Advanced Database Management

HADOOP AND ITS ECOSYSTEM

Under the Guidance of Prof. Yann Chang

University of Illinois at Chicago

IDS 521 – Term Paper

SUBMISSION BY-

SHIVAM DUSEJA

PAWANJEET KAUR

KARANSINH RAJ

Table of Contents

Executive Summary

It has been correctly said by Clive Humby – 'Data is the new Oil'. In the recent past, we have seen an exponential increase in the amount of data and the evolution of Big Data to extract valuable information from petabytes of data. This large amount of data further led to the development of distributed and parallel computing solutions. Hadoop's capability of processing, analyzing, and transforming Big Data has attracted a lot of customers/users making it – one of the biggest players in the market. The two main components of Hadoop – HDFS and MapReduce have enabled parallel computation by partitioning data across thousands of hosts. One of the major advantages of Hadoop is that it offers easy scalable solutions at a comparatively lower cost for petabytes of data. In order to provide a SQL-like interface for data processing on file systems, Hadoop is integrated with a data warehousing solution – Apache Hive – that is built on top of Hadoop. Apart from the SQL compatibility, Hadoop is also integrated with Apache Pig, that provides a high-level platform for running programs using – Pig Latin language.

As Apache does not provide any kind of support – this may lead to different stability and security concerns, hence, there arises a need for different vendors to help distribute Hadoop across platforms. A few vendors that support and ensure the reliability of Hadoop are – Cloudera, MapR, Hortonworks etc.

Hadoop – Introduction

1. Origin and Overview

Doug Cutting and Mike Cafarella started Hadoop in the year 2002, while they both were on Apache Nutch project. Originally Apache Nutch project was the process of building a search engine that could index around 1 billion pages.

As per Doug Cutting, Hadoop was a made-up name and not an acronym. As per him – *'The name my kid gave a stuffed yellow elephant. Short, relatively easy to spell and pronounce, meaningless and not used elsewhere: those are my naming criteria.'* The Nutch developers created a working crawler and a search system, however, the major problem in front of them was that their architecture was not able to scale to billions of pages on the web. Google's paper on their distributed filesystems (GFS – Google's distributed filesystem) in 2003 turned out to be a silver lining for the Nutch developers as this paper could solve their problem of storing very large files, however, this was only a half solution to their problem. The other half solution was addressed when Google published one more paper on the technique MapReduce in 2004. Both the techniques – GFS and MapReduce were just on paper with Google.

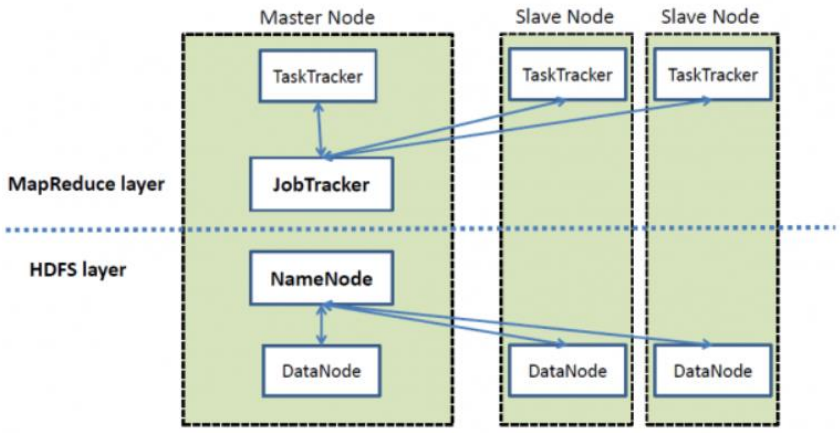
Doug Cutting, from his prior work on Apache Lucene was aware that the best way to spread a technology to more people is to make it open source. He then started working with Mike Cafarella on implementing GFS and MapReduce technique as an open-source project.

In January 2008, Hadoop was released by Yahoo as an open source project to Apache Software Foundation (ASF). Further in July 2008, ASF successfully tested a 4000-node cluster with Hadoop.

I. What is Hadoop

Apache Hadoop is an open source framework that is capable of storing and processing large datasets ranging from gigabytes to petabytes. Instead of using a conventional way of storing and processing data in a single large computer, Hadoop allows clustering of multiple computers which helps in parallel processing thereby analyzing massive datasets more quickly. The Hadoop ecosystem has grown significantly since its inception and today this ecosystem offers many tools and application to manage – store – process – analyze big data.

II. Hadoop Architecture



High Level Architecture of Hadoop

Major Components of the Hadoop Architecture:

- Master – Slave mechanism
- Made up of 2 major components – HDFS and MapReduce

- **Hadoop Distributed File System (HDFS):** The HDFS component replicates data across multiple nodes thereby offering a distributed storage. Unlike other regular file systems, HDFS creates multiple blocks of data by automatically splitting it and storing it across different data nodes. This helps in ensuring higher availability and fault tolerance.
- **MapReduce:** The MapReduce component provides an analysis system that performs complex computations on large sized datasets. These complex computations are broken into multiple tasks that are assigned to individual slave nodes. Further the algorithm takes works on coordinating and consolidating the results.
- **Master:** The master node consists of the job tracker and NameNode components:
    - ✓ **NameNode** – The NameNode component holds all the useful information for operation of Hadoop cluster. It holds information about all the nodes and files within the cluster and other building blocks of these files and their locations in the cluster.
    - ✓ **Job Tracker** – The job tracker component is responsible for tracking individual jobs/tasks assigned to all the nodes and it further coordinates information exchange and results.
- The **Slave** component in the framework contains the task tracker and a DataNode component:
    - ✓ **DataNode:** Holds the data
    - ✓ **Task Tracker:** Responsible for running the tasks assigned to it.
- The above framework has no dependency on the physical location of the server.

III. Characteristics of Hadoop

- **Faster:** Hadoop is extremely good in processing high volumes of data given the fact that it has the capability of processing batches in parallel. This performance is much better than a single thread server on a mainframe.
- **Distributed Processing:** Data in Hadoop is processed in parallel on a cluster of nodes. This is provided – the data is stored in a distributed manner in HDFS.
- **Fault Tolerance:** As per the Hadoop architecture, the data that is sent to one node is replicated across other nodes within the same cluster. Hence, in case the original node fails in processing the data – the other nodes would process it.
- **Reliability:** Due to Hadoop's characteristics of data replication across nodes, the data is reliably stored on clusters thereby protecting it from any kind of machine failures.
- **Scalable Solution:** Hadoop allows users to run and process large data sets (thousands of petabytes of data) by distributing this data across multiple parallel operating servers. Apart from that, Hadoop also provides the capability to add nodes while processing, without any downtime. This is commonly known as *'Hardware horizontal scalability'*.
- **Flexible:** Hadoop is highly capable in dealing with structures/unstructured, encoded, or formatted types of data.
- **Availability:** Data replication of Hadoop – makes it available and accessible from different paths even if the hardware machine fails.
- **Ease of use:** As Hadoop takes care of the distributed computing itself – it is relatively easier to use.
- **Cost Effective:** Hadoop is a cost-effective storage solution for very large data as it runs on a cluster of commodity hardware.

- **Locality of Data:** While submitting a new MapReduce algorithm – Hadoop moves the algorithm to the same data cluster instead of moving data to the location where algorithm is submitted.

IV. When should be use Hadoop?

- **Volume and Diversity of Data:** Hadoop should be used - when the data volume is very large (gigabytes or petabytes) and is coming from a different source in a variety of formats.
- **Lifetime availability of Data:** Hadoop does not limit the size of different clusters and also provides a functionality of adding nodes to a cluster, if required. This feature stands out - if we want this data to be live and available forever.
- **Multiple Frameworks:** Hadoop is easily integrable with different technologies/tools like R, Python, Spark, HBase, MongoDB, NoSQL databases, etc.
- **Design for Future Planning:** Hadoop provides a functionality to plan for future scalabilities. Before using Hadoop infrastructure – the first step should be to understand the complexity of our processed and the rate at which data is expected to grow.

V. When we should not use Hadoop

- **Processing smaller data volumes:** In order to process smaller data volumes – tools like MS Excel, MySQL should be used as Hadoop would be slower and costlier in this scenario. One way to use multiple smaller datasets is to combine them (provided they are of same format and type) and create a large dataset. Hadoop can then be used to store and process this large dataset.
- **Replaceable Infrastructures:** We can run multiple processes with Hadoop; however, we cannot simply replace existing databases. There are generally different tools for different jobs. For e.g. data can be stored and processed in the Hadoop ecosystem – which can then

be passed into other relational databases and other BI tools like Tableau, MicroStrategy etc.

- **Sensitive Data:** When the data is highly sensitive, it cannot be directly moved to Hadoop because of the possibility of data breach. If Hadoop has to be used, data should be encrypted first before loading it into the Hadoop ecosystem.

2. Key Technologies within the Hadoop Ecosystem

I. HDFS (Hadoop Distributed File System)

HDFS is a distributed file system that follows a network-based approach to store different files across various systems. HDFS is designed to work on product hardware having low costs that can handle large volumes of data. This is a highly self-healing and fault tolerant distributed file system.

II. HDFS Architecture

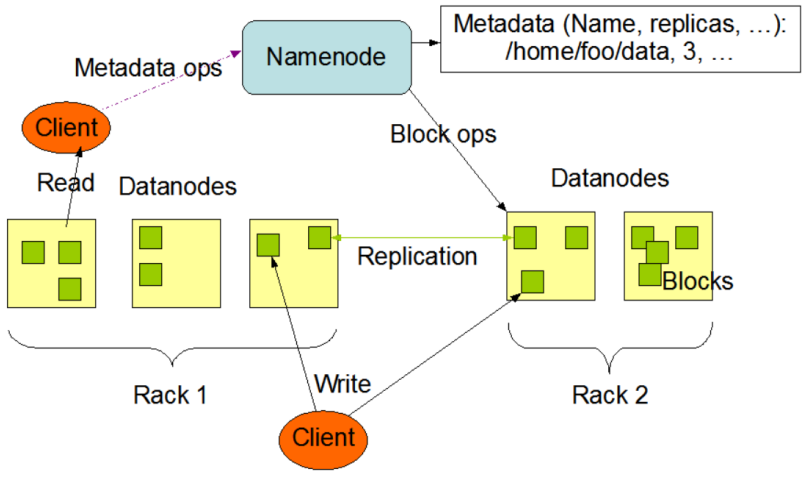


Figure on the previous page shows the HDFS architecture – that follows a master/slave mechanism. HDFS architecture is designed in such a way that the master daemon contains NameNode, secondary NameNode and job tracker whereas the slave daemons contains the data node and task tracker. The NameNode is responsible for keeping the directory tree of all files in

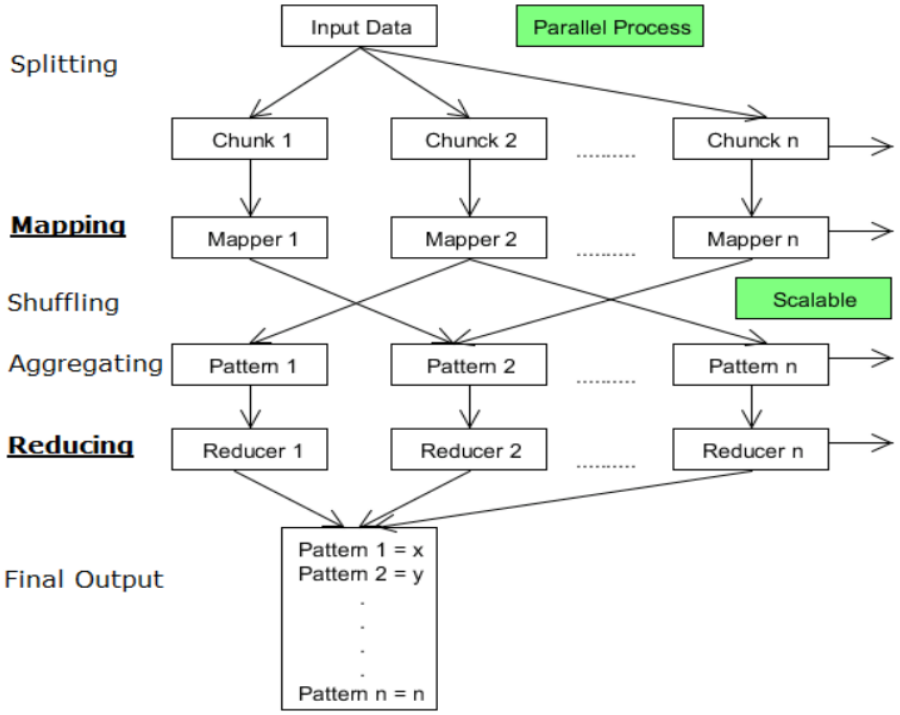
the system and tracking the location of file within the cluster. It also maintains the file system and the file system further contains all the information about the meta data. This is in general a single point of failure for HDFS cluster and when it goes down – the entire file system goes offline. However, when the primary node goes down, the secondary node comes into picture. This helps to maintain the file size containing HDFS modification logs within certain limits at name node.

The task tracker monitors and instantiates the individual maps and thereby reduces work. Every task tracker resides on top of the data node and has a certain slot allocated to take care of different scheduling tasks in the form of MapReduce jobs. This sits on top of the NameNode that manages MapReduce tasks and distributes individual tasks to the task tracker machine. The data node is responsible for storing the data in Hadoop File System in the form of HDFS blocks that has a default size of 64 MB. Initially the service is established when the data node connects to the name node which further responds to the requests back from the name node for different file system operations.

III. Map Reduce

The Map Reduce algorithm is a parallel programming model that is used for processing huge volume of data. It helps in writing applications to process high amount of data in parallel across different large clusters. It further provides automatic parallelization, I/O scheduling, monitoring, distributed fault- tolerance and status updates. As the computational process generally occurs on both structured and unstructured datasets, thus, making it reliable, fault-tolerant that supports thousands of nodes.

Map Reduce Algorithm



A general Map Reduce job is further divided into 4 phases:

- **Input Split:** The map reduce input split is divided into fixed sizes chunks which is a fixed piece of input being consumed by a single map.
- **Mapper:** Data residing in the input split is passed on to the mapper function to produce mapper output values. An intermittent output is produced in this section depending upon the business/user requirement.
- **Shuffling/Aggregation:** The output from the mapper function is fed to the shuffling/aggregation phase. This phase further consolidates the data records for processing in the reducer function
- **Reducer:** The shuffled/aggregated output is fed to the Reducer for final processing. This function returns a final output summarizing the job/task at hand (for example – determining frequency of words, clustering etc.)

In general, this algorithm cannot control the order in which the mappers or reducers are running, however, a reducer job would not start until and unless all the mapper jobs are complete. These

algorithms/programs are usually written in scripting languages (Java, Python) using streaming APIs.

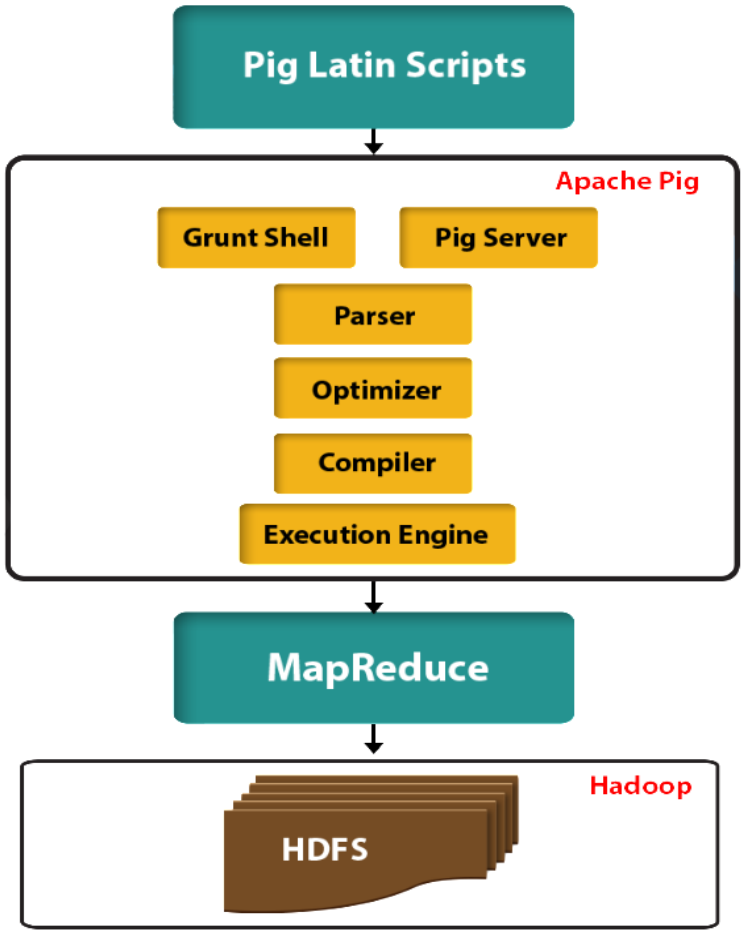
3. Hadoop – Projects

I. Apache Pig

In order to analyze data using the Pig script in Hadoop – Apache Pig is most commonly used. Apache Pig, being a high-level data processing language, offers different types of data types, operators, and data processing operations. The developers must write a Pig script using the Pig Latin language in order to perform different tasks and these tasks can be executed using different execution mechanisms like Embedded and Grunt Shell.

Once the scripts have executed, they undergo different transformations in order to produce the required/desired output by the Apache Pig framework.

As per the Pig architecture, these scripts are transformed into a number of Map Reduce jobs making the process much simpler and faster. A high-level architecture of Apache Pig is displayed on the page below –



Major Components of the Pig Architecture

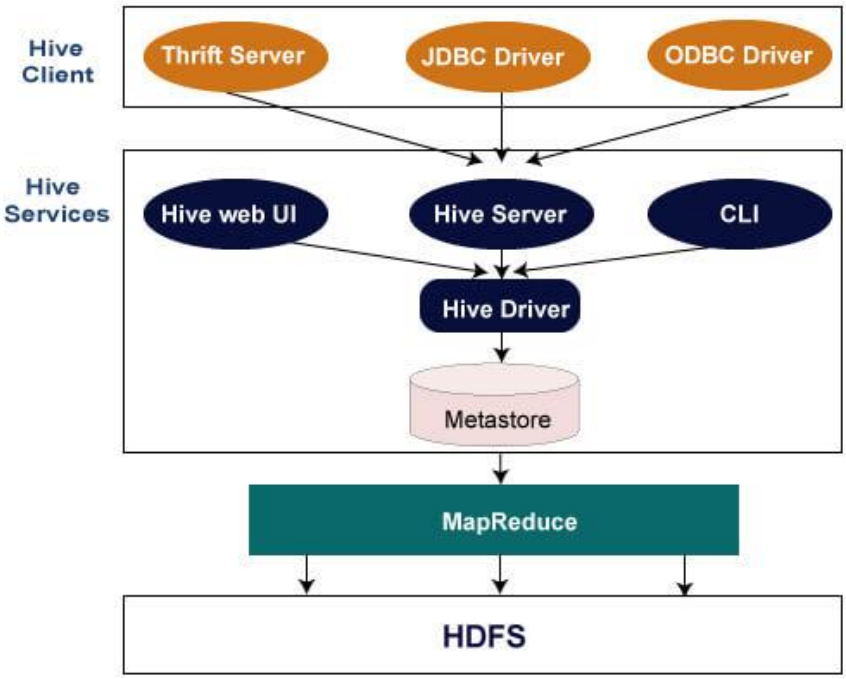
- **Parser:** As per the architecture, the parser is responsible for handling the pig scripts. Different types of validations like – syntax, types checks, etc. are performed by the parser. Directed Acyclic Graph (DAG) is the output generated by the parser which basically represents the statements of Pig Latin with different logical operators.
- **Optimizer:** Various logical optimizations like pushing, projecting, etc. are performed by the logical optimizers (whose input is DAG).
- **Compiler:** Once the DAG is optimized into a logical plan, the compiler compiles it into a series of MapReduce jobs which is further used by the execution engine.

- **Execution Engine:** The MapReduce jobs produced in the compiler step are further fed in a sorted order to Hadoop. These MapReduce jobs/tasks run on Hadoop in order to generate the desired/required results.

II. Apache Hive

In order to support SQL-like query processing, Hive is a data warehousing solution built on top of Hadoop. These queries within the Hive ecosystem are known as HiveQL or HQL and are compiled into Hadoop based Map Reduce jobs. HQL also offers a feasibility to connect different customized map scripts to SQL-like queries.

Hive Architecture and its Components



The above figure shows a high-level architecture view of Hive and its components. From the figure, we can see the flow in which a simple query is processed in Hive which is finally processed by the MapReduce algorithm.

Major components of Hive are as follows:

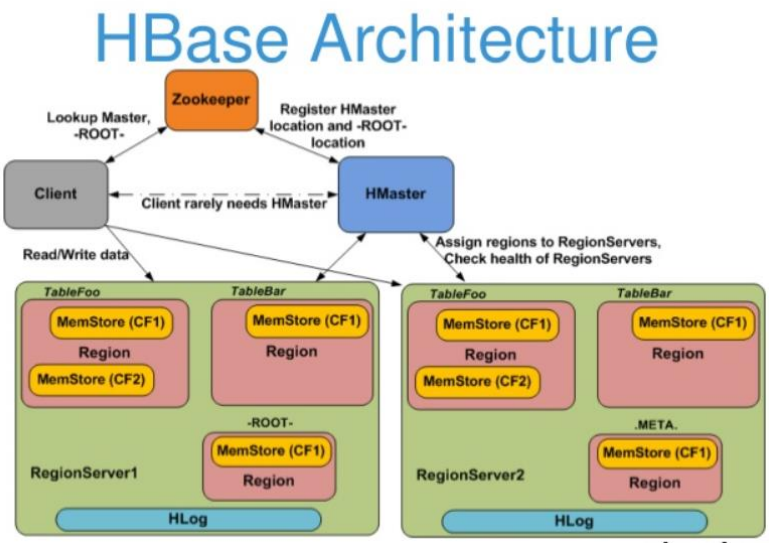
- **Hive Client:** Hive is one of the most versatile languages in a sense that it supports applications written in different languages like – Java, Python, C++ etc. using JDBC/ODBC and Thrift drivers. Hence, a Hive application can be developed easily written in the language of their choice.
- **Hive Service:** Apache hive provides various kinds of services like web interface, CLI, in order to perform/process queries in a more user-friendly manner.
- **Processing and Resource Management:** The MapReduce framework/algorithm is used internally to execute the queries and process the data.
- **Storage:** As Hive is a data warehousing solution built on top of Hadoop, it uses the underlying HDFS architecture for distributed storage and processing.

III. HBase

The datasets have become sparser with the increased application of Big Data. HBase is a columnar database with a Hadoop Distributed File System most suitable for scenarios wherein the datasets are sparse. HBase is not a relational database and does not support SQL-like structured queries to analyze or process data. These HBase applications are generally written in Java which is pretty similar to the MapReduce algorithm.

A simple HBase system is made up of a set of tables. Similar to a traditional database, each table is made up of rows and columns, having a primary key, however, all the access attempts to the HBase tables should use this primary key.

The figure on the below page shows a high-level view of HBase architecture and its components:



The Major components of the HBase architecture are –

- **HMaster:** HBase HMaster is the process that performs load balancing by assigning regions to region servers within the Hadoop cluster. Major tasks taken care by the HMaster are –
  - ✓ Monitoring and Managing the Hadoop cluster
  - ✓ All the different kinds of DDL operations are managed by HMaster
  - ✓ Responsible for administrative tasks (interface for creating, deleting, updating tables)
  - ✓ It is also responsible for the changes at the schema level as well as changes involving any metadata operations.
- **Region Server:** Different client requests like – read, write, delete, update and handled by working nodes (Regional servers). This regional server process runs on every node within the Hadoop cluster. This includes the following components –
  - ✓ **MemStore:** This refers to the write cache – that stores new data which has not been written to the disk yet. Each column family has MemStore within a region.

- ✓ **Block Cache:** This refers to the read cache. As per the architecture, the most frequently read data is stored in the read cache, however, when the block cache is full, the recently used data is disposed of.
- ✓ **WAL (Write Ahead Log):** Any new data that is not permanently written is stored in the form of a file (WAL)
- ✓ **HFile** is the storage file responsible for saving rows on a disk as sorted key values.

- **Zookeeper:** It is used as a distributed coordinating service for different regional assignments that is used to recover any regional server crash by loading it into other functioning region servers. The major responsibility of Zookeeper is to act as a centralized monitoring server thereby maintaining configuration and distributing synchronization information.

  In order to approach regions, the Zookeeper must be contacted first. The Region servers and HMaster are registered with the Zookeeper service whereas the clients require zookeeper quorum to connect to different region and HMaster servers.

4. Hadoop – Vendors providing Big Data Solutions

In recent years the increased amount of data quantum at a very higher rate has increased our data sizes to 90 percent. Hadoop vendors have increased in number due to high variety, speed and volume in data. This has resulted into increased demand of Big-Data technologies. Cloud and ventures are at their best competition these days. There are 4 core components of the free source big data tools, viz. HDFS, YARN, Common and MapReduce.

Following are the recent upgrades in the vendor circulations:

- Technical solution support which simplify solutions for users at vendor levels
- Further, extra add-on instruments to customize their apps for users are also provided.
- Also, they are proven to be consistent for response to patches, fixes and bug detection.

I. Need for commercial Hadoop Vendors:

As we know, not all big-data platforms are suitable for small data requirements, Apache Hadoop is also going through a constantly improvement stage. Further, to avoid such problem Organizations are developing following distributed Systems:

a. **Support**: They are providing assistance and technical guidance to facilitate the smoother adaptation of their systems

b. **Completeness**: They also provide customizing options to fulfill user specific requirements and provide additional tools and helps to achieve the same.

c. **Reliability**: To maintain the customer centricity, the bug related problems are quickly solved by Hadoop Vendors for reliable resources to users

II. Hadoop Vendors Market Share:

To fulfil the user specific tasks, Hadoop suppliers' partner with other distributions and provide additional tools.

With a compound annual growth rate (CAGR) of 10.48%, Worldwide Big Data software and services market revenues are projected to increase from USD 42B in 2018 to USD 103B in 2027. Including this, Wikibon also estimated that the global big data market is growing at 11.4% CAGR between 2017 and 2027, from USD 34.33B to USD 103B.

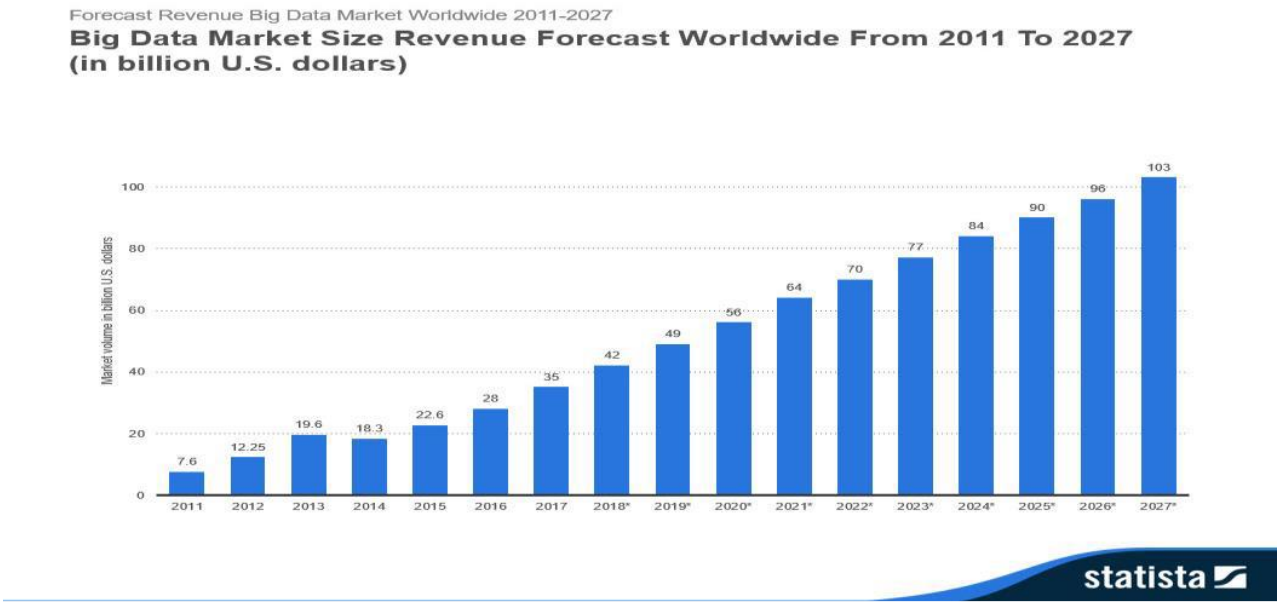


Image source: Wikibon and reported by Statista.

The market share is generally known as the width of the sector. As the earliest Hadoop distributor, Closure has the largest user base and a higher market share, as shown in below figure. The highlighted companies are active and leading supplier on the Hadoop Market.

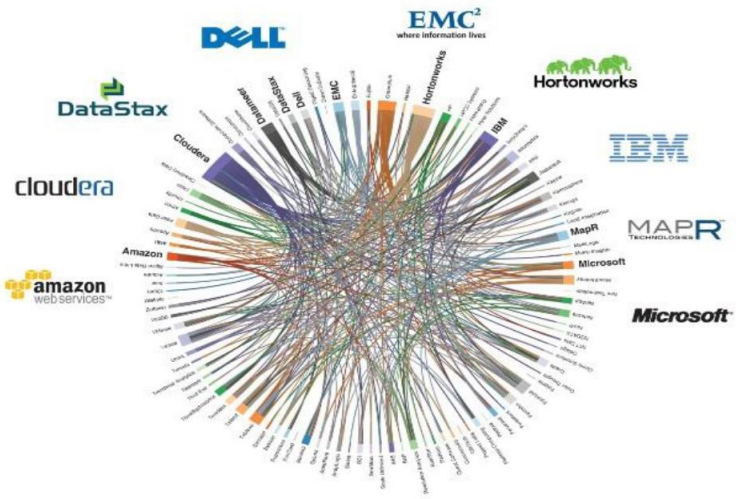


Image Source: randomramblings.postach.io

Following are the top 6 vendors offering the Big Data Hadoop Solutions:

a. **Cloudera:** This is the top company amongst the big-data vendors to make Hadoop a reliable data platform for big-data. It has around 350+ customers including US Army, All State and Monsanto. It captures around 53 percent of market shares.

b. **Amazon Web Services Elastic MapReduce Distribution:** AWS is been active since Hadoop's earliest days. It loads a simple to use data analysis stand built on an influential structural design of HDFS.

c. **Microsoft Hadoop Distributions:** It is not a free foundation software provider being a Big-Data vendor. Microsoft rather, offers it as a manufactured goods from a community cloud. It also provides a Polybase feature tha allows the user to track the data on SQL server during query execution.

d. **HortonWorks:** The USP of this organization is that it promises an open source distribution of 100 percent. It also acquires the companies that meets company gaps and contribute to Apache Community codes.

e. **IBM InfoSphere Insights**: It combines key data management parts and analytics assets into an open source distribution. It has also launched a ML package known as Apache System Machine Learning. It enables customers to market their apps into advance integration of Big Data analytics in a very rapid manner.

f. **MapR**: It was mainly developed for low effort and high potential implementation of Hadoop systems. MapR belongs to MapR Technologies linchpin, the HDFS API inherits MapR filesystem, and it can save trillions of files. It delivers largest cluster implementation than any other present vendor.

5. Cloudera Hadoop Distribution

Including Apache Hadoop, Cloudera distribution also provides an analytics platform and the latest open-source technologies to their store, discover, process, model and serve large amounts of data. Cloudera has created a functionally advanced system by integrating Hadoop with more than a dozen other critical open source projects. It helps in better performance of end-to-end Big Data workflows. It further, endures that all independent ecosystems such as Hive, Pig etc co-exist as independent clusters & are provided to consumers as Cloudera Hadoop Distribution (CDH). It also provides commercial support for their own versions of Hadoop.

Till the year 2017, Cloudera was a proven leading Hadoop distribution vendor with 55% of market share while HortonWorks has only 16%. In around October 2018, the two open source and commercial license software distribution companies announced an all stock merger of equals.

Vial following bundles of packages, Cloudera successfully provides on-premise as well as on cloud services:

a. **Cloudera Enterprise Data Hub:** Its comprehensive data management platforms including all the Data Science and Engineering, Operational DB, Analytic DB, and Cloudera Essentials Platform.
b. **Cloudera Analytics DB:** This bundle provides fast, flexible, and scalable Business Intelligence (BI) and SQL analytics built on the core Cloudera Essentials Platform.
c. **Cloudera Data Science and Engineering:** This bundle allows high speed data processing with high efficiency. It also allows Data Science and Machine Learning applications possible on top of the Core Essentials platform.
d. **Cloudera Essentials:** It is the platform for fast, easy and secure large-scale data processing that include Cloudera's enterprise ready management capabilities know as Cloudera Manger and open source platform distribution (CDH).

I. Overview of CDH:

The CDH counts under the most complete, tested and popular distribution of Apache Hadoop and related projects that are responsible to deliver the core elements of Hadoop- scalable storage and distributed computing – along with a web-based user interaction and vital enterprise capabilities. CDH is the only Hadoop solution to offer unified batch processing with Apache license. It also includes interactive SQL and interactive search, and role-based access controls.

It further provides following key advantages:

a. **Integration**: It gets up and run quickly on a complete Hadoop Platform that works with a broad range of hardware and software solutions.

b. **Scalability**: It also enables a broad range of application and extends them to suit user requirements.

c. **Flexibility**: CDH allows us to store any type of data and manipulate it with a variety of different computation frameworks including batch processing, interactive SQL, free text search, machine learning and statistical computation.

d. **Security**: It is good at processing sensitive data.

e. **Compatibility**: CDH allows user to leverage their IT infrastructures and investment.

f. **High availability**: It performs critical business tasks with enough required confidence.

CDH integrates Apache Hadoop with critical open source projects and creates a functionally advances system that helps perform end-to-end Big Data workflows. It also meets all the enterprise demands with its 100% open source distribution over Hadoop Framework. Following figure shows the core components of CDH including Spark, MapReduce etc.

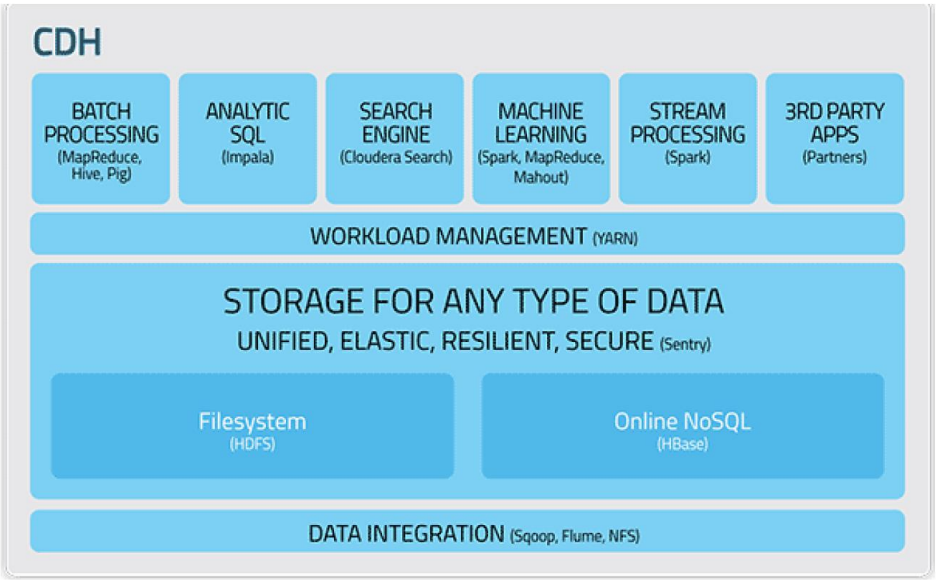


Figure 6.1. (a): CDH and its Components (source: Cloudera.com)

6. MapR Distribution

MapR provides a fast performing a user friendly interface. It's technology work on public cloud computing services and runs on board commodity hardware.

Further, limitations of Hadoop are addressed by underlying data platform with no Java dependencies or reliance on Linux file system. It's dynamic read-write data layer brings unprecedented ease of use dependability and high speed to NoSQL, Hadoop database and streaming applications in one converged big data platform. The converged data platform of MapR provides distinct capabilities for data protection business continuity and management. It further allows direct processing of tables, files an event stream. Also, the main reason behind the development of MapR was to converge Hadoop which part web scale storage no SQL into one unified cluster. Ask for the consumers and gates it has the ability to leverage multiple data types. it is achieved by implementation of a hybrid approach towards using a mixture of data source for data storage known as “Polyglot Persistence”.

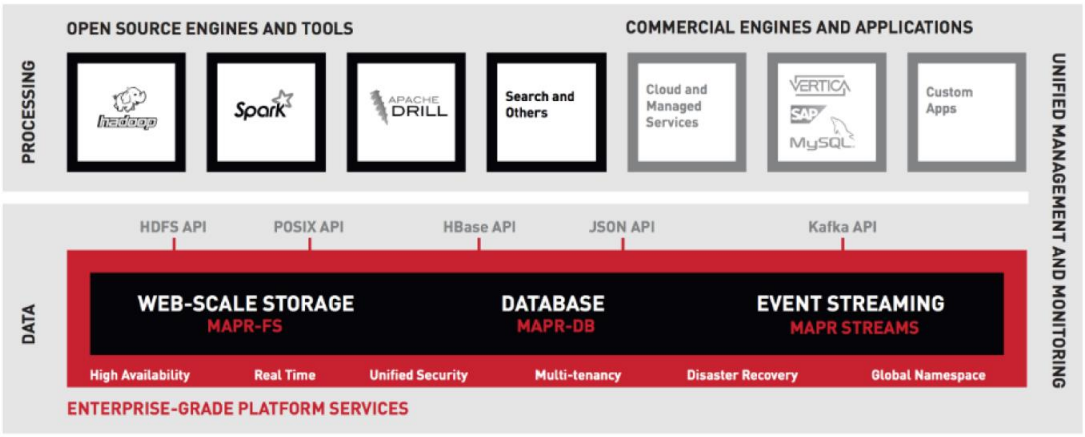


Figure 7 (a): The MapR Converged Data Platform ***(Source:*** *MapR Technologies**)***

MapR Allows the user to avoid the cost an error of resource allocation separate management framework and security models by running analytical workloads (working on Analytical Data) in the same cluster big operational workloads (working on historical data).

a. **Web scale storage**: It is a file system with full read write semantics, which can scale to exabytes of data and trillions of files in a single cluster.
b. **Event streaming:** this is a publish-subscribe. It allows for reliable delivering orders message at high volumes and velocity by event stream transport engine.
c. **NoSQL Database:** It is a multi-model NoSQL database that contains white column data models with high performance strong consistency consistent low latency, multi master replication, granular security, and completely automatic self-tuning. It also natively supports JSON documents.

7. HortonWorks Data Platform

It is 100% open source Hadoop distribution platform founded in 2011. It provides have a massively scalable open source platform for storing, pricing, and analyzing large volume of multi-source data. Which is powered by Apache Hadoop. It also provides a data platform for multi workload data processing across an area of processing methods because of YARN placed at the center of its architecture. A new metadata system, known as HCatalog allows Hive and Pig to work together easily by sharing schemas. It also includes Hadoop Distributed File System (HDFS), Pig, Hive, HBase, Zookeeper and few other components.

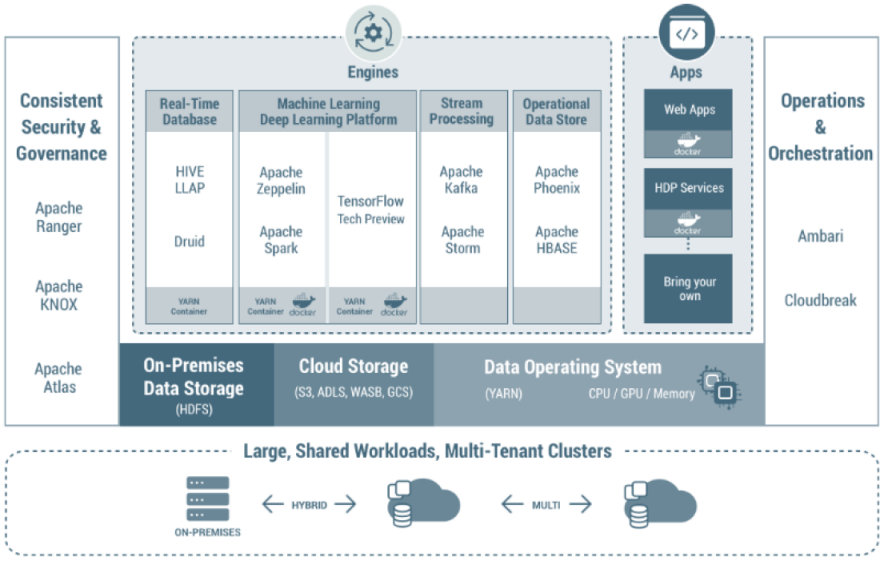
Following are the key capabilities of this platform:

a. **Erasure Coding:** It eliminates the need to store 3 full copies of each piece of data across clustering allows more efficient data replication. this is how it offers data protection method known as Erasure Coding

b. **GPU Pooling and Isolation**: This feature enables force class resource type in Hadoop which makes smoother running of machine learning and deep learning algorithms for customers.

c. **Containerization**: This feature is ensured via YARN support for docker containers. It allows start party application to run on Apache Hadoop. It also reduces the deployment time.

d. **NameNode federation:** This feature allows cluster to continue the operation even if one node goes down since it supports multiple standby NameNodes. This largely helps in Disaster recovery.



References:

https://www.geeksforgeeks.org/hadoop-history-or-evolution/

https://hadoop.apache.org/docs/current/hadoop-project-dist/hadoop-hdfs/HdfsDesign.html

https://www.guru99.com/introduction-to-mapreduce.html

https://hortonworks.com/products/data-platforms/hdp/

https://hortonworks.com/datasheet/hortonworks-data-platform-3-0-datasheet/

https://www.cloudera.com/documentation/enterprise/5-9-x/topics/cdh_intro.html

https://intellipaat.com/blog/top-6-hadoop-vendors-providing-big-data-solutions-in-open-data-platform/

https://www.tutorialspoint.com/apache_pig/apache_pig_architecture.html

https://mapr.com/datasheets/mapr-converged-data-platform/

Ashish Thusoo, J. S. (2010). Hive – A Petabyte Scale Data Warehouse Using. IEEE, 10.

Apache Hive Architecture & Components BY DATAFLAIR TEAM · PUBLISHED SEPTEMBER 2, 2017 · UPDATED NOVEMBER 17, 2018

https://www.wisdomjobs.com/e-university/hadoop-tutorial-484/a-brief-history-of-hadoop-14745.html/

https://opensource.com/life/14/8/intro-apache-hadoop-big-data

https://www.mssqltips.com/sqlservertip/3140/big-data-basics--part-3--overview-of-hadoop/

https://www.tutorialscampus.com/tutorials/hadoop/characteristics.htm

https://www.edureka.co/blog/5-reasons-when-to-use-and-not-to-use-hadoop/