Data Warehouse Service

Best Practices

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Contents

1 Import and Export

1.1 Importing Data to DWS

Importing Data from OBS in Parallel

- Splitting a data file into multiple files

  Importing a huge amount of data takes a long period of time and consumes many computing resources.

  To improve the performance of importing data from OBS, split a data file into multiple files as evenly as possible before importing it to OBS. The preferred number of split files is an integer multiple of the DN quantity.

- Verifying data files before and after an import

  When importing data from OBS, first import your files to your OBS bucket, and then verify that the bucket contains all the correct files, and only those files.

  After the import is complete, run the **SELECT** statement to verify that the required files have been imported.

- Ensuring no Chinese characters are contained in paths used for importing data to or exporting data from OBS.

Using GDS to Import Data

- Gauss Data Service (GDS) is a command line tool that runs on Linux servers. It cooperates with the foreign table mechanism to import and export data efficiently. The GDS tool package needs to be installed on the server where the data source file is located. This server is called the data server or the GDS server. For details about how to use GDS to import data, see **Using GDS to Import Table Data from a Remote Server to a DWS Cluster**.
- Data skew causes the query performance to deteriorate. 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. For details, see **Checking for Data Skew**.

- To speed up the import, you are advised to split files and use multiple Gauss Data Service (GDS) tools to import data in parallel. An import task can be split into multiple concurrent import tasks. If multiple import tasks use the same GDS, you can specify the **-t** parameter to enable GDS multi-thread concurrent import. To prevent physical I/O and network bottleneck, you are advised to mount GDSs to different physical disks and NICs.
- If the GDS I/O and NICs do not reach their physical bottlenecks, you can enable SMP on DWS for acceleration. SMP will multiply the pressure on GDSs. Note that SMP adaptation is implemented based on the DWS CPU pressure rather than the GDS pressure. For more information about SMP, see **SMP Manual Optimization Suggestions**.
- For the proper communication between GDSs and DWS, you are advised to use 10GE networks. 1GE networks cannot bear the high-speed data transmission, and cannot ensure proper communication between GDSs and DWS. To maximize the import rate of a single file, ensure that a 10GE network is used and the data disk group I/O rate is greater than the upper limit of the GDS single-core processing capability (about 400 MB/s).
- Similar to the single-table import, ensure that the I/O rate is greater than the maximum network throughput in the concurrent import.
- It is recommended that the ratio of GDS quantity to DN quantity be in the range of 1:3 to 1:6.
- To improve the efficiency of importing data in batches to column-store partitioned tables, the data is buffered before being written into a disk. You can specify the number of buffers and the buffer size by setting **partition_mem_batch** and **partition_max_cache_size**, respectively. Smaller values indicate the slower the batch import to column-store partitioned tables. The larger the values, the higher the memory consumption.

Using INSERT to Insert Multiple Rows

If the COPY statement cannot be used during data import, you can use multi-row inserts to insert data in batches. Multi-row inserts improve performance by batching up a series of inserts.

The following example inserts three rows into a three-column table using a single **INSERT** statement. This is still a small insert, shown simply to illustrate the syntax of a multi-row insert.

To insert multiple rows of data to the table **customer_t1**, run the following statement:

```
INSERT INTO customer_t1 VALUES
(6885, 'maps', 'Joes'),
(4321, 'tpcds', 'Lily'),
(9527, 'world', 'James');
```

For more details and examples, see **INSERT**.

Using the COPY Statement to Import Data

The **COPY** statement imports data from local and remote databases in parallel. **COPY** imports large amounts of data more efficiently than **INSERT** statements.

For how to use the **COPY** command, see **Running the COPY FROM STDIN Statement to Import Data**.

Using a gsql Meta-Command to Import Data

The **\copy** command can be used to import data after you log in to a database through any **gsql** client. Compared with the **COPY** command, the **\copy** command directly reads or writes local files instead of reading or writing files on the database server.

Data read or written using the **\copy** command is transferred through the connection between the server and the client and may not be efficient than the **SQL COPY** command. The **COPY** statement is recommended when the amount of data is large.

For how to use the **\copy** command, see **Using a gsql Meta-Command to Import Data**.

NOTE

\copy only applies to small-batch data import with uniform formats but poor error tolerance capability. GDS or **COPY** is preferred for data import.

1.2 Transferring Data Between OBS Buckets and DWS Clusters

This guide shows how to upload sample data to OBS and access it through an OBS foreign table. You can import OBS data into DWS or export data from DWS to OBS.

- Data can be imported to OBS in TXT, CSV, ORC, PARQUET, CARBONDATA, or JSON formats.
- Data can be exported from OBS in the following formats:
  - **ORC, CARBONDATA, and PARQUET**: You will need to create a foreign server. For how to create a foreign server, see **Step 2: Create an OBS Foreign Server and a Foreign Table**. This example exports data of this type.
  - **TXT and CSV**: No foreign server is required as the system provides the **gsmpp_server** server by default. For how to export data in this format, see **Exporting CSV/TXT Data to OBS**.

OBS is an object-based storage service that offers secure, reliable, and cost-effective data storage for various users, websites, enterprises, and developers. You can use OBS Console or OBS Browser to access and manage data stored on OBS from any computer connected to the Internet. For details, see **Object Storage Service Documentation**.

This practice takes approximately 1 hour. The basic procedure is as follows:

- **Preparations**: Create a DWS cluster and an OBS bucket, and obtain the AK and SK.
- **Step 1: Prepare OBS Data**: Upload the preset sample data to the OBS bucket.
- **Step 2: Create an OBS Foreign Server and a Foreign Table**: Prepare for importing data from the OBS bucket.
- **Step 3: Access and Import OBS Bucket Data to a DWS Cluster**: Import data using an OBS foreign table.

- **Step 4: Export Data from a DWS Table to an OBS Bucket**: Verify that data cannot be updated or deleted in a write-only foreign table after data export.

Preparations

- Create a DWS cluster. For details, see **Creating a Dedicated DWS Cluster**
- Create an OBS bucket in the same region as DWS. You can name the bucket **obs-demo01**. If **01** is taken, use **obs-demo02**. Follow this pattern. For details, see **Object Storage Service Documentation**.
- Obtain the AK and SK of the account for accessing data in the OBS bucket. For details, see **Access Keys**

Step 1: Prepare OBS Data

Step 1 Download the **data sample file**.

Step 2 **Log in to OBS Console** and click the **dws-demo01** bucket in the bucket list.

Step 3 Select **Objects** on the left, click **Create Folder**, and name the folder **obs-dws**.

Step 4 Go to the **obs-dws** folder, click **Upload Object**, and upload the sample file downloaded in **Step 1** to the **obs-dws** folder.

Step 5 Obtain the OBS endpoint.

1. Go back to the **obs-dwst** page and click **Overview** on the left.
2. Record the endpoint from the **Domain Name Details** list, for example, **obs.xxx.myhuaweicloud.com**.

----End

Step 2: Create an OBS Foreign Server and a Foreign Table

A foreign server is a virtual link that helps organize and control external data sources like databases and file systems in a database system or data warehouse. It enables unified access to diverse distributed data and plays a key role in data integration, real-time analysis, and data virtualization.

To access OBS bucket data through a foreign server, set up a foreign OBS server and provide the endpoint, Access Key (AK), and Secret Key (SK) for OBS.

Step 1 Run the following SQL statement to create a foreign server after connecting to the database.

Set **ADDRESS** to the address obtained in **Step 5**, and set **ACCESS_KEY** and **SECRET_ACCESS_KEY** to the AK and SK obtained in **Preparations**.

```
CREATE SERVER obs_server FOREIGN DATA WRAPPER DFS_FDW
OPTIONS (
  ADDRESS 'obs.aaaaa.bbbbb.com',
  ACCESS_KEY 'xxxxxxxxx',
  SECRET_ACCESS_KEY 'yyyyyyyyyyyy',
  TYPE 'OBS'
  );
```

Step 2 Run the following SQL statement to create a schema named **dws_data**:

```
CREATE SCHEMA dws_data;
```

Step 3 Switch to the newly created schema and create a foreign table.

Replace **'/obs-demo01/obs-dws/'** with your actual OBS path where the data files are stored. Make sure the OBS bucket and the DWS cluster are in the same region. In this example, the OBS path is the **obs-dws** folder in the **obs-demo01** bucket.

SERVER obs_server indicates the name of the foreign server created in **Step 1**, for example, **obs_server**.

```
CREATE FOREIGN TABLE dws_data.obs_pq_order
( order_idVARCHAR(14)PRIMARY KEY NOT ENFORCED,
order_channel VARCHAR(32),
order_timeTIMESTAMP,
cust_codeVARCHAR(6),
pay_amountDOUBLE PRECISION,
real_payDOUBLE PRECISION )
SERVER obs_server
OPTIONS (
foldername '/obs-demo01/obs-dws/',
format 'parquet',
encoding 'utf8' )
READ ONLY
DISTRIBUTE BY roundrobin;
```

----End

Step 3: Access and Import OBS Bucket Data to a DWS Cluster

Step 1 Use the foreign table created in the preceding steps to directly access data in the OBS bucket.

```
SELECT * FROM dws_data.obs_pq_order;
```

Step 2 Execute the **SELECT** statement with conditions through a foreign table.

```
SELECT COUNT(*) FROM dws_data.obs_pq_order;

SELECT order_id, order_channel, order_time, cust_code FROM dws_data.obs_pq_order;

SELECT TO_CHAR(order_time, 'Month, YYYY') AS order_month, cust_code, COUNT(*) AS order_cnt
FROM dws_data.obs_pq_order
WHERE DATE_PART('Year', order_time) = 2023
GROUP BY TO_CHAR(order_time, 'Month, YYYY'), cust_code
HAVING COUNT(*) >= 10;
```

Step 3 Create a local table to import data to a DWS cluster through an OBS foreign table.

```
CREATE TABLE dws_data.dws_monthly_order
( order_monthCHAR(8),
cust_codeVARCHAR(6),
order_countINT,
total_pay_amountDOUBLE PRECISION,
total_real_payDOUBLE PRECISION );
```

Step 4 Use the OBS foreign table data to calculate the monthly order details of 2023 and import the result to the local table of the DWS cluster.

```
INSERT INTO dws_data.dws_monthly_order
( order_month, cust_code, order_count
, total_pay_amount, total_real_pay )
SELECT TO_CHAR(order_time, 'MON-YYYY'), cust_code, COUNT(*)
, SUM(pay_amount), SUM(real_pay)
FROM dws_data.obs_pq_order
WHERE DATE_PART('Year', order_time) = 2023
GROUP BY TO_CHAR(order_time, 'MON-YYYY'), cust_code;
```

Step 5 Check the table data import status.

```
SELECT * FROM dws_data.dws_monthly_order;
```

----End

Step 4: Export Data from a DWS Table to an OBS Bucket

Step 1 Create a local table.

```
CREATE TABLE dws_data.dws_order
( order_idVARCHAR(14)PRIMARY KEY,
order_channel VARCHAR(32),
order_timeTIMESTAMP,
cust_codeVARCHAR(6),
pay_amountDOUBLE PRECISION,
real_payDOUBLE PRECISION );
```

Step 2 Insert three data records.

```
INSERT INTO dws_data.dws_order
VALUES ('20230627000001', 'webShop', TIMESTAMP '2023-06-27 10:00:00', 'CUST1', 1000, 1000)
, ('20230627000002', 'webShop', TIMESTAMP '2023-06-27 11:00:00', 'CUST2', 5000, 5000)
, ('20240309000003', 'webShop', TIMESTAMP '2024-03-09 13:00:00', 'CUST1', 2000, 2000);
```

Step 3 Create a foreign table for exporting data to an OBS bucket.

Replace **'/obs-demo01/obs-dws/'** with your actual OBS bucket path.

```
CREATE FOREIGN TABLE dws_data.obs_orc_order
( order_idVARCHAR(14)PRIMARY KEY NOT ENFORCED,
order_channel VARCHAR(32),
order_timeTIMESTAMP,
cust_codeVARCHAR(6),
pay_amountDOUBLE PRECISION,
real_payDOUBLE PRECISION )
SERVER obs_server
OPTIONS (
foldername '/obs-demo01/obs-dws/',
format 'ORC',
encoding 'utf8' )
WRITE ONLY
DISTRIBUTE BY roundrobin;
```

Step 4 Write the local table data to the OBS foreign table.

```
INSERT INTO dws_data.obs_orc_order ( order_id, order_channel, order_time, cust_code, pay_amount, 
real_pay )
SELECT order_id, order_channel, order_time, cust_code, pay_amount, real_pay
  FROM dws_data.dws_order;
```

Step 5 Query whether the data import is successful.

```
SELECT * FROM dws_data.obs_orc_order;
```

Step 6 Log in to the **OBS console** to check whether there are data files in the OBS bucket.

Step 7 Check whether extra data can be inserted into the same foreign table.

```
INSERT INTO dws_data.obs_orc_order ( order_id, order_channel, order_time, cust_code, pay_amount, 
real_pay )
SELECT order_id, order_channel, order_time, cust_code, pay_amount, real_pay
  FROM dws_data.dws_order;
```

The error "the file path specified in the foreign table is not empty" appears. If you delete the data file in the OBS file path, you can insert data again.

Step 8 Check whether foreign table data can be updated and deleted.

```
UPDATE dws_data.obs_orc_order  SET pay_amount = 3000, real_pay = 3000 WHERE order_id   = 
'20240309000003';
DELETE FROM dws_data.obs_orc_order WHERE order_id = '20240309000003';
```


According to the command output, foreign table data cannot be updated or deleted.

----End

1.3 Using GDS to Import Table Data from a Remote Server to a DWS Cluster

Overview

This tutorial demonstrates how to use General Data Service (GDS) to import data from a remote server to DWS. DWS allows you to import data in TXT, CSV, or FIXED format.

GDS is a command line tool that runs on Linux servers. It cooperates with the foreign table mechanism to import and export data efficiently. The GDS tool package needs to be installed on the server where the data source file is located. This server is called the data server or the GDS server.

It is used only for demonstration in the test environment. In actual service import scenarios, you need to consider the network between the GDS server and the DWS cluster and the GDS server configurations. For details, see **Learn More: Practices for Importing Data Using GDS**.

In this tutorial, you will:

- Generate the source data files in CSV format to be used in this tutorial.
- Upload the source data files to a data server.
- Create foreign tables used for importing data from a data server to DWS through GDS.
- Start DWS, create a table, and import data to the table.
- Analyze import errors based on the information in the error table and correct these errors.

Preparing an ECS as the GDS Server

For details about how to purchase a Linux ECS, see section "Purchasing an ECS" in the *Elastic Cloud Server Getting Started*. After the purchase, log in to the ECS by referring to section "Logging In to a Linux ECS".

CAUTION

- The ECS is configured with the following minimum specifications:
  - Production environment: Network: >= 10GE; CPUs: 16; Memory: 64 GB; Storage: on-demand (recommended: >= 500 GB)
  - Test environment: Network: >= 10GE; CPUs: 8; Memory: 32 GB; Storage: on-demand (recommended: >= 500 GB)
- The ECS OS must be supported by the GDS package.
- The ECS and DWS are in the same region, VPC, and subnet.
- The ECS security group rule must allow access to the DWS cluster, that is, the inbound rule of the security group is as follows:
  - **Protocol**: **TCP**
  - **Port**: **5000**
  - **Source**: Select **IP Address** and enter the IP address of the DWS cluster, for example, **192.168.0.10/32**.
- If the firewall is enabled in the ECS, ensure that the listening port of GDS is enabled on the firewall:
```
iptables  -I INPUT -p tcp -m tcp --dport <gds_port> -j ACCEPT
```

Downloading the GDS Package

Step 1 Log in to the **DWS console**.

Step 2 In the navigation tree on the left, choose **Management** > **Client Connections**.

Step 3 Select the GDS client of the corresponding version from the drop-down list of **CLI Client**.

Select a version based on the cluster version and the OS where the client is installed.

NOTE

The CPU architecture of the client must be the same as that of the cluster. If the cluster uses the x86 specifications, select the x86 client.

Step 4 Click **Download**.

----End

Preparing Source Data Files

- Data file **product_info0.csv**
```
100,XHDK-A,2017-09-01,A,2017 Shirt Women,red,M,328,2017-09-04,715,good!
205,KDKE-B,2017-09-01,A,2017 T-shirt Women,pink,L,584,2017-09-05,40,very good!
300,JODL-X,2017-09-01,A,2017 T-shirt men,red,XL,15,2017-09-03,502,Bad.
310,QQPX-R,2017-09-02,B,2017 jacket women,red,L,411,2017-09-05,436,It's nice.
150,ABEF-C,2017-09-03,B,2017 Jeans Women,blue,M,123,2017-09-06,120,good.
```
- Data file **product_info1.csv**
```
200,BCQP-E,2017-09-04,B,2017 casual pants men,black,L,997,2017-09-10,301,good quality.
250,EABE-D,2017-09-10,A,2017 dress women,black,S,841,2017-09-15,299,This dress fits well.
108,CDXK-F,2017-09-11,A,2017 dress women,red,M,85,2017-09-14,22,It's really amazing to buy.
450,MMCE-H,2017-09-11,A,2017 jacket women,white,M,114,2017-09-14,22,very good.
260,OCDA-G,2017-09-12,B,2017 woolen coat women,red,L,2004,2017-09-15,826,Very comfortable.
```


- Data file **product_info2.csv**

```
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."
```

Step 1 Create a text file, open it using a local editing tool (for example, Visual Studio Code), and copy the sample data to the text file.

Step 2 Choose **Format** > **Encode in UTF-8 without BOM**.

Step 3 Choose **File** > **Save as**.

Step 4 In the displayed dialog box, enter the file name, set the file name extension to .csv, and click **Save**.

Step 5 Log in to the GDS server as user **root**.

Step 6 Create the **/input_data** directory for storing the data file.

```
mkdir -p /input_data
```

Step 7 Use MobaXterm to upload source data files to the created directory.

----End

Installing and Starting GDS

Step 1 Log in to the GDS server as user **root** and create the **/opt/bin/dws** directory for storing the GDS package.

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

Step 2 Upload the GDS package to the created directory.

For example, upload the **dws_client_8.1.*x*_redhat_x64.zip** package to the created directory.

Step 3 Go to the directory and decompress the package.

```
cd /opt/bin/dws
unzip dws_client_8.1.x_redhat_x64.zip
```

Step 4 Create a user (**gds_user**) and the user group (**gdsgrp**) to which the user belongs. This user is used to start GDS and must have the permission to read the source data file directory.

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

Step 5 Change the owner of the GDS package and source data file directory to **gds_user** and change the user group to **gdsgrp**.

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

Step 6 Switch to user **gds_user**.

```
su - gds_user
```

If the current cluster version is 8.0.*x* or earlier, skip **Step 7** and go to **Step 8**.

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

Step 7 Execute the script on which the environment depends (applicable only to 8.1.*x*).

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

Step 8 Start GDS.

```
/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
```

Replace the italic parts as required.

- **-d** *dir*: directory for storing data files that contain data to be imported. This practice 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 DWS. The port number ranges from 1024 to 65535. The default value is **8098**. This practice uses **192.168.0.90:5000** as an example.
- **-H** *address_string*: hosts that are allowed to connect to and use GDS. The value must be in CIDR format. Set this parameter to enable a DWS cluster to access GDS for data import. Ensure that the network segment covers all hosts in a DWS cluster.
- **-l** *log_file*: GDS log directory and log file name. This practice uses **/opt/bin/dws/gds/gds_log.txt** as an example.
- **-D**: GDS in daemon mode. This parameter is used only in Linux.

----End

Creating a Foreign Table

Step 1 Use an SQL client to connect to the DWS database.

Step 2 Create the following foreign table:

CAUTION

LOCATION: Replace it with the actual GDS address and port number.

```
DROP FOREIGN TABLE IF EXISTS 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 'gsfs://192.168.0.90:5000/*',
FORMAT 'CSV' ,
```

```
DELIMITER ',',
ENCODING 'utf8',
HEADER 'false',
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
```

----End

Importing Data

Step 1 Run the following statements to create the **product_info** table in DWS to store imported data:

```
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 Import data from source data files to the **product_info** table through the foreign table **product_info_ext**.

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

If the following information is displayed, the data is successfully imported:

```
INSERT 0 20
```

Step 3 Run the **SELECT** statement to view the data imported to DWS.

```
SELECT count(*) FROM product_info;
```

If the following information is displayed, the data has been imported:

```
count
-------
    20
(1 row)
```

Step 4 Run **VACUUM FULL** on the **product_info** table.

```
VACUUM FULL product_info
```

Step 5 Update statistics of the **product_info** table.

```
ANALYZE product_info;
```

----End

Stopping GDS

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

Step 2 Perform the following operations to stop GDS:

1. Query the GDS process ID. 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 /opt/bin/gds/gds_log.txt  -D
gds_user 129003 118723  0 15:04 pts/0    00:00:00 grep gds
```
2. Run the **kill** command to stop GDS. **128954** indicates the GDS process ID.
```
kill -9 128954
```

----End

Deleting Resources

Step 1 Run the following command to delete the target table **product_info**:
```
DROP TABLE product_info;
```
If the following information is displayed, the table has been deleted:
```
DROP TABLE
```

Step 2 Run the following command to delete the foreign table **product_info_ext**:
```
DROP FOREIGN TABLE product_info_ext;
```
If the following information is displayed, the table has been deleted:
```
DROP FOREIGN TABLE
```

----End

Learn More: Practices for Importing Data Using GDS

- Before installing GDS, ensure that the system parameters of the server where GDS is deployed are consistent with those of the database cluster.
- If GDS is deployed on an ECS, ensure that the ECS must meet the following minimum specifications:
  – Production environment: Network: >= 10GE; CPUs: 16; Memory: 64 GB; Storage: on-demand (recommended: >= 500 GB)
  – Test environment: Network: >= 10GE; CPUs: 8; Memory: 32 GB; Storage: on-demand (recommended: >= 500 GB)
- For the proper communication between GDSs and DWS, you are advised to use 10GE networks. The 1GE network cannot guarantee smooth communication between GDS and DWS, because it cannot bear the high-speed data transmission pressure and is prone to disconnection. To maximize the import rate of a single file, ensure that a 10GE network is used and the data disk group I/O rate is greater than the upper limit of the GDS single-core processing capability (about 400 MB/s).
- Deploy the service in advance. It is recommended that one or two GDSs be deployed on a RAID of a data server. It is recommended that the ratio of GDS quantity to DN quantity be in the range of 1:3 to 1:6. Do not deploy too many GDS processes on a loader. Deploy only one GDS process if an 1GE NIC is used, and no more than four GDS processes if a 10GE NIC is used.

- Hierarchically divide the data directories for data imported and exported by GDS in advance, Do not put too many files under a data directory, and delete expired files in a timely manner.
- Properly plan the character set of the target database. You are advised to use UTF-8 instead of the SQL_ASCII characters which can easily incur mixed encoding. When exporting data using GDS, ensure that the character set of the foreign table is the same as that of the client. When importing data, ensure that the client and data file content use the same encoding method.
- If the character set of the database, client, or foreign table cannot be changed, run the **iconv** command to manually change the character set.

```
#Note: -f indicates the character set of the source file, and -t indicates the target character set.
iconv -f utf8 -t gbk utf8.txt -o gbk.txt
```

- For details about GDS import practices, see **Using GDS to Import Data**.
- GDS supports CSV, TEXT, and FIXED formats. The default format is TEXT. The binary format is not supported. However, the encode or decode function can be used to process data of the binary type. The following shows an example.

  Export a binary table.

```
-- Create a table.
CREATE TABLE blob_type_t1
(
    BT_COL BYTEA
) DISTRIBUTE BY REPLICATION;
-- Create a foreign table.
CREATE FOREIGN TABLE f_blob_type_t1( BT_COL  text ) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://127.0.0.1:7789/', FORMAT 'text', DELIMITER E'\x08',  NULL '', EOL '0x0a' ) WRITE ONLY;
INSERT INTO blob_type_t1 VALUES(E'\\xDEADBEEF');
INSERT INTO blob_type_t1 VALUES(E'\\xDEADBEEF');
INSERT INTO blob_type_t1 VALUES(E'\\xDEADBEEF');
INSERT INTO blob_type_t1 VALUES(E'\\xDEADBEEF');
INSERT INTO f_blob_type_t1 select encode(BT_COL,'base64') from blob_type_t1;
```

  Import a binary table.

```
-- Create a table.
CREATE TABLE blob_type_t2
(
    BT_COL BYTEA
) DISTRIBUTE BY REPLICATION;
-- Create a foreign table.
CREATE FOREIGN TABLE f_blob_type_t2( BT_COL  text ) SERVER gsmpp_server OPTIONS (LOCATION 'gsfs://127.0.0.1:7789/f_blob_type_t1.dat.0', FORMAT 'text', DELIMITER E'\x08',  NULL '', EOL '0x0a' );
insert into  blob_type_t2 select decode(BT_COL,'base64') from f_blob_type_t2;
SELECT * FROM blob_type_t2;
   bt_col
------------
 \xdeadbeef
 \xdeadbeef
 \xdeadbeef
 \xdeadbeef
(4 rows)
```

- Do not repeatedly export data from the same foreign table. Otherwise, the previously exported file will be overwritten.
- If you are not sure whether the file is in the standard CSV format, you are advised to set **quote** to invisible characters such as **0x07**, **0x08**, or **0x1b** to import and export data using GDS. This prevents task failures caused by incorrect file format.

```
CREATE FOREIGN TABLE foreign_HR_staffS_ft1
(
  MANAGER_ID     NUMBER(6),
  section_ID     NUMBER(4)
) SERVER gsmpp_server OPTIONS (location 'file:///input_data/*', format 'csv', mode 'private', quote '0x07', delimiter ',') WITH err_HR_staffS_ft1;
```

- 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 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.
- If the delimiter of a GDS foreign table consists of multiple characters, do not use the same characters in the TEXT format, for example **---**.
- GDS imports a single file through multiple tables in parallel to improve data import performance. (Only CSV and TEXT files can be imported.)

```
-- Create a target table.

CREATE TABLE pipegds_widetb_1 (city integer, tel_num varchar(16), card_code varchar(15), 
phone_code varchar(16), region_code varchar(6), station_id varchar(10), tmsi varchar(20), rec_date 
integer(6), rec_time integer(6), rec_type numeric(2), switch_id  varchar(15), attach_city varchar(6), 
opc varchar(20), dpc varchar(20));

-- Create a foreign table that contains the file_sequence column.
CREATE FOREIGN TABLE gds_pip_csv_r_1( like pipegds_widetb_1) SERVER gsmpp_server  OPTIONS 
(LOCATION 'gsfs://127.0.0.1:8781/wide_tb.txt', FORMAT 'text', DELIMITER E'|+|', NULL '', file_sequence 
'5-1');

CREATE FOREIGN TABLE gds_pip_csv_r_2( like pipegds_widetb_1) SERVER gsmpp_server  OPTIONS 
(LOCATION 'gsfs://127.0.0.1:8781/wide_tb.txt', FORMAT 'text', DELIMITER E'|+|', NULL '', file_sequence 
'5-2');

CREATE FOREIGN TABLE gds_pip_csv_r_3( like pipegds_widetb_1) SERVER gsmpp_server  OPTIONS 
(LOCATION 'gsfs://127.0.0.1:8781/wide_tb.txt', FORMAT 'text', DELIMITER E'|+|', NULL '', file_sequence 
'5-3');

CREATE FOREIGN TABLE gds_pip_csv_r_4( like pipegds_widetb_1) SERVER gsmpp_server  OPTIONS 
(LOCATION 'gsfs://127.0.0.1:8781/wide_tb.txt', FORMAT 'text', DELIMITER E'|+|', NULL '', file_sequence 
'5-4');

CREATE FOREIGN TABLE gds_pip_csv_r_5( like pipegds_widetb_1) SERVER gsmpp_server  OPTIONS 
(LOCATION 'gsfs://127.0.0.1:8781/wide_tb.txt', FORMAT 'text', DELIMITER E'|+|', NULL '', file_sequence 
'5-5');

-- Import the wide_tb.txt file to the pipegds_widetb_1 table in parallel.
\parallel on
INSERT INTO pipegds_widetb_1 SELECT * FROM gds_pip_csv_r_1;
INSERT INTO pipegds_widetb_1 SELECT * FROM gds_pip_csv_r_2;
INSERT INTO pipegds_widetb_1 SELECT * FROM gds_pip_csv_r_3;
INSERT INTO pipegds_widetb_1 SELECT * FROM gds_pip_csv_r_4;
INSERT INTO pipegds_widetb_1 SELECT * FROM gds_pip_csv_r_5;
\parallel off
```

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

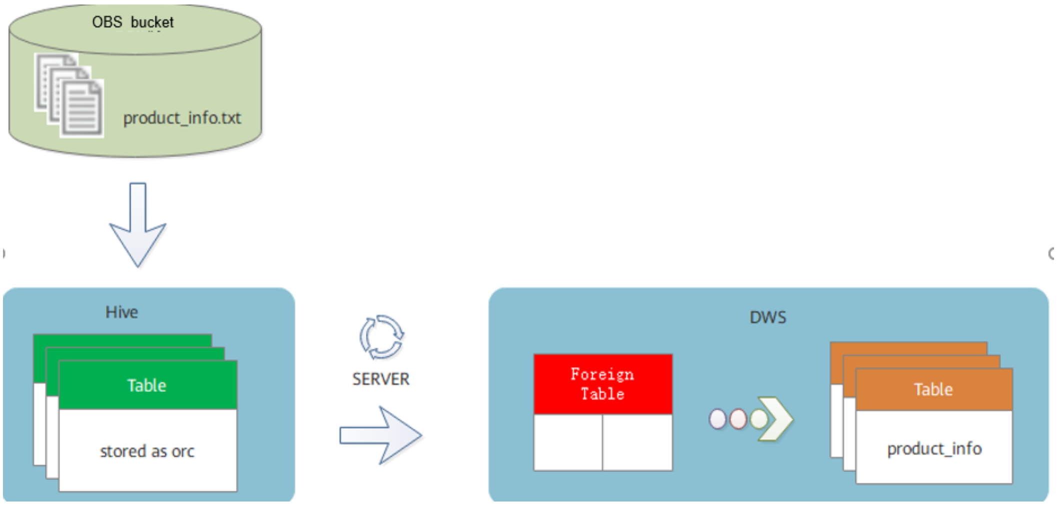
1.4 Importing Table Data from MRS Hive to a DWS Cluster

An HDFS foreign table is created to enable DWS to remotely access or read MRS data sources. DWS transmits data through foreign servers and foreign tables. The practice simulates the process of writing data from ORC table data stored in MRS Hive to DWS by creating a cross-source foreign server and foreign table.

A foreign server is a virtual object configured in a database. It is used to define parameters (such as the address, protocol, and authentication information) for connecting to an external data source. Through the foreign servers, the local database can directly query and insert external data, just like operating local tables. (The syntax is similar, but may be restricted by performance or functions.)

A foreign table is a virtual table in a database. Data is stored outside the database system (such as file systems, other databases, and cloud storage). However, through the definition and access interface of the table schema (metadata), users can query the external data using standard SQL statements without importing the data to the database.

Based on the type of the interconnected data source, there are HDFS foreign tables and OBS foreign tables. The former reads data from the HDFS distributed file system and the latter reads data from the OBS object storage service.



- For details about MRS, see **MRS Documentation**.
- For details about the foreign server syntax, see **CREATE SERVER**
- For details about the foreign table syntax, see **CREATE FOREIGN TABLE (SQL on OBS or Hadoop)**.

This practice takes approximately 1 hour. The basic procedure is as follows:

1. **Step 1: Buy an MRS Cluster and Prepare the ORC Table Data Source of MRS**: Create an MRS analysis cluster, upload the local TXT data files to an OBS bucket, and import the files to a Hive storage table, and then to an ORC storage table.
2. **Step 2: Create an MRS Data Source Connection**: Create an MRS data source on the DWS console. By default, a foreign server named **mrs** is generated.
3. **Step 3: Create a Foreign Table**: Create an HDFS foreign table to access data on MRS.
4. **Step 4: Import Data**: Import data to a local DWS table through an HDFS foreign table.

Preparing the Environment

Create a DWS cluster. Ensure that the MRS and DWS clusters are in the same region, AZ, and VPC subnet and that the clusters can communicate with each other.

Step 1: Buy an MRS Cluster and Prepare the ORC Table Data Source of MRS

Step 1 Buy an MRS analysis cluster. Set the key parameters as described in **Table 1-1** and retain default values of other parameters. For details, see **Buying MRS Clusters**.

It takes about 15 minutes to create a cluster. You can continue with the following operations during the cluster creation.

Table 1-1 Parameters

Parameter	Value
Region	EU-Dublin
Billing Mode	Pay-per-use
Cluster Type	Analysis cluster
Version Type	Normal
Cluster Version	MRS 1.9.2 (recommended) **CAUTION** • DWS clusters of version 8.1.1.300 or later support MRS 1.6.*, 1.7.*, 1.8.*, 1.9.*, 2.0.*, 3.0.*, 3.1.*, and later (*indicates a number). • DWS clusters of earlier than version 8.1.1.300 support MRS 1.6.*, 1.7.*, 1.8.*, 1.9.*, and 2.0.* (*indicates a number).
Metadata	Local
AZ	**AZ 1**
CPU Architecture	**x86**
Kerberos Authentication	Disabled
Login Mode	Password

Step 2 Create a **product_info.txt** file on the local PC, copy the following data to the file, and save the file to the local PC.

```
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,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
```

Step 3 Log in to the **OBS console**, click **Create Bucket**, set the key parameters in the following table, retain the default values for other parameters, and click **Create Now**.

Table 1-2 Bucket parameters

Parameter	Value
Region	EU-Dublin
Data Redundancy Policy	Single-AZ storage
Bucket Name	mrs-datasource
Default Storage Class	Standard
Bucket Policy	Private
Default Encryption	Disabled
Direct Reading	Disabled
Tags	N/A

Step 4 After the bucket is created, click the bucket name and choose **Object** > **Upload Object** to upload the **product_info.txt** file to the OBS bucket.

Step 5 Go back to the **MRS console** and click the name of the created MRS cluster. On the **Dashboard** page, click **Synchronize** next to **IAM User Sync**. The synchronization takes about one minute.

Step 6 Click **Nodes** and click a master node. On the displayed page, switch to the **EIPs** tab, click **Bind EIP**, select an existing EIP, and click **OK**. If no EIP is available, create one. Record the EIP.

Step 7 Determine the active master node.

1. Use SSH to log in to the preceding node as user **root**. Run the following command to switch to user **omm**:

su - omm

2. Run the following command to query the primary node:

   sh ${BIGDATA_HOME}/om-0.0.1/sbin/status-oms.sh

   If the value of **HAActive** is **active**, the node is the primary node.

   – If the current node is the primary node, go to **Step 9**
   – If the current node is not the primary node, go to **Step 8**.

Step 8 Log out and then log in to the primary node as the **root** user, and switch to the **omm** user.

su - omm

Step 9 G to the directory where the Hive client is located.

cd /opt/client

Step 10 Create the **product_info** table whose storage format is TEXTFILE on Hive.

1. Import environment variables to the **/opt/client** directory.

   source bigdata_env

2. Log in to the Hive client.

   beeline

3. Run the following SQL commands in sequence to create a demo database and the **product_info** table:

```
CREATE DATABASE demo;
USE demo;
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;
```

Step 11 Import the **product_info.txt** file to Hive.

1. Switch back to the MRS cluster, click **Files** > **Import Data**.

   – **OBS Path**: Find the **product_info.txt** file in the created OBS bucket and click **Yes**.
   – **HDFS Path**: Select **/user/hive/warehouse/demo.db/product_info/** and click **Yes**.

2. Click **OK** to import the **product_info** table data.

Step 12 Create an ORC table and import data to the table.

1. Go back to the SQL window that is connected to the Hive client and run the following SQL statement to create an ORC table:

```
DROP TABLE product_info_orc;

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;
```

2. Insert data in the **product_info** table into the Hive ORC table **product_info_orc**.
```
INSERT INTO product_info_orc select * from product_info;
```
3. Query whether the data import is successful.
```
SELECT * FROM product_info_orc;
```

----End

Step 2: Create an MRS Data Source Connection

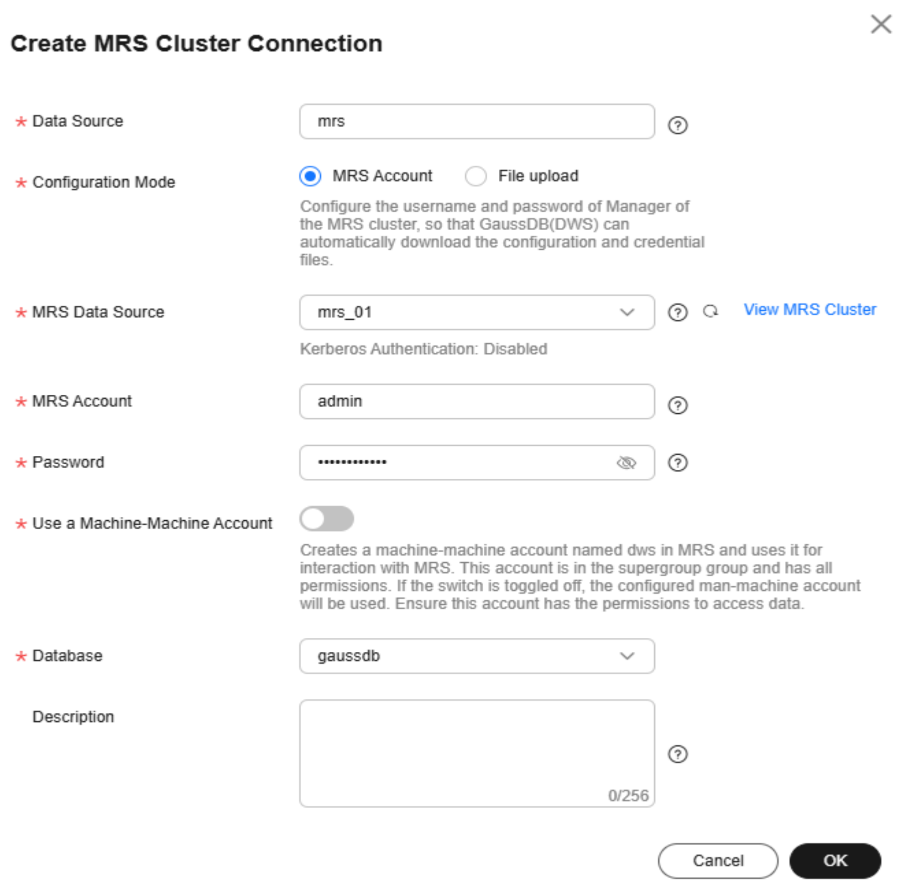
Step 1 Log in to the **DWS console**. In the navigation pane, choose **Dedicated Clusters** > **Clusters**. Click the created DWS cluster. Ensure that the DWS cluster and MRS are in the same region, AZ, and VPC subnet.

Step 2 In the navigation pane, choose **Data Source** > **MRS Data Source** and click **Create MRS Cluster Connection**.

Step 3 Configure the parameters listed in the following table, retain the default values for other parameters, and click **OK**.

Table 1-3 Parameters

Parameter	Value
Data Source	mrs
Configuration Mode	MRS Account
MRS Data Source	**mrs_01** created in the previous step
MRS Account	admin
Password	User-defined password
Database	**gaussdb**



----End

Step 3: Create a Foreign Table

Step 1 Connect to the created DWS cluster.

Step 2 View the external servers in the system.

```
SELECT * FROM pg_foreign_server;
```

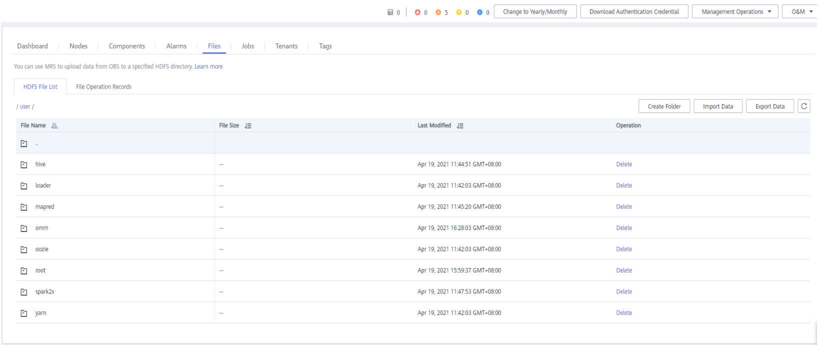
The query result shows that after the MRS data source is created, the system automatically generates an external server named **mrs**.

Step 3 Obtain the **product_info_orc** file path of Hive.

1. Log in to the **MRS console**.
2. Choose **Cluster** > **Active Cluster** and click the name of the cluster to be queried to enter the page displaying the cluster's basic information.
3. Click the **Files** and click **HDFS File List**.

4. Go to the storage directory of the data to be imported to the DWS cluster and record the path.

Figure 1-1 Checking the data storage path on MRS



Step 4 Create a foreign table and set **foldername** to the path queried in **Step 3**.

```
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 mrs
OPTIONS (
format 'orc',
encoding 'utf8',
foldername '/user/hive/warehouse/demo.db/product_info_orc/'
)
DISTRIBUTE BY ROUNDROBIN;
```

----End

Step 4: Import Data

Step 1 Create a local table for data import.

```
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
```

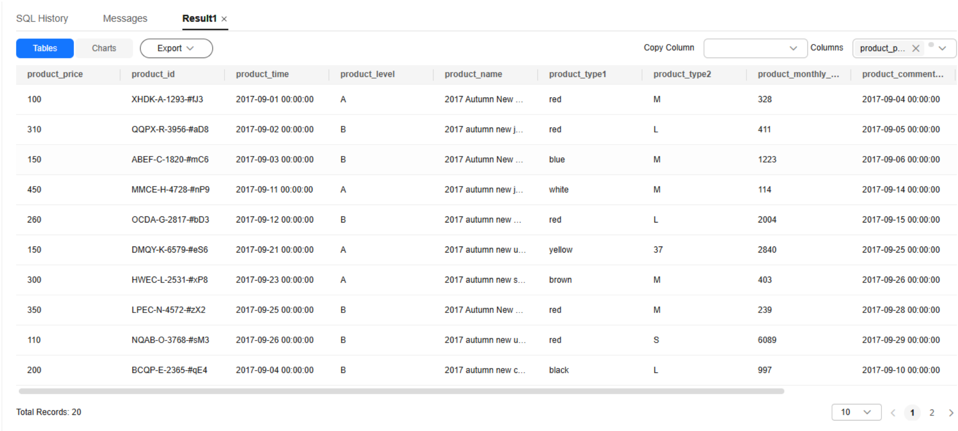
```
)
DISTRIBUTE BY HASH (product_id);
```

Step 2 Import data to the target table from the foreign table.

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

Step 3 Query the import result.

```
SELECT * FROM product_info;
```



product_price	product_id	product_time	product_level	product_name	product_type1	product_type2	product_monthly_...	product_comment...
100	XHDK-A-1293-#fJ3	2017-09-01 00:00:00	A	2017 Autumn New ...	red	M	328	2017-09-04 00:00:00
310	QQPX-R-3956-#aD8	2017-09-02 00:00:00	B	2017 autumn new j...	red	L	411	2017-09-05 00:00:00
150	ABEF-C-1820-#mC6	2017-09-03 00:00:00	B	2017 Autumn New ...	blue	M	1223	2017-09-06 00:00:00
450	MMCE-H-4728-#nP9	2017-09-11 00:00:00	A	2017 autumn new j...	white	M	114	2017-09-14 00:00:00
260	OCDA-G-2817-#bD3	2017-09-12 00:00:00	B	2017 autumn new ...	red	L	2004	2017-09-15 00:00:00
150	DMQY-K-6579-#eS6	2017-09-21 00:00:00	A	2017 autumn new u...	yellow	37	2840	2017-09-25 00:00:00
300	HWEC-L-2531-#xP8	2017-09-23 00:00:00	A	2017 autumn new s...	brown	M	403	2017-09-26 00:00:00
350	LPEC-N-4572-#zX2	2017-09-25 00:00:00	B	2017 Autumn New ...	red	M	239	2017-09-28 00:00:00
110	NQAB-O-3768-#sM3	2017-09-26 00:00:00	B	2017 autumn new u...	red	S	6089	2017-09-29 00:00:00
200	BCQP-E-2365-#qE4	2017-09-04 00:00:00	B	2017 autumn new c...	black	L	997	2017-09-10 00:00:00

Total Records: 20   10   1 2

----End

1.5 Enabling Cross-Cluster Access of Hive Metastore Through an External Schema

DWS 3.0 (with decoupled storage and compute) allows users to access data stored in MRS Hive (including when Hive is connected to HDFS or OBS) by simply creating an external schema. This topic describes how to enable cross-cluster access of the data stored in a Hive metastore.

Preparing the Environment

- You have created a DWS 3.0 cluster. The MRS and DWS clusters are in the same region, AZ, and VPC subnet, and can communicate with each other.
- You have obtained the AK and SK.

Constraints

- Currently, only the SELECT, INSERT, and INSERT OVERWRITE operations can be performed on tables in the Hive database through external schemas.
- MRS supports two types of data sources. For details, see **Table 1-4**.

Table 1-4 Operations supported by the two types of MRS data sources

Data Source	Table Type	Operation	TEXT	CSV	PARQUET	ORC
HDFS	Non-partitioned table	SELECT	√	√	√	√
		INSERT/ INSERT OVERWRITE	x	x	x	√
	Partitioned table	SELECT	√	√	√	√
		INSERT/ INSERT OVERWRITE	x	x	x	√
OBS	Non-partitioned table	SELECT	√	√	√	√
		INSERT/ INSERT OVERWRITE	x	x	x	√
	Partitioned table	SELECT	x	x	√	√
		INSERT/ INSERT OVERWRITE	x	x	x	x

- Transaction atomicity is no longer guaranteed. If a transaction fails, data consistency cannot be guaranteed. Rollback is not supported.
- GRANT and REVOKE operations cannot be performed on tables created on Hive using external schemas.
- Concurrency support: Concurrent read and write operations on DWS, Hive, and Spark may cause dirty reads. Concurrent operations including INSERT OVERWRITE on the same non-partitioned table or the same partition of the same partitioned table may not guarantee the expected result. Therefore, avoid such operations.
- Hive metastores do not support the federation mechanism.

Procedure

This practice takes approximately 1 hour. The basic procedure is as follows:

1. Create an MRS analysis cluster. (The Hive component must be selected.)
2. Create a table on Hive.

3. Insert data on Hive, or upload a local TXT file to an OBS bucket, then import the file to Hive from the OBS bucket, and import the file from the TXT storage table to the ORC storage table.
4. Create a connection to the MRS data source.
5. Create a foreign server.
6. Create an external schema.
7. Use the external schema to import data to or read data from Hive tables.

Creating an MRS Cluster

Step 1 Log in to the **MRS console**.

Step 2 Click **Buy Cluster** and select **Custom Config**.

Step 3 Configure software parameters, and click **Next**.

Table 1-5 Software configuration

Parameter	Value
Region	Dublin
Cluster Name	mrs_01
Version	Normal
Cluster Version	**MRS 3.1.3** (recommended) **NOTE** MRS clusters support 3.0.*, 3.1.*, and later versions (* indicates a number).
Cluster Type	Analysis Cluster
Metadata	Local

Step 4 Configure hardware parameters and click **Next**.

Table 1-6 Hardware configuration

Parameter	Value
Billing Mode	Pay-per-use
AZ	AZ2
VPC	vpc-01
Subnet	subnet-01
Security Group	Auto create
EIP	*10.x.x.x*
Enterprise Project	default

Parameter	Value
Master	2
Analysis Core	3
Analysis Task	0

Step 5 Configure the advanced settings based on the following table, and click **Buy Now**. Cluster creation takes approximately 15 minutes.

Table 1-7 Advanced settings

Parameter	Value
Tag	test01
Hostname Prefix	(Optional) Prefix for the names of ECSs or BMSs in the cluster.
Auto Scaling	Retain the default value.
Bootstrap Action	Retain the default value. MRS 3.x does not support this parameter.
Agency	Retain the default value.
Data Disk Encryption	This function is disabled by default. Retain the default value.
Alarm	Retain the default value.
Rule Name	Retain the default value.
Topic Name	Select a topic.
Kerberos Authentication	This function is enabled by default.
User Name	admin
Password	This password is used for logging in to the cluster management page.
Confirm Password	Enter the password of user **admin** again.
Login Mode	Password
User Name	root
Password	This password is used to remotely log in to an ECS.
Confirm Password	Enter the password of user **root** again.
Agency	In **Advanced Settings**, set **Agency** to the preset agency **MRS_ECS_DEFAULT_AGENCY** of MRS in IAM.

Parameter	Value
Secure Communications	Select **Enable**.

----End

Preparing an ORC Table

Step 1 Create a **product_info.txt** file on the local PC, copy the following data to the file, and save the file to the local PC.

```
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,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
```

Step 2 Log in to the OBS console, click **Create Parallel File System**, set the following parameters, and click **Create Now**.

Table 1-8 Bucket parameters

Parameter	Value
Region	Dublin
Data Redundancy Policy	Single-AZ Storage

Parameter	Value
Bucket Name	mrs-datasource
Default Storage Class	Standard
Bucket Policy	Private
Default Encryption	Disable
Direct Reading	Disable
Enterprise Project	default
Tag	-

Step 3 After successful bucket creation, switch back to the MRS console and click the name of the created MRS cluster. On the **Dashboard** page, click the Synchronize button next to **IAM User Sync**. The synchronization takes around 5 minutes.

Step 4 Click **Nodes** and click a master node. On the displayed page, switch to the **EIPs** tab, click **Bind EIP**, select an existing EIP, and click **OK**. If no EIP is available, create one. Record the EIP.

Step 5 (Optional) Connect Hive to OBS.

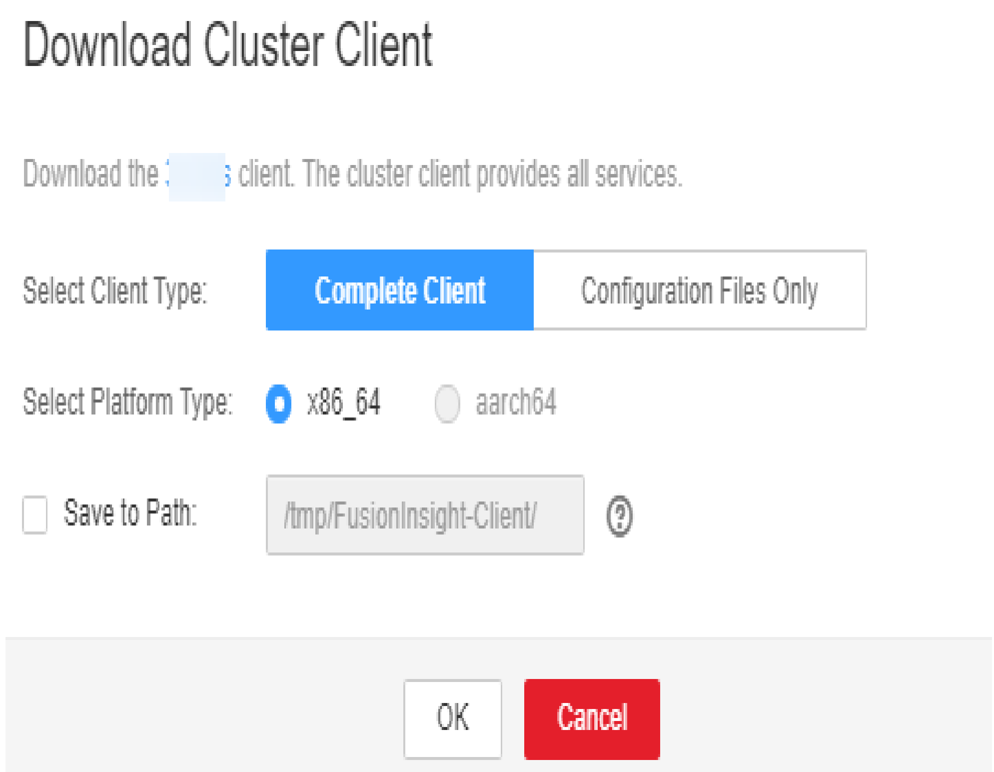
NOTE

Perform this step when Hive interconnects with OBS. Skip this step when Hive interconnects with HDFS.

1. Go back to the MRS cluster page. Click the cluster name. On the **Dashboard** tab of the cluster details page, click **Access Manager**. If a message is displayed indicating that an EIP needs to be bound, bind an EIP first.
2. In the **Access MRS Manager** dialog box, click **OK**. You will be redirected to the MRS Manager login page. 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.
3. Interconnect Hive with OBS by referring to **Interconnecting Hive with OBS**.

Step 6 Download the client.

1. Go back to the MRS cluster page. Click the cluster name. On the **Dashboard** tab of the cluster details page, click **Access Manager**. If a message is displayed indicating that EIP needs to be bound, bind an EIP first.
2. In the **Access MRS Manager** dialog box, click **OK**. You will be redirected to the MRS Manager login page. 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.
3. Choose **Services** > **Download Client**. Set **Client Type** to **Only configuration files** and set **Download To** to **Server**. Click **OK**.



Step 7 Log in to the active master node as user **root** and update the client configuration of the active management node.

cd /opt/client

sh refreshConfig.sh /opt/client *Full_path_of_client_configuration_file_package*

In this example, run the following command:

sh refreshConfig.sh /opt/client /tmp/MRS-client/MRS_Services_Client.tar

Step 8 Switch to user **omm** and go to the directory where the Hive client is located.

su - omm

cd /opt/client

Step 9 Create the **product_info** table whose storage format is TEXTFILE on Hive.

1. Import environment variables to the **/opt/client** directory.

   source bigdata_env

   NOTE

   If **find: 'opt/client/Hudi': Permission denied** is displayed, ignore it. This does not affect subsequent operations.

2. Log in to the Hive client.

   a. 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. . Configure a role with the required permissions. . Bind a role to the user. If Kerberos authentication is not enabled for the current cluster, there is no need to run the following command:

kinit *MRS cluster user*

b. Run the following command to start the Hive client:

beeline

3. Run the following SQL commands in sequence to create a demo database and the **product_info** table:

```
CREATE DATABASE demo;
USE demo;
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;
```

Step 10 Import the **product_info.txt** file to Hive.

- Hive is interconnected with OBS: Go back to OBS Console, click the name of the bucket, choose **Objects** > **Upload Object**, and upload the **product_info.txt** file to the path of the **product_info table** in the OBS bucket.
- When Hive is interconnected with HDFS, import the **product_info.txt** file to the HDFS path **/user/hive/warehouse/demo.db/product_info/**. For details about how to import data to the MRS cluster, see **Uploading Application Data to an MRS Cluster** in *MapReduce Service User Guide*.

Step 11 Create an ORC table and import data to the table.

1. Run the following SQL commands to create an ORC table:

```
DROP TABLE product_info_orc;

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;
```

2. Insert data in the **product_info** table into the Hive ORC table **product_info_orc**.

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

3. Query whether the data import is successful.

```
SELECT * FROM product_info_orc;
```

----End

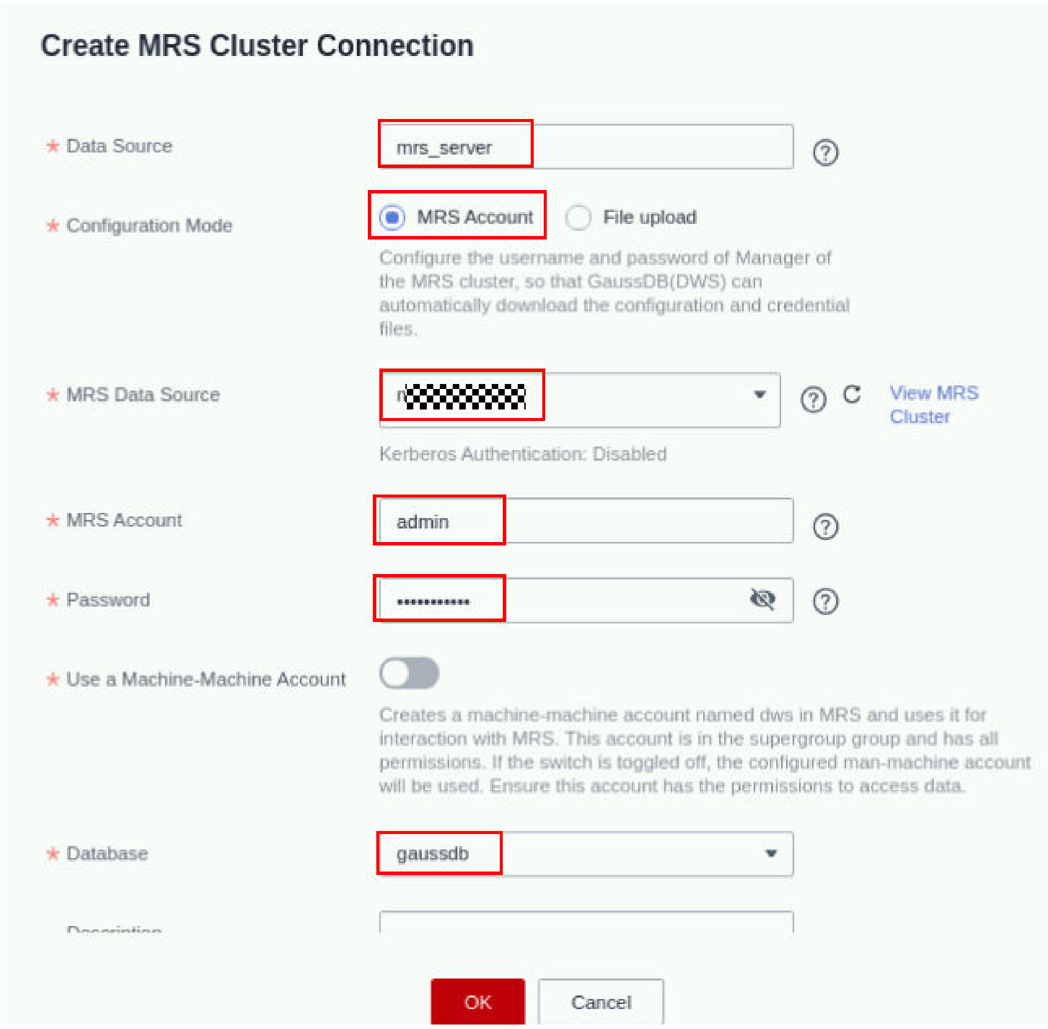
Creating an MRS Cluster Connection

Step 1 Log in to the **DWS console** and click the created DWS cluster. **Ensure that the DWS cluster and MRS are in the same region, AZ, and VPC subnet**.

Step 2 Click the **MRS Data Source** tab and click **Create MRS Cluster Connection**.

Step 3 Set the following parameters and click **OK**.

- **Data Source**: mrs_server
- **Configuration Mode**: **MRS Account**
- **MRS Data Source**: Select the created **mrs_01** cluster.
- **MRS Account**: admin
- **Password**: Enter the password of the **admin** user created for the MRS data source.



----End

Creating a Foreign Server

Perform this step only when Hive is connected to OBS. Skip this step if Hive is connected to HDFS.

Step 1 Connect to the created DWS cluster.

Step 2 Run the following statement to create a foreign server. {AK value} and {SK value} are obtained from **Preparing the Environment**.

NOTICE

Hard-coded or plaintext AK/SK is risky. For security, encrypt your AK/SK and store them in the configuration file or environment variables.

```
CREATE SERVER obs_server FOREIGN DATA WRAPPER DFS_FDW
OPTIONS
(
address 'obs.example.com:5443', //Address for accessing OBS
encrypt 'on',
access_key '{AK value}',
secret_access_key '{SK value}',
 type 'obs'
);
```

Step 3 View the foreign server.

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

The server is successfully created if information similar to the following is displayed:

```
                    srvname                     | srvowner | srvfdw | srvtype | srvversion | srvacl
|                                                srvoptions
--------------------------------------------------+----------+--------+---------+------------+--------
+-----------------------------------------------------------------------------------------------------------------
 obs_server |    16476 |  14337 |         |            |        |
{address=obs.example.com:5443,type=obs,encrypt=on,access_key=***,secret_access_key=***}
(1 row)
```

----End

Creating an External Schema

Step 1 Obtain the internal IP address and port number of the Hive metastore service and the name of the Hive database to be accessed.

1. Log in to the **MRS console**.
2. Choose **Cluster** > **Active Cluster** and click the name of the cluster to be queried to enter the page displaying the cluster's basic information.
3. Click **Go to manager** on the O&M Management page and enter the username and password to log in to the FusionInsight management page.
4. Click **Cluster**, **Hive**, **Configuration**, **All Configurations**, **MetaStore**, and **Port** in sequence, and record the value of **hive.metastore.port**.
5. Click **Cluster**, **Hive**, and **Instance** in sequence, and record the MetaStore management IP address of the host whose name contains **master1**.

Step 2 Create an external schema.

```
//When interconnecting Hive with OBS: Set Server to the name of the external server created in Step 2,
DATABASE to the database created on Hive, METAADDRESS to the IP address and port number of the Hive
metastore service recorded in Step 1, and CONFIGURATION to the default configuration path of the MRS
data source.
DROP SCHEMA IF EXISTS ex1;
```



```
CREATE EXTERNAL SCHEMA ex1
    WITH SOURCE hive
         DATABASE 'demo'
         SERVER obs_server
         METAADDRESS '***.***.***.***:***'
         CONFIGURATION '/MRS/gaussdb/mrs_server'

//When interconnecting Hive with HDFS: Set Server to mrs_server (name of the data source created in Creating an MRS Cluster Connection), METAADDRESS to the IP address and port number of the Hive metastore service recorded in Step 1, and CONFIGURATION to the default configuration path of the MRS data source.
DROP SCHEMA IF EXISTS ex1;

CREATE EXTERNAL SCHEMA ex1
    WITH SOURCE hive
         DATABASE 'demo'
         SERVER mrs_server
         METAADDRESS '***.***.***.***:***'
         CONFIGURATION '/MRS/gaussdb/mrs_server'
```

Step 3 Check the created external schema.

```
SELECT * FROM pg_namespace WHERE nspname='ex1';
SELECT * FROM pg_external_namespace WHERE nspid = (SELECT oid FROM pg_namespace WHERE nspname = 'ex1');

                     nspid                     | srvname | source | address | database | confpath
|                                   ensoptions    | catalog
------------------------------------------------+----------+--------+---------+------------+--------
+-------------------------------------------------------------------------------------------------------------
                 16393                        |    obs_server |  hive | ***.***.***.***:***        |  demo          | ***
|                         |
(1 row)
```

----End

Importing Data

Step 1 Create a local table for data import.

```
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)
) ;
```

Step 2 Import the target table from the Hive table.

```
INSERT INTO product_info SELECT * FROM ex1.product_info_orc;
```

Step 3 Query the import result.

```
SELECT * FROM product_info;
```

----End

Exporting Data

Step 1 Create a local source table.

```
DROP TABLE IF EXISTS product_info_export;
CREATE TABLE product_info_export
(
    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)
) ;
INSERT INTO product_info_export SELECT * FROM product_info;
```

Step 2 Create a target table on Hive.

```
DROP TABLE product_info_orc_export;

CREATE TABLE product_info_orc_export
(
    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;
```

Step 3 Import data from the local source table to the Hive table.

```
INSERT INTO ex1.product_info_orc_export SELECT * FROM product_info_export;
```

Step 4 Query the data import result on Hive.

```
SELECT * FROM product_info_orc_export;
```

----End

1.6 Importing Table Data from DLI to a DWS Cluster

This exercise demonstrates how to use the DWS foreign table function to import data from **DLI** to **DWS**.

For details about DLI, see **What Is Data Lake Insight?**

This exercise lasts for approximately 60 minutes and involves utilizing various cloud services such as **Virtual Private Cloud (VPC) and Subnet**, **Data Lake Insight (DLI)**, **Object Storage Service (OBS)**, and **DWS**. The following is an outline of the exercise.

1. **Preparations**
2. **Step 1: Preparing DLI Source Data**

3. **Step 2: Creating a DWS Cluster**
4. **Step 3: Obtaining Authentication Information Required by the DWS External Server**.
5. **Step 4: Importing DLI Table Data Using a Foreign Table**

Preparations

- You have sign up for a Huawei ID and enabled Huawei Cloud services. The account cannot be in arrears or frozen.
- You have created a VPC and subnet. For details, see **Creating a VPC**.
- You have obtained the AK and SK of your Huawei account. For details, see **Access Keys**.

Step 1: Preparing DLI Source Data

Step 1 Create a DLI elastic resource pool and queue.

1. Log in to the **DLI console**.
2. In the navigation pane on the left, choose **Resources** > **Resource Pool**.
3. Click **Buy Resource Pool** in the upper right corner, set the following parameters, and retain the default values for other parameters that are not described in the table.

Table 1-9 DLI elastic resource pool parameters

Parameter	Value
Billing Mode	Pay-per-use
Region	Europe-Dublin
Name	dli_dws
Specifications	Standard
CIDR Block	172.16.0.0/18.

4. Click **Buy** and click **Submit**.

   After the resource pool is created, go to the next step.
5. On the elastic resource pool page, locate the row that contains the created resource pool, click **Add Queue** in the **Operation** column, and set the following parameters. Retain the default values for other parameters that are not described in the table.

Table 1-10 Adding a queue

Parameter	Value
Name	dli_dws
Type	For SQL

6. Click **Next** and click **OK**. The queue is created.

Step 2 Upload the source data to the OBS bucket.

1. An OBS bucket has been created with a user-defined name, for example, **dli-obs01** (if the bucket name is already in use, use **dli-obs02** instead). The region is EU-Dublin.
2. Download the **data sample file**.
3. Create a folder **dli_order** in the OBS bucket and upload the downloaded data file to that folder.

Step 3 Go back to the DLI management console. In the navigation pane, click **SQL Editor**. Select **dli_dws** for **Queue** and **default** for **Database**. Run the following command to create a database named **dli_data**:

```
CREATE DATABASE dli_data;default
```

Step 4 Create a table.

NOTE

LOCATION specifies the OBS directory where the data file is stored, formatted as **obs://*OBS bucket name*/*folder name***. In this example, the directory is **obs://dli-obs01/dli_order**. If the bucket name or folder name changes, substitute it accordingly.

```
CREATE EXTERNAL TABLE dli_data.dli_order
   ( order_id       VARCHAR(12),
     order_channel VARCHAR(32),
     order_time     TIMESTAMP,
     cust_code      VARCHAR(6),
     pay_amount     DOUBLE,
     real_pay       DOUBLE )
STORED AS parquet
LOCATION 'obs://dli-obs01/dli_order';
```

Step 5 Run the following statement to query data.

```
SELECT * FROM dli_data.dli_order;
```

----End

Step 2: Creating a DWS Cluster

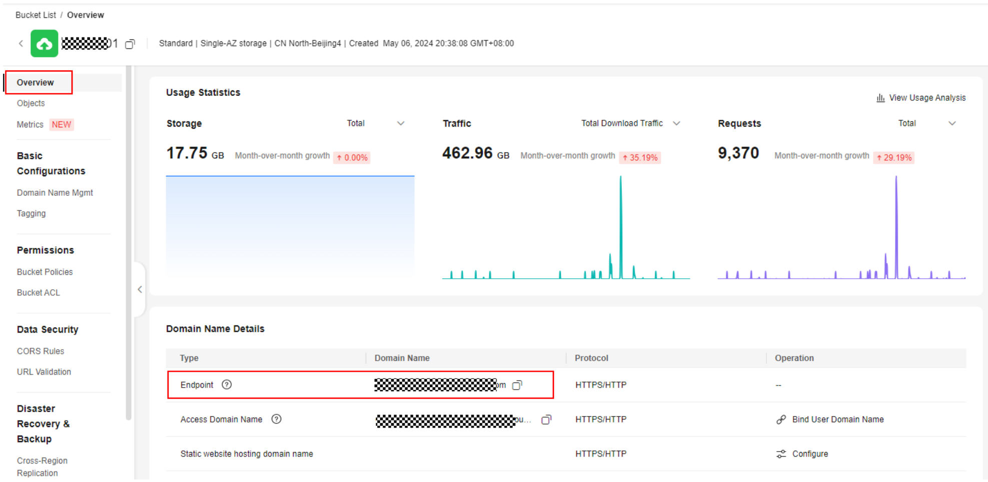
Step 1 **Create a cluster**. To ensure network connectivity, set the region of the DWS cluster to EU-Dublin.

----End

Step 3: Obtaining Authentication Information Required by the DWS External Server

Step 1 Obtain the endpoint of the OBS bucket.

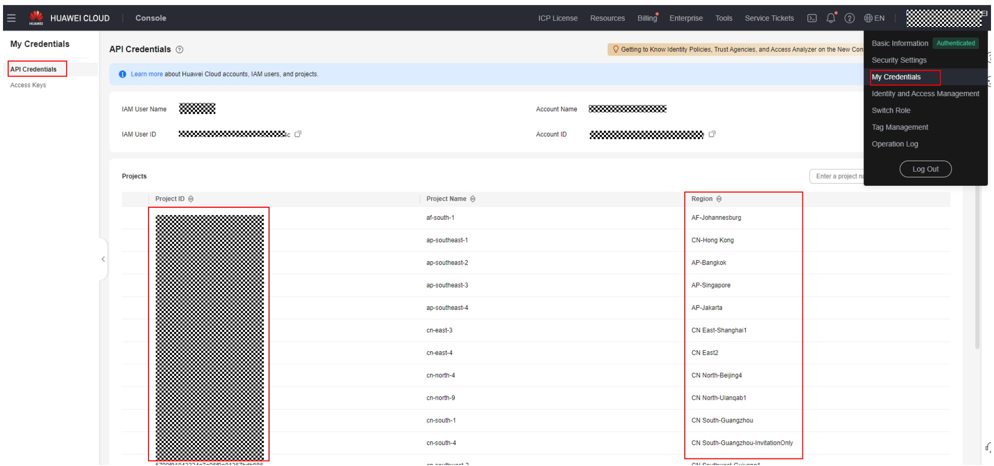
1. Log in to **OBS console**.
2. Click the bucket name, choose **Overview** on the left, and record the endpoint.



Step 2 Obtain the DLI endpoint from **Endpoints**.

Step 3 Obtain the project ID for the specific region of the account used to create DLI.

1. Move the cursor to the account name in the upper right corner and click **My Credentials**.
2. Choose **API Credentials** on the left.
3. In the list, find the region where the DLI instance is deployed, for example, EU-Dublin, and record the project ID corresponding to the region name.



Step 4 Obtain the AK and SK of your account. For details, see **Prerequisites**.

----End

Step 4: Importing DLI Table Data Using a Foreign Table

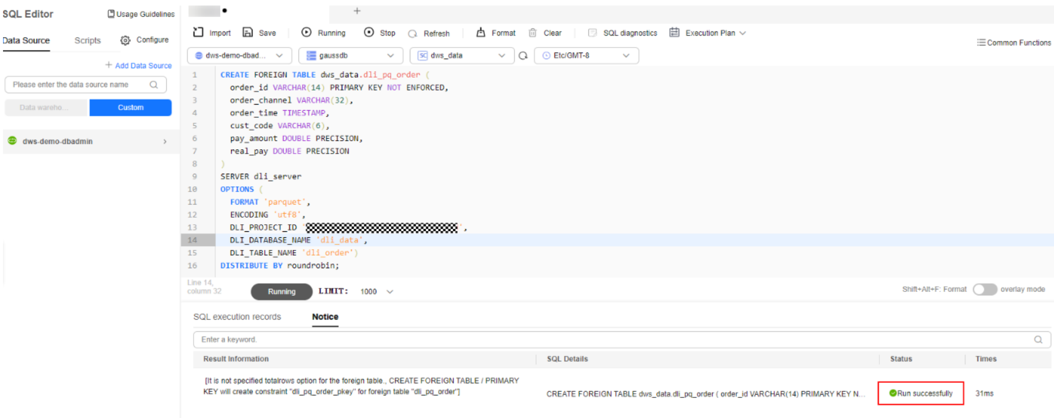
Step 1 Log in to the DWS database as the system administrator **dbadmin**. By default, you can log in to the **GaussDB** database.

Step 2 Run the following SQL statements to create a foreign server: The OBS endpoint is obtained from **Step 1**, the AK and SK are obtained from **Preparations**, and the DLI endpoint is obtained from **Step 2**.

NOTE

If the DWS and DLI instances are created by the same account, enter the AK and SK twice.

```
CREATE SERVER dli_server FOREIGN DATA WRAPPER DFS_FDW OPTIONS
(ADDRESS'OBS endpoint',
ACCESS_KEY'AK value'
SECRET_ACCESS_KEY'SK value'
      TYPE 'DLI',
DLI_ADDRESS'DLI endpoint',
DLI_ACCESS_KEY'AK value',
DLI_SECRET_ACCESS_KEY 'SK value'
    );
```

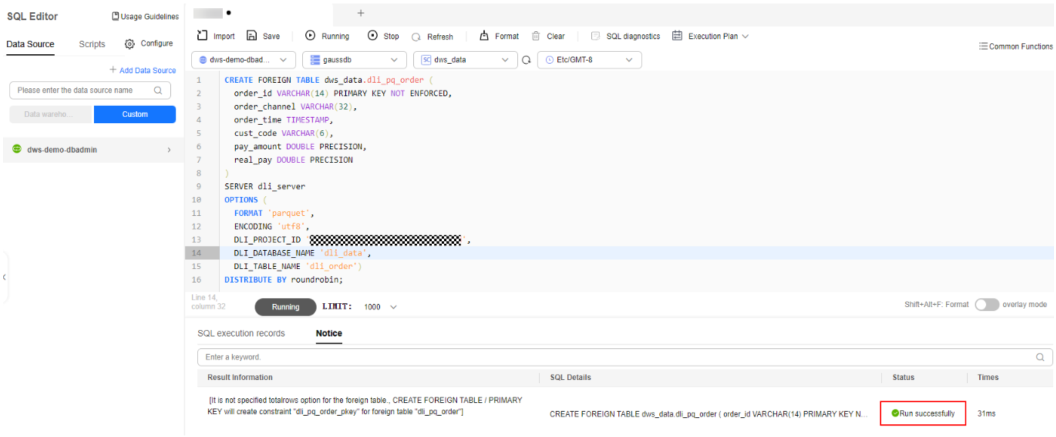


Step 3 Run the following SQL statement to create a target schema:

```
CREATE SCHEMA dws_data;
```

Step 4 Run the following SQL statements to create a foreign table: Replace **Project ID** with the actual value obtained in **Step 3**.

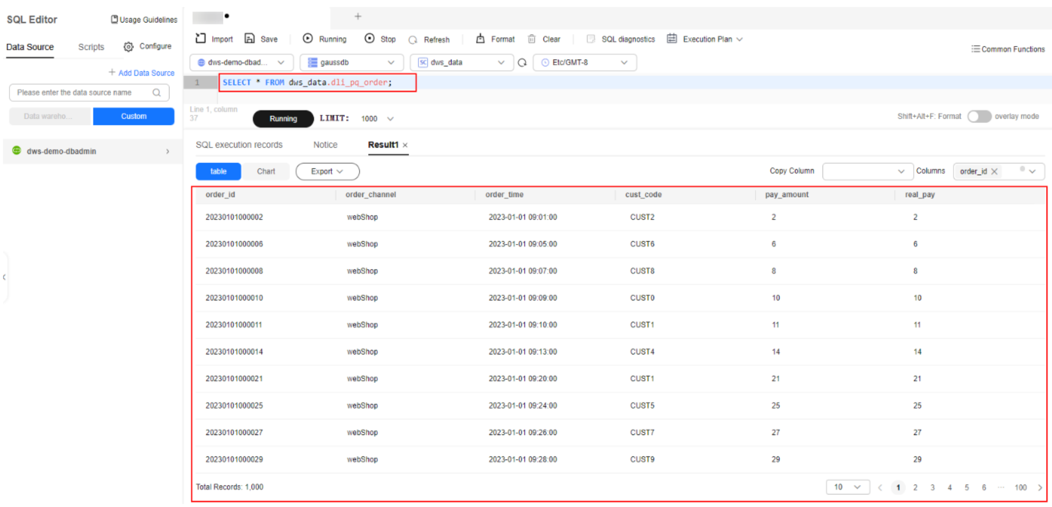
```
CREATE FOREIGN TABLE dws_data.dli_pq_order (
  order_id VARCHAR(14) PRIMARY KEY NOT ENFORCED,
  order_channel VARCHAR(32),
  order_time TIMESTAMP,
  cust_code VARCHAR(6),
  pay_amount DOUBLE PRECISION,
  real_pay DOUBLE PRECISION
)
SERVER dli_server
OPTIONS (
  FORMAT 'parquet',
  ENCODING 'utf8',
DLI_PROJECT_ID'Project ID'
  DLI_DATABASE_NAME 'dli_data',
  DLI_TABLE_NAME 'dli_order')
DISTRIBUTE BY roundrobin;
```



Step 5 Run the following SQL statement to query the DLI table data through the foreign table.

The DLI table data is successfully accessed.

```
SELECT * FROM dws_data.dli_pq_order;
```



Step 6 Run the following SQL statements to create a local table for importing DLI table data:

```
CREATE TABLE dws_data.dws_monthly_order
    ( order_month       CHAR(8),
      cust_code         VARCHAR(6),
      order_count       INT,
      total_pay_amount  DOUBLE PRECISION,
      total_real_pay    DOUBLE PRECISION );
```

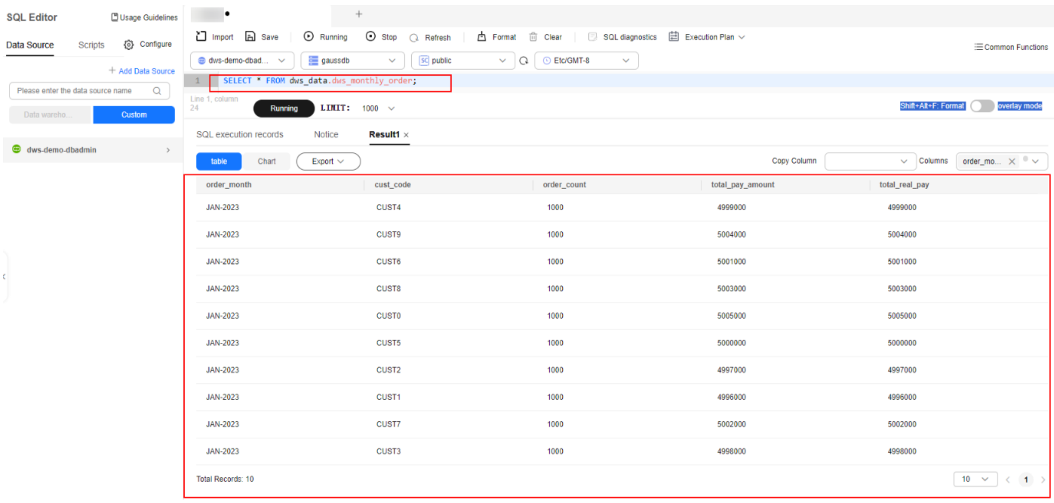
Step 7 Run the following SQL statements to query the monthly order details of 2023 and import the result to the DWS table:

```
INSERT INTO dws_data.dws_monthly_order
    ( order_month, cust_code, order_count
    , total_pay_amount, total_real_pay )
SELECT TO_CHAR(order_time, 'MON-YYYY'), cust_code, COUNT(*)
    , SUM(pay_amount), SUM(real_pay)
  FROM dws_data.dli_pq_order
 WHERE DATE_PART('Year', order_time) = 2023
GROUP BY TO_CHAR(order_time, 'MON-YYYY'), cust_code;
```

Step 8 Run the following SQL statement to query table data.

The DLI table data is successfully imported to the DWS database.

```
SELECT * FROM dws_data.dws_monthly_order;
```



----End

1.7 Exporting ORC Data from a DWS Cluster to an MRS Cluster

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 DWS in parallel using multiple DNs and stored in HDFS. In this way, the overall export performance is improved.

Preparing the Environment

Create a DWS cluster. Ensure that the MRS and DWS clusters are in the same region, AZ, and VPC subnet and that the clusters can communicate with each other.

Creating an MRS Cluster

Step 1 Log in to the **MRS console** and click **Buy Cluster**. In the displayed page, select **Custom Config**, configure software parameters, and click **Next**.

Table 1-11 Software configuration

Parameter	Example Value
Region	
Cluster Name	mrs_01

Parameter	Example Value
Cluster Version	MRS 1.9.2 (recommended) **NOTE** ● For clusters of version 8.1.1.300 and later, MRS clusters support versions 1.6.*, 1.7.*, 1.8.*, 1.9.*, 2.0.*, 3.0.*, 3.1.*, and later (* indicates a number). ● For clusters earlier than version 8.1.1.300, MRS clusters support versions 1.6.*, 1.7.*, 1.8.*, 1.9.*, and 2.0.* (*indicates a number).
Cluster Type	Analysis Cluster

Step 2 Configure hardware parameters and click **Next**.

Table 1-12 Hardware configuration

Parameter	Example Value
Billing Mode	Pay-per-use
AZ	AZ2
VPC	vpc-01
Subnet	subnet-01
Security Group	Auto create
EIP	*10.x.x.x*
Enterprise Project	default
Master	2
Analysis Core	3
Analysis Task	0

Step 3 Configure the advanced settings based on the following table, click **Buy Now**, and wait for about 15 minutes for the cluster creation to complete.

Table 1-13 Advanced settings

Parameter	Example Value
Tag	test01
Hostname Prefix	(Optional) Prefix for the name of an ECS or BMS in the cluster.
Auto Scaling	Retain the default value.
Bootstrap Action	Retain the default value. MRS 3.x does not support this parameter.

Parameter	Example Value
Agency	Retain the default value.
Data Disk Encryption	This function is disabled by default. Retain the default value.
Alarm	Retain the default value.
Rule Name	Retain the default value.
Topic Name	Select a topic.
Kerberos Authentication	This parameter is enabled by default.
User Name	admin
Password	This password is used to log in to the cluster management page.
Confirm Password	Enter the password of user **admin** again.
Login Mode	Password
User Name	root
Password	This password is used to remotely log in to the ECS.
Confirm Password	Enter the password of user **root** again.
Secure Communications	Select **Enable**.

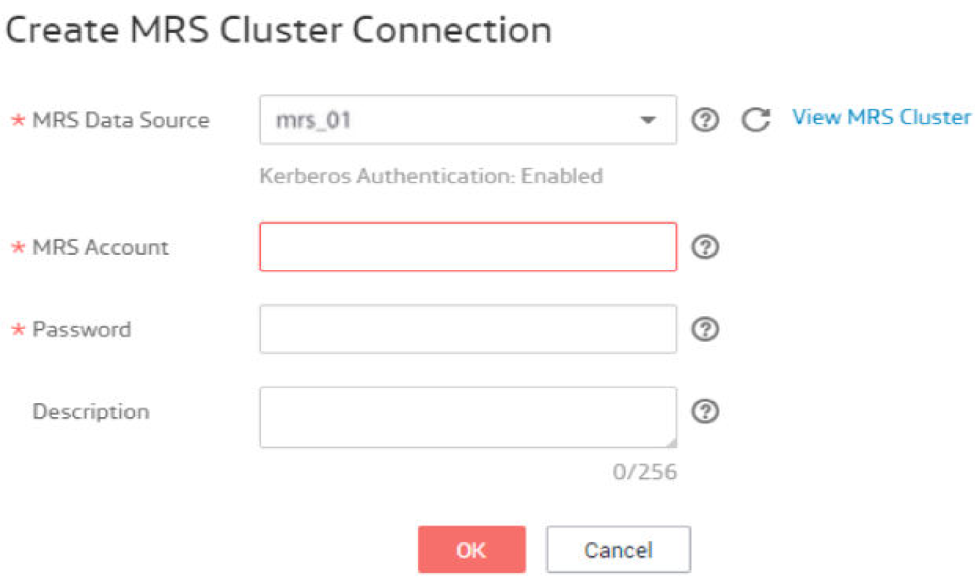
----End

Creating an MRS Cluster Connection

Step 1 Log in to the **DWS console** and click the created DWS cluster. Ensure that the DWS cluster and MRS are in the same region, AZ, and VPC subnet.

Step 2 Click the **MRS Data Source** tab and click **Create MRS Cluster Connection**.

Step 3 Select data source **mrs_01** created in the previous step, enter the MRS account name **admin** and its password, and click **OK**.



----End

Creating a Foreign Server

Step 1 Connect to the created DWS cluster.

Step 2 Create a user *dbuser* that has the permission for creating databases.

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

Step 3 Switch to user *dbuser*.

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

Step 4 Create a database *mydatabase*.

```
CREATE DATABASE mydatabase;
```

Step 5 Switch to the new database **mydatabase** and grant the permission to create external servers to user **dbuser**. In 8.1.1 and later versions, you also need to grant the permission to use the public mode.

```
GRANT ALL ON FOREIGN DATA WRAPPER hdfs_fdw TO dbuser;
In GRANT ALL ON SCHEMA public TO dbuser; //8.1.1 and later versions, common users do not have
permission on the public mode and need to grant permission. In versions earlier than 8.1.1, you do not need
to perform this operation.
```

The name of **FOREIGN DATA WRAPPER** must be **hdfs_fdw**. *dbuser* indicates the username of **CREATE SERVER**.

Step 6 Grant user *dbuser* the permission for using foreign tables.

```
ALTER USER dbuser USEFT;
```

Step 7 Switch to the Postgres database and query the foreign server automatically created by the system after the MRS data source is created.

```
SELECT * FROM pg_foreign_server;
```

Information similar to the following is displayed:

```
                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=192.168.1.245:9820,192.168.1.218:9820",hdfscfgpath=/MRS/8f79ada0-d998-4026-9020-80d6de2692ca,type=hdfs}
(3 rows)
```

Step 8 Switch to database *mydatabase* and switch to user *dbuser*.

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

Step 9 Create a foreign server.

The server name, address, and configuration path must be the same as those in **Step 7**.

```
CREATE SERVER hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca FOREIGN DATA WRAPPER HDFS_FDW
OPTIONS
(
address '192.168.1.245:9820,192.168.1.218:9820',   //The intranet IP addresses of the active and standby master nodes on the MRS management plane, which can be used to communicate with DWS.
hdfscfgpath '/MRS/8f79ada0-d998-4026-9020-80d6de2692ca',
type 'hdfs'
);
```

Step 10 View the foreign server.

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

The server is successfully created if information similar to the following is displayed:

```
                     srvname                      | srvowner | srvfdw | srvtype | srvversion | srvacl
|                                                  srvoptions
-------------------------------------------------+----------+--------+---------+------------+--------
+-------------------------------------------------------------------------------------------------------------------
 hdfs_server_8f79ada0_d998_4026_9020_80d6de2692ca |    16476 |  13685 |        |            |        |
{"address=192.168.1.245:9820,192.168.1.218:9820",hdfscfgpath=/MRS/8f79ada0-d998-4026-9020-80d6de2692ca,type=hdfs}
(1 row)
```

----End

Creating a Foreign Table

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/**.

```
DROP FOREIGN TABLE IF EXISTS product_info_output_ext;
CREATE FOREIGN TABLE product_info_output_ext
(
    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',
foldername  '/user/hive/warehouse/product_info_orc/',
   compression 'snappy',
    version '0.12'
) Write Only;
```

Exporting Data

Create an ordinary table **product_info_output**.

```
DROP TABLE product_info_output;
CREATE TABLE product_info_output
(
    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)
)
with (orientation = column,compression=middle)
distribute by hash (product_name);
```

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;
```

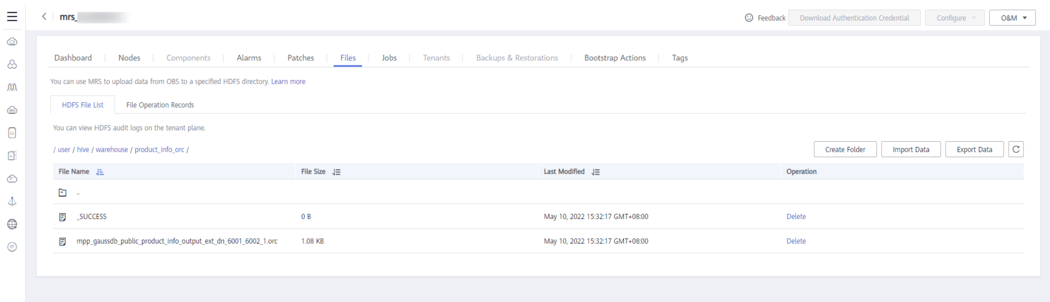
If the following information is displayed, the data is successfully exported:

```
INSERT 0 10
```

Viewing the Export Result

Step 1 Go to the MRS cluster list. Click a cluster name to go to the cluster details page.

Step 2 Click the **Files** tab and click **HDFS File List**. Check the exported ORC file in the **user/hive/warehouse/product_info_orc** directory.



NOTE

ORC data exported from DWS complies with the following rules:

- 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**_*DatabaseName_SchemaName_TableName_NodeName_n*.**orc**.
- 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 the maximum size of a stripe is 64 MB.
- After the export is complete, the **_SUCCESS** file is generated.

----End

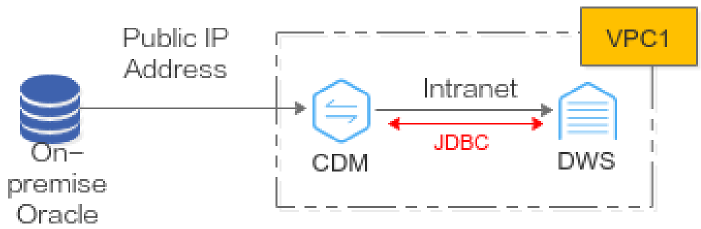
2 Data Migration

2.1 Using CDM to Migrate Oracle Data to a DWS Cluster

2.1.1 Migration Process

This tutorial demonstrates how to migrate Oracle table data to DWS. **Figure 2-2** and **Table 2-1** show the migration process.

Figure 2-1 Migration scenario



NOTICE

- This practice describes how to migrate data in the **APEX2_DYNAMIC_ADD_REMAIN_TEST** table of user **db_user01** in the Oracle database.
- Network connection: In this practice, the Oracle database is deployed on-premises, so CDM is used to connect Oracle to DWS. CDM connects to Oracle via a public IP address. CDM and DWS are in the same region and VPC and can communicate with each other. **Ensure that all the network is connected during the migration.**
- This practice is for reference only. The actual migration may be complex due to factors such as the network environment, service complexity, node scale, and data volume. It is better to perform the migration under the guidance of technical personnel.

Figure 2-2 Basic process of migrating data from Oracle to DWS

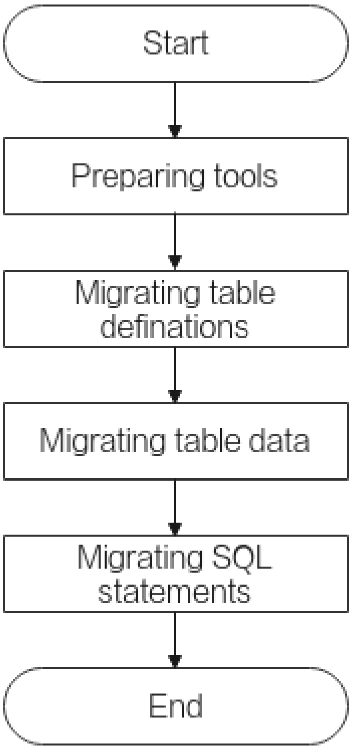


Table 2-1 Basic process of migrating data from Oracle to DWS

Process	Description
Required Tools	Software tools to be prepared before the migration.
Migrating Table Definition	Use the PL/SQL Developer to migrate table definitions.
Migrating Full Table Data	Use Huawei Cloud Data Migration Service (CDM) to migrate data.
Migrating Service SQL Statements	Use the DSC syntax migration tool to rewrite the syntax so that the Oracle service SQL statements can be compatible with DWS.

2.1.2 Required Tools

The tools required for the migration include PL/SQL Developer, Instant Client, and DSC. For details about how to download the tools, see **Table 2-2**.

Table 2-2 Required tools

Tool	Description	Download Address
PL/SQL Developer	Oracle visual development tool	**PL/SQL Developer download address**

Tool	Description	Download Address
Oracle Instant Client	Oracle client	**Instant Client download address**
DSC	Syntax migration tool for GaussDB(DWS)	**DSC Download Address**

2.1.3 Migrating Table Definition

2.1.3.1 Installing the PL/SQL Developer on the Local Host

Procedure

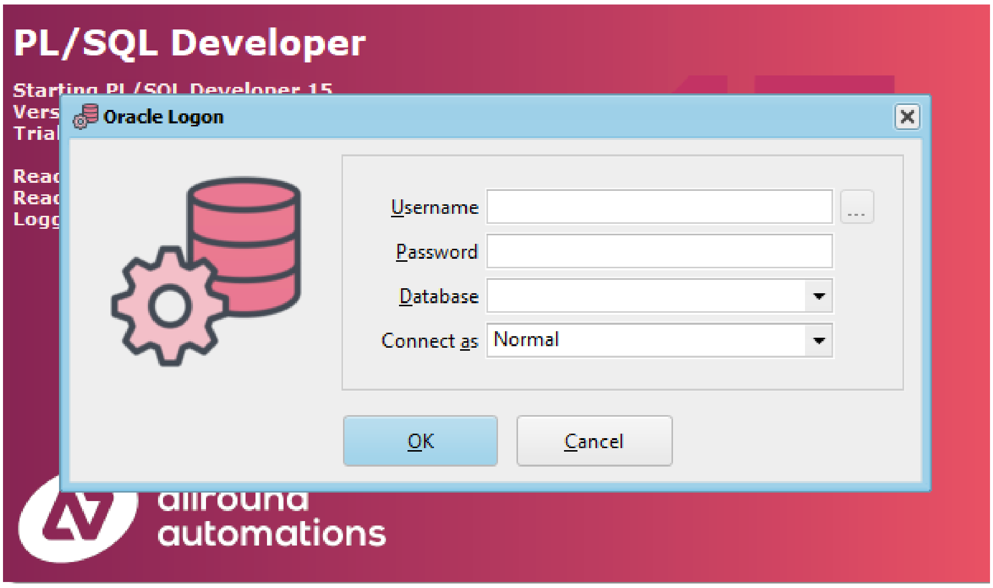
Step 1 Decompress the PL/SQL Developer, Instant Client, and DSC packages.

Step 2 Configure an Oracle home and OCL library for PL/SQL Developer.

NOTE

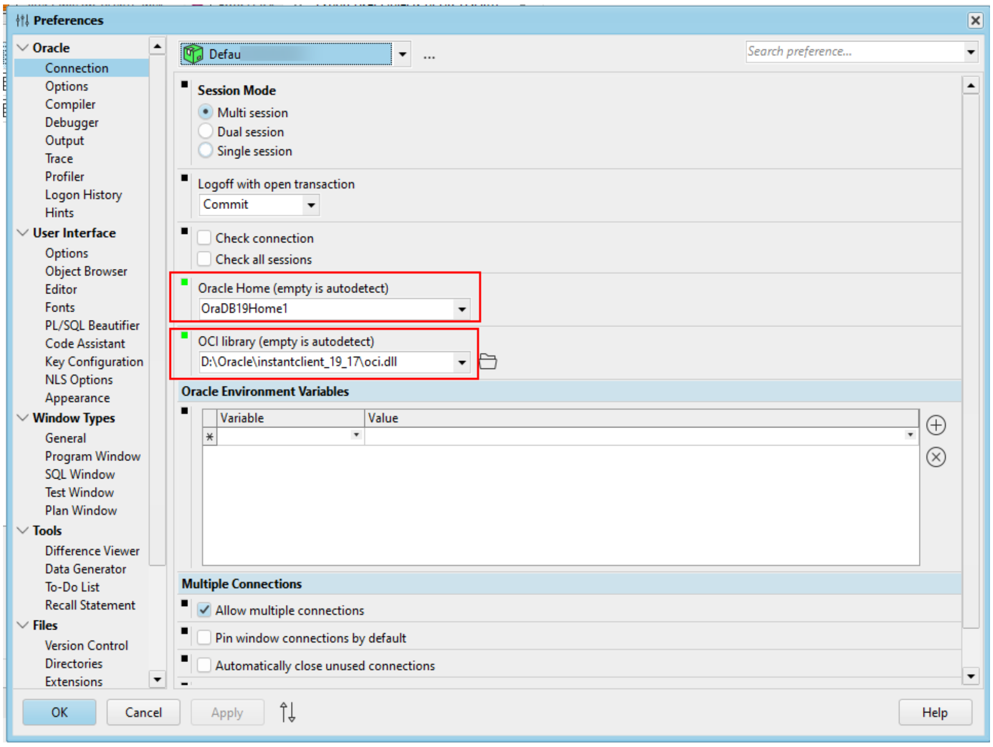
The following uses the PL/SQL Developer Trial Version as an example.

1. On the login page, click Cancel.

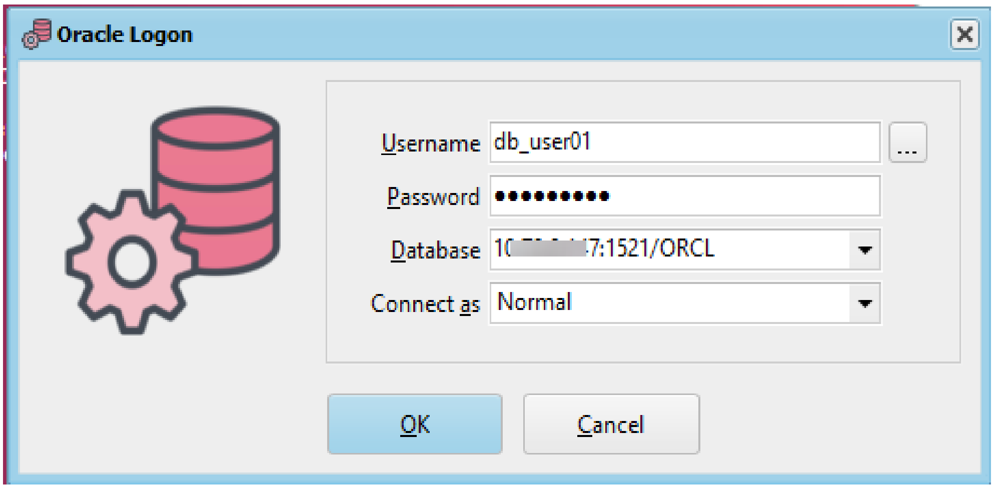


2. Choose **Configure** > **Preferences** > **Connection**, and add the Oracle Home and OCl library configurations.
3. Copy the instantclient path obtained from **Step 1** (for example, **D:\Oracle\instantclient_19_17\oci.dll**) to the home directory of the Oracle database.

   Copy the **oci.dll** file path (for example, **D:\Oracle\instantclient_19_17\oci.dll**) in the instantclient file to the OCI library.



Step 3 Go back to the PL/SQL Developer login page. Enter the username, password, and database address.



Step 4 Click **OK**. If the database is connected, it indicates that the PL/SQL Developer is installed successfully.

----End

2.1.3.2 Migrating Table Definitions and Syntax

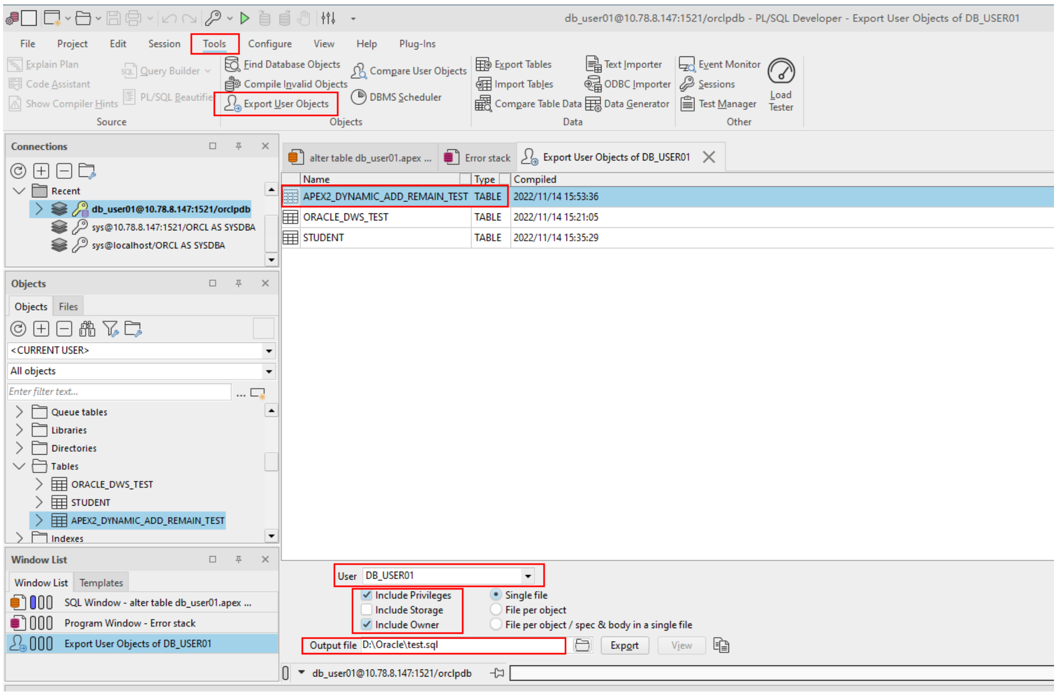
Step 1 Log in to the PL/SQL Developer use an account with the **sysdba** permission. In this example, the account **db_user01** is used.

NOTE

The following uses the PL/SQL Developer Trial Version as an example.

Step 2 On the menu bar, choose **Tools** > **Export User Objects**.

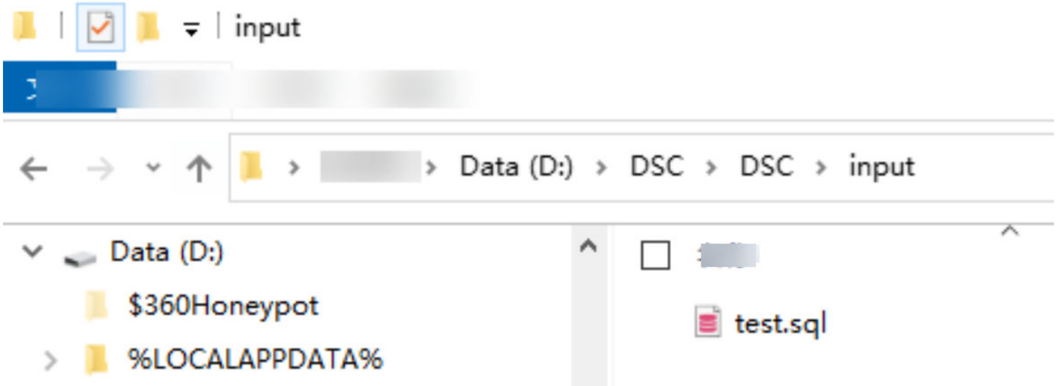
Step 3 Select the logged-in user **db_user01**, select the table object **APEX2_DYNAMIC_ADD_REMAIN_TEST** of the user, select the path to the output file (name the output SQL file as **test**), and click **Export**.



The exported DDL file is as follows:

```
D: > DSC > DSC > output > output > test.sql
prompt PL
/
SQL Developer Export USER Objects FOR USER DB_USER01@10.78.8.147 :1521 / ORCLPDB \echo Created by le[redacted]) on
 /* SET define off; */
/*spool test.log*/
\echo
 \echo Creating table APEX2_DYNAMIC_ADD_REMAIN_TEST
 \echo ============================================
 \echo
 CREATE
     UNLOGGED TABLE
          DB_USER01.APEX2_DYNAMIC_ADD_REMAIN_TEST (
               id INTEGER NOT NULL
               ,TIME DATE
               ,add_users NUMBER
               ,remain_users NUMBER
               ,PRIMARY KEY (ID)
          ) ;
\echo Done
 /*spool off*/
SET define
     ON ;
```

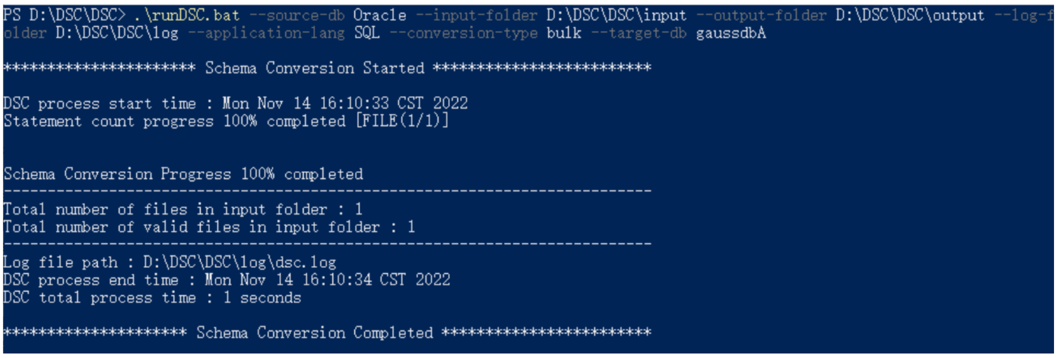
Step 4 Place the exported DDL file in the **input** directory of the decompressed DSC folder.

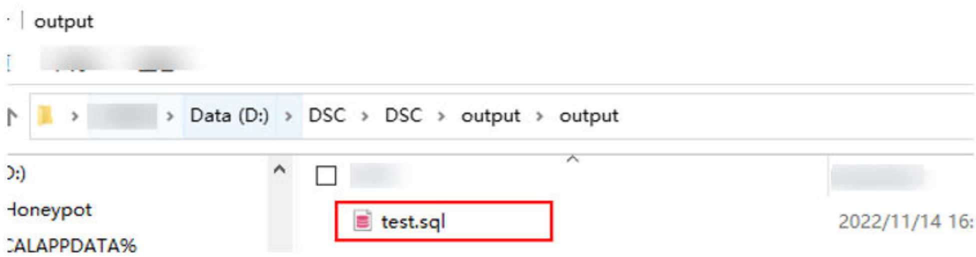


Step 5 In the directory of runDSC.bat, press Shift and right-click. Choose **Open PowerShell window here** and perform the conversion. Replace **D:\DSC\DSC\input**, **D:\DSC\DSC\output**, and **D:\DSC\DSC\log** with the actual DSC paths.

```
.\runDSC.bat --source-db Oracle --input-folder D:\DSC\DSC\input --output-folder D:\DSC\DSC\output --log-folder D:\DSC\DSC\log --application-lang SQL --conversion-type bulk --target-db gaussdbA
```

Step 6 After the conversion is complete, the converted DDL file is automatically generated in the **output** directory of DSC.





Step 7 The table definition structure of DWS is different from that of Oracle. You need to manually modify the converted table definition.

Comment out **\echo** in the file (if you use gsql to import table definitions, you do not need to do this) and manually change the distribution column of the specified table.

- Before the change:

```
D: > DSC > DSC > output > output > test.sql
prompt PL
/
SQL Developer Export USER Objects FOR USER DB_USER01@10.78.8.147 :1521 / ORCLPDB \echo Created by 1[redacted] on
 /* SET define off; */
/*spool test.log*/
\echo
 \echo Creating table APEX2_DYNAMIC_ADD_REMAIN_TEST
 \echo ============================================
 \echo
 CREATE
     UNLOGGED TABLE
          DB_USER01.APEX2_DYNAMIC_ADD_REMAIN_TEST (
               id INTEGER NOT NULL
               ,TIME DATE
               ,add_users NUMBER
               ,remain_users NUMBER
               ,PRIMARY KEY (ID)
          ) ;
\echo Done
 /*spool off*/
SET define
     ON ;
```

- After the change:

```
prompt PL
/
SQL Developer Export USER Objects FOR USER DB_USER01@10.78.8.147 :1521 / ORCLPDB \echo Created by [redacted] on
 /* SET define off; */
/*spool test.log*/
--\echo
--\echo Creating table APEX2_DYNAMIC_ADD_REMAIN_TEST
 --\echo ============================================
 --\echo
 CREATE
     UNLOGGED TABLE
          DB_USER01.APEX2_DYNAMIC_ADD_REMAIN_TEST (
               id INTEGER NOT NULL
               ,TIME DATE
               ,add_users NUMBER
               ,remain_users NUMBER
               ,PRIMARY KEY (ID)
          ) DISTRIBUTE BY HASH (ID);
\echo Done
 /*spool off*/
SET define
     ON ;
```

NOTE

The distribution column in a hash table must meet the following requirements, which are ranked by priority in descending order:

1. The values of the distribution key should be discrete so that data can be evenly distributed on each DN. You can select the primary key of the table as the distribution key. For example, for a person information table, choose the ID number column as the distribution key.
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 key.
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.

Step 8 Create a DWS cluster. For details, see **Creating a Cluster**.

Step 9 Connect to the DWS database as system administrator **dbadmin**. The default database **gaussdb** is connected for the first time.

Step 10 Create a new target database **test**, and then switch to it.

```
CREATE DATABASE test WITH ENCODING 'UTF-8' DBCOMPATIBILITY 'ORA' TEMPLATE template0;
```

Step 11 Create a schema and switch to it. The schema name must be the same as the Oracle user name (**db_user01** in this example).

```
CREATE SCHEMA db_user01;
SET CURRENT_SCHEMA = db_user01;
```

Step 12 Copy the converted DDL statements in **Step 7** to the SQL window for execution.

Step 13 If the **APEX2_DYNAMIC_ADD_REMAIN_TEST** table can be found in the schema in the **test** database of the DWS cluster, the table definition is migrated.

```
SELECT COUNT(*) FROM db_user01.APEX2_DYNAMIC_ADD_REMAIN_TEST;
```

----End

2.1.4 Migrating Full Table Data

2.1.4.1 Configuring a DWS Data Source Connection

Step 1 Create a CDM cluster and bind an EIP to the cluster by referring to **Creating a CDM cluster**.

NOTICE

Ensure that the CDM cluster and the DWS cluster are in the same region and VPC to ensure network connectivity.

Step 2 Log in to the **CDM console**, choose **Cluster Management**. Locate a cluster, click **Job Management** in the **Operation** column, and choose **Links** > **Create Link**.

Step 3 Select **Data Warehouse Service** and click **Next**.

Step 4 Configure the DWS connection, click **Test**. If the connection is successful, click **Save**.

Table 2-3 DWS connection information

Parameter	Value
Name	dws
Database Server	Click **Select** and select the DWS cluster to be connected from the cluster list. **NOTE** The system automatically displays the DWS clusters in the same region and VPC. If no DWS cluster is available, manually enter the IP address of the DWS cluster that has been connected to the network.
Host Port	8000
Database Name	test
User Name	dbadmin
Password	Password of user **dbadmin**
Use Agent	No

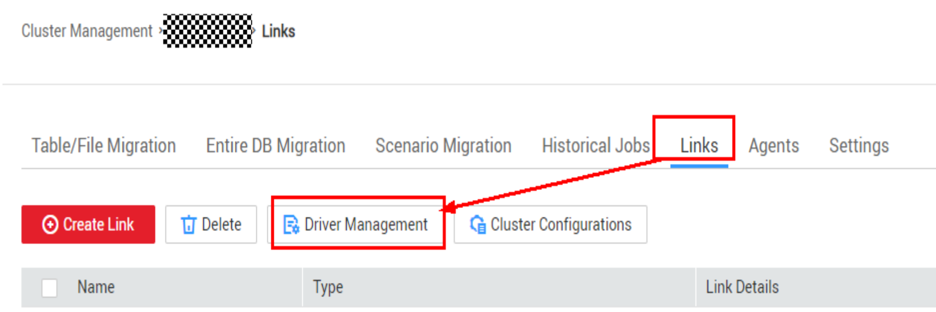
----End

2.1.4.2 Configuring an Oracle Data Source Connection

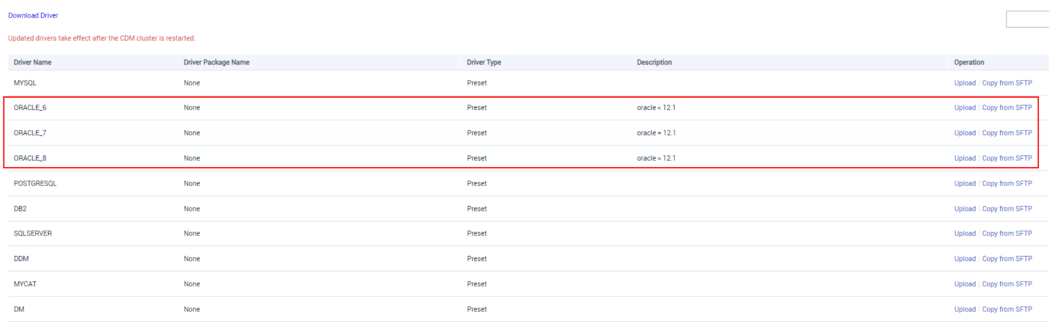
To migrate data from Oracle to DWS, you need to configure an Oracle data source connection first.

Procedure

Step 1 On the **Cluster Management** page, click **Job Management** in the **Operation** column of the cluster and choose **Links** > **Driver Management**.



Step 2 Click **Upload** on the right of ORACLE, select an Oracle driver package (if no driver package is available on the local PC, download it by referring to **Managing Drivers**), and click **Upload**.



Step 3 On the **Cluster Management** page, click **Job Management** in the **Operation** column of the cluster and choose **Links** > **Create Link**.

Step 4 Select Oracle as the connector and click **Next**.

Step 5 Configure the Oracle connection, click **Test**. If the connection is successful, click **Save**.

Table 2-4 Oracle connection information

Parameter	Value
Name	oracle

Parameter	Value
Database Server	192.168.1.100 (This is an example. Enter the actual public IP address of the Oracle database.)
Host Port	1521
Connection Type	Service Name
Database Name	orcl
User Name	db_user01
Password	-
Use Local API	No
Use Agent	No
Oracle Version	Later than 12.1

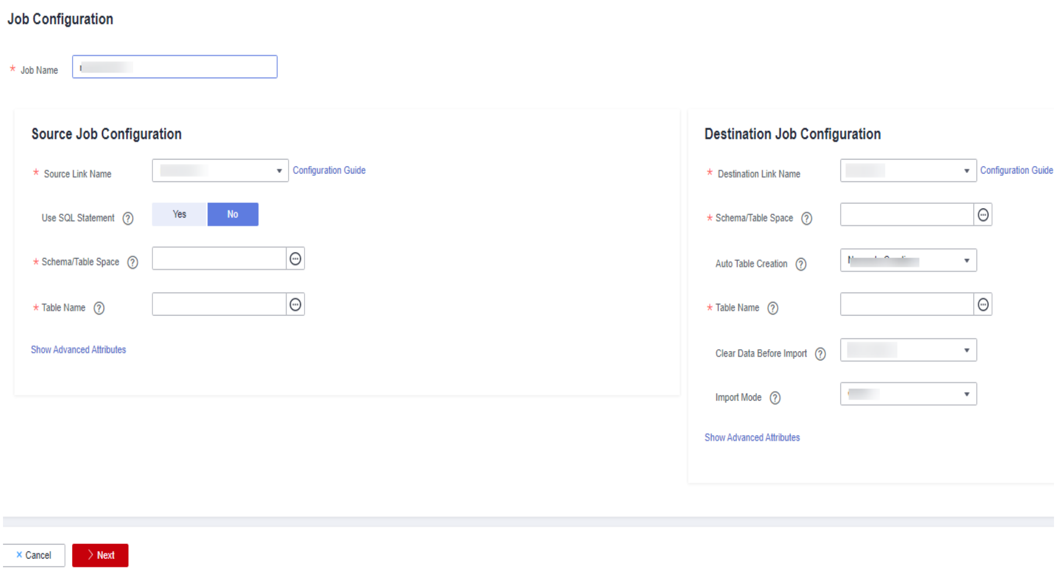
----End

2.1.4.3 Migrating Tables

Procedure

Step 1 On the **Cluster Management** page, click **Job Management** in the **Operation** column of the cluster and choose **Table/File Migration** > **Create Job**.

Step 2 Configure jobs at the source end and destination end.



Step 3 Configure source job parameters based on the type of the source database.

Table 2-5 Source job parameters

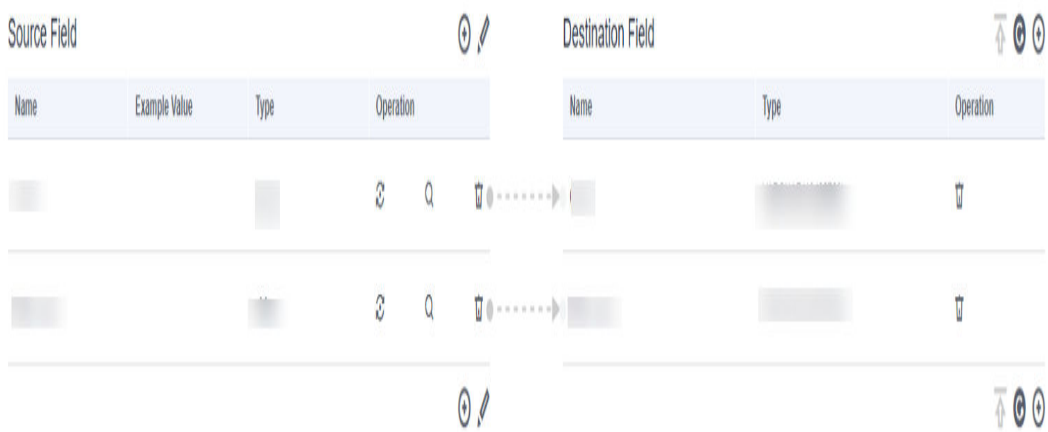
Parameter	Example Value
Schema/Table Space	db_user01
Use SQL Statement	No
Table Name	APEX2_DYNAMIC_ADD_REMAIN_TEST
WHERE Clause	-
Null in Partition Column	Yes

Step 4 Configure the destination job parameters based on the destination cloud service.

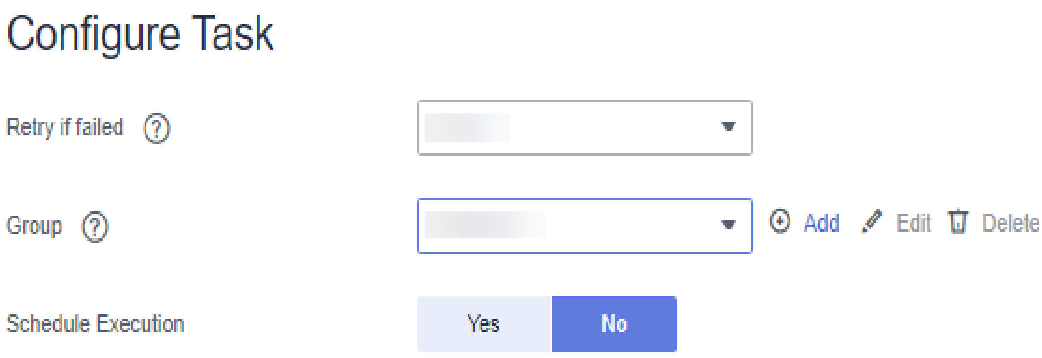
Table 2-6 Destination job parameters

1. Parameter	Example Value
Schema/Table Space	db_user01
Auto Table Creation	Non-auto creation
Table Name	apex2_dynamic_add_remain_test
Clear Data Before Import	Clear all data
Import Mode	COPY
Import to Staging Table	No
Prepare for Data Import	-
Complete Statement After Data Import	analyze db_user01. apex2_dynamic_add_remain_test;

Step 5 Mapping between source fields and destination fields.



Step 6 If the task fails to be configured, retry for three times, save the configuration, and run the task.



Step 7 The task is executed, and the data migration is finished.

----End

2.1.4.4 Verification

Step 1 In the **test** database of DWS, run the following SQL statement to query the number of rows in the table **apex2_dynamic_add_remain_test**. If the number of rows is the same as that in the source table, the data is consistent.

```
SELECT COUNT(*) FROM  db_user01.apex2_dynamic_add_remain_test;
```

Step 2 Run the following statement to check the data skewness:

If the data skewness is within 10%, the data distribution is normal. The data migration is complete.

```
SELECT TABLE_SKEWNESS('db_user01.apex2_dynamic_add_remain_test');
```

	table_skewness
1	("dn_6001_6002 ",97,32.119%)
2	("dn_6003_6004 ",105,34.768%)
3	("dn_6005_6006 ",100,33.113%)

----End

2.1.5 Migrating Service SQL Statements

2.1.5.1 Migrating Syntax

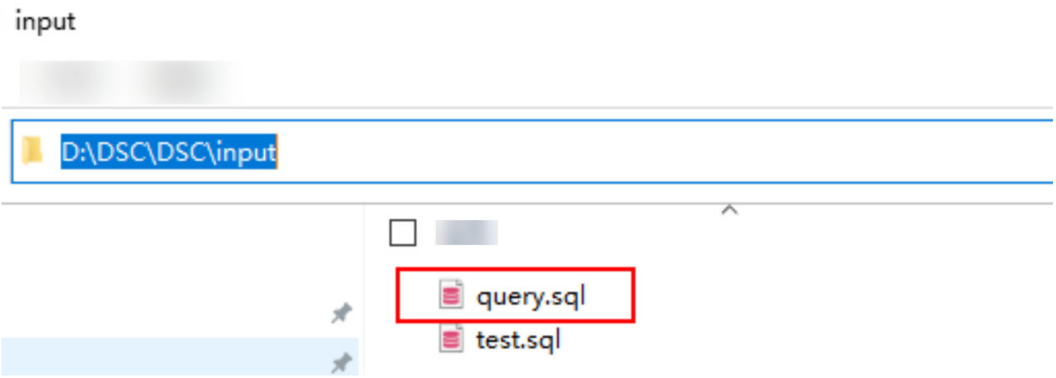
Step 1 Save the following SQL statements in an Oracle database as an query.sql file.

```
-- Generally, the HAVING clause must appear after the GROUP BY clause, but Oracle allows HAVING to appear before or after the GROUP BY clause. Therefore, you need to move the HAVING clause after the GROUP BY clause in the target database.
SELECT
id,
count(*),
sum(remain_users)
FROM LYC.APEX2_DYNAMIC_ADD_REMAIN_TEST
HAVING id <= 5
GROUP BY id;
```


UNIQUE keywords are migrated as DISTINCT keywords.
SELECT UNIQUE add_users FROM LYC.APEX2_DYNAMIC_ADD_REMAIN_TEST;

-- In **NVL2**(*expression*,*value1*,*value2*), if the *expression* is not Null, **NVL2** returns **Value1**. If the *expression* is Null, **NVL2** returns **Value2**.
SELECT NVL2(add_users, 1, 2) FROM LYC.APEX2_DYNAMIC_ADD_REMAIN_TEST SHERE rownum <= 2;

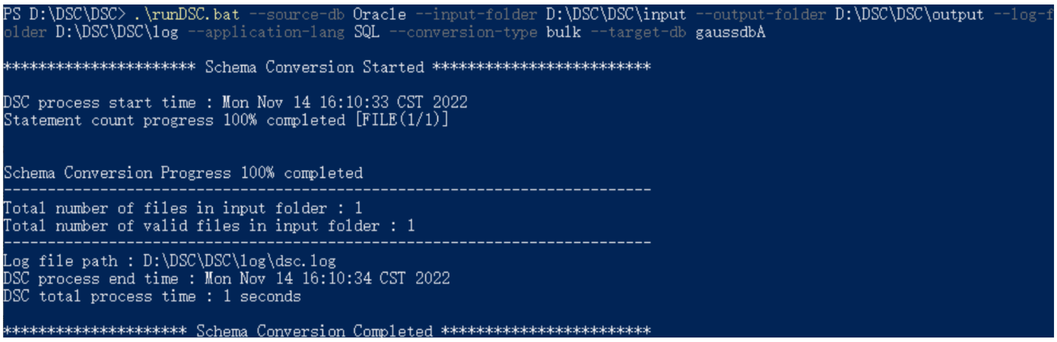
Step 2 Place the query.sql file obtained in **Step 1** in the **input** directory of the decompressed DSC folder.



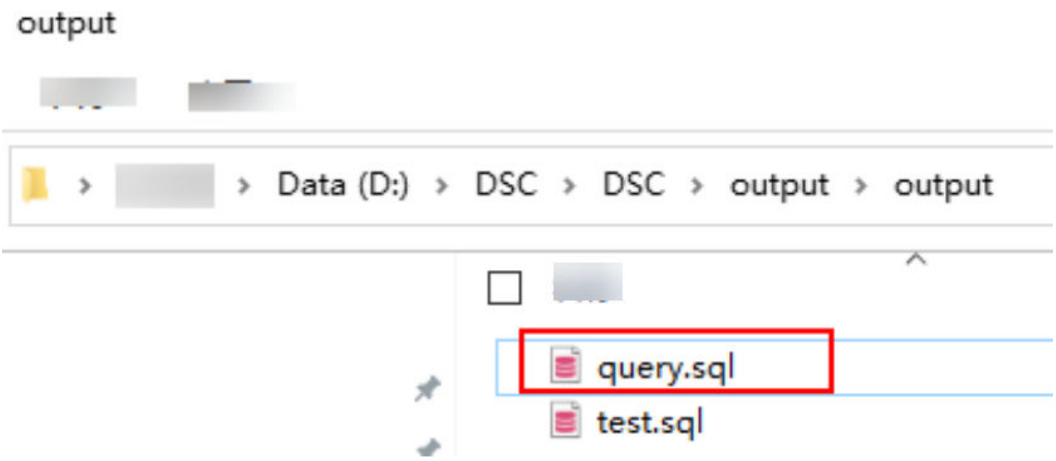
Step 3 In the directory of runDSC.bat, press Shift and right-click. Choose **Open PowerShell window here** and perform the conversion.

Replace **D:\DSC\DSC\input**, **D:\DSC\DSC\output**, and **D:\DSC\DSC\log** with the actual DSC paths.

.\runDSC.bat --source-db Oracle --input-folder **D:\DSC\DSC\input** --output-folder **D:\DSC\DSC\output** --log-folder **D:\DSC\DSC\log** --application-lang SQL --conversion-type bulk --target-db gaussdbA



Step 4 After the conversion is complete, a DML file is generated in the output directory.



----End

2.1.5.2 Verification

Step 1 Execute the SQL statements in the Oracle database before migration.

Step 2 Execute the migrated SQL statements in the SQL window.

Step 3 Compare the execution results. If they are the same, the SQL migration is complete.

----End

2.2 Using CDM to Migrate MySQL Data to a DWS Cluster

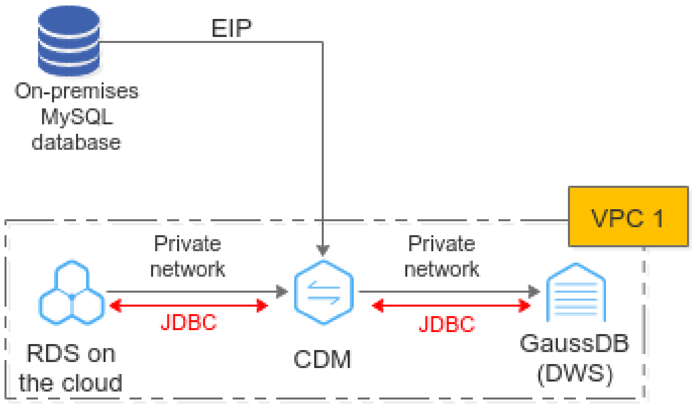
This section describes how to use Cloud Data Migration (CDM) to migrate MySQL data to DWS clusters in batches.

This section contains the following parts:

1. **Checking Data Before Migration**
2. **Creating a DWS Cluster**
3. **Creating a CDM cluster**
4. **Creating a Connection**
5. **Creating and Migrating a Job**
6. **Verifying Data Consistency After Migration**

Scenario Description

Figure 2-3 Migration



CDM can migrate an entire cloud/on-premises MySQL database or a single table. The migration of an on-premises MySQL database is used as an example.

- On-premises MySQL data migration:

  CDM accesses the MySQL database through the public IP address. CDM and DWS are in the same VPC. CDM establishes JDBC connections respectively with MySQL and DWS.

- Cloud RDS for MySQL data migration:

  RDS, CDM, and DWS are in the same VPC. CDM establishes JDBC connections respectively with MySQL and DWS. If cloud RDS and DWS are not in the same VPC, CDM uses the EIP to access RDS.

Checking Data Before Migration

Step 1 Connect to the MySQL DB instance and check the MySQL database status.

mysql -h *<host>***-P***<port>****-u*** *<userName>****-p--ssl-ca=****<caDIR>*

Table 2-7 Parameter description

Parameter	Description
<host>	Address for connecting to the MySQL database.
<port>	Database port. By default, the value is **3306**.
<userName>	MySQL administrator account. The default value is **root**.
<caDIR>	Path of the CA certificate. The file must be stored in the path where the command is executed.

Enter the password of the database account as prompted:

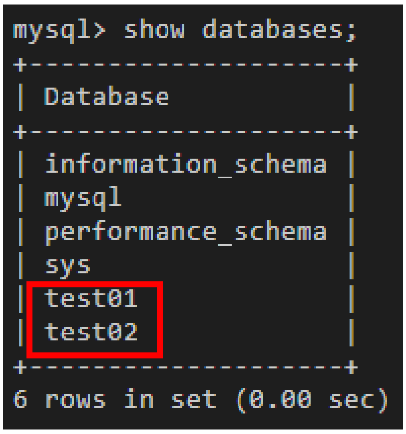
```
Enter password:
```


Step 2 Analyze the name and code of the databases to be migrated, and the name and attributes of the tables to be migrated.

For example, the destination MySQL databases to be migrated are **test01**, **test02**, and the encoding format. The test01 library contains the **orders**, **persons**, and **persons_b** tables and the **persons_beijing view**. The **test02** library contains the **persons_c table**.

1. Query the database name.

```
show databases;
```

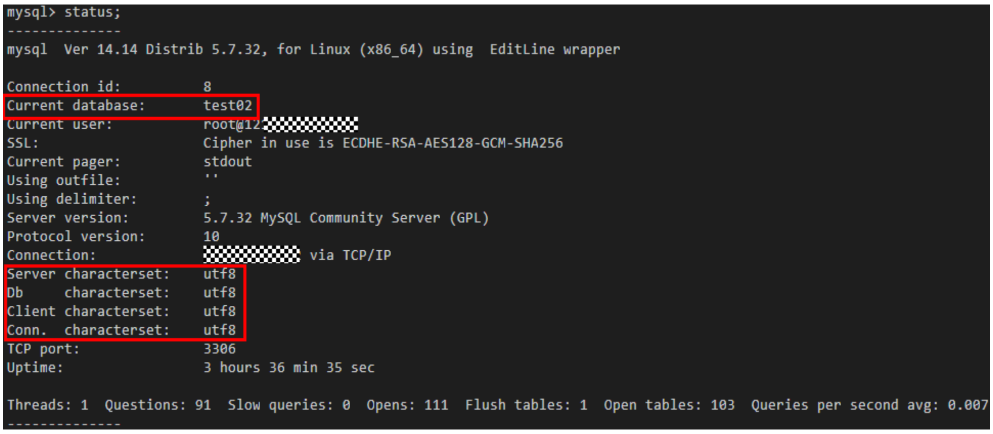


2. Query the database code.

```
use <databasename>;
status;
```

Figure 2-4 Query database code 1

Figure 2-5 Query database code 2



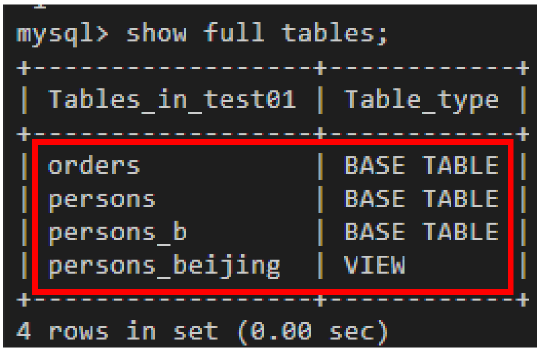
3. Query database tables.

```
use <databasename>;
show full tables;
```

NOTICE

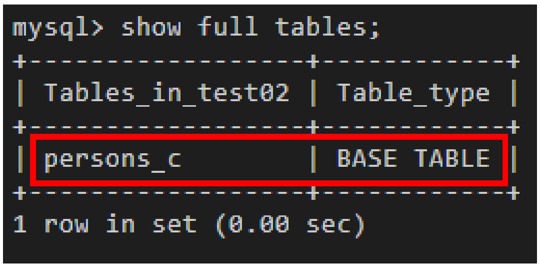
- The DWS database is case-insensitive. If the original MySQL database contains table names that contain both uppercase and lowercase letters or only uppercase letters, for example, **Table01** and **TABLE01**, you need to change the table names to lowercase letters before the migration. Otherwise, DWS cannot identify the tables after migration.
- You are advised to set the MySQL database to be case-insensitive by modifying **lower_case_table_names** to **1** in **/etc/my.cnf** and restarting the MySQL service.

Figure 2-6 Querying database tables



```
mysql> show full tables;
+------------------+------------+
| Tables_in_test01 | Table_type |
+------------------+------------+
| orders           | BASE TABLE |
| persons          | BASE TABLE |
| persons_b        | BASE TABLE |
| persons_beijing  | VIEW       |
+------------------+------------+
4 rows in set (0.00 sec)
```

Figure 2-7 Querying database tables

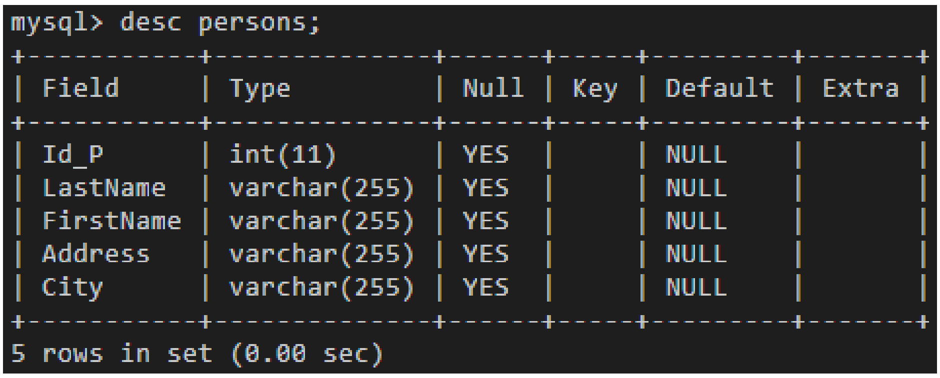


```
mysql> show full tables;
+------------------+------------+
| Tables_in_test02 | Table_type |
+------------------+------------+
| persons_c        | BASE TABLE |
+------------------+------------+
1 row in set (0.00 sec)
```

4. Check the attributes of each table for comparison after the migration.

```
use <databasename>;
desc <table name>;
```

Figure 2-8 Viewing table properties



```
mysql> desc persons;
+-----------+--------------+------+-----+---------+-------+
| Field     | Type         | Null | Key | Default | Extra |
+-----------+--------------+------+-----+---------+-------+
| Id_P      | int(11)      | YES  |     | NULL    |       |
| LastName  | varchar(255) | YES  |     | NULL    |       |
| FirstName | varchar(255) | YES  |     | NULL    |       |
| Address   | varchar(255) | YES  |     | NULL    |       |
| City      | varchar(255) | YES  |     | NULL    |       |
+-----------+--------------+------+-----+---------+-------+
5 rows in set (0.00 sec)
```

----End

Creating a DWS Cluster

Step 1 For how to create a cluster, see **Creating a Cluster**. You can select the EU-Dublin region

NOTE

Ensure that the DWS cluster and CDM cluster are in the same region and VPC.

Step 2 Connect to a cluster by referring to **Using the gsql CLI Client to Connect to a Cluster**.

Step 3 Create the target databases **test01** and **test02** in **Checking Data Before Migration** with the same name and database code as the original MySQL database.

```
create database test01 with encoding 'UTF-8' dbcompatibility 'mysql' template template0;
create database test02 with encoding 'UTF-8' dbcompatibility 'mysql' template template0;
```

----End

Creating a CDM cluster

Step 1 Log in to the **CDM console**.

Step 2 Click **Buy CDM Cluster** and set the following parameters:

Table 2-8 CDM cluster parameters

Parameter	Value
Region	Select the EU-Dublin region, which is in the same location as DWS.
AZ	AZ1 (If the desired resources are sold out in the current AZ, change the AZ and try again.)
Name	CDM-demo
Instance Type	cdm.large (Select other flavors if the flavor is sold out.)
VPC	demo-vpc, which is in the same location as DWS.
Subnet	subnet-f377(10.1.0.0/24) (example)
Security Group	-
Enterprise Project	default

Step 3 Click **Buy Now**, confirm all the parameters, and click **Submit**.

Step 4 Go back to the **Cluster Management** page. Cluster creation takes about 5 minutes. After the cluster is created, click **Bind EIP** in the **Operation** column of the cluster.

Step 5 Select an available EIP and click **OK**. If no EIP is available, switch to the EIP page to purchase an EIP.

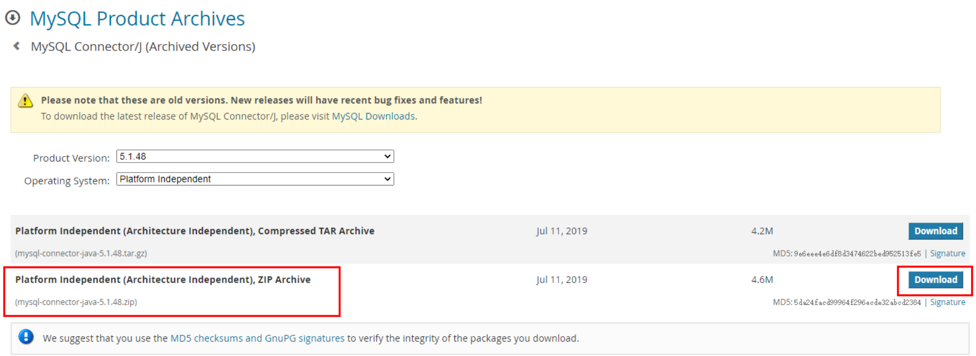
----End

Creating a Connection

Step 1 When creating a MySQL connection for the first time, upload a driver.

1. Access the **MySQL** driver and download the 5.1.48 version.

Figure 2-9 Downloading a driver



2. Download the package to the local host and decompress it to obtain **mysql-connector-java-*xxx*.jar**.
3. On the **Cluster Management** page, click **Job Management** in the **Operation** column of the cluster and choose **Links** > **Driver Management**.
4. Click **Upload** on the right of MySQL, select mysql-connector-java-xxx.jar, and click **Upload**.

Step 2 Create a MySQL connection.

1. On the **Cluster Management** page, click **Job Management** in the **Operation** column of the cluster and choose **Links** > **Create Link**.
2. Select **MySQL** and click **Next**. (If the RDS is deployed on the cloud, select RDS for MySQL.)
3. Enter the connection information according to **Table 2-9**, and click **Test**. If the test is successful, click **Save**.

NOTE

If the test fails, check whether CDM connects to the MySQL database using the public IP address. If the public IP address is used, bind the public IP address by referring to **Step 4**.

Table 2-9 MySQL connection information

Parameter	Value
Name	MySQL

Parameter	Value
Database Server	192.168.1.100 (This is an example, enter the actual public IP address of the on-premises MySQL database. Ensure that the whitelist access permission has been enabled on the MySQL server.)
Port	3306
Database Name	test01
User	root
Password	Password of the user **root**.
Use Local API	No
Use Agent	No

Step 3 Create a DWS link.

1. On the **Cluster Management** page, click **Job Management** in the **Operation** column of the cluster and choose **Links** > **Create Link**.
2. Select **Data Warehouse Service** and click **Next**.
3. Enter the connection information according to **Table 2-10**, and click **Test**. If the test is successful, click **Save**.

Table 2-10 DWS connection information

Parameter	Value
Name	DWS-test01
Database Server	Click **Select** and select the DWS cluster to be connected from the cluster list. **NOTE** The system automatically displays the DWS clusters in the same region and VPC. If no DWS cluster is available, manually enter the IP address of the DWS cluster that has been connected to the network.
Port	8000
Database Name	test01 (Ensure that the corresponding database has been manually created on DWS by referring to **Step 3**.)
Username	dbadmin
Password	Password of user **dbadmin**
Use Agent	No

4. Repeat **Step 3.1** to **Step 3.3** to create the **DWS-test02** link.

----End

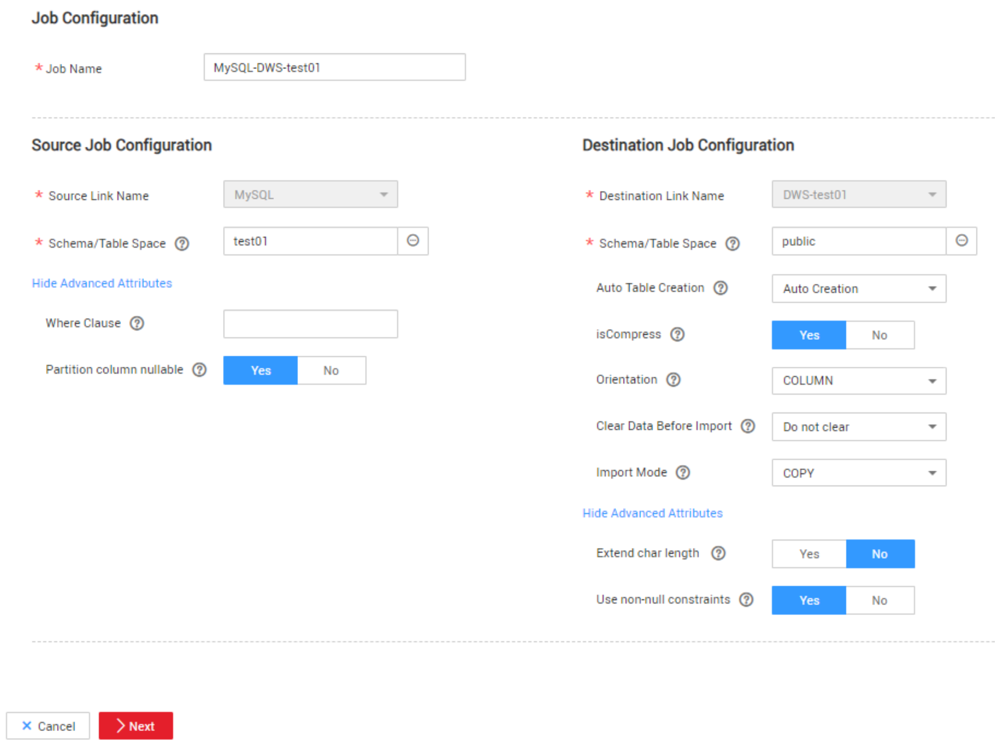
Creating and Migrating a Job

Step 1 On the **Cluster Management** page, click **Job Management** in the **Operation** column of the cluster and choose **Entire DB Migration** > **Create Job**.

Step 2 Set the following parameters and click **Next**.

- Job Name: MySQL-DWS-test01
- Source Job Configuration:
  - Source Link Name: MySQL
- Destination Job Configuration:
  - Destination Link Name: DWS-test01
  - Automatic Table Creation: The table is created when it does not exist.
  - isCompress: Yes
  - Orientation: COLUMN
  - Retain the default value for other settings.

Figure 2-10 Configuring a Job

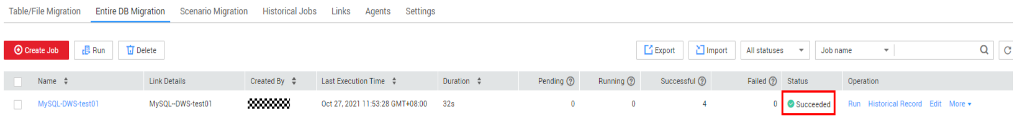


Step 3 Select all tables, click , and click **Next**.

Step 4 Retain the default settings and click **Save and Run**.

Step 5 Check the job running status. If the status is **Succeeded**, the migration is successful.

Figure 2-11 Viewing the job running status



Step 6 Repeat **Step 1** to **Step 5** to migrate all tables in the **test02** database.

NOTICE

When creating a job, select **test02** for the DWS database of the target source.

----End

Verifying Data Consistency After Migration

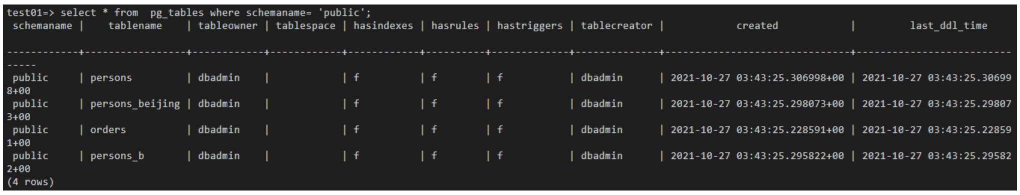
Step 1 Use gsql to connect to the **test01** cluster of DWS.

gsql -d *test01* **-h** *IP address of the host* **-p 8000 -U dbadmin -W** *Database user password* **-r;**

Step 2 Query the tables in the **test01** database.

```
select * from  pg_tables where schemaname= 'public';
```

Figure 2-12 Query the tables in the **test01** database.



Step 3 Check whether the data in each table is complete and whether the columns are complete.

```
select count(*) from table name;
\d+ table name;
```

Figure 2-13 Querying table fields

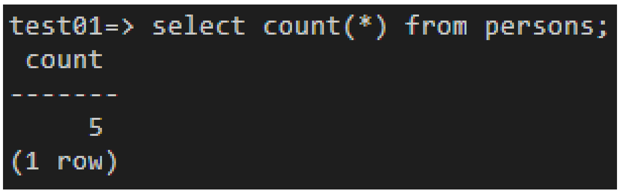


Figure 2-14 Querying table data

```
test01=> \d+ persons;
                                   Table "public.persons"
  Column   |          Type          | Modifiers | Storage  | Stats target | Description
-----------+------------------------+-----------+----------+--------------+-------------
 Id_P      | integer                |           | plain    |              |
 LastName  | character varying(255) |           | extended |              |
 firstname | character varying(255) |           | extended |              |
 address   | character varying(255) |           | extended |              |
 city      | character varying(255) |           | extended |              |
Has OIDs: no
Distribute By: HASH(Id_P)
Location Nodes: ALL DATANODES
Options: orientation=column, compression=high, colversion=2.0, enable_delta=false
```

Step 4 Perform sampling check to verify table data.

```
select * from persons where city = 'Beijing' order by id_p;
```

Figure 2-15 Verifying table data

```
test01=> select * from persons where city = 'Beijing' order by "Id_P";
 Id_P | LastName | firstname |     address     |  city
------+----------+-----------+-----------------+---------
    1 | Gates    | Bill      | Xuanwumen 10    | Beijing
    4 | Carter   | Thomas    | Changan Street  | Beijing
    5 | Carter   | William   | Xuanwumen 10    | Beijing
(3 rows)
```

Step 5 Repeat **Step 2** to **Step 4** to check whether the data in other databases and tables is correct.

----End

2.3 Using a Flink Job of DLI to Synchronize MySQL Data to a DWS Cluster in Real Time

This practice demonstrates how to use a Flink job of DLI (Flink 1.15 is used as an example) to synchronize MySQL data to DWS in real time.

For details, see **What Is Data Lake Insight?**

This practice lasts for approximately 90 minutes and involves utilizing various cloud services such as Virtual Private Cloud (VPC) and Subnet, Relational Database Service (RDS), Data Lake Insight (DLI), Object Storage Service (OBS), and DWS. The following is an outline of the practice.

1. **Preparations**: Create an account and prepare the network.
2. **Step 1: Prepare MySQL Data**: Purchase an RDS instance and then create a source table and insert data in the table.
3. **Step 2: Create a DWS Cluster**: Purchase a DWS cluster and create a target table.
4. **Step 3: Create a DLI Elastic Resource Pool and Queue**: Create a DLI elastic resource pool and add queues to the resource pool.
5. **Step 4: Create an Enhanced Datasource Connection**: Connect the RDS instance and the DWS cluster.

6. **Step 5: Prepare the dws-connector-flink Tool for Interconnecting DWS with Flink**: Use this plugin to import data from MySQL to DWS efficiently.
7. **Step 6: Create a DLI Flink Job**: Create a Flink SQL job and configure SQL code.
8. **Step 7: Verify Data Synchronization**: Verify that data is consistent.
9. **More Information**: In the Flink cross-source development, if the data source authentication information is directly configured in job scripts, the password may be disclosed. To enhance security, you are advised to use DLI's datasource authentication instead of specifying MySQL and DWS usernames and passwords directly in job scripts.

Preparations

- You have sign up for a Huawei ID and enabled Huawei Cloud services. The account cannot be in arrears or frozen.
- You have created a VPC and subnet. For details, see **Creating a VPC**.

Step 1: Prepare MySQL Data

Step 1 Log in to the **RDS console** and purchase an RDS DB instance. Configure key parameters listed in **Table 2-11** and retain the default values for other parameters. For details, see **RDS Documentation**.

Table 2-11 RDS parameters

Parameter	Value
Billing Mode	Pay-per-use
Region	Europe-Dublin
DB Instance Name	rds-demo
DB Engine	MySQL
DB Engine Version	5.7 or later
Database Port	3306

Step 2 Connect to the RDS instance and create an instance named **mys_data**.

```
CREATE DATABASE mys_data;
```

Step 3 Switch to the new database **mys_data** and run the following command to create the **mys_orders** table:

```
CREATE TABLE mys_data.mys_order
   ( order_id      VARCHAR(12),
     order_channel VARCHAR(32),
     order_time    DATETIME,
     cust_code     VARCHAR(6),
     pay_amount    DOUBLE,
     real_pay      DOUBLE,
     PRIMARY KEY (order_id) );
```

Step 4 insert data to the table.

```
INSERT INTO mys_data.mys_order VALUES ('202306270001', 'webShop', TIMESTAMP('2023-06-27
10:00:00'), 'CUST1', 1000, 1000);
INSERT INTO mys_data.mys_order VALUES ('202306270002', 'webShop', TIMESTAMP('2023-06-27
11:00:00'), 'CUST2', 5000, 5000);
```

Step 5 Check whether the data is inserted.

```
SELECT * FROM mys_data.mys_order;
```

----End

Step 2: Create a DWS Cluster

Step 1 **Creating a Cluster**. To ensure network connectivity, select the same region and VPC as those of the RDS instance. In this practice, select Europe-Dublin. The VPC must be the same as that created for RDS.

Step 2 Log in to the **DWS console**. Choose **Dedicated Clusters** > **Clusters**. Locate the target cluster and click **Log In** in the **Operation** column. The login information is as follows:

- Data source name: dws-demo
- Cluster: the created DWS cluster.
- Database: gaussdb
- Username: dbadmin
- Password: password set when the DWS cluster is created

Step 3 Select **Remember Password**, click **Test Connection**, and wait until the connection is successful.

Step 4 Copy the following SQL statements. In the SQL window, click **Execute SQL** to create a schema named **dws_data**.

```
CREATE SCHEMA dws_data;
```

Step 5 Create the **dws_order** table in the new schema.

```
CREATE TABLE dws_data.dws_order
       ( order_id      VARCHAR(12),
         order_channel VARCHAR(32),
         order_time    TIMESTAMP,
         cust_code     VARCHAR(6),
         pay_amount    DOUBLE PRECISION,
         real_pay      DOUBLE PRECISION );
```

Step 6 Query data. The current table is empty.

```
SELECT * FROM dws_data.dws_order;
```

----End

Step 3: Create a DLI Elastic Resource Pool and Queue

Step 1 Log in to the **Huawei Cloud DLI console**.

Step 2 In the navigation pane on the left, choose **Resources** > **Resource Pool**.

Step 3 Click **Buy Resource Pool** in the upper right corner, set the following parameters, and retain the default values for other parameters that are not described in the table.

Table 2-12 Parameters

Parameter	Value
Billing Mode	Pay-per-use
Region	Europe-Dublin
Name	dli_dws
Specifications	Standard
CIDR Block	172.16.0.0/18, which must be in a different network segment from MySQL and DWS. For example, if MySQL and DWS are in the **192.168.x.x** network segment, select **172.16.x.x** for DLI.

Step 4 Click **Buy** and click **Submit**.

After the resource pool is created, go to the next step.

Step 5 On the elastic resource pool page, locate the row that contains the created resource pool, click **Add Queue** in the **Operation** column, and set the following parameters. Retain the default values for other parameters that are not described in the table.

Table 2-13 Adding a queue

Parameter	Value
Name	dli_dws
Type	General purpose queue

Step 6 Click **Next** and click **OK**. The queue is created.

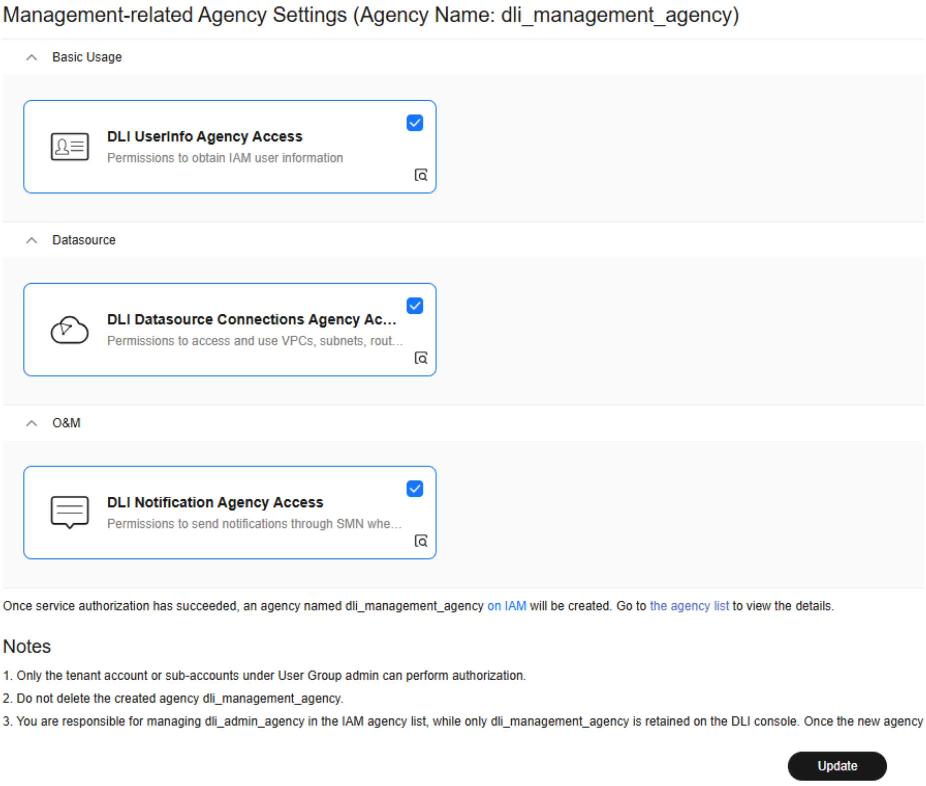
----End

Step 4: Create an Enhanced Datasource Connection

Step 1 Update the DLI agency permissions.

1. Return to the DLI console and choose **Global Configuration** > **Service Authorization** on the left.
2. Select **DLI UserInfo Agency Access**, **DLI Datasource Connections Agency Access**, and **DLI Notification Agency Access**.
3. Click **Update**. Click **OK**.

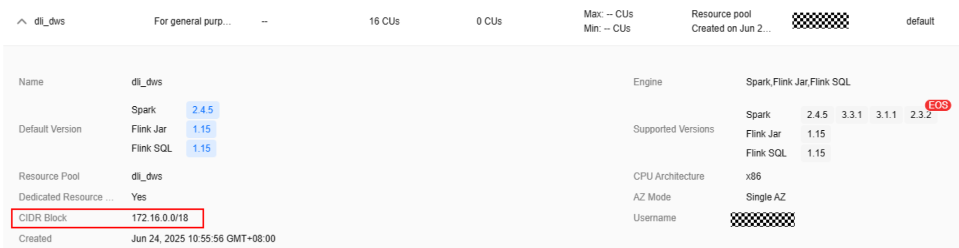
Figure 2-16 Updating DLI agency permissions



Step 2 In the security group of RDS, allow the network segment where the DLI queue is located.

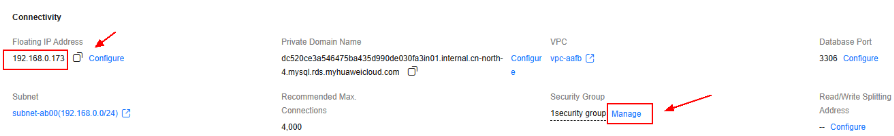
1. In the navigation pane on the left, choose **Resources** > **Queue Management** and record the CIDR block of **dli_dws**.

Figure 2-17 CIDR block of a DLI queue



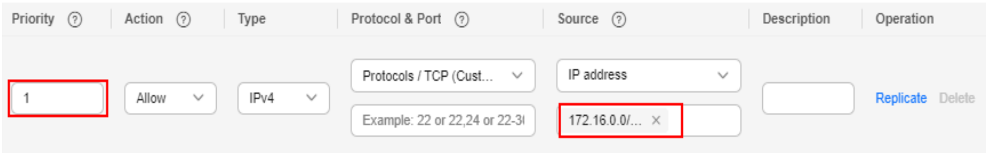
2. Go to the RDS console, choose **Instances** in the navigation pane, and click the name of the created RDS instance.
3. Record the value of **Floating IP Address** in the **Connectivity** area, which will be used in the subsequent connectivity test.
4. Click **Manage** next to the security group in **Connectivity**.

Figure 2-18 RDS security group



5. In the security group list that is displayed, click the security group name to go to the security group configuration page.
6. Choose **Inbound Rules** > **Add Rule**, as shown in the following figure. Add the network segment of the DLI queue. In this example, the network segment is **172.16.0.0/18**. Ensure that the network segment is the same as that entered in **Step 3: Create a DLI Elastic Resource Pool and Queue**.

Figure 2-19 Adding a rule to the RDS security group



7. Click **OK**.

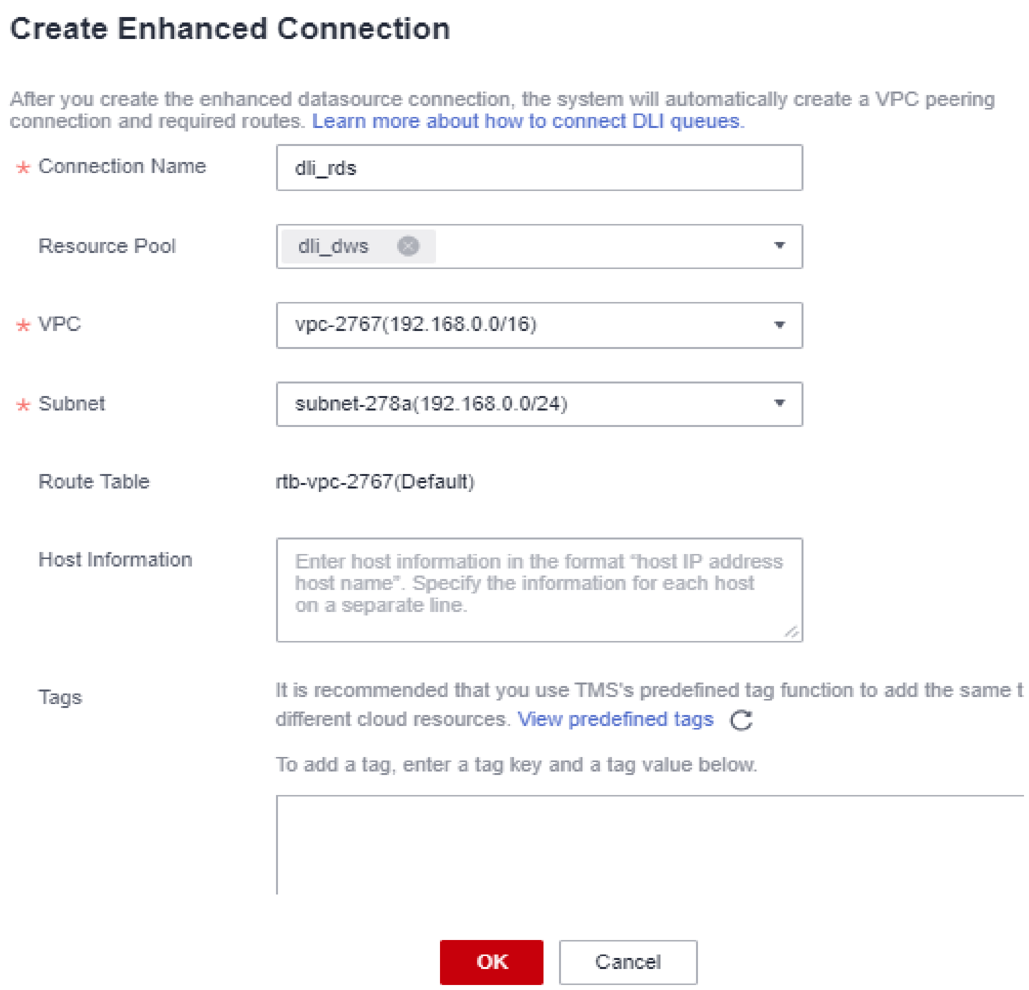
Step 3 Return to the DLI console, click **Datasource Connections** on the left, select **Enhanced**, and click **Create**.

Step 4 Set the following parameters. Retain the default values for other parameters that are not described in the table.

Table 2-14 Connection from DLI to RDS

Parameter	Value
Connection Name	dli_rds
Resource Pool	Select the created DLI elastic resource pool.
VPC	Select the VPC where RDS is located.
Subnet	Select the subnet where RDS is located.
Other parameters	Retain the default values.

Figure 2-20 Creating a datasource connection

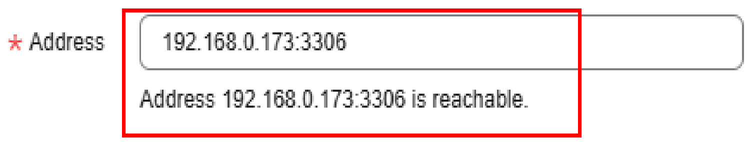


Step 5 Click **OK**. Wait until the RDS connection is created.

Step 6 Test the connectivity between DLI and RDS.

1. Choose **Resources** > **Queue Management** on the left, and choose **More** > **Test Address Connectivity** on the right of **dli_dws**.
2. Enter the private IP address of RDS recorded in **Step 2.3** and port **3306** in the address box.
3. Click **Test** to verify that DLI is successfully connected to RDS.

Figure 2-21 Testing the connection between RDS and DLI



Step 7 If the connection fails, perform the following operations:

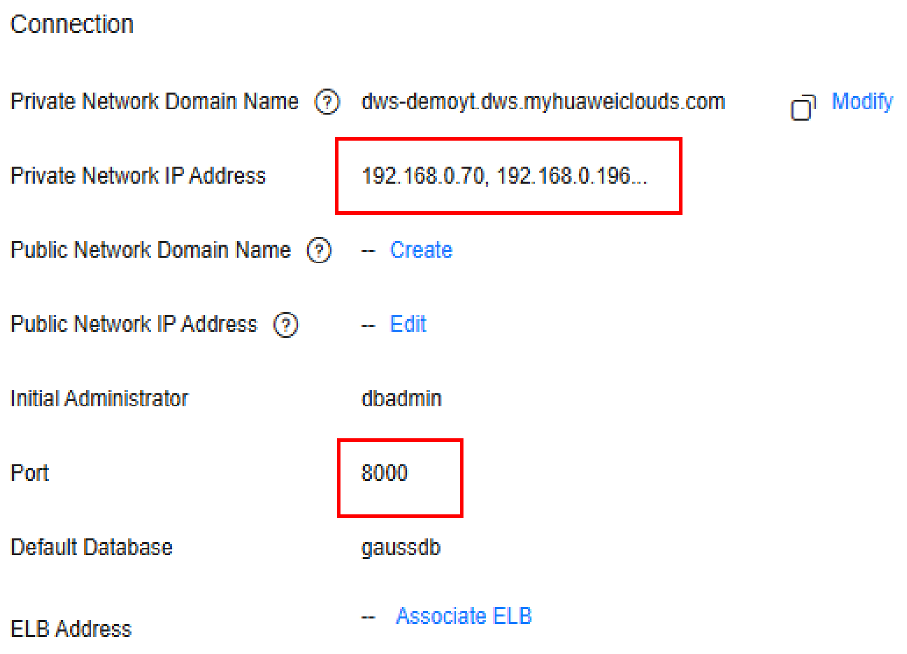
Ensure that the security group that RDS is associated with allows access from the CIDR block where the DLI resource pool is located and that the agency has been updated.

1. Log in to the DLI console and click **Datasource Connections**. Locate the created connection and click **More** in the **Operation** column, and select **Unbind Resource Pool**.
2. Deselect the existing elastic resource pool and click **OK**.
3. Click **More** in the **Operation** column and select **Bind Resource Pool**.
4. Select the created elastic resource pool **dli_dws** and click **OK**.
5. Wait for about 2 minutes and test the connection again.
6. If the connection still fails, rectify the fault by referring to **How Do I Do If the Datasource Connection Is Successfully Created but the Network Connectivity Test Fails?**

Step 8 Test the connectivity between DLI and DWS.

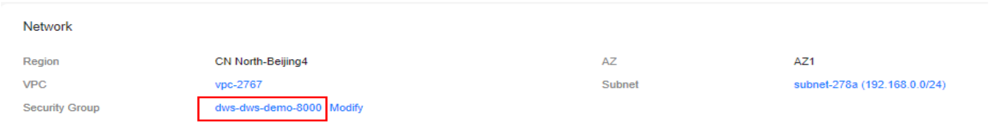
1. Log in to the **DWS console**. In the navigation pane, choose **Dedicated Clusters** > **Clusters**. Click the cluster name to view the cluster details.
2. As shown in the following figure, record the private IP address and port number of the DWS cluster for future use.

Figure 2-22 DWS internal IP address



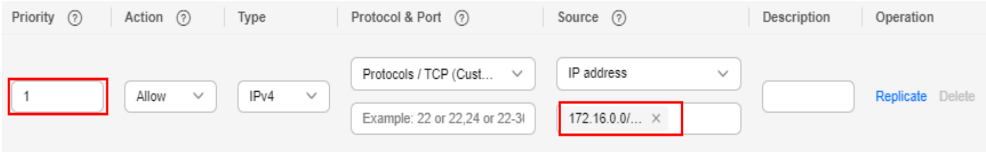
3. Click the security group name.

Figure 2-23 DWS security group



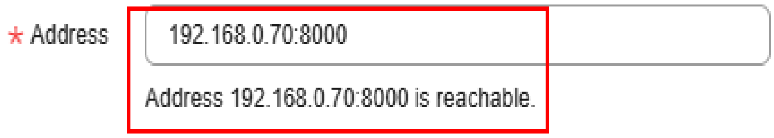
4. Choose **Inbound Rules** > **Add Rule**, as shown in the following figure. Add the network segment of the DLI queue. In this example, the network segment is **172.16.0.0/18**. Ensure that the network segment is the same as that entered in **4**.

Figure 2-24 Adding a rule to the DWS security group



5. Click **OK**.
6. Switch to the DLI console, choose **Resources** > **Queue Management** on the left, and click **More** > **Test Address Connectivity** on the right of **dli_dws**.
7. In the address box, enter the private IP address and port number of the DWS cluster.
8. Click **Test** to verify that DLI is successfully connected to DWS.

Figure 2-25 Testing DWS connectivity



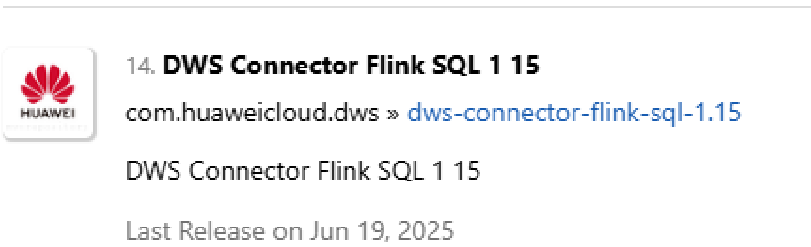
----End

Step 5: Prepare the dws-connector-flink Tool for Interconnecting DWS with Flink

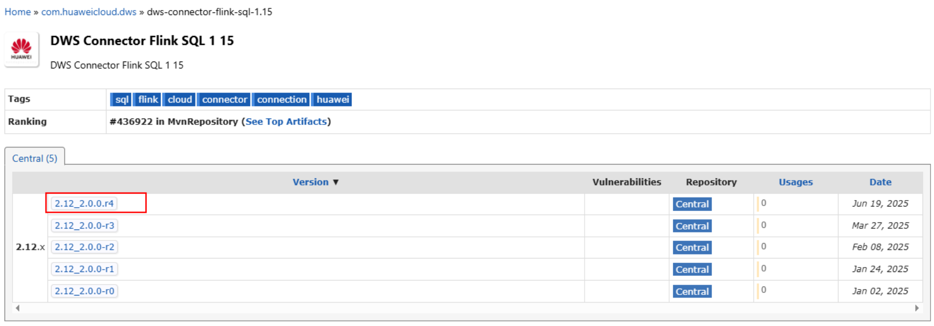
dws-connector-flink is a tool for interconnecting with Flink based on DWS JDBC APIs. During DLI job configuration, this tool and its dependencies are stored in the Flink class loading directory to better import Flink jobs to DWS.

Step 1 Go to **https://mvnrepository.com/artifact/com.huaweicloud.dws** using a browser.

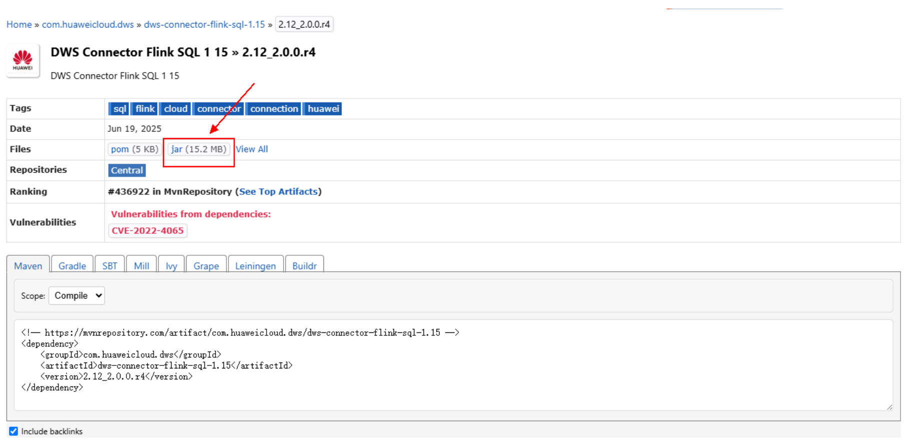
Step 2 In the software list, select Flink 1.15. In this practice, **DWS Connector Flink SQL 1 15** is selected.



Step 3 Select the latest branch. The actual branch is subject to the new branch released on the official website.



Step 4 Click the **jar** icon to download the file.



Step 5 Create an OBS bucket. In this practice, set the bucket name to **obs-flink-dws** and upload the file **dws-connector-flink-sql-1.15-2.12_2.0.0.r4.jar** to the OBS bucket. Ensure that the bucket is in the same region as DLI. In this practice, the **Europe-Dublin** region is used.

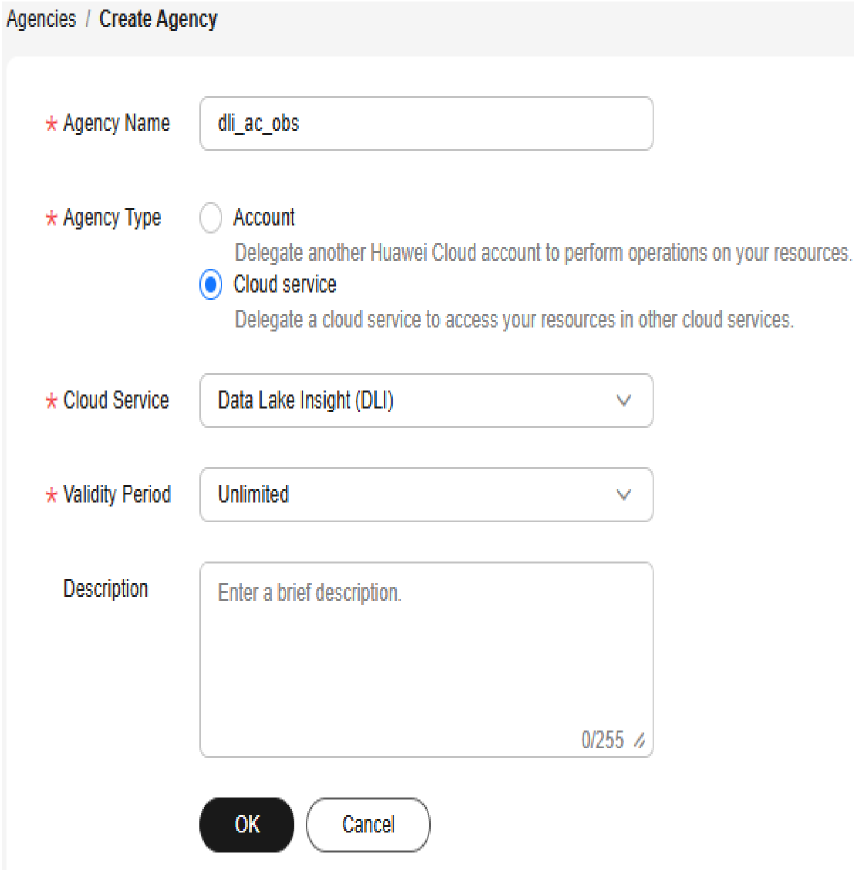
----End

Step 6: Create a DLI Flink Job

Step 1 Create an OBS agency policy.

1. Hover over the account name in the upper right corner of the console, and click **Identity and Access Management**.
2. In the navigation pane on the left, choose **Agencies** and then click **Create Agency** in the upper right corner.
   - **Agency Name**: **dli_ac_obs**
   - **Agency Type**: **Cloud service**
   - **Cloud Service**: **Data Lake Insight (DLI)**
   - **Validity Period**: **Unlimited**

Figure 2-26 Creating an OBS agency



3. Click **OK** and then click **Authorize**.
4. On the displayed page, click **Create Policy**.
5. Configure policy information. Enter a policy name, for example, **dli_ac_obs**, and select **JSON**.
6. In the **Policy Content** area, paste a custom policy. Replace OBS bucket name with the actual bucket name created in **Step 5**.

```
{
   "Version": "1.1",
   "Statement": [
      {
         "Effect": "Allow",
         "Action": [
            "obs:object:GetObject",
            "obs:object:DeleteObjectVersion",
            "obs:bucket:GetBucketLocation",
            "obs:bucket:GetLifecycleConfiguration",
            "obs:object:AbortMultipartUpload",
            "obs:object:DeleteObject",
            "obs:bucket:GetBucketLogging",
            "obs:bucket:HeadBucket",
            "obs:object:PutObject",
            "obs:object:GetObjectVersionAcl",
            "obs:bucket:GetBucketAcl",
            "obs:bucket:GetBucketVersioning",
            "obs:bucket:GetBucketStoragePolicy",
            "obs:bucket:ListBucketMultipartUploads",
            "obs:object:ListMultipartUploadParts",
            "obs:bucket:ListBucketVersions",
            "obs:bucket:ListBucket",
```

```
            "obs:object:GetObjectVersion",
            "obs:object:GetObjectAcl",
            "obs:bucket:GetBucketPolicy",
            "obs:bucket:GetBucketStorage"
        ],
        "Resource": [
            "OBS:*:*:object:*",
            "OBS:*:*:bucket:OBS bucket name"
        ]
    },
    {
        "Effect": "Allow",
        "Action": [
            "obs:bucket:ListAllMyBuckets"
        ]
    }
  ]
}
```

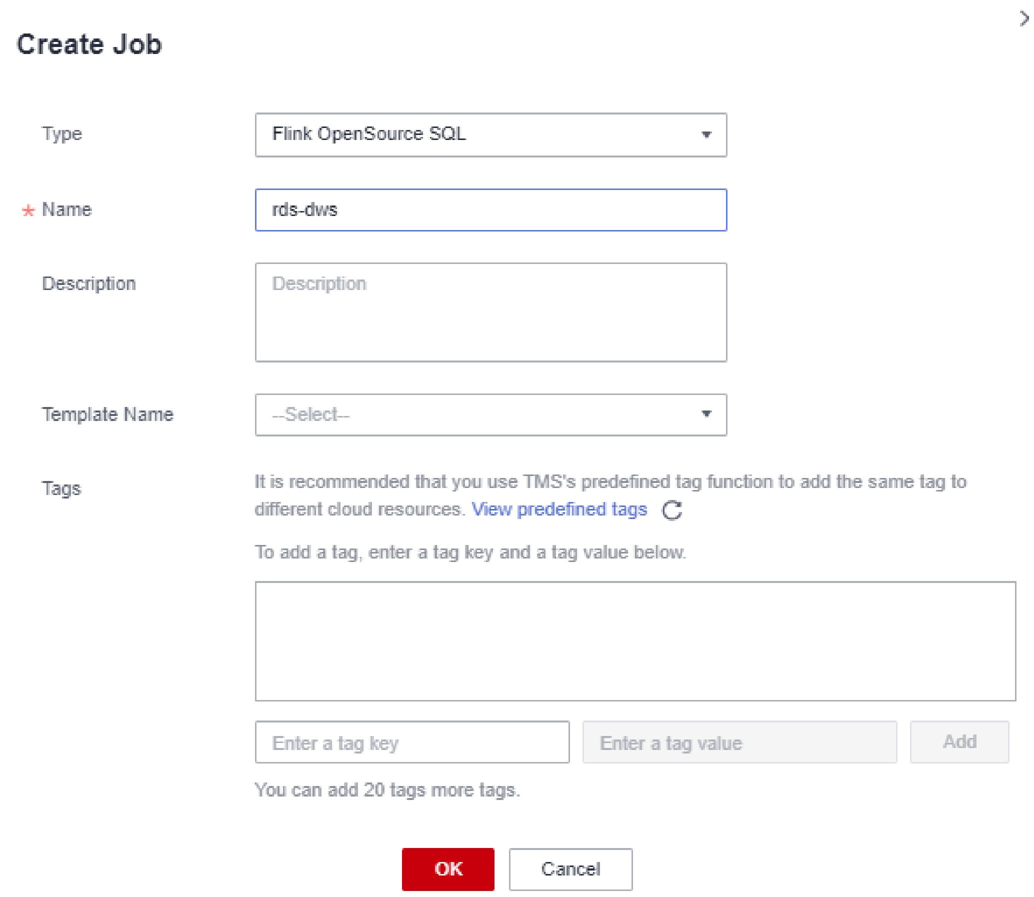
7. Click **Next**.
8. Select the created custom policy.
9. Click **Next**. Select **All resources**.
10. Click **OK**.

    It takes 15 to 30 minutes for the authorization to take effect.

Step 2 Return to the DLI console, choose **Job Management** > **Flink Jobs** on the left, and click **Create Job** in the upper right corner.

Step 3 Set **Type** to **Flink OpenSource SQL** and **Name** to **rds-dws**.

Figure 2-27 Creating a job

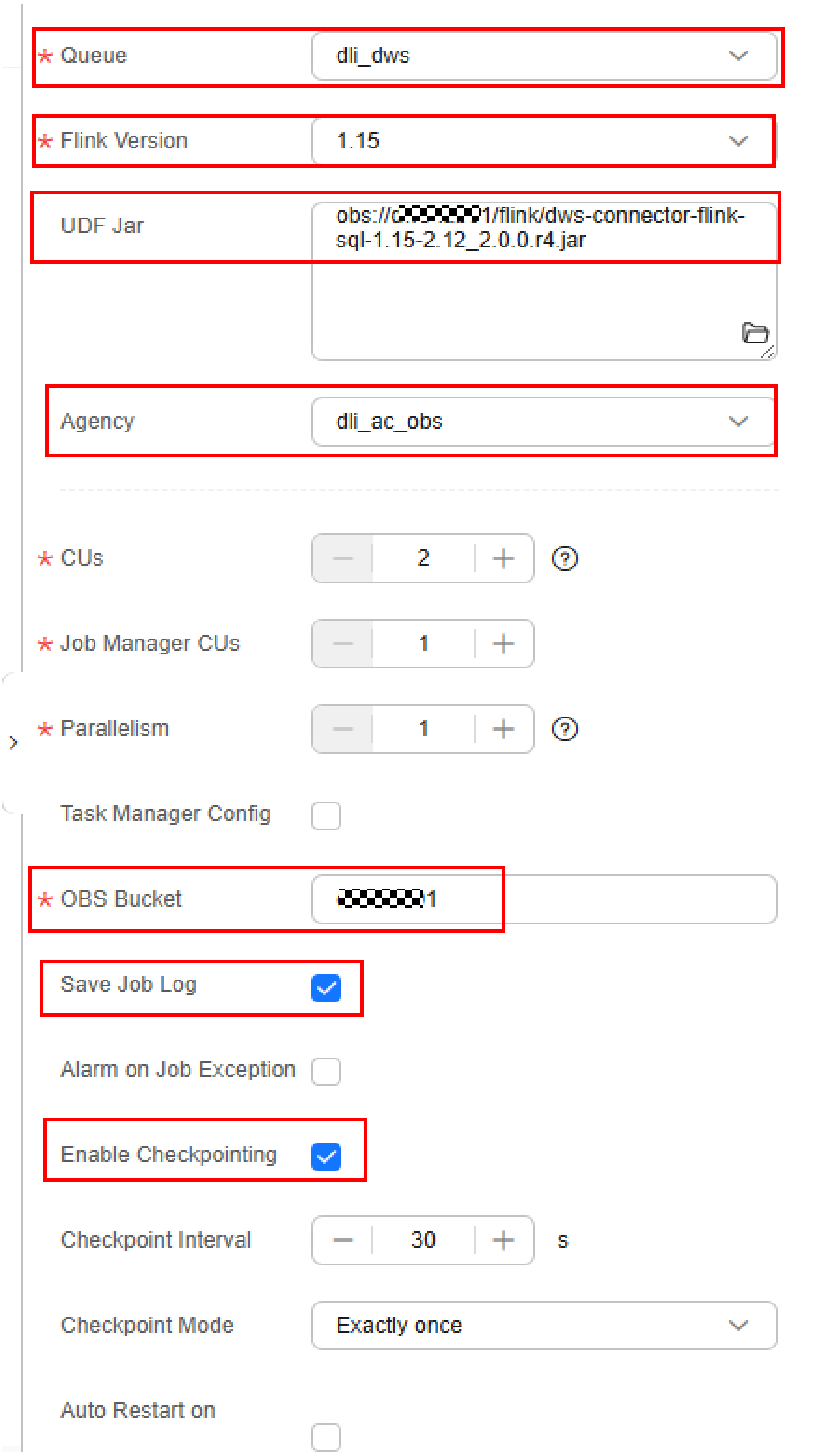


Step 4 Click **OK**. The page for editing the job is displayed.

Step 5 Set the following parameters on the right of the page. Retain the default values for other parameters that are not described in the table.

Table 2-15 Flink job parameters

Parameter	Value
Queue	**dli_dws** created in **4**.
Flink Version	1.15 or later. (The actual version is subject to the GUI.)
UDF Jar	JAR file in the OBS bucket created in **Step 5**.
Agency	Agency created in **Step 1**.
OBS Bucket	Bucket created in **Step 5**.
Save Job Log	Check the box.
Enable Checkpointing	Check the box.
Other parameters	Retain the default value.



Step 6 Copy the following SQL code to the SQL code window on the left.

For how to obtain the internal IP address of the RDS database, see **Step 2.3**. For details about how to obtain the internal IP address of the DWS cluster, see **Step 8.2**. Change the password of user **root** of the RDS database and the password of user **dbadmin** of DWS.

The following describes the common parameters in the Flink SQL job code:

- **connector**: connector type of the data source. For MySQL, set this parameter to **mysql-cdc**. For DWS, set this parameter to **gaussdb**. For more information, see **Connectors**.
- **driver**: JDBC driver name of the DWS. The value can be fixed to **com.huawei.gauss200.jdbc.Driver**.
- **write.mode**: data import mode. The value can be **copy**, **insert**, or **upsert**.

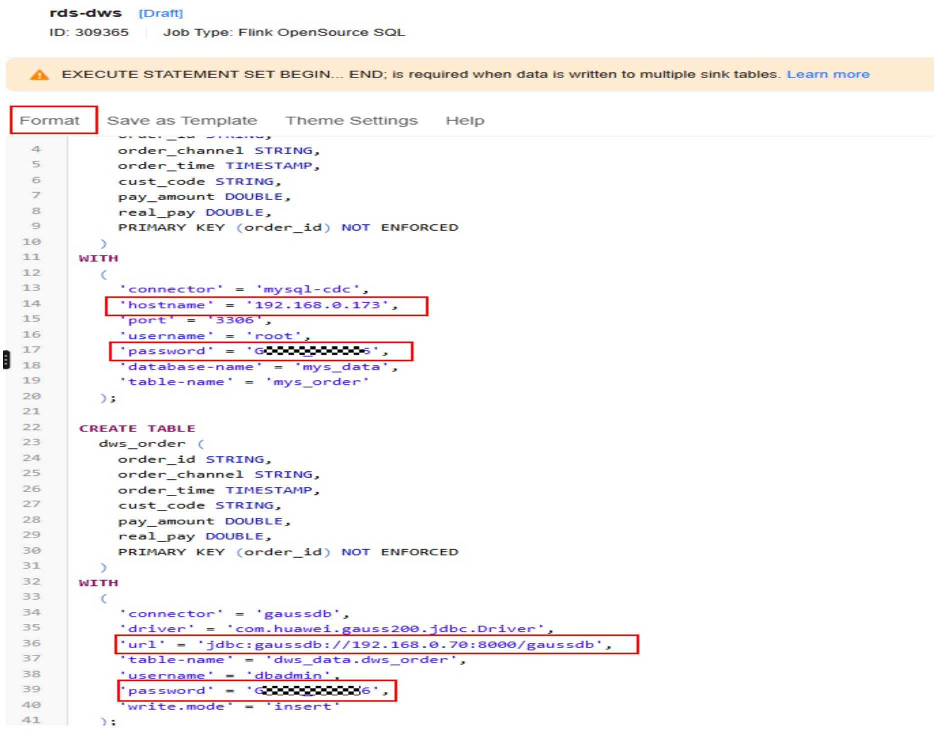
```
CREATE TABLE
  mys_order (
    order_id STRING,
    order_channel STRING,
    order_time TIMESTAMP,
    cust_code STRING,
    pay_amount DOUBLE,
    real_pay DOUBLE,
    PRIMARY KEY (order_id) NOT ENFORCED
  )
WITH
  (
    'connector' = 'mysql-cdc',
    'hostname' = 'Private IP address of the RDS DB instance',
    'port' = '3306',
    'username' = 'root',
    'password' = 'Password of user root of the RDS DB instance',
    'database-name' = 'mys_data',
    'table-name' = 'mys_order'
  );

CREATE TABLE
  dws_order (
    order_id STRING,
    order_channel STRING,
    order_time TIMESTAMP,
    cust_code STRING,
    pay_amount DOUBLE,
    real_pay DOUBLE,
    PRIMARY KEY (order_id) NOT ENFORCED
  )
WITH
  (
    'connector' = 'gaussdb',
    'driver' = 'com.huawei.gauss200.jdbc.Driver',
    'url' = 'jdbc:gaussdb://DWS cluster private IP address:8000/gaussdb',
    'table-name' = 'dws_data.dws_order',
    'username' = 'dbadmin',
    'password' = 'Password of DWS user dbadmin',
    'write.mode' = 'insert'
  );

INSERT INTO
  dws_order
SELECT
  *
FROM
  mys_order;
```

Step 7 Click **Format** and click **Save**.

NOTICE

Click **Format** to format the SQL code. Otherwise, new null characters may be introduced during code copy and paste, causing job execution failures.

Figure 2-28 Flink job parameters

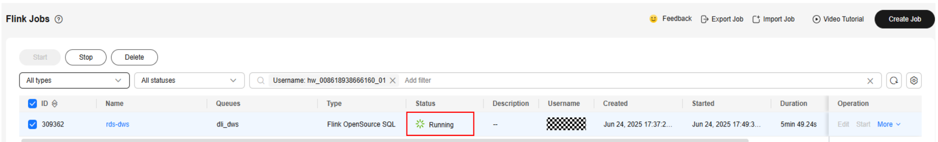


Step 8 Return to the DLI console home page and choose **Job Management** > **Flink Jobs** on the left.

Step 9 Click **Start** on the right of the job name **rds-dws** and click **Start Now**.

Wait for about 1 minute and refresh the page. If the status is **Running**, the job is executed.

Figure 2-29 Running succeeded



----End

Step 7: Verify Data Synchronization

Step 1 Go back to the SQL window of the DWS database. If the connection times out, perform the following operations to log in again:

1. Go to the DWS console.
2. In the navigation pane on the left, choose **Dedicated Clusters** > **Clusters**, and click **Log In** on the right of **dws-demo**.

Step 2 Check whether two rows of data in the MySQL table have been synchronized to DWS.

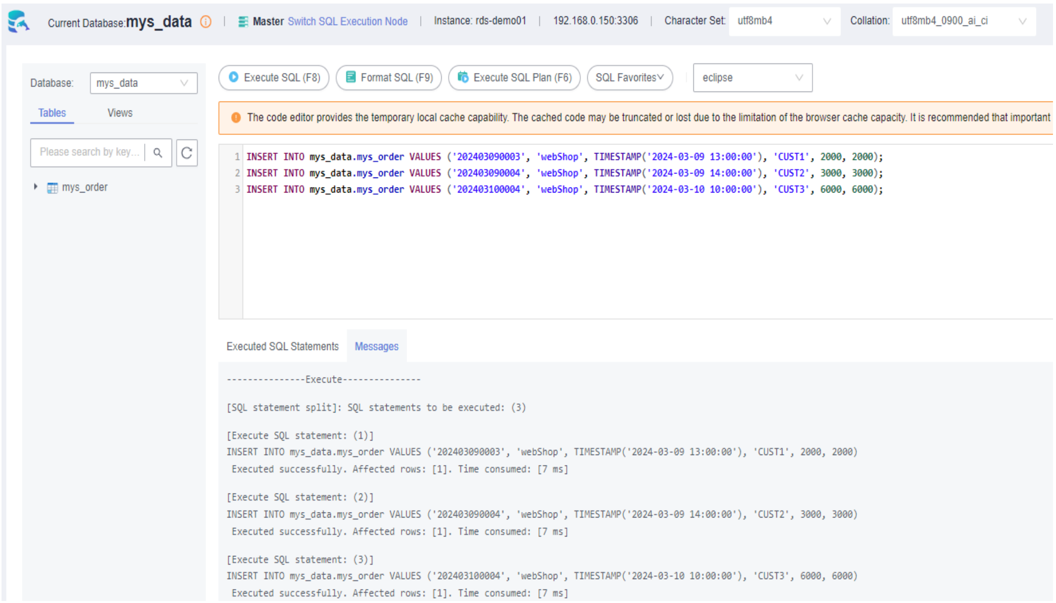
```
SELECT * FROM dws_data.dws_order;
```

Figure 2-30 Query result

Step 3 Switch to the RDS for MySQL page and run the following statements to insert three new data records:

```
INSERT INTO mys_data.mys_order VALUES ('202403090003', 'webShop', TIMESTAMP('2024-03-09 13:00:00'), 'CUST1', 2000, 2000);
INSERT INTO mys_data.mys_order VALUES ('202403090004', 'webShop', TIMESTAMP('2024-03-09 14:00:00'), 'CUST2', 3000, 3000);
INSERT INTO mys_data.mys_order VALUES ('202403100004', 'webShop', TIMESTAMP('2024-03-10 10:00:00'), 'CUST3', 6000, 6000);
```

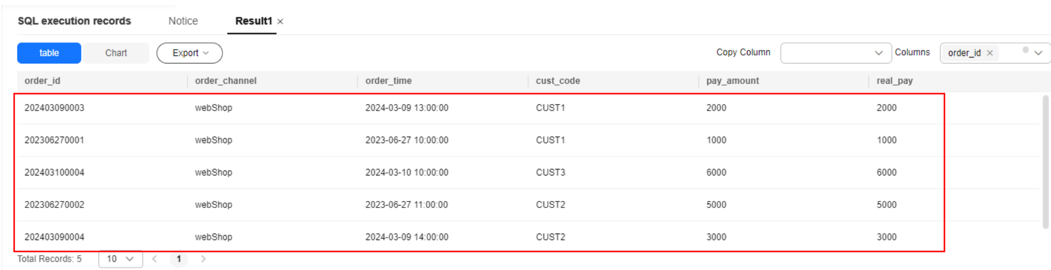
Figure 2-31 New MySQL data



Step 4 Go back to the SQL window of DWS and run the following SQL statement again. The returned result shows that the MySQL data has been synchronized to DWS in real time.

```
SELECT * FROM dws_data.dws_order;
```

Figure 2-32 Real-time data synchronization



----End

More Information

Storing authentication information for a data source directly in the job script for Flink cross-source development can result in password exposure. To enhance security, use DLI's datasource authentication function instead of specifying MySQL and DWS usernames and passwords directly in job scripts.

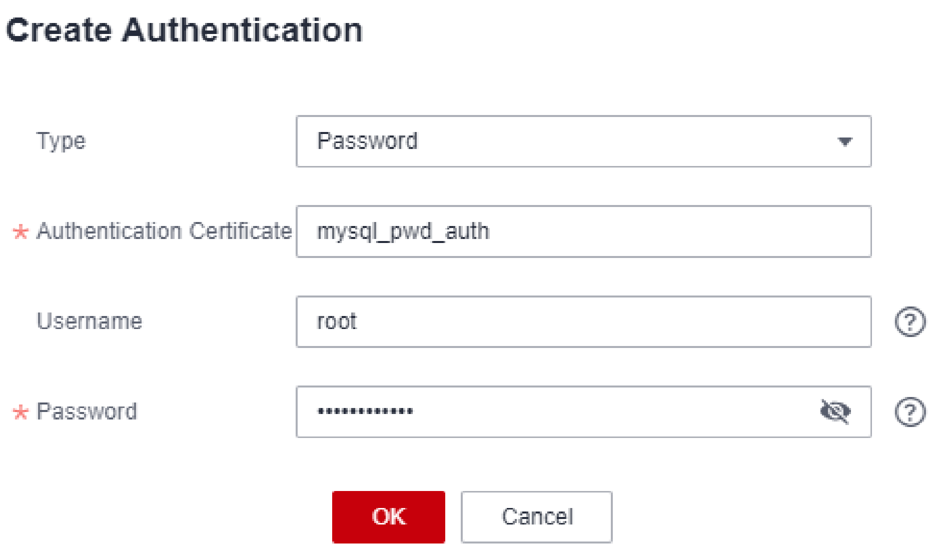
Step 1 Log in to the **DLI console** and choose **Datasource Connections** > **Datasource Authentication**.

Step 2 Click **Create**.

Step 3 Create the password authentication for the **root** user of the MySQL database.

1. Set the following parameters:
   – **Type**: **Password**
   – **Authentication Certificate**: **mysql_pwd_auth**
   – **Username**: **root**
   – **Password**: password of user **root**

   Figure 2-33 MySQL password authentication

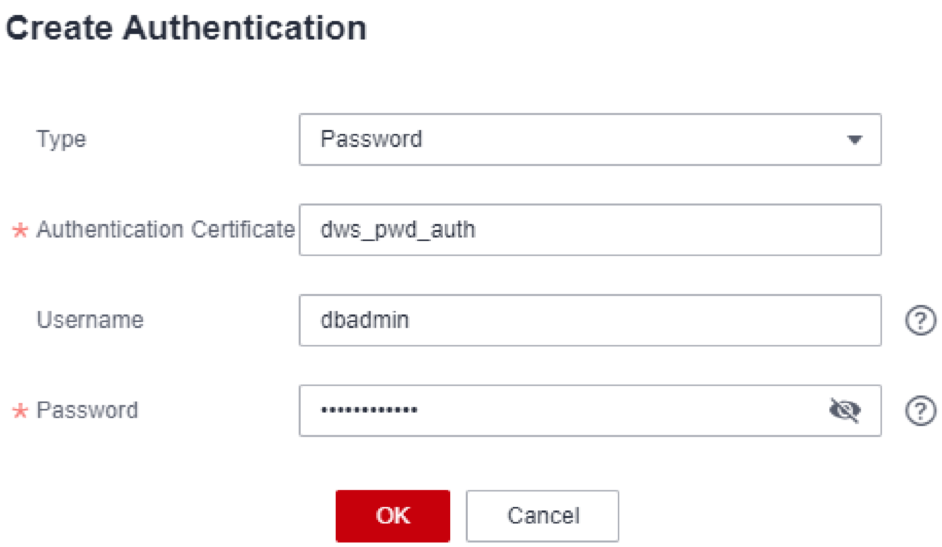
   

2. Click **OK**.

Step 4 Create password authentication for the **dbadmin** user of DWS.

1. Set the following parameters:
   – **Type**: **Password**
   – **Authentication Certificate**: **dws_pwd_auth**
   – **Username**: **dbadmin**
   – **Password**: password of user **dbadmin**

Figure 2-34 DWS password authentication



2. Click **OK**.

Step 5 On the DLI console, choose **Job Management** > **Flink Jobs**. Locate the row that contains the job created in **Step 6: Create a DLI Flink Job**, and choose **More** > **Stop** to stop the job.

Step 6 After the job is stopped, you can edit the job name.

Step 7 Replace the SQL script with the latest one.

Replace the private IP addresses of RDS and DWS.

```
CREATE TABLE mys_order (
 order_id STRING,
 order_channel STRING,
 order_time TIMESTAMP,
 cust_code STRING,
 pay_amount DOUBLE,
 real_pay DOUBLE,
 PRIMARY KEY (order_id) NOT ENFORCED )
WITH (
 'connector' = 'mysql-cdc',
 'hostname' = 'Private IP address of RDS',
 'port' = '3306',
 'pwd_auth_name' = 'mysql_pwd_auth',
 'database-name' = 'mys_data',
 'table-name' = 'mys_order' );

CREATE TABLE dws_order (
  order_id STRING,
  order_channel STRING,
  order_time TIMESTAMP,
  cust_code STRING,
  pay_amount DOUBLE,
  real_pay DOUBLE,
  PRIMARY KEY (order_id) NOT ENFORCED )
WITH (
  'connector' = 'gaussdb',
  'driver' = 'com.huawei.gauss200.jdbc.Driver',
  'url' = 'jdbc:gaussdb://DWS private IP address:8000/gaussdb',
  'table-name' = 'dws_data.dws_order',
  'pwd_auth_name' = 'dws_pwd_auth',
  'write.mode' = 'insert' );

INSERT INTO dws_order SELECT * FROM mys_order;
```

Step 8 Click **Format** and click **Save**.

Step 9 Restart the job and verify data synchronization by referring to **Step 7: Verify Data Synchronization**.

----End

2.4 Using CDM to Migrate Data from Hologres to a DWS Cluster

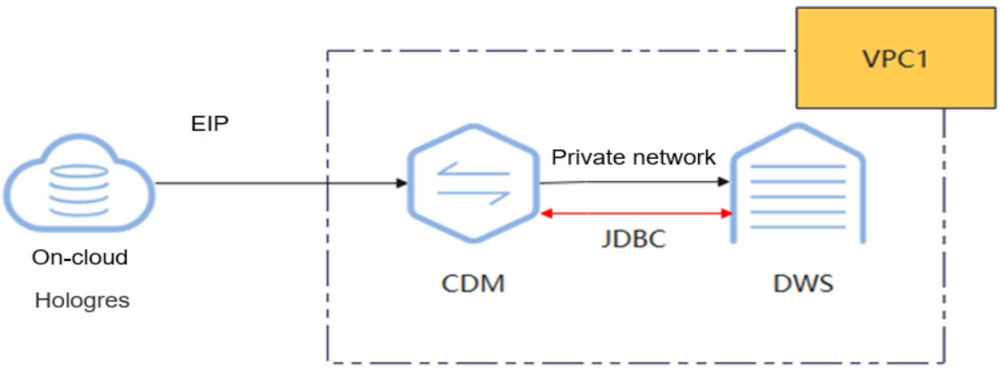
This practice demonstrates how to use Cloud Data Migration (CDM) to migrate data from Hologres to DWS.

CDM is an efficient and easy-to-use service for batch data migration. For more information, see **Cloud Data Migration**.

This practice takes about 90 minutes and uses cloud services such as **Virtual Private Cloud (VPC) and Subnet**, **Elastic IP (EIP)**, **Cloud Data Migration (CDM)**, and **DWS**. The basic process is as follows:

1. **Prerequisites**
2. **Step 1: Migrating Metadata**
3. **Step 2: Migrating Table Data**
4. **Step 3: Checking Table Data**

Figure 2-35 Hologres migration



Notes and Constraints

- If there are many tables to migrate, it is recommended to perform the migration in batches. You can batch by service or by table data volume.
- If DELETE or UPDATE operations occur during CDM migration, data consistency cannot be guaranteed afterward. Re-migration will be required in such cases.
- For large table data, migrate the data in slices.
- A single database migration job can migrate only one database at a time. To migrate multiple databases, you need to configure multiple migration jobs.

Prerequisites

- You have purchased DWS and CDM clusters. For details, see **CDM User Guide**.
- The Hologres cluster and DWS cluster can communicate with CDM. In this example, DWS and CDM are created in the same region, private cloud, and subnet.
- You have the migration permission.
- The source and destination clients have been installed.
- The migration tools listed in **Table 2-16** have been prepared: DSC and DataCheck.
- The runtime environment of DataCheck meets the following requirements:
  - The server is compatible with 64-bit operating systems and can run on either Linux or Windows.
  - Either JDK or JRE 1.8 has been installed on the system.
  - The server where DataCheck is installed and running can communicate with the database to be connected.

Table 2-16 Tools for Hologres migration

Tool	Description	How to Obtain
DSC	Syntax migration tool for DWS	Obtain the **download link**.
DataCheck	Data check tool	Contact technical support.

Step 1: Migrating Metadata

Step 1 Query user roles and permissions in Hologres:

```
SELECT ROLNAME FROM pg_roles;
SELECT user_display_name(ROLNAME) FROM pg_roles;
```

Step 2 In DWS, the separation of permissions is disabled by default after cluster creation. Database system administrators have the same permissions as object owners. By default, only the object owner or system administrator can query, modify, or destroy the object. Based on the roles and permissions queried in Hologres, create corresponding roles and permissions in DWS and grant user permissions accordingly:

- Use GRANT statements to grant object permissions to the target user.
```
GRANT USAGE ON SCHEMA schema TO user;
GRANT SELECT ON TABLE schema.table To user;
```
- Enable the user to inherit the object permissions of the role.
```
CREATE ROLE role_name WITH CREATEDB PASSWORD '*******';
GRANT role_name to user;
```

Step 3 Export the source syntax. Exporting the source syntax, which represents the implementation logic of customer's services, from Hologres and modifying it to be compatible with DWS can reduce the modeling workload and improve service migration efficiency.

Export all syntax:

```
SELECT hg_dump_script('schema_name.table_name');
```

NOTE

- Since the source syntax involves the identification of the service scope, operations require a DBA familiar with the service. It is recommended that the source syntax be provided by the customer's DBA.
- To export data in batches, you can use UNION ALL to associate all tables to be queried. The syntax format is as follows:
  ```
  SELECT hg_dump_script('schema_name.table_name')
  UNION ALL
  SELECT hg_dump_script('schema_name.table_name')
  ...
  ```
- If the execution fails, use the command below to create an extension in the database, and then execute the preceding SQL statements.
  ```
  CREATE EXTENSION hg_toolkit;
  ```

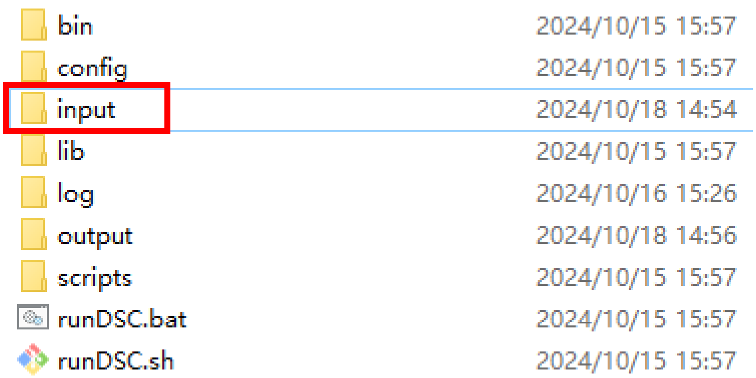
Step 4 Connect to DWS and execute the SQL statement below to create a database. You are advised to use the MySQL-compatible mode to create the database.

```
CREATE DATABASE tldg WITH ENCODING 'UTF-8' TEMPLATE template0 DBCOMPATIBILITY 'MYSQL';
```

Step 5 Use the DSC tool to convert the DDL syntax.

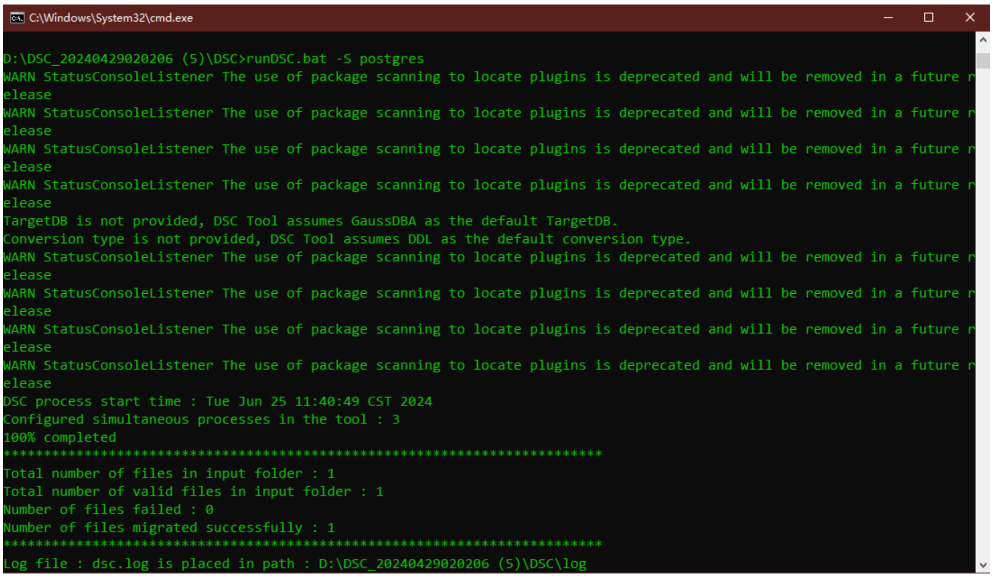
1. Unzip the DSC tool package obtained in **Prerequisites**.
2. Save the DDL syntax files to be converted into the **input** folder of DSC.

Figure 2-36 input directory



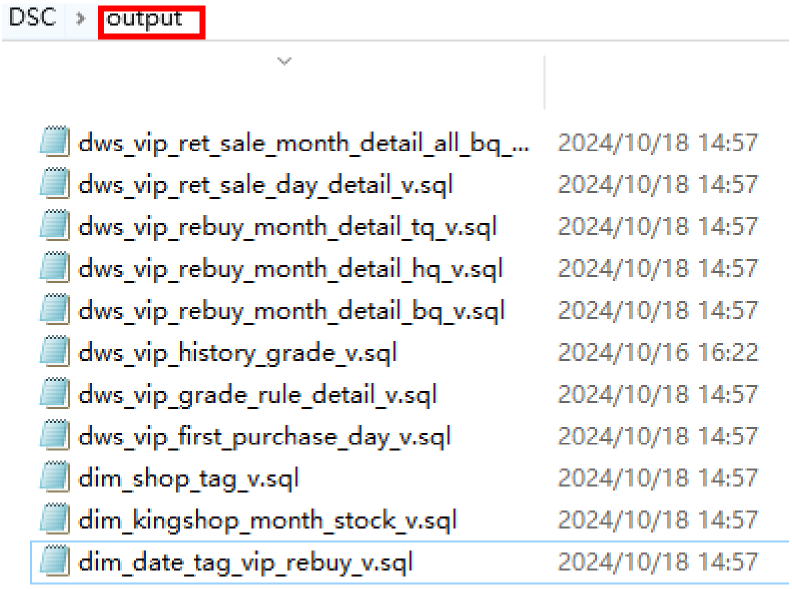
3. Open the command line tool and double-click **runDSC.bat** in Windows. Run **runDSC.sh** in Linux.
4. Convert the syntax:
   ```
   runDSC.bat -S Hologres
   ```

Figure 2-37 DDL syntax conversion



5. View the conversion result in the **output** folder.

Figure 2-38 DDL conversion result



6. Connect to DWS, execute the DDL statement converted in the previous step to create a table.

NOTE

For more information about DSC, see **DSC Tool Guide**.

----End

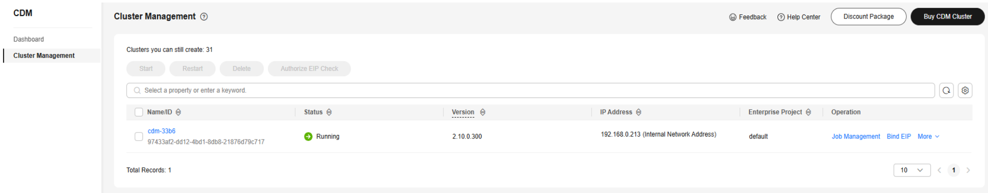
Step 2: Migrating Table Data

CDM supports both **table-level** and **database-level** migrations.

Step 1 Configure the source link for CDM. Since Hologres' table creation syntax is compatible with PostgreSQL, you can simply choose PostgreSQL data sources when configuring the CDM link.

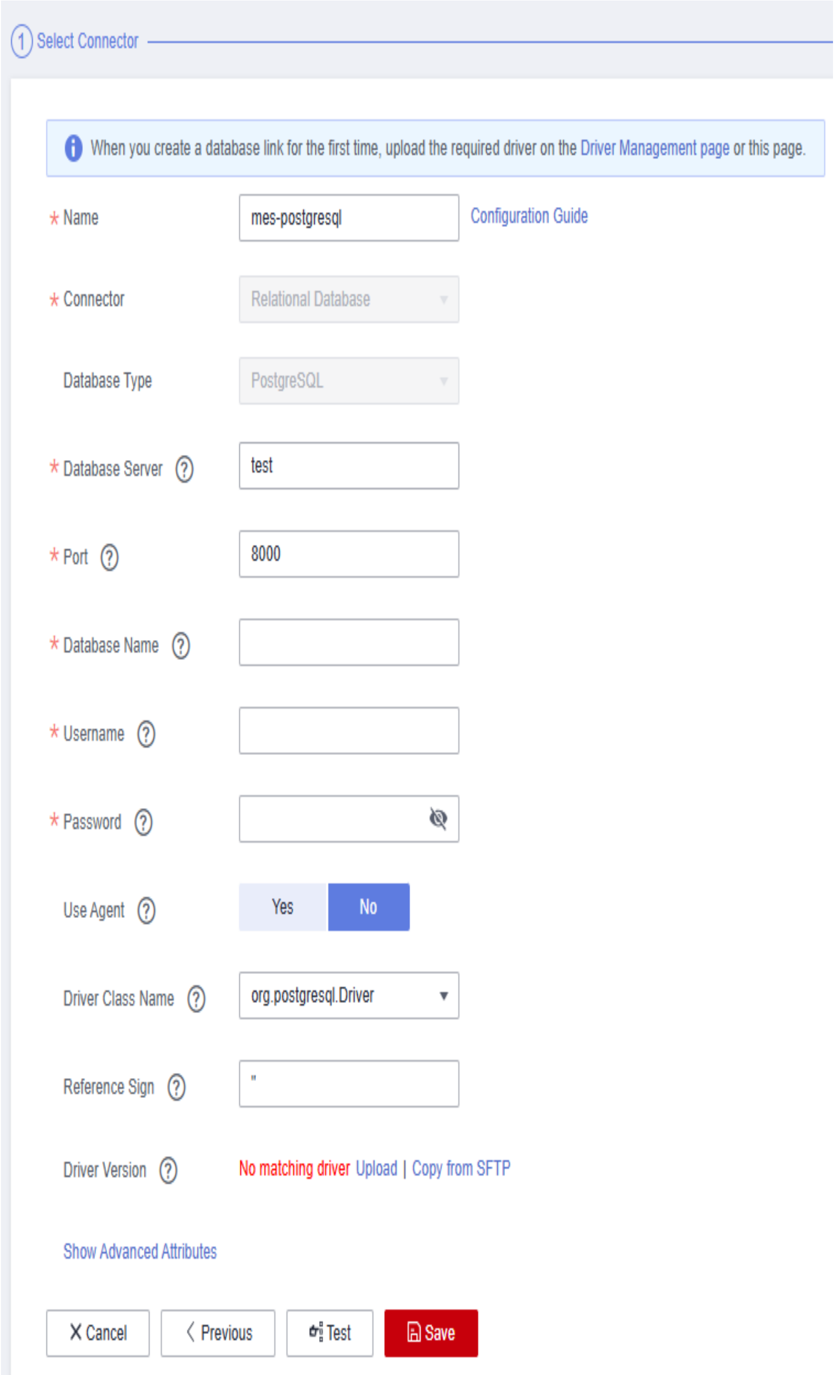
1. Log in to the **CDM console**. In the navigation pane, click **Cluster Management**.
2. If CDM is connected to Hologres through the public network, bind an EIP. For details, see **Binding or Unbinding an EIP**.
3. Click **Job Management** next to the cluster name.

Figure 2-39 CDM cluster management page



4. Before establishing a job link for the first time, install the driver. Choose **Links** > **Driver Management** and **install the PostgreSQL driver**.
5. After the driver installation, click **Create Link** on the link management page, select **PostgreSQL** and then click **Next**.
6. Enter the Hologres database information.

Figure 2-40 Hologres connection information

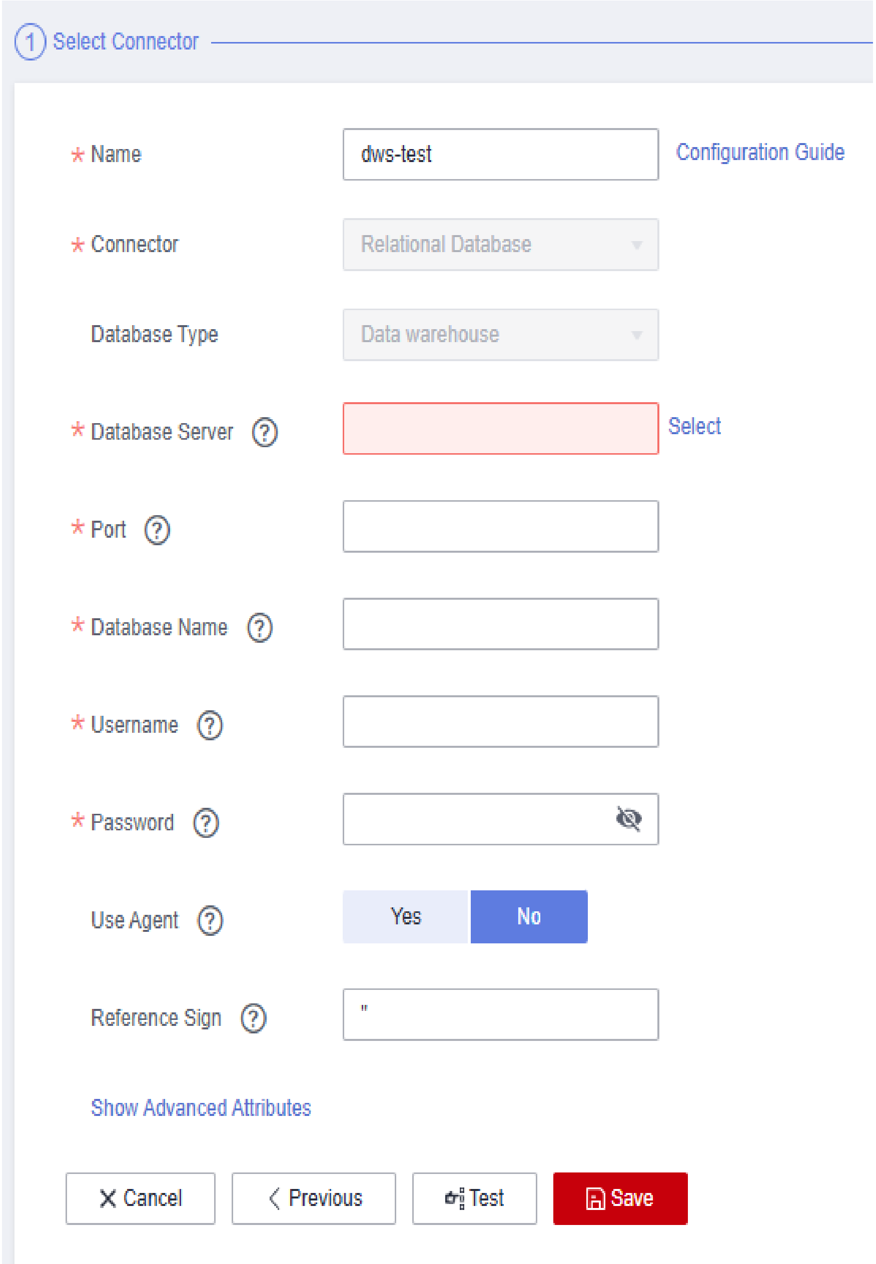


7. Click **Test** to check connectivity, and then click **Save**.

Step 2 Configure the destination link for CDM.

1. Similarly, choose **Job Management** > **Links** and click **Create Link**.
2. Select **Data Warehouse Service** and click **Next**.
3. Enter the DWS database information.

Figure 2-41 DWS connection information

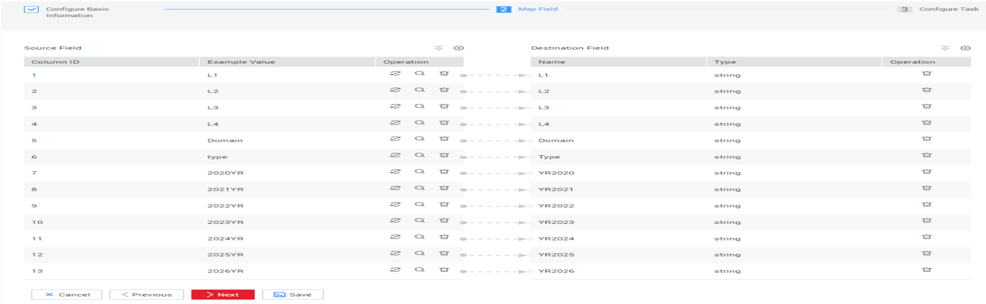


4. Click **Test** to check connectivity, and then click **Save**.

Step 3 Configure and start a table-level migration job.

1. Click the **Table/File Migration** tab. This tab displays single-table migration jobs.
2. Enter the source and destination information.
3. Click **Next** to map fields.

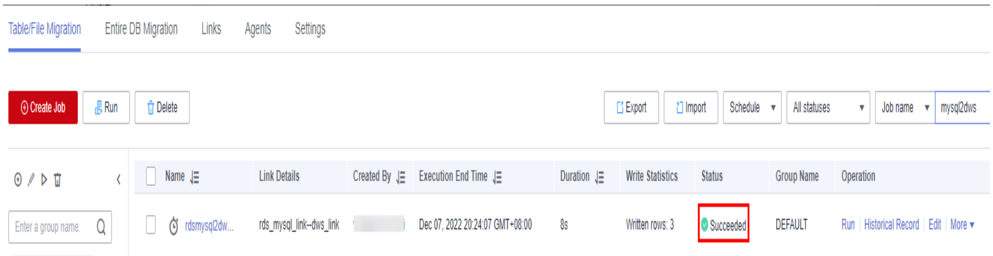
Figure 2-42 Mapping fields for table-level migration



4. Confirm the information and click **Next**.
5. On the task configuration page, configure **Concurrent Extractors** (data extracted concurrently). The default value is **1**, but you can increase it. However, it is recommended to keep it at or below **4**. Then, click **Save and Run**.

   After the migration job begins, you can view the status in the job list.

Figure 2-43 Job status



Step 4 Configure and start a database-level migration job.

1. Click the **Entire DB Migration** tab and click **Create Job**.
2. Enter the source information on the left and the destination information on the right. Click **Next**.
3. Select all tables or the tables to migrate, click the right arrow in the middle to move them to the right pane, and then click **Next**.
4. Configure job parameters.
   – **Concurrent Subjobs**: Indicates the number of tables to migrate simultaneously. The default value is **10**; it is recommended to set it to a value less than **5**.
   – **Concurrent Extractors**: Indicates data extracted concurrently. The default value is **1**, but you can increase it. However, it is recommended to keep it at or below **4**.

   Confirm the information and click **Save and Run**.
5. Wait until the migration job is complete. Click the job name to view the migration status of each table.

----End

Step 3: Checking Table Data

After the migration, check whether the data on the source and destination databases is consistent using DataCheck.

Step 1 Download and unzip **DataCheck-*.zip**, and then go to the **DataCheck-*** directory to use it. For details about how to use the files in the directory, see **Table 2-17**.

Step 2 Configure the tool package.

- **In Windows**:

  Open the **dbinfo.properties** file in the **conf** folder and configure it based on your actual needs. The following figure shows the configuration of the Holo source.

Figure 2-44 Configuring DataCheck

```
[Source Database Info]
## src.dbtype support: mysql/pg/oracle/dws_src/hive/holo/redshift/bigquery
src.dbtype = holo
src.dbname = j[redacted]t
src.ip = hgpost[redacted].hologres.aliyuncs.com
src.port = 80
src.username = [redacted]
src.passwd = C0[redacted]9

#Bigquery OAuth
src.projectid =
src.oauthtype = 0
src.oauthserviceacctemail =
src.oauthpvtkeypath =

#
#
src.jar.path =
input.file.path =

[DWS Database Info]
## dws.dbtype support: dws
dws.dbtype = dws
dws.dbname = t[redacted]
dws.ip = 1[redacted]76
dws.port = 8000
dws.username = d[redacted]n
dws.passwd = [redacted]8

[Config Info]
#
config.sum.switch = on
config.avg.switch = on
```

NOTE

You can use the command below in the tool to generate the ciphertext of **src.passwd** and **dws.passwd**.

encryption.bat *password*

```
D:\temp\0116\3\DataCheck\bin>encryption.bat B[redacted]
0xwQnR1hwIytw6r9s3[redacted]
```

After the command is executed, an encrypted file is generated in the local **bin** directory.

datacheck.bat	2023/8/1 15:47
datacheck.sh	2023/8/1 15:47
DATE_CHECK_KEY	2024/1/18 17:24
DATE_CHECK_VI	2024/1/18 17:24
encryption.bat	2023/8/30 9:47
encryption.sh	2023/8/30 9:47

- **In Linux**:

  The method of generating the ciphertext is similar to that for Windows. The command is **sh encryption.sh** *Password*. Other steps are the same.

```
[root@MRS-node-master2Ima0 bin]# sh encryption.sh G[redacted]
qKTec6ahImcc+1JE5[redacted]
```

Step 3 Check data.

In Windows:

1. Open the **check.input** file, enter the schemas, databases, source table, and destination table to be checked, and fill in **Row Range** with a data query statement to specify the query scope.

   NOTE

   – After configuring the source database name in the configuration file, the source database name in the **check.input** file defaults to this. However, if a different source database name is specified in the **check.input** file, it will take precedence.

   – The **Check Strategy** offers three levels: **high**, **middle**, and **low**. If unspecified, the default is **low**.

   – The **Check Mode** supports **statistics** (statistical value checks).

   The following figure shows the **check_input** file for metadata comparison.

   Figure 2-45 check_input

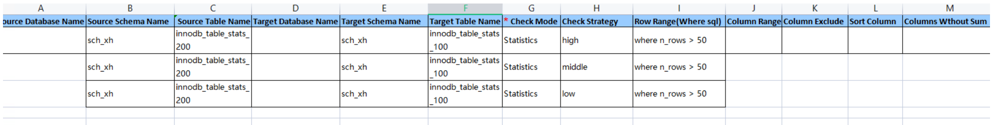
A	B	C	D	E	F	G	H	I	J	K	L	M
Source Database Name	Source Schema Name	Source Table Name	Target Database Name	Target Schema Name	Target Table Name	* Check Mode	Check Strategy	Row Range(Where sql)	Column Range	Column Exclude	Sort Column	Columns Wthout Sum
	sch_xh	t_metadata_different		sch_xh	t_metadata_different	Metadata						

2. Run the **datacheck.bat** command in the **bin** directory to execute the check tool.

```
C:\Users\Administrator\Desktop\DataCheck-1.0-SNAPSHOT\DataCheck-1.0-SNAPSHOT\bin>datacheck.bat
```

3. View the generated check result file **check_input_result.xlsx**.

   The following figure shows the statistical value check.



A	B	C	D	E	F	G	H	I	J	K	L	M
ource Database Name	Source Schema Name	Source Table Name	Target Database Name	Target Schema Name	Target Table Name	* Check Mode	Check Strategy	Row Range(Where sql)	Column Range	Column Exclude	Sort Column	Columns Wthout Sum
	sch_xh	innodb_table_stats_200		sch_xh	innodb_table_stats_100	Statistics	high	where n_rows > 50				
	sch_xh	innodb_table_stats_200		sch_xh	innodb_table_stats_100	Statistics	middle	where n_rows > 50				
	sch_xh	innodb_table_stats_200		sch_xh	innodb_table_stats_100	Statistics	low	where n_rows > 50				

In Linux:

1. Edit and upload the **check_input.xlsx** file. Refer to the step 1 for Windows.
2. Run the **sh datacheck.sh** command to execute the check tool.

```
[root@ecs-[redacted] bin]# sh datacheck.sh
```

3. View the check result in the **check_input_result.xlsx** file. (The check result analysis is the same as that for Windows.)

----End

Related Information

Table 2-17 Description of the **DataCheck** directory

File or Folder		Description
DataCheck	bin	Saves the entry script of the check tool. • Windows version: **datacheck.bat** • Linux version: **datacheck.sh**
	conf	Configuration file, which is used to configure the connection between the source database and the destination database and set log printing.
	lib	Stores JAR packages required for running the check tool.
	check_input.xlsx	• Information about the table to be checked, including schema, table, and column names. • Check level information and check rules of users. Three check levels are supported: **high**, **middle**, and **low**. The default value is **low**.
	logs	The package does not include this file. Once the check tool runs, it automatically generates this file to log the tool's execution process.
	check_input_result.xlsx	The package does not include this file. Once the check tool runs, a check result file will be created in the same location as **check_input.xlsx**.

Table 2-18 Basic functions of the data check tool

DataCheck
• Check data in DWS, MySQL, and PostgreSQL databases. • Check common fields, such as numeric, time, and character types. • Support three check levels, including high, middle, and low. • Check schemas, table names, and column names. • Specify the check scope of records. By default, all records are checked. • Support various check methods, including **count(*)**, **max**, **min**, **sum**, **avg**, and sampling details check. • Output the check result and related check details.

Table 2-19 Data check levels

Check Level	Description	Syntax
Low	• Quantity check	• Number of records: **COUNT(*)**
Middle	• Quantity check • Numeric type check	• Number of records: **COUNT(*)** • Value check: **MAX**, **MIN**, **SUM**, and **AVG**
High	• Quantity check • Numeric type check • Date type check • Character type check	• Number of records: **COUNT(*)** • Value check: **MAX**, **MIN**, **SUM**, and **AVG** • Date check: **MAX** and **MIN** • Character check: **order by limit 1000**, which reads the data and checks whether the content is the same

2.5 Using CDM to Migrate Data from AnalyticDB for MySQL to a DWS Cluster

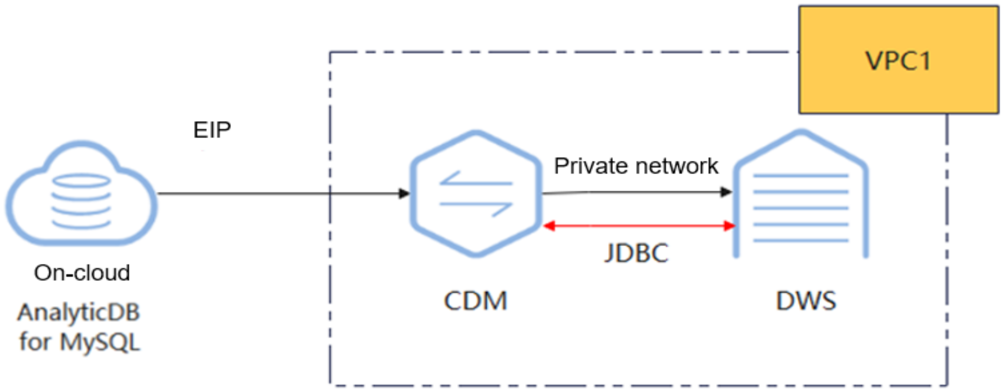
This practice demonstrates how to use CDM to migrate data from AnalyticDB for MySQL (ADB) to DWS.

CDM is an efficient and easy-to-use service for batch data migration. For more information, see **Cloud Data Migration**.

This practice takes about 90 minutes and uses cloud services such as **Virtual Private Cloud (VPC) and Subnet**, **Elastic IP (EIP)**, **Cloud Data Migration (CDM)**, and **DWS**. The basic process is as follows:

1. **Prerequisites**
2. **Step 1: Migrating Metadata**
3. **Step 2: Migrating Table Data**
4. **Step 3: Verifying Data Consistency**

Figure 2-46 ADB migration



Notes and Constraints

- If DELETE or UPDATE operations occur during CDM migration, data consistency cannot be guaranteed afterward. Re-migration will be required in such cases.
- A single database migration job can migrate only one database at a time. To migrate multiple databases, you need to configure multiple migration jobs.
- You need to create databases and schemas to be synchronized in the destination DWS.
- In ADB, the database level corresponds to the schema level in DWS.

Prerequisites

- You have purchased DWS and CDM clusters. For details, see **CDM User Guide**.
- The ADB cluster and DWS cluster can communicate with CDM. In this example, DWS and CDM are created in the same region, private cloud, and subnet.
- You have the migration permission.
- The source and destination clients have been installed.
- The IP address of the CDM cluster has been whitelisted in the data security settings within the ADB source cluster.
- The migration tools listed in **Table 2-20** have been prepared: DSC and DataCheck.
- The runtime environment of DataCheck meets the following requirements:

– The server is compatible with 64-bit operating systems and can run on either Linux or Windows.
– Either JDK or JRE 1.8 has been installed on the system.
– The server where DataCheck is installed and running can communicate with the database to be connected.

Table 2-20 Tools for ADB migration

Tool	Description	How to Obtain
DSC	Syntax migration tool for DWS	Obtain the **download link**.
DataCheck	Data check tool	Contact technical support.

Step 1: Migrating Metadata

Step 1 Export the source syntax. Exporting the source syntax, which represents the implementation logic of customer's services, from ADB and modifying it to be compatible with DWS can reduce the modeling workload and improve service migration efficiency.

To do so, select the target database in the ADB console, choose **Export** > **Export Table Creation Statements**, and save **DDL_migration.sql**.

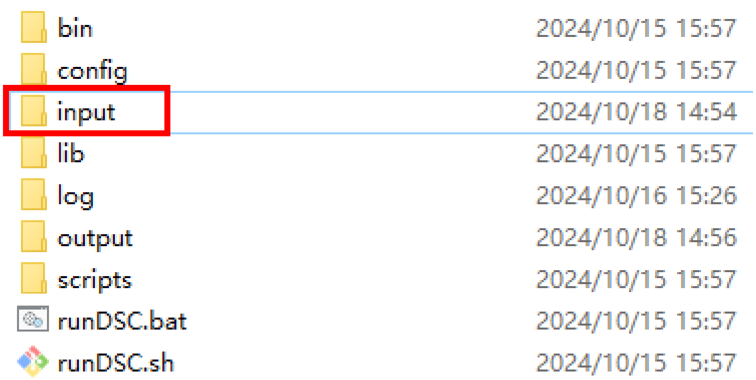
NOTE

Since the source syntax involves the identification of the service scope, operations require a DBA familiar with the service. It is recommended that the source syntax be provided by the customer's DBA.

Step 2 Use the DSC tool to convert the DDL syntax.

1. Unzip the DSC tool package obtained in **Prerequisites**.
2. Save the DDL syntax files to be converted into the **input** folder of DSC.

Figure 2-47 input directory

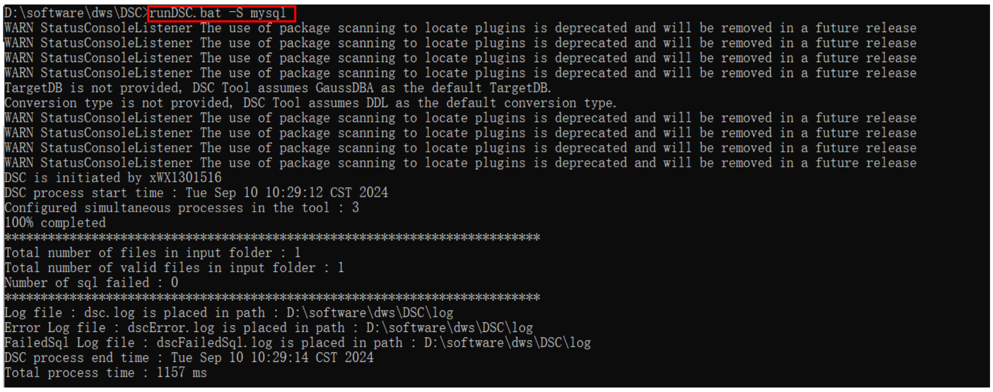


3. Open the command line tool and double-click **runDSC.bat** in Windows. Run **runDSC.sh** in Linux.

4. Convert the syntax:

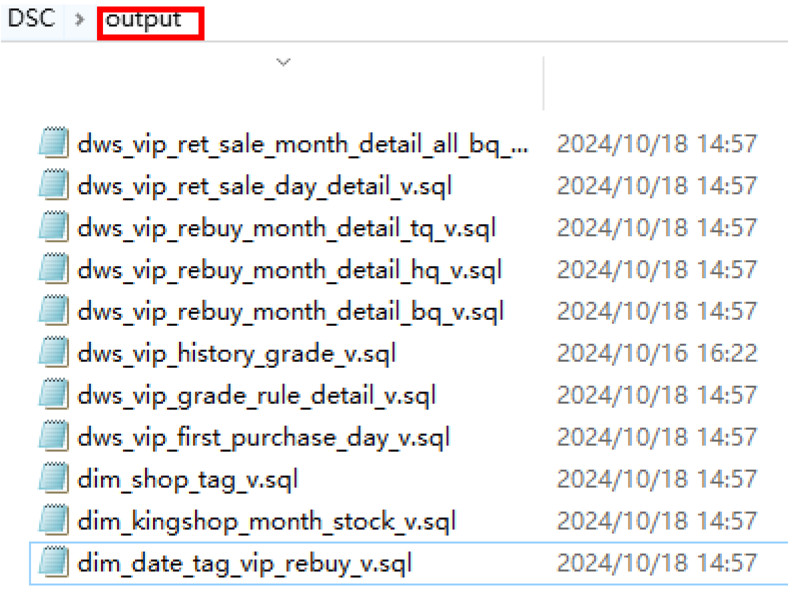
```
runDSC.bat -S mysql
```

Figure 2-48 DDL conversion



5. View the conversion result in the **output** folder.

Figure 2-49 DDL conversion result



Step 3 Connect to DWS and run the SQL statement below to create a destination database, which in this practice is **migration**.

```
CREATE DATABASE database_name WITH ENCODING 'UTF-8' DBCOMPATIBILITY 'mysql' TEMPLATE template0;
```

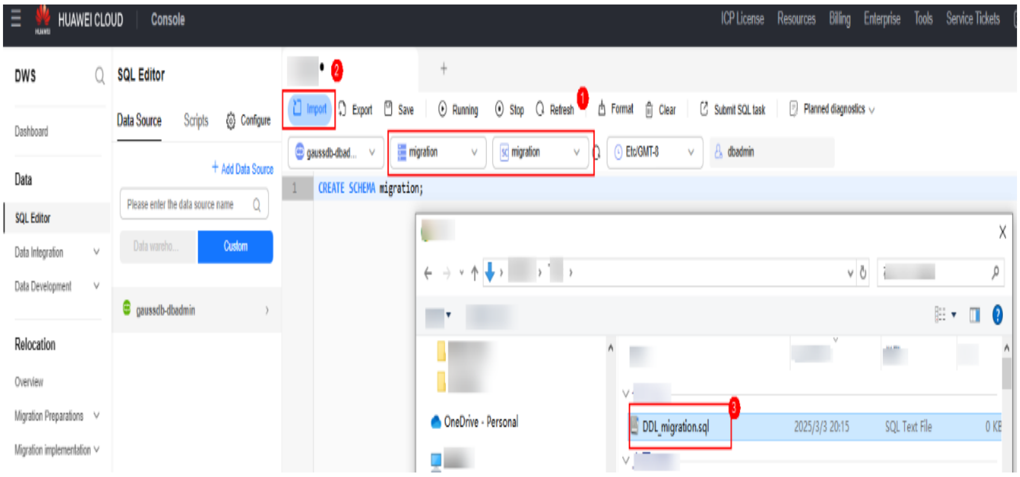
Step 4 The concept of a database in ADB is equivalent to the concept of a schema in DWS. A schema needs to be created in the destination DWS database.

First, switch to the newly created database, then execute the following SQL statement to create a schema.

```
CREATE SCHEMA schema_name;
```

Step 5 In the SQL editor window of DWS, select the created database and schema, and click **Import** to import the table creation statement converted in **Step 2**.

Figure 2-50 Importing DDL statements



Step 6 After the import, click the run button to run the SQL statement to create a table.

Step 7 Check whether the table is created:

```
SELECT table_name FROM information_schema.tables WHERE table_schema = 'migration';
```

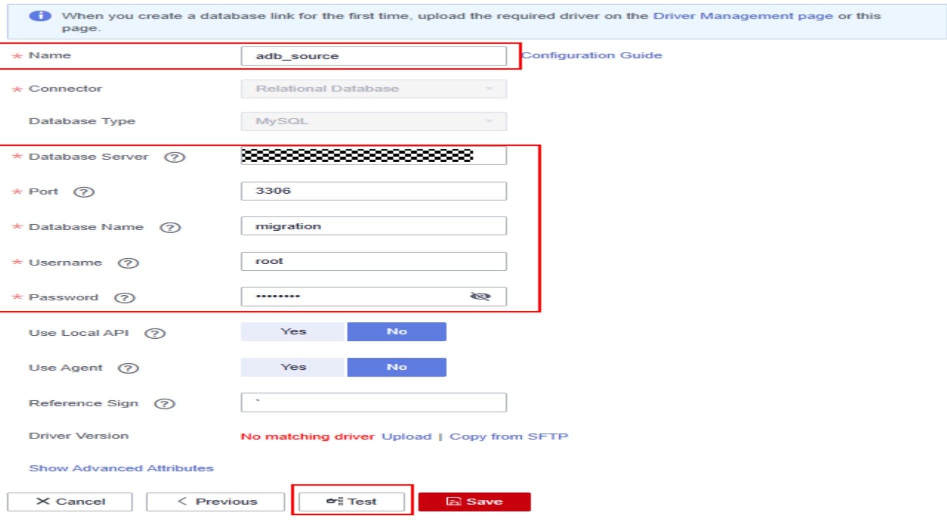
----End

Step 2: Migrating Table Data

Step 1 Configure the source link for CDM.

1. Log in to the **CDM console**. In the navigation pane, click **Cluster Management**.
2. If CDM is connected to ADB through the public network, bind an EIP. For details, see **Binding or Unbinding an EIP**.
3. Click **Job Management** next to the cluster name.
4. Before establishing a job link for the first time, install the driver. Choose **Links** > **Driver Management** and **install the MySQL driver**.
5. After the driver installation, click **Create Link** on the link management page, select **MySQL** and then click **Next**.
6. Enter the ADB database information.

Figure 2-51 ADB information

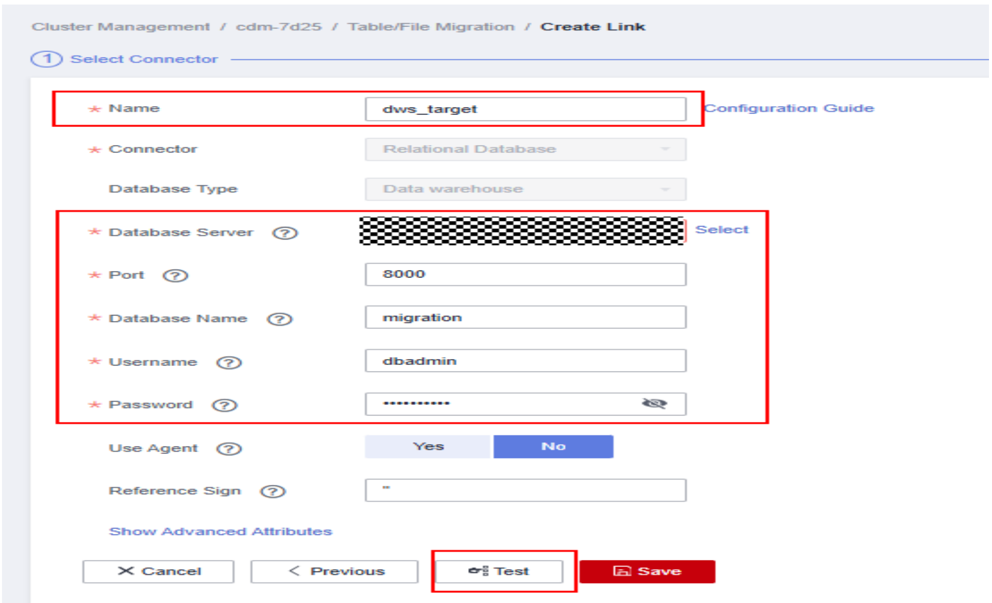


7. Click **Test** to check connectivity, and then click **Save**.

Step 2 Configure the destination link for CDM.

1. Similarly, choose **Job Management** > **Links** and click **Create Link**.
2. Select **Data Warehouse Service** and click **Next**.
3. Enter the DWS database information.

Figure 2-52 DWS information



4. Click **Test** to check connectivity, and then click **Save**.

Step 3 Configure and start a table-level migration job.

1. Click the **Table/File Migration** tab. This tab displays single-table migration jobs.
2. Enter the source and destination information.
   – **Job Name**: Enter a unique name.

- **Source Job Configuration**
  - **Source Link Name**: Select the created MySQL source link.
  - **Use SQL Statement**: Select **No**.
  - **Schema/Tablespace**: Select the name of the schema or tablespace from which data is to be extracted.
  - **Table Name**: Select the name of the table from which data is to be extracted.
  - Retain default settings for other parameters.
- **Destination Job Configuration**
  - **Destination Link Name**: Select the created DWS destination link.
  - **Schema/Tablespace**: Select the DWS database to which data is to be written.
  - **Auto Table Creation**: This parameter is displayed only when both the migration source and destination are relational databases.
  - **Table Name**: Select the name of the table to which data is to be written. You can also enter a table name that does not exist. CDM automatically creates the table in DWS.
  - **Clear Data Before Import**: Specify whether to clear data in the destination table before the migration task starts.

3. Click **Next** to map fields.
   - If the field mapping is incorrect, you can drag the fields to adjust the mapping.
   - CDM expressions have built-in ability to convert fields of common strings, dates, and numbers. For details, see **Field Conversion**.
4. Confirm the information and click **Next**.
5. On the task configuration page, configure the following parameters:
   - **Retry Upon Failure**: If the job fails to be executed, you can determine whether to automatically retry. Retain the default value **Never**.
   - **Group**: Select the group to which the job belongs. The default group is **DEFAULT**. On the **Job Management** page, jobs can be displayed, started, or exported by group.
   - **Schedule Execution**: To configure scheduled jobs, enable this function. Retain the default value **No**.
   - **Concurrent Extractors**: Indicates data extracted concurrently. The default value is **1**, but you can increase it. However, it is recommended to keep it at or below **4**.
   - **Write Dirty Data**: Dirty data may be generated during data migration between tables. You are advised to select **Yes**.
6. Confirm the information and click **Save and Run**.

   After the migration job begins, you can view the status in the job list.

Step 4 Configure and start a database-level migration job.

1. Click the **Entire DB Migration** tab and click **Create Job**.
2. Enter the source information on the left and the destination information on the right.
   - **Job Name**: Enter a unique name.
   - **Source Job Configuration**
     - **Source Link Name**: Select the created MySQL source link.
     - **Use SQL Statement**: Select **No**.
     - **Schema/Tablespace**: Select the name of the schema or tablespace from which data is to be extracted.
     - **Table Name**: Select the name of the table from which data is to be extracted.
     - Retain default settings for other parameters.
   - **Destination Job Configuration**
     - **Destination Link Name**: Select the created DWS destination link.
     - **Schema/Tablespace**: Select the DWS database to which data is to be written.
     - **Auto Table Creation**: This parameter is displayed only when both the migration source and destination are relational databases.
     - **Clear Data Before Import**: Specify whether to clear data in the destination table before the migration task starts.
3. Click **Next**.
4. Select all tables or the tables to migrate, click the right arrow in the middle to move them to the right pane, and then click **Next**.
5. Configure job parameters.
   - **Concurrent Subjobs**: Indicates the number of tables to migrate simultaneously. The default value is **10**; it is recommended to set it to a value less than **5**.
   - **Concurrent Extractors**: Indicates data extracted concurrently. The default value is **1**, but you can increase it. However, it is recommended to keep it at or below **4**.

   Confirm the information and click **Save and Run**.
6. Wait until the migration job is complete. Click the job name to view the migration status of each table.

Step 5 Connect to DWS and run the following SQL statements to check if the data has been migrated:

```
SELECT 'migration.users',count(1) FROM migration.users UNION ALL
SELECT 'migration.products',count(1) FROM migration.products UNION ALL
SELECT 'migration.orders',count(1) FROM migration.orders UNION ALL
SELECT 'migration.employees',count(1) FROM migration.employees;
```

----End

Step 3: Verifying Data Consistency

After the migration, check whether the data on the source and destination databases is consistent using DataCheck.

Step 1 Download and unzip **DataCheck-*.zip**, and then go to the **DataCheck-*** directory to use it. For details about how to use the files in the directory, see **Table 2-21**.

Step 2 Configure the tool package.

- **In Windows**:

  Open the **dbinfo.properties** file in the **conf** folder and configure it based on your actual needs.

  > NOTE
  >
  > You can use the command below in the tool to generate the ciphertext of **src.passwd** and **dws.passwd**.
  >
  > **encryption.bat** *password*

```
D:\temp\0116\3\DataCheck\bin>encryption.bat B[redacted]
0xwQnR1hwIytw6r9s3[redacted]
```

  > After the command is executed, an encrypted file is generated in the local **bin** directory.

datacheck.bat	2023/8/1 15:47	[redacted]	2 KB
datacheck.sh	2023/8/1 15:47	[redacted]	1 KB
DATE_CHECK_KEY	2024/1/18 17:24	[redacted]	1 KB
DATE_CHECK_VI	2024/1/18 17:24	[redacted]	1 KB
encryption.bat	2023/8/30 9:47	[redacted]	2 KB
encryption.sh	2023/8/30 9:47	[redacted]	1 KB

- **In Linux**:

  The method of generating the ciphertext is similar to that for Windows. The command is **sh encryption.sh** *Password*. Other steps are the same.

```
[root@MRS-node-master2Ima0 bin]# sh encryption.sh G[redacted]
qKTec6ahImcc+1JE5[redacted]
```

Step 3 Check data.

In Windows:

1. Open the **check.input** file, enter the databases (if they are not entered, the content in the **conf** file is used), source table, and destination table to be checked, and fill in **Row Range** with a data query statement to specify the query scope.

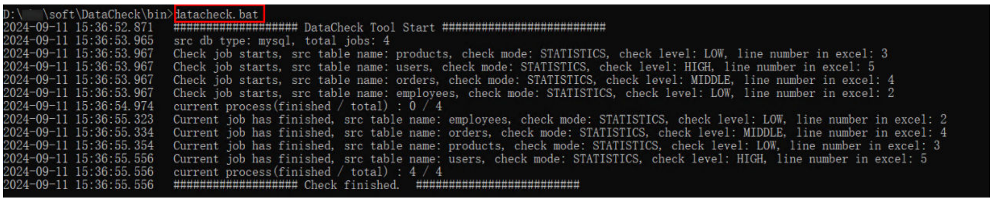
   > NOTE
   >
   > – After configuring the source database name in the configuration file, the source database name in the **check.input** file defaults to this. However, if a different source database name is specified in the **check.input** file, it will take precedence.
   >
   > – The **Check Strategy** offers three levels: **high**, **medium**, and **low**. If unspecified, the default is **low**.

   The following figure shows the **check_input** file for metadata comparison.

Figure 2-53 check_input

Source Database Nam	Source Schema Nam	Source Table Name	Target Database Nam	Target Schema Nam	Target Table Nam	* Check Mode	Check Strategy	Row Range(Where s	Column Ran	Column Exclud	Sort Colum	Columns Wthout Sum
	migration	employees		migration	employees	Statistics	low					
	migration	products		migration	products	Statistics	low					
	migration	orders		migration	orders	Statistics	middle					
	migration	users		migration	users	Statistics	high					

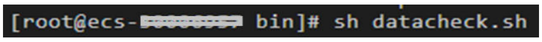
2. Run the **datacheck.bat** command in the **bin** directory to execute the check tool.



3. View the generated check result file **check_input_result.xlsx**.

In Linux:

1. Edit and upload the **check_input.xlsx** file. Refer to the step 1 for Windows.
2. Run the **sh datacheck.sh** command to execute the check tool.



3. View the check result in the **check_input_result.xlsx** file. (The check result analysis is the same as that for Windows.)

----End

Related Information

Table 2-21 Description of the **DataCheck** directory

File or Folder		Description
DataCheck	bin	Saves the entry script of the check tool. ● Windows version: **datacheck.bat** ● Linux version: **datacheck.sh**
	conf	Configuration file, which is used to configure the connection between the source database and the destination database and set log printing.
	lib	Stores JAR packages required for running the check tool.
	check_input.xlsx	● Information about the table to be checked, including schema, table, and column names. ● Check level information and check rules of users. Three check levels are supported: **high**, **middle**, and **low**. The default value is **low**.
	logs	The package does not include this file. Once the check tool runs, it automatically generates this file to log the tool's execution process.
	check_input_result.xlsx	The package does not include this file. Once the check tool runs, a check result file will be created in the same location as **check_input.xlsx**.

Table 2-22 Basic functions of the data check tool

DataCheck
• Check data in DWS, MySQL, and PostgreSQL databases. • Check common fields, such as numeric, time, and character types. • Support three check levels, including high, middle, and low. • Check schemas, table names, and column names. • Specify the check scope of records. By default, all records are checked. • Support various check methods, including **count(*)**, **max**, **min**, **sum**, **avg**, and sampling details check. • Output the check result and related check details.

Table 2-23 Data check levels

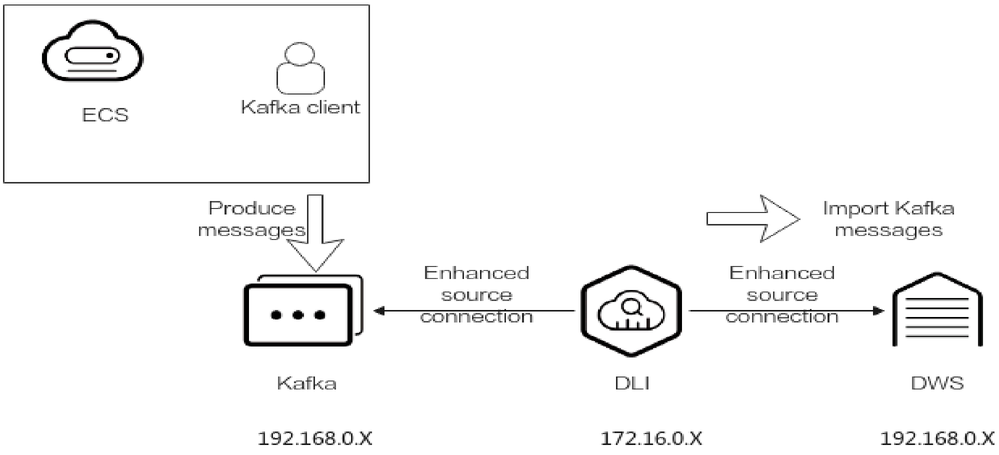
Check Level	Description	Syntax
Low	• Quantity check	• Number of records: **COUNT(*)**
Middle	• Quantity check • Numeric type check	• Number of records: **COUNT(*)** • Value check: **MAX**, **MIN**, **SUM**, and **AVG**
High	• Quantity check • Numeric type check • Date type check • Character type check	• Number of records: **COUNT(*)** • Value check: **MAX**, **MIN**, **SUM**, and **AVG** • Date check: **MAX** and **MIN** • Character check: **order by limit 1000**, which reads the data and checks whether the content is the same

2.6 Using a Flink Job of DLI to Synchronize Kafka Data to a DWS Cluster in Real Time

This practice demonstrates how to use DLI Flink (Flink 1.15 is used as an example) to synchronize consumption data from Kafka to DWS in real time. The demonstration process includes writing and updating existing data in real time.

- For details, see **What Is Data Lake Insight?**
- For details about Kafka, see **What Is DMS for Kafka?**

Figure 2-54 Importing Kafka data to DWS in real time



This practice takes about 90 minutes. The cloud services used in this practice include **Virtual Private Cloud (VPC) and subnets**, **Elastic Load Balance (ELB)**, **Elastic Cloud Server (ECS)**, **Object Storage Service (OBS)**, **Distributed Message Service (DMS) for Kafka**, **Data Lake Insight (DLI)**, and **Data Warehouse Service (DWS)**. The basic process is as follows:

1. **Preparations**: Register an account and prepare the network.
2. **Step 1: Create a Kafka Instance**: Purchase DMS for Kafka and prepare Kafka data.
3. **Step 2: Create a DWS Cluster and Target Table**: Purchase a DWS cluster and bind an EIP to it.
4. **Step 3: Create a DLI Elastic Resource Pool and Queue**: Create a DLI elastic resource pool and add queues to the resource pool.
5. **Step 4: Create an Enhanced Datasource Connection for Kafka and DWS**: Connect Kafka and DWS.
6. **Step 5: Prepare the dws-connector-flink Tool for Interconnecting DWS with Flink**: Use this plugin to import data from MySQL to DWS efficiently.
7. **Step 6: Create and Edit a DLI Flink Job**: Create a Flink SQL job and configure SQL code.
8. **Step 7: Create and Modify Messages on the Kafka Client**: Import data to DWS in real time.

Scenario Description

Assume that the sample data of the data source Kafka is a user information table, as shown in **Table 2-24**, which contains the **id**, **name**, and **age** fields. The **id** field is unique and fixed, which is shared by multiple service systems. Generally, the **id** field does not need to be modified. Only the **name** and **age** fields need to be modified.

Use Kafka to generate the following three groups of data and use DLI Flink jobs to synchronize the data to DWS: Change the users whose IDs are **2** and **3** to **jim** and **tom**, and use DLI Flink jobs to update data and synchronize the data to DWS.

Table 2-24 Sample data

id	name	age
1	lily	16
2	lucy > jim	17
3	lilei > tom	15

Constraints

- Ensure that VPC, ECS, OBS, Kafka, DLI, and DWS are in the same region, for example, Europe-Dublin.
- Ensure that Kafka, DLI, and DWS can communicate with each other. In this practice, Kafka and DWS are created in the same region and VPC, and the security groups of Kafka and DWS allow the network segment of the DLI queues.
- To ensure that the link between DLI and DWS is stable, bind the ELB service to the created DWS cluster.

Preparations

- You have sign up for a Huawei ID and enabled Huawei Cloud services. The account cannot be in arrears or frozen.
- You have created a VPC and subnet. For details, see **Creating a VPC**.

Step 1: Create a Kafka Instance

Step 1 Log in to the **Kafka console**.

Step 2 Configure the following parameters as instructed. Retain default settings for other parameters.

Table 2-25 Kafka instance parameters

Parameter	Value
Billing Mode	Pay-per-use
Region	Europe-Dublin
AZ	AZ 1 (If not available, select another AZ.)
Bundle	Starter
VPC	Select a created VPC. If no VPC is available, create one.

Parameter	Value
Security Group	Select a created security group. If no security group is available, create one.
Other parameters	Retain the default value.

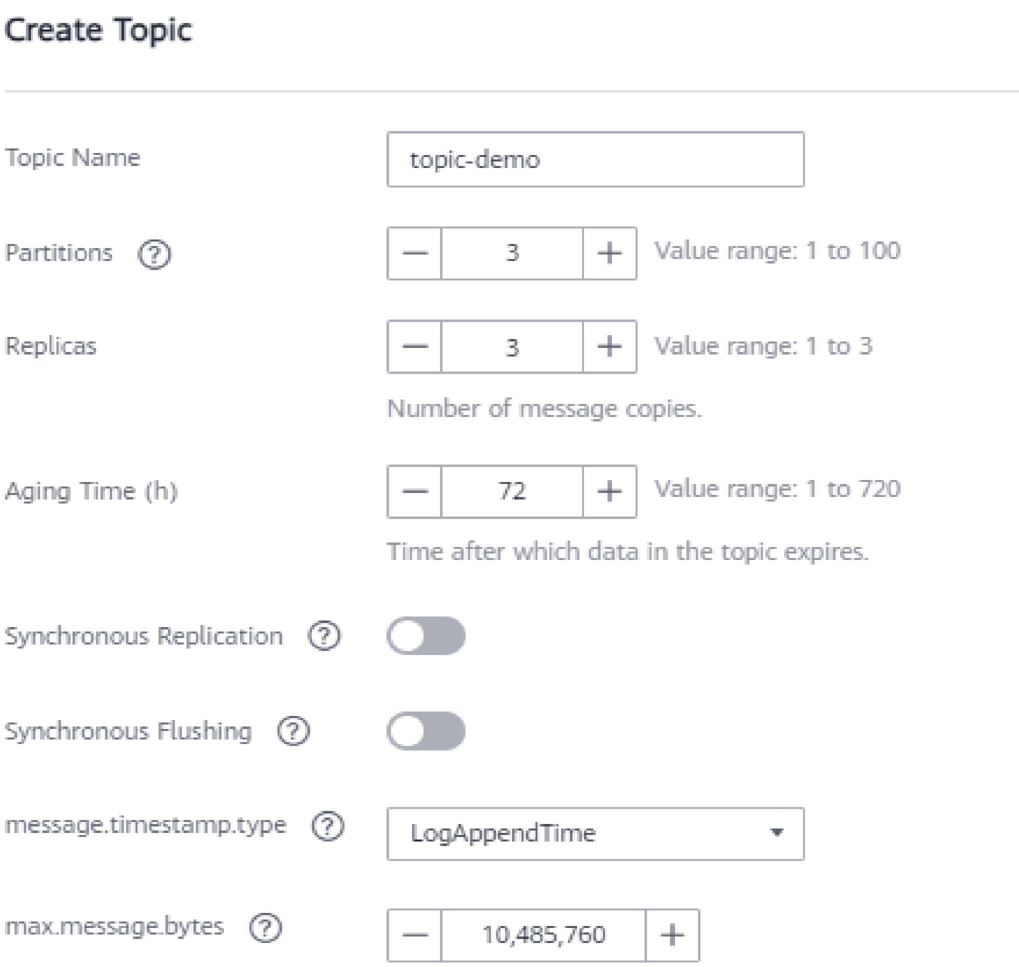
Step 3 Click **Confirm**, confirm the information, and click **Submit**. Wait until the creation is successful.

Step 4 In the Kafka instance list, click the name of the created Kafka instance. The **Basic Information** page is displayed.

Step 5 Choose **Topics** on the left and click **Create Topic**.

Set **Topic Name** to **topic-demo** and retain the default values for other parameters.

Figure 2-55 Creating a topic



Step 6 Click **OK**. In the topic list, you can see that **topic-demo** is successfully created.

Step 7 Choose **Consumer Groups** on the left and click **Create Consumer Group**.

Step 8 Enter **kafka01** for **Consumer Group Name** and click **OK**.

----End

Step 2: Create a DWS Cluster and Target Table

Step 1 **Create a dedicated load balancer**, set **Network Type** to **IPv4 private network**. Set Region and VPC to the same values as those of the Kafka instance. In this example, set Region to Europe-Dublin.

Step 2 **Creating a Cluster**. To ensure network connectivity, the region and VPC of the DWS cluster must be the same as those of the Kafka instance. In this practice, the region and VPC are Europe-Dublin. The VPC must be the same as that created for Kafka.

Step 3 Log in to the **DWS console**. Choose **Dedicated Clusters** > **Clusters**. Locate the target cluster and click **Log In** in the **Operation** column.

NOTE

This login mode is available only for clusters of version 8.1.3.*x*. For clusters of version 8.1.2 or earlier, you need to use gsql to log in.

Step 4 After the login is successful, the SQL editor is displayed.

Step 5 Copy the following SQL statement. In the SQL window, click Execute SQL to create the target table **user_dws**.

```
CREATE TABLE user_dws (
id int,
name varchar(50),
age int,
PRIMARY KEY (id)
);
```

----End

Step 3: Create a DLI Elastic Resource Pool and Queue

Step 1 Log in to the **DLI console**.

Step 2 In the navigation pane on the left, choose **Resources** > **Resource Pool**.

Step 3 Click **Buy Resource Pool** in the upper right corner, configure the following parameters as instructed, and retain default settings for other parameters.

Table 2-26 Parameters

Parameter	Value
Billing Mode	Pay-per-use
Region	Europe-Dublin
Name	dli_dws

Parameter	Value
Specifications	Standard
CIDR Block	172.16.0.0/18. It must be in a different network segment from Kafka and DWS. For example, if Kafka and DWS are in the **192.168.x.x** network segment, select **172.16.x.x** for DLI.

Step 4 Click **Buy** and click **Submit**.

After the resource pool is created, go to the next step.

Step 5 On the elastic resource pool page, locate the row that contains the created resource pool, click **Add Queue** in the **Operation** column, and set the following parameters. Retain the default values for other parameters that are not described in the table.

Table 2-27 Adding a queue

Parameter	Value
Name	dli_dws
Type	General purpose queue

Step 6 Click **Next** and click **OK**. The queue is created.

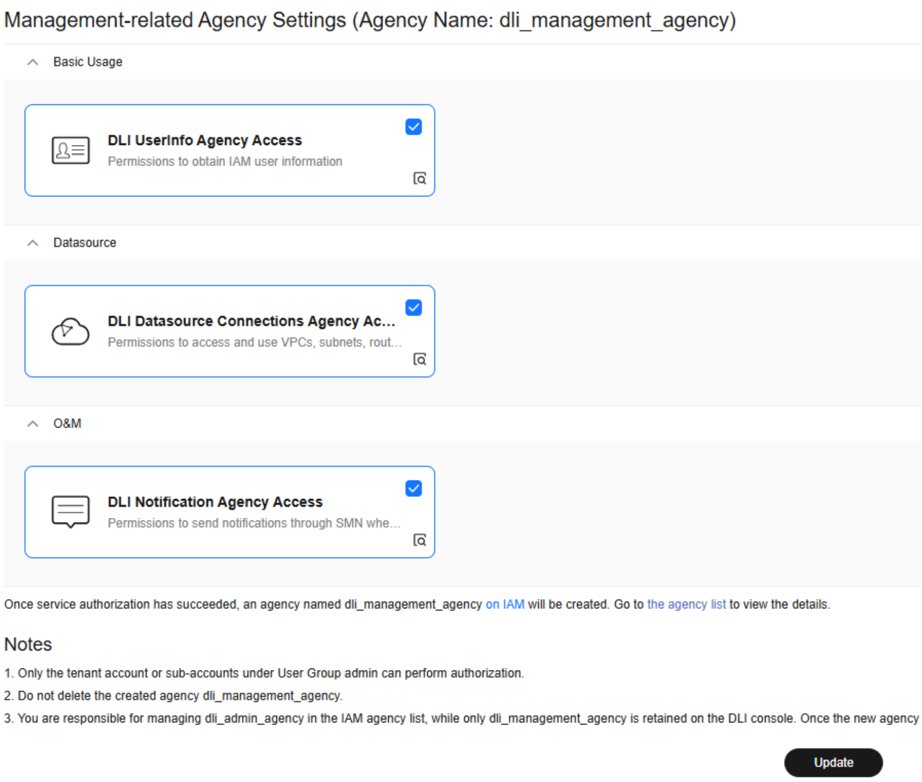
----End

Step 4: Create an Enhanced Datasource Connection for Kafka and DWS

Step 1 Update the DLI agency permissions.

1. Return to the DLI console and choose **Global Configuration** > **Service Authorization** on the left.
2. Select **DLI UserInfo Agency Access**, **DLI Datasource Connections Agency Access**, and **DLI Notification Agency Access**.
3. Click **Update** and then click **OK**.

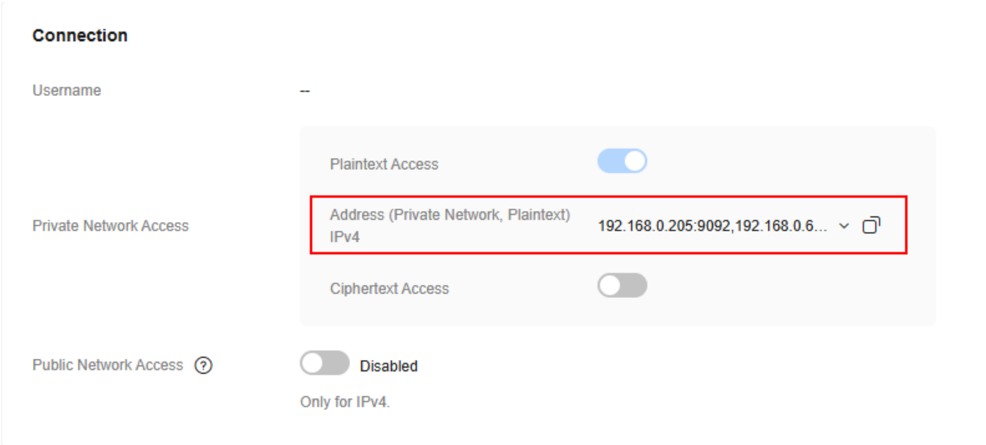
Figure 2-56 Updating DLI agency permissions



Step 2 In the security group of Kafka, allow the network segment where the DLI queue is located.

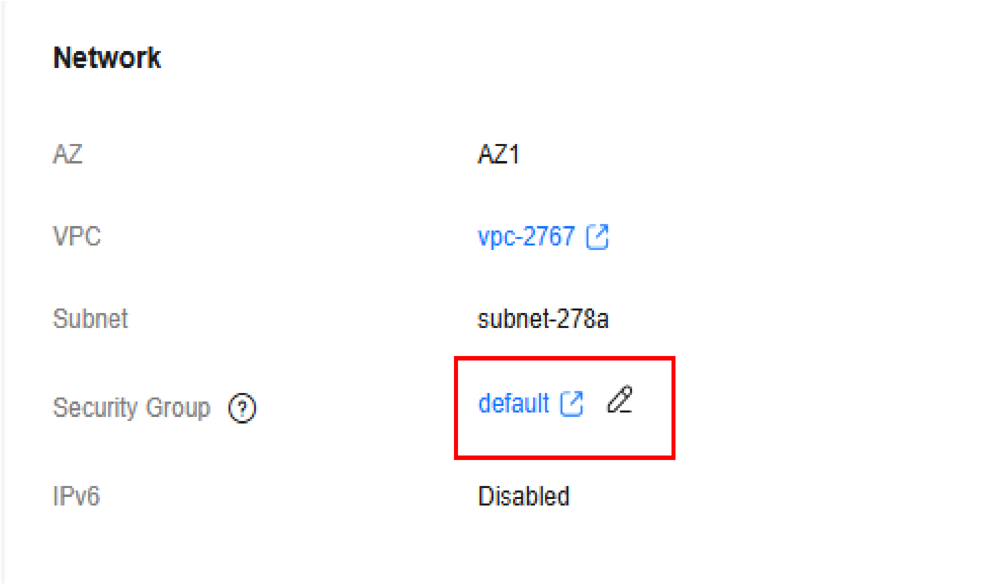
1. Return to the Kafka console and click the Kafka instance name to go to the **Basic Information** page. View the value of **Instance Address (Private Network)** in connection information and record the address for future use.

Figure 2-57 Kafka private network address



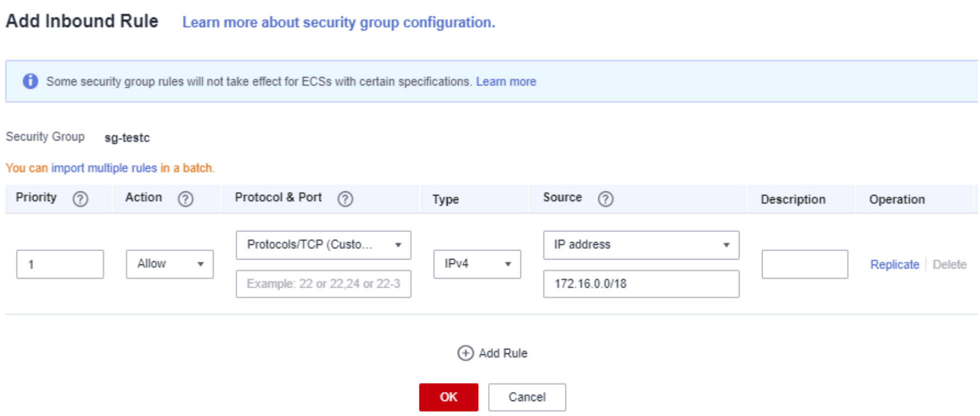
2. Click the security group name.

Figure 2-58 Kafka security group



3. Choose **Inbound Rules** > **Add Rule**, as shown in the following figure. Add the network segment of the DLI queue. In this example, the network segment is **172.16.0.0/18**. Ensure that the network segment is the same as that entered during **Step 3: Create a DLI Elastic Resource Pool and Queue**.

Figure 2-59 Adding rules to the Kafka security group



4. Click **OK**.

Step 3 Return to the DLI management console, click **Datasource Connections** on the left, select **Enhanced**, and click **Create**.

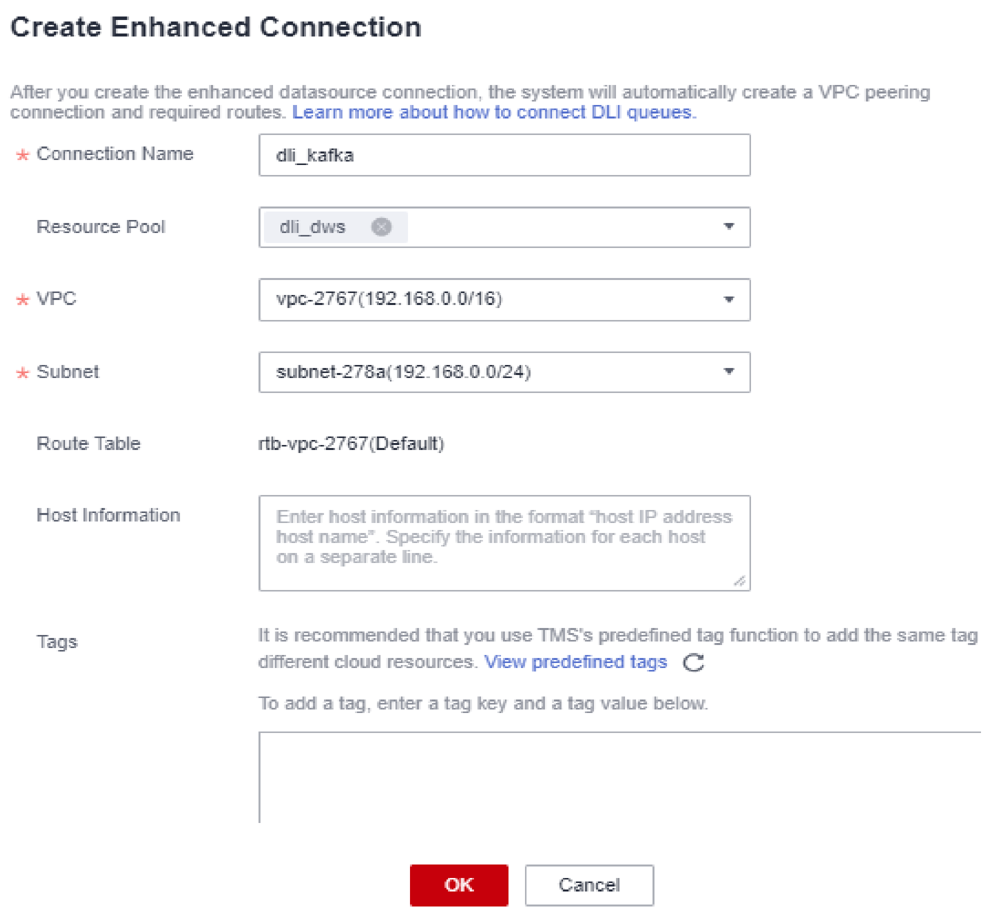
Step 4 Set the following parameters. Retain the default values for other parameters that are not described in the table.

Table 2-28 Connection from DLI to Kafka

Parameter	Value
Connection Name	dli_kafka
Resource Pool	Select the created DLI queue **dli_dws**.

Parameter	Value
VPC	Select the VPC of Kafka.
Subnet	Select the subnet where Kafka is located.
Other parameters	Retain the default value.

Figure 2-60 Creating an enhanced connection

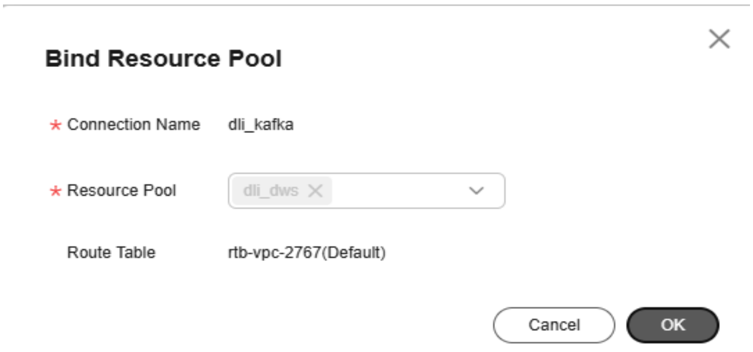


Step 5 Click **OK**. Wait until the Kafka connection is successfully created.

NOTE

If you do not select a resource pool when creating an enhanced datasource connection, you can manually bind one afterwards.

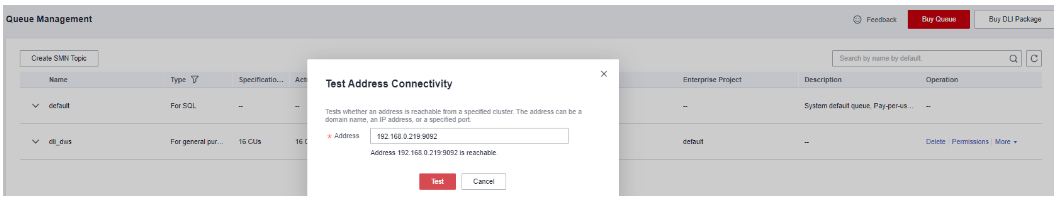
1. Locate the row that contains the target datasource connection and choose **More** > **Bind Resource Pool** in the **Operation** column.
2. Select a resource pool and click **OK**.



Step 6 Choose **Resources** > **Queue Management** on the left, and choose **More** > **Test Address Connectivity** on the right of **dli_dws**.

Step 7 In the address box, enter the private IP address and port number of the Kafka instance obtained in **Step 2.1**. (There are three Kafka addresses. Enter only one of them.)

Figure 2-61 Testing Kafka connectivity



Step 8 Click **Test** to verify that DLI is successfully connected to Kafka.

Step 9 If the connection fails, perform the following operations:

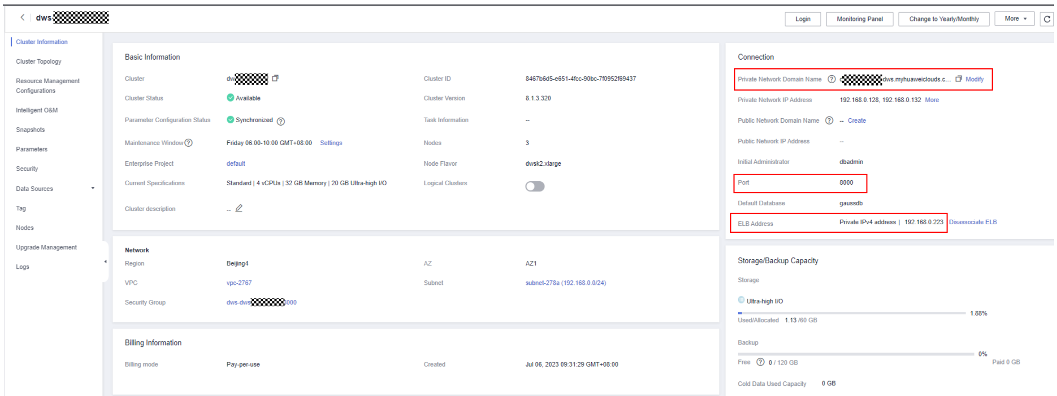
Ensure that the security group that RDS is associated with allows access from the CIDR block where the DLI resource pool is located and that the agency has been updated.

1. Log in to the DLI console and click **Datasource Connections**. Locate the created connection and click **More** in the **Operation** column, and select **Unbind Resource Pool**.
2. Deselect the existing elastic resource pool and click **OK**.
3. Click **More** in the **Operation** column and select **Bind Resource Pool**.
4. Select the created elastic resource pool **dli_dws** and click **OK**.
5. Wait for about 2 minutes and test the connection again.
6. If the connection still fails, rectify the fault by referring to **How Do I Do If the Datasource Connection Is Successfully Created but the Network Connectivity Test Fails?**

Step 10 Log in to the DWS console, choose **Dedicated Clusters** > **Clusters** on the left, and click the cluster name to go to the details page.

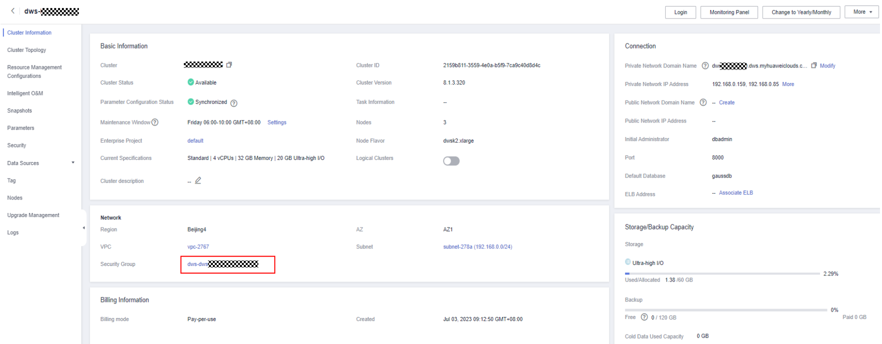
Step 11 Record the private network domain name, port number, and ELB address of the DWS cluster for future use.

Figure 2-62 Private domain name and ELB address



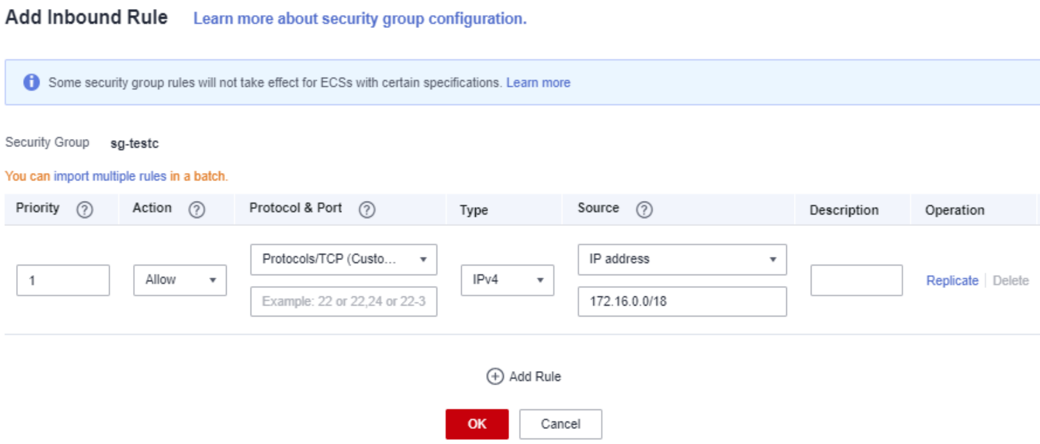
Step 12 Click the security group name.

Figure 2-63 DWS security group



Step 13 Choose **Inbound Rules** > **Add Rule**, as shown in the following figure. Add the network segment of the DLI queue. In this example, the network segment is **172.16.0.0/18**. Ensure that the network segment is the same as that entered during **Step 3: Create a DLI Elastic Resource Pool and Queue**.

Figure 2-64 Adding a rule to the DWS security group

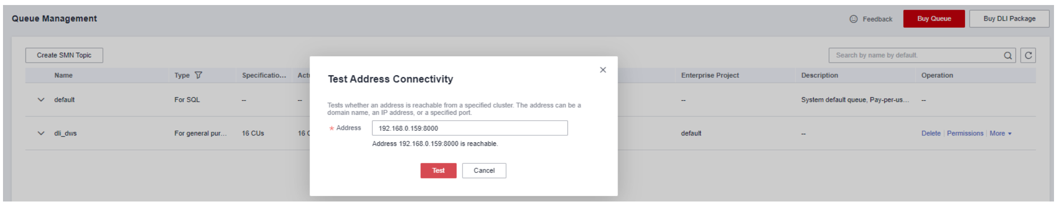


Step 14 Click **OK**.

Step 15 Switch to the DLI console, choose **Resources** > **Queue Management** on the left, and click **More** > **Test Address Connectivity** on the right of **dli_dws**.

Step 16 In the address box, enter the ELB address and port number of the DWS cluster obtained in **Step 11**.

Figure 2-65 Testing DWS connectivity



Step 17 Click **Test** to verify that DLI is successfully connected to DWS.

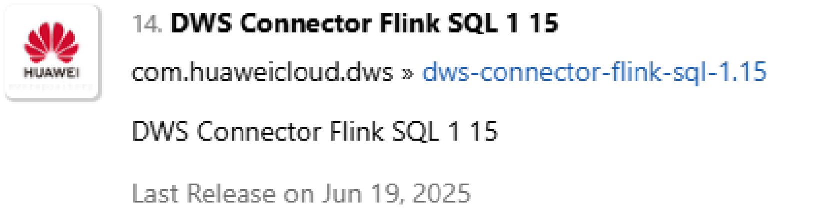
----End

Step 5: Prepare the dws-connector-flink Tool for Interconnecting DWS with Flink

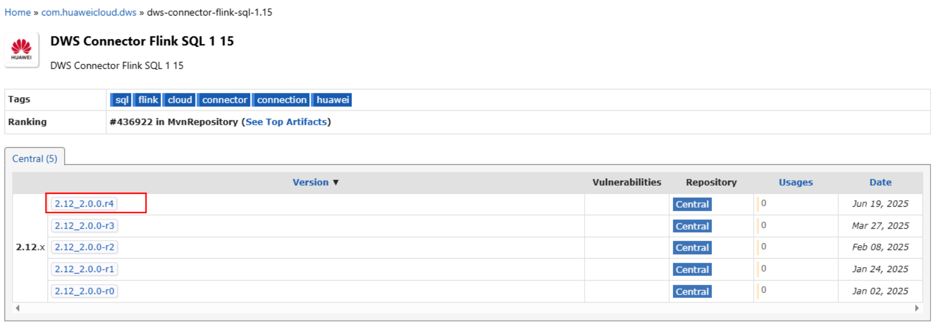
dws-connector-flink is a tool for interconnecting with Flink based on DWS JDBC APIs. During DLI job configuration, this tool and its dependencies are stored in the Flink class loading directory to improve the capability of importing Flink jobs to DWS.

Step 1 Go to **https://mvnrepository.com/artifact/com.huaweicloud.dws** using a browser.

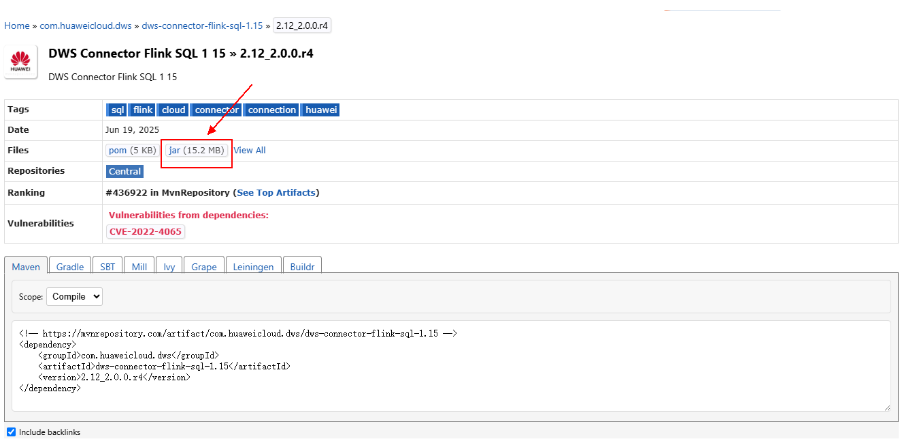
Step 2 In the software list, select Flink 1.15. In this practice, **DWS Connector Flink SQL 1 15** is selected.



Step 3 Select the latest branch. The actual branch is subject to the new branch released on the official website.



Step 4 Click the **jar** icon to download the file.



Step 5 Create an OBS bucket. In this practice, set the bucket name to **obs-flink-dws** and upload the file **dws-connector-flink-sql-1.15-2.12_2.0.0.r4.jar** to the OBS bucket. Ensure that the bucket is in the same region as DLI. In this practice, the **Europe-Dublin** region is used.

----End

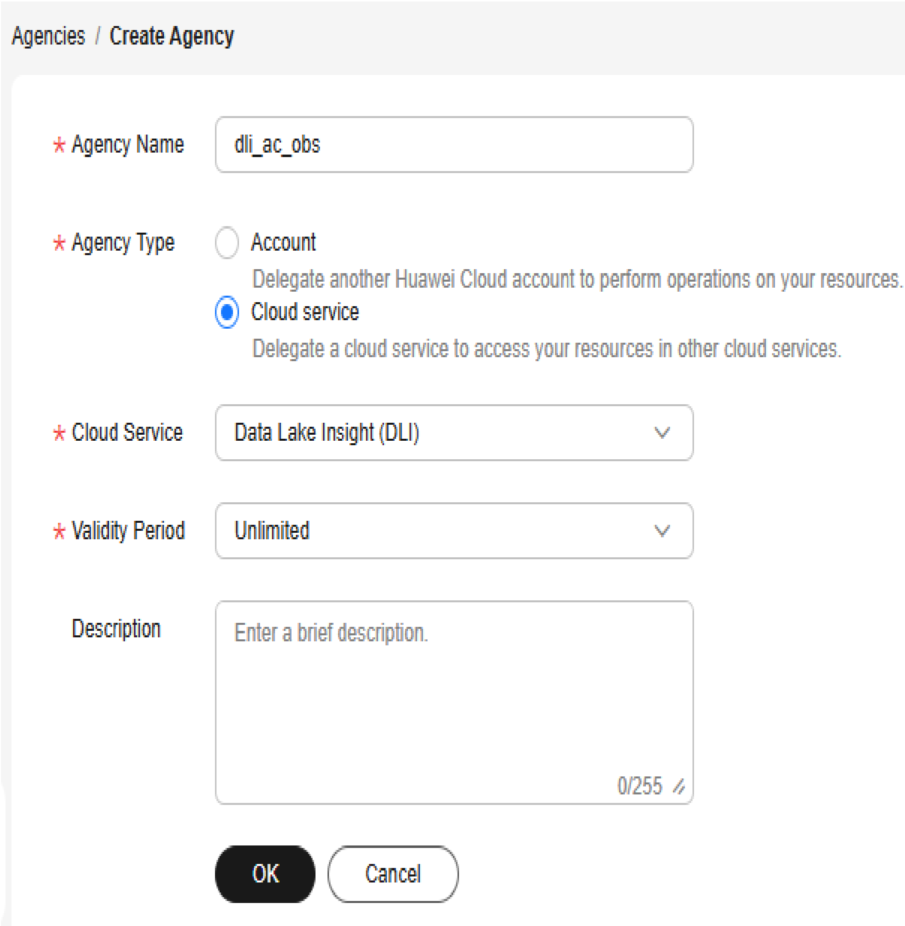
Step 6: Create and Edit a DLI Flink Job

Step 1 Create an OBS agency policy.

1. Hover over the account name in the upper right corner of the console, and click **Identity and Access Management**.
2. In the navigation pane on the left, choose **Agencies** and then click **Create Agency** in the upper right corner.

– **Agency Name**: **dli_ac_obs**
– **Agency Type**: **Cloud service**
– **Cloud Service**: **Data Lake Insight (DLI)**
– **Validity Period**: **Unlimited**

Figure 2-66 Creating an OBS agency



3. Click **OK** and then click **Authorize**.
4. On the displayed page, click **Create Policy**.
5. Configure policy information. Enter a policy name, for example, **dli_ac_obs**, and select **JSON**.
6. In the **Policy Content** area, paste a custom policy. Replace *OBS bucket name* with the actual bucket name.

```
{
  "Version": "1.1",
  "Statement": [
    {
      "Effect": "Allow",
      "Action": [
        "obs:object:GetObject",
        "obs:object:DeleteObjectVersion",
        "obs:bucket:GetBucketLocation",
        "obs:bucket:GetLifecycleConfiguration",
        "obs:object:AbortMultipartUpload",
        "obs:object:DeleteObject",
```

```
                "obs:bucket:GetBucketLogging",
                "obs:bucket:HeadBucket",
                "obs:object:PutObject",
                "obs:object:GetObjectVersionAcl",
                "obs:bucket:GetBucketAcl",
                "obs:bucket:GetBucketVersioning",
                "obs:bucket:GetBucketStoragePolicy",
                "obs:bucket:ListBucketMultipartUploads",
                "obs:object:ListMultipartUploadParts",
                "obs:bucket:ListBucketVersions",
                "obs:bucket:ListBucket",
                "obs:object:GetObjectVersion",
                "obs:object:GetObjectAcl",
                "obs:bucket:GetBucketPolicy",
                "obs:bucket:GetBucketStorage"
            ],
            "Resource": [
                "OBS:*:*:object:*",
                "OBS:*:*:bucket:OBS bucket name"
            ]
        },
        {
            "Effect": "Allow",
            "Action": [
                "obs:bucket:ListAllMyBuckets"
            ]
        }
    ]
}
```

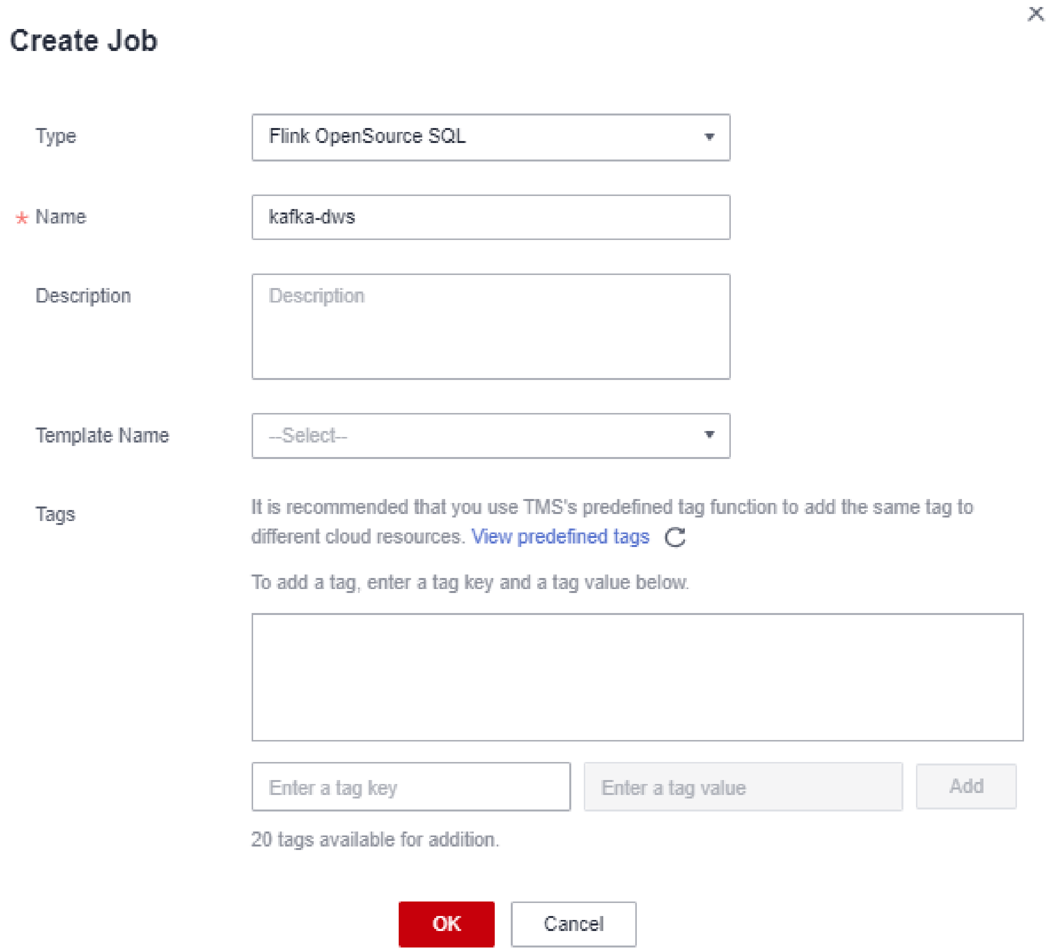
7. Click **Next**.
8. Select the created custom policy.
9. Click **Next**. Select **All resources**.
10. Click **OK**.

    It takes 15 to 30 minutes for the authorization to take effect.

Step 2 Return to the DLI management console, choose **Job Management** > **Flink Jobs** on the left, and click **Create Job** in the upper right corner.

Step 3 Set **Type** to **Flink OpenSource SQL** and **Name** to **kafka-dws**.

Figure 2-67 Creating a job



Step 4 Click **OK**. The page for editing the job is displayed.

Step 5 Set the following parameters on the right of the page. Retain the default values for other parameters that are not described in the table.

Table 2-29 Flink job parameters

Parameter	Value
Queue	dli_dws
Flink Version	1.15
UDF Jar	Select the JAR file in the OBS bucket created in **Step 5: Prepare the dws-connector-flink Tool for Interconnecting DWS with Flink**.
Agency	Select the agency created in **Step 1**.
OBS Bucket	Select the bucket created in **Step 5: Prepare the dws-connector-flink Tool for Interconnecting DWS with Flink**.
Enable Checkpointing	Check the box.

Parameter	Value
Other parameters	Retain the default value.

Step 6 Copy the following SQL code to the SQL code window on the left.

Obtain the private IP address and port number of the Kafka instance from **Step 2.1**, and obtain the private domain name from **Step 11**.

The following describes the common parameters in the Flink SQL job code:

- **connector**: connector type of the data source. For Kafka, set this parameter to **kafka**. For DWS, set this parameter to **dws**. For more information, see **Connectors**.
- **write.mode**: import mode. The value can be **auto**, **copy_merge**, **copy_upsert**, **upsert**, **update**, **copy_update**, or **copy_auto**.
- **autoFlushBatchSize**: number of records to be buffered before an automatic flush. When the number of buffered records reaches this value, Flink writes data to the target system in batches. For example, Flink writes data to the target system **Sink** target after 5000 lines of records are buffered. In Flink SQL, Sink (also translated as receiver or output end) is the final output destination in the data stream processing pipeline. It is responsible for writing processed data to external storage systems or sending the data to downstream applications.
- **autoFlushMaxInterval**: maximum interval between automatic flushes. Even if the number of buffered records does not reach the value of **autoFlushBatchSize**, a flush is triggered after the interval expires.
- **key-by-before-sink**: Whether to group data by primary key before data is written to the sink. This ensures that records with the same primary key are written consecutively ad it is useful for some systems (such as some databases) that require primary keys to be ordered. This parameter aims to resolve the problem of interlocking between two subtasks when they acquire row locks based on the primary key from DWS, multiple concurrent writes occur, and **write.mode** is **upsert**. This happens when a batch of data written to the sink by multiple subtasks has more than one record with the same primary key, and the order of these records with the same primary key is inconsistent.

```
CREATE TABLE user_kafka (
  id string,
  name string,
  age int
) WITH (
  'connector' = 'kafka',
  'topic' = 'topic-demo',
'properties.bootstrap.servers' ='Private IP address and port number of the Kafka instance',
  'properties.group.id' = 'kafka01',
  'scan.startup.mode' = 'latest-offset',
  'format' = 'json'
);

CREATE TABLE user_dws (
  id string,
  name string,
  age int,
  PRIMARY KEY (id) NOT ENFORCED
) WITH (
```

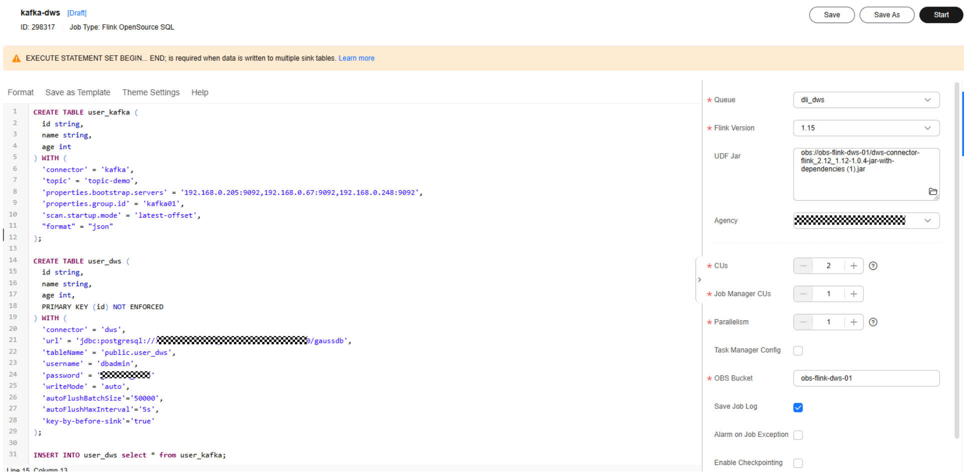
```
  'connector' = 'dws',
'url'='jdbc:postgresql://DWS private network domain name:8000/gaussdb',
  'tableName' = 'public.user_dws',
  'username' = 'dbadmin',
'password' ='Password of database user dbadmin'
  'writeMode' = 'auto',
  'autoFlushBatchSize'='50000',
  'autoFlushMaxInterval'='5s',
  'key-by-before-sink'='true'
);

INSERT INTO user_dws select * from user_kafka; -- Write the processing result to the sink.
```

Step 7 Click **Format** and click **Save**.

NOTICE

Click **Format** to format the SQL code. Otherwise, new null characters may be introduced during code copy and paste, causing job execution failures.

Figure 2-68 SQL statement of a job

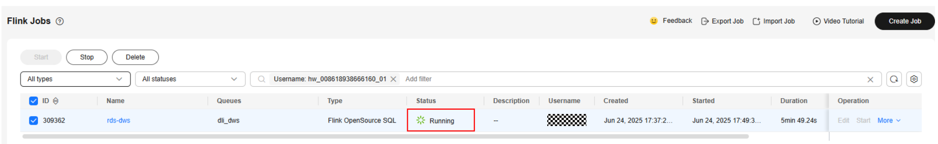


Step 8 Return to the DLI console home page and choose **Job Management** > **Flink Jobs** on the left.

Step 9 Click **Start** on the right of the job name **kafka-dws** and click **Start Now**.

Wait for about 1 minute and refresh the page. If the status is **Running**, the job is successfully executed.

Figure 2-69 Job execution status



----End

Step 7: Create and Modify Messages on the Kafka Client

Step 1 Create an ECS by referring to the ECS document. Ensure that the region and VPC of the ECS are the same as those of Kafka.

Step 2 Install JDK.

1. Log in to the ECS, go to the **/usr/local** directory, and download the JDK package.

```
cd /usr/local
wget https://download.oracle.com/java/17/latest/jdk-17_linux-x64_bin.tar.gz
```

2. Decompress the downloaded JDK package.

```
tar -zxvf jdk-17_linux-x64_bin.tar.gz
```

3. Run the following command to open the **/etc/profile** file:

```
vim /etc/profile
```

4. Press **i** to enter editing mode and add the following content to the end of the **/etc/profile** file:

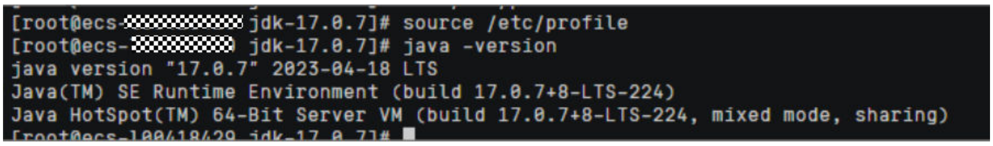
```
export JAVA_HOME=/usr/local/jdk-17.0.7 #JDK installation directory
export JRE_HOME=${JAVA_HOME}/jre
export CLASSPATH=.:${JAVA_HOME}/lib:${JRE_HOME}/lib:${JAVA_HOME}/test:${JAVA_HOME}/lib/
gsjdbc4.jar:${JAVA_HOME}/lib/dt.jar:${JAVA_HOME}/lib/tools.jar:$CLASSPATH
export JAVA_PATH=${JAVA_HOME}/bin:${JRE_HOME}/bin
export PATH=$PATH:${JAVA_PATH}
```

5. Press **Esc** and enter **:wq!** to save the settings and exit.
6. Run the following command for the environment variables to take effect:

```
source /etc/profile
```

7. Run the following command. If the following information is displayed, the JDK is successfully installed:

```
java -version
```



Step 3 Install the Kafka client.

1. Go to the **/opt** directory and run the following command to obtain the Kafka client software package.

```
cd /opt
wget https://archive.apache.org/dist/kafka/2.7.2/kafka_2.12-2.7.2.tgz
```

2. Decompress the downloaded software package.

```
tar -zxf kafka_2.12-2.7.2.tgz
```

3. Go to the Kafka client directory.

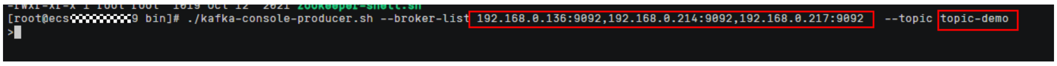
```
cd /opt/kafka_2.12-2.7.2/bin
```

Step 4 Run the following command to connect to Kafka: {*Connection address*} indicates the internal network connection address of Kafka. For details about how to obtain the address, see **Step 2.1**. *topic* indicates the name of the Kafka topic created in **Step 5**.

```
./kafka-console-producer.sh --broker-list {connection address} --topic {Topic name}
```

The following is an example:

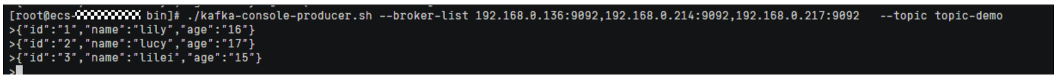
./kafka-console-producer.sh --broker-list 192.168.0.136:9092,192.168.0.214:9092,192.168.0.217:9092 --topic topic-demo



If **>** is displayed and no other error message is displayed, the connection is successful.

Step 5 In the window of the connected Kafka client, copy the following content (one line at a time) based on the data planned in the **Scenario Description** and press **Enter** to produce messages:

```
{"id":"1","name":"lily","age":"16"}
{"id":"2","name":"lucy","age":"17"}
{"id":"3","name":"lilei","age":"15"}
```



Step 6 Return to the DWS console, choose **Dedicated Clusters** > **Clusters** on the left, and click **Log In** on the right of the DWS cluster. The SQL page is displayed.

Step 7 Run the following SQL statement to verify that data is successfully imported to the database in real time:

```
SELECT * FROM user_dws ORDER BY id;
```

	id	name	age
1	1	lily	16
2	2	lucy	17
3	3	lilei	15

Step 8 Go back to the client window for connecting to Kafka on the ECS, copy the following content (one line at a time), and press **Enter** to produce messages.

```
{"id":"2","name":"jim","age":"17"}
{"id":"3","name":"tom","age":"15"}
```

Step 9 Go back to the opened SQL window of DWS and run the following SQL statement. It is found that the names whose IDs are **2** and **3** have been changed to **jim** and **tom**.

The scenario description is as expected. End of this practice.

```
SELECT * FROM user_dws ORDER BY id;
```

	id	name	age
1	1	lily	16
2	2	jim	17
3	3	tom	15

----End

2.7 Migrating Data Between DWS Clusters Using GDS

This practice demonstrates how to migrate 15 million rows of data between two DWS clusters within minutes based on the high concurrency of GDS import and export.

NOTE

- This function is supported only by clusters of version 8.1.2 or later.
- GDS is a high-concurrency import and export tool developed by DWS. For more information, visit **GDS Usage Guide**.
- This section describes only the operation practice. For details about GDS interconnection and syntax description, see **GDS-based Cross-Cluster Interconnection**.

This practice takes about 90 minutes. The cloud services used in this practice are DWS, Elastic Cloud Server (ECS), and Virtual Private Cloud (VPC). The basic process is as follows:

1. **Prerequisites**
2. **Step 1: Creating Two DWS Clusters**
3. **Step 2: Preparing Source Data**
4. **Step 3: Installing and Starting the GDS Server**
5. **Step 4: Implementing Data Interconnection Across DWS Clusters**

Supported Regions

Table 2-30 Regions and OBS bucket names

Region	OBS Bucket
EU-Dublin	dws-demo-eu-west-101

Constraints

In this practice, two sets of DWS and ECS services are deployed in the same region and VPC to ensure network connectivity.

Prerequisites

- You have sign up for a Huawei ID and enabled Huawei Cloud services. The account cannot be in arrears or frozen.
- You have obtained the AK and SK of the account.
- You have created a VPC and subnet. For details, see **Creating a VPC**.

Step 1: Creating Two DWS Clusters

Create two DWS clusters. For details, see **Creating a Cluster**. You are advised to create the clusters in the EU-Dublin region. Name the two clusters **dws-demo01** and **dws-demo02**.

Step 2: Preparing Source Data

Step 1 Log in to the **DWS console** and choose **Clusters** from the navigation pane. In the cluster list, locate the cluster **dws-demo01** and click **Login** in the **Operation** column.

NOTE

This login mode is available only for clusters of version 8.1.3.*x*. For clusters of version 8.1.2 or earlier, you need to use gsql to log in.

Step 2 After the login is successful, the SQL editor is displayed.

Step 3 Copy the following SQL statements to the SQL window and click **Execute SQL** to create the test TPC-H table **ORDERS**.

```
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)
 distribute by hash(O_ORDERKEY)
 PARTITION BY RANGE(O_ORDERDATE)
 (
 PARTITION O_ORDERDATE_1 VALUES LESS THAN('1993-01-01 00:00:00'),
 PARTITION O_ORDERDATE_2 VALUES LESS THAN('1994-01-01 00:00:00'),
 PARTITION O_ORDERDATE_3 VALUES LESS THAN('1995-01-01 00:00:00'),
 PARTITION O_ORDERDATE_4 VALUES LESS THAN('1996-01-01 00:00:00'),
 PARTITION O_ORDERDATE_5 VALUES LESS THAN('1997-01-01 00:00:00'),
 PARTITION O_ORDERDATE_6 VALUES LESS THAN('1998-01-01 00:00:00'),
 PARTITION O_ORDERDATE_7 VALUES LESS THAN('1999-01-01 00:00:00')
 );
```

Step 4 Run the SQL statements below to create an OBS foreign table.

Replace AK and SK with the actual AK and SK of the account. <obs_bucket_name> is obtained from **Supported Regions**.

NOTE

Hard-coded or plaintext AK/SK is risky. For security, encrypt your AK/SK and store them in the configuration file or environment variables.

```
CREATE FOREIGN TABLE ORDERS01
 (
LIKE orders
 )
 SERVER gsmpp_server
 OPTIONS (
 ENCODING 'utf8',
 LOCATION 'obs://<obs_bucket_name>/tpch/orders.tbl',
 FORMAT 'text',
 DELIMITER '|',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
 CHUNKSIZE '64',
 IGNORE_EXTRA_DATA 'on'
 );
```

Step 5 Run the SQL statement below to import data from the OBS foreign table to the source DWS cluster. The import takes about 2 minutes.

NOTE

If an import error occurs, the AK and SK values of the foreign table are incorrect. In this case, run **DROP FOREIGN TABLE order01** to delete the foreign table, create a foreign table again, and run the following statement to import data again.

```
INSERT INTO orders SELECT * FROM orders01;
```

Step 6 Repeat the preceding steps to log in to the destination cluster **dws-demo02** and run the following SQL statements to create the target table **orders**.

```
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)
 distribute by hash(O_ORDERKEY)
 PARTITION BY RANGE(O_ORDERDATE)
 (
 PARTITION O_ORDERDATE_1 VALUES LESS THAN('1993-01-01 00:00:00'),
 PARTITION O_ORDERDATE_2 VALUES LESS THAN('1994-01-01 00:00:00'),
 PARTITION O_ORDERDATE_3 VALUES LESS THAN('1995-01-01 00:00:00'),
 PARTITION O_ORDERDATE_4 VALUES LESS THAN('1996-01-01 00:00:00'),
 PARTITION O_ORDERDATE_5 VALUES LESS THAN('1997-01-01 00:00:00'),
 PARTITION O_ORDERDATE_6 VALUES LESS THAN('1998-01-01 00:00:00'),
 PARTITION O_ORDERDATE_7 VALUES LESS THAN('1999-01-01 00:00:00')
 );
```

----End

Step 3: Installing and Starting the GDS Server

Step 1 Create an ECS by referring to **Purchasing an ECS**. The ECS and DWS must be in the same region and VPC. In this example, the CentOS 7.6 image is used.

Step 2 Download the GDS package.

1. Log in to the **DWS console**.
2. In the navigation tree on the left, choose **Management** > **Client Connections**.
3. Select the GDS client of the target version from the drop-down list of **CLI Client**.

   Select a version based on the cluster version and the OS where the client is installed.

   NOTE

   The CPU architecture of the client must be the same as that of the cluster. If the cluster uses the x86 specifications, select the x86 client.
4. Click **Download**.

Step 3 Use the SFTP tool to upload the downloaded client (for example, **dws_client_8.2.x_redhat_x64.zip**) to the **/opt directory** of the ECS.

Step 4 Log in to the ECS as the **root** user and run the following commands to go to the **/opt** directory and decompress the client package.

```
cd /opt
unzip dws_client_8.2.x_redhat_x64.zip
```

Step 5 Create a GDS user and the user group to which the user belongs. This user is used to start GDS and read source data.

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

Step 6 Change the owner of the GDS package directory and source data file directory to the GDS user.

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

Step 7 Switch to user **gds**.

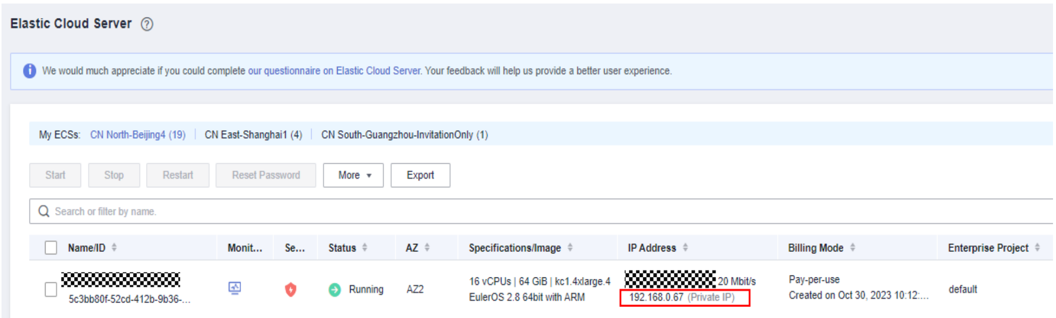
```
su - gds_user
```

Step 8 Run the following commands to go to the **gds** directory and execute environment variables.

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

Step 9 Run the following command to start GDS. You can view the private IP address of the ECS on the **ECS console**.

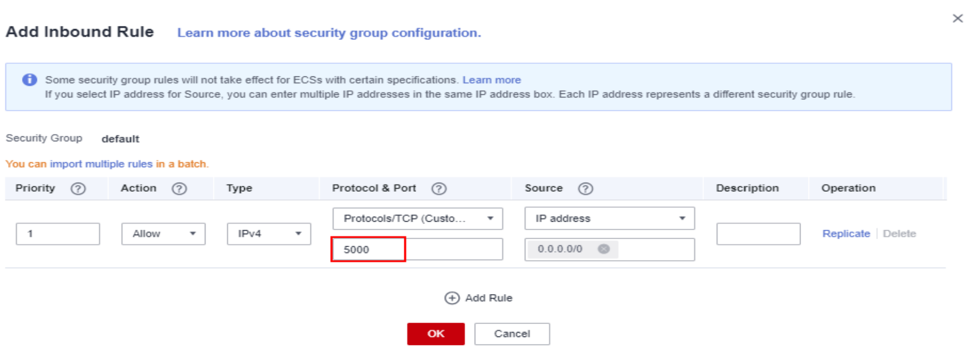
/opt/gds/bin/gds -d /opt -p *Private IP address of the ECS*:**5000 -H 0.0.0.0/0 -l /opt/gds/bin/gds_log.txt -D -t 2**



Step 10 Enable the network port between the ECS and DWS.

The GDS server (ECS in this practice) needs to communicate with DWS. The default security group of the ECS does not allow inbound traffic from GDS port 5000 and DWS port 8000. Perform the following steps:

1. Return to the ECS console and click the ECS name to go to the ECS details page.
2. Click the **Security Groups** tab and click **Manage Rule**.
3. Choose **Inbound Rules** and click **Add Rule**. Set **Priority** to **1**, set **Protocol & Port** to **5000**, and click **OK**.



4. Repeat the preceding steps to add an inbound rule of 8000.

----End

Step 4: Implementing Data Interconnection Across DWS Clusters

Step 1 Create a server.

1. Obtain the private IP address of the source DWS cluster. Specifically, go to the DWS console, choose **Dedicated Clusters** > **Clusters**, and click the source cluster name **dws-demo01**.
2. Go to the cluster details page and record the private network IP address.

3. Switch back to the DWS console and click **Log In** in the **Operation** column of the destination cluster **dws-demo02**. The SQL window is displayed.

   Run the commands below to create a server.

   In the commands, *Private network IP address of the source DWS cluster* is obtained in the previous step, *Private IP address of the ECS* is obtained from the ECS console, and *Login password of user dbadmin* is set when the DWS cluster is created.

```
CREATE SERVER server_remote FOREIGN DATA WRAPPER GC_FDW OPTIONS
 (
 address 'Private network IP address of the source DWS cluster:8000',
 dbname 'gaussdb',
 username 'dbadmin',
 password 'Login password of user dbadmin',
 syncsrv 'gsfs://Private IP address of the ECS:5000'
 )
 ;
```

Step 2 Create a foreign table for interconnection.

In the SQL window of the destination cluster **dws-demo02**, run the following statements to create a foreign table for interconnection:

```
CREATE FOREIGN TABLE ft_orders
 (
 O_ORDERKEY BIGINT ,
 O_CUSTKEY BIGINT ,
 O_ORDERSTATUS CHAR(1) ,
 O_TOTALPRICE DECIMAL(15,2) ,
 O_ORDERDATE DATE ,
 O_ORDERPRIORITY CHAR(15) ,
 O_CLERK CHAR(15) ,
```

```
O_SHIPPRIORITY BIGINT ,
O_COMMENT VARCHAR(79)

)
SERVER server_remote
OPTIONS
(
schema_name 'public',
table_name 'orders',
encoding 'SQL_ASCII'
);
```

Step 3 Import all table data.

In the SQL window, run the SQL statement below to import full data from the **ft_orders** foreign table: Wait for about 1 minute.

```
INSERT INTO orders SELECT * FROM ft_orders;
```

Run the following SQL statement to verify that 15 million rows of data are successfully imported.

```
SELECT count(*) FROM orders;
```

Step 4 Import data based on filter criteria.

```
INSERT INTO orders SELECT * FROM ft_orders WHERE o_orderkey < '10000000';
```

----End

3 Data Analytics

3.1 Using DWS to Query Vehicle Routes at Traffic Checkpoints in Seconds

This practice shows you how to analyze passing vehicles at checkpoints. In this practice, 890 million data records from checkpoints are loaded to a single database table on DWS for accurate and fuzzy query, demonstrating the ability of DWS to perform high-performance query for historical data.

NOTE

The sample data has been uploaded to the **traffic-data** folder in an OBS bucket, and all Huawei Cloud accounts have been granted the read-only permission for accessing the OBS bucket.

General Procedure

This practice takes about 40 minutes. The basic process is as follows:

1. **Making Preparations**
2. **Step 1: Creating a Cluster**
3. **Step 2: Importing Sample Data**
4. **Step 3: Performing Vehicle Analysis**

Supported Regions

Table 3-1 Regions and OBS bucket names

Region	OBS Bucket
EU-Dublin	dws-demo-eu-west-101

Making Preparations

- You have registered a DWS account and checked the account status before using DWS. The account cannot be in arrears or frozen.
- You have obtained the AK and SK of the account.

Step 1: Creating a Cluster

Step 1 Log in to the **DWS console**.

Step 2 Click **Service List** and choose **Analytics** > **DWS**.

Step 3 Choose **Dedicated Clusters** > **Clusters**. On the displayed page, click **Create GaussDB(DWS) Cluster** in the upper right corner.

Step 4 Configure the parameters according to **Table 3-2**.

Table 3-2 Basic configurations

Parameter	Configuration
Region	Select **CN North-Beijing4** or **CN-Hong KongEU-Dublin**. **NOTE** **EU-Dublin** is used as an example. You can select other regions as required. Ensure that all operations are performed in the same region.
AZ	Single AZ > AZ2
Version	Coupled storage and compute
Storage Type	Cloud SSD
CPU Architecture	x86
Node Flavor	dws2.m6.4xlarge.8 (16 vCPUs | 128 GB | 2000 GB SSD) **NOTE** If this flavor is sold out, select other AZs or flavors.
Hot Storage	100 GB/node
Nodes	3

Step 5 Verify that the information is correct and click **Next: Configure Network**. Configure the network by referring to **Table 3-3**.

Table 3-3 Configuring the network

Parameter	Configuration
VPC	vpc-default
Subnet	subnet-default(192.168.0.0/24)

Parameter	Configuration
Security Group	Automatic creation
EIP	Buy now
Bandwidth	1 Mbit/s
ELB	Do not use

Step 6 Click **Next: Configure Advanced Settings** to access advanced configurations. **Table 3-4** lists the required parameters.

Table 3-4 Configuring advanced settings

Parameter	Configuration
Cluster Name	dws-demo
Cluster Version	Use the recommended version.
Administrator Account	dbadmin
Administrator Password	N/A
Confirm Password	N/A
Database Port	8000
Enterprise Project	Default
Advanced Settings	Default

Step 7 Click **Next: Confirm**, confirm the settings, and click **Buy Now**.

Step 8 Wait about 6 minutes. After the cluster is created, click next to the cluster name. On the displayed cluster information page, record the value of **Public Network Address**.

Figure 3-1 Cluster information

----End

Step 2: Importing Sample Data

After connecting to the cluster using the SQL client tool, perform the following operations on the SQL client tool to import the sample data from traffic checkpoints and perform data queries.

Step 1 Create a database **traffic**.

```
CREATE DATABASE traffic encoding 'utf8' template template0;
```

Step 2 Switch to the new database **traffic** and create a database table for storing checkpoint vehicle information.

```
CREATE SCHEMA traffic_data;
SET current_schema= traffic_data;
DROP TABLE if exists GCJL;
CREATE TABLE GCJL
(
        kkbh   VARCHAR(20),
        hphm   VARCHAR(20),
        gcsj   DATE ,
        cplx   VARCHAR(8),
        cllx   VARCHAR(8),
        csys   VARCHAR(8)
)
with (orientation = column, COMPRESSION=MIDDLE)
distribute by hash(hphm);
```

Step 3 Create a foreign table, which is used to identify and associate the source data on OBS.

CAUTION

- *<obs_bucket_name>* indicates the OBS bucket name corresponding to the region where DWS is located. For details about supported regions, see **Supported Regions**. The OBS bucket and sample data have been preset in the system, and you do not need to create them.
- Replace *<Access_Key_Id>* and *<Secret_Access_Key>* with the actual values obtained in **Making Preparations**.
- Hard-coded or plaintext AK/SK is risky. For security, encrypt your AK/SK and store them in the configuration file or environment variables.
- If the message "ERROR: schema "*xxx*" does not exist Position" is displayed when you create a foreign table, the schema does not exist. Perform the previous step to create a schema.

```
CREATE SCHEMA tpchobs;
SET current_schema = 'tpchobs';
DROP FOREIGN table if exists GCJL_OBS;
CREATE FOREIGN TABLE GCJL_OBS
(
        like traffic_data.GCJL
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/traffic-data/gcxx',
        format 'text',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);
```

Step 4 Import data from a foreign table to a database table.

```
INSERT INTO traffic_data.GCJL SELECT * FROM tpchobs.GCJL_OBS;
```

It takes some time to import data.

----End

Step 3: Performing Vehicle Analysis

1. **Execute ANALYZE.**

   This statement collects statistics related to ordinary tables in databases. The statistics are saved to the system catalog **PG_STATISTIC**. When you run the planner, the statistics help you develop an efficient query execution plan.

   Execute the following statement to generate the table statistics:

   ```
   ANALYZE;
   ```

2. **Querying the data volume of the data table**

   Execute the following statement to query the number of loaded data records:

   ```
   SET current_schema= traffic_data;
   SELECT count(*) FROM traffic_data.gcjl;
   ```

3. **Accurate vehicle query**

Run the following statements to query the driving route of a vehicle by the license plate number and time segment. DWS responds to the request in seconds.

```
SET current_schema= traffic_data;
SELECT hphm, kkbh, gcsj
FROM traffic_data.gcjl
where hphm =  'YD38641'
and gcsj between '2016-01-06' and '2016-01-07'
order by gcsj desc;
```

4. **Fuzzy vehicle query**

   Run the following statements to query the driving route of a vehicle by the license plate number and time segment. DWS responds to the request in seconds.

```
SET current_schema= traffic_data;
SELECT hphm, kkbh, gcsj
FROM traffic_data.gcjl
where hphm like  'YA23F%'
and kkbh in('508', '1125', '2120')
and gcsj between '2016-01-01' and '2016-01-07'
order by hphm,gcsj desc;
```

3.2 Using DWS to Analyze the Supply Chain Requirements of a Company

This practice describes how to load the sample data set from OBS to a data warehouse cluster and perform data queries. This example comprises multi-table analysis and theme analysis in the data analysis scenario.

NOTE

In this example, a standard TPC-H-1x data set of 1 GB size has been generated on DWS, and has been uploaded to the **tpch** folder of an OBS bucket. All accounts have been granted the read-only permission to access the OBS bucket. Users can easily import the data set using their accounts.

General Procedure

This practice takes about 60 minutes. The process is as follows:

1. **Making Preparations**
2. **Step 1: Importing Sample Data**
3. **Step 2: Performing Multi-Table Analysis and Theme Analysis**

Supported Regions

Table 3-5 Regions and OBS bucket names

Region	OBS Bucket
EU-Dublin	dws-demo-eu-west-101

Scenario Description

Understand the basic functions of DWS and how to import data. Analyze the order data of a company and its suppliers as follows:

1. Analyze the revenue brought by suppliers in a region to the company. The statistics can be used to determine whether a local allocation center needs to be established in a given region.
2. Analyze the relationship between parts and suppliers to obtain the number of suppliers for parts based on the specified contribution conditions. The information can be used to determine whether suppliers are sufficient for large order quantities when the task is urgent.
3. Analyze the revenue loss of small orders. You can query the average annual revenue loss if there are no small orders. Filter out small orders that are lower than 20% of the average supply volume, and calculate the total amount of those small orders to figure out the average annual revenue loss.

Making Preparations

- You have registered a DWS account and checked the account status before using DWS. The account cannot be in arrears or frozen.
- You have obtained the AK and SK of the account.
- A cluster has been created and connected.

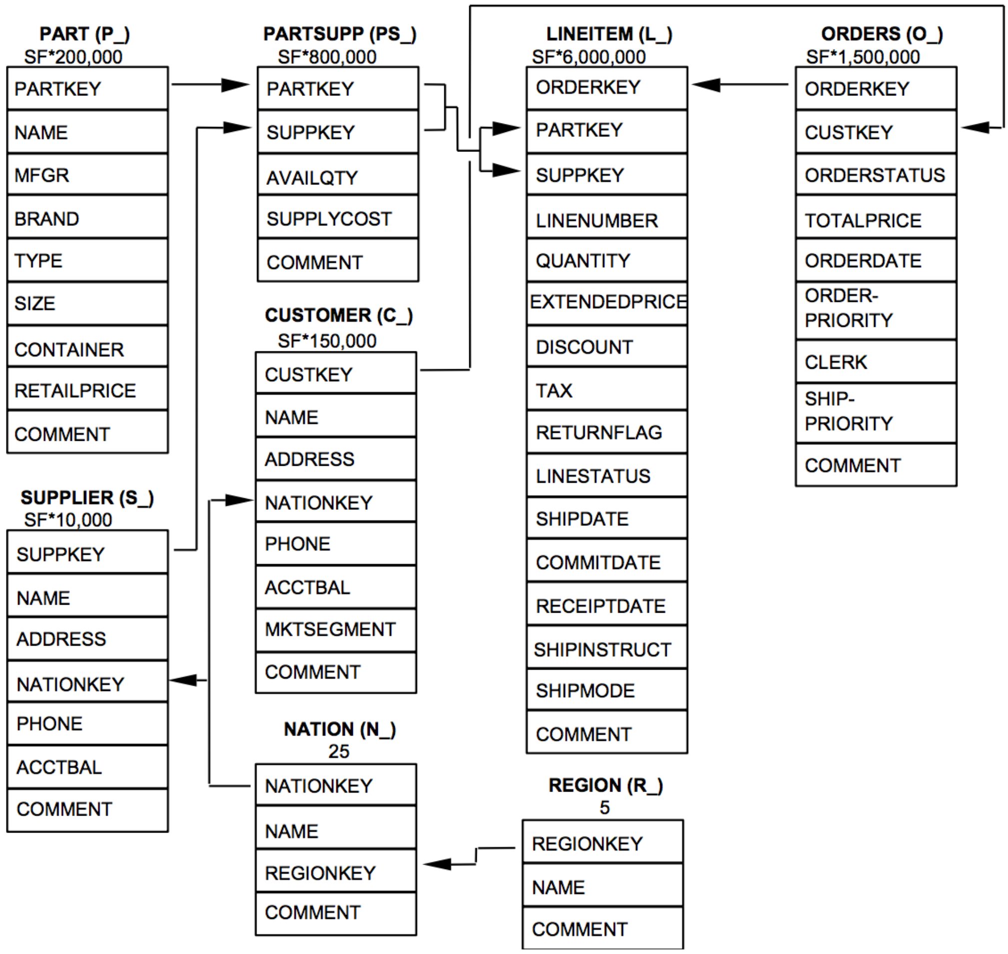
Step 1: Importing Sample Data

After connecting to the cluster using the SQL client tool, perform the following operations in the SQL client tool to import the TPC-H sample data and perform data queries.

Step 1 Create a database table.

The TPC-H sample data consists of eight database tables whose associations are shown in **Figure 3-2**.

Figure 3-2 TPC-H data tables



Execute the following statements to create tables in the **gaussdb** database.

```
CREATE SCHEMA tpch;
SET current_schema = tpch;

DROP TABLE if exists region;
CREATE TABLE REGION
(
        R_REGIONKEY  INT NOT NULL ,
        R_NAME       CHAR(25) NOT NULL ,
        R_COMMENT    VARCHAR(152)
)
with (orientation = column, COMPRESSION=MIDDLE)
distribute by replication;

DROP TABLE if exists nation;
CREATE TABLE NATION
(
        N_NATIONKEY  INT NOT NULL,
        N_NAME       CHAR(25) NOT NULL,
        N_REGIONKEY  INT NOT NULL,
        N_COMMENT    VARCHAR(152)
)
with (orientation = column,COMPRESSION=MIDDLE)
distribute by replication;

DROP TABLE if exists supplier;
CREATE TABLE SUPPLIER
```

```
(
        S_SUPPKEY     BIGINT NOT NULL,
        S_NAME        CHAR(25) NOT NULL,
        S_ADDRESS     VARCHAR(40) NOT NULL,
        S_NATIONKEY   INT NOT NULL,
        S_PHONE       CHAR(15) NOT NULL,
        S_ACCTBAL     DECIMAL(15,2) NOT NULL,
        S_COMMENT     VARCHAR(101) NOT NULL
)
with (orientation = column,COMPRESSION=MIDDLE)
distribute by hash(S_SUPPKEY);

DROP TABLE if exists customer;
CREATE TABLE CUSTOMER
(
        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
)
with (orientation = column,COMPRESSION=MIDDLE)
distribute by hash(C_CUSTKEY);

DROP TABLE if exists part;
CREATE TABLE PART
(
        P_PARTKEY     BIGINT NOT NULL,
        P_NAME        VARCHAR(55) NOT NULL,
        P_MFGR        CHAR(25) NOT NULL,
        P_BRAND       CHAR(10) NOT NULL,
        P_TYPE        VARCHAR(25) NOT NULL,
        P_SIZE        BIGINT NOT NULL,
        P_CONTAINER   CHAR(10) NOT NULL,
        P_RETAILPRICE DECIMAL(15,2) NOT NULL,
        P_COMMENT     VARCHAR(23) NOT NULL
)
with (orientation = column,COMPRESSION=MIDDLE)
distribute by hash(P_PARTKEY);

DROP TABLE if exists partsupp;
CREATE TABLE PARTSUPP
(
        PS_PARTKEY     BIGINT NOT NULL,
        PS_SUPPKEY     BIGINT NOT NULL,
        PS_AVAILQTY    BIGINT NOT NULL,
        PS_SUPPLYCOST  DECIMAL(15,2)  NOT NULL,
        PS_COMMENT     VARCHAR(199) NOT NULL
)
with (orientation = column,COMPRESSION=MIDDLE)
distribute by hash(PS_PARTKEY);

DROP TABLE if exists orders;
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);

DROP TABLE if exists lineitem;
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);
```

Step 2 Create a foreign table, which is used to identify and associate the source data on OBS.

CAUTION

- *<obs_bucket_name>* indicates the OBS bucket name corresponding to the region where DWS is located. For details about supported regions, see **Supported Regions**. The OBS bucket and sample data have been preset in the system, and you do not need to create them.
- Replace *<Access_Key_Id>* and *<Secret_Access_Key>* with the actual values obtained in **Making Preparations**.
- Hard-coded or plaintext AK/SK is risky. For security, encrypt your AK/SK and store them in the configuration file or environment variables.
- If the message "ERROR: schema "*xxx*" does not exist Position" is displayed when you create a foreign table, the schema does not exist. Perform the previous step to create a schema.

```
CREATE SCHEMA tpchobs;
SET current_schema='tpchobs';
DROP FOREIGN table if exists region;
CREATE FOREIGN TABLE REGION
(
        like tpch.region
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/tpch/region.tbl',
        format 'text',
        delimiter '|',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);

DROP FOREIGN table if exists nation;
```

```
CREATE FOREIGN TABLE NATION
(
        like tpch.nation
)
SERVER gsmpp_server
OPTIONS (
         encoding 'utf8',
         location 'obs://<obs_bucket_name>/tpch/nation.tbl',
         format 'text',
         delimiter '|',
         access_key '<Access_Key_Id>',
         secret_access_key '<Secret_Access_Key>',
         chunksize '64',
         IGNORE_EXTRA_DATA 'on'
);

DROP FOREIGN table if exists supplier;
CREATE FOREIGN TABLE SUPPLIER
(
        like tpch.supplier
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/tpch/supplier.tbl',
        format 'text',
        delimiter '|',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);

DROP FOREIGN table if exists customer;
CREATE FOREIGN TABLE CUSTOMER
(
        like tpch.customer
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/tpch/customer.tbl',
        format 'text',
        delimiter '|',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);
DROP FOREIGN table if exists part;
CREATE FOREIGN TABLE PART
(
        like tpch.part

)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/tpch/part.tbl',
        format 'text',
        delimiter '|',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);
DROP FOREIGN table if exists partsupp;
CREATE FOREIGN TABLE PARTSUPP
(
```

```
        like tpch.partsupp
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/tpch/partsupp.tbl',
        format 'text',
        delimiter '|',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);
DROP FOREIGN table if exists orders;
CREATE FOREIGN TABLE ORDERS
(
        like tpch.orders
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/tpch/orders.tbl',
        format 'text',
        delimiter '|',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);
DROP FOREIGN table if exists lineitem;
CREATE FOREIGN TABLE LINEITEM
(
        like tpch.lineitem
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/tpch/lineitem.tbl',
        format 'text',
        delimiter '|',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on'
);
```

Step 3 Copy and execute the following statements to import the foreign table data to the corresponding database table.

Run the **insert** command to import the data in the OBS foreign table to the DWS database table. The database kernel concurrently imports the OBS data at a high speed to DWS.

```
INSERT INTO tpch.lineitem SELECT * FROM tpchobs.lineitem;
INSERT INTO tpch.part SELECT * FROM tpchobs.part;
INSERT INTO tpch.partsupp SELECT * FROM tpchobs.partsupp;
INSERT INTO tpch.customer SELECT * FROM tpchobs.customer;
INSERT INTO tpch.supplier SELECT * FROM tpchobs.supplier;
INSERT INTO tpch.nation SELECT * FROM tpchobs.nation;
INSERT INTO tpch.region SELECT * FROM tpchobs.region;
INSERT INTO tpch.orders SELECT * FROM tpchobs.orders;
```

It takes 10 minutes to import data.

----End

Step 2: Performing Multi-Table Analysis and Theme Analysis

The following uses standard TPC-H query as an example to demonstrate how to perform basic data query on DWS.

Before querying data, run the **Analyze** command to generate statistics related to the database table. The statistics data is stored in system table PG_STATISTIC and is useful when you run the planner, which provides you with an efficient query execution plan.

The following are querying examples:

- **Querying revenue of a supplier in a region (TPCH-Q5)**

  By executing the TPCH-Q5 query statement, you can query the revenue statistics of a spare parts supplier in a region. The revenue is calculated based on **sum(l_extendedprice * (1 - l_discount))**. The statistics can be used to determine whether a local allocation center needs to be established in a given region.

  Copy and execute the following TPCH-Q5 statement for query. This statement features multi-table join query with **GROUP BY**, **ORDER BY**, and **AGGREGATE**.

```
SET current_schema='tpch';
SELECT
n_name,
sum(l_extendedprice * (1 - l_discount)) as revenue
FROM
customer,
orders,
lineitem,
supplier,
nation,
region
where
c_custkey = o_custkey
and l_orderkey = o_orderkey
and l_suppkey = s_suppkey
and c_nationkey = s_nationkey
and s_nationkey = n_nationkey
and n_regionkey = r_regionkey
and r_name = 'ASIA'
and o_orderdate >= '1994-01-01'::date
and o_orderdate < '1994-01-01'::date + interval '1 year'
group by
n_name
order by
revenue desc;
```

- **Querying relationships between spare parts and suppliers (TPCH-Q16)**

  By executing the TPCH-Q16 query statement, you can obtain the number of suppliers that can supply spare parts with the specified contribution conditions. This information can be used to determine whether there are sufficient suppliers when the order quantity is large and the task is urgent.

  Copy and execute the following TPCH-Q16 statement for query. The statement features multi-table connection operations with group by, sort by, aggregate, deduplicate, and NOT IN subquery.

```
SET current_schema='tpch';
SELECT
p_brand,
p_type,
p_size,
count(distinct ps_suppkey) as supplier_cnt
FROM
```

```
partsupp,
part
where
p_partkey = ps_partkey
and p_brand <> 'Brand#45'
and p_type not like 'MEDIUM POLISHED%'
and p_size in (49, 14, 23, 45, 19, 3, 36, 9)
and ps_suppkey not in (
        select
        s_suppkey
        from
        supplier
        where
        s_comment like '%Customer%Complaints%'
)
group by
p_brand,
p_type,
p_size
order by
supplier_cnt desc,
p_brand,
p_type,
p_size
limit 100;
```

- **Querying revenue loss of small orders (TPCH-Q17)**

  You can query the average annual revenue loss if there are no small orders. Filter out small orders that are lower than the 20% of the average supply volume, and calculate the total amount of those small orders to figure out the average annual revenue loss.

  Copy and execute the following TPCH-Q17 statement for query. The statement features multi-table connection operations with aggregate and aggregate subquery.

```
SET current_schema='tpch';
SELECT
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
);
```

3.3 Using DWS to Analyze the Operational Status of a Retail Department Store

Background

In this practice, the daily business data of each retail store is loaded from OBS to the corresponding table in the data warehouse cluster for summarizing and querying KPIs. This data includes store turnover, customer flow, monthly sales ranking, monthly customer flow conversion rate, monthly price-rent ratio, and sales per unit area. This practice demonstrates the multidimensional query and analysis of DWS in retail scenarios.

NOTE

The sample data has been uploaded to the **retail-data** folder in an OBS bucket, and all Huawei Cloud accounts have been granted the read-only permission to access the OBS bucket.

General Procedure

This practice takes about 60 minutes. The process is as follows:

1. **Preparations**
2. **Step 1: Importing Sample Data from the Retail Department Store**
3. **Step 2: Performing Operations Status Analysis**

Supported Regions

Table 3-6 Regions and OBS bucket names

Region	OBS Bucket
EU-Dublin	dws-demo-eu-west-101

Preparations

- You have registered a DWS account, and the account is not in arrears or frozen.
- You have obtained the AK and SK of the account.
- A cluster has been created and connected.

Step 1: Importing Sample Data from the Retail Department Store

After connecting to the cluster using the SQL client tool, perform the following operations in the SQL client tool to import the sample data from retail department stores and perform queries.

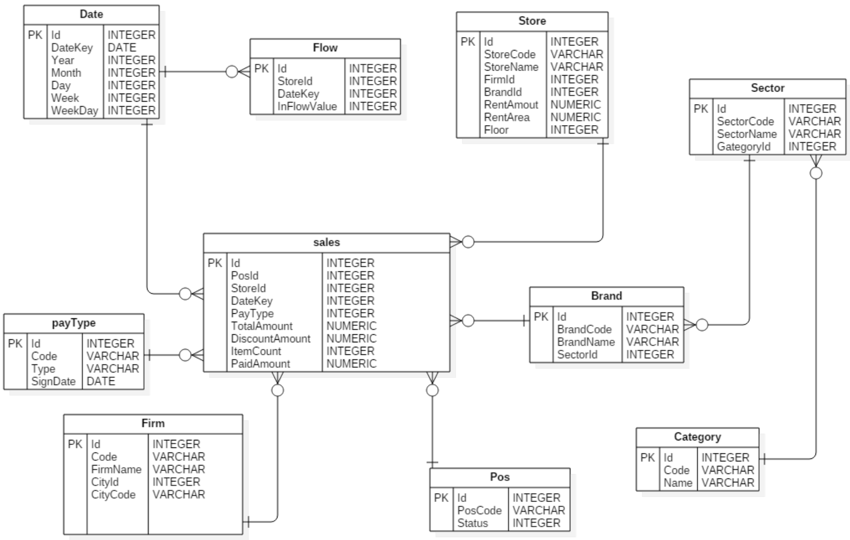
Step 1 Execute the following statement to create the **retail** database:

```
CREATE DATABASE retail encoding 'utf8' template template0;
```

Step 2 Switch to the newly created database **retail** and create database tables.

The sample data consists of 10 database tables whose associations are shown in **Figure 3-3**.

Figure 3-3 Sample data tables of retail department stores



Copy and execute the following statements to switch to create a database table of retail department store information.

```
CREATE SCHEMA retail_data;
SET current_schema='retail_data';

DROP TABLE IF EXISTS STORE;
CREATE TABLE STORE (
    ID INT,
    STORECODE VARCHAR(10),
    STORENAME VARCHAR(100),
    FIRMID INT,
    FLOOR INT,
    BRANDID INT,
    RENTAMOUNT NUMERIC(18,2),
    RENTAREA NUMERIC(18,2)
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS POS;
CREATE TABLE POS(
    ID INT,
    POSCODE VARCHAR(20),
    STATUS INT,
    MODIFICATIONDATE DATE
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS BRAND;
CREATE TABLE BRAND (
    ID INT,
    BRANDCODE VARCHAR(10),
    BRANDNAME VARCHAR(100),
    SECTORID INT
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS SECTOR;
CREATE TABLE SECTOR(
    ID INT,
    SECTORCODE VARCHAR(10),
    SECTORNAME VARCHAR(20),
    CATEGORYID INT
)
```

```
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS CATEGORY;
CREATE TABLE CATEGORY(
        ID INT,
        CODE VARCHAR(10),
        NAME VARCHAR(20)
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS FIRM;
CREATE TABLE FIRM(
        ID INT,
        CODE VARCHAR(4),
        NAME VARCHAR(40),
        CITYID INT,
        CITYNAME VARCHAR(10),
        CITYCODE VARCHAR(20)
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS DATE;
CREATE TABLE DATE(
        ID INT,
        DATEKEY DATE,
        YEAR INT,
        MONTH INT,
        DAY INT,
        WEEK INT,
        WEEKDAY INT
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS PAYTYPE;
CREATE TABLE PAYTYPE(
        ID INT,
        CODE VARCHAR(10),
        TYPE VARCHAR(10),
        SIGNDATE DATE
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY REPLICATION;

DROP TABLE IF EXISTS SALES;
CREATE TABLE SALES(
         ID INT,
         POSID INT,
         STOREID INT,
         DATEKEY INT,
         PAYTYPE INT,
         TOTALAMOUNT NUMERIC(18,2),
         DISCOUNTAMOUNT NUMERIC(18,2),
         ITEMCOUNT INT,
         PAIDAMOUNT NUMERIC(18,2)
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY HASH(ID);

DROP TABLE IF EXISTS FLOW;
CREATE TABLE FLOW (
         ID INT,
         STOREID INT,
         DATEKEY INT,
         INFLOWVALUE INT
)
WITH (ORIENTATION = COLUMN, COMPRESSION=MIDDLE) DISTRIBUTE BY HASH(ID);
```

Step 3 Create a foreign table, which is used to identify and associate the source data on OBS.

CAUTION

- *<obs_bucket_name>* indicates the OBS bucket name corresponding to the region where DWS is located. For details about supported regions, see **Supported Regions**. The OBS bucket and sample data have been preset in the system, and you do not need to create them.
- Replace *<Access_Key_Id>* and *<Secret_Access_Key>* with the actual values obtained in **Preparations**.
- Hard-coded or plaintext AK/SK is risky. For security, encrypt your AK/SK and store them in the configuration file or environment variables.
- If the message "ERROR: schema "*xxx*" does not exist Position" is displayed when you create a foreign table, the schema does not exist. Perform the previous step to create a schema.

```
CREATE SCHEMA retail_obs_data;
SET current_schema='retail_obs_data';
DROP FOREIGN table if exists SALES_OBS;
CREATE FOREIGN TABLE SALES_OBS
(
        like retail_data.SALES
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/sales',
        format 'csv',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);

DROP FOREIGN table if exists FLOW_OBS;
CREATE FOREIGN TABLE FLOW_OBS
(
        like retail_data.flow
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/flow',
        format 'csv',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);

DROP FOREIGN table if exists BRAND_OBS;
CREATE FOREIGN TABLE BRAND_OBS
(
        like retail_data.brand
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/brand',
        format 'csv',
        delimiter ',',
```



```
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);


DROP FOREIGN table if exists CATEGORY_OBS;
CREATE FOREIGN TABLE CATEGORY_OBS
(
       like retail_data.category
)
SERVER gsmpp_server
OPTIONS (
       encoding 'utf8',
       location 'obs://<obs_bucket_name>/retail-data/category',
       format 'csv',
       delimiter ',',
       access_key '<Access_Key_Id>',
       secret_access_key '<Secret_Access_Key>',
       chunksize '64',
       IGNORE_EXTRA_DATA 'on',
       header 'on'
);

DROP FOREIGN table if exists DATE_OBS;
CREATE FOREIGN TABLE DATE_OBS
(
        like retail_data.date
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/date',
        format 'csv',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);

DROP FOREIGN table if exists FIRM_OBS;
CREATE FOREIGN TABLE FIRM_OBS
(
        like retail_data.firm
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/firm',
        format 'csv',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);


DROP FOREIGN table if exists PAYTYPE_OBS;
CREATE FOREIGN TABLE PAYTYPE_OBS
(
        like retail_data.paytype
)
SERVER gsmpp_server
```

```
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/paytype',
        format 'csv',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);


DROP FOREIGN table if exists POS_OBS;
CREATE FOREIGN TABLE POS_OBS
(
        like retail_data.pos
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/pos',
        format 'csv',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);

DROP FOREIGN table if exists SECTOR_OBS;
CREATE FOREIGN TABLE SECTOR_OBS
(
        like retail_data.sector
)
SERVER gsmpp_server
OPTIONS (
        encoding 'utf8',
        location 'obs://<obs_bucket_name>/retail-data/sector',
        format 'csv',
        delimiter ',',
        access_key '<Access_Key_Id>',
        secret_access_key '<Secret_Access_Key>',
        chunksize '64',
        IGNORE_EXTRA_DATA 'on',
        header 'on'
);


DROP FOREIGN table if exists STORE_OBS;
CREATE FOREIGN TABLE STORE_OBS
(
         like retail_data.store
)
SERVER gsmpp_server
OPTIONS (
         encoding 'utf8',
         location 'obs://<obs_bucket_name>/retail-data/store',
         format 'csv',
         delimiter ',',
         access_key '<Access_Key_Id>',
         secret_access_key '<Secret_Access_Key>',
         chunksize '64',
         IGNORE_EXTRA_DATA 'on',
         header 'on'
);
```


Step 4 Copy and execute the following statements to import the foreign table data to the cluster:

```
INSERT INTO retail_data.store SELECT * FROM retail_obs_data.STORE_OBS;
INSERT INTO retail_data.sector SELECT * FROM retail_obs_data.SECTOR_OBS;
INSERT INTO retail_data.paytype SELECT * FROM retail_obs_data.PAYTYPE_OBS;
INSERT INTO retail_data.firm SELECT * FROM retail_obs_data.FIRM_OBS;
INSERT INTO retail_data.flow SELECT * FROM retail_obs_data.FLOW_OBS;
INSERT INTO retail_data.category SELECT * FROM retail_obs_data.CATEGORY_OBS;
INSERT INTO retail_data.date SELECT * FROM retail_obs_data.DATE_OBS;
INSERT INTO retail_data.pos SELECT * FROM retail_obs_data.POS_OBS;
INSERT INTO retail_data.brand SELECT * FROM retail_obs_data.BRAND_OBS;
INSERT INTO retail_data.sales SELECT * FROM retail_obs_data.SALES_OBS;
```

It takes some time to import data.

Step 5 Copy and execute the following statement to create the **v_sales_flow_details** view:

```
SET current_schema='retail_data';
CREATE VIEW v_sales_flow_details AS
SELECT
FIRM.ID FIRMID, FIRM.NAME FIRNAME, FIRM. CITYCODE,
CATEGORY.ID CATEGORYID, CATEGORY.NAME CATEGORYNAME,
SECTOR.ID SECTORID, SECTOR.SECTORNAME,
BRAND.ID BRANDID, BRAND.BRANDNAME,
STORE.ID STOREID, STORE.STORENAME, STORE.RENTAMOUNT, STORE.RENTAREA,
DATE.DATEKEY, SALES.TOTALAMOUNT, DISCOUNTAMOUNT, ITEMCOUNT, PAIDAMOUNT, INFLOWVALUE
FROM SALES
INNER JOIN STORE ON SALES.STOREID = STORE.ID
INNER JOIN FIRM ON STORE.FIRMID = FIRM.ID
INNER JOIN BRAND ON STORE.BRANDID = BRAND.ID
INNER JOIN SECTOR ON BRAND.SECTORID = SECTOR.ID
INNER JOIN CATEGORY ON SECTOR.CATEGORYID = CATEGORY.ID
INNER JOIN DATE ON SALES.DATEKEY = DATE.ID
INNER JOIN FLOW ON FLOW.DATEKEY = DATE.ID AND FLOW.STOREID = STORE.ID;
```

----End

Step 2: Performing Operations Status Analysis

The following uses standard query of retail information from department stores as an example to demonstrate how to perform basic data query on DWS.

Before querying data, run the **Analyze** command to generate statistics related to the database table. The statistics data is stored in system table PG_STATISTIC and is useful when you run the planner, which provides you with an efficient query execution plan.

The following are querying examples:

- **Querying the monthly sales revenue of each store**

  Copy and execute the following statements to query the total revenue of each store in a certain month:

  ```
  SET current_schema='retail_data';
  SELECT DATE_TRUNC('month',datekey)
  AT TIME ZONE 'UTC' AS __timestamp,
  SUM(paidamount)
  AS sum__paidamount
  FROM v_sales_flow_details
  GROUP BY DATE_TRUNC('month',datekey) AT TIME ZONE 'UTC'
  ORDER BY SUM(paidamount) DESC;
  ```

- **Querying the sales revenue and price-rent ratio of each store**

Copy and execute the following statement to query the sales revenue and price-rent ratio of each store:

```
SET current_schema='retail_data';
SELECT firname AS firname,
storename AS storename,
SUM(paidamount)
AS sum__paidamount,
AVG(RENTAMOUNT)/SUM(PAIDAMOUNT)
AS rentamount_sales_rate
FROM v_sales_flow_details
GROUP BY firname, storename
ORDER BY SUM(paidamount) DESC;
```

- **Analyzing the sales revenue of each city**

  Copy and execute the following statement to analyze and query the sales revenue of all provinces:

```
SET current_schema='retail_data';
SELECT citycode AS citycode,
SUM(paidamount)
AS sum__paidamount
FROM v_sales_flow_details
GROUP BY citycode
ORDER BY SUM(paidamount) DESC;
```

- **Analyzing and comparing the price-rent ratio and customer flow conversion rate of each store**

```
SET current_schema='retail_data';
SELECT brandname AS brandname,
firname AS firname,
SUM(PAIDAMOUNT)/AVG(RENTAREA) AS sales_rentarea_rate,
SUM(ITEMCOUNT)/SUM(INFLOWVALUE) AS poscount_flow_rate,
AVG(RENTAMOUNT)/SUM(PAIDAMOUNT) AS rentamount_sales_rate
FROM v_sales_flow_details
GROUP BY brandname,  firname
ORDER BY sales_rentarea_rate DESC;
```

- **Analyzing brands in the retail industry**

```
SET current_schema='retail_data';
SELECT categoryname AS categoryname,
brandname AS brandname,
SUM(paidamount) AS sum__paidamount
FROM v_sales_flow_details
GROUP BY categoryname,
brandname
ORDER BY sum__paidamount DESC;
```

- **Querying daily sales information of each brand**

```
SET current_schema='retail_data';
SELECT brandname AS brandname,
DATE_TRUNC('day', datekey) AT TIME ZONE 'UTC' AS __timestamp,
SUM(paidamount) AS sum__paidamount
FROM v_sales_flow_details
WHERE datekey >= '2016-01-01 00:00:00'
AND datekey <= '2016-01-30 00:00:00'
GROUP BY brandname,
DATE_TRUNC('day', datekey) AT TIME ZONE 'UTC'
ORDER BY sum__paidamount ASC
LIMIT 50000;
```

3.4 Interconnecting DWS with Power BI

Power BI is a self-service business intelligence tool. It extracts, cleans, integrates, summarizes, analyzes, and displays data visually from various systems. Power BI handles all data analysis steps, from getting data, to cleaning, modeling, and visualizing it.

This practical shows how to install Power BI on a Windows ECS and connect it to DWS using an on-premises data gateway.

The process takes about 120 minutes. The steps include:

1. **Making Preparations**: Set up a Windows ECS and buy DWS.
2. **Installing the Power BI Environment and Software**: Install the .NET Framework, Npgsql driver, and Power BI.
3. **Preparing DWS Sample Data**: On DWS, create a database, schema, table, and user, and grant table access to the user.
4. **Interconnecting DWS with Power BI to Generate and Publish Reports**: Connect Power BI to DWS, then create and publish reports.
5. **Adding the DWS Connection Information to the Gateway List of Power BI**: Synchronize data in Power BI reports with DWS data in real time.

Making Preparations

- You have purchased a Windows ECS and the Windows Server is running properly. (If the existing ECS or local PC meets the requirements, you do not need to purchase an ECS separately.)
- You have purchased a DWS cluster.
- The DWS cluster can communicate with the ECS over the internal network. If using the public network, bind a public IP address to the DWS cluster.

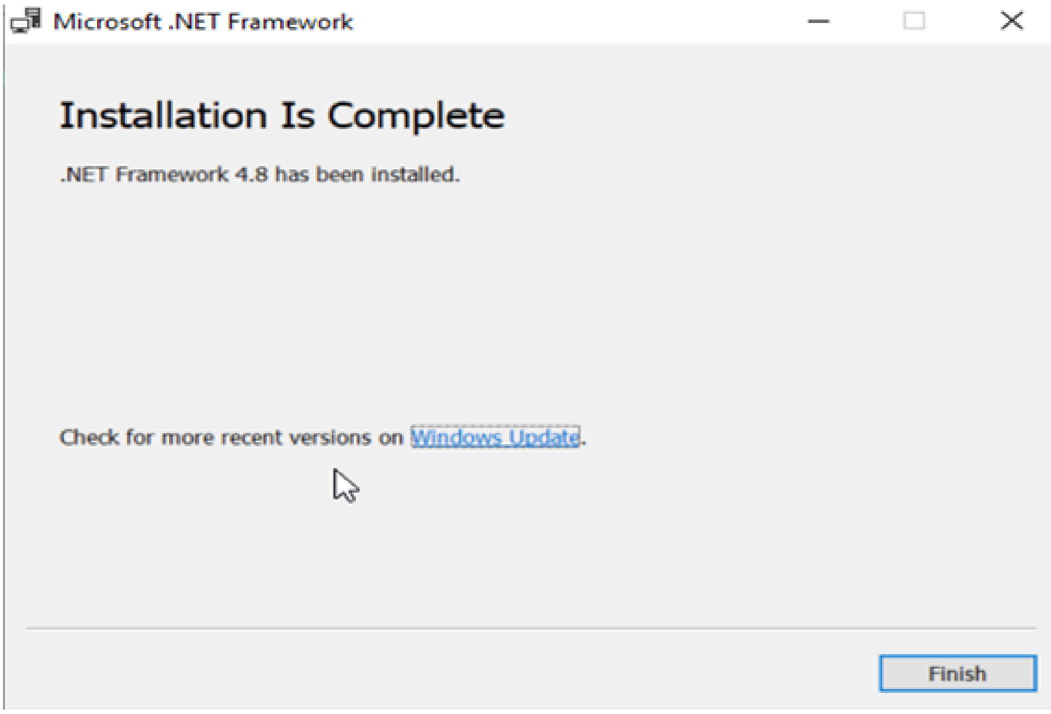
Installing the Power BI Environment and Software

Step 1 Log in to an ECS.

Step 2 Install the **.NET Framework** in the Windows operating system (take **.NET Framework 4.8** as an example).

After the installation is complete, the following information is displayed.

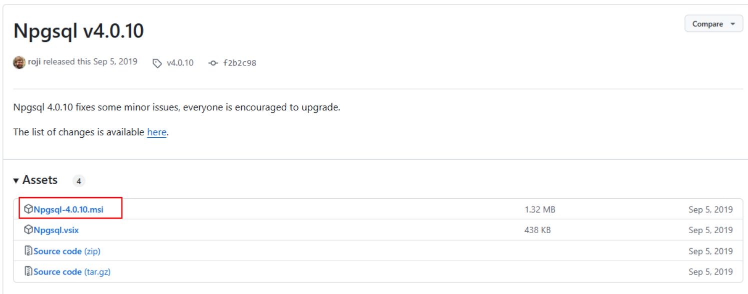
Figure 3-4 Installing the .NET Framework



Step 3 Install the PostgreSQL driver in Windows.

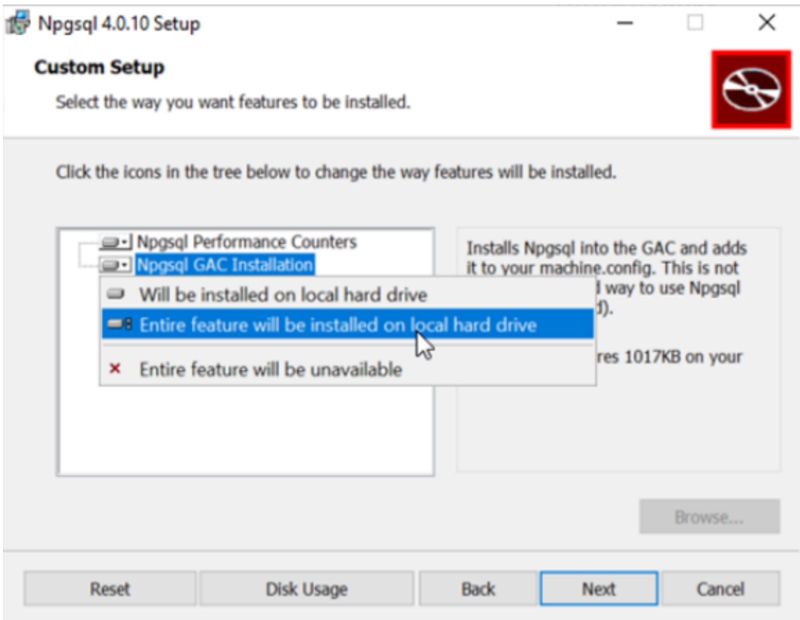
1. Obtain the **Npgsql driver** (version 4.0.10 is used as an example) installation package.

   Figure 3-5 Npgsql v4.0.10

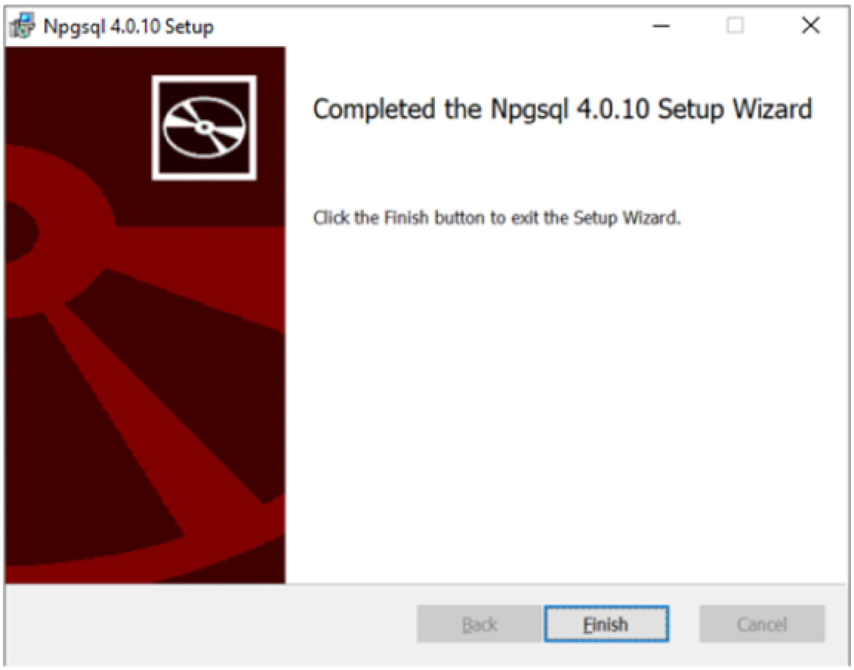
2. During the installation, select **Npgsql GAC Installation**, as shown in the following figure.

Figure 3-6 Installing the Npgsql



After the installation is complete, the following figure is displayed.

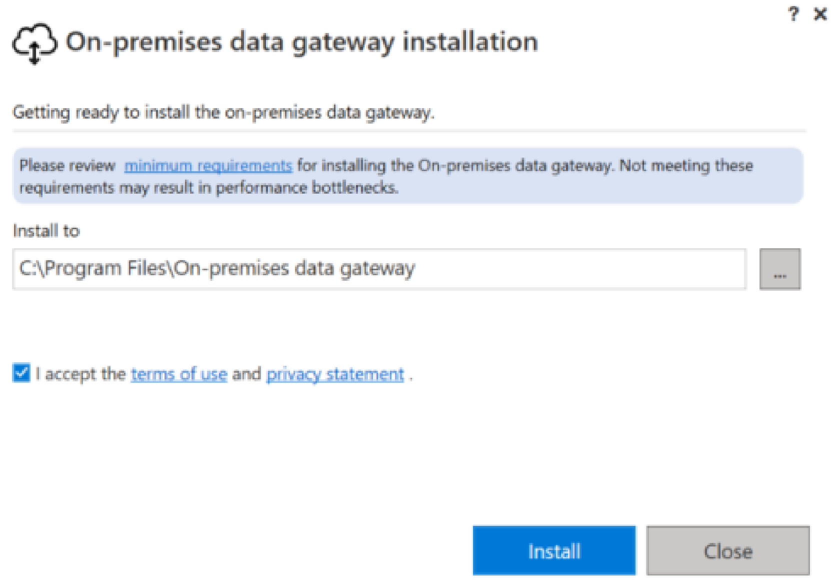
Figure 3-7 Npgsql installed



Step 4 Install the Power BI Gateway standard edition.

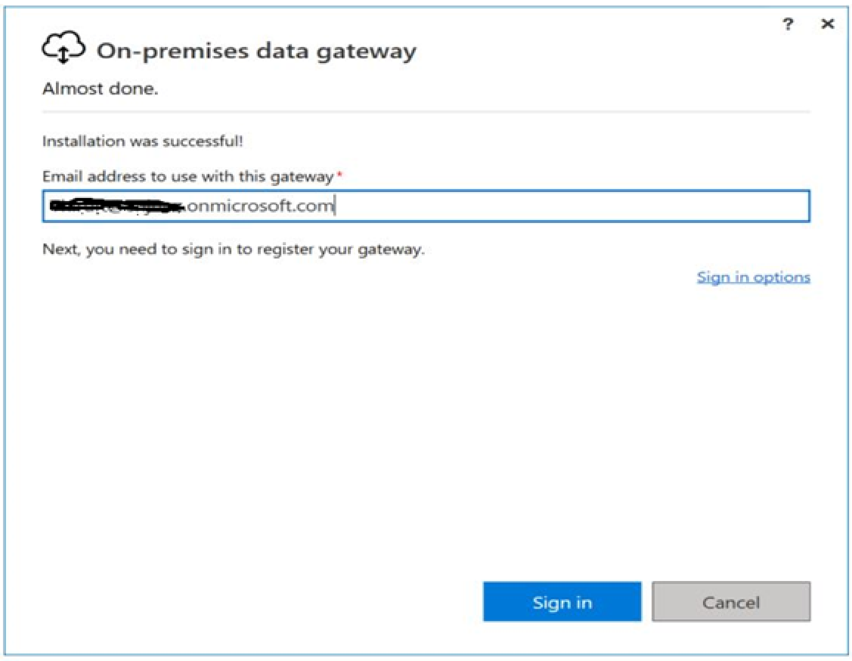
1. Visit **Power BI** to download the installation program of the standard edition.
2. In the gateway installation program, retain the default installation path, accept the terms of use, and click **Install**.

Figure 3-8 Installing Power BI



3. Enter the email address of your Office 365 account and click **Sign in**.

Figure 3-9 Entering an email address

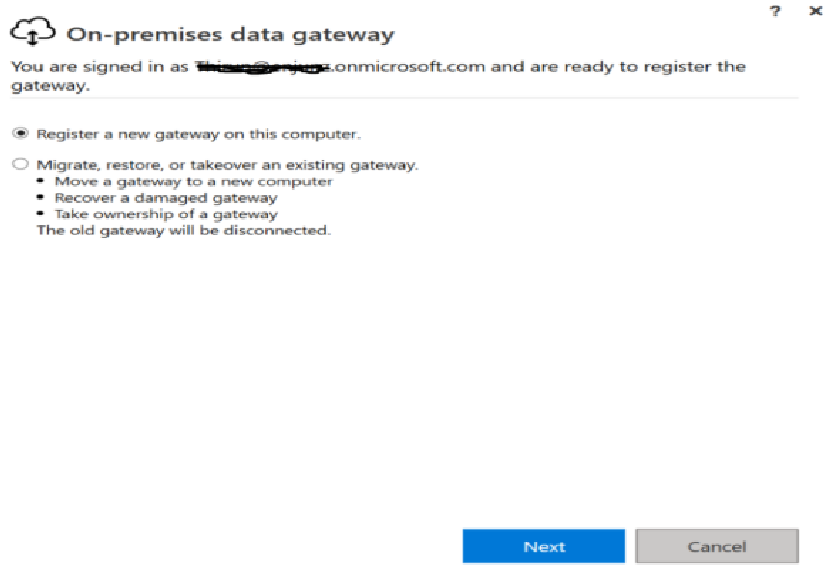


NOTE

If you are registered with Office 365, your email might look like *xxx***@contoso.onmicrosoft.com**.

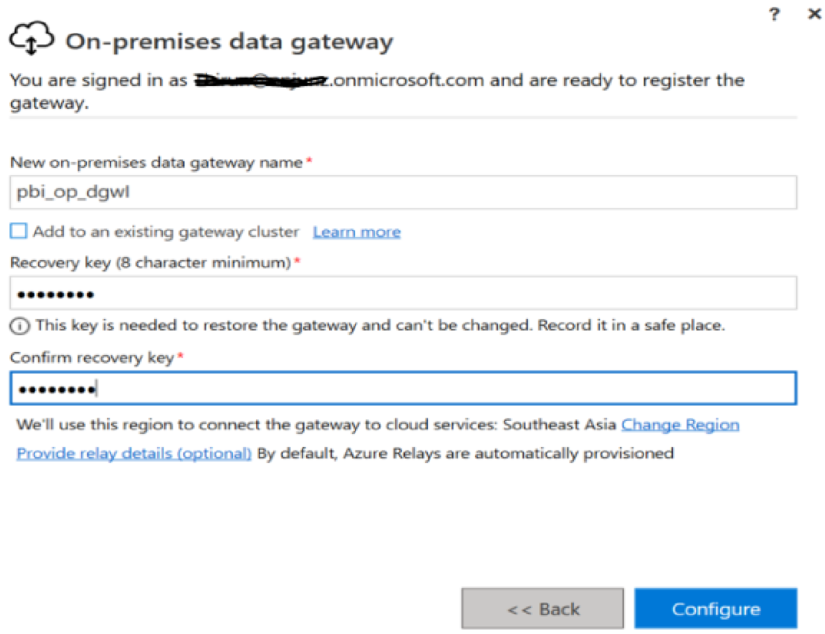
4. Select **Register a new gateway on this computer.** and click **Next**.

Figure 3-10 Registering a new gateway



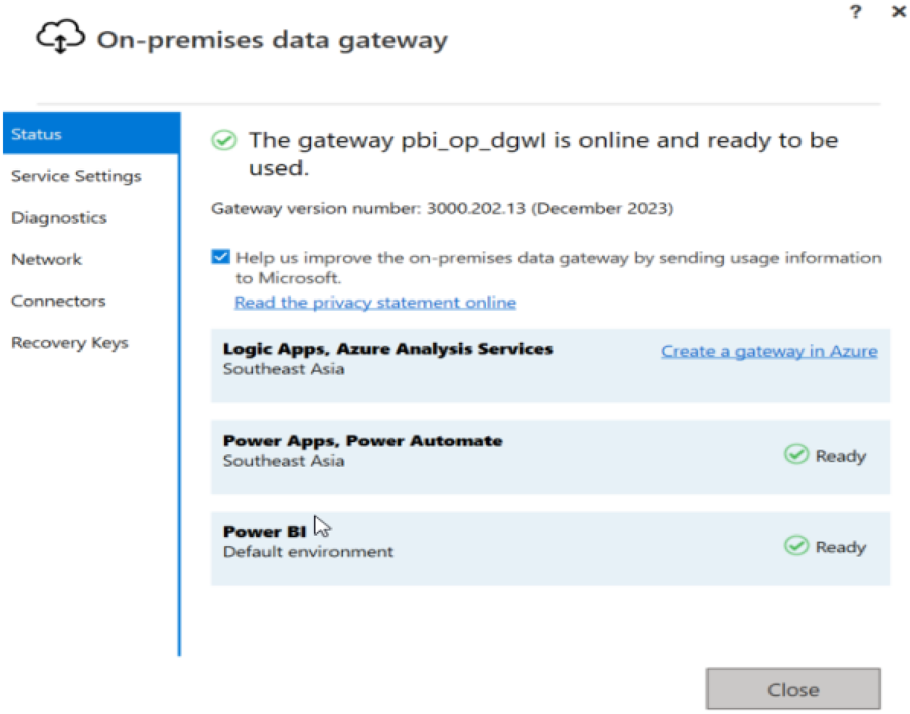
5. Enter the gateway name, which must be unique in the tenant. Do not select **Add to an existing gateway cluster**.
6. Enter the recovery key, which is required in the recovery or mobile gateway scenario, and click **Configure**.

Figure 3-11 Entering the gateway name



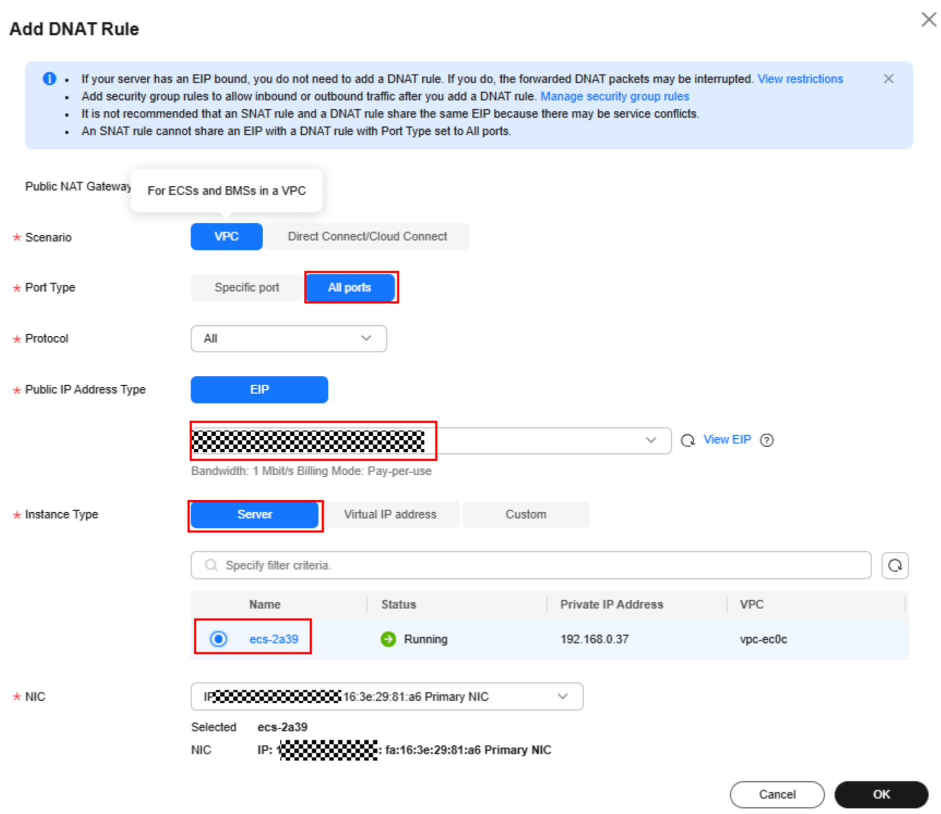
After the installation is complete, the following figure is displayed.

Figure 3-12 Installing Power BI



Step 5 Configure the NAT gateway.

1. Log in to the **NAT Gateway console** and choose **Network Connectivity** > **NAT Gateway** > **Public NAT Gateways**.
2. Buy a public NAT gateway. For details, see **NAT Gateway Documentation**.
3. Click **Add Rule** on the right of the purchased public network NAT, click the **DNAT Rules** tab, click **Add DNAT Rule**, and set the parameters shown in the following figure.



4. Click **OK**.

----End

Preparing DWS Sample Data

Step 1 Connect to the default DWS database **gaussdb** and create a database named **dws_test**.

```
CREATE DATABASE dws_test;
```

Step 2 Connect to the newly created database **dws_test**, create a schema named **dws_data**, create a table named **rpg_order** in the schema, and insert four data records.

```
CREATE SCHEMA dws_data;

CREATE TABLE dws_data.dws_order
        ( order_id      VARCHAR,
          order_channel VARCHAR,
          order_time    VARCHAR,
          cust_code     VARCHAR,
          pay_amount    DOUBLE PRECISION,
          real_pay      DOUBLE PRECISION )
DISTRIBUTE BY HASH (order_id);

INSERT INTO dws_data.dws_order VALUES ('202306270001', 'webShop', '2023-06-27 10:00:00', 'CUST1',
1000, 1000);
INSERT INTO dws_data.dws_order VALUES ('202306270002', 'webShop', '2023-06-27 11:00:00', 'CUST2',
5000, 5000);
INSERT INTO dws_data.dws_order VALUES ('202307100003', 'webShop', '2023-07-10 13:00:00', 'CUST1',
3000, 3000);
INSERT INTO dws_data.dws_order VALUES ('202307200004', 'webShop', '2023-07-20 14:00:00', 'CUST2',
4000, 4000);
```

Step 3 Check whether data is inserted into the table.

```
SELECT * FROM dws_data.dws_order;
```

Step 4 Create a Power BI database user. The password needs to be customized.

```
CREATE USER dws_thiru PASSWORD '{password}';
```

Step 5 Grant the user the permission to access the corresponding schema and table.

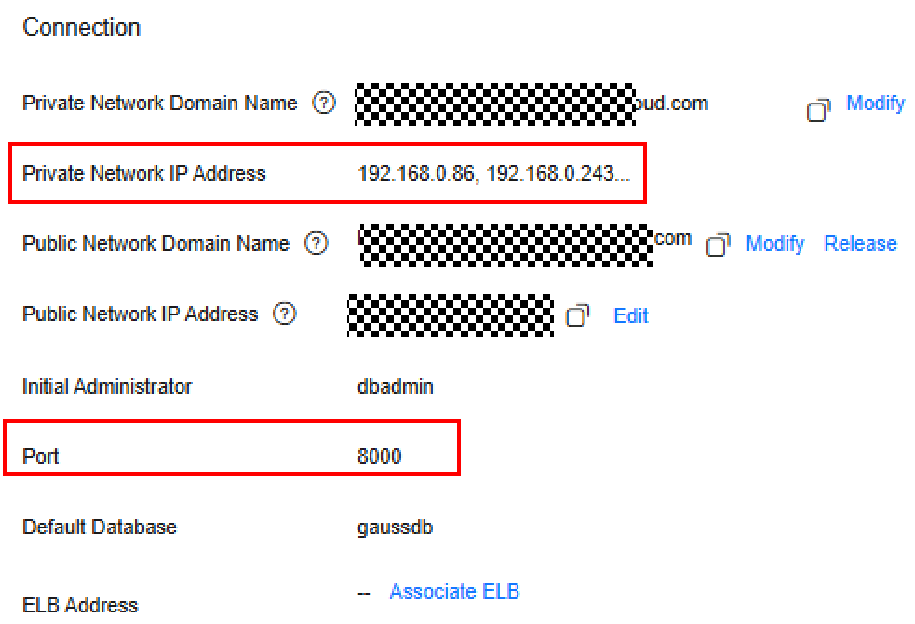
```
GRANT USAGE ON SCHEMA dws_data TO dws_thiru;
GRANT SELECT ON dws_data.dws_order TO dws_thiru;
```

----End

Interconnecting DWS with Power BI to Generate and Publish Reports

Step 1 Ensure that you have obtained the internal network IP address and port number of DWS.

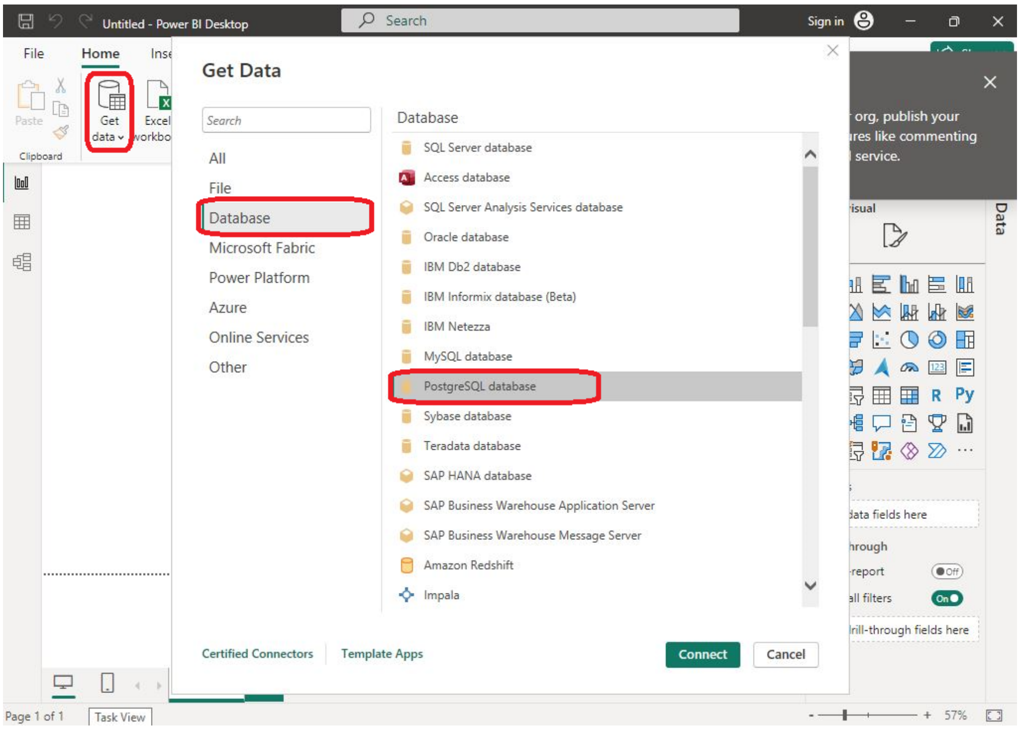
1. Log in to the **DWS console**. In the navigation pane, choose **Dedicated Clusters** > **Clusters**. Click the cluster name to view the cluster details.
2. In the **Connection** area on the right, record the private IP address and port number.



Step 2 Log in to the Windows desktop of the ECS, double-click **Power BI Desktop**, and click **Get Data**.

Step 3 Choose **Database** > **PostgreSQL Database** and click **Connect**.

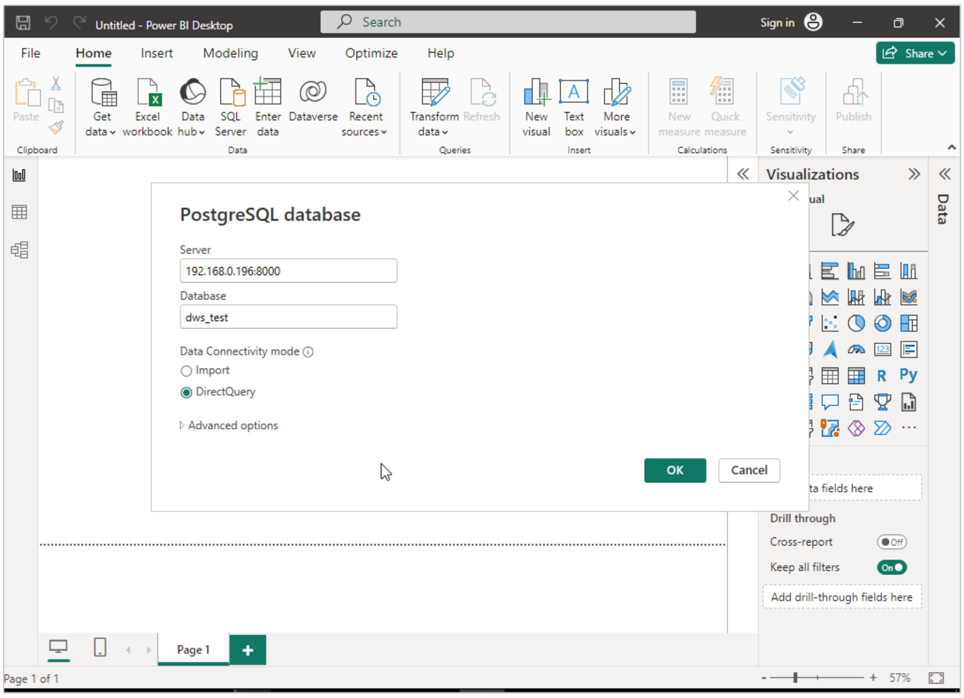
Figure 3-13 Connecting to a database



Step 4 Enter the DWS connection information.

- **Server**: In this example, DWS and the ECS are in the same VPC. Enter the private IP address and port number obtained in **Step 1**.
- **Database**: Enter the name of the database created in **Step 1**, for example, **dws_test**.
- **Data Connectivity mode**: Select **DirectQuery**.

Figure 3-14 DWS connection information

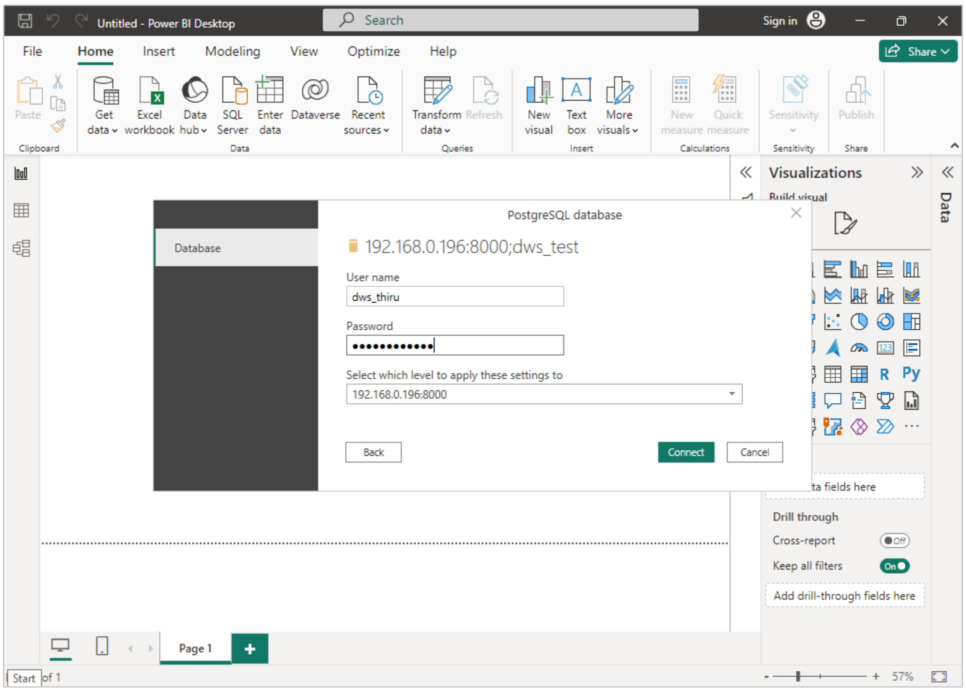


Step 5 Click **OK**.

Step 6 Enter the following information:

- **User name**: Enter the user name for connecting to the database, for example, **dws_thiru**.
- **Password**: Enter the password of **dws_thiru**, which is defined during creation.

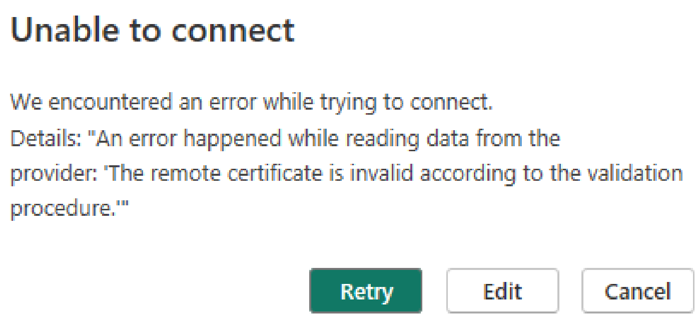
Figure 3-15 Username and password



Step 7 Click **Connect** to test the connection.

The connection fails, showing this error message. The connection is encrypted by default. To switch to a non-encrypted connection, see the following steps.

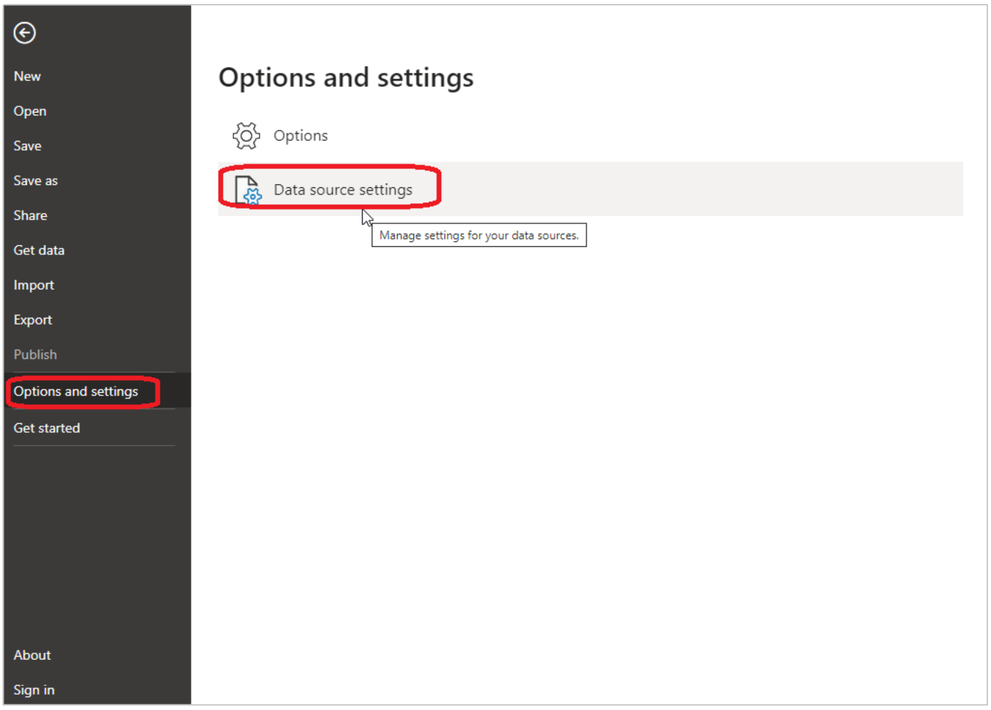
Figure 3-16 Encrypted connection error information



Step 8 Click **Cancel** to exit.

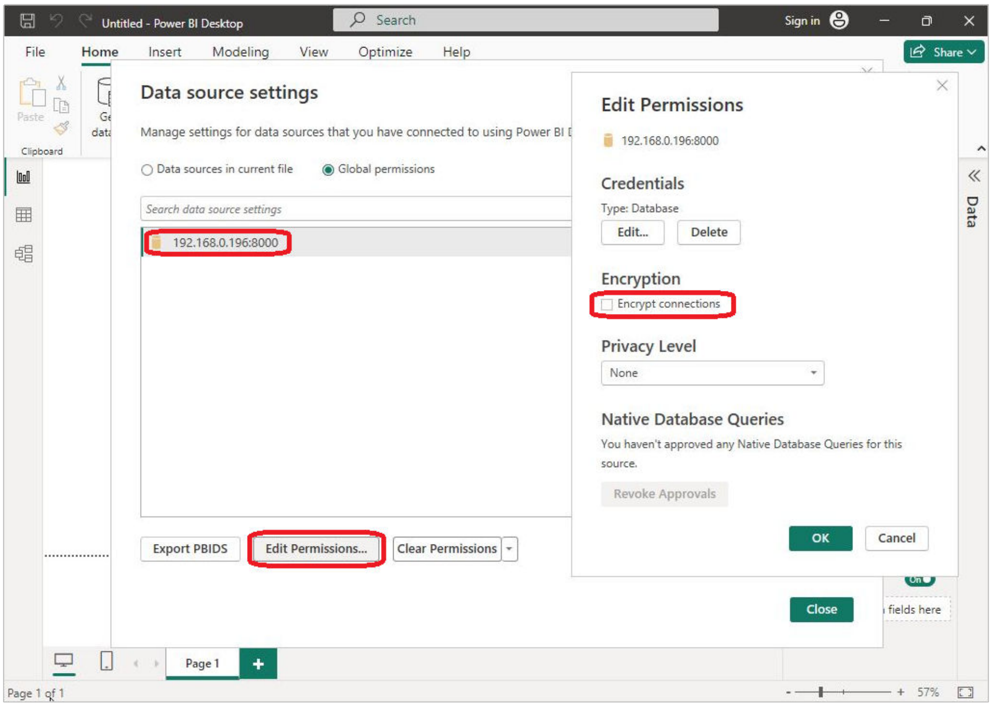
Step 9 Return to the Power BI homepage, choose **File** > **Options and settings**, and click **Data source settings**.

Figure 3-17 Setting data sources



Step 10 Select the DWS connection information, click **Edit Permissions**, deselect **Encrypt connections**, and click **OK**.

Figure 3-18 Switching to a non-encrypted connection

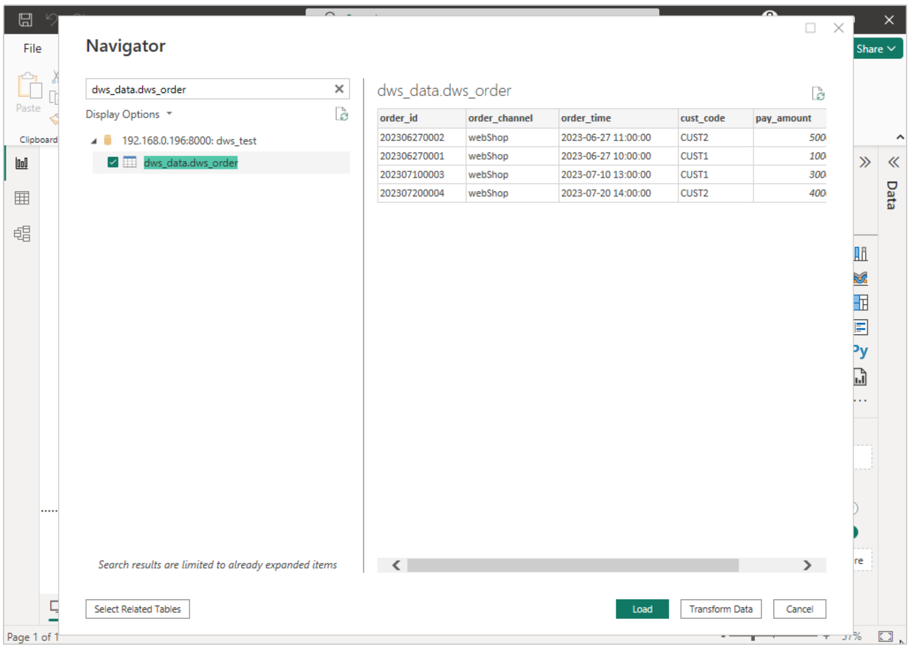


Step 11 Close the window for setting the data source.

Step 12 Return to the Power BI homepage and perform **Step 3** to **Step 7** again.

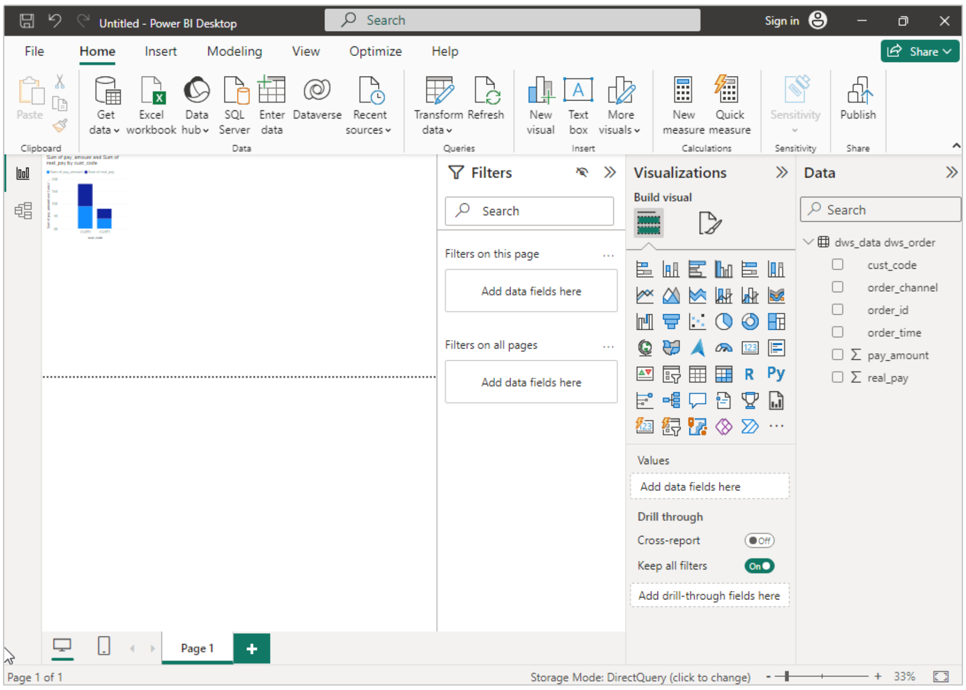
Step 13 Select the data table to be loaded after the connection is established and click **Load**.

Figure 3-19 Selecting the table to be loaded



Step 14 Go to the report creation page, click **File**, and click **Save** to save the report to the local host.

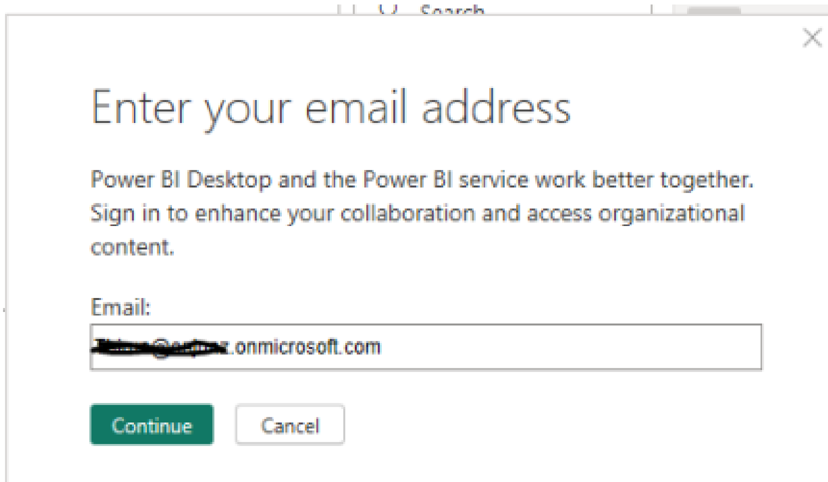
Figure 3-20 Saving a report



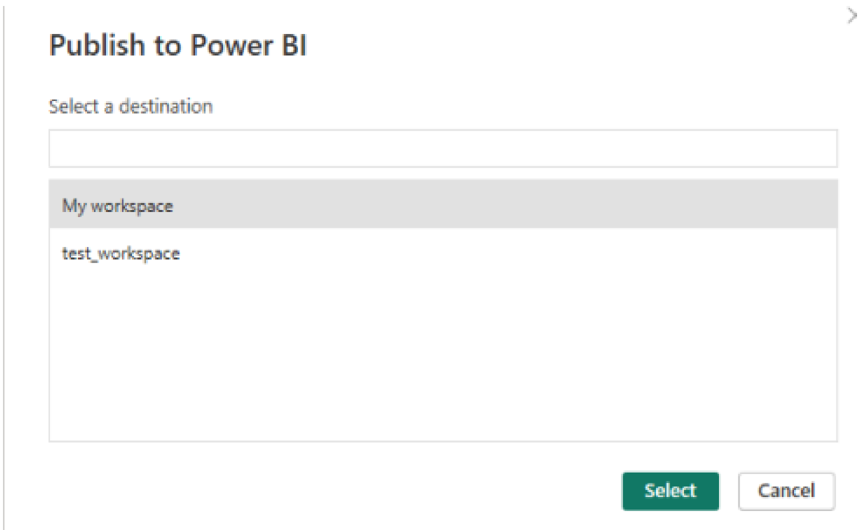
Step 15 Publish the report to the Power BI online page.

1. Return to the Power BI homepage and choose **File** > **Publish** > **Publish to Power BI**.

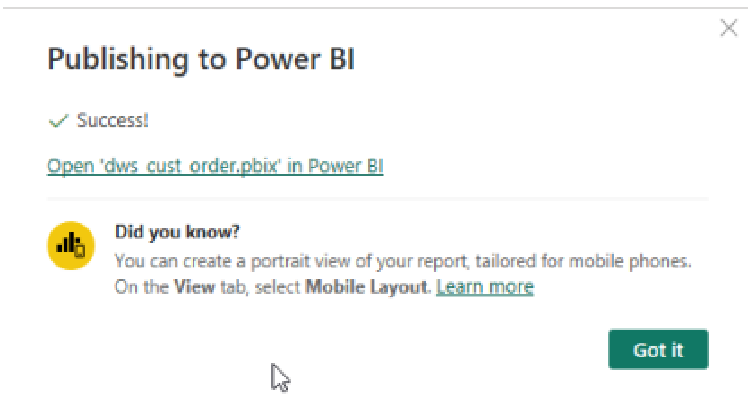
2. If you are not logged in, you will need to enter your email and password.



3. After the login is successful, the release page is displayed. Select a workspace and click **Select**.



If the following information is displayed, the report is published.



----End

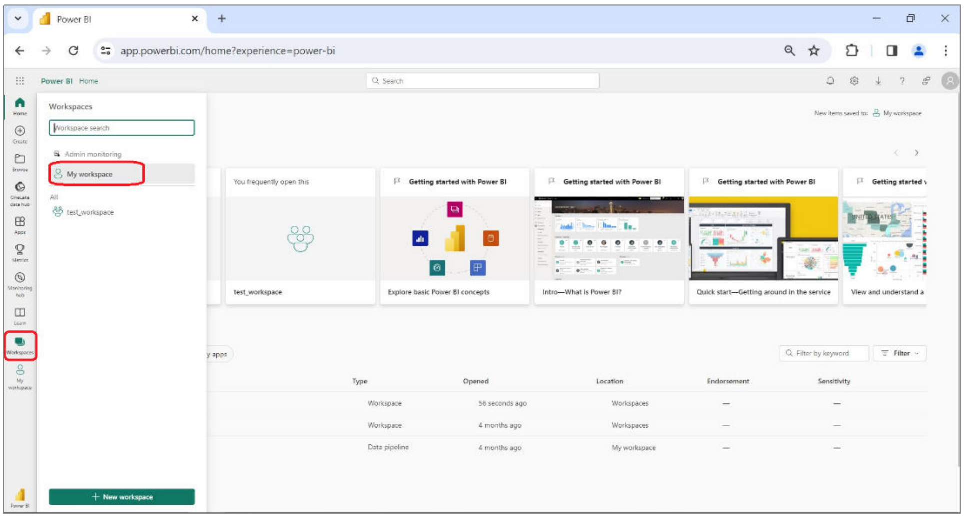
Adding the DWS Connection Information to the Gateway List of Power BI

DWS must not be directly connected to the public network for security. This means Power BI cannot always update live report data from DWS. To fix this, follow these steps to add the DWS connection details to Power BI's gateway list.

Step 1 Visit **here**, log in to the Power BI online page, enter your email address and password, and click **Submit**.

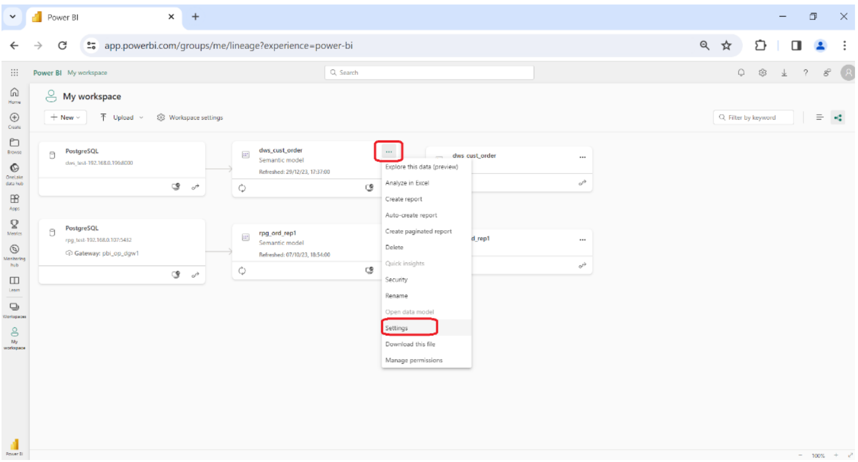
Step 2 On the Power BI online page, click **Workspaces** on the left and click the workspace where the report has been saved.

Figure 3-21 Selecting a workspace



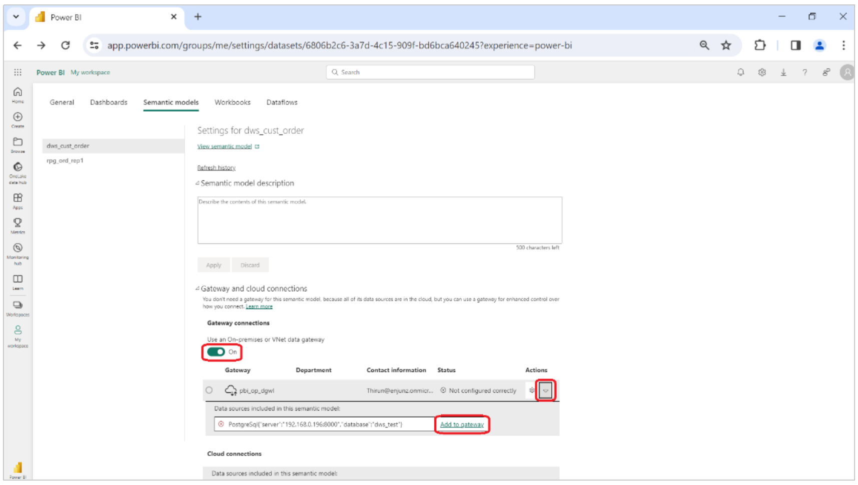
Step 3 Click in the upper right corner of the report to be set and click **Settings**.

Figure 3-22 Setting a report



Step 4 Toggle **Use an On-premises or VNet data gateway** on, click  under **Actions**, and click **Add to gateway**.

Figure 3-23 Clicking Add to gateway

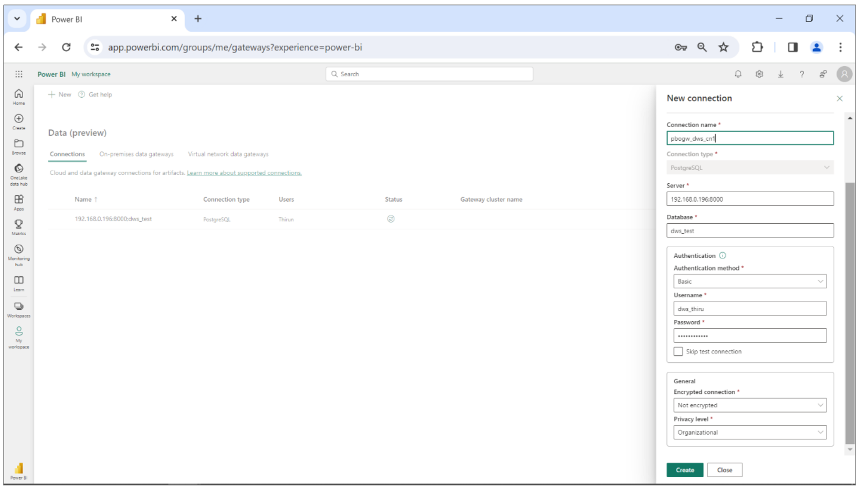


Step 5 Enter the DWS connection information, as shown in **Table 3-7**.

Table 3-7 Parameters for adding gateway information

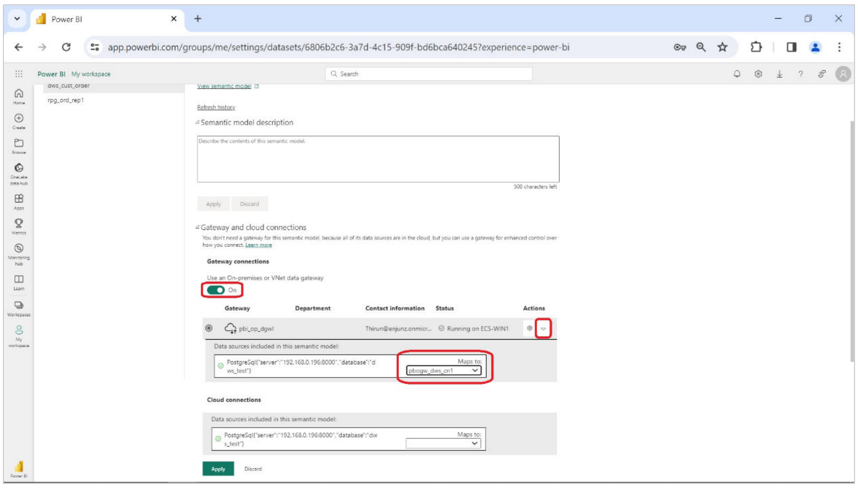
Parameter	Description	Example
Connection name	Name of a connection.	Enter a name.
Server	DWS connection address and port	192.168.0.196:8000
Database	Name of the DWS database to be connected	dws_test
Authentication method	Authentication method	Basic
Username	Username of the database	dws_thiru
Password	Database user password	Enter a password.
Encrypted connection	Whether to encrypt the connection.	Not encrypted
Privacy level	Privacy level	Organizational

Figure 3-24 Adding gateway information



Step 6 Confirm the parameter settings and click **Create**. The newly created connection is displayed in the gateway list.

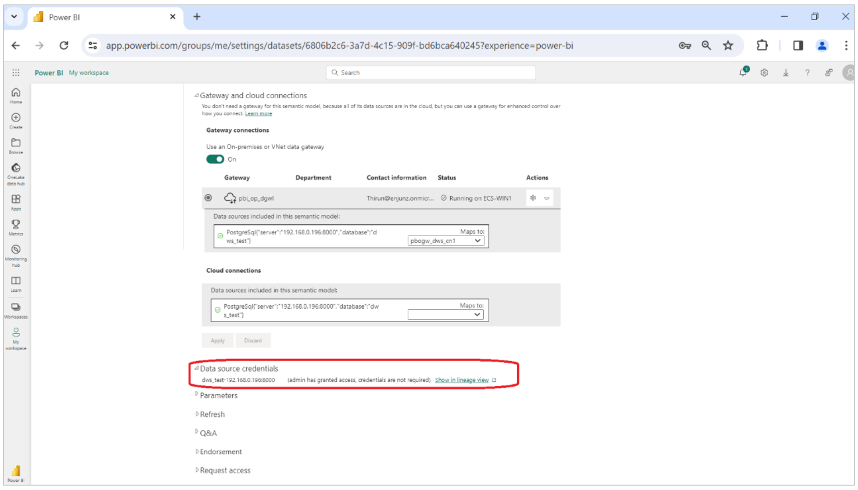
Figure 3-25 Gateway information added



Step 7 Select the new connection name **pbogw_dws_cn1** and click **Apply**.

The gateway mapping is successful. The report has been interconnected with DWS.

Figure 3-26 Mapping succeeded



----End

Reference

- For details about Power BI, visit the **official website**.
- For details about the installation process, visit the **official website**.

4 Data Development

4.1 Using Hybrid Data Warehouses and HStore Tables

Hybrid Data Warehouse Scenarios

As the intelligent data era evolves, the enterprise data ecosystem exhibits three significant characteristics: massive data expansion, diversified data types (including structured, semi-structured, and unstructured data), and increasing complex scenarios. To cope with these challenges, hybrid data warehouses emerge. Based on the large-scale data query and analysis capabilities, hybrid data warehouses feature high concurrency, high performance, low latency, and low cost in transaction processing. **HStore tables** play a key role in the digital transformation of the Internet, IoT, and traditional industries. Typical application scenarios are as follows:

- Intelligent user behavior analysis: It collects web page browsing logs in real time to construct user profiles throughout the life cycle and supports multi-dimensional behavior path analysis. Thanks to OLAP of hybrid data warehouses, it can calculate core indicators such as user retention rate and conversion funnel in seconds, facilitating refined operation decision-making.
- **Real-time risk control center**: In Internet finance and e-commerce transaction scenarios, the risk feature calculation engine is constructed to process real-time data in milliseconds. By associating multi-source user behavior data, it dynamically identifies abnormal patterns and intercepts fraudulent transactions in hundreds of milliseconds, ensuring service security.
- **Industrial IoT and intelligent O&M**: In traditional industries such as electric power and manufacturing, hybrid data warehouses can integrate massive device sensor data (including time series data flows such as vibration and temperature) and semi-structured data such as device maintenance logs to build a predictive maintenance model. Real-time trend analysis is used to dynamically monitor device health status and predict faults, transforming traditional passive O&M into intelligent preventive O&M.

Hybrid data warehouses support two efficient data import methods: direct method and buffer method.

Table 4-1 Import methods

Import Method	Import Format	How to Import Data	Characteristics	Scenario
Direct	SQL	Parse Change Data Capture (CDC) data into INSERT, DELETE, and UPDATE operations and transfer them to DWS.	1. The table structure is the same as that in the remote storage. 2. Easy deployment, short data link, and low latency	● The amount of modified data is not large. ● There are high requirements on real-time data synchronization.
Buffer	Micro-batch data	Converts a large number of small transactions into micro-batch data in buffer mode. The batch import achieves high performance, and data can be synchronized in a short period of time.	1. Extended columns are supported for subsequent ETL services. 2. The operation history is retained. 3. The operation information at the source end is retained in extended columns. You can choose whether to retain the operation history. 4. You can flexibly configure the access. Multiple instances can be deployed based on the service volume. 5. Lightweight processes can be flexibly deployed.	● A large amount of data is changed. ● The requirement on real-time synchronization is not strict. ● The historical operation information at the source end needs to be retained.

Storage Mechanism for Ordinary Column-Store Tables

In DWS, column-store tables use a compression unit (CU) as the smallest storage unit. By default, each CU stores 60,000 rows per column and operates in append write mode. This means that UPDATE and DELETE operations do not directly modify the original CU. Once a CU is created, its data cannot be altered, leading to the generation of a new complete CU whenever data is inserted, regardless of the quantity.

This approach can lead to several issues:

1. DELETE operations: Old data is flagged as obsolete in the dictionary but not released, leading to potential space wastage.
2. UPDATE operation: New records are written to a new CU after old data is marked as deleted.
3. Space problem: Frequent UPDATE and DELETE operations may result in tablespace bloat, reducing effective storage utilization.

Advantages of HStore Tables

A HStore table uses an additional delta table to effectively balance storage and updates. Here are the key points:

Table 4-2 HStore table advantages

Dimension	Advantage
Batch data processing	• Insert data in batches and write directly to the CU. • Maintain the compression efficiency similar to traditional column-based storage.
Incremental data processing	• Serialize and compress updated column data and perform small-batch insertions. • Periodically execute the **MERGE** operation in the background to merge data into the primary table CU.
Storage efficiency	• Minimize the disk space usage. • Retain the high compression ratio in column-store format.
Performance	• Support high-concurrency UPDATE operations. • Offer excellent query response speed.
Scenario	• Real-time data import and queries • Traditional TP transaction processing • High-concurrency loads involving both updates and queries

CAUTION

To enhance performance, DWS 9.1.0 retains the old HStore table for forward compatibility. The optimized tables are known as HStore Opt tables. HStore tables can be replaced by HStore Opt tables for better performance, except in scenarios requiring high performance without micro-batch updates.

Suggestions on Using HStore Tables

- **Parameter setting**

  Set the parameters according to **Table 4-5** to improve query performance and storage for HStore tables:

- **Suggestions on importing data to the database** (HStore Opt table are recommended.)
  a. UPDATE operations:
     Use the UPSERT mode instead of the UPDATE mode.
  b. DELETE operations:
     - Ensure that the execution plan is scanned by index.
     - The JDBC batch mode is the most efficient.
  c. Batch data import:
     - If the amount of data to be imported at once exceeds 1 million records per DN and the data is unique, consider using MERGE INTO.
     - Use UPSERT for common scenarios.
- **Suggestions on point queries** (HStore Opt table are recommended.)
  a. Create a level-2 partition on columns with evenly distributed distinct values and frequent equivalent filter criteria. Avoid level-2 partitions on columns with skewed or few distinct values.
  b. When dealing with fixed filter criteria columns (excluding level-2 partitions), use the CBTREE index (up to 5 columns).
  c. When dealing with variable filter criteria columns (excluding level-2 partitions), use the GIN index (up to 5 columns).
  d. For all string columns involving equivalent filtering, use the BITMAP index during table creation. The number of columns is not limited, but cannot be modified later.
  e. Specify columns that can be filtered by time range as the partition columns.
  f. If point queries return over 100,000 records per DN, index scanning may outperform non-index scanning. Use the GUC parameter **enable_seqscan** to compare performance.
- **Index-related precautions**
  a. Indexes consume additional storage.
  b. Indexes are created to improve performance.
  c. Indexes are used when **UPSERT** operations need to be performed.
  d. Indexes are used for point queries with unique or near-unique requirements.
- **MERGE-related precautions**
  a. Data import speed control:
     - The data import speed cannot exceed the MERGE processing capability.
     - Controlling the concurrency of importing data to the database can prevent the **Delta** table from being expanded.
  b. Tablespace reuse
     - Delta tablespace reuse is affected by oldestXmin.

- Long-running transactions may cause tablespace reuse delay and expansion.

Hybrid Data Warehouse Flavors

To use hybrid data warehouse capabilities, choose the storage-compute coupled architecture when you create a cluster on the console and ensure the vCPU to memory ratio is 1:4 when setting up cloud disk flavors. For details about the hybrid data warehouse flavors and corresponding service scenarios, see **Table 4-3**.

Table 4-3 Cloud disk flavors with a vCPU to memory ratio of 1:4 for storage-compute clusters

Flavor	CPU Architecture	vCPU	Memory (GB)	Storage Capacity Per Node	Step (GB)	Number of DNs	Scenario
dwsx2.h.xlarge.4.c7	x86	4	16	20 GB–2,000 GB	20	1	Suitable for DWS starters. These flavors can be used for testing, learning environments, or small-scale analytics systems.
dwsk2.h.xlarge.4.kc1	Arm	4	16	20 GB–2,000 GB	20	1	
dwsk2.h.xlarge.kc2	Arm	4	16	20 GB–2,000 GB	20	1	
dwsx2.h.xlarge.4.c7n	x86	4	16	20 GB–2,000 GB	20	1	
dwsx2.h.2xlarge.4.c6	x86	8	32	100 GB–4,000 GB	100	1	Suitable for internal data warehousing and report analysis in small- and medium-sized enterprises (SMEs).
dwsx2.h.2xlarge.4.c7	x86	8	32	100 GB–4,000 GB	100	1	
dwsk2.h.2xlarge.4.kc1	Arm	8	32	100 GB–4,000 GB	100	1	
dwsk2.h.2xlarge.kc2	Arm	8	32	100 GB–4,000 GB	100	1	
dwsx2.h.2xlarge.4.c7n	x86	8	32	100 GB–4,000 GB	100	1	

Flavor	CPU Architecture	vCPU	Memory (GB)	Storage Capacity Per Node	Step (GB)	Number of DNs	Scenario
dwsx2.h.4xlarge.4.c7	x86	16	64	100 GB–8,000 GB	100	1	Recommended for the production environment. These flavors are applicable to OLAP systems that have to deal with large data volumes, BI reports, and data visualizations on large screens for most companies.
dwsk2.h.4xlarge.4.kc1	Arm	16	64	100 GB–8,000 GB	100	1	
dwsk2.h.4xlarge.kc2	Arm	16	64	100 GB–8,000 GB	100	1	
dwsx2.h.4xlarge.4.c7n	x86	16	64	100 GB–8,000 GB	100	1	
dwsx2.h.8xlarge.4.c7	x86	32	128	100 GB–16,000 GB	100	2	
dwsk2.h.8xlarge.4.kc1	Arm	32	128	100 GB–16,000 GB	100	2	
dwsk2.h.8xlarge.kc2	Arm	32	128	100 GB–16,000 GB	100	2	
dwsx2.h.8xlarge.4.c7n	x86	32	128	100 GB–16,000 GB	100	2	
dwsk2.h.12xlarge.4.kc1	Arm	48	192	100 GB–24,000 GB	100	4	These flavors can deliver excellent performance and are applicable to high-throughput data warehouse processing and high-concurrency online query.
dwsk2.h.12xlarge.kc2	Arm	48	192	100 GB–24,000 GB	100	4	
dwsx2.h.16xlarge.4.c7	x86	64	256	100 GB–32,000 GB	100	4	
dwsx2.h.16xlarge.4.c7n	x86	64	256	100 GB–32,000 GB	100	4	

Flavor	CPU Architecture	vCPU	Memory (GB)	Storage Capacity Per Node	Step (GB)	Number of DNs	Scenario
dwsk2.h.16xlarge	Arm	64	256	100 GB–32,000 GB	100	4	
dwsk2.h.24xlarge	Arm	96	384	100 GB–48,000 GB	100	4	
dwsk2.h.32xlarge	Arm	128	512	100 GB–64,000 GB	100	4	

Optimal GUC Parameters for Hybrid Data Warehouses

After creating a hybrid data warehouse, configure the GUC parameters as recommended in **Table 4-4**.

Table 4-4 GUC parameters

Parameter	Description	Type	Value Range	Recommended Value
enable_codegen	Specifies whether to enable code optimization. Currently, LLVM optimization is used.	USERSET	• **on** indicates code optimization can be enabled. • **off** indicates code optimization cannot be enabled.	off
enable_numa_bind	Specifies whether to enable NUMA binding. This parameter is available only for clusters of version 9.1.0.100 or later.	SIGHUP	• **on** indicates that NUMA binding is enabled. • **off** indicates that NUMA binding is disabled.	Set the value to **on** for DNs and **off** for CNs.

Parameter	Description	Type	Value Range	Recommended Value
abnormal_check_general_task	Specifies the interval at which the CM Agent periodically clears idle CN connections.	CM parameter	The value is a non-negative integer, in seconds. The default value is **60**.	3600

Step 1 Change the value of **enable_codegen** to **off** to reduce the memory overhead applied when dynamic execution code is generated for short queries.

1. On the DWS console, choose **Dedicated Clusters** > **Clusters**.
2. In the cluster list, find the target cluster and click the cluster name to go to the cluster details page.
3. Click the **Parameter Modifications** tab, search for **enable_codegen**, change the value to **off**, and click **Save**.

Step 2 Set **NUMA** on DNs to **on** and **NUMA** on CNs to **off**. NUMA process binding can reduce the overhead of cross-NUMA access processes.

Contact technical support to change the value of **enable_numa_bind**.

Step 3 Change the value of **abnormal_check_general_task** to **3600** to reduce the overhead of repeatedly establishing connections. The default value is **60**.

> **CAUTION**
>
> The default clearance interval is 60 seconds, which can significantly impact millisecond-level service performance. Re-creating a single thread incurs a cost of approximately 300 ms, so you are advised to increase the interval for scenarios with millisecond-level performance sensitivity. If connections are cleared slowly within the interval, it can result in high memory usage.

Contact technical support to change the value of **abnormal_check_general_task**.

----End

Optimal Parameter Settings for Creating HStore Opt Tables in Hybrid Data Warehouses

When using hybrid data warehouses, you are advised to use HStore Opt tables. Before using such tables, set the following parameters by referring to Table 4-5.

Table 4-5 Parameters related to HStore Opt tables

Mandatory	Parameter	Description	Recommended Value	Take Effect Upon Restart
Yes	autovacuum	Specifies whether to enable autovacuum. The default value is **on**. Contact technical support to change the value of this parameter.	on	No
	autovacuum_max_workers	Specifies the maximum number of concurrent autovacuum threads. **0** indicates that autovacuum is disabled.	● The default value of this parameter is **6** for clusters of version 9.1.0.*xx* or earlier. ● The default value of this parameter is **2** for clusters of version 9.1.1 or later.	No

Mandatory	Parameter	Description	Recommended Value	Take Effect Upon Restart
	autovacuum_max_workers_hstore	Specifies the number of autovacuum worker threads for HStore tables. The **value of autovacuum_max_workers** must be greater than that of **autovacuum_max_workers_hstore**. You are advised to set **autovacuum_max_workers** to **6** and **autovacuum_max_workers_hstore** to **3**.	3	No
	enable_col_index_vacuum	Specifies whether to enable index clearing to prevent index expansion and performance deterioration after data is updated and stored to the database. This parameter is supported only by clusters of 8.2.1.100 or later. Contact technical support to change the value of this parameter.	on	No
No	autovacuum_naptime	Specifies the minimum delay between autovacuum runs on any given database.	20s	No

Mandatory	Parameter	Description	Recommended Value	Take Effect Upon Restart
	colvacuum_threshold_scale_factor	Specifies the minimum percentage of dead tuples for vacuum rewriting in column-store tables. A file is rewritten only when the ratio of dead tuples to (**all_tuple** - n**ull_tuple**) in the file is greater than the value of this parameter. ● **–2** indicates that vacuum rewriting and vacuum cleanup are not performed. ● **–1** indicates that vacuum rewriting is not performed and only vacuum cleanup is performed. ● The value ranges from 0 to 100, indicating the percentage of dead tuples. Contact technical support to change the value of this parameter.	70	No
	col_min_file_size	Specifies the minimum size of a file required to trigger a cleanup process. If the file size exceeds 128 MB, the file can be cleared. By default, the file can be cleared only when the file size exceeds 1 GB. You are advised to use this parameter in scenarios where updates or rollbacks are frequently performed.	1 GB	No
	autovacuum_compaction_rows_limit	Controls the combination of small CUs and clearance of 0 CUs in the background. The value **0** indicates that only 0 CUs are cleared and small CUs are not processed.	2500	No
	autovacuum_compaction_time_limit	Specifies the number of minutes for triggering background 0CU clearance. Contact technical support to change the value of this parameter.	1	No

Mandatory	Parameter	Description	Recommended Value	Take Effect Upon Restart
	autovacuum_merge_cu_limit	Specifies the number of CUs to be automatically merged in a transaction. The value **0** indicates that all CUs to be merged are processed in a transaction. Contact technical support to change the value of this parameter.	10	No

Step 1 Configuring GUC parameters.

1. On the DWS console, choose **Dedicated Clusters** > **Clusters**.
2. In the cluster list, find the target cluster and click the cluster name to go to the cluster details page.
3. Modifying mandatory parameters: Click the **Parameter Modifications** tab, search for **autovacuum_max_workers** and **autovacuum_max_workers_hstore**, set them to the recommended values by referring to **Table 4-5**, and click **Save**.

   NOTE

   You are advised to use the default values of **autovacuum** and **enable_col_index_vacuum**, and do not need to set them separately.

4. Modify optional parameters: Search for **autovacuum_naptime** and **cost_model_version**, set them to the recommended values by referring to **Table 4-5**, and click **Save**.

   NOTE

   For other optional parameters, contact technical support.

Step 2 Use the SQL editor to connect to the DWS cluster and create a HStore Opt table. The following is an example of creating such a table:

Select a proper distribution key and partition key based on the data characteristics. For details, see **DWS Development Design Proposal**.

```
CREATE table public.hstore_opt_table_demo(
t_code character varying(20),
t_gisid character varying(800),
t_datatime timestamp(6) without time zone,
t_gmid character varying(64)
)
WITH (orientation=column, enable_hstore_opt=on) --This configuration is used by default when a table is
created.
DISTRIBUTE BY hash (t_gmid) --Distribution key, which can be a primary key or an associated column.
PARTITION BY range (t_datatime) -- Partition key
(
partition p2024_1 start('2024-01-01') end ('2024-06-01') every (interval '1 month'),
```

```
partition p2024_7 start('2024-06-01') end ('2024-12-31') every (interval '1 month')
);
```

Step 3 Adjust partitions when abnormal data is processed.

```
ALTER TABLE public.hstore_opt_table_demo ADD PARTITION pmax VALUES LESS THAN (maxvalue);
```

Step 4 For details about other usage suggestions and performance comparison of HStore Opt tables, see **Performance Comparison Between HStore Tables and Ordinary Row- and Column-Store Tables**.

----End

Performance Comparison Between HStore Tables and Ordinary Row- and Column-Store Tables

1. **Concurrent Update**

   Once a batch of data is inserted into an ordinary column-store table, two sessions are initiated. In session 1, a piece of data is deleted, and the transaction is not committed.

   ```
   CREATE TABLE col(a int , b int)with(orientation=column);
   CREATE TABLE

   INSERT INTO col select * from data;
   INSERT 0 100

   BEGIN;
   BEGIN

   DELETE col where a = 1;
   DELETE 1
   ```

   When session 2 attempts to delete more data, it becomes evident that session 2 can only proceed after session 1 is committed. This scenario imitates the CU lock issue in column storage.

   ```
   BEGIN;
   BEGIN
   DELETE col where a = 2;
   ```

   Repeat the previous operations using a HStore table. Session 2 can be executed successfully without any lock wait.

   ```
   BEGIN;
   BEGIN
   DELETE hs where a = 2;
   DELETE 1
   ```

2. **Compression efficiency**

   Create a data table with 3 million data records.

   ```
   CREATE TABLE data( a int, b bigint, c varchar(10), d varchar(10));
   CREATE TABLE

   INSERT INTO data values(generate_series(1,100),1,'asdfasdf','gergqer');
   INSERT 0 100
   INSERT INTO data select * from data;
   INSERT 0 100
   INSERT INTO data select * from data;
   INSERT 0 200

   ---Insert data cyclically until the data volume reaches 3 million.

   INSERT INTO data select * from data;
   INSERT 0 1638400

   SELECT COUNT(*) FROM data;
     count
   ```

```
---------
 3276800
(1 row)
```

Import data to a row-store table in batches and check whether the size is 223 MB.

```
CREATE TABLE row (like data including all);
CREATE TABLE

INSERT INTO row SELECT * FROM data;
INSERT 0 3276800

SELECT pg_size_pretty(pg_relation_size('row'));
 pg_size_pretty
----------------
 223 MB
(1 row)
```

Import data to a HStore Opt table in batches and check whether the size is 3.5 MB.

```
CREATE TABLE hs(a int, b bigint, c varchar(10),d varchar(10))with(orientation= column,
enable_hstore_opt=on);
CREATE TABLE

INSERT INTO hs SELECT * FROM data;
INSERT 0 3276800

SELECT pg_size_pretty(pg_relation_size('hs'));

 pg_size_pretty
----------------
 3568 KB
(1 row)
```

HStore tables have a good compression effect because of their simple table structure and duplicate data. They are usually compressed three to five times more than row-store tables.

3. **Batch query performance**

It takes approximately four seconds to query the fourth column in the row-store table.

```
EXPLAIN ANALYZE SELECT d FROM data;
EXPLAIN ANALYZE                                                        QUERY PLAN

-------------------------------------------------------------------------------------------------------------------------------
------------------
  id |          operation           |        A-time        | A-rows  | E-rows  | Peak Memory  | E-memory | A-
width | E-width | E-costs
  ----+-----------------------------+---------------------+---------+---------+--------------+----------+---------
+---------+----------
   1 | ->  Streaming (type: GATHER) | 4337.881             | 3276800 | 3276800 | 32KB         |
|         |       8 | 61891.00
   2 |    ->  Seq Scan on data      | [1571.995, 1571.995] | 3276800 | 3276800 | [32KB, 32KB] | 1MB
|         |       8 | 61266.00
```

It takes about 300 milliseconds to query the fourth column in the HStore Opt table.

```
EXPLAIN ANALYZE SELECT d from hs;
                                                       QUERY PLAN

-------------------------------------------------------------------------------------------------------------------------------
---------------------------
  id |               operation                |       A-time       | A-rows  | E-rows  |  Peak Memory   | E-memory |
A-width | E-width | E-costs
  ----+----------------------------------------+--------------------+---------+---------+----------------+----------
+---------+---------+----------
   1 | ->  Row Adapter                        | 335.280            | 3276800 | 3276800 | 24KB           |
|         |       8 | 15561.80
```

```
  2 |    ->  Vector Streaming (type: GATHER) | 111.492           | 3276800 | 3276800 | 96KB
|          |          |       8 | 15561.80
  3 |       ->  CStore Scan on hs           | [111.116, 111.116] | 3276800 | 3276800 | [254KB, 254KB] |
1MB       |          |       8 | 14936.80
```

The stored tables and HStore tables outperform row-store tables in terms of batch query.

Changing Ordinary Row- and Column-Store Tables to HStore Tables

When using a column-store delta table, MERGE operations may not occur promptly due to the absence of a scheduled merge mechanism for disk bandwidth and the column-store delta table. This can lead to delta table expansion and a decline in query performance and concurrent update efficiency.

In comparison to column-store delta tables, HStore tables feature concurrent data import, high-performance queries, and an asynchronous merge mechanism. HStore tables can replace column-store delta tables.

Here is a guide for changing ordinary column-store and row-store tables to HStore tables:

1. Check the delta table list and replace **nspname** with the target namespace.
```
select n.nspname||'.'||c.relname as tbname,reloptions::text as op from pg_class c,pg_namespace n
where c.relnamespace = n.oid and c.relkind = 'r' and c.oid > 16384 and n.nspname ='public' and (op
like '%enable_delta=on%' or op like '%enable_delta=true%') and op not like '%enable_hstore_opt%';
```
   After steps 2 and 3 are executed, execute the table creation statements generated in step 2 and the data import statements generated in step 3 in sequence.
2. Generate the table creation statement containing the **enable_hstore_opt** parameter.
```
select 'create table if not exists '|| tbname ||'_opt (like '|| tbname ||' INCLUDING all EXCLUDING
reloptions) with(orientation=column,enable_hstore_opt=on);' from(
select n.nspname||'.'||c.relname as tbname,reloptions::text as op from pg_class c,pg_namespace n
where c.relnamespace = n.oid and c.relkind = 'r' and c.oid > 16384 and n.nspname ='public' and (op
like '%enable_delta=on%' or op like '%enable_delta=true%') and op not like '%enable_hstore_opt%');
```
3. Generate the statement for data import. Replace the table name and delete the statement of the old table.
```
select 'start transaction;
lock table '|| tbname ||' in EXCLUSIVE mode;
insert into '|| tbname ||'_opt select * from '|| tbname ||';
alter table '|| tbname ||' rename to '|| tbname ||'_bk;
alter table '|| tbname ||'_opt rename to '|| tbname ||';
commit;
drop table '|| tbname ||'_bk;'
from(select n.nspname||'.'||c.relname as tbname,reloptions::text as op from pg_class c,pg_namespace n
where c.relnamespace = n.oid and c.relkind = 'r' and c.oid > 16384 and n.nspname ='public' and (op
like '%enable_delta=on%' or op like '%enable_delta=true%')  and op not like '%enable_hstore_opt%');
```

4.2 Converting a Time Series Table to an HStore Table

The column-store HStore tables outperform time series tables in terms of data import performance, compression ratio, and query performance. This section describes how to convert existing time series tables to HStore tables.

For details about how to use the HStore tables, see **Using Hybrid Data Warehouses and HStore Tables**.

A time series table consists of three columns: **TSTime**, **TSTag**, and **TSField**.

- **TSTime** represents the time sequence, with automatic partitioning based on this sequence.
- **TSTag** serves as the dimension column.
- **TSField** represents a fact column where dimension and fact data coexist.

For example, create a time series table **CPU**.

```
CREATE TABLE CPU(
scope_name text TSTag,
server_ip text TSTag,
group_path text TSTag,
time timestamptz TSTime,
idle numeric TSField,
users numeric TSField)
with (TTL='30 days', PERIOD = '1 hour', orientation=TIMESERIES);
```

To convert a time series table to an HStore table, create the HStore table, establish level-2 partitions, and implement bitmap indexes for optimal HStore table performance.

- Use the **TSTime** column as the partition key.
- Use the first **TSTag** column as the secondary partition column.
- Use all **TSTag** columns as bitmap index columns.

The table creation statements post-reconstruction are as follows:

```
CREATE TABLE CPU(
scope_name text,
server_ip text,
group_path text,
time timestamptz,
idle numeric,
users numeric)
WITH(TTL='30 days', PERIOD = '1 hour',
ORIENTATION=column, ENABLE_HSTORE_OPT=true, --Use the column-store hstore_opt type.
SECONDARY_PART_COLUMN='scope_name', --Use the first TSTag column as the secondary partition
column.
BITMAP_COLUMNS='scope_name,server_ip,group_path' --Use all TSTag columns as bitmap index columns.
)
PARTITION BY RANGE(time) --time is the TSTime column in TIMESERIES.
(
   PARTITION p1 VALUES LESS THAN('2023-02-13 12:00:00'),
   PARTITION p2 VALUES LESS THAN('2023-02-13 13:00:00')
   ...
);
--Create one or more B-tree indexes on other TSTag columns based on query performance.
```

4.3 Using the Turbo Engine to Improve Data Query Performance

Scenario

The vectorized Turbo engine is a high-performance data processing engine that uses vectorization to greatly enhance efficiency and speed. It innovatively overcomes the main performance bottlenecks of traditional column storage execution engines. Performance gains are achieved by optimizing data formats, developing advanced hash algorithms, customizing data processing algorithms based on runtime data features, and reconstructing operators and algorithms.

Compared to the original column storage execution engine, the Turbo engine optimizes memory and disk storage formats for strings and numeric types, and enhances the performance of common operators like sort, aggregate (agg), join, and scan. This results in doubling the overall performance of the executor and significantly reducing computing costs.

In in-memory data caching scenarios, benchmark tests show impressive results:

- TPC-H performance: Improved by 50% to 1.5 times.
- TPC-DS performance: Improved by 50% to 80%.
- SSB performance: Increased by 70%.
- Full sorting performance: Enhanced by 90%.

Notes and Constraints

- If the job query does not involve the merge join or sort agg operators, the executor can use the Turbo execution engine. Confirm this during service planning.
- To use the Turbo engine, the base table must be a Turbo table. This means **enable_turbo_store** is set to **on**, and the GUC parameter **turbo_engine_version** is set to **3**. To disable the Turbo engine, set **turbo_engine_version** to **0**.
- Only clusters of 9.1.0.210 and later versions support this function.
- Ordinary column-store tables in version 3.0 do not support the Turbo storage format. To use Turbo storage, set the table to an HStore Opt table. When creating a 3.0 column-store table, turn on **enable_hstore_opt** to enable Turbo storage.

Using a Turbo Table

Step 1 Use the client to connect to the DWS cluster.

Step 2 Run the following commands and ensure that the GUC parameter **turbo_engine_version** is set to **3**:

```
SHOW turbo_engine_version;
SET turbo_engine_version = 3;
```

Step 3 Run the following SQL statement to create a temporary table named **src**. The table contains only one row of data and provides data sources for subsequent INSERT operations.

```
CREATE TABLE src AS SELECT 1;
```

Step 4 Run the following SQL statements to create two tables. One is named **non_turbo_table** with Turbo disabled and the other is named **turbo_table** with Turbo enabled.

```
CREATE TABLE non_turbo_table(a int, b numeric(15,2)) WITH(orientation=column,enable_turbo_store=off);
CREATE TABLE turbo_table(a int, b numeric(15,2)) WITH(orientation=column,enable_turbo_store=on);
```

Step 5 Run the SQL statements below to insert 20 million rows of data into the two tables. The execution takes about half a minute.

```
INSERT INTO non_turbo_table SELECT generate_series(1,20000000) % 1000,generate_series(1,20000000)
FROM src;
INSERT INTO turbo_table SELECT generate_series(1,20000000) % 1000,generate_series(1,20000000) FROM
src;
```


Step 6 Run the following SQL statements to obtain the query performance of the two tables:

```
EXPLAIN PERFORMANCE SELECT sum(b) FROM non_turbo_table GROUP BY a;
EXPLAIN PERFORMANCE SELECT sum(b) FROM turbo_table GROUP BY a;
```

The command output for the table with Turbo disabled is as follows (only query plan overview and query summary are displayed). The **total query duration is 196.335 ms**.

```
                                                    QUERY PLAN

 id |                       operation                        |       A-time       |  A-rows  |  E-rows  | E-distinct |  Peak
Memory   | E-memory | A-width | E-width | E-costs
 ----+--------------------------------------------------------+--------------------+----------+----------+------------
+----------------+----------+---------+---------+----------
   1 | ->  Row Adapter                                        | 193.352            |     1000 |     1000 |            |
23KB           |          |         |      42 | 26197.71
   2 |    ->  Vector Streaming (type: GATHER)                 | 193.283            |     1000 |     1000 |            |
167KB          |          |         |      42 | 26197.71
   3 |       ->  Vector Sonic Hash Aggregate                  | [181.540, 182.619] |     1000 |     1000 |            |
[1MB, 1MB]     | 16MB     | [21,21] |      42 | 26161.18
   4 |          ->  Vector Streaming(type: REDISTRIBUTE)      | [180.863, 182.166] |     3000 |     6000 |
| [183KB, 215KB] | 2MB      |         |      42 | 26154.51
   5 |             ->  Vector Sonic Hash Aggregate            | [88.320, 117.714]  |     3000 |     6000 |            |
[1MB, 1MB]     | 16MB     | [21,21] |      42 | 26114.00
   6 |                ->  CStore Scan on public.non_turbo_table | [32.022, 41.146]   | 20000000 | 20000000
|            | [869KB, 869KB] | 1MB      |         |      10 | 9437.33


...

                        ====== Query Summary =====
-------------------------------------------------------------------------------
 Datanode executor start time [dn_6003_6004, dn_6009_6010]: [1.949 ms,2.231 ms]
 Datanode executor run time [dn_6005_6006, dn_6007_6008]: [181.600 ms,182.674 ms]
 Datanode executor end time [dn_6003_6004, dn_6009_6010]: [0.041 ms,0.056 ms]
 Remote query poll time: 186.041 ms, Deserialze time: 0.036 ms
 System available mem: 2129920KB
 Query Max mem: 2129920KB
 Query estimated mem: 4063KB
 Enqueue time: 0.015 ms
 Coordinator executor start time: 0.551 ms
 Coordinator executor run time: 193.649 ms
 Coordinator executor end time: 0.071 ms
 Total network : 59kB
 Parser runtime: 0.000 ms
 Planner runtime: 1.945 ms
 Query Id: 145241088537559390
 Unique SQL Id: 1249234219
 Unique SQL Hash: sql_41862c1cdf0f08d7e33d51f39bfda62d
 Total runtime: 196.335 ms
```

The command output for the table with Turbo enabled is as follows (only query plan overview and query summary are displayed). The **total query duration is 51.101 ms**.

After the Turbo engine is enabled, the query time is greatly reduced.

```
                                                  QUERY PLAN


 id |                      operation                       |      A-time      |  A-rows  |  E-rows  | E-distinct |  Peak
Memory   | E-memory | A-width | E-width | E-costs
 ----+------------------------------------------------------+------------------+----------+----------+------------
+----------------+----------+---------+---------+----------
   1 | ->  Row Adapter                                      | 49.316           |     1000 |     1000 |            | 23KB
|          |         |      42 | 27429.71
   2 |    ->  Vector Streaming (type: GATHER)               | 49.253           |     1000 |     1000 |            |
```

```
167KB         |         |        |      42 | 27429.71
   3 |       ->  Vector Sonic Hash Aggregate             | [37.402, 38.366] |     1000 |     1000 |           | [942KB,
942KB] | 16MB     | [30,30] |      42 | 27393.18
   4 |         ->  Vector Streaming(type: REDISTRIBUTE)    | [37.111, 38.200] |     3000 |     6000 |           |
[183KB, 183KB] | 2MB      |         |      42 | 27386.51
   5 |           ->  Vector Sonic Hash Aggregate         | [29.227, 31.946] |     3000 |     6000 |           | [942KB,
942KB] | 16MB     | [30,30] |      42 | 27346.00
   6 |             ->  CStore Scan on public.turbo_table | [10.392, 11.590] | 20000000 | 20000000 |           |
[917KB, 917KB] | 1MB      |         |      10 | 10669.33

...



                  ====== Query Summary =====
 --------------------------------------------------------------------------
 Datanode executor start time [dn_6005_6006, dn_6001_6002]: [1.056 ms,1.803 ms]
 Datanode executor run time [dn_6001_6002, dn_6009_6010]: [37.429 ms,38.416 ms]
 Datanode executor end time [dn_6009_6010, dn_6005_6006]: [0.037 ms,0.110 ms]
 Remote query poll time: 41.001 ms, Deserialze time: 0.013 ms
 System available mem: 2129920KB
 Query Max mem: 2129920KB
 Query estimated mem: 4063KB
 Turbo Engine: true
 Enqueue time: 0.016 ms
 Coordinator executor start time: 0.451 ms
 Coordinator executor run time: 49.599 ms
 Coordinator executor end time: 0.105 ms
 Total network : 33kB
 Parser runtime: 0.000 ms
 Planner runtime: 0.859 ms
 Query Id: 145241088537562603
 Unique SQL Id: 1906062289
 Unique SQL Hash: sql_be1160458499bd4c66933be3ecd942cc
 Total runtime: 51.101 ms
```

----End

4.4 Cutting Costs by Switching Between Cold and Hot Data Storage in DWS

Scenarios

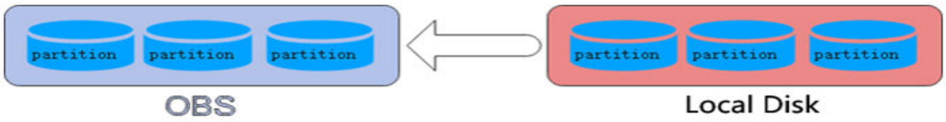
In massive big data scenarios, with the growing of data, data storage and consumption increase rapidly. The need for data may vary in different time periods, therefore, data is managed in a hierarchical manner, improving data analysis performance and reducing service costs. In some data usage scenarios, data can be classified into hot data and cold data by accessing frequency.

Hot and cold data is classified based on the data access frequency and update frequency.

- Hot data: Data that is frequently accessed and updated and requires fast response.
- Cold data: Data that cannot be updated or is seldom accessed and does not require fast response

You can define cold and hot management tables to switch cold data that meets the specified rules to OBS for storage. Cold and hot data can be automatically determined and migrated by partition.

Figure 4-1 Hot and cold data management

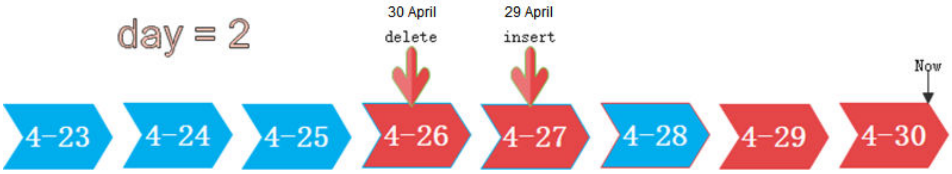


When data is written to DWS column-store tables, the data is first stored in hot partitions. If there is a large amount of data in the partitions, the data that meets the cold data rules can be manually or automatically migrated to OBS for storage. The metadata, description tables, and indexes of the migrated cold data are stored locally to ensure the read performance.

The hot and cold partitions can be switched based on LMT (Last Modify Time) and HPN (Hot Partition Number) policies. LMT indicates that the switchover is performed based on the last update time of the partition, and HPN indicates that the switchover is performed based on the number of reserved hot partitions.

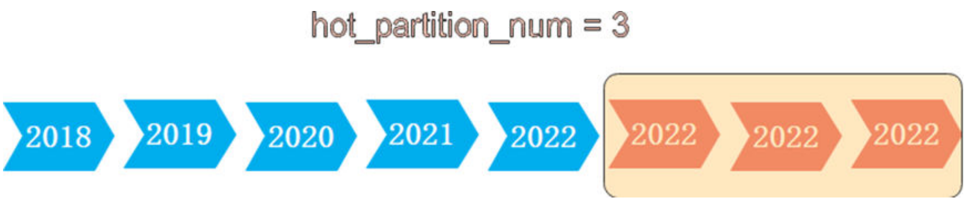
- **LMT**: Switch the hot partition data that is not updated in the last *[day]* days to the OBS tablespace as cold partition data. *[day]* is an integer ranging from 0 to 36500, in days.

  In the following figure, *day* is set to **2**, indicating that the partitions modified in the last two days are retained as the hot partitions, while the rest is retained as the cold partitions. Assume that the current time is April 30. The delete operation is performed on the partition **[4-26]** on April 30, and the insert operation is performed on the partition **[4-27]** on April 29. Therefore, partitions **[4-26]** **[4-27]** **[4-29]** **[4-30]** are retained as hot partitions.



- HPN: indicates the number of hot partitions to be reserved. The partitions are sequenced based on partition sequence IDs. The sequence ID of a partition is a built-in sequence number generated based on the partition boundary values and is not shown. For a range partition, a larger boundary value indicates a larger sequence ID. For a list partition, a larger maximum enumerated value of the partition boundary indicates a larger sequence ID. During the cold and hot switchover, data needs to be migrated to OBS. HPN is an integer ranging from 0 to 1600. If HPN is set to **0**, hot partitions are not reserved. During a cold/hot switchover, all partitions with data are converted to cold partitions and stored on OBS.

  In the following figure, HPN is set to 3, indicating that the last three partitions with data are retained as the hot partitions with the rest as the cold partitions during hot and cold partition switchover.



Constraints

- Supports DML operations on cold and hot tables, such as **INSERT**, **COPY**, **DELETE**, **UPDATE**, and **SELECT**.
- Supports DCL operations such as permission management on cold and hot tables.
- Supports **ANALYZE**, **VACUUM**, and **MERGE INTO** operations on cold and hot tables.
- Supports common column-store partitioned tables to be upgraded to hot and cold data tables.
- Supports upgrade, scale-out, scale-in, and redistribution operations on tables with cold and hot data management enabled.
- 8.3.0 and later versions support mutual conversion between cold and hot partitions. Versions earlier than 8.3.0 support only conversion from hot data to cold data.
- If a table has both cold and hot partitions, the query becomes slow because cold data is stored on OBS and the read/write speed are lower than those of local queries.
- Currently, cold and hot tables support only column-store partitioned tables of version 2.0. Foreign tables do not support cold and hot partitions.
- Only the cold and hot switchover policies can be modified. The tablespace of cold data in cold and hot tables cannot be modified.
- Restrictions on partitioning cold and hot tables:
  - Data in cold partitions cannot be exchanged.
  - **MERGE PARTITION** supports only the merge of hot-hot partitions and cold-cold partitions.
  - Partition operations, such as **ADD**, **MERGE**, and **SPLIT**, cannot be performed on an OBS tablespace.
  - Tablespaces of cold and hot table partitions cannot be specified or modified during table creation.
- Cold and hot data switchover is not performed immediately upon conditions are met. Data switchover is performed only after users manually, or through a scheduler, invoke the switchover command. Currently, the automatic scheduling time is 00:00 every day and can be modified.
- Cold and hot data tables do not support physical fine-grained backup and restoration. Only hot data is backed up during physical backup. Cold data on OBS does not change. The backup and restoration does not support file deletion statements, such as **TRUNCATE TABLE** and **DROP TABLE**.

Procedure

This practice takes about 30 minutes. The basic process is as follows:

1. **Creating a cluster**.
2. **Using the gsql CLI Client to Connect to a Cluster**.
3. **Creating Hot and Cold Tables**.
4. **Hot and Cold Data Switchover**.

5. **Viewing Data Distribution in Hot and Cold Tables**.

Creating a cluster

Step 1 Create a cluster on the **DWS console**. For details, see **Creating a DWS Storage-Compute Coupled Cluster**.

----End

Using the gsql CLI Client to Connect to a Cluster

Step 1 Remotely log in to the Linux server where gsql is to be installed as user **root**, and run the following command in the Linux command window to download the gsql client:

```
wget https://obs.eu-west-101.myhuaweicloud.com/dws/download/dws_client_8.1.x_redhat_x64.zip --no-check-certificate
```

Step 2 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_x64.zip*: This is the client tool package name of **RedHat x64**. Replace it with the actual name.

Step 3 Configure the DWS client.

```
source gsql_env.sh
```

If the following information is displayed, the gsql client is successfully configured:

```
All things done.
```

Step 4 Use the gsql client to connect to a DWS database (using the password you defined when creating the cluster).

```
gsql -d gaussdb -p 8000 -h 192.168.0.86 -U dbadmin -W password -r
```

If the following information is displayed, the connection succeeded:

```
gaussdb=>
```

----End

Creating Hot and Cold Tables

Create a column-store cold and hot data management table **lifecycle_table** and set the hot data validity period LMT to 100 days.

```
CREATE TABLE lifecycle_table(i int, val text) WITH (ORIENTATION = COLUMN, storage_policy = 'LMT:100')
PARTITION BY RANGE (i)
(
PARTITION P1 VALUES LESS THAN(5),
PARTITION P2 VALUES LESS THAN(10),
PARTITION P3 VALUES LESS THAN(15),
PARTITION P8 VALUES LESS THAN(MAXVALUE)
)
ENABLE ROW MOVEMENT;
```

Hot and Cold Data Switchover

Switch hot partition data to cold partition data.

- Automatic switchover: The scheduler automatically triggers the switchover at 00:00 every day.

  You can use the **pg_obs_cold_refresh_time(table_name, time)** function to customize the automatic switchover time. For example, set the automatic triggering time to 06:30 every morning.

```
SELECT * FROM pg_obs_cold_refresh_time('lifecycle_table', '06:30:00');
pg_obs_cold_refresh_time
---------------------------
 SUCCESS
(1 row)
```

- Manual

  Run the **ALTER TABLE** statement to manually switch a single table.

```
ALTER TABLE lifecycle_table refresh storage;
ALTER TABLE
```

  Use the **pg_refresh_storage()** function to switch all hot and cold tables in batches.

```
SELECT pg_catalog.pg_refresh_storage();
 pg_refresh_storage
--------------------
 (1,0)
(1 row)
```

Convert cold partition data into hot partition data. This function is supported only in 8.3.0 or later.

- Convert all cold partitions to hot partitions.

```
SELECT pg_catalog.reload_cold_partition('lifecycle_table');
```

- Convert a specified cold partition to a hot partition:

```
SELECT pg_catalog.reload_cold_partition('lifecycle_table', 'cold_partition_name');
```

Viewing Data Distribution in Hot and Cold Tables

- View the data distribution in a single table:

```
SELECT * FROM pg_catalog.pg_lifecycle_table_data_distribute('lifecycle_table');
schemaname |    tablename    |    nodename    | hotpartition | coldpartition | switchablepartition |
hotdatasize | colddatasize | switchabledatasize
------------+-----------------+--------------+--------------+---------------+---------------------+-------------
+--------------+--------------------
 public     | lifecycle_table | dn_6001_6002 | p1,p2,p3,p8  |               |                     | 96 KB       | 0
bytes       | 0 bytes
 public     | lifecycle_table | dn_6003_6004 | p1,p2,p3,p8  |               |                     | 96 KB       | 0
bytes       | 0 bytes
 public     | lifecycle_table | dn_6005_6006 | p1,p2,p3,p8  |               |                     | 96 KB       | 0
bytes       | 0 bytes
(3 rows)
```

- View data distribution in all hot and cold tables:

```
SELECT * FROM pg_catalog.pg_lifecycle_node_data_distribute();
schemaname |    tablename    |    nodename    | hotpartition | coldpartition | switchablepartition |
hotdatasize | colddatasize | switchabledatasize
------------+-----------------+--------------+--------------+---------------+---------------------+-------------
+--------------+--------------------
 public     | lifecycle_table | dn_6001_6002 | p1,p2,p3,p8  |               |                     |       98304 |
0 |                  0
 public     | lifecycle_table | dn_6003_6004 | p1,p2,p3,p8  |               |                     |       98304 |
0 |                  0
 public     | lifecycle_table | dn_6005_6006 | p1,p2,p3,p8  |               |                     |       98304 |
0 |                  0
(3 rows)
```


Delete cold and hot partitions and partition data.

- Delete data from a specified partition in a hot and cold table.
```
ALTER TABLE lifecycle_table TRUNCATE PARTITION P1;
```
- Delete a specified partition from a hot and cold table.
```
ALTER TABLE lifecycle_table DROP PARTITION P2;
```

4.5 Cutting Partition Maintenance Costs for the E-commerce and IoT Industries by Leveraging Automatic Partition Management Feature

Scenarios

For partition tables whose partition columns are time, the automatic partition management function can be added to automatically create partitions and delete expired partitions, reducing partition table maintenance costs and improving query performance. To facilitate data query and maintenance, the time column is often used as the partition column of a partitioned table that stores time-related data, such as e-commerce order information and real-time IoT data. When the time-related data is imported to a partitioned table, the table should have partitions of the corresponding time ranges. Common partition tables do not automatically create new partitions or delete expired partitions. Therefore, maintenance personnel need to periodically create new partitions and delete expired partitions, leading to increased O&M costs.

Addressing this, DWS introduces the automatic partition management feature. You can set the table-level parameters **period** and **ttl** to enable the automatic partition management function, which automatically creates partitions and deletes expired partitions, reducing partitioned table maintenance costs and improving query performance.

The automatic partition management also works with both time-based and non-time-based columns like **INT**, **BIGINT**, **VARCHAR**, and **TEXT**. This expands the function's usefulness and flexibility.

period: interval for automatically creating partitions. The default value is 1 day. The value range is 1 hour ~ 100 years.

ttl: time for automatically eliminate partitions. The value range is 1 hour ~ 100 years. Partition elimination occurs when nowtime - Partition boundary > ttl, resulting in the removal of qualifying partitions.

time_format:

If the partition column is **VARCHAR**, **TEXT**, **INT**, or **BIGINT**, set the table-level parameter **time_format** to specify the time format. This tells the system how to parse the time value in the partition column for automatic partition management. You can set **time_format** only if the partition key is INT4, INT8, VARCHAR, or TEXT, and a period is specified.

Here are the **time_format** options and restrictions for each type of partition column:

Table 4-6 Time format supported by the **VARCHAR**/**TEXT** type

Format	Description	Sample Input
YYYY	Use four digits for the year (0000-9999).	2024
MM	Use two digits for the month (01-12).	05
DD	Use two digits for the date (01–31).	17
HH24	Use two digits for the hour (00–23).	14
MI	Use two digits for the minute (00–59).	32
SS	Use two digits for the second (00–59).	45

NOTICE

- The precision can be accurate to seconds.
- The entered content cannot contain letters, such as **MONTH**, **AM**, and **PM**.
- The time format must be in descending order, for example, **YYYYMMDDHH24MISS**.

Table 4-7 Time formats supported by the INT/BIGINT type

Format	Description	Sample Input
YYYY	Use four digits for the year (0000-9999).	2024
MM	Use two digits for the month (01-12).	05
DD	Use two digits for the date (01–31).	17
HH24	Use two digits for the hour (00–23).	14

NOTICE

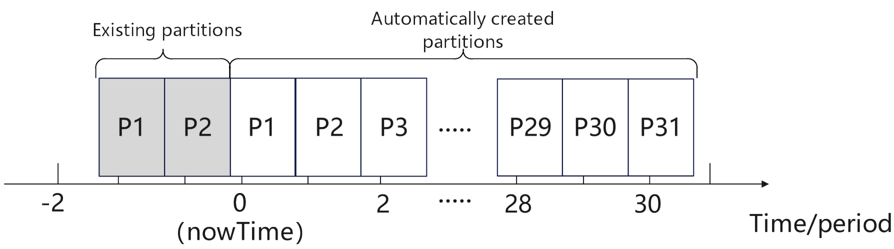
- The precision can be accurate to hours.
- The input content cannot contain non-numeric elements.
- The time format must be in descending order, for example, **YYYYMMDDHH24**.

Automatic Partition Creation Rules

- Automatic partition creation

  One or more partitions are automatically created at the interval specified by **period** to make the maximum partition boundary time greater than nowTime + 30 x period. As long as there is an automatically created partition, real-time data will not fail to be imported within the next 30 periods.

  Figure 4-2 Automatic partition creation



- Automatically deleting expired partitions

  Partitions whose boundary time is earlier than **nowTime-ttl** are considered expired partitions. The automatic partition management function traverses all partitions and deletes expired partitions after each **period**. If all partitions are expired partitions, the system retains one partition and truncates the table.

Constraints

When using the partition management function, ensure that the following requirements are met:

- It cannot be used on midrange servers or acceleration clusters.
- It can be used in clusters of version 8.1.3 or later.
- It can only be used for row-store range partitioned tables, column-store range partitioned tables, time series tables, and cold and hot tables.
- The partition key must be unique. The supported data types include TIMESTAMP, TIMESTAMPTZ, DATE, and INT, BIGINT, VARCHAR, and TEXT added in 9.1.0.200.
- The maxvalue partition is not supported.
- The value of (nowTime - boundaryTime)/period must be less than the maximum number of partitions. **nowTime** indicates the current time, and **boundaryTime** indicates the earliest partition boundary time.
- The values of **period** and **ttl** range from 1 hour to 100 years. In addition, in a database compatible with Teradata or MySQL, if the partition key type is date, the value of period cannot be less than 1day.

- The table-level parameter **ttl** cannot exist independently. You must set **period** in advance or at the same time, and the value of **ttl** must be greater than or equal to that of **period**.
- During online cluster scale-out, partitions cannot be automatically added. Partitions reserved each time partitions are added will ensure that services are not affected.
- The **time_format** option cannot be modified using **SET**. When period is reset (indicating that automatic partitioning is disabled and a message is displayed), you can reset this option.

Creating an ECS

For details, see "Creating an ECS" in the *Elastic Cloud Server User Guide*. When the ECS is created, log in to the ECS. For details, see "Remotely Logging In to a Linux ECS Using a Password (SSH)".

NOTICE

When creating an ECS, ensure that the ECS is in the same region, AZ, and VPC subnet as the stream data warehouse. Select the OS used by the gsql client (CentOS 7.6 is used as an example) as the ECS OS, and select using passwords to log in.

Creating a cluster

Step 1 Create a cluster on the **DWS console**. For details, see **Creating a DWS Storage-Compute Coupled Cluster**.

----End

Using the gsql CLI Client to Connect to a Cluster

Step 1 Remotely log in to the Linux server where gsql is to be installed as user **root**, and run the following command in the Linux command window to download the gsql client:

```
wget https://obs.eu-west-101.myhuaweicloud.com/dws/download/dws_client_8.1.x_redhat_x64.zip --no-check-certificate
```

Step 2 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_x64.zip*: This is the client tool package name of **RedHat x64**. Replace it with the actual name.

Step 3 Configure the DWS client.

```
source gsql_env.sh
```

If the following information is displayed, the gsql client is successfully configured:

```
All things done.
```

Step 4 Use the gsql client to connect to a DWS database (using the password you defined when creating the cluster).

```
gsql -d gaussdb -p 8000 -h 192.168.0.86 -U dbadmin -W password -r
```

If the following information is displayed, the connection succeeded:

```
gaussdb=>
```

----End

Automatic partition management

The partition management function is bound to the table-level parameters **period** and **ttl**. Automatic partition creation is enabled with the enabling of **period**, and automatic partition deletion is enabled with the enabling of **ttl**. 30 seconds after **period** or **ttl** is set, the automatic partition creation or deletion works for the first time.

You can enable the partition management function in either of the following ways:

- Specify **period** and **ttl** when creating a table.

  This way is applicable when you create a partition management table. There are two syntaxes for creating a partition management table. One specifies partitions, and the other does not.

  If partitions are specified when a partition management table is created, the syntax rules are the same as those for creating a common partitioned table. The only difference is that the syntax specifies the table-level parameters **period** and **ttl**.

  The following example shows how to create a partition management table **CPU1** and specify partitions.

```
-- Time type
CREATE TABLE CPU1(
    id integer,
    IP text,
    time timestamp
) with (TTL='7 days',PERIOD='1 day')
partition by range(time)
(
    PARTITION P1 VALUES LESS THAN('2023-02-13 16:32:45'),
    PARTITION P2 VALUES LESS THAN('2023-02-15 16:48:12')
);

-- INT type
CREATE TABLE CPU1(
    id integer,
    IP text,
    time integer
) with (TTL='7 days',PERIOD='1 day', TIME_FORMAT='YYYYMMDD')
partition by range(time)
(
    PARTITION P1 VALUES LESS THAN('20230213'),
    PARTITION P2 VALUES LESS THAN('20230215')
);

-- VARCHAR type
CREATE TABLE CPU1(
    id integer,
    IP text,
    time varchar
) with (TTL='7 days',PERIOD='1 day', TIME_FORMAT='YYYY-MM-DD HH24:MI:SS')
```

```
partition by range(time)
(
    PARTITION P1 VALUES LESS THAN('2023-02-13 16:32:45'),
    PARTITION P2 VALUES LESS THAN('2023-02-15 16:48:12')
);
```

For partitioned tables with INT, BIGINT, VARCHAR, or TEXT types, if the automatic partitioning feature is on, the system adds missing partitions within the TTL range. This is based on the TTL setting and the existing minimum partition boundary (**min_bound**).

The rules depend on the relationship between **min_bound** and the current time (**cur_time**), and are categorized as follows:

Condition	Description
min_bound > cur_time + 29 * period	The current minimum partition size is sufficient. The system sees no need for additional partitions and will not create them automatically.
min_bound > cur_time and min_bound < cur_time + 29 * period	The system advances partitions until the earliest partition boundary is before **cur_time - ttl**.
min_bound < cur_time and min_bound > cur_time - ttl	The system advances partitions until the earliest partition boundary is before **cur_time - ttl**.
min_bound < cur_time - ttl	The current minimum partition is outside the TTL range and will soon be removed. Thus, it will not be moved forward.

NOTE

- **cur_time** indicates the current system time.
- **period** indicates the period of automatic partitioning.
- The automatic completion logic ensures that partitions exist completely in a valid time window, facilitating data import and query.

When creating a partition management table, you can specify only the partition key but not partitions. In this case, two default partitions will be created with **period** as the partition time range. The boundary time of the first default partition is the first hour, day, week, month, or year past the current time. The time unit is selected based on the maximum unit of PERIOD. The boundary time of the second default partition is the boundary time of the first partition plus PERIOD. Assume that the current time is 2023-02-17 16:32:45, and the boundary of the first default partition is described in the following table.

Table 4-8 Description of the period parameter

period	Maximum PERIOD Unit	Boundary of First Default Partition
1hour	Hour	2023-02-17 17:00:00
1day	Day	2023-02-18 00:00:00
1month	Month	2023-03-01 00:00:00
13months	Year	2024-01-01 00:00:00

For INT, BIGINT, VARCHAR, and TEXT partition tables, if no partition is set, the system automatically creates initial partitions when the automatic partition management is turned on. The creation rules are as follows:

- Add two partitions forward (compared with the current time).
- Add **ttl**/**period** partitions backward (calculated based on the lifecycle **ttl** and partition **period**).

Run the following command to create the partition management table **CPU2** with no partitions specified:

```
CREATE TABLE CPU2(
    id integer,
    IP text,
    time timestamp
) with (TTL='7 days',PERIOD='1 day')
partition by range(time);
```

- Run the **ALTER TABLE RESET** command to set **period** and **ttl**.

  This method is used to add the partition management function to an ordinary partitioned table that meets the partition management constraints.

  - Run the following command to create an ordinary partition table **CPU3**:

```
-- Time type
CREATE TABLE CPU3(
    id integer,
    IP text,
    time timestamp
)
partition by range(time)
(
    PARTITION P1 VALUES LESS THAN('2023-02-14 16:32:45'),
    PARTITION P2 VALUES LESS THAN('2023-02-15 16:56:12')
);

-- VARCHAR type
CREATE TABLE CPU3(
    id integer,
    IP text,
    time varchar
)
partition by range(time)
(
    PARTITION P1 VALUES LESS THAN('2023-02-13 16:32:45'),
    PARTITION P2 VALUES LESS THAN('2023-02-15 16:48:12')
);
```

  - To enable the automatic partition creation and deletion functions, run the following command:

```
ALTER TABLE CPU3 SET (PERIOD='1 day',TTL='7 days');
```


- To enable only the automatic partition creation function, run the following command:
```
ALTER TABLE CPU3 SET (PERIOD='1 day');
```
- To enable only the automatic partition deletion function, run the following command (If automatic partition creation is not enabled in advance, the operation will fail):
```
ALTER TABLE CPU3 SET (TTL='7 days');
```
- Modify the **period** and **ttl** parameters to modify the partition management function.
```
ALTER TABLE CPU3 SET (TTL='10 days',PERIOD='2 days');
```

- Disabling the partition management function

  You can run the **ALTER TABLE RESET** command to delete the table-level parameters **period** and **ttl** to disable the partition management function.

  NOTE

  - The **period** cannot be deleted separately with **TTL**.
  - The time series table does not support **ALTER TABLE RESET**.

- Run the following command to disable the automatic partition creation and deletion functions:
```
ALTER TABLE CPU1 RESET (PERIOD,TTL);
```
- To disable only the automatic partition deletion, run the following command:
```
ALTER TABLE CPU3 RESET (TTL);
```
- To disable only the automatic partition creation function, run the following command (If the table contains the **ttl** parameter, the operation will fail):
```
ALTER TABLE CPU3 RESET (PERIOD);
```
- For partition tables of the INT, BIGINT, VARCHAR, and TEXT types, disable the **TIME_FORMAT** option as prompted.
```
ALTER TABLE CPU3 RESET (TIME_FORMAT);
```

4.6 Improving Development Efficiency by Leveraging the View Decoupling and Rebuilding Function

Base table objects cannot be modified independently due to view and table dependency. To solve this problem, DWS supports view decoupling and rebuilding. This document describes when and how to use the automatic view rebuilding function.

Scenario

DWS uses object identifiers (OIDs) to store reference relationships between objects. When a view is defined, the OID of the database object on which the view depends is bound to it. No matter how the view name changes, the dependency does not change. If you modify some columns in the base table, an error will be reported because the columns are strongly bound some objects. If you want to delete a table column or the entire table, you need to use the **cascade** keyword to delete the associated views. After the table column is deleted or the table is re-created, you need to re-create the views of different levels one by one. This increases the workload and deteriorates the usability.

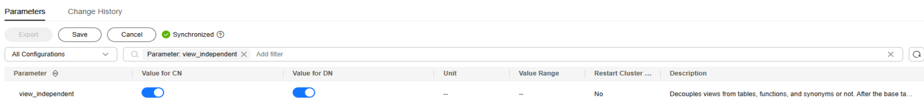
To solve this problem, DWS 8.1.0 decouples views from their dependent base tables or other database objects (views, synonyms, functions, and table columns), so that these objects can be deleted independently. After the base table is rebuilt, you can run the **ALTER VIEW REBUILD** command to rebuild the dependency. As a development, the version 8.1.1 supports automatic rebuilding. Dependencies can be automatically rebuilt without user awareness. After automatic rebuilding is enabled, lock conflicts may occur. Therefore, you are advised not to enable automatic rebuilding. In cluster 8.2.1.200, automatic rebuilding is disabled and local automatic rebuilding is used. That is, system catalogs are not updated after views are automatically rebuilt. In this case, invalid views are still invalid, but DML operations can still be performed on invalid views. To update view metadata to the valid state, perform the ALTER VIEW REBUILD operation.

Usage

Step 1 Create a cluster on the **DWS console**. For details, see **Creating a DWS Storage-Compute Coupled Cluster**.

Step 2 Enable the GUC parameter **view_independent**.

The GUC parameter **view_independent** controls whether to decouple a view from its objects. This parameter is disabled by default. You need to manually enable the parameter. To enable the **view_independent** parameter, log in to the **DWS console** and click the cluster name to go to the cluster details page. Click the **Parameters** tab, search for **view_independent**, modify the parameter, and save the modification.



Step 3 Use the gsql client to connect to a DWS database (using the password you defined when creating the cluster).

```
gsql -d gaussdb -p 8000 -h 192.168.0.86 -U dbadmin -W password -r
```

If the following information is displayed, the connection succeeded:

```
gaussdb=>
```

Step 4 Create a sample table **t1** and insert data into the table.

```
SET current_schema='public';
CREATE TABLE t1 (a int, b int, c char(10)) DISTRIBUTE BY HASH (a);
INSERT INTO t1 VALUES(1,1,'a'),(2,2,'b');
```

Step 5 Create view **v1** that depends on table **t1**, and create view **v11** that depends on view **v1**. Query view **v11**.

```
CREATE VIEW v1 AS SELECT a, b FROM t1;
CREATE VIEW v11 AS SELECT a FROM v1;

SELECT * FROM v11;
 a
---
 1
 2
(2 rows)
```

Step 6 After table **t1** is deleted, an error is reported when you query the view **v11**. However, the views still exist.

DWS provides the **GS_VIEW_INVALID** view to query all invalid views visible to the 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".

```
DROP TABLE t1;

SELECT * FROM v11;
ERROR:  relation "public.t1" does not exist

SELECT * FROM gs_view_invalid;
  oid   | schemaname | viewname | viewowner |         definition          | validtype
--------+------------+----------+-----------+-----------------------------+-----------
 213563 | public     | v1       | dbadmin   | SELECT a, b FROM public.t1; | invalid
 213567 | public     | v11      | dbadmin   | SELECT a FROM public.v1;    | invalid
(2 rows)
```

Step 7 After the table **t1** is recreated in a cluster of a version earlier than 8.2.1.200, the view is automatically recreated. The views are automatically refreshed only when they are used.

```
CREATE TABLE t1 (a int, b int, c char(10)) DISTRIBUTE BY HASH (a);
INSERT INTO t1 VALUES(1,1,'a'),(2,2,'b');

SELECT * from v1;
 a | b
---+---
 1 | 1
 2 | 2
(2 rows)

SELECT * FROM gs_view_invalid;
  oid   | schemaname | viewname | viewowner |        definition        | validtype
--------+------------+----------+-----------+--------------------------+-----------
 213567 | public     | v11      | dbadmin   | SELECT a FROM public.v1; | invalid
(1 row)

SELECT * from v11;
 a
---
 1
 2
(2 rows)

SELECT * FROM gs_view_invalid;
 oid | schemaname | viewname | viewowner | definition | validtype
-----+------------+----------+-----------+------------+-----------
(0 rows)
```

Step 8 After the table **t1** is recreated for a cluster of version 8.2.1.200 or later, the view is not automatically recreated. The view can be automatically refreshed only after the **ALTER VIEW REBUILD** operation is performed.

```
CREATE TABLE t1 (a int, b int, c char(10)) DISTRIBUTE BY HASH (a);
INSERT INTO t1 VALUES(1,1,'a'),(2,2,'b');

SELECT * from v1;
 a | b
---+---
 1 | 1
 2 | 2
(2 rows)

SELECT * FROM gs_view_invalid;
  oid   | schemaname | viewname | viewowner |         definition          | validtype
--------+------------+----------+-----------+-----------------------------+-----------
 213563 | public     | v1       | dbadmin   | SELECT a, b FROM public.t1; | invalid
```

```
 213567 | public     | v11      | dbadmin   | SELECT a FROM public.v1;    | invalid
(1 row)

ALTER VIEW ONLY v1 REBUILD;

SELECT * FROM gs_view_invalid;
  oid   | schemaname | viewname | viewowner |        definition        | validtype
--------+------------+----------+-----------+--------------------------+-----------
 213567 | public     | v11      | dbadmin   | SELECT a FROM public.v1; | invalid
(1 rows)
```

----End

4.7 Best Practices of GIN Index

A GIN index is a data structure that pairs a key with its posting list. The key indicates a specific value, and the posting list tracks all the locations that this key occurs. For example, 'hello', '14:2 23:4' indicates that **hello** is found at the locations **14:2** and **23:4**. A GIN index efficiently locates tuples with specific keywords, making it ideal for searching elements within multi-valued fields. This section describes how to use GIN indexes to search through array and JSONB types, as well as how to conduct full-text searches.

Using a GIN Index to Search Through the Array Type

Create a GIN index to speed up tag searches.

Step 1 Create a cluster on the **DWS console**. For details, see **Creating a DWS Storage-Compute Coupled Cluster**.

Step 2 Use the gsql client to connect to a DWS database (using the password you defined when creating the cluster).

```
gsql -d gaussdb -p 8000 -h 192.168.0.86 -U dbadmin -W password -r
```

If the following information is displayed, the connection succeeded:

```
gaussdb=>
```

Step 3 Create the **books** table. The **tags** column stores the tag information of **books** using the array type.

```
CREATE TABLE books (id SERIAL PRIMARY KEY, title VARCHAR(100), tags TEXT[]);
```

Step 4 Insert data.

```
INSERT INTO books (title, tags)
VALUES   ('Book 1', ARRAY['fiction', 'adventure']),
   ('Book 2', ARRAY['science', 'fiction']),
   ('Book 3', ARRAY['romance', 'fantasy']),
   ('Book 4', ARRAY['adventure']);
```

Step 5 Create a GIN index.

```
CREATE INDEX idx_books_tags_gin ON books USING GIN (tags);
```

Step 6 Use the GIN index to perform a search query to find books that contain a specific tag in the **tags** column. Search for books containing the tag "fiction":

```
SELECT * FROM books WHERE tags @> ARRAY['fiction'];
 id | title  |        tags
----+--------+---------------------
  1 | Book 1 | {fiction,adventure}
  2 | Book 2 | {science,fiction}
(2 rows)
```

Step 7 Use the GIN index to search for books that contain both the "fiction" and "adventure" tags.

```
SELECT * FROM books WHERE tags @> ARRAY['fiction', 'adventure'];
 id | title  |        tags
----+--------+---------------------
  1 | Book 1 | {fiction,adventure}
(1 row)
```

----End

Using a GIN Index to Search Through the JSONB Type

When using the JSONB type to store and query JSON data, you can use GIN indexes to improve query performance. GIN indexes are suitable for querying JSONB columns that contain a large number of different key-value pairs.

Step 1 Create the **my_table** table. The **data** column stores information about each person using the JSONB type.

```
CREATE TABLE my_table (id SERIAL PRIMARY KEY, data JSONB);
```

Step 2 Insert data.

```
INSERT INTO my_table (data)
 VALUES ('{"name": "John", "age": 30, "address": {"career": "announcer", "state": "NY"}}'),
      ('{"name": "Alice", "age": 25, "address": {"career": "architect", "state": "CA"}}'),
      ('{"name": "Bob", "age": 35, "address": {"career": "dentist", "state": "WA"}}');
```

Step 3 Create a GIN index to accelerate the query of JSONB columns.

```
CREATE INDEX my_table_data_gin_index ON my_table USING GIN (data);
```

Step 4 Use the GIN index to perform queries on JSONB columns. For example, search for a person whose occupation is dentist::

```
SELECT * FROM my_table WHERE data @> '{"address": {"career": "dentist"}}';
 id |                                 data
----+---------------------------------------------------------------------------
  3 | {"age": 35, "name": "Bob", "address": {"state": "WA", "career": "dentist"}}
(1 row)
```

Step 5 GIN indexes can also be queried on keys of JSONB columns. For example, search for people who are 30 years old or older:

```
SELECT * FROM my_table WHERE data ->> 'age' >= '30';
 id |                                    data
----+--------------------------------------------------------------------------------
  3 | {"age": 35, "name": "Bob", "address": {"state": "WA", "career": "dentist"}}
  1 | {"age": 30, "name": "John", "address": {"state": "NY", "career": "announcer"}}
(2 rows)
```

----End

Using a GIN Index for Full-Text Search

When using GIN indexes for full-text search, you can use the tsvector and tsquery data types and related functions.

NOTE

To build a tsquery object, you need to use the **to_tsquery** function and provide the search criteria and the corresponding text search configuration (english in this case). Other text search functions and operators can also be used for more complex full-text searches, such as **plainto_tsquery** and **ts_rank**. The specific usage depends on your needs.

Step 1 Create an **articles** table in which the **content** column stores the article content.

```
CREATE TABLE articles (id SERIAL PRIMARY KEY,title VARCHAR(100),content TEXT);
```

Step 2 Insert data.

```
INSERT INTO articles (title, content)
 VALUES ('Article 1', 'This is the content of article 1.'),
   ('Article 2', 'Here is the content for article 2.'),
   ('Article 3', 'This article discusses various topics.'),
   ('Article 4', 'The content of the fourth article is different.');
```

Step 3 Creates an auxiliary column **tsvector** for the **content** column that stores the processed text indexes.

```
ALTER TABLE articles ADD COLUMN content_vector tsvector;
```

Step 4 Update the value in the **content_vector** column and convert the text in the **content** column to the tsvector type.

```
UPDATE articles SET content_vector = to_tsvector('english', content);
```

Step 5 Create a GIN index.

```
CREATE INDEX idx_articles_content_gin ON articles USING GIN (content_vector);
```

Step 6 Perform a full-text search, using the tsquery type to specify the search criteria. For example, search for an article that contains the word "content":

```
SELECT * FROM articles WHERE content_vector @@ to_tsquery('english', 'content');
```

----End

4.8 Encrypting and Decrypting Data Columns

Data encryption is widely used in various information systems as a technology to effectively prevent unauthorized access and prevent data leakage. As the core of an information system, the DWS data warehouse also provides transparent encryption and encryption using SQL functions. This section describes SQL function encryption.

NOTE

Currently, DWS does not support decrypting data encrypted in Oracle, Teradata, and MySQL databases. The encryption and decryption of Oracle, Teradata, and MySQL databases are different from those of DWS. DWS can only decrypt unencrypted data migrated from Oracle, Teradata, and MySQL databases.

Background

- Hash Functions

  The hash function is also called the digest algorithm. It maps input data of an arbitrary length to an output of fixed length. For example, Hash(data)=result. This process is irreversible. That is, the hash function does not have an inverse function, and data cannot be obtained from the result. In scenarios where plaintext passwords should not be stored (passwords are sensitive) or known by system administrators, hash algorithms should be used to store one-way hash values of passwords.

  In actual use, salt values and iteration are added to prevent same hash values generated by same passwords, hence to prevent rainbow table attacks.

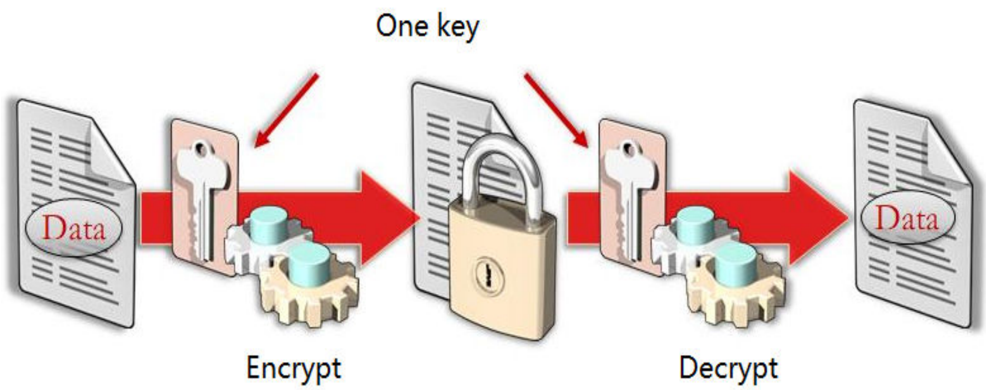
- Symmetric Encryption Algorithms

Symmetric encryption algorithms use the same key to encrypt and decrypt data. There are two subcategories of symmetric encryption algorithms: block ciphers and stream ciphers.

Block ciphers break the plaintext into fixed-length groups of bits known as blocks and Each block then gets encrypted as a unit. And if there's not enough data to completely fill a block, "padding" is then used to ensure that the blocks meet the fixed-length requirements. Due to padding, the length of the ciphertext obtained by block ciphers is greater than that of the plaintext.

In stream ciphers, encryption and decryption parties use same pseudo-random encrypted data stream as keys, and plaintext data is sequentially encrypted by these keys. In practice, data is encrypted one bit at a time using an XOR operation. Stream cyphers do not need to be padded. Therefore the length of the obtained ciphertext is same as the length of the plaintext.

Figure 4-3 Symmetric encryption algorithms



Technical Details

DWS provides hash functions and symmetric cryptographic algorithms to encrypt and decrypt columns. Hash functions support sha256, sha384, sha512, and SM3. Symmetric cryptographic algorithms support AES128, AES192, AES256, and SM4.

- Hash Functions
  - md5(string)

    Use MD5 to encrypt string and return a hexadecimal value. MD5 is insecure and is not recommended.
  - gs_hash(hashstr, hashmethod)

    Obtains the digest string of a **hashstr** string based on the algorithm specified by **hashmethod**. **hashmethod** can be **sha256**, **sha384**, **sha512**, or **sm3**.
- Symmetric Encryption Algorithms
  - gs_encrypt(encryptstr, keystr, cryptotype, cryptomode, hashmethod)

    Encrypts an **encryptstr** string using the **keystr** key based on the encryption algorithm specified by **cryptotype** and **cryptomode** and the HMAC algorithm specified by **hashmethod**, and returns the encrypted string.
  - gs_decrypt(decryptstr, keystr, cryptotype, cryptomode, hashmethod)

Decrypts a **decryptstr** string using the **keystr** key based on the encryption algorithm specified by **cryptotype** and **cryptomode** and the HMAC algorithm specified by **hashmethod**, and returns the decrypted string. The **keystr** used for decryption must be consistent with that used for encryption.

– gs_encrypt_aes128(encryptstr, keystr)

  Encrypts **encryptstr** strings using **keystr** as the key and returns encrypted strings. The length of **keystr** ranges from 1 to 16 bytes.

– gs_decrypt_aes128(decryptstr, keystr)

  Decrypts a **decryptstr** string using the **keystr** key and returns the decrypted string. The **keystr** used for decryption must be consistent with that used for encryption. **keystr** cannot be empty.

For more information about functions, see **Security Functions**.

Examples

Step 1 Connect to the database.

For details, see **Using the gsql CLI Client to Connect to a Cluster**.

Step 2 Create the table **student** with the columns **id**, **name**, and **score**. Then use hash functions to encrypt and save names, and use symmetric cryptographic algorithms to save scores.

```
CREATE TABLE student (id int, name text, score text, subject text);

INSERT INTO student VALUES (1, gs_hash('alice', 'sha256'), gs_encrypt('95', '12345', 'aes128', 'cbc', 
'sha256'),gs_encrypt_aes128('math', '1234'));
INSERT INTO student VALUES (2, gs_hash('bob', 'sha256'), gs_encrypt('92', '12345', 'aes128', 'cbc', 
'sha256'),gs_encrypt_aes128('english', '1234'));
INSERT INTO student VALUES (3, gs_hash('peter', 'sha256'), gs_encrypt('98', '12345', 'aes128', 'cbc', 
'sha256'),gs_encrypt_aes128('science', '1234'));
```

Step 3 Query the table **student** without using keys. The query result shows that the encrypted data in the name and score columns cannot be viewed even if you have the **SELECT** permission.

```
SELECT * FROM student;
 id |                              name                              |
score                                                |
                               subject
----+-----------------------------------------------------------------
+----------------------------------------------------------------------------------------------------------------------------
+-----------
----------------------------------------------------------------------------------
  1 | 2bd806c97f0e00af1a1fc3328fa763a9269723c8db8fac4f93af71db186d6e90 | AAAAAAAAAABAuUC3VQ
+MvPCDAaTUySl1e2gGLr4/ATdCUjTEvova3cb/Ba3ZKqIn1yNVGEFBvJnTq/3sLF4//
Gm8qG7AyfNbbqdW3aYErLVpbE/QWFX9Ig== | aFEWQR2gkj
iu6sfsAad+dHzfFDHePZ6xd44zyekh+qVFlh9FODZ0DoaFAJXctwUsiqaiitTxW8cCSEaNjS/E7Ke1ruY=
  2 | 81b637d8fcd2c6da6359e6963113a1170de795e4b725b84d1e0b4cfd9ec58ce9 | AAAAAAAAAABAuUC3VQ
+MvPCDAaTUySl1taXxAoDqE793hgyCJvC0ESdAX5Mtgdq2LXI1f5ZxraQ73WIJVtIBX8oe3gTDxoXGlHbHht4kzM
4U8dOwr5rjgg== | aFEWQR2gkj
iu6sfsAad+dM8tPTDo/Pds6ZmqdmjGiKxf39+Wzx5NoQ6c8FrzihnRzgc0fycWSu5YGWNOKYWhRsE84Ac=
  3 | 026ad9b14a7453b7488daa0c6acbc258b1506f52c441c7c465474c1a564394ff |
AAAAAAAAAACnyusORPeApqMUgh56ucQu3uso/
Llw5MbPFMkOXuspEzhhnc9vErwOFe6cuGtx8muEyHCX7V5yXs+8FxhNh3n5L3419LDWJJLY2O4merHpSg== |
zomphRfHV4
H32hTtgkio1PyrobVO8N+hN7kAKwtygKP2E7Aaf1vsjmtLHcL88jyeJNe1lxe0fAvodzPJAxAuV3UJN4M=
(3 rows)
```

Step 4 Query the table **student** using keys. The query result shows that the data is decrypted by the function **gs_decrypt** (corresponding to **gs_encrypt**) and can be viewed.

```
SELECT id, gs_decrypt(score, '12345', 'aes128', 'cbc', 'sha256'),gs_decrypt_aes128(subject, '1234') FROM student;
 id | gs_decrypt | gs_decrypt_aes128
----+------------+-------------------
  1 | 95         | math
  2 | 92         | english
  3 | 98         | science
(3 rows)
```

----End

4.9 Managing Data Permissions Through Views

This section describes how to use views to allow various users to access specific data within the same table, ensuring data permissions management and security.

Scenario

After connecting to a cluster as user **dbadmin**, create an example table **customer**.

```
CREATE TABLE customer (id bigserial NOT NULL, province_id bigint NOT NULL, user_info varchar, primary key (id)) DISTRIBUTE BY HASH(id);
```

Insert test data into the example table **customer**.

```
INSERT INTO customer(province_id,user_info) VALUES (1,'Alice'),(1,'Jack'),(2,'Jack'),(3,'Matu');
INSERT 0 4
```

Query the **customer** table.

```
SELECT * FROM customer;
 id | province_id | user_info
----+-------------+-----------
  3 |           2 | Jack
  1 |           1 | Alice
  2 |           1 | Jack
  4 |           3 | Matu
(4 rows)
```

Requirement: User **u1** can view only the data of province 1 (**province_id** = **1**), and user **u2** can view only the data of province 2 (**province_id** = **2**).

Implementation

You can create a view to meet the requirements in the preceding scenario. The procedure is as follows:

Step 1 After connecting to a cluster as user **dbadmin**, create views **v1** and **v2** for provinces 1 and 2 in **dbadmin** mode.

Run the **CREATE VIEW** statement to create view **v1** for querying the data of province 1.

```
CREATE VIEW v1 AS
    SELECT * FROM customer WHERE province_id=1;
```

Run the **CREATE VIEW** statement to create view **v2** for querying the data of province 2.

```
CREATE VIEW v2 AS
   SELECT * FROM customer WHERE province_id=2;
```

Step 2 Create users **u1** and **u2**.

```
CREATE USER u1 PASSWORD '*********';
CREATE USER u2 PASSWORD '*********';
```

Step 3 Run the **GRANT** statement to grant the data query permission to the target user.

Grant the permission on the target view schema to **u1** and **u2**.

```
GRANT USAGE ON schema dbadmin TO u1,u2;
```

Grant **u1** the permission to query data of province 1 in the **v1** view.

```
GRANT SELECT ON v1 TO u1;
```

Grant **u2** the permission to query data of province 2 in the **v2** view.

```
GRANT SELECT ON v2 TO u2;
```

----End

Verifying the Query Result

- Switch to **u1** to connect to the cluster.

  ```
  SET ROLE u1 PASSWORD '*********';
  ```

  Query the **v1** view. **u1** can query only the **v1** view data.

  ```
  SELECT * FROM dbadmin.v1;
   id | province_id | user_info
  ----+-------------+-----------
    1 |           1 | Alice
    2 |           1 | Jack
  (2 rows)
  ```

  If **u1** attempts to query data in view **v2**, the following error information is displayed:

  ```
  SELECT * FROM dbadmin.v2;
  ERROR:  SELECT permission denied to user "u1" for relation "dbadmin.v2"
  ```

  The result shows that user **u1** can view only the data of province 1 (**province_id** = **1**).

- Use **u2** to connect to the cluster.

  ```
  SET ROLE u2 PASSWORD '*********';
  ```

  Query the **v2** view. **u2** can query only the **v2** view data.

  ```
  SELECT * FROM dbadmin.v2;
   id | province_id | user_info
  ----+-------------+-----------
    3 |           2 | Jack
  (1 row)
  ```

  If **u2** attempts to query data in view **v1**, the following error information is displayed:

  ```
  SELECT * FROM dbadmin.v1;
  ERROR:  SELECT permission denied to user "u2" for relation "dbadmin.v1"
  ```

  The result shows that user **u2** can view only the data of province 2 (**province_id** = **2**).

5 Database Management

5.1 Role-based Access Control (RBAC)

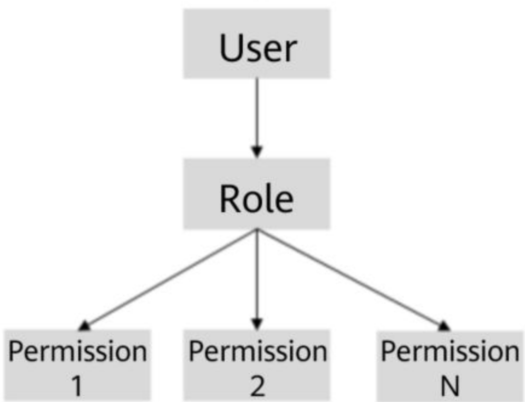
What is RBAC?

- Role-based access control (RBAC) is to grant permissions to roles and let users obtain permissions by associating with roles.
- A role is a set of permissions.
- RBAC greatly simplifies permissions management.

What is the RBAC Model?

Assign appropriate permissions to roles.

Associate users with the roles.

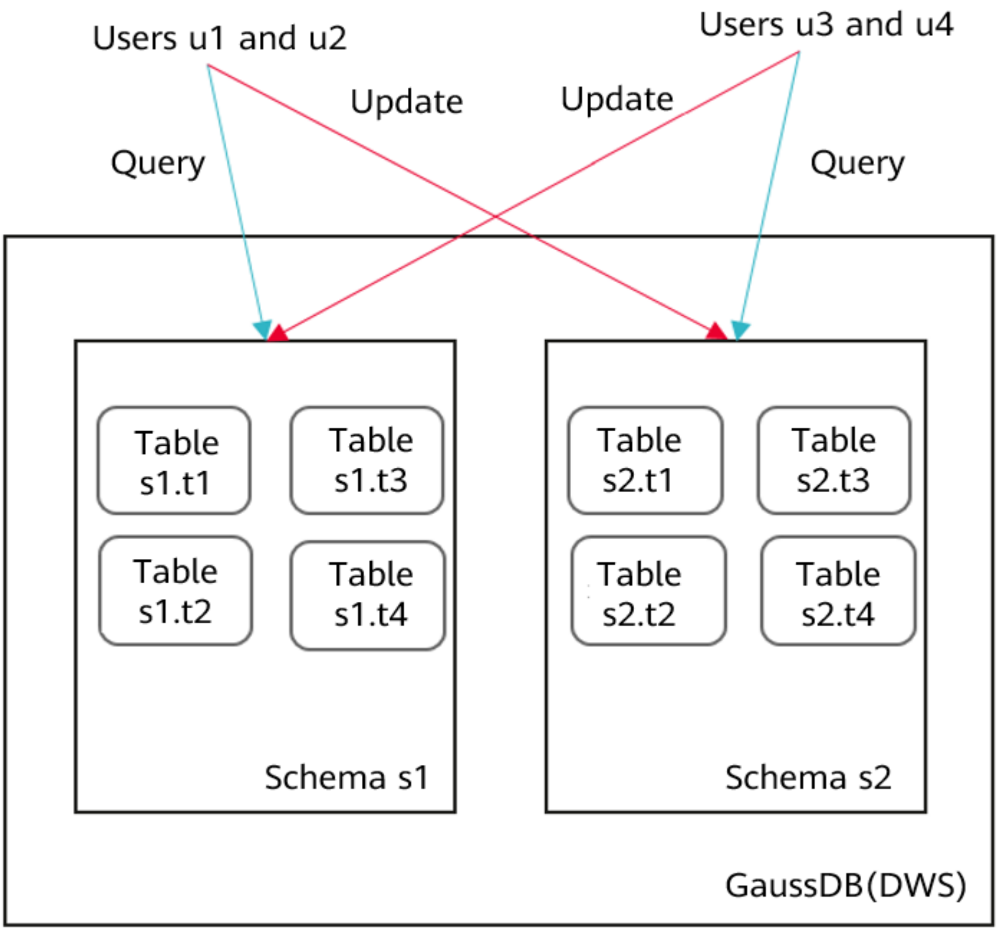


Scenarios

Assume there are two schemas, **s1** and **s2**.

There are two groups of users:

- Users **u1** and **u2** can query all the tables in **s1** and update all the tables in **s2**.
- Users **u3** and **u4** can query all the tables in **s2** and update all the tables in **s1**.



Granting Permissions

Step 1 Connect to the DWS database as user **dbadmin**.

Step 2 Run the following statements to create schemas **s1** and **s2** and users **u1** to **u4**:

NOTE

Replace *{password}* with the actual password.

```
CREATE SCHEMA s1;
CREATE SCHEMA s2;
CREATE USER u1 PASSWORD '{password}';
CREATE USER u2 PASSWORD '{password}';
CREATE USER u3 PASSWORD '{password}';
CREATE USER u4 PASSWORD '{password}';
```

Step 3 Copy and run the following statements to create the **s1.t1** and **s2.t1** tables:

```
CREATE TABLE s1.t1 (c1 int, c2 int);
CREATE TABLE s2.t1 (c1 int, c2 int);
```

Step 4 Run the following statement to insert data to the tables:

```
INSERT INTO s1.t1 VALUES (1,2);
INSERT INTO s2.t1 VALUES (1,2);
```

Step 5 Run the following statements to create four roles, each having the query or update permission of table **s1** or **s2**:

```
CREATE ROLE rs1_select PASSWORD disable;  -- Permission to query s1
CREATE ROLE rs1_update PASSWORD disable; -- Permission to update s1
CREATE ROLE rs2_select PASSWORD disable; -- Permission to query s2
CREATE ROLE rs2_update PASSWORD disable; -- Permission to update s2
```

Step 6 Run the following statements to grant the access permissions of schemas **s1** and **s2** to the roles:

```
GRANT USAGE ON SCHEMA s1, s2 TO rs1_select, rs1_update,rs2_select, rs2_update;
```

Step 7 Run the following statements to grant specific permissions to the roles:

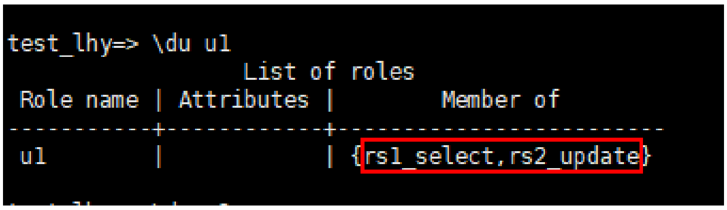
```
GRANT SELECT ON ALL TABLES IN SCHEMA s1 TO rs1_select; -- Grant the query permission on all the tables in s1 to the rs1_select role.
GRANT SELECT,UPDATE ON ALL TABLES IN SCHEMA s1 TO rs1_update;  -- Grant the query and update permissions on all the tables in s1 to the rs1_update role.
GRANT SELECT ON ALL TABLES IN SCHEMA s2 TO rs2_select;  -- Grant the query permission on all the tables in s2 to the rs2_select role.
GRANT SELECT,UPDATE ON ALL TABLES IN SCHEMA s2 TO rs2_update;  -- Grant the query and update permissions on all the tables in s2 to the rs2_update role.
```

Step 8 Run the following statements to grant roles to users:

```
GRANT rs1_select, rs2_update TO u1, u2;  -- Users u1 and u2 have the permissions to query s1 and update s2.
GRANT rs2_select, rs1_update TO u3, u4;  -- Users u3 and u4 have the permissions to query s2 and update s1.
```

Step 9 Run the following statement to view the role bound to a specific user:

```
\du u1;
```

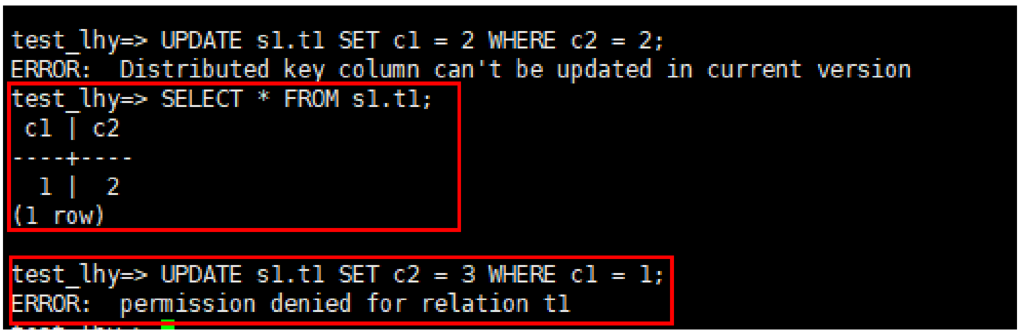


Step 10 Start another session. Connect to the database as user **u1**.

gsql -d gaussdb -h *DWS_EIP* **-U u1 -p 8000 -r -W** *{password}***;**

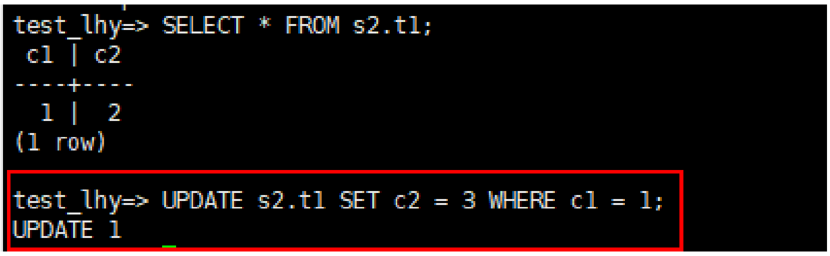
Step 11 Run the following statements in the new session verify that user **u1** can query but cannot update **s1.t1**:

```
SELECT * FROM s1.t1;
UPDATE s1.t1 SET c2 = 3 WHERE c1 = 1;
```



Step 12 Run the following statements in the new session to verify that user **u1** can update **s2.t1**:

```
SELECT * FROM s2.t1;
UPDATE s2.t1 SET c2 = 3 WHERE c1 = 1;
```



----End

5.2 Best Practices for User Management

A DWS cluster mainly consists of system administrators and common users. This section describes the permissions of system administrators and common users and describes how to create users and query user information.

System Administrator

The user **dbadmin** created when you start a DWS cluster is a system administrator. It has the highest system permission and can perform all operations, including operations on tablespaces, tables, indexes, schemas, functions, and custom views, as well as query for system catalogs and views.

To create a database administrator, connect to the database as an administrator and run the **CREATE USER** or **ALTER USER** statement with **SYSADMIN** specified.

Examples:

Create user **Jim** as a system administrator.

```
CREATE USER Jim WITH SYSADMIN password '{Password}';
```

Change user **Tom** to a system administrator. **ALTER USER** can be used only for existing users.

```
ALTER USER Tom SYSADMIN;
```

Common User

You can run the **CREATE USER** SQL statement to create a common user. A common user cannot create, modify, delete, or assign tablespaces, and needs to be assigned the permission for accessing tablespaces. A common user has all permissions for its own tables, schemas, functions, and custom views, creates indexes on its own tables, and queries only some system catalogs and views.

The database cluster has one or more named databases. Users are shared within the entire cluster, but their data is not shared.

Common user operations are as follows. Replace **password** with the actual password.

1. Creating a user
   ```
   CREATE USER Tom PASSWORD '{Password}';
   ```
2. Changing a user password

   Change the login password of user **Tom** from **password** to **newpassword**.

```
ALTER USER Tom IDENTIFIED BY 'newpassword' REPLACE '{Password}';
```

3. Assigning permissions to a user
   – Add **CREATEDB** when you create a user that has the permission for creating a database.
```
CREATE USER Tom CREATEDB PASSWORD '{Password}';
```
   – Add the **CREATEROLE** permission for a user.
```
ALTER USER Tom CREATEROLE;
```
4. Revoking user permissions
```
REVOKE ALL PRIVILEGES FROM Tom;
```
5. Locking or unlocking a user
   – Lock user **Tom**.
```
ALTER USER Tom ACCOUNT LOCK;
```
   – Unlock user **Tom**.
```
ALTER USER Tom ACCOUNT UNLOCK;
```
6. Deleting a user
```
DROP USER Tom CASCADE;
```

User Information Query

System views related to users, roles, and permissions include **ALL_USERS**, **PG_USER**, and **PG_ROLES**, and system catalogs include **PG_AUTHID** and **PG_AUTH_MEMBERS**.

- **ALL_USERS** displays all users in the database but does not show the details of them.
- **PG_USER** displays user information, including user IDs, the permission to create databases, and resource pools.
- **PG_ROLES** displays information about database roles.
- **PG_AUTHID** records information about database authentication identifiers (roles), including role permissions to log in or create databases.
- **PG_AUTH_MEMBERS** stores information of roles contained in a role group.

1. You can run **PG_USER** to query all users in the database. User ID (**USESYSID**) and permissions can also be queried.
```
SELECT * FROM pg_user;
 usename | usesysid | usecreatedb | usesuper | usecatupd | userepl |  passwd  | valbegin | valuntil |
respool    | parent | spacelimit | useconfig | nodegroup | tempspacelimit | spillspacelim
it
---------+----------+-------------+----------+-----------+---------+----------+----------+----------+--------------
+--------+------------+-----------+-----------+----------------+--------------
---
 Ruby    |       10 | t           | t        | t         | t       | ******** |          |          | default_pool |      0 |
|            |            |                |
 kim     |    21661 | f           | f        | f         | f       | ******** |          |          | default_pool |      0 |
|            |            |                |
 u3      |    22662 | f           | f        | f         | f       | ******** |          |          | default_pool |      0 |
|            |            |                |
 u1      |    22666 | f           | f        | f         | f       | ******** |          |          | default_pool |      0 |
|            |            |                |
 dbadmin |    16396 | f           | f        | f         | f       | ******** |          |          | default_pool |      0
|            |            |            |                |
 u5      |    58421 | f           | f        | f         | f       | ******** |          |          | default_pool |      0 |
|            |            |                |
(6 rows)
```
2. **ALL_USERS** displays all users in the database but does not show the details of them.

```
SELECT * FROM all_users;
 username | user_id
----------+---------
 Ruby     |      10
 manager  |   21649
 kim      |   21661
 u3       |   22662
 u1       |   22666
 u2       |   22802
 dbadmin  |   16396
 u5       |   58421
(8 rows)
```

3. **PG_ROLES** stores information about roles that have accessed the database.

```
SELECT * FROM pg_roles;
 rolname | rolsuper | rolinherit | rolcreaterole | rolcreatedb | rolcatupdate | rolcanlogin | rolreplication | rolauditadmin | rolsystemadmin | rolconnlimit | rolpassword | rolvalidbegin | rolv
aliduntil |  rolrespool  | rolparentid | roltabspace | rolconfig |  oid  | roluseft | rolkind | nodegroup | roltempspace | rolspillspace
---------+----------+------------+---------------+-------------+--------------+-------------+----------------
+---------------+----------------+--------------+-------------+---------------+-----
----------+--------------+-------------+-------------+-----------+-------+----------+---------+-----------
+--------------+---------------
 Ruby    | t        | t          | t             | t           | t            | t           | t              | t
|           -1 | ********    |               |
         | default_pool |           0 |             |           |    10 | t        | n       |           |              |
 manager | f        | t          | f             | f           | f            | f           | f              | f
|           -1 | ********    |               |
         | default_pool |           0 |             |           | 21649 | f        | n       |           |              |
 kim     | f        | t          | f             | f           | f            | t           | f              | f
|           -1 | ********    |               |
         | default_pool |           0 |             |           | 21661 | f        | n       |           |              |
 u3      | f        | t          | f             | f           | f            | t           | f              | f
|           -1 | ********    |               |
         | default_pool |           0 |             |           | 22662 | f        | n       |           |              |
 u1      | f        | t          | f             | f           | f            | t           | f              | f
|           -1 | ********    |               |
         | default_pool |           0 |             |           | 22666 | f        | n       |           |              |
 u2      | f        | t          | f             | f           | f            | f           | f              | f
|           -1 | ********    |               |
         | default_pool |           0 |             |           | 22802 | f        | n       |           |              |
 dbadmin | f        | t          | f             | f           | f            | t           | f              | f
|           -1 | ********    |               |
         | default_pool |           0 |             |           | 16396 | f        | n       |           |              |
 u5      | f        | t          | f             | f           | f            | t           | f              | f
|           -1 | ********    |               |
         | default_pool |           0 |             |           | 58421 | f        | n       |           |              |
(8 rows)
```

4. To view user properties, query the system catalog **PG_AUTHID**, which stores information about database authorization identifiers (roles). Each cluster, not each database, has only one **PG_AUTHID** system catalog. Only users with system administrator permissions can access the catalog.

```
SELECT * FROM pg_authid;
rolname  | rolsuper | rolinherit | rolcreaterole | rolcreatedb | rolcatupdate | rolcanlogin | rolreplication | rolauditadmin | rolsystemadmin | rolconnlimit
|

rolpassword
                                                 | rolvalidbegin | rolvaliduntil |  rolrespool  | roluseft | rolparentid | roltabspace | rolkind | rolnodegroup | roltempspace | rolspillspace | rolexcpdata | rolauthinfo
----------+----------+------------+---------------+-------------+--------------+-------------+----------------
+---------------+----------------+--------------
+-----------------------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------------------------
-------------------+---------------+---------------+--------------+----------+-------------+-------------+---------
+--------------+--------------+---------------+-------------+-------------
 Ruby     | t        | t          | t             | t           | t            | t           | t              | t
```

```
|          -1 |
sha256366f1e665be208e6015bc3c5795d13e4dc297a148dca6c60346018c80e5c04c9ba170384ce44609b
31baa741f09a3ea5bedc7dadb906286ca994067c3fbf672dc08c981929e326ca08c005d8df942994e146ed
3302af47000b36e9852b50e39dmd585de11aafebd90ec620b201fc36f07a5ecdficefade3a1456ec0aca9a0
ee01e3bf2971d1dbafd604e596149e2e2928be4060dec2bd8688776588b4cd8c64fd38f1b0beab1603129f
a396556ba8aa4c7d6e137a04623 |              |              | default_pool | t        |          0 |            |
n       |            0 |              |              |            |
 sysadmin | f        | t          | f            | f          | f           | t          | f             | f            | t
|          -1 |
sha256ecaa7f0ca4436143af43074f16cdd825783ad1a5d659fd94f5e2fa5124e7da44045ecf40bda1a9797
5fcf5920dca0c8be375be5c71b51cb1eeeba0851fb3648cfa49f55989f83fd9baf1a9d5853ce19125f4fc29a7
c709c095ed02d00638410dmd556d6e2dcc41594dc7ad8ee909ef81637ecdficefadefd7d9704ee06affef958
1cd6a50a546607f88891198e96a5e84e7e83dccf56c5cd20a500bbc5248e8ea51f0bca70c5a8dcf00953f8b
62c7a181368153abce760 |              |              | default_pool | f        |          0 |            | n
|             |             |              |            |
 Tom      | f        | t          | f            | t          | f           | t          | f             | f            | f
|          -1 |
sha256f43c4f52ac51e297bc4dbdbc751fcf05319c15681dbf5a9c5777d2edce45cb592a948b25457a728e9
9a3e0608592f33b0a4312eba6124936522304ba298caa2002a04578860fecb0286d7c7baec09365eafd049
b2b99f74f21a08864dd7d3f2amd515ee49f0b18ef8e7d0cd27d91ce2fa9decdficefade16bab5f05b6d7c86a
19ae6406cc59c437506c3f6187bfdf3eefc7a7c7033afa076361b255cc8b6ccb6e19d4767effaec654b3308cc
72cebb891d00a4a10362da |              |              | default_pool | f        |          0 |            | n
|             |             |              |            |
(3 rows)
```

User Resource Query

1. Querying the resource quota and usage of all users

```
SELECT * FROM PG_TOTAL_USER_RESOURCE_INFO;
```

Example of the resource usage of all users:

```
 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
|               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
userg1    |          34 |        13972 |    23.53 |        48 |          0 |          -1 |               0 |              -1 |
814972419 |               -1 |     6111952 |      1145864 |      763994 |       143233 |       42710 |        8007
(4 rows)
```

2. Querying the resource quota and usage of a specified user

```
SELECT * FROM GS_WLM_USER_RESOURCE_INFO('username');
```

Example of the resource usage of user **Tom**:

```
SELECT * FROM GS_WLM_USER_RESOURCE_INFO('Tom');
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
-------+-------------+--------------+----------+-----------+------------+------------+-----------------
+------------------+------------------+-------------------+-------------+--------------+-------------+--------------
+------------+-------------
 16523 |          18 |         2831 |        0 |        19 |          0 |          -1 |               0 |              -1
|               0 |              -1 |           0 |           0 |          0 |           0 |          0 |           0
(1 row)
```

3. Querying the I/O usage of a specified user

```
SELECT * FROM pg_user_iostat('username');
```

Example of the I/O usage of user **Tom**:

```
SELECT * FROM pg_user_iostat('Tom');
userid | min_curr_iops | max_curr_iops | min_peak_iops | max_peak_iops | io_limits | io_priority
-------+---------------+---------------+---------------+---------------+-----------+-------------
 16523 |             0 |             0 |             0 |             0 |         0 | None
(1 row)
```


5.3 Viewing Table and Database Information

Querying Table Information

- Use the **PG_TABLES** system catalog to query the information about all tables in a database.

```
SELECT * FROM PG_TABLES;
```

- Use the **DBA_TAB_COLUMNS** system view to query the table columns, data types, and comments of all tables in a specified schema.

  Example: Query information about all table columns in a specified schema.

```
SELECT * FROM DBA_TAB_COLUMNS WHERE schema = 'public';
```

- Querying the table structure using **\d+** command of the **gsql** tool.

  Example: Create a table **customer_t1** and insert data into the table.

```
CREATE TABLE customer_t1
(
    c_customer_sk             integer,
    c_customer_id             char(5),
    c_first_name              char(6),
    c_last_name               char(8)
)
with (orientation = column,compression=middle)
distribute by hash (c_last_name);
INSERT INTO customer_t1 (c_customer_sk, c_customer_id, c_first_name) VALUES
    (6885, 'map', 'Peter'),
    (4321, 'river', 'Lily'),
    (9527, 'world', 'James');
```

  Query the table structure. If no schema is specified when you create a table, the schema of the table defaults to **public**.

```
\d+ customer_t1;
                          Table "public.customer_t1"
    Column     |     Type     | Modifiers | Storage  | Stats target | Description
---------------+--------------+-----------+----------+--------------+-------------
 c_customer_sk | integer      |           | plain    |              |
 c_customer_id | character(5) |           | extended |              |
 c_first_name  | character(6) |           | extended |              |
 c_last_name   | character(8) |           | extended |              |
Has OIDs: no
Distribute By: HASH(c_last_name)
Location Nodes: ALL DATANODES
Options: orientation=column, compression=middle, colversion=2.0, enable_delta=false
```

  NOTE

  The options may vary in different versions but the difference does not affect services. The options here are for reference only. The actual options are subject to the version.

- Use **pg_get_tabledef** to query the table definition.

```
SELECT * FROM PG_GET_TABLEDEF('customer_t1');
                                  pg_get_tabledef
-----------------------------------------------------------------------------------
 SET search_path = tpchobs;                                                       +
 CREATE  TABLE customer_t1 (                                                      +
         c_customer_sk integer,                                                   +
         c_customer_id character(5),                                              +
         c_first_name character(6),                                               +
         c_last_name character(8)                                                 +
 )                                                                                +
 WITH (orientation=column, compression=middle, colversion=2.0, enable_delta=false)+
 DISTRIBUTE BY HASH(c_last_name)                                                  +
 TO GROUP group_version1;
(1 row)
```


- Querying all data in **customer_t1**

```
SELECT * FROM customer_t1;
 c_customer_sk | c_customer_id | c_first_name | c_last_name
---------------+---------------+--------------+-------------
          6885 | map           | Peter        |
          4321 | river         | Lily         |
          9527 | world         | James        |
(3 rows)
```

- Querying all data of a column in **customer_t1** using **SELECT**

```
SELECT c_customer_sk FROM customer_t1;
 c_customer_sk
---------------
          6885
          4321
          9527
(3 rows)
```

- Check whether a table has been analyzed. The time when the table was analyzed will be returned. If nothing is returned, it indicates that the table has not been analyzed.

```
SELECT pg_stat_get_last_analyze_time(oid),relname FROM pg_class where relkind='r';
```

  Query the time when the **public** table was analyzed.

```
SELECT pg_stat_get_last_analyze_time(c.oid),c.relname FROM pg_class c LEFT JOIN pg_namespace n
ON c.relnamespace = n.oid WHERE c.relkind='r' AND n.nspname='public';
 pg_stat_get_last_analyze_time |        relname
-------------------------------+----------------------
 2022-05-17 07:48:26.923782+00 | warehouse_t19
 2022-05-17 07:48:26.964512+00 | emp
 2022-05-17 07:48:27.016709+00 | test_trigger_src_tbl
 2022-05-17 07:48:27.045385+00 | customer
 2022-05-17 07:48:27.062486+00 | warehouse_t1
 2022-05-17 07:48:27.114884+00 | customer_t1
 2022-05-17 07:48:27.172256+00 | product_info_input
 2022-05-17 07:48:27.197014+00 | tt1
 2022-05-17 07:48:27.212906+00 | timezone_test
(9 rows)
```

- Quickly query the column information of a table. If a view in **information_schema** has a large number of objects in the database, it takes a long time to return the result. You can run the following SQL statement to quickly query the column information of one or more tables:

```
SELECT /*+ set (enable_hashjoin off) */T.table_schema AS tableschema,
    T.TABLE_NAME AS tablename,
    T.dtd_identifier AS srcAttrId,
    COLUMN_NAME AS fieldName,
    'N' AS isPrimaryKey,
    nvl ( nvl ( T.character_maximum_length, T.numeric_precision ), 0 ) AS fieldLength,
    T.udt_name AS fieldType
from (
 SELECT  /*+ indexscan(co) indexscan(nco) indexscan(a) indexscan(t) leading((nc c a)) leading((co
nco)) indexscan(bt) indexscan(nt) */
    nc.nspname AS table_schema,
    c.relname AS table_name,
    a.attname AS column_name,
    information_schema._pg_char_max_length(information_schema._pg_truetypid(a.*, t.*),
information_schema._pg_truetypmod(a.*, t.*))::information_schema.cardinal_number AS
character_maximum_length,
    information_schema._pg_numeric_precision(information_schema._pg_truetypid(a.*, t.*),
information_schema._pg_truetypmod(a.*, t.*))::information_schema.cardinal_number AS
numeric_precision,
    COALESCE(bt.typname, t.typname)::information_schema.sql_identifier AS udt_name,
    a.attnum AS dtd_identifier
   FROM pg_attribute a
   LEFT JOIN pg_attrdef ad ON a.attrelid = ad.adrelid AND a.attnum = ad.adnum
   JOIN (pg_class c
   JOIN pg_namespace nc ON c.relnamespace = nc.oid) ON a.attrelid = c.oid
   JOIN (pg_type t
```



```
  JOIN pg_namespace nt ON t.typnamespace = nt.oid) ON a.atttypid = t.oid
  LEFT JOIN (pg_type bt
  JOIN pg_namespace nbt ON bt.typnamespace = nbt.oid) ON t.typtype = 'd'::"char" AND
t.typbasetype = bt.oid
  LEFT JOIN (pg_collation co
  JOIN pg_namespace nco ON co.collnamespace = nco.oid) ON a.attcollation = co.oid AND
(nco.nspname <> 'pg_catalog'::name OR co.collname <> 'default'::name)
 WHERE NOT pg_is_other_temp_schema(nc.oid) AND a.attnum > 0 AND NOT a.attisdropped AND
(c.relkind = ANY (ARRAY['r'::"char", 'v'::"char", 'f'::"char"])) AND (pg_has_role(c.relowner,
'USAGE'::text) OR has_column_privilege(c.oid, a.attnum, 'SELECT, INSERT, UPDATE, REFERENCES'::text))

) t
WHERE
    1 = 1
    AND UPPER ( T.TABLE_NAME ) <> 'DIS_USER_DATARIGHT_IF_SPLIT_T'
    AND UPPER ( T.TABLE_NAME ) NOT LIKE'DIS_TMP_%'
    AND UPPER ( T.COLUMN_NAME ) <> '_DISAPP_AUTO_ID_'
    AND (  ( T.TABLE_NAME ),  ( T.table_schema ) ) IN ( ( lower ( 'table_name' )::name, lower
( 'schema_name' )::name ) );
```

Quickly query the column information of the **promotion** table.

```
SELECT /*+ set (enable_hashjoin off) */T.table_schema AS tableschema,
    T.TABLE_NAME AS tablename,
    T.dtd_identifier AS srcAttrId,
    COLUMN_NAME AS fieldName,
    'N' AS isPrimaryKey,
    nvl ( nvl ( T.character_maximum_length, T.numeric_precision ), 0 ) AS fieldLength,
    T.udt_name AS fieldType
from (
 SELECT  /*+ indexscan(co) indexscan(nco) indexscan(a) indexscan(t) leading((nc c a)) leading((co
nco)) indexscan(bt) indexscan(nt) */
    nc.nspname AS table_schema,
    c.relname AS table_name,
    a.attname AS column_name,
    information_schema._pg_char_max_length(information_schema._pg_truetypid(a.*, t.*),
information_schema._pg_truetypmod(a.*, t.*))::information_schema.cardinal_number AS
character_maximum_length,
    information_schema._pg_numeric_precision(information_schema._pg_truetypid(a.*, t.*),
information_schema._pg_truetypmod(a.*, t.*))::information_schema.cardinal_number AS
numeric_precision,
    COALESCE(bt.typname, t.typname)::information_schema.sql_identifier AS udt_name,
    a.attnum AS dtd_identifier
  FROM pg_attribute a
  LEFT JOIN pg_attrdef ad ON a.attrelid = ad.adrelid AND a.attnum = ad.adnum
  JOIN (pg_class c
  JOIN pg_namespace nc ON c.relnamespace = nc.oid) ON a.attrelid = c.oid
  JOIN (pg_type t
  JOIN pg_namespace nt ON t.typnamespace = nt.oid) ON a.atttypid = t.oid
  LEFT JOIN (pg_type bt
  JOIN pg_namespace nbt ON bt.typnamespace = nbt.oid) ON t.typtype = 'd'::"char" AND
t.typbasetype = bt.oid
  LEFT JOIN (pg_collation co
  JOIN pg_namespace nco ON co.collnamespace = nco.oid) ON a.attcollation = co.oid AND
(nco.nspname <> 'pg_catalog'::name OR co.collname <> 'default'::name)
 WHERE NOT pg_is_other_temp_schema(nc.oid) AND a.attnum > 0 AND NOT a.attisdropped AND
(c.relkind = ANY (ARRAY['r'::"char", 'v'::"char", 'f'::"char"])) AND (pg_has_role(c.relowner,
'USAGE'::text) OR has_column_privilege(c.oid, a.attnum, 'SELECT, INSERT, UPDATE, REFERENCES'::text))

) t
WHERE
    1 = 1
    AND UPPER ( T.TABLE_NAME ) <> 'DIS_USER_DATARIGHT_IF_SPLIT_T'
    AND UPPER ( T.TABLE_NAME ) NOT LIKE'DIS_TMP_%'
    AND UPPER ( T.COLUMN_NAME ) <> '_DISAPP_AUTO_ID_'
    AND (  ( T.TABLE_NAME ),  ( T.table_schema ) ) IN ( ( lower ( 'promotion' )::name, lower
( 'public' )::name ) );
```

- Obtain the table definition by querying audit logs.

Use the **pgxc_query_audit** function to query audit logs of all CNs. The syntax is as follows:

```
pgxc_query_audit(timestamptz startime,timestamptz endtime)
```

Query the audit records of multiple objects.

```
SET audit_object_name_format TO 'all';
SELECT object_name,result,operation_type,command_text FROM pgxc_query_audit('2024-05-26 8:00:00','2024-05-26 22:55:00') where command_text like '%student%';
```

Querying the Distribution Key of a Table

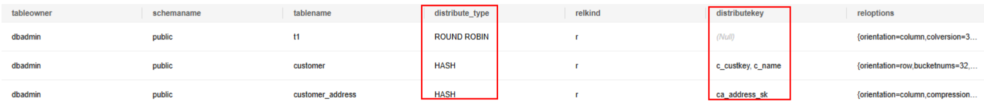
- Use the **PG_GET_TABLEDEF** function to query the distribution key of a table (for example, **customer_t1**). In the command output, **HASH(c_last_name)** indicates that the distribution mode of the table is **HASH** and the distribution key is **c_last_name**.

```
SELECT * FROM PG_GET_TABLEDEF('customer_t1');
                          pg_get_tabledef
-------------------------------------------------------------------------------
 SET search_path = tpchobs;                                          +
 CREATE  TABLE customer_t1 (                                         +
        c_customer_sk integer,                                       +
        c_customer_id character(5),                                  +
        c_first_name character(6),                                   +
        c_last_name character(8)                                     +
 )                                                                   +
 WITH (orientation=column, compression=middle, colversion=2.0, enable_delta=false)+
 DISTRIBUTE BY HASH(c_last_name)                                     +
 TO GROUP group_version1;
(1 row)
```

- Use the following SQL statement to query the distribution mode and distribution key of multiple tables in batches. Replace **dbadmin** at the end of the statement with the actual table owner. The following example shows how to query the distribution mode and distribution key of all tables created by **dbadmin**.

  distribute_type indicates the distribution mode, for example, **HASH**. **distributekey** indicates the distribution key, for example, **ca_address_sk**.

```
SELECT pg_catalog.pg_get_userbyid(pc.relowner) AS tableowner,
 pn.nspname AS schemaname,
 pc.relname AS tablename,
 CASE pxc.pclocatortype WHEN 'N' THEN
 'ROUND ROBIN' WHEN 'R' THEN
 'REPLICATION' WHEN 'H' THEN
 'HASH' WHEN 'M' THEN
 'MODULO' END AS distribute_type,
 pc.relkind,
 getdistributekey(pxc.pcrelid) AS distributekey,
 pc.reloptions
 FROM pgxc_class pxc, pg_class pc,pg_namespace pn
 WHERE pxc.pcrelid = pc.oid AND pn.oid=pc.relnamespace AND tableowner='dbadmin';
```



tableowner	schemaname	tablename	distribute_type	relkind	distributekey	reloptions
dbadmin	public	t1	ROUND ROBIN	r	(Null)	{orientation=column,colversion=3...
dbadmin	public	customer	HASH	r	c_custkey, c_name	{orientation=row,bucketnums=32,...
dbadmin	public	customer_address	HASH	r	ca_address_sk	{orientation=column,compression...

Querying the Table Size

- Querying the total size of a table (indexes and data included)

```
SELECT pg_size_pretty(pg_total_relation_size('<schemaname>.<tablename>'));
```

  Example:

  First, create an index on **customer_t1**.

```
CREATE INDEX index1 ON customer_t1 USING btree(c_customer_sk);
```

Then, query the size of table **customer_t1** of **public**.

```
SELECT pg_size_pretty(pg_total_relation_size('public.customer_t1'));
 pg_size_pretty
----------------
 264 kB
(1 row)
```

- Querying the size of a table (indexes excluded)

```
SELECT pg_size_pretty(pg_relation_size('<schemaname>.<tablename>'));
```

Example: Query the size of table **customer_t1** of **public**.

```
SELECT pg_size_pretty(pg_relation_size('public.customer_t1'));
 pg_size_pretty
----------------
 208 kB
(1 row)
```

- Query all the tables, ranked by their occupied space.

```
SELECT table_schema || '.' || table_name AS table_full_name, pg_size_pretty(pg_total_relation_size('"' ||
table_schema || '"."' || table_name || '"')) AS size FROM information_schema.tables
ORDER BY
pg_total_relation_size('"' || table_schema || '"."' || table_name || '"') DESC limit xx;
```

Example 1: Query the 15 tables that occupy the most space.

```
SELECT table_schema || '.' || table_name AS table_full_name, pg_size_pretty(pg_total_relation_size('"' ||
table_schema || '"."' || table_name || '"')) AS size FROM information_schema.tables
ORDER BY
pg_total_relation_size('"' || table_schema || '"."' || table_name || '"') DESC limit 15;
      table_full_name      |  size
---------------------------+---------
 pg_catalog.pg_attribute   | 2048 KB
 pg_catalog.pg_rewrite     | 1888 KB
 pg_catalog.pg_depend      | 1464 KB
 pg_catalog.pg_proc        | 1464 KB
 pg_catalog.pg_class       | 512 KB
 pg_catalog.pg_description | 504 KB
 pg_catalog.pg_collation   | 360 KB
 pg_catalog.pg_statistic   | 352 KB
 pg_catalog.pg_type        | 344 KB
 pg_catalog.pg_operator    | 224 KB
 pg_catalog.pg_amop        | 208 KB
 public.tt1                | 160 KB
 pg_catalog.pg_amproc      | 120 KB
 pg_catalog.pg_index       | 120 KB
 pg_catalog.pg_constraint  | 112 KB
(15 rows)
```

Example 2: Query the top 20 tables with the largest space usage in the **public** schema.

```
SELECT table_schema || '.' || table_name AS table_full_name, pg_size_pretty(pg_total_relation_size('"' ||
table_schema || '"."' || table_name || '"')) AS size FROM information_schema.tables where
table_schema='public'
ORDER BY
pg_total_relation_size('"' || table_schema || '"."' || table_name || '"') DESC limit 20;
       table_full_name       |  size
-----------------------------+---------
 public.tt1                  | 160 KB
 public.product_info_input   | 112 KB
 public.customer_t1          | 96 KB
 public.warehouse_t19        | 48 KB
 public.emp                  | 32 KB
 public.customer             | 0 bytes
 public.test_trigger_src_tbl | 0 bytes
 public.warehouse_t1         | 0 bytes
(8 rows)
```

Quickly Querying the Space Occupied by All Tables in the Database

In a large cluster (8.1.3 or later) with a large amount of data (more than 1000 tables), you are advised to use the **pgxc_wlm_table_distribution_skewness** view to query all tables in the database. This view can be used to query the tablespace usage and data skew in the database. The unit of **total_size** and **avg_size** is byte.

```
SELECT *, pg_size_pretty(total_size) as tableSize FROM pgxc_wlm_table_distribution_skewness ORDER BY total_size desc;
   schema_name     |                    table_name                    | total_size | avg_size  | max_percent | min_percent | skew_percent | tablesize
--------------------+-------------------------------------------------+------------+-----------+-------------+-------------+--------------+-----------
 public            | history_tbs_test_row_1                          |  804347904 | 134057984 |       18.02 |       15.63 |         7.53 | 767 MB
 public            | history_tbs_test_row_3                          |  402096128 |  67016021 |       18.30 |       15.60 |         8.90 | 383 MB
 public            | history_tbs_test_row_2                          |  401743872 |  66957312 |       18.01 |       15.01 |         7.47 | 383 MB
 public            | i_history_tbs_test_1                            |  325263360 |  54210560 |       17.90 |       15.50 |         6.90 | 310 MB
```

The query result shows that the **history_tbs_test_row_1** table occupies the largest space and data skew occurs.

CAUTION

1. The **pgxc_wlm_table_distribution_skewness** view can be queried only when the GUC parameter **use_workload_manager and enable_perm_space** is enabled. In earlier versions, you are advised to use the **table_distribution()** function to query the entire database. If only the size of a table is queried, the **table_distribution(schemaname text, tablename text)** function is recommended.
2. In 8.2.1 and later cluster versions, DWS supports the **pgxc_wlm_table_distribution_skewness** view, which can be directly used for query.
3. In the 8.1.3 cluster version, you can use the following definition to create a view and then perform query:

```
CREATE OR REPLACE VIEW
pgxc_wlm_table_distribution_skewness AS
WITH skew AS
(
SELECT
schemaname,
tablename,
pg_catalog.sum(dnsize)
AS totalsize,
pg_catalog.avg(dnsize)
AS avgsize,
pg_catalog.max(dnsize)
AS maxsize,
pg_catalog.min(dnsize)
AS minsize,
(maxsize
- avgsize) * 100 AS skewsize
FROM
pg_catalog.gs_table_distribution()
GROUP
BY schemaname, tablename
)
SELECT
    schemaname AS schema_name,
    tablename AS table_name,
    totalsize AS total_size,
    avgsize::numeric(1000) AS avg_size,
    (
        CASE
            WHEN totalsize = 0 THEN 0.00
            ELSE (maxsize * 100 /
totalsize)::numeric(5, 2)
        END
    ) AS max_percent,
    (
        CASE
            WHEN totalsize = 0 THEN 0.00
            ELSE (minsize * 100 /
totalsize)::numeric(5, 2)
        END
    ) AS min_percent,
    (
        CASE
            WHEN totalsize = 0 THEN 0.00
            ELSE (skewsize /
maxsize)::numeric(5, 2)
        END
    ) AS skew_percent
FROM skew;
```

Querying Database Information

- Querying the database list using the **\l** meta-command of the **gsql** tool.

```
\l
                          List of databases
   Name    | Owner | Encoding  | Collate | Ctype | Access privileges
-----------+-------+-----------+---------+-------+-------------------
 gaussdb   | Ruby  | SQL_ASCII | C       | C     |
 template0 | Ruby  | SQL_ASCII | C       | C     | =c/Ruby          +
           |       |           |         |       | Ruby=CTc/Ruby
 template1 | Ruby  | SQL_ASCII | C       | C     | =c/Ruby          +
           |       |           |         |       | Ruby=CTc/Ruby
(3 rows)
```

NOTE

- If the parameters **LC_COLLATE** and **LC_CTYPE** are not specified during database installation, the default values of them are **C**.
- If **LC_COLLATE** and **LC_CTYPE** are not specified during database creation, the sorting order and character classification of the template database are used by default.

  For details, see **CREATE DATABASE**.

- Querying the database list using the **pg_database** system catalog

```
SELECT datname FROM pg_database;
  datname
-----------
 template1
 template0
 gaussdb
(3 rows)
```

Querying the Database Size

Querying the size of databases

```
select datname,pg_size_pretty(pg_database_size(datname)) from pg_database;
```

Example:

```
select datname,pg_size_pretty(pg_database_size(datname)) from pg_database;
  datname  | pg_size_pretty
-----------+----------------
 template1 | 61 MB
 template0 | 61 MB
 postgres  | 320 MB
(3 rows)
```

Querying the Size of a Table and the Size of the Corresponding Index in a Specified Schema

```
SELECT
    t.tablename,
    indexname,
    c.reltuples AS num_rows,
    pg_size_pretty(pg_relation_size(quote_ident(t.tablename)::text)) AS table_size,
    pg_size_pretty(pg_relation_size(quote_ident(indexrelname)::text)) AS index_size,
    CASE WHEN indisunique THEN 'Y'
       ELSE 'N'
    END AS UNIQUE,
    idx_scan AS number_of_scans,
    idx_tup_read AS tuples_read,
    idx_tup_fetch AS tuples_fetched
FROM pg_tables t
LEFT OUTER JOIN pg_class c ON t.tablename=c.relname
LEFT OUTER JOIN
    ( SELECT c.relname AS ctablename, ipg.relname AS indexname, x.indnatts AS number_of_columns,
```

```
idx_scan, idx_tup_read, idx_tup_fetch, indexrelname, indisunique FROM pg_index x
          JOIN pg_class c ON c.oid = x.indrelid
          JOIN pg_class ipg ON ipg.oid = x.indexrelid
          JOIN pg_stat_all_indexes psai ON x.indexrelid = psai.indexrelid )
    AS foo
    ON t.tablename = foo.ctablename
WHERE t.schemaname='public'
ORDER BY 1,2;
```

5.4 Best Practices of Database SEQUENCE

A sequence is a database object that generates unique integers. A sequence's value automatically adjusts according to certain rules. Typically, sequences serve as primary keys. In DWS, when a sequence is created, a metadata table with the same name is created to record sequence information. For example:

```
CREATE SEQUENCE seq_test;
CREATE SEQUENCE

SELECT * FROM seq_test;
 sequence_name | last_value | start_value | increment_by |      max_value      | min_value | cache_value |
log_cnt | is_cycled | is_called |  uuid
---------------+------------+-------------+--------------+---------------------+-----------+-------------+---------
+-----------+-----------+---------
 seq_test      |         -1 |           1 |            1 | 9223372036854775807 |         1 |           1 |       0 | f         |
f         | 1400050
(1 row)
```

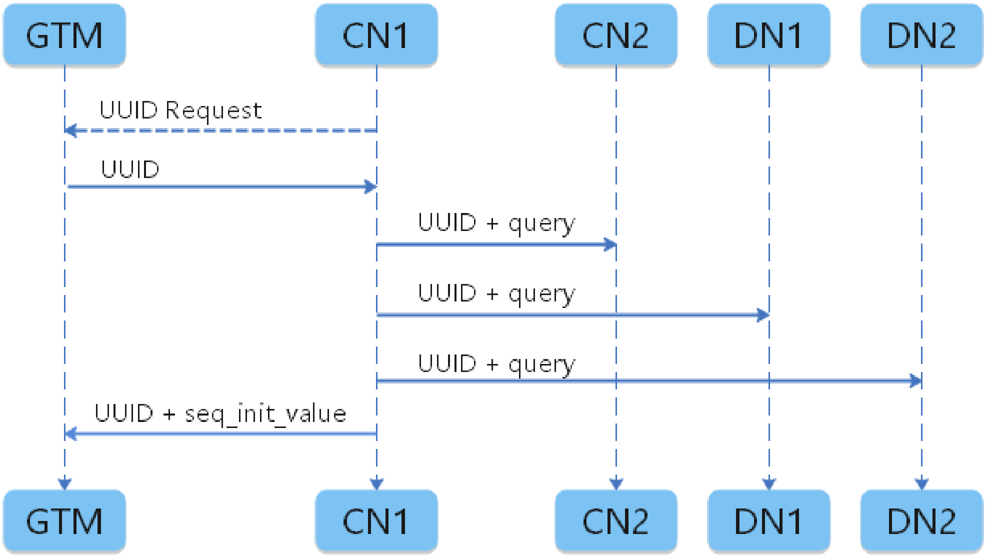
In the preceding information:

- **sequence_name** indicates the name of the sequence.
- **last_value** is meaningless.
- **start_value** indicates the initial value of the sequence.
- **increment_by** indicates the step of the sequence.
- **max_value** indicates the maximum value of the sequence.
- **min_value** indicates the minimum sequence value.
- **cache_value** determines how many sequence values are preloaded for rapid access to subsequent values. (After this cache is set, the continuity of sequence values cannot be ensured, and unacknowledged sequences may be generated, causing waste of sequences.)
- **log_cnt** indicates the number of sequence values recorded in WAL logs. In DWS, sequences are obtained and managed from GTM. Therefore, **log_cnt** is meaningless.
- **is_cycled** indicates whether to continue the loop after the sequence reaches the minimum or maximum value.
- **is_called** indicates whether the sequence has been called. (It only indicates whether the sequence has been called on the current instance. For example, after the sequence is called on cn1, the value of the field on cn1 changes to **t**, and the value of the field on cn2 is still **f**.)
- **uuid** indicates the unique ID of the sequence.

Creating a Sequence

In DWS, the Global Transaction Manager (GTM) generates and maintains the global unique information about a transaction, such as the global transaction ID, transaction snapshot, and sequence. The following figure shows the process of creating a sequence in DWS.

Figure 5-1 Creating a sequence



The specific process is as follows:

1. The CN that receives the SQL command applies for a UUID from the GTM.
2. The GTM returns a UUID.
3. The CN binds the obtained UUID to the sequenceName created by the user.
4. The CN delivers the binding relationship to other nodes, and other nodes create the sequence metadata table synchronously.
5. The CN sends the UUID and startID of the sequence to the GTM for permanent storage.

Therefore, sequence maintenance and request are actually completed on the GTM. **When requesting nextval, each instance obtains a sequence value from the GTM using the sequence's UUID. The number of values requested correlates with the cache size. An instance will only request a new sequence value from the GTM once its cache is depleted. Thus, enlarging the sequence's cache minimizes the communication frequency between the CN/DN and the GTM.**

Two Methods of Creating a Sequence

Method 1: Run the **CREATE SEQUENCE** statement to create a sequence and use nextval to invoke the sequence in the new table.

```
CREATE SEQUENCE seq_test increment by 1 minvalue 1 no maxvalue start with 1;
CREATE SEQUENCE

CREATE TABLE table_1(id int not null default nextval('seq_test'), name text);
CREATE TABLE
```

Method 2: If the serial type is used during table creation, a sequence is automatically created and the default value of the column is set to **nextval**.

```
CREATE TABLE mytable(a int, b serial) distribute by hash(a);
NOTICE:  CREATE TABLE will create implicit sequence "mytable_b_seq" for serial column "mytable.b"
```

```
CREATE TABLE

 \d+ mytable
                                        Table "dbadmin.mytable"
 Column |  Type   |                        Modifiers                        | Storage | Stats target | Description
--------+---------+---------------------------------------------------------+---------+--------------+-------------
 a      | integer |                                                         | plain   |              |
 b      | integer | not null default nextval('mytable_b_seq'::regclass) | plain   |              |
Has OIDs: no
Distribute By: HASH(a)
Location Nodes: ALL DATANODES
Options: orientation=row, compression=no
```

In this example, a sequence named **mytable_b_seq** is automatically created. Technically speaking, the serial type is not an actual data type but rather a method for assigning a unique identifier to a table column. Creating a serial involves generating a linked sequence for that specific column.

It is equivalent to the following statements:

```
CREATE TABLE mytable01(a int, b int) distribute by hash(a);
CREATE TABLE

CREATE SEQUENCE mytable01_b_seq owned by mytable.b;
CREATE SEQUENCE

ALTER SEQUENCE mytable01_b_seq owner to u1; --u1 is the owner of the mytable01 table. The owner does not need to run this statement.
ALTER SEQUENCE

ALTER TABLE mytable01 alter b set default nextval('mytable01_b_seq'), alter b set not null;
ALTER TABLE

\d+ mytable01
                                        Table "dbadmin.mytable01"
 Column |  Type   |                        Modifiers                          | Storage | Stats target | Description
--------+---------+-----------------------------------------------------------+---------+--------------+-------------
 a      | integer |                                                           | plain   |              |
 b      | integer | not null default nextval('mytable01_b_seq'::regclass) | plain   |              |
Has OIDs: no
Distribute By: HASH(a)
Location Nodes: ALL DATANODES
Options: orientation=row, compression=no
```

Common Usage of Sequences in Services

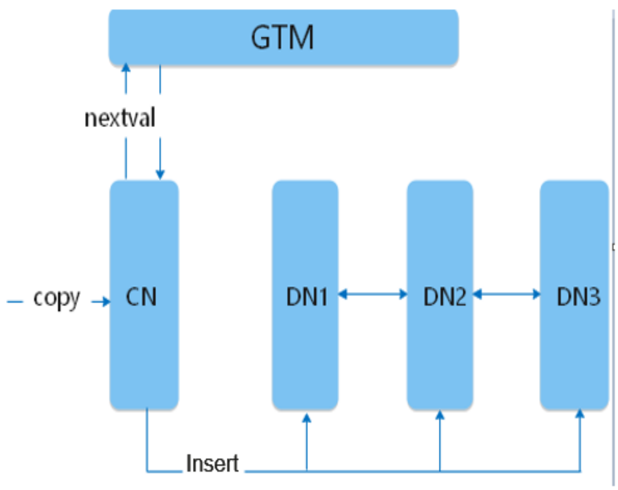
Sequences are commonly used to generate primary keys or unique columns during data import, a frequent practice in data migration scenarios. Different migration tools or service import scenarios use different import methods. Common import methods are classified into **copy** and **insert**. For sequences, the processing in the two scenarios is slightly different.

- **Scenario 1: Insert pushdown**

```
CREATE TABLE test1(a int, b serial) distribute by hash(a);
NOTICE:  CREATE TABLE will create implicit sequence "test1_b_seq" for serial column "test1.b"
CREATE TABLE

CREATE TABLE test2(a int) distribute by hash(a);
CREATE TABLE

EXPLAIN VERBOSE INSERT INTO test1(a) SELECT a FROM test2;
                                   QUERY PLAN
---------------------------------------------------------------------------------------------------
  id |              operation              | E-rows | E-distinct | E-memory | E-width | E-costs
 ----+-------------------------------------+--------+------------+----------+---------+---------
   1 | ->  Streaming (type: GATHER)        |      1 |            |          |       4 | 16.34
```

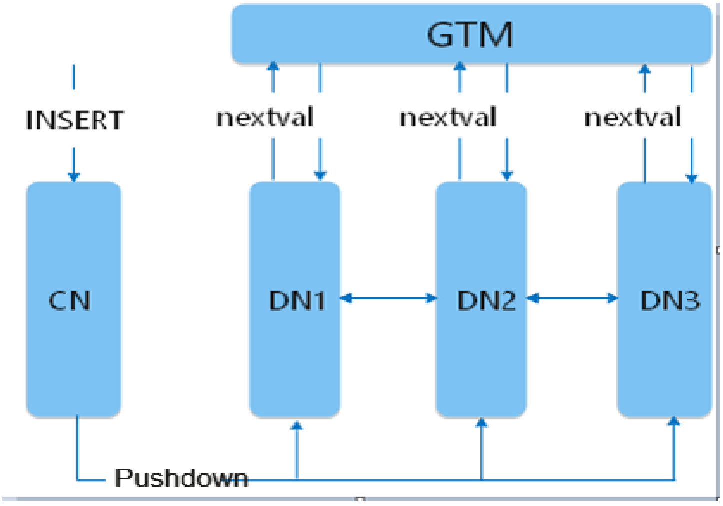
```
  2 |    ->  Insert on dbadmin.test1      |     30 |            |          |       4 | 16.22
  3 |       ->  Seq Scan on dbadmin.test2 |     30 |            | 1MB      |       4 | 14.21

          RunTime Analyze Information
-----------------------------------------------------
       "dbadmin.test2" runtime: 9.586ms, sync stats

    Targetlist Information (identified by plan id)
----------------------------------------------------------
  1 --Streaming (type: GATHER)
       Node/s: All datanodes
  3 --Seq Scan on dbadmin.test2
       Output: test2.a, nextval('test1_b_seq'::regclass)
       Distribute Key: test2.a

  ====== Query Summary =====
--------------------------------
System available mem: 1351680KB
Query Max mem: 1351680KB
Query estimated mem: 1024KB
Parser runtime: 0.076 ms
Planner runtime: 12.666 ms
Unique SQL Id: 831364267
(26 rows)
```

During an INSERT operation, nextval is executed on the DNs. This occurs whether nextval is called with its default value or invoked explicitly. The execution plan confirms that nextval operates at the sequence layer on the DNs. In this scenario, DNs obtain sequence values directly from the GTM and execute the request simultaneously, resulting in a relatively high level of efficiency.



- **Scenario 2: Copy scenario**

  In service development, alongside the INSERT method, the COPY method is also for data import into the database. It allows for the direct copying of file contents or using the CopyManager interface for this purpose. Moreover, the CDM data synchronization tool facilitates batch data import by copying. If the target table to be copied uses the default value **nextval**, the process is as follows.

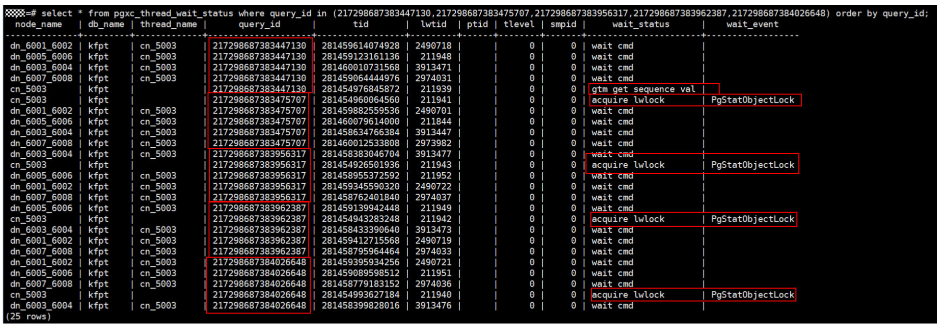


In the copy process, the CN requests sequence values from the GTM. If the sequence's cache size is too small, the CN must repeatedly connect with the GTM to request nextval, which can lead to a performance bottleneck. **Typical Optimization Scenarios Related to Sequences** describes the service performance in this scenario and provides optimization methods.

Typical Optimization Scenarios Related to Sequences

Service scenarios:

In a service scenario, the CDM data synchronization tool is used to transfer data and import data from the source database to the target database DWS. Despite changing the CDM concurrency from 1 to 5, the synchronization rate remains unchanged, and there is a significant difference between the import rate and the expected value. Apart from data copying, all other services run smoothly without any performance or resource issues. Thus, it is likely that a bottleneck exists within the service. You are advised to review the job queue specifically for the COPY operation.



```
=# select * from pgxc_thread_wait_status where query_id in (217298687383447130,217298687383475707,217298687383956317,217298687383962387,217298687384026648) order by query_id;
  node_name   | db_name | thread_name |      query_id      |       tid       |  lwtid  | ptid | tlevel | smpid |     wait_status      |    wait_event
--------------+---------+-------------+--------------------+-----------------+---------+------+--------+-------+----------------------+------------------
 dn_6001_6002 | kfpt    | cn_5003     | 217298687383447130 | 281459614074928 | 2490718 |      |      0 |     0 | wait cmd             |
 dn_6005_6006 | kfpt    | cn_5003     | 217298687383447130 | 281459123161136 |  211948 |      |      0 |     0 | wait cmd             |
 dn_6003_6004 | kfpt    | cn_5003     | 217298687383447130 | 281460010731568 | 3913471 |      |      0 |     0 | wait cmd             |
 dn_6007_6008 | kfpt    | cn_5003     | 217298687383447130 | 281459064444976 | 2974031 |      |      0 |     0 | wait cmd             |
 cn_5003      | kfpt    |             | 217298687383447130 | 281454976845872 |  211939 |      |      0 |     0 | gtm get sequence val |
 cn_5003      | kfpt    |             | 217298687383475707 | 281454960064560 |  211941 |      |      0 |     0 | acquire lwlock       | PgStatObjectLock
 dn_6001_6002 | kfpt    | cn_5003     | 217298687383475707 | 281459882559536 | 2490701 |      |      0 |     0 | wait cmd             |
 dn_6005_6006 | kfpt    | cn_5003     | 217298687383475707 | 281460079614000 |  211844 |      |      0 |     0 | wait cmd             |
 dn_6003_6004 | kfpt    | cn_5003     | 217298687383475707 | 281458634766384 | 3913447 |      |      0 |     0 | wait cmd             |
 dn_6007_6008 | kfpt    | cn_5003     | 217298687383475707 | 281460012533808 | 2973982 |      |      0 |     0 | wait cmd             |
 dn_6003_6004 | kfpt    | cn_5003     | 217298687383956317 | 281458383046704 | 3913477 |      |      0 |     0 | wait cmd             |
 cn_5003      | kfpt    |             | 217298687383956317 | 281454926501936 |  211943 |      |      0 |     0 | acquire lwlock       | PgStatObjectLock
 dn_6005_6006 | kfpt    | cn_5003     | 217298687383956317 | 281458955372592 |  211952 |      |      0 |     0 | wait cmd             |
 dn_6001_6002 | kfpt    | cn_5003     | 217298687383956317 | 281459345590320 | 2490722 |      |      0 |     0 | wait cmd             |
 dn_6007_6008 | kfpt    | cn_5003     | 217298687383956317 | 281458762401840 | 2974037 |      |      0 |     0 | wait cmd             |
 dn_6005_6006 | kfpt    | cn_5003     | 217298687383962387 | 281459139942448 |  211949 |      |      0 |     0 | wait cmd             |
 cn_5003      | kfpt    |             | 217298687383962387 | 281454943283248 |  211942 |      |      0 |     0 | acquire lwlock       | PgStatObjectLock
 dn_6003_6004 | kfpt    | cn_5003     | 217298687383962387 | 281458433390640 | 3913473 |      |      0 |     0 | wait cmd             |
 dn_6001_6002 | kfpt    | cn_5003     | 217298687383962387 | 281459412715568 | 2490719 |      |      0 |     0 | wait cmd             |
 dn_6007_6008 | kfpt    | cn_5003     | 217298687383962387 | 281458795964464 | 2974033 |      |      0 |     0 | wait cmd             |
 dn_6001_6002 | kfpt    | cn_5003     | 217298687384026648 | 281459395934256 | 2490721 |      |      0 |     0 | wait cmd             |
 dn_6005_6006 | kfpt    | cn_5003     | 217298687384026648 | 281459089598512 |  211951 |      |      0 |     0 | wait cmd             |
 dn_6007_6008 | kfpt    | cn_5003     | 217298687384026648 | 281458779183152 | 2974036 |      |      0 |     0 | wait cmd             |
 cn_5003      | kfpt    |             | 217298687384026648 | 281454993627184 |  211940 |      |      0 |     0 | acquire lwlock       | PgStatObjectLock
 dn_6003_6004 | kfpt    | cn_5003     | 217298687384026648 | 281458399828016 | 3913476 |      |      0 |     0 | wait cmd             |
(25 rows)
```

As shown in the preceding figure, five CDM jobs are executed concurrently. You can see five COPY statements in the active view. Check the waiting view based on **query_id** corresponding to the five COPY statements. Out of the five COPY operations, only one requests a sequence value from the GTM concurrently, while the rests wait for a lightweight lock. As a result, enabling five concurrent jobs does not substantially enhance performance compared to just running a single job.

Causes:

The serial type is used when the target table is created. By default, the cache of the created sequence is 1. As a result, when data is concurrently copied to the database, the CN frequently establishes connections with the GTM, and lightweight lock contention exists between multiple concurrent jobs, resulting in low data synchronization efficiency.

Solutions:

In this scenario, increase the cache value of the sequence to prevent bottlenecks caused by frequent GTM connection establishment. In this service scenario example, about 100,000 data records are synchronized each time. Based on service evaluation, change the cache value to 10,000. (In practice, set a proper cache value based on services to ensure quick access and avoid sequence number waste.)

In cluster versions 8.2.1.100 and later, you can use **ALTER SEQUENCE** to change the cache value.

DWS clusters of version 8.2.1 or earlier do not allow for the modification of cache values through **ALTER SEQUENCE**. To change the cache value of an existing sequence, follow these steps (the **mytable** table is used as an example):

Step 1 Remove the association between the current sequence and the target table.

```
ALTER SEQUENCE mytable_b_seq owned by none;
ALTER TABLE mytable alter b drop default;
```

Step 2 Record the current sequence value as the start value of the new sequence.

```
SELECT nextval('mytable_b_seq');
```

Delete the sequence.

```
DROP SEQUENCE mytable_b_seq;
```

Step 3 Create a sequence and bind it to the target table. Replace **xxx** with the value of nextval obtained in the previous step.

```
CREATE SEQUENCE mytable_b_seq START with xxx cache 10000 owned by mytable.b;
ALTER SEQUENCE mytable_b_seq owner to u1;--u1 is the owner of the mytable table. The owner does not need to run this statement.
ALTER TABLE mytable alter b set default nextval('mytable_b_seq');
```

----End

6 Performance Tuning

6.1 Optimizing Table Structure Design to Enhance DWS Query Performance

6.1.1 Before Optimization: Learning Table Structure Design

In this practice, you will learn how to optimize the design of your tables. You will start by creating tables without specifying their storage mode, distribution key, distribution mode, or compression mode. Load test data into these tables and test system performance. Then, follow excellent practices to create the tables again using new storage modes, distribution keys, distribution modes, and compression modes. Load the test data and test performance again. Compare the two test results to find out how table design affects the storage space, and the loading and query performance of the tables.

Before you optimize a table, you need to understand the structure of the table. 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.

This section describes how to optimize table performance in DWS by properly designing the table structure (for example, by selecting the table model, table storage mode, compression level, distribution mode, distribution column, partitioned tables, and local clustering).

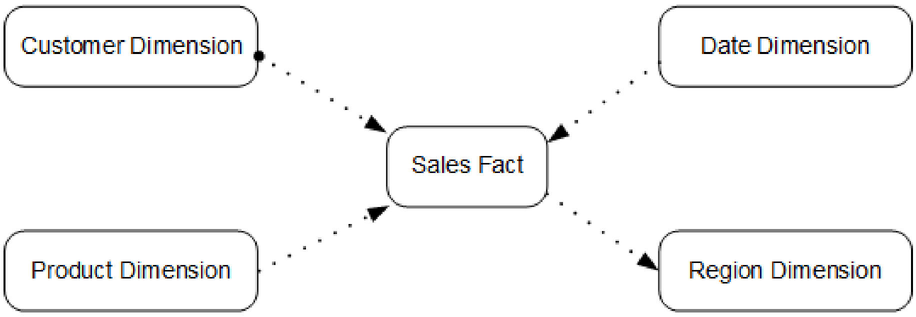
Selecting a Table Model

The most common types of data warehouse table models are star and snowflake models. Consider service and performance requirements when you choose a model for your tables.

- In the **star model**, a central fact table contains the core data for the database and several dimension tables provide descriptive attribute information for the fact table. The primary key of a dimension table associates a foreign key in a fact table, as shown in **Figure 6-1**.

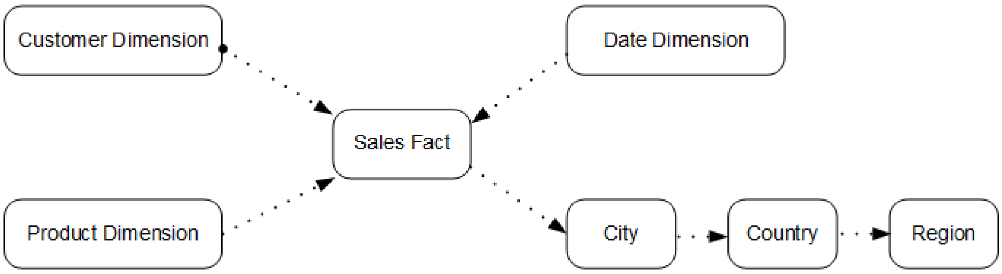
- All facts must have the same granularity.
- Different dimensions are not associated.

Figure 6-1 Star model



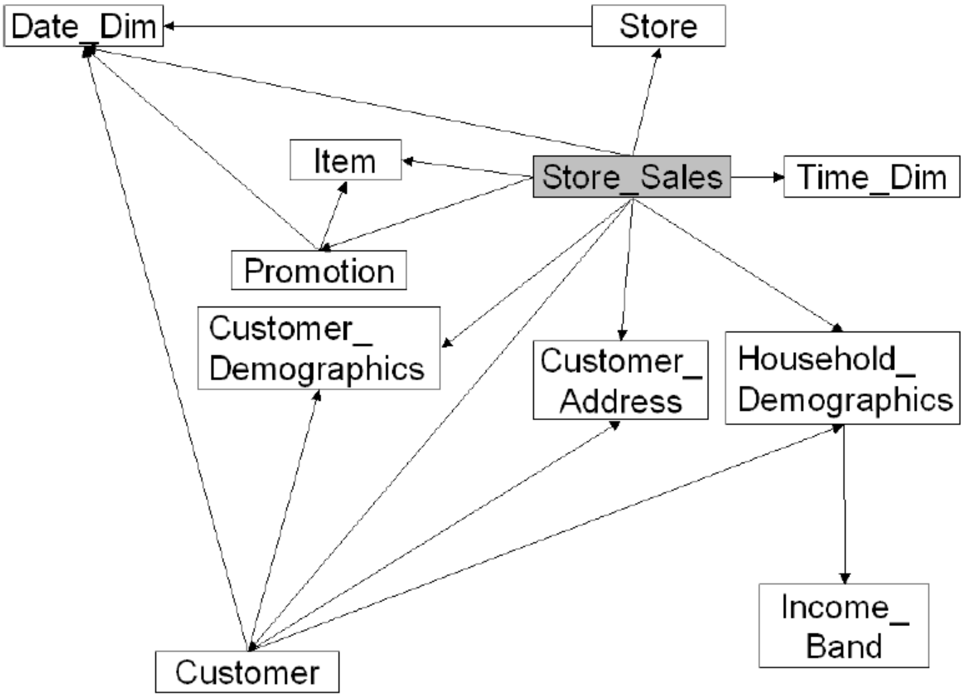
- The **snowflake model** is developed based on the star model. In this model, each dimension can be associated with multiple dimensions and split into tables of different granularities based on the dimension level, as shown in **Figure 6-2**.
  - Dimension tables can be associated as needed, and the data stored in them is reduced.
  - This model has more dimension tables to maintain than the star schema does.

Figure 6-2 Snowflake model



This practice verifies performance using the Store Sales (SS) model of TPC-DS. The model uses the snowflake model. **Figure 6-3** illustrates its structure.

Figure 6-3 TPC-DS store sales ER-Diagram



For details about the **store_sales** fact table and dimension tables in the model, see the official document of TPC-DS at **http://www.tpc.org/tpc_documents_current_versions/current_specifications5.asp**.

Selecting a Storage Mode

Selecting a model for table storage is the first step of table definition. Select a proper storage model for your service based on the table below.

Generally, if a table contains many columns (called a wide table) and its query involves only a few columns, column storage is recommended. If a table contains only a few columns and a query involves most of the columns, row storage is recommended.

Storage Model	Application Scenario
Row storage	Point query (simple index–based query that returns only a few records). Query involving many **INSERT**, **UPDATE**, and **DELETE** operations.
Column storage	Statistical analysis queries. Queries with many groups and joins.

The row/column storage of a table is specified by the **orientation** attribute in the table definition. The value **row** indicates a row-store table and **column** indicates a column-store table. The default value is **row**.

Table Compression

Table compression can be enabled when a table is created. Table compression enables data in the table to be stored in compressed format to reduce memory usage.

In scenarios where I/O is large (much data is read and written) and CPU is sufficient (little data is computed), select a high compression ratio. In scenarios where I/O is small and CPU is insufficient, select a low compression ratio. Based on this principle, you are advised to select different compression ratios and test and compare the results to select the optimal compression ratio as required. Specify a compressions ratio using the **COMPRESSION** parameter. The supported values are as follows:

- The valid value of column-store tables is **YES**, **NO**, **LOW**, **MIDDLE**, or **HIGH**, and the default value is **LOW**.
- The valid values of row-store tables are **YES** and **NO**, and the default is **NO**. (The row-store table compression function is not put into commercial use. To use this function, contact technical support.)

The service scenarios applicable to each compression level are described in the following table.

Compression Level	Application Scenario
LOW	The system CPU usage is high and the disk storage space is sufficient.
MIDDLE	The system CPU usage is moderate and the disk storage space is insufficient.
HIGH	The system CPU usage is low and the disk storage space is insufficient.

Selecting a Distribution Mode

DWS supports the following distribution modes: replication, hash, and Round-robin.

NOTE

Round-robin is supported in cluster 8.1.2 and later.

Policy	Description	Application Scenario	Advantages/ disadvantages
Replication	Full data in a table is stored on each DN in the cluster.	Small tables and dimension tables	• The advantage of replication is that each DN has full data of the table. During the join operation, data does not need to be redistributed, reducing network overheads and reducing plan segments (each plan segment starts a corresponding thread). • The disadvantage of replication is that each DN retains the complete data of the table, resulting in data redundancy. Generally, replication is only used for small dimension tables.
Hash	Table data is distributed on all DNs in the cluster.	Fact tables containing a large amount of data	• The I/O resources of each node can be used during data read/write, greatly improving the read/write speed of a table. • Generally, a large table (containing over 1 million records) is defined as a hash table.

Policy	Description	Application Scenario	Advantages/ disadvantages
Polling (Round-robin)	Each row in the table is sent to each DN in turn. Data can be evenly distributed on each DN.	Fact tables that contain a large amount of data and cannot find a proper distribution key in hash mode	• Round-robin can avoid data skew, improving the space utilization of the cluster. • Round-robin does not support local DN optimization like a hash table does, and the query performance of Round-robin is usually lower than that of a hash table. • If a proper distribution key can be found for a large table, use the hash distribution mode with better performance. Otherwise, define the table as a round-robin table.

Selecting a Distribution Key

If the hash distribution mode is used, a distribution key must be specified for the user table. If a record is inserted, the system performs hash computing based on values in the distribute column and then stores data on the related DN.

Select a hash distribution key based on the following principles:

1. **The values of the distribution key should be discrete so that data can be evenly distributed on each DN.** You can select the primary key of the table as the distribution key. For example, for a person information table, choose the ID number column as the distribution key.
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 key.
3. **With the above principles met, you can select join conditions as distribution keys**, so that join tasks can be pushed down to DNs for execution, 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 for data skew:

   ```
   SELECT
   xc_node_id, count(1)
   FROM tablename
   ```

```
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 key.**

4. You are not advised to add a column as a distribution key, especially add a new column and use the SEQUENCE value to fill the column. (Sequences may cause performance bottlenecks and unnecessary maintenance costs.)

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.

The partitioned tables supported by DWS include range partitioned tables and list partitioned tables. (List partitioned tables are supported only in cluster 8.1.3).

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.

Selecting a Data type

You can use data types with the following features to improve efficiency:

1. **Data types that boost execution efficiency**

   Generally, the 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 perform a point query on a column-store table whose **NUMERIC** column is used as a filter criterion, the query will take over 10 seconds. If you change the data type from **NUMERIC** to **INT**, the query takes only about 1.8 seconds.

2. **Selecting data types with a short length**

   Data types with short length reduce 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. **Same data type for a join**

   You are advised to use the same data type for a join. To join columns with different data types, the database needs to convert them to the same type, which leads to additional performance overheads.

Using Indexes

- The purpose of creating indexes is to accelerate queries. Therefore, ensure that indexes can be used in some queries. If an index is not used by any query statement, the index is meaningless. Delete such an index.
- Do not create unnecessary secondary indexes. Useful secondary indexes can accelerate query. However, the space occupied by indexes increases with the number of indexes. Each time an index is added, an additional key-value pair needs to be added when a piece of data is inserted. Therefore, the more indexes, the slower the write speed, and the larger the space usage. In addition, too many indexes affect the optimizer running time, and inappropriate indexes mislead the optimizer. Having more indexes does not necessarily lead to better results.
- Create proper indexes based on service characteristics. In principle, indexes need to be created for columns required in a query to improve performance. Indexes can be created in the following scenarios:
  - For columns with high differentiation, indexes can significantly reduce the number of rows after filtering. For example, you are advised to create an index in the ID card number column, but not in the gender column.
  - If there are multiple query conditions, you can select a combination index. Note that the column of the equivalent condition must be placed before the combination index. For example, if your query is **SELECT * FROM t where c1 = 10 and c2 = 100 and c3 > 10;**, create a composite index **Index cidx (c1, c2, c3)** to optimize scanning.
- When an index column is used as a query condition, do not perform calculation, function, or type conversion on the index column. Otherwise, the optimizer cannot use the index.
- Ensure that the index column contains the query column. Do not always run the **SELECT *** statement to query all columns.
- Indexes are not utilized when **!= or NOT IN** are used in query conditions.
- When LIKE is used, if the condition starts with the wildcard %, the index cannot be used.
- If multiple indexes are available for a query condition but you know which index is the optimal one, you are advised to use the optimizer hint to force the optimizer to use the index. This prevents the optimizer from selecting an incorrect index due to inaccurate statistics or other problems.
- When the IN expression is used as the query condition, the number of matched conditions should not be too large. Otherwise, the execution efficiency is low.

6.1.2 Step 1: Creating an Initial Table and Loading Sample Data

Supported Regions

Table 6-1 Regions and OBS bucket names

Region	OBS Bucket
EU-Dublin	dws-demo-eu-west-101

Create a group of tables without specifying their storage modes, distribution keys, distribution modes, or compression modes. Load sample data into these tables.

Step 1 (Optional) Create a cluster.

If a cluster is available, skip this step. For details about how to create a cluster, see **Creating a DWS Storage-Compute Coupled Cluster**.

Furthermore, connect to the cluster and test the connection. For details, see **Methods of Connecting to a Cluster**.

This practice uses an 8-node cluster as an example. You can also use a four-node cluster to perform the test.

Step 2 Create an SS test table **store_sales**.

NOTE

If SS tables already exist in the current database, run the **DROP TABLE** statement to delete these tables first.

For example, delete the **store_sales** table.

```
DROP TABLE store_sales;
```

Do not configure the storage mode, distribution key, distribution mode, or compression mode when you create this table.

Run the **CREATE TABLE** command to create the 11 tables in **Figure 6-3**. This section only provides the syntax for creating the **store_sales** table. To create all tables, copy the syntax in **Creating an Initial Table**.

```
CREATE TABLE store_sales
(
    ss_sold_date_sk           integer                       ,
    ss_sold_time_sk           integer                       ,
    ss_item_sk                integer               not null,
    ss_customer_sk            integer                       ,
    ss_cdemo_sk               integer                       ,
    ss_hdemo_sk               integer                       ,
    ss_addr_sk                integer                       ,
    ss_store_sk               integer                       ,
    ss_promo_sk               integer                       ,
    ss_ticket_number          bigint                not null,
    ss_quantity               integer                       ,
    ss_wholesale_cost         decimal(7,2)                  ,
    ss_list_price             decimal(7,2)                  ,
    ss_sales_price            decimal(7,2)                  ,
```

```
    ss_ext_discount_amt       decimal(7,2)                ,
    ss_ext_sales_price        decimal(7,2)                ,
    ss_ext_wholesale_cost     decimal(7,2)                ,
    ss_ext_list_price         decimal(7,2)                ,
    ss_ext_tax                decimal(7,2)                ,
    ss_coupon_amt             decimal(7,2)                ,
    ss_net_paid               decimal(7,2)                ,
    ss_net_paid_inc_tax       decimal(7,2)                ,
    ss_net_profit             decimal(7,2)
) ;
```

Step 3 Load sample data into these tables.

An OBS bucket provides sample data used for this practice. The bucket can be read by all authenticated cloud users. Perform the following operations to load the sample data:

1. Create a foreign table for each table.

   DWS uses the foreign data wrappers (FDWs) provided by PostgreSQL to import data in parallel. To use FDWs, create FDW tables first (also called foreign tables). This section only provides the syntax for creating the **obs_from_store_sales_001** foreign table corresponding to the **store_sales** table. To create all foreign tables, copy the syntax in **Creating a Foreign Table**.

   NOTE

   - Note that *<obs_bucket_name>* in the following statement indicates the OBS bucket name. Only some regions are supported. For details about the supported regions and OBS bucket names, see **Table 6-1**. DWS clusters do not support cross-region access to OBS bucket data.
   - The columns of the foreign table must be the same as that of the corresponding ordinary table. In this example, **store_sales** and **obs_from_store_sales_001** should have the same columns.
   - The foreign table syntax obtains the sample data used for this practice from the OBS bucket. To load other sample data, modify **SERVER gsmpp_server OPTIONS** as needed. For details, see **About Parallel Data Import from OBS**.
   - Hard-coded or plaintext AK/SK is risky. For security, encrypt your AK/SK and store them in the configuration file or environment variables.

```
CREATE FOREIGN TABLE obs_from_store_sales_001
(
    ss_sold_date_sk           integer                     ,
    ss_sold_time_sk           integer                     ,
    ss_item_sk                integer               not null,
    ss_customer_sk            integer                     ,
    ss_cdemo_sk               integer                     ,
    ss_hdemo_sk               integer                     ,
    ss_addr_sk                integer                     ,
    ss_store_sk               integer                     ,
    ss_promo_sk               integer                     ,
    ss_ticket_number          bigint                not null,
    ss_quantity               integer                     ,
    ss_wholesale_cost         decimal(7,2)                ,
    ss_list_price             decimal(7,2)                ,
    ss_sales_price            decimal(7,2)                ,
    ss_ext_discount_amt       decimal(7,2)                ,
    ss_ext_sales_price        decimal(7,2)                ,
    ss_ext_wholesale_cost     decimal(7,2)                ,
    ss_ext_list_price         decimal(7,2)                ,
    ss_ext_tax                decimal(7,2)                ,
    ss_coupon_amt             decimal(7,2)                ,
    ss_net_paid               decimal(7,2)                ,
    ss_net_paid_inc_tax       decimal(7,2)                ,
```

```
    ss_net_profit             decimal(7,2)
)
-- Configure OBS server information and data format details.
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/store_sales',
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
-- If create foreign table failed,record error message
WITH err_obs_from_store_sales_001;
```

2. Set **ACCESS_KEY** and **SECRET_ACCESS_KEY** parameters as needed in the foreign table creation statement, and run this statement in a client tool to create a foreign table.

   For the values of **ACCESS_KEY** and **SECRET_ACCESS_KEY**, see **Creating Access Keys (AK and SK)**.

3. Import data.

   Create the **insert.sql** script containing the following statements and execute it:

```
\timing on
\parallel on 4
INSERT INTO store_sales SELECT * FROM obs_from_store_sales_001;
INSERT INTO date_dim SELECT * FROM obs_from_date_dim_001;
INSERT INTO store SELECT * FROM obs_from_store_001;
INSERT INTO item SELECT * FROM obs_from_item_001;
INSERT INTO time_dim SELECT * FROM obs_from_time_dim_001;
INSERT INTO promotion SELECT * FROM obs_from_promotion_001;
INSERT INTO customer_demographics SELECT * from obs_from_customer_demographics_001 ;
INSERT INTO customer_address SELECT * FROM obs_from_customer_address_001 ;
INSERT INTO household_demographics SELECT * FROM obs_from_household_demographics_001;
INSERT INTO customer SELECT * FROM obs_from_customer_001;
INSERT INTO income_band SELECT * FROM obs_from_income_band_001;
\parallel off
```

   The returned result is as follows:

```
SET
Timing is on.
SET
Time: 2.831 ms
Parallel is on with scale 4.
Parallel is off.
INSERT 0 402
Time: 1820.909 ms
INSERT 0 73049
Time: 2715.275 ms
INSERT 0 86400
Time: 2377.056 ms
INSERT 0 1000
Time: 4037.155 ms
INSERT 0 204000
Time: 7124.190 ms
INSERT 0 7200
Time: 2227.776 ms
INSERT 0 1920800
Time: 8672.647 ms
INSERT 0 20
Time: 2273.501 ms
INSERT 0 1000000
Time: 11430.991 ms
INSERT 0 1981703
```

```
Time: 20270.750 ms
INSERT 0 287997024
Time: 341395.680 ms
total time: 341584  ms
```

4. Calculate the total time spent in creating the 11 tables. The result will be recorded as the loading time in the benchmark table in **Step 1** in the next section.
5. Run the following command to verify that each table is loaded correctly and records lines into the table:

```
SELECT COUNT(*) FROM store_sales;
SELECT COUNT(*) FROM date_dim;
SELECT COUNT(*) FROM store;
SELECT COUNT(*) FROM item;
SELECT COUNT(*) FROM time_dim;
SELECT COUNT(*) FROM promotion;
SELECT COUNT(*) FROM customer_demographics;
SELECT COUNT(*) FROM customer_address;
SELECT COUNT(*) FROM household_demographics;
SELECT COUNT(*) FROM customer;
SELECT COUNT(*) FROM income_band;
```

The number of rows in each SS table is as follows:

Table name	Number of Rows
Store_Sales	287997024
Date_Dim	73049
Store	402
Item	204000
Time_Dim	86400
Promotion	1000
Customer_Demographics	1920800
Customer_Address	1000000
Household_Demographics	7200
Customer	1981703
Income_Band	20

Step 4 Run the **ANALYZE** command to update statistics.

```
ANALYZE;
```

If **ANALYZE** is returned, the execution is successful.

```
ANALYZE
```

The **ANALYZE** statement collects statistics about table content in databases, which will be stored in the **PG_STATISTIC** system catalog. Then, the query optimizer uses the statistics to work out the most efficient execution plan.

After executing batch insertions and deletions, you are advised to run the **ANALYZE** statement on the table or the entire library to update statistics.

----End

6.1.3 Step 2: Testing System Performance of the Initial Table and Establishing a Baseline

Before and after tuning table structures, test and record the following information to compare differences in system performance:

- Load time
- Storage space occupied by tables
- Query performance

The examples in this practice are based on a dws.d2.xlarge cluster consisting of eight nodes. Because system performance is affected by many factors, clusters of the same flavor may have different results.

Table 6-2 Cluster specifications

Model	dws.d2.xlarge VM
CPU	4*CPU E5-2680 v2 @ 2.80GHZ
Memory	32 GB
Network	1 GB
Disk	1.63 TB
Number of Nodes	8

Record the results using the following benchmark table.

Table 6-3 Recording results

Benchmark	Before	After
Loading time (11 tables)	341584 ms	-
Occupied storage space		
Store_Sales	-	-
Date_Dim	-	-
Store	-	-
Item	-	-
Time_Dim	-	-

Benchmark	Before	After
Promotion	-	-
Customer_Demographics	-	-
Customer_Address	-	-
Household_Demographics	-	-
Customer	-	-
Income_Band	-	-
Total storage space	-	-
Query execution time		
Query 1	-	-
Query 2	-	-
Query 3	-	-
Total execution time	-	-

Perform the following steps to test the system performance before tuning to establish a benchmark:

Step 1 Enter the cumulative load time for all the 11 tables in the benchmarks table in the **Before** column.

Step 2 Record the storage space usage of each table.

Determine how much disk space is used for each table using the **pg_size_pretty** function and record the results in base tables.

```
SELECT T_NAME, PG_SIZE_PRETTY(PG_RELATION_SIZE(t_name)) FROM (VALUES('store_sales'),('date_dim'),
('store'),('item'),('time_dim'),('promotion'),('customer_demographics'),('customer_address'),
('household_demographics'),('customer'),('income_band')) AS names1(t_name);
```

The following information is displayed:

```
         t_name          | pg_size_pretty
-------------------------+----------------
 store_sales             | 42 GB
 date_dim                | 11 MB
 store                   | 232 kB
 item                    | 110 MB
 time_dim                | 11 MB
 promotion               | 256 kB
 customer_demographics   | 171 MB
 customer_address        | 170 MB
 household_demographics | 504 kB
 customer                | 441 MB
 income_band             | 88 kB
(11 rows)
```

Step 3 Test query performance.

Run the following queries and record the time spent on each query. The execution durations of the same query can be different, depending on the OS cache during execution. You are advised to perform several rounds of tests and select a group with average values.

```
\timing on
SELECT * FROM (SELECT  COUNT(*)
FROM store_sales
    ,household_demographics
    ,time_dim, store
WHERE ss_sold_time_sk = time_dim.t_time_sk
    AND ss_hdemo_sk = household_demographics.hd_demo_sk
    AND ss_store_sk = s_store_sk
    AND time_dim.t_hour = 8
    AND time_dim.t_minute >= 30
    AND household_demographics.hd_dep_count = 5
    AND store.s_store_name = 'ese'
ORDER BY COUNT(*)
 ) LIMIT 100;

SELECT * FROM (SELECT  i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact,
SUM(ss_ext_sales_price) ext_price
 FROM date_dim, store_sales, item,customer,customer_address,store
 WHERE d_date_sk = ss_sold_date_sk
   AND ss_item_sk = i_item_sk
   AND i_manager_id=8
   AND d_moy=11
   AND d_year=1999
   AND ss_customer_sk = c_customer_sk
   AND c_current_addr_sk = ca_address_sk
   AND substr(ca_zip,1,5) <> substr(s_zip,1,5)
   AND ss_store_sk = s_store_sk
 GROUP BY i_brand
      ,i_brand_id
      ,i_manufact_id
      ,i_manufact
 ORDER BY ext_price desc
         ,i_brand
         ,i_brand_id
         ,i_manufact_id
         ,i_manufact
 ) LIMIT 100;

SELECT * FROM (SELECT  s_store_name, s_store_id,
        SUM(CASE WHEN (d_day_name='Sunday') THEN ss_sales_price ELSE null END) sun_sales,
        SUM(CASE WHEN (d_day_name='Monday') THEN ss_sales_price ELSE null END) mon_sales,
        SUM(CASE WHEN (d_day_name='Tuesday') THEN ss_sales_price ELSE  null END) tue_sales,
        SUM(CASE WHEN (d_day_name='Wednesday') THEN ss_sales_price ELSE null END) wed_sales,
        SUM(CASE WHEN (d_day_name='Thursday') THEN ss_sales_price ELSE null END) thu_sales,
        SUM(CASE WHEN (d_day_name='Friday') THEN ss_sales_price ELSE null END) fri_sales,
        SUM(CASE WHEN (d_day_name='Saturday') THEN ss_sales_price ELSE null END) sat_sales
 FROM date_dim, store_sales, store
 WHERE d_date_sk = ss_sold_date_sk AND
       s_store_sk = ss_store_sk AND
       s_gmt_offset = -5 AND
       d_year = 2000
 GROUP BY s_store_name, s_store_id
 ORDER BY s_store_name, s_store_id,sun_sales,mon_sales,tue_sales,wed_sales,thu_sales,fri_sales,sat_sales
  ) LIMIT 100;
```

----End

After the preceding statistics are collected, the benchmark table is as follows:

Benchmark	Before	After
Loading time (11 tables)	341584 ms	-

Benchmark	Before	After
Occupied storage space		
Store_Sales	42 GB	-
Date_Dim	11 MB	-
Store	232 KB	-
Item	110 MB	-
Time_Dim	11 MB	-
Promotion	256 KB	-
Customer_Demographics	171 MB	-
Customer_Address	170 MB	-
Household_Demographics	504 KB	-
Customer	441 MB	-
Income_Band	88 KB	-
Total storage space	42 GB	-
Query execution time		
Query 1	14552.05 ms	-
Query 2	27952.36 ms	-
Query 3	17721.15 ms	-
Total execution time	60225.56 ms	-

6.1.4 Step 3: Optimizing a Table

Selecting a Storage Mode

Sample tables used in this practice are typical multi-column TPC-DS tables where many statistical analysis queries are performed. Therefore, the column storage mode is recommended.

```
WITH (ORIENTATION = column)
```

Selecting a Compression Level

No compression ratio is specified in **Step 1: Creating an Initial Table and Loading Sample Data**, and the low compression ratio is selected by DWS by default. Specify **COMPRESSION** to **MIDDLE**, and compare the result to that when **COMPRESSION** is set to **LOW**.

The following is an example of selecting a storage mode and the **MIDDLE** compression ratio for a table.

```
CREATE TABLE store_sales
(
    ss_sold_date_sk           integer                       ,
    ss_sold_time_sk           integer                       ,
    ss_item_sk                integer               not null,
    ss_customer_sk            integer                       ,
    ss_cdemo_sk               integer                       ,
    ss_hdemo_sk               integer                       ,
    ss_addr_sk                integer                       ,
    ss_store_sk               integer                       ,
    ss_promo_sk               integer                       ,
    ss_ticket_number          bigint                not null,
    ss_quantity               integer                       ,
    ss_wholesale_cost         decimal(7,2)                  ,
    ss_list_price             decimal(7,2)                  ,
    ss_sales_price            decimal(7,2)                  ,
    ss_ext_discount_amt       decimal(7,2)                  ,
    ss_ext_sales_price        decimal(7,2)                  ,
    ss_ext_wholesale_cost     decimal(7,2)                  ,
    ss_ext_list_price         decimal(7,2)                  ,
    ss_ext_tax                decimal(7,2)                  ,
    ss_coupon_amt             decimal(7,2)                  ,
    ss_net_paid               decimal(7,2)                  ,
    ss_net_paid_inc_tax       decimal(7,2)                  ,
    ss_net_profit             decimal(7,2)
)
WITH (ORIENTATION = column,COMPRESSION=middle);
```

Selecting a Distribution Mode

Based on table sizes provided in **Step 2: Testing System Performance of the Initial Table and Establishing a Baseline**, set the distribution mode as follows.

Table Name	Number of Rows	Distribution Mode
Store_Sales	287997024	Hash
Date_Dim	73049	Replication
Store	402	Replication
Item	204000	Replication
Time_Dim	86400	Replication
Promotion	1000	Replication
Customer_Demographics	1920800	Hash
Customer_Address	1000000	Hash
Household_Demographics	7200	Replication
Customer	1981703	Hash
Income_Band	20	Replication

Selecting a Distribution Key

If your table is distributed using hash, choose a proper distribution key. You are advised to select a distribution key according to **Selecting a Distribution Key**.

Select the primary key of each table as the distribution key of the hash table.

Table Name	Number of Records	Distribution Mode	Distribution Key
Store_Sales	287997024	Hash	ss_item_sk
Date_Dim	73049	Replication	-
Store	402	Replication	-
Item	204000	Replication	-
Time_Dim	86400	Replication	-
Promotion	1000	Replication	-
Customer_Demographics	1920800	Hash	cd_demo_sk
Customer_Address	1000000	Hash	ca_address_sk
Household_Demographics	7200	Replication	-
Customer	1981703	Hash	c_customer_sk
Income_Band	20	Replication	-

6.1.5 Step 4: Creating Another Table and Loading Data

After selecting a storage mode, compression level, distribution mode, and distribution key for each table, use these attributes to create tables and reload data. Compare the system performance before and after the table recreation.

Step 1 Delete the tables created before.

```
DROP TABLE store_sales;
DROP TABLE date_dim;
DROP TABLE store;
DROP TABLE item;
DROP TABLE time_dim;
DROP TABLE promotion;
DROP TABLE customer_demographics;
DROP TABLE customer_address;
DROP TABLE household_demographics;
DROP TABLE customer;
DROP TABLE income_band;

DROP FOREIGN TABLE obs_from_store_sales_001;
DROP FOREIGN TABLE obs_from_date_dim_001;
DROP FOREIGN TABLE obs_from_store_001;
DROP FOREIGN TABLE obs_from_item_001;
DROP FOREIGN TABLE obs_from_time_dim_001;
DROP FOREIGN TABLE obs_from_promotion_001;
```



```
DROP FOREIGN TABLE obs_from_customer_demographics_001;
DROP FOREIGN TABLE obs_from_customer_address_001;
DROP FOREIGN TABLE obs_from_household_demographics_001;
DROP FOREIGN TABLE obs_from_customer_001;
DROP FOREIGN TABLE obs_from_income_band_001;
```

Step 2 Create tables and specify storage and distribution modes for them.

Only the syntax for recreating the **store_sales** table is provided for simplicity. To recreate all the other tables, copy the syntax in **Creating a Another Table After Design Optimization**.

```
CREATE TABLE store_sales
(
    ss_sold_date_sk           integer                       ,
    ss_sold_time_sk           integer                       ,
    ss_item_sk                integer               not null,
    ss_customer_sk            integer                       ,
    ss_cdemo_sk               integer                       ,
    ss_hdemo_sk               integer                       ,
    ss_addr_sk                integer                       ,
    ss_store_sk               integer                       ,
    ss_promo_sk               integer                       ,
    ss_ticket_number          bigint                not null,
    ss_quantity               integer                       ,
    ss_wholesale_cost         decimal(7,2)                  ,
    ss_list_price             decimal(7,2)                  ,
    ss_sales_price            decimal(7,2)                  ,
    ss_ext_discount_amt       decimal(7,2)                  ,
    ss_ext_sales_price        decimal(7,2)                  ,
    ss_ext_wholesale_cost     decimal(7,2)                  ,
    ss_ext_list_price         decimal(7,2)                  ,
    ss_ext_tax                decimal(7,2)                  ,
    ss_coupon_amt             decimal(7,2)                  ,
    ss_net_paid               decimal(7,2)                  ,
    ss_net_paid_inc_tax       decimal(7,2)                  ,
    ss_net_profit             decimal(7,2)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY hash (ss_item_sk);
```

Step 3 **Load sample data into these tables.**

Step 4 Record the loading time in the benchmark tables.

Benchmark	Before	After
Loading time (11 tables)	341584 ms	257241 ms
Occupied storage space		
Store_Sales	42 GB	-
Date_Dim	11 MB	-
Store	232 KB	-
Item	110 MB	-
Time_Dim	11 MB	-
Promotion	256 KB	-
Customer_Demographics	171 MB	-
Customer_Address	170 MB	-

Benchmark	Before	After
Household_Demographics	504 KB	-
Customer	441 MB	-
Income_Band	88 KB	-
Total storage space	42 GB	-
Query execution time		
Query 1	14552.05 ms	-
Query 2	27952.36 ms	-
Query 3	17721.15 ms	-
Total execution time	60225.56 ms	-

Step 5 Run the **ANALYZE** command to update statistics.

```
ANALYZE;
```

If **ANALYZE** is returned, the execution is successful.

```
ANALYZE
```

Step 6 Check for data skew.

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 for data skew:

```
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;
```

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 key.** In DWS, you can select multiple distribution keys to distribute data evenly.

----End

6.1.6 Step 5: Testing System Performance in the New Table

After recreating the test data set with the selected storage modes, compression levels, distribution modes, and distribution keys, you will retest the system performance.

Step 1 Record the storage space usage of each table.

Determine how much disk space is used for each table using the **pg_size_pretty** function and record the results in base tables.

```
SELECT T_NAME, PG_SIZE_PRETTY(PG_RELATION_SIZE(t_name)) FROM (VALUES('store_sales'),('date_dim'),
('store'),('item'),('time_dim'),('promotion'),('customer_demographics'),('customer_address'),
('household_demographics'),('customer'),('income_band')) AS names1(t_name);
```

```
         t_name          | pg_size_pretty
-------------------------+----------------
 store_sales             | 14 GB
 date_dim                | 27 MB
 store                   | 4352 kB
 item                    | 259 MB
 time_dim                | 14 MB
 promotion               | 3200 kB
 customer_demographics   | 11 MB
 customer_address        | 27 MB
 household_demographics  | 1280 kB
 customer                | 111 MB
 income_band             | 896 kB
(11 rows)
```

Step 2 Test the query performance and record the performance data in the benchmark table.

Execute the following queries again and record the time spent on each query.

```
\timing on
SELECT * FROM (SELECT  COUNT(*)
FROM store_sales
    ,household_demographics
    ,time_dim, store
WHERE ss_sold_time_sk = time_dim.t_time_sk
    AND ss_hdemo_sk = household_demographics.hd_demo_sk
    AND ss_store_sk = s_store_sk
    AND time_dim.t_hour = 8
    AND time_dim.t_minute >= 30
    AND household_demographics.hd_dep_count = 5
    AND store.s_store_name = 'ese'
ORDER BY COUNT(*)
 ) LIMIT 100;

SELECT * FROM (SELECT  i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact,
SUM(ss_ext_sales_price) ext_price
 FROM date_dim, store_sales, item,customer,customer_address,store
 WHERE d_date_sk = ss_sold_date_sk
   AND ss_item_sk = i_item_sk
   AND i_manager_id=8
   AND d_moy=11
   AND d_year=1999
   AND ss_customer_sk = c_customer_sk
   AND c_current_addr_sk = ca_address_sk
   AND substr(ca_zip,1,5) <> substr(s_zip,1,5)
   AND ss_store_sk = s_store_sk
 GROUP BY i_brand
      ,i_brand_id
      ,i_manufact_id
      ,i_manufact
 ORDER BY ext_price desc
         ,i_brand
         ,i_brand_id
         ,i_manufact_id
         ,i_manufact
 ) LIMIT 100;

SELECT * FROM (SELECT  s_store_name, s_store_id,
        SUM(CASE WHEN (d_day_name='Sunday') THEN ss_sales_price ELSE null END) sun_sales,
        SUM(CASE WHEN (d_day_name='Monday') THEN ss_sales_price ELSE null END) mon_sales,
        SUM(CASE WHEN (d_day_name='Tuesday') THEN ss_sales_price ELSE  null END) tue_sales,
        SUM(CASE WHEN (d_day_name='Wednesday') THEN ss_sales_price ELSE null END) wed_sales,
        SUM(CASE WHEN (d_day_name='Thursday') THEN ss_sales_price ELSE null END) thu_sales,
        SUM(CASE WHEN (d_day_name='Friday') THEN ss_sales_price ELSE null END) fri_sales,
        SUM(CASE WHEN (d_day_name='Saturday') THEN ss_sales_price ELSE null END) sat_sales
 FROM date_dim, store_sales, store
 WHERE d_date_sk = ss_sold_date_sk AND
       s_store_sk = ss_store_sk AND
       s_gmt_offset = -5 AND
```



```
      d_year = 2000
GROUP BY s_store_name, s_store_id
ORDER BY s_store_name, s_store_id,sun_sales,mon_sales,tue_sales,wed_sales,thu_sales,fri_sales,sat_sales
 ) LIMIT 100;
```

The following benchmark table shows the validation results of the cluster used in this tutorial. Your results may vary based on a number of factors, but the relative results should be similar. The execution durations of queries having the same table structure can be different, depending on the OS cache during execution. You are advised to perform several rounds of tests and select a group with average values.

Benchmark	Before	After
Loading time (11 tables)	341584 ms	257241 ms
Occupied storage space		
Store_Sales	42 GB	14 GB
Date_Dim	11 MB	27 MB
Store	232 KB	4352 KB
Item	110 MB	259 MB
Time_Dim	11 MB	14 MB
Promotion	256 KB	3200 KB
Customer_Demographics	171 MB	11 MB
Customer_Address	170 MB	27 MB
Household_Demographics	504 KB	1280 KB
Customer	441 MB	111 MB
Income_Band	88 KB	896 KB
Total storage space	42 GB	15 GB
Query execution time		
Query 1	14552.05 ms	1783.353 ms
Query 2	27952.36 ms	14247.803 ms
Query 3	17721.15 ms	11441.659 ms
Total execution time	60225.56 ms	27472.815 ms

Step 3 If you have higher expectations for the performance after the table design, you can run the **EXPLAIN PERFORMANCE** command to view the execution plan for tuning.

For details about execution plans and query tuning, see **SQL Execution Plan** and **GaussDB(DWS) Performance Tuning Overview**.

----End

6.1.7 Step 6: Evaluating the Performance of the Optimized Table

Compare the loading time, storage space usage, and query execution time before and after the table tuning.

The following table shows the example results of the cluster used in this tutorial. Your results will be different, but should show similar improvement.

Benchmark	Before	After	Change	Percentage (%)
Loading time (11 tables)	341584 ms	257241 ms	-84343 ms	-24.7%
Occupied storage space			-	-
Store_Sales	42 GB	14 GB	-28 GB	-66.7%
Date_Dim	11 MB	27 MB	16 MB	145.5%
Store	232 KB	4352 KB	4120 KB	1775.9%
Item	110 MB	259 MB	149 MB	1354.5%
Time_Dim	11 MB	14 MB	13 MB	118.2%
Promotion	256 KB	3200 KB	2944 KB	1150%
Customer_Demographics	171 MB	11 MB	-160 MB	-93.6
Customer_Address	170 MB	27 MB	-143 MB	-84.1%
Household_Demographics	504 KB	1280 KB	704 KB	139.7%
Customer	441 MB	111 MB	-330 MB	-74.8%
Income_Band	88 KB	896 KB	808 KB	918.2%
Total storage space	42 GB	15 GB	-27 GB	-64.3%
Query execution time			-	-
Query 1	14552.05 ms	1783.353 ms	-12768.697 ms	-87.7%
Query 2	27952.36 ms	14247.803 ms	-13704.557 ms	-49.0%
Query 3	17721.15 ms	11441.659 ms	-6279.491 ms	-35.4%
Total execution time	60225.56 ms	27472.815 ms	-32752.745 ms	-54.4%

Evaluating the Table After Optimization

- The loading time was reduced by 24.7%.

  The distribution mode has obvious impact on loading data. The hash distribution mode improves the loading efficiency. The replication distribution mode reduces the loading efficiency. When the CPU and I/O are sufficient, the compression level has little impact on the loading efficiency. Typically, the efficiency of loading a column-store table is higher than that of a row-store table.

- The storage usage space was reduced by 64.3%.

  The compression level, column storage, and hash distribution can save the storage space. A replication table increases the storage usage, but reduces the network overhead. Using the replication mode for small tables is a positive way to use small space for performance.

- The query performance (speed) increased by 54.4%, indicating that the query time decreased by 54.4%.

  The query performance is improved by optimizing storage modes, distribution modes, and distribution keys. In a statistical analysis query on multi-column tables, column storage can improve query performance. In a hash table, I/O resources on each node can be used during I/O read/write, which improves the read/write speed of a table.

  Often, query performance can be improved further by rewriting queries and configuring workload management (WLM). For more information, see **GaussDB(DWS) Performance Tuning Overview**.

You can adapt the operations in **Optimizing Table Structure Design to Enhance DWS Query Performance** to further improve the distribution of tables and the performance of data loading, storage, and query.

Deleting Resources

After this practice is completed, delete the cluster.

To retain the cluster and delete the SS tables, run the following command:

```
DROP TABLE store_sales;
DROP TABLE date_dim;
DROP TABLE store;
DROP TABLE item;
DROP TABLE time_dim;
DROP TABLE promotion;
DROP TABLE customer_demographics;
DROP TABLE customer_address;
DROP TABLE household_demographics;
DROP TABLE customer;
DROP TABLE income_band;
```

6.1.8 Appendix: Table Creation Syntax

This section provides SQL test statements used in this tutorial. You are advised to copy the SQL statements in each section and save them as an .sql file. For example, create a file named **create_table_fir.sql** file and paste the SQL statements in section **Creating an Initial Table** to the file. Executing the file on an SQL client tool is efficient, and the total elapsed time of test cases is easy to calculate. Execute the **.sql** file using **gsql** as follows:

gsql -d *database_name* **-h** *dws_ip* **-U** *username* **-p** *port_number* **-W** *password* **-f** *XXX.sql*

Replace the italic parts in the example with actual values in DWS. For example:

gsql -d *postgres* **-h** *10.10.0.1* **-U** *dbadmin* **-p** *8000* **-W** *password* **-f** *create_table_fir.sql*

Replace the following information in the example based on the site requirements:

- **postgres**: indicates the name of the database to be connected.
- **10.10.0.1**: cluster connection address.
- **dbadmin**: username of the cluster database. The default administrator is **dbadmin**.
- **8000**: database port set during cluster creation.
- **password**: password set during cluster creation.

Creating an Initial Table

This section contains the table creation syntax used when you create a table for the first time in this tutorial. Tables are created without specifying their storage modes, distribution keys, distribution modes, or compression modes.

```
CREATE TABLE store_sales
(
    ss_sold_date_sk           integer                       ,
    ss_sold_time_sk           integer                       ,
    ss_item_sk                integer               not null,
    ss_customer_sk            integer                       ,
    ss_cdemo_sk               integer                       ,
    ss_hdemo_sk               integer                       ,
    ss_addr_sk                integer                       ,
    ss_store_sk               integer                       ,
    ss_promo_sk               integer                       ,
    ss_ticket_number          bigint                not null,
    ss_quantity               integer                       ,
    ss_wholesale_cost         decimal(7,2)                  ,
    ss_list_price             decimal(7,2)                  ,
    ss_sales_price            decimal(7,2)                  ,
    ss_ext_discount_amt       decimal(7,2)                  ,
    ss_ext_sales_price        decimal(7,2)                  ,
    ss_ext_wholesale_cost     decimal(7,2)                  ,
    ss_ext_list_price         decimal(7,2)                  ,
    ss_ext_tax                decimal(7,2)                  ,
    ss_coupon_amt             decimal(7,2)                  ,
    ss_net_paid               decimal(7,2)                  ,
    ss_net_paid_inc_tax       decimal(7,2)                  ,
    ss_net_profit             decimal(7,2)
) ;

CREATE TABLE date_dim
(
    d_date_sk                 integer               not null,
    d_date_id                 char(16)              not null,
    d_date                    date                          ,
    d_month_seq               integer                       ,
    d_week_seq                integer                       ,
    d_quarter_seq             integer                       ,
    d_year                    integer                       ,
    d_dow                     integer                       ,
    d_moy                     integer                       ,
    d_dom                     integer                       ,
    d_qoy                     integer                       ,
    d_fy_year                 integer                       ,
    d_fy_quarter_seq          integer                       ,
    d_fy_week_seq             integer                       ,
    d_day_name                char(9)                       ,
```

```
    d_quarter_name            char(6)                       ,
    d_holiday                 char(1)                       ,
    d_weekend                 char(1)                       ,
    d_following_holiday       char(1)                       ,
    d_first_dom               integer                       ,
    d_last_dom                integer                       ,
    d_same_day_ly             integer                       ,
    d_same_day_lq             integer                       ,
    d_current_day             char(1)                       ,
    d_current_week            char(1)                       ,
    d_current_month           char(1)                       ,
    d_current_quarter         char(1)                       ,
    d_current_year            char(1)
) ;

CREATE TABLE store
(
    s_store_sk                integer               not null,
    s_store_id                char(16)              not null,
    s_rec_start_date          date                          ,
    s_rec_end_date            date                          ,
    s_closed_date_sk          integer                       ,
    s_store_name              varchar(50)                   ,
    s_number_employees        integer                       ,
    s_floor_space             integer                       ,
    s_hours                   char(20)                      ,
    s_manager                 varchar(40)                   ,
    s_market_id               integer                       ,
    s_geography_class         varchar(100)                  ,
    s_market_desc             varchar(100)                  ,
    s_market_manager          varchar(40)                   ,
    s_division_id             integer                       ,
    s_division_name           varchar(50)                   ,
    s_company_id              integer                       ,
    s_company_name            varchar(50)                   ,
    s_street_number           varchar(10)                   ,
    s_street_name             varchar(60)                   ,
    s_street_type             char(15)                      ,
    s_suite_number            char(10)                      ,
    s_city                    varchar(60)                   ,
    s_county                  varchar(30)                   ,
    s_state                   char(2)                       ,
    s_zip                     char(10)                      ,
    s_country                 varchar(20)                   ,
    s_gmt_offset              decimal(5,2)                  ,
    s_tax_percentage          decimal(5,2)
) ;

CREATE TABLE item
(
    i_item_sk                 integer               not null,
    i_item_id                 char(16)              not null,
    i_rec_start_date          date                          ,
    i_rec_end_date            date                          ,
    i_item_desc               varchar(200)                  ,
    i_current_price           decimal(7,2)                  ,
    i_wholesale_cost          decimal(7,2)                  ,
    i_brand_id                integer                       ,
    i_brand                   char(50)                      ,
    i_class_id                integer                       ,
    i_class                   char(50)                      ,
    i_category_id             integer                       ,
    i_category                char(50)                      ,
    i_manufact_id             integer                       ,
    i_manufact                char(50)                      ,
    i_size                    char(20)                      ,
    i_formulation             char(20)                      ,
    i_color                   char(20)                      ,
    i_units                   char(10)                      ,
```

```
    i_container               char(10)                      ,
    i_manager_id              integer                       ,
    i_product_name            char(50)
) ;

CREATE TABLE time_dim
(
    t_time_sk                 integer               not null,
    t_time_id                 char(16)              not null,
    t_time                    integer                       ,
    t_hour                    integer                       ,
    t_minute                  integer                       ,
    t_second                  integer                       ,
    t_am_pm                   char(2)                       ,
    t_shift                   char(20)                      ,
    t_sub_shift               char(20)                      ,
    t_meal_time               char(20)
) ;

CREATE TABLE promotion
(
    p_promo_sk                integer               not null,
    p_promo_id                char(16)              not null,
    p_start_date_sk           integer                       ,
    p_end_date_sk             integer                       ,
    p_item_sk                 integer                       ,
    p_cost                    decimal(15,2)                 ,
    p_response_target         integer                       ,
    p_promo_name              char(50)                      ,
    p_channel_dmail           char(1)                       ,
    p_channel_email           char(1)                       ,
    p_channel_catalog         char(1)                       ,
    p_channel_tv              char(1)                       ,
    p_channel_radio           char(1)                       ,
    p_channel_press           char(1)                       ,
    p_channel_event           char(1)                       ,
    p_channel_demo            char(1)                       ,
    p_channel_details         varchar(100)                  ,
    p_purpose                 char(15)                      ,
    p_discount_active         char(1)
) ;

CREATE TABLE customer_demographics
(
    cd_demo_sk                integer               not null,
    cd_gender                 char(1)                       ,
    cd_marital_status         char(1)                       ,
    cd_education_status       char(20)                      ,
    cd_purchase_estimate      integer                       ,
    cd_credit_rating          char(10)                      ,
    cd_dep_count              integer                       ,
    cd_dep_employed_count     integer                       ,
    cd_dep_college_count      integer
) ;

CREATE TABLE customer_address
(
    ca_address_sk             integer               not null,
    ca_address_id             char(16)              not null,
    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)
) ;

CREATE TABLE household_demographics
(
    hd_demo_sk                integer               not null,
    hd_income_band_sk         integer                       ,
    hd_buy_potential          char(15)                      ,
    hd_dep_count              integer                       ,
    hd_vehicle_count          integer
) ;

CREATE TABLE customer
(
    c_customer_sk             integer               not null,
    c_customer_id             char(16)              not null,
    c_current_cdemo_sk        integer                       ,
    c_current_hdemo_sk        integer                       ,
    c_current_addr_sk         integer                       ,
    c_first_shipto_date_sk    integer                       ,
    c_first_sales_date_sk     integer                       ,
    c_salutation              char(10)                      ,
    c_first_name              char(20)                      ,
    c_last_name               char(30)                      ,
    c_preferred_cust_flag     char(1)                       ,
    c_birth_day               integer                       ,
    c_birth_month             integer                       ,
    c_birth_year              integer                       ,
    c_birth_country           varchar(20)                   ,
    c_login                   char(13)                      ,
    c_email_address           char(50)                      ,
    c_last_review_date        char(10)
) ;

CREATE TABLE income_band
(
    ib_income_band_sk         integer               not null,
    ib_lower_bound            integer                       ,
    ib_upper_bound            integer
) ;
```

Creating a Another Table After Design Optimization

This section contains the syntax of creating another table after the storage modes, compression levels, distribution modes, and distribution keys are selected in this practice.

```
CREATE TABLE store_sales
(
    ss_sold_date_sk           integer                       ,
    ss_sold_time_sk           integer                       ,
    ss_item_sk                integer               not null,
    ss_customer_sk            integer                       ,
    ss_cdemo_sk               integer                       ,
    ss_hdemo_sk               integer                       ,
    ss_addr_sk                integer                       ,
    ss_store_sk               integer                       ,
    ss_promo_sk               integer                       ,
    ss_ticket_number          bigint                not null,
    ss_quantity               integer                       ,
    ss_wholesale_cost         decimal(7,2)                  ,
    ss_list_price             decimal(7,2)                  ,
    ss_sales_price            decimal(7,2)                  ,
    ss_ext_discount_amt       decimal(7,2)                  ,
    ss_ext_sales_price        decimal(7,2)                  ,
    ss_ext_wholesale_cost     decimal(7,2)                  ,
    ss_ext_list_price         decimal(7,2)                  ,
    ss_ext_tax                decimal(7,2)                  ,
```

```
    ss_coupon_amt             decimal(7,2)                  ,
    ss_net_paid               decimal(7,2)                  ,
    ss_net_paid_inc_tax       decimal(7,2)                  ,
    ss_net_profit             decimal(7,2)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY hash (ss_item_sk);

CREATE TABLE date_dim
(
    d_date_sk                 integer               not null,
    d_date_id                 char(16)              not null,
    d_date                    date                          ,
    d_month_seq               integer                       ,
    d_week_seq                integer                       ,
    d_quarter_seq             integer                       ,
    d_year                    integer                       ,
    d_dow                     integer                       ,
    d_moy                     integer                       ,
    d_dom                     integer                       ,
    d_qoy                     integer                       ,
    d_fy_year                 integer                       ,
    d_fy_quarter_seq          integer                       ,
    d_fy_week_seq             integer                       ,
    d_day_name                char(9)                       ,
    d_quarter_name            char(6)                       ,
    d_holiday                 char(1)                       ,
    d_weekend                 char(1)                       ,
    d_following_holiday       char(1)                       ,
    d_first_dom               integer                       ,
    d_last_dom                integer                       ,
    d_same_day_ly             integer                       ,
    d_same_day_lq             integer                       ,
    d_current_day             char(1)                       ,
    d_current_week            char(1)                       ,
    d_current_month           char(1)                       ,
    d_current_quarter         char(1)                       ,
    d_current_year            char(1)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY replication;

CREATE TABLE store
(
    s_store_sk                integer               not null,
    s_store_id                char(16)              not null,
    s_rec_start_date          date                          ,
    s_rec_end_date            date                          ,
    s_closed_date_sk          integer                       ,
    s_store_name              varchar(50)                   ,
    s_number_employees        integer                       ,
    s_floor_space             integer                       ,
    s_hours                   char(20)                      ,
    s_manager                 varchar(40)                   ,
    s_market_id               integer                       ,
    s_geography_class         varchar(100)                  ,
    s_market_desc             varchar(100)                  ,
    s_market_manager          varchar(40)                   ,
    s_division_id             integer                       ,
    s_division_name           varchar(50)                   ,
    s_company_id              integer                       ,
    s_company_name            varchar(50)                   ,
    s_street_number           varchar(10)                   ,
    s_street_name             varchar(60)                   ,
    s_street_type             char(15)                      ,
    s_suite_number            char(10)                      ,
    s_city                    varchar(60)                   ,
    s_county                  varchar(30)                   ,
    s_state                   char(2)                       ,
```

```
    s_zip                   char(10)                  ,
    s_country               varchar(20)               ,
    s_gmt_offset            decimal(5,2)              ,
    s_tax_percentage        decimal(5,2)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY replication;

CREATE TABLE item
(
    i_item_sk               integer             not null,
    i_item_id               char(16)            not null,
    i_rec_start_date        date                      ,
    i_rec_end_date          date                      ,
    i_item_desc             varchar(200)              ,
    i_current_price         decimal(7,2)              ,
    i_wholesale_cost        decimal(7,2)              ,
    i_brand_id              integer                   ,
    i_brand                 char(50)                  ,
    i_class_id              integer                   ,
    i_class                 char(50)                  ,
    i_category_id           integer                   ,
    i_category              char(50)                  ,
    i_manufact_id           integer                   ,
    i_manufact              char(50)                  ,
    i_size                  char(20)                  ,
    i_formulation           char(20)                  ,
    i_color                 char(20)                  ,
    i_units                 char(10)                  ,
    i_container             char(10)                  ,
    i_manager_id            integer                   ,
    i_product_name          char(50)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY replication;

CREATE TABLE time_dim
(
    t_time_sk               integer             not null,
    t_time_id               char(16)            not null,
    t_time                  integer                   ,
    t_hour                  integer                   ,
    t_minute                integer                   ,
    t_second                integer                   ,
    t_am_pm                 char(2)                   ,
    t_shift                 char(20)                  ,
    t_sub_shift             char(20)                  ,
    t_meal_time             char(20)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY replication;

CREATE TABLE promotion
(
    p_promo_sk              integer             not null,
    p_promo_id              char(16)            not null,
    p_start_date_sk         integer                   ,
    p_end_date_sk           integer                   ,
    p_item_sk               integer                   ,
    p_cost                  decimal(15,2)             ,
    p_response_target       integer                   ,
    p_promo_name            char(50)                  ,
    p_channel_dmail         char(1)                   ,
    p_channel_email         char(1)                   ,
    p_channel_catalog       char(1)                   ,
    p_channel_tv            char(1)                   ,
    p_channel_radio         char(1)                   ,
    p_channel_press         char(1)                   ,
    p_channel_event         char(1)                   ,
```

```
    p_channel_demo            char(1)                       ,
    p_channel_details         varchar(100)                  ,
    p_purpose                 char(15)                      ,
    p_discount_active         char(1)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY replication;

CREATE TABLE customer_demographics
(
    cd_demo_sk                integer               not null,
    cd_gender                 char(1)                       ,
    cd_marital_status         char(1)                       ,
    cd_education_status       char(20)                      ,
    cd_purchase_estimate      integer                       ,
    cd_credit_rating          char(10)                      ,
    cd_dep_count              integer                       ,
    cd_dep_employed_count     integer                       ,
    cd_dep_college_count      integer
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY hash (cd_demo_sk);

CREATE TABLE customer_address
(
    ca_address_sk             integer               not null,
    ca_address_id             char(16)              not null,
    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)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY hash (ca_address_sk);

CREATE TABLE household_demographics
(
    hd_demo_sk                integer               not null,
    hd_income_band_sk         integer                       ,
    hd_buy_potential          char(15)                      ,
    hd_dep_count              integer                       ,
    hd_vehicle_count          integer
)
 WITH (ORIENTATION = column,COMPRESSION=middle)
 DISTRIBUTE BY replication;

 CREATE TABLE customer
(
    c_customer_sk             integer               not null,
    c_customer_id             char(16)              not null,
    c_current_cdemo_sk        integer                       ,
    c_current_hdemo_sk        integer                       ,
    c_current_addr_sk         integer                       ,
    c_first_shipto_date_sk    integer                       ,
    c_first_sales_date_sk     integer                       ,
    c_salutation              char(10)                      ,
    c_first_name              char(20)                      ,
    c_last_name               char(30)                      ,
    c_preferred_cust_flag     char(1)                       ,
    c_birth_day               integer                       ,
    c_birth_month             integer                       ,
    c_birth_year              integer                       ,
```



```
    c_birth_country          varchar(20)                  ,
    c_login                  char(13)                     ,
    c_email_address          char(50)                     ,
    c_last_review_date       char(10)
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY hash (c_customer_sk);

CREATE TABLE income_band
(
    ib_income_band_sk         integer               not null,
    ib_lower_bound            integer                       ,
    ib_upper_bound            integer
)
WITH (ORIENTATION = column,COMPRESSION=middle)
DISTRIBUTE BY replication;
```

Creating a Foreign Table

This section contains the syntax of foreign tables for obtaining sample data used in this tutorial. The sample data is stored in an OBS bucket accessible to all authenticated cloud users.

NOTE

- Note that *<obs_bucket_name>* in the following statement indicates the OBS bucket name. Only some regions are supported. For details about the supported regions and OBS bucket names, see **Supported Regions**. DWS clusters do not support cross-region access to OBS bucket data.
- You can replace **ACCESS_KEY** and **SECRET_ACCESS_KEY** with your own credentials in this example.
- When an OBS foreign table is created, only the mapping relationship is created, and data is not pulled to the DWS disk.

```
CREATE FOREIGN TABLE obs_from_store_sales_001
(
    ss_sold_date_sk           integer                       ,
    ss_sold_time_sk           integer                       ,
    ss_item_sk                integer               not null,
    ss_customer_sk            integer                       ,
    ss_cdemo_sk               integer                       ,
    ss_hdemo_sk               integer                       ,
    ss_addr_sk                integer                       ,
    ss_store_sk               integer                       ,
    ss_promo_sk               integer                       ,
    ss_ticket_number          bigint                not null,
    ss_quantity               integer                       ,
    ss_wholesale_cost         decimal(7,2)                  ,
    ss_list_price             decimal(7,2)                  ,
    ss_sales_price            decimal(7,2)                  ,
    ss_ext_discount_amt       decimal(7,2)                  ,
    ss_ext_sales_price        decimal(7,2)                  ,
    ss_ext_wholesale_cost     decimal(7,2)                  ,
    ss_ext_list_price         decimal(7,2)                  ,
    ss_ext_tax                decimal(7,2)                  ,
    ss_coupon_amt             decimal(7,2)                  ,
    ss_net_paid               decimal(7,2)                  ,
    ss_net_paid_inc_tax       decimal(7,2)                  ,
    ss_net_profit             decimal(7,2)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/store_sales',
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
```

```
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_store_sales_001;

CREATE FOREIGN TABLE obs_from_date_dim_001
(
    d_date_sk                 integer               not null,
    d_date_id                 char(16)              not null,
    d_date                    date                          ,
    d_month_seq               integer                       ,
    d_week_seq                integer                       ,
    d_quarter_seq             integer                       ,
    d_year                    integer                       ,
    d_dow                     integer                       ,
    d_moy                     integer                       ,
    d_dom                     integer                       ,
    d_qoy                     integer                       ,
    d_fy_year                 integer                       ,
    d_fy_quarter_seq          integer                       ,
    d_fy_week_seq             integer                       ,
    d_day_name                char(9)                       ,
    d_quarter_name            char(6)                       ,
    d_holiday                 char(1)                       ,
    d_weekend                 char(1)                       ,
    d_following_holiday       char(1)                       ,
    d_first_dom               integer                       ,
    d_last_dom                integer                       ,
    d_same_day_ly             integer                       ,
    d_same_day_lq             integer                       ,
    d_current_day             char(1)                       ,
    d_current_week            char(1)                       ,
    d_current_month           char(1)                       ,
    d_current_quarter         char(1)                       ,
    d_current_year            char(1)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/date_dim' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_date_dim_001;

CREATE FOREIGN TABLE obs_from_store_001
(
    s_store_sk                integer               not null,
    s_store_id                char(16)              not null,
    s_rec_start_date          date                          ,
    s_rec_end_date            date                          ,
    s_closed_date_sk          integer                       ,
    s_store_name              varchar(50)                   ,
    s_number_employees        integer                       ,
    s_floor_space             integer                       ,
    s_hours                   char(20)                      ,
    s_manager                 varchar(40)                   ,
    s_market_id               integer                       ,
    s_geography_class         varchar(100)                  ,
    s_market_desc             varchar(100)                  ,
    s_market_manager          varchar(40)                   ,
```

```
    s_division_id              integer                        ,
    s_division_name            varchar(50)                    ,
    s_company_id               integer                        ,
    s_company_name             varchar(50)                    ,
    s_street_number            varchar(10)                    ,
    s_street_name              varchar(60)                    ,
    s_street_type              char(15)                       ,
    s_suite_number             char(10)                       ,
    s_city                     varchar(60)                    ,
    s_county                   varchar(30)                    ,
    s_state                    char(2)                        ,
    s_zip                      char(10)                       ,
    s_country                  varchar(20)                    ,
    s_gmt_offset               decimal(5,2)                   ,
    s_tax_percentage           decimal(5,2)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/store' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_store_001;

CREATE FOREIGN TABLE obs_from_item_001
(
    i_item_sk                  integer               not null,
    i_item_id                  char(16)              not null,
    i_rec_start_date           date                           ,
    i_rec_end_date             date                           ,
    i_item_desc                varchar(200)                   ,
    i_current_price            decimal(7,2)                   ,
    i_wholesale_cost           decimal(7,2)                   ,
    i_brand_id                 integer                        ,
    i_brand                    char(50)                       ,
    i_class_id                 integer                        ,
    i_class                    char(50)                       ,
    i_category_id              integer                        ,
    i_category                 char(50)                       ,
    i_manufact_id              integer                        ,
    i_manufact                 char(50)                       ,
    i_size                     char(20)                       ,
    i_formulation              char(20)                       ,
    i_color                    char(20)                       ,
    i_units                    char(10)                       ,
    i_container                char(10)                       ,
    i_manager_id               integer                        ,
    i_product_name             char(50)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/item' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_item_001;
```

```
CREATE FOREIGN TABLE obs_from_time_dim_001
(
    t_time_sk                 integer               not null,
    t_time_id                 char(16)              not null,
    t_time                    integer                       ,
    t_hour                    integer                       ,
    t_minute                  integer                       ,
    t_second                  integer                       ,
    t_am_pm                   char(2)                       ,
    t_shift                   char(20)                      ,
    t_sub_shift               char(20)                      ,
    t_meal_time               char(20)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/time_dim' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_time_dim_001;

CREATE FOREIGN TABLE obs_from_promotion_001
(
    p_promo_sk                integer               not null,
    p_promo_id                char(16)              not null,
    p_start_date_sk           integer                       ,
    p_end_date_sk             integer                       ,
    p_item_sk                 integer                       ,
    p_cost                    decimal(15,2)                 ,
    p_response_target         integer                       ,
    p_promo_name              char(50)                      ,
    p_channel_dmail           char(1)                       ,
    p_channel_email           char(1)                       ,
    p_channel_catalog         char(1)                       ,
    p_channel_tv              char(1)                       ,
    p_channel_radio           char(1)                       ,
    p_channel_press           char(1)                       ,
    p_channel_event           char(1)                       ,
    p_channel_demo            char(1)                       ,
    p_channel_details         varchar(100)                  ,
    p_purpose                 char(15)                      ,
    p_discount_active         char(1)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/promotion' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_promotion_001;

CREATE FOREIGN TABLE obs_from_customer_demographics_001
(
    cd_demo_sk                integer               not null,
    cd_gender                 char(1)                       ,
    cd_marital_status         char(1)                       ,
    cd_education_status       char(20)                      ,
```

```
    cd_purchase_estimate       integer                       ,
    cd_credit_rating           char(10)                      ,
    cd_dep_count               integer                       ,
    cd_dep_employed_count      integer                       ,
    cd_dep_college_count       integer
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/customer_demographics' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_customer_demographics_001;

CREATE FOREIGN TABLE obs_from_customer_address_001
(
ca_address_sk integer not null,
ca_address_id char(16) not null,
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 float4 ,
ca_location_type char(20)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/customer_address' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_customer_address_001;

CREATE FOREIGN TABLE obs_from_household_demographics_001
(
    hd_demo_sk                integer               not null,
    hd_income_band_sk         integer                       ,
    hd_buy_potential          char(15)                      ,
    hd_dep_count              integer                       ,
    hd_vehicle_count          integer
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/household_demographics' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
```

```
)
WITH err_obs_from_household_demographics_001;

CREATE FOREIGN TABLE obs_from_customer_001
(
    c_customer_sk             integer               not null,
    c_customer_id             char(16)              not null,
    c_current_cdemo_sk        integer                       ,
    c_current_hdemo_sk        integer                       ,
    c_current_addr_sk         integer                       ,
    c_first_shipto_date_sk    integer                       ,
    c_first_sales_date_sk     integer                       ,
    c_salutation              char(10)                      ,
    c_first_name              char(20)                      ,
    c_last_name               char(30)                      ,
    c_preferred_cust_flag     char(1)                       ,
    c_birth_day               integer                       ,
    c_birth_month             integer                       ,
    c_birth_year              integer                       ,
    c_birth_country           varchar(20)                   ,
    c_login                   char(13)                      ,
    c_email_address           char(50)                      ,
    c_last_review_date        char(10)
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/customer' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_customer_001;

CREATE FOREIGN TABLE obs_from_income_band_001
(
    ib_income_band_sk         integer               not null,
    ib_lower_bound            integer                       ,
    ib_upper_bound            integer
)
SERVER gsmpp_server
OPTIONS (
LOCATION 'obs://<obs_bucket_name>/tpcds/income_band' ,
FORMAT 'text',
DELIMITER '|',
ENCODING 'utf8',
NOESCAPING 'true',
ACCESS_KEY 'access_key_value_to_be_replaced',
SECRET_ACCESS_KEY 'secret_access_key_value_to_be_replaced',
REJECT_LIMIT 'unlimited',
CHUNKSIZE '64'
)
WITH err_obs_from_income_band_001;
```

6.2 Excellent Practices for SQL Queries

Based on a large number of SQL execution mechanisms and practices, we can optimize SQL statements following certain rules to more quickly execute SQL statements and obtain correct results.

- 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 6-4 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)
```

- 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 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.

For details, see**SQL Tuning**.

6.3 Data Skew Queries

6.3.1 Real-Time Detection of Storage Skew During Data Import

During the import, the system collects statistics on the number of rows imported on each DN. After the import is complete, the system calculates the skew ratio. If the skew ratio exceeds the specified threshold, an alarm is generated immediately. The skew ratio is calculated as follows: Skew ratio = (Maximum number of rows imported on a DN – Minimum number of rows imported on a DN)/Number of imported rows. Currently, data can be imported only by running **INSERT** or **COPY**.

NOTE

enable_stream_operator must be set to **on** so that DNs can return the number of imported rows at a time when a plan is delivered to them. Then, the skew ratio is calculated on the CN based on the returned values.

Usage

1. Set parameters **table_skewness_warning_threshold** (threshold for triggering a table skew alarm) and **table_skewness_warning_rows** (minimum number of rows for triggering a table skew alarm).

   – The value of **table_skewness_warning_threshold** ranges from **0** to **1**. The default value is **1**, indicating that the alarm is disabled. Other values indicate that the alarm is enabled.

   – The value of **table_skewness_warning_rows** ranges from **0** to **2147483647**. The default value is **100,000**. The alarm is triggered only when the following condition is met: Total number of imported rows > Value of **table_skewness_warning_rows** x Number of DNs involving in the import.

```
show table_skewness_warning_threshold;
set table_skewness_warning_threshold = xxx;
show table_skewness_warning_rows;
set table_skewness_warning_rows = xxx;
```

2. Use **INSERT** or **COPY** to import data.
3. Detect and handle alarms. The alarm information includes the table name, minimum number of rows, maximum number of rows, total number of rows, average number of rows, skew rate, and prompt information about data distribution or parameter modification.
```
WARNING:  Skewness occurs, table name: xxx, min value: xxx, max value: xxx, sum value: xxx, avg value: xxx, skew ratio: xxx
HINT:  Please check data distribution or modify warning threshold
```

6.3.2 Quickly Locating the Tables That Cause Data Skew

Currently, the following skew query APIs are provided: **table_distribution(schemaname text, tablename text)**, **table_distribution()**, and **PGXC_GET_TABLE_SKEWNESS**. You can select one based on service requirements.

Scenario 1: Data Skew Caused by a Full Disk

First, use the **pg_stat_get_last_data_changed_time(oid)** function to query the tables whose data is changed recently. The last change time of a table is recorded only on the CN where **INSERT**, **UPDATE**, and **DELETE** operations are performed. Therefore, you need to query tables that are changed within the last day (the period can be changed in the function).

```
CREATE OR REPLACE FUNCTION get_last_changed_table(OUT schemaname text, OUT relname text)
RETURNS setof record
AS $$
DECLARE
row_data record;
row_name record;
query_str text;
query_str_nodes text;
BEGIN
query_str_nodes := 'SELECT node_name FROM pgxc_node where node_type = ''C''';
FOR row_name IN EXECUTE(query_str_nodes) LOOP
query_str := 'EXECUTE DIRECT ON (' || row_name.node_name || ') ''SELECT b.nspname,a.relname FROM pg_class a INNER JOIN pg_namespace b on a.relnamespace = b.oid where pg_stat_get_last_data_changed_time(a.oid) BETWEEN current_timestamp - 1 AND current_timestamp;''';
FOR row_data IN EXECUTE(query_str) LOOP
schemaname = row_data.nspname;
relname = row_data.relname;
return next;
END LOOP;
END LOOP;
return;
END; $$
LANGUAGE plpgsql;
```

Then, execute the **table_distribution(schemaname text, tablename text)** function to query the storage space occupied by the tables on each DN.

```
SELECT table_distribution(schemaname,relname) FROM get_last_changed_table();
```

Scenario 2: Routine Data Skew Inspection

- If the number of tables in the database is less than 10,000, use the **PGXC_GET_TABLE_SKEWNESS** view to query data skew of all tables in the database.
```
SELECT * FROM pgxc_get_table_skewness ORDER BY totalsize DESC;
```
- If the number of tables in the database is no less than 10,000, you are advised to use the **table_distribution()** function instead of the

PGXC_GET_TABLE_SKEWNESS view because the view takes a longer time (hours) due to the query of the entire database for skew columns. When you use the **table_distribution()** function, you can define the output based on **PGXC_GET_TABLE_SKEWNESS**, optimizing the calculation and reducing the output columns. For example:

```
SELECT schemaname,tablename,max(dnsize) AS maxsize, min(dnsize) AS minsize
FROM pg_catalog.pg_class c
INNER JOIN pg_catalog.pg_namespace n ON n.oid = c.relnamespace
INNER JOIN pg_catalog.table_distribution() s ON s.schemaname = n.nspname AND s.tablename =
c.relname
INNER JOIN pg_catalog.pgxc_class x ON c.oid = x.pcrelid AND x.pclocatortype = 'H'
GROUP BY schemaname,tablename;
```

Scenario 3: Querying Data Skew of a Table

Run the following SQL statement to query the data skew of a table. 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;
```

The following is an example of the information returned. If the data distribution deviation on each DN is less than 10%, data is evenly distributed. If it is greater than 10%, data skew occurs.

```
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)
```

6.4 Analyzing SQL Statements That Are Being Executed to Handle DWS Performance Issues

During development, developers often encounter problems such as excessive SQL connections, long SQL query time, and SQL query blocking. You can use the **PG_STAT_ACTIVITY** and **PGXC_THREAD_WAIT_STATUS** views to analyze and locate SQL problems. This section describes some common locating methods.

Table 6-4 Some PG_STAT_ACTIVITY fields

Name	Type	Description
usename	name	Name of the user logging in to the backend
client_addr	inet	IP address of the client connected to the backend **null** 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.

Name	Type	Description
application_name	text	Name of the application connected to the backend
state	text	Overall state of the backend. The value can be: ● **active**: The backend is executing queries. ● **idle**: The backend is waiting for new client commands. ● **idle in transaction**: The backend is in a transaction, but there is no statement being executed in the transaction. ● **idle in transaction (aborted)**: The backend is in a transaction, but there are statements failed in the transaction. ● **fastpath function call**: The backend is executing a **fast-path** function. ● **disabled**: This state is reported if **track_activities** is disabled in this backend. **NOTE** Common users can view only the session status of their own accounts. That is, the state information of other accounts is empty.
waiting	boolean	If the back end is currently waiting for a lock, the value is **t**. Otherwise, the value is **f**. ● **t** stands for true. ● **f** stands for false.

Name	Type	Description
enqueue	text	Queuing status of a statement. Its value can be: ● **waiting in global queue**: The statement is queuing in the global concurrency queue. The number of concurrent statements exceeds the value of **max_active_statements** configured for a single CN. ● **waiting in respool queue**: The statement is queuing in the resource pool and the concurrency of simple jobs is limited. The main reason is that the concurrency of simple jobs exceeds the upper limit **max_dop** of the fast track. ● **waiting in ccn queue**: The job is in the CCN queue, which may be global memory queuing, slow lane memory queuing, or concurrent queuing. The scenarios are: 1. The available global memory exceeds the upper limit, the job is queuing in the global memory queue. 2. Concurrent requests on the slow lane in the resource pool exceed the upper limit, which is specified by **active_statements**. 3. The slow lane memory of the resource pool exceeds the upper limit, that is, the estimated memory of concurrent jobs in the resource pool exceeds the upper limit specified by **mem_percent**. ● Empty or **no waiting queue**: The statement is running.
pid	bigint	ID of the backend thread.

Viewing Connection Information

- Set **track_activities** to **on**.

  ```
  SET track_activities = on;
  ```

  The database collects the running information about active queries only if this parameter is set to **on**.

- You can run the following SQL statements to check the current connection user, connection address, connection application, status, whether to wait for a lock, queuing status, and thread ID.

  ```
  SELECT usename,client_addr,application_name,state,waiting,enqueue,pid FROM PG_STAT_ACTIVITY
  WHERE DATNAME='database name';
  ```

  The following command output is displayed:

  ```
   usename |  client_addr  | application_name | state  | waiting | enqueue |       pid
  ---------+---------------+------------------+--------+---------+---------+-----------------
  ```

```
 leo     | 192.168.0.133 | gsql            | idle   | f       |         | 139666091022080
 dbadmin | 192.168.0.133 | gsql            | active | f       |         | 139666212681472
 joe     | 192.168.0.133 |                 | idle   | f       |         | 139665671489280
(3 rows)
```

- End a session (only the system administrator has the permission).

```
SELECT PG_TERMINATE_BACKEND(pid);
```

Viewing SQL Running Information

- Run the following command to obtain all SQL information that the current user has permission to view (if the current user has administrator or preset role permission, all user query information can be displayed):

```
SELECT usename,state,query FROM PG_STAT_ACTIVITY WHERE DATNAME='database name';
```

  If the value of **state** is **active**, the **query** column indicates the SQL statement that is being executed. In other cases, the **query** column indicates the previous query statement. If the value of **state** is **idle**, the connection is idle and waits for the user to enter a command. The following command output is displayed:

```
 usename | state  |                                  query
---------+--------+---------------------------------------------------------------------------
 leo     | idle   | select * from joe.mytable;
 dbadmin | active | SELECT usename,state,query FROM PG_STAT_ACTIVITY WHERE
DATNAME='gaussdb';
 joe     | idle   | GRANT SELECT ON TABLE mytable to leo;
(3 rows)
```

- Run the following command to view the information about the SQL statements that are not in the idle state:

```
SELECT datname,usename,query FROM PG_STAT_ACTIVITY WHERE state != 'idle' ;
```

Viewing Time-Consuming Statements

- Check the SQL statements that take a long time to execute.

```
SELECT current_timestamp - query_start as runtime, datname, usename, query FROM
PG_STAT_ACTIVITY WHERE state != 'idle' order by 1 desc;
```

  Query statements are returned and sorted by execution time length in descending order. The first record is the query statement that takes the longest time to execute.

```
    runtime     | datname  | usename |
query
-----------------+----------+---------
+-----------------------------------------------------------------------------------------------------------------------
--------------------
 00:04:47.054958 | gaussdb  | leo     | insert into mytable1 select generate_series(1, 10000000);
 00:00:01.72789  | gaussdb  | dbadmin | SELECT current_timestamp - query_start as runtime, datname,
usename, query FROM PG_STAT_ACTIVITY WHERE state != 'idle' order by 1 desc;
(2 rows)
```

- 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.

```
SELECT query from PG_STAT_ACTIVITY WHERE current_timestamp - query_start > interval '2 days';
```

Querying Blocked Statements

- Run the following command to view blocked query statements:

```
SELECT pid, datname, usename, state, query FROM PG_STAT_ACTIVITY WHERE state <> 'idle' and
waiting=true;
```

  Run the following statement to end the blocked SQL session:

```
SELECT PG_TERMINATE_BACKEND(pid);
```

NOTE

- In most cases, blocking is caused by internal locks and **waiting=true** is displayed. You can view the blocking in the **pg_stat_activity** view.
- The blocked statements about file write and event schedulers cannot be viewed in the **pg_stat_activity** view.

- View information about the blocked query statements, tables, and schemas:

```
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,
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 command output includes a session ID, user information, query status, and table or schema that caused the block.

After finding the blocked table or schema information, end the faulty session based on the session ID.

```
SELECT pgxc_terminate_query(query_id);
```

If **t** or **true** is returned, the session is ended.

If information similar to the following is returned, the user is attempting to terminate the session, but the session will be reconnected rather than 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 by the gsql client to terminate the background threads of the session, the client will be reconnected automatically rather than be terminated.

7 Cluster Management and Resource Load Monitoring

7.1 Binding Different Resource Pools to Two Types of Jobs to Balance Load for DWS

This practice demonstrates how to use DWS for resource management, helping enterprises eliminate bottlenecks in concurrent queries. SQL jobs can run smoothly without affecting each other and consume less resources than before.

This practice takes about 60 minutes. The process is as follows:

1. **Step 1: Creating a Cluster**
2. **Step 2: Connecting to a Cluster and Importing Data**
3. **Step 3: Creating a Resource Pool**
4. **Step 4: Verifying Exception Rules**

Scenarios

When multiple database users execute SQL jobs on DWS at the same time, the following situations may occur:

1. Some complex SQL statements occupy cluster resources for a long time, affecting the performance of other queries. For example, a group of database users continuously submit complex and time-consuming queries, and another group of users frequently submit short queries. In this case, short queries may have to wait in the resource pool for the time-consuming queries to complete.
2. Some SQL statements occupy too much memory or disk space due to data skew or unoptimized execution plans. As a result, the statements that fail to apply for memory report errors, or the cluster switches to the read-only mode.

To increase the system throughput and improve SQL performance, you can use workload management of DWS. For example, create a resource pool for users who frequently submit complex query jobs, and allocate more resources to this resource pool. The complex jobs submitted by these users can use only the resources of this resource pool. Create another resource pool that occupies less resources and add users who submit short queries to this resource pool. In this way, the two types of jobs can be smoothly executed at the same time.

For example, user A processes online transaction processing (OLTP) and online analytical processing (OLAP) services. The priority of the OLAP service is lower than that of OLTP service. A large number of concurrent complex SQL queries may cause server resource contention, whereas a large number of concurrent simple SQL queries can be quickly processed without being queued. Resources must be properly allocated and managed to ensure both OLAP and OLTP services can run smoothly.

OLAP services are often complex, and do not require high priority or real-time response. OLAP and OLTP services are operated by different users. For example, the database user **budget_config_user** is used for core transaction services, and the database user **report_user** is used for report services. The users are under independent CPU and concurrency management to improve database stability.

Based on the workload survey, routine monitoring, and test and verification of OLAP services, it is found that less than 50 concurrent SQL queries do not cause server resource contention or slow service system response. OLAP users can use 20% CPU resources.

Based on the workload survey, routine monitoring, and test and verification of OLTP services, it is found that less than 100 concurrent SQL queries do not pose continuous pressure onto the system. OLTP users can use 60% of CPU resources.

- Resource configuration for OLAP users (corresponding to **pool_1**): CPU = 20%, memory = 20%, storage = 1,024,000 MB, concurrency = 20.
- Resource configuration for OLTP users (corresponding to **pool_2**): CPU = 60%, memory = 60%, storage = 1,024,000 MB, concurrency = 200.

Set the maximum memory that can be used by a single statement. An error will be reported if the memory usage exceeds the value.

In **Exception Rule**, set **Blocking Time** to 1200s and **Execution Time** to 1800s. A query job will be terminated after being executed for more than 1800 seconds.

Step 1: Creating a Cluster

Create a cluster by referring to **Creating a cluster**.

Step 2: Connecting to a Cluster and Importing Data

Step 1 Use the client to connect to the cluster.

Step 2 Import sample data. For details, see **Importing TPC-H Data**.

Step 3 Run the following statements to create the OLTP user **budget_config_user** and OLAP user **report_user**.

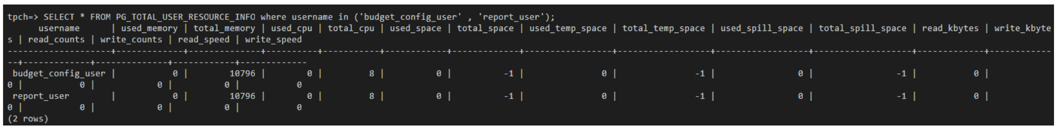
```
CREATE USER budget_config_user PASSWORD 'password';
CREATE USER report_user PASSWORD 'password';
```

Step 4 For test purposes, grant all permissions on all tables in schema **tpch** to both users.

```
GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA tpch to budget_config_user,report_user;
```

Step 5 Check the resource allocation of the two users.

SELECT * FROM PG_TOTAL_USER_RESOURCE_INFO where username in ('*budget_config_user*' , '*report_user*');



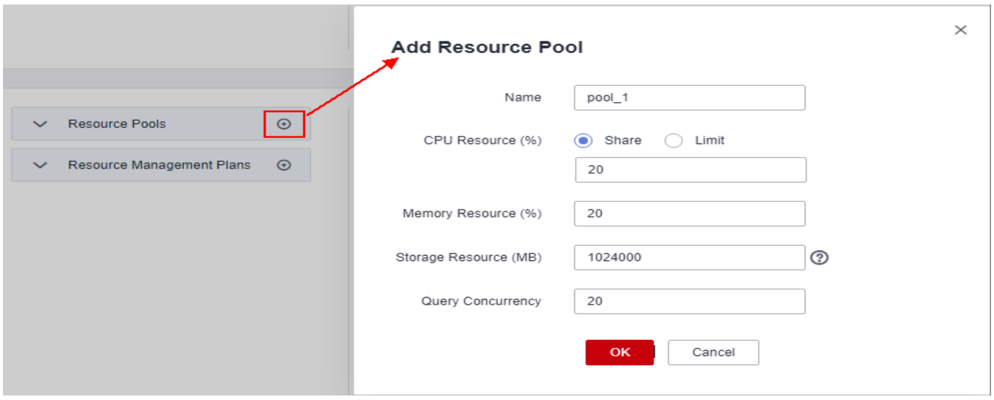
```
tpch=> SELECT * FROM PG_TOTAL_USER_RESOURCE_INFO where username in ('budget_config_user' , 'report_user');
      username      | used_memory | total_memory | used_cpu | total_cpu | used_space | total_space | used_temp_space | total_temp_space | used_spill_space | total_spill_space | read_kbytes | write_kbyte
s | read_counts | write_counts | read_speed | write_speed
--------------------+-------------+--------------+----------+-----------+------------+-------------+-----------------+------------------+------------------+-------------------+-------------+------------
--+-------------+--------------+------------+-------------
 budget_config_user |           0 |        10796 |        0 |         8 |          0 |          -1 |               0 |               -1 |                0 |                -1 |           0 |
0 |           0 |            0 |          0 |           0
 report_user        |           0 |        10796 |        0 |         8 |          0 |          -1 |               0 |               -1 |                0 |                -1 |           0 |
0 |           0 |            0 |          0 |           0
(2 rows)
```

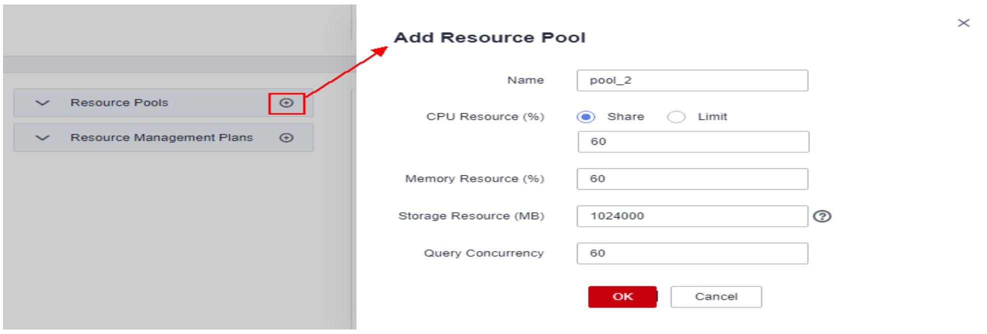
----End

Step 3: Creating a Resource Pool

Step 1 Log in to the **DWS console**. In the cluster list, click a cluster name and switch to the **Resource Management** page.

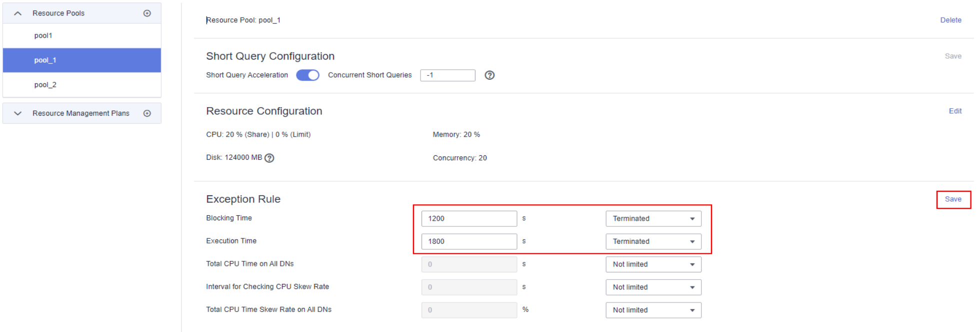
Step 2 Click **Add Workload Queue**. Create the report resource pool **pool_1** and transaction resource pool **pool_2** by referring to **Scenarios**.





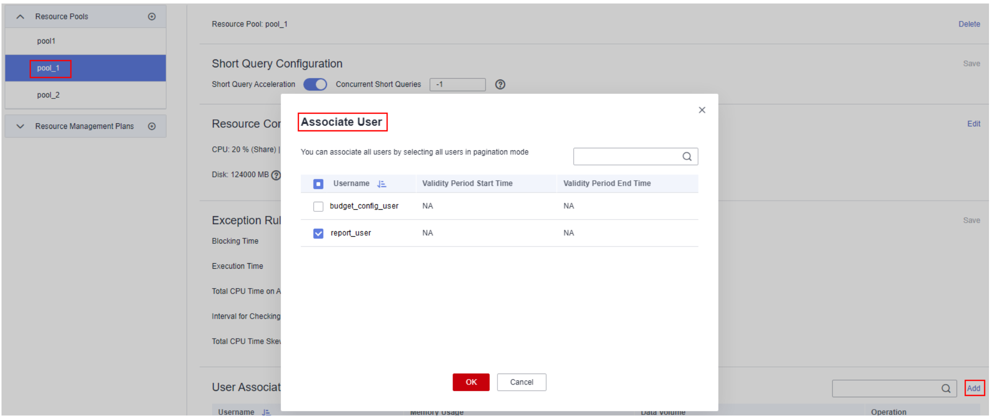
Step 3 Modify the exception rules.

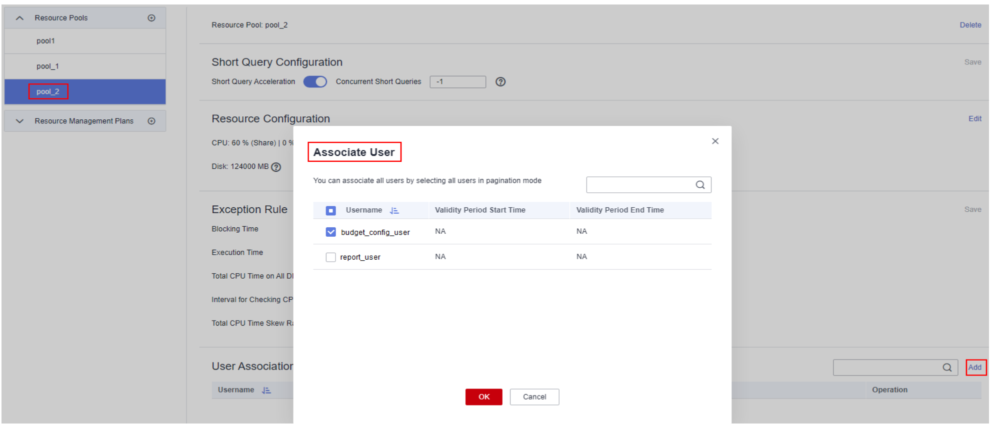
1. Click the created **pool_1**.
2. In the **Exception Rule** area, set **Blocking Time** to 1200s and **Execution Time** to 1800s.
3. Click **Save**.
4. Repeat the preceding steps to configure **pool_2**.



Step 4 Associate users.

1. Click **pool_1** on the left.
2. Click **Add** on the right of **User Association**.
3. Select **report_user** and click **OK**.
4. Repeat the preceding steps to add **budget_config_user** to **pool_2**.





----End

Step 4: Verifying Exception Rules

Step 1 Log in to the database as user **report_user**.

Step 2 Run the following command to check the resource pool to which the **report_user** user belongs:

```
SELECT usename,respool FROM pg_user WHERE usename = 'report_user';
```

```
gaussdb=> select usename,respool from pg_user where usename = 'report_user';
   usename   | respool
-------------+---------
 report_user | pool_1
(1 row)
```

The query result shows that the resource pool to which the **report_user** user belongs is **pool_1**.

Step 3 Verify the exception rule bound to the resource pool **pool_1**.

```
SELECT respool_name,mem_percent,active_statements,except_rule FROM pg_resource_pool WHERE
respool_name='pool_1';
```

```
gaussdb=> select respool_name,mem_percent,active_statements,except_rule from pg_resource_pool where respool_name='pool_1';
 respool_name | mem_percent | active_statements | except_rule
--------------+-------------+-------------------+-------------
 pool_1       |          20 |                20 | rule_1
(1 row)
```

It is confirmed that the exception rule **rule_1** is bound to **pool_1**.

Step 4 View the rule type and threshold of the exception rule for the current user.

```
SELECT * FROM pg_except_rule WHERE name = 'rule_1';
```

```
gaussdb=> select * from pg_except_rule where name = 'rule_1';
  name  |     rule     | value
--------+--------------+-------
 rule_1 | action       | abort
 rule_1 | blocktime    | 1200
 rule_1 | elapsedtime  | 1800
(3 rows)
```

The return shows that rule_1 has 1200 seconds of block time and 1800 seconds of running duration.

NOTICE

- **PG_EXCEPT_RULE** records information about exception rules and is supported only in cluster 8.2.0 or later.
- The relationship between parameters in the same exception rule is AND.

Step 5 When the block time of a job exceeds 1200s and the running duration exceeds 1800s, an error message is displayed, indicating that the exception rule is triggered and the job is canceled.

```
gaussdb=> insert into mytable select * from table1;
ERROR: canceling statement due to workload manager exception.
DETAIL: except rule [rule 1] is meet condition: rule [elapsedtime] is over limit. current value is: 1800. rule [blocktime] is over limit. current value is: 1200.
```

If error information similar to "ERROR: canceling statement due to workload manager exception." is displayed during job execution, the job is terminated because it exceeds the threshold of the exception rule. If the rules do not need to be modified, you need to optimize the service statements to reduce the execution time.

----End

7.2 Scaling Options for DWS with a Coupled Storage-Compute Architecture

Scalability is a critical feature for cloud services. It refers to cloud services' ability to increase or decrease compute and storage resources to meet changing demand, achieving a balance between performance and cost.

Typically, a distributed architecture offers the following types of scalability:

- Scale-out (horizontal scaling)

  With a scale-out, more nodes are added to an existing system to increase storage and compute capacities. For DWS, this means to expand the cluster size. To ensure proper resource utilization, make sure the hardware devices you add use the same specifications as the ones already in the cluster do.
- Scale-in (horizontal scaling)

  Scale-in is the opposite of scale-out. With a scale-in, nodes are removed from an existing system to decrease storage and compute capacities and by doing so, increase resource utilization. DWS is deployed by security ring, which means DWS clusters are scaled in or out by security ring as well. We will talk about security rings in more detail in a later section.
- Scale-up (vertical scaling)

  With a scale-up, more CPUs, memory, disks, or NICs are added to existing servers to increase the corresponding capacities. In some cases, lower-capacity hardware is replaced by higher-capacity ones. This is also referred to as hardware upgrade, which may entail an OS upgrade sometimes.
- Scale-down (vertical scaling)

  Scale-down is the opposite of scale-up. With a scale-down, the hardware of an existing system is downgraded to match demand.

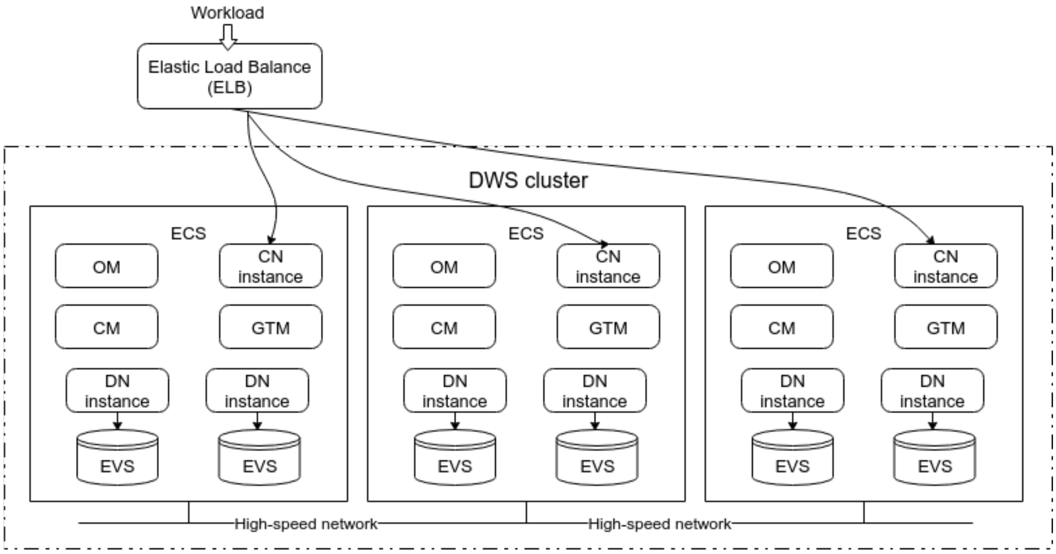
DWS offers various auto-scaling capabilities. You can adjust storage and computing resources by modifying hardware configurations (such as disks, memory, CPUs, and NICs) or by scaling distributed nodes. Additionally, you can scale out or scale up the cluster and adjust its topology.

A Closer Look at DWS Cluster Topology

To fully understand the scalability of DWS, one needs to understand DWS's typical cluster topology. The following figure shows a simplified ECS+EVS deployment structure of DWS.

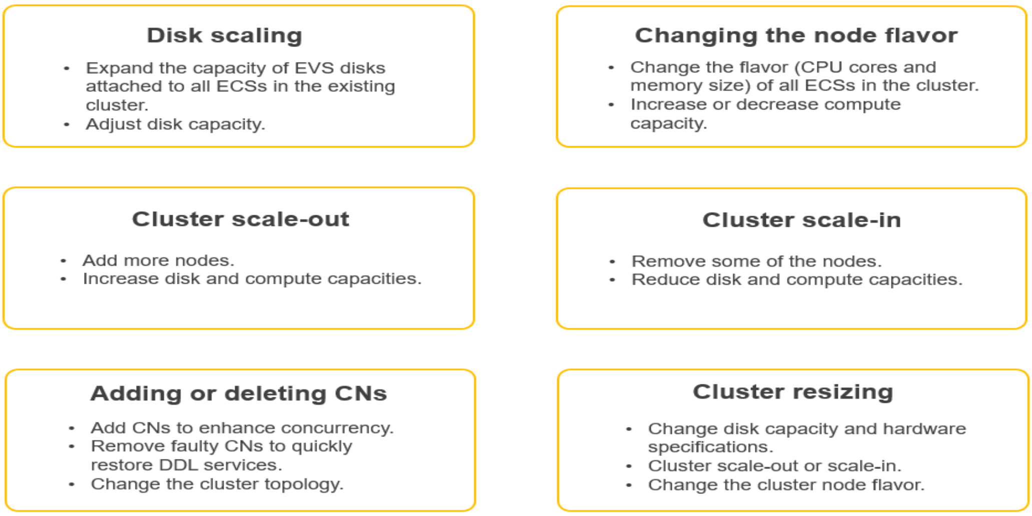
- ECSs provide compute resources, including CPUs and memory. DWS database instances (such as CNs and DNs) are deployed on ECSs.
- EVS provides storage resources. An EVS disk is attached to each DN.
- All ECSs in a DWS cluster are within the same VPC to ensure high-speed connections between them.
- All the database instances deployed on ECSs form a distributed, massively parallel processing database (MPPDB) cluster to provide data analysis and processing capabilities as a whole.

Figure 7-1 Cluster topology



Once you have had a good look at the typical topology of a DWS cluster, you can better understand DWS's scalability features. At present, DWS offers the following scaling options: disk scaling, node flavor change, cluster scale-out, cluster scale-in, cluster resizing, and CN addition or deletion, as illustrated by the figure below:

Figure 7-2 DWS scaling options

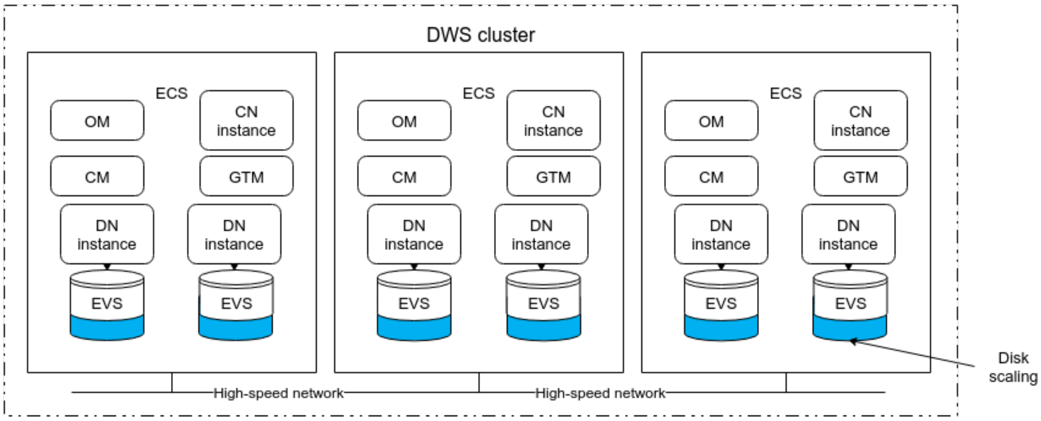


Disk Scaling

- With disk scaling, the size of all EVS disks attached to all ECSs in a cluster is changed. This option can be used to quickly scale disk capacity.
- Disk capacity can only be scaled up, and not down.
- Disk scaling is a lightweight operation that typically can be completed within 5 to 10 minutes. **It does not entail data migration or the restarting of services, so it does not interrupt services**. Nonetheless, you are advised to perform this operation during off-peak hours.

- For DWS's coupled storage-compute architecture, EVS disk specifications support disk scaling. The cluster version must be 8.1.1.203 or later.
- For details, see **Disk Capacity Expansion of an EVS Cluster**.

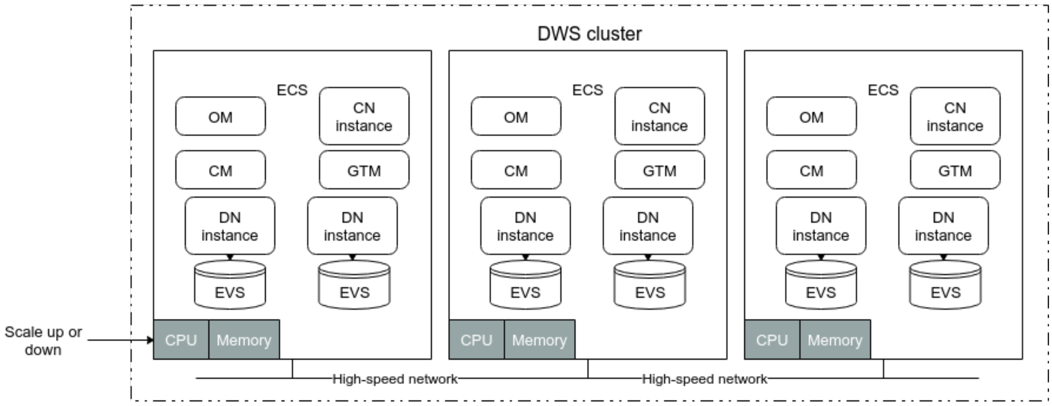
Figure 7-3 Disk scaling



Changing the Node Flavor

- This operation changes the flavor of all ECSs in a cluster. It can be used to quickly change CPU and memory specifications.
- A flavor is a preset resource template of a combination of a specific number of vCPUs and memory. For example, the flavor dwsx.16xlarge includes 64 vCPUs and 512 GB memory.
- Changing the node flavor is a lightweight operation that typically can be completed within 5 to 10 minutes. It does not involve data migration, but **services will need to be restarted once, causing a service interruption in minutes**. You are advised to perform this operation during off-peak hours.
- For DWS's coupled storage-compute architecture, EVS specifications support specification scaling. The cluster version must be 8.1.1.300 or later.
- For details, see **Changing the Node Flavor**.

Figure 7-4 Changing the node flavor



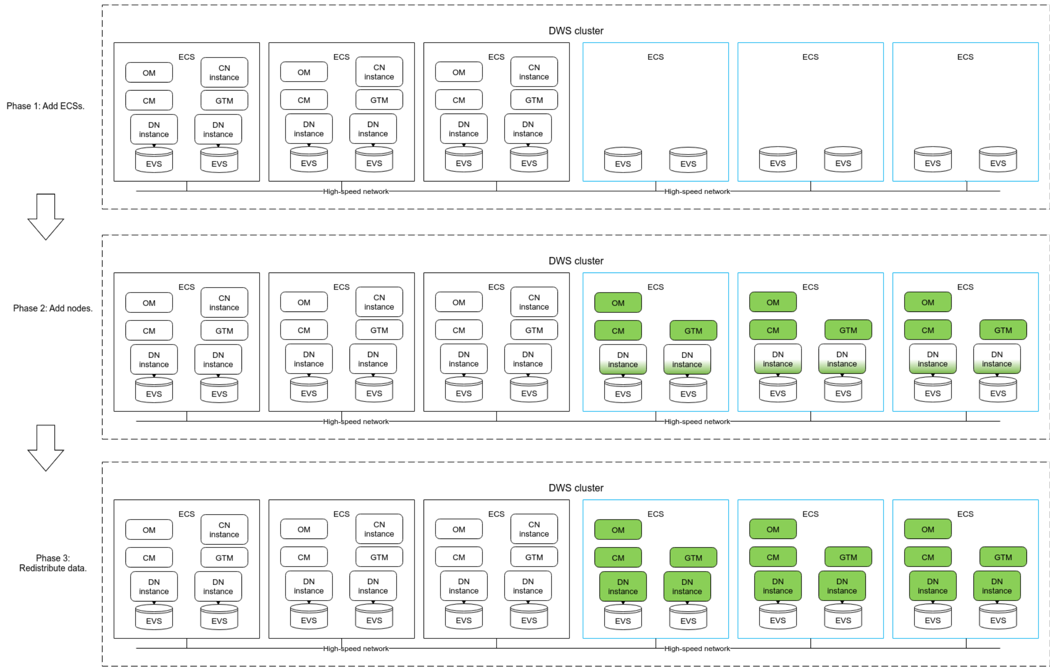
Scaling Out a Cluster

Cluster scale-out is a typical horizontal scaling scenario for MPPDBs, where homogeneous nodes are added to an existing cluster to increase capacity. DWS 2.0

uses coupled storage and compute, so a cluster scale-out expands both compute and storage capacities.

To balance the load and achieve optimal performance, metadata replication and data redistribution are performed during a cluster scale-out. Therefore, the time needed to complete a cluster scale-out is positively correlated with the number of database objects as well as the data size. To ensure reliability, new nodes are automatically added to security rings. This is why at least three nodes must be added for a scale-out operation.

Figure 7-5 Scaling out a cluster



8.1.1 and later versions support online scale-out. **During an online scale-out, DWS does not restart and can continue to provide services.** During data redistribution, you can perform insert, update, and delete operations on tables, but data updates may still be blocked for a short period of time. Redistribution consumes large quantities of CPU and I/O resources, significantly impacting job performance. Therefore, you are advised to perform redistribution when services are stopped or during periods of light load. A phase-by-phase approach is recommended for cluster scale-out: Perform high-concurrency redistribution during periods of light load, and stop redistribution or perform low-concurrency redistribution during periods of heavy load.

Cluster scale-out can be performed phase by phase or in one-click mode.

A phase-by-phase approach separates a scale-out operation into three phases: adding ECSs, adding nodes, and data redistribution. You can schedule the scale-out tasks in a way that can minimize the risk of service interruption.

On the other hand, a one-click scale-out is more convenient to users.

Table 7-1 Comparing two different scale-out approaches

Approach	Characteristics	Impact
Phase-by-phase scale-out	A scale-out operation is divided into three phases: adding ECSs, adding nodes, and data redistribution. You can schedule each phase for the most appropriate times and perform them separately.	The risk of service interruption can be minimized.
One-click scale-out	During a one-click scale-out, adding ECSs, adding nodes, and redistributing data are all performed automatically.	It is more convenient to users.

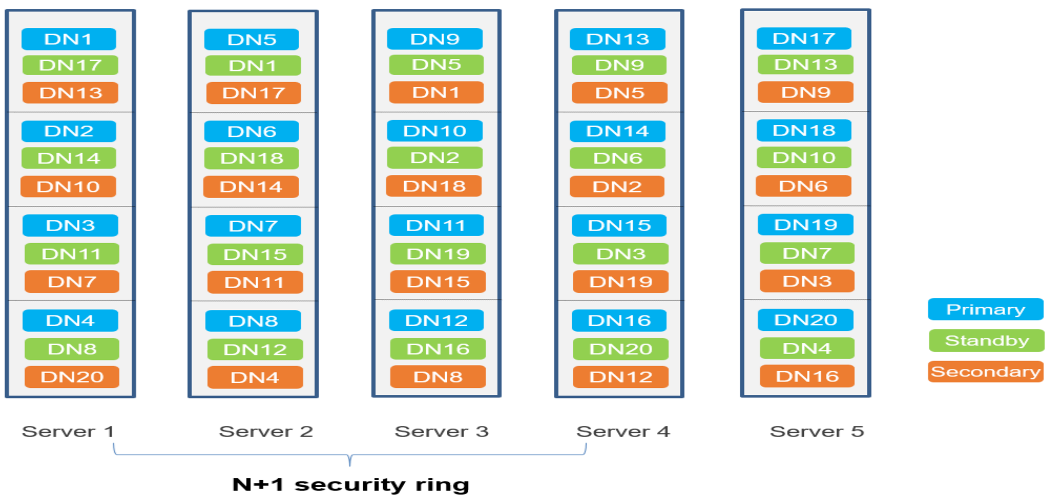
DWS Cluster Security Ring

A security ring is the minimum set of nodes required for the horizontal deployment of multi-replica DNs. Cluster scale-out and scale-in are both performed by security ring. The main idea behind security rings is fault isolation. Any fault that occurs within a security ring stays within that ring.

DWS uses a primary-standby-secondary architecture, so the minimum number of nodes in a security ring is **3**. When a fault occurs within a ring, it has no impact on nodes outside that ring. The scope of impact is minimized (3 nodes), and the impact on each node in that faulty ring is 1/(N-1), that is, 1/2. In extreme scenarios, the entire cluster is a security ring. If a fault occurs within this ring, the scope of impact is the largest (the entire cluster), but the impact on each node in the ring is the smallest, that is, 1/(N-1).

A common practice is to form an **N+1 ring**, where each node evenly distributes its N replicas to the remaining N nodes in the same ring. When a fault occurs in the ring, the scope of impact in the entire cluster is N+1 nodes, and the impact on each node in the ring is 1/N.

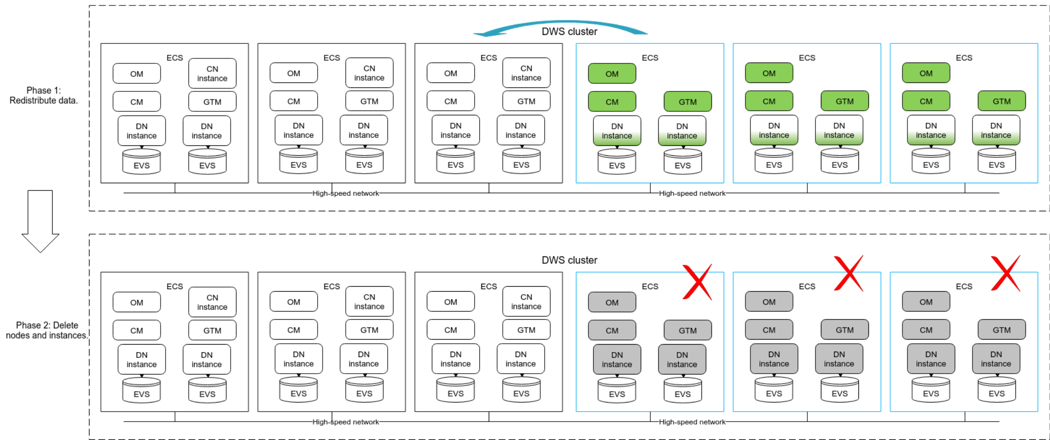
Figure 7-6 Typical N+1 security ring



Scaling In a Cluster

- Cluster scale-in is also a typical horizontal scaling scenario for MPPDBs, where some of the nodes of an existing cluster are removed to reduce capacity. A cluster scale-in reduces both compute and storage capacities.
- Each DWS cluster physically consists of multiple ECSs. To improve reliability, a set number of ECSs (typically three) form a logical security ring, so each DWS cluster consists of a number of security rings. **A cluster scale-in is performed by security ring. The security rings at the end of a cluster are first removed.**
- A cluster scale-in involves data migration. Data on the removed nodes needs to be redistributed to the remaining nodes. This means the time needed to complete a cluster scale-in is positively correlated with the number of database objects as well as the data size.
- DWS's coupled storage-compute architecture supports cluster scale-in. 8.1.1.300 and later versions support online scale-in. **During an online scale-in, DWS does not restart and can continue to provide services**. During data redistribution, you can perform insert, update, and delete operations on tables, but data updates may still be blocked for a short period of time. Redistribution consumes large quantities of CPU and I/O resources, significantly impacting job performance. Therefore, you are advised to perform redistribution when services are stopped or during periods of light load.

Figure 7-7 Scaling in a cluster

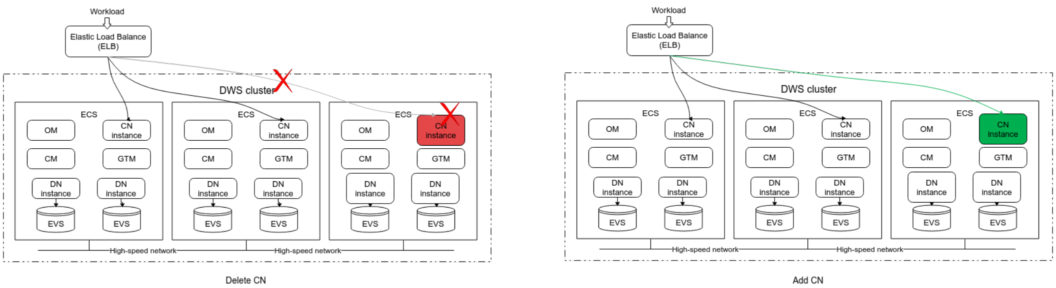


Adding or Deleting CNs

- Adding or deleting coordinator nodes (CNs) is another way of cluster scaling in DWS.
- CNs are an important component of DWS. It provides interfaces to external applications, optimizes global execution plans, distributes execution plans to data nodes (DNs), and summarizes results from each node into a single result set.
- CN capacities determine the entire cluster's concurrency handling capability. By adding more CNs, you increase the cluster's concurrency handling capability.

- CNs use a multi-active architecture. To ensure data consistency, if data on some CNs is damaged, DDL services will be blocked. To quickly restore DDL services, you can remove the faulty CNs.
- DWS supports adding or deleting CNs in 8.1.1 and later versions.
- When a CN is added, metadata needs to be synchronized. The time it takes to add a CN depends on the metadata size. In 8.1.3, CNs can be added and deleted online. **During CN addition, DWS does not restart and can continue to provide services**. DDL services will be blocked for a short period of time (with no error reported). No other services are affected.

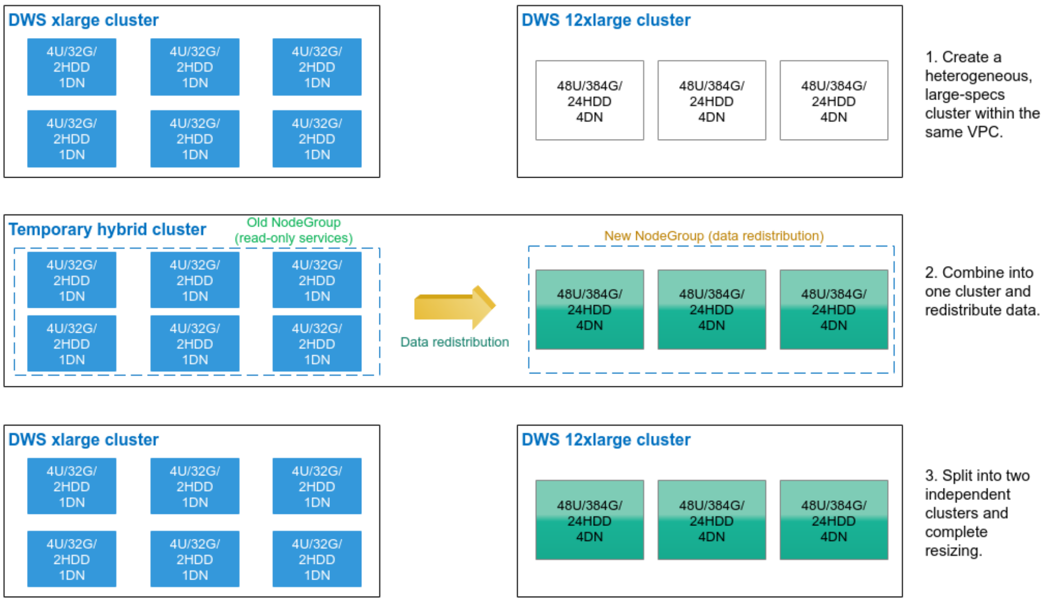
Figure 7-8 Adding or deleting a CN



Resizing a Cluster

- Cluster resizing allows you to perform horizontal and vertical scaling at the same time, including cluster scale-out and scale-in, as well as scale-up and scale-down. The cluster topology can also be adjusted.
- Clustering resizing relies on multiple node groups and data redistribution. During cluster resizing, a new cluster is created based on new resource requirements and cluster planning. Then, data is redistributed between the old and new clusters. Once data migration is complete, services are migrated to the new cluster, and after that, the old cluster is released.
- Cluster resizing involves data migration. Data on the nodes in the old cluster needs to be redistributed to the nodes in the new cluster, with the data still available in the old cluster. The time it takes to resize a cluster is positively correlated with the number of database objects as well as the data size.
- DWS supports cluster resizing, but agents must be upgraded to 8.2.0.2. **Currently, during cluster resizing, the old cluster can only support read-only services.** Online service capabilities can be expected later.
- For details, see **Changing All Specifications**.

Figure 7-9 Resizing a cluster



Comparing Different Scaling Options

The table below compares different scaling options for DWS.

Table 7-2 Comparing different scaling options for DWS

Option	Scaled Object	Scope	Impact	Product
Disk scaling	Disk capacity	EVS disks attached to all ECSs in a cluster	Can be completed within 5 to 10 minutes. **There is no need to restart services, so it has no impact on services**. Should be performed during off-peak hours.	Cluster version: 8.1.1.203 or later
Changing the node flavor	Compute capacity	The flavor (CPU cores and memory size) of all ECSs in a cluster	Can be completed within 5 to 10 minutes. **Services will need to be restarted once, causing a service interruption in minutes**. Should be performed during off-peak hours.	Cluster version: 8.1.1.300 or later

Option	Scaled Object	Scope	Impact	Product
Cluster scale-out	Disk and compute capacities	Adding homogeneous ECSs in a distributed architecture	Online scale-out supported. **During an online scale-out, DWS does not restart and can continue to provide services.** The duration is positively correlated with the number of database objects as well as the data size.	Cluster version: all versions. Online scale-out is supported since 8.1.1.
Cluster scale-in	Disk and compute capacities	Removing some of the ECSs in a distributed architecture	Online scale-in supported. **During an online scale-in, DWS does not restart and can continue to provide services.** The duration is positively correlated with the number of database objects as well as the data size.	Cluster version: 8.1.1.300
Cluster resizing	Disk and compute capacities, and cluster topology	Using a new ECS flavor (new hardware specifications) and new cluster topology to create a new cluster, and redistributing data between the old and new clusters	The duration is positively correlated with the number of database objects as well as the data size. Read-only services can be provided during cluster resizing.	Cluster version: Agent 8.2.0.2 or later
Adding or deleting CNs	CN instances	Adding CNs to enhance concurrency, or removing faulty CNs to quickly restore DDL services	Online addition and deletion of CNs is supported in 8.1.3 and later. **During CN addition, DWS does not restart and can continue to provide services.**	Cluster version: 8.1.1. (Online addition and deletion of CNs is supported in 8.1.3 and later.)

Application Scenarios for Different Scaling Options

Table 7-3 describes when to use each scaling option.

Table 7-3 Application scenarios for different scaling options for DWS

Category	Problem to Solve	Recommended Scaling Option	Impact on Services	Estimated Duration
Storage	Insufficient storage space. CPU, memory, and disk I/O capacities are sufficient.	Increase disk capacity.	Online services can be maintained.	No need for data migration. Can be completed within 5 to 10 minutes.
	Excessive storage space, which needs to be reduced to cut costs. CPU, memory, and disk I/O capacities are sufficient.	Create a cluster with smaller disk capacity (but otherwise unchanged), and migrate data to the new cluster by performing a DR switchover.	Data becomes read-only during the DR switchover, which typically takes less than 30 minutes.	The duration is positively correlated with the data size.
Compute	Insufficient CPU or memory capacity	Use a larger ECS flavor.	The cluster needs to restart once.	No need for data migration. Can be completed within 5 to 10 minutes.
	Insufficient disk I/O	Create a cluster with smaller disk capacity (but otherwise unchanged), and migrate data to the new cluster by performing a DR switchover.	Data becomes read-only during the DR switchover, which typically takes less than 30 minutes.	The duration is positively correlated with the data size.
Distributed compute and storage	Insufficient distributed capabilities due to insufficient nodes	Scale out the cluster.	Online services can be maintained (partially impacted).	Data migration is needed. The duration is positively correlated with the sizes of metadata as well as service data.

Category	Problem to Solve	Recommended Scaling Option	Impact on Services	Estimated Duration
	Too many nodes, leading to a high cost	Scale in the cluster.	Online services can be maintained (partially impacted).	Data migration is needed. The duration is positively correlated with the size of service data.
Cluster topology	Change both the cluster topology and node flavor (the number of DNs changes).	Resizes the cluster.	Read-only services	Data migration is needed. The duration is positively correlated with the sizes of metadata as well as service data.
	Change both the cluster topology and node flavor (the number of DNs remains the same).	Perform cluster DR switchover and data migration	Online services can be maintained (partially impacted).	Data migration is needed. The duration is positively correlated with the size of service data.
	Insufficient concurrency support	Add CNs.	Online services can be maintained (partially impacted).	Data migration is needed. The duration is positively correlated with the size of metadata.

8 Security Management

8.1 DWS Security Best Practices

Security is a shared responsibility between Huawei Cloud and you. Huawei Cloud is responsible for the security of cloud services to provide a secure cloud. As a tenant, you should properly use the security capabilities provided by cloud services to protect data, and securely use the cloud. For details, see **Shared Responsibilities**.

This practice provides actionable guidance for enhancing the overall security of your service data when using DWS.

Configure security settings in the following phases of using DWS to meet your service needs.

1. DWS cluster creation and database connection:
   - **Controlling Resource Access**
   - **Enabling Critical Operation Protection for the Console**
   - **Enabling Cluster-Level Transparent Encryption**
   - **Connecting to a Database Through SSL-encrypted Data Transmission**
2. Database object design:
   - **Isolating Workloads Through Database and Schema Configurations**
   - **Granting Permissions for Accessing and Modifying Table Data Using the Grant Syntax**
3. SQL service development:
   - **Enabling Row-level Access Control to Make Row-level Data Partially Visible**
   - **Masking Column Data**
   - **Using DWS Built-in Functions to Encrypt Data**
   - **Viewing Audit Logs to Check the Users Who Have Modified Service Data**
   - **Employing Intelligent O&M (Automatic Vacuum) to Address Service Performance Bottlenecks as They Arise**

4. O&M:
   – **Monitoring the Database Health on the Monitoring Panel**
   – **Periodically Backing Up Service Data**
   – **Enabling Cross-AZ Dual-Cluster DR**

Controlling Resource Access

If you want to give varying levels of access to your company's DWS resources on Huawei Cloud, using IAM is an effective way to manage permissions in detail. IAM provides identity authentication, permissions management, and access control, helping you securely manage access to your Huawei Cloud resources. With IAM, you can use your Huawei Cloud account to create IAM users and assign permissions to them to control their access to specific resources.

- **Scenario 1**: To allow software developers in your company to use DWS resources while restricting high-risk operations and resource deletion, you can create IAM users tailored for these developers and grant them only the essential permissions for DWS usage.
- **Scenario 2**: Allow employees to use only DWS resources, but not the resources of other services. To this end, grant them only the permissions for DWS.

You can use IAM to control cloud resource access and prevents misoperations on cloud resources.

Enabling Critical Operation Protection for the Console

DWS protects mission-critical operations. If you want to perform a mission-critical operation on the console, you must enter a credential for identity verification. You can perform the operation only after your identity is verified. For account security, you are advised to enable the operation protection function. This function takes effect for the account and its sub-users.

Currently, the following operations are supported: binding an EIP, scaling out a cluster, changing specifications, deleting a cluster, restarting a cluster, starting a cluster, stopping a cluster, adding or deleting a CN, upgrading a cluster, modifying parameters, deleting idle nodes, and enabling or disabling auto scaling.

For details, see **Enabling Critical Operation Protection for the DWS Console**.

Enabling Cluster-Level Transparent Encryption

In a traditional database cluster, user data is stored in plaintext in column-store or row-store files. Malicious cluster maintenance personnel or attackers can bypass the database permission control mechanism in the OS or steal disks to access user data. DWS interconnects with Huawei Cloud KMS to implement transparent data encryption and enhance user data security.

In DWS database-level TDE, each DWS cluster has a CEK and is configured with a DEK. DEKs are encrypted using the CEKs and their ciphertext is stored in DWS. Keys are applied for, encrypted, and decrypted through the KMS service. The cryptographic algorithm is configured using configuration items. Currently, AES and SM4 algorithms are supported.

For details, see **Using KMS to Encrypt DWS Clusters**.

Connecting to a Database Through SSL-encrypted Data Transmission

DWS supports the standard SSL. As a highly secure protocol, SSL authenticates bidirectional identification between the server and client using digital signatures and digital certificates to ensure secure data transmission. To support SSL connection, DWS has obtained the formal certificates and keys for the server and client from the CA certification center. It is assumed that the key and certificate for the server are **server.key** and **server.crt** respectively; the key and certificate for the client are **client.key** and **client.crt** respectively, and the name of the CA root certificate is **cacert.pem**.

The SSL mode delivers higher security than the common mode. By default, the SSL function is enabled in a cluster to allow SSL or non-SSL connections from the client. For security purposes, you are advised to enable SSL connection. The server certificate, private key, and root certificate have been configured in DWS by default.

For details, see **Establishing Secure TCP/IP Connections in SSL Mode**.

Isolating Workloads Through Database and Schema Configurations

In DWS, you can isolate workloads through database and schema configurations. The differences are:

- Databases cannot communicate with each other and share very few resources. Their connections and permissions can be isolated.
- Schemas share more resources than databases do. User permissions on schemas and subordinate objects can be flexibly configured using the **GRANT** and **REVOKE** syntax.

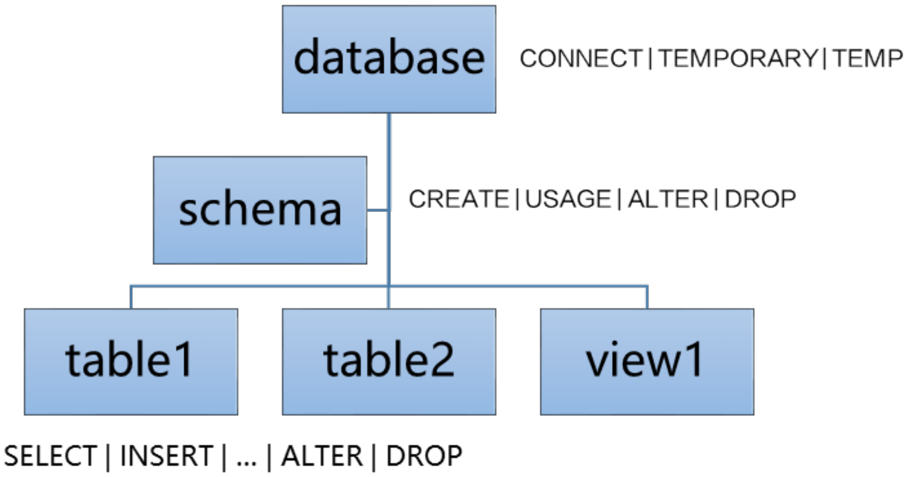
You are advised to use schemas to isolate services for convenience and resource sharing purposes. It is recommended that system administrators create schemas and databases and then assign required permissions to users.

1. Each database has one or more schemas. Each schema contains various types of objects, such as tables, views, and functions.
2. To access an object at the bottom layer, a user must be granted the permission on the object at the upper layer.

3. To create or delete a schema, you must have the **CREATE** permission for its database.
4. To access **table1** in a schema, a user must be granted the **CONNECT** permission for its **database**, the **USAGE** permission of the **schema**, and the **SELECT** permission of **table1**.

For details, see **How Does DWS Implement Workload Isolation?**

Figure 8-1 Permission levels



Granting Permissions for Accessing and Modifying Table Data Using the Grant Syntax

Authorizations

DWS uses the **GRANT** syntax to grant permissions to roles and users. A common user cannot access a table without the permissions granted by the system administrator **dbadmin** or the table owner. This default mechanism controls user access to data and can prevent data leakage.

GRANT is used in the following scenarios:

- Granting **system permissions** to roles or users

  System permissions are also called user attributes, including **SYSADMIN**, **CREATEDB**, **CREATEROLE**, **AUDITADMIN**, and **LOGIN**.

  They can be specified only by the **CREATE ROLE** or **ALTER ROLE** syntax. The **SYSADMIN** permission can be granted and revoked using **GRANT ALL PRIVILEGE** and **REVOKE ALL PRIVILEGE**, respectively. System permissions cannot be inherited by a user from a role, and cannot be granted using **PUBLIC**.

- Granting **database object permissions** to roles or users

  Grant permissions for a database object (table, view, column, database, function, or schema) to a role or user.

  GRANT grants specified database object permissions to one or more roles. These permissions are appended to those already granted, if any.

DWS grants the permissions on certain types of objects to **PUBLIC**. By default, permissions on tables, columns, sequences, foreign data sources, foreign servers, schemas, and tablespaces are not granted to **PUBLIC**, but the following permissions are granted to **PUBLIC**: **CONNECT** and **CREATE TEMP TABLE** permissions on databases, **EXECUTE** permission on functions, and **USAGE** permission on languages and data types (including domains). An object owner can revoke the default permissions granted to **public** and grant permissions to other users. For security purposes, create an object and set its permissions in the same transaction, so that the object will not be accessible to any other users until you configure its permissions and end the transaction. In addition, you can run the **ALTER DEFAULT PRIVILEGES** statement to modify the default permissions.

- Granting **a role's or user's permissions** to other roles or users

  Grant a role's or user's permissions to one or more roles or users. In this case, every role or user can be regarded as a set of one or more database permissions.

  If **WITH ADMIN OPTION** is specified, the member can in turn grant permissions in the role to others, and revoke permissions in the role as well. If a role or user granted with certain permissions is changed or revoked, the permissions inherited from the role or user also change.

  A database administrator can grant permissions to and revoke them from any role or user. Roles having **CREATEROLE** permission can grant or revoke membership in any role that is not an administrator.

For more information, see **GRANT**.

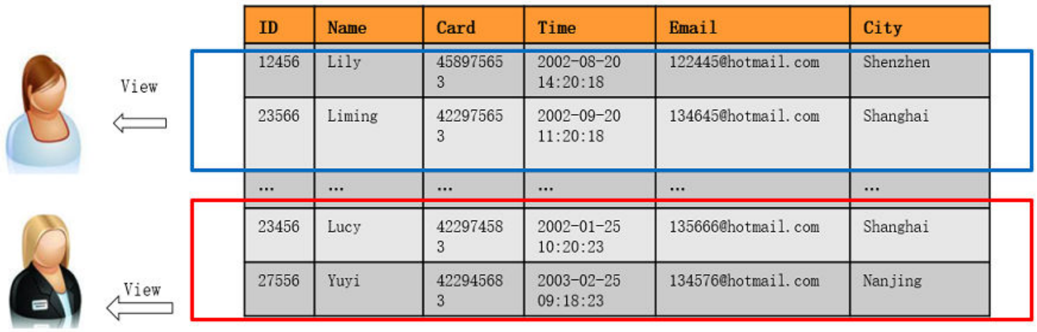
Revoking Permissions

After a user is granted with a database object permission, you can use the **REVOKE** syntax to revoke a permission from a user if the user no longer needs it, or if you need to control the user's permissions.

For more information, see **REVOKE**.

Enabling Row-level Access Control to Make Row-level Data Partially Visible

Multiple users may need to access and perform operations on the same table at the same time. In this case, you need to grant users the permissions for specific rows in the table. DWS can implement row-level access control. For example, a table administrator can see an entire table, but user A is allowed to view only specific rows in the table when they run **SELECT * FROM** *table_name*. This 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.



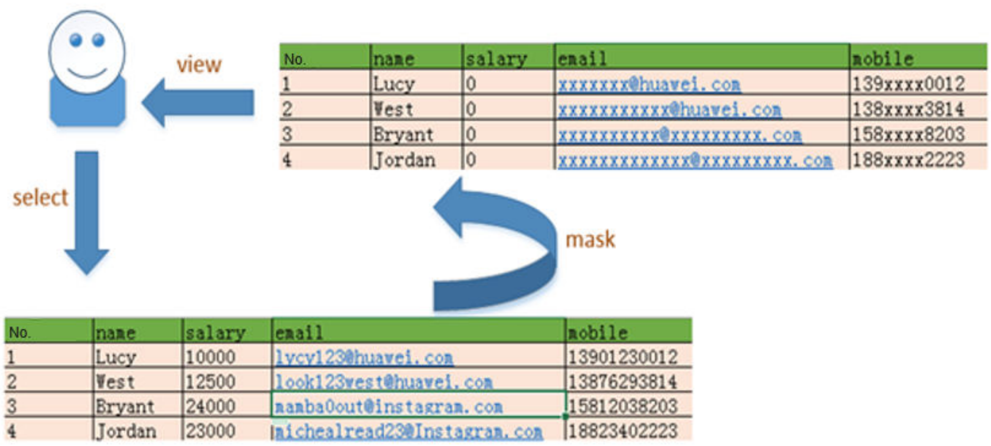
You can create a row-level access control policy for a data table. The policy defines an expression that takes effect only for specific database users and SQL operations. When a database user accesses the data table, if a SQL statement meets the specified row-level access control policies of the data 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**.

For details, see **Row-Level Access Control**.

Masking Column Data

DWS provides the column-level dynamic data masking function. For sensitive data, such as the ID card number, mobile number, and bank card number, the dynamic data masking function is used to redact the original data to protect data security and user privacy.



For details, see **Data Redaction**.

Using DWS Built-in Functions to Encrypt Data

Data encryption is widely used in information systems to prevent unauthorized access and data leakage. As the core of an information system, the DWS data warehouse also provides transparent encryption and encryption using SQL functions.

DWS provides hash functions and symmetric cryptographic algorithms to encrypt and decrypt columns. Hash functions include sha256, sha384, sha512, and SM3. Symmetric cryptographic algorithms include AES128, AES192, AES256, and SM4.

- Hash functions
  - md5(string)

    Use MD5 to encrypt string and return a hexadecimal value. MD5 is insecure and is not recommended.
  - gs_hash(hashstr, hashmethod)

    Obtains the digest string of a **hashstr** string based on the algorithm specified by **hashmethod**. **hashmethod** can be **sha256**, **sha384**, **sha512**, or **sm3**.
- Symmetric encryption algorithms
  - gs_encrypt(encryptstr, keystr, cryptotype, cryptomode, hashmethod)

    Encrypts an **encryptstr** string using the **keystr** key based on the cryptographic algorithm specified by **cryptotype** and **cryptomode** and the HMAC algorithm specified by **hashmethod**, and returns the encrypted string.
  - gs_decrypt(decryptstr, keystr, cryptotype, cryptomode, hashmethod)

    Decrypts a **decryptstr** string using the **keystr** key based on the cryptographic algorithm specified by **cryptotype** and **cryptomode** and the HMAC algorithm specified by **hashmethod**, and returns the decrypted string. The **keystr** used for decryption must be the same as that used for encryption.
  - gs_encrypt_aes128(encryptstr,keystr)

    Encrypts **encryptstr** strings using **keystr** as the key and returns encrypted strings. The length of **keystr** ranges from 1 to 16 bytes.
  - gs_decrypt_aes128(decryptstr,keystr)

    Decrypts **decryptstr** strings using **keystr** as the key and returns decrypted strings. The **keystr** used for decryption must be the same as that used for encryption. **keystr** cannot be empty.

For details, see **Encrypting and Decrypting Data Columns**.

Viewing Audit Logs to Check the Users Who Have Modified Service Data

Database audit logs record users' daily activities, including accessing and modifying service data. By reviewing these logs, database administrators can stay informed about the current state of service data access and modification, and proactively identify any potential risks related to data leakage or malicious tampering. For users who maliciously tamper with data, promptly disable their permissions to ensure service security. For details, see **Viewing Database Audit Logs**.

Employing Intelligent O&M (Automatic Vacuum) to Address Service Performance Bottlenecks as They Arise

Intelligent O&M helps DWS users with O&M tasks. With this feature, you can specify the proper time window and number of tasks to execute based on the cluster workload. Besides, Intelligent O&M can adjust task execution policies according to service changes in a timely manner to reduce the impact on services. Periodic tasks and one-off tasks are supported, and you can configure the time window as required.

The database administrator can configure the following tasks on the console to implement auto clean. For details, see **Intelligent O&M Overview**.

- Frequent table creation and deletion can lead to table bloating. To free up space, you can run the **VACUUM** command on system catalogs.
- Frequently update and delete operations can lead to table bloating. To free up space, you can run the **VACUUM** or **VACUUM FULL** command on system catalogs.

Monitoring the Database Health on the Monitoring Panel

DMS is provided by DWS to ensure the fast and stable running of databases. It collects, monitors, and analyzes disk, network, OS, and cluster performance metrics. It also diagnoses database hosts, instances, and service SQL statements based on the collected metrics to expose key faults and performance problems in a database in a timely manner, and guides customers to optimize and resolve the problems. For details, see **Cluster O&M**.

Periodically Backing Up Service Data

DWS supports cluster-level data backup to prevent data loss. Service data can be backed up to OBS. For details, see **Snapshot Overview**.

Enabling Cross-AZ Dual-Cluster DR

When a cluster is deployed within a single AZ, a fault in the AZ impacts all nodes in the cluster. Under these circumstances, cluster-level backup and recovery are inadequate for ensuring data security. Therefore, you can create two cross-AZ clusters to implement DR management.

A homogeneous DWS DR cluster is deployed in another AZ (within the region). If the production cluster fails to provide read and write services due to natural disasters in the specified region or cluster internal faults, the DR cluster becomes the production cluster to ensure service continuity.

For details, see **DWS Cluster DR Scenarios**.

