Department of Computer Engineering
Academic Term: July-November 2023

Rubrics for Lab Experiments

Class : B.E. Computer **Subject Name: *Distributed Computing***
Semester : VIII **Subject Code : *CSC801***

Practical No:	
Title:	
Date of Performance:	
Roll No:	
Name of the Student:	

Evaluation:

Performance Indicator	Below average	Average	Good	Excellent	Marks
On time Submission (2)	Not submitted(0)	Submitted after deadline (1)	Early or on time submission(2)	---	
Test cases and output (4)	Incorrect output (1)	The expected output is verified only a for few test cases (2)	The expected output is Verified for all test cases but is not presentable (3)	Expected output is obtained for all test cases. Presentable and easy to follow (4)	
Coding efficiency (2)	The code is not structured at all (0)	The code is structured but not efficient (1)	The code is structured and efficient. (2)	-	
Knowledge(2)	Basic concepts not clear (0)	Understood the basic concepts (1)	Could explain the concept with suitable example (1.5)	Could relate the theory with real world application(2)	
Total					

Signature of the Teacher :

Lab 10

Aim: To Study HDFS and MapReduce

Lab Outcome:

Describe the concepts of distributed File Systems with some case studies **Theory:**

<u>Hadoop:</u>

With growing data velocity, the data size easily outgrows the storage limit of a machine. A solution would be to store the data across a network of machines. Such filesystems are called *distributed filesystems*. Since data is stored across a network all the complications of a network come in.
This is where Hadoop comes in. It provides one of the most reliable filesystems. HDFS (Hadoop Distributed File System) is a unique design that provides storage for *extremely large files* with streaming data access pattern and it runs on *commodity hardware*.

Let's elaborate the terms:

- ***Extremely large files***: Here we are talking about the data in range of petabytes (1000 TB).
- ***Streaming Data Access Pattern***: HDFS is designed on principle of *write-once and read-many-times*. Once data is written large portions of dataset can be processed any number times.
- ***Commodity hardware:*** Hardware that is inexpensive and easily available in the market. This is one of feature which specially distinguishes HDFS from other file system.

Nodes: Master-slave nodes typically forms the HDFS cluster.

1. **NameNode(MasterNode):**
    - Manages all the slave nodes and assign work to them.
    - It executes filesystem namespace operations like opening, closing, renaming files and directories.
    - It should be deployed on reliable hardware which has the high config. not on commodity hardware.
2. **DataNode(SlaveNode):**
    - Actual worker nodes, who do the actual work like reading, writing, processing etc.
    - They also perform creation, deletion, and replication upon instruction from the master.
    - They can be deployed on commodity hardware.

HDFS daemons: Daemons are the processes running in background. • **Namenodes:**

• Run on the master node.

• Store metadata (data about data) like file path, the number of blocks, block Ids. etc.

• Require high amount of RAM.

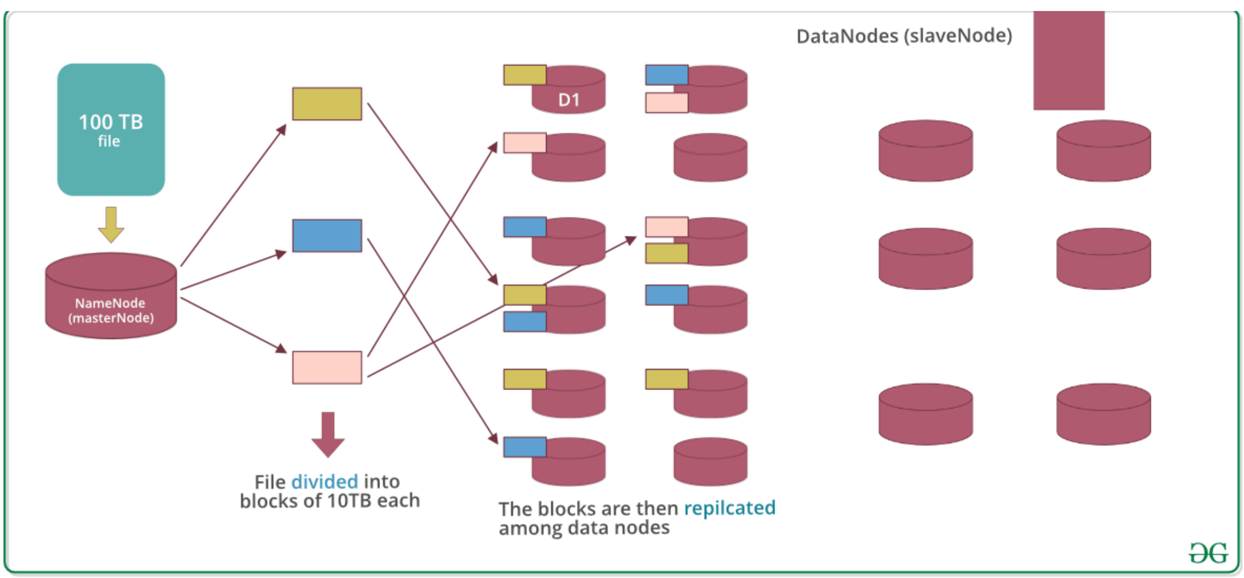
• Store meta-data in RAM for fast retrieval i.e to reduce seek time. Though a persistent copy of it is kept on disk.

• **DataNodes:**

• Run on slave nodes.

• Require high memory as data is actually stored here.

Data storage in HDFS: Now let us see how the data is stored in a distributed manner.



Assuming that 100TB file is inserted, then masternode(namenode) will first divide the file into blocks of 10TB (default size is 128 MB in Hadoop 2.x and above). Then these blocks are stored across different datanodes(slavenode). Datanodes(slavenode)replicate the blocks among themselves and the information of what blocks they contain is sent to the master. Default replication factor is 3 means for each block 3 replicas are created (including itself). In hdfs.site.xml we can increase or decrease the replication factor i.e we can edit its configuration here.

Terms related to HDFS: • HeartBeat: It is the signal that datanode continuously sends to namenode. If namenode doesn't receive heartbeat from a datanode then it will consider it dead. • Balancing: If a datanode is crashed the blocks present on it will be gone too and the blocks will be under-replicated compared to the remaining blocks. Here master node(namenode) will give a signal to datanodes containing replicas of those lost blocks to replicate so that overall distribution of blocks is balanced. • Replication: It is done by datanode.

Features: • Distributed data storage. • Blocks reduce seek time. • The data is highly available as the same block is present at multiple datanodes. • Even if multiple datanodes are down we can still do our work, thus making it highly reliable. • High fault tolerance. MapReduce: MapReduce is a framework using which we can write applications to process huge amounts of data, in parallel, on large clusters of commodity hardware in a reliable manner. MapReduce is a processing technique and a program model for distributed computing based on java. The MapReduce algorithm contains two important tasks, namely Map and Reduce. Map takes a set of data and converts it into another set of data, where individual elements are broken down into tuples (key/value pairs). Secondly, reduce task, which takes the output from a map as an input and combines those data tuples into a smaller set of tuples. As the sequence of the name MapReduce implies, the reduce task is always performed after the map job. MapReduce Architecture explained in detail: • One map task is created for each split which then executes map function for each record in the split.

• It is always beneficial to have multiple splits because the time taken to process a split is small as compared to the time taken for processing of the whole input. When the splits are smaller, the processing is better to load balanced since we are processing the splits in parallel. • However, it is also not desirable to have splits too small in size. When splits are too small, the overload of managing the splits and map task creation begins to dominate the total job execution time. • For most jobs, it is better to make a split size equal to the size of an HDFS block (which is 64 MB, by default). • Execution of map tasks results into writing output to a local disk on the respective node and not to HDFS. • Reason for choosing local disk over HDFS is, to avoid replication which takes place in case of HDFS store operation. • Map output is intermediate output which is processed by reduce tasks to produce the final output. • Once the job is complete, the map output can be thrown away. So, storing it in HDFS with replication becomes overkill. • In the event of node failure, before the map output is consumed by the reduce task, Hadoop reruns the map task on another node and re-creates the map output. • Reduce task doesn't work on the concept of data locality. An output of every map task is fed to the reduce task. Map output is transferred to the machine where reduce task is running. • On this machine, the output is merged and then passed to the user-defined reduce function. • Unlike the map output, reduce output is stored in HDFS (the first replica is stored on the local node and other replicas are stored on off-rack nodes). So, writing the reduce output How MapReduce Organizes Work? Hadoop divides the job into tasks. There are two types of tasks: • Map tasks (Splits & Mapping) • Reduce tasks (Shuffling, Reducing) The complete execution process (execution of Map and Reduce tasks, both) is controlled by two types of entities called a • Jobtracker: Acts like a master (responsible for complete execution of submitted job) • Multiple Task Trackers: Acts like slaves, each of them performing the job For every job submitted for execution in the system, there is one Jobtracker that resides on Namenode and there are multiple tasktrackers which reside on Datanode.

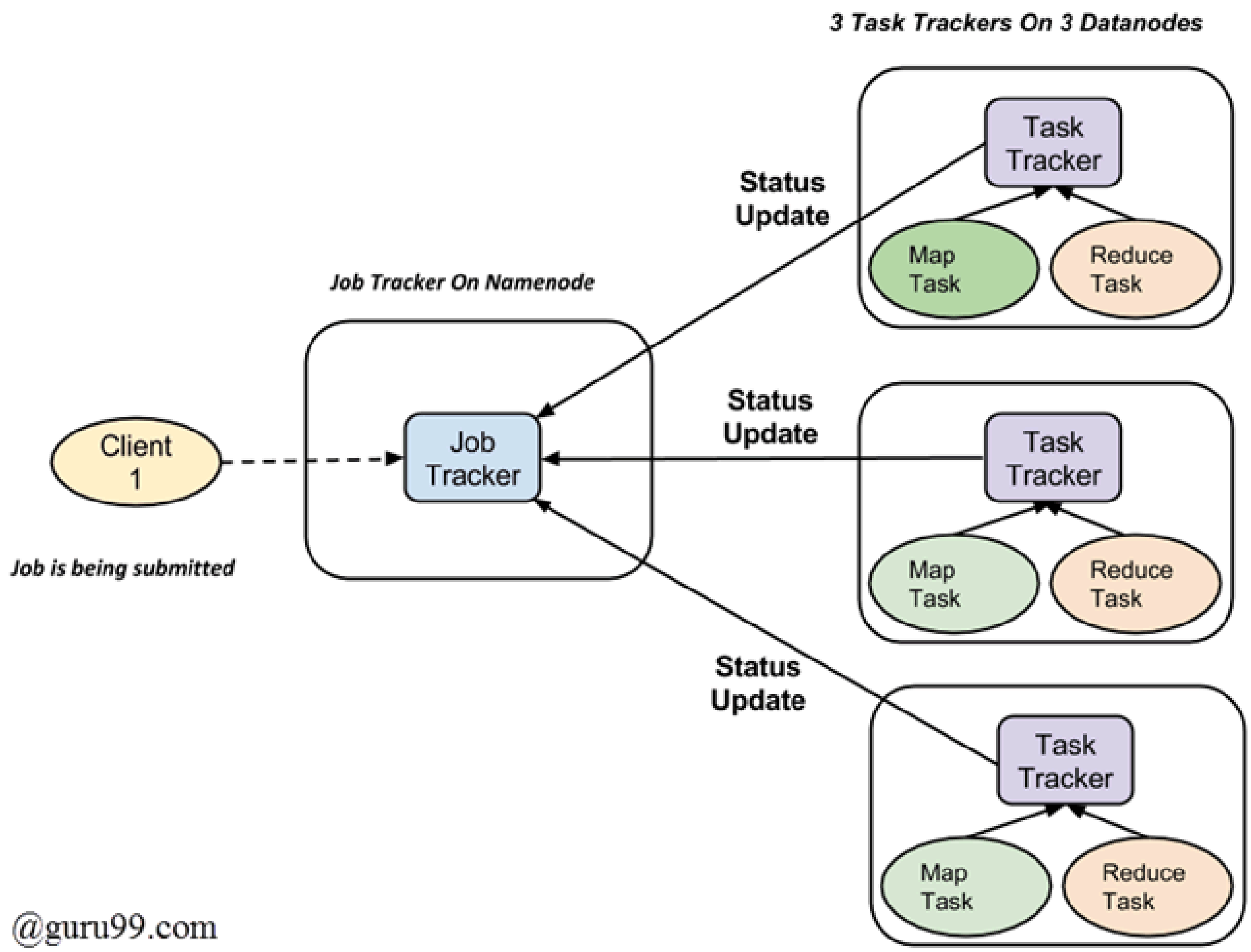


Fig. How Hadoop Mapreduce Works • A job is divided into multiple tasks which are then run onto multiple data nodes in a cluster. • It is the responsibility of job tracker to coordinate the activity by scheduling tasks to run on different data nodes. • Execution of individual task is then to look after by task tracker, which resides on every data node executing part of the job. • Task tracker's responsibility is to send the progress report to the job tracker. • In addition, task tracker periodically sends 'heartbeat' signal to the Jobtracker so as to notify him of the current state of the system. • Thus job tracker keeps track of the overall progress of each job. In the event of task failure, the job tracker can reschedule it on a different task tracker.

Implementation of Hadoop Cluster and HDFS:

To demonstrate the working and configuration of HDFS, a cluster consisting of 1 Master and 2 Slaves is configured. The machine nodes are independent AWS ec2 instances. For ease of operation a tool called MobaXterm is used for remote login (SSH) into the instances.

After successful configuration, the daemons are started in both master and slave nodes. Subsequently, our HDFS can be tested by storing files.

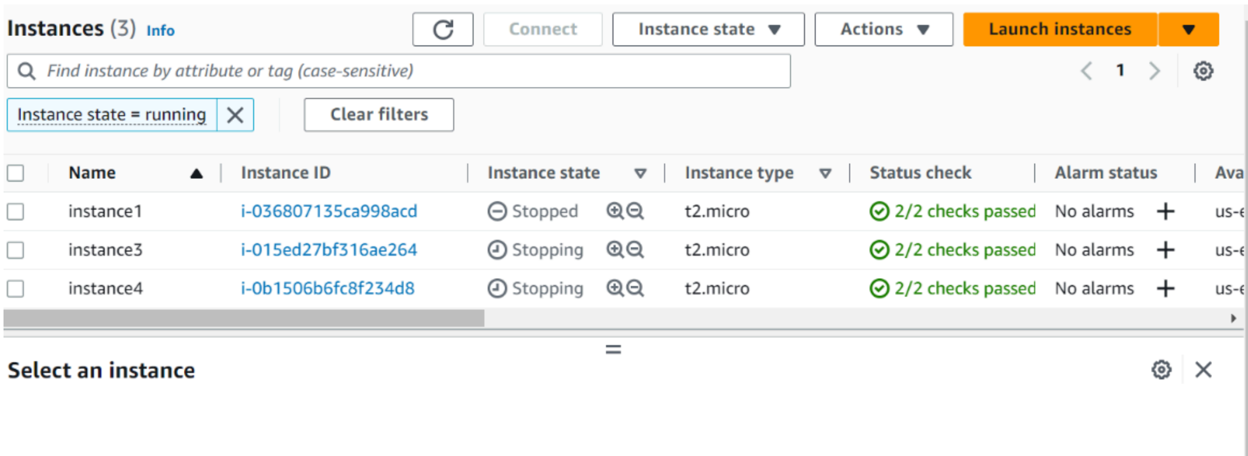
Step 1: Setting up Remote Machines

Three ec2 instances having Ubuntu as local OS were created using AWS Free Tier account.

Instance1 -> Master Private IP: 172.31.87.194

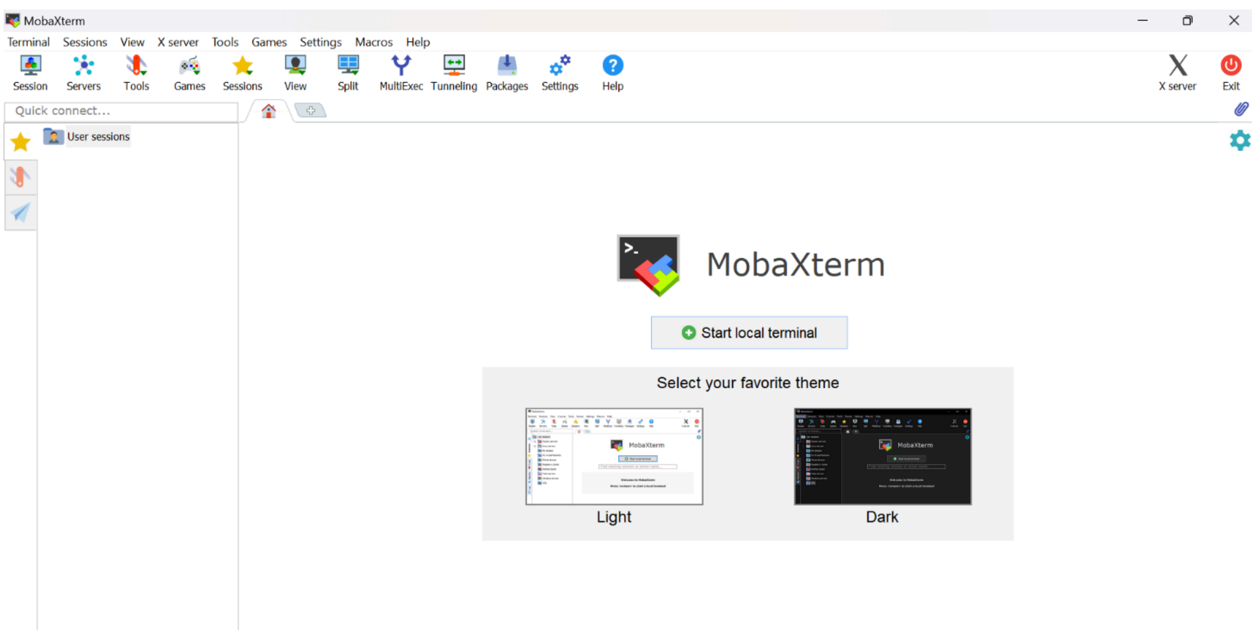
Instance3 -> Slave1 Private IP: 172.31.92.80

Instance4 -> Slave2 Private IP: 172.31.28.27

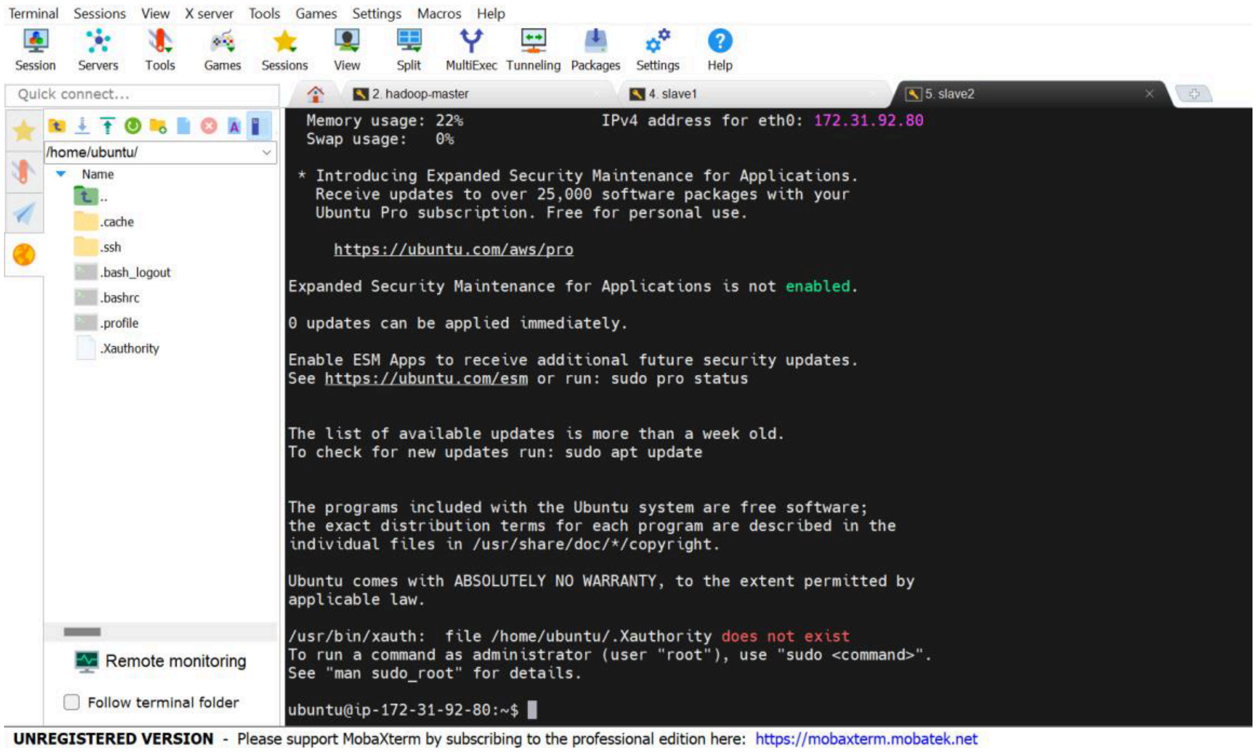


Step 2: Setting up SSH Client

MobaXterm is used an SSH Client to login to remote machines



After connecting to all our nodes, the environment looks like this. SSH connections to our remote machines are lined up as tabs

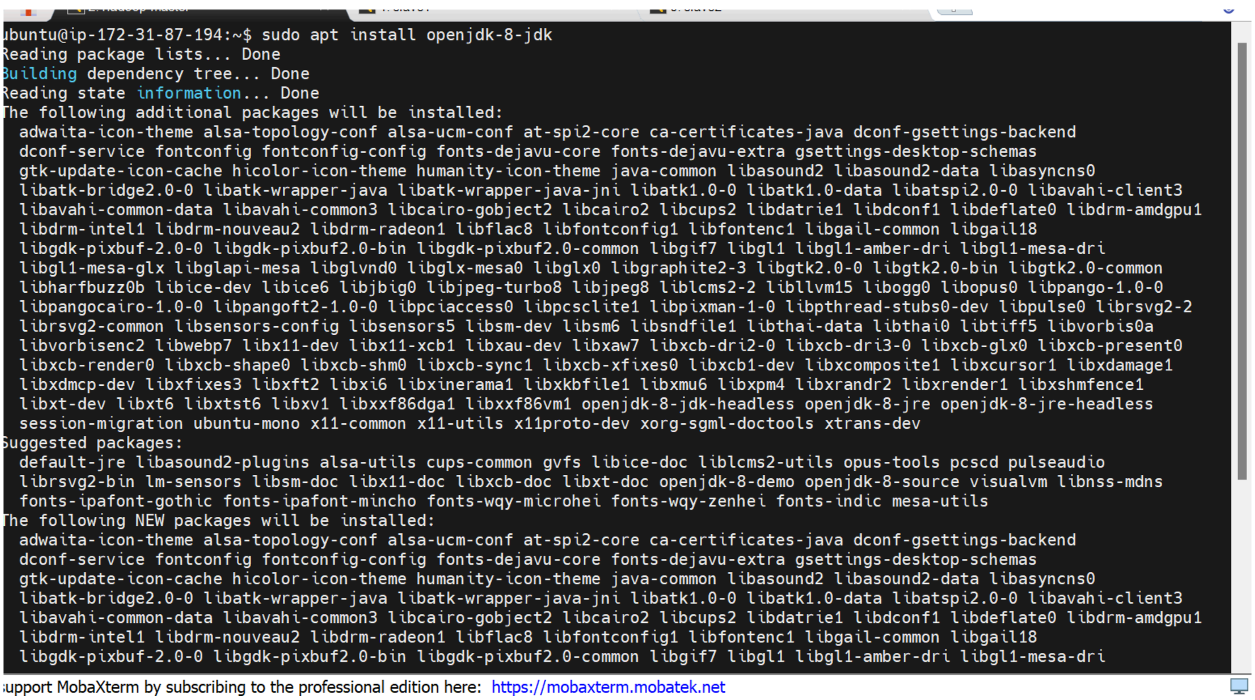


Step 3: Configuration of Hadoop Cluster

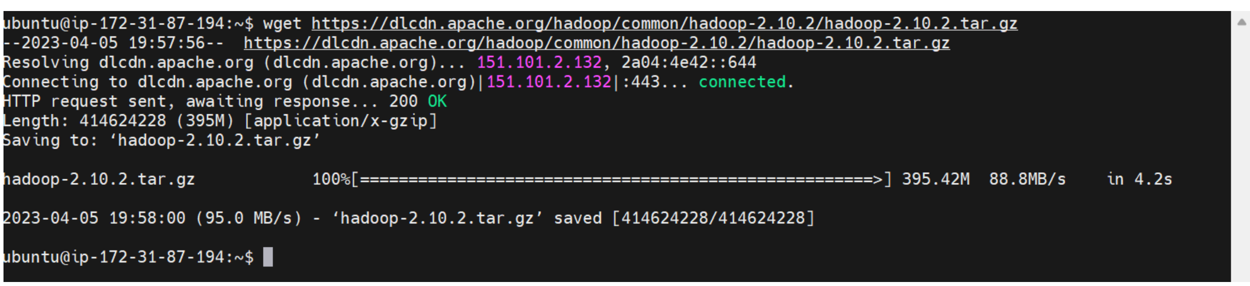
Step 3.1: Download Hadoop and JDK in all three machines

The step is repeated for all the 3 nodes

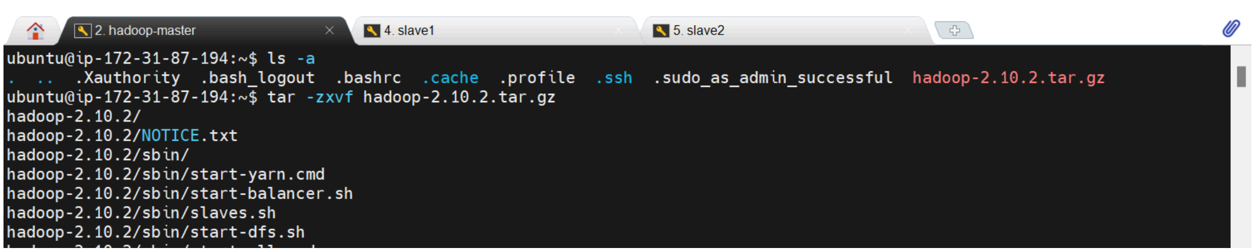
Download jdk-8



Download Hadoop



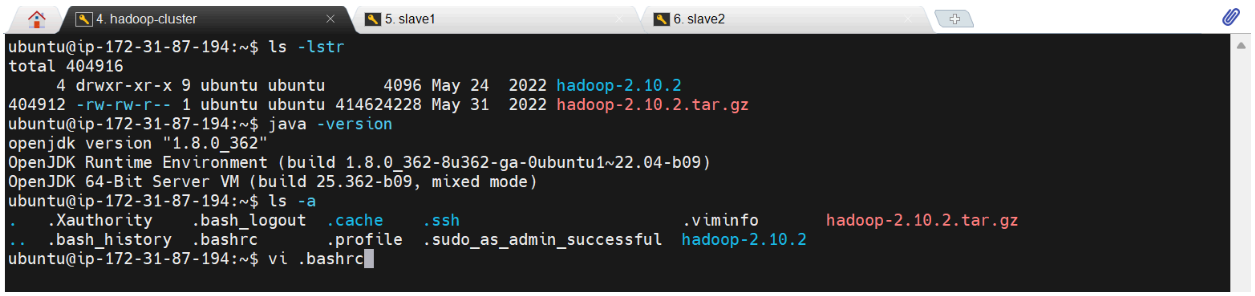
Extracting Hadoop

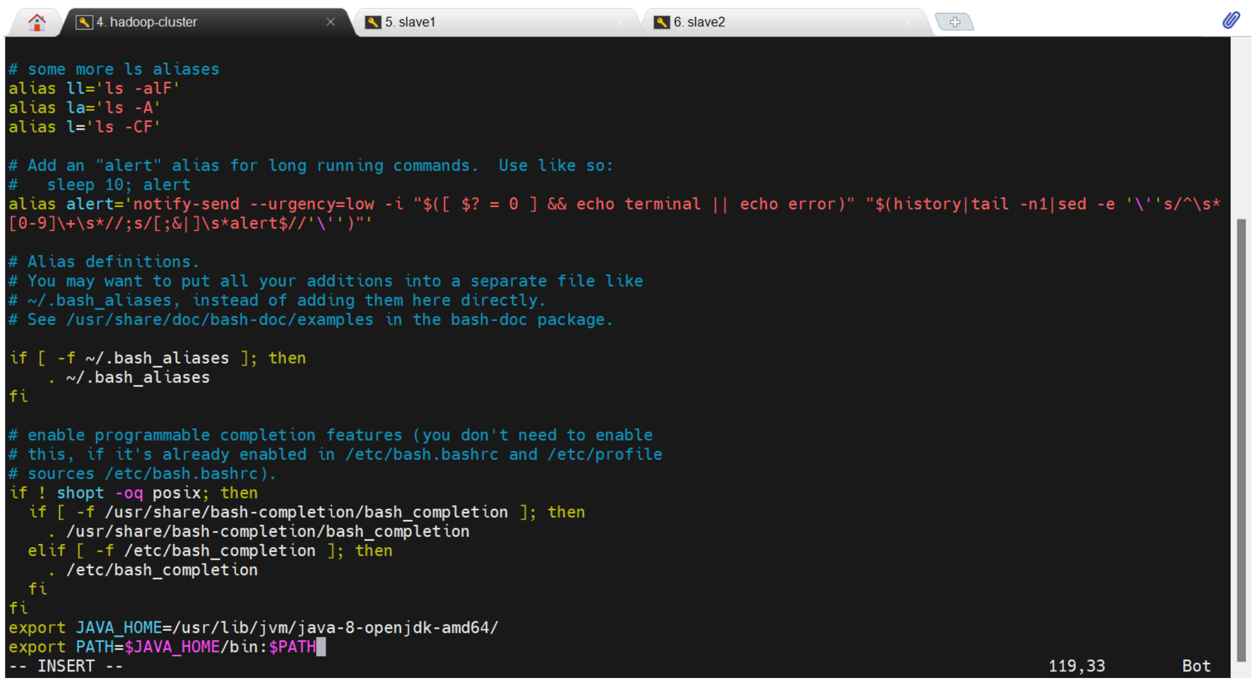


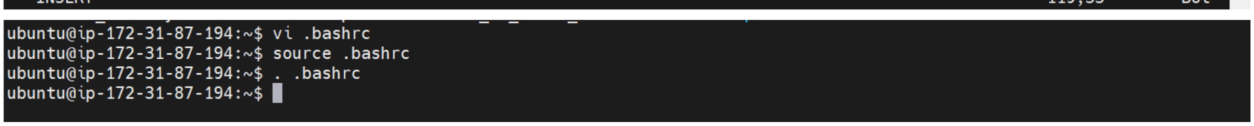
Step 3.2: Environment Setup for java

This step is repeated for all three nodes

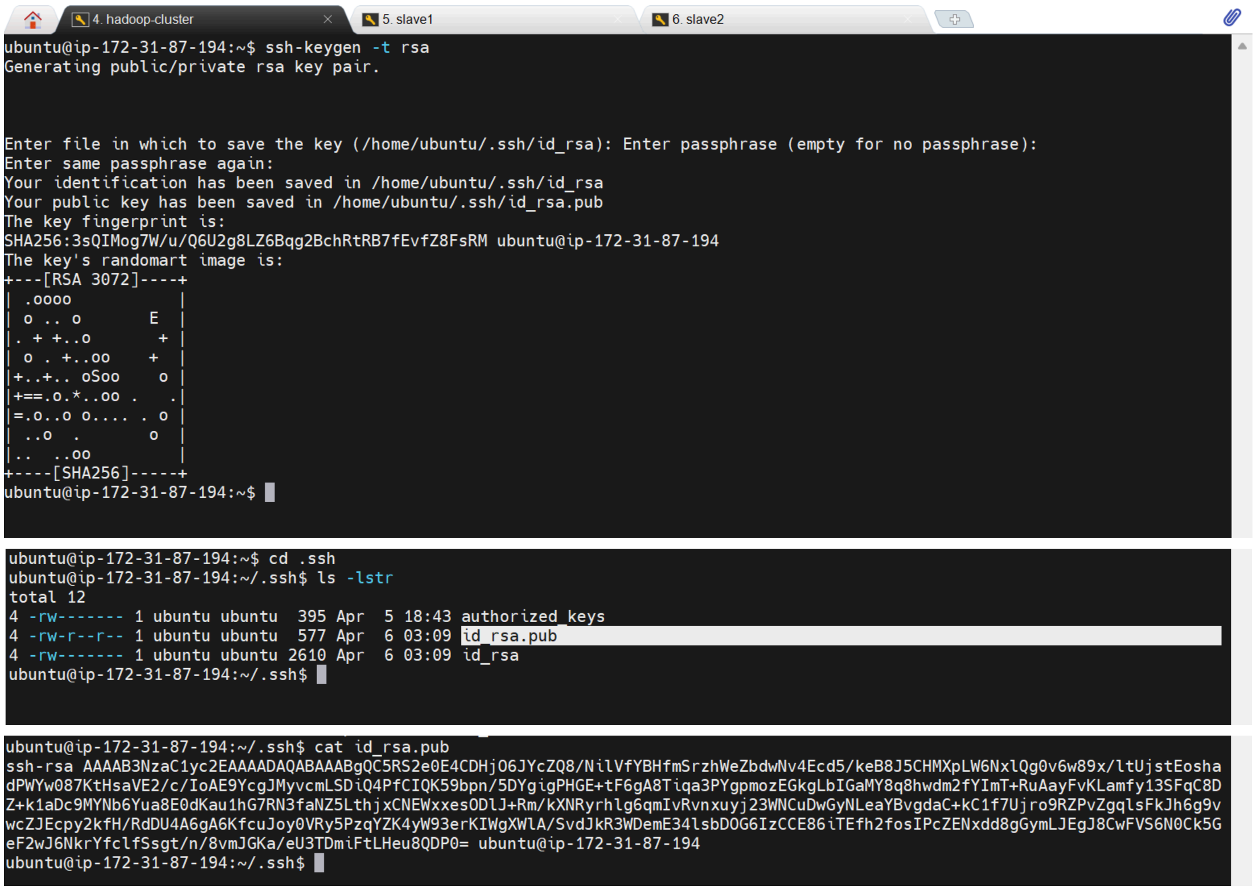
Adding JDK Path in .bashrc file and executing it







Step 3.3: SSH Setup Between Master and Slaves



• Generate Key Pairs on each node using: ssh-keygen -t rsa. The generated pairs are stored in id_rsa.pub in .ssh folder

• Key Pairs from all the nodes are copied together and pasted in authorized_keys file present in .ssh folder at every node.

Key Pair generation at slave nodes

4. hadoop-cluster 5. slave1 6. slave2

```
ubuntu@ip-172-31-85-217:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.

Enter file in which to save the key (/home/ubuntu/.ssh/id_rsa): Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/ubuntu/.ssh/id_rsa
Your public key has been saved in /home/ubuntu/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:4qvySXlWHEUK32v9bXLDMlEIXF3rMe4vsdvDGB3Bsq0 ubuntu@ip-172-31-85-217
The key's randomart image is:
+---[RSA 3072]----+
|      .  .+...o o|
|       o + ....+.|
|        + .  .+=.|
|       . . o .+oo|
|      . S o ..oo.|
|     o o .   E=o |
|    o +      o**+|
|  .. + .     .=Bo|
|   o+..       .o+|
+----[SHA256]-----+
ubuntu@ip-172-31-85-217:~$
```

4. hadoop-cluster 5. slave1 6. slave2

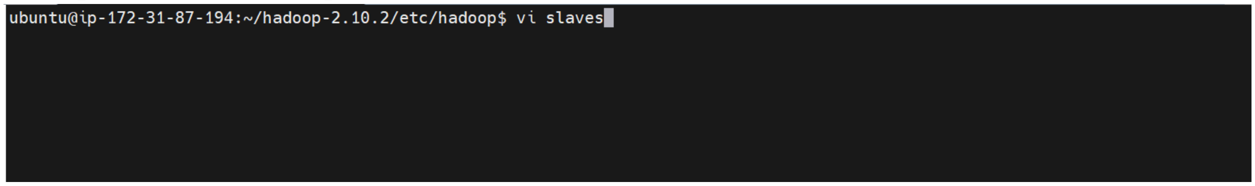
```
ubuntu@ip-172-31-92-80:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.


Enter file in which to save the key (/home/ubuntu/.ssh/id_rsa): Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/ubuntu/.ssh/id_rsa
Your public key has been saved in /home/ubuntu/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:m4hFtD2hRzb+2sa+Xe1W4jJN/V6W+VWTidFIhGDfoFk ubuntu@ip-172-31-92-80
The key's randomart image is:
+---[RSA 3072]----+
|      . =o.Eoo   |
|     . B.o=.+ o  |
|      + =o . + . |
|     . . o    o o|
|      . S .  . =.|
|     o . *    o.B|
|    . . + +  +.+B|
|        o .o.oo*|
|         o..o o+|
+----[SHA256]-----+
ubuntu@ip-172-31-92-80:~$
```

Final authorized_keys file: This file needs to be maintained at every node

4. hadoop-master 11. slave1 6. slave2

```
ubuntu@ip-172-31-87-194:~$ cd .ssh
ubuntu@ip-172-31-87-194:~/.ssh$ la -a
.  ..  authorized_keys  id_rsa  id_rsa.pub
ubuntu@ip-172-31-87-194:~/.ssh$ vi authorized_keys
ubuntu@ip-172-31-87-194:~/.ssh$ cat authorized_keys
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCvT/R8WVLxg5JOUryhOcJOjODAiYOA6NGCxOZ8s6TPPZCAwKyE3JCIOyvS/fDn+tIheFv3r0A7srkaRMfv8
0Zg8/lmapJuMqqIHy7DcqdjG1ZMV8WyCg4hK4F7KK33MiRaOcqy34uiImQDmZdAb3B96TX8YUmXYSMzB8fCQxifOihXEbUTW8tICLqcdPSuhLZeafJmprejFT
gIPnxIPruWUmDoHvUmrH7TW1UNoOY7slmPAVgastnS/E3VaYGuyxKXLVQGQBFCyrIovRQ4utQiTxihC7j83eOIUr4/VPGvtEsML1+hOXtA4JVnMWK0p2RXQtx
5UBWXLmjx6E7njSLj instance1-key
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABgQC5RS2e0E4CDHjO6JYcZQ8/NilVfYBHfmSrzhWeZbdwNv4Ecd5/keB8J5CHMXpLW6NxlQg0v6w89x/ltUjst
EoshadPWYw087KtHsaVE2/c/IoAE9YcgJMyvcmLSDiQ4PfCIQK59bpn/5DYgigPHGE+tF6gA8Tiqa3PYgpmozEGkgLbIGaMY8q8hwdm2fYImT+RuAayFvKLam
fy13SFqC8DZ+k1aDc9MYNb6Yua8E0dKau1hG7RN3faNZ5LthjxCNEWxxesODlJ+Rm/kXNRyrhlg6qmIvRvnxuyj23WNCuDwGyNLeaYBvgdaC+kC1f7Ujro9RZ
PvZgqlsFkJh6g9vwcZJEcpy2kfH/RdDU4A6gA6KfcuJoy0VRy5PzqYZK4yW93erKIWgXWlA/SvdJkR3WDemE34lsbDOG6IzCCE86iTEfh2fosIPcZENxdd8gG
ymLJEgJ8CwFVS6N0Ck5GeF2wJ6NkrYfclfSsgt/n/8vmJGKa/eU3TDmiFtLHeu8QDP0= ubuntu@ip-172-31-87-194
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABgQCvtX6lHSIfkU+WbAdQ6f5bKyJ0VYHZIRV43byeont3AqL5unasytNwn9IiP7VJVMJEdUsoppFcT8LHjZLaB
9QwOnR4pzTdnzuhrkKMJmI/FA4ym+jg4tlzx0pEhTr+NGZznmiFWUVneuXFl/n8wdKSudjCW+2Q5Mhh3x9QIQFivt9eTfMs0zgX7yPuPQ2tMlUveJbDosX+qE
dxUouQbfx+G+kQ+uDBgNzGeQ0/aRUiH2rNShbOMNCgmkwnzmNp0w//zxzQ65M7YHhSOKN0bJ/fIANhwLqk9DDSTAfXUTUvUNDTcPaUatFfmvqBHEGgJczA29V
XbzaRO/m6E8gwsWl7QWlriji7Lup3PegGy2riOlTPxaCgU9zCICxFz6achdEGbvoU+jWab2PN2mo0gZz8UsJ5LYckb2hKC81X/76XW/ZdQkjoObK/L10JAqaX
f2GYlqBbJUEIEcnP1g9jnJG3lBIDDSme8FB0s30N1r+xFj65CosVJnodor6VTaSlJE8= ubuntu@ip-172-31-28-27
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABgQCp9MLicln9I110u9ybskEkamlRCOCyZQw0HoUtxXBmEHB/RPHW9zq8rt3w+slUyUUZwlhXU32sV6NNcLQGx
bUY2yRTbuB/eXlSWfQ+ZlpkdsPhYhC48usEvHCkip6BYgGOd4BsU5ntAfZjiE3JJEwRaRkkPmAExMHND/elh+urYl9ylMlhavl+/pMT07yaJsimvzEt1XZ3jb
tdH6Kc/W0nDb2I9t24cmv4lHFB+FTVb+dMWvZrELgpYBPDyeLz7fsG6ZTTwtM9TdBpt4sD9ZTuRbTvfF8SNDSpIZd+v/9noHX2ccvLEj/3DAlyD6ho2+m7P7W
7xa4iplDRME9/j8gkiq5cDbt57saXcDO2kgJobakRYw2kZY4TIklGvURMKmhwlHZsC4urIq3anI9+419ntFNotL11qwUCJiRIWfXK2lK88rBJrraYlzK5x+sj
Zjdgd81oZH73vt58S1XDoC7xYgNqxDHZztofCgdyNG3qlJ9+2LHESs/KIIcQdApD9eE= ubuntu@ip-172-31-92-80
ubuntu@ip-172-31-87-194:~/.ssh$
```

Step 3.4: Configuration of Hadoop Files. Files present in path:
hadoop-2.10.2/etc/Hadoop



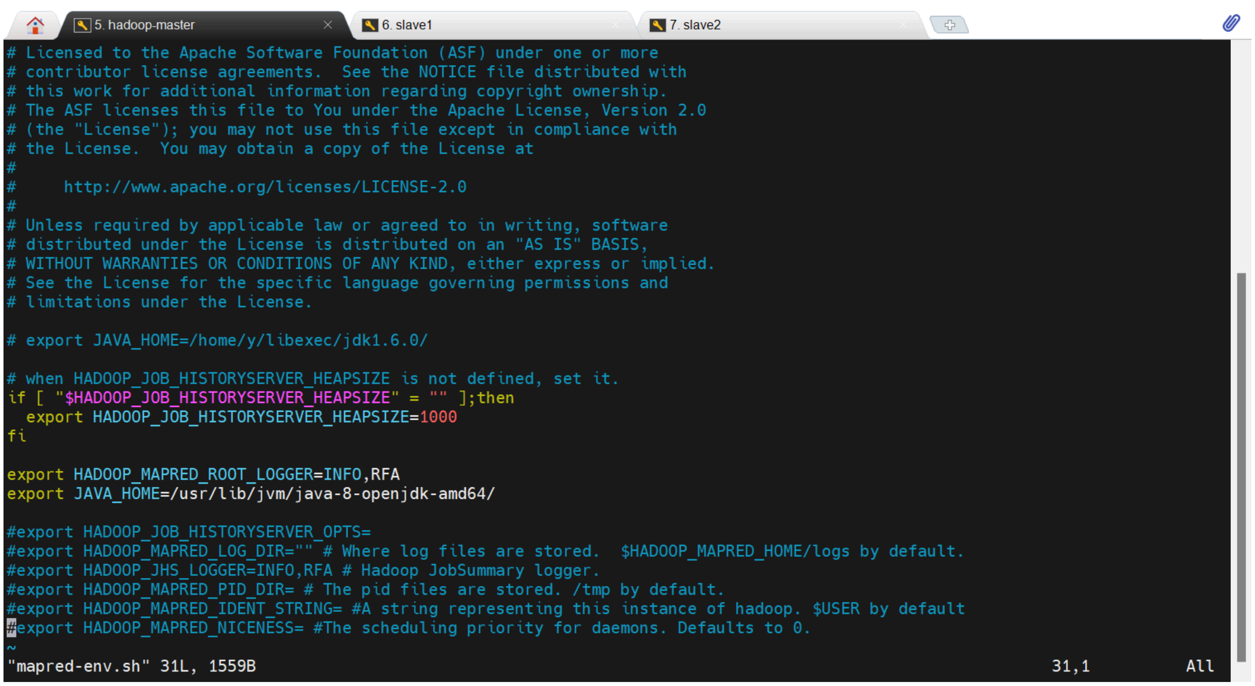
```
ubuntu@ip-172-31-87-194:~/hadoop-2.10.2/etc/hadoop$ vi slaves
```

Configuration of slaves files (Only at Master Node): Add Private IPs of Slaves in slaves file present in master node

```
172.31.28.27
172.31.92.80
~
~
~
~
~
~
~
~
```

Configuration of env files (Needs to be repeated for every node): Adding JDK path to each file

mapred-env.sh




```
# Licensed to the Apache Software Foundation (ASF) under one or more
# contributor license agreements.  See the NOTICE file distributed with
# this work for additional information regarding copyright ownership.
# The ASF licenses this file to You under the Apache License, Version 2.0
# (the "License"); you may not use this file except in compliance with
# the License.  You may obtain a copy of the License at
#
#     http://www.apache.org/licenses/LICENSE-2.0
#
# Unless required by applicable law or agreed to in writing, software
# distributed under the License is distributed on an "AS IS" BASIS,
# WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
# See the License for the specific language governing permissions and
# limitations under the License.

# export JAVA_HOME=/home/y/libexec/jdk1.6.0/

# when HADOOP_JOB_HISTORYSERVER_HEAPSIZE is not defined, set it.
if [ "$HADOOP_JOB_HISTORYSERVER_HEAPSIZE" = "" ];then
  export HADOOP_JOB_HISTORYSERVER_HEAPSIZE=1000
fi

export HADOOP_MAPRED_ROOT_LOGGER=INFO,RFA
export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64/

#export HADOOP_JOB_HISTORYSERVER_OPTS=
#export HADOOP_MAPRED_LOG_DIR="" # Where log files are stored.  $HADOOP_MAPRED_HOME/logs by default.
#export HADOOP_JHS_LOGGER=INFO,RFA # Hadoop JobSummary logger.
#export HADOOP_MAPRED_PID_DIR= # The pid files are stored. /tmp by default.
#export HADOOP_MAPRED_IDENT_STRING= #A string representing this instance of hadoop. $USER by default
#export HADOOP_MAPRED_NICENESS= #The scheduling priority for daemons. Defaults to 0.
~
"mapred-env.sh" 31L, 1559B                                                    31,1          All
```

yarn-env.sh

```
fi

# restore ordinary behaviour
unset IFS


YARN_OPTS="$YARN_OPTS -Dhadoop.log.dir=$YARN_LOG_DIR"
YARN_OPTS="$YARN_OPTS -Dyarn.log.dir=$YARN_LOG_DIR"
YARN_OPTS="$YARN_OPTS -Dhadoop.log.file=$YARN_LOGFILE"
YARN_OPTS="$YARN_OPTS -Dyarn.log.file=$YARN_LOGFILE"
YARN_OPTS="$YARN_OPTS -Dyarn.home.dir=$YARN_COMMON_HOME"
YARN_OPTS="$YARN_OPTS -Dyarn.id.str=$YARN_IDENT_STRING"
YARN_OPTS="$YARN_OPTS -Dhadoop.root.logger=${YARN_ROOT_LOGGER:-INFO,console}"
YARN_OPTS="$YARN_OPTS -Dyarn.root.logger=${YARN_ROOT_LOGGER:-INFO,console}"
if [ "x$JAVA_LIBRARY_PATH" != "x" ]; then
  YARN_OPTS="$YARN_OPTS -Djava.library.path=$JAVA_LIBRARY_PATH"
fi
YARN_OPTS="$YARN_OPTS -Dyarn.policy.file=$YARN_POLICYFILE"

export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64/
```

hadoop-env.sh

```
# HDFS Mover specific parameters
###
# Specify the JVM options to be used when starting the HDFS Mover.
# These options will be appended to the options specified as HADOOP_OPTS
# and therefore may override any similar flags set in HADOOP_OPTS
#
# export HADOOP_MOVER_OPTS=""

###
# Router-based HDFS Federation specific parameters
# Specify the JVM options to be used when starting the RBF Routers.
# These options will be appended to the options specified as HADOOP_OPTS
# and therefore may override any similar flags set in HADOOP_OPTS
#
# export HADOOP_DFSROUTER_OPTS=""
###

###
# Advanced Users Only!
###

# The directory where pid files are stored. /tmp by default.
# NOTE: this should be set to a directory that can only be written to by
#       the user that will run the hadoop daemons.  Otherwise there is the
#       potential for a symlink attack.
export HADOOP_PID_DIR=${HADOOP_PID_DIR}
export HADOOP_SECURE_DN_PID_DIR=${HADOOP_PID_DIR}

# A string representing this instance of hadoop. $USER by default.
export HADOOP_IDENT_STRING=$USER

export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64/
"hadoop-env.sh" 119L, 5022B                                    119,17        Bot
```

Configuration of XML Files:

core-site.xml: Same for master as slaves

The IP address provided is the private IP address of the Master Node

```
<!-- Put site-specific property overrides in this file. -->

<configuration>
<property>
<name>fs.default.name</name>
<value>hdfs://172.31.87.194:50000</value>
</property>
</configuration>
~
~
```

yarn-site.xml: Same for master and slaves

The IP address provided is the private IP address of the Master Node

```
<property>
<name>yarn.nodemanager.aux-services</name> <value>mapreduce_shuffle</value>
</property>
<property>
<name>yarn.nodemanager.aux-services.mapreduce.shuffle.class</name>
<value>org.apache.hadoop.mapred.ShuffleHandler</value>
</property>
<property>
<description>The hostname of the RM.</description>
<name>yarn.resourcemanager.hostname</name>
<value>172.31.87.194</value>
</property>
<property>
<description>The address of the applications manager interface in the RM.</description>
<name>yarn.resourcemanager.address</name>
<value>172.31.87.194:8032</value>
</property>
```

hdfs-site.xml:

Mater Node:

```
<configuration>
<property>
<name>dfs.namenode.name.dir</name>
<value>/home/ubuntu/hadoop2-dir/namenode-dir</value>
</property>
</configuration>
~
```

Slave Nodes:

```
<configuration>

<property>
<name>dfs.datanode.data.dir</name>
<value>/home/ubuntu/hadoop2-dir/datanode-dir</value>
</property>

</configuration>
```

mapred-site.xml: Same for master and slaves

```
<configuration>
<property>
<name>mapreduce.framework.name</name>
<value>yarn</value>
</property>
</configuration>
~
```

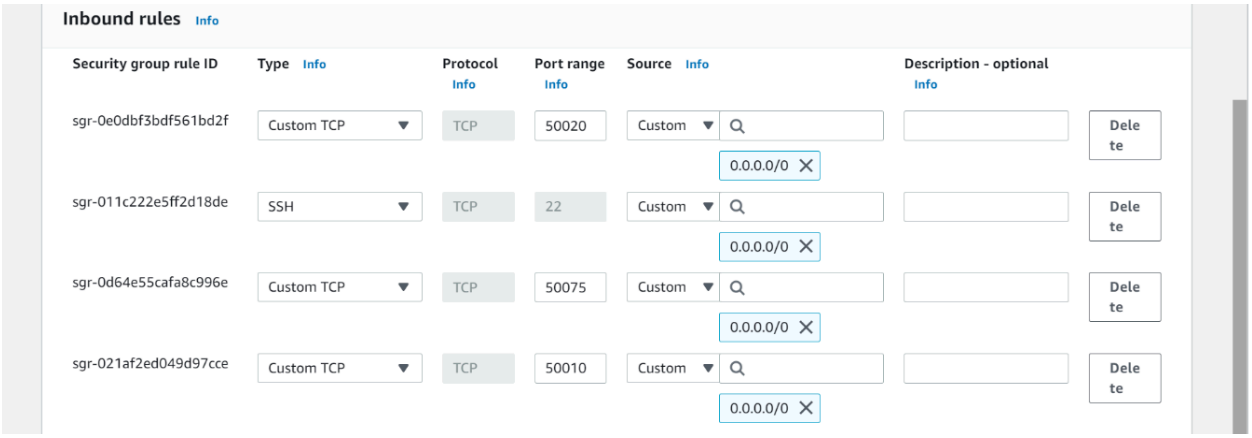
Step 4: Adding inbound rules in security groups of instances

Master Instance:

Inbound rules Info

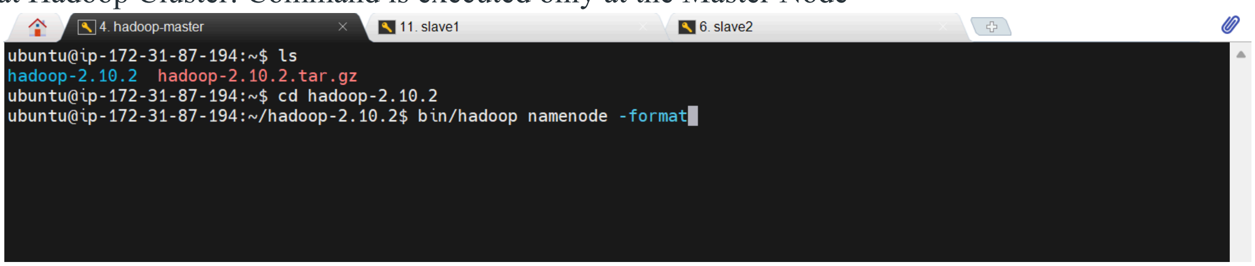
Security group rule ID	Type Info	Protocol Info	Port range Info	Source Info	Description - optional Info	
sgr-01dbf782726765778	Custom TCP	TCP	8032	Custom 0.0.0.0/0		Delete
sgr-066505b604cc38522	Custom TCP	TCP	50090	Custom 0.0.0.0/0		Delete
sgr-0094cc3175570dd00	Custom TCP	TCP	8020	Custom 0.0.0.0/0		Delete
sgr-0f44d937cec22fc9d	Custom TCP	TCP	9000	Custom 0.0.0.0/0		Delete
sgr-030038630b08ee42f	SSH	TCP	22	Custom 0.0.0.0/0		Delete

Slave Instances:



Step 5: Formatting of Hadoop Cluster and Starting of the daemons

Format Hadoop Cluster: Command is executed only at the Master Node



```
23/04/06 08:34:37 INFO namenode.FSDirectory: ACLs enabled? false
23/04/06 08:34:37 INFO namenode.FSDirectory: XAttrs enabled? true
23/04/06 08:34:37 INFO namenode.NameNode: Caching file names occurring more than 10 times
23/04/06 08:34:37 INFO snapshot.SnapshotManager: Loaded config captureOpenFiles: falseskipCaptureAccessTimeOnlyChange: fa
lse
23/04/06 08:34:37 INFO util.GSet: Computing capacity for map cachedBlocks
23/04/06 08:34:37 INFO util.GSet: VM type       = 64-bit
23/04/06 08:34:37 INFO util.GSet: 0.25% max memory 966.7 MB = 2.4 MB
23/04/06 08:34:37 INFO util.GSet: capacity      = 2^18 = 262144 entries
23/04/06 08:34:37 INFO metrics.TopMetrics: NNTop conf: dfs.namenode.top.window.num.buckets = 10
23/04/06 08:34:37 INFO metrics.TopMetrics: NNTop conf: dfs.namenode.top.num.users = 10
23/04/06 08:34:37 INFO metrics.TopMetrics: NNTop conf: dfs.namenode.top.windows.minutes = 1,5,25
23/04/06 08:34:37 INFO namenode.FSNamesystem: Retry cache on namenode is enabled
23/04/06 08:34:37 INFO namenode.FSNamesystem: Retry cache will use 0.03 of total heap and retry cache entry expiry time i
s 600000 millis
23/04/06 08:34:37 INFO util.GSet: Computing capacity for map NameNodeRetryCache
23/04/06 08:34:37 INFO util.GSet: VM type       = 64-bit
23/04/06 08:34:37 INFO util.GSet: 0.029999999329447746% max memory 966.7 MB = 297.0 KB
23/04/06 08:34:37 INFO util.GSet: capacity      = 2^15 = 32768 entries
23/04/06 08:34:37 INFO namenode.FSImage: Allocated new BlockPoolId: BP-1635550088-172.31.87.194-1680770077648
23/04/06 08:34:37 INFO common.Storage: Storage directory /home/ubuntu/hadoop2-dir/namenode-dir has been successfully form
atted.
23/04/06 08:34:37 INFO namenode.FSImageFormatProtobuf: Saving image file /home/ubuntu/hadoop2-dir/namenode-dir/current/fs
image.ckpt_0000000000000000000 using no compression
23/04/06 08:34:37 INFO namenode.FSImageFormatProtobuf: Image file /home/ubuntu/hadoop2-dir/namenode-dir/current/fsimage.c
kpt_0000000000000000000 of size 325 bytes saved in 0 seconds .
23/04/06 08:34:37 INFO namenode.NNStorageRetentionManager: Going to retain 1 images with txid >= 0
23/04/06 08:34:37 INFO namenode.FSImage: FSImageSaver clean checkpoint: txid = 0 when meet shutdown.
23/04/06 08:34:37 INFO namenode.NameNode: SHUTDOWN_MSG:
/************************************************************
SHUTDOWN_MSG: Shutting down NameNode at ip-172-31-87-194.ec2.internal/172.31.87.194
************************************************************/
ubuntu@ip-172-31-87-194:~/hadoop-2.10.2$
```

Starting of daemons: Command Executed only at Master Node

```
ubuntu@ip-172-31-87-194:~/hadoop-2.10.2$ jps
9492 Jps
ubuntu@ip-172-31-87-194:~/hadoop-2.10.2$ sbin/start-all.sh
This script is Deprecated. Instead use start-dfs.sh and start-yarn.sh
Starting namenodes on [ip-172-31-87-194.ec2.internal]
ip-172-31-87-194.ec2.internal: starting namenode, logging to /home/ubuntu/hadoop-2.10.2/logs/hadoop-ubuntu-namenode-ip-172-31-8
7-194.out
172.31.92.80: starting datanode, logging to /home/ubuntu/hadoop-2.10.2/logs/hadoop-ubuntu-datanode-ip-172-31-92-80.out
172.31.28.27: starting datanode, logging to /home/ubuntu/hadoop-2.10.2/logs/hadoop-ubuntu-datanode-ip-172-31-28-27.out
Starting secondary namenodes [0.0.0.0]
0.0.0.0: starting secondarynamenode, logging to /home/ubuntu/hadoop-2.10.2/logs/hadoop-ubuntu-secondarynamenode-ip-172-31-87-194.out
starting yarn daemons
starting resourcemanager, logging to /home/ubuntu/hadoop-2.10.2/logs/yarn-ubuntu-resourcemanager-ip-172-31-87-194.out
172.31.28.27: starting nodemanager, logging to /home/ubuntu/hadoop-2.10.2/logs/yarn-ubuntu-nodemanager-ip-172-31-28-27.out
172.31.92.80: starting nodemanager, logging to /home/ubuntu/hadoop-2.10.2/logs/yarn-ubuntu-nodemanager-ip-172-31-92-80.out
ubuntu@ip-172-31-87-194:~/hadoop-2.10.2$
```

Daemons running at the Master:

```
ubuntu@ip-172-31-87-194:~/hadoop-2.10.2$ jps
10225 Jps
9974 ResourceManager
9848 SecondaryNameNode
9643 NameNode
ubuntu@ip-172-31-87-194:~/hadoop-2.10.2$
```

Daemons running at slave 1:

```
4. hadoop-master    11. slave1    6. slave2
ubuntu@ip-172-31-28-27:~$ jps
12248 Jps
ubuntu@ip-172-31-28-27:~$ jps
12452 NodeManager
12329 DataNode
12558 Jps
ubuntu@ip-172-31-28-27:~$
```

Daemons running at slave 2:

```
4. hadoop-master    11. slave1    6. slave2
ubuntu@ip-172-31-92-80:~$ jps
12015 Jps
ubuntu@ip-172-31-92-80:~$ jps
12325 Jps
12220 NodeManager
12095 DataNode
ubuntu@ip-172-31-92-80:~$
```

Step 6: Launching the Namenode Web Interface

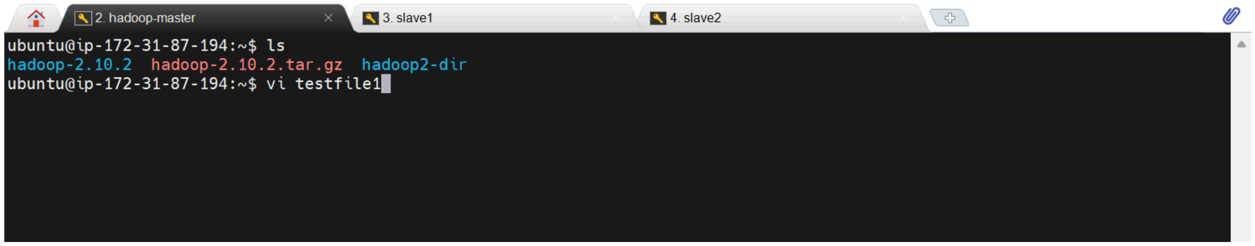
The Web UI Provided by Apache, provides the following information about the cluster:

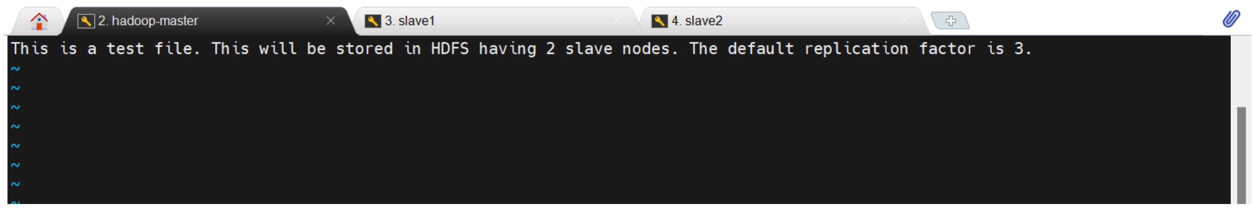
Non Heap Memory used 49.74 MB of 50.94 MB Commited Non Heap Memory. Max Non Heap Memory is <unbounded>.

Configured Capacity:	15.15 GB
DFS Used:	48 KB (0%)
Non DFS Used:	7.72 GB
DFS Remaining:	7.4 GB (48.84%)
Block Pool Used:	48 KB (0%)
DataNodes usages% (Min/Median/Max/stdDev):	0.00% / 0.00% / 0.00% / 0.00%
Live Nodes	2 (Decommissioned: 0, In Maintenance: 0)
Dead Nodes	0 (Decommissioned: 0, In Maintenance: 0)
Decommissioning Nodes	0
Entering Maintenance Nodes	0
Total Datanode Volume Failures	0 (0 B)
Number of Under-Replicated Blocks	0
Number of Blocks Pending Deletion	0
Block Deletion Start Time	Fri Apr 07 13:21:05 +0530 2023
Last Checkpoint Time	Fri Apr 07 12:57:09 +0530 2023

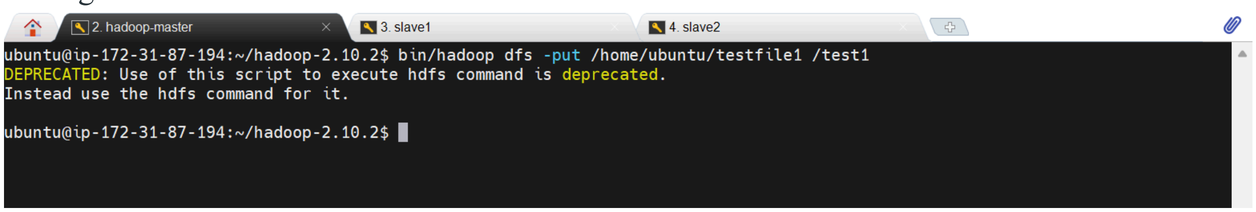
Step 7: Testing HDFS by storing files

Creating a Test File

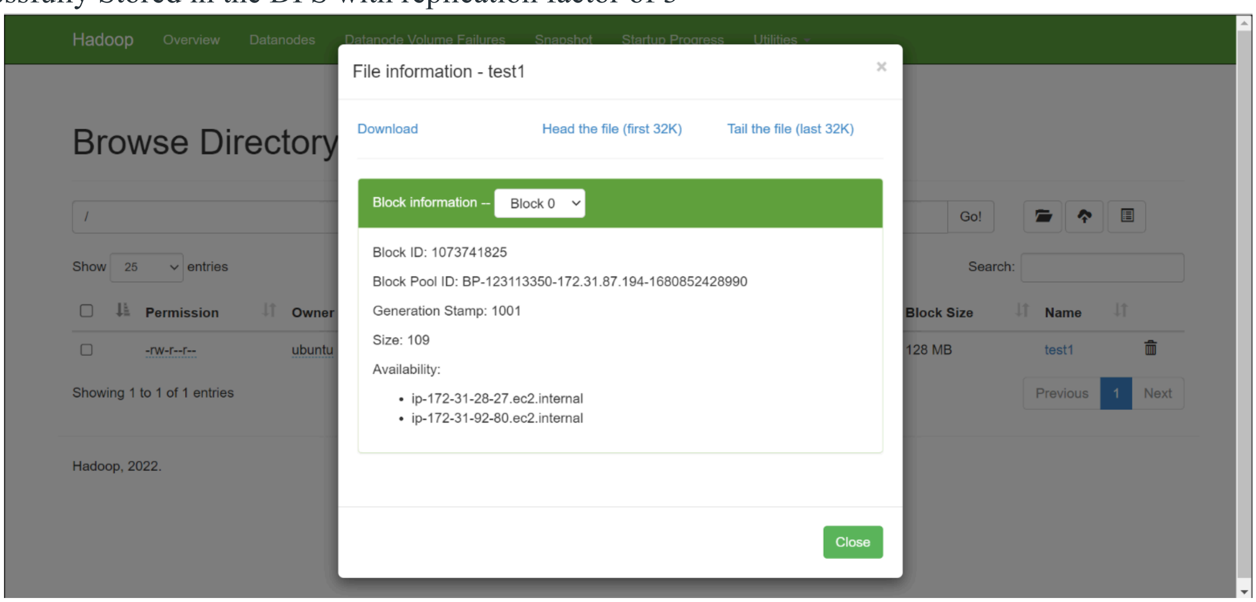




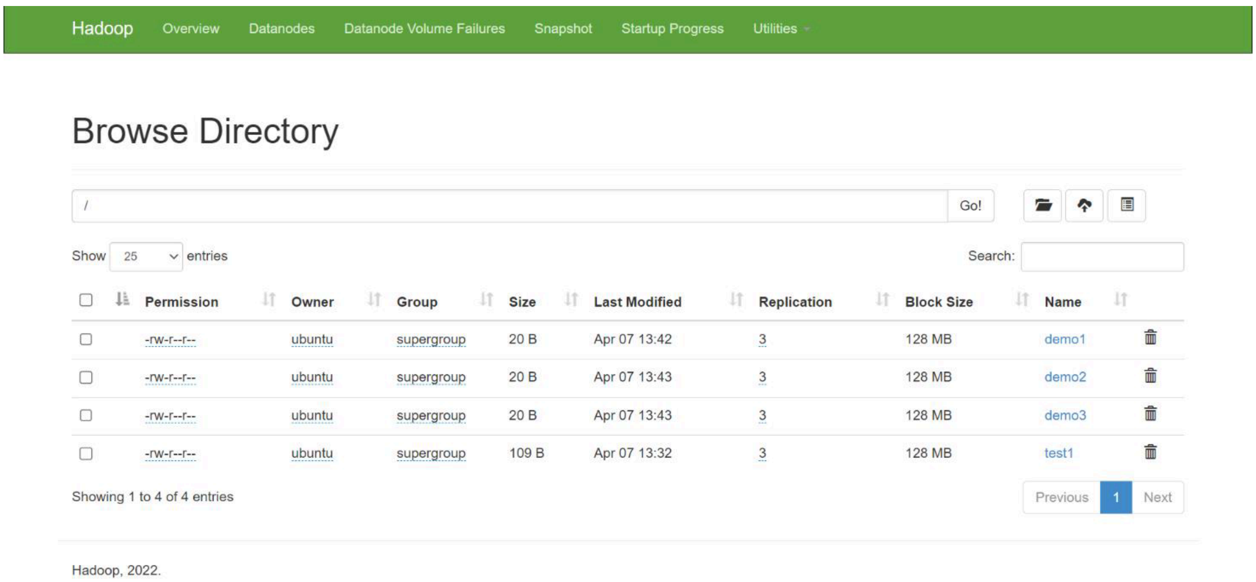
Storing it in the HDFS:



Successfully Stored in the DFS with replication factor of 3



Storing more files:



Conclusion:

In conclusion, our experiment studying MapReduce and Hadoop Distributed File System (HDFS) has shown that these technologies are powerful tools for managing and processing large-scale data sets in a distributed computing environment.

The implementation of Hadoop Distributed File System (HDFS) with one master and two slave nodes on Amazon Web Services (AWS) EC2 instances was successful. The experiment showed that HDFS can be deployed and managed on the cloud, allowing for the storage and processing of large amounts of data in a distributed manner.

References:

• Data Engineering. (2022, April 12). Hadoop Multi Node Cluster Setup

[Video]. YouTube. https://www.youtube.com/watch?v=_iP2Em-5Abw

• Kumar, M. R. N. (2022, September 17). Hadoop-3.3.1 Installation guide for Ubuntu - Dev Genius [Video]. Medium. https://blog.devgenius.io/install-configure-and-setup-hadoop-in-ubuntu-a3cdd6305a0e

• Gaurav Sharma. (2022, October 20). AWS Tutorials - 10 - Create First EC2 Instance | EC2 Instance Creation in AWS [Video]. YouTube. https://www.youtube.com/watch?v=f-T4xWUZWSk

Postlab Questions:

1. What are the differences between traditional file systems and HDFS?

Feature	Traditional File Systems	HDFS
Architecture	Typically single-node	Distributed across multiple nodes
Data storage	Data stored in a single server or disk	Data stored across a cluster of machines
Fault tolerance	Generally less fault-tolerant	Built-in fault tolerance through replication
Scalability	Limited scalability, especially for large datasets	Highly scalable, can handle petabytes of data
Access patterns	Optimized for random reads and writes	Optimized for streaming reads and writes
Consistency	Strong consistency, typically immediate updates	Eventual consistency, eventual updates

Metadata management	Centralized metadata management	Distributed metadata management
Data locality	Limited data locality, data may need to be moved to computation nodes	Maximizes data locality, computation happens where data resides
Processing framework	Not inherently integrated with big data processing frameworks	Integrated with Hadoop ecosystem for distributed processing
Use cases	General-purpose file storage for single servers or small clusters	Specifically designed for storing and processing large datasets in a distributed environment, commonly used in big data applications

2. Enlist key features and components of HDFS.

1. Distributed Storage: HDFS distributes data across multiple nodes in a cluster, enabling scalability and fault tolerance.

2. High Fault Tolerance: Data replication across multiple nodes ensures high availability and fault tolerance. If a node fails, data can be retrieved from replicas stored on other nodes.

3. Scalability: HDFS is designed to scale horizontally, allowing it to handle massive amounts of data by adding more nodes to the cluster.

4. Data Locality: HDFS optimizes data processing by moving computation to where the data resides, minimizing data movement across the network.

5. Streaming Data Access: HDFS is optimized for streaming data access rather than random reads and writes, making it suitable for large-scale data processing.

6. Block-based Storage: Data is stored in large blocks (typically 128MB or 256MB), which improves throughput and reduces the overhead of managing a large number of small files.

7. Metadata Management: HDFS maintains metadata about files and directories in a centralized metadata server called the NameNode.

8. Data Replication: HDFS replicates data across multiple nodes to ensure fault tolerance and data durability. The replication factor is configurable, typically set to three.

9. Rack Awareness: HDFS is aware of the physical network topology, allowing it to place replicas across multiple racks for improved fault tolerance and data locality.

10. Checksums: HDFS uses checksums to detect and handle data corruption, ensuring data integrity during storage and transmission.

11. Command Line Interface (CLI): HDFS provides a command-line interface for users to interact with the file system, similar to traditional file systems.

12. Web User Interface (UI): HDFS includes a web-based UI that provides information about the cluster, file system, and data nodes.

13. Hadoop Ecosystem Integration: HDFS is a core component of the Apache Hadoop ecosystem, seamlessly integrating with other Hadoop projects such as MapReduce, HBase, Hive, and Spark for distributed data processing and analysis.