# COMP9313: Big Data Management


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**Course web site: http://www.cse.unsw.edu.au/~cs9313/**

# Chapter 10: NoSQL, HBase, and Hive

# Part 1: Introduction to NoSQL

# What does RDBMS provide?

Relational model with schemas

Powerful, flexible query language (SQL)

Transactional semantics: ACID

Rich ecosystem, lots of tool support (MySQL, PostgreSQL, etc.)

# What is NoSQL?

The name stands for **N**ot **O**nly **SQL**

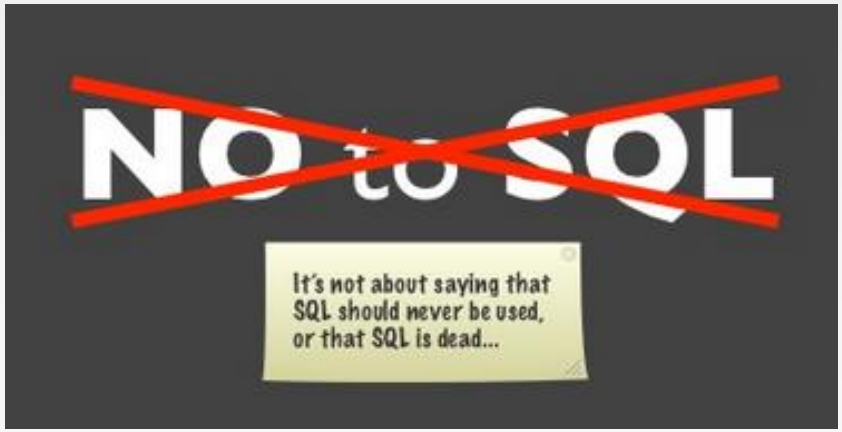
Does not use SQL as querying language

Class of non-relational data storage systems

The term NOSQL was introduced by Eric Evans when an event was organized to discuss open source distributed databases

It's not a replacement for a RDBMS but compliments it

All NoSQL offerings relax one or more of the ACID properties (will talk about the CAP theorem)



# What is NoSQL?

Key features (advantages):

non-relational

don’t require strict schema

data are replicated to multiple nodes (so, identical & fault-tolerant) and can be partitioned:

- down nodes easily replaced
- no single point of failure

horizontal scalable

cheap, easy to implement (open-source)

massive write performance

fast key-value access

# Why NoSQL ?

Web apps have different needs (than the apps that RDBMS were designed for)

- Low and predictable response time (latency)
- Scalability & elasticity (at low cost!)
- High availability
- Flexible schemas / semi-structured data
- Geographic distribution (multiple datacenters)

Web apps can (usually) do without

- Transactions / strong consistency / integrity
- Complex queries

# Who are Using NoSQL?

Google (BigTable)

LinkedIn (Voldemort)

Facebook (Cassandra)

Twitter (HBase, Cassandra)

Baidu (HyperTable)

# Three Major Papers for NoSQL

Three major papers were the seeds of the NoSQL movement

BigTable (Google)

Dynamo (Amazon)

- Ring partition and replication
- Gossip protocol (discovery and error detection)
- Distributed key-value data store
- Eventual consistency

CAP Theorem (discuss in the next few slides)

# CAP Theorem

Suppose three properties of a distributed system (sharing data)

**Consistency:**

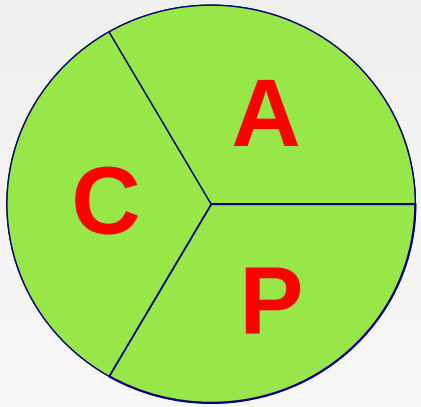
- all copies have same value

**Availability:**

- reads and writes always succeed

**Partition-tolerance:**

- system properties (consistency and/or availability) hold even when network failures prevent some machines from communicating with others



# CAP Theorem

Brewer's CAP Theorem:

*For any system sharing data, it is "impossible" to guarantee simultaneously all of these three properties*

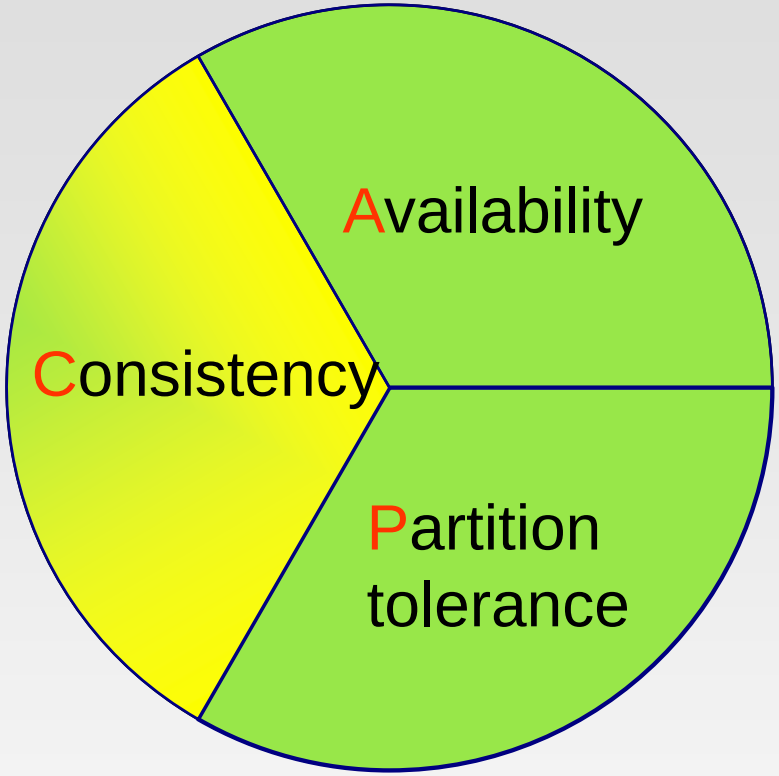
You can have at most two of these three properties for any shared-data system

Very large systems will "partition" at some point:

That leaves either **C** or **A** to choose from (traditional DBMS prefers **C** over **A** and **P** )

In almost all cases, you would choose **A** over **C** (except in specific applications such as order processing)

# CAP Theorem: Consistency




All client always have the same view of the data

Once a writer has written, all readers will see that write

Two kinds of consistency:

- strong consistency – ACID (Atomicity Consistency Isolation Durability)
- weak consistency – BASE (Basically Available Soft-state Eventual consistency )

# ACID & CAP

**ACID**

A DBMS is expected to support “ACID transactions,” processes that are:

**Atomicity:** either the whole process is done or none is

**Consistency:** only valid data are written

**Isolation:** one operation at a time

**Durability:** once committed, it stays that way

**CAP**

**Consistency:** all data on cluster has the same copies

**Availability:** cluster always accepts reads and writes

**Partition tolerance:** guaranteed properties are maintained even when network failures prevent some machines from communicating with others

# Consistency Model

A consistency model determines rules for visibility and apparent order of updates

Example:

Row X is replicated on nodes M and N

Client A writes row X to node N

Some period of time t elapses

Client B reads row X from node M

**Does client B see the write from client A?**

Consistency is a continuum with tradeoffs

**For NOSQL, the answer would be: “maybe”**

CAP theorem states: *“strong consistency can't be achieved at the same time as availability and partition-tolerance”*

# Eventual Consistency

When no updates occur for a long period of time, eventually all updates will propagate through the system and all the nodes will be consistent

For a given accepted update and a given node, eventually either the update reaches the node or the node is removed from service

Known as BASE (**B**asically **A**vailable, **S**oft state, **E**ventual consistency), as opposed to ACID

http://en.wikipedia.org/wiki/Eventual_consistency

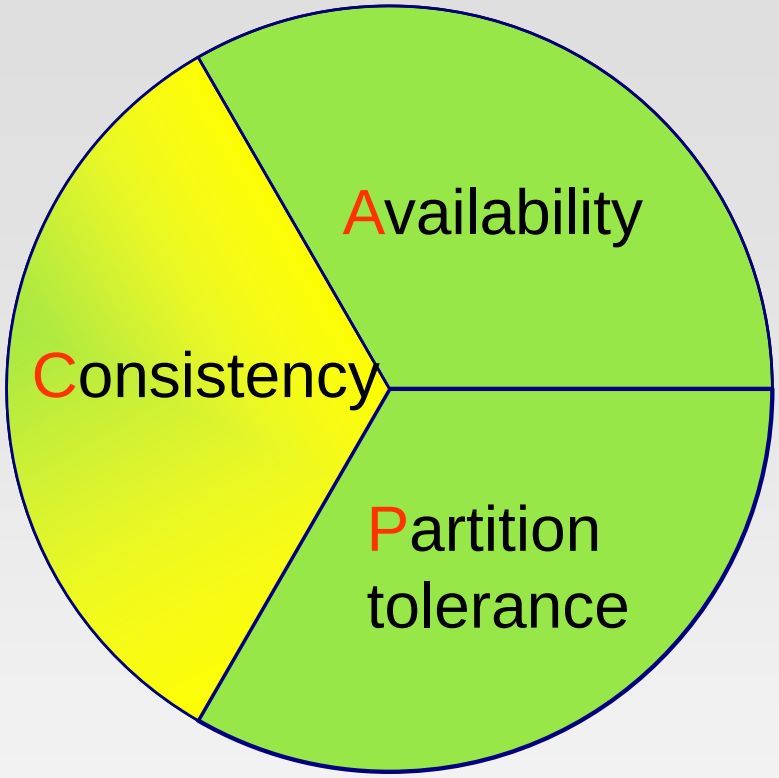
# Eventual Consistency

The types of large systems based on CAP aren't ACID they are BASE (http://queue.acm.org/detail.cfm?id=1394128):

- Basically Available - system seems to work all the time
- Soft State - it doesn't have to be consistent all the time
- Eventually Consistent - becomes consistent at some later time

Everyone who builds big applications builds them on CAP and BASE: Google, Yahoo, Facebook, Amazon, eBay, etc.

# CAP Theorem: Availability



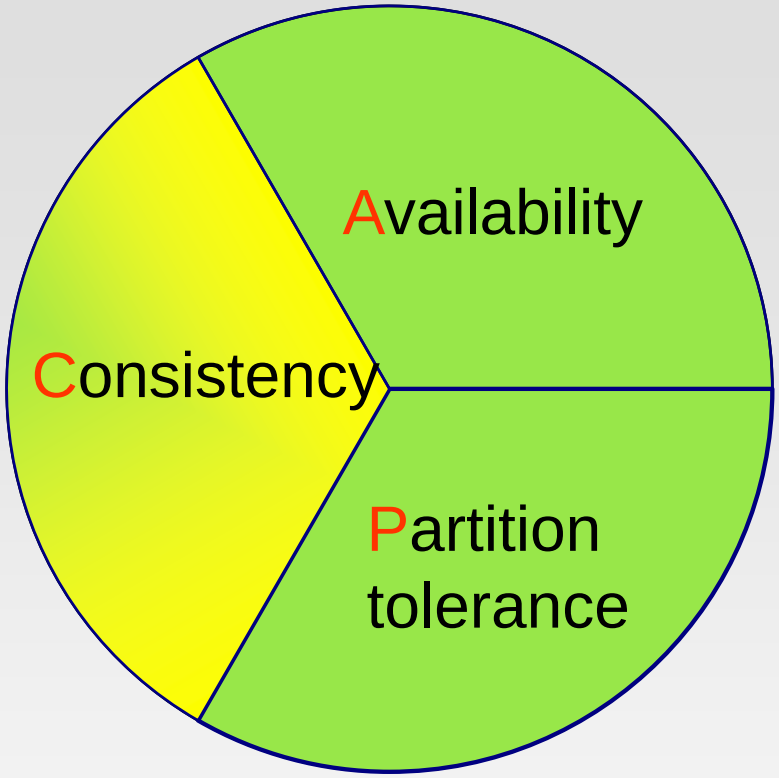

System is available during software and hardware upgrades and node failures.

Traditionally, thought of as the server/process available five 9's (99.999 %).

However, for large node system, at almost any point in time there's a good chance that a node is either down or there is a network disruption among the nodes.

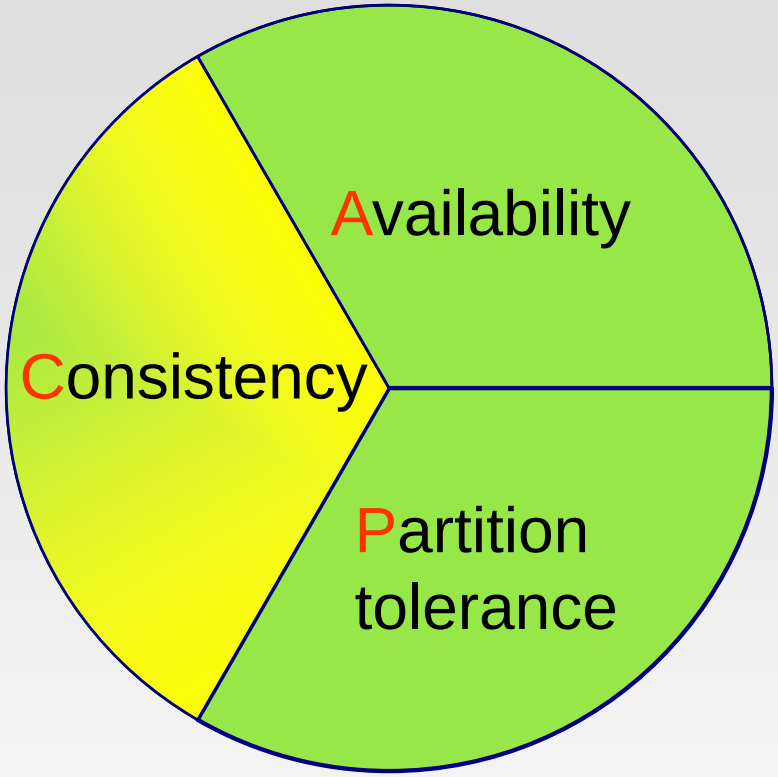
Want a system that is resilient in the face of network disruption

# CAP Theorem: Partition-Tolerance



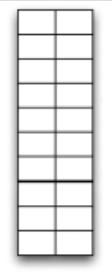

A system can continue to operate in the presence of a network partitions.

# CAP Theorem




CAP Theorem: You can have at most **two** of these properties for any shared-data system

# NoSQL Taxonomy

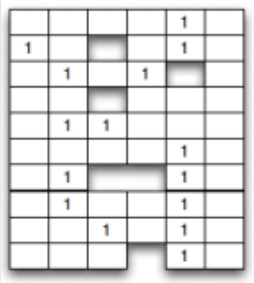


Key-Value stores

- Simple K/V lookups (DHT)

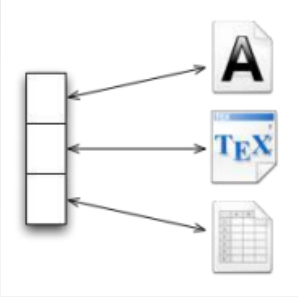
Column stores

- Each key is associated with many attributes (columns)
- NoSQL column stores are actually hybrid row/column stores
  - Different from “pure” relational column stores!



Document stores

- Store semi-structured documents (JSON)




Graph databases

- Neo4j, etc.
- Not exactly NoSQL
  - can’t satisfy the requirements for High Availability and Scalability/Elasticity very well

# Key-value

Focus on scaling to huge amounts of data

Designed to handle massive load

Based on Amazon's dynamo paper

Data model: (global) collection of Key-value pairs

*Dynamo ring partitioning* and *replication*

Example: (DynamoDB)

- *items* having one or more attributes (name, value)
- An *attribute* can be single-valued or multi-valued like set.
- items are combined into a *table*

# Key-value

Basic API access:

- get(key): extract the value given a key
- put(key, value): create or update the value given its key
- delete(key): remove the key and its associated value
- execute(key, operation, parameters): invoke an operation to the value (given its key) which is a special data structure (e.g. List, Set, Map .... etc)

# Key-value

Pros:

- very fast
- very scalable (horizontally distributed to nodes based on key)
- simple data model
- eventual consistency
- fault-tolerance

Cons

- Can’t model more complex data structure such as objects

# Key-value

| Name | Producer | Data model | Querying |
|---|---|---|---|
| | | | |
| SimpleDB | Amazon | set of couples (key, {attribute}), where attribute is a couple (name, value) | restricted SQL; select, delete, GetAttributes, and PutAttributes operations |
| Redis | Salvatore Sanfilippo | set of couples (key, value), where value is simple typed value, list, ordered (according to ranking) or unordered set, hash value | primitive operations for each value type |
| Dynamo | Amazon | like SimpleDB | simple get operation and put in a context |
| Voldemort | LinkeIn | like SimpleDB | similar to Dynamo |

# Document-based

Can model more complex objects

Inspired by Lotus Notes

Data model: collection of documents

Document: JSON (**J**ava**S**cript **O**bject **N**otation is a data model, key-value pairs, which supports objects, records, structs, lists, array, maps, dates, Boolean with **nesting**), XML, other semi-structured formats.

Example: (MongoDB) document

{Name:"Jaroslav",

Address:"Malostranske nám. 25, 118 00 Praha 1”,

Grandchildren: {Claire: "7", Barbara: "6", "Magda: "3", "Kirsten: "1", "Otis: "3", Richard: "1“}

Phones: [ “123-456-7890”, “234-567-8963” ]

}

# Document-based

| Name | Producer | Data model | Querying |
|---|---|---|---|
| | | | |
| MongoDB | 10gen | object-structured documents stored in collections;<br>each object has a primary key called ObjectId | manipulations with objects in collections (find object or objects via simple selections and logical expressions, delete, update,) |
| Couchbase | Couchbase | document as a list of named (structured) items (JSON document) | by key and key range, views via Javascript and MapReduce |

# Column-based

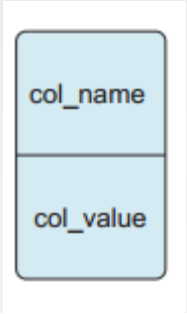
Based on Google's BigTable paper

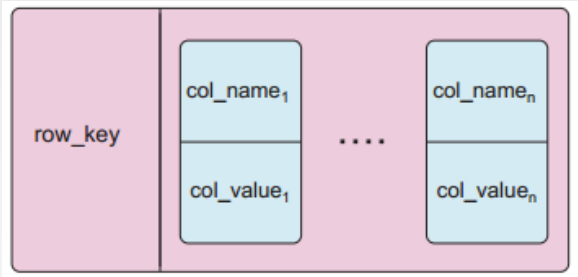
Like column oriented relational databases (store data in column order) but with a twist

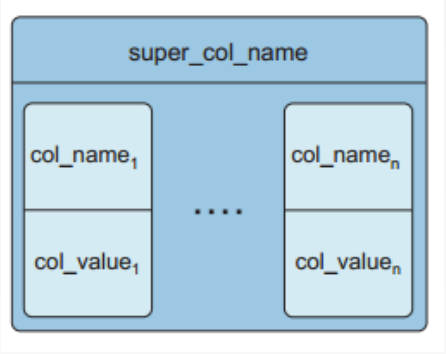
Tables similarly to RDBMS, but handle semi-structured

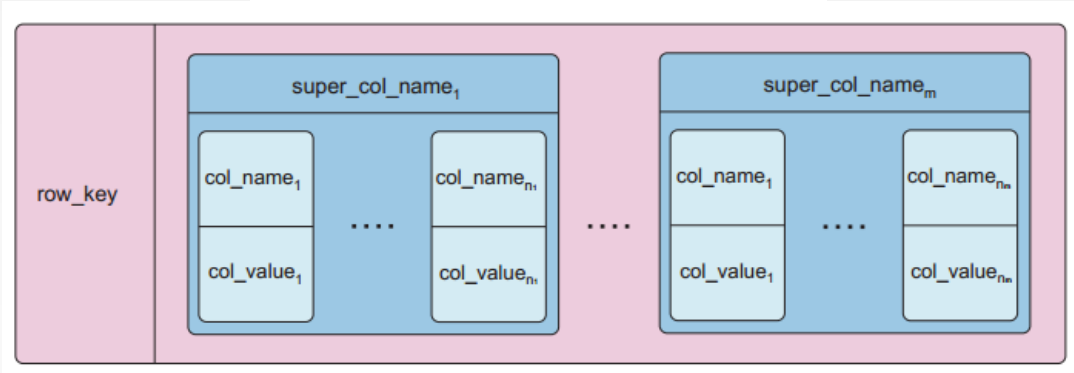
Data model:

- Collection of Column Families
- Column family = (key, value) where value = set of **related** columns (standard, super)
- indexed by *row key*, *column key* and *timestamp*



# Column-based

One column family can have variable numbers of columns

Cells within a column family are sorted “physically”

Very sparse, most cells have null values

Comparison: RDBMS vs column-based NoSQL

Query on multiple tables

- RDBMS: must fetch data from several places on disk and glue together
- Column-based NoSQL: only fetch column families of those columns that are required by a query (all columns in a column family are stored together on the disk, so multiple rows can be retrieved in one read operation data locality)

# Column-based

| Name | Producer | Data model | Querying |
|---|---|---|---|
| | | | |
| BigTable | Google | set of couples (key, {value}) | selection (by combination of row, column, and time stamp ranges) |
| HBase | Apache | groups of columns (a BigTable clone) | JRUBY IRB-based shell (similar to SQL) |
| Hypertable | Hypertable | like BigTable | HQL (Hypertext Query Language) |
| CASSANDRA | Apache (originally Facebook) | columns, groups of columns corresponding to a key (supercolumns) | simple selections on key, range queries, column or columns ranges |
| PNUTS | Yahoo | (hashed or ordered) tables, typed arrays, flexible schema | selection and projection from a single table (retrieve an arbitrary single record by primary key, range queries, complex predicates, ordering, top-k) |

# Graph-based

Focus on modeling the structure of data (*interconnectivity*)

Scales to the complexity of data

Inspired by mathematical Graph Theory (G=(E,V))

Data model:

(Property Graph) nodes and edges

- Nodes may have properties (including ID)
- Edges may have labels or roles

Key-value pairs on both

Interfaces and query languages vary

*Single-step* vs *path expressions* vs *full recursion*

Example:

Neo4j, FlockDB, InfoGrid …

# NoSQL Pros/Cons

Advantages

- Massive scalability
- High availability
- Lower cost (than competitive solutions at that scale)
- (usually) predictable elasticity
- Schema flexibility, sparse & semi-structured data

Disadvantages

- Don’t fully support relational features
  - no join, group by, order by operations (except within partitions)
  - no referential integrity constraints across partitions
- No declarative query language (e.g., SQL) → more programming
- Eventual consistency is not intuitive to program for
  - Makes client applications more complicated
- No easy integration with other applications that support SQL
- Relaxed ACID (see CAP theorem later) → fewer guarantees

# Conclusion

NOSQL database cover only a part of data-intensive cloud applications (mainly Web applications)

Problems with cloud computing:

SaaS (Software as a Service or on-demand software) applications require enterprise-level functionality, including ACID transactions, security, and other features associated with commercial RDBMS technology, i.e. NOSQL should not be the only option in the cloud

Hybrid solutions:

- Voldemort with MySQL as one of storage backend
- deal with NOSQL data as semi-structured data

->integrating RDBMS and NOSQL via SQL/XML

# Part 2: Introduction to HBase

# What is HBase?

HBase is an **open-source**, **distributed**, **column-oriented** database built on top of HDFS based on BigTable

- Distributed – uses HDFS for storage
- Row/column store
- Column-oriented - nulls are free
- Multi-Dimensional (Versions)
- Untyped - stores byte[]

HBase is part of Hadoop

HBase is the Hadoop application to use when you require real-time read/write random access to very large datasets

- Aim to support low-latency random access

# How Data is Stored in HBase ?

A *sparse*, *distributed*, *persistent multi-dimensional sorted* map

Sparse

- Sparse data is supported with no waste of costly storage space
- HBase can handle the fact that we don't (yet) know that information
- HBase as a schema-less data store; that is, it's fluid — we can add to, subtract from or modify the schema as you go along

Distributed and persistent

- Persistent simply means that the data you store in HBase will persist or remain after our program or session ends
- Just as HBase is an open source implementation of BigTable, HDFS is an open source implementation of GFS.
- HBase leverages HDFS to persist its data to disk storage.
- By storing data in HDFS, HBase offers reliability, availability, seamless scalability and high performance — all on cost effective distributed servers.

# What is HBase? (Cont')

Multi-dimensional sorted map

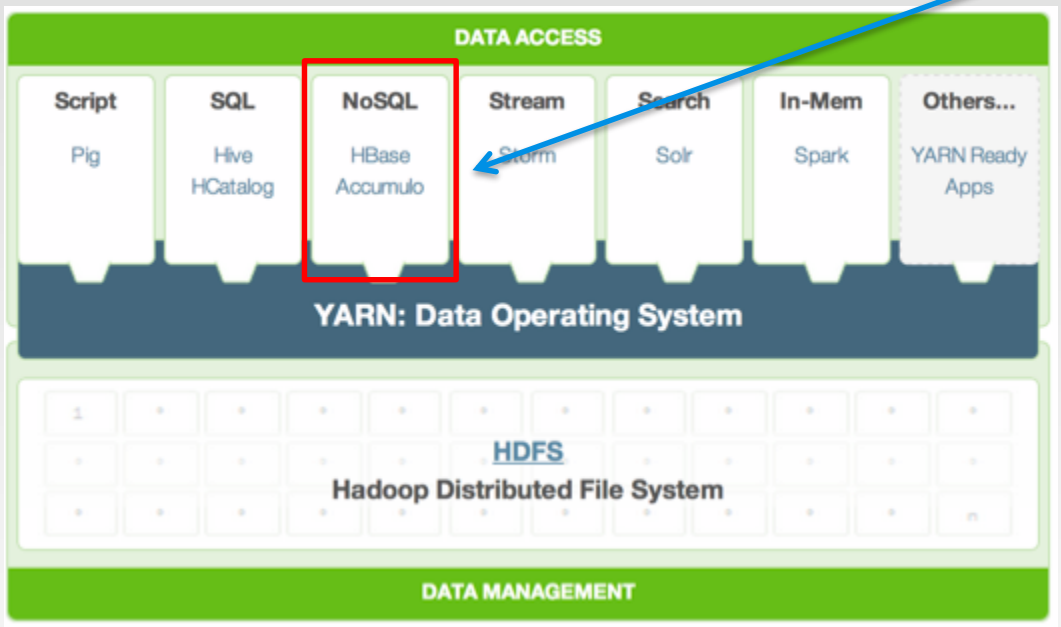
A map (also known as an associative array) is an abstract collection of key-value pairs, where the key is unique.

The keys are stored in HBase and sorted.

Each value can have multiple versions, which makes the data model multidimensional. By default, data versions are implemented with a timestamp.

# HBase: Part of Hadoop's Ecosystem

**HBase is built on top of YARN and HDFS**




**HBase files are internally stored in HDFS**

# HBase vs. HDFS

Both are distributed systems that scale to hundreds or thousands of nodes

HDFS is good for batch processing (scans over big files)

- Not good for record lookup
- Not good for incremental addition of small batches
- Not good for updates

HBase is designed to efficiently address the above points

- Fast record lookup
- Support for record-level insertion
- Support for updates (not in place)

HBase updates are done by creating new versions of values

# HBase vs. HDFS

| | Plain HDFS/MR | HBase |
|---|---|---|
| Write pattern | Append-only | Random write, bulk incremental |
| Read pattern | Full table scan, partition table scan | Random read, small range scan, or table scan |
| Hive (SQL) performance | Very good | 4-5x slower |
| Structured storage | Do-it-yourself / TSV / SequenceFile / Avro / ? | Sparse column-family data model |
| Max data size | 30+ PB | ~1PB |

If application has neither random reads or writes ➔ Stick to HDFS

# HBase Characteristics

Tables have one primary index, the *row key*.

No join operators.

Scans and queries can select a subset of available columns, perhaps by using a wildcard.

There are three types of lookups:

- Fast lookup using row key and optional timestamp.
- Full table scan
- Range scan from region start to end.

Limited atomicity and transaction support.

- HBase supports multiple batched mutations of single rows only.
- Data is unstructured and untyped.

No accessed or manipulated via SQL.

- Programmatic access via Java, HBase shell, Thrift (Ruby, Python, Perl, C++, ..) etc.

# Too Big, or Not Too Big

Two types of data: two big, or not too big

If data is not too big, a relational database should be used

The model is less likely to change as your business needs change. You may want to ask different questions over time, but if you got the logical model correct, you'll have the answers.

The data is too big?

The relational model doesn't acknowledge scale.

You need to:

- Add indexes
- Write really complex, messy SQL
- Denormalize
- Cache
- … …

How NoSQL/HBase can help?

# HBase Data Model

Table: Design-time namespace, has multiple sorted rows.

Row:

Atomic key/value container, with one row key

Rows are sorted alphabetically by the row key as they are stored

- store data in such a way that related rows are near each other (e.g., a website domain)

Column:

A column in HBase consists of a column family and a column qualifier, which are delimited by a : (colon) character.

Table schema only define it's Column Families

Column families physically co-locate a set of columns and their values

- Column: a key in the k/v container inside a row
- Value: a time-versioned value in the k/v container

Each column consists of any number of versions

Each column family has a set of storage properties, such as whether its values should be cached in memory etc.

Columns within a family are sorted and stored together

# HBase Data Model (Cont')

Column:

A column qualifier is added to a column family to provide the index for a given piece of data

Given a column family content, a column qualifier might be content:html, and another might be content:pdf

Column families are fixed at table creation, but column qualifiers are mutable and may differ greatly between rows.

Timestamp: long milliseconds, sorted descending

A timestamp is written alongside each value, and is the identifier for a given version of a value.

By default, the timestamp represents the time on the RegionServer when the data was written, but you can specify a different timestamp value when you put data into the cell

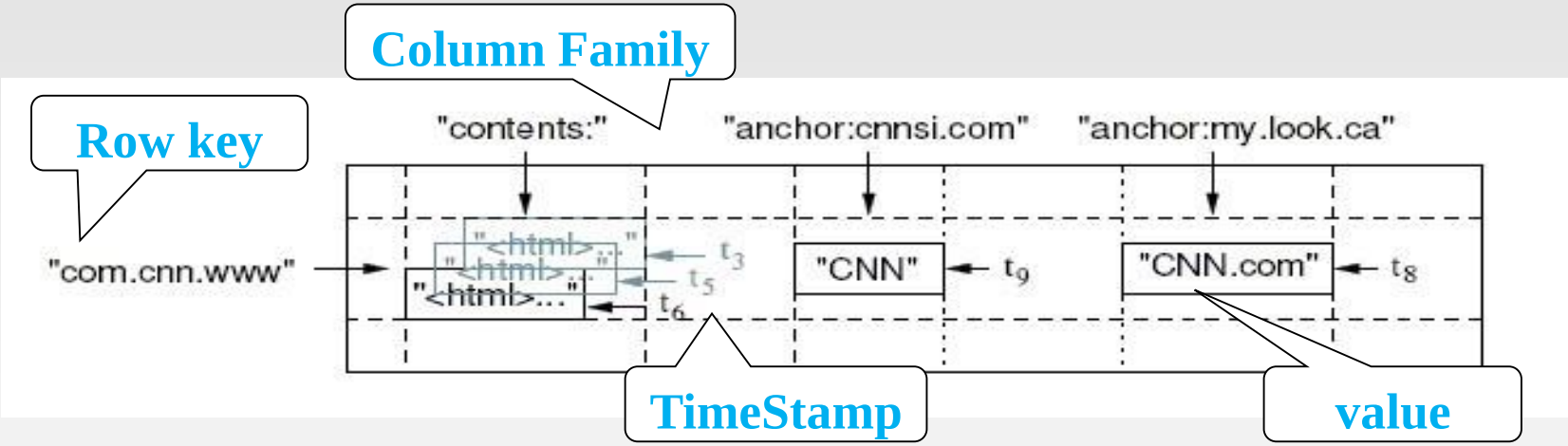
Cell:

A combination of row, column family, and column qualifier, and contains a value and a timestamp, which represents the value's version

(Row, Family:<Column, Value>, Timestamp) → Value

# HBase Data Model Examples

HBase is based on Google's Bigtable model



# HBase Data Model Examples

- Key
  - Byte array
  - Serves as the primary key for the table
  - Indexed for fast lookup
- Column Family
  - Has a name (string)
  - Contains one or more related columns
- Column Qualifier
  - Belongs to one column family
  - Included inside the row
    - *familyName:columnName*

Column family named "Contents"

Column family named "anchor"

Column qualifier

| Row key | Time Stamp | Column "contents:" | Column "anchor:" | |
|---|---|---|---|---|
| "com.apache.www" | t12 | "<html>…" | | |
| | t11 | "<html>…" | | |
| | t10 | | "anchor:apache.com" | "APACHE" |
| "com.cnn.www" | t15 | | "anchor:cnnsi.com" | "CNN" |
| | t13 | | "anchor:my.look.ca" | "CNN.com" |
| | t6 | "<html>…" | | |
| | t5 | "<html>…" | | |
| | t3 | "<html>…" | | |

# HBase Data Model Examples

- Version Number
  - Unique within each key
  - By default→ System's timestamp
  - Data type is Long
- Value
  - Byte array

Version number for each row

| Row key | Time Stamp | Column "contents:" | Column "anchor:" | |
|---|---|---|---|---|
| "com.apache.www" | t12 | "<html>…" | | |
| | t11 | "<html>…" | | value |
| | t10 | | "anchor:apache.com" | "APACHE" |
| "com.cnn.www" | t15 | | "anchor:cnnsi.com" | "CNN" |
| | t13 | | "anchor:my.look.ca" | "CNN.com" |
| | t6 | "<html>…" | | |
| | t5 | "<html>…" | | |
| | t3 | "<html>…" | | |

# HBase Data Model Examples

| Row | Timestamp | Column family: animal: | | Column family: repairs: |
|---|---|---|---|---|
| | | animal:type | animal:size | repairs:cost |
| enclosure1 | t2 | zebra | | 1000 EUR |
| | t1 | lion | big | |
| enclosure2 | … | … | … | … |

Storage: every "cell" (i.e. the time-versioned value of one column in one row) is stored "fully qualified" (with its full rowkey, column family, column name, etc.) on disk

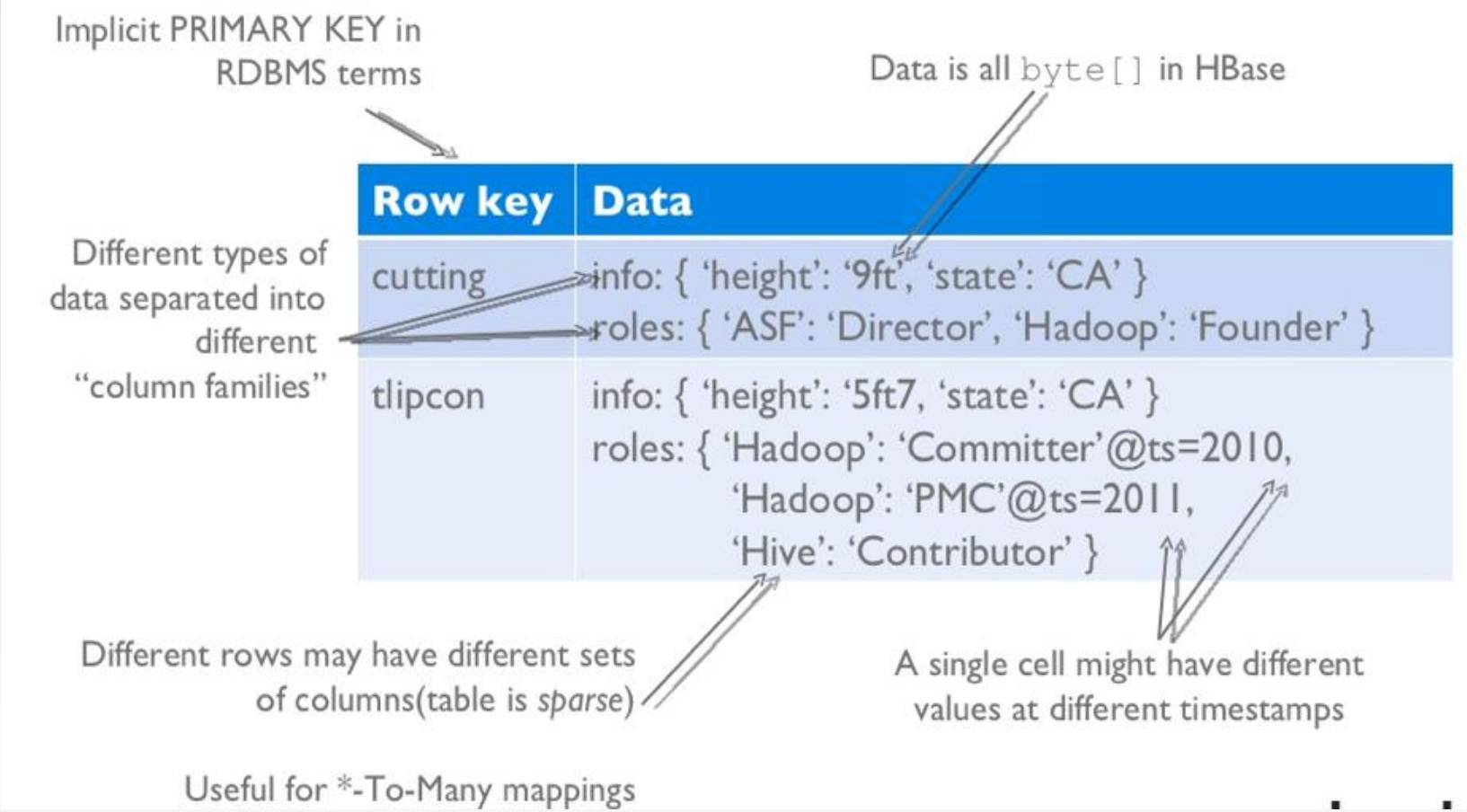
Column family animal:

| | |
|---|---|
| (enclosure1, t2, animal:type) | zebra |
| (enclosure1, t1, animal:size) | big |
| (enclosure1, t1, animal:type) | lion |

Column family repairs:

| | |
|---|---|
| (enclosure1, t1, repairs:cost) | 1000 EUR |

# HBase Data Model Examples



# HBase Data Model

Row:

The "row" is atomic, and gets flushed to disk periodically. But it doesn't have to be flushed into just a single file!

It can be broken up into different files with different properties, an reads can look at just a subset.

Column Family: divide columns into physical files

Columns within the same family are stored together

Why? Table is sparse, many columns

- No need to scan the whole row when accessing a few columns
- Each column a file will generate too many files

Row keys, column names, values: arbitrary bytes

Table and column family names: printable characters

Timestamps: long integers

# Notes on Data Model

HBase schema consists of several ***Tables***

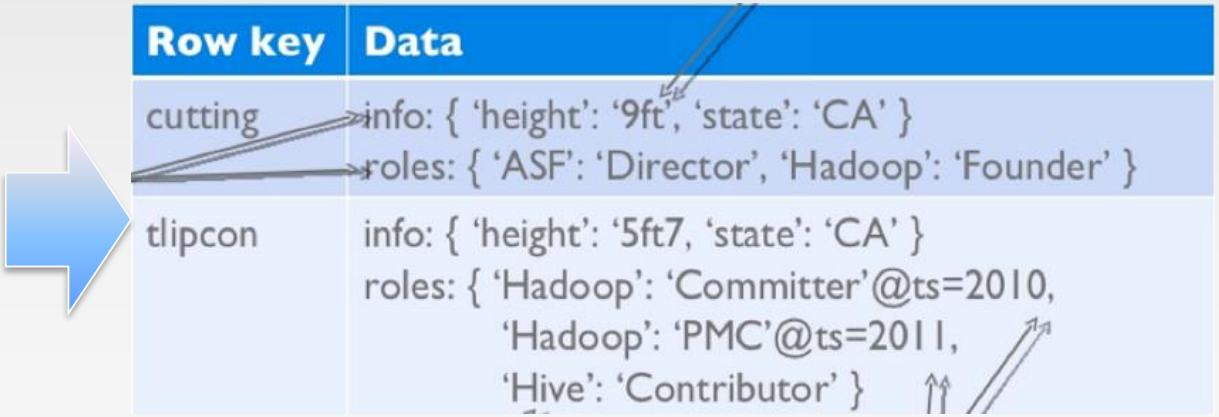
Each table consists of a set of ***Column Families***

- Columns are not part of the schema

HBase has ***Dynamic Columns***

- Because column names are encoded inside the cells
- Different cells can have different columns

"Roles" column family has different columns in different cells



| Row key | Data |
| --- | --- |
| cutting | info: { 'height': '9ft', 'state': 'CA' }<br>roles: { 'ASF': 'Director', 'Hadoop': 'Founder' } |
| tlipcon | info: { 'height': '5ft7, 'state': 'CA' }<br>roles: { 'Hadoop': 'Committer'@ts=2010,<br>'Hadoop': 'PMC'@ts=2011,<br>'Hive': 'Contributor' } |

# Notes on Data Model (Cont'd)

The ***version number*** can be user-supplied

- Even does not have to be inserted in increasing order
- Version number are unique within each key

Table can be very sparse

- Many cells are empty

***Keys*** are indexed as the primary key

| Row Key | Time Stamp | ColumnFamily `contents` | ColumnFamily `anchor` |
|---|---|---|---|
| "com.cnn.www" | t9 | | `anchor:cnnsi.com` = "CNN" |
| "com.cnn.www" | t8 | | `anchor:my.look.ca` = "CNN.com" |
| "com.cnn.www" | t6 | `contents:html` = "<html>..." | |
| "com.cnn.www" | t5 | `contents:html` = "<html>..." | |
| "com.cnn.www" | t3 | `contents:html` = "<html>..." | |

A conceptual view of HBase table

# HBase Physical View

Each column family is stored in a separate file (called ***HTables***)

Key & Version numbers are replicated with each column family

Empty cells are not stored

| Row Key | Time Stamp | ColumnFamily "contents:" |
|---|---|---|
| "com.cnn.www" | t6 | contents:html = "<html>..." |
| "com.cnn.www" | t5 | contents:html = "<html>..." |
| "com.cnn.www" | t3 | contents:html = "<html>..." |

| Row Key | Time Stamp | Column Family anchor |
|---|---|---|
| "com.cnn.www" | t9 | anchor:cnnsi.com = "CNN" |
| "com.cnn.www" | t8 | anchor:my.look.ca = "CNN.com" |

# HBase Physical Model

| Row key | Data |
|---|---|
| cutting | info: { 'height': '9ft', 'state': 'CA' }<br>roles: { 'ASF': 'Director', 'Hadoop': 'Founder' } |
| tlipcon | info: { 'height': '5ft7, 'state': 'CA' }<br>roles: { 'Hadoop': 'Committer'@ts=2010,<br>'Hadoop': 'PMC'@ts=2011,<br>'Hive': 'Contributor' } |

`info` **Column Family**

| Row key | Column key | Timestamp | Cell value |
|---|---|---|---|
| cutting | info:height | 1273516197868 | 9ft |
| cutting | info:state | 1043871824184 | CA |
| tlipcon | info:height | 1273878447049 | 5ft7 |
| tlipcon | info:state | 1273616297446 | CA |

`roles` **Column Family**

| Row key | Column key | Timestamp | Cell value |
|---|---|---|---|
| cutting | roles:ASF | 1273871823022 | Director |
| cutting | roles:Hadoop | 1183746289103 | Founder |
| tlipcon | roles:Hadoop | 1300062064923 | PMC |
| tlipcon | roles:Hadoop | 1293388212294 | Committer |
| tlipcon | roles:Hive | 1273616297446 | Contributor |

Sorted on disk by Row key, Col key, descending timestamp

Milliseconds since unix epoch

# HBase Physical Model

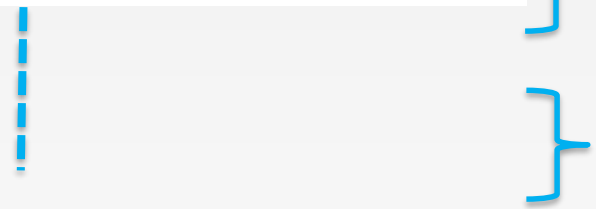
Column Families stored separately on disk: access one without wasting I/O on the other

HBase Regions

Each HTable (column family) is partitioned horizontally into ***regions***

- Regions are counterpart to HDFS blocks

| Row Key | Time Stamp | ColumnFamily "contents:" |
|---|---|---|
| "com.cnn.www" | t6 | contents:html = "<html>..." |
| "com.cnn.www" | t5 | contents:html = "<html>..." |
| "com.cnn.www" | t3 | contents:html = "<html>..." |



Each will be one region

# HBase Architecture

Major Components

The MasterServer (HMaster)

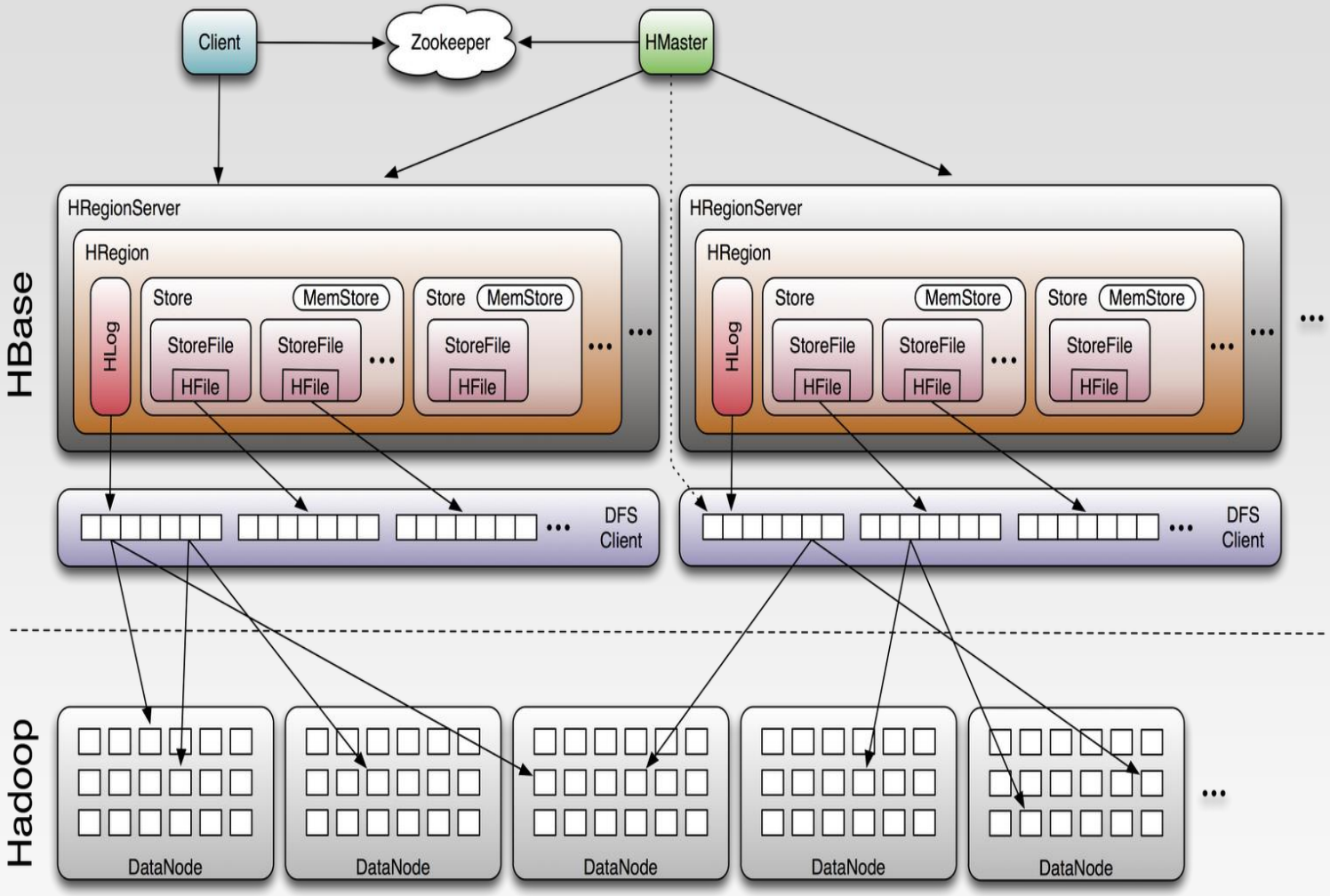
- One master server
- Responsible for coordinating the slaves
- Assigns regions, detects failures
- Admin functions

The RegionServer (HRegionServer)

- Many region servers
- Region (HRegion)
  - A subset of a table's rows, like horizontal range partitioning
  - Automatically done
- Manages data regions
- Serves data for reads and writes (using a log)

The HBase client

# HBase Architecture



# ZooKeeper

HBase clusters can be huge and coordinating the operations of the MasterServers, RegionServers, and clients can be a daunting task, but that's where **Zookeeper** enters the picture.

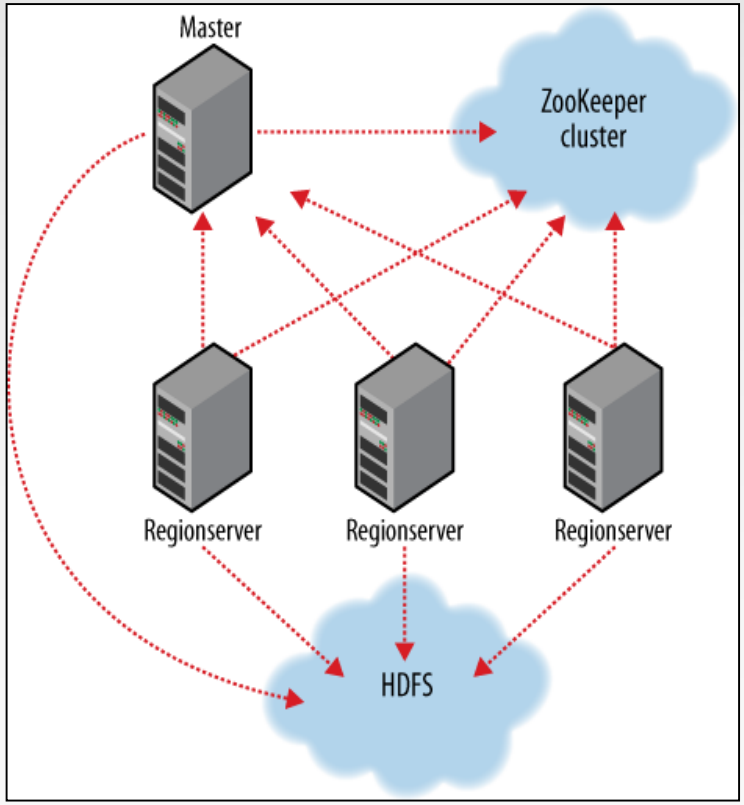
Zookeeper is a distributed cluster of servers that collectively provides reliable coordination and synchronization services for clustered applications.

HBase depends on ZooKeeper

By default HBase manages the ZooKeeper instance

E.g., starts and stops ZooKeeper

HMaster and HRegionServers register themselves with ZooKeeper



# Install HBase

Install Java and Hadoop first

Download at: https://hbase.apache.org/

The current stable version：2.1.0

Install:

```
$ tar xzf hbase- 2.1.0.tar.gz
$ mv hbase- 2.1.0 ~/hbase
```

Environment variables in ~/.bashrc

```
export HBASE_HOME = ~/hbase
export PATH = $HBASE_HOME/bin:$PATH
```

Edit hbase-env.sh: $ vim $HBASE_HOME/conf/hbase-env.sh

```
export JAVA_HOME = /usr/lib/jvm/…
export HBASE_MANAGES_ZK = true
```

hbase maintains its own ZooKeeper

# Configure HBase as Pseudo-Distributed Mode

Configure hbase-site.xml: $ vim $HBASE_HOME/conf/hbase-site.xml

```
<configuration>
        <property>
                <name>hbase.rootdir</name>
                <value>hdfs://localhost:9000/hbase</value>
        </property>
        <property>
                <name>hbase.cluster.distributed</name>
                <value>true</value>
        </property>
</configuration>
```

hbase.rootdir：must be consistent with HDFS configuration

hbase.cluster.distributed: directs HBase to run in distributed mode, with one JVM instance per daemon

More configurations refer to:
https://hbase.apache.org/book.html#config.files

Start HBase: $ start-hbase.sh

Launch the HBase Shell: $ hbase shell

# HBase Shell Commands

Create a table

```
hbase(main):004:0> create 'test', 'data'
0 row(s) in 1.4200 seconds

=> Hbase::Table - test
```

List Information About your Table

```
hbase(main):005:0> list
TABLE
test
1 row(s) in 0.0160 seconds

=> ["test"]
```

Put data into your table

```
hbase(main):006:0> put 'test', 'row1', 'data:1', 'value1'
0 row(s) in 0.1270 seconds

hbase(main):007:0> put 'test', 'row1', 'data:2', 'value2'
0 row(s) in 0.0070 seconds

hbase(main):008:0> put 'test', 'row1', 'data:3', 'value3'
0 row(s) in 0.0040 seconds
```

Scan the table for all data at once

```
hbase(main):009:0> scan 'test'
ROW                   COLUMN+CELL
 row1                 column=data:1, timestamp=1472096331975, value=value1
 row1                 column=data:2, timestamp=1472096340030, value=value2
 row1                 column=data:3, timestamp=1472096344892, value=value3
1 row(s) in 0.0670 seconds
```

# HBase Shell Commands

Describe a table

```
hbase(main):010:0> describe 'test'
Table test is ENABLED
test
COLUMN FAMILIES DESCRIPTION
{NAME => 'data', DATA_BLOCK_ENCODING => 'NONE', BLOOMFILTER => 'ROW', REPLICATIO
N_SCOPE => '0', VERSIONS => '1', COMPRESSION => 'NONE', MIN_VERSIONS => '0', TTL
 => 'FOREVER', KEEP_DELETED_CELLS => 'FALSE', BLOCKSIZE => '65536', IN_MEMORY =>
 'false', BLOCKCACHE => 'true'}
1 row(s) in 0.0420 seconds
```

Get a single row of data

```
hbase(main):012:0> get 'test', 'row1'
COLUMN                CELL
 data:1               timestamp=1472096331975, value=value1
 data:2               timestamp=1472096340030, value=value2
 data:3               timestamp=1472096344892, value=value3
3 row(s) in 0.0250 seconds
```

Assign a defined table to a variable; use the variable for operation

```
hbase(main):015:0> t = get_table 'test'
0 row(s) in 0.0030 seconds

=> Hbase::Table - test
```

```
hbase(main):016:0> t.get 'row1'
COLUMN                CELL
 data:1               timestamp=1472096331975, value=value1
 data:2               timestamp=1472096340030, value=value2
 data:3               timestamp=1472096344892, value=value3
3 row(s) in 0.0100 seconds
```

# HBase Shell Commands

Disable a table

If you want to delete a table or change its settings, as well as in some other situations, you need to disable the table first

```
hbase(main):020:0> disable 'test'
0 row(s) in 2.2760 seconds
```

You can re-enable it using the enable command.

```
hbase(main):021:0> enable 'test'
0 row(s) in 1.2450 seconds
```

Drop (delete) the table

```
hbase(main):023:0> disable 'test'
0 row(s) in 2.2320 seconds

hbase(main):024:0> drop 'test'
0 row(s) in 1.2520 seconds

hbase(main):025:0> list
TABLE
0 row(s) in 0.0060 seconds
```

Exit the HBase Shell

To exit the HBase Shell and disconnect from your cluster, use the quit command. HBase is still running in the background.

# HBase Shell Commands

You can also enter HBase Shell commands into a text file, one command per line, and pass that file to the HBase Shell.

```
create 'test', 'cf'
list 'test'
put 'test', 'row1', 'cf:a', 'value1'
put 'test', 'row2', 'cf:b', 'value2'
put 'test', 'row3', 'cf:c', 'value3'
scan 'test'
get 'test', 'row1'
```

```
TABLE
test
1 row(s) in 0.0140 seconds

0 row(s) in 0.3370 seconds

0 row(s) in 0.0040 seconds

0 row(s) in 0.0040 seconds

ROW                   COLUMN+CELL
 row1                 column=cf:a, timestamp=1472097843848, value=value1
 row2                 column=cf:b, timestamp=1472097843869, value=value2
 row3                 column=cf:c, timestamp=1472097843874, value=value3
3 row(s) in 0.0770 seconds

COLUMN                CELL
 cf:a                 timestamp=1472097843848, value=value1
1 row(s) in 0.0500 seconds
```

# HBase benefits than RDBMS

*No real indexes*

*Automatic partitioning*

*Scale linearly and automatically with new nodes*

*Commodity hardware*

*Fault tolerance*

*Batch processing*

# HBase vs. RDBMS

| | RDBMS | HBase |
|---|---|---|
| Data layout | Row-oriented | Column-family-oriented |
| Transactions | Multi-row ACID | Single row only |
| Query language | SQL | get/put/scan/etc * |
| Security | Authentication/Authorization | Work in progress |
| Indexes | On arbitrary columns | Row-key only |
| Max data size | TBs | ~1PB |
| Read/write throughput limits | 1000s queries/second | Millions of queries/second |

# When to use HBase

You need random write, random read, or both (but not neither, otherwise stick to HDFS)

You need to do many thousands of operations per second on multiple TB of data

Your acces patterns are well-known and simple

# Part 4: Introduction to Hive

# What is Hive?

A data warehouse system for Hadoop that

- facilitates easy data summarization
- supports ad-hoc queries (still batch though…)
- created by Facebook

A mechanism to project structure onto this data and query the data using a SQL-like language – HiveQL

- Interactive-console –or-
- Execute scripts
- Kicks off one or more MapReduce jobs in the background

An ability to use indexes, built-in user-defined functions

# Motivation of Hive

Limitation of MR

- Have to use M/R model
- Not Reusable
- Error prone
- For complex jobs:
  - Multiple stage of Map/Reduce functions
  - Just like ask developer to write specified physical execution plan in the database

Hive intuitive

- Make the unstructured data looks like tables regardless how it really lays out
- SQL based query can be directly against these tables
- Generate specified execution plan for this query

# Hive Features

A subset of SQL covering the most common statements

Agile data types: Array, Map, Struct, and JSON objects

User Defined Functions and Aggregates

Regular Expression support

MapReduce support

JDBC support

Partitions and Buckets (for performance optimization)

Views and Indexes

# Word Count using MapReduce

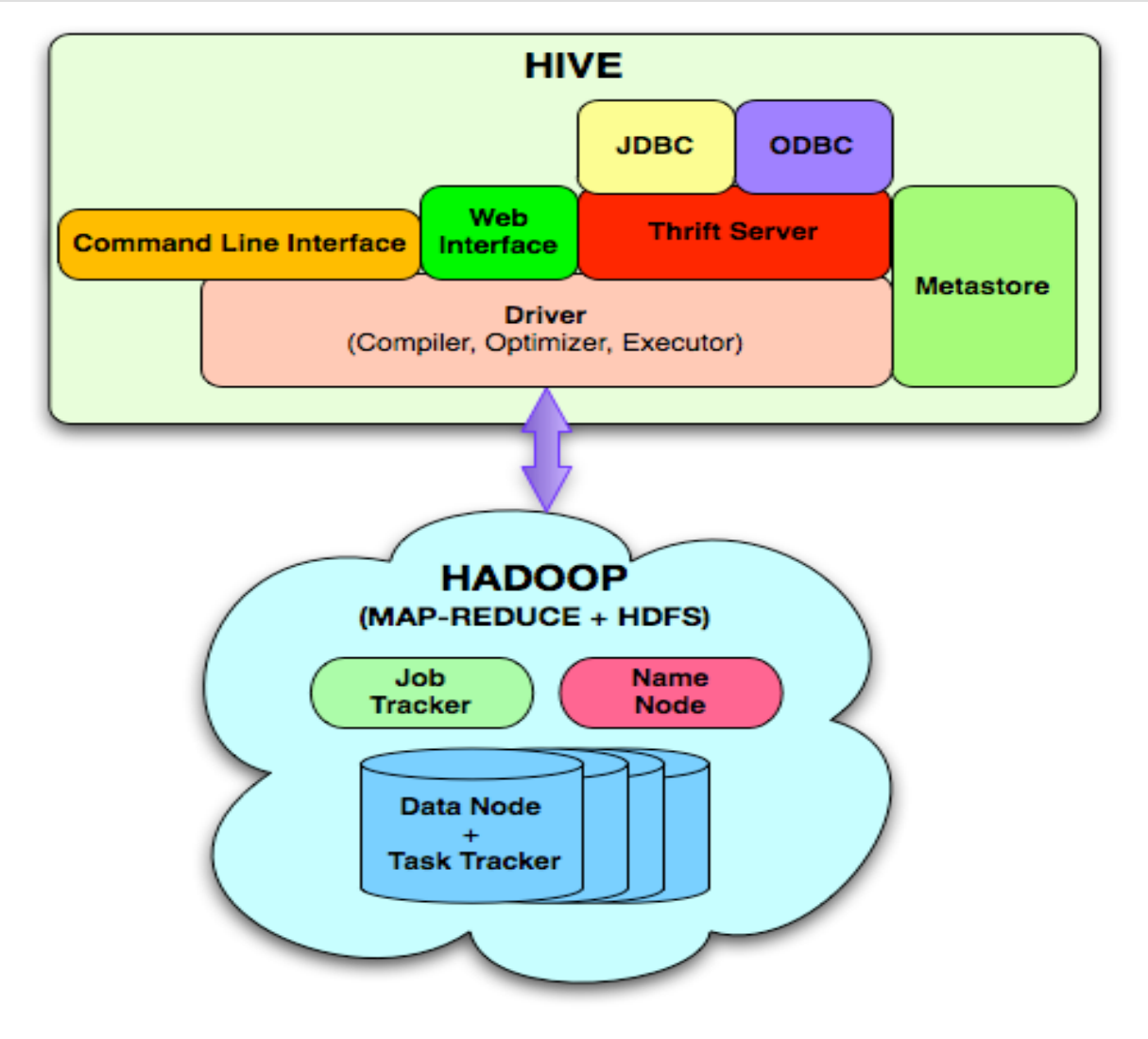
```
import java.io.IOException;
import java.util.ArrayList;
import java.util.Iterator;
import java.util.List;
import java.util.StringTokenizer;

import org.apache.hadoop.conf.Configuration;
import org.apache.hadoop.conf.Configured;
import org.apache.hadoop.fs.Path;
import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.LongWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapred.FileInputFormat;
import org.apache.hadoop.mapred.FileOutputFormat;
import org.apache.hadoop.mapred.JobClient;
import org.apache.hadoop.mapred.JobConf;
import org.apache.hadoop.mapred.MapReduceBase;
import org.apache.hadoop.mapred.Mapper;
import org.apache.hadoop.mapred.OutputCollector;
import org.apache.hadoop.mapred.Reducer;
import org.apache.hadoop.mapred.Reporter;
import org.apache.hadoop.util.Tool;
import org.apache.hadoop.util.ToolRunner;

public class WordCount extends Configured implements Tool {

  public static class MapClass extends MapReduceBase
    implements Mapper<LongWritable, Text, Text, IntWritable> {

    private final static IntWritable one = new IntWritable(1);
    private Text word = new Text();

    public void map(LongWritable key, Text value,
                    OutputCollector<Text, IntWritable> output,
                    Reporter reporter) throws IOException {
      String line = value.toString();
      StringTokenizer itr = new StringTokenizer(line);
      while (itr.hasMoreTokens()) {
        word.set(itr.nextToken());
        output.collect(word, one);
      }
    }
  }

  public static class Reduce extends MapReduceBase
    implements Reducer<Text, IntWritable, Text, IntWritable> {

    public void reduce(Text key, Iterator<IntWritable> values,
                       OutputCollector<Text, IntWritable> output,
                       Reporter reporter) throws IOException {
      int sum = 0;
      while (values.hasNext()) {
        sum += values.next().get();
      }
      output.collect(key, new IntWritable(sum));
    }
  }
```

```
  public int run(String[] args) throws Exception {
    JobConf conf = new JobConf(getConf(), WordCount.class);
    conf.setJobName("wordcount");

    conf.setOutputKeyClass(Text.class);
    conf.setOutputValueClass(IntWritable.class);

    conf.setMapperClass(MapClass.class);
    conf.setCombinerClass(Reduce.class);
    conf.setReducerClass(Reduce.class);

    List<String> other_args = new ArrayList<String>();
    for(int i=0; i < args.length; ++i) {
      try {
        if ("-m".equals(args[i])) {
          conf.setNumMapTasks(Integer.parseInt(args[++i]));
        } else if ("-r".equals(args[i])) {
          conf.setNumReduceTasks(Integer.parseInt(args[++i]));
        } else {
          other_args.add(args[i]);
        }
      } catch (NumberFormatException except) {
        System.out.println("ERROR: Integer expected instead of " + args[i]);
        return printUsage();
      } catch (ArrayIndexOutOfBoundsException except) {
        System.out.println("ERROR: Required parameter missing from " +
                           args[i-1]);
        return printUsage();
      }
    }
    // Make sure there are exactly 2 parameters left.
    if (other_args.size() != 2) {
      System.out.println("ERROR: Wrong number of parameters: " +
                         other_args.size() + " instead of 2.");
      return printUsage();
    }
    FileInputFormat.setInputPaths(conf, other_args.get(0));
    FileOutputFormat.setOutputPath(conf, new Path(other_args.get(1)));
    JobClient.runJob(conf);
    return 0;
  }

  public static void main(String[] args) throws Exception {
    int res = ToolRunner.run(new Configuration(), new WordCount(), args);
    System.exit(res);
  }
}
```

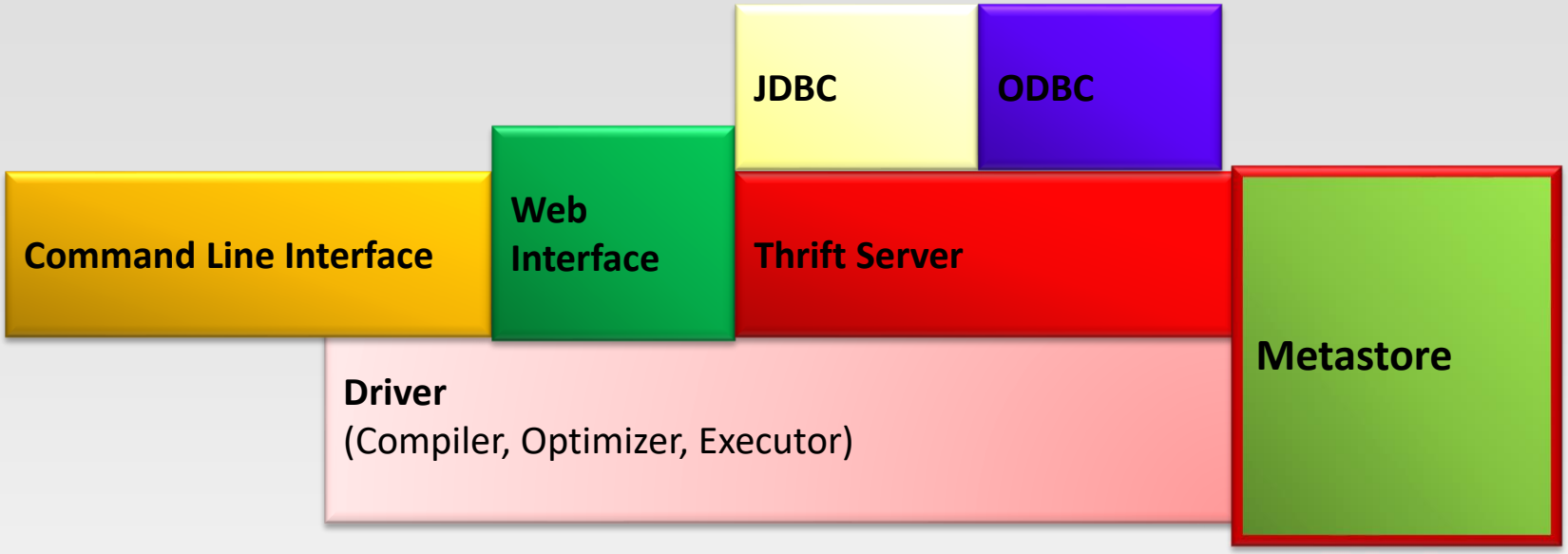
# Word Count using Hive

```
create table doc(
text string
) row format delimited fields terminated by '\n' stored as textfile;

load data local inpath '/home/Words' overwrite into table doc;

SELECT word, COUNT(*) FROM doc LATERAL VIEW
explode(split(text, ' ')) Table as word GROUP BY word;
```

# Architecture of Hive



# Architecture of Hive

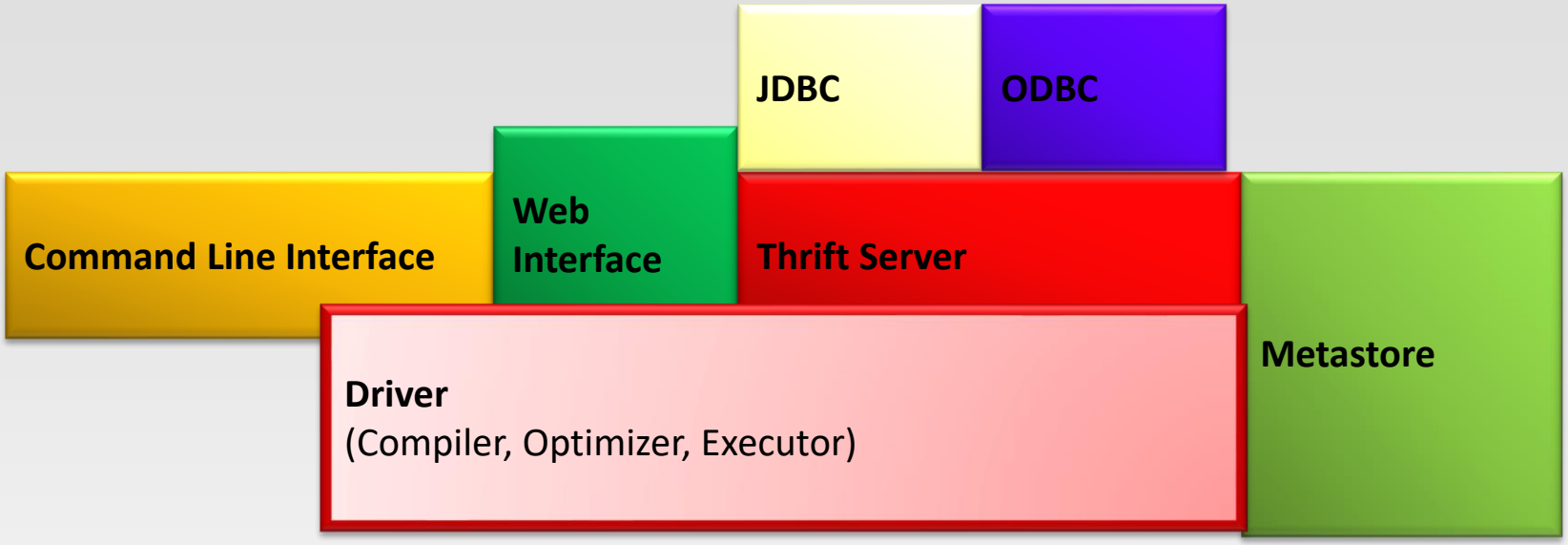



Metastore

The component that store the system catalog and meta data about tables, columns, partitions etc.

Stored in a relational RDBMS (built-in Derby)

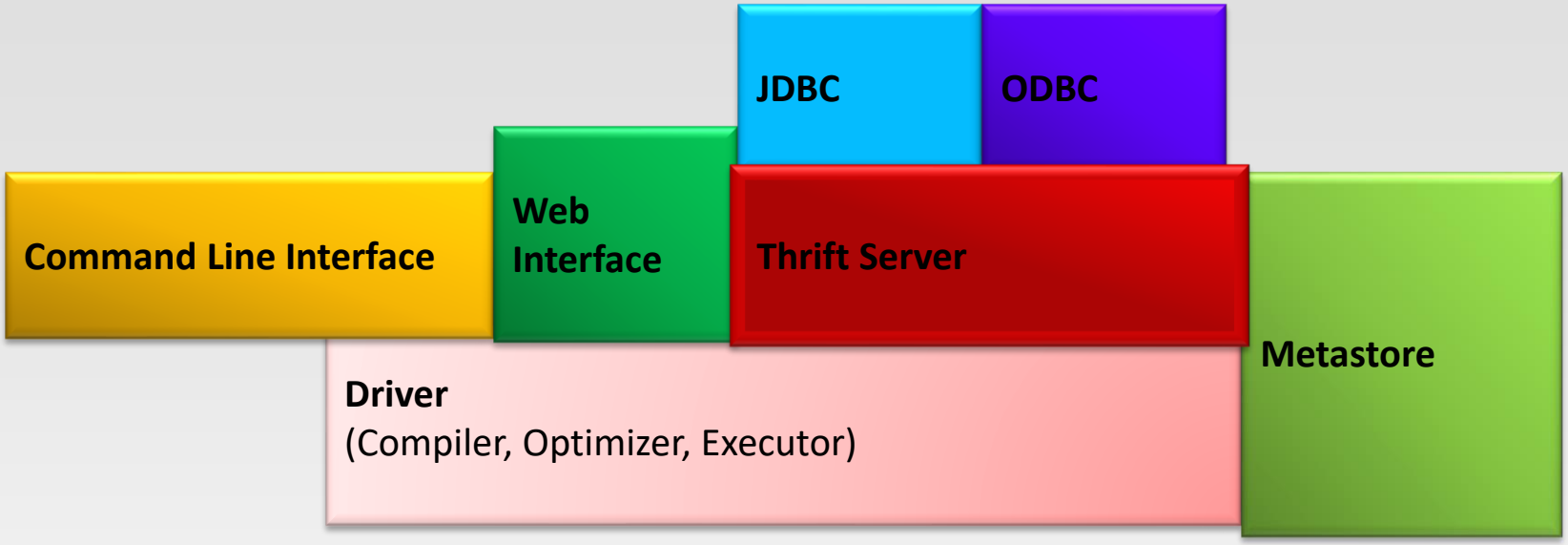
# Architecture of Hive




Driver: manages the lifecycle of a HiveQL statement as it moves through Hive.

- Query Compiler: compiles HiveQL into map/reduce tasks
- Optimizer: generate the best execution plan
- Execution Engine: executes the tasks produced by the compiler in proper dependency order. The execution engine interacts with the underlying Hadoop instance.

# Architecture of Hive

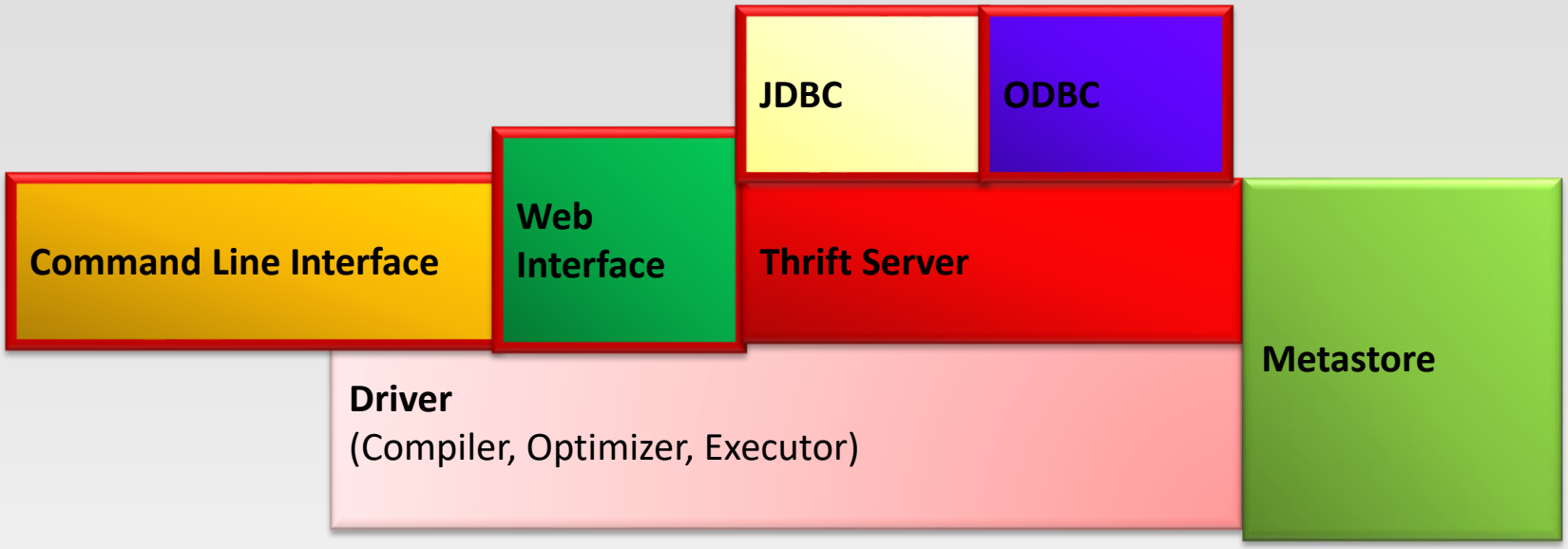



Thrift Server

Cross-language support

Provides a thrift interface and a JDBC/ODBC server and provides a way of integrating Hive with other applications.

# Architecture of Hive




Client Components

Including Command Line Interface(CLI), the web UI and JDBC/ODBC driver.

# Hive Installation and Configuration

Download at: https://hive.apache.org/downloads.html

The latest version: 3.1.0

Install:

```
$ tar xzf apache-hive-3.1.0-bin.tar.gz
$ mv apache-hive-3.1.0 ~/hive
```

Environment variables in ~/.bashrc

```
export HIVE_HOME = ~/hive
export PATH = $HIVE_HOME/bin:$PATH
```

Create /tmp and /user/hive/warehouse and set them chmod g+w for more than one user usage

```
$ hdfs dfs -mkdir /tmp
$ hdfs dfs -mkdir /user/hive/warehouse
$ hdfs dfs -chmod g+w /tmp
$ hdfs dfs -chmod g+w /user/hive/warehouse
```

Run the schematool command to initialize Hive

```
$ schematool -dbType derby -initSchema
```

Start Hive Shell: $ hive

# Hive Type System

Primitive types

- Integers: TINYINT, SMALLINT, INT, BIGINT.
- Boolean: BOOLEAN.
- Floating point numbers: FLOAT, DOUBLE.
- Fixed point numbers: DECIMAL
- String: STRING, CHAR, VARCHAR.
- Date and time types: TIMESTAMP, DATE

Complex types

- Structs: c has type {a INT; b INT}. c.a to access the first field
- Maps: M['group'].
- Arrays: ['a', 'b', 'c'], A[1] returns 'b'.

Example

- list< map<string, struct< p1:int,p2:int > > >
- Represents list of associative arrays that map strings to structs that contain two ints

# Hive Data Model

Databases: Namespaces function to avoid naming conflicts for tables, views, partitions, columns, and so on.

Tables: Homogeneous units of data which have the same schema.

Analogous to tables in relational DBs.

Each table has corresponding directory in HDFS.

An example table: page_views:

- timestamp—which is of INT type that corresponds to a UNIX timestamp of when the page was viewed.
- userid —which is of BIGINT type that identifies the user who viewed the page.
- page_url—which is of STRING type that captures the location of the page.
- referer_url—which is of STRING that captures the location of the page from where the user arrived at the current page.
- IP—which is of STRING type that captures the IP address from where the page request was made.

# Hive Data Model (Cont')

Partitions:

Each Table can have one or more partition Keys which determines how the data is stored

Example:

- Given the table page_views, we can define two partitions a date_partition of type STRING and country_partition of type STRING
- All "US" data from "2009-12-23" is a partition of the page_views table

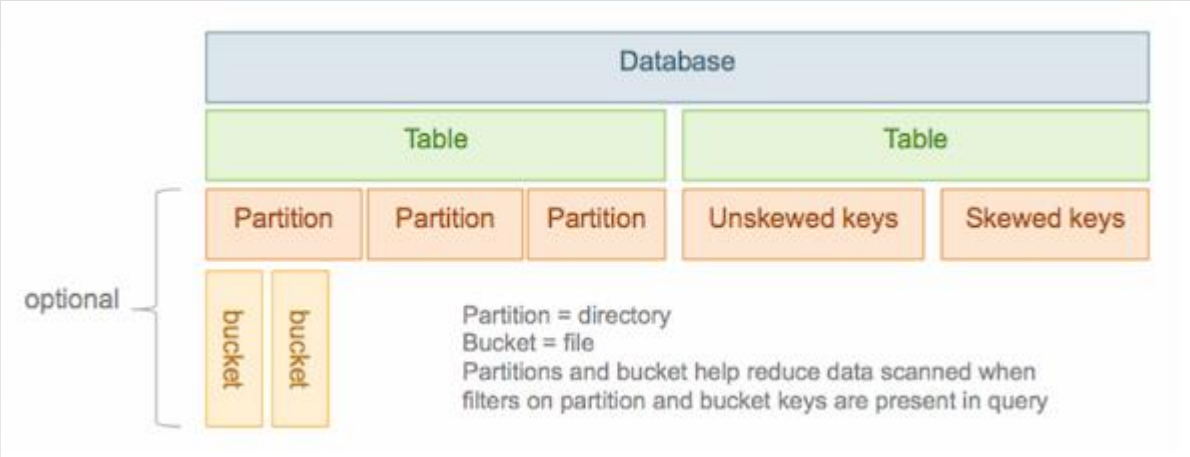
Partition columns are virtual columns, they are not part of the data itself but are derived on load

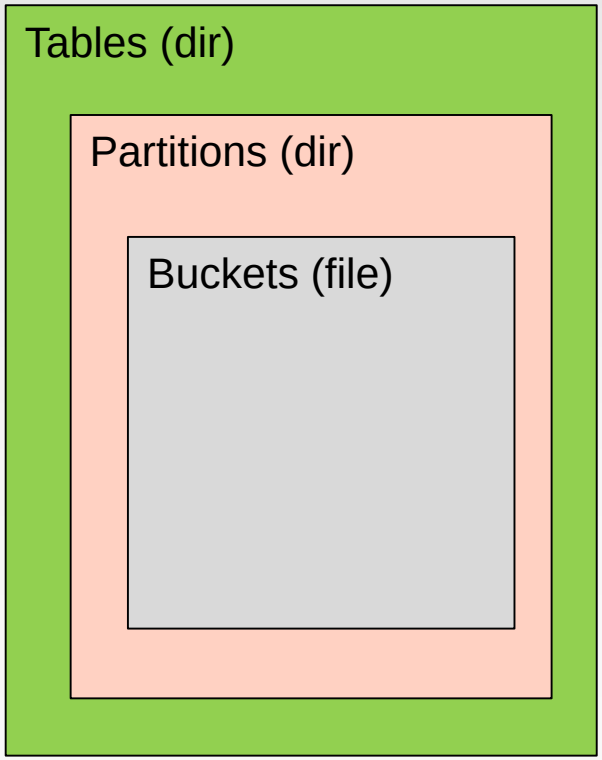
It is the user's job to guarantee the relationship between partition name and data content

Buckets: Data in each partition may in turn be divided into Buckets based on the value of a hash function of some column of the Table

Example:  the page_views table may be bucketed by userid

# Data Model and Storage




/root-path
/table1
/partition1
(2011-11)
/bucket1 (1/3)
/bucket2 (2/3)
/bucket3 (3/3)
/partition2
(2011-12)
/bucket1 (1/3)
/bucket2 (2/3)
/bucket3 (3/3)
/table2
/bucket1 (1/2)
/bucket2 (2/2)

# Create Table

Syntax:

```
CREATE TABLE [IF NOT EXISTS] [db_name.]table_name
  [(col_name data_type [COMMENT col_comment], ...)]
  [COMMENT table_comment]
  [PARTITIONED BY (col_name data_type [COMMENT
col_comment], ...)]
  [CLUSTERED BY (col_name, col_name, ...) [SORTED BY
(col_name [ASC|DESC], ...)] INTO num_buckets
BUCKETS]
   [ROW FORMAT row_format]
   [STORED AS file_format]
```

See full CREATE TABLE command at:
https://cwiki.apache.org/confluence/display/Hive/LanguageManual+DDL

# Hive SerDe

SerDe is a short name for "Serializer and Deserializer.“

> Describe how to load the data from the file into a representation that make it looks like a table;

Hive uses SerDe (and FileFormat) to read and write table rows.

HDFS files --> InputFileFormat --> <key, value> --> Deserializer --> Row object

Row object --> Serializer --> <key, value> --> OutputFileFormat --> HDFS files

More details see:
https://cwiki.apache.org/confluence/display/Hive/DeveloperGuide#DeveloperGuide-HiveSerDe

# Hive SerDe

row_format

: DELIMITED [FIELDS TERMINATED BY char [ESCAPED BY char]] [COLLECTION ITEMS TERMINATED BY char]

[MAP KEYS TERMINATED BY char] [LINES TERMINATED BY char]

Default values: Ctrl+A, Ctrl+B, Ctrl+C, new line, respectively

file_format:

: SEQUENCEFILE

| TEXTFILE -- (Default, depending on hive.default.fileformat configuration)

| RCFILE -- (Note: Available in Hive 0.6.0 and later)

| ORC -- (Note: Available in Hive 0.11.0 and later)

| PARQUET -- (Note: Available in Hive 0.13.0 and later)

| AVRO -- (Note: Available in Hive 0.14.0 and later)

| INPUTFORMAT input_format_classname OUTPUTFORMAT output_format_classname

# Create Table Example

Example:

```
CREATE TABLE page_view(viewTime INT, userid BIGINT,
     page_url STRING, referrer_url STRING,
     ip STRING COMMENT 'IP Address of the User')
 COMMENT 'This is the page view table'
 PARTITIONED BY(dt STRING, country STRING)
 CLUSTERED BY(userid) SORTED BY(viewTime)
INTO 32 BUCKETS

 ROW FORMAT DELIMITED
   FIELDS TERMINATED BY '\001'
   COLLECTION ITEMS TERMINATED BY '\002'
   MAP KEYS TERMINATED BY '\003'
   LINES TERMINATED BY '\n'
 STORED AS TEXTFILE;
```

# Browsing Tables and Partitions

To list existing tables in the warehouse

```
SHOW TABLES;
```

To list tables with prefix 'page'

```
SHOW TABLES 'page.*';
```

To list partitions of a table

```
SHOW PARTITIONS page_view;
```

To list columns and column types of table.

```
DESCRIBE page_view;
```

# Alter Table/Partition/Column

To rename existing table to a new name

ALTER TABLE old_table_name RENAME TO new_table_name;

To rename the columns of an existing table

ALTER TABLE old_table_name REPLACE COLUMNS (col1 TYPE, ...);

To add columns to an existing table

ALTER TABLE tab1 ADD COLUMNS (c1 INT COMMENT 'a new int column', c2 STRING DEFAULT 'def val');

To rename a partition

ALTER TABLE table_name PARTITION old_partition_spec RENAME TO PARTITION new_partition_spec;

To rename a column

ALTER TABLE table_name CHANGE old_col_name new_col_name column_type

More details see:
https://cwiki.apache.org/confluence/display/Hive/LanguageManual+DDL#LanguageManualDDL-AlterTable

# Drop Table/Partition

To drop a table

DROP TABLE [IF EXISTS] table_name

Example:

- DROP TABLE page_view

To drop a paritition

ALTER TABLE table_name DROP [IF EXISTS] PARTITION partition_spec[, PARTITION partition_spec, ...]

Example:

- ALTER TABLE pv_users DROP PARTITION (ds='2008-08-08')

# Loading Data

Hive does not do any transformation while loading data into tables. Load operations are currently pure copy/move operations that move datafiles into locations corresponding to Hive tables.

Syntax:

```
LOAD DATA [LOCAL] INPATH 'filepath' [OVERWRITE] INTO
TABLE  tablename [PARTITION (partcol1=val1, partcol2=val2 ...)]
```

Load data from a file in the local files system

- LOAD DATA LOCAL INPATH /tmp/pv_2008-06-08_us.txt INTO TABLE page_view PARTITION(date='2008-06-08', country='US')

Load data from a file in HDFS

- LOAD DATA INPATH '/user/data/pv_2008-06-08_us.txt' INTO TABLE page_view PARTITION(date='2008-06-08', country='US')

The input data format must be the same as the table format!

# Insert Data

Insert rows into a table:

Syntax

```
INSERT INTO TABLE tablename [PARTITION (partcol1[=val1],
partcol2[=val2] ...)] VALUES values_row [, values_row ...]
```

Inserting data into Hive Tables from queries

Syntax

```
INSERT INTO TABLE tablename [PARTITION (partcol1=val1,
partcol2=val2 ...)] select_statement FROM from_statement;
```

Example:

```
INSERT OVERWRITE TABLE user_active
SELECT user.*
FROM user
WHERE user.active = 1;
```

# Update Data

Syntax:

```
UPDATE tablename SET column = value [, column = value ...] [WHERE expression]
```

Synopsis

The referenced column must be a column of the table being updated.

The value assigned must be an expression that Hive supports in the select clause. Thus arithmetic operators, UDFs, casts, literals, etc. are supported. Subqueries are not supported.

Only rows that match the WHERE clause will be updated.

Partitioning columns cannot be updated.

Bucketing columns cannot be updated.

# Query Data

Select Syntax:

```
SELECT [ALL | DISTINCT] select_expr, select_expr, ...
  FROM table_reference
  [WHERE where_condition]
  [GROUP BY col_list]
  [ORDER BY col_list]
  [CLUSTER BY col_list
    | [DISTRIBUTE BY col_list] [SORT BY col_list]
  ]
 [LIMIT number]
```

# Order, Sort, Cluster, and Distribute By

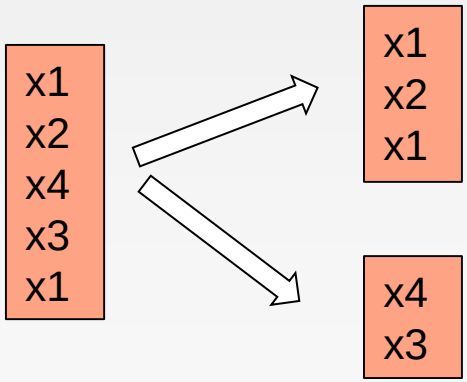
Difference between *Order By* and *Sort By*

The former guarantees total order in the output while the latter only guarantees ordering of the rows within a reducer

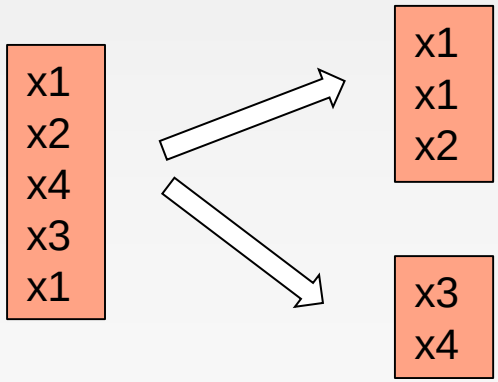
Cluster By

*Cluster By* is a short-cut for both *Distribute By* and *Sort By*.

Hive uses the columns in *Distribute By* to distribute the rows among reducers. All rows with the same *Distribute By* columns will go to the same reducer. However, *Distribute By* does not guarantee clustering or sorting properties on the distributed keys.




Distribute By




Cluster By

# Query Examples

Selects column 'foo' from all rows of partition ds=2008-08-15 of the invites table. The results are not stored anywhere, but are displayed on the console.

```
hive> SELECT a.foo FROM invites a WHERE a.ds='2008-08-15';
```

Selects all rows from partition ds=2008-08-15 of the invites table into an HDFS directory.

```
hive> INSERT OVERWRITE DIRECTORY '/tmp/hdfs_out' SELECT
a.* FROM invites a WHERE a.ds='2008-08-15';
```

Selects all rows from pokes table into a local directory.

```
hive> INSERT OVERWRITE LOCAL DIRECTORY '/tmp/local_out'
SELECT a.* FROM pokes a;
```

# Group By

Count the number of distinct users by gender

```
INSERT OVERWRITE TABLE pv_gender_sum
SELECT pv_users.gender, count (DISTINCT pv_users.userid)
FROM pv_users
GROUP BY pv_users.gender;
```

Multiple DISTINCT expressions in the same query is not allowed

```
INSERT OVERWRITE TABLE pv_gender_agg
SELECT pv_users.gender, count(DISTINCT pv_users.userid),
count(DISTINCT pv_users.ip)
FROM pv_users
GROUP BY pv_users.gender;
```

# Joins

Hive does not support join conditions that are not equality conditions

it is very difficult to express such conditions as a map/reduce job

SELECT a.* FROM a JOIN b ON (a.id = b.id)

However, the following statement is not allowed:

- SELECT a.* FROM a JOIN b ON (a.id <> b.id)

More than 2 tables can be joined in the same query.

SELECT a.val, b.val, c.val FROM a JOIN b ON (a.key = b.key1) JOIN c ON (c.key = b.key2)

Example:

```
SELECT s.word, s.freq, k.freq
FROM shakespeare s
  JOIN bible k ON (s.word =
k.word) WHERE s.freq >= 1
AND k.freq >= 1 ORDER BY
s.freq DESC LIMIT 10;
```

| | | |
|---|---|---|
| the | 25848 | 62394 |
| I | 23031 | 8854 |
| and | 19671 | 38985 |
| to | 18038 | 13526 |
| of | 16700 | 34654 |
| a | 14170 | 8057 |
| you | 12702 | 2720 |
| my | 11297 | 4135 |
| in | 10797 | 12445 |
| is | 8882 | 6884 |

# Behind the Scenes

```
SELECT s.word, s.freq, k.freq FROM shakespeare s
  JOIN bible k ON (s.word = k.word) WHERE s.freq >= 1 AND k.freq >= 1
  ORDER BY s.freq DESC LIMIT 10;
```

(Abstract Syntax Tree)

```
(TOK_QUERY (TOK_FROM (TOK_JOIN (TOK_TABREF shakespeare s) (TOK_TABREF bible k) (= (. (TOK_TABLE_OR_COL s)
word) (. (TOK_TABLE_OR_COL k) word)))) (TOK_INSERT (TOK_DESTINATION (TOK_DIR TOK_TMP_FILE)) (TOK_SELECT
(TOK_SELEXPR (. (TOK_TABLE_OR_COL s) word)) (TOK_SELEXPR (. (TOK_TABLE_OR_COL s) freq)) (TOK_SELEXPR (.
(TOK_TABLE_OR_COL k) freq))) (TOK_WHERE (AND (>= (. (TOK_TABLE_OR_COL s) freq) 1) (>= (. (TOK_TABLE_OR_COL k)
freq) 1))) (TOK_ORDERBY (TOK_TABSORTCOLNAMEDESC (. (TOK_TABLE_OR_COL s) freq))) (TOK_LIMIT 10)))
```

(one or more of MapReduce jobs)

# Hive Operators and User-Defined Functions (UDFs)

Built-in operators:

relational, arithmetic, logical, etc.

Built-in functions:

mathematical, date function, string function, etc.

Built-in aggregate functions:

max, min, count, etc.

Built-in table-generating functions: transform a single input row to multiple output rows

explode(ARRAY): Returns one row for each element from the array.

explode(MAP): Returns one row for each key-value pair from the input map with two columns in each row

Create Custom UDFs

More details see:
https://cwiki.apache.org/confluence/display/Hive/LanguageManual+UDF#LanguageManualUDF-explode

# WordCount in Hive

Create a table in Hive

```
create table doc(
        text string
) row format delimited fields terminated by '\n' stored as textfile;
```

Load file into table

```
load data local inpath '/home/Words' overwrite into table doc;
```

Compute word count using select

```
SELECT word, COUNT(*) FROM doc LATERAL VIEW
explode(split(text, ' ')) Table as word GROUP BY word;
```

explode() takes in an array (or a map) as an input and outputs the elements of the array (map) as separate rows.

Lateral view is used in conjunction with user-defined table generating functions such as explode()

A lateral view first applies the UDTF to each row of base table and then joins resulting output rows to form a virtual table

# Pros/Cons

Pros

- A easy way to process large scale data
- Support SQL-based queries
- Provide more user defined interfaces to extend
- Programmability
- Efficient execution plans for performance
- Interoperability with other database

Cons

- No easy way to append data
- Files in HDFS are immutable

# Applications of Hive

- Log processing
  - Daily Report
  - User Activity Measurement
- Data/Text mining
  - Machine learning (Training Data)
- Business intelligence
  - Advertising Delivery
  - Spam Detection

# References

https://hbase.apache.org/book.html

https://cwiki.apache.org/confluence/display/Hive/Home#Home-HiveDocumentation

http://www.tutorialspoint.com/hive/

Hadoop The Definitive Guide. HBase Chapter.

Hadoop the Definitive Guide. Hive Chapter

# End of Chapter 10