CS 523 – BDT
Big Data Technology

Lesson 8

Apache Hive

Principle of Least Action

Maharishi International University

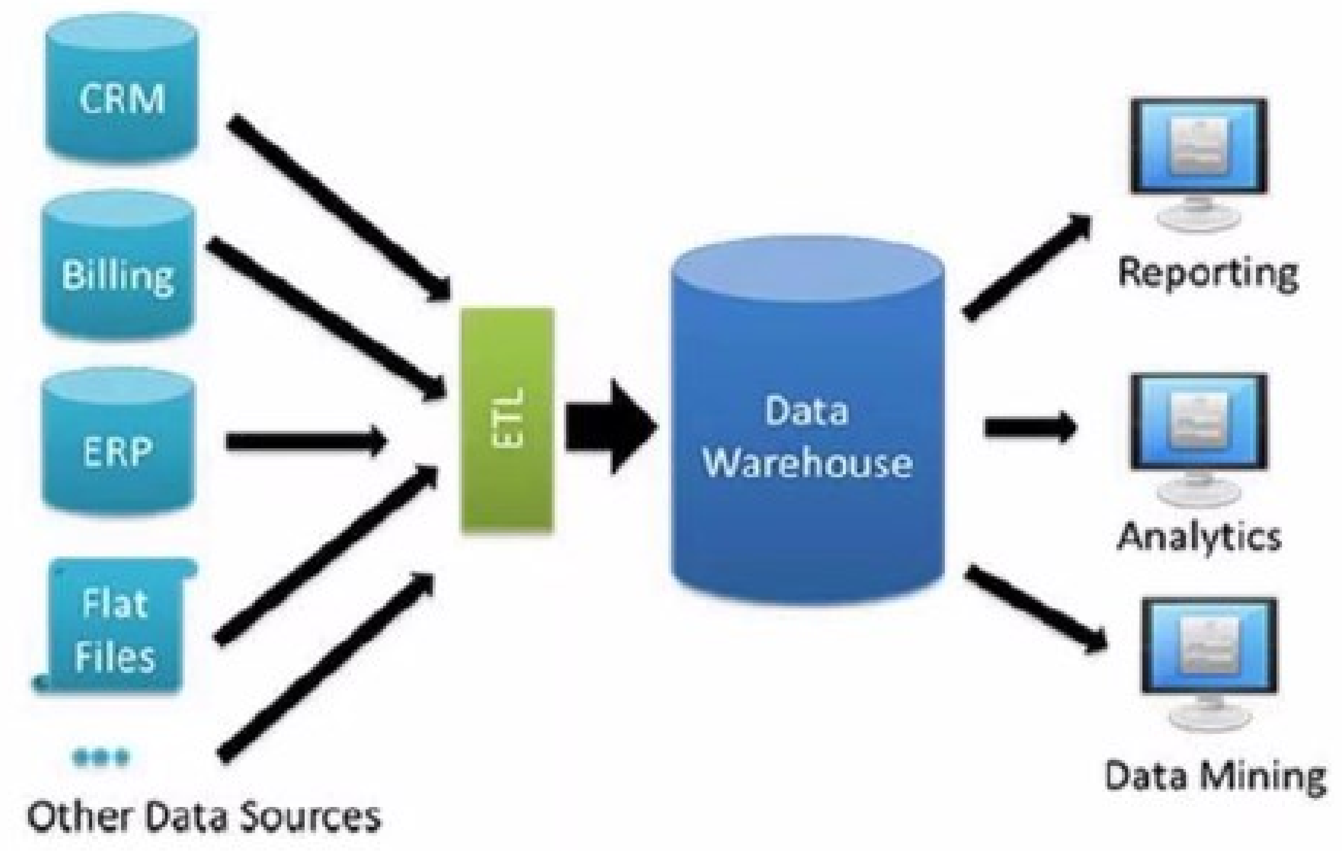
WHOLENESS OF THE LESSON

Apache Hive is a data warehouse infrastructure built on top of MapReduce for providing data summarization, query and analysis. It provides a very well-known SQL-like language called HiveQL with schema-on-read and transparently converts queries to MR, Apache Tez or Spark jobs.

Science & Technology of Consciousness: Just like the infinite reservoir of creative intelligence at the source of thought can be open to experience, the infinite knowledge of SQL can be used to experience new insights from the big data. Thus, with Hive, there is no need to learn any new language to be more efficient.

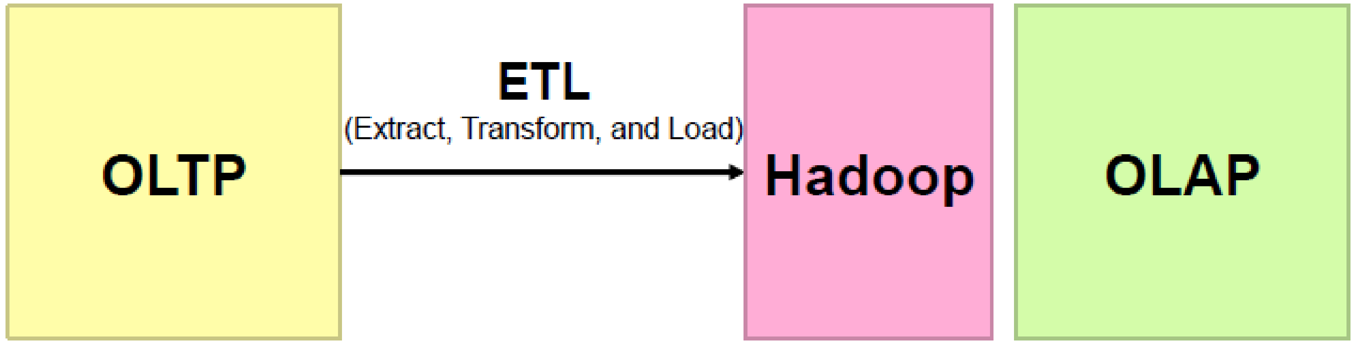
Data Warehouse

- A large store of data accumulated from a wide range of sources within a company and used to guide management decisions. They provide a SQL interface.



Situation Before 2006

- At Facebook
  - Data was collected by nightly cron jobs into Oracle
  - “ETL” into D/W systems via hand-coded python
  - Data Grew from 10s of GBs (2006) to 1 TB/day of new data (2007), now 10x of that number.
  - Every day need to fire 70,000 queries on their data



cron is a Linux utility which schedules a command or script on your server to **run** automatically at a specified time and date. A cron job is the scheduled task itself. Cron jobs can be very useful to automate repetitive tasks.

Apache Hive

- Developed by Facebook, now open source
- Hive was created to make it possible for analysts with strong SQL skills (but very poor Java skills) to run queries on the huge volumes of data that FB stored in HDFS.
- Today, Hive is a successful Apache project used by many organizations as a general-purpose, scalable data processing platform.
- Hive is not a Database, especially in terms of optimizations and it doesn’t have it’s own storage.
- It enables you to write SQL code which then gets converted to MapReduce programs.
- Of course, SQL isn’t ideal for every big data problem—it’s not a good fit for building complex machine-learning algorithms, for example—but it’s great for many analyses, and it has the huge advantage of being very well known in the industry.
- What’s more, SQL is the common language in business intelligence tools (ODBC is a common bridge, for example), so Hive is well placed to integrate with these products.

Apache Hive

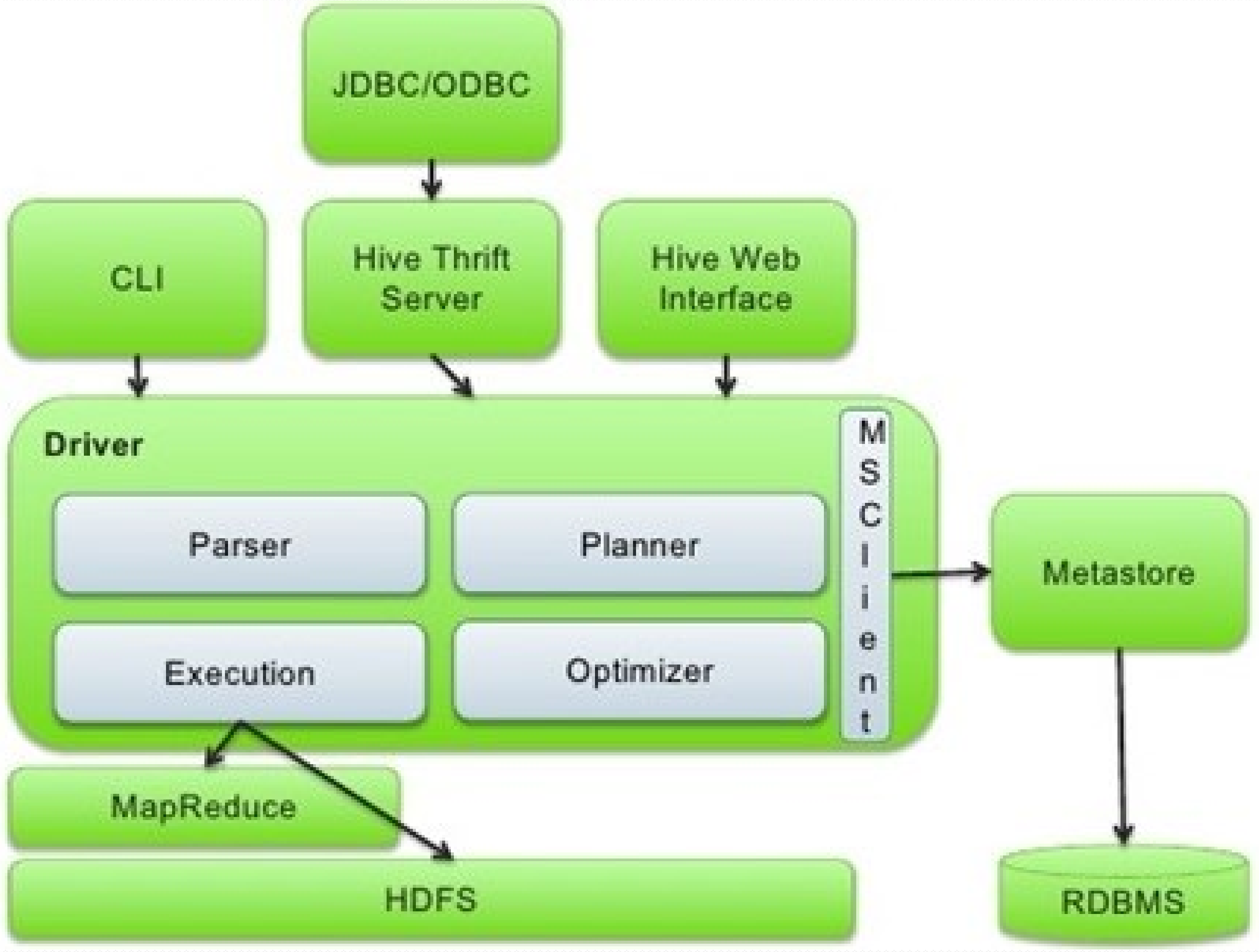
- **Hive is not**
  - A relational database
  - A design for OnLine Transaction Processing (OLTP)
  - A language for real-time queries

- **Hive is**
  - A system for managing and querying unstructured data as if it was structured!
  - Designed for OLAP
  - Familiar, fast, scalable, and extensible.

Apache Hive

- Data warehouse infrastructure built on top of Hadoop.
- Hive provides a mechanism to project structure onto the data and query the data using SQL-like language called HiveQL.
- Hive uses MapReduce and HDFS for processing and storage/retrieval of data
  - Tables are stored in HDFS as flat files
  - Can also use Tez or Spark as execution engine
- It stores schema in a database and processed data into HDFS as files.
- In Hive, tables and databases are created first and then data is loaded into these tables.
- **Main Idea:**
  - Provide higher-level language to facilitate large-data processing
  - Higher-level language “compiles down” to MapReduce jobs

Hive Architecture



Hive Major Components

- **CLI, Web Interface, and Thrift Server**
  - A command-line interface (CLI) provides a user interface for an external user to interact with Hive by submitting queries.
  - Thrift server allows external clients to interact with Hive over a network.
  - Web interface provides the execute interface to the driver.

- **Driver** : Acts like a controller which receives the HiveQL statements.
  - It executes the statement by creating sessions and monitors the life cycle.
  - Stores the necessary metadata generated during the execution of an HiveQL statement.
  - The driver also acts as a collection point of data i.e. query results obtained after the Reduce operation.

Hive Major Components

- **Compiler** :- It parses the query, does semantic analysis on the different query blocks and query expressions and eventually generates an execution plan with the help of the table and partition metadata looked up from the Metastore.
  - The plan is a DAG of stages.
- **Execution Engine** :- This is the component which executes the execution plan created by the compiler.
  - The execution engine manages the dependencies between different stages of the plan and executes these stages on the appropriate system components.
  - Default execution engine is MapReduce which will change to Tez starting from Hive 3 onwards.

Data Hierarchy

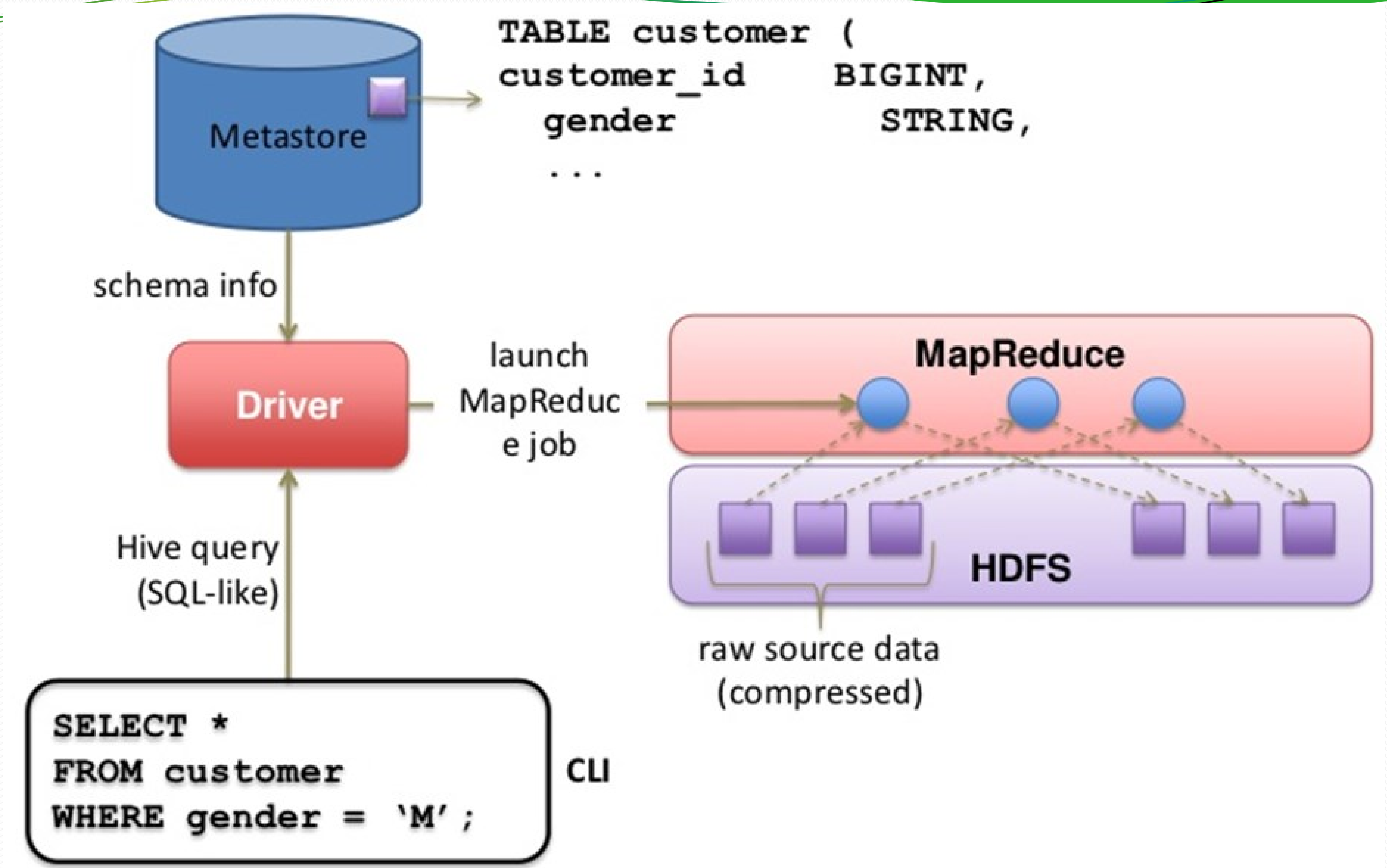
- Hive is organized hierarchically into:
  - **Databases**: namespaces that separate tables and other objects
  - **Tables**: homogeneous units of data with the same schema
    - Analogous to tables in an RDBMS
  - **Partitions**: determine how the data is stored
    - Allow efficient access to subsets of the data
    - For example, range-partition tables by date
  - **Buckets/clusters**
    - For subsampling within a partition
    - Join optimization

Schema on Read Vs. Schema on Write

- In a traditional database, a table’s schema is enforced at data load time.
- If the data being loaded doesn’t conform to the schema, then it is rejected. This design is sometimes called ***schema on write*** because the data is checked against the schema when it is written into the database.
- Hive, on the other hand, doesn’t verify the data when it is loaded, but rather when a query is issued. This is called ***schema on read***.
  - Hive has an advantage when the schema is not available at the load time but is instead generated later dynamically.
  - Adds more flexibility to hive in the form of having two schemas for the same underlying data, depending on the analysis being performed.

Hive Major Components : MetaStore

- **MetaStore** :- The component that maintains metadata about Hive tables in a relational database.
  - This metadata contains information about what tables exist, their columns, user privileges, the corresponding HDFS files where the data is stored, partitioning information and more.
  - By default, Hive uses Derby, an embedded Java relational database, to store the metadata.
  - For multiuser systems, MySQL or any other RDBMS can be used.
  - All components in Hive interact with Metastore



```
TABLE customer (
customer_id    BIGINT,
  gender          STRING,
  ...
```

```
SELECT *
FROM customer
WHERE gender = 'M';
```

Hive Table

- A Hive table is a logical concept that’s physically composed of several files in HDFS.
- A Hive table is logically made up of the data being stored and the associated metadata describing the layout of the data in the table.
- The data typically resides in HDFS, although it may reside in any Hadoop filesystem, including the local filesystem or Amazon S3.
- Hive stores the table metadata in a relational database and not in HDFS.
- Tables can be partitioned, which is a physical arrangement of data, into distinct subdirectories for each unique partitioned key.

Hive Warehouse

- **Hive tables are stored in subdirectories of Hive "warehouse"**
  - Each table has a corresponding HDFS directory
  - Partitions form subdirectories of tables directory
  - Hive's warehouse layout looks like:

    /user/hive/warehouse/*$database/$table/$partition*

    /user/hive/warehouse/empDB.db/employee/state=IA

- **Actual data stored in flat files**
  - Users can associate a table with a custom SerDe format
    - SerDe - Describes how to load the data from the file into a representation that makes it look like a table and other way round

Hive SerDe

- SerDe is short for Serializer/Deserializer. Hive uses the SerDe interface for IO. The interface handles both serialization and deserialization and also interpreting the results of serialization as individual fields for processing.
- A SerDe allows Hive to read in data from a table, and write it back out to HDFS in any custom format. Anyone can write their own SerDe for their own data formats.

HDFS files –> InputFileFormat –> <key, value> –> Deserializer –> Row object
Row object –> Serializer –> <key, value> –> OutputFileFormat –> HDFS files

HiveQL

- HiveQL is Hive’s query language, a dialect of SQL. It is heavily influenced by MySQL.
- HiveQL / HQL provides the basic SQL-like operations:
  - Select columns using SELECT
  - Filter rows using WHERE
  - JOIN between tables
  - Evaluate aggregates using GROUP BY
  - Store query results into another table
  - Download results to a local directory (i.e., export from HDFS)
  - Manage tables and queries with CREATE, DROP, and ALTER

Primitive Data Types in Hive

Type	Description	Literal examples
BOOLEAN	True/false value	TRUE
SMALLINT	2-byte signed integer, from -32,768 to 32,767	1S
INT	4-byte signed integer, from -2,147,483,648 to 2,147,483,647	1
BIGINT	8-byte signed integer, from -9,223,372,036,854,775,808 to 9,223,372,036,854,775,807	1L
FLOAT	4-byte single-precision floating-point number	1.0
DOUBLE	8-byte double-precision floating-point number	1.0
DECIMAL	Arbitrary-precision signed decimal number	1.0
STRING	Unbounded variable-length character string (Theoretical maximum size is 2 GB, although in practice it may be inefficient to materialize such large values)	‘a’, “a”
VARCHAR	Variable-length character string	‘a’, “a”
CHAR	Fixed-length character string	‘a’, “a”
BINARY	Byte array	
TIMESTAMP	Timestamp with nanosecond precision	1325502245000, ‘2019-01-02’ 03:04:05.123456789’
DATE	Date	‘2019-01-02’

Complex Data Types in Hive

ARRAY	An ordered collection of fields. The fields must all be of the same type.	array(1, 2)[a]
MAP	An unordered collection of key-value pairs. Keys must be primitives; values may be any type. For a particular map, the keys must be the same type, and the values must be the same type.	map('a',1,'b',2)
STRUCT	A collection of named fields. The fields may be of different types.	struct('a',1,1.0),[b] named_struct('col1','a','col2', 1, 'col3', 1.0)
UNION	A value that may be one of a number of defined data types. The value is tagged with an integer (zero-indexed) representing its data type in the union.	create_union(1,'a', 63)

[a] The literal forms for arrays, maps, structs and unions are provided as functions. That is, array, map, struct and create_union are built-in Hive functions.

[b] The columns are named col1, col2, col3, etc.

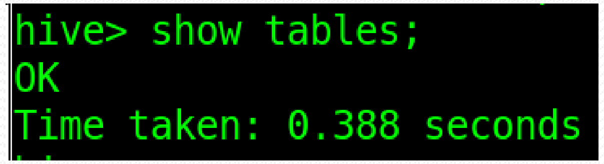
Hive Shell/Beeline Shell

- The shell is the primary way that we will interact with Hive, by issuing commands in HiveQL.
- Open new terminal and fire up hive by typing *hive* or *beeline*.
  - Hive CLI is deprecated; beeline is recommended.
- If you use beeline shell, then first run the following command to establish connection with hive server.

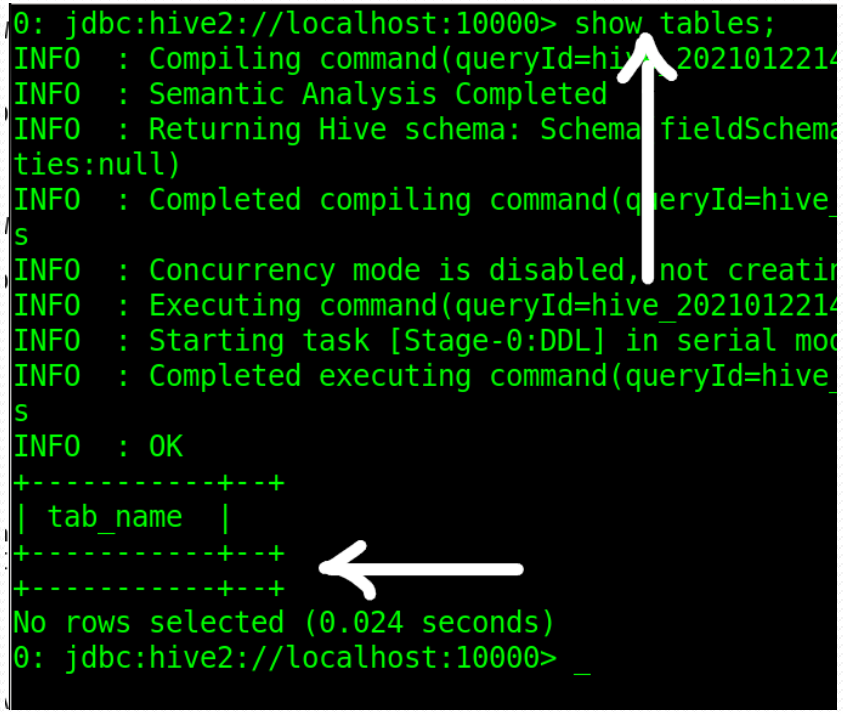
```
!connect jdbc:hive2://localhost:10000 cloudera cloudera
```

Hive Shell/Beeline Shell

- When starting Hive for the first time, we can check that it is working by listing its tables—there should be none.
  - The command must be terminated with a semicolon to tell Hive to execute it:
- For executing shell commands from hive shell, you can use **"!"** character before the shell command. Ctrl-D for quitting from the hive shell.
- For Beeline shell, use **Ctrl – L** for clear and **!q** for quitting from the Beeline.



```
hive> show tables;
OK
Time taken: 0.388 seconds
```



```
0: jdbc:hive2://localhost:10000> show tables;
INFO  : Compiling command(queryId=hive_2021012214
INFO  : Semantic Analysis Completed
INFO  : Returning Hive schema: Schema(fieldSchema
ties:null)
INFO  : Completed compiling command(queryId=hive_
s
INFO  : Concurrency mode is disabled, not creatin
INFO  : Executing command(queryId=hive_2021012214
INFO  : Starting task [Stage-0:DDL] in serial mod
INFO  : Completed executing command(queryId=hive_
s
INFO  : OK
+-----------+--+
| tab_name  |
+-----------+--+
+-----------+--+
No rows selected (0.024 seconds)
0: jdbc:hive2://localhost:10000> _
```

HQL Example

- hive> show tables;
- hive> CREATE TABLE shakespeare (word STRING, freq INT)
  ROW FORMAT DELIMITED FIELDS TERMINATED BY '\t'
  STORED AS TEXTFILE
- hive> LOAD DATA LOCAL INPATH 'shakespeareWrdFqy.txt'
  INTO TABLE shakespeare;
- hive> SELECT * FROM shakespeare
  WHERE freq>100
  SORT BY freq ASC
  LIMIT 10;

Internal and External Tables

- Tables can either be **internal (managed table)**, where Hive organizes them inside a warehouse directory (controlled by the *hive.metastore.warehouse.dir* property with a default value of */user/hive/warehouse* [in HDFS]), or they can be **external**, in which case Hive doesn't manage them.
- Internal tables are useful if you want Hive to manage the complete lifecycle of your data, including the deletion, whereas external tables are useful when the files are being used outside of Hive.
- By default, a created table in Hive is an internal (managed) table.

Creating Schema for Hive Table: Create Table Syntax

```
CREATE TABLE employees (
     name        STRING,
     salary      FLOAT,
     dept        STRING
     )
ROW FORMAT
     DELIMITED
          FIELDS TERMINATED BY ','
          LINES TERMINATED BY '\n';
```

- The **ROW FORMAT** clause, is particular to HiveQL. This declaration is saying that each field is separated by “comma” and each row in the data file is separated by new line.
- **The above query will create an internal table.**

Creating Schema for Hive Table: Create Table Syntax

- By default, tables are assumed to be of text input format.
  - Hive supports several other file formats: Text File, SequenceFile, RCFile, Avro Files, ORC Files, Parquet, Custom INPUTFORMAT and OUTPUTFORMAT
- Default field delimiter is ^A(ctrl-a) –\u0001
- Default record delimiter is – \n
- **Custom SerDe** - Depending on the nature of data the user has, the inbuilt SerDe may not satisfy the format of the data. So, users need to use custom SERDE with SERDEPROPERTIES.

Table for Apache Weblog Data

```
CREATE TABLE apachelog (
    host STRING,
    identity STRING,
    user STRING,
    time STRING,
    request STRING,
    status STRING,
    size STRING,
    referer STRING,
    agent STRING)
ROW FORMAT SERDE 'org.apache.hadoop.hive.serde2.RegexSerDe'
WITH SERDEPROPERTIES (
    "input.regex" = "([^ ]*) ([^ ]*) ([^ ]*) (-|\\[[^\\]]*\\])
    ([^ \"]*|\"[^\"]*\") (-|[0-9]*) (-|[0-9]*) (?:([^ \"]*|\".*\")
    ([^ \"]*|\".*\"))?")
STORED AS TEXTFILE;
```

Creating a Complex Schema for Hive Table

```
CREATE TABLE employees (
    name                STRING,
    salary              FLOAT,
    subordinates        ARRAY<STRING>,
    deductions          MAP<STRING, FLOAT>,
    address             STRUCT<street:STRING, city:STRING, state:STRING, zip:INT>)
COMMENT 'This is the page view table'
PARTITIONED BY(department STRING)
ROW FORMAT DELIMITED FIELDS TERMINATED BY '\t'
COLLECTION ITEMS TERMINATED BY ','
MAP KEYS TERMINATED BY '#'
LINES TERMINATED BY '\n'
STORED AS TEXTFILE;
```

Loading Local Data into Hive Table

```
LOAD DATA LOCAL INPATH
'/home/cloudera/cs523/Hive/employee.txt'
INTO TABLE employees;
```

- Running this command tells Hive to **copy** the specified local file into its warehouse directory (by default).
- '**LOCAL**' signifies that the input file is on the local file system.
- If 'LOCAL' is omitted, then it looks for the file in HDFS.

Loading HDFS Data into Hive Table

```
LOAD DATA INPATH
'/user/cloudera/cs523/input/employee.txt'
OVERWRITE INTO TABLE employees;
```

- When HDFS data is loaded into the table, the input files are **moved** to the warehouse directory. The files are not examined or checked for errors until they are used in a query. (NO verification of data against the schema is performed by the LOAD command.)
- The OVERWRITE keyword in the LOAD DATA statement tells Hive to delete any existing files in the directory for the table.
  - If it is omitted, the new files are simply added to the table's directory.

Create External Table

```
CREATE EXTERNAL TABLE employees (
     name STRING,
     salary    FLOAT,
     departmentSTRING
     )
ROW FORMAT
     DELIMETED
          FIELDS TERMINATED BY ‘,'
          LINES TERMINATED BY '\n';
```

- When you LOAD the data with above approach, it’ll move/copy your data to /user/hive/warehouse directory.
- If you don’t want your data to get moved, then you need to mention the external location of the data while creating the table as shown next.

Create External Table

```
CREATE EXTERNAL TABLE employees (
     name STRING,
     salary    FLOAT,
     departmentSTRING
     )
ROW FORMAT
     DELIMETED
          FIELDS TERMINATED BY ','
          LINES TERMINATED BY '\n'
LOCATION '/user/hive/cs523';
```

- Here we have specified the location of the data in the table creation itself. Now if you delete the table, nothing will happen to the data. Data will be intact!
- Also, with this LOCATION clause added with the actual file path, there is no need to LOAD the data explicitly!

Create External Table

```
CREATE EXTERNAL TABLE employees (
     name STRING,
     salary    FLOAT,
     departmentSTRING
     )
ROW FORMAT
     DELIMETED
          FIELDS TERMINATED BY ‘,'
          LINES TERMINATED BY '\n';
```

- After deleting the External table, only the meta data related to the table is deleted but not the contents of the table.
- The default location of Hive table can be overwritten by using LOCATION clause in the CREATE TABLE command.
- But LOCATION clause is mostly used with External tables only.

External Tables

- The EXTERNAL keyword in the “create table” statement tells Hive that this table is external and the LOCATION … clause will tell Hive where the data is located.
- Because it’s external, Hive does not assume it owns the data. Therefore, dropping the table does not delete the data, although the metadata for the table will be deleted.
- You can tell whether or not a table is managed or external using the output of
  ```
  DESCRIBE EXTENDED <tablename> or
  DESCRIBE FORMATTED <tablename>;
  ```
  command.

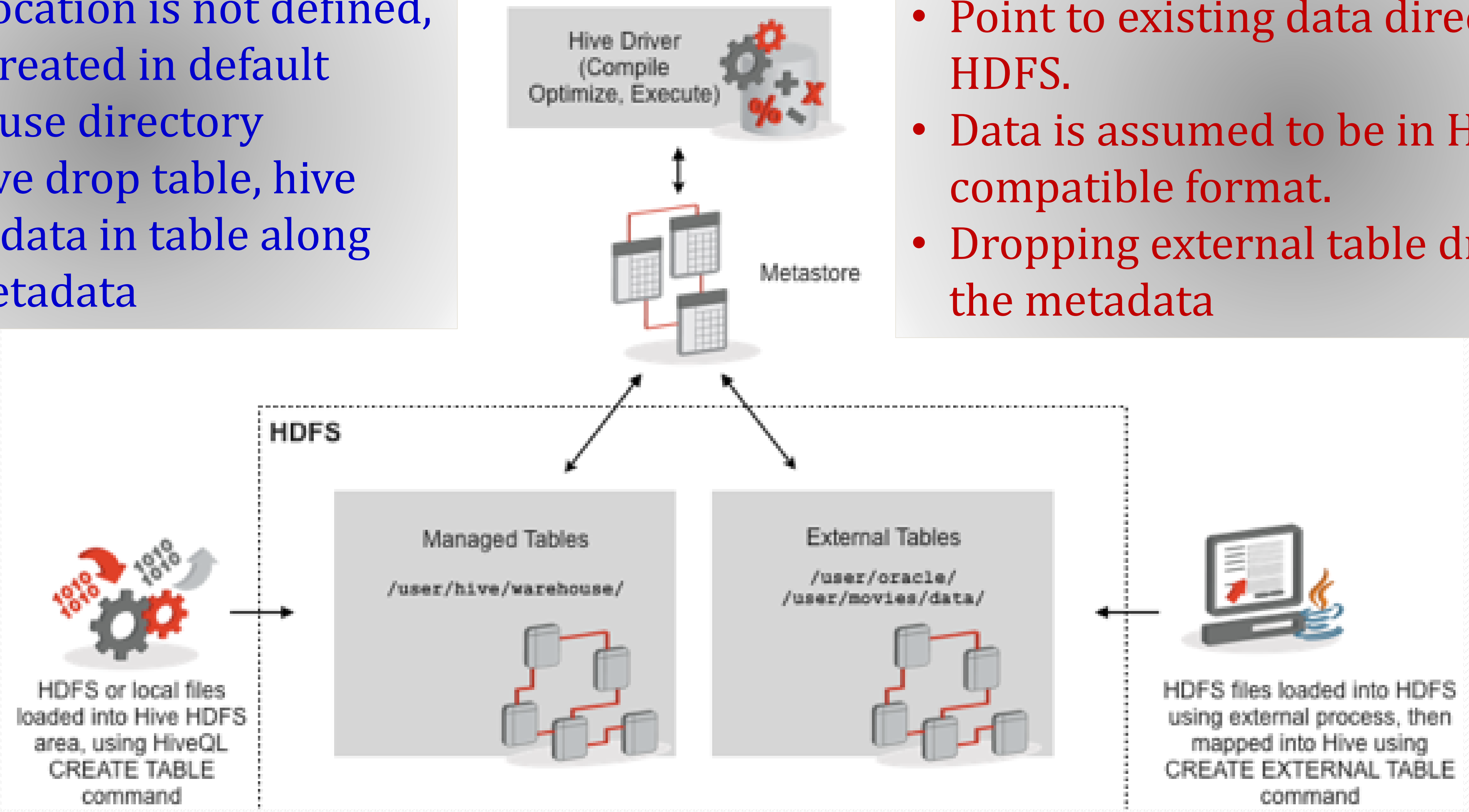
Internal & External Tables

Managed or Internal Tables

- When location is not defined, tables created in default warehouse directory
- When we drop table, hive deletes data in table along with metadata

External Tables

- Point to existing data directories in HDFS.
- Data is assumed to be in Hive-compatible format.
- Dropping external table drops only the metadata


Hive Driver (Compile Optimize, Execute)
Metastore
HDFS
Managed Tables
/user/hive/warehouse/
External Tables
/user/oracle/
/user/movies/data/
HDFS or local files loaded into Hive HDFS area, using HiveQL CREATE TABLE command
HDFS files loaded into HDFS using external process, then mapped into Hive using CREATE EXTERNAL TABLE command

When to use Internal & External tables?

- **Internal table**
  - Data is temporary
  - Hive to Manage the table data completely not allowing any external source to use the table
  - Don’t want data after deletion
- **External table**
  - The data is also used outside of Hive. For example, the data files are read and processed by an existing program that doesn’t lock the files.
  - Hive should not own data and control settings, etc., you have another program or process that will do those things.
  - Can create table back with the same schema and point to the location of the data.
  - Use this when sharing with other Hadoop applications, or when you want to use multiple schemas on the same data.

Main Point

Managed and External tables are the two different types of tables in hive used to determine how data is loaded. Use managed table when you don’t want the data after deletion. Use external tables with the location clause when the data is also used outside of Hive and is not supposed to be managed by Hive.

Science & Technology of Consciousness: External tables concept is reminiscent of the incorruptible quality of pure consciousness – "No weapon can cut it into pieces, nor can it be burned by fire, nor moistened by water, nor withered by the wind."

Optimization Techniques

- In Hive if you do simple query like `select * from table`, no map reduce job is going to run as we are just dumping the data.
- This is an optimization technique used by Hive to reduce the latency of MapReduce overhead.
- Simple queries like `Select *`, `Filter`, `Limit` do not require MapReduce jobs, it'll just use FETCH task.
- You can add **explain** before your query and it will display how the query is going to be executed by the execution engine and displays how many map-reduce phases are going to be required for the query.
- Whenever you do **aggregations** then the **reducer phase** will be executed along with map phase.

Some more Table Commands

- Accepts only a subset of SQL queries

- **Drop table**

```
DROP TABLE tableName;
```

- **Alter table**

```
ALTER TABLE tableName RENAME TO tableNameNew;
ALTER TABLE tableName ADD COLUMNS (new_col INT);
```

Relational Operators

- **ALL and DISTINCT**
  - Specify whether duplicate rows should be returned
  - ALL is the default (all matching rows are returned)
  - DISTINCT removes duplicate rows from the result set
- **WHERE**
  - Filters by expression
- **LIMIT**
  - Indicates the number of rows to be returned

Relational Operators

- **GROUP BY**
  - Group data by column values
  - Select statement can only include columns included in the GROUP BY clause

- **ORDER BY / SORT BY**
  - ORDER BY performs total ordering
    - Slow, poor performance
  - SORT BY performs partial ordering
    - Sorts output from each reducer

Store Query Results into File

- The following command outputs the table to a local directory :

```
INSERT OVERWRITE LOCAL DIRECTORY '/home/cloudera/HiveOutput'
ROW FORMAT DELIMITED FIELDS TERMINATED BY '\t'
STORED AS TEXTFILE
SELECT * FROM employees;
```

- The following command outputs the table to an HDFS file

```
INSERT OVERWRITE DIRECTORY '/user/cloudera/hiveOutput'
select dept, AVG(salary) from employees group by dept;
```

- By default, Hive generates output file names as 000000_0.

Word Count in Hive

```
CREATE TABLE WordCount (line string);

LOAD DATA INPATH '/user/cloudera/test.txt' INTO
TABLE wordcount;

SELECT each_word, count(*) AS count
  FROM(
     SELECT explode(split(line,‘\s’)) AS each_word
           FROM wordcount) resultTable
  GROUP BY each_word
  ORDER BY each_word;
```

----***explode()*** takes in an ***array*** (or a map) as an ***input*** and gives the elements of the array (map) as ***separate rows*** for ***output.***

```
hive -f /home/cloudera/cs523/Hive/wc.sql
```

JOIN Example

- Example: Relational join on two tables:
  - Table of word counts from Shakespeare collection
  - Table of word counts from HTDG

```
SELECT s.word, s.freq, h.freq FROM shakespeare s
  JOIN htdg h ON (s.word = h.word)
      WHERE s.freq >= 1 AND h.freq >= 1
            ORDER BY s.freq DESC LIMIT 8;

the   25848 62394
I     23031 8854
and   19671 38985
to    18038 13526
of    16700 34654
a     14170 8057
you   12702 2720
my    11297 4135
```

Partitions

- By default, a simple query in Hive scans the whole Hive table. This slows down the performance when querying a large-size table.
- The issue could be resolved by creating Hive partitions, which is very similar to what's in the RDBMS.
  - Hadoop's programming works on flat files. So, Hive can use directory structures to "partition" data to improve performance on certain queries.
- In Hive, each partition corresponds to a predefined partition column(s) and stores it as a subdirectory in the table's directory in HDFS.
- When the table gets queried, only the required partitions (directory) of data in the table are queried, so the I/O and time of query is greatly reduced.

Partitions contd..

- It is very easy to implement Hive partitions at the time when the table is created.
- Each table can have one or more partitions which determine the distribution of data within sub-directories of the table directory.
- Partition keys are basic elements for determining how the data is stored in the table.
  - Can make some queries faster
  - Divide data based on partition column
  - Use `PARTITIONED BY` clause when creating table
  - Use `PARTITION` clause when loading data
  - `SHOW PARTITIONS` will show a table’s partitions

Static Partitions

- Static Partitioning is a type of partitioning where we manually create all partitions when **loading the data**.
- Suppose data for table employee is in the directory */warehouse/employee*.
- If employee is partitioned on column state, then data with a particular state value ‘IA’ will be stored in files within the directory */warehouse/employee/state=IA*.

```
CREATE TABLE employee
    (name STRING, salary FLOAT, dept STRING)
PARTITIONED BY (state STRING)
ROW FORMAT DELIMITED FIELDS TERMINATED BY ',';


LOAD DATA INPATH '/user/cloudera/input/employeeIA.txt’
OVERWRITE INTO TABLE employees
PARTITION (state=‘IA');
```

Main Point

Hive organizes tables into partitions. It is a way of dividing a table into related parts based on the values of partitioned columns such as date, city, and department. Using partition, it is easy and fast to query only a portion of the data. Science & Technology of Consciousness: Pure consciousness manifests as individuals in space. So even though individuals look different, like different hive partitions, basically they are the same representation of the underlying reality of Unity consciousness.