CS 444: Big Data Systems

Chapter 4. Big Data Storage and Management

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Some of the slides were provided through the courtesy of Dr. Ching-Yung Lin at Columbia University

Remind -- Apache Hadoop

The Apache™ Hadoop® project develops open-source software for reliable, scalable, distributed computing.

The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models. It is designed to scale up from single servers to thousands of machines, each offering local computation and storage. Rather than relying on hardware to deliver high-availability, the library itself is designed to detect and handle failures at the application layer, so delivering a highly-available service on top of a cluster of computers, each of which may be prone to failures.

The project includes these modules:

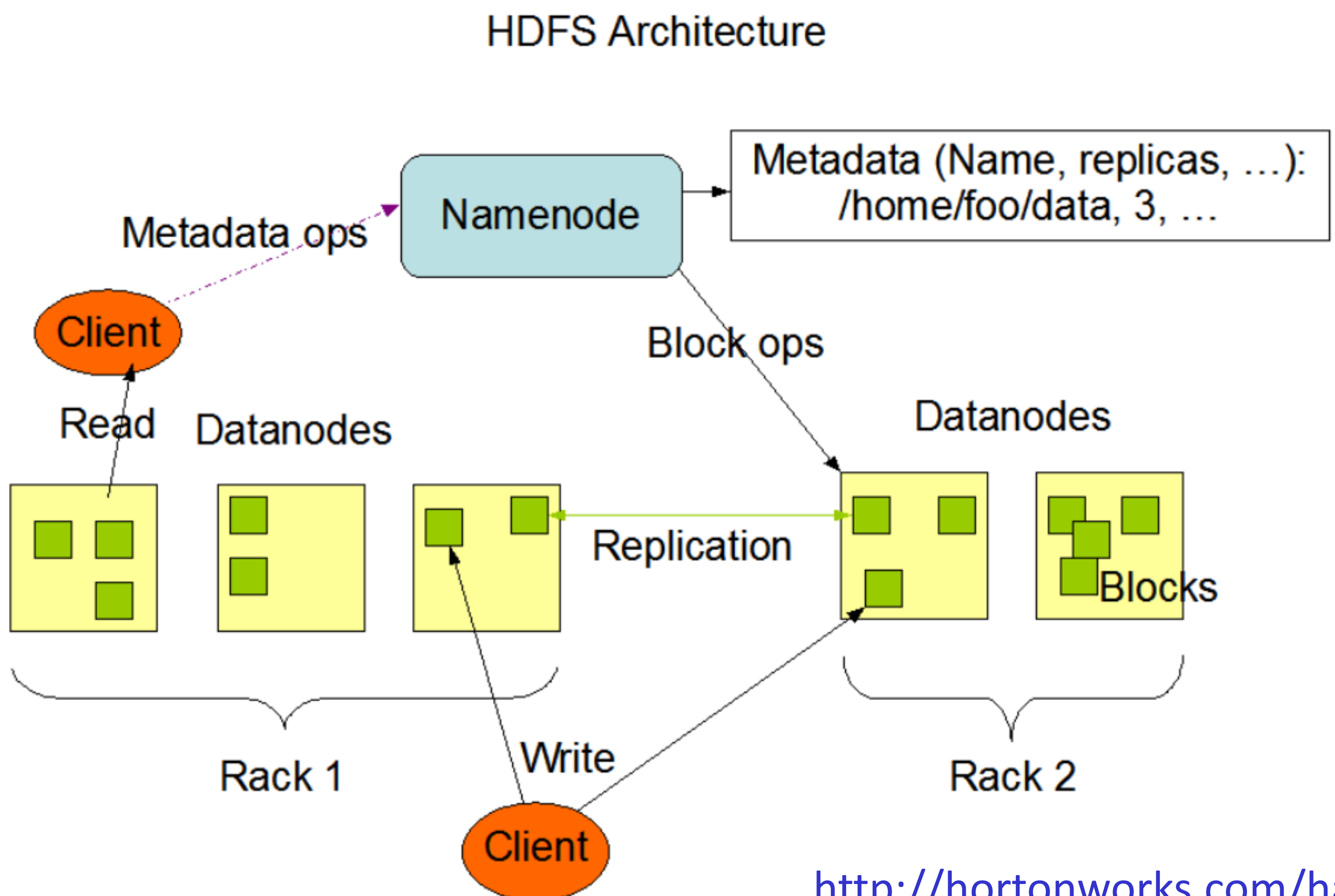
- **Hadoop Common**: The common utilities that support the other Hadoop modules.
- **Hadoop Distributed File System (HDFS™)**: A distributed file system that provides high-throughput access to application data.
- **Hadoop YARN**: A framework for job scheduling and cluster resource management.
- **Hadoop MapReduce**: A YARN-based system for parallel processing of large data sets.

http://hadoop.apache.org

Remind -- Hadoop-related Apache Projects

- Ambari™: A web-based tool for provisioning, managing, and monitoring Hadoop clusters.It also provides a dashboard for viewing cluster health and ability to view MapReduce, Pig and Hive applications visually.
- Avro™: A data serialization system.
- Cassandra™: A scalable multi-master database with no single points of failure.
- Chukwa™: A data collection system for managing large distributed systems.
- HBase™: A scalable, distributed database that supports structured data storage for large tables.
- Hive™: A data warehouse infrastructure that provides data summarization and ad hoc querying.
- Mahout™: A Scalable machine learning and data mining library.
- Pig™: A high-level data-flow language and execution framework for parallel computation.
- Spark™: A fast and general compute engine for Hadoop data. Spark provides a simple and expressive programming model that supports a wide range of applications, including ETL, machine learning, stream processing, and graph computation.
- Tez™: A generalized data-flow programming framework, built on Hadoop YARN, which provides a powerful and flexible engine to execute an arbitrary DAG of tasks to process data for both batch and interactive use-cases.
- ZooKeeper™: A high-performance coordination service for distributed applications.

Remind -- Hadoop Distributed File System (HDFS)



http://hortonworks.com/hadoop/hdfs/

- **Namenode:** This is the daemon that runs on all the masters. Name node stores metadata like filename, the number of blocks, number of replicas, a location of blocks, block IDs etc. This metadata is available in memory in the master for faster retrieval of data. In the local disk, a copy of metadata is available for persistence. So name node memory should be high as per the requirement.
- **Datanode:** This is the daemon that runs on the slave. These are actual worker nodes that store the data.

Data Storage Operations on HDFS

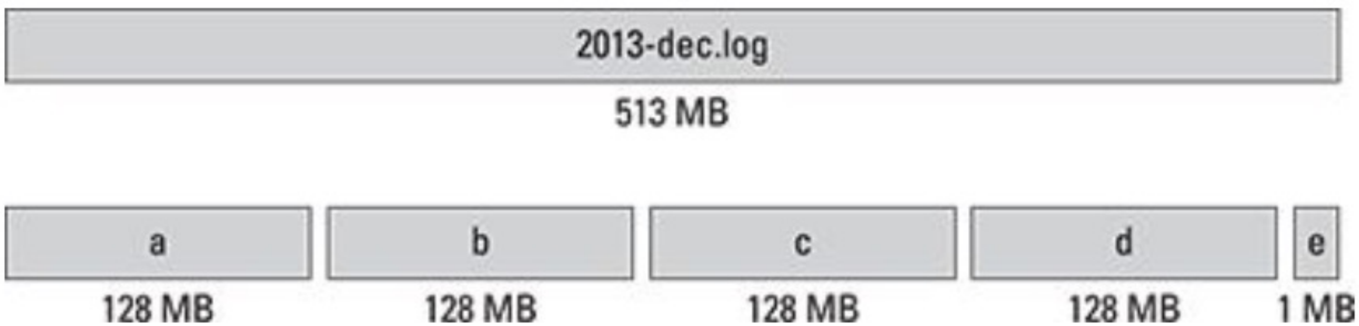
- Hadoop is designed to work best with a modest number of extremely large files.
- Average file sizes ➔ larger than 500MB.

- Write Once, Read Often model.
- Content of individual files cannot be modified, other than appending new data at the end of the file.

- What we can do:
  - Create a new file
  - Append contents to the end of a file
  - Delete a file
  - Rename a file
  - Modify file attributes like owner

HDFS blocks

- File is divided into blocks (default: 64MB in Hadoop 1 and 128 MB in Hadoop 2) and duplicated in multiple places (default: 3, which could be changed to the required values according to the requirement by editing the configuration files hdfs-site.xml)



- Dividing into blocks is normal for a native file system, e.g., the default block size in Linux is 4KB. The difference of HDFS is the scale.
- Hadoop was designed to operate at the petabyte scale.
- Every data block stored in HDFS has its own metadata and needs to be tracked by a central server.

Why replicate? How to set the replication number?

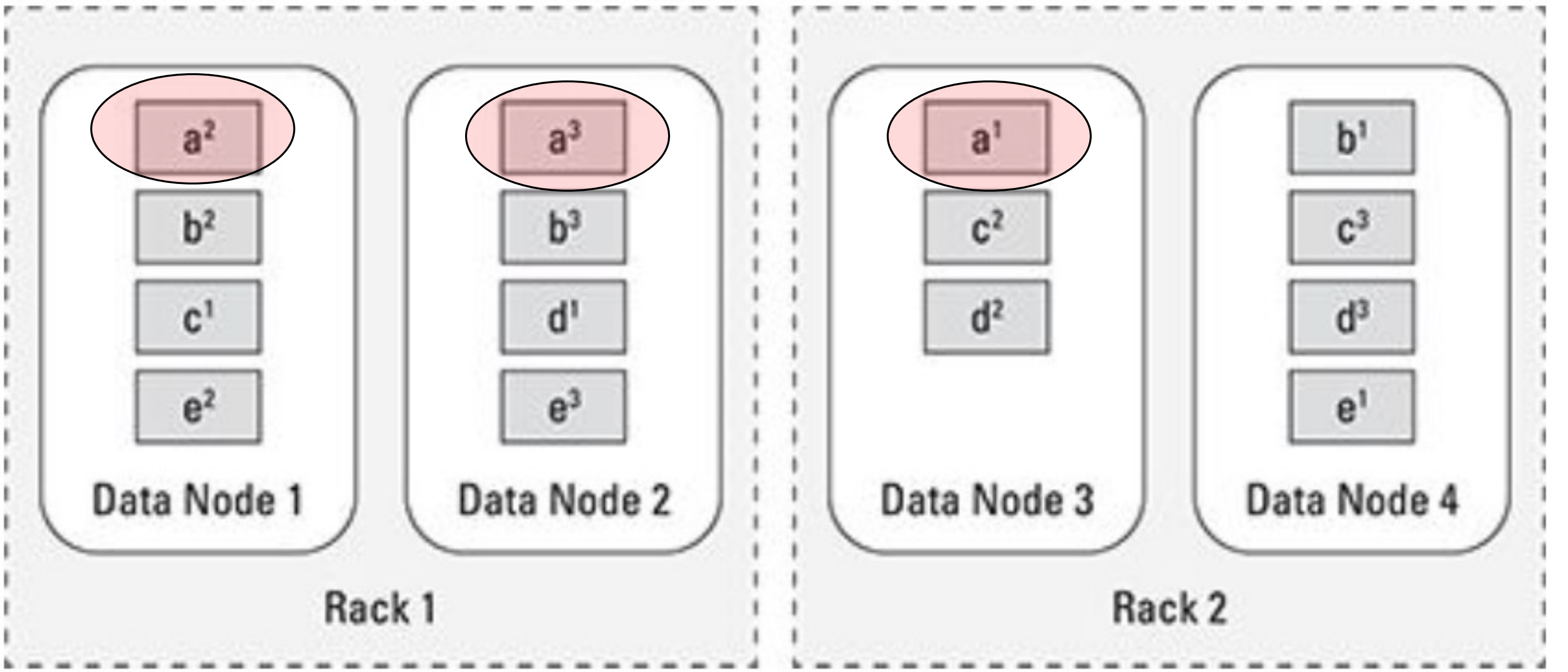
- Reliability
- Performance

How to set the block size properly?

- Block in HDFS vs. sector in native file system
- Degree of parallelism

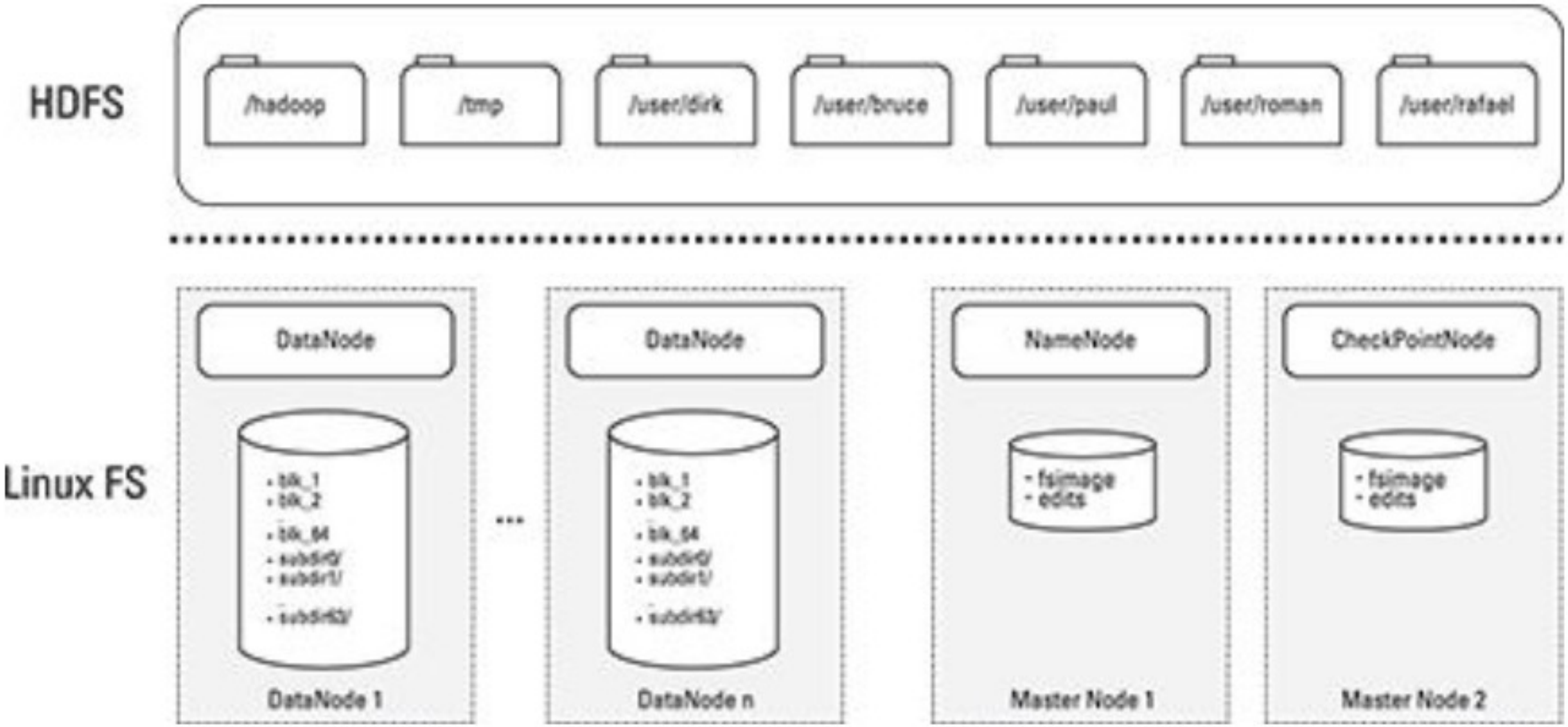
HDFS block replica placement

- Replication patterns of data blocks in HDFS.

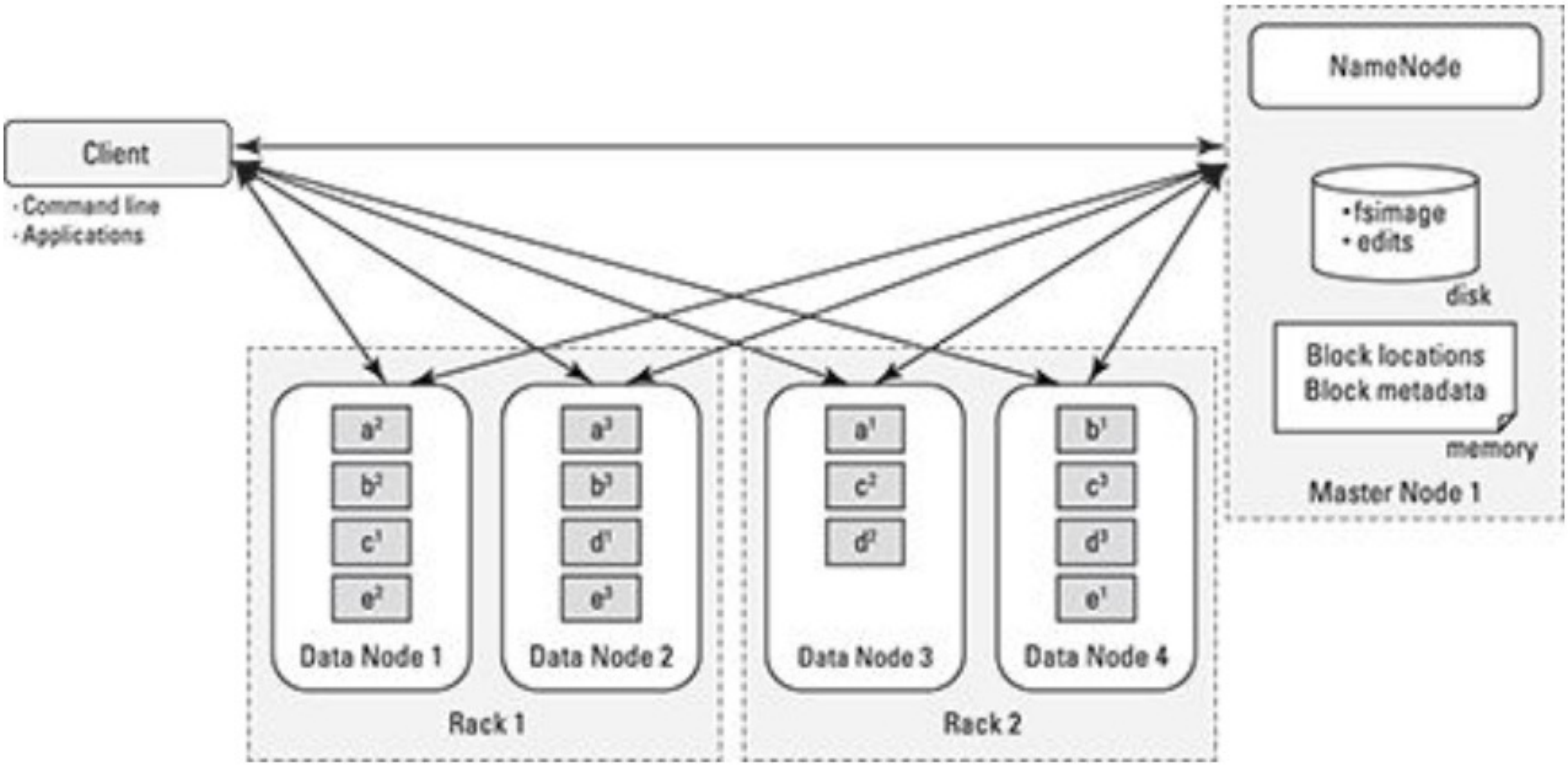


- When HDFS stores the replicas of the original blocks across the Hadoop cluster, it tries to ensure that the block replicas are stored at different failure points.
- Rack-aware replica placement to improve data reliability, availability, and network bandwidth utilization, in a hierarchical (multi-rack, multi-node) architecture
  - NameNode places replicas of a block on multiple racks for improved fault tolerance.
    - tries to place at least one replica of a block in each rack, so that if a complete rack goes down, the system will be still available on other racks.

HDFS is a User-Space-Level file system

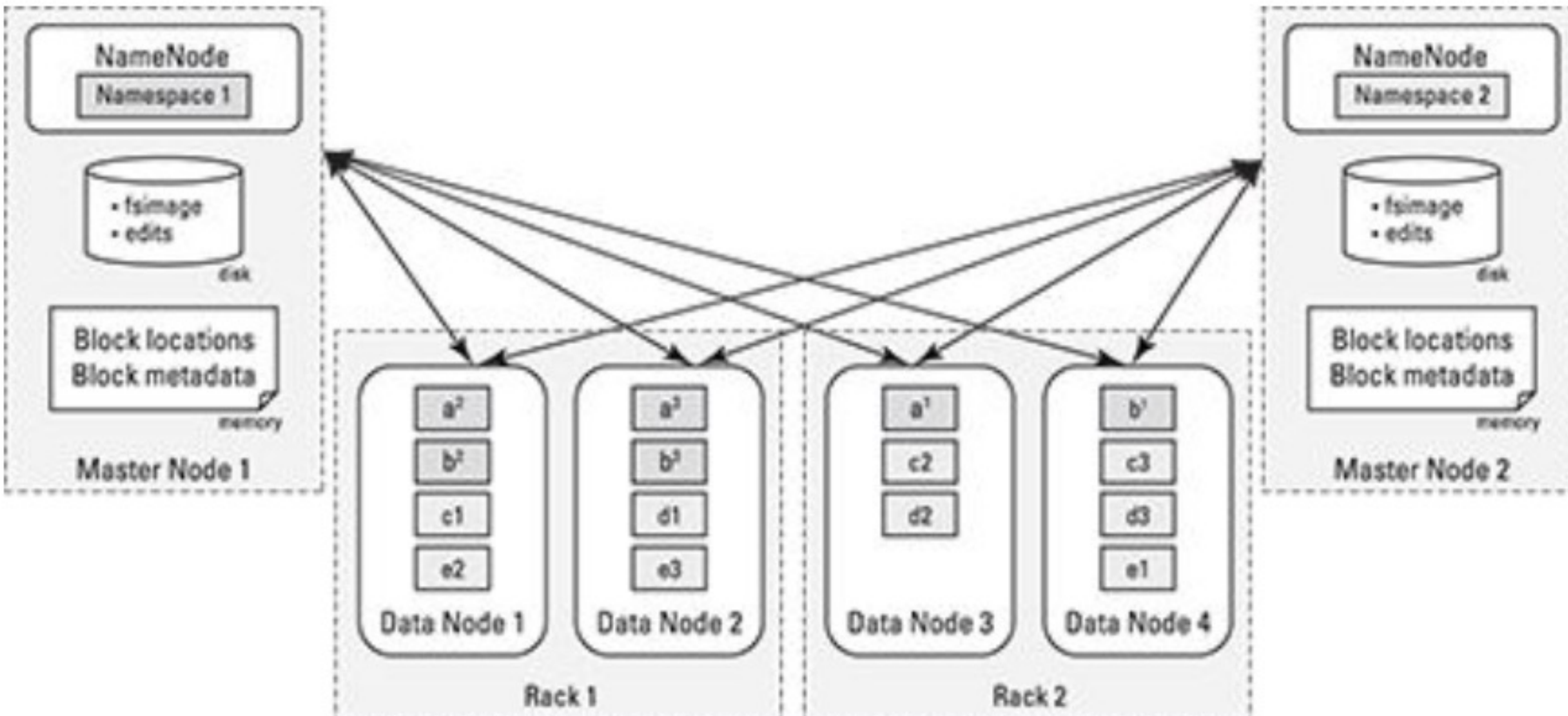


Interaction between HDFS components



HDFS Federation

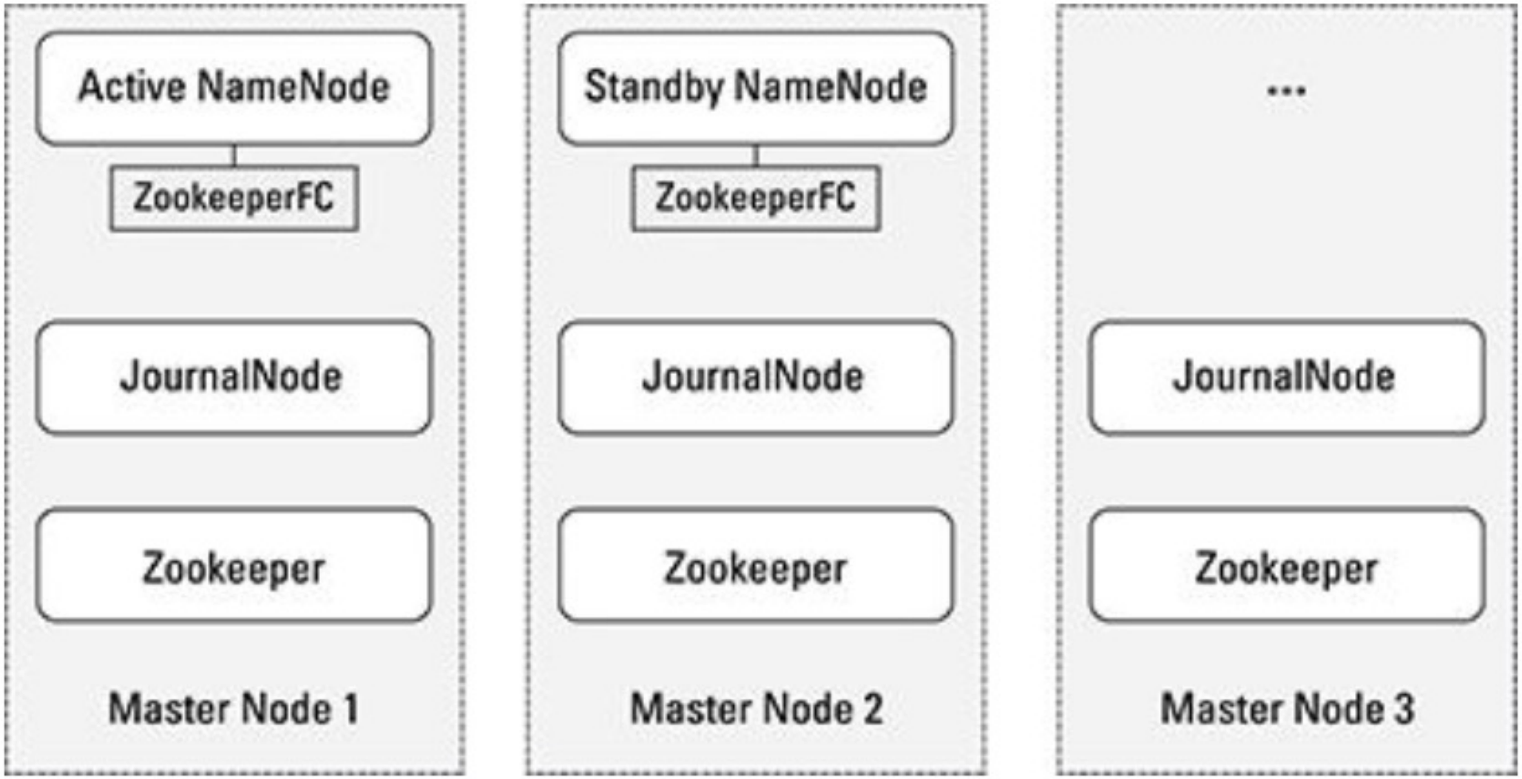
- Before Hadoop 2.0
  - NameNode was a single point of failure and operation limitation.
  - Hadoop clusters could hardly scale beyond 3,000 or 4,000 nodes.
- In Hadoop 2.x
  - Multiple NameNodes can be used (HDFS High Availability feature – one is in an Active state, the other one is in a Standby state).



http://hadoop.apache.org/docs/r2.3.0/hadoop-yarn/hadoop-yarn-site/HDFSHighAvailabilityWithNFS.html

High Availability of the NameNodes

- Active NameNode
- Standby NameNode – keeping the state of the block locations and block metadata in memory -> HDFS checkpointing responsibilities.



- JournalNode – if a failure occurs, the Standby Node reads all completed journal entries to ensure the new Active NameNode is fully consistent with the state of the cluster.
- Zookeeper – provides coordination and configuration services for distributed systems.

Data Compression in HDFS

Table 5-1		Hadoop Codecs		
Codec	***File Extension***	***Splittable?***	***Degree of Compression***	***Compression Speed***
Gzip	`.gz`	No	Medium	Medium
Bzip2	`.bz2`	Yes	High	Slow
Snappy	`.snappy`	No	Medium	Fast
LZO	`.lzo`	No, unless indexed	Medium	Fast

HDFS Commands

- All Hadoop commands are invoked by the bin/hadoop script.

  hadoop [--config confdir] [COMMAND]
  [GENERIC_OPTIONS] [COMMAND_OPTIONS]

- % hadoop fsck / -files –blocks:
  → list the blocks that make up each file in HDFS.

- For HDFS, the schema name is hdfs, and for the local file system, the schema name is file.

- A file or directory in HDFS can be specified in a fully qualified way, such as:
  hdfs://namenodehost/parent/child or hdfs://namenodehost

- The HDFS file system shell command is similar to Linux file commands, with the following general syntax: ***hadoop fs or hdfs dfs –file_cmd***

- For instance, mkdir runs as:
  $hadoop fs –mkdir /user/directory_name

Some useful commands for HDFS

COMMAND	DESCRIPTION
-ls	List files with permissions and other details
-mkdir	Creates a directory named path in HDFS
-rm	To Remove File or a Directory
-rmr	Removes the file that identified by path / Folder and subfolders
-rmdir	Delete a directory
-put	Upload a file / Folder from the local disk to HDFS
-cat	Display the contents for a file
-du	Shows the size of the file on hdfs.
-dus	Directory/file of total size
-get	Store file / Folder from HDFS to local file
-getmerge	Merge Multiple Files in an HDFS
-count	Count number of directory, number of files and file size
-setrep	Changes the replication factor of a file
-mv	HDFS Command to move files from source to destination
-moveFromLocal	Move file / Folder from local disk to HDFS
-moveToLocal	Move a File to HDFS from Local
-cp	Copy files from source to destination
-tail	Displays last kilobyte of the file
-touch	create, change and modify timestamps of a file
-touchz	Create a new file on HDFS with size 0 bytes
-appendToFile	Appends the content to the file which is present on HDF
-copyFromLocal	Copy file from local file system
-copyToLocal	Copy files from HDFS to local file system
-usage	Return the Help for Individual Command
-checksum	Returns the checksum information of a file
-chgrp	Change group association of files/change the group of a file or a path
-chmod	Change the permissions of a file
-chown	change the owner and group of a file
-df	Displays free space
-head	Displays first kilobyte of the file
-Create Snapshots	Create a snapshot of a snapshottable directory
-Delete Snapshots	Delete a snapshot of from a snapshottable directory
-Rename Snapshots	Rename a snapshot
-expunge	create new checkpoint
-Stat	Print statistics about the file/directory
-truncate	Truncate all files that match the specified file pattern to the specified length
-find	Find File Size in HDFS

Big Data Management

- File-based Data Management (Data Encoding Format)
  - JSON
  - XML
  - CSV
  - Hierarchical Data Format (HDF4/5)
  - Network Common Data Form (netCDF)
- System-based Data Management (NoSQL Database)
  - Key-Value Store (the most primary unit for others)
  - Document Store (mongoDB)
  - Tabular Store (HBase)
  - Object Database
  - Graph Database
    - Property graphs
    - Resource Description Framework (RDF) graphs

Commonly Used Data Encoding Formats

JSON (JavaScript Object Notation, .json)

- An open-standard language-independent data format
- Use text to transmit data objects: attribute–value pairs and array data types
- Used for asynchronous browser–server communication

```json
{
  "firstName": "John",
  "lastName": "Smith",
  "age": 25,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021"
  },
  "phoneNumber": [
    {
      "type": "home",
      "number": "212 555-1234"
    },
    {
      "type": "fax",
      "number": "646 555-4567"
    }
  ],
  "gender": {
    "type": "male"
  }
}
```

Commonly Used Data Encoding Formats

XML (Extensible Markup Language, .xml)

- Use tag pairs to describe structured data and to serialize objects
- XML supports comments, but JSON does not


```xml
<person>
  <firstName>John</firstName>
  <lastName>Smith</lastName>
  <age>25</age>
  <address>
    <streetAddress>21 2nd Street</streetAddress>
    <city>New York</city>
    <state>NY</state>
    <postalCode>10021</postalCode>
  </address>
  <phoneNumber>
    <type>home</type>
    <number>212 555-1234</number>
  </phoneNumber>
  <phoneNumber>
    <type>fax</type>
    <number>646 555-4567</number>
  </phoneNumber>
  <gender>
    <type>male</type>
  </gender>
</person>
```

Commonly Used Data Encoding Formats

CSV (Comma-Separated Values, .csv)

- A delimited data format
- Fields/columns are separated by the comma character
- Records/rows are terminated by newlines
- All records have the same number of fields in the same order
- Any field may be quoted

Year	Make	Model	Description	Price
1997	Ford	E350	ac, abs, moon	3000.00
1999	Chevy	Venture "Extended Edition"		4900.00
1999	Chevy	Venture "Extended Edition, Very Large"		5000.00
1996	Jeep	Grand Cherokee	MUST SELL! air, moon roof, loaded	4799.00

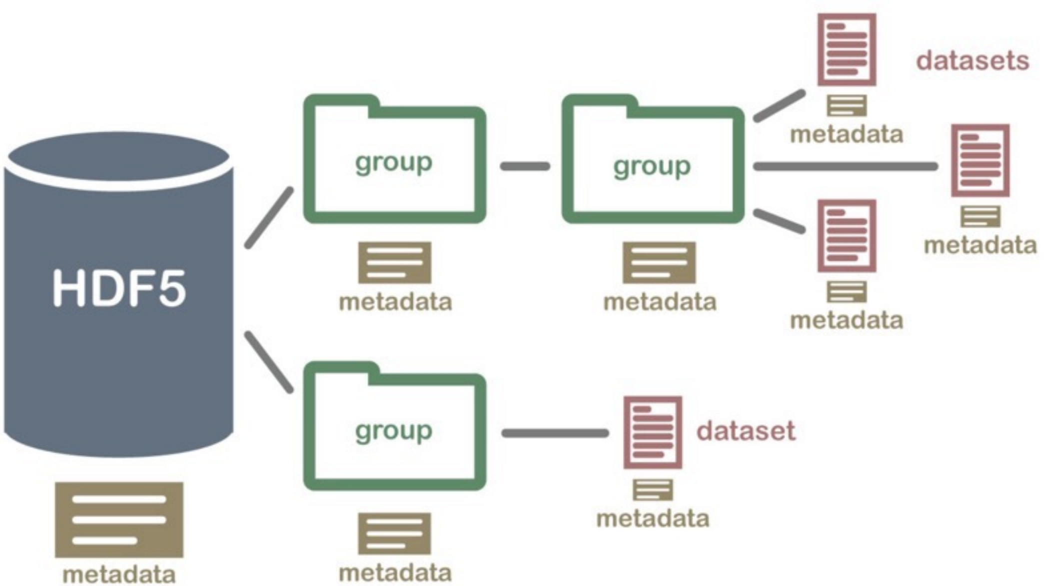
The above table of data may be represented in CSV format as follows:

```
Year,Make,Model,Description,Price
1997,Ford,E350,"ac, abs, moon",3000.00
1999,Chevy,"Venture ""Extended Edition""","",4900.00
1999,Chevy,"Venture ""Extended Edition, Very Large""",,5000.00
1996,Jeep,Grand Cherokee,"MUST SELL!
air, moon roof, loaded",4799.00
```

Commonly Used Data Encoding Formats

Hierarchical Data Format (HDF4/5, .hdf)

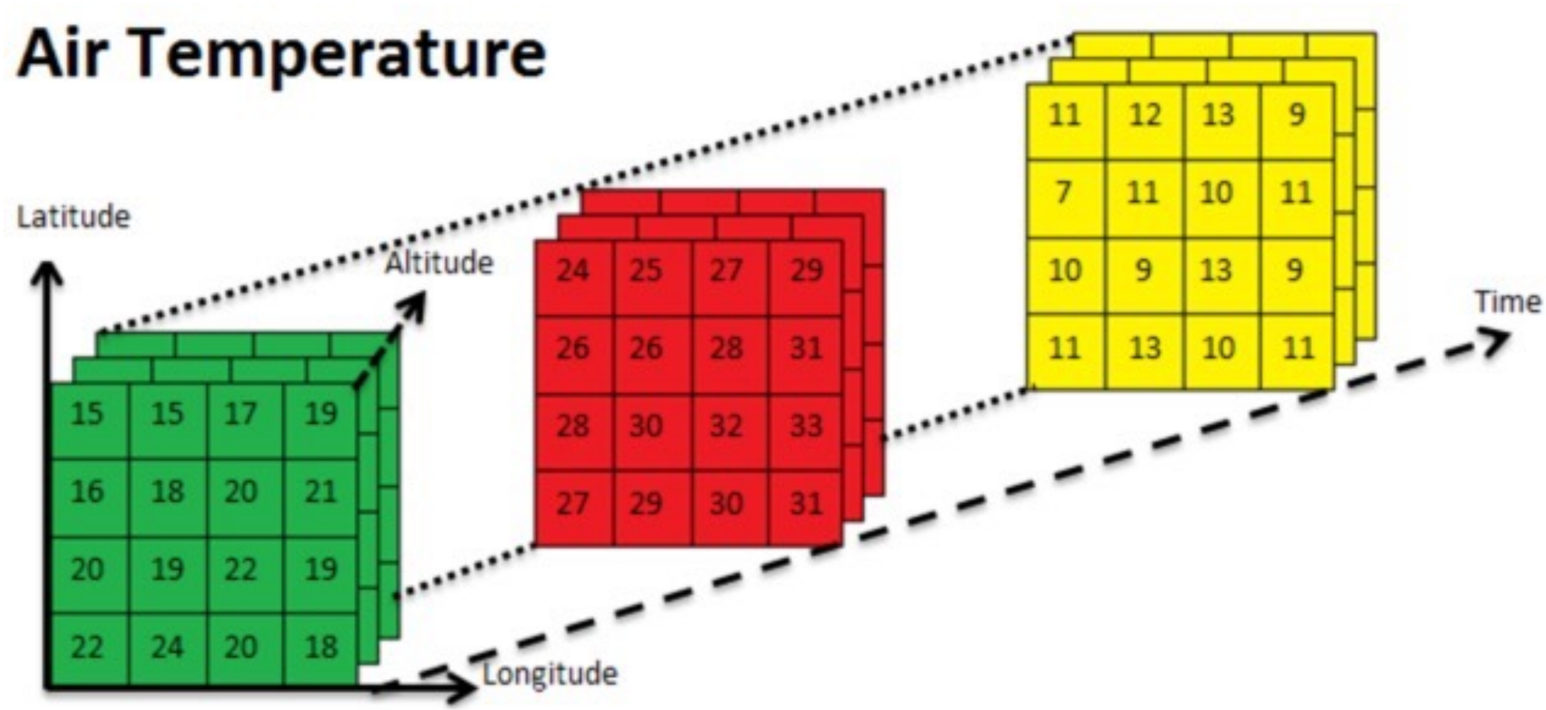
- A set of file formats (**HDF4**, **HDF5**) designed to store and organize large amounts of data
- Supported by many commercial and non-commercial software platforms, including Java, MATLAB, Scilab, Octave, Mathematica, IDL, Python, R, Fortran, and Julia.
- HDF5 simplifies the file structure to include only two major types
  - Datasets, which are multidimensional arrays of a homogeneous type
  - Groups, which are container structures that can hold datasets and other groups



Commonly Used Data Encoding Formats

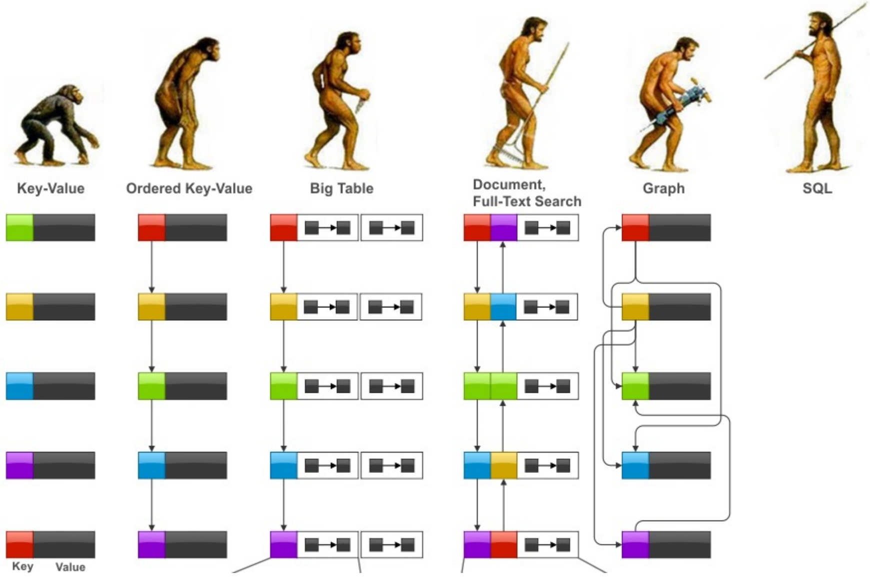
Network Common Data Form (netCDF, .nc)

- A set of self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data
- Starting with version 4.0, the netCDF API allows the use of the HDF5 data format
- An extension of netCDF for parallel computing called Parallel-NetCDF (or PnetCDF) has been developed by Argonne National Laboratory and Northwestern University



System-based NoSQL Databases: Key-Value Store

- Considered as the most primary and the simplest version of all NoSQL databases
- Use a one-way mapping from the key to the value to store a basic data item



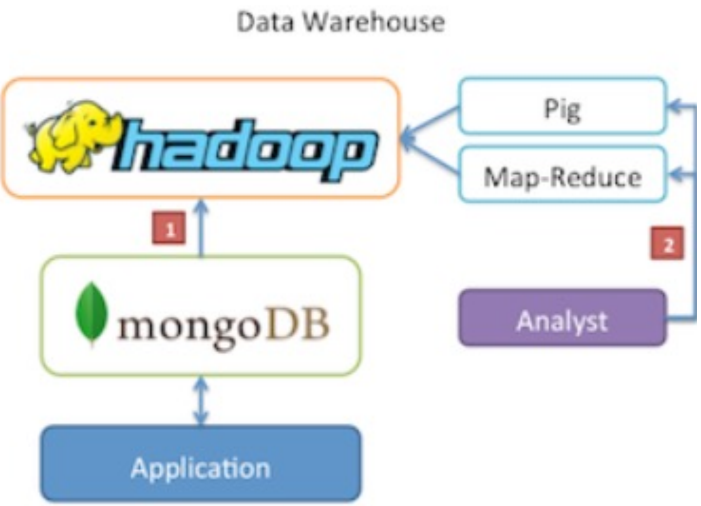
Only provide some simple operations:

- Get(*key*), which returns the value associated with the provided *key*.
- Put(*key*, *value*), which associates the *value* with the *key*.
- Multi-get(*key1*, *key2*,.., *keyN*), which returns the list of values associated with the list of *keys*.
- Delete(*key*), which removes the entry for the *key* from the data store.

Example Data Represented in a Key–Value Store

Key	Value
…	
"BMW"	{"1-Series", "3-Series", "5-Series", "5-Series GT", "7-Series", "X3", "X5", "X6", "Z4"}
"Buick"	{"Enclave", "LaCrosse", "Lucerne", "Regal"}
"Cadillac"	{"CTS", "DTS", "Escalade", "Escalade ESV", "Escalade EXT", "SRX", "STS"}
…	

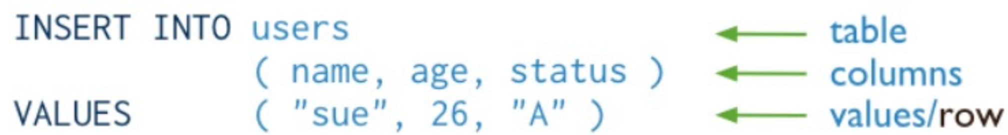
NoSQL: Document Store



The following diagram highlights the components of a MongoDB insert operation:

The components of a MongoDB insert operations.

The following diagram shows the same query in SQL:



The components of a SQL INSERT statement.

Relational data model

Highly-structured table organization with rigidly-defined data formats and record structure.

Document data model

Collection of complex documents with arbitrary, nested data formats and varying "record" format.

NoSQL: Graph Database

Graph Models

- Labeled-Property Graphs
  - Represented by a set of nodes, relationships, properties, and labels
  - Both nodes of data and their relationships are named and can store properties represented by key/value pairs
- RDF (Resource Description Framework: Triplestore) Graphs

Apache TinkerPop

Apache TinkerPop™ is a graph computing framework for both graph databases (OLTP: Online Transactional Processing) and graph analytic systems (OLAP: Online Analytical Processing).

Amazon Neptune

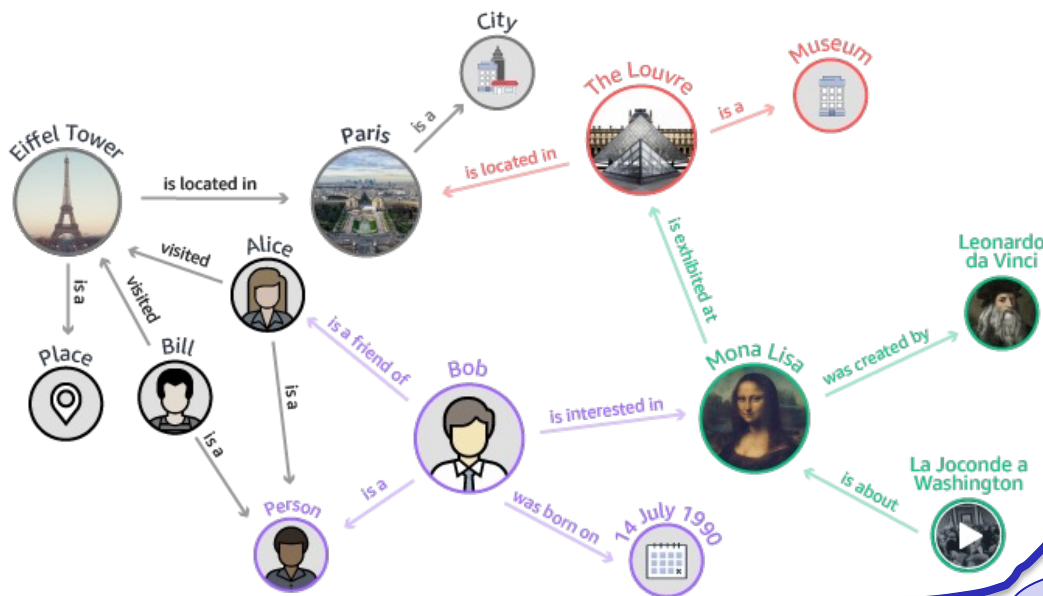
Fast, reliable graph database built for the cloud

- ArangoDB - OLTP Provider for ArangoDB.
- Bitsy - A small, fast, embeddable, durable in-memory graph database.
- Blazegraph - RDF graph database with OLTP support.
- CosmosDB - Microsoft's distributed OLTP graph database.
- ChronoGraph - A versioned graph database.
- DSEGraph - DataStax graph database with OLTP and OLAP support.
- GRAKN.AI - Distributed OLTP/OLAP knowledge graph system.
- Hadoop (Spark) - OLAP graph processor using Spark.
- HGraphDB - OLTP graph database running on Apache HBase.
- Huawei Graph Engine Service - Fully-managed, distributed, at-scale graph query/analysis service that provides a visualized interactive analytics platform.
- IBM Graph - OLTP graph database as a service.
- JanusGraph - Distributed OLTP and OLAP graph database with BerkeleyDB, Apache Cassandra and Apache HBase support.
- JanusGraph (Amazon) - The Amazon DynamoDB Storage Backend for JanusGraph.
- Neo4j - OLTP graph database (embedded and high availability).
- neo4j-gremlin-bolt - OLTP graph database (using Bolt Protocol).
- OrientDB - OLTP graph database
- Apache S2Graph - OLTP graph database running on Apache HBase.
- Sqlg - OLTP implementation on SQL databases.
- Stardog - RDF graph database with OLTP and OLAP support.
- TinkerGraph - In-memory OLTP and OLAP reference implementation.
- Titan - Distributed OLTP and OLAP graph database with BerkeleyDB, Apache Cassandra and Apache HBase support.
- Titan (Amazon) - The Amazon DynamoDB storage backend for Titan.
- Titan (Tupl) - The Tupl storage backend for Titan.
- Unipop - OLTP Elasticsearch and JDBC backed graph.

How is a graph stored?

- Linked list
- Adjacency matrix

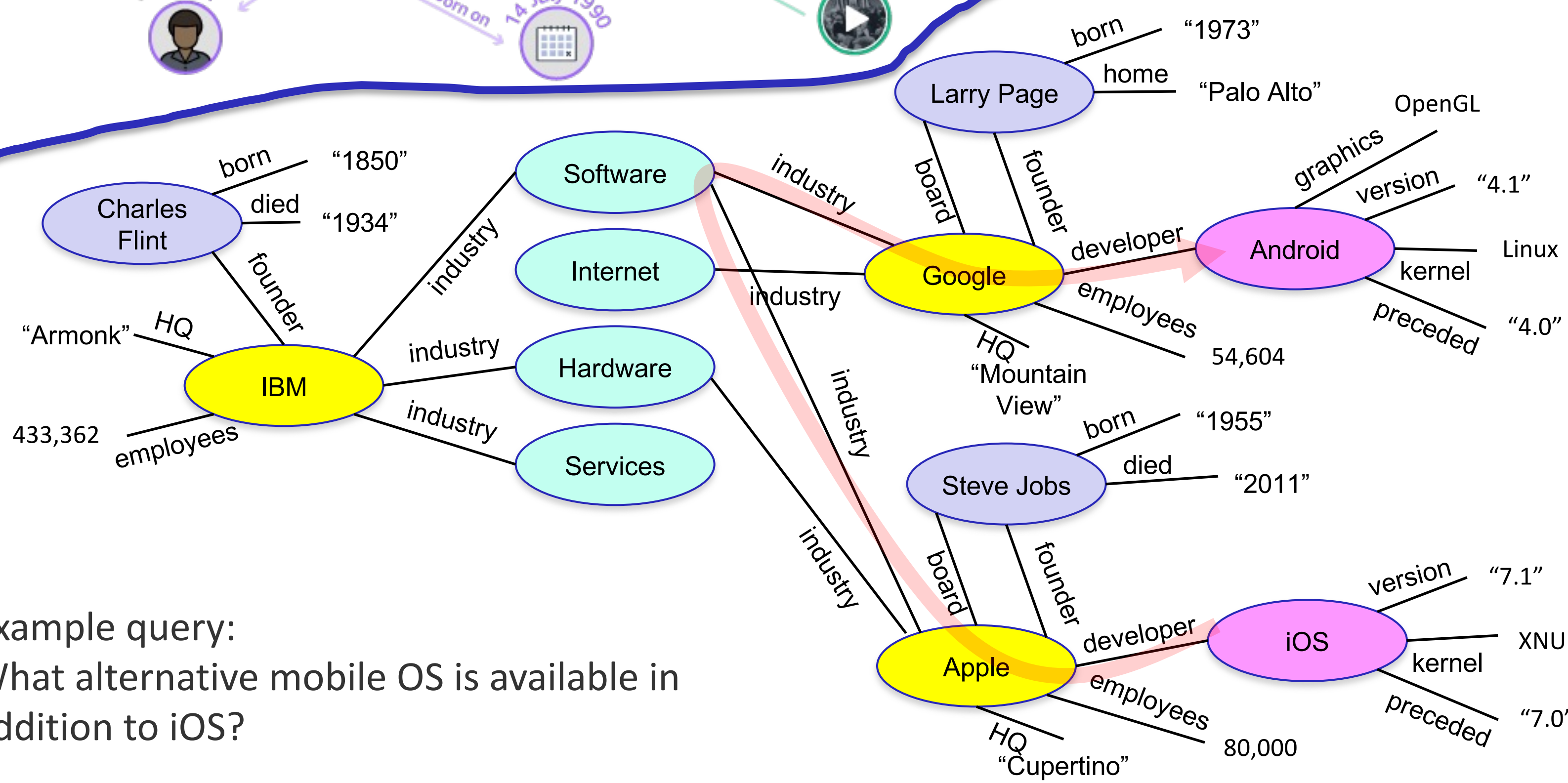
NoSQL: Graph Database Use Cases



Knowledge Graphs

Example query:
I'm interested in The Mona Lisa.
Help me find other artworks

- by Leonardo da Vinci, or
- located in The Louvre.



Example query:
What alternative mobile OS is available in addition to iOS?

What is the fundamental challenge for RDB on Linked Data?

In Relational DB, relationships are *distributed.* It takes a long time to *JOIN* to retrieve a graph from data

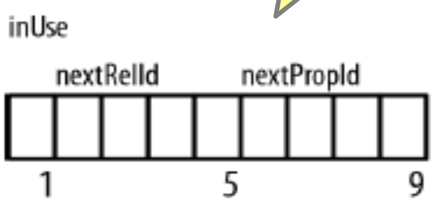
User					
UserID	**User**	**Address**	**Phone**	**Email**	**Alternate**
1	Alice	123 Foo St.	12345678	alice@example.org	alice@neo4j.org
2	Bob	456 Bar Ave.		bob@example.org	
...	...	...	...	...	...
99	Zach	99 South St.		zach@example.org	

Order	
OrderID	**UserID**
1234	1
5678	1
...	...
5588	99

LineItem		
OrderID	**ProductID**	**Quantity**
1234	765	2
1234	987	1
...	...	...
5588	765	1

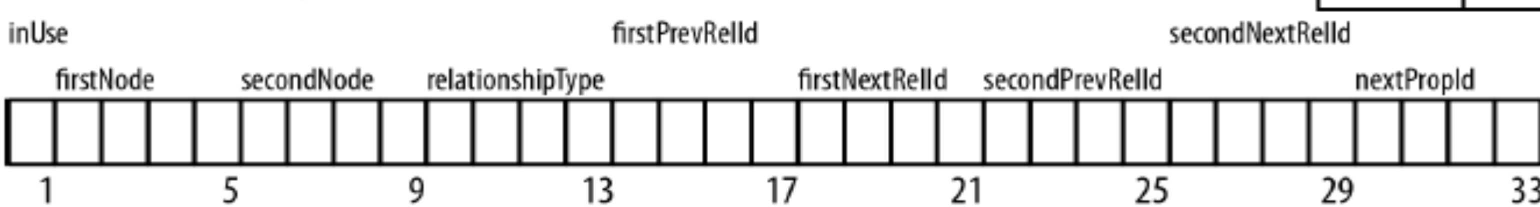
Product		
ProductID	**Description**	**Handling**
321	strawberry ice cream	freezer
765	potatoes	
...	...	
987	dried spaghetti	

Native Graph DB stores nodes and relationships directly. It makes retrieval efficient.



Example query:
What is the backlog of the product purchased by User A?

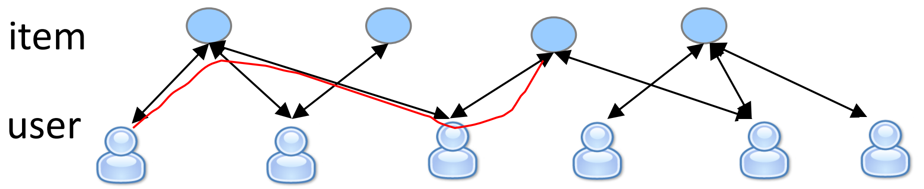
Relationship (33 bytes)



*Retrieving multi-step relationships is a '**graph traversal**' problem*

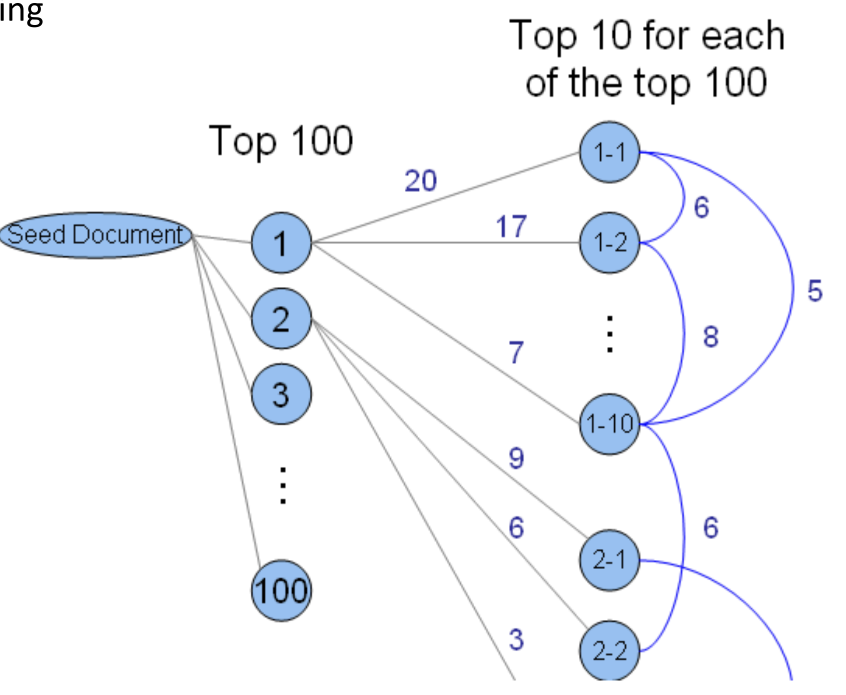
Cited "Graph Database" O'liey 2013

Preliminary datastore comparison for Recommendation & Visualization



People who bought this also bought that..

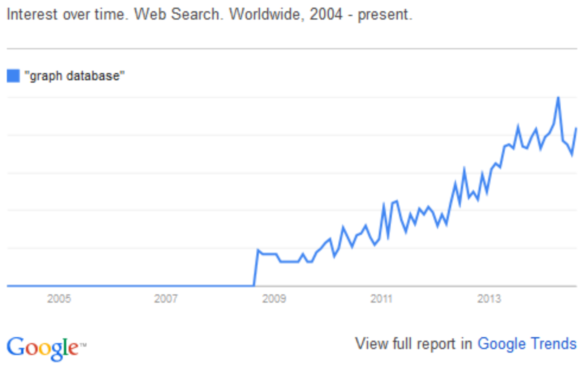
Recommendation ==> 2-hop traversal & ranking

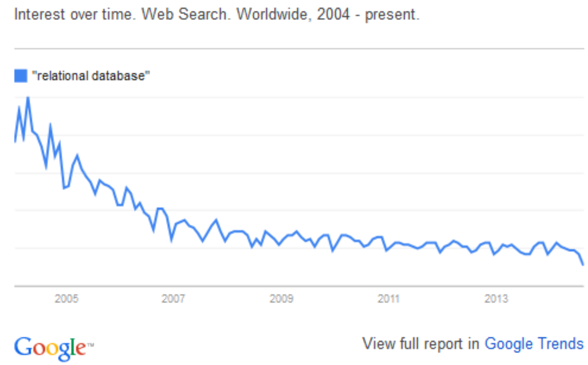


Document Visualization ==> 4-hop traversal & rankings

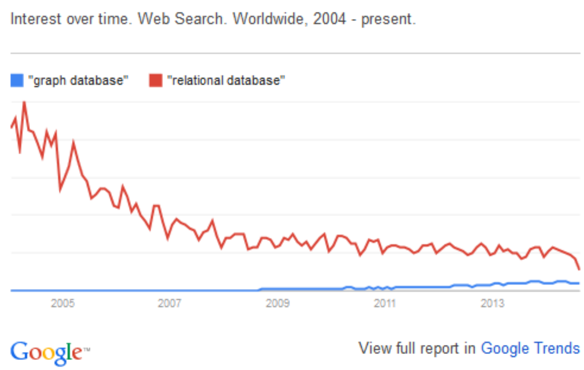
Google Trends on Relational vs Graph Databases

Trends of search interest on **Graph Database** and **Relational Database**, realitme from Google (Google Trend normalizes Y-axis to the highest value in a chart to 100%):





Comparison of relative amounts of searches on **Relational Database** and **Graph Database**:



"By 2025, graph technologies will be used in 80% of data and analytics innovations, up from 10% in 2021, facilitating rapid decision making across the enterprise."

- Gartner "Market Guide: Graph Database Management Solutions" Merv Adrian, Afraz Jaffri 30 August 2022

NoSQL Tabular Database: HBase

- **HBase** is modeled after Google's BigTable and written in Java, and is developed on top of HDFS

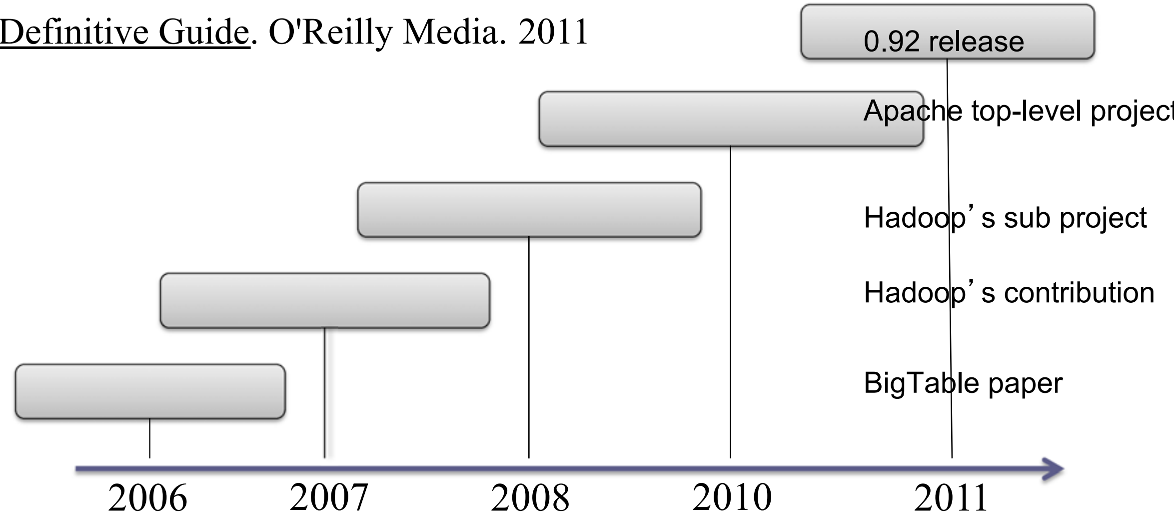
- It provides a fault-tolerant way of storing large quantities of **sparse data**
  - Small amounts of information caught within a large collection of empty or unimportant data, e.g.,
    - Finding the 50 largest items in a group of 2 billion records
    - Finding the non-zero items representing less than 0.1% of a huge collection

- HBase features compression, in-memory operation, and Bloom filters on a per-column basis

- An HBase system comprises a set of tables
  - Each table contains rows and columns, much like a traditional database.
  - An HBase column represents an attribute of an object
  - Each table must have an element defined as a Primary Key, and all access attempts to HBase tables must use this Primary Key

HBase History

Source: Lars, George. HBase The Definitive Guide. O'Reilly Media. 2011



Who Uses HBase?

- **Here is a very limited list of well-known names**
  - Facebook
  - Adobe
  - Twitter
  - Yahoo!
  - Netflix
  - Meetup
  - Stumbleupon
  - You????

When to use HBase?

- **Not suitable for every problem**
  - Compared to RDBMs, it has VERY simple and limited APIs
- **Good for large amounts of data**
  - 100s of millions or billions of rows
  - If data is too small all the records will end up on a single node leaving the rest of the cluster idle
- **Must have enough hardware!!**
  - At the minimum 5 nodes
    - There are multiple management daemon processes: Namenode, HBaseMaster, Zookeeper, etc....
    - HDFS won't do well on anything under 5 nodes anyway; particularly with a block replication of 3
    - HBase is memory and CPU intensive
- **Carefully evaluate HBase for mixed workloads**
  - Client request (interactive, time-sensitive) vs. Batch processing (MapReduce)
    - SLAs on client requests would need evaluation
  - HBase has intermittent but large I/O access
    - May affect response latency!
- **Two well-known use cases**
  - Lots and lots of data (already mentioned)
  - Large amounts of clients/requests (usually cause a lot of data)
- **Great for single random selects and range scans by key**
- **Great for variable schema**
  - Rows may drastically differ
  - If your schema has many columns and most of them are null

When NOT to use HBase?

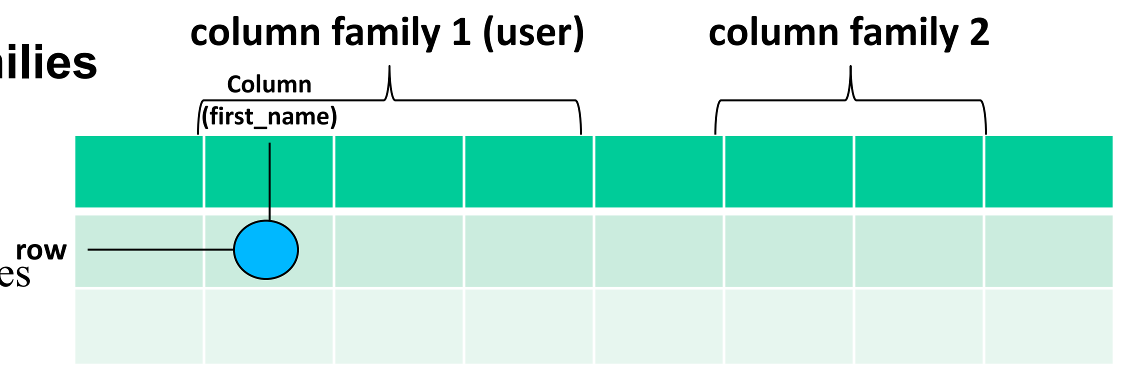
- **Bad for traditional RDBMS retrieval**
  - Transactional applications
  - Relational analytics
    - 'group by', 'join', and 'where column like', etc....
- **Currently bad for text-based search access**
  - There is work being done in this arena
    - HBasene: https://github.com/akkumar/hbasene/wiki
    - HBASE-3529: 100% integration of HBase and Lucene based on HBase' coprocessors
  - Some projects provide solutions that use HBase
    - Lily=HBase+Solr http://www.lilyproject.org

HBase Data Model

- **Data is stored in Tables**
- **Tables contain rows**
  - Rows are referenced by a unique (Primary) key
    - Key is an array of bytes – good news
    - Anything can be a key: string, long and your own serialized data structures
- **Rows made of columns**
- **Data is stored in cells**
  - Identified by "row x column-family:column"
  - Cell's content is also an array of bytes

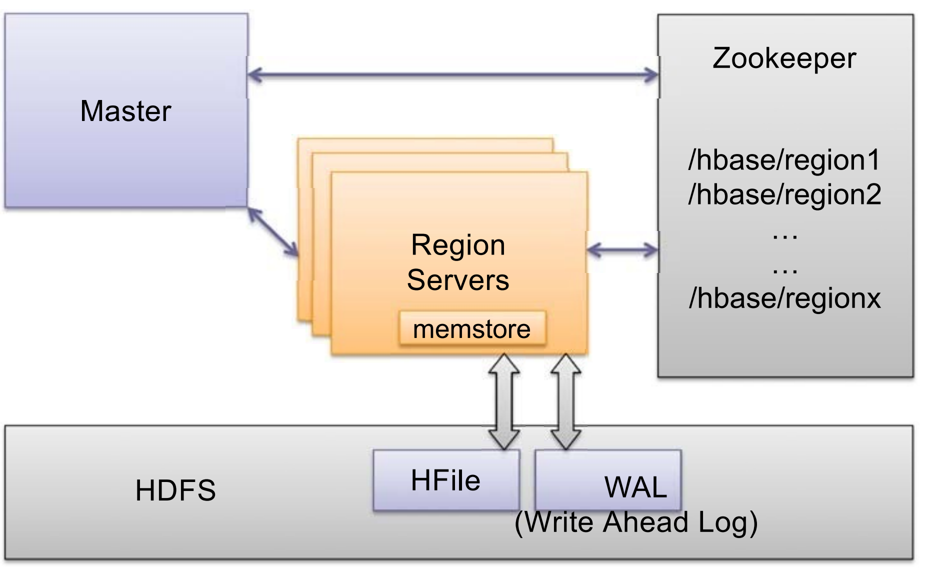
HBase Families

- **Columns are grouped into families**
  - Labeled as "family:column"
    - Example "user:first_name"
  - A way to organize your data
  - Various features are applied to families
    - Compression
    - In-memory option
    - Stored together - in a file called HFile/StoreFile
- **Family definitions are static**
  - Created with table, should be rarely added and changed
  - Limited to a small number of families
    - unlike columns that you can have millions of

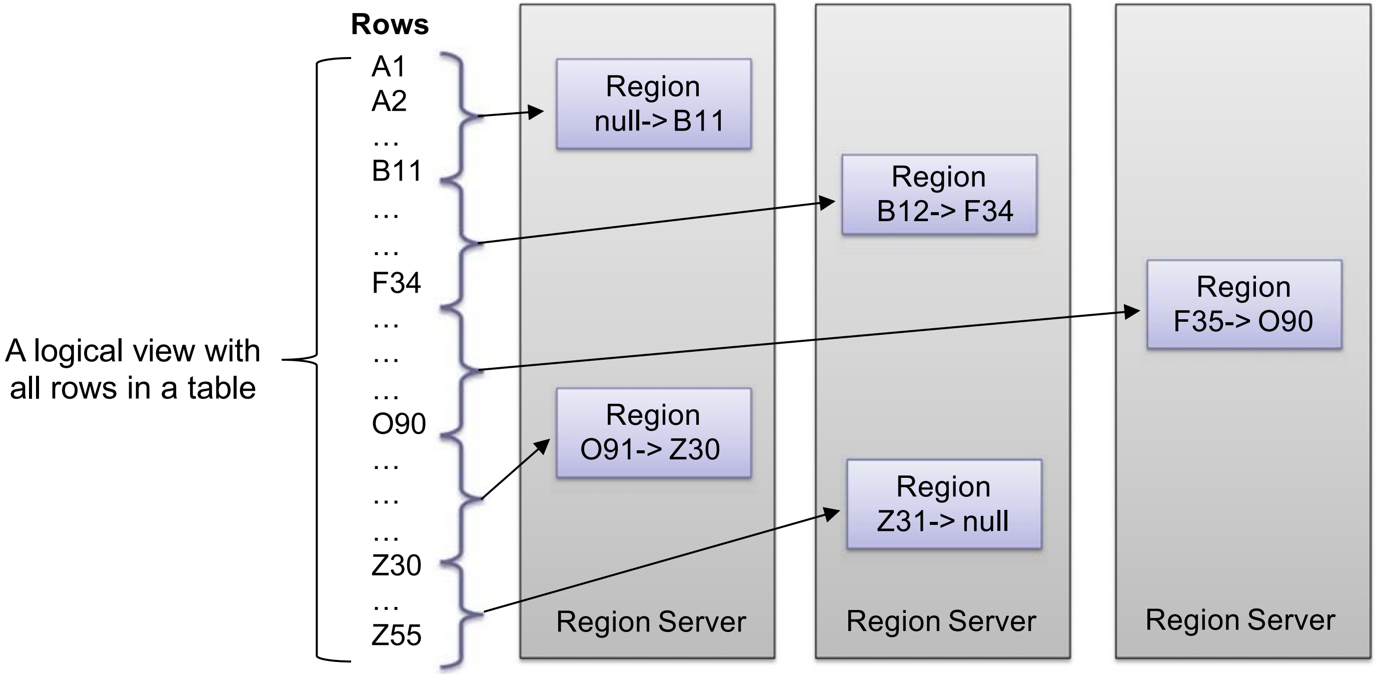


HBase Distributed Architecture

- **Table is made of regions**
- **Region – a range of rows stored together**
  - Single shard, used for scaling
  - Dynamically split as they become too big and merged if too small
- **Region Server – serves one or more regions**
  - A region is served by only 1 Region Server
- **Master Server – daemon responsible for managing HBase cluster, or Region Servers**
- **HBase stores its data into HDFS**
  - Relies on HDFS's high availability and fault-tolerance features
- **HBase utilizes Zookeeper for distributed coordination**



Row Distribution Between Region Servers

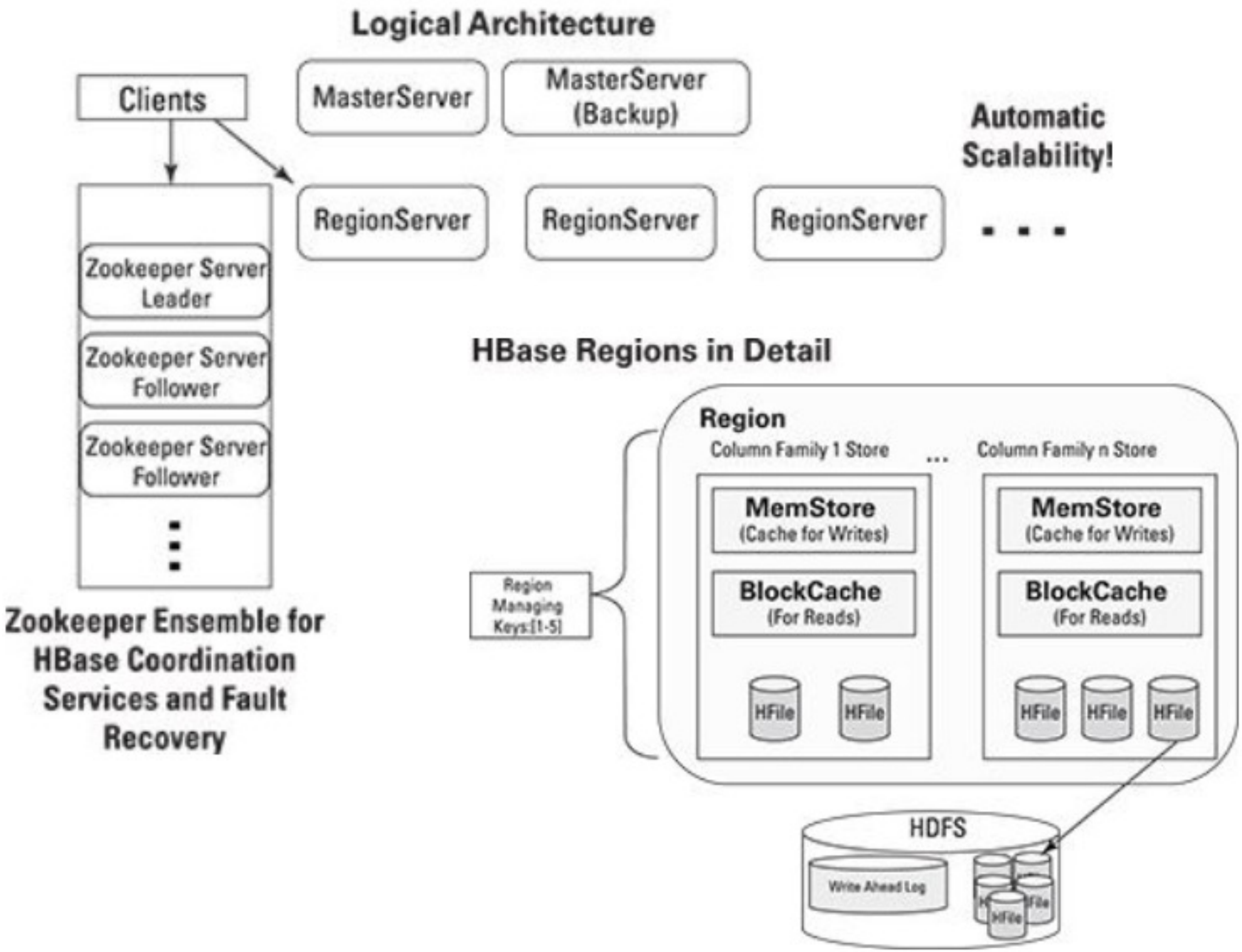


- **Regions per server depend on hardware specs. With today's hardware, it's common to have:**
  - 10 to 1000 regions per Region Server
  - Managing as much as 1GB to 2GB per region
    - How many rows per region? Depending on the size of each row and the size of a region
- **Benefits of splitting data into regions allows**
  - Fast recovery when a region fails
  - Load balancing when a region server is overloaded
    - May be moved between region servers
  - Splitting is fast
    - Reads from an original file while asynchronous process performs a split
  - Background processing: all of these happen automatically without user's involvement

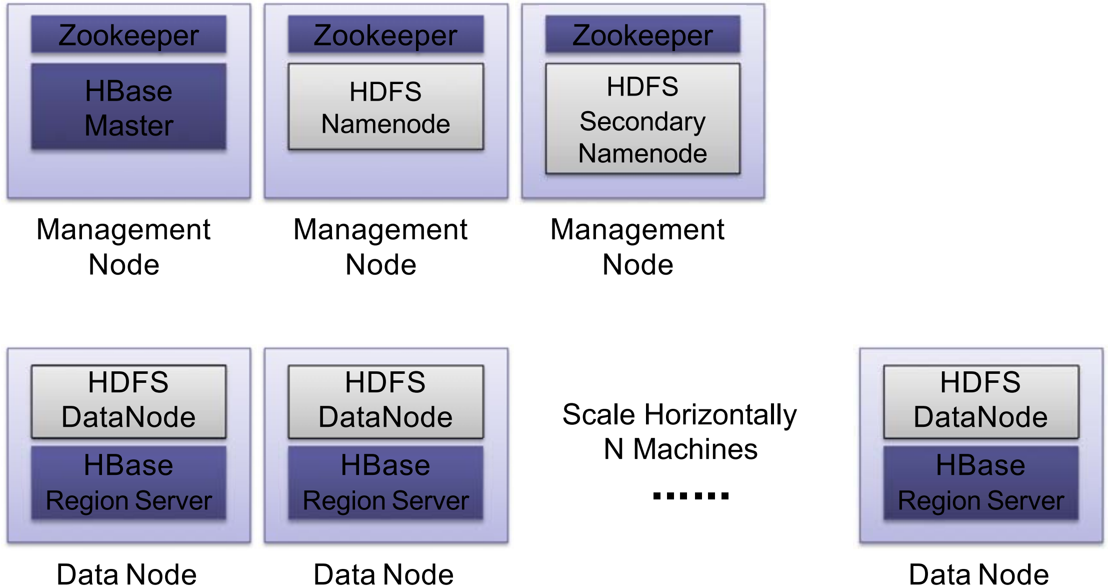
HBase Data Storage

- **Data (vertically along column families) is stored in files called HFiles/StoreFiles**
  - Usually saved in HDFS
- **HFile is basically a key-value map**
  - Keys are sorted lexicographically
- **When data is added, it's written to a log called Write Ahead Log (WAL) and is also stored in memory (memstore)**
- **Flush: when in-memory data exceeds maximum value, it is flushed to an HFile**
  - Data persisted to HFile can then be removed from WAL
  - Region Server continues serving read-writes during the flush operations, writing values to the WAL and memstore
- **HBase periodically performs data compaction**
  - ❖ Why?
    - ✓ To control the number of HFiles
    - ✓ To keep the cluster well balanced
  - Minor Compaction: Smaller HFiles are merged into larger HFiles (n-way merge)
    - Fast - Data is already sorted within files
    - Delete markers not applied
  - Major Compaction:
    - For each region, merge all the files within a column-family into a single file
    - Scan all the entries and apply all the deletes as necessary

HBase Architecture



HBase Deployment on HDFS



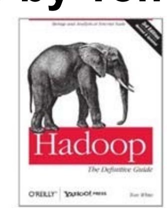
Resources

- **Home Page**
  - http://hbase.apache.org
- **Mailing Lists**
  - http://hbase.apache.org/mail-lists.html
  - Subscribe to User List
- **Wiki**
  - http://wiki.apache.org/hadoop/Hbase
- **Videos and Presentations**
  - http://hbase.apache.org/book.html#other.info

Books

- **HBase: The Definitive Guide by Lars George**
  - Publication Date: September 20, 2011

- **Apache HBase Reference Guide**
  - Comes packaged with HBase
  - http://hbase.apache.org/book/book.html
- **Hadoop: The Definitive Guide by Tom White**
  - Publication Date: May 22, 2012
  - Chapter about Hbase



Characteristics of Data in HBase

Sparse data

Table 12-1 Traditional Customer Contact Information Table

Customer ID	*Last Name*	*First Name*	*Middle Name*	*E-mail Address*	*Street Address*
00001	Smith	John	Timothy	John.Smith@xyz.com	1 Hadoop Lane, NY 11111
00002	Doe	Jane	NULL	NULL	7 HBase Ave, CA 22222

Multiple versions of data for each cell

Row Key	*Column Family: {Column Qualifier:Version:Value}*
00001	CustomerName: {'FN': 1383859182496:'John', 'LN': 1383859182858:'Smith', 'MN': 1383859183001:'Timothy', 'MN': 1383859182915:'T'}
	ContactInfo: {'EA': 1383859183030:'John.Smith@xyz.com', 'SA': 1383859183073:'1 Hadoop Lane, NY 11111'}
00002	CustomerName: {'FN': 1383859183103:'Jane', 'LN': 1383859183163:'Doe',
	ContactInfo: { 'SA': 1383859185577:'7 HBase Ave, CA 22222'}

HDFS lacks **random read and write access**. This is where HBase comes into picture. It's a **distributed, scalable, big data store**, modeled after Google's BigTable. It stores data as key/value pairs.

Creating a table

```
hbase(main):002:0> create 'CustomerContactInfo', 'CustomerName', 'ContactInfo'
0 row(s) in 1.2080 seconds
```

Table name

Column family 1

Column family 2

HBase Example

Entering Records

```
hbase(main):008:0> put 'CustomerContactInfo', '00001', 'CustomerName:FN', 'John'
0 row(s) in 0.2870 seconds

hbase(main):009:0> put 'CustomerContactInfo', '00001', 'CustomerName:LN', 'Smith'
0 row(s) in 0.0170 seconds

hbase(main):010:0> put 'CustomerContactInfo', '00001', 'CustomerName:MN', 'T'
0 row(s) in 0.0070 seconds

hbase(main):011:0> put 'CustomerContactInfo', '00001', 'CustomerName:MN', 'Timothy'
0 row(s) in 0.0050 seconds

hbase(main):012:0> put 'CustomerContactInfo', '00001', 'ContactInfo:EA', 'John.Smith@xyz.com'
0 row(s) in 0.0170 seconds

hbase(main):013:0> put 'CustomerContactInfo', '00001', 'ContactInfo:SA', '1 Hadoop Lane, NY 11111'
0 row(s) in 0.0030 seconds

hbase(main):014:0> put 'CustomerContactInfo', '00002', 'CustomerName:FN', 'Jane'
0 row(s) in 0.0290 seconds

hbase(main):015:0> put 'CustomerContactInfo', '00002', 'CustomerName:LN', 'Doe'
0 row(s) in 0.0090 seconds

hbase(main):016:0> put 'CustomerContactInfo', '00002', 'ContactInfo:SA', '7 HBase Ave, CA 22222'
0 row(s) in 0.0240 seconds
```

HBase Example

Scan Results

```
hbase(main):020:0> scan 'CustomerContactInfo', {VERSIONS => 2}
ROW       COLUMN+CELL
00001     column=ContactInfo:EA, timestamp=1383859183030, value=John.Smith@xyz.com
00001     column=ContactInfo:SA, timestamp=1383859183073, value=1 Hadoop Lane, NY 11111
00001     column=CustomerName:FN, timestamp=1383859182496, value=John
00001     column=CustomerName:LN, timestamp=1383859182858, value=Smith
00001     column=CustomerName:MN, timestamp=1383859183001, value=Timothy
00001     column=CustomerName:MN, timestamp=1383859182915, value=T
00002     column=ContactInfo:SA, timestamp=1383859185577, value=7 HBase Ave, CA 22222
00002     column=CustomerName:FN, timestamp=1383859183103, value=Jane
00002     column=CustomerName:LN, timestamp=1383859183163, value=Doe
2 row(s) in 0.0520 seconds
```

HBase Example

Using the *get* Command to Retrieve Entire Rows and Individual Values

```
(1) hbase(main):037:0> get 'CustomerContactInfo', '00001'
COLUMN              CELL
 ContactInfo:EA       timestamp=1383859183030, value=John.Smith@xyz.com
 ContactInfo:SA       timestamp=1383859183073, value=1 Hadoop Lane, NY 11111
 CustomerName:FN      timestamp=1383859182496, value=John
 CustomerName:LN      timestamp=1383859182858, value=Smith
 CustomerName:MN      timestamp=1383859183001, value=Timothy
5 row(s) in 0.0150 seconds

(2) hbase(main):038:0> get 'CustomerContactInfo', '00001',
        {COLUMN => 'CustomerName:MN'}
COLUMN              CELL
 CustomerName:MN      timestamp=1383859183001, value=Timothy
1 row(s) in 0.0090 seconds

(3) hbase(main):039:0> get 'CustomerContactInfo', '00001',
        {COLUMN => 'CustomerName:MN',
        TIMESTAMP => 1383859182915}
COLUMN              CELL
 CustomerName:MN      timestamp=1383859182915, value=T
1 row(s) in 0.0290 seconds
```

Create HBase table in Java

```java
public static void main(String[] args) throws IOException {

    // Instantiating configuration class
    Configuration con = HBaseConfiguration.create();

    // Instantiating HbaseAdmin class
    HBaseAdmin admin = new HBaseAdmin(con);

    // Instantiating table descriptor class
    HTableDescriptor tableDescriptor = new
    HTableDescriptor(TableName.valueOf("emp"));

    // Adding column families to table descriptor
    tableDescriptor.addFamily(new HColumnDescriptor("personal"));
    tableDescriptor.addFamily(new HColumnDescriptor("professional"));

    // Execute the table through admin
    admin.createTable(tableDescriptor);
    System.out.println(" Table created ");
  }
}
```

```java
Configuration config = HBaseConfiguration.create();
Job job = new Job(config,"ExampleReadWrite");
job.setJarByClass(MyReadWriteJob.class);    // class that contains mapper

Scan scan = new Scan();
scan.setCaching(500);        // 1 is the default in Scan, which will be bad for MapReduce jobs
scan.setCacheBlocks(false);  // don't set to true for MR jobs
// set other scan attrs

TableMapReduceUtil.initTableMapperJob(
  sourceTable,      // input table
  scan,             // Scan instance to control CF and attribute selection
  MyMapper.class,   // mapper class
  null,             // mapper output key
  null,             // mapper output value
  job);
TableMapReduceUtil.initTableReducerJob(
  targetTable,      // output table
  null,             // reducer class
  job);
job.setNumReduceTasks(0);

boolean b = job.waitForCompletion(true);
if (!b) {
    throw new IOException("error with job!");
}
```

HBase Table Mapper and Reducer

JAVA

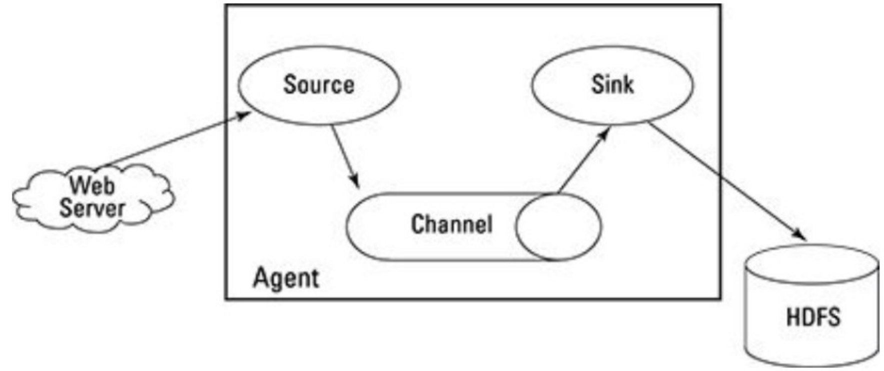
```java
public static class MyMapper extends TableMapper<Text, IntWritable>  {
  public static final byte[] CF = "cf".getBytes();
  public static final byte[] ATTR1 = "attr1".getBytes();

  private final IntWritable ONE = new IntWritable(1);
  private Text text = new Text();

  public void map(ImmutableBytesWritable row, Result value, Context context) throws IOException,
InterruptedException {
     String val = new String(value.getValue(CF, ATTR1));
     text.set(val);     // we can only emit Writables...
     context.write(text, ONE);
  }
}
```

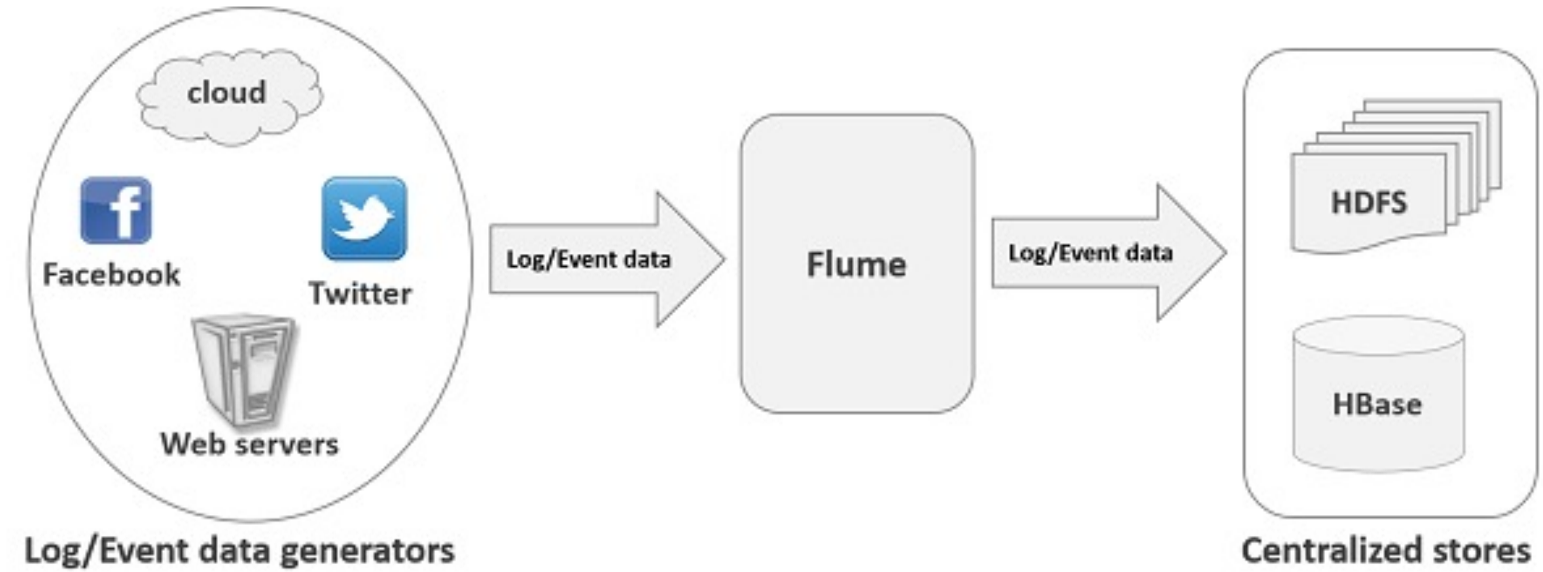
JAVA

```java
public static class MyTableReducer extends TableReducer<Text, IntWritable,
ImmutableBytesWritable>  {
  public static final byte[] CF = "cf".getBytes();
  public static final byte[] COUNT = "count".getBytes();

  public void reduce(Text key, Iterable<IntWritable> values, Context context) throws IOException,
InterruptedException {
     int i = 0;
     for (IntWritable val : values) {
       i += val.get();
     }
     Put put = new Put(Bytes.toBytes(key.toString()));
     put.add(CF, COUNT, Bytes.toBytes(i));

     context.write(null, put);
  }
}
```

Ingesting Data into HDFS/HBase – Apache Flume

Ingesting stream (log/event) data





Flume Features:

- Ingest log data from multiple web servers into a centralized store (HDFS, HBase) efficiently
- Import huge volumes of event data produced by social networking sites like Facebook and Twitter, and e-commerce websites like Amazon and Flipkart, along with the log files
- Support a large set of sources and destinations types
- Support multi-hop flows, fan-in fan-out flows, contextual routing, etc.
- Can be scaled horizontally

Questions?