What is Big Data

Data which are very large in size is called Big Data. Normally we work on data of size MB(WordDoc ,Excel) or maximum GB(Movies, Codes) but data in Peta bytes i.e. 10^15 byte size is called Big Data. It is stated that almost 90% of today's data has been generated in the past 3 years.

Sources of Big Data

These data come from many sources like

- **Social networking sites:** Facebook, Google, LinkedIn all these sites generates huge amount of data on a day to day basis as they have billions of users worldwide.
- **E-commerce site:** Sites like Amazon, Flipkart, Alibaba generates huge amount of logs from which users buying trends can be traced.
- **Weather Station:** All the weather station and satellite gives very huge data which are stored and manipulated to forecast weather.
- **Telecom company:** Telecom giants like Airtel, Vodafone study the user trends and accordingly publish their plans and for this they store the data of its million users.
- **Share Market:** Stock exchange across the world generates huge amount of data through its daily transaction.

3V's of Big Data

1. **Velocity:** The data is increasing at a very fast rate. It is estimated that the volume of data will double in every 2 years.
2. **Variety:** Now a days data are not stored in rows and column. Data is structured as well as unstructured. Log file, CCTV footage is unstructured data. Data which can be saved in tables are structured data like the transaction data of the bank.
3. **Volume:** The amount of data which we deal with is of very large size of Peta bytes.

Use case

An e-commerce site XYZ (having 100 million users) wants to offer a gift voucher of 100$ to its top 10 customers who have spent the most in the previous year.Moreover, they want to find the buying trend of these customers so that company can suggest more items related to them.

Issues

Huge amount of unstructured data which needs to be stored, processed and analyzed.

Solution

Storage: This huge amount of data, Hadoop uses HDFS (Hadoop Distributed File System) which uses commodity hardware to form clusters and store data in a distributed fashion. It works on Write once, read many times principle.

Processing: Map Reduce paradigm is applied to data distributed over network to find the required output.

Analyze: Pig, Hive can be used to analyze the data.

Cost: Hadoop is open source so the cost is no more an issue.

What is Hadoop

Hadoop is an open source framework from Apache and is used to store process and analyze data which are very huge in volume. Hadoop is written in Java and is not OLAP (online analytical processing). It is used for batch/offline processing.It is being used by Facebook, Yahoo, Google, Twitter, LinkedIn and many more. Moreover it can be scaled up just by adding nodes in the cluster.

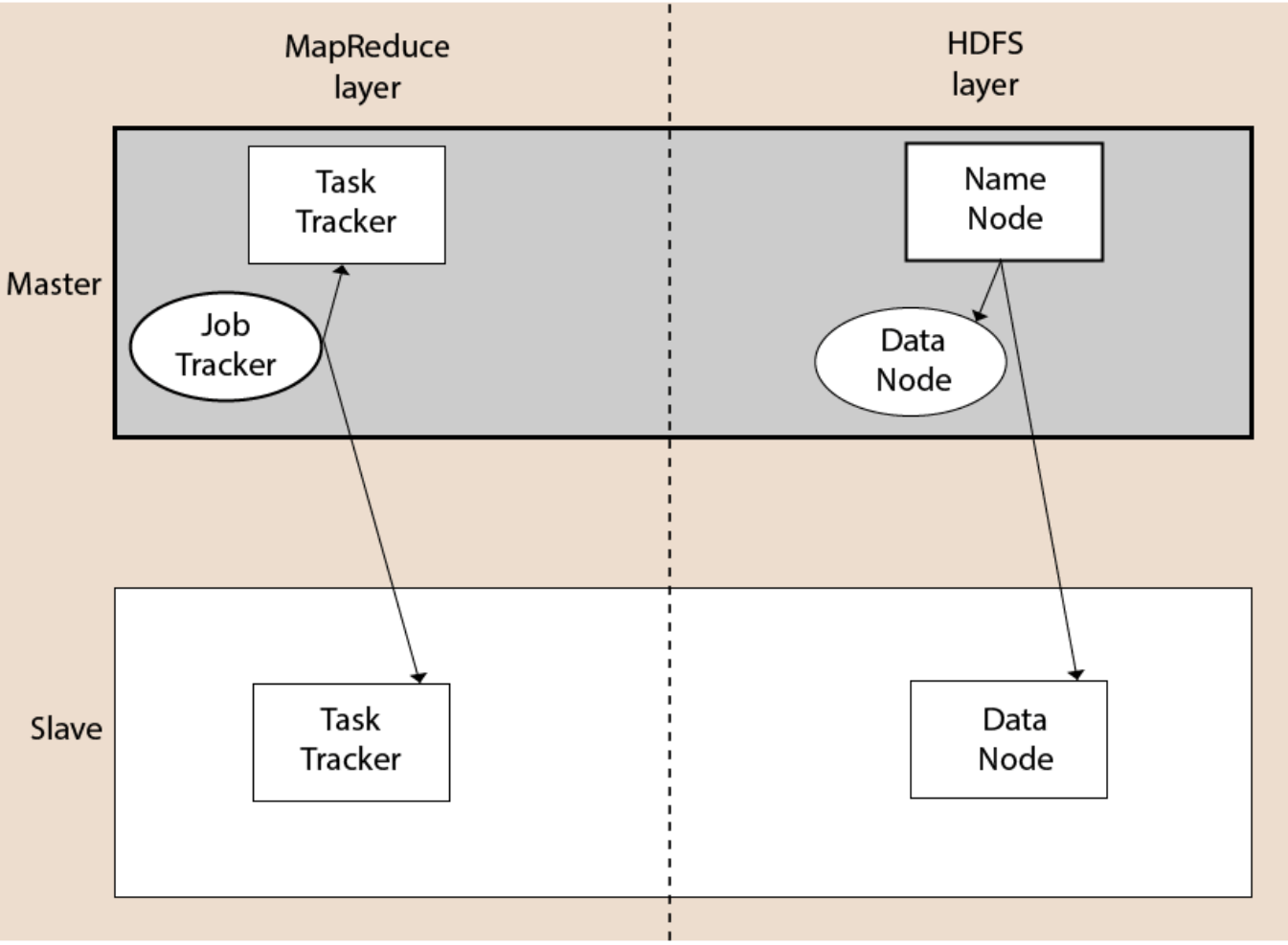
Modules of Hadoop

1. **HDFS:** Hadoop Distributed File System. Google published its paper GFS and on the basis of that HDFS was developed. It states that the files will be broken into blocks and stored in nodes over the distributed architecture.
2. **Yarn:** Yet another Resource Negotiator is used for job scheduling and manage the cluster.
3. **Map Reduce:** This is a framework which helps Java programs to do the parallel computation on data using key value pair. The Map task takes input data and converts it into a data set which can be computed in Key value pair. The output of Map task is consumed by reduce task and then the out of reducer gives the desired result.
4. **Hadoop Common:** These Java libraries are used to start Hadoop and are used by other Hadoop modules.

Hadoop Architecture

The Hadoop architecture is a package of the file system, MapReduce engine and the HDFS (Hadoop Distributed File System). The MapReduce engine can be MapReduce/MR1 or YARN/MR2.

A Hadoop cluster consists of a single master and multiple slave nodes. The master node includes Job Tracker, Task Tracker, NameNode, and DataNode whereas the slave node includes DataNode and TaskTracker.



Hadoop Distributed File System

The Hadoop Distributed File System (HDFS) is a distributed file system for Hadoop. It contains a master/slave architecture. This architecture consist of a single NameNode performs the role of master, and multiple DataNodes performs the role of a slave.

Both NameNode and DataNode are capable enough to run on commodity machines. The Java language is used to develop HDFS. So any machine that supports Java language can easily run the NameNode and DataNode software.

NameNode

- It is a single master server exist in the HDFS cluster.
- As it is a single node, it may become the reason of single point failure.

- It manages the file system namespace by executing an operation like the opening, renaming and closing the files.
- It simplifies the architecture of the system.

DataNode

- The HDFS cluster contains multiple DataNodes.
- Each DataNode contains multiple data blocks.
- These data blocks are used to store data.
- It is the responsibility of DataNode to read and write requests from the file system's clients.
- It performs block creation, deletion, and replication upon instruction from the NameNode.

Job Tracker

- The role of Job Tracker is to accept the MapReduce jobs from client and process the data by using NameNode.
- In response, NameNode provides metadata to Job Tracker.

Task Tracker

- It works as a slave node for Job Tracker.
- It receives task and code from Job Tracker and applies that code on the file. This process can also be called as a Mapper.

MapReduce Layer

The MapReduce comes into existence when the client application submits the MapReduce job to Job Tracker. In response, the Job Tracker sends the request to the appropriate Task Trackers. Sometimes, the TaskTracker fails or time out. In such a case, that part of the job is rescheduled.

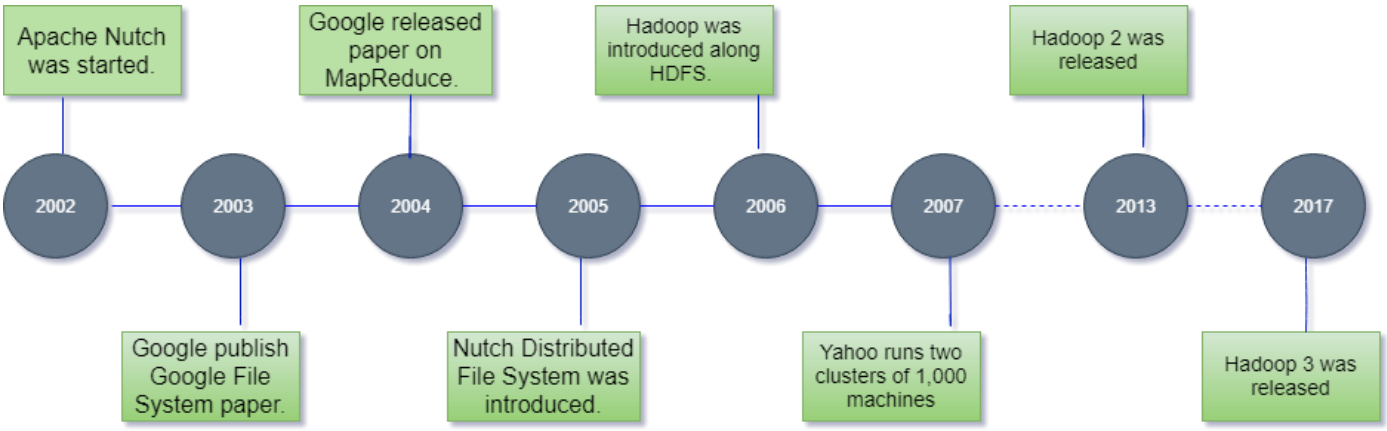
Advantages of Hadoop

- **Fast:** In HDFS the data distributed over the cluster and are mapped which helps in faster retrieval. Even the tools to process the data are often on the same servers, thus reducing the processing time. It is able to process terabytes of data in minutes and Peta bytes in hours.
- **Scalable:** Hadoop cluster can be extended by just adding nodes in the cluster.

- **Cost Effective:** Hadoop is open source and uses commodity hardware to store data so it really cost effective as compared to traditional relational database management system.
- **Resilient to failure:** HDFS has the property with which it can replicate data over the network, so if one node is down or some other network failure happens, then Hadoop takes the other copy of data and use it. Normally, data are replicated thrice but the replication factor is configurable.

History of Hadoop

The Hadoop was started by Doug Cutting and Mike Cafarella in 2002. Its origin was the Google File System paper, published by Google.



Let's focus on the history of Hadoop in the following steps: -

- In 2002, Doug Cutting and Mike Cafarella started to work on a project, **Apache Nutch.** It is an open source web crawler software project.
- While working on Apache Nutch, they were dealing with big data. To store that data they have to spend a lot of costs which becomes the consequence of that project. This problem becomes one of the important reason for the emergence of Hadoop.
- In 2003, Google introduced a file system known as GFS (Google file system). It is a proprietary distributed file system developed to provide efficient access to data.
- In 2004, Google released a white paper on Map Reduce. This technique simplifies the data processing on large clusters.
- In 2005, Doug Cutting and Mike Cafarella introduced a new file system known as NDFS (Nutch Distributed File System). This file system also includes Map reduce.
- In 2006, Doug Cutting quit Google and joined Yahoo. On the basis of the Nutch project, Dough Cutting introduces a new project Hadoop with a file system known as

HDFS (Hadoop Distributed File System). Hadoop first version 0.1.0 released in this year.

- Doug Cutting gave named his project Hadoop after his son's toy elephant.
- In 2007, Yahoo runs two clusters of 1000 machines.
- In 2008, Hadoop became the fastest system to sort 1 terabyte of data on a 900 node cluster within 209 seconds.
- In 2013, Hadoop 2.2 was released.
- In 2017, Hadoop 3.0 was released.

Hadoop Modules

What is HDFS

Hadoop comes with a distributed file system called HDFS. In HDFS data is distributed over several machines and replicated to ensure their durability to failure and high availability to parallel application.

It is cost effective as it uses commodity hardware. It involves the concept of blocks, data nodes and node name.

Where to use HDFS

- **Very Large Files:** Files should be of hundreds of megabytes, gigabytes or more.
- **Streaming Data Access:** The time to read whole data set is more important than latency in reading the first. HDFS is built on write-once and read-many-times pattern.
- **Commodity Hardware:**It works on low cost hardware.

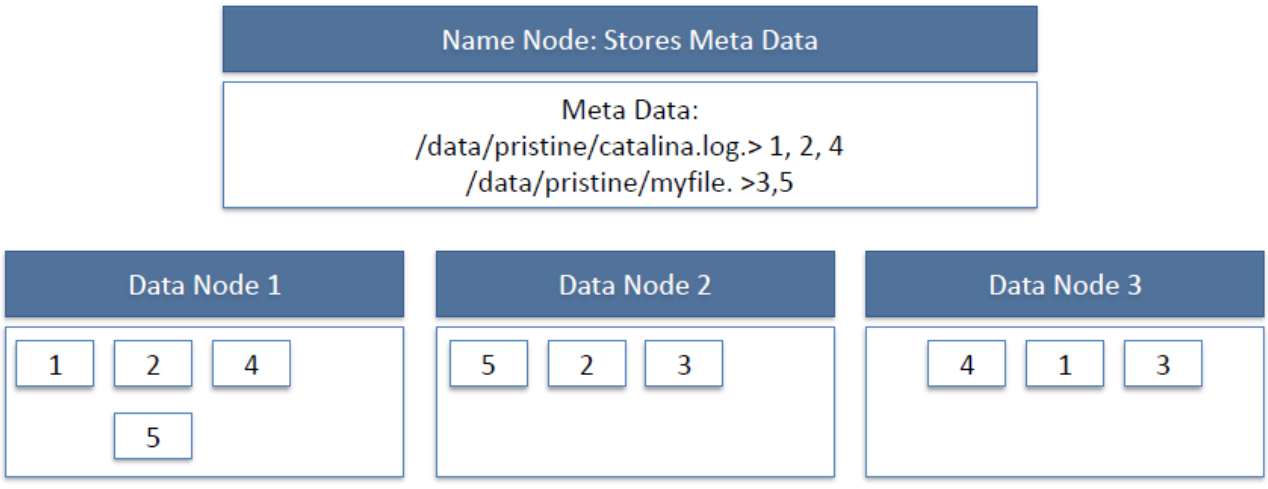
Where not to use HDFS

- **Low Latency data access:** Applications that require very less time to access the first data should not use HDFS as it is giving importance to whole data rather than time to fetch the first record.
- **Lots Of Small Files:**The name node contains the metadata of files in memory and if the files are small in size it takes a lot of memory for name node's memory which is not feasible.
- **Multiple Writes:**It should not be used when we have to write multiple times.

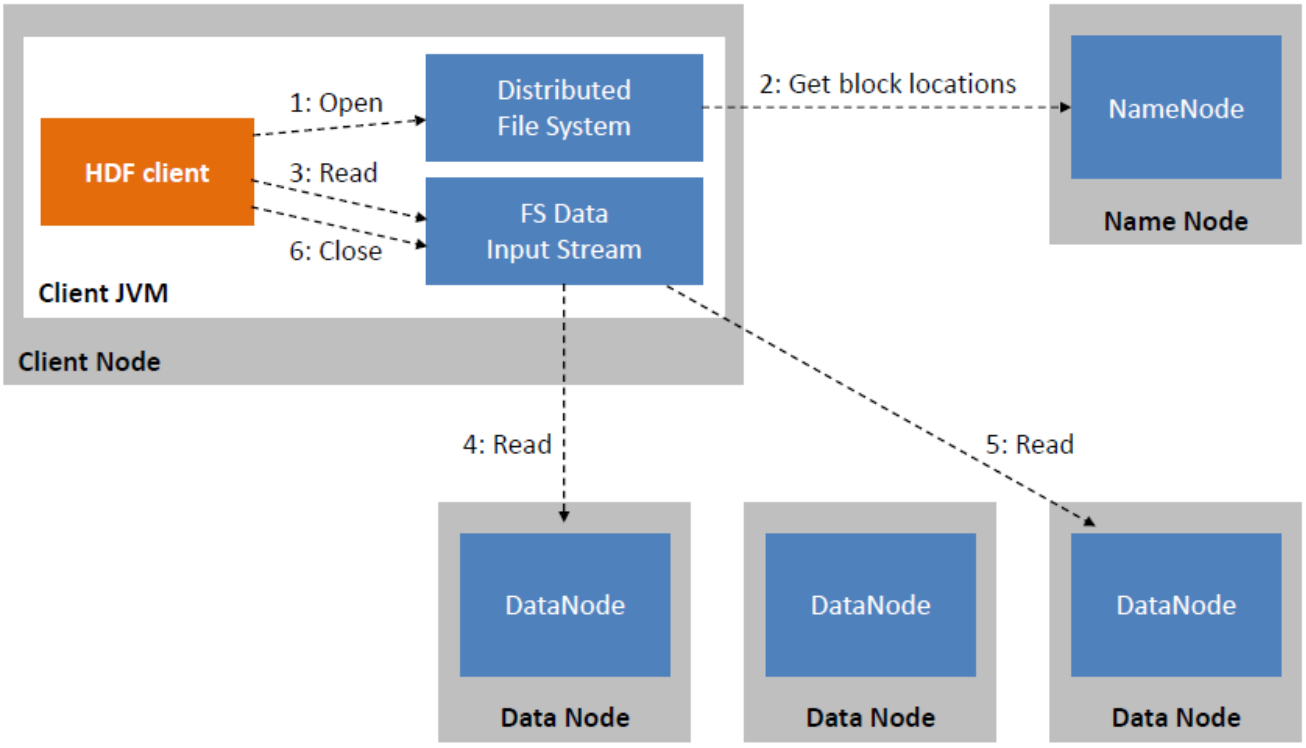
HDFS Concepts

1. **Blocks:** A Block is the minimum amount of data that it can read or write.HDFS blocks are 128 MB by default and this is configurable.Files n HDFS are broken into block-sized chunks,which are stored as independent units.Unlike a file system, if the file is in HDFS is smaller than block size, then it does not occupy full block?s size, i.e. 5 MB of file stored in HDFS of block size 128 MB takes 5MB of space only.The HDFS block size is large just to minimize the cost of seek.
2. **Name Node:** HDFS works in master-worker pattern where the name node acts as master.Name Node is controller and manager of HDFS as it knows the status and the metadata of all the files in HDFS; the metadata information being file permission, names and location of each block.The metadata are small, so it is stored in the memory of name node,allowing faster access to data. Moreover the HDFS cluster is accessed by multiple clients concurrently,so all this information is handled bya single machine. The file system operations like opening, closing, renaming etc. are executed by it.
3. **Data Node:** They store and retrieve blocks when they are told to; by client or name node. They report back to name node periodically, with list of blocks that they are storing. The data node being a commodity hardware also does the work of block creation, deletion and replication as stated by the name node.

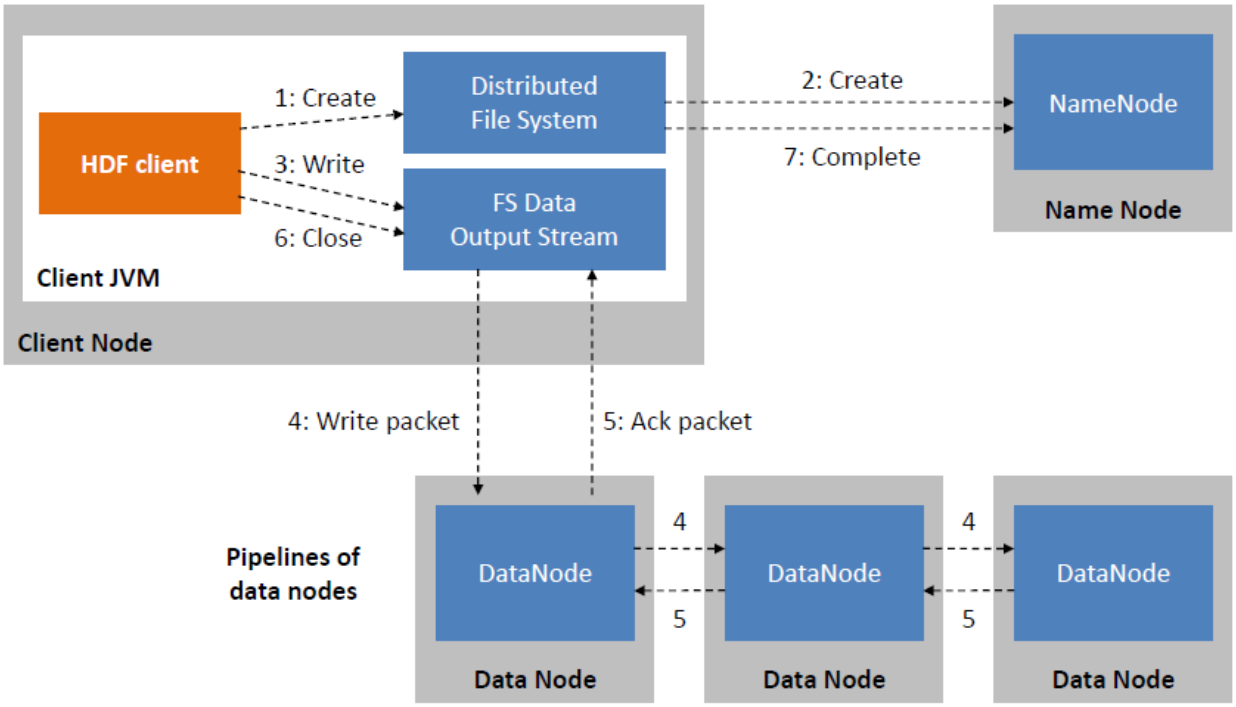
HDFS DataNode and NameNode Image:



HDFS Read Image:



HDFS Write Image:



Since all the metadata is stored in name node, it is very important. If it fails the file system can not be used as there would be no way of knowing how to reconstruct the files from blocks present in data node. To overcome this, the concept of secondary name node arises.

Secondary Name Node: It is a separate physical machine which acts as a helper of name node. It performs periodic check points.It communicates with the name node and take snapshot of meta data which helps minimize downtime and loss of data.

Starting HDFS

The HDFS should be formatted initially and then started in the distributed mode. Commands are given below.

To Format **$ hadoop namenode -format**

To Start **$ start-dfs.sh**

HDFS Basic File Operations

1. Putting data to HDFS from local file system
    - First create a folder in HDFS where data can be put form local file system.

      $ hadoop fs -mkdir /user/test

    - Copy the file "data.txt" from a file kept in local folder /usr/home/Desktop to HDFS folder /user/ test

      $ hadoop fs -copyFromLocal /usr/home/Desktop/data.txt /user/test

    - Display the content of HDFS folder

      $ Hadoop fs -ls /user/test

2. Copying data from HDFS to local file system
    - $ hadoop fs -copyToLocal /user/test/data.txt /usr/bin/data_copy.txt
3. Compare the files and see that both are same
    - $ md5 /usr/bin/data_copy.txt /usr/home/Desktop/data.txt

   Recursive deleting

    - hadoop fs -rmr <arg>

   Example:

- hadoop fs -rmr /user/sonoo/

HDFS Other commands

The below is used in the commands

"<path>" means any file or directory name.

"<path>..." means one or more file or directory names.

"<file>" means any filename.

"<src>" and "<dest>" are path names in a directed operation.

"<localSrc>" and "<localDest>" are paths as above, but on the local file system

- put <localSrc><dest>

  Copies the file or directory from the local file system identified by localSrc to dest within the DFS.

- copyFromLocal <localSrc><dest>

  Identical to -put

- copyFromLocal <localSrc><dest>

  Identical to -put

- moveFromLocal <localSrc><dest>

  Copies the file or directory from the local file system identified by localSrc to dest within HDFS, and then deletes the local copy on success.

- get [-crc] <src><localDest>

  Copies the file or directory in HDFS identified by src to the local file system path identified by localDest.

- cat <filen-ame>

  Displays the contents of filename on stdout.

- moveToLocal <src><localDest>

  Works like -get, but deletes the HDFS copy on success.

- setrep [-R] [-w] rep <path>

  Sets the target replication factor for files identified by path to rep. (The actual replication factor will move toward the target over time)

- touchz <path>

  Creates a file at path containing the current time as a timestamp. Fails if a file already exists at path, unless the file is already size 0.

- test -[ezd] <path>

  Returns 1 if path exists; has zero length; or is a directory or 0 otherwise.

- stat [format] <path>

  Prints information about path. Format is a string which accepts file size in blocks (%b), filename (%n), block size (%o), replication (%r), and modification date (%y, %Y).

HDFS Features and Goals

The Hadoop Distributed File System (HDFS) is a distributed file system. It is a core part of Hadoop which is used for data storage. It is designed to run on commodity hardware.

Unlike other distributed file system, HDFS is highly fault-tolerant and can be deployed on low-cost hardware. It can easily handle the application that contains large data sets.

Let's see some of the important features and goals of HDFS.

Features of HDFS

- **Highly Scalable -** HDFS is highly scalable as it can scale hundreds of nodes in a single cluster.
- **Replication -** Due to some unfavorable conditions, the node containing the data may be loss. So, to overcome such problems, HDFS always maintains the copy of data on a different machine.
- **Fault tolerance -** In HDFS, the fault tolerance signifies the robustness of the system in the event of failure. The HDFS is highly fault-tolerant that if any machine fails, the other machine containing the copy of that data automatically become active.

- **Distributed data storage -** This is one of the most important features of HDFS that makes Hadoop very powerful. Here, data is divided into multiple blocks and stored into nodes.
- **Portable -** HDFS is designed in such a way that it can easily portable from platform to another.

Goals of HDFS

- **Handling the hardware failure -** The HDFS contains multiple server machines. Anyhow, if any machine fails, the HDFS goal is to recover it quickly.
- **Streaming data access -** The HDFS applications usually run on the general-purpose file system. This application requires streaming access to their data sets.
- **Coherence Model -** The application that runs on HDFS require to follow the write-once-ready-many approach. So, a file once created need not to be changed. However, it can be appended and truncate.

What is YARN

Yet Another Resource Manager takes programming to the next level beyond Java , and makes it interactive to let another application Hbase, Spark etc. to work on it.Different Yarn applications can co-exist on the same cluster so MapReduce, Hbase, Spark all can run at the same time bringing great benefits for manageability and cluster utilization.

Components Of YARN

- **Client:** For submitting MapReduce jobs.
- **Resource Manager:** To manage the use of resources across the cluster
- **Node Manager:**For launching and monitoring the computer containers on machines in the cluster.
- **Map Reduce Application Master:** Checks tasks running the MapReduce job. The application master and the MapReduce tasks run in containers that are scheduled by the resource manager, and managed by the node managers.

Jobtracker & Tasktrackerwere were used in previous version of Hadoop, which were responsible for handling resources and checking progress management. However, Hadoop 2.0 has Resource manager and NodeManager to overcome the shortfall of Jobtracker & Tasktracker.

Benefits of YARN

- **Scalability:** Map Reduce 1 hits ascalability bottleneck at 4000 nodes and 40000 task, but Yarn is designed for 10,000 nodes and 1 lakh tasks.
- **Utiliazation:** Node Manager manages a pool of resources, rather than a fixed number of the designated slots thus increasing the utilization.
- **Multitenancy:** Different version of MapReduce can run on YARN, which makes the process of upgrading MapReduce more manageable.

Hadoop - MapReduce

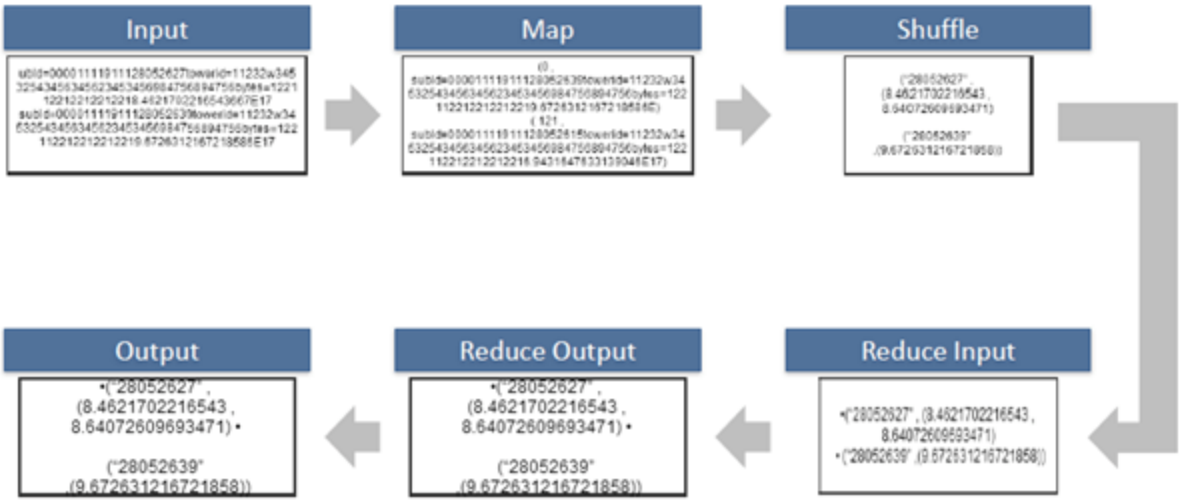
What is MapReduce?

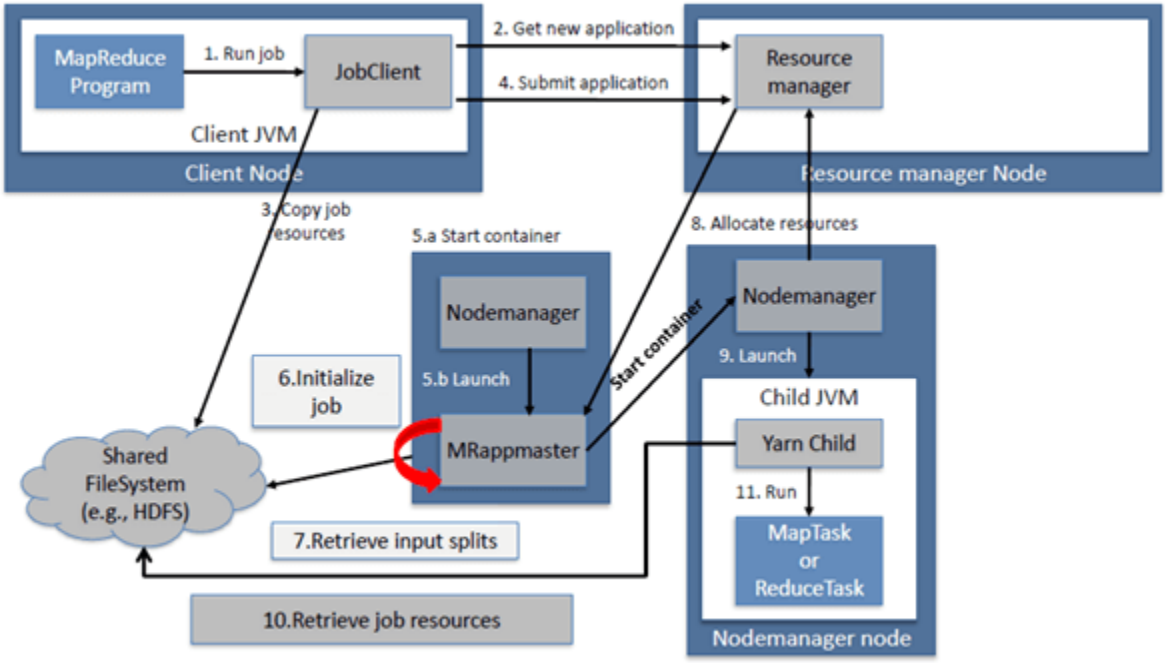
A MapReduce is a data processing tool which is used to process the data parallelly in a distributed form. It was developed in 2004, on the basis of paper titled as "MapReduce: Simplified Data Processing on Large Clusters," published by Google.

The MapReduce is a paradigm which has two phases, the mapper phase, and the reducer phase. In the Mapper, the input is given in the form of a key-value pair. The output of the Mapper is fed to the reducer as input. The reducer runs only after the Mapper is over. The reducer too takes input in key-value format, and the output of reducer is the final output.

Steps in Map Reduce

- The map takes data in the form of pairs and returns a list of <key, value> pairs. The keys will not be unique in this case.
- Using the output of Map, sort and shuffle are applied by the Hadoop architecture. This sort and shuffle acts on these list of <key, value> pairs and sends out unique keys and a list of values associated with this unique key <key, list(values)>.
- An output of sort and shuffle sent to the reducer phase. The reducer performs a defined function on a list of values for unique keys, and Final output <key, value> will be stored/displayed.





Sort and Shuffle

The sort and shuffle occur on the output of Mapper and before the reducer. When the Mapper task is complete, the results are sorted by key, partitioned if there are multiple reducers, and then written to disk. Using the input from each Mapper <k2,v2>, we collect

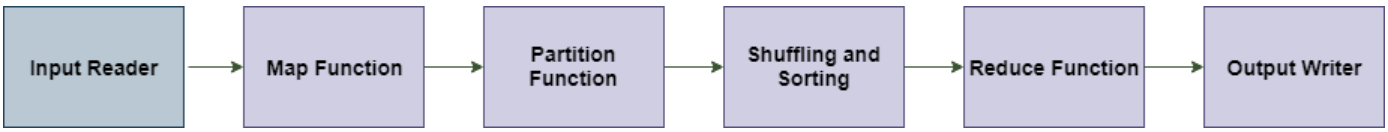
all the values for each unique key k2. This output from the shuffle phase in the form of <k2, list(v2)> is sent as input to reducer phase.

Usage of MapReduce

- It can be used in various application like document clustering, distributed sorting, and web link-graph reversal.
- It can be used for distributed pattern-based searching.
- We can also use MapReduce in machine learning.
- It was used by Google to regenerate Google's index of the World Wide Web.
- It can be used in multiple computing environments such as multi-cluster, multi-core, and mobile environment.

Data Flow In MapReduce

MapReduce is used to compute the huge amount of data . To handle the upcoming data in a parallel and distributed form, the data has to flow from various phases.



Phases of MapReduce data flow

Input reader

The input reader reads the upcoming data and splits it into the data blocks of the appropriate size (64 MB to 128 MB). Each data block is associated with a Map function.

Once input reads the data, it generates the corresponding key-value pairs. The input files reside in HDFS.

> *Note - The input data can be in any form.*

Map function

The map function process the upcoming key-value pairs and generated the corresponding output key-value pairs. The map input and output type may be different from each other.

Partition function

The partition function assigns the output of each Map function to the appropriate reducer. The available key and value provide this function. It returns the index of reducers.

Shuffling and Sorting

The data are shuffled between/within nodes so that it moves out from the map and get ready to process for reduce function. Sometimes, the shuffling of data can take much computation time.

The sorting operation is performed on input data for Reduce function. Here, the data is compared using comparison function and arranged in a sorted form.

Reduce function

The Reduce function is assigned to each unique key. These keys are already arranged in sorted order. The values associated with the keys can iterate the Reduce and generates the corresponding output.

Output writer

Once the data flow from all the above phases, Output writer executes. The role of Output writer is to write the Reduce output to the stable storage.

MapReduce API

In this section, we focus on MapReduce APIs. Here, we learn about the classes and methods used in MapReduce programming.

MapReduce Mapper Class

In MapReduce, the role of the Mapper class is to map the input key-value pairs to a set of intermediate key-value pairs. It transforms the input records into intermediate records.

These intermediate records associated with a given output key and passed to Reducer for the final output.

Methods of Mapper Class

void cleanup(Context context)	This method called only once at the end of the task.
void map(KEYIN key, VALUEIN value,	This method can be called only once for each key-

Context context)	value in the input split.
void run(Context context)	This method can be override to control the execution of the Mapper.
void setup(Context context)	This method called only once at the beginning of the task.

MapReduce Reducer Class

In MapReduce, the role of the Reducer class is to reduce the set of intermediate values. Its implementations can access the Configuration for the job via the JobContext.getConfiguration() method.

Methods of Reducer Class

void cleanup(Context context)	This method called only once at the end of the task.
void map(KEYIN key, Iterable<VALUEIN> values, Context context)	This method called only once for each key.
void run(Context context)	This method can be used to control the tasks of the Reducer.
void setup(Context context)	This method called only once at the beginning of the task.

MapReduce Job Class

The Job class is used to configure the job and submits it. It also controls the execution and query the state. Once the job is submitted, the set method throws IllegalStateException.

Methods of Job Class

Methods	Description
Counters getCounters()	This method is used to get the counters for the job.
long getFinishTime()	This method is used to get the finish time for the job.
Job getInstance()	This method is used to generate a new Job without any cluster.
Job getInstance(Configuration conf)	This method is used to generate a new Job without any cluster and provided configuration.
Job getInstance(Configuration conf, String jobName)	This method is used to generate a new Job without any cluster and provided configuration and job name.
String getJobFile()	This method is used to get the path of the submitted job configuration.
String getJobName()	This method is used to get the user-specified job name.
JobPriority getPriority()	This method is used to get the scheduling function of the job.
void setJarByClass(Class<?> c)	This method is used to set the jar by providing the class name with .class extension.
void setJobName(String name)	This method is used to set the user-specified job

	name.
void setMapOutputKeyClass(Class<?> class)	This method is used to set the key class for the map output data.
void setMapOutputValueClass(Class<?> class)	This method is used to set the value class for the map output data.
void setMapperClass(Class<? extends Mapper> class)	This method is used to set the Mapper for the job.
void setNumReduceTasks(int tasks)	This method is used to set the number of reduce tasks for the job
void setReducerClass(Class<? extends Reducer> class)	This method is used to set the Reducer for the job.