

..

Using Apache Iceberg

Date published: 2022-03-15

Date modified: 2023-11-20

CLOUDERA

Legal Notice

© Cloudera Inc. 2024. All rights reserved.

The documentation is and contains Cloudera proprietary information protected by copyright and other intellectual property rights. No license under copyright or any other intellectual property right is granted herein.

Unless otherwise noted, scripts and sample code are licensed under the Apache License, Version 2.0.

Copyright information for Cloudera software may be found within the documentation accompanying each component in a particular release.

Cloudera software includes software from various open source or other third party projects, and may be released under the Apache Software License 2.0 (“ASLv2”), the Affero General Public License version 3 (AGPLv3), or other license terms. Other software included may be released under the terms of alternative open source licenses. Please review the license and notice files accompanying the software for additional licensing information.

Please visit the Cloudera software product page for more information on Cloudera software. For more information on Cloudera support services, please visit either the Support or Sales page. Feel free to contact us directly to discuss your specific needs.

Cloudera reserves the right to change any products at any time, and without notice. Cloudera assumes no responsibility nor liability arising from the use of products, except as expressly agreed to in writing by Cloudera.

Cloudera, Cloudera Altus, HUE, Impala, Cloudera Impala, and other Cloudera marks are registered or unregistered trademarks in the United States and other countries. All other trademarks are the property of their respective owners.

Disclaimer: EXCEPT AS EXPRESSLY PROVIDED IN A WRITTEN AGREEMENT WITH CLOUDERA, CLOUDERA DOES NOT MAKE NOR GIVE ANY REPRESENTATION, WARRANTY, NOR COVENANT OF ANY KIND, WHETHER EXPRESS OR IMPLIED, IN CONNECTION WITH CLOUDERA TECHNOLOGY OR RELATED SUPPORT PROVIDED IN CONNECTION THEREWITH. CLOUDERA DOES NOT WARRANT THAT CLOUDERA PRODUCTS NOR SOFTWARE WILL OPERATE UNINTERRUPTED NOR THAT IT WILL BE FREE FROM DEFECTS NOR ERRORS, THAT IT WILL PROTECT YOUR DATA FROM LOSS, CORRUPTION NOR UNAVAILABILITY, NOR THAT IT WILL MEET ALL OF CUSTOMER’S BUSINESS REQUIREMENTS. WITHOUT LIMITING THE FOREGOING, AND TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, CLOUDERA EXPRESSLY DISCLAIMS ANY AND ALL IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY, QUALITY, NON-INFRINGEMENT, TITLE, AND FITNESS FOR A PARTICULAR PURPOSE AND ANY REPRESENTATION, WARRANTY, OR COVENANT BASED ON COURSE OF DEALING OR USAGE IN TRADE.

Contents

Apache Iceberg features.....	5
Alter table feature.....	5
Create table feature.....	6
Create table as select feature.....	8
Create partitioned table as select feature.....	8
Create table ... like feature.....	9
Delete data feature.....	9
Describe table metadata feature.....	11
Drop table feature.....	12
Expire snapshots feature.....	12
Insert table data feature.....	13
Load data inpath feature.....	14
Load or replace partition data feature.....	14
Materialized view feature.....	15
Materialized view rebuild feature.....	16
Merge feature.....	18
Migrate Hive table to Iceberg feature.....	19
Changing the table metadata location.....	19
Flexible partitioning.....	20
Partition evolution feature.....	20
Partition transform feature.....	21
Query metadata tables feature.....	22
Rollback table feature.....	23
Select Iceberg data feature.....	24
Schema evolution feature.....	24
Schema inference feature.....	25
Snapshot management.....	26
Time travel feature.....	26
Truncate table feature.....	27
Update data feature.....	27
 Best practices for Iceberg in CDP.....	 28
Making row-level changes on V2 tables only.....	29
 Performance tuning.....	 29
Caching manifest files.....	29
 Unsupported features and limitations.....	 30
 Prerequisites.....	 31
 Accessing Iceberg tables.....	 31
Editing a storage handler policy to access Iceberg files on the file system.....	32
Creating a SQL policy to query an Iceberg table.....	35

Accessing Iceberg files in Ozone.....	36
Creating an Iceberg partitioned table.....	38
Expiring snapshots.....	39
Inserting data into a table.....	39
Table migration overview.....	39
Migrating a Hive table to Iceberg.....	40
Selecting an Iceberg table.....	41
Running time travel queries.....	41
Updating an Iceberg partition.....	42
Test driving Iceberg from Impala.....	43
Test driving Iceberg from Hive.....	44
Hive demo data.....	46
Iceberg data types.....	49
Iceberg table properties.....	50

Apache Iceberg features

You can quickly build on your past experience with SQL to analyze Iceberg tables.

From Hive or Impala, you run SQL queries to create and query Iceberg tables. Impala queries are table-format agnostic. For example, Impala options are supported in queries of Iceberg tables. You can run nested, correlated, or analytic queries on all supported table types. Most Hive queries are also table-format agnostic.

This documentation does not attempt to show every possible query supported from Impala. Many examples of how to run queries on Iceberg tables from Impala are covered.

Supported ACID transaction properties

Iceberg supports atomic and isolated database transaction properties. Writers work in isolation, not affecting the live table, and perform a metadata swap only when the write is complete, making the changes in one atomic commit.

Iceberg uses snapshots to guarantee isolated reads and writes. You see a consistent version of table data without locking the table. Readers always see a consistent version of the data without the need to lock the table. Writers work in isolation, not affecting the live table, and perform a metadata swap only when the write is complete, making the changes in one atomic commit.

Iceberg partitioning

The Iceberg partitioning technique has performance advantages over conventional partitioning, such as Apache Hive partitioning. Iceberg hidden partitioning is easier to use. Iceberg supports in-place partition evolution; to change a partition, you do not rewrite the entire table to add a new partition column, and queries do not need to be rewritten for the updated table. Iceberg continuously gathers data statistics, which supports additional optimizations, such as partition pruning.

Iceberg uses multiple layers of metadata files to find and prune data. Hive and Impala keep track of data at the folder level and not at the file level, performing file list operations when working with data in a table. Performance problems occur during the execution of multiple list operations. Iceberg keeps track of a complete list of files within a table using a persistent tree structure. Changes to an Iceberg table use an atomic object/file level commit to update the path to a new snapshot file. The snapshot points to the individual data files through manifest files.

The manifest files track several data files across many partitions. These files store partition information and column metrics for each data file. A manifest list is an additional index for pruning entire manifests. File pruning increases efficiency.

Iceberg relieves Hive metastore (HMS) pressure by storing partition information in metadata files on the file system/object store instead of within the HMS. This architecture supports rapid scaling without performance hits.

Alter table feature

In Hive or Impala, you can use `ALTER TABLE` to set table properties. From Impala, you can use `ALTER TABLE` to rename a table, to change the table owner, or to change the role of the table owner. From Hive, you can alter the metadata location of the table if the new metadata does not belong to another table; otherwise, an exception occurs.

You can convert an Iceberg v1 table to v2 by setting a table property as follows: `'format-version' = '2'`.

Hive or Impala syntax

```
ALTER TABLE table_name SET TBLPROPERTIES table_properties;
```

- table_properties

A list of properties and values using the following syntax:

```
('key' = 'value', 'key' = 'value', ... )
```

Impala syntax

```
ALTER TABLE table_name RENAME TO new_table_name;

ALTER TABLE table_name SET OWNER USER user_name;

ALTER TABLE table_name SET OWNER ROLE role_name;
```

Hive example

```
ALTER TABLE test_table SET TBLPROPERTIES('metadata_location'='hdfs://ice_table/metadata/v1.metadata.json');

ALTER TABLE test_table2 SET TBLPROPERTIES('format-version' = '2');
```

Impala examples

```
ALTER TABLE t1 RENAME TO t2;

ALTER TABLE ice_table1 set OWNER USER john_doe;

ALTER TABLE ice_table2 set OWNER ROLE some_role;

ALTER TABLE ice_8 SET TBLPROPERTIES ('read.split.target-size'='268435456');

ALTER TABLE ice_table3 SET TBLPROPERTIES('format-version' = '2');
```

Create table feature

You use CREATE TABLE from Impala or CREATE EXTERNAL TABLE from Hive to create an external table in Iceberg. You learn the subtle differences in these features for creating Iceberg tables from Hive and Impala. You also learn about partitioning.

Hive and Impala handle external table creation a little differently, and that extends to creating tables in Iceberg. By default, Iceberg tables you create are v1. To create an Iceberg v2 table from Hive or Impala, you need to set a table property as follows: 'format-version' = '2'.

Iceberg table creation from Hive

From Hive, CREATE EXTERNAL TABLE is recommended to create an Iceberg table in CDP.

When you use the EXTERNAL keyword to create the Iceberg table, by default only the schema is dropped when you drop the table. The actual data is not purged. Conversely, if you do not use EXTERNAL, by default the schema and actual data is purged. You can override the default behavior. For more information, see the Drop table feature.

From Hive, you can create a table that reuses existing metadata by setting the metadata_location table property to the object store path of the metadata. The operation skips generation of new metadata and re-registers the existing metadata. Use the following syntax:

```
CREATE EXTERNAL TABLE ice_fm_hive (i int) STORED BY ICEBERG TBLPROPERTIES ('
metadata_location'='<object store or file system path>')
```

See examples below.

Iceberg table creation from Impala

From Impala, CREATE TABLE is recommended to create an Iceberg table in CDP. Impala creates the Iceberg table metadata in the metastore and also initializes the actual Iceberg table data in the object store.

The difference between Hive and Impala with regard to creating an Iceberg table is related to Impala compatibility with Kudu, HBase, and other tables. For more information, see the Apache documentation, ["Using Impala with Iceberg Tables"](#).

Metadata storage of Iceberg tables

When you create an Iceberg table using CREATE EXTERNAL TABLE in Hive or using CREATE TABLE in Impala, HiveCatalog creates an HMS table and also stores some metadata about the table on your object store, such as S3. Creating an Iceberg table generates a metadata.json file, but not a snapshot. In the metadata.json, the snapshot-id of a new table is -1. Inserting, deleting, or updating table data generates a snapshot. The Iceberg metadata files and data files are stored in the table directory under the warehouse folder. Any optional partition data is converted into Iceberg partitions instead of creating partitions in the Hive Metastore, thereby removing the bottleneck.

To create an Iceberg table from Hive or from Impala, you associate the Iceberg storage handler with the table using one of the following clauses, respectively:

- Hive: STORED BY ICEBERG
- Impala: STORED AS ICEBERG or STORED BY ICEBERG

Supported file formats

You can write Iceberg tables in the following formats:

- From Hive: Parquet (default), Avro, ORC
- From Impala: Parquet

Impala supports writing Iceberg tables in only Parquet format. Impala does not support defining both file format and storage engine. For example, CREATE TABLE tbl ... STORED AS PARQUET STORED BY ICEBERG works from Hive, but not from Impala.

You can read Iceberg tables in the following formats:

- From Hive: Parquet, Avro, ORC
- From Impala: Parquet, Avro, ORC



Note: Reading Iceberg tables in Avro format from Impala is available as a technical preview. Cloudera recommends that you use this feature in test and development environments. It is not recommended for production deployments.

Hive syntax

```
CREATE [EXTERNAL] TABLE [IF NOT EXISTS] [db_name.]table_name
[(col_name data_type, ...)]
[PARTITIONED BY [SPEC]([col_name][, spec(value)][, spec(value)]...)]
[STORED AS file_format]
  STORED BY ICEBERG
[TBLPROPERTIES ('key'='value', 'key'='value', ...)]
```

Impala syntax

```
CREATE TABLE [IF NOT EXISTS] [db_name.]table_name
[(col_name data_type, ...)]
[PARTITIONED BY [SPEC]([col_name][, spec(value)][, spec(value)]...)]
  STORED {AS | BY} ICEBERG
[TBLPROPERTIES (property_name=property_value, ...)]
```

Hive examples

```
CREATE EXTERNAL TABLE ice_1 (i INT, t TIMESTAMP, j BIGINT) STORED BY ICEBERG
;
CREATE EXTERNAL TABLE ice_2 (i INT, t TIMESTAMP) PARTITIONED BY (j BIGINT) STORED BY ICEBERG;
CREATE EXTERNAL TABLE ice_4 (i INT) STORED AS ORC STORED BY ICEBERG;
CREATE EXTERNAL TABLE ice_5 (i INT) STORED BY ICEBERG TBLPROPERTIES ('metadata_location'='hdfs://ice_table/metadata/v1.metadata.json')
CREATE EXTERNAL TABLE ice_6 (i INT) STORED AS ORC STORED BY ICEBERG TBLPROPERTIES ('format-version' = '2');
```

Impala examples

```
CREATE TABLE ice_7 (i INT, t TIMESTAMP, j BIGINT) STORED BY ICEBERG; //creates only the schema
CREATE TABLE ice_8 (i INT, t TIMESTAMP) PARTITIONED BY (j BIGINT) STORED BY ICEBERG; //creates schema and initializes data
CREATE TABLE ice_v2 (i INT, t TIMESTAMP) PARTITIONED BY (j BIGINT) STORED BY ICEBERG TBLPROPERTIES ('format-version' = '2'); //creates a v2 table
```

Create table as select feature

You can create an Iceberg table based on an existing Hive or Impala table.

The create table as select (CTAS) query can optionally include a partitioning spec for the table being created.

Hive examples

```
CREATE EXTERNAL TABLE ctas STORED BY ICEBERG AS SELECT i, t, j FROM ice_1;
```

Impala examples

```
CREATE TABLE ctas STORED BY ICEBERG AS SELECT i, b FROM ice_11;
```

Create partitioned table as select feature

You can create a partitioned Iceberg table by selecting another table. You see an example of how to use `PARTITIONED BY` and `TBLPROPERTIES` to declare the partition spec and table properties for the new table.

You see an example of using a [partition transform](#) with the `PARTITIONED BY SPEC` clause.

The newly created table does not inherit the partition spec and table properties from the source table in `SELECT`. The Iceberg table and the corresponding Hive table is created at the beginning of the query execution. The data is inserted / committed when the query finishes. So for a transient period the table exists but contains no data.

Hive syntax

```
CREATE [EXTERNAL] TABLE prod.db.sample
  USING iceberg
  PARTITIONED BY (part)
  TBLPROPERTIES ('key'='value')
  AS SELECT ...
```


Hive examples

```
CREATE EXTERNAL TABLE ctas STORED BY ICEBERG AS SELECT i, t, j FROM ice_1;

CREATE EXTERNAL TABLE ctas_part PARTITIONED BY(z) STORED BY ICEBERG TBLPROPERTIES ('format-version'='2')
AS SELECT x, ts, z FROM t;
CREATE EXTERNAL TABLE ctas_part_spec PARTITIONED BY SPEC (month(d)) STORED BY ICEBERG TBLPROPERTIES ('format-version'='2')
AS SELECT x, ts, d FROM source_t;
```

Impala examples

```
CREATE TABLE ctas STORED BY ICEBERG AS SELECT i, b FROM ice_11;

CREATE TABLE ctas_part PARTITIONED BY(b) STORED BY ICEBERG AS SELECT i, s, b FROM ice_11;
CREATE TABLE ctas_part_spec PARTITIONED BY SPEC (month(d)) STORED BY ICEBERG TBLPROPERTIES ('format-version'='2')
AS SELECT x, ts, d FROM source_t;
```

Create table ... like feature

You learn by example how to create an empty table based on another table.

From Hive or Impala, you can create an Iceberg table schema based on another table. The table contains no data. The table properties of the original table are carried over to the new table definition. The following examples show how to use this feature:

Hive example

```
CREATE EXTERNAL TABLE target LIKE source STORED BY ICEBERG;
```

Impala example

```
CREATE TABLE target LIKE source STORED BY ICEBERG;
```

Delete data feature

You can delete data in a V2 Iceberg table.

Hive and Impala delete Iceberg V2 table data using position delete files, [one type of formatting](#) defined by the [Iceberg Spec](#).

Position delete files contain the following information:

- file_path, which is a full URI
- pos, the file position of the row

Delete files are sorted by file_path and pos. The following table shows an example of delete files in a partitioned table:

Table 1:

Partition	Partition information	Delete file
YEAR(ts)=2022	ts_year=2022/data-abcd.parquet ts_year=2022/data-bcde.parquet	ts_year=2022/delete-wxyz.parquet
YEAR(ts)=2023	ts_year=2023/data-efgh.parquet	ts_year=2023/delete-hxkw.parquet
MONTH(ts)=2023-06	ts_month=2023-06/data-ijkl.parquet	ts_month=2023-06/delete-uzwd.parquet
MONTH(ts)=2023-07	ts_month=2023-07/data-mnop.parquet	ts_month=2023-07/delete-udqx.parquet

If you have a problem with deletes in the following situations, an equality delete file in the table is the likely cause:

- In Change Data Capture (CDC) applications
- In upserts from Apache Flink
- From a third-party engine

Inserting, deleting, or updating table data generates a snapshot.

You use a **WHERE** clause in your **DELETE** statement. For example:

```
delete from tbl_ice where a <= 2,1;
```

Hive and Impala evaluate rows from one table against a **WHERE** clause, and delete all the rows that match **WHERE** conditions. If you want delete all rows, use the Truncate feature. The **WHERE** expression is similar to the **WHERE** expression used in **SELECT**. The conditions in the **WHERE** clause can refer to any columns.

Concurrent operations that include **DELETE** do not introduce inconsistent table states. Iceberg runs validation checks to check for concurrent modifications, such as **DELETE+INSERT**. Only one will succeed. On the other hand, **DELETE+DELETE**, and **INSERT+INSERT** can both succeed, but in the case of a concurrent **DELETE+UPDATE**, **UPDATE+UPDATE**, **DELETE+INSERT**, **UPDATE+INSERT** from Hive, only the first operation will succeed.

From joined tables, you can delete all matching rows from one of the tables. You can join tables of any kind, but the table from which the rows are deleted must be an Iceberg table. The **FROM** keyword is required in this case, to separate the name of the table whose rows are being deleted from the table names of the join clauses.

Hive or Impala syntax

```
delete from tablename [where expression]
```

```
delete joined_tablename from [joined_tablename, joined_tablename2, ...] [ where expression ]
```

Hive or Impala examples

```
create external table tbl_ice(a int, b string, c int) stored by iceberg tblp
roperties ('format-version'='2');
```

```
insert into tbl_ice values (1, 'one', 50), (2, 'two', 51), (3, 'three', 5
2), (4, 'four', 53), (5, 'five', 54), (111, 'one', 55), (333, 'two', 56);
```

```
delete from tbl_ice where a <= 2,1;
```

The following example deletes 0, 1, or more rows of the table. If **coll** is a primary key, 0 or 1 rows are deleted:

```
delete from ice_table where coll = 100;
```

For more information, including examples, see [Using Impala with Iceberg Tables](#).

Describe table metadata feature

You can use certain Hive and Impala show and describe commands to get information about table metadata. You can also query metadata tables.

The following table lists SHOW and DESCRIBE commands supported by Hive and Impala.

Command Syntax	Description	SQL Engine Support
SHOW CREATE TABLE table_name	Reveals the schema that created the table.	Hive and Impala
SHOW FILES IN table_name	Lists the files related to the table.	Impala
SHOW PARTITIONS table_name	Returns the Iceberg partition spec, just the column information, not actual partitions or files.	Impala
DESCRIBE [EXTENDED] table_name	The optional EXTENDED shows all the metadata for the table in Thrift serialized form, which is useful for debugging.	Hive and Impala
DESCRIBE [FORMATTED] table_name	The optional FORMATTED shows the metadata in tabular format.	Hive
DESCRIBE HISTORY table_name [BETWEEN timestamp1 AND timestamp2]	Optionally limits the output history to a period of time.	Impala

Hive example

```
DESCRIBE t;
```

Hive output includes the following information:

col_name	data_type	comment
x	int	
y	int	
	NULL	NULL
# Partition Transform Information	NULL	NULL
# col_name	transform_type	NULL
y	IDENTITY	NULL

The output of DESCRIBE HISTORY includes the following columns about the snapshot. The first three are self-explanatory. The is_current_ancestor column value is TRUE if the snapshot is the ancestor of the table:

- creation_time
- snapshot_id
- parent_id
- is_current_ancestor

Impala examples

```
DESCRIBE HISTORY ice_t FROM '2022-01-04 10:00:00';
DESCRIBE HISTORY ice_t FROM now() - interval 5 days;
DESCRIBE HISTORY ice_t BETWEEN '2022-01-04 10:00:00' AND '2022-01-05 10:00:00';
```

Drop table feature

The syntax you use to create the table determines the default behavior when you drop the Iceberg table from Hive or Impala.

If you use CREATE TABLE, the external.table.purge flag is set to true. When the table is dropped, the contents of the table directory (actual data) are removed. If you use CREATE EXTERNAL TABLE from Hive, the external.table.purge flag is set to false. Dropping a table purges the schema only. The actual data is not removed. You can explicitly set the external.table.purge property to true to drop the data as well as the schema.

To prevent data loss during migration of a table to Iceberg, do not drop or move the table during migration.

Exception: If you set the table property 'external.table.purge'='FALSE', no data loss occurs if you drop the table.

Hive or Impala syntax

```
DROP TABLE [IF EXISTS] table_name
```

Hive or Impala example

```
ALTER TABLE t SET TBLPROPERTIES('external.table.purge'='true');
DROP TABLE t;
```

Expire snapshots feature

You can expire snapshots that Iceberg generates when you create or modify a table. During the lifetime of a table the number of snapshots of the table accumulate. You learn how to remove snapshots you no longer need.

You should periodically expire snapshots to delete data files that are no longer needed, and to reduce the size of table metadata. Each write to an Iceberg table from Hive creates a new snapshot, or version, of a table. Snapshots accumulate until expired.

You can expire snapshots based on the following conditions:

- All snapshots older than a timestamp or timestamp expression
- A snapshot having a given ID
- Snapshots having IDs matching a given list of IDs
- Snapshots within the range of two timestamps

You can keep snapshots you are likely to need, for example recent snapshots, and expire old snapshots. For example, you can keep daily snapshots for the last 30 days, then weekly snapshots for the past year, then monthly snapshots for the last 10 years. You can remove specific snapshots to meet GDPR “right to be forgotten” requirements.

Hive or Impala syntax

```
ALTER TABLE <table Name> EXECUTE EXPIRE_SNAPSHOTS(<timestamp expression>)

ALTER TABLE <table Name> EXECUTE EXPIRE_SNAPSHOTS('<Snapshot Id>')

ALTER TABLE <table Name> EXECUTE EXPIRE_SNAPSHOTS('<Snapshot Id1>,<Snapshot Id2>... ')

ALTER TABLE <table Name> EXECUTE EXPIRE_SNAPSHOTS BETWEEN (<timestamp expression>) AND (<timestamp expression>)
```

Hive or Impala example

The first example removes snapshots having a timestamp older than August 15, 2022 1:50 pm. The second example removes snapshots from 10 days ago and before.

```
ALTER TABLE ice_l1 EXECUTE EXPIRE_SNAPSHOTS('2022-08-15 13:50:00');
ALTER TABLE ice_t EXECUTE EXPIRE_SNAPSHOTS(now() - interval 10 days);
```

Preventing snapshot expiration

You can prevent expiration of recent snapshots by configuring the `history.expire.min-snapshots-to-keep` table property. You can use the alter table feature to set a property. The `history.expire.min-snapshots-to-keep` property refers to a number of snapshots, not a time delta. For example, assume you always want to keep all snapshots of your table for the last 24 hours. You configure `history.expire.min-snapshots-to-keep` as a safety mechanism to enforce this. If your table receives only one modification (insert / update / merge) per hour, then setting `history.expire.min-snapshots-to-keep = 24` is sufficient to meet your requirement. However, if your table was consistently receiving updates every minute, then the last 24 hour period would entail 1440 snapshots, and the `history.expire.min-snapshots-to-keep` setting would need to be configured appropriately.

Table data and orphan maintenance

The contents of the table directory (actual data) might, or might not, be removed when you drop the table. An orphan data file can remain when you drop an Iceberg table, depending on the `external.table.purge` flag table property. An orphaned data file is one that has contents in the table directory, but no snapshot.

Expiring a snapshot does not remove old metadata files by default. You must clean up metadata files using `write.metadata.delete-after-commit.enabled=true` and `write.metadata.previous-versions-max` table properties. For more information, see "Iceberg table properties" below. Setting this property controls automatic metadata file removal after metadata operations, such as expiring snapshots or inserting data.

Related Information

[Iceberg table properties](#)

Insert table data feature

From Hive and Impala, you can insert data into Iceberg tables using the standard `INSERT INTO` a single table. `INSERT` statements work for V1 and V2 tables.

You can replace data in the table with the result of a query. To replace data, Hive and Impala dynamically overwrite partitions that have rows returned by the `SELECT` query. Partitions that do not have rows returned by the `SELECT` query, are not replaced. Using `INSERT OVERWRITE` on tables that use the `BUCKET` partition transform is not recommended. Results are unpredictable because dynamic overwrite behavior would be too random in this case.

From Hive, CDP also supports inserting into multiple tables as a technical preview; however, this operation is not atomic, so data consistency of Iceberg tables is equivalent to that of Hive external tables. Changes within a single table will remain atomic.

Inserting, deleting, or updating table data generates a snapshot. A new snapshot corresponds to a new manifest list. Manifest lists are named `snap-*.avro`.

Iceberg specification defines sort orders. At this point, Hive doesn't support defining sort orders. But if there are sort orders defined by using other engines Hive can utilize them on write operations. For more information about sorting, see [sort orders specification](#).

Hive or Impala syntax

```
INSERT INTO TABLE tablename VALUES values_row [, values_row ...]

INSERT INTO TABLE tablename1 select_statement1 FROM tablename2
```

```
INSERT OVERWRITE TABLE tablename1 select_statement1 FROM tablename2
```

Hive or Impala examples

```
CREATE TABLE ice_10 (i INT, s STRING, b BOOLEAN) STORED BY ICEBERG;
INSERT INTO ice_10 VALUES (1, 'asf', true);
CREATE TABLE ice_11 (i INT, s STRING, b BOOLEAN) STORED BY ICEBERG;
INSERT INTO ice_11 VALUES (2, 'apache', false);
INSERT INTO ice_11 SELECT * FROM ice_10;
SELECT * FROM ice_11;
INSERT OVERWRITE ice_11 SELECT * FROM ice_10;
```

Hive example

```
FROM customers
  INSERT INTO target1 SELECT customer_id, first_name;
  INSERT INTO target2 SELECT last_name, customer_id;
```

Load data inpath feature

From Impala, you can load Parquet or ORC data from a file in a directory on your file system or object store into an Iceberg table. You might need to set the `mem_limit` or pool configuration (`max-query-mem-limit`, `min-query-mem-limit`) to accommodate the load.

Impala syntax

```
LOAD DATA INPATH '<path to file>' INTO table t;
```

Impala example

In this example, you create a table using the `LIKE` clause to point to a table stored as Parquet. This is required for Iceberg to infer the schema. You also load data stored as ORC.

```
CREATE TABLE test_iceberg LIKE my_parquet_table STORED AS ICEBERG;
SET MEM_LIMIT=1MB;

LOAD DATA INPATH '/tmp/some_db/parquet_files/' INTO TABLE iceberg_tbl;

LOAD DATA INPATH '/tmp/some_db/orc_files/' INTO TABLE iceberg2_tbl;
```

Load or replace partition data feature

There is no difference in the way you insert data into a partitioned or unpartitioned Iceberg table.

Working with partitions is easy because you write the query in the same way for the following operations:

- Insert into, or replace, an unpartitioned table
- Insert into, or replace, an identity partitioned table
- Insert into, or replace, a transform-partitioned table

Do not use `INSERT OVERWRITE` on tables that went through partition evolution. Truncate such tables first, and then `INSERT` the tables.

Impala example

```
CREATE TABLE ice_12 (i int, s string, t timestamp, t2 timestamp) STORED BY ICEBERG;
```

Hive or Impala examples

```
INSERT INTO ice_12 VALUES (42, 'impala', now(), to_date(now()));
INSERT OVERWRITE ice_t VALUES (42, 'impala', now(), to_date(now()));
```

Materialized view feature

Using a materialized view can accelerate query execution. Creating a materialized view on top of Iceberg tables in CDP can further accelerate the performance. You can create a materialized view of an Iceberg V1 or V2 table based on an existing Hive or Iceberg table.

The materialized view is stored in Hive ACID or Iceberg format. Materialized view source tables either must be native ACID tables or must support table snapshots. Automatic rewriting of a materialized view occurs under the following conditions:

- The view definition contains the following operators only:
 - TableScan
 - Project
 - Filter
 - Join(inner)
 - Aggregate
- Source tables are native ACID or Iceberg v1 or v2
- The view is not based on time travel queries because those views do not have up-to-date data by definition.

Hive example

The following example creates a materialized view of an Iceberg table from Hive.

```
drop table if exists tbl_ice;
create external table tbl_ice(a int, b string, c int) stored by iceberg stored as orc tblproperties ('format-version'='2');

create materialized view mat1 as
select b, c from tbl_ice for system_version as of 5422037307753150798;
```

The following example creates a materialized view of two Iceberg tables. Joined tables must be in the same table format, either Iceberg or Hive ACID.

```
drop table if exists tbl_ice2;
create table tbl_ice2(a int, b string, c int) stored as orc TBLPROPERTIES ('transactional'='true');
INSERT INTO tbl_ice2 VALUES (2, 'apache', 3);

drop table if exists tbl_ice;
create external table tbl_ice(a int, b string, c int) stored by iceberg stored as orc tblproperties ('format-version'='2');
INSERT INTO tbl_ice VALUES (4, 'iceberg', 5);
create materialized view mat1 as
select tbl_ice2.b, tbl_ice2.c from tbl_ice join tbl_ice2 on tbl_ice.a = tbl_ice2.a;
```

The following example uses `explain` to examine a materialized view and then creates a materialized view of an Iceberg V1 table from Hive.

```
drop materialized view if exists mat1;
drop table if exists tbl_ice;

create table tbl_ice(a int, b string, c int) stored by iceberg stored as orc
tblproperties ('format-version'='1');
insert into tbl_ice values (1, 'one', 50), (2, 'two', 51), (3, 'three', 52),
(4, 'four', 53), (5, 'five', 54);
explain create materialized view mat1 stored by iceberg stored as orc tblpr
operties ('format-version'='1') as
select tbl_ice.b, tbl_ice.c from tbl_ice where tbl_ice.c > 52;

create materialized view mat1 stored by iceberg stored as orc tblproperties
('format-version'='1') as
select tbl_ice.b, tbl_ice.c from tbl_ice where tbl_ice.c > 52;
```

Materialized view rebuild feature

Updates to materialized view contents when new data is added to the underlying table are critical; otherwise, queries can return stale data.

An update can occur under the following conditions:

- As a row-level incremental rebuild of the view after inserting data into a table
Source tables can be Iceberg V2 or Hive full ACID.
- As a full rebuild of the view

A full rebuild can be expensive. An incremental rebuild updates only the affected parts of the materialized view, decreasing rebuild step execution time.

An incremental rebuild occurs automatically when you insert (append) data into a source table; otherwise, after you make some other type of change, for example a delete, you must manually start a full rebuild.

You use the `ALTER` command to manually start a full rebuild of the materialized view from Hive as follows:

Hive syntax

```
ALTER MATERIALIZED VIEW <name of view> REBUILD;
```

Full rebuild example

In this example, first you set required properties. Next, you create Iceberg tables, a V1 table and a V2 table, from Hive. You insert data into the tables and create a materialized view of the joined tables. You insert some new values into one of the source tables, rendering the materialized view stale. Finally, you rebuild the materialized view using `explain cbo` to show the rebuild plan. The rebuild plan indicates a full rebuild will occur, which means the definition query will be executed.

```
drop table if exists tbl_ice;
drop table if exists tbl_ice_v2;
create external table tbl_ice(a int, b string, c int) stored by iceberg sto
red as orc tblproperties ('format-version'='1');
create external table tbl_ice_v2(d int, e string, f int) stored by iceberg
stored as orc tblproperties ('format-version'='2');
insert into tbl_ice_v2 values (1, 'one v2', 50), (4, 'four v2', 53), (5, 'f
ive v2', 54);
```



```

create materialized view mat1 as
select tbl_ice.b, tbl_ice.c, tbl_ice_v2.e from tbl_ice
join tbl_ice_v2 on tbl_ice.a=tbl_ice_v2.d where tbl_ice.c > 52;
group by tbl_ice.b tbl_ice.c;

-- view should be empty
select * from mat1;

-- view is up-to-date, use it
explain cbo
select tbl_ice.b, tbl_ice.c, tbl_ice_v2.e from tbl_ice join tbl_ice_v2 on
tbl_ice.a=tbl_ice_v2.d where tbl_ice.c > 52;

-- insert some new values to one of the source tables
insert into tbl_ice values (1, 'one', 50), (2, 'two', 51), (3, 'three', 52),
(4, 'four', 53), (5, 'five', 54);

-- view is outdated, cannot be used
explain cbo
select tbl_ice.b, tbl_ice.c, tbl_ice_v2.e from tbl_ice join tbl_ice_v2 on tb
l_ice.a=tbl_ice_v2.d where tbl_ice.c > 52;

explain cbo
alter materialized view mat1 rebuild;

-- view should contain data
select * from mat1;

-- view is up-to-date again, use it
explain cbo
select tbl_ice.b, tbl_ice.c, tbl_ice_v2.e from tbl_ice join tbl_ice_v2 on tb
l_ice.a=tbl_ice_v2.d where tbl_ice.c > 52;
group by tbl_ice.b tbl_ice.c;

```

Automatic query rewrite example

In this example, you create an Iceberg table, insert some values, and create the materialized view. The view is partitioned using a partition specification and stored in the Iceberg ORC format. The v1 format version is specified in this example (the v2 format is also supported). You then look at a description of the view and see that the query rewrite option is enabled by default. An automatic incremental rebuild is possible when this option is enabled.

```

drop table if exists tbl_ice;
create external table tbl_ice(a int, b string, c int) stored by iceberg
stored as orc tblproperties ('format-version'='1');

-- insert some new values into one of the source tables

insert into tbl_ice values (1, 'one', 50), (2, 'two', 51), (3, 'three', 5
2), (4, 'four', 53), (5, 'five', 54);

explain
create materialized view mat1 partitioned on spec (bucket(16, b), trunc
ate(3, c)) stored by Iceberg stored as orc tblproperties('format-version'='1
')as
select tbl_ice.b, tbl_ice.c from tbl_ice where tbl_ice.c > 52;

-- the output query plan query indicates a rewrite is enabled

POSTHOOK: query: explain
create materialized view mat1 ...
...

```

```

    STAGE PLANS
    ...
    -- In stage one, the materialized view is created by calling the Iceberg
    API to create the table object.
    rewrite enabled
    ...

```

You use the DESCRIBE command to see the output query plan, which shows details about the view, including if it can be used in automatic query rewrites.

```

-- check the materialized view details
describe formatted mat1;

...
#col_name      data_type      comment
b              string
c              int

#Partition Transform Information
#col_name      transform_type
b              bucket(16)
c              TRUNCATE[3]

#detailed table information
...
Table_type:    MATERIALIZED_VIEW
Table Parameters:
...
current-snapshot-id  563939E424367334713
...
metadata_location    ...
...
Table_type            Iceberg
...
#Materialized View Information
Original Query:  ...
Expanded Query:  ...
Rewrite Enabled: Yes

```

With the query rewrite option enabled, you insert data into the source table, and incremental rebuild occurs automatically. You do not need to rebuild the view manually before running queries.

Merge feature

You can perform actions on an Iceberg table based on the results of a join with a v2 Iceberg table.

Hive syntax

```

MERGE INTO <target table> AS T USING <source expression/table> AS S
ON <boolean expression1>
WHEN MATCHED [AND <boolean expression2>] THEN UPDATE SET <set clause list>
WHEN MATCHED [AND <boolean expression3>] THEN DELETE
WHEN NOT MATCHED [AND <boolean expression4>] THEN INSERT VALUES <value list>

```

Hive example

Use the MERGE INTO statement to update an Iceberg table based on a staging table:

```

MERGE INTO customer USING (SELECT * FROM new_customer_stage) sub ON sub.id =
customer.id

```

```
WHEN MATCHED THEN UPDATE SET name = sub.name, state = sub.new_state
WHEN NOT MATCHED THEN INSERT VALUES (sub.id, sub.name, sub.state);
```

Create an Iceberg table and merge it with a non-Iceberg table.

```
create external table target_ice(a int, b string, c int) partitioned by spec
(bucket(16, a), truncate(3, b)) stored by iceberg stored as orc tblproperties
('format-version'='2');
create table source(a int, b string, c int);
...

merge into target_ice as t using source src ON t.a = src.a
when matched and t.a > 100 THEN DELETE
when matched then update set b = 'Merged', c = t.c + 10
when not matched then insert values (src.a, src.b, src.c);
```

Migrate Hive table to Iceberg feature

CDP supports Hive table migration from Hive to Iceberg tables using ALTER TABLE to set the table properties.



Note: Do not drop or move the old table during a migration operation. Doing so will delete the data files of the old and new tables. Exception: If you set the table property 'external.table.purge'='FALSE', no data loss occurs when you drop the table.

In-place table migration process

In-place table migration saves time generating Iceberg tables. There is no need to regenerate data files. Only metadata, which points to source data files, is regenerated.

To convert a Hive table to an Iceberg V1 table from Impala, use the following syntax:

```
ALTER TABLE table_name CONVERT TO ICEBERG;
```

To convert a Hive table to an Iceberg V2 table from Impala you must run two queries. Use the following syntax:

```
ALTER TABLE table_name CONVERT TO ICEBERG

ALTER TABLE table_name SET TBLPROPERTIES ('format-version' = '2'
...)
```

In-place table migration saves time generating Iceberg tables. There is no need to regenerate data files. Only metadata, which points to source data files, is regenerated.

Changing the table metadata location

From Hive and Impala, you can change the table metadata location, also known as the snapshot location.

Configuring security of Iceberg file metadata

In this release, you can prevent overrides of the Iceberg file metadata location by unauthorized users. If you do not prevent overrides, an unauthorized party who knows the underlying schema and file location outside the table location can rewrite the manifest files within one table location to point to the data files in another table location to read your data. You accept the default (true), or set a property in the Virtual Warehouse to true to prevent overrides:

- Hive property: `hive.iceberg.allow.datafiles.in.table.location.only`

```
SET hive.iceberg.allow.datafiles.in.table.location.only = true;
```

- Impala property: iceberg_restrict_data_file_location

```
SET iceberg_restrict_data_file_location = true;
```

Prerequisites for changing the metadata location

- The new location must contain exactly the same metadata json file as the old location.
- Before changing the metadata location, you must migrate the table to Iceberg.

After migrating a table to Iceberg, you can change the metadata location using ALTER TABLE as shown below:

Hive and Impala example

```
ALTER TABLE test_table SET TBLPROPERTIES('metadata_location'='s3a://bucketName/ice_table/metadata/v1.metadata.json');
```

Flexible partitioning

Iceberg partition evolution, which is a unique Iceberg feature, and the partition transform feature, greatly simplify partitioning tables and changing partitions.

Partitions based on transforms are stored in the Iceberg metadata layer, not in the directory structure. You can change the partitioning completely, or just refine existing partitioning, and write new data based on the new partition layout--no need to rewrite existing data files. For example, change a partition by month to a partition by day.

Use partition transforms, such as IDENTITY, TRUNCATE, BUCKET, YEAR, MONTH, DAY, HOUR. Iceberg solves scalability problems caused by having too many partitions. Partitioning can also include columns with a large number of distinct values. Partitioning is hidden in the Iceberg metadata layer, eliminating the need to explicitly write partition columns (YEAR, MONTH for example) or to add extra predicates to queries for partition pruning.

```
SELECT * FROM tbl WHERE ts = '2023-04-21 20:56:08'
AND YEAR = 2023 AND MONTH = 4 AND DAY = 21
```

Year, month, and day can be automatically extracted from '2023-04-21 20:56:08' if the table is partitioned by DAY(ts)

Partition evolution feature

Partition evolution means you can change the partition layout of the table without rewriting existing data files. Old data files can remain partitioned by the old partition layout, while newly added data files are partitioned based on the new layout.

You can use the ALTER TABLE SET PARTITION SPEC statement to change the partition layout of an Iceberg table. A change to the partition spec results in a new metadata.json and a commit, but does not create a new snapshot.

Hive or Impala syntax

```
ALTER TABLE table_name SET PARTITION SPEC ([col_name][, spec(value)][, spec(value)]...)]
```

- spec

The specification for a transform listed in the next topic, "Partition transform feature".

Hive or Impala examples

```
ALTER TABLE t
```

```
SET PARTITION SPEC ( TRUNCATE(5, level), HOUR(event_time),
BUCKET(15, message), price);
ALTER TABLE ice_p
SET PARTITION SPEC (VOID(i), VOID(d), TRUNCATE(3, s), HOUR(t), i);
```

Partition transform feature

From Hive or Impala, you can use one or more partition transforms to partition your data. Each transform is applied to a single column. Identity-transform means no transformation; the column values are used for partitioning. The other transforms apply a function to the column values and the data is partitioned by the transformed values.

Using CREATE TABLE ... PARTITIONED BY you create identity-partitioned Iceberg tables. Identity-partitioned Iceberg tables are similar to the Hive or Impala partitioned tables, which are stored in the same directory structure as the data files. Iceberg stores the partitioning columns of identity-partitioned Iceberg tables in a different directory structure from the data files if the tables are migrated to Iceberg from Hive external tables. Iceberg handles the tables and files regardless of the location.

Hive and Impala support Iceberg advanced partitioning through the PARTITION BY SPEC clause. Using this clause, you can define the Iceberg partition fields and partition transforms.

The following table lists the available transformations of partitions and corresponding transform spec.

Transformation	Spec	Supported by SQL Engine
Partition by year	years(time_stamp) year(time_stamp)	Hive and Impala
Partition by month	months(time_stamp) month(time_stamp)	Hive and Impala
Partition by a date value stored as int (dateint)	days(time_stamp) date(time_stamp)	Hive
Partition by hours	hours(time_stamp)	Hive
Partition by a dateint in hours	date_hour(time_stamp)	Hive
Partition by hashed value mod N buckets	bucket(N, col)	Hive and Impala
Partition by value truncated to L, which is a number of characters	truncate(L, col)	Hive and Impala

Strings are truncated to length L. Integers and longs are truncated to bins. For example, truncate(10, i) yields partitions 0, 10, 20, 30 ...

The idea behind transformation partition by hashed value mod N buckets is the same as [hash bucketing for Hive tables](#). A hashing algorithm calculates the bucketed column value (modulus). For example, for 10 buckets, data is stored in column value % 10, ranging from 0-9 (0 to n-1) buckets.

You use the PARTITIONED BY SPEC clause to partition a table by an identity transform.

Hive syntax

```
CREATE [EXTERNAL] TABLE [IF NOT EXISTS] [db_name.]table_name
[(col_name data_type)[, time_stamp TIMESTAMP] ]
[PARTITIONED BY SPEC([col_name][, spec(value)][, spec(value)]...)]
[STORED AS file_format]
STORED BY ICEBERG
[TBLPROPERTIES (property_name=property_value, ...)]
```

Where spec(value) represents one or more of the following transforms:

- YEARS(col_name)
- MONTHS(col_name)
- DAYS(col_name)
- BUCKET(bucket_num,col_name)
- TRUNCATE(length, col_name)

Impala syntax

```
CREATE TABLE [IF NOT EXISTS] [db_name.]table_name
  [(col_name data_type, ... )]
  [PARTITIONED BY SPEC([col_name][, spec(value)][, spec(value)]...)]
  STORED (AS | BY) ICEBERG
  [TBLPROPERTIES (property_name=property_value, ...)]
```

Where spec(value) represents one or more of the following transforms:

- YEARS(col_name)
- MONTHS(col_name)
- DAYS(col_name)
- BUCKET(bucket_num,col_name)
- TRUNCATE(length, col_name)

Hive example

The following example creates a top level partition based on column i, a second level partition based on the hour part of the timestamp, and a third level partition based on the first 1000 characters in column j.

```
CREATE EXTERNAL TABLE ice_3 (i INT, t TIMESTAMP, j BIGINT) PARTITIONED BY SPEC (i, HOUR(t), TRUNCATE(1000, j)) STORED BY ICEBERG;
```

Impala examples

```
CREATE TABLE ice_13 (i INT, t TIMESTAMP, j BIGINT) PARTITIONED BY SPEC (i, HOUR(t), TRUNCATE(1000, j)) STORED BY ICEBERG;
```

The following examples show how to use the PARTITION BY SPEC clause in a CREATE TABLE query from Impala. The same transforms are available in a CREATE EXTERNAL TABLE query from Hive.

```
CREATE TABLE ice_t(id INT, name STRING, dept STRING)
PARTITIONED BY SPEC (bucket(19, id), dept)
STORED BY ICEBERG
TBLPROPERTIES ('format-version'='2');
```

```
CREATE TABLE ice_ctas
PARTITIONED BY SPEC (truncate(1000, id))
STORED BY ICEBERG
TBLPROPERTIES ('format-version'='2')
AS SELECT id, int_col, string_col FROM source_table;
```

Related Information

[Creating an Iceberg partitioned table](#)

Query metadata tables feature

From Hive and Impala, you can query Iceberg metadata tables as you would query a Hive table. For example, you can use projections, joins, filters, and so on.

The following Iceberg metadata tables are available from Hive and Impala:

- entries
- files
- manifests
- partitions

- snapshots

The following additional Iceberg metadata tables are available from Impala:

- history
- all_data_files
- all_entries
- all_manifests

For more information about querying Iceberg metadata, see the [Apache Iceberg Spark documentation](#).

Hive and Impala Syntax

To reference a metadata table, use the full name of the table as shown in the following syntax:

```
<DATABASE_NAME> . <TABLE_NAME> . <METADATA_TABLE_NAME>
```

Hive and Impala Example

```
SELECT * FROM default.table_a.files;
```

Limitations

- The following types are not supported: ARRAY, MAP, BINARY
- Nested types are not expanded by default when the you execute a SELECT *.
- You cannot explore the tables. For example, you cannot list the available metadata tables or describe the tables.

Rollback table feature

In the event of a problem with your table, you can reset a table to a good state as long as the snapshot of the good table is available. You can roll back the table data based on a snapshot id or a timestamp.

When you modify an Iceberg table, a new snapshot of the earlier version of the table is created. When you roll back a table to a snapshot, a new snapshot is created. The creation date of the new snapshot is based on the Timezone of your session. The snapshot id does not change.

Hive and Impala syntax

```
ALTER TABLE test_table EXECUTE rollback(snapshotID);
ALTER TABLE test_table EXECUTE rollback('timestamp');
```

Hive and Impala examples

The following example rolls back to an earlier table, creating a new snapshot having a new creation date timestamp, but keeping the same snapshot id 3088747670581784990.

```
ALTER TABLE ice_t EXECUTE ROLLBACK(3088747670581784990);
```

The following example rolls the table back to the latest snapshot having a creation timestamp earlier than '2022-08-08 00:00:00'.

```
ALTER TABLE ice_7 EXECUTE ROLLBACK('2022-08-08 00:00:00')
```

Select Iceberg data feature

You can read Iceberg tables from Impala as you would any table. Joins, aggregations, and analytical queries, for example, are supported.

Impala supports reading V2 tables with [position deletes](#).

Hive or Impala example

```
SELECT * FROM ice_t;

SELECT count(*) FROM ice_t i LEFT OUTER JOIN other_t b
ON (i.id = other_t.fid)
WHERE i.col = 42;
```

Schema evolution feature

You learn that the Hive or Impala schema changes when the associated Iceberg table changes. You see examples of changing the schema.

Although you can change the schema of your table over time, you can still read old data files because Iceberg uniquely identifies schema elements. A schema change results in a new metadata.json and a commit, but does not create a new snapshot.

The Iceberg table schema is synchronized with the Hive/Impala table schema. A change to the schema of the Iceberg table by an outside entity, such as Spark, changes the corresponding Hive/Impala table. You can change the Iceberg table using ALTER TABLE to make the following changes:

From Hive:

- Add a column
- Replace a column
- Change a column type or its position in the table

From Impala:

- Add a column
- Rename a column
- Drop a column
- Change a column type

An unsafe change to a column type, which would require updating each row of the table for example, is not allowed. The following type changes are safe:

- int to long
- float to double
- decimal(P, S) to decimal(P', S) if precision is increased

You can drop a column by changing the old column to the new column.

Hive syntax

```
ALTER TABLE table_name ADD COLUMNS (col_name type[, ...])
ALTER TABLE table_name CHANGE COLUMN col_old_name col_new_name type

ALTER TABLE table_name CHANGE COLUMN col_old_name col_new_name type [FIRST|
AFTER col_name] [existing_col_name
]
```



```
ALTER TABLE table_name REPLACE COLUMNS (col_name type)
```

Impala syntax

```
ALTER TABLE table_name ADD COLUMNS(col_name type[, ...])

ALTER TABLE table_name CHANGE COLUMN col_old_name col_new_name type
ALTER TABLE table_name DROP COLUMN col_name
```

Hive examples

```
ALTER TABLE t ADD COLUMNS(message STRING, price DECIMAL(8,1));

ALTER TABLE t REPLACE COLUMNS (i int comment '...', a string, ...);
ALTER TABLE t CHANGE COLUMN col_x col_x DECIMAL (22, 3) AFTER col_y;
```

Impala examples

```
ALTER TABLE ice_12 ADD COLUMNS(message STRING, price DECIMAL(8,1));
ALTER TABLE ice_12 DROP COLUMN i;

ALTER TABLE ice_12 CHANGE COLUMN s str STRING;
```

Schema inference feature

From Hive or Impala, you can base a new Iceberg table on a schema in a Parquet file. You see a difference in the Hive and Impala syntax and examples.

From Hive, you must use `FILE` in the `CREATE TABLE LIKE ...` statement. From Impala, you must omit `FILE` in the `CREATE TABLE LIKE ...` statement. The column definitions in the Iceberg table are inferred from the Parquet data file when you create a table like Parquet from Hive or Impala. Set the following table property for creating the table:

```
hive.parquet.infer.binary.as = <value>
```

Where `<value>` is `binary` (the default) or `string`.

This property determines the interpretation of the unannotated Parquet binary type. Some systems expect binary to be interpreted as string.

Hive syntax

```
CREATE [EXTERNAL] TABLE [IF NOT EXISTS] [db_name.]table_name LIKE FILE PARQUET 'object_storage_path_of_parquet_file'
[PARTITIONED BY [SPEC]([col_name][, spec(value)][, spec(value)]...)]
[STORED AS file_format]
STORED BY ICEBERG
[TBLPROPERTIES (property_name=property_value, ...)]
```

Impala syntax

```
CREATE TABLE [IF NOT EXISTS] [db_name.]table_name LIKE PARQUET 'object_storage_path_of_parquet_file'
[PARTITIONED BY [SPEC]([col_name][, spec(value)][, spec(value)]...)]
STORED (AS | BY) ICEBERG
[TBLPROPERTIES (property_name=property_value, ...)]
```

Hive example

```
CREATE TABLE ctlf_table LIKE FILE PARQUET 'hdfs://files/schema.parq'
      STORED BY ICEBERG;
```

Impala example

```
CREATE TABLE ctlf_table LIKE PARQUET 'hdfs://files/schema.parq'
      STORED BY ICEBERG;
```

Snapshot management

In addition to time travel queries, expiring a snapshot, and using a snapshot to rollback to a version of a table, you can also set any snapshot to be the current snapshot from Hive.

Hive syntax

```
ALTER TABLE TBL_ICEBERG_PART EXECUTE SET_CURRENT_SNAPSHOT (<snapshot ID>)
```

Hive example

```
ALTER TABLE TBL_ICEBERG_PART EXECUTE SET_CURRENT_SNAPSHOT (75212489901265493
11)
```

Time travel feature

From Hive or Impala, you can run point in time queries for auditing and regulatory workflows on Iceberg tables. Time travel queries can be time-based or based on a snapshot ID.

Iceberg generates a snapshot when you create, or modify, a table. A snapshot stores the state of a table. You can specify which snapshot you want to read, and then view the data at that timestamp. In Hive, you can use projections, joins, and filters in time travel queries. You can add expressions to the timestamps, as shown in the examples. You can expire snapshots.

Snapshot storage is incremental and dependent on the frequency and scale of updates. By default, Hive and Impala use the latest snapshot. You can query an earlier snapshot of Iceberg tables to get historical information. Hive and Impala use the latest schema to query an earlier table snapshot even if it has a different schema.

Hive or Impala syntax

```
SELECT * FROM table_name FOR SYSTEM_TIME AS OF 'time_stamp' [expression]
SELECT * FROM table_name FOR SYSTEM_VERSION AS OF snapshot_id [expression]
```

- `time_stamp`
The state of the Iceberg table at the time specified by the UTC timestamp.
- `snapshot_id`
The ID of the Iceberg table snapshot from the history output.

Hive or Impala examples

```
SELECT * FROM t FOR SYSTEM_TIME AS OF '2021-08-09 10:35:57' LIMIT 100;
```

```
SELECT * FROM t FOR SYSTEM_VERSION AS OF 3088747670581784990 limit 100;
SELECT * from ice_11 FOR SYSTEM_TIME AS OF now() - interval 30 minutes;
```

Truncate table feature

Truncating an Iceberg table removes all rows from the table. A new snapshot is created. Truncation works for partitioned and unpartitioned tables.

Although the table data and the table and column stats are cleared, the old snapshots and their data files continue to exist to support time travel in the future.

Hive syntax

```
TRUNCATE table_name
```

Impala syntax

```
TRUNCATE [TABLE] table_name
```

Hive or Impala example

```
TRUNCATE t;
```

Update data feature

From Hive or Impala, you can update data from a V2 Iceberg table.

The Iceberg V2 format allows row-level modifications using delete files. Row-level updates are supported. Hive and Impala write position to denote deleted or updated records. For information about position delete files, see the Delete data feature and Row-level operations topics.

Updating table data generates a new snapshot for the table.

You can use a WHERE clause in your UPDATE statement. For example:

```
update tbl_ice set b='Changed' where b in (select b from tbl_ice where a < 4);
```

Hive or Impala evaluates rows from the target table against a WHERE clause, and updates all the rows that match the WHERE condition. The WHERE condition is similar to the WHERE condition used in SELECT.

Impala prerequisites

The target table should be an Iceberg V2 table. Therefore set the following table property during table creation, or use ALTER TABLE SET TBLPROPERTIES on existing Iceberg V1 tables: 'format-version' = '2'

You must write data and delete files in Parquet format. Set the following table properties to meet this prerequisite:

- 'write.format.default' = 'PARQUET'
- 'write.delete.format.default' = 'PARQUET'

Hive or Impala syntax

```
update tablename set column = value [, column = value ...] [where expres
sion]
```

Hive examples

```
create external table tbl_ice(a int, b string, c int) stored by iceberg tblp
roperties ('format-version'='2');
insert into tbl_ice values (1, 'one', 50), (2, 'two', 51), (3, 'three', 52),
(4, 'four', 53), (5, 'five', 54), (111, 'one', 55), (333, 'two', 56);

update tbl_ice set b='Changed' where b in (select b from tbl_ice where a <
4);
```

Updating a table from a non-Iceberg source

From Impala, you can use UPDATE FROM to update an Iceberg table based on a source table or view that is another Iceberg or non-Iceberg table. For example:

```
UPDATE tbl_ice SET tbl_ice.one = t.one, tbl_ice.two = t.two, FROM tbl_ice, t
bl_hive one where tbl_ice.pk = one.pk;
```

Best practices for Iceberg in CDP

Based on large scale TPC-DS benchmark testing, performance testing and real-world experiences, Cloudera recommends several best practices when using Iceberg.

Follow these key best practices listed below when using Iceberg:

- Use Iceberg as intended for analytics.

The table format is designed to manage a large, slow-changing collection of files. For more information, see the [Iceberg spec](#).

- Reduce read amplification

Monitor the growth of positional delta files, and perform timely compactions.

- Speed up drop table performance, preventing deletion of data files by using the following table properties:

```
Set external.table.purge=false and gc.enabled=false
```

- Tune the following table properties to improve concurrency on writes and reduce commit failures: commit.retry.num-retries (default is 4), commit.retry.min-wait-ms (default is 100)
- Maintain a relatively small number of data files under the iceberg table/partition directory for efficient reads. To alleviate poor performance caused by too many small files, run the following queries:

```
TRUNCATE TABLE target;
INSERT OVERWRITE TABLE target select * from target FOR SYST
EM_VERSION AS OF <preTruncateSnapshotId>;
```

- To minimize the number of delete files and file handles and improve performance, ensure that the Spark write.distribution.mode table property value is “hash” (the default setting for Spark Iceberg 1.2.0 onwards).

Making row-level changes on V2 tables only

Learn the types of workloads best suited for Iceberg. Under certain conditions, using V2 tables versus V1 tables might improve query response.

Iceberg atomic DELETE and UPDATE operations resemble traditional RDBMS systems, but are not suitable for OLTP workloads. Iceberg is not designed to handle high frequency transactions. To handle very large datasets and frequent updates, use Apache Kudu.

Use Iceberg for managing large, infrequently changing datasets. You can update and delete Iceberg V2 tables at the [row-level](#) and not incur the overhead of rewriting the data files of V1 tables. Iceberg stores information about the deleted records in [position delete files](#). These files store the file paths and positions of the deleted records, eliminating the need to rewrite the files. Iceberg performs a DELETE plus an INSERT operation in a single transaction. This technique speeds up queries. Query engines scan the data files and delete files associated with a snapshot and merge them, removing the deleted rows. For example, to remove all data belonging to a single customer:

```
DELETE FROM ice_tbl WHERE user_id = 1234;
```

To update a column value in a specific record:

```
UPDATE ice_tbl SET col_v = col_v + 1 WHERE id = 4321;
```

You can convert an Iceberg v1 table to v2 by setting a table property as follows: 'format-version' = '2'.

Performance tuning

Impala uses its own C++ implementation to deal with Iceberg tables. This implementation provides significant performance advantages over other engines.

To tune performance, try the following actions:

- Speed up drop table performance, preventing deletion of data files by using the following table properties:

```
Set external.table.purge=false and gc.enabled=false
```

- Tune the following table properties to improve concurrency on writes and reduce commit failures: commit.retry.num-retries (default is 4), commit.retry.min-wait-ms (default is 100)
- Read Iceberg V2 tables from Hive using vectorization when heavy table scanning occurs as in `SELECT COUNT(*) FROM TBL_ICEBERG_PART`.
 - set hive.llap.io.memory.mode=cache;
 - set hive.llap.io.enabled=true;
 - set hive.vectorized.execution.enabled=true;
- Use Iceberg from Impala for querying Iceberg tables when latency is a concern.

The massively parallel SQL query engine, backend executors written in C++, and frontend (analyzer, planner) written in Java delivers query results fast.

- Cache manifest files as described in the next topic.

Caching manifest files

Apache Iceberg provides a mechanism to cache the contents of Iceberg manifest files in memory. The manifest caching feature helps to reduce repeated reads of small Iceberg manifest files from remote storage by Impala Coordinators and Catalogd.

Impala caches table metadata in CatalogD and the local Coordinator's catalog, making table metadata analysis fast if the targeted table metadata and files were previously accessed. Impala might analyze the same table multiple times across concurrent query planning and also within single query planning, so caching is very important.

Having a frontend written in Java, Impala can directly analyze many aspects of the Iceberg table metadata through the Java Library provided by Apache Iceberg. Metadata analysis such as listing the table data file, selecting the table snapshot, partition filtering, and predicate filtering is delegated through Iceberg Java API.

To use the Iceberg Java API while still maintaining fast query planning, Iceberg implements caching strategies in the Iceberg Java Library similar to those used by Apache Impala. The Iceberg manifest caching feature constitutes these caching strategies. For more information about manifest caching, see the [Iceberg Manifest Caching Blog](#).

Unsupported features and limitations

Cloudera does not support all features in Apache Iceberg. The list of unsupported features for Cloudera Data Platform (CDP) differs from release to release. Also, Apache Iceberg in CDP has some limitations you need to understand.

Unsupported features

The following features are not supported in this release of CDP:

- Tagging and branching

A technical preview is supported from Hive (not Impala or Spark) in Cloudera Data Warehouse Public Cloud.
- Writing equality deletes

Hive and Impala only read equality deletes.
- Reading files outside the table directory

An unauthorized party who knows the underlying schema and file location outside the table location can rewrite the manifest files within one table location to point to the data files in another table location to read your data.
- Buckets defined from Hive do not create like buckets in Iceberg.

For more information, see "Bucketing workaround" below.
- Using Iceberg tables as Spark Structured Streaming sources or sinks
- PyIceberg
- Migration of Delta Lake tables to Iceberg

Limitations

The following features have limitations or are not supported in this release:

- When the underlying table is changed, you need to rebuild the materialized view manually, or use the Hive query scheduling to rebuild the materialized view.
- From Impala, you can read, but not write, [position updates and deletes](#).
- Equality updates and deletes are not supported as previously mentioned.
- An equality delete file in the table is the likely cause of a problem with updates or deletes in the following situations:
 - In Change Data Capture (CDC) applications
 - In upserts from Apache Flink
 - From a third-party engine
- An Iceberg table that points to another Iceberg table in the HiveCatalog is not supported.

For example:

```
CREATE EXTERNAL TABLE ice_t
STORED BY ICEBERG
TBLPROPERTIES ('iceberg.table_identifier'='db.tb');
```

- See also Iceberg data types.

Bucketing workaround

A query from Hive to define buckets/folders in Iceberg do not create the same number of buckets/folders as the same query creates in Hive. In Hive bucketing by multiple columns using the following clause creates 64 buckets maximum inside each partition.

```
CLUSTERED BY (
  id,
  partition_id)
INTO 64 BUCKETS
```

Defining bucketing from Hive on multiple columns of an Iceberg table using this query creates 64*64 buckets/folders; consequently, bucketing by group does not occur as expected. The operation will create many small files at scale, a drag on performance.

Add multiple bucket transforms (partitions) to more than one column in the current version of Iceberg as follows:

```
bucket(p, col1, col2) =[ bucket(m, col1) , bucket(n, col2) ] where p = m * n
```

Prerequisites

You need to meet environment prerequisites for querying Iceberg tables in CDP. You learn which query editors are supported and which roles are required.



Note: Do not drop, move, or change the old table during a migration operation. Doing so will delete the data files of the old and new tables.

The following list covers prerequisites for using Iceberg.

- You are using the CDP Private Cloud Data Warehouse Data Service.
- Your Base cluster must be Cloudera Private Cloud Base 7.1.9 (Open Data Lakehouse) to use Iceberg GA-certified features.
- You must have the role: DWUser.
- You must obtain permission to run SQL queries from the Env Admin, who must add you to the Hadoop SQL Storage Handler and the Hadoop SQL policies.

Migrating from Impala Prerequisites

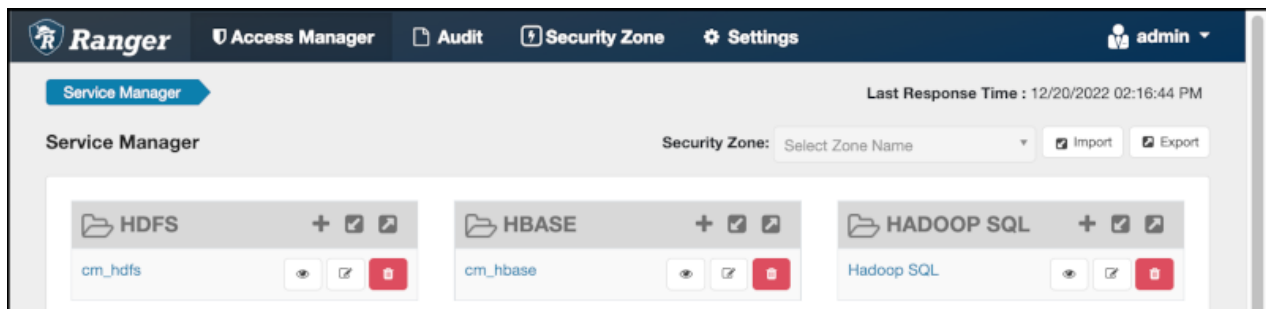
- The original table is an EXTERNAL table from the Impala perspective: The EXTERNAL table property value is true.
- The original table is a non-ACID table.
- You have “ALL” privileges on the database containing the table.

Accessing Iceberg tables

CDP uses Apache Ranger to provide centralized security administration and management. The Ranger Admin UI is the central interface for security administration. You can use Ranger to create two policies that allow users to query Iceberg tables.

How you open the Ranger Admin UI differs from one CDP service to another. In Management Console, you can select your environment, and then click [Environment Details Quick Links Ranger](#).

You log into the Ranger Admin UI, and the Ranger Service Manager appears.



Policies for accessing tables on HDFS

The default policies that appear differ from service to service. You need to set up two Hadoop SQL policies to query Iceberg tables:

- One to authorize users to access the Iceberg files
Follow steps in "Editing a policy to access Iceberg files" below.
- One to authorize users to query Iceberg tables
Follow steps in "Creating a policy to query an Iceberg table" below.

Prerequisites

- Obtain the RangerAdmin role.
- Get the user name and password your Administrator set up for logging into the Ranger Admin.

The default credentials for logging into the Ranger Admin Web UI are admin/admin123.

Editing a storage handler policy to access Iceberg files on the file system

You learn how to edit the existing default Hadoop SQL Storage Handler policy to access files. This policy is one of the two Ranger policies required to use Iceberg.

About this task

The Hadoop SQL Storage Handler policy allows references to Iceberg table storage location, which is required for creating or altering a table. You use a storage handler when you create a file stored as Iceberg on the file system or object store.

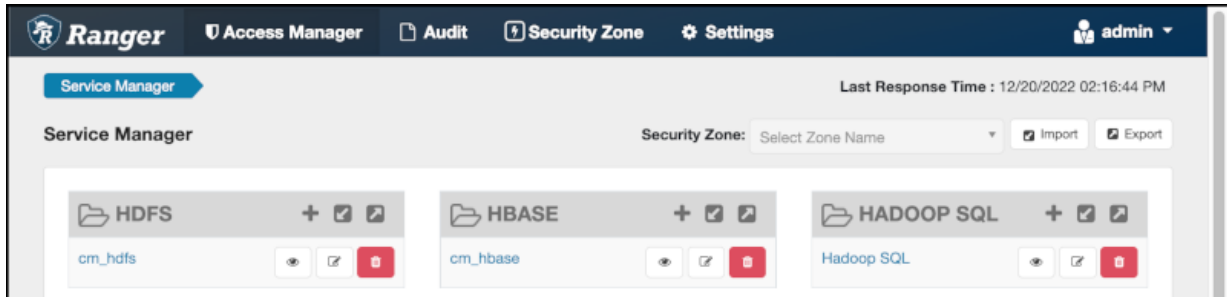
In this task, you specify Iceberg as the storage-type and allow the broadest access by setting the URL to *.

The Hadoop SQL Storage Handler policy supports only the RW Storage permission. A user having the required RW Storage permission on a resource, such as Iceberg, that you specify in the storage-type properties, is allowed only to reference the table location (for create/alter operations) in Iceberg. The RW Storage permission does not provide access to any table data. You need to create the Hadoop SQL policy described in the next topic in addition to this Hadoop SQL Storage Handler policy to access data in tables.

For more information about these policy settings, see [Ranger Storage Handler documentation](#).

Procedure

1. Log into Ranger Admin Web UI.
The Ranger Service Manager appears:




2. In Policy Name, enable the all - storage-type, storage-url policy.

List of Policies : Hadoop SQL

Search for your policy...

Policy ID	Policy Name	Policy Labels	Status
8	all - global	--	Enabled
9	all - database, table, column	--	Enabled
10	all - database, table	--	Enabled
11	all - storage-type, storage-url	--	Enabled

3. In Service Manager, in Hadoop SQL, select Edit  and edit the all storage-type, storage-url policy.
4. Below Policy Label, select storage-type, and enter iceberg..

5. In Storage URL, enter the value *, enable Include.

Policy Type **Access**

Policy ID* **11**

Policy Name* **Enabled**

Policy Label

Storage Type *****

Storage URL **Include**

Description

Audit Logging* **Yes**

For more information about these policy settings, see [Ranger storage handler documentation](#).

6. In Allow Conditions, specify roles, users, or groups to whom you want to grant RW storage permissions. You can specify PUBLIC to grant access to Iceberg tables permissions to all users. Alternatively, you can grant access to one user. For example, add the systest user to the list of users who can access Iceberg:

Allow Conditions:

Select Role	Select Group	Select User
<input type="text" value="Select Roles"/>	<input type="text" value="Select Groups"/>	<input type="text" value="x hive"/> <input type="text" value="x beacon"/> <input type="text" value="x dpprofiler"/>
		<input type="text" value="x hue"/> <input type="text" value="x admin"/> <input type="text" value="x impala"/>
		<input type="text" value="x systest"/>

For more information about granting permissions, see [Configure a resource-based policy: Hadoop-SQL](#).

7. Add the RW Storage permission to the policy.
8. Save your changes.

Creating a SQL policy to query an Iceberg table

You learn how to set up the second required policy for using Iceberg. This policy manages SQL query access to Iceberg tables.

About this task

You create a Hadoop SQL policy to allow roles, groups, or users to query an Iceberg table in a database. In this task, you see an example of just one of many ways to configure the policy conditions. You grant (allow) the selected roles, groups, or users the following add or edit permissions on the table: Select, Update, Create, Drop, Alter, and All. You can also deny permissions.

For more information about creating this policy, see [Ranger documentation](#).

Procedure

1. Log into Ranger Admin Web UI.
The Ranger Service Manager appears.

2. Click Add New Policy.

3. Fill in required fields.

For example, enter the following required settings:

- In Policy Name, enter the name of the policy, for example IcebergPolicy1.
- In database, enter the name of the database controlled by this policy, for example icedb.
- In table, enter the name of the table controlled by this policy, for example icetable.
- In columns, enter the name of the column controlled by this policy, for example enter the wildcard asterisk (*) to allow access to all columns of icetable.
- Accept defaults for other settings.

The screenshot shows the 'Create Policy' form in the Ranger Admin Web UI. The breadcrumb navigation at the top indicates the path: Service Manager > Hadoop SQL Policies > Create Policy. The form is titled 'Create Policy' and contains a section for 'Policy Details'. The 'Policy Type' is set to 'Access'. The 'Policy Name' field contains 'IcebergPolicy1' and has an 'Enabled' toggle switch. The 'Policy Label' field contains 'Policy Label'. Below this, there are three rows for permissions, each with a dropdown menu, a text input field, and an 'Include' toggle switch. The first row is for 'database' with the value 'icedb'. The second row is for 'table' with the value 'icetable'. The third row is for 'column' with the value '*'. All 'Include' toggle switches are turned on.

4. Scroll down to Allow Conditions, and select the roles, groups, or users you want to access the table.

You can use Deny All Other Accesses to deny access to all other roles, groups, or users other than those specified in the allow conditions for the policy.

5. Select permissions to grant.

For example, select Create, Select, and Alter. Alternatively, to provide the broadest permissions, select All.

Ignore RW Storage and other permissions not named after SQL queries. These are for future implementations.

6. Click Add.

Accessing Iceberg files in Ozone

Learn how to set up policies to give users access to Iceberg files in Ozone. For example, if you query Iceberg tables from Impala, you must set up a Hadoop SQL access policy and Ozone file system access policy.

About this task

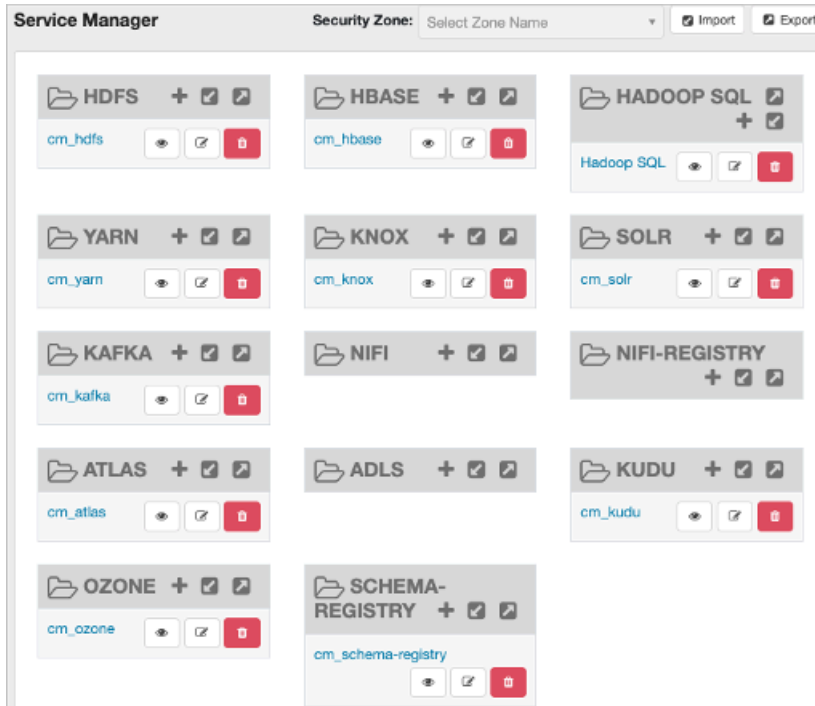
When Ranger is enabled in the cluster, any user other than the default admin user, "om" requires the necessary Ranger permissions and policy updates to access the Ozone filesystem. To create an Iceberg table on the Ozone file system, you need Ranger permissions.


In this task, you first enable Ozone in the Ranger service, and then set up the required policies.


Procedure

1. In Cloudera Manager, click **Clusters Ozone Configuration** to navigate to the configuration page for Ozone.
2. Search for `ranger_service`, and enable the property.

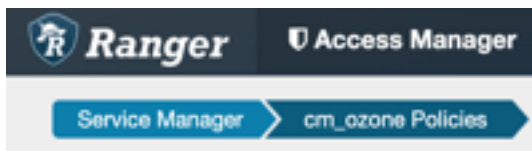
- Click Clusters Ranger Ranger Admin Web UI , enter your user name and password, then click Sign In. The **Service Manager for Resource Based Policies** page is displayed in the Ranger console.




- Click the cm_ozone preloaded resource-based service to modify an Ozone policy.
- In the cm_ozone policies page, click the Policy ID or click  Edit against the "all - volume, bucket, key" policy to modify the policy details.
- In the Allow Conditions pane, add roles, groups, or users, choose the necessary permissions, and then click Save.

Select User	Policy Conditions	Permissions
<div> <div>✕ om</div> <div>✕ hive</div> </div>	<div>Add Conditions</div> <div>+</div>	<div> <div>All Read Write Create</div> <div>List Delete Read_ACL</div> <div>Write_ACL</div> </div> <div></div>

- Click the Service Manager link in the breadcrumb trail and then click the Hadoop SQL preloaded resource-based service to update the Hadoop SQL URL policy.



- In the Hadoop SQL policies page, click the Policy ID or click  Edit against the "all - url" policy to modify the policy details.

9. Select roles, users, or groups in addition to the default.

By default, "hive", "hue", "impala", "admin" and a few other users are provided access to all the Ozone URLs. To grant everyone access, add the "public" group to the group list. Every user is then subject to your allow conditions.

Select Group	Select User	Permissions
<input type="text" value="x public"/>	<div> <input checked="" type="checkbox"/> hive <input checked="" type="checkbox"/> beacon <input checked="" type="checkbox"/> dpprofiler </div> <div> <input checked="" type="checkbox"/> hue <input checked="" type="checkbox"/> admin <input checked="" type="checkbox"/> impala </div>	<div> <input checked="" type="checkbox"/> select <input checked="" type="checkbox"/> update <input checked="" type="checkbox"/> Create <input checked="" type="checkbox"/> Drop <input checked="" type="checkbox"/> Alter <input checked="" type="checkbox"/> Index </div> <div> <input checked="" type="checkbox"/> Lock <input checked="" type="checkbox"/> All <input checked="" type="checkbox"/> Read <input checked="" type="checkbox"/> Write <input checked="" type="checkbox"/> ReplAdmin </div> <div> <input checked="" type="checkbox"/> Service Admin <input checked="" type="checkbox"/> Temporary UDF Admin <input checked="" type="checkbox"/> Refresh </div> <div> <input checked="" type="checkbox"/> RW Storage </div>

Creating an Iceberg partitioned table

The ease of use of the Iceberg partitioning is clear from an example of how to partition a table using the backward compatible, identity-partition syntax. Alternatively, you can partition an Iceberg table by column values from Hive or Impala.

About this task

You can specify partitioning that is backward compatible with Iceberg V1 using the PARTITION BY clause. This type of table is called an identity-partitioned table. For more information about partitioning, see the [Apache Iceberg documentation](#).

Procedure

1. Select, or use, a database.
2. Create an identity-partitioned table and run the query.
Hive:

```
CREATE EXTERNAL TABLE ice_ext1 (i int, s string, ts timestamp, d date) P
ARTITIONED BY (state string)
STORED BY ICEBERG
STORED AS ORC;
```

Impala:

```
CREATE TABLE ice_ext2 (i int, s string, ts timestamp, d date) PARTITIONED
BY (state string)
STORED BY ICEBERG;
```

3. Create a table and specify an identity transform, such as bucket, truncate, or date, using the Iceberg V2 PARTITION BY SPEC clause.
Hive:

```
CREATE TABLE ice_t_transforms (i int, s string, ts timestamp, d date)
PARTITIONED BY SPEC (TRUNCATE(10, i), BUCKET(11, s), YEAR(ts))
STORED BY ICEBERG;
```

Impala:

```
CREATE TABLE ice_t_transforms (i int, s string, ts timestamp, d date)
PARTITIONED BY SPEC (TRUNCATE(10, i), BUCKET(11, s), YEAR(ts))
STORED AS ICEBERG;
```

Related Information

[Partition transform feature](#)

Expiring snapshots

You can expire snapshots of an Iceberg table using an ALTER TABLE query. You should periodically expire snapshots to delete data files that are no longer needed, and reduce the size of table metadata.

About this task

Each write to an Iceberg table creates a new snapshot, or version, of a table. You can use snapshots for time-travel queries, or to roll back a table to a valid snapshot. Snapshots accumulate until they are expired by the expire_snapshots operation.

Procedure

1. Enter a query to expire snapshots older than the following timestamp: '2021-12-09 05:39:18.689000000'

```
ALTER TABLE test_table EXECUTE EXPIRE_SNAPSHOTS('2021-12-09 05:39:18.689000000');
```

2. Enter a query to expire snapshots having between December 10, 2022 and November 8, 2023.

```
ALTER TABLE test_table EXECUTE EXPIRE_SNAPSHOTS BETWEEN ('2022-12-10 00:00:00.000000000') AND ('2023-11-08 00:00:00.000000000');
```

Inserting data into a table

You can append data to an Iceberg table by inserting values or by selecting the data from another table. You can update data, replacing the old data.

You use the INSERT command in one of the following ways to populate an Iceberg table from Hive:

- INSERT INTO t VALUES (1, 'asf', true);
- INSERT INTO t SELECT * FROM s;
- INSERT OVERWRITE t SELECT * FROM s;

Examples

```
INSERT INTO t VALUES (1, 'asf', true);
INSERT INTO t SELECT * FROM s;
INSERT OVERWRITE t SELECT * FROM s;
```

Table migration overview

You learn what happens under the covers during Hive table to Iceberg table migration.

Migration from Hive

When you migrate an external Hive table to Iceberg, Hive makes the following changes:

1. Converts the storage_handler, serde, inputformat and outputformat properties of the table in HMS to use the Iceberg specific classes.
2. Reads the footers of the existing data files and generates the necessary Iceberg metadata files based on the footers.
3. Commits all the data files to the Iceberg table in a single commit.

Migration from Impala

Impala's table migration process consists of multiple steps under the hood:

1. Sets table properties on the Hive table, such as 'external.table.purge'=false
2. Renames the original table name to a temporary name in the format "<original_name>_tmp_<random_ID>"
3. Refreshes the renamed Hive table.
4. Creates an Iceberg table using the original table name and the same location as Hive table.
5. Using the metadata for the data files of the Hive table, populates the Iceberg table with the data files. Reads the footer of the data files and saves statistics to Iceberg metadata.
6. Sets the Iceberg table 'external.table.purge' property to true.
7. Drops the renamed Hive table. The 'external.table.purge' property set to false prevents dropping the data files just deletes the metadata of the Hive table.

If for any reason the table migration fails, Impala cleans up the Iceberg metadata files created during step 6. Perhaps the original Hive table had already been renamed when the table migration failed. In this case, you see an error message about how to rename the Hive table to the original name. For example:

```
ALTER TABLE <tbl_name>_tmp_<random_ID> RENAME TO <tbl_name>;
```

Migrating a Hive table to Iceberg

You see how to use a simple ALTER TABLE statement from Hive or Impala to migrate an external Hive table to an Iceberg table. You see how to configure table input and output by setting table properties.

About this task



Note: To prevent loss of new and old table data during migration of a table to Iceberg, do not drop, move, or change the old table during migration.

Before you begin

In Impala, you can configure the NUM_THREADS_FOR_TABLE_MIGRATION query option to tweak the performance of the table migration. It sets the maximum number of threads to be used for the migration process but could also be limited by the number of CPUs. If set to zero then the number of available CPUs on the coordinator node is used as the maximum number of threads. Parallelism occurs on the basis of data files within a partition, which means one partition is processed at a time with multiple threads processing the files inside the partition. In case there is only one file in each partition, sequential execution occurs.

Procedure

1. Log in to the CDP web interface and navigate to the Data Warehouse service.
2. In the Data Warehouse service, in the Overview page, locate your Virtual Warehouse, and click Hue.

Instead of using Hue, you can connect over JDBC to the Virtual Warehouse, and run the query.

3. Enter a query to use a database.

For example:

```
USE mydb;
```

4. Enter a query to migrate an existing external Hive table to an Iceberg v2 table.

Hive example:

```
ALTER TABLE tbl
SET TBLPROPERTIES ('storage_handler'='org.apache.iceberg.mr.hive.HiveIcebergStorageHandler',
```




```
'format-version' = '2');
```

Impala example, which requires two queries:

```
ALTER TABLE table_name CONVERT TO ICEBERG;
ALTER TABLE table_name SET TBLPROPERTIES ('format-version'='2');
```

The first ALTER command converts the Hive table to an Iceberg V1 table.

5. Click  to run the queries.
An Iceberg V2 table is created, replacing the Hive table.

Selecting an Iceberg table

You see an example of how to read an Apache Iceberg table, and understand the advantages of Iceberg.

About this task

Working with timestamps in Iceberg, you do not need to know whether the table is actually partitioned by month, day or hour, based on the timestamp value. You can simply supply a predicate for the timestamp value and Iceberg converts the timestamp to month/day/hour transparently. Hive/Impala must maintain actual partition values in a separate column (for example, `ts_month` or `ts_day`). Forgetting to reference the derived partition column in your query can lead to inadvertent full table scans.

By default `iceberg.table_identifier` is not set in CDP, so you can use the familiar `<db_name.<table_name>` in queries.

Procedure

1. Use a database.

For example:

```
USE mydatabase;
```

2. Query an Iceberg table partitioned by city.

For example:

```
SELECT * FROM ice_t2 WHERE city="Bangalore";
```

Running time travel queries

You query historical snapshots of data using the `FOR SYSTEM_TIME AS OF '<timestamp>'` `FOR SYSTEM_VERSION AS OF <snapshot_id>` clauses in a select statement. You see how to use `AS OF` to specify a snapshot of your Iceberg data at a certain time.

About this task

You can inspect the history of an Iceberg table to see the snapshots. You can query the metadata of the Iceberg table using a `SELECT ... AS OF` statement to run time travel queries. You use history information from a query of the database to identify and validate snapshots, and then query a specific snapshot `AS OF` a certain Timestamp value.

Before you begin

- You must be aware of the table history.

However, this can include commits that have been rolled back.

- You must have access to valid snapshots.

Procedure

1. View the table history.

```
SELECT * FROM db.table.history;
```

2. Check the valid snapshots of the table.

```
SELECT * FROM db.table.snapshots;
```

3. Query a specific snapshot by providing the timestamp and snapshot_id.

```
SELECT * FROM T
FOR SYSTEM_TIME AS OF <TIMESTAMP>;
SELECT * FROM t
FOR SYSTEM_VERSION AS OF <SNAPSHOT_ID>;
```

Updating an Iceberg partition

You see how to update Iceberg table partitioning in an existing table and then how to change the partitioning to be more granular.

About this task

Partition information is stored logically, and only in table metadata. When you update a partition spec, the old data written with an earlier spec remains unchanged. New data is written using the new spec in a new layout. Metadata for each of the partition versions is separate.

Procedure

1. Create a table partitioned by year.
Hive

```
CREATE EXTERNAL TABLE ice_t (i int, j int, ts timestamp)
PARTITIONED BY SPEC (truncate(5, j), year(ts))
STORED BY ICEBERG;
```

Impala:

```
CREATE TABLE ice_t (i int, j int, ts timestmap)
PARTITIONED BY SPEC (truncate(5, j), year(ts))
STORED BY ICEBERG;
```

2. Split the data into manageable files using buckets.

```
ALTER TABLE ice_t SET PARTITION SPEC (bucket(13, i));
```

3. Partition the table by month.

```
ALTER TABLE ice_t SET PARTITION SPEC (truncate(5, j), month(ts));
```

Test driving Iceberg from Impala

You complete a task that creates Iceberg tables from Impala with mock data that you can test drive using your own queries. You learn how to work with partitioned tables.

Before you begin

- You must obtain Ranger access permissions.

Procedure

- In Impala, use a database.
- Create an Impala table to hold mock data for this task.

```
create external table mock_rows stored as parquet as
select x from (
with v as (values (1 as x), (1), (1), (1), (1))
select v.x from v, v v2, v v3, v v4, v v5, v v6
) a;
```

- Create another Impala table based on mock_rows.

```
create external table customer_demo stored as parquet as
select
FROM_TIMESTAMP(DAYS_SUB(now(), cast ( TRUNC(RAND(7)*365*1) as bigint)), '
yyyy-MM') as year_month,
DAYS_SUB(now(), cast ( TRUNC(RAND(7)*365*1) as bigint)) as ts,
CONCAT(
  cast ( TRUNC(RAND(1) * 250 + 2) as string), '.',
  cast ( TRUNC(RAND(2) * 250 + 2) as string), '.',
  cast ( TRUNC(RAND(3) * 250 + 2) as string), '.',
  cast ( TRUNC(RAND(4) * 250 + 2) as string)
) as ip,
CONCAT("USER_", cast ( TRUNC(RAND(4) * 1000) as string), '@somedomain.com')
as email,
CONCAT("USER_", cast ( TRUNC(RAND(5) * 1000) as string)) as username,
CONCAT("USER_", cast ( TRUNC(RAND(6) * 100) as string)) as country,
cast( RAND(8)*10000 as double) as metric_1,
cast( RAND(9)*10000 as double) as metric_2,
cast( RAND(10)*10000 as double) as metric_3,
cast( RAND(11)*10000 as double) as metric_4,
cast( RAND(12)*10000 as double) as metric_5
from mock_rows
;
```

- Create another Impala table based on mock_rows.

```
create external table customer_demo2 stored as parquet as
select
FROM_TIMESTAMP(DAYS_SUB(now(), cast ( TRUNC(RAND(7)*365*1) as bigint)),
'yyyy-MM') as year_month,
DAYS_SUB(now(), cast ( TRUNC(RAND(7)*365*1) as bigint)) as ts,
CONCAT(
  cast ( TRUNC(RAND(1) * 250 + 2) as string), '.',
  cast ( TRUNC(RAND(2) * 250 + 2) as string), '.',
  cast ( TRUNC(RAND(3) * 250 + 2) as string), '.',
  cast ( TRUNC(RAND(4) * 250 + 2) as string)
) as ip,
```

```

CONCAT("USER_", cast ( TRUNC(RAND(4) * 1000) as string), '@somedomain.com')
  as email,
CONCAT("USER_", cast ( TRUNC(RAND(5) * 1000) as string)) as username,
CONCAT("USER_", cast ( TRUNC(RAND(6) * 100) as string)) as country,
cast( RAND(8)*10000 as double) as metric_1,
cast( RAND(9)*10000 as double) as metric_2,
cast( RAND(10)*10000 as double) as metric_3,
cast( RAND(11)*10000 as double) as metric_4,
cast( RAND(12)*10000 as double) as metric_5
from mock_rows
;

```

5. Create an Iceberg table from the customer_demo table.

```

CREATE TABLE customer_demo_iceberg STORED BY ICEBERG AS SELECT * FROM cu
stomer_demo;

```

6. Insert into the customer_demo_iceberg table the results of selecting all data from the customer_demo2 table.

```

INSERT INTO customer_demo_iceberg select * from customer_demo2;
INSERT INTO customer_demo_iceberg select * from customer_demo2;
INSERT INTO customer_demo_iceberg select * from customer_demo2;

```

7. Create an Iceberg table partitioned by the year_month column and based on the customer_demo_iceberg table.

```

CREATE TABLE customer_demo_iceberg_part PARTITIONED BY(year_month) STORED
BY ICEBERG
AS SELECT ts, ip , email, username , country, metric_1 , metric_2 , metric
_3 , metric_4 , metric_5, year_month
FROM customer_demo_iceberg;

```

8. Split the partitioned data into manageable files.

```

ALTER TABLE customer_demo_iceberg_part SET PARTITION SPEC (year_month,BU
CKET(15, country));

```

9. Insert the results of reading the customer_demo_iceberg table into the partitioned table.

```

INSERT INTO customer_demo_iceberg_part (year_month, ts, ip, email, usern
ame, country, metric_1, metric_2, metric_3, metric_4, metric_5)
SELECT year_month, ts, ip, email, username, country, metric_1, metric_2,
metric_3, metric_4, metric_5
FROM customer_demo_iceberg;

```

10. Run time travel queries on the Iceberg tables, using the history output to get the snapshot id, and substitute the id in the second SELECT query.

```

SELECT * FROM customer_demo_iceberg FOR SYSTEM_TIME AS OF '2021-12-09 05
:39:18.689000000' LIMIT 100;
DESCRIBE HISTORY customer_demo_iceberg;
SELECT * FROM customer_demo_iceberg FOR SYSTEM_VERSION AS OF <snapshot
id> LIMIT 100;

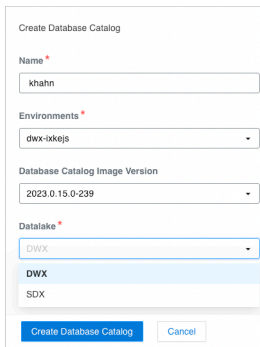
```

Test driving Iceberg from Hive

You learn how to access the Hive demo data, which you can use to get hands-on experience running Iceberg queries.

About this task

A DWAdmin can optionally load demo data in Hue when you create a new Database Catalog.



Create Database Catalog

Name *
khahn

Environments *
dwx-icejs

Database Catalog Image Version
2023.0.15.0-239

Datalake *
DWX
SDX

Create Database Catalog Cancel

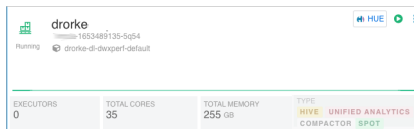
The Admin enables Load Demo Data when creating the Database Catalog. Users can then query sample airline demo data in Hue.

Before you begin

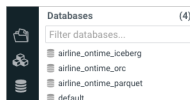
- You must meet the prerequisites to query Iceberg tables from a Virtual Warehouse mentioned earlier.
- You have access to a Hive Virtual Warehouse, having a Database Catalog in which demo data has been loaded.
- You obtained the required role for querying the Virtual Warehouse: DWUser

Procedure

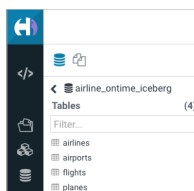
1. In Cloudera Data Warehouse Overview, select a Hive Virtual Warehouse, and click Hue.



2. In Hue, expand the default database and verify that the airline demo data is available in your Virtual Warehouse. You see the following list of demo databases:



3. Select airline_ontime_iceberg to use the airline_ontime_iceberg database.
4. Take a look at the tables in the airline_ontime_iceberg database.



Flights is the fact table. It has 100M rows and three dimensions, airline, airports, and planes. This records flights for more than 10 years in the US, and includes the following details:

- origin
 - destination
 - delay
 - air time
5. Become familiar with the Iceberg airline queries to set up this database. See the next topic.
 6. Query the demo data from Hive.
For example, find the flights that departed each year, by IATA code, airport, city, state, and country. Find the average departure delay.

```
SELECT f.month, a.iata, a.airport, a.city, a.state, a.country
FROM flights f,
```

```

airports a
WHERE f.origin = a.iata
GROUP BY
f.month,
a.iata,
a.airport,
a.city,
a.state,
a.country
HAVING COUNT(*) > 10000
ORDER BY AVG(f.DepDelay) DESC
LIMIT 10;

```

Output appears as follows:

```

+-----+-----+-----+-----+
+-----+-----+
| f.month | a.iata | a.airport | a.city |
| a.state | a.country |
+-----+-----+-----+-----+
+-----+-----+
| 12      | ORD    | Chicago O'Hare International | Chicago |
| NULL    | USA    | | |
| 6       | EWR    | Newark Intl | Newark |
| NULL    | USA    | | |
| 7       | JFK    | John F Kennedy Intl | New York |
| NULL    | USA    | | |
| 6       | IAD    | Washington Dulles International | Chantilly |
| NULL    | USA    | | |
| 7       | EWR    | Newark Intl | Newark |
| NULL    | USA    | | |
| 6       | PHL    | Philadelphia Intl | Philadelphia |
| NULL    | USA    | | |
| 1       | ORD    | Chicago O'Hare International | Chicago |
| NULL    | USA    | | |
| 6       | ORD    | Chicago O'Hare International | Chicago |
| NULL    | USA    | | |
| 7       | ATL    | William B Hartsfield-Atlanta Intl | Atlanta |
| NULL    | USA    | | |
| 12      | MDW    | Chicago Midway | Chicago |
| NULL    | USA    | | |
+-----+-----+-----+-----+
+-----+-----+
10 rows selected (103.812 seconds)

```

7. Split the partitioned data into manageable files.

```

ALTER TABLE airports SET PARTITION SPEC (iata,BUCKET(15, country));

```

Hive demo data

To test drive Iceberg from Hive, you use demo data in the `airline_online_iceberg` database.

Iceberg Database creation and setup

The Airlines demo data for Iceberg is stored in the `airline_online_iceberg` database. The following queries created and set up this database.

```

create database if not exists airline_ontime_iceberg;

```

```
use airline_ontime_iceberg;  
set hive.vectorized.execution.enabled=false;  
set hive.stats.column.autogather=false;
```

Hive external table creation

The following Hive external tables were created in the airline_online_iceberg database:

- airports
- airlines
- planes
- flights

```
create external table if not exists airports (  
    iata string,  
    airport string,  
    city string,  
    state double,  
    country string,  
    lat double,  
    lon double  
)  
stored as orc;  
  
create external table if not exists airlines (  
    code string,  
    description string  
)  
stored as orc;  
  
create external table if not exists planes (  
    tailnum string,  
    owner_type string,  
    manufacturer string,  
    issue_date string,  
    model string,  
    status string,  
    aircraft_type string,  
    engine_type string,  
    year int  
)  
stored as orc;  
  
create external table if not exists flights (  
    month int,  
    dayofmonth int,  
    dayofweek int,  
    deptime int,  
    crsdeptime int,  
    arrtime int,  
    crsarrrtime int,  
    uniquecarrier string,  
    flightnum int,  
    tailnum string,  
    actualelapsedtime int,  
    crselapsedtime int,  
    airtime int,  
    arrdelay int,  
    depdelay int,  
    origin string,  
    dest string,  
    distance int,  
    taxiin int,
```

```

        taxiout int,
        cancelled int,
        cancellationcode string,
        diverted string,
        carrierdelay int,
        weatherdelay int,
        nasdelay int,
        securitydelay int,
        lateaircraftdelay int
    )
    partitioned by (year int)
    stored as orc;

```

Load data into the newly created tables

```

load data inpath '${datapath}/airline_ontime_iceberg.db/airports' into table
airports;

load data inpath '${datapath}/airline_ontime_iceberg.db/airlines' into table
airlines;

load data inpath '${datapath}/airline_ontime_iceberg.db/planes' into table p
lanes;

load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=1995' i
nto table flights partition (year=1995);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=1996'
into table flights partition (year=1996);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=1997'
into table flights partition (year=1997);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=1998'
into table flights partition (year=1998);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=1999' i
nto table flights partition (year=1999);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2000'
into table flights partition (year=2000);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2001'
into table flights partition (year=2001);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2002'
into table flights partition (year=2002);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2003' i
nto table flights partition (year=2003);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2004'
into table flights partition (year=2004);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2005'
into table flights partition (year=2005);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2006'
into table flights partition (year=2006);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2007' i
nto table flights partition (year=2007);
load data inpath '${datapath}/airline_ontime_iceberg.db/flights/year=2008'
into table flights partition (year=2008);

```

Convert these existing Hive external tables to Iceberg tables

```

ALTER TABLE planes ADD CONSTRAINT planes_pk PRIMARY KEY (tailnum) DISABLE NO
VALIDATE;
ALTER TABLE flights ADD CONSTRAINT planes_fk FOREIGN KEY (tailnum) REFEREN
CES planes(tailnum) DISABLE NOVALIDATE RELY;

```



```

ALTER TABLE airlines ADD CONSTRAINT airlines_pk PRIMARY KEY (code) DISABLE NOVALIDATE;
ALTER TABLE flights ADD CONSTRAINT airlines_fk FOREIGN KEY (uniquecarrier) REFERENCES airlines(code) DISABLE NOVALIDATE RELY;

ALTER TABLE airports ADD CONSTRAINT airports_pk PRIMARY KEY (iata) DISABLE NOVALIDATE;
ALTER TABLE flights ADD CONSTRAINT airports_orig_fk FOREIGN KEY (origin) REFERENCES airports(iata) DISABLE NOVALIDATE RELY;
ALTER TABLE flights ADD CONSTRAINT airports_dest_fk FOREIGN KEY (dest) REFERENCES airports(iata) DISABLE NOVALIDATE RELY;

ALTER TABLE airports SET TBLPROPERTIES ('storage_handler'='org.apache.iceberg.mr.hive.HiveIcebergStorageHandler');
ALTER TABLE airlines SET TBLPROPERTIES ('storage_handler'='org.apache.iceberg.mr.hive.HiveIcebergStorageHandler');
ALTER TABLE planes SET TBLPROPERTIES ('storage_handler'='org.apache.iceberg.mr.hive.HiveIcebergStorageHandler');
ALTER TABLE flights SET TBLPROPERTIES ('storage_handler'='org.apache.iceberg.mr.hive.HiveIcebergStorageHandler');

```

Iceberg data types

References include Iceberg data types and a table of equivalent SQL data types by Hive/Impala SQL engine types.

Iceberg supported data types

Table 2:

Iceberg data type	SQL data type	Hive	Impala
binary		BINARY	BINARY
boolean	BOOLEAN	BOOLEAN	BOOLEAN
date	DATE	DATE	DATE
decimal(P, S)	DECIMAL(P, S)	DECIMAL (P, S)	DECIMAL (P, S)
double	DOUBLE	DOUBLE	DOUBLE
fixed(L)		BINARY	Not supported
float	FLOAT	FLOAT	FLOAT
int	TINYINT, SMALLINT, INT	INTEGER	INTEGER
list	ARRAY	ARRAY	Read only
long	BIGINT	BIGINT	BIGINT
map	MAP	MAP	Read only
string	VARCHAR, CHAR	STRING	STRING
struct	STRUCT	STRUCT	Read only
time		STRING	Not supported
timestamp	TIMESTAMP	TIMESTAMP	TIMESTAMP (see limitation below)
timestamptz	TIMESTAMP WITH LOCAL TIME ZONE	Use TIMESTAMP WITH LOCAL TIMEZONE for handling these in queries	Read timestamptz into TIMESTAMP values Writing not supported

Iceberg data type	SQL data type	Hive	Impala
uuid	none	STRING Writing to Parquet is not supported	Not supported

Data type limitations

An implicit conversion to an Iceberg type occurs only if there is an exact match; otherwise, a cast is needed. For example, to insert a VARCHAR(N) column into an Iceberg table you need a cast to the VARCHAR type as Iceberg does not support the VARCHAR(N) type. To insert a SMALLINT or TINYINT into an Iceberg table, you need a cast to the INT type as Iceberg does not support these types.

Unsupported data types

Impala does not support the following Iceberg data types:

- TIMESTAMPTZ (only read support)
- TIMESTAMP in tables in AVRO format
- FIXED
- UUID

Iceberg table properties

The CDP environment for querying tables from Hive overrides some Iceberg table properties. You learn which table properties are supported for querying tables from Impala.

[Iceberg documentation](#) describes all the properties for configuring tables. This documentation focuses on key properties for working with Iceberg tables in CDP.

Iceberg supports concurrent writes by default. You can tune Iceberg v2 table properties for concurrent writes. You set the following properties if you plan to have concurrent writers on Iceberg v2 tables:

- commit.retry.min-wait-ms
- commit.retry.num-retries

CDP supports adding the Parquet compression type using table properties. For more information, see Iceberg documentation about [Compression Types](#).

You can use the Alter Table feature to set a property. From Hive, the following Iceberg table property overrides are in effect:

- iceberg.mr.split.size overrides read.split.target-size.
- read.split.open-file-cost is overridden.

You can tune Iceberg v2 table properties for concurrent writes. From Impala, the following subset of Iceberg table properties are supported:

- history.expire.min-snapshots-to-keep
Valid values: integers. Default = 1
- write.format.default
Valid value: Parquet
- write.metadata.delete-after-commit.enabled
Valid values: true or false.
- write.metadata.previous-versions-max
Valid values: integers. Default = 100.

- `write.parquet.compression-codec`
Valid values: GZIP, LZ4, NONE, SNAPPY (default value), ZSTD
- `write.parquet.compression-level`
Valid values: 1 - 22. Default = 3
- `write.parquet.row-group-size-bytes`
Valid values: 8388608 (or 8 MB) - 2146435072 (or 2047MB). Overriden by `PARQUET_FILE_SIZE`.
- `write.parquet.page-size-bytes`
Valid values: 65536 (or 64KB) - 1073741824 (or 1GB).
- `write.parquet.dict-size-bytes`
Valid values: 65536 (or 64KB) - 1073741824 (or 1GB)