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UNIVERSITY OF MINNESOTA

Optimize Hive Query Performance

MSBA 6330 Prof Liu

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Hive Optimization

- In this chapter, you will learn
  - Use faster engines for Hive
  - How to choose storage formats for Hive tables
  - How to partition tables to reduce amount of data read for a query
  - How to understand and write better performing Hive queries
  - Why/how to use bucketing

Optimize Hive Query Performance

USE FASTER PROCESSING ENGINES

Uses a Faster Execution Engine

- Hive uses MapReduce (MR) engine by default, but it can also leverage faster engines
  - Tez: `set hive.execution.engine=tez;`
    - Tez also offers a customizable execution architecture, permitting dynamic performance optimizations, and dramatically improving the speed of execution.
  - Spark: `set hive.execution.engine=spark;`
    - In memory computing, more customizable execution architecture.
    - Expect a long delay as Spark initializes after you submit the first query
    - Subsequent queries run without a delay
    - Hive on Spark requires more memory on cluster than Hive on MapReduce
- To see the current engine, use `SET hive.execution.engine;`

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USE FASTER STORAGE FORMATS

Choose a File Format

- Hive supports multiple storage formats

```
CREATE TABLE tablename (colname DATATYPE, …)
ROW FORMAT DELIMITED FIELDS TERMINATED BY char
STORED AS format;
```

- Format Options
  - TEXTFILE
  - SEQUENCEFILE
  - AVRO
  - PARQUET
  - RCFILE
  - ORCFILE

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Considerations for Choosing a File Format

- Hadoop and its ecosystem support many file formats
  - You can ingest data in one format and convert to another as needed
- Selecting the format for your dataset involves several considerations
  - Ingest pattern
  - Tool compatibility
  - Expected lifetime
  - Storage and performance requirements

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TEXTFILE

- Text files are the most basic file type in Hadoop
  - Can be read or written from virtually any programming language
  - Comma- and tab-delimited files are compatible with many applications
- Text files are human-readable
  - All values are represented as strings
  - Useful when debugging
- At scale, this format is inefficient
  - Representing numeric values as strings wastes storage space
  - Difficult to represent binary data such as images
    - Often resort to techniques such as Base64 encoding
  - Conversion to/from native types adds performance penalty
- **Verdict: Good interoperability, but poor performance**

How many bytes to store `108125150` as text (9 bytes) or integer (4 bytes)?

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SequenceFile Format

- SequenceFiles store key-value pairs in a **binary** container format
  - Less verbose and more efficient than text files
  - Capable of storing binary data such as images
  - Format is **Java-specific** and tightly coupled to Hadoop
    - Use internally for temporal outputs of mappers
  - Support splitable compression
- **Verdict: Good performance, but poor interoperability**

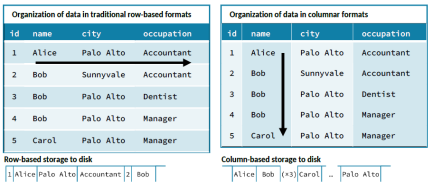
SequenceFile File Layout

Apache Avro File Format

- Apache Avro is an efficient data serialization framework
- Avro also defines a **binary** data file format for storing Avro records
  - Similar to SequenceFile format
- Efficient storage due to optimized binary encoding
  - Support compression
- Widely supported throughout the Hadoop ecosystem
  - Can also be used outside of Hadoop
- Ideal for long-term storage of important data
  - Many languages can read and write Avro files
  - Embeds schema in the file, so will always be readable
  - Schema evolution can accommodate changes
- **Verdict: Excellent interoperability and performance**
  - Best choice for general-purpose storage in Hadoop

Columnar formats

- Organize data storage on disk by column, rather than by row
  - Very efficient when selecting only a subset of a table's column
  - Including Apache Parquet, RCFile, and ORCFile



Columnar File Format: Apache **Parquet**

- Apache Parquet is an open source columnar format
  - Originally developed by engineers at Cloudera and Twitter
  - Now an Apache Software Foundation project
  - Supported in MapReduce, Hive, Pig, Impala, Spark, and others
  - Schema is embedded in the file
  - Stores **binary-encoded** records
- Uses advanced optimizations described in Google's Dremel paper
  - Reduces storage space
  - Increases performance
- Most efficient when adding many records at once
  - Some optimizations rely on identifying repeated patterns
- **Verdict: Excellent interoperability and performance**
  - Good choice for column-based access patterns

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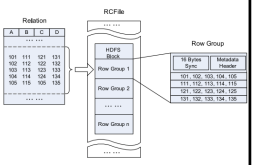
Columnar File Formats: RCFile and ORCFile

- RCFile
  - Splits data horizontally into row groups, each row group saves data in a columnar format
  - All data stored as strings (inefficient)
  - **Verdict: Poor performance and limited interoperability**
- ORCFile – Optimized RCFile
  - An improved version of RCFile
  - Currently supported in Hive, Spark, but limited in Impala
  - **Verdict: Good performance but limited interoperability**



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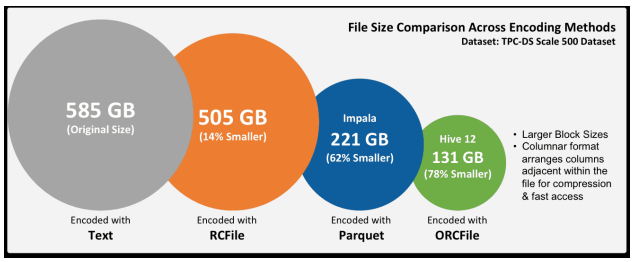
HortonWorks (2013) Study of Storage Format and File Sizes



https://hortonworks.com/blog/orcfile-in-hdp-2-better-compression-better-performance/

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Convert between formats

- Load data in the original format, then use INSERT INTO TABLE to convert it into a new format.
- Create a new table stored in Parquet format

```
CREATE TABLE order_details_parquet (
order_id INT,
prod_id INT)
STORED AS PARQUET;
```

- Load data from another table into a Parquet table

```
INSERT OVERWRITE TABLE order_details_parquet
SELECT * FROM order_details;
```

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Optimize Hive Query Performance

TABLE PARTITIONS

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Motivation for Partitions

- When you perform lots of repetitive FILTER based queries and the FILTER conditions lend themselves to partitioning

```
SELECT event_type, COUNT(event_type)
FROM call_log
WHERE call_date = '2013-06-03'
GROUP BY event_type;
```

- It does not make sense to read and scan the whole dataset when you only need a small part of it.
  - An appropriate table partition allows Hive to fetch only a portion of the data.

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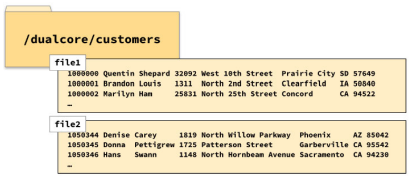
Table Partitioning

- By default, all data files for a table are stored in a single directory
  - All files in the directory are read during a query
- Partitioning subdivides the data
  - Data is physically divided during loading, based on values from one or more columns
- Speeds up queries that filter on partition columns
  - Only the files containing the selected data need to be read
  - Does not prevent you from running queries that span multiple partitions

Example: Partitioning Customers by State

- `customers` is a non-partitioned table
- Data files are stored in a single directory
- All files are scanned for every query



Creating a Partitioned Table

- Using PARTITIONED BY

```
CREATE EXTERNAL TABLE customers (
cust_id INT,
fname STRING,
lname STRING,
address STRING,
city STRING,
state STRING,
zipcode STRING)
ROW FORMAT DELIMITED FIELDS TERMINATED
BY '\t'
LOCATION '/dualcore/customers';
```

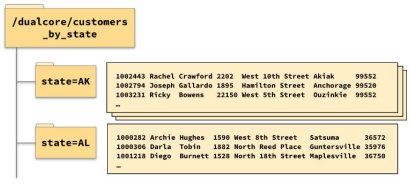
Non-partitioned

```
CREATE EXTERNAL TABLE customers_by_state(
cust_id INT,
fname STRING,
lname STRING,
address STRING,
city STRING,
zipcode STRING)
PARTITIONED BY (state STRING)
ROW FORMAT DELIMITED FIELDS TERMINATED BY
'\t'
LOCATION '/dualcore/customers';
```

Partitioned

Partitioning File Structure

- Partitioned tables store data in subdirectories
  - Queries that filter on partitioned fields limit amount of data read



Partition fields

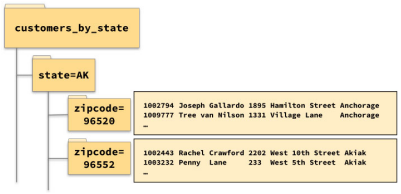
- The partition field(s) is removed from the table, since it is redundant, given the directory name in which the data is stored
- Each subdirectory is not limited to a single file
- A partition field is a *virtual field*. Column values are not stored in the files but the column is displayed if you DESCRIBE the table

```
DESCRIBE customers_by_state;
+-----------+---------+---------+
| name      | ty      | comment |
+-----------+---------+---------+
| cust_id   | int     |         |
| fname     | string  |         |
| lname     | string  |         |
| address   | string  |         |
| city      | string  |         |
| zipcode   | string  |         |
| state     | string  |         |
+-----------+---------+---------+
```


Nested Partitions

- You can also create nested partitions

```
... PARTITIONED BY (state STRING, zipcode STRING)
```



When to Use Partitioning

- Use partitioning for tables when
  - Reading the entire dataset takes too long
  - Queries almost always filter on the partition columns
  - There are a reasonable number of different values for partition columns
  - Data generation or ETL process splits data by file or directory names
  - Partition column values are not in the data itself

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When *Not* to Use Partitioning

- Avoid partitioning data into numerous small data files
  - Partitioning on columns with too many unique values
- Caution: This can happen easily when using dynamic partitioning!
  - For example, partitioning customers by first name could produce thousands of partitions

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Loading Data into a Partitioned Table

- Dynamic partitioning
  - Hive/Impala automatically creates partitions
  - Inserted data is stored in the correct partitions based on column values
- Static partitioning
  - You manually create new partitions using `ADD PARTITION`
  - When loading data, you specify which partition to store it in

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Static Partitioning

- With static partitioning, you create new partitions as needed

```
ALTER TABLE customers_by_state
ADD PARTITION (state='NY');
```

  - Adds the partition to the table's metadata if it does not already exist.
  - Creates subdirectory `state=NY` in `/user/hive/warehouse/customers_by_state/`
- Then add data one partition at a time, e.g.

```
INSERT OVERWRITE TABLE customers_by_state
PARTITION(state='NY')
SELECT cust_id, fname, lname, address,
city, zipcode FROM customers WHERE state='NY';
```

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Dynamic Partitioning

- With dynamic partitioning, you use an INSERT statement to load data
  - The partition column(s) must be included in the PARTITION clause
  - The partition column(s) must be specified last in the SELECT list

```
INSERT OVERWRITE TABLE customers_by_state
     PARTITION(state)
     SELECT cust_id, fname, lname, address, city,
          zipcode, state FROM customers
```

- Hive automatically creates partitions and inserts data into them based on the values of partition column(s)
  - If the partition does not already exist, it will be created
  - If the partition does exist, it will be overwritten

https://cwiki.apache.org/confluence/display/Hive/Tutorial#Tutorial-Dynamic-PartitionInsert

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Dynamic Partition Inserts (2 Of 3)

- Dynamic partitioning is not enabled by default
  - Enable it by setting these two properties

Property Name	Value
hive.exec.dynamic.partition	true
hive.exec.dynamic.partition.mode	nonstrict

- Remember: Avoid creating an excessive number of partitions
  - This can happen when your data contains many unique values
- Caution: If the partition column has many different values, many partitions will be created
  - Partitioning by date is a popular, but common example

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Viewing, Adding, And Removing Partitions

- To view the current partitions in a table

```
SHOW PARTITIONS call_logs;
```

- Use ALTER TABLE to add or drop partitions

```
ALTER TABLE call_logs
     ADD PARTITION (call_date='2018-06-05');
ALTER TABLE call_logs
     DROP PARTITION (call_date='2018-06-06');
```

  - Provides a very efficient way to drop data
    - Rather than filtering an entire table, Hive just deletes a subdirectory
  - Drops actual data whether or not it is a Hive-managed table.

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Optimize Hive Query Performance

UNDERSTAND AND WRITE BETTER PERFORMING HIVE QUERIES

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Write better Performing Hive Queries

- Generally speaking, Hive query performance improves if you can
  - Compress intermediate output
    - List columns you need, avoid `SELECT *`
  - Filter early in workflows consisting of several steps
    - e.g. if you can, use `WHERE` in the sub-query instead of in the main query
  - Write better queries that reduce the number of processing steps (e.g. avoid a costly join)
- This requires you to have a better understanding of how Hive executes a query.

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Viewing The Execution Plan

- Prefix your query with EXPLAIN to view Hive's execution plan

```
hive>  EXPLAIN SELECT zipcode, COUNT(cust_id) AS num
               FROM customers
               GROUP BY zipcode;
```

- The output of EXPLAIN can be very long and complex
  - Useful for determine, e.g. how many MapReduce phases it would require?
  - However, fully understanding it requires in-depth knowledge of MapReduce
  - We will cover the basics here

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Viewing The Query Plan With EXPLAIN

- Query plan has stages, but stage numbers do not represent the execution sequence
  - They are merely identifiers
  - A root stage always runs first
  - Dependencies define the order of execution
- In the previous example, the stages run in the following order:
  - Stage-1 (MapReduce) runs first
  - Stage-0 (HDFS operation "ListSink") runs next
  - Hive is smart enough to run stages in parallel when there are no dependencies among them

```
STAGE DEPENDENCIES:
  Stage-1 is a root stage
  Stage-0 depends on stages: Stage-1

STAGE PLANS:
  Stage: Stage-1
    Map Reduce
      Map Operator Tree:...
```

(for more details) https://cwiki.apache.org/confluence/display/Hive/LanguageManual+Explain

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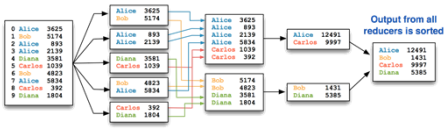
Sorting Results

- As in SQL, ORDER BY sorts specified fields in HiveQL
  - Consider the result from the following query, utilizing 5 Mappers and 2 Reducers

```
hive> SELECT name, SUM(total)
        FROM order_info
        GROUP BY name
        ORDER BY name;
```



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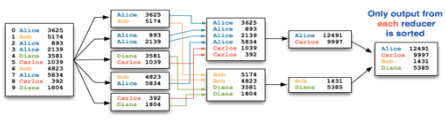
Using SORT BY For Partial Ordering (1 Of 2)

- HiveQL also supports partial ordering via SORT BY
  - Offers much better performance if global order isn't required
    - e.g. You want ordering within each Reducer, but not across multiple Reducers

```
hive> SELECT name, SUM(total)
        FROM order_info
        GROUP BY name
        SORT BY name;
```



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Using SORT BY For Partial Ordering (2 Of 2)

- Behind the scene
  - ORDER BY uses a single reducer to ensure global sorting
  - SORT BY sorts the input before feeding them into reducers
    - So that output of each reducer is sorted (partial sorting), but collective output is not.
- SORT BY can improve performance on large queries in 2 ways:
  - Bringing the benefits of parallelism to the reduce phase
  - In some case, it can eliminate the need for a second MapReduce job dedicated to global ordering of results.
- https://cwiki.apache.org/confluence/display/Hive/LanguageManual+SortBy

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Optimize Hive Query Performance

BUCKETING

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Bucketing Data in Hive

- *Bucketing* data is another way of subdividing data
  - Stores data in separate files
  - Divides data into buckets in **an effectively random** way
  - Calculates **hash codes** based on column values
  - Use hash codes to assign records to a bucket
- Goal: Distribute rows across a predefined number of buckets
  - Useful for jobs that need samples of data.
  - Joins may be faster if all tables are bucketed on the join column

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Example of Bucketing

- Each bucket should contain roughly 5% of the table's data

```
CREATE TABLE orders_bucketed  (order_id INT,
    cust_id INT,  order_date TIMESTAMP)
  CLUSTERED BY (order_id) INTO 20 BUCKETS;

-- enforce bucketing when inserting data
SET hive.enforce.bucketing=true;
INSERT OVERWRITE TABLE orders_bucketed
   SELECT * FROM orders;

-- sample 10% of data
SELECT * FROM orders_bucketed
  TABLESAMPLE (BUCKET 1 OUT OF 10 ON order_id);
```

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Essential Points

- Tez/Spark engine can lead to superior performance than the MR engine.
- ORC/PARQUET are significantly faster than the text format.
- Partitioning may reduce the amount of data a query must read
- Understanding Hive execution using the Explain command.
- SORT BY (partial ordering) is faster than ORDER BY
- Bucketing may also improve performance of certain types of queries