Big Data Analytics

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Outline

NoSQL Databases

HBase (Hadoop database)

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Distributed File System (DFS)

- A DFS (Hadoop, GFS,...) is the opposite of a virtual machine. A virtual machine chops one machine into multiple virtual machines. A distributed file system combines many virtual machines into one virtual machine.
- It includes a NoSQL database
- Relational databases are like sports cars, Hadoop is like a freight train.
- Relational database is for online transaction processing (OLTP), ACID transactions, etc. DSF is good for analyzing massive amounts of data, handling unstructured data, handling very complex analyses, etc.

Relational Databases

- Advantages of relational DB.
  - persistence
  - integration
  - transaction
  - reporting
- The disadvantage of relational databases is that one object in the program is split into many tables in the data base (impedance mismatch).

Object-Oriented Databases

- The motivation was to solve the impedance mismatch issue.
- It could not replace the relational data bases because the integration aspect of relational data bases was very powerful.
- Therefore, relational databases dominated the market for 20 years (1990-2010).

The Rise of Internet

- Solution 1: centralized solution ×
- Problems:
  - cost
  - limited
- Solution 2: Distributed solution √
- SQL does not work well for big distributed databases.
- NoSQL databases were innovated for big distributed databases.

Characteristics of NoSQL Databases

- Non-relational
- Cluster-friendly
- Open source
- Web-oriented
- Schema-less

What is missing in NoSQL Databases

- No joint operation
- No complex transaction
- No constrains

The objectives of NoSQL Databases

- horizontal scalability
- availability
- high performance

When to use NoSQL Databases

- Large amount of data
- Relationships are not important
- Dealing with growing list of elements
- The data is not structured or the structure is changing
- Prototype and fast applications
- No need for constraints or validation rules in data bases

When NOT to use NoSQL Databases

- Complex transactions
- Joint
- Constrains in data bases

NoSQL Databases

- Key-value
- Document
- Column
- Graph

Key–Value stores

- Key–Value stores use the associative array as their fundamental data model.
- In this model, data is represented as a collection of key–value pairs.
- The key–value model is one of the simplest non-trivial data models.

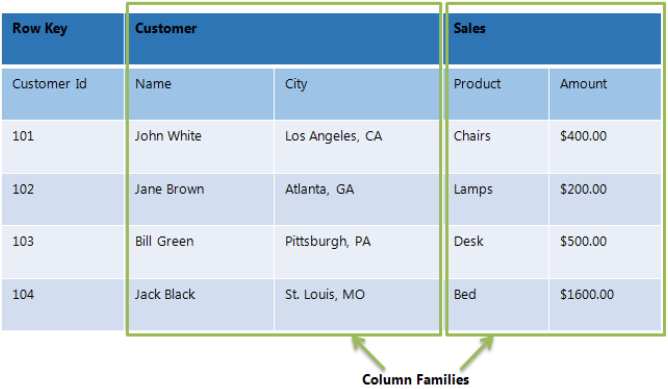
Example:

```
{
"Great Expectations": "John",
"Pride and Prejudice": "Alice",
"Wuthering Heights": "Alice"
}
```

Document Databases

- Documents are addressed in the database via a unique key that represents that document.
- Documents can be retrieved by their
  - key
  - content
- Documents are organized through
  - Collections
  - Tags
  - Non-visible Metadata
  - Directory hierarchies
  - Buckets

Elements of Column Databases



Row Key	Customer		Sales	
Customer Id	Name	City	Product	Amount
101	John White	Los Angeles, CA	Chairs	$400.00
102	Jane Brown	Atlanta, GA	Lamps	$200.00
103	Bill Green	Pittsburgh, PA	Desk	$500.00
104	Jack Black	St. Louis, MO	Bed	$1600.00

Column Families

- Column
- Column Family
- KeySpace

Column

- Columns are a tuple (a key-value pair) consisting of three elements:
  - Unique name: Used to reference the column
  - Value: The content of the column.
  - Timestamp: The system timestamp used to determine the valid content.
- Example:

{
street: name: ”street”, value: ”1234 x street”, timestamp: 123456789,
city: name: ”city”, value: ”san francisco”, timestamp: 123456789,
zip: name: ”zip”, value: ”94107”, timestamp: 123456789,
}

Column Family

- A set of column sets that are about related data.
- It also includes a key-value pair, where the key is mapped to a value that is a column set.
- In analogy with relational databases, a standard column family is as a "table", each key-value pair being a "row".

KeySpace

- A keyspace is an object that holds together all column families in a design.
- It resembles to the schema concept in Relational database management systems
- Column Family 1:
  UserProfile = {
  Cassandra = { emailAddress:"casandra@apache.org" , age:"20"}
  TerryCho = { emailAddress:"terry.cho@apache.org" , gender:"male"}
  Cath = { emailAddress:"cath@apache.org" , age:"20", gender:"female", address:"Seoul"}
  }

KeySpace

- Column Family 2:
  Products = {
  book = { name:” introduction to Java” , year:”2001”}
  movie = { name:”The Lord of the Rings” , director:”Peter Jackson”}
  Shirt = { Brand:”lacoste ” , color:”blue”, price:”100”}
  }

KeySpace

$$< KeyspaceName = ''Company'' >$$
$$< KeysCachedFraction > 0.01 < /KeysCachedFraction >$$
$$< ColumnFamilyCompareWith = ''UTF8Type'' \; Name = ''UserProfiles'' / >$$
$$< ColumnFamilyCompareWith = ''UTF8Type'' \; Name = ''Products'' / >$$
$$< /Keyspace >$$

Aggregation in Column Databases

- As an example, a relational table could consist of the columns UID, first name, surname, birthdate, gender.
- Suppose that we are searching people who are male and were born between 1950 and 1960.
- In the relational database, all the table has to be read.
- In Column datasets, we only read the two columns.
- The Columns in a family are stored together in a low level storage file known.

Graph Database

- Key-value, Document, and Column databases are aggregate databases.
- Graph databases are not an aggregate database.
- Graph databases are used for the data that is not aggregated and there are many relationships
- Graph databases are schema-less like aggregate databases.
- Graph databases support transactions.

Summary of Databases

- Aggregate databases (Key-value, Document, and Column).
- Graph databases
- Relational Databases

ACID transactions

- In relational databases, ACID transactions guarantee that the database is consistent.
- Aggregate databases do not have ACID transactions.
- Graph databases have ACID transactions.
- In aggregate databases, time stamps are used to resolve the conflicts.

Big data and consistency

- Replication leads to more availability
  - More nodes are able to execute requests
  - If one nodes goes down, other nodes can still process requests
- But it also causes more problems in consistence
- Consistence or availability? which one is more important?

Example

- There is an international booking website with several servers all over the world.
- Two persons from different continents request a particular room of a hotel in the same time.
- Two servers communicate and in the end the room is assigned to one of the persons.

Example

- What about if the connection between the servers go down?
- If consistency is more important, both requests are rejected.
- If availability is more important, both requests are accepted.
- The choice between availability and consistency depends on the business rules of the application.

CAP theorem

It is impossible for a distributed computer system to simultaneously provide all three of the following guarantees:

- Consistency (all nodes see the same data at the same time)
- Availability (a guarantee that every request receives a response about whether it was successful or failed)
- Partition tolerance (the system continues to operate despite arbitrary message loss or failure of part of the system)

Consistency vs. Availability

- The choice is not binary, but a spectrum.
- In practice, the trade off is not always between consistency and availability or partitioning, but consistency and response time.

The reasons of going for NoSQL databases

- Big Data
- Easy and rapid development
- The importance of integration issue has deceased due to service-oriented programming.
- Analytics

Challenges of NoSQL databases

- Organizational change
- Immaturity
- Eventual consistency

SQL database will still play important role in databases at least for one decade.

Outline

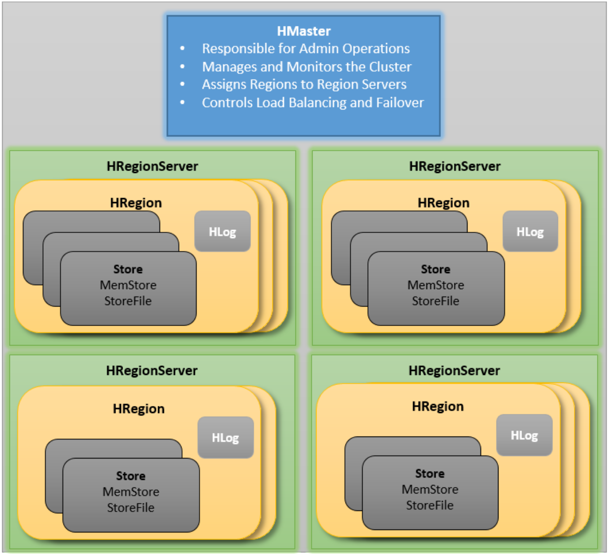
NoSQL Databases

HBase (Hadoop database)

HBase (Hadoop database)

- it is a distributed column-oriented database, which lays between HDFS and MapReduce.
- It is open-source implementation of Google's Big Table database.
- has some built-in features such as
  - Scalability
  - Versioning
  - Compression
  - Garbage collection
  - Fault tolerance

The architecture of HBase



HMaster

- Performing Administration
- Managing and Monitoring the Cluster
- Assigning Regions to the Region Servers
- Controlling the Load Balancing and Failover

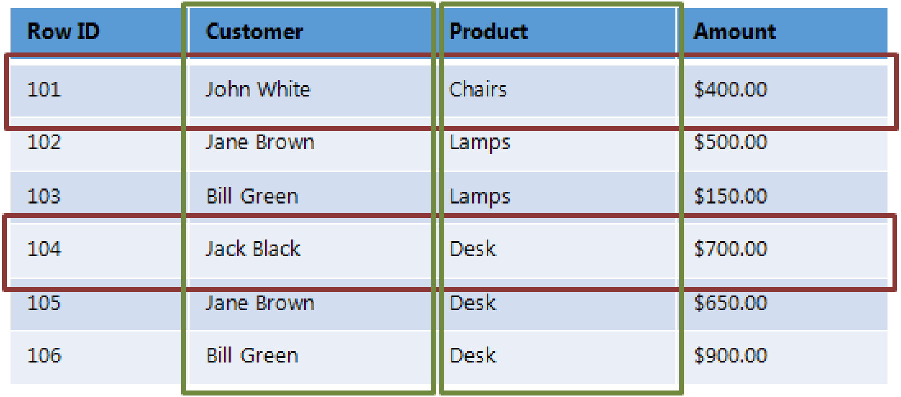
HRegionServer

- Hosting and managing Regions
- Splitting the Regions automatically
- Handling the read/write requests
- Communicating with the Clients directly

HRegionServer

- Each Region Server contains a Log (called HLog) and multiple Regions.
- Each Region in turn is made up of a MemStore and multiple StoreFiles (HFile).
- The data lives in these StoreFiles in the form of Column Families.
- The MemStore holds in-memory modifications to the Store (data).

Column vs. row-oriented database



Row ID	Customer	Product	Amount
101	John White	Chairs	$400.00
102	Jane Brown	Lamps	$500.00
103	Bill Green	Lamps	$150.00
104	Jack Black	Desk	$700.00
105	Jane Brown	Desk	$650.00
106	Bill Green	Desk	$900.00

Characteristics of Row-oriented database

- Data is stored and retrieved one row at a time and hence could read unnecessary data if only some of the data in a row is required.
- Easy to read and write records
- Well suited for OLTP systems
- Not efficient in performing operations applicable to the entire dataset and hence aggregation is an expensive operation
- Typical compression mechanisms provide less effective results than those on column-oriented data stores
- In the hard disk, each row is stored together.

Characteristics of column-oriented database

- Data is stored and retrieved in columns and hence can read only relevant data if only some data is required
- Read and Write are typically slower operations
- Well suited for OLAP systems
- Can efficiently perform operations applicable to the entire dataset and hence enables aggregation over many rows and columns
- In the hard disk, each column is stored together.

RDBMS vs. HBase

- HBase is schema-less, but RDBMS is based on a fixed schema
- HBase is for big data (million columns, billion rows), but RDBMS was not initially created to store big data
- HBase stores denormalized data, but RDBMS stores normalized data
- HBase supports automatic partitioning, but RDBMS does not.

HBase vs. HDFS

- HBase is is built for Low Latency operations, but HDFS is suited for High Latency operations batch processing
- HBase Data is accessed through shell commands, Client APIs in Java, etc. , but in HDFS Data is primarily accessed through MapReduce
- HBase Provides access to single rows from billions of records, but HDFS is designed for batch processing and hence doesn't have a concept of random reads/writes

Powered by HBase

- **Facebook** uses HBase to power their Messages infrastructure.
- **Twitter** runs HBase across its entire Hadoop cluster
- **Yahoo!** uses HBase to store document fingerprint.
- **Adobe** use HBase in several areas from social services to structured data and processing for internal use.