current running commands used to trace each active session.

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**Type**: POSTMASTER

**Value range**: an integer ranging from 100 to 102400

**Default value**: **1024**

## update_process_title

**Parameter description:** Collects statistics updated with a process name each time the server receives a new SQL statement.

The process name can be viewed on Windows task manager by running the **ps** command.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the statistics collection function is enabled.
- **off** indicates that the statistics collection function is disabled.

**Default value**: **off**

## track_thread_wait_status_interval

**Parameter description**: Specifies the interval of collecting the thread status information periodically.

**Type**: SUSET

**Value range**: an integer ranging from 0 to 1440. The unit is minute (min).

**Default value**: **30min**

## enable_save_datachanged_timestamp

**Parameter description**: Specifies whether to record the time when **INSERT**, **UPDATE**, **DELETE**, or **EXCHANGE**/**TRUNCATE**/**DROP PARTITION** is performed on table data.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the time when an operation is performed on table data will be recorded.
- **off** indicates that the time when an operation is performed on table data will not be recorded.

**Default value**: on

## instr_unique_sql_count

**Parameter description**: Specifies whether to collect Unique SQL statements and the maximum number of unique SQL statements that can be collected.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to INT_MAX

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- If it is set to **0**, Unique SQL statistics are not collected.
- If the value is greater than **0**, the number of Unique SQL statements collected on the CN cannot exceed the value of this parameter. When the number of collected unique SQL statements reaches the upper limit, new unique SQL statements are not collected. In this case, you can increase the value of **reload** to continue collecting new unique SQL statements.

**Default value**: **0**

**CAUTION**

If a new value is loaded using **reload** and the new value is less than the original value, the Unique SQL statistics collected by the corresponding CN will be cleared. Note that the clearing operation is performed by the background thread of the resource management module. If the GUC parameter **use_workload_manager** is set to **off**, the clearing operation may fail. In this case, you can use the **reset_instr_unique_sql** function for clearing.

## track_sql_count

**Parameter description**: Specifies whether to collect statistics on the number of the **SELECT**, **INSERT**, **UPDATE**, **DELETE**, and **MERGE INTO** statements that are being executed in each session, the response time of the **SELECT**, **INSERT**, **UPDATE**, and **DELETE** statements, and the number of DDL, DML, and DCL statements.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the statistics collection function is enabled.
- **off** indicates that the statistics collection function is disabled.

**Default value**: **on**

NOTE

- The **track_sql_count** parameter is restricted by the **track_activities** parameter.
  - If **track_activities** is set to **on** and **track_sql_count** is set to **off**, a warning message indicating that **track_sql_count** is disabled will be displayed when the view **gs_sql_count**, **pgxc_sql_count**, **gs_workload_sql_count**, **pgxc_workload_sql_count**, **global_workload_sql_count**, **gs_workload_sql_elapse_time**, **pgxc_workload_sql_elapse_time**, or **global_workload_sql_elapse_time** are queried.
  - If both **track_activities** and **track_sql_count** are set to **off**, two logs indicating that **track_activities** is disabled and **track_sql_count** is disabled will be displayed when the views are queried.
  - If **track_activities** is set to **off** and **track_sql_count** is set to **on**, a log indicating that **track_activities** is disabled will be displayed when the views are queried.
- If this parameter is disabled, querying the view returns **0**.

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## enable_track_wait_event

**Parameter description**: Specifies whether to collect statistics on waiting events, including the number of occurrence times, number of failures, duration, maximum waiting time, minimum waiting time, and average waiting time.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the statistics collection function is enabled.
- **off** indicates that the statistics collection function is disabled.

**Default value**: **off**

NOTE

- The **enable_track_wait_event** parameter is restricted by **track_activities**. Its functions cannot take effect no matter whether it is enabled if **track_activities** is disabled.
- When **track_activities** or **enable_track_wait_event** is disabled, if you query the **get_instr_wait_event** function, **gs_wait_events** view, or **pgxc_wait_events** view, a message is displayed indicating that the GUC parameter is disabled and the query result is 0.
- If **track_activities** or **enable_track_wait_event** is disabled during cluster running, GaussDB(DWS) will not collect statistics on waiting events. However, statistics that have been collected are not affected.

## enable_wdr_snapshot

**Parameter description**: Specifies whether to enable the performance view snapshot function. After this function is enabled, GaussDB(DWS) will periodically create snapshots for some system performance views and save them permanently. In addition, it will accept manual snapshot creation requests.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the snapshot function is enabled.
- **off** indicates that the snapshot function is disabled.

**Default value**: **off**

NOTE

- If the **create_wdr_snapshot** function is executed to manually create a view when the **enable_wdr_snapshot** parameter is disabled, a message is displayed indicating that the GUC parameter is not enabled.
- If the **enable_wdr_snapshot** parameter is modified during the snapshot creation process, the snapshot that is being created is not affected. The modification takes effect when the snapshot is manually or periodically created next time.

## wdr_snapshot_interval

**Parameter description**: Specifies the interval for automatically creating performance view snapshots.

**Type**: SIGHUP

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**Value range**: an integer ranging from 10 to 180, in minutes

**Default value**: **60**

NOTE

- The value of this parameter must be set in accordance with the cluster load. You are advised to set this parameter to a value greater than the time required for creating a snapshot.
- If the value of **wdr_snapshot_interval** is less than the time required for creating a snapshot, the system will skip this snapshot creation because it finds that the previous snapshot creation is not complete when the time for this automatic snapshot creation arrives.

### wdr_snapshot_retention_days

**Parameter description**: Specifies the maximum number of days for storing performance snapshot data.

**Type**: SIGHUP

**Value range**: an integer ranging from 1 to 15 days

**Default value**: **8**

NOTE

- If **enable_wdr_snapshot** is enabled, snapshot data that has been stored for **wdr_snapshot_retention_days** days will be automatically deleted.
- The value of this parameter must be set in accordance with the available disk space. A larger value requires more disk space.
- The modification of this parameter does not take effect immediately. The expired snapshot data will be cleared only when a snapshot is automatically created next time.

## 15.12.2 Performance Statistics

During the running of the database, the lock access, disk I/O operation, and invalid message process are involved. All these operations are the bottleneck of the database performance. The performance statistics method provided by GaussDB(DWS) can facilitate the performance fault location.

### Generating Performance Statistics Logs

**Parameter description**: For each query, the following four parameters control the performance statistics of corresponding modules recorded in the server log:

- The **og_parser_stats** parameter controls the performance statistics of a parser recorded in the server log.
- The **log_planner_stats** parameter controls the performance statistics of a query optimizer recorded in the server log.
- The **log_executor_stats** parameter controls the performance statistics of an executor recorded in the server log.
- The **log_statement_stats** parameter controls the performance statistics of the whole statement recorded in the server log.

All these parameters can only provide assistant analysis for administrators, which are similar to the getrusage() of the Linux OS.

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**Type**: SUSET

NOTICE

- **log_statement_stats** records the total statement statistics while other parameters only record statistics about each statement.
- The **log_statement_stats** parameter cannot be enabled together with other parameters recording statistics about each statement.

**Value range**: Boolean

- **on** indicates the function of recording performance statistics is enabled.
- **off** indicates the function of recording performance statistics is disabled.

**Default value**: **off**

# 15.13 Workload Management

If database resource usage is not controlled, concurrent tasks easily preempt resources. As a result, the OS will be overloaded and cannot respond to user tasks; or even crash and cannot provide any services to users. The GaussDB(DWS) workload management function balances the database workload based on available resources to avoid database overloading.

## use_workload_manager

**Parameter description**: Specifies whether to enable the resource management function. This parameter must be applied on both CNs and DNs.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the resource management function is enabled.
- **off** indicates the resource management function is disabled.

  NOTE

  - If a method in **Setting GUC Parameters** is used to change the parameter value, the new value takes effect only for the threads that are started after the change. In addition, the new value does not take effect for new jobs that are executed by backend threads and reused threads. You can make the new value take effect for these threads by using **kill session** or restarting the node.
  - After the value of **use_workload_manager** changes from **off** to **on**, the resource management view becomes available, and you can query the storage resource usage collected in the **off** state. If there are slight errors and the storage resource usage needs to be corrected, run the following command. If data is inserted into the table during the command execution, the statistics may be inaccurate.

    ```
    select gs_wlm_readjust_user_space(0);
    ```

**Default value**: **on**

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## enable_control_group

**Parameter description**: Specifies whether to enable the Cgroup management function. This parameter must be applied on both CNs and DNs.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the Cgroup management function is enabled.
- **off** indicates the Cgroup management function is disabled.

**Default value**: on

NOTE

If a method in **Setting GUC Parameters** is used to change the parameter value, the new value takes effect only for the threads that are started after the change. In addition, the new value does not take effect for new jobs that are executed by backend threads and reused threads. You can make the new value take effect for these threads by using **kill session** or restarting the node.

## enable_backend_control

**Parameter description**: Specifies whether to control the database permanent thread to the **DefaultBackend** Cgroup. This parameter must be applied on both CNs and DNs.

**Type**: POSTMASTER

**Value range**: Boolean

- **on**: Controls the permanent thread to the **DefaultBackend** Cgroup.
- **off**: Does not control the permanent thread to the **DefaultBackend** Cgroup.

**Default value**: **on**

## enable_vacuum_control

**Parameter description**: Specifies whether to control the database permanent thread autoVacuumWorker to the **Vacuum** Cgroup. This parameter must be applied on both CNs and DNs.

**Type**: POSTMASTER

**Value range**: Boolean

- **on**: Controls the database permanent thread autoVacuumWorker to the **Vacuum** Cgroup.
- **off**: Does not control the database permanent thread autoVacuumWorker to the **Vacuum** Cgroup.

**Default value**: **on**

## enable_perm_space

**Parameter description**: Specifies whether to enable the perm space function. This parameter must be applied on both CNs and DNs.

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**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates the perm space function is enabled.
- **off** indicates the perm space function is disabled.

**Default value**: **on**

## enable_verify_active_statements

**Parameter description**: Specifies whether to enable the background calibration function in static adaptive load scenarios. This parameter must be used on CNs.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the background calibration function is enabled.
- **off** indicates the background calibration function is disabled.

**Default value**: **on**

## max_active_statements

**Parameter description**: Specifies the maximum global concurrency. This parameter applies to one CN.

The database administrator changes the value of this parameter based on system resources (for example, CPU, I/O, and memory resources) so that the system fully supports the concurrency tasks and avoids too many concurrency tasks resulting in system crash.

**Type**: SIGHUP

**Value range**: an integer ranging from -1 to INT_MAX. The values **-1** and **0** indicate that the number of concurrent requests is not limited.

**Default value**: **60**

## parctl_min_cost

**Parameter description**: Specifies the minimum execution cost of a statement under the concurrency control of a resource pool.

**Type**: SIGHUP

**Value range**: an integer ranging from –1 to INT_MAX

- If the value is **–1** or the cost of executing statements is less than 10, the job is controlled by the fast lane.
- If the value is greater than or equal to **0**, and the cost of executing statements exceeds the value and is greater than or equal to 10, the statements are subject to the concurrent limit of a resource pool.

**Default value**: **100000**

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## cgroup_name

**Parameter description**: Specifies the name of the Cgroup in use. It can be used to change the priorities of jobs in the queue of a Cgroup.

If you set **cgroup_name** and then **session_respool**, the Cgroups associated with **session_respool** take effect. If you reverse the order, Cgroups associated with **cgroup_name** take effect.

If the Workload Cgroup level is specified during the **cgroup_name** change, the database does not check the Cgroup level. The level ranges from 1 to 10.

**Type**: USERSET

You are not advised to set **cgroup_name** and **session_respool** at the same time.

**Value range**: a string

**Default value**: **DefaultClass:Medium**

NOTE

**DefaultClass:Medium** indicates the **Medium** Cgroup belonging to the **Timeshare** Cgroup under the **DefaultClass** Cgroup.

## cpu_collect_timer

**Parameter description**: Specifies how frequently CPU data is collected during statement execution on DNs.

The database administrator changes the value of this parameter based on system resources (for example, CPU, I/O, and memory resources) so that the system fully supports the concurrency tasks and avoids too many concurrency tasks resulting in system crash.

**Type**: SIGHUP

**Value range**: an integer ranging from -1 to INT_MAX. The unit is second.

**Default value**: **30**

## enable_cgroup_switch

**Parameter description**: Specifies whether the database automatically switches to the **TopWD** group when executing statements by group type.

**Type**: USERSET

**Value range**: Boolean

- **on**: The database automatically switches to the **TopWD** group when executing statements by group type.
- **off**: The database does not automatically switch to the **TopWD** group when executing statements by group type.

**Default value**: **off**

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## memory_tracking_mode

**Parameter description**: Specifies the memory information recording mode.

**Type**: USERSET

**Value range**:

- **none**: Memory statistics is not collected.
- **normal:** Only memory statistics is collected in real time and no file is generated.
- **executor:** The statistics file is generated, containing the context information about all allocated memory used by the execution layer.
- **fullexec**: The generated file includes the information about all memory contexts requested by the execution layer.

**Default value**: **none**

## memory_detail_tracking

**Parameter description**: Specifies the sequence number of the memory background information distributed in the needed thread and **plannodeid** of the query where the current thread is located.

**Type**: USERSET

**Value range**: a string

**Default value**: empty

NOTICE

It is recommended that you retain the default value for this parameter.

## enable_resource_track

**Parameter description**: Specifies whether the real-time resource monitoring function is enabled. This parameter must be applied on both CNs and DNs.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the resource monitoring function is enabled.
- **off** indicates the resource monitoring function is disabled.

**Default value**: **on**

## enable_resource_record

**Parameter description**: Specifies whether resource monitoring records are archived. If this parameter is set to **on**, records in the **history** views (**GS_WLM_SESSION_HISTORY** and **GS_WLM_OPERATOR_HISTORY**) are archived to the corresponding **info** views (**GS_WLM_SESSION_INFO** and

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**GS_WLM_OPERATOR_INFO**) at an interval of 3 minutes. After being archived, the records are deleted from the **history** views. This parameter must be applied on both CNs and DNs.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the resource monitoring records are archived.
- **off** indicates that the resource monitoring records are not archived.

**Default value**: **off**

## enable_user_metric_persistent

**Parameter description**: Specifies whether the user historical resource monitoring dumping function is enabled. If this function is enabled, data in view **PG_TOTAL_USER_RESOURCE_INFO** is periodically sampled and saved to system catalog **GS_WLM_USER_RESOURCE_HISTORY**.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the user historical resource monitoring dumping function is enabled.
- **off** indicates that the user historical resource monitoring dumping function is disabled.

**Default value**: **on**

## user_metric_retention_time

**Parameter description**: Specifies the retention time of the user historical resource monitoring data. This parameter is valid only when **enable_user_metric_persistent** is set to **on**.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 3650. The unit is day.

- If this parameter is set to **0**, user historical resource monitoring data is permanently stored.
- If the value is greater than **0**, user historical resource monitoring data is stored for the specified number of days.

**Default value**: **7**

## enable_instance_metric_persistent

**Parameter description**: Specifies whether the instance resource monitoring dumping function is enabled. When this function is enabled, the instance monitoring data is saved to the system catalog **GS_WLM_INSTANCE_HISTORY**.

**Type**: SIGHUP

**Value range**: Boolean

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- **on** indicates that the instance resource monitoring dumping function is enabled.
- **off**: Specifies that the instance resource monitoring dumping function is disabled.

**Default value**: **on**

## instance_metric_retention_time

**Parameter description**: Specifies the retention time of the instance historical resource monitoring data. This parameter is valid only when **enable_instance_metric_persistent** is set to **on**.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 3650. The unit is day.

- If this parameter is set to **0**, instance historical resource monitoring data is permanently stored.
- If the value is greater than **0**, the instance historical resource monitoring data is stored for the specified number of days.

**Default value**: **7**

## resource_track_level

**Parameter description**: Specifies the resource monitoring level of the current session. This parameter is valid only when **enable_resource_track** is set to **on**.

**Type**: USERSET

**Value range**: enumerated values

- **none**: Resources are not monitored.
- **query**: Enables query-level resource monitoring. If this function is enabled, the plan information (similar to the output information of EXPLAIN) of SQL statements will be recorded in top SQL statements.
- **perf**: Enables the perf-level resource monitoring. If this function is enabled, the plan information (similar to the output information of EXPLAIN ANALYZE) that contains the actual execution time and the number of execution rows will be recorded in the top SQL.
- **operator**: enables the operator-level resource monitoring. If this function is enabled, not only the information including the actual execution time and number of execution rows is recorded in the top SQL statement, but also the operator-level execution information is updated to the top SQL statement.

**Default value**: **query**

## resource_track_cost

**Parameter description**: Specifies the minimum execution cost for resource monitoring on statements in the current session. This parameter is valid only when **enable_resource_track** is set to **on**.

**Type**: USERSET

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**Value range**: an integer ranging from -1 to INT_MAX

- **–1** indicates that resource monitoring is disabled.
- A value greater than or equal to **0** indicates that statements whose execution cost exceeds this value will be monitored.

**Default value**: **100000**

## resource_track_duration

**Parameter description**: Specifies the minimum statement execution time that determines whether information about jobs of a statement recorded in the real-time view (see **Table 10-1**) will be dumped to a historical view after the statement is executed. Job information will be dumped from the real-time view (with the suffix **statistics**) to a historical view (with the suffix **history**) if the statement execution time is no less than this value.

**Type**: USERSET

**Value range**: an integer ranging from 0 to INT_MAX. The unit is second (s).

- **0** indicates that information about all statements recorded in the real-time resource monitoring view (see **Table 10-1**) will be archived into historical views.
- If the value is greater than **0**, information about statements recorded in the real-time resource monitoring view (see **Table 10-1**), whose execution time exceeds this value will be archived into historical views.

**Default value**: **1min**

## dynamic_memory_quota

**Parameter description**: Specifies the memory quota in adaptive load scenarios, that is, the proportion of maximum available memory to total system memory.

**Type**: SIGHUP

**Value range**: an integer ranging from 1 to 100

**Default value**: **80**

## disable_memory_protect

**Parameter description:** Stops memory protection. To query system views when system memory is insufficient, set this parameter to **on** to stop memory protection. This parameter is used only to diagnose and debug the system when system memory is insufficient. Set it to **off** in other scenarios.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that memory protection stops.
- **off** indicates that memory is protected.

**Default value**: **off**

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## query_band

**Parameter description**: Specifies the job type of the current session.

**Type**: USERSET

**Value range**: a string

**Default value**: empty

## enable_bbox_dump

**Parameter description**: Specifies whether the black box function is enabled. The core files can be generated even through the core dump mechanism is not configured in the system. This parameter must be simultaneously used on CNs and DNs.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the black box function is enabled.
- **off** indicates that the black box function is disabled.

**Default value**: **off**

## enable_dynamic_workload

**Parameter description**: Specifies whether to enable the dynamic workload management function.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates the dynamic workload management function is enabled.
- **off** indicates the dynamic workload management function is disabled.

**Default value: on**

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NOTICE

- If memory adaptation is enabled, you do not need to use **work_mem** to optimize the operator memory usage after collecting statistics. The system will generate a plan for each statement based on the current load, estimating the memory used by each operator and by the entire statement. In a concurrency scenario, statements are queued based on the system load and their memory usage.
- The optimizer cannot accurately estimate the number of rows and will probably underestimate or overestimate memory usage. If the memory usage is underestimated, the allocated memory will be automatically increased during statement running. If the memory usage is overestimated, system resources will not be fully used, and the number of statements waiting in a queue will increase, which probably results in low performance. To improve performance, identify the statements whose estimated memory usage is much greater than the DN peak memory and adjust the value of **query_max_mem**. For details, see **Adjusting Key Parameters During SQL Tuning**.

## bbox_dump_count

**Parameter description**: Specifies the maximum number of core files that are generated by GaussDB(DWS) and can be stored in the path specified by **bbox_dump_path**. If the number of core files exceeds this value, old core files will be deleted. This parameter is valid only if **enable_bbox_dump** is set to **on**.

**Type**: USERSET

**Value range**: an integer ranging from 1 to 20

**Default value**: **8**

NOTE

When core files are generated during concurrent SQL statement execution, the number of files may be larger than the value of **bbox_dump_count**.

## io_limits

**Parameter description**: Specifies the upper limit of IOPS triggered.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 1073741823

**Default value**: **0**

## io_priority

**Parameter description**: Specifies the I/O priority for jobs that consume many I/O resources. It takes effect when the I/O usage reaches 90%.

**Type**: USERSET

**Value range**: enumerated values

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- **None** indicates no control.
- **Low** indicates that the IOPS is reduced to 20% of the original value.
- **Medium** indicates that the IOPS is reduced to 50% of the original value.
- **High** indicates that the IOPS is reduced to 80% of the original value.

**Default value**: **None**

## session_respool

**Parameter description**: Specifies the resource pool associated with the current session.

**Type**: USERSET

If you set **cgroup_name** and then **session_respool**, the Cgroups associated with **session_respool** take effect. If you reverse the order, Cgroups associated with **cgroup_name** take effect.

If the Workload Cgroup level is specified during the **cgroup_name** change, the database does not check the Cgroup level. The level ranges from 1 to 10.

You are not advised to set **cgroup_name** and **session_respool** at the same time.

**Value range**: a string. This parameter can be set to the resource pool configured through **create resource pool**.

**Default value**: **invalid_pool**

## enable_transaction_parctl

**Parameter description**: whether to control transaction block statements and stored procedure statements.

**Type**: USERSET

**Value range**: Boolean

- **on**: Transaction block statements and stored procedure statements are controlled.
- **off**: Transaction block statements and stored procedure statements are not controlled.

**Default value**: **on**

## session_statistics_memory

**Parameter description**: Specifies the memory size of a real-time query view.

**Type**: SIGHUP

**Value range**: an integer ranging from 5 MB to 50% of **max_process_memory**

**Default value**: **5 MB**

## session_history_memory

**Parameter description**: Specifies the memory size of a historical query view.

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**Type**: SIGHUP

**Value range**: an integer ranging from 10 MB to 50% of **max_process_memory**

**Default value: 100 MB**

## topsql_retention_time

**Parameter description**: Specifies the retention period of historical TopSQL data in the **gs_wlm_session_info** and **gs_wlm_operator_info** tables.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 3650. The unit is day.

- If it is set to **0**, the data is stored permanently.
- If the value is greater than **0**, the data is stored for the specified number of days.

**Default value**: **0**

**CAUTION**

Before setting this GUC parameter to enable the data retention function, delete data from the **gs_wlm_session_info** and **gs_wlm_operator_info** tables.

## transaction_pending_time

**Parameter description**: maximum queuing time of transaction block statements and stored procedure statements if **enable_transaction_parctl** is set to **on**.

**Type**: USERSET

**Value range**: an integer ranging from –1 to INT_MAX. The unit is second (s).

- **–1** or **0**: No queuing timeout is specified for transaction block statements and stored procedure statements. The statements can be executed when resources are available.
- Value greater than **0**: If transaction block statements and stored procedure statements have been queued for a time longer than the specified value, they are forcibly executed regardless of the current resource situation.

**Default value**: **0**

**NOTICE**

This parameter is valid only for internal statements of stored procedures and transaction blocks. That is, this parameter takes effect only for the statements whose **enqueue** value (for details, see **PG_SESSION_WLMSTAT**) is **Transaction** or **StoredProc**.

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### wlm_sql_allow_list

**Parameter description**: Specifies whitelisted SQL statements for resource management. Whitelisted SQL statements are not monitored by resource management.

**Type**: SIGHUP

**Value range**: a string

**Default value**: empty

NOTICE

- One or more whitelisted SQL statements can be specified in **wlm_sql_allow_list**. If multiple SQL statements are to be whitelisted, use semicolons (;) to separate them.
- The system determines whether SQL statements are monitored based on the prefix match. The SQL statements are case insensitive. For example, if **wlm_sql_allow_list** is set to **'SELECT'**, all **SELECT** statements are not monitored by the resource management module.
- The system identifies spaces at the beginning of the parameter value. For example, **'SELECT'** and **' SELECT'** have different representations. **' SELECT'** filters only the **SELECT** statements with spaces at the beginning.
- The system has some whitelisted SQL statements by default, which cannot be modified. You can query the default whitelisted SQL statements and the SQL statements that have been successfully added to the whitelist by GUC through the system view **gs_wlm_sql_allow**.
- New SQL statements cannot be appended to the whitelisted SQL statements specified by **wlm_sql_allow_list** but can be set only through overwriting. To add an SQL statement, query the original GUC value, add the new statement to the end of the original value, separate the statements with a semicolon (;), and set the GUC value again.

## 15.14 Automatic Cleanup

The automatic cleanup process (autovacuum) in the system automatically runs the **VACUUM** and **ANALYZE** commands to recycle the record space marked by the deleted status and update statistics in the table.

### autovacuum

**Parameter description**: Enables the automatic cleanup process (autovacuum) in the database. Ensure that the **track_counts** parameter is set to **on** before enabling the automatic cleanup process.

**Type**: SIGHUP

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NOTE

- Set the **autovacuum** parameter to **on** if you want to enable the function to automatically clean up two-phase transactions after the system recovers from faults.
- If **autovacuum** is set to **on** and the value of **autovacuum_max_workers** is **0**, the system will not automatically clean up two-phase transactions. The system will clean up them after recovering from faults.
- If **autovacuum** is set to **on** and the value of **autovacuum_max_workers** is greater than **0**, the system will automatically clean up the two-phase transactions and processes after recovering from faults.

NOTICE

Even if the **autovacuum** parameter is set to **off**, the automatic cleanup process will be enabled automatically by the database when a transaction ID wrap is about to occur. When the create database or drop database operation fails, some nodes may be submitted or rolled back while others in the prepared status may not be submitted. In this case, the system cannot automatically restore these nodes and the manual restoration is required. The restoration steps are as follows:

1. Use the **gs_clean** tool (setting the **option** parameter to **-N**) to query the xid of the abnormal two-phase transactions and nodes in the prepared state.
2. Log in to the nodes whose transactions are in the prepared status. Administrators connect to an available database such as gaussdb to run the **set xc_maintenance_mode = on** statement.
3. Submit or roll back the two-phase transactions (for example, submit or roll back a statement) based on global transaction status.

**Value range**: Boolean

- **on** indicates the database automatic cleanup process is enabled.
- **off** indicates the database automatic cleanup process is disabled.

**Default value**: **off**

## autovacuum_mode

**Parameter description**: Specifies whether the autoanalyze or autovacuum function is enabled. This parameter is valid only when **autovacuum** is set to **on**.

**Type**: SIGHUP

**Value range**: enumerated values

- **analyze** indicates that only autoanalyze is performed.
- **vacuum** indicates that only autovacuum is performed.
- **mix** indicates that both autoanalyze and autovacuum are performed.
- **none** indicates that neither of them is performed.

**Default value**: **mix**

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## autoanalyze_timeout

**Parameter description**: Specifies the timeout period of autoanalyze. If the duration of autoanalyze on a table exceeds the value of **autoanalyze_timeout**, the autoanalyze is automatically canceled.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 2147483. The unit is second.

**Default value**: **5min**

## autovacuum_io_limits

**Parameter description**: Specifies the upper limit of I/Os triggered by the autovacuum process per second.

**Type**: SIGHUP

**Value range**: an integer ranging from –1 to 1073741823. **–1** indicates that the default Cgroup is used.

**Default value**: **–1**

## log_autovacuum_min_duration

**Parameter description**: Records each step performed by the automatic cleanup process to the server log when the execution time of the automatic cleanup process is greater than or equal to a certain value. This parameter helps track the automatic cleanup behaviors.

**Type**: SIGHUP

For example, set the **log_autovacuum_min_duration** parameter to 250 ms to record the information related to the automatic cleanup commands running the parameters whose values are greater than or equal to 250 ms.

**Value range**: an integer ranging from –1 to INT_MAX. The unit is ms.

- If this parameter is set to **0**, all the automatic cleanup operations are recorded in the log.
- If this parameter is set to **–1**, all the automatic cleanup operations are not recorded in the log.
- If this parameter is not set to **–1**, an automatic cleanup operation is skipped and a message is recorded due to lock conflicts.

**Default value**: **–1**

## autovacuum_max_workers

**Parameter description**: Specifies the maximum number of automatic cleanup threads running at the same time.

**Type**: POSTMASTER

**Value range**: an integer ranging from 0 to 262143. **0** indicates that autovacuum is disabled.

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**Default value**: **3**

## autovacuum_naptime

**Parameter description**: Specifies the interval between two automatic cleanup operations.

**Type**: SIGHUP

**Value range**: an integer ranging from 1 to 2147483. The unit is second.

**Default value**: **10min**

## autovacuum_vacuum_threshold

**Parameter description**: Specifies the threshold for triggering the **VACUUM** operation. When the number of deleted or updated records in a table exceeds the specified threshold, the **VACUUM** operation is executed on this table.

**Type**: SIGHUP

**Value range**: an integer ranging from **0** to **INT_MAX**

**Default value**: **50**

## autovacuum_analyze_threshold

**Parameter description**: Specifies the threshold for triggering the **ANALYZE** operation. When the number of deleted, inserted, or updated records in a table exceeds the specified threshold, the **ANALYZE** operation is executed on this table.

**Type**: SIGHUP

**Value range**: an integer ranging from **0** to **INT_MAX**

**Default value**: **50**

## autovacuum_vacuum_scale_factor

**Parameter description**: Specifies the size scaling factor of a table added to the **autovacuum_vacuum_threshold** parameter when a **VACUUM** event is triggered.

**Type**: SIGHUP

**Value range**: a floating point number ranging from 0.0 to 100.0

**Default value**: **0.2**

## autovacuum_analyze_scale_factor

**Parameter description**: Specifies the size scaling factor of a table added to the **autovacuum_analyze_threshold** parameter when an **ANALYZE** event is triggered.

**Type**: SIGHUP

**Value range**: a floating point number ranging from 0.0 to 100.0

**Default value**: **0.1**

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### autovacuum_freeze_max_age

**Parameter description**: Specifies the maximum age (in transactions) that a table's **pg_class.relfrozenxid** column can attain before a VACUUM operation is forced to prevent transaction ID wraparound within the table.

The old files under the subdirectory of **pg_clog/** can also be deleted by the VACUUM operation. Even if the automatic cleanup process is forbidden, the system will invoke the automatic cleanup process to prevent the cyclic repetition.

**Type**: POSTMASTER

**Value range**: an integer ranging from 100000 to 576460752303423487

**Default value**: **20000000000**

### autovacuum_vacuum_cost_delay

**Parameter description**: Specifies the value of the cost delay used in the autovacuum operation.

**Type**: SIGHUP

**Value range**: an integer ranging from –1 to 100. The unit is ms. **-1** indicates that the normal vacuum cost delay is used.

**Default value**: **20ms**

### autovacuum_vacuum_cost_limit

**Parameter description**: Specifies the value of the cost limit used in the autovacuum operation.

**Type**: SIGHUP

**Value range**: an integer ranging from –1 to 10000. **-1** indicates that the normal vacuum cost limit is used.

**Default value**: **–1**

# 15.15 Default Settings of Client Connection

## 15.15.1 Statement Behavior

This section describes related default parameters involved in the execution of SQL statements.

### search_path

**Parameter description**: Specifies the order in which schemas are searched when an object is referenced with no schema specified. The value of this parameter consists of one or more schema names. Different schema names are separated by commas (,).

**Type**: USERSET

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- If the schema of a temporary table exists in the current session, the scheme can be listed in **search_path** by using the alias **pg_temp**, for example, **'pg_temp,public'**. The schema of a temporary table has the highest search priority and is always searched before all the schemas specified in **pg_catalog** and **search_path**. Therefore, do not explicitly specify **pg_temp** to be searched after other schemas in **search_path**. This setting will not take effect and an error message will be displayed. If the alias **pg_temp** is used, the temporary schema will be only searched for database objects, including tables, views, and data types. Functions or operator names will not be searched for.
- The schema of a system catalog, **pg_catalog**, has the second highest search priority and is the first to be searched among all the schemas, excluding **pg_temp**, specified in **search_path**. Therefore, do not explicitly specify **pg_catalog** to be searched after other schemas in **search_path**. This setting will not take effect and an error message will be displayed.
- When an object is created without specifying a particular schema, the object will be placed in the first valid schema listed in **search_path**. An error will be reported if the search path is empty.
- The current effective value of the search path can be examined through the SQL function current_schema. This is different from examining the value of **search_path**, because the current_schema function displays the first valid schema name in **search_path**.

**Value range**: a string

NOTE

- When this parameter is set to **"$user", public**, a database can be shared (where no users have private schemas, and all share use of public), and private per-user schemas and combinations of them are supported. Other effects can be obtained by modifying the default search path setting, either globally or per-user.
- When this parameter is set to a null string (''), the system automatically converts it into a pair of double quotation marks ("").
- If the content contains double quotation marks, the system considers them as insecure characters and converts each double quotation mark into a pair of double quotation marks.

**Default value**: **"$user",public**

NOTE

**$user** indicates the name of the schema with the same name as the current session user. If the schema does not exist, **$user** will be ignored.

## current_schema

**Parameter description**: Specifies the current schema.

**Type**: USERSET

**Value range**: a string

**Default value**: **"$user",public**

NOTE

**$user** indicates the name of the schema with the same name as the current session user. If the schema does not exist, **$user** will be ignored.

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## default_tablespace

**Parameter description**: Specifies the default tablespace of the created objects (tables and indexes) when a **CREATE** command does not explicitly specify a tablespace.

- The value of this parameter is either the name of a tablespace, or an empty string that specifies the use of the default tablespace of the current database. If a non-default tablespace is specified, users must have CREATE privilege for it. Otherwise, creation attempts will fail.
- This parameter is not used for temporary tables. For them, the **temp_tablespaces** is consulted instead.
- This parameter is not used when users create databases. By default, a new database inherits its tablespace setting from the template database.

**Type**: USERSET

**Value range**: a string. An empty string indicates that the default tablespace is used.

**Default value**: empty

## default_storage_nodegroup

**Parameter description**: Specifies the Node Group where a table is created by default. This parameter takes effect only for ordinary tables.

- **installation** indicates that tables will be created in the Node Group created during database installation.
- A value other than **installation** indicates that tables will be created in the Node Group specified by this parameter.

**Type**: USERSET

**Value range**: a string

**Default value**: **installation**

## default_colversion

**Parameter description**: Sets the storage format version of the column-store table that is created by default.

**Type**: SIGHUP

**Value range**: enumerated values

- **1.0**: Each column in a column-store table is stored in a separate file. The file name is **relfilenode.C1.0**, **relfilenode.C2.0**, **relfilenode.C3.0**, or similar.
- **2.0**: All columns of a column-store table are combined and stored in a file. The file is named **relfilenode.C1.0**.

**Default value: 2.0**

## temp_tablespaces

**Parameter description**: Specifies tablespaces to which temporary objects will be created (temporary tables and their indexes) when a **CREATE** command does not

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explicitly specify a tablespace. Temporary files for sorting large data are created in these tablespaces.

The value of this parameter is a list of names of tablespaces. When there is more than one name in the list, GaussDB(DWS) chooses a random tablespace from the list upon the creation of a temporary object each time. Except that within a transaction, successively created temporary objects are placed in successive tablespaces in the list. If the element selected from the list is an empty string, GaussDB(DWS) will automatically use the default tablespace of the current database instead.

**Type**: USERSET

**Value range**: a string An empty string indicates that all temporary objects are created only in the default tablespace of the current database. For details, see **default_tablespace**.

**Default value**: empty

## check_function_bodies

**Parameter description**: Specifies whether to enable validation of the function body string during the execution of **CREATE FUNCTION**. Verification is occasionally disabled to avoid problems, such as forward references when you restore function definitions from a dump.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that validation of the function body string is enabled during the execution of **CREATE FUNCTION**.
- **off** indicates that validation of the function body string is disabled during the execution of **CREATE FUNCTION**.

**Default value**: **on**

## default_transaction_isolation

**Parameter description**: Specifies the default isolation level of each transaction.

**Type**: USERSET

**Value range**: enumerated values

- **READ COMMITTED**: Only committed data is read. This is the default.
- **READ UNCOMMITTED**: GaussDB(DWS) does not support **READ UNCOMMITTED**. If **READ UNCOMMITTED** is set, **READ COMMITTED** is executed instead.
- **REPEATABLE READ**: Only the data committed before transaction start is read. Uncommitted data or data committed in other concurrent transactions cannot be read.
- **SERIALIZABLE**: GaussDB(DWS) does not support **SERIALIZABLE**. If **SERIALIZABLE** is set, **REPEATABLE READ** is executed instead.

**Default value**: **READ COMMITTED**

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## default_transaction_read_only

**Parameter description**: Specifies whether each new transaction is in read-only state.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates the transaction is in read-only state.
- **off** indicates the transaction is in read/write state.

**Default value**: **off**

## default_transaction_deferrable

**Parameter description**: Specifies the default delaying state of each new transaction. It currently has no effect on read-only transactions or those running at isolation levels lower than serializable.

GaussDB(DWS) does not support the serializable isolation level of each transaction. The parameter is insignificant.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates a transaction is delayed by default.
- **off** indicates a transaction is not delayed by default.

**Default value**: **off**

## session_replication_role

**Parameter description**: Specifies the behavior of replication-related triggers and rules for the current session.

**Type**: USERSET

**NOTICE**

Setting this parameter will discard all the cached execution plans.

**Value range**: enumerated values

- **origin** indicates that the system copies operations such as insert, delete, and update from the current session.
- **replica** indicates that the system copies operations such as insert, delete, and update from other places to the current session.
- **local** indicates that the system will detect the role that has logged in to the database when using the function to copy operations and will perform related operations.

**Default value**: **origin**

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## statement_timeout

**Parameter description**: If the statement execution time (starting when the server receives the command) is longer than the duration specified by the parameter, error information is displayed when you attempt to execute the statement and the statement then exits.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 2147483647. The unit is ms.

**Default value**: **0**

## vacuum_freeze_min_age

**Parameter description**: Specifies the minimum cutoff age (in the same transaction), based on which **VACUUM** decides whether to replace transaction IDs with FrozenXID while scanning a table.

**Type**: USERSET

**Value range**: an integer from 0 to 576460752303423487.

NOTE

Although you can set this parameter to a value ranging from **0** to **1000000000** anytime, **VACUUM** will limit the effective value to half the value of autovacuum_freeze_max_age by default.

**Default value**: **5000000000**

## vacuum_freeze_table_age

**Parameter description**: Specifies the time that VACUUM freezes tuples while scanning the whole table. **VACUUM** performs a whole-table scan if the value of the **pg_class.relfrozenxid** column of the table has reached the specified time.

**Type**: USERSET

**Value range**: an integer from 0 to 576460752303423487.

NOTE

Although users can set this parameter to a value ranging from **0** to **2000000000** anytime, **VACUUM** will limit the effective value to 95% of autovacuum_freeze_max_age by default. Therefore, a periodic manual VACUUM has a chance to run before an anti-wraparound autovacuum is launched for the table.

**Default value**: **15000000000**

## bytea_output

**Parameter description**: Specifies the output format for values of the bytea type.

**Type**: USERSET

**Value range**: enumerated values

- **hex** indicates the binary data is converted to the two-byte hexadecimal digit.

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- **escape** indicates the traditional PostgreSQL format is used. It takes the approach of representing a binary string as a sequence of ASCII characters, while converting those bytes that cannot be represented as an ASCII character into special escape sequences.

**Default value**: **hex**

## xmlbinary

**Parameter description**: Specifies how binary values are to be encoded in XML.

**Type**: USERSET

**Value range**: enumerated values

- base64
- hex

**Default value**: **base64**

## xmloption

**Parameter description**: Specifies whether DOCUMENT or CONTENT is implicit when converting between XML and string values.

**Type**: USERSET

**Value range**: enumerated values

- **document** indicates an HTML document.
- **content** indicates a common string.

**Default value**: **content**

## max_compile_functions

**Parameter description**: Specifies the maximum number of function compilation results stored in the server. Excessive functions and compilation results generated during the storage may occupy large memory space. Setting this parameter to a proper value can reduce the memory usage and improve system performance.

**Type**: POSTMASTER

**Value range**: an integer ranging from 1 to INT_MAX

**Default value**: **1000**

## gin_pending_list_limit

**Parameter description**: Specifies the maximum size of the GIN pending list which is used when **fastupdate** is enabled. If the list grows larger than this maximum size, it is cleaned up by moving the entries in it to the main GIN data structure in batches. This setting can be overridden for individual GIN indexes by modifying index storage parameters.

**Type**: USERSET

**Value range**: an integer ranging from 64 to INT_MAX. The unit is KB.

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**Default value**: **4 MB**

## 15.15.2 Zone and Formatting

This section describes parameters related to the time format setting.

### DateStyle

**Parameter description**: Specifies the display format for date and time values, as well as the rules for interpreting ambiguous date input values.

This variable contains two independent components: the output format specifications (ISO, Postgres, SQL, or German) and the input/output order of year/month/day (DMY, MDY, or YMD). The two components can be set separately or together. The keywords Euro and European are synonyms for DMY; the keywords US, NonEuro, and NonEuropean are synonyms for MDY.

**Type**: USERSET

**Value range**: a string

**Default value**: **ISO, MDY**

NOTE

**gs_initdb** will initialize this parameter so that its value is the same as that of **lc_time**.

**Suggestion**: The ISO format is recommended. Postgres, SQL, and German use abbreviations for time zones, such as **EST**, **WST**, and **CST**. These abbreviations can be ambiguous. For example, **CST** can represent Central Standard Time (USA) UT-6:00, Central Standard Time (Australia) UT+9:30, and others. This may lead to incorrect time zone conversion and cause errors.

### IntervalStyle

**Parameter description**: Specifies the display format for interval values.

**Type**: USERSET

**Value range**: enumerated values

- **sql_standard** indicates that output matching SQL standards will be generated.
- **postgres** indicates that output matching PostgreSQL 8.4 will be generated when the **DateStyle** parameter is set to **ISO**.
- **postgres_verbose** indicates that output matching PostgreSQL 8.4 will be generated when the **DateStyle** parameter is set to **non_ISO**.
- **iso_8601** indicates that output matching the time interval "format with designators" defined in ISO 8601 will be generated.
- **oracle** indicates the output result that matches the numtodsinterval function in the Oracle database. For details, see numtodsinterval.

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NOTICE

The **IntervalStyle** parameter also affects the interpretation of ambiguous interval input.

**Default value**: **postgres**

## TimeZone

**Parameter description**: Specifies the time zone for displaying and interpreting time stamps.

**Type**: USERSET

**Value range**: a string. You can obtain it by querying the **pg_timezone_names** view.

**Default value**: **PRC**

NOTE

**gs_initdb** will set a time zone value that is consistent with the system environment.

## timezone_abbreviations

**Parameter description**: Specifies the time zone abbreviations that will be accepted by the server.

**Type**: USERSET

**Value range**: a string. You can obtain it by querying the pg_timezone_names view.

**Default value**: **Default**

NOTE

**Default** indicates an abbreviation that works in most of the world. There are also other abbreviations, such as **Australia** and **India** that can be defined for a particular installation.

## extra_float_digits

**Parameter description**: Specifies the number of digits displayed for floating-point values, including float4, float8, and geometric data types. The parameter value is added to the standard number of digits (FLT_DIG or DBL_DIG as appropriate).

**Type**: USERSET

**Value range**: an integer ranging from –15 to 3

NOTE

- This parameter can be set to **3** to include partially-significant digits. It is especially useful for dumping float data that needs to be restored exactly.
- This parameter can also be set to a negative value to suppress unwanted digits.

**Default value**: **0**

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## client_encoding

**Parameter description**: Specifies the client-side encoding type (character set).

Set this parameter as needed. Try to keep the client code and server code consistent to improve efficiency.

**Type**: USERSET

**Value range**: encoding compatible with PostgreSQL. **UTF8** indicates that the database encoding is used.

NOTE

- You can run the **locale -a** command to check and set the system-supported zone and the corresponding encoding format.
- By default, **gs_initdb** will initialize the setting of this parameter based on the current system environment. You can also run the **locale** command to check the current configuration environment.
- To use consistent encoding for communication within a cluster, you are advised to retain the default value of **client_encoding**. Modification to this parameter in the **postgresql.conf** file (by using the **gs_guc** tool, for example) does not take effect.

**Default value**: **UTF8**

**Recommended value**: **SQL_ASCII** or **UTF8**

## lc_messages

**Parameter description**: Specifies the language in which messages are displayed.

Valid values depend on the current system. On some systems, this zone category does not exist. Setting this variable will still work, but there will be no effect. In addition, translated messages for the desired language may not exist. In this case, you can still see the English messages.

**Type**: SUSET

**Value range**: a string

NOTE

- You can run the **locale -a** command to check and set the system-supported zone and the corresponding encoding format.
- By default, **gs_initdb** will initialize the setting of this parameter based on the current system environment. You can also run the **locale** command to check the current configuration environment.

**Default value**: **C**

## lc_monetary

**Parameter description**: Specifies the display format of monetary values. It affects the output of functions such as to_char. Valid values depend on the current system.

**Type**: USERSET

**Value range**: a string

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NOTE

- You can run the **locale -a** command to check and set the system-supported zone and the corresponding encoding format.
- By default, **gs_initdb** will initialize the setting of this parameter based on the current system environment. You can also run the **locale** command to check the current configuration environment.

**Default value**: **C**

## lc_numeric

**Parameter description**: Specifies the display format of numbers. It affects the output of functions such as to_char. Valid values depend on the current system.

**Type**: USERSET

**Value range**: a string

NOTE

- You can run the **locale -a** command to check and set the system-supported zone and the corresponding encoding format.
- By default, **gs_initdb** will initialize the setting of this parameter based on the current system environment. You can also run the **locale** command to check the current configuration environment.

**Default value**: **C**

## lc_time

**Parameter description**: Specifies the display format of time and zones. It affects the output of functions such as to_char. Valid values depend on the current system.

**Type**: USERSET

**Value range**: a string

NOTE

- You can run the **locale -a** command to check and set the system-supported zone and the corresponding encoding format.
- By default, **gs_initdb** will initialize the setting of this parameter based on the current system environment. You can also run the **locale** command to check the current configuration environment.

**Default value**: **C**

## default_text_search_config

**Parameter description**: Specifies the text search configuration.

If the specified text search configuration does not exist, an error will be reported. If the specified text search configuration is deleted, set **default_text_search_config** again. Otherwise, an error will be reported, indicating incorrect configuration.

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- The text search configuration is used by text search functions that do not have an explicit argument specifying the configuration.
- When a configuration file matching the environment is determined, gs_initdb will initialize the configuration file with a setting that corresponds to the environment.

**Type**: USERSET

**Value range**: a string

NOTE

GaussDB(DWS) supports the following two configurations: pg_catalog.english and pg_catalog.simple.

**Default value**: **pg_catalog.english**

# 15.15.3 Other Default Parameters

This section describes the default database loading parameters of the database system.

## dynamic_library_path

**Parameter description**: Specifies the path for saving the shared database files that are dynamically loaded for data searching. When a dynamically loaded module needs to be opened and the file name specified in the **CREATE FUNCTION** or **LOAD** command does not have a directory component, the system will search this path for the required file.

The value of **dynamic_library_path** must be a list of absolute paths separated by colons (:) or by semi-colons (;) on the Windows OS. The special variable **$libdir** in the beginning of a path will be replaced with the module installation directory provided by GaussDB(DWS). Example:

```
dynamic_library_path = '/usr/local/lib/postgresql:/opt/testgs/lib:$libdir'
```

**Type**: SUSET

**Value range**: a string

NOTE

If the value of this parameter is set to an empty character string, the automatic path search is turned off.

**Default value**: **$libdir**

## gin_fuzzy_search_limit

**Parameter description**: Specifies the upper limit of the size of the set returned by GIN indexes.

**Type**: USERSET

**Value range**: an integer ranging from 0 to INT_MAX. The value **0** indicates no limit.

**Default value**: **0**

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# 15.16 Lock Management

In GaussDB(DWS), a deadlock may occur when concurrently executed transactions compete for resources. This section describes parameters used for managing transaction lock mechanisms.

## deadlock_timeout

**Parameter description**: Specifies the time, in milliseconds, to wait on a lock before checking whether there is a deadlock condition. When the applied lock exceeds the preset value, the system will check whether a deadlock occurs.

- The check for deadlock is relatively expensive. Therefore, the server does not check it when waiting for a lock every time. Deadlocks do not frequently occur when the system is running. Therefore, the system just needs to wait on the lock for a while before checking for a deadlock. Increasing this value reduces the time wasted in needless deadlock checks, but slows down reporting of real deadlock errors. On a heavily loaded server, you may need to raise it. The value you have set needs to exceed the transaction time. By doing this, the possibility that a lock will be released before the waiter decides to check for deadlocks will be reduced.
- When **log_lock_waits** is set, this parameter also determines the duration you need to wait before a log message about the lock wait is issued. If you are trying to investigate locking delays, you need to set this parameter to a value smaller than normal **deadlock_timeout**.

**Type**: SUSET

**Value range**: an integer ranging from 1 to 2147483647. The unit is millisecond (ms).

**Default value**: **1s**

## lockwait_timeout

**Parameter description**: Specifies the longest time to wait before a single lock times out. If the time you wait before acquiring a lock exceeds the specified time, an error is reported.

**Type**: SUSET

**Value range**: an integer ranging from 0 to INT_MAX. The unit is millisecond (ms).

**Default value**: **20 min**

## update_lockwait_timeout

**Parameter description**: sets the maximum duration that a lock waits for concurrent updates on a row to complete when the concurrent update feature is enabled. If the time you wait before acquiring a lock exceeds the specified time, an error is reported.

**Type**: SUSET

**Value range**: an integer ranging from 0 to INT_MAX. The unit is millisecond (ms).

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**Default value**: **2min**

## max_locks_per_transaction

**Parameter description**: Controls the average number of object locks allocated for each transaction.

- The size of the shared lock table is calculated under the condition that a maximum of *N* independent objects need to be locked at any time. *N* = max_locks_per_transaction x (max_connections + max_prepared_transactions). Objects that do not exceed the preset number can be locked simultaneously at any time. You may need to increase this value when you modify many different tables in a single transaction. This parameter can only be set at database start.
- If this parameter is set to a large value, GaussDB(DWS) may require more System V shared memory than the default setting.
- When running a standby server, you must set this parameter to a value that is no less than that on the primary server. Otherwise, queries will not be allowed on the standby server.

**Type**: POSTMASTER

**Value range**: an integer ranging from 10 to INT_MAX

**Default value**: **256**

## max_pred_locks_per_transaction

**Parameter description**: Controls the average number of predicated locks allocated for each transaction.

- The size of the shared and predicated lock table is calculated under the condition that a maximum of *N* independent objects need to be locked at any time. *N* = max_pred_locks_per_transaction x (max_connections + max_prepared_transactions). Objects that do not exceed the preset number can be locked simultaneously at any time. You may need to increase this value when you modify many different tables in a single transaction. This parameter can only be set at server start.
- If this parameter is set to a large value, GaussDB(DWS) may require more System V shared memory than the default setting.

**Type**: POSTMASTER

**Value range**: an integer ranging from 10 to INT_MAX

**Default value**: **64**

## partition_lock_upgrade_timeout

**Parameter description**: Specifies the time to wait before the attempt of a lock upgrade from ExclusiveLock to AccessExclusiveLock times out on partitions.

- When you do MERGE PARTITION and CLUSTER PARTITION on a partitioned table, temporary tables are used for data rearrangement and file exchange. To concurrently perform as many operations as possible on the partitions,

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ExclusiveLock is acquired for the partitions during data rearrangement and AccessExclusiveLock is acquired during file exchange.

- Generally, a partition waits until it acquires a lock, or a timeout occurs if the partition waits for a period of time longer than specified by the **lockwait_timeout** parameter.
- When doing MERGE PARTITION or CLUSTER PARTITION on a partitioned table, you need to acquire AccessExclusiveLock during file exchange. If the lock fails to be acquired, the acquisition is retried in 50 ms. This parameter specifies the time to wait before the lock acquisition attempt times out.
- If this parameter is set to **-1**, the lock upgrade never times out. The lock upgrade is continuously retried until it succeeds.

**Type**: USERSET

**Value range**: an integer ranging from -1 to 3000. The unit is second (s).

**Default value**: **1800**

### enable_online_ddl_waitlock

**Parameter description**: Specifies whether to block DDL operations to wait for the release of cluster locks, such as pg_advisory_lock and pgxc_lock_for_backup. This parameter is mainly used in online OM operations and you are not advised to modify the settings.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that DDL operations will be blocked to wait for the release of cluster locks.
- **off** indicates that DDL operations will not be blocked.

**Default value**: **off**

# 15.17 Version and Platform Compatibility

## 15.17.1 Compatibility with Earlier Versions

This section describes the parameter control of the downward compatibility and external compatibility features of GaussDB(DWS). Backward compatibility of the database system provides support for the application of databases of earlier versions. This section describes parameters used for controlling backward compatibility of a database.

### array_nulls

**Parameter description**: Determines whether the array input parser recognizes unquoted NULL as a null array element.

**Type**: USERSET

**Value range**: Boolean

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- **on** indicates that null values can be entered in arrays.
- **off** indicates backward compatibility with the old behavior. Arrays containing **NULL** values can still be created when this parameter is set to **off**.

**Default value**: **on**

## backslash_quote

**Parameter description**: Determines whether a single quotation mark can be represented by \' in a string text.

**Type**: USERSET

**NOTICE**

When the string text meets the SQL standards, \ has no other meanings. This parameter only affects the handling of non-standard-conforming string texts, including escape string syntax (E'...').

**Value range**: enumerated values

- **on** indicates that the use of \' is always allowed.
- **off** indicates that the use of \' is rejected.
- **safe_encoding** indicates that the use of \' is allowed only when client encoding does not allow ASCII \ within a multibyte character.

**Default value**: **safe_encoding**

## default_with_oids

**Parameter description**: Determines whether **CREATE TABLE** and **CREATE TABLE AS** include an **OID** field in newly-created tables if neither **WITH OIDS** nor **WITHOUT OIDS** is specified. It also determines whether OIDs will be included in tables created by **SELECT INTO**.

It is not recommended that OIDs be used in user tables. Therefore, this parameter is set to **off** by default. When OIDs are required for a particular table, **WITH OIDS** needs to be specified during the table creation.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates **CREATE TABLE** and **CREATE TABLE AS** can include an **OID** field in newly-created tables.
- **off** indicates **CREATE TABLE** and **CREATE TABLE AS** cannot include any **OID** field in newly-created tables.

**Default value**: **off**

## escape_string_warning

**Parameter description**: Specifies a warning on directly using a backslash (\) as an escape in an ordinary character string.

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- Applications that wish to use a backslash (\) as an escape need to be modified to use escape string syntax (E'...'). This is because the default behavior of ordinary character strings is now to treat the backslash as an ordinary character in each SQL standard.
- This variable can be enabled to help locate codes that need to be changed.

**Type**: USERSET

**Value range**: Boolean

**Default value**: **on**

## lo_compat_privileges

**Parameter description**: Determines whether to enable backward compatibility for the privilege check of large objects.

**Type**: SUSET

**Value range**: Boolean

**on** indicates that the privilege check is disabled when users read or modify large objects. This setting is compatible with versions earlier than PostgreSQL 9.0.

**Default value**: **off**

## quote_all_identifiers

**Parameter description**: When the database generates SQL, this parameter forcibly quotes all identifiers even if they are not keywords. This will affect the output of EXPLAIN as well as the results of functions, such as pg_get_viewdef. For details, see the **--quote-all-identifiers** parameter of **gs_dump**.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates the forcible quotation function is enabled.
- **off** indicates the forcible quotation function is disabled.

**Default value**: **off**

## sql_inheritance

**Parameter description**: Determines whether to inherit semantics.

**Type**: USERSET

**Value range**: Boolean

**off** indicates that child tables cannot be accessed by various commands. That is, an ONLY keyword is used by default. This setting is compatible with versions earlier than PostgreSQL 7.1.

**Default value**: **on**

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### standard_conforming_strings

**Parameter description**: Determines whether ordinary string texts ('...') treat backslashes as ordinary texts as specified in the SQL standard.

- Applications can check this parameter to determine how string texts will be processed.
- It is recommended that characters be escaped by using the escape string syntax (E'...').

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the function is enabled.
- **off** indicates that the function is disabled.

**Default value**: **on**

### synchronize_seqscans

**Parameter description**: Controls sequential scans of tables to synchronize with each other. Concurrent scans read the same data block about at the same time and share the I/O workload.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that a scan may start in the middle of the table and then "wrap around" the end to cover all rows to synchronize with the activity of scans already in progress. This may result in unpredictable changes in the row ordering returned by queries that have no ORDER BY clause.
- **off** indicates that the scan always starts from the table heading.

**Default value**: **on**

### enable_beta_features

**Parameter description**: Controls whether certain limited features, such as GDS table join, are available. These features are not explicitly prohibited in earlier versions, but are not recommended due to their limitations in certain scenarios.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the features are enabled and forward compatible, but may incur errors in certain scenarios.
- **off** indicates that the features are disabled.

**Default value**: **off**

## 15.17.2 Platform and Client Compatibility

Many platforms use the database system. External compatibility of the database system provides a lot of convenience for platforms.

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## transform_null_equals

**Parameter description**: Determines whether expressions of the form expr = NULL (or NULL = expr) are treated as expr IS NULL. They return true if expr evaluates to **NULL**, and false otherwise.

- The correct SQL-standard-compliant behavior of expr = NULL is to always return null (unknown).
- Filtered forms in Microsoft Access generate queries that appear to use expr = NULL to test for null values. If you turn this option on, you can use this interface to access the database.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates expressions of the form expr = NULL (or NULL = expr) are treated as expr IS NULL.
- **off** indicates expr = NULL always returns NULL.

**Default value**: **off**

NOTE

New users are always confused about the semantics of expressions involving **NULL** values. Therefore, **off** is used as the default value.

## td_compatible_truncation

**Parameter description**: Determines whether to enable features compatible with a Teradata database. You can set this parameter to **on** when connecting to a database compatible with the Teradata database, so that when you perform the INSERT operation, overlong strings are truncated based on the allowed maximum length before being inserted into char- and varchar-type columns in the target table. This ensures all data is inserted into the target table without errors reported.

NOTE

- The string truncation function cannot be used if the **INSERT** statement includes a foreign table.
- If inserting multi-byte character data (such as Chinese characters) to database with the character set byte encoding (SQL_ASCII, LATIN1), and the character data crosses the truncation position, the string is truncated based on its bytes instead of characters. Unexpected result will occur in tail after the truncation. If you want correct truncation result, you are advised to adopt encoding set such as UTF8, which has no character data crossing the truncation position.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates overlong strings are truncated.
- **off** indicates overlong strings are not truncated.

**Default value**: **off**

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# 15.18 Fault Tolerance

This section describes parameters used for controlling the methods that the server processes an error occurring in the database system.

## exit_on_error

**Parameter description**: Specifies whether to terminate the current session.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that any error will terminate the current session.
- **off** indicates that only a FATAL error will terminate the current session.

**Default value**: **off**

## omit_encoding_error

**Parameter description**: If this parameter is set to **on** and the client character set of the database is encoded in UTF-8 format, the occurring character encoding conversion errors will be recorded in logs. Additionally, converted characters that have conversion errors will be ignored and replaced with question marks (?).

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that characters that have conversion errors will be ignored and replaced with question marks (?), and error information will be recorded in logs.
- **off** indicates that characters that have conversion errors cannot be converted and error information will be directly displayed.

**Default value**: **off**

## max_query_retry_times

**Parameter description**: Specifies the maximum number of automatic retry times when an SQL statement error occurs. Currently, a statement can start retrying if the following errors occur: **Connection reset by peer**, **Lock wait timeout**, and **Connection timed out**. If this parameter is set to **0**, the retry function is disabled.

**Type**: USERSET

**Value range**: an integer ranging from 0 to 20

**Default value**: **6**

## cn_send_buffer_size

**Parameter description**: Specifies the size of the data buffer used for data transmission on the CN.

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**Type**: POSTMASTER

**Value range**: an integer ranging from 8 to 128. The unit is KB.

**Default value**: **8 KB**

### max_cn_temp_file_size

**Parameter description**: Specifies the maximum number of temporary files that can be used by the CN during automatic SQL statement retries. The value **0** indicates that no temporary file is used.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 10485760. The unit is KB.

**Default value**: **5 GB**

### retry_ecode_list

**Parameter description**: Specifies the list of SQL error types that support automatic retry.

**Type**: USERSET

**Value range**: a string

**Default value**: YY001 YY002 YY003 YY004 YY005 YY006 YY007 YY008 YY009 YY010 YY011 YY012 YY013 YY014 YY015 53200 08006 08000 57P01 XX003 XX009 YY016 CG003 CG004 F0011

### data_sync_retry

**Parameter description**: Specifies whether to keep running the database when updated data fails to be written into disks by using the **fsync** function. In some OSs, no error is reported even if **fsync** has failed for multiple times. As a result, data is lost.

**Type**: POSTMASTER

**Value range**: Boolean

- **on**: The database keeps running and **fsync** is executed again after **fsync** fails.
- **off**: **PANIC** is reported and the database is stopped after **fsync** fails.

**Default value**: **off**

## 15.19 Connection Pool Parameters

When a connection pool is used to access the database, database connections are established and then stored in the memory as objects during system running. When you need to access the database, no new connection is established. Instead, an existing idle connection is selected from the connection pool. After you finish accessing the database, the database does not disable the connection but puts it back into the connection pool. The connection can be used for the next access request.

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## min_pool_size

**Parameter description**: Specifies the minimum number of connections between a CN's connection pool and another CN/DN.

**Type**: POSTMASTER

**Value range**: an integer ranging from 1 to 65535

**Default value**: **1**

## max_pool_size

**Parameter description**: Specifies the maximum number of connections between a CN's connection pool and another CN/DN.

**Type**: POSTMASTER

**Value range**: an integer ranging from 1 to 65535

**Default value**: **800**

## persistent_datanode_connections

**Parameter description**: Specifies whether to release the connection for the current session.

**Type**: USERSET

**Value range**: Boolean

- **off** indicates that the connection for the current session will be released.
- **on** indicates that the connection for the current session will not be released.

> **NOTICE**
>
> After this function is enabled, a session may hold a connection but does not run a query. As a result, other query requests fail to be connected. To fix this problem, the number of sessions must be less than or equal to **max_active_statements**.

**Default value**: **off**

## max_coordinators

**Parameter description**: Specifies the maximum number of CNs in a cluster.

**Type**: POSTMASTER

**Value range**: an integer ranging from 2 to 40

**Default value**: **40**

## max_datanodes

**Parameter description**: Specifies the maximum number of DNs in a cluster.

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**Type**: POSTMASTER

**Value range**: an integer ranging from 2 to 65535

**Default value**: 4096

### cache_connection

**Parameter description**: Specifies whether to reclaim the connections of a connection pool.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the connections of a connection pool will be reclaimed.
- **off** indicates that the connections of a connection pool will not be reclaimed.

**Default value**: **on**

### enable_force_reuse_connections

**Parameter description**: Specifies whether a session forcibly reuses a new connection.

**Type**: BACKEND

**Value range**: Boolean

- **on** indicates that the new connection is forcibly used.
- **off** indicates that the current connection is used.

**Default value**: **off**

NOTE

Session connection parameter. Users are not advised to configure this parameter.

### enable_pooler_parallel

**Parameter description**: Specifies whether a CN's connection pool can be connected in parallel mode.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that a CN's connection pool can be connected in parallel mode.
- **off** indicates that a CN's connection pool cannot be connected in parallel mode.

**Default value**: **on**

## 15.20 Cluster Transaction Parameters

This section describes the settings and value ranges of cluster transaction parameters.

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## transaction_isolation

**Parameter description**: Specifies the isolation level of the current transaction.

**Type**: USERSET

**Value range**:

- **READ COMMITTED**: Only committed data is read. This is the default.
- **READ UNCOMMITTED**: GaussDB(DWS) does not support **READ UNCOMMITTED**. If **READ UNCOMMITTED** is set, **READ COMMITTED** is executed instead.
- **REPEATABLE READ**: Only the data committed before transaction start is read. Uncommitted data or data committed in other concurrent transactions cannot be read.
- **SERIALIZABLE**: GaussDB(DWS) does not support **SERIALIZABLE**. If **SERIALIZABLE** is set, **REPEATABLE READ** is executed instead.

**Default value**: **READ COMMITTED**

## transaction_read_only

**Parameter description**: Specifies that the current transaction is a read-only transaction.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the current transaction is a read-only transaction.
- **off** indicates that the current transaction can be a read/write transaction.

**Default value**: **off** for CNs and **on** for DNs

## xc_maintenance_mode

**Parameter description**: Specifies whether the system is in maintenance mode.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that maintenance mode is enabled.
- **off** indicates that the maintenance mode is disabled.

**Default value**: **off**

NOTICE

Enable the maintenance mode with caution to avoid cluster data inconsistencies.

## allow_concurrent_tuple_update

**Parameter description**: Specifies whether to allow concurrent update.

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**Type**: USERSET

**Value range**: Boolean

- **on** indicates it is enabled.
- **off** indicates it is disabled.

**Default value**: **on**

## gtm_backup_barrier

**Parameter description**: Specifies whether to create a restoration point for the GTM starting point.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that a restoration point will be created for the GTM starting point.
- **off** indicates that a restoration point will not be created for the GTM starting point.

**Default value**: **off**

## gtm_conn_check_interval

**Parameter description**: Sets the CN to check whether the connection between the local thread and the primary GTM is normal.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to INT_MAX/1000. The unit is second.

**Default value**: **10s**

## transaction_deferrable

**Parameter description**: Specifies whether to delay the execution of a read-only serial transaction without incurring an execution failure. Assume this parameter is set to **on**. When the server detects that the tuples read by a read-only transaction are being modified by other transactions, it delays the execution of the read-only transaction until the other transactions finish modifying the tuples. Currently, this parameter is not used in GaussDB(DWS). Similar to this parameter, the **default_transaction_deferrable** parameter is used to specify whether to allow delayed execution of a transaction.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the execution of a read-only serial transaction can be delayed.
- **off** indicates that the execution of a read-only serial transaction cannot be delayed.

**Default value**: **off**

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## enforce_two_phase_commit

**Parameter description**: This parameter is reserved for compatibility with earlier versions. This parameter is invalid in the current version.

## enable_show_any_tuples

**Parameter description**: This parameter is available only in a read-only transaction and is used for analysis. When this parameter is set to **on/true**, all versions of tuples in the table are displayed.

**Type**: USERSET

**Value range**: Boolean

- **on/true** indicates that all versions of tuples in the table are displayed.
- **off/false** indicates that no versions of tuples in the table are displayed.

**Default value**: **off**

## gtm_connect_retries

**Parameter description**: Specifies the number of GTM reconnection attempts.

**Type**: SIGHUP

**Value range**: an integer ranging from 1 to 2147483647.

**Default value**: **30**

## enable_redistribute

**Parameter description**: Specifies whether unmatched nodes are redistributed.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that unmatched nodes are redistributed.
- **off** indicates that unmatched nodes are not redistributed.

**Default value**: **off**

## enable_gtm_free

**Parameter description**: Specifies whether the GTM-FREE mode is enabled. In large concurrency scenarios, the snapshots delivered by the GTM increase in number and size. The network between the GTM and the CN becomes the performance bottleneck. The GTM-FREE mode is used to eliminate the bottleneck. In this mode, the CN communicates with DNs instead of the GTM. The CN sends queries to each DN, which locally generates snapshots and xids, ensuring external write consistency but not external read consistency.

You are not advised to set this parameter to **on** in OLTP or OLAP scenarios where strong read consistency is required. This parameter is invalid for GaussDB(DWS).

**Type**: SUSET

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**Value range**: Boolean

- **on** indicates that the GTM-FREE mode is enabled and the cluster ensures eventual read consistency.
- **off** indicates that the GTM-FREE mode is disabled.

**Default value**: **off**

# 15.21 Developer Operations

## enable_light_colupdate

**Parameter description**: Specifies whether to enable the lightweight column-store update.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the lightweight column-store update is enabled.
- **off** indicates that the lightweight column-store update is disabled.

**Default value**: **off**

## enable_fast_query_shipping

**Parameter description**: Specifies whether to use the distributed framework for a query planner.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that execution plans are generated on CNs and DNs separately.
- **off** indicates that the distributed framework is used. Execution plans are generated on CNs and then sent to DNs for execution.

**Default value**: **on**

## enable_trigger_shipping

**Parameter description**: Specifies whether the trigger can be pushed to DNs for execution.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the trigger can be pushed to DNs for execution.
- **off** indicates that the trigger cannot be pushed to DNs. It must be executed on the CN.

**Default value**: **on**

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## enable_remotejoin

**Parameter description:** Specifies whether JOIN operation plans can be delivered to DNs for execution.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that JOIN operation plans can be delivered to DNs for execution.
- **off** indicates that JOIN operation plans cannot be delivered to DNs for execution.

**Default value**: **on**

## enable_remotegroup

**Parameter description:** Specifies whether the execution plans of **GROUP BY** and **AGGREGATE** can be delivered to DNs for execution.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the execution plans of **GROUP BY** and **AGGREGATE** can be delivered to DNs for execution.
- **off** indicates that the execution plans of **GROUP BY** and **AGGREGATE** cannot be delivered to DNs for execution.

**Default value**: **on**

## enable_remotelimit

**Parameter description**: Specifies whether the execution plan specified in the LIMIT clause can be pushed down to DNs for execution.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the execution plan specified in the LIMIT clause can be pushed down to DNs for execution.
- **off** indicates that the execution plan specified in the LIMIT clause cannot be delivered to DNs for execution.

**Default value**: **on**

## enable_remotesort

**Parameter description:** Specifies whether the execution plan of the ORDER BY clause can be delivered to DNs for execution.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the execution plan of the ORDER BY clause can be delivered to DNs for execution.

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- **off** indicates that the execution plan of the ORDER BY clause cannot be delivered to DNs for execution.

**Default value**: **on**

## enable_join_pseudoconst

**Parameter description**: Specifies whether joining with the pseudo constant is allowed. A pseudo constant indicates that the variables on both sides of a join are identical to the same constant.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that joining with the pseudo constant is allowed.
- **off** indicates that joining with the pseudo constant is not allowed.

**Default value**: **off**

## cost_model_version

**Parameter description**: Specifies the model used for cost estimation in the application scenario. This parameter affects the distinct estimation of the expression, HashJoin cost model, estimation of the number of rows, distribution key selection during redistribution, and estimation of the number of aggregate rows.

**Type**: USERSET

**Value range**: **0**, **1**, or **2**

- **0** indicates that the original cost estimation model is used.
- **1** indicates that the enhanced distinct estimation of the expression, HashJoin cost estimation model, estimation of the number of rows, distribution key selection during redistribution, and estimation of the number of aggregate rows are used on the basis of **0**.
- **2** indicates that the ANALYZE sampling algorithm with better randomicity is used on the basis of **1** to improve the accuracy of statistics collection.

**Default value**: **1**

## debug_assertions

**Parameter description**: Specifies whether to enable various assertion checks. This parameter assists in debugging. If you are experiencing strange problems or crashes, set this parameter to **on** to identify programming defects. To use this parameter, the macro USE_ASSERT_CHECKING must be defined (through the configure option **--enable-cassert**) during the GaussDB(DWS) compilation.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that various assertion checks are enabled.
- **off** indicates that various assertion checks are disabled.

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NOTE

This parameter is set to **on** by default if GaussDB(DWS) is compiled with various assertion checks enabled.

**Default value**: **off**

## distribute_test_param

**Parameter description**: Specifies whether the embedded test stubs for testing the distribution framework take effect. In most cases, developers embed some test stubs in the code during fault injection tests. Each test stub is identified by a unique name. The value of this parameter is a triplet that includes three values: thread level, test stub name, and error level of the injected fault. The three values are separated by commas (,).

**Type**: USERSET

**Value range**: a string indicating the name of any embedded test stub.

**Default value**: **-1, default, default**

## ignore_checksum_failure

**Parameter description**: Sets whether to ignore check failures (but still generates an alarm) and continues reading data. This parameter is valid only when enable_crc_check is set to **on**. Continuing reading data may result in breakdown, damaged data being transferred or hidden, failure of data recovery from remote nodes, or other serious problems. You are not advised to modify the settings.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that data check errors are ignored.
- **off** indicates that data check errors are reported.

**Default value**: **off**

## enable_colstore

**Parameter description**: Specifies whether to create a table as a column-store table by default when no storage method is specified. The value for each node must be the same. This parameter is used for tests. Users are not allowed to enable it.

**Type**: SUSET

**Value range**: Boolean

**Default value**: **off**

## enable_force_vector_engine

**Parameter description**: Specifies whether to forcibly generate vectorized execution plans for a vectorized execution operator if the operator's child node is a non-vectorized operator. When this parameter is set to **on**, vectorized execution

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plans are forcibly generated. When **enable_force_vector_engine** is enabled, no matter it is a row-store table, column-store table, or hybrid row-column store table, if the plantree does not contain scenarios that do not support vectorization, the vectorized executor is forcibly used.

**Type**: USERSET

**Value range**: Boolean

**Default value**: **off**

## enable_csqual_pushdown

**Parameter description**: Specifies whether to deliver filter criteria for a rough check during query.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that a rough check is performed with filter criteria delivered during query.
- **off** indicates that a rough check is performed without filter criteria delivered during query.

**Default value**: **on**

## explain_dna_file

**Parameter description**: Specifies the name of a CSV file exported when **explain_perf_mode** is set to **run**.

**Type**: USERSET

NOTICE

The value of this parameter must be an absolute path plus a file name with the extension **.csv**.

**Value range**: a string

**Default value**: **NULL**

## explain_perf_mode

**Parameter description**: Specifies the display format of the **explain** command.

**Type**: USERSET

**Value range**: **normal**, **pretty**, **summary**, and **run**

- **normal** indicates that the default printing format is used.
- **pretty** indicates that the optimized display mode of GaussDB(DWS) is used. A new format contains a plan node ID, directly and effectively analyzing performance.

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- **summary** indicates that the analysis result based on such information is printed in addition to the printed information in the format specified by **pretty**.
- **run** indicates that in addition to the printed information specified by **summary**, the database exports the information as a CSV file.

**Default value**: **pretty**

## join_num_distinct

**Parameter description**: Controls the default distinct value of the join column or expression in application scenarios.

**Type**: USERSET

**Value range**: a double-precision floating point number greater than or equal to **-100**. Decimals may be truncated when displayed on clients.

- If the value is greater than **0**, the value is used as the default distinct value.
- If the value is greater than or equal to **-100** and less than **0**, it means the percentage used to estimate the default distinct value.
- If the value is **0**, the default distinct value is **200**.

**Default value**: **-20**

## qual_num_distinct

**Parameter description**: Controls the default distinct value of the filter column or expression in application scenarios.

**Type**: USERSET

**Value range**: a double-precision floating point number greater than or equal to **-100**. Decimals may be truncated when displayed on clients.

- If the value is greater than **0**, the value is used as the default distinct value.
- If the value is greater than or equal to **-100** and less than **0**, it means the percentage used to estimate the default distinct value.
- If the value is **0**, the default distinct value is **200**.

**Default value**: **200**

## trace_notify

**Parameter description**: Specifies whether to generate a large amount of debugging output for the **LISTEN** and **NOTIFY** commands. **client_min_messages** or **log_min_messages** must be **DEBUG1** or lower so that such output can be recorded in the logs on the client or server separately.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the function is enabled.
- **off** indicates that the function is disabled.

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**Default value**: **off**

## trace_recovery_messages

**Parameter description**: Specifies whether to enable logging of recovery-related debugging output. This parameter allows users to overwrite the normal setting of **log_min_messages**, but only for specific messages. This is intended for use in debugging the standby server.

**Type**: SIGHUP

**Value range**: enumerated values. Valid values include **debug5**, **debug4**, **debug3**, **debug2**, **debug1**, and **log**. For details about the parameter values, see **log_min_messages**.

**Default value**: **log**

NOTE

- **log** indicates that recovery-related debugging information will not be logged.
- Except the default value **log**, each of the other values indicates that recovery-related debugging information at the specified level will also be logged. Common settings of **log_min_messages** will unconditionally record information into server logs.

## trace_sort

**Parameter description**: Specifies whether to display information about resource usage during sorting operations in logs. This parameter is available only when the macro TRACE_SORT is defined during the GaussDB(DWS) compilation. However, TRACE_SORT is currently defined by default.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the function is enabled.
- **off** indicates that the function is disabled.

**Default value**: **off**

## zero_damaged_pages

**Parameter description**: Specifies whether to detect a damaged page header that causes GaussDB(DWS) to report an error, aborting the current transaction.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the function is enabled.
- **off** indicates that the function is disabled.

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NOTE

- Setting this parameter to **on** causes the system to report a warning, pad the damaged page with zeros, and then continue with subsequent processing. This behavior will damage data, that is, all rows on the damaged page. However, it allows you to bypass the error and retrieve rows from any undamaged pages that are present in the table. Therefore, it is useful for restoring data that is damaged due to a hardware or software error. In most cases, you are not advised to set this parameter to **on** unless you do not want to restore data from the damaged pages of a table.
- For a column-store table, the system will skip the entire CU and then continue processing. The supported scenarios include the CRC check failure, magic check failure, and incorrect CU length.

**Default value**: **off**

## string_hash_compatible

**Parameter description**: Specifies whether to use the same method to calculate char-type hash values and varchar- or text-type hash values. Based on the setting of this parameter, you can determine whether a redistribution is required when a distribution column is converted from a char-type data distribution into a varchar- or text-type data distribution.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates that the same calculation method is used and a redistribution is not required.
- **off** indicates that different calculation methods are used and a redistribution is required.

NOTE

Calculation methods differ in the length of input strings used for calculating hash values. (For a char-type hash value, spaces following a string are not counted as the length. For a text- or varchar-type hash value, the spaces are counted.) The hash value affects the calculation result of queries. To avoid query errors, do not modify this parameter during database running once it is set.

**Default value**: **off**

## replication_test

**Parameter description**: Specifies whether to enable internal testing on the data replication function.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that internal testing on the data replication function is enabled.
- **off** indicates that internal testing on the data replication function is disabled.

**Default value**: **off**

## cost_param

**Parameter description**: Controls use of different estimation methods in specific customer scenarios, allowing estimated values approximating to onsite values.

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This parameter can control various methods simultaneously by performing AND (&) operations on the bit for each method. A method is selected if its value is not **0**.

If **cost_param & 1** is not set to **0**, an improvement mechanism is selected for calculating a non-equi join selection rate, which is more accurate in estimation of self-join (join between two same tables). In V300R002C00 and later, **cost_param & 1=0** is not used. That is, an optimized formula is selected for calculation.

When **cost_param & 2** is set to a value other than **0**, the selection rate is estimated based on multiple filter criteria. The lowest selection rate among all filter criteria, but not the product of the selection rates for two tables under a specific filter criterion, is used as the total selection rate. This method is more accurate when a close correlation exists between the columns to be filtered.

When **cost_param & 4** is not **0**, the selected debugging model is not recommended when the stream node is evaluated.

When **cost_param & 16** is not **0**, the model between fully correlated and fully uncorrelated models is used to calculate the comprehensive selection rate of two or more filtering conditions or join conditions. If there are many filtering conditions, the strongly-correlated model is preferred.

**Type**: USERSET

**Value range**: an integer ranging from 1 to INT_MAX

**Default value**: **16**

## convert_string_to_digit

**Parameter description**: Specifies the implicit conversion priority, which determines whether to preferentially convert strings into numbers.

In MySQL-compatible mode, this parameter has no impact.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that strings are preferentially converted into numbers.
- **off** indicates that strings are not preferentially converted into numbers.

**Default value**: **on**

**NOTICE**

Modify this parameter only when absolutely necessary because the modification will change the rule for converting internal data types and may cause unexpected results.

## nls_timestamp_format

**Parameter description**: Specifies the default timestamp format.

**Type**: USERSET

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**Value range**: a string

**Default value**: **DD-Mon-YYYY HH:MI:SS.FF AM**

## enable_partitionwise

**Parameter description**: Specifies whether to select an intelligent algorithm for joining partitioned tables.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that an intelligent algorithm is selected.
- **off** indicates that an intelligent algorithm is not selected.

**Default value**: **off**

## enable_partition_dynamic_pruning

**Parameter description**: Specifies whether dynamic pruning is enabled during partition table scanning.

**Type**: USERSET

**Value range**: Boolean

- **on**: enable
- **off**: disable

**Default value**: **on**

## max_user_defined_exception

**Parameter description**: Specifies the maximum number of exceptions. The default value cannot be changed.

**Type**: USERSET

**Value range**: an integer

**Default value**: **1000**

## datanode_strong_sync

**Parameter description**: This parameter no longer takes effect.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that forcible synchronization between stream nodes is enabled.
- **off** indicates that forcible synchronization between stream nodes is disabled.

**Default value**: **off**

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## enable_debug_vacuum

**Parameter description**: Specifies whether to allow output of some VACUUM-related logs for problem locating. This parameter is used only by developers. Common users are advised not to use it.

**Type**: SIGHUP

**Value range**: Boolean

- **on/true** indicates that output of vacuum-related logs is allowed.
- **off/false** indicates that output of vacuum-related logs is disallowed.

**Default value**: **off**

## enable_global_stats

**Parameter description**: Specifies the current statistics mode. This parameter is used to compare global statistics generation plans and the statistics generation plans for a single DN. This parameter is used for tests. Users are not allowed to enable it.

**Type**: SUSET

**Value range**: Boolean

- **on** or **true** indicates the global statistics mode.
- **off** or **false** indicates the single-DN statistics mode.

**Default value**: **on**

## enable_fast_numeric

**Parameter description**: Specifies whether to enable optimization for numeric data calculation. Calculation of numeric data is time-consuming. Numeric data is converted into int64- or int128-type data to improve numeric data calculation performance.

**Type**: USERSET

**Value range**: Boolean

- **on/true** indicates that optimization for numeric data calculation is enabled.
- **off/false** indicates that optimization for numeric data calculation is disabled.

**Default value**: **on**

## enable_row_fast_numeric

**Parameter description**: Specifies the format in which numeric data in a row-store table is spilled to disks.

**Type**: USERSET

**Value range**: Boolean

- **on/true** indicates that numeric data in a row-store table is spilled to disks in bigint format.

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- **off/false** indicates that numeric data in a row-store table is spilled to disks in the original format.

NOTICE

If this parameter is set to **on**, you are advised to enable **enable_force_vector_engine** to improve the query performance of large data sets. However, compared with the original format, there is a high probability that the bigint format occupies more disk space. For example, the TPC-H test set occupies about 7% more space (reference value, may vary depending on the environment).

**Default value**: **off**

## rewrite_rule

**Parameter description**: Specifies the rewriting rule for enabled optional queries. Some query rewriting rules are optional. Enabling them cannot always improve query efficiency. In a specific customer scenario, you can set the query rewriting rules through the GUC parameter to achieve optimal query efficiency.

This parameter can control the combination of query rewriting rules, for example, there are multiple rewriting rules: rule1, rule2, rule3, and rule4. To set the parameters, you can perform the following operations:

```
set rewrite_rule=rule1;          --Enable query rewriting rule rule1.
set rewrite_rule=rule2,rule3;    --Enable query rewriting rules rule2 and rule3.
set rewrite_rule=none;           --Disable all optional query rewriting rules.
```

**Type**: USERSET

**Value range**: a string

- **none**: Does not use any optional query rewriting rules.
- **lazyagg**: Uses the Lazy Agg query rewriting rules for eliminating aggregation operations in subqueries.
- **magicset**: Uses the Magic Set query rewriting rules (from the main query to subqueries).
- **uniquecheck**: Uses the Unique Check rewriting rules. (The scenario where the target column does not contain the expression sublink of the aggregate function can be improved. The function can be enabled only when the value of the target column is unique after the sublink is aggregated based on the associated column. This function is recommended to be used by optimization engineers.)
- **disablerep**: Uses the function that prohibit pulling up sublinks of the replication table. (Disable sublink pull-up for the replication table.)
- **projection_pushdown**: Uses the Projection Pushdown rewriting rules.

**Default value**: **magicset**

## enable_compress_spill

**Parameter description**: Specifies whether to enable the compression function of writing data to a disk.

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**Type**: USERSET

**Value range**: Boolean

- **on/true** indicates that optimization for writing data to a disk is enabled.
- **off/false** indicates that optimization for writing data to a disk is disabled.

**Default value**: **on**

## analysis_options

**Parameter description**: Specifies whether to enable function options in the corresponding options to use the corresponding location functions, including data verification and performance statistics. For details, see the options in the value range.

**Type**: USERSET

**Value range**: a string

- **LLVM_COMPILE** indicates that the codegen compilation time of each thread is displayed on the explain performance page.
- **HASH_CONFLICT** indicates that the log file in the **pg_log** directory of the DN process displays the hash table statistics, including the hash table size, hash chain length, and hash conflict information.
- **STREAM_DATA_CHECK** indicates that a CRC check is performed on data before and after network data transmission.

**Default value**: **off(ALL)**, which indicates that no location function is enabled.

## resource_track_log

**Parameter description**: Specifies the log level of self-diagnosis. Currently, this parameter takes effect only in multi-column statistics.

**Type**: USERSET

**Value range**: a string

- **summary**: Brief diagnosis information is displayed.
- **detail**: Detailed diagnosis information is displayed.

Currently, the two parameter values differ only when there is an alarm about multi-column statistics not collected. If the parameter is set to **summary**, such an alarm will not be displayed. If it is set to **detail**, such an alarm will be displayed.

**Default value**: **summary**

## hll_default_log2m

**Parameter description**: Specifies the number of buckets for HLL data. The number of buckets affects the precision of distinct values calculated by HLL. The more buckets there are, the smaller the deviation is. The deviation range is as follows: $[-1.04/2^{log2m*1/2}, +1.04/2^{log2m*1/2}]$

**Type**: USERSET

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**Value range**: an integer ranging from 10 to 16

**Default value**: **11**

## hll_default_regwidth

**Parameter description**: Specifies the number of bits in each bucket for HLL data. A larger value indicates more memory occupied by HLL. **hll_default_regwidth** and **hll_default_log2m** determine the maximum number of distinct values that can be calculated by HLL. For details, see **Table 15-2**.

**Type**: USERSET

**Value range**: an integer ranging from 1 to 5

**Default value**: **5**

**Table 15-2** Maximum number of calculated distinct values determined by hll_default_log2m and hll_default_regwidth

| log2m | regwidth = 1 | regwidth = 2 | regwidth = 3 | regwidth = 4 | regwidth = 5 |
|---|---|---|---|---|---|
| 10 | 7.4e+02 | 3.0e+03 | 4.7e+04 | 1.2e+07 | 7.9e+11 |
| 11 | 1.5e+03 | 5.9e+03 | 9.5e+04 | 2.4e+07 | 1.6e+12 |
| 12 | 3.0e+03 | 1.2e+04 | 1.9e+05 | 4.8e+07 | 3.2e+12 |
| 13 | 5.9e+03 | 2.4e+04 | 3.8e+05 | 9.7e+07 | 6.3e+12 |
| 14 | 1.2e+04 | 4.7e+04 | 7.6e+05 | 1.9e+08 | 1.3e+13 |
| 15 | 2.4e+04 | 9.5e+04 | 1.5e+06 | 3.9e+08 | 2.5e+13 |

## hll_default_expthresh

**Parameter description**: Specifies the default threshold for switching from the **explicit** mode to the **sparse** mode.

**Type**: USERSET

**Value range**: an integer ranging from –1 to 7 **–1** indicates the auto mode; **0** indicates that the **explicit** mode is skipped; a value from 1 to 7 indicates that the mode is switched when the number of distinct values reaches $2^{hll\_default\_expthresh}$.

**Default value**: **–1**

## hll_default_sparseon

**Parameter description**: Specifies whether to enable the **sparse** mode by default.

**Type**: USERSET

**Valid value**: **0** and **1 0** indicates that the **sparse** mode is disabled by default. **1** indicates that the **sparse** mode is enabled by default.

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**Default value**: **1**

## hll_max_sparse

**Parameter description**: Specifies the size of **max_sparse**.

**Type**: USERSET

**Value range**: an integer ranging from –1 to **INT_MAX**

**Default value**: **–1**

## enable_compress_hll

**Parameter description**: Specifies whether to enable memory optimization for HLL.

**Type**: USERSET

**Value range**: Boolean

- **on** or **true** indicates that memory optimization is enabled.
- **off** or **false** indicates that memory optimization is disabled.

**Default value**: **off**

## udf_memory_limit

**Parameter description**: Controls the maximum physical memory that can be used when each CN or DN executes UDFs.

**Type**: POSTMASTER

**Value range**: an integer. The value range is from 200 x 1024 to the value of **max_process_memory** and the unit is KB.

**Default value**: **200 MB**

## FencedUDFMemoryLimit

**Parameter description**: Controls the virtual memory used by each fenced udf worker process.

**Type**: USERSET

**Suggestion**: You are not advised to set this parameter. You can set **udf_memory_limit** instead.

**Value range**: an integer. The unit can be KB, MB, or GB. **0** indicates that the memory is not limited.

**Default value**: **0**

## UDFWorkerMemHardLimit

**Parameter description**: Specifies the maximum value of **fencedUDFMemoryLimit**.

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**Type**: POSTMASTER

**Suggestion**: You are not advised to set this parameter. You can set **udf_memory_limit** instead.

**Value range**: an integer. The unit can be KB, MB, or GB.

**Default value**: **1 GB**

## pljava_vmoptions

**Parameter description**: Specifies the startup parameters for JVMs used by the PL/Java function.

**Type**: SUSET

**Value range**: a string, supporting:

- JDK8 JVM startup parameters.
- JDK8 JVM system attributes (starting with **–D**, for example, **–Djava.ext.dirs**).
- User-defined parameters (starting with **–D**, for example, **–Duser.defined.option**).

**NOTICE**

If **pljava_vmoptions** is set to a value beyond the value range, an error will be reported when PL/Java functions are used.

**Default value**: empty

## javaudf_disable_feature

**Parameter description**: Specifies the granularity of Java UDF actions.

**Type**: SIGHUP

**Value range**: a string

- **none** indicates that any action specified in other fine-grained parameters is enabled. When this parameter is set together with other parameters, **none** is invalid.
- **all** indicates that all Java UDF functions are disabled. This option has the highest priority.
- **extdir** indicates that the function of storing dependency JAR packages in a third-party path is disabled.
- **hadoop** indicates that Hadoop functions are disabled.
- **reflection** indicates that the reflection permission (**ReflectPermission**) is disabled during the execution of Java UDF functions.
- **loadlibrary** indicates that the dynamic library loading permission (**loadLibrary**) is disabled during the execution of Java UDF functions.
- **net** indicates that the network permission (**NetPermission**) is disabled during the execution of Java UDF functions.

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- **socket** indicates that the socket permission (**SocketPermission**) is disabled during the execution of Java UDF functions.
- **security** indicates that the security configuration permission (**SecurityPermission**) is disabled during the execution of Java UDF functions.
- **classloader** indicates that the **classLoder** creation permission (**createClassLoader**) is disabled during the execution of Java UDF functions.
- **access_declared_members** indicates that the permission of accessing other declared members (**accessDeclaredMembers**) is disabled during the execution of Java UDF functions.

**Default value**:
**extdir,hadoop,reflection,loadlibrary,net,socket,security,classloader,access_declared_members**

## enable_pbe_optimization

**Parameter description**: Specifies whether the optimizer optimizes the query plan for statements executed in Parse Bind Execute (PBE) mode.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the optimizer optimizes the query plan.
- **off** indicates that the optimization does not optimize the query plan.

**Default value**: **on**

## enable_light_proxy

**Parameter description**: Specifies whether the optimizer optimizes the execution of simple queries on CNs.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates that the optimizer optimizes the execution.
- **off** indicates that the optimization does not optimize the execution.

**Default value**: **on**

## checkpoint_flush_after

**Parameter description**: Specifies the number of consecutive disk pages that the checkpointer writer thread writes before asynchronous flush. In GaussDB(DWS), the size of a disk page is 8 KB.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 256. **0** indicates that the asynchronous flush function is disabled. For example, if the value is **32**, the checkpointer thread continuously writes 32 disk pages (that is, 32 x 8 = 256 KB) before asynchronous flush.

**Default value**: **32**

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## enable_parallel_ddl

**Parameter description**: Controls whether multiple CNs can concurrently perform DDL operations on the same database object.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that DDL operations can be performed safely and that no distributed deadlock occurs.
- **off** indicates that DDL operations cannot be performed safely and that distributed deadlocks may occur.

**Default value**: **on**

## show_acce_estimate_detail

**Parameter description**: When the GaussDB(DWS) cluster is accelerated (**acceleration_with_compute_pool** is set to **on**), specifies whether the **EXPLAIN** statement displays the evaluation information about execution plan pushdown to computing Node Groups. The evaluation information is generally used by O&M personnel during maintenance, and it may affect the output display of the **EXPLAIN** statement. Therefore, this parameter is disabled by default. The evaluation information is displayed only if the **verbose** option of the **EXPLAIN** statement is enabled.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the evaluation information is displayed in the output of the **EXPLAIN** statement.
- **off** indicates that the evaluation information is not displayed in the output of the **EXPLAIN** statement.

**Default value**: **off**

## support_batch_bind

**Parameter description**: Specifies whether to batch bind and execute PBE statements through interfaces such as JDBC, ODBC, and Libpq.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that batch binding and execution are used.
- **off** indicates that batch binding and execution are not used.

**Default value**: **on**

## enable_immediate_interrupt

**Parameter description**: Specifies whether the execution of the current statement or session can be immediately interrupted in the signal processing function.

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**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the execution of the current statement or session can be immediately interrupted in the signal processing function.
- **off** indicates that the execution of the current statement or session cannot be immediately interrupted in the signal processing function.

**Default value**: **off**

NOTE

Exercise caution when setting this parameter to **on**. If the execution of the current statement or session can be immediately interrupted in the signal processing function, the execution of some key processes may be interrupted, causing the failure to release the global lock in the system. It is recommended that this parameter be set to **on** only during system debugging or fault prevention.

# 15.22 Auditing

## 15.22.1 Audit Switch

### audit_enabled

**Parameter description**: Specifies whether to enable or disable the audit process. After the audit process is enabled, the auditing information written by the background process can be read from the pipe and written into audit files.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the auditing function is enabled.
- **off** indicates that the auditing function is disabled.

**Default value**: **on**

### audit_data_format

**Parameter description**: Specifies the format of the audit log files. Currently, only the binary format is supported.

**Type**: POSTMASTER

**Value range**: a string

**Default value**: **binary**

### audit_rotation_interval

**Parameter description**: Specifies the interval of creating an audit log file. If the difference between the current time and the time when the previous audit log file is created is greater than the value of **audit_rotation_interval**, a new audit log file will be generated.

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**Type**: SIGHUP

**Value range**: an integer ranging from 1 to **INT_MAX/60**. The unit is min.

**Default value**: **1d**

NOTICE

Adjust this parameter only when required. Otherwise, **audit_resource_policy** may fail to take effect. To control the storage space and time of audit logs, set the **audit_resource_policy**, **audit_space_limit**, and **audit_file_remain_time** parameters.

## audit_rotation_size

**Parameter description**: Specifies the maximum capacity of an audit log file. If the total number of messages in an audit log exceeds the value of **audit_rotation_size**, the server will generate a new audit log file.

**Type**: SIGHUP

**Value range**: an integer ranging from 1 to 1024. The unit is MB.

**Default value**: **10 MB**

NOTICE

Adjust this parameter only when required. Otherwise, **audit_resource_policy** may fail to take effect. To control the storage space and time of audit logs, set the **audit_resource_policy**, **audit_space_limit**, and **audit_file_remain_time** parameters.

## audit_resource_policy

**Parameter description**: Specifies the policy for determining whether audit logs are preferentially stored by space or time.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that audit logs are preferentially stored by space. A maximum of **audit_space_limit** logs can be stored.
- **off** indicates that audit logs are preferentially stored by time. A minimum duration of **audit_file_remain_time** logs must be stored. If the value of **audit_file_remain_time** is too large, the disk space occupied by stored audit logs reaches the value of **audit_space_limit**. In this case, the earliest audit files are deleted.

**Default value**: **on**

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### audit_file_remain_time

**Parameter description**: Specifies the minimum duration required for recording audit logs. This parameter is valid only when **audit_resource_policy** is set to **off**.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 730. The unit is day. **0** indicates that the storage duration is not limited.

**Default value**: **90**

### audit_space_limit

**Parameter description**: Specifies the total disk space occupied by audit files.

**Type**: SIGHUP

**Value range**: an integer ranging from **1024 KB** to **1024 GB**. The unit is KB.

**Default value**: **1GB**

### audit_file_remain_threshold

**Parameter description**: Specifies the maximum number of audit files in the audit directory.

**Type**: SIGHUP

**Value range**: an integer ranging from 1 to 1048576

**Default value**: **1048576**

NOTICE

Ensure that the value of this parameter is **1048576**. If the value is changed, the **audit_resource_policy** parameter may not take effect. To control the storage space and time of audit logs, use the **audit_resource_policy**, **audit_space_limit**, and **audit_file_remain_time** parameters.

## 15.22.2 Operation Audit

### audit_operation_exec

**Parameter description**: Specifies whether to audit successful operations in GaussDB(DWS). Set this parameter as required.

**Type**: SIGHUP

**Value range**: a string

- **none**: indicates that no audit item is configured. If any audit item is configured, **none** becomes invalid.
- **all**: indicates that all successful operations are audited. This value overwrites the concurrent configuration of any other audit items. Note that even if this

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parameter is set to **all**, not all DDL operations are audited. You need to control the object level of DDL operations by referring to **audit_system_object**.

- **login**: indicates that successful logins are audited.
- **logout**: indicates that user logouts are audited.
- **database_process**: indicates that database startup, stop, switchover, and recovery operations are audited.
- **user_lock**: indicates that successful locking and unlocking operations are audited.
- **grant_revoke**: indicates that successful granting and reclaiming of a user's permission are audited.
- **ddl**: indicates that successful DDL operations are audited. DDL operations are controlled at a fine granularity based on operation objects. Therefore, **audit_system_object** is used to control the objects whose DDL operations are to be audited. (The audit function takes effect as long as **audit_system_object** is configured, no matter whether **ddl** is set.)
- **select**: indicates that successful SELECT operations are audited.
- **copy**: indicates that successful COPY operations are audited.
- **userfunc**: indicates that successful operations for user-defined functions, stored procedures, and anonymous blocks are audited.
- **set**: indicates that successful SET operations are audited.
- **transaction**: indicates that successful transaction operations are audited.
- **vacuum**: indicates that successful VACUUM operations are audited.
- **analyze**: indicates that successful ANALYZE operations are audited.
- **explain**: indicates that successful EXPLAIN operations are audited.
- **specialfunc**: indicates that successful calls to special functions are audited. Special functions include **pg_terminate_backend** and **pg_cancel_backend**.
- **insert**: indicates that successful INSERT operations are audited.
- **update**: indicates that successful UPDATE operations are audited.
- **delete**: indicates that successful DELETE operations are audited.
- **merge**: indicates that successful MERGE operations are audited.
- **show**: indicates that successful SHOW operations are audited.
- **checkpoint**: indicates that successful CHECKPOINT operations are audited.
- **barrier**: indicates that successful BARRIER operations are audited.
- **cluster**: indicates that successful CLUSTER operations are audited.
- **comment**: indicates that successful COMMENT operations are audited.
- **cleanconn**: indicates that successful CLEANCONNECTION operations are audited.
- **prepare**: indicates that successful PREPARE, EXECUTE, and DEALLOCATE operations are audited.
- **constraints**: indicates that successful CONSTRAINTS operations are audited.
- **cursor**: indicates that successful cursor operations are audited.

**Default value**: **login**, **logout**, **database_process**, **user_lock**, **grant_revoke**, **set**, **transaction**, and **cursor**

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NOTICE

- You are advised to reserve **transaction**. Otherwise, statements in a transaction will not be audited.
- You are advised to reserve **cursor**. Otherwise, the **SELECT** statements in a cursor will not be audited. To audit the **SELECT** statement within transactions and cursors, retain both transaction and cursor audit items.
- The Data Studio client automatically encapsulates **SELECT** statements using **CURSOR**.

## audit_operation_error

**Parameter description**: Specifies whether to audit failed operations in GaussDB(DWS). Set this parameter as required.

**Type**: SIGHUP

**Value range**: a string

- **none**: indicates that no audit item is configured. If any audit item is configured, **none** becomes invalid.
- **syn_success**: synchronizes the **audit_operation_exec** configuration. To be specific, if the audit of a successful operation is configured, the corresponding failed operation is also audited. Note that even after **syn_success** is configured, you can continue to configure the audit of other failed operations. If **audit_operation_exec** is set to **all**, all failed operations are audited. If **audit_operation_exec** is set to **none**, **syn_success** is equivalent to **none**, that is, no audit item is configured.
- **parse**: indicates that the failed command parsing is audited, including the timeout of waiting for a command execution.
- **login**: indicates that failed logins are audited.
- **user_lock**: indicates that failed locking and unlocking operations are audited.
- **violation**: indicates that a user's access violation operations are audited.
- **grant_revoke**: indicates that failed granting and reclaiming of a user's permission are audited.
- **ddl**: indicates that failed DDL operations are audited. DDL operations are controlled at a fine granularity based on operation objects and configuration of **audit_system_object**. Therefore, failed DDL operations of the type specified in **audit_system_object** will be audited after **ddl** is configured.
- **select**: indicates that failed SELECT operations are audited.
- **copy**: indicates that failed COPY operations are audited.
- **userfunc**: indicates that failed operations for user-defined functions, stored procedures, and anonymous blocks are audited.
- **set**: indicates that failed SET operations are audited.
- **transaction**: indicates that failed transaction operations are audited.
- **vacuum**: indicates that failed VACUUM operations are audited.
- **analyze**: indicates that failed ANALYZE operations are audited.

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- **explain**: indicates that failed EXPLAIN operations are audited.
- **specialfunc**: indicates that failed calls to special functions are audited. Special functions include **pg_terminate_backend** and **pg_cancel_backend**.
- **insert**: indicates that failed INSERT operations are audited.
- **update**: indicates that failed UPDATE operations are audited.
- **delete**: indicates that failed DELETE operations are audited.
- **merge**: indicates that failed MERGE operations are audited.
- **show**: indicates that failed SHOW operations are audited.
- **checkpoint**: indicates that failed CHECKPOINT operations are audited.
- **barrier**: indicates that failed BARRIER operations are audited.
- **cluster**: indicates that failed CLUSTER operations are audited.
- **comment**: indicates that failed COMMENT operations are audited.
- **cleanconn**: indicates that failed CLEANCONNECTION operations are audited.
- **prepare**: indicates that failed PREPARE, EXECUTE, and DEALLOCATE operations are audited.
- **constraints**: indicates that failed CONSTRAINTS operations are audited.
- **cursor**: indicates that failed cursor operations are audited.
- **blacklist**: indicates that the blacklist execution failure is audited.

**Default value**: **login**

## audit_inner_tool

**Parameter description**: Specifies whether to audit the operations of the internal maintenance tool in GaussDB(DWS).

**Type**: SIGHUP

**Value range**: Boolean

- **on**: indicates that all operations of the internal maintenance tool are audited.
- **off**: indicates that all operations of the internal maintenance tool are not audited.

**Default value**: **off**

## audit_system_object

**Parameter description**: Specifies whether to audit the CREATE, DROP, and ALTER operations on the GaussDB(DWS) database object. The GaussDB(DWS) database objects include databases, users, schemas, and tables. The operations on the database object can be audited by changing the value of this parameter.

**Type**: SIGHUP

**Value range**: an integer ranging from 0 to 4194303

- **0** indicates that the function of auditing the CREATE, DROP, and ALTER operations on the GaussDB(DWS) database object can be disabled.
- Other values indicate that the CREATE, DROP, and ALTER operations on a certain or some GaussDB(DWS) database objects are audited.

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**Value description**:

The value of this parameter is calculated by 22 binary bits. The 22 binary bits represent 22 types of GaussDB(DWS) database objects. If the corresponding binary bit is set to **0**, the CREATE, DROP, and ALTER operations on corresponding database objects are not audited. If it is set to **1**, the CREATE, DROP, and ALTER operations are audited. For details about the audit content represented by these 22 binary bits, see **Table 15-3**.

**Default value**: **12303**

**Table 15-3** Meaning of each value for the **audit_system_object** parameter

| Binary Bit | Meaning | Value Description |
| --- | --- | --- |
| Bit 0 | Whether to audit the CREATE, DROP, and ALTER operations on databases. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 1 | Whether to audit the CREATE, DROP, and ALTER operations on schemas. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 2 | Whether to audit the CREATE, DROP, and ALTER operations on users. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 3 | Whether to audit the CREATE, DROP, ALTER, and TRUNCATE operations on tables. | • **0** indicates that the CREATE, DROP, ALTER, and TRUNCATE operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, ALTER, and TRUNCATE operations on these objects are audited. |
| Bit 4 | Whether to audit the CREATE, DROP, and ALTER operations on indexes. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |

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| Binary Bit | Meaning | Value Description |
| --- | --- | --- |
| Bit 5 | Whether to audit the CREATE, DROP, and ALTER operations on views. | • **0** indicates that the CREATE and DROP operations on these objects are not audited.<br>• **1** indicates that the CREATE and DROP operations on these objects are audited. |
| Bit 6 | Whether to audit the CREATE, DROP, and ALTER operations on triggers. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 7 | Whether to audit the CREATE, DROP, and ALTER operations on procedures/ functions. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 8 | Whether to audit the CREATE, DROP, and ALTER operations on tablespaces. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 9 | Whether to audit the CREATE, DROP, and ALTER operations on resource pools. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 10 | Whether to audit the CREATE, DROP, and ALTER operations on workloads. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 11 | Whether to audit the CREATE, DROP, and ALTER operations on SERVER FOR HADOOP objects. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |

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| Binary Bit | Meaning | Value Description |
| --- | --- | --- |
| Bit 12 | Whether to audit the CREATE, DROP, and ALTER operations on data sources. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 13 | Whether to audit the CREATE, DROP, and ALTER operations on Node Groups. | • **0** indicates that the CREATE and DROP operations on these objects are not audited.<br>• **1** indicates that the CREATE and DROP operations on these objects are audited. |
| Bit 14 | Whether to audit the CREATE, DROP, and ALTER operations on ROW LEVEL SECURITY objects. | • **0** indicates that the CREATE, DROP, and ALTER operations on these objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on these objects are audited. |
| Bit 15 | Whether to audit the CREATE, DROP, and ALTER operations on types. | • **0** indicates that the CREATE, DROP, and ALTER operations on types are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on types are audited. |
| Bit 16 | Whether to audit the CREATE, DROP, and ALTER operations on text search objects (configurations and dictionaries) | • **0** indicates that the CREATE, DROP, and ALTER operations on text search objects are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on text search objects are audited. |
| Bit 17 | Whether to audit the CREATE, DROP, and ALTER operations on directories. | • **0** indicates that the CREATE, DROP, and ALTER operations on directories are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on directories are audited. |
| Bit 18 | Whether to audit the CREATE, DROP, and ALTER operations on workloads. | • **0** indicates that the CREATE, DROP, and ALTER operations on types are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on types are audited. |

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| Binary Bit | Meaning | Value Description |
| --- | --- | --- |
| Bit 19 | Whether to audit the CREATE, DROP, and ALTER operations on redaction policies. | • **0** indicates that the CREATE, DROP, and ALTER operations on redaction policies are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on redaction policies are audited. |
| Bit 20 | Whether to audit the CREATE, DROP, and ALTER operations on sequences. | • **0** indicates that the CREATE, DROP, and ALTER operations on sequences are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on sequences are audited. |
| Bit 21 | Whether to audit the CREATE, DROP, and ALTER operations on nodes. | • **0** indicates that the CREATE, DROP, and ALTER operations on nodes are not audited.<br>• **1** indicates that the CREATE, DROP, and ALTER operations on nodes are audited. |

## enableSeparationOfDuty

**Parameter description**: Specifies whether the separation of permissions is enabled.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates that the separation of permissions is enabled.
- **off** indicates that the separation of permissions is disabled.

**Default value**: **off**

## enable_grant_option

**Parameter description**: Specifies whether the **with grant option** function can be used in security mode.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the **with grant option** function can be used in security mode.
- **off** indicates that the **with grant option** function cannot be used in security mode.

**Default value**: **off**

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### enable_copy_server_files

**Parameter description**: Specifies whether to enable the permission to copy server files.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates that the permission to copy server files is enabled.
- **off** indicates that the permission to copy server files is disabled.

**Default value**: **true**

NOTICE

**COPY FROM/TO** *file* requires system administrator permissions. However, if the separation of permissions is enabled, system administrator permissions are different from initial user permissions. In this case, you can use **enable_copy_server_file** to control the **COPY** permission of system administrators to prevent escalation of their permissions.

## 15.23 Transaction Monitoring

The automatic rollback transaction can be monitored and its statement problems can be located by setting the transaction timeout warning. In addition, the statements with long execution time can also be monitored.

### transaction_sync_naptime

**Parameter description**: For data consistency, when the local transaction's status differs from that in the snapshot of the GTM, other transactions will be blocked. You need to wait for a few minutes until the transaction status of the local host is consistent with that of the GTM. The **gs_clean** tool is automatically triggered for cleansing when the waiting period on the CN exceeds that of **transaction_sync_naptime**. The tool will shorten the blocking time after it completes the cleansing.

**Type**: USERSET

**Value range**: an integer. The minimum value is **0**. The unit is second.

**Default value**: **5s**

NOTE

If the value of this parameter is set to **0**, gs_clean will not be automatically invoked for the cleansing before the blocking arrives the duration. Instead, the gs_clean tool is invoked by gs_clean_timeout. The default value is 5 minutes.

### transaction_sync_timeout

**Parameter description**: For data consistency, when the local transaction's status differs from that in the snapshot of the GTM, other transactions will be blocked.

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You need to wait for a few minutes until the transaction status of the local host is consistent with that of the GTM. An exception is reported when the waiting duration on the CN exceeds the value of **transaction_sync_timeout**. Roll back the transaction to avoid system blocking due to long time of process response failures (for example, sync lock).

**Type**: USERSET

**Value range**: an integer. The minimum value is **0**. The unit is second.

**Default value**: **10min**

NOTE

- If the value is **0**, no error is reported when the blocking times out or the transaction is rolled back.
- The value of this parameter must be greater than **gs_clean_timeout**. Otherwise, unnecessary transaction rollback will probably occur due to a block timeout caused by residual transactions that have not been deleted by **gs_clean** on a DN.

# 15.24 Miscellaneous Parameters

## enable_cluster_resize

**Parameter description**: If an SQL statement involves tables belonging to different groups, you can enable this parameter to push the execution plan of the statement to improve performance.

**Type**: SUSET

**Value range**: Boolean

- **on** indicates the execution plan of the statement can be pushed.
- **off** indicates the execution plan of the statement cannot be pushed.

**Default value**: **off**

NOTE

This parameter is used for internal O&M. Do not set it to **on** unless absolutely necessary.

## cstore_insert_mode

**Parameter description**: Specifies the storage location of data to be imported to an HDFS table. This parameter is needed for operations that involve data import, such as INSERT, UPDATE, COPY, and VACUUM FULL.

**Type**: USERSET

**Value range**: enumerated values

- **AUTO**: The major part of imported data is stored in HDFS, and the tail is stored in the delta table.
- **DELTA**: All the imported data is stored in the delta table.
- **MAIN**: All the imported data is stored in HDFS.

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**Default value**: **auto**

NOTE

You can set other values as the default in the configuration file.

## remote_read_mode

**Parameter description**: When **enable_crc_check** is set to **on** and the data read by the primary DN fails the verification, **remote_read_mode** is used to specify whether to enable remote read and whether to use secure authentication for connection upon the data verification failure. The setting takes effect only after the cluster is restarted.

**Type**: POSTMASTER

**Value range**: **off**, **non_authentication**, **authentication**

- **off**: indicates that the remote read function is disabled.
- **non_authentication**: indicates that the standby DN is connected and data is obtained when non-authentication is used.
- **authentication**: indicates that the standby DN is connected and data is obtained through authentication. Before restarting the cluster, ensure that a certificate exists in the **$GAUSSHOME/share/sslcert/grpc/** directory. Otherwise, the cluster cannot be started.

**Default value**: **non_authentication**

## enable_upgrade_merge_lock_mode

**Parameter description**: If this parameter is set to **on**, the delta merge operation internally increases the lock level, and errors can be avoided when update and delete operations are performed at the same time.

**Type**: USERSET

**Value range**: Boolean

- If this parameter is set to **on**, the delta merge operation internally increases the lock level. In this way, when any two of the **DELTAMERGE**, **UPDATE**, and **DELETE** operations are concurrently performed, an operation can be performed only after the previous one is complete.
- If this parameter is set to **off**, and any two of the **DELTAMERGE**, **UPDATE**, and **DELETE** operations are concurrently performed to data in a row in the delta table of the HDFS table, errors will be reported during the later operation, and the operation will stop.

**Default value**: **off**

## job_queue_processes

**Parameter description**: Specifies the number of jobs that can be concurrently executed. This parameter is a postmaster parameter. You can set it using **gs_guc**, and you need to restart **gaussdb** to make the setting take effect.

**Type**: POSTMASTER

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**Value range**: 0 to 1000

**Functions**:

- Setting **job_queue_processes** to **0** indicates that the scheduled task function is disabled and that no job will be executed. (Enabling scheduled tasks may affect the system performance. At sites where this function is not required, you are advised to disable it.)
- Setting **job_queue_processes** to a value that is greater than **0** indicates that the scheduled task function is enabled and this value is the maximum number of tasks that can be concurrently processed.

After the scheduled task function is enabled, the **job_scheduler** thread at a scheduled interval polls the **pg_jobs** system catalog. The scheduled task check is performed every second by default.

Too many concurrent tasks consume many system resources, so you need to set the number of concurrent tasks to be processed. If the current number of concurrent tasks reaches **job_queue_processes** and some of them expire, these tasks will be postponed to the next polling period. Therefore, you are advised to set the polling interval (the **interval** parameter of the submit interface) based on the execution duration of each task to avoid the problem that tasks in the next polling period cannot be properly processed because overlong task execution time.

Note: If the number of parallel jobs is large and the value is too small, these jobs will wait in queues. However, a large parameter value leads to large resource consumption. You are advised to set this parameter to **100** and change it based on the system resource condition.

**Default value**: **10**

## ngram_gram_size

**Parameter description**: Specifies the length of the ngram parser segmentation.

**Type**: USERSET

**Value range**: an integer ranging from 1 to 4

**Default value**: **2**

## ngram_grapsymbol_ignore

**Parameter description**: Specifies whether the ngram parser ignores graphical characters.

**Type**: USERSET

**Value range**: Boolean

- **on**: Ignores graphical characters.
- **off**: Does not ignore graphical characters.

**Default value**: **off**

## ngram_punctuation_ignore

**Parameter description**: Specifies whether the ngram parser ignores punctuations.

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**Type**: USERSET

**Value range**: Boolean

- **on**: Ignores punctuations.
- **off**: Does not ignore punctuations.

**Default value**: **on**

## zhparser_dict_in_memory

**Parameter description**: Specifies whether Zhparser adds a dictionary to memory.

**Type**: POSTMASTER

**Value range**: Boolean

- **on**: Adds the dictionary to memory.
- **off**: Does not add the dictionary to memory.

**Default value**: **on**

## zhparser_multi_duality

**Parameter description**: Specifies whether Zhparser aggregates segments in long words with duality.

**Type**: USERSET

**Value range**: Boolean

- **on**: Aggregates segments in long words with duality.
- **off**: Does not aggregate segments in long words with duality.

**Default value**: **off**

## zhparser_multi_short

**Parameter description**: Specifies whether Zhparser executes long words composite divide.

**Type**: USERSET

**Value range**: Boolean

- **on**: Performs compound segmentation for long words.
- **off**: Does not perform compound segmentation for long words.

**Default value**: **on**

## zhparser_multi_zall

**Parameter description**: Specifies whether Zhparser displays all single words individually.

**Type**: USERSET

**Value range**: Boolean

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- **on**: Displays all single words separately.
- **off**: Does not display all single words separately.

**Default value**: **off**

## zhparser_multi_zmain

**Parameter description**: Specifies whether Zhparser displays important single words separately.

**Type**: USERSET

**Value range**: Boolean

- **on**: Displays important single words separately.
- **off**: Does not display important single words separately.

**Default value**: **off**

## zhparser_punctuation_ignore

**Parameter description**: Specifies whether the Zhparser segmentation result ignores special characters including punctuations (\r and \n will not be ignored).

**Type**: USERSET

**Value range**: Boolean

- **on**: Ignores all the special characters including punctuations.
- **off**: Does not ignore all the special characters including punctuations.

**Default value**: **on**

## zhparser_seg_with_duality

**Parameter description**: Specifies whether Zhparser aggregates segments in long words with duality.

**Type**: USERSET

**Value range**: Boolean

- **on**: Aggregates segments in long words with duality.
- **off**: Does not aggregate segments in long words with duality.

**Default value**: **off**

## acceleration_with_compute_pool

**Parameter description**: Specifies whether to use the computing resource pool for acceleration when OBS is queried.

**Type**: USERSET

**Value range**: Boolean

- **on** indicates that the query covering OBS is accelerated based on the cost when the computing resource pool is available.

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- **off** indicates that no query is accelerated using the computing resource pool.

**Default value**: **off**

## behavior_compat_options

**Parameter description**: Specifies database compatibility behavior. Multiple items are separated by commas (,).

**Type**: USERSET

**Value range**: a string

**Default value**: In upgrade scenarios, the default value of this parameter is the same as that in the cluster before the upgrade. When a new cluster is installed, the default value of this parameter is **check_function_conflicts** to prevent serious problems caused by incorrect function attributes defined by users.

NOTE

- Currently, only **Table 15-4** is supported.
- Multiple items are separated by commas (,), for example, **set behavior_compat_options='end_month_calculate,display_leading_zero';**
- **strict_concat_functions** and **strict_text_concat_td** are mutually exclusive.

**Table 15-4** Compatibility configuration items

| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| display_leading_zero | Specifies how floating point numbers are displayed.<br>• If this item is not specified, for a decimal number between -1 and 1, the 0 before the decimal point is not displayed. For example, 0.25 is displayed as **.25**.<br>• If this item is specified, for a decimal number between -1 and 1, the 0 before the decimal point is displayed. For example, 0.25 is displayed as **0.25**. | ORA<br>TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| end_month_calculate | Specifies the calculation logic of the add_months function.<br>Assume that the two parameters of the add_months function are **param1** and **param2**, and that the sum of **param1** and **param2** is **result**.<br>● If this item is not specified, and the **Day** of **param1** indicates the last day of a month shorter than **result**, the **Day** in the calculation result will equal that in **param1**. For example:<br>`select add_months('2018-02-28',3) from dual;`<br>`add_months`<br>`---------------------`<br>`2018-05-28 00:00:00`<br>`(1 row)`<br>● If this item is specified, and the **Day** of **param1** indicates the last day of a month shorter than **result**, the **Day** in the calculation result will equal that in **result**. For example:<br>`select add_months('2018-02-28',3) from dual;`<br>`add_months`<br>`---------------------`<br>`2018-05-31 00:00:00`<br>`(1 row)` | ORA<br>TD |
| compat_analyze_sample | Specifies the sampling behavior of the ANALYZE operation.<br>If this item is specified, the sample collected by the ANALYZE operation will be limited to around 30,000 records, controlling CN memory consumption and maintaining the stability of ANALYZE. | ORA<br>TD<br>MySQL |
| bind_schema_tablespace | Binds a schema with the tablespace with the same name.<br>If a tablespace name is the same as *sche_name*, **default_tablespace** will also be set to *sche_name* if **search_path** is set to *sche_name*. | ORA<br>TD<br>MySQL |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| bind_procedure_searchpath | Specifies the search path of the database object for which no schema name is specified.<br>If no schema name is specified for a stored procedure, the search is performed in the schema to which the stored procedure belongs.<br>If the stored procedure is not found, the following operations are performed:<br>● If this item is not specified, the system reports an error and exits.<br>● If this item is specified, the search continues based on the settings of **search_path**. If the issue persists, the system reports an error and exits. | ORA<br>TD<br>MySQL |
| correct_to_number | Controls the compatibility of the to_number() result.<br>If this item is specified, the result of the **to_number()** function is the same as that of PG11. Otherwise, the result is the same as that of Oracle. | ORA |
| unbind_divide_bound | Controls the range check on the result of integer division.<br>● If this item is not specified, the division result is checked. If the result is out of the range, an error is reported. In the following example, an out-of-range error is reported because the value of **INT_MIN/(-1)** is greater than the value of **INT_MAX**.<br>`SELECT (-2147483648)::int / (-1)::int;`<br>`ERROR:  integer out of range`<br>● If this item is specified, the range of the division result does not need to be checked. In the following example, **INT_MIN/(-1)** can be used to obtain the output result **INT_MAX+1**.<br>`SELECT (-2147483648)::int / (-1)::int;`<br>`  ?column?`<br>`------------`<br>` 2147483648`<br>`(1 row)` | ORA<br>TD |
| merge_update_multi | Performs an update if multiple rows are matched for **MERGE INTO**.<br>If this item is specified, no error is reported if multiple rows are matched. Otherwise, an error is reported (same as Oracle). | ORA<br>TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| return_null_string | Specifies how to display the empty result (empty string '') of the lpad(), rpad(), repeat(), regexp_split_to_table(), and split_part() functions.<br>● If this item is not specified, the empty string is displayed as **NULL**.<br>`select length(lpad('123',0,'*')) from dual;`<br>`length`<br>`--------`<br>`(1 row)`<br>● If this item is specified, the empty string is displayed as single quotation marks (''').<br>`select length(lpad('123',0,'*')) from dual;`<br>`length`<br>`--------`<br>`0`<br>`(1 row)` | ORA |
| compat_concat_variadic | Specifies the compatibility of variadic results of the concat() and concat_ws() functions.<br>If this item is specified and a **concat** function has a parameter of the **variadic** type, different result formats in Oracle and Teradata are retained. If this item is not specified and a **concat** function has a parameter of the **variadic** type, the result format of Oracle is retained for both Oracle and Teradata. | ORA<br>TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| convert_string_digit_to_numeric | Specifies the type casting priority for binary BOOL operations on the CHAR type and INT type.<br>● If this item is not specified, the type casting priority is the same as that of PG9.6.<br>● After this item is configured, all binary BOOL operations of the CHAR type and INT type are forcibly converted to the NUMERIC type for computation.<br>After this configuration item is set, the CHAR types that are affected include BPCHAR, VARCHAR, NVARCHAR2, and TEXT, and the INT types that are affected include INT1, INT2, INT4, and INT8.<br>**CAUTION**<br>This configuration item is valid only for binary BOOL operation, for example, **INT2>TEXT** and **INT4=BPCHAR**. Non-BOOL operation is not affected. This configuration item does not support conversion of UNKNOWN operations such as **INT>'1.1'**. After this configuration item is enabled, all BOOL operations of the CHAR and INT types are preferred to be converted to the NUMERIC type for computation, which affects the computation performance of the database. When the JOIN column is a combination of affected types, the execution plan is affected. | ORA<br>TD<br>MySQL |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| check_function_conflicts | Controls the check of the custom **plpgsql/SQL** function attributes.<br>• If this parameter is not specified, the **IMMUTABLE/STABLE/VOLATILE** attributes of a custom function are not checked.<br>• If this parameter is specified, the IMMUTABLE attribute of a custom function is checked. If the function contains a table or the STABLE/VOLATILE function, an error is reported during the function execution. In a custom function, a table or the STABLE/VOLATILE function conflicts with the IMMUTABLE attribute, thus function behaviors are not IMMUTABLE in this case.<br>For example, when this parameter is specified, an error is reported in the following scenarios:<br>`CREATE OR replace FUNCTION sql_immutable (INTEGER)`<br>`RETURNS INTEGER AS 'SELECT a+$1 from shipping_schema.t4 where a=1;'`<br>`LANGUAGE SQL IMMUTABLE`<br>`RETURNS NULL`<br>`ON NULL INPUT;`<br>`select sql_immutable(1);`<br>`ERROR:  IMMUTABLE function cannot contain SQL statements with relation or Non-IMMUTABLE function.`<br>`CONTEXT:  SQL function "sql_immutable" during startup referenced column: sql_immutable` | ORA<br>TD<br>MySQL |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| varray_verification | Indicates whether to verify the array length and array type length. Compatible with GaussDB(DWS) versions earlier than 8.1.0.<br>If this parameter is specified, the array length and array type length are not verified.<br>Scenario 1<br>CREATE OR REPLACE PROCEDURE varray_verification<br>AS<br>TYPE org_varray_type IS varray(5) OF VARCHAR2(2);<br>v_org_varray org_varray_type;<br>BEGIN<br>v_org_varray(1) := '111'; --If the value exceeds the limit of **VARCHAR2(2)**, the setting will be consistent with that in the historical version and no verification is performed after configuring this option.<br>END;<br>/<br>Scenario 2<br>CREATE OR REPLACE PROCEDURE varray_verification_i3_1<br>AS<br>TYPE org_varray_type IS varray(2) OF NUMBER(2);<br>v_org_varray org_varray_type;<br>BEGIN<br>v_org_varray(3) := 1; --If the value exceeds the limit of **varray(2)** specified for array length, the setting will be consistent with that in the historical version and no verification is performed after configuring this option.<br>END;<br>/ | ORA<br>TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| strict_concat_functions | Indicates whether the **textanycat()** and **anytextcat()** functions are compatible with the return value if there are null parameters. This parameter and **strict_text_concat_td** are mutually exclusive.<br>In MySQL-compatible mode, this parameter has no impact.<br>● If this configuration item is not specified, the returned values of the **textanycat()** and **anytextcat()** functions are the same as those in the Oracle database.<br>● When this configuration item is specified, if there are null parameters in the **textanycat()** and **anytextcat()** functions, the returned value is also null. Different result formats in Oracle and Teradata are retained.<br>If this configuration item is not specified, the returned values of the **textanycat()** and **anytextcat()** functions are the same as those in the Oracle database.<br>`SELECT textanycat('gauss', cast(NULL as BOOLEAN));`<br>` textanycat`<br>`------------`<br>` gauss`<br>`(1 row)`<br><br>`SELECT 'gauss' \|\| cast(NULL as BOOLEAN); -- In this case, the \|\| operator is converted to the **textanycat** function.`<br>` ?column?`<br>`----------`<br>` gauss`<br>`(1 row)`<br>When setting this configuration item, retain the results that are different from those in Oracle and Teradata:<br>`SELECT textanycat('gauss', cast(NULL as BOOLEAN));`<br>` textanycat`<br>`------------`<br><br>`(1 row)`<br><br>`SELECT 'gauss' \|\| cast(NULL as BOOLEAN); -- In this case, the \|\| operator is converted to the **textanycat** function.`<br>` ?column?`<br>`----------`<br><br>`(1 row)` | ORA<br>TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| strict_text_concat_td | In Teradata compatible mode, whether the **textcat()**, **textanycat()** and **anytextcat()** functions are compatible with the return value if there are null parameters. This parameter and **strict_concat_functions** are mutually exclusive.<br>● If this parameter is not specified, the return values of the **textcat()**, **textanycat()**, and **anytextcat()** functions in Teradata-compatible mode are the same as those in GaussDB(DWS).<br>● When this parameter is specified, if the **textcat()**, **textanycat()**, and **anytextcat()** functions contain any null parameter values, the return value is null in the Teradata-compatible mode.<br>If this parameter is not specified, the returned values of the **textcat()**, **textanycat()**, and **anytextcat()** functions are the same as those in the GaussDB(DWS).<br>td_data_compatible_db=# SELECT textcat('abc', NULL);<br>textcat<br>---------<br>abc<br>(1 row)<br>td_data_compatible_db=# SELECT 'abc' \|\| NULL; -- In this case, the operator \|\| is converted to the **textcat()** function.<br>?column?<br>----------<br>abc<br>(1 row)<br>When this parameter is specified, **NULL** is returned if any of the **textcat()**, **textanycat()**, and **anytextcat()** functions returns a null value.<br>td_data_compatible_db=# SELECT textcat('abc', NULL);<br>textcat<br>---------<br><br>(1 row)<br>td_data_compatible_db=# SELECT 'abc' \|\| NULL;<br>?column?<br>----------<br><br>(1 row) | TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| compat_display_ref_table | Sets the column display format in the view.<br>● If this parameter is not specified, the prefix is used by default, in the **tab.col** format.<br>● Specify this parameter to the same original definition. It is displayed only when the original definition contains a prefix.<br>SET behavior_compat_options='compat_display_ref_table';<br>CREATE OR REPLACE VIEW viewtest2 AS SELECT a.c1, **c2**, a.c3, 0 AS c4 FROM viewtest_tbl a;<br>SELECT pg_get_viewdef('viewtest2');<br>pg_get_viewdef<br>----------<br>SELECT a.c1, **c2**, a.c3, 0 AS c4 FROM viewtest_tbl a;<br>(1 row) | ORA<br>TD |
| para_support_set_func | Whether the input parameters of the **COALESCE()**, **NVL()**, **GREATEST()**, and **LEAST()** functions in a column-store table support multiple result set expressions.<br>● If this item is not specified and the input parameter contains multiple result set expressions, an error is reported, indicating that the function is not supported.<br>SELECT COALESCE(regexp_split_to_table(c3,'#'), regexp_split_to_table(c3,'#')) FROM regexp_ext2_tb1 ORDER BY 1 LIMIT 5;<br>ERROR: set-valued function called in context that cannot accept a set<br>● When this configuration item is specified, the function input parameter can contain multiple result set expressions.<br>SELECT COALESCE(regexp_split_to_table(c3,'#'), regexp_split_to_table(c3,'#')) FROM regexp_ext2_tb1 ORDER BY 1 LIMIT 5;<br>coalesce<br>----------<br>a<br>a<br>a<br>a<br>a<br>(5 rows) | ORA<br>TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| disable_select_truncate_parallel | Controls the DDL lock level such as TRUNCATE in a partitioned table.<br>• If this item is specified, the concurrent execution of TRUNCATE and DML operations (such as SELECT) on different partitions is forbidden, and the fast query shipping (FQS) of the SELECT operation on the partitioned table is allowed. You can set this parameter in the OLTP database, where there are many simple queries on partitioned tables, and there is no requirement for concurrent TRUNCATE and DML operations on different partitions.<br>• If this item is not specified, SELECT and TRUNCATE operations can be concurrently performed on different partitions in a partitioned table, and the FQS of the partitioned table is disabled to avoid possible inconsistency. | ORA<br>TD<br>MySQL |
| bpchar_text_without_rtrim | In Teradata-compatible mode, controls the space to be retained on the right during the character conversion from **bpchar** to **text**. If the actual length is less than the length specified by **bpchar**, spaces are added to the value to be compatible with the Teradata style of the **bpchar** character string.<br>Currently, ignoring spaces at the end of a string for comparison is not supported. If the concatenated string contains spaces at the end, the comparison is space-sensitive.<br>The following is an example:<br>`td_compatibility_basic_db=# select length('a'::char(10)::text);`<br>`length`<br>`--------`<br>`10`<br>`(1 row)`<br><br>`td_compatibility_basic_db=# select length('a'\|\|'a'::char(10));`<br>`length`<br>`--------`<br>`11`<br>`(1 row)` | TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| convert_empty_str_to_null_td | In Teradata-compatible mode, controls the **to_date**, **to_timestamp**, and **to_number** type conversion functions to return **null** when they encounter empty strings, and controls the format of the return value when the **to_char** function encounters an input parameter of the date type.<br>Example:<br>If this parameter is not specified:<br>`td_compatibility_db=# select to_number('');`<br>` to_number`<br>`-----------`<br>`         0`<br>`(1 row)`<br><br>`td_compatibility_db=# select to_date('');`<br>`ERROR:  the format is not correct`<br>`DETAIL:  invalid date length "0", must between 8 and 10.`<br>`CONTEXT:  referenced column: to_date`<br><br>`td_compatibility_db=# select to_timestamp('');`<br>`      to_timestamp`<br>`------------------------`<br>` 0001-01-01 00:00:00 BC`<br>`(1 row)`<br><br>`td_compatibility_db=# select to_char(date '2020-11-16');`<br>`        to_char`<br>`------------------------`<br>` 2020-11-16 00:00:00+08`<br>`(1 row)`<br>If this parameter is specified, and parameters of **to_number**, **to_date**, and **to_timestamp** functions contain empty strings:<br>`td_compatibility_db=# select to_number('');`<br>` to_number`<br>`-----------`<br><br>`(1 row)`<br><br>`td_compatibility_db=# select to_date('');`<br>` to_date`<br>`---------`<br><br>`(1 row)`<br><br>`td_compatibility_db=# select to_timestamp('');`<br>` to_timestamp`<br>`--------------`<br><br>`(1 row)`<br><br>`td_compatibility_db=# select to_char(date '2020-11-16');`<br>`  to_char`<br>`------------`<br>` 2020/11/16`<br>`(1 row)` | TD |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| disable_case_specific | Determines whether to ignore case sensitivity during character type match. This parameter is valid only in Teradata-compatible mode.<br>● If this item is not specified, characters are case sensitive during character type match.<br>● If this item is specified, characters are case insensitive during character type match.<br>After being specified, this item will affect five character types (**CHAR**, **TEXT**, **BPCHAR**, **VARCHAR**, and **NVARCHAR**), 12 operators (**<**, **>**, **=**, **>=**, **<=**, **!=**, **<>**, **!=**, **like**, **not like**, **in**, and **not in**), and expressions **case when** and **decode**.<br>**CAUTION**<br>After this item is enabled, the **UPPER** function is added before the character type, which affects the estimation logic. Therefore, an enhanced estimation model is required. (Suggested settings: **cost_param=16**, **cost_model_version = 1**, **join_num_distinct=-20**, and **qual_num_distinct=200**) | TD |
| enable_interval_to_text | Controls the implicit conversion from the **interval** type to the **text** type.<br>● When this option is enabled, the implicit conversion from the **interval** type to the **text** type is supported.<br>`SELECT TO_DATE('20200923', 'yyyymmdd') - TO_DATE('20200920', 'yyyymmdd') = '3'::text;`<br>`?column?`<br>`----------`<br>`f`<br>`(1 row)`<br>● When this option is disabled, the implicit conversion from the **interval** type to the **text** type is not supported.<br>`SELECT TO_DATE('20200923', 'yyyymmdd') - TO_DATE('20200920', 'yyyymmdd') = '3'::text;`<br>`?column?`<br>`----------`<br>`t`<br>`(1 row)` | ORA<br>TD<br>MySQL |

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| Configuration Item | Behavior | Applicable Compatibility Mode |
| --- | --- | --- |
| light_object_mtime | Specifies whether the **mtime** column in the **pg_object** system catalog records object operations.<br>• If this parameter is configured, the **GRANT**, **REVOKE**, and **TRUNCATE** operations are not recorded by **mtime**, that is, the **mtime** column is not updated.<br>• If this parameter is not configured (by default), the **ALTER**, **COMMENT**, **GRANT**, **REVOKE**, and **TRUNCATE** operations are recorded by **mtime**, that is, the **mtime** column is updated. | ORA<br>TD<br>MySQL |

## table_skewness_warning_threshold

**Parameter description**: Specifies the threshold for triggering a table skew alarm.

**Type**: SUSET

**Value range**: a floating point number ranging from 0 to 1

**Default value**: **1**

## table_skewness_warning_rows

**Parameter description**: Specifies the minimum number of rows for triggering a table skew alarm.

**Type**: SUSET

**Value range**: an integer ranging from **0** to **INT_MAX**

**Default value**: **100000**

## max_cache_partition_num

**Parameter description**: Specifies the number of memory-saving partitions in column-store mode during redistribution after scale-out. If the number of partitions exceeds the upper limit, the earliest cached partition is directly written to the column-store file.

**Type**: SIGHUP

**Value range**: an integer ranging from **0** to **32767**.

- **0** indicates that the memory-saving mode is disabled in column storage.
- Values from **1** to **32767** indicate the maximum number of partitions that can be cached in a partitioned table.

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**Default value**: **0**

NOTE

This parameter is used for redistribution during scale-out. A proper value can reduce the memory consumption during redistribution of a partitioned column-store table. However, tables with unbalanced data distribution in some partitions may generate a large number of small CUs after the redistribution. If there are a large number of small CUs, execute the **VACUUM FULL** statement to merge them.

## enable_prevent_job_task_startup

**Parameter description**: Specifies whether to prevent the thread startup of scheduled jobs. This is an internal parameter. You are not advised to change the value of this parameter.

**Type**: SIGHUP

**Value range**: Boolean

- **on**: Threads of scheduled jobs will not be started.
- **off**: Threads of scheduled jobs will be started.

**Default value**: **off**

NOTE

Set this parameter only on CNs.

## auto_process_residualfile

**Parameter description**: Specifies whether to enable the residual file recording function.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the residual file recording function is enabled.
- **off** indicates that the residual file recording function is disabled.

**Default value**: **off**

## enable_view_update

**Parameter description**: Enables the view update function or not.

**Type**: POSTMASTER

**Value range**: Boolean

- **on** indicates that the view update function is enabled.
- **off** indicates that the view update function is disabled.

**Default value**: **off**

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## view_independent

**Parameter description**: Decouples views from tables, functions, and synonyms or not. After the base table is restored, automatic association and re-creation are supported.

**Type**: SIGHUP

**Value range**: Boolean

- **on** indicates that the view decoupling function is enabled. Tables, functions, synonyms, and other views on which views depend can be deleted separately (except temporary tables and temporary views). Associated views are reserved but unavailable.
- **off** indicates that the view decoupling function is disabled. Tables, functions, synonyms, and other views on which views depend cannot be deleted separately. You can only delete them in the cascade mode.

**Default value**: **off**

## bulkload_report_threshold

**Parameter description**: Sets the threshold for reporting import and export statistics.

**Type**: SIGHUP

**Value range**: an integer ranging from **0** to **INT_MAX**

**Default value**: **50**

## assign_abort_xid

**Parameter description**: Determines the transaction to be aborted based on the specified XID in a query.

**Type**: USERSET

**Value range**: a character string with the specified XID

**CAUTION**

This parameter is used only for quick restoration if a user deletes data by mistake (DELETE operation). Do not use this parameter in other scenarios. Otherwise, visible transaction errors may occur.

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# 16 Glossary

| Term | Description |
| --- | --- |
| **A – E** | |
| ACID | Atomicity, Consistency, Isolation, and Durability (ACID). These are a set of properties of database transactions in a DBMS. |
| cluster ring | A cluster ring consists of several physical servers. The primary-standby-secondary relationships among its DNs do not involve external DNs. That is, none of the primary, standby, or secondary counterparts of DNs belonging to the ring are deployed in other rings. A ring is the smallest unit used for scaling. |
| Bgwriter | A background write thread created when the database starts. The thread pushes dirty pages in the database to a permanent device (such as a disk). |
| bit | The smallest unit of information handled by a computer. One bit is expressed as a 1 or a 0 in a binary numeral, or as a true or a false logical condition. A bit is physically represented by an element such as high or low voltage at one point in a circuit, or a small spot on a disk that is magnetized in one way or the other. A single bit conveys little information a human would consider meaningful. A group of eight bits, however, makes up a byte, which can be used to represent many types of information, such as a letter of the alphabet, a decimal digit, or other character. |
| Bloom filter | Bloom filter is a space-efficient binary vectorized data structure, conceived by Burton Howard Bloom in 1970, that is used to test whether an element is a member of a set. False positive matches are possible, but false negatives are not, in other words, a query returns either "possibly in set (possible error)" or "definitely not in set". In the cases, Bloom filter sacrificed the accuracy for time and space. |

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| Term | Description |
| --- | --- |
| CCN | The Central Coordinator (CCN) is a node responsible for determining, queuing, and scheduling complex operations in each CN to enable the dynamic load management of GaussDB(DWS). |
| CIDR | Classless Inter-Domain Routing (CIDR). CIDR abandons the traditional class-based (class A: 8; class B: 16; and class C: 24) address allocation mode and allows the use of address prefixes of any length, effectively improving the utilization of address space. A CIDR address is in the format of *IP address*/*Number of bits in a network ID*. For example, in **192.168.23.35/21**, **21** indicates that the first 21 bits are the network prefix and others are the host ID. |
| Cgroups | A control group (Cgroup), also called a priority group (PG) in GaussDB(DWS). The Cgroup is a kernel feature of SUSE Linux and Red Hat that can limit, account for, and isolate the resource usage of a collection of processes. |
| CLI | Command-line interface (CLI). Users use the CLI to interact with applications. Its input and output are based on texts. Commands are entered through keyboards or similar devices and are compiled and executed by applications. The results are displayed in text or graphic forms on the terminal interface. |
| CM | Cluster Manager (CM) manages and monitors the running status of functional units and physical resources in the distributed system, ensuring stable running of the entire system. |
| CMS | The Cluster Management Service (CMS) component manages the cluster status. |
| CN | The Coordinator (CN) stores database metadata, splits query tasks and supports their execution, and aggregates the query results returned from DNs. |
| CU | Compression Unit (CU) is the smallest storage unit in a column-storage table. |
| core file | A file that is created when memory overwriting, assertion failures, or access to invalid memory occurs in a process, causing it to fail. This file is then used for further analysis.<br>A core file contains a memory dump, in an all-binary and port-specific format. The name of a core file consists of the word "core" and the OS process ID.<br>The core file is available regardless of the type of platform. |

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| Term | Description |
| --- | --- |
| core dump | When a program stops abnormally, the core dump, memory dump, or system dump records the state of the working memory of the program at that point in time. In practice, other key pieces of program state are usually dumped at the same time, including the processor registers, which may include the program counter and stack pointer, memory management information, and other processor and OS flags and information. A core dump is often used to assist diagnosis and computer program debugging. |
| DBA | A database administrator (DBA) instructs or executes database maintenance operations. |
| DBLINK | An object defining the path from one database to another. A remote database object can be queried with DBLINK. |
| DBMS | Database Management System (DBMS) is a piece of system management software that allows users to access information in a database. This is a collection of programs that allows you to access, manage, and query data in a database. A DBMS can be classified as memory DBMS or disk DBMS based on the location of the data. |
| DCL | Data control language (DCL) |
| DDL | Data definition language (DDL) |
| DML | Data manipulation language (DML) |
| DN | Datanode performs table data storage and query operations. |
| ETCD | The Editable Text Configuration Daemon (ETCD) is a distributed key-value storage system used for configuration sharing and service discovery (registration and search). |
| ETL | Extract-Transform-Load (ETL) refers to the process of data transmission from the source to the target database. |
| Extension Connector | Extension Connector is provided by GaussDB(DWS) to process data across clusters. It can send SQL statements to Spark, and can return execution results to your database. |
| Backup | A backup, or the process of backing up, refers to the copying and archiving of computer data in case of data loss. |
| backup and restoration | A collection of concepts, procedures, and strategies to protect data loss caused by invalid media or misoperations. |
| standby server | A node in the GaussDB(DWS) HA solution. It functions as a backup of the primary server. If the primary server is behaving abnormally, the standby server is promoted to primary, ensuring data service continuity. |

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| Term | Description |
| --- | --- |
| crash | A crash (or system crash) is an event in which a computer or a program (such as a software application or an OS) ceases to function properly. Often the program will exit after encountering this type of error. Sometimes the offending program may appear to freeze or hang until a crash reporting service documents details of the crash. If the program is a critical part of the OS kernel, the entire computer may crash (possibly resulting in a fatal system error). |
| encoding | Encoding is representing data and information using code so that it can be processed and analyzed by a computer. Characters, digits, and other objects can be converted into digital code, or information and data can be converted into the required electrical pulse signals based on predefined rules. |
| encoding technology | A technology that presents data using a specific set of characters, which can be identified by computer hardware and software. |
| table | A set of columns and rows. Each column is referred to as a field. The value in each field represents a data type. For example, if a table contains people's names, cities, and states, it has three columns: **Name**, **City**, and **State**. In every row in the table, the **Name** column contains a name, the **City** column contains a city, and the **State** column contains a state. |
| tablespace | A tablespace is a logical storage structure that contains tables, indexes, large objects, and long data. A tablespace provides an abstract layer between physical data and logical data, and provides storage space for all database objects. When you create a table, you can specify which tablespace it belongs to. |
| concurrency control | A DBMS service that ensures data integrity when multiple transactions are concurrently executed in a multi-user environment. In a multi-threaded environment, GaussDB(DWS) concurrency control ensures that database operations are safe and all database transactions remain consistent at any given time. |
| query | Specifies requests sent to the database, such as updating, modifying, querying, or deleting information. |
| query operator | An iterator or a query tree node, which is a basic unit for the execution of a query. Execution of a query can be split into one or more query operators. Common query operators include scan, join, and aggregation. |
| query fragment | Each query task can be split into one or more query fragments. Each query fragment consists of one or more query operators and can independently run on a node. Query fragments exchange data through data flow operators. |

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| Term | Description |
| --- | --- |
| durability | One of the ACID features of database transactions. Durability indicates that transactions that have been committed will permanently survive and not be rolled back. |
| stored procedure | A group of SQL statements compiled into a single execution plan and stored in a large database system. Users can specify a name and parameters (if any) for a stored procedure to execute the procedure. |
| OS | An operating system (OS) is loaded by a bootstrap program to a computer to manage other programs in the computer. applications on a computer or similar device. |
| secondary server | To ensure high cluster availability, the primary server synchronizes logs to the secondary server if data synchronization between the primary and standby servers fails. If the primary server suddenly breaks down, the standby server is promoted to primary and synchronizes logs from the secondary server for the duration of the breakdown. |
| BLOB | Binary large object (BLOB) is a collection of binary data stored in a database, such as videos, audio, and images. |
| dynamic load balancing | In GaussDB(DWS), dynamic load balancing automatically adjusts the number of concurrent jobs based on the usage of CPU, I/O, and memory to avoid service errors and to prevent the system from stop responding due to system overload. |
| segment | A segment in the database indicates a part containing one or more regions. Region is the smallest range of a database and consists of data blocks. One or more segments comprise a tablespace. |
| **F – J** | |
| failover | Automatic switchover from a faulty node to its standby node. Reversely, automatic switchback from the standby node to the primary node is called failback. |
| FDW | A foreign data wrapper (FDW) is a SQL interface provided by Postgres. It is used to access big data objects stored in remote data so that DBAs can integrate data from unrelated data sources and store them in public schema in the database. |

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| Term | Description |
| --- | --- |
| freeze | An operation automatically performed by the AutoVacuum Worker process when transaction IDs are exhausted. GaussDB(DWS) records transaction IDs in row headings. When a transaction reads a row, the transaction ID in the row heading and the actual transaction ID are compared to determine whether this row is explicit. Transaction IDs are integers containing no symbols. If exhausted, transaction IDs are re-calculated outside of the integer range, causing the explicit rows to become implicit. To prevent such a problem, the freeze operation marks a transaction ID as a special ID. Rows marked with these special transaction IDs are explicit to all transactions. |
| GDB | As a GNU debugger, GDB allows you to see what is going on 'inside' another program while it executes or what another program was doing the moment that it crashed. GDB can perform four main kinds of things (make PDK functions stronger) to help you catch bugs in the act:<br>• Starts your program, specifying anything that might affect its behavior.<br>• Stops a program in a specific condition.<br>• Checks what happens when a program stops.<br>• Changes things in your program, so you can experiment with correcting the effects of one bug and go on to learn about another. |
| GDS | General Data Service (GDS). To import data to GaussDB(DWS), you need to deploy the tool on the server where the source data is stored so that DNs can use this tool to obtain data. |
| GIN index | Generalized inverted index (GIN) is used for handling cases where the items to be indexed are composite values, and the queries to be handled by the index need to search for element values that appear within the composite items. |
| GNU | The GNU Project was publicly announced on September 27, 1983 by Richard Stallman, aiming at building an OS composed wholly of free software. GNU is a recursive acronym for "GNU's Not Unix!". Stallman announced that GNU should be pronounced as Guh-NOO. Technically, GNU is similar to Unix in design, a widely used commercial OS. However, GNU is free software and contains no Unix code. |
| gsql | GaussDB(DWS) interaction terminal. It enables you to interactively type in queries, issue them to GaussDB(DWS), and view the query results. Queries can also be entered from files. **gsql** supports many meta commands and shell-like commands, allowing you to conveniently compile scripts and automate tasks. |
| GTM | Global Transaction Manager (GTM) manages the status of transactions. |

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| Term | Description |
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| GUC | Grand unified configuration (GUC) includes parameters for running databases, the values of which determine database system behavior. |
| HA | High availability (HA) is a solution in which two modules operate in primary/standby mode to achieve high availability. This solution helps to minimize the duration of service interruptions caused by routine maintenance (planned) or sudden system breakdowns (unplanned), improving the system and application usability. |
| HBA | Host-based authentication (HBA) allows hosts to authenticate on behalf of all or some of the system users. It can apply to all users on a system or a subset using the **Match** directive. This type of authentication can be useful for managing computing clusters and other fairly homogenous pools of machines. In all, three files on the server and one on the client must be modified to prepare for host-based authentication. |
| HDFS | Hadoop Distributed File System (HDFS) is a subproject of Apache Hadoop. HDFS is highly fault tolerant and is designed to run on low-end hardware. The HDFS provides high-throughput access to large data sets and is ideal for applications having large data sets. |
| server | A combination of hardware and software designed for providing clients with services. This word alone refers to the computer running the server OS, or the software or dedicated hardware providing services. |
| advanced package | Logical and functional stored procedures and functions provided by GaussDB(DWS). |
| isolation | One of the ACID features of database transactions. Isolation means that the operations inside a transaction and data used are isolated from other concurrent transactions. The concurrent transactions do not affect each other. |
| relational database | A database created using a relational model. It processes data using methods of set algebra. |
| archive thread | A thread started when the archive function is enabled on a database. The thread archives database logs to a specified path. |
| failover | The automatic substitution of a functionally equivalent system component for a failed one. The system component can be a processor, server, network, or database. |
| environment variable | An environment variable defines the part of the environment in which a process runs. For example, it can define the part of the environment as the main directory, command search path, terminal that is in use, or the current time zone. |

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| Term | Description |
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| checkpoint | A mechanism that stores data in the database memory to disks at a certain time. GaussDB(DWS) periodically stores the data of committed and uncommitted transactions to disks. The data and redo logs can be used for database restoration if a database restarts or breaks down. |
| encryption | A function hiding information content during data transmission to prevent the unauthorized use of the information. |
| node | Cluster nodes (or nodes) are physical and virtual severs that make up the GaussDB(DWS) cluster environment. |
| error correction | A technique that automatically detects and corrects errors in software and data streams to improve system stability and reliability. |
| process | An instance of a computer program that is being executed. A process may be made up of multiple threads of execution. Other processes cannot use a thread occupied by the process. |
| PITR | Point-In-Time Recovery (PITR) is a backup and restoration feature of GaussDB(DWS). Data can be restored to a specified point in time if backup data and WAL logs are normal. |
| record | In a relational database, a record corresponds to data in each row of a table. |
| cluster | A cluster is an independent system consisting of servers and other resources, ensuring high availability. In certain conditions, clusters can implement load balancing and concurrent processing of transactions. |
| **K – O** | |
| LLVM | LLVM is short for Low Level Virtual Machine. Low Level Virtual Machine (LLVM) is a compiler framework written in C++ and is designed to optimize the compile-time, link-time, run-time, and idle-time of programs that are written in arbitrary programming languages. It is open to developers and compatible with existing scripts.<br>GaussDB(DWS) LLVM dynamic compilation can be used to generate customized machine code for each query to replace original common functions. Query performance is improved by reducing redundant judgment conditions and virtual function invocation, and by making local data more accurate during actual queries. |
| LVS | Linux Virtual Server (LVS), a virtual server cluster system, is used for balancing the load of a cluster. |
| MPP | Massive Parallel Processing (MPP) refers to cluster architecture that consists of multiple machines. The architecture is also called a cluster system. |

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| Term | Description |
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| MVCC | Multi-Version Concurrency Control (MVCC) is a protocol that allows a tuple to have multiple versions, on which different query operations can be performed. A basic advantage is that read and write operations do not conflict. |
| NameNode | The NameNode is the centerpiece of a Hadoop file system, managing the namespace of the file system and client access to files. |
| OLAP | Online analytical processing (OLAP) is the most important application in the database warehouse system. It is dedicated to complex analytical operations, helps decision makers and executives to make decisions, and rapidly and flexibly processes complex queries involving a great amount of data based on analysts' requirements. In addition, the OLAP provides decision makers with query results that are easy to understand, allowing them to learn the operating status of the enterprise. These decision makers can then produce informed and accurate solutions based on the query results. |
| OM | Operations Management (OM) provides management interfaces and tools for routine maintenance and configuration management of the cluster. |
| ORC | Optimized Row Columnar (ORC) is a widely used file format for structured data in a Hadoop system. It was introduced from the Hadoop HIVE project. |
| client | A computer or program that accesses or requests services from another computer or program. |
| free space management | A mechanism for managing free space in a table. This mechanism enables the database system to record free space in each table and establish an easy-to-search data structure, accelerating operations (such as INSERT) performed on the free space. |
| cross-cluster | In GaussDB(DWS), users can access data in other DBMS through foreign tables or using an Extension Connector. Such access is cross-cluster. |
| junk tuple | A tuple that is deleted using the **DELETE** and **UPDATE** statements. When deleting a tuple, GaussDB(DWS) only marks the tuples that are to be cleared. The Vacuum thread will then periodically clear these junk tuples. |
| column | An equivalent concept of "field". A database table consists of one or more columns. Together they describe all attributes of a record in the table. |
| logical node | Multiple logical nodes can be installed on the same node. A logical node is a database instance. |

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| Term | Description |
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| schema | Collection of database objects, including logical structures, such as tables, views, sequences, stored procedures, synonyms, indexes, clusters, and database links. |
| schema file | A SQL file that determines the database structure. |
| **P – T** | |
| Page | Minimum memory unit for row storage in the GaussDB(DWS) relational object structure. The default size of a page is 8 KB. |
| PostgreSQL | An open-source DBMS developed by volunteers all over the world. PostgreSQL is not controlled by any companies or individuals. Its source code can be used for free. |
| Postgres-XC | Postgres-XC is an open source PostgreSQL cluster to provide write-scalable, synchronous, multi-master PostgreSQL cluster solution. |
| Postmaster | A thread started when the database service is started. It listens to connection requests from other nodes in the cluster or from clients.<br>After receiving and accepting a connection request from the standby server, the primary server creates a WAL Sender thread to interact with the standby server. |
| RHEL | Red Hat Enterprise Linux (RHEL) |
| redo log | A log that contains information required for performing an operation again in a database. If a database is faulty, redo logs can be used to restore the database to its original state. |
| SCTP | The Stream Control Transmission Protocol (SCTP) is a transport-layer protocol defined by Internet Engineering Task Force (IETF) in 2000. The protocol ensures the reliability of datagram transport based on unreliable service transmission protocols by transferring SCN narrowband signaling over IP network. |
| savepoint | A savepoint marks the end of a sub-transaction (also known as a nested transaction) in a relational DBMS. The process of a long transaction can be divided into several parts. After a part is successfully executed, a savepoint will be created. If later execution fails, the transaction will be rolled back to the savepoint instead of being totally rolled back. This is helpful for recovering database applications from complicated errors. If an error occurs in a multi-statement transaction, the application can possibly recover by rolling back to the save point without terminating the entire transaction. |
| session | A task created by a database for a connection when an application attempts to connect to the database. Sessions are managed by the session manager. They execute initial tasks to perform all user operations. |

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| Term | Description |
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| shared-nothing architecture | A distributed computing architecture, in which none of the nodes share CPUs or storage resources. This architecture has good scalability. |
| SLES | SUSE Linux Enterprise Server (SLES) is an enterprise Linux OS provided by SUSE. |
| SMP | Symmetric multiprocessing (SMP) lets multiple CPUs run on a computer and share the same memory and bus. To ensure an SMP system achieves high performance, an OS must support multi-tasking and multi-thread processing. In databases, SMP means to concurrently execute queries using the multi-thread technology, efficiently using all CPU resources and improving query performance. |
| SQL | Structure Query Language (SQL) is a standard database query language. It consists of DDL, DML, and DCL. |
| SSL | Secure Socket Layer (SSL) is a network security protocol introduced by Netscape. SSL is a security protocol based on the TCP and IP communications protocols and uses the public key technology. SSL supports a wide range of networks and provides three basic security services, all of which use the public key technology. SSL ensures the security of service communication through the network by establishing a secure connection between the client and server and then sending data through this connection. |
| convergence ratio | Downlink to uplink bandwidth ratio of a switch. A high convergence ratio indicates a highly converged traffic environment and severe packet loss. |
| TCP | Transmission Control Protocol (TCP) sends and receives data through the IP protocol. It splits data into packets for sending, and checks and reassembles received package to obtain original information. TCP is a connection-oriented, reliable protocol that ensures information correctness in transmission. |
| trace | A way of logging to record information about the way a program is executed. This information is typically used by programmers for debugging purposes. System administrators and technical support can diagnose common problems by using software monitoring tools and based on this information. |
| full backup | Backup of the entire database cluster. |
| full synchronization | A data synchronization mechanism specified in the GaussDB(DWS) HA solution. Used to synchronize all data from the primary server to a standby server. |
| Log File | A file to which a computer system writes a record of its activities. |

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| Term | Description |
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| transaction | A logical unit of work performed within a DBMS against a database. A transaction consists of a limited database operation sequence, and must have ACID features. |
| data | A representation of facts or directives for manual or automatic communication, explanation, or processing. Data includes constants, variables, arrays, and strings. |
| data redistribution | A process whereby a data table is redistributed among nodes after users change the data distribution mode. |
| data distribution | A mode in which table data is split and stored on each database instance in a distributed system. Table data can be distributed in hash, replication, or random mode. In hash mode, a hash value is calculated based on the value of a specified column in a tuple, and then the target storage location of the tuple is determined based on the mapping between nodes and hash values. In replication mode, tuples are replicated to all nodes. In random mode, data is randomly distributed to the nodes. |
| data partitioning | A division of a logical database or its constituent elements into multiple parts (partitions) whose data does not overlap based on specified ranges. Data is mapped to storage locations based on the value ranges of specific columns in a tuple. |
| Database Name | A collection of data that is stored together and can be accessed, managed, and updated. Data in a view in the database can be classified into the following types: numerals, full text, digits, and images. |
| DB instance | A database instance consists of a process in GaussDB(DWS) and files controlled by the process. GaussDB(DWS) installs multiple database instances on one physical node. GTM, CM, CN, and DN installed on cluster nodes are all database instances. A database instance is also called a logical node. |
| database HA | GaussDB(DWS) provides a highly reliable HA solution. Every logical node in GaussDB(DWS) is identified as a primary or standby node. Only one GaussDB(DWS) node is identified as primary at a time. When the HA system is deployed for the first time, the primary server synchronizes all data from each standby server (full synchronization). The HA system then synchronizes only data that is new or has been modified from each standby server (incremental synchronization). When the HA system is running, the primary server can receive data read and write operation requests and the standby servers only synchronize logs. |
| database file | A binary file that stores user data and the data inside the database system. |

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| Term | Description |
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| data flow operator | An operator that exchanges data among query fragments. By their input/output relationships, data flows can be categorized into Gather flows, Broadcast flows, and Redistribution flows. **Gather** combines multiple query fragments of data into one. Broadcast forwards the data of one query fragment to multiple query fragments. **Redistribution** reorganizes the data of multiple query fragments and then redistributes the reorganized data to multiple query fragments. |
| data dictionary | A reserved table within a database which is used to store information about the database itself. The information includes database design information, stored procedure information, user rights, user statistics, database process information, database increase statistics, and database performance statistics. |
| deadlock | Unresolved contention for the use of resources. |
| index | An ordered data structure in the database management system. An index accelerates querying and the updating of data in database tables. |
| statistics | Information that is automatically collected by databases, including table-level information (number of tuples and number of pages) and column-level information (column value range distribution histogram). Statistics in databases are used to estimate the cost of execution plans to find the plan with the lowest cost. |
| stop word | In computing, stop words are words which are filtered out before or after processing of natural language data (text), saving storage space and improving search efficiency. |
| **U – Z** | |
| vacuum | A thread that is periodically started up by a database to clear junk tuples. Multiple Vacuum threads can be started concurrently by setting a parameter. |
| verbose | The VERBOSE option specifies the information to be displayed. |
| WAL | Write-ahead logging (WAL) is a standard method for logging a transaction. Corresponding logs must be written into a permanent device before a data file (carrier for a table and index) is modified. |
| WAL Receiver | A thread created by the standby server during database duplication. The thread is used to receive data and commands from the primary server and to tell the primary server that the data and commands have been acknowledged. Only one WAL receiver thread can run on one standby server. |

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| Term | Description |
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| WAL Sender | A thread created on the primary server when the primary server has received a connection request from a standby server during database replication. This thread is used to send data and commands to standby servers and to receive responses from the standby servers. Multiple WAL Sender threads may run on one primary server. Each WAL Sender thread corresponds to a connection request initiated by a standby server. |
| WAL Writer | A thread for writing redo logs that are created when a database is started. This thread is used to write logs in the memory to a permanent device, such as a disk. |
| WLM | The WorkLoad Manager (WLM) is a module for controlling and allocating system resources in GaussDB(DWS). |
| Xlog | A transaction log. A logical node can have only one Xlog file. |
| xDR | X detailed record. It refers to detailed records on the user and signaling plans and can be categorized into charging data records (CDRs), user flow data records (UFDRs), transaction detail records (TDRs), and data records (SDRs). |
| network backup | Network backup provides a comprehensive and flexible data protection solution to Microsoft Windows, UNIX, and Linux platforms. Network backup can back up, archive, and restore files, folders, directories, volumes, and partitions on a computer. |
| physical node | A physical machine or device. |
| system catalog | A table storing meta information about the database. The meta information includes user tables, indexes, columns, functions, and the data types in a database. |
| pushdown | GaussDB(DWS) is a distributed database, where CN can send a query plan to multiple DNs for parallel execution. This CN behavior is called pushdown. It achieves better query performance than extracting data to CN for query. |
| compression | Data compression, source coding, or bit-rate reduction involves encoding information that uses fewer bits than the original representation. Compression can be either lossy or lossless. Lossless compression reduces bits by identifying and eliminating statistical redundancy. No information is lost in lossless compression. Lossy compression reduces bits by identifying and removing unnecessary or unimportant information. The process of reducing the size of a data file is commonly referred as data compression, although its formal name is source coding (coding done at the source of the data, before it is stored or transmitted). |

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| Term | Description |
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| consistency | One of the ACID features of database transactions. Consistency is a database status. In such a status, data in the database must comply with integrity constraints. |
| metadata | Data that provides information about other data. Metadata describes the source, size, format, or other characteristics of data. In database columns, metadata explains the content of a data warehouse. |
| atomicity | One of the ACID features of database transactions. Atomicity means that a transaction is composed of an indivisible unit of work. All operations performed in a transaction must either be committed or uncommitted. If an error occurs during transaction execution, the transaction is rolled back to the state when it was not committed. |
| online scale-out | Online scale-out means that data can be saved to the database and query services are not interrupted during redistribution in GaussDB(DWS). |
| dirty page | A page that has been modified and is not written to a permanent device. |
| incremental backup | Incremental backup stores all files changed since the last valid backup. |
| incremental synchronization | A data synchronization mechanism in the GaussDB(DWS) HA solution. Only data modified since the last synchronization is synchronized to the standby server. |
| Host | A node that receives data read and write operations in the GaussDB(DWS) HA system and works with all standby servers. At any time, only one node in the HA system is identified as the primary server. |
| thesaurus | Standardized words or phrases that express document themes and are used for indexing and retrieval. |
| dump file | A specific type of the trace file. A dump is typically a one-time output of diagnostic data in response to an event, whereas a trace tends to be continuous output of diagnostic data. |
| resource pool | Resource pools used for allocating resources in GaussDB(DWS). By binding a user to a resource pool, you can limit the priority of the jobs executed by the user and resources available to the jobs. |
| tenant | A database service user who runs services using allocated computing (CPU, memory, and I/O) and storage resources. Service level agreements (SLAs) are met through resource management and isolation. |

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| Term | Description |
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| minimum restoration point | A method used by GaussDB(DWS) to ensure data consistency. During startup, GaussDB(DWS) checks consistency between the latest WAL logs and the minimum restoration point. If the record location of the minimum restoration point is greater than that of the latest WAL logs, the database fails to start. |

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