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Hadoop Distributed File System

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Laurea Magistrale in
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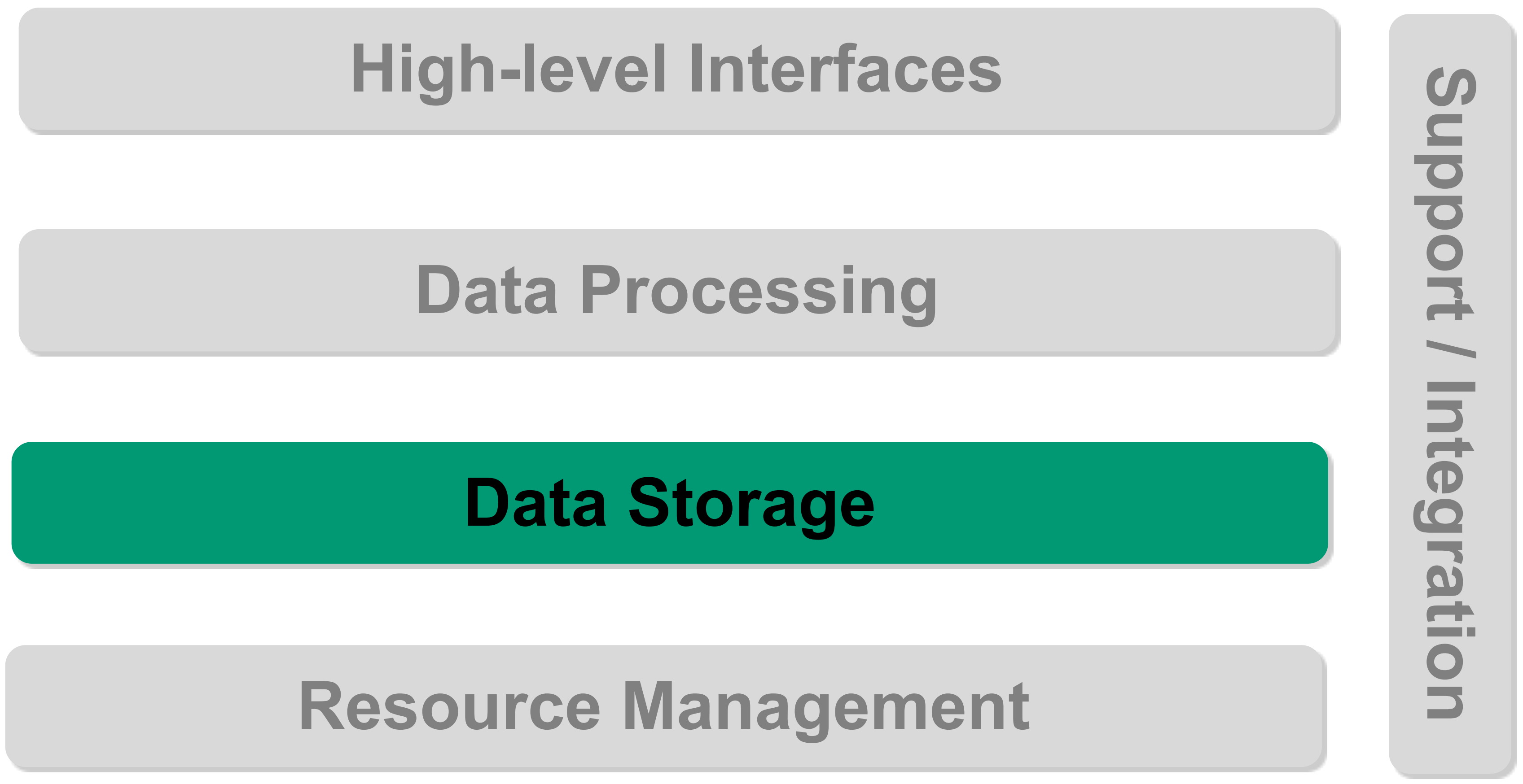
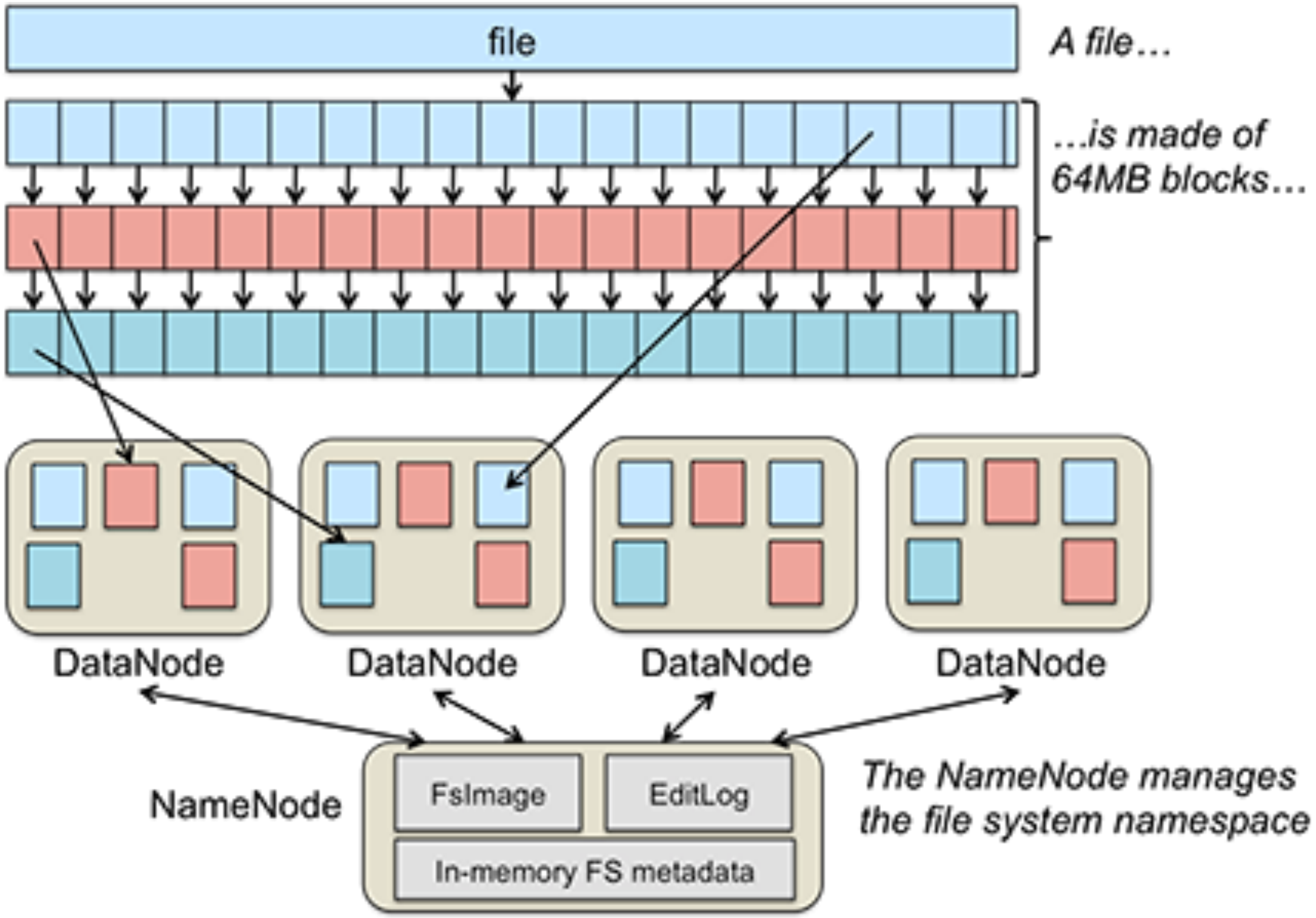
The reference Big Data stack



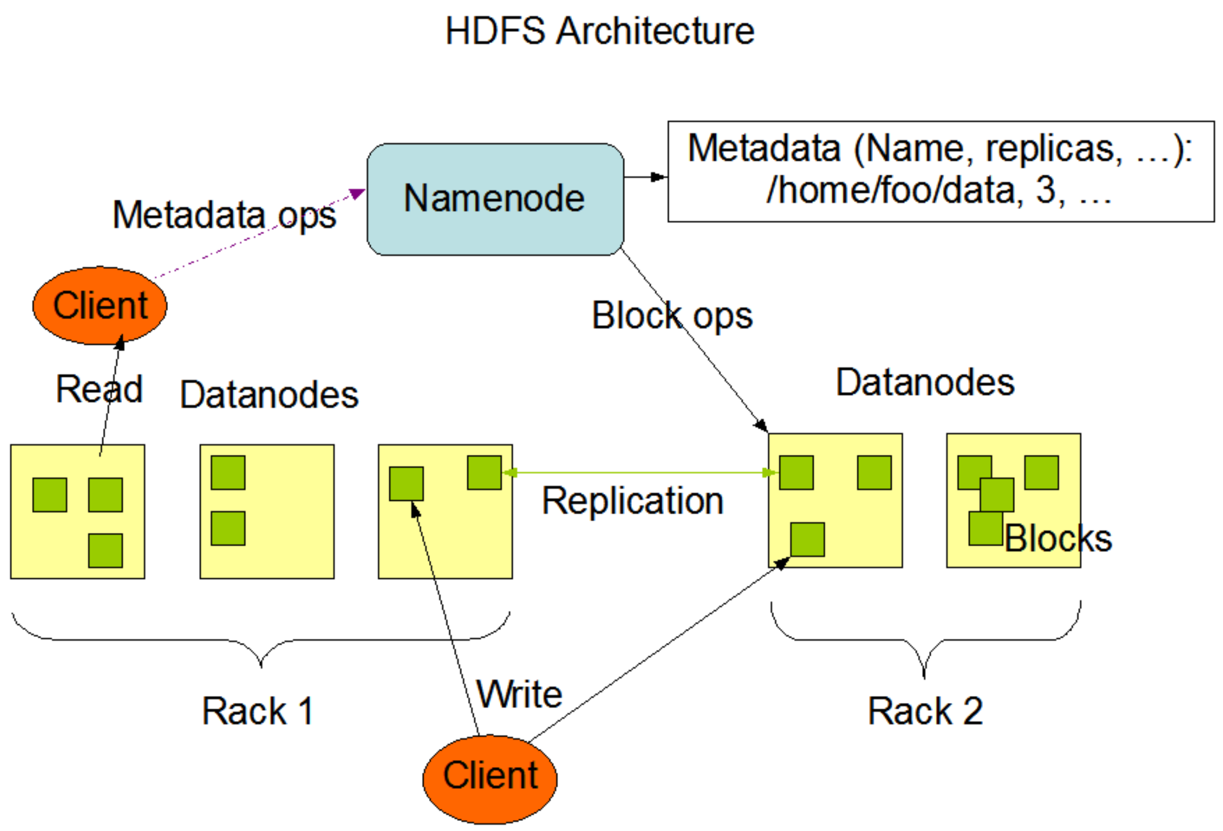
HDFS: a very short summary

A file is split into one or more **blocks** and these blocks are stored in a set of storing nodes (named DataNodes)

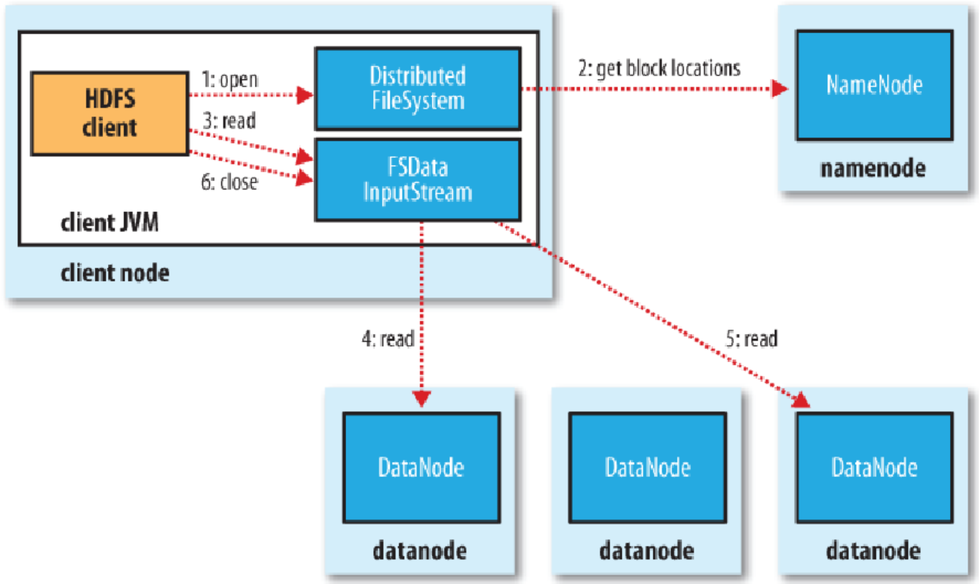


HDFS: a very short summary

- An HDFS cluster has two types of nodes:
  - One master, called NameNode
  - Multiple workers, called DataNodes



HDFS: a very short summary

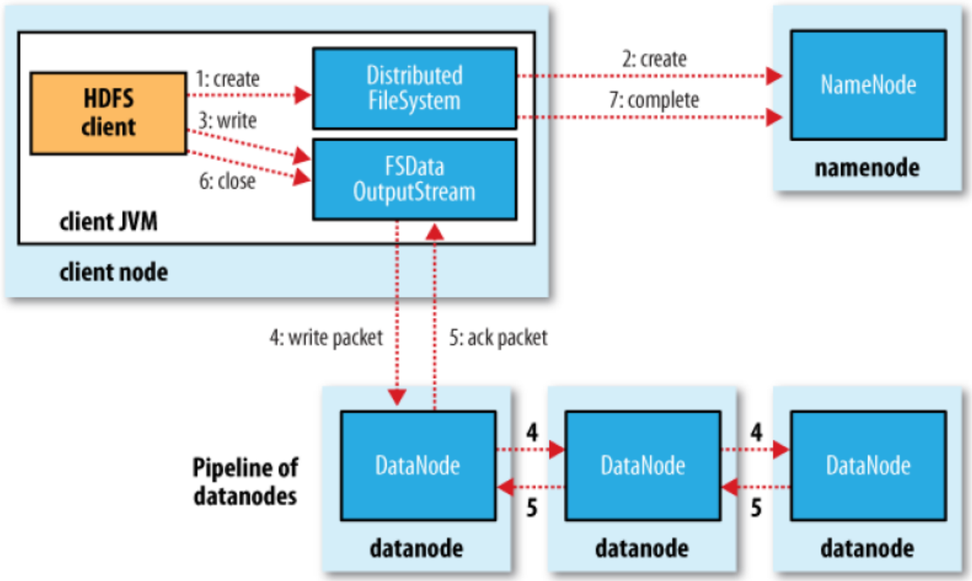


Read

- NameNode used to get block location

Write

- Clients ask NameNode for a list of suitable DataNodes
- This list forms a pipeline: first DataNode stores a copy of a block, then forwards it to the second, and so on



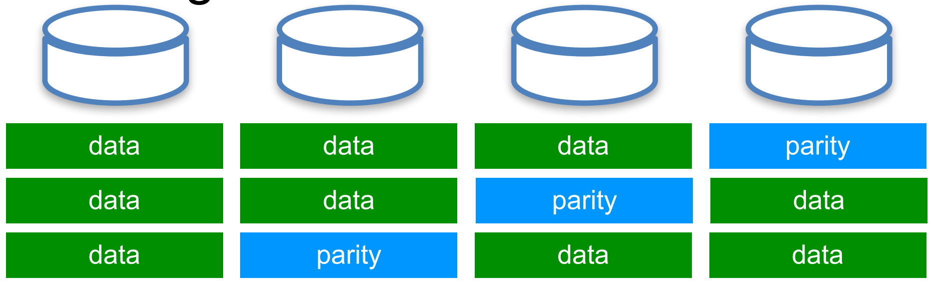
Hadoop 3: What's new? Erasure Coding

Replication is expensive!

- e.g., 3x replication adds 200% overhead in storage space
- For warm/cold datasets, additional block replicas are rarely accessed during normal operations

Erasure Coding

- Fault tolerance with reduced storage overhead (no more than 50%).
- Different policies (e.g, RS-3-2-1024k, XOR-2-1-1024k):
  - EC Schema (number of data and parity blocks + codec algorithm)
  - Striping cell size
- Replication factor of an EC file is meaningless
  - Always 1, and cannot be changed
- Note: Not all operations supported
  - e.g. append() throws exception



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

Installation and Configuration of HDFS
(step by step)

Apache Hadoop: Configuration

Download

http://hadoop.apache.org/releases.html

Configure environment variables

In the **.profile** (or **.bash_profile**) export all needed environment variables

```
$ cd
$ nano .profile
```

```
export JAVA_HOME=/usr/lib/jvm/java-8-oracle/jre
export HADOOP_HOME=/usr/local/hadoop-X.Y.Z
export PATH=$PATH:$JAVA_HOME/bin:$HADOOP_HOME/bin
```

(on a Linux/Mac OS system)

Apache Hadoop: Configuration

Allow remote login

- Your system should accept connection through SSH (i.e., run a SSH server, set your firewall to allow incoming connections)
- Enable login without password and a RSA key
- Create a new RSA key and add it into the list of authorized keys

```
$ ssh-keygen –t rsa –P “”
$ cat $HOME/.ssh/id_rsa.pub >>$HOME/.ssh/authorized_keys
```

(on a Linux/Mac OS system)

Apache Hadoop: Configuration

Hadoop Configuration
in $HADOOP_HOME/etc/hadoop:

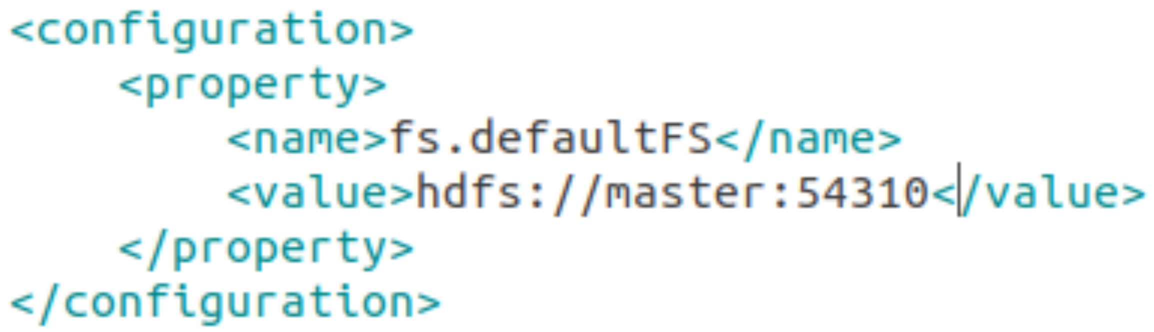
- **core-site.xml**: common settings for HDFS, MapReduce, and YARN
- **hdfs-site.xml**: configuration settings for HDFS deamons
  (i.e., namenode, secondary namenode, and datanodes)
- **mapred-site.xml**: configuration settings for MapReduce
  (e.g., job history server)
- **yarn-site.xml**: configuration settings for YARN daemons
  (e.g., resource manager, node managers)

By default, Hadoop runs in a non-distributed mode, as a single Java process. We will configure Hadoop to execute in a pseudo-distributed mode

More on the Hadoop configuration: https://hadoop.apache.org/docs/current/

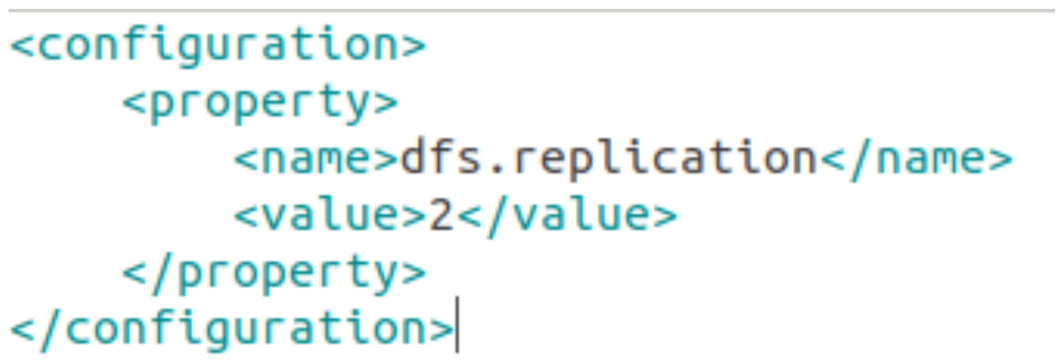
Apache Hadoop: Configuration

core-site.xml



```
<configuration>
    <property>
        <name>fs.defaultFS</name>
        <value>hdfs://master:54310</value>
    </property>
</configuration>
```

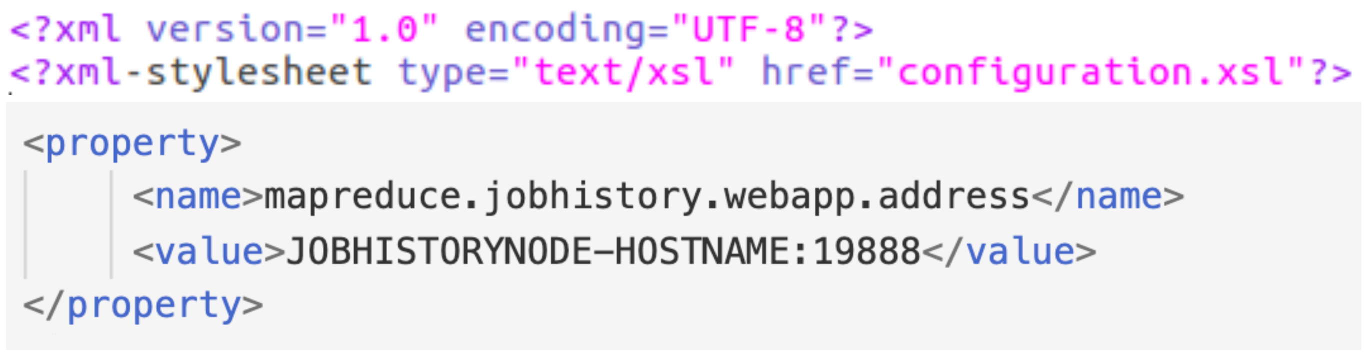
hdfs-site.xml



```
<configuration>
    <property>
        <name>dfs.replication</name>
        <value>2</value>
    </property>
</configuration>
```

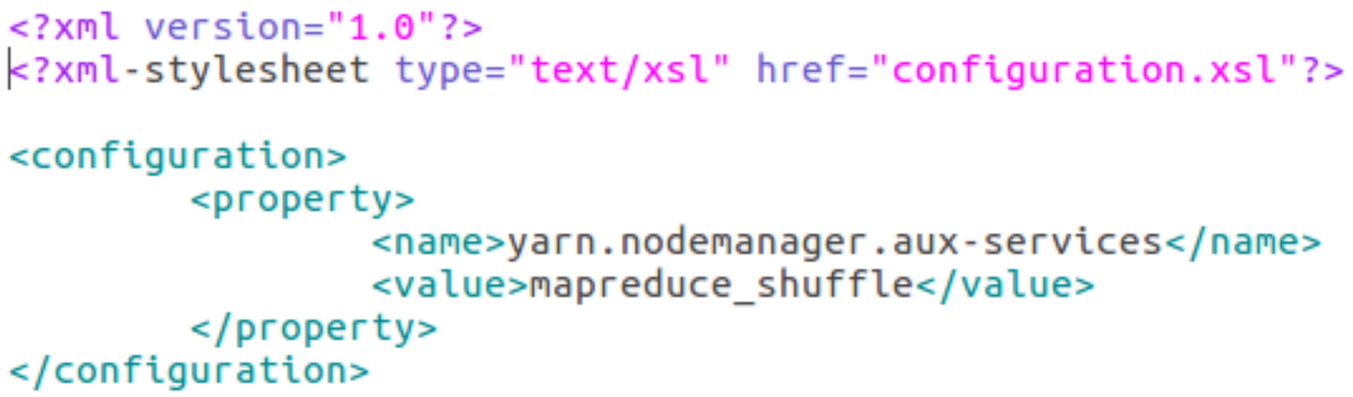
Apache Hadoop: Configuration

mapred-site.xml



```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<property>
    <name>mapreduce.jobhistory.webapp.address</name>
    <value>JOBHISTORYNODE-HOSTNAME:19888</value>
</property>
```

yarn-site.xml



```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>

<configuration>
        <property>
                <name>yarn.nodemanager.aux-services</name>
                <value>mapreduce_shuffle</value>
        </property>
</configuration>
```

http://www.michael-noll.com/tutorials/running-hadoop-on-ubuntu-linux-multi-node-cluster/

Installation and Configuration of HDFS

(our pre-configured Docker image)

HDFS with Dockers

```
$ docker pull matnar/hadoop
```

- create a small network named hadoop_network with one namenode (master) and 3 datanodes (slave)

```
$ docker network create --driver bridge hadoop_network


$ docker run -t -i -p 9864:9864 -d --network=hadoop_network
  --name=slave1 matnar/hadoop
$ docker run -t -i -p 9863:9864 -d --network=hadoop_network
--name=slave2 matnar/hadoop
$ docker run -t -i -p 9862:9864 -d --network=hadoop_network
--name=slave3 matnar/hadoop
$ docker run -t -i -p 9870:9870 --network=hadoop_network
--name=master matnar/hadoop
```

HDFS with Dockers

How to remove the containers

- stop and delete the namenode and datanodes

```
$ docker kill slave1 slave2 slave3
$ docker rm master slave1 slave2 slave3
```

- remove the network

```
$ docker network rm hadoop_network
```

HDFS: initialization and operations

Apache Hadoop: Configuration

At the first execution, the HDFS needs to be initialized

```
$ hdfs namenode -format
```

- this operation **erases the content of the HDFS**
- it should be executed only during the initialization phase

HDFS: Configuration

Start HDFS:

```
$ $HADOOP_HOME/sbin/start-dfs.sh
```

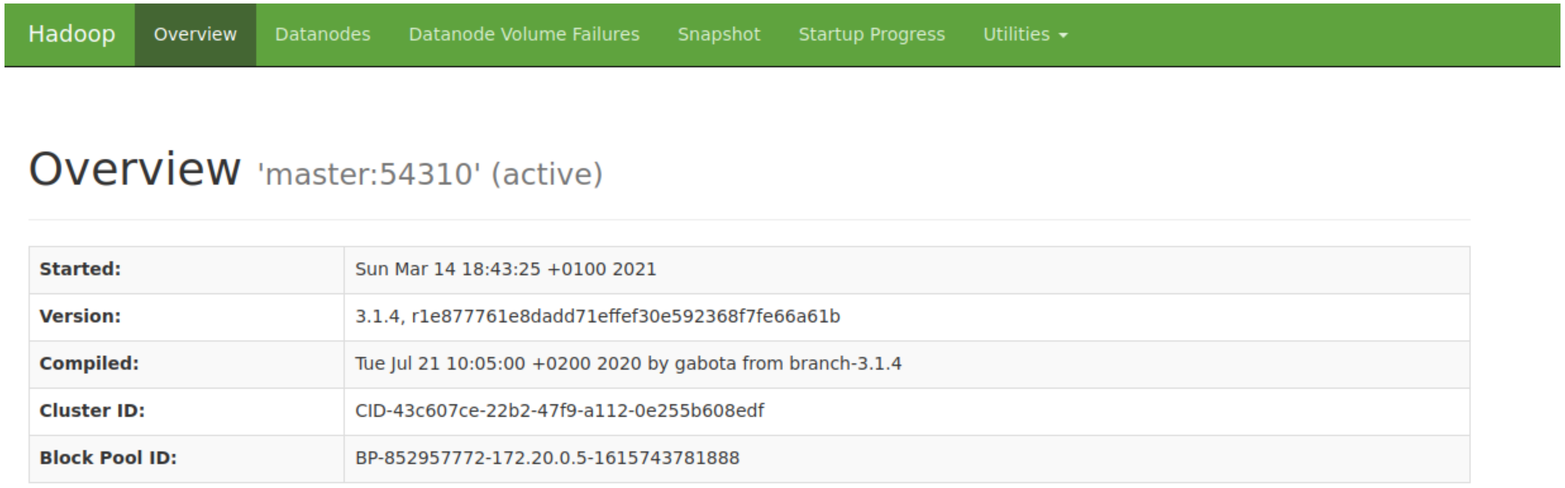
Stop HDFS:

```
$ $HADOOP_HOME/sbin/stop-dfs.sh
```

HDFS: Configuration

When the HDFS is started, you can check its WebUI:

- http://localhost:9870/



Overview 'master:54310' (active)

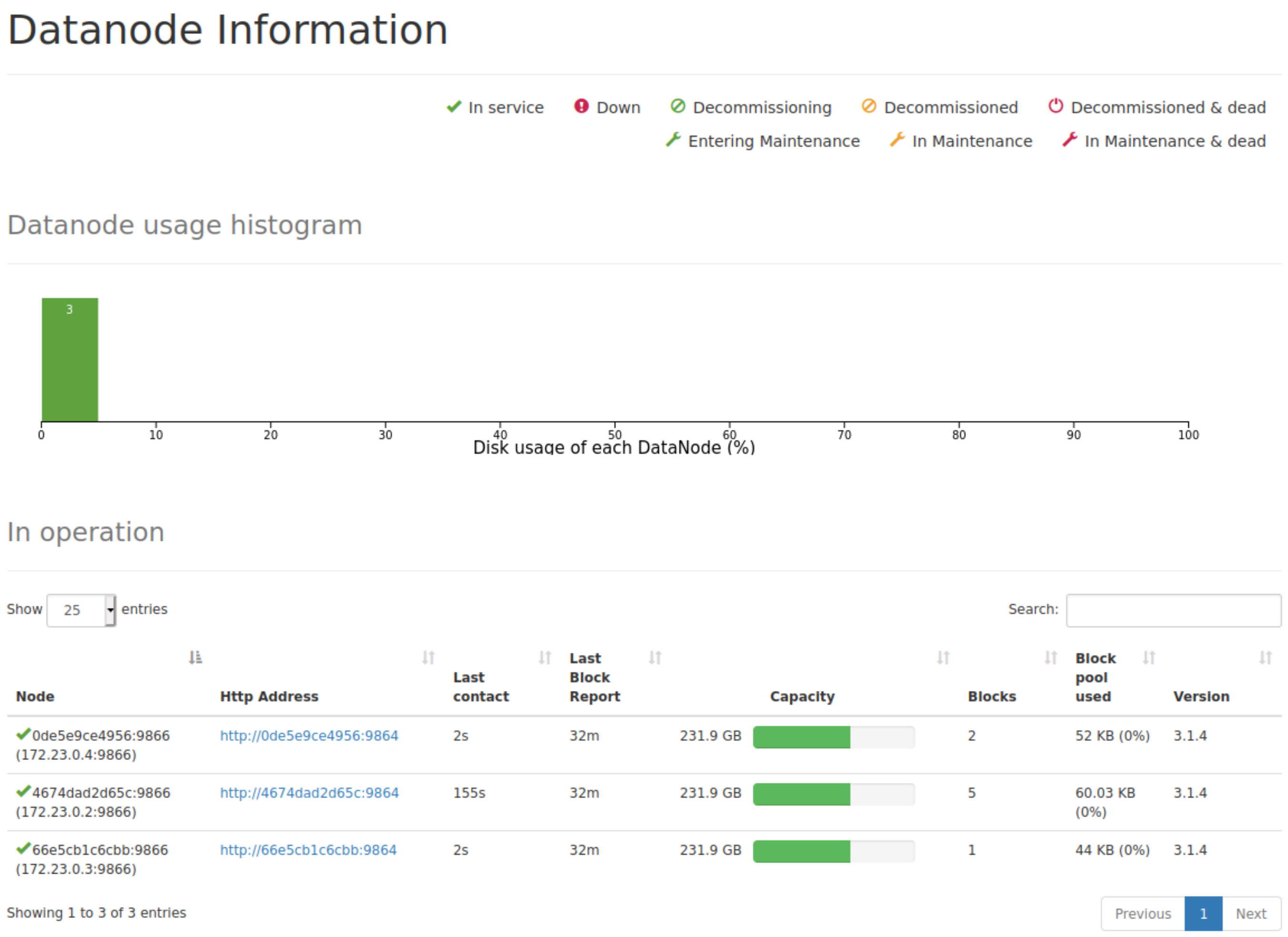
Started:	Sun Mar 14 18:43:25 +0100 2021
Version:	3.1.4, r1e877761e8dadd71effef30e592368f7fe66a61b
Compiled:	Tue Jul 21 10:05:00 +0200 2020 by gabota from branch-3.1.4
Cluster ID:	CID-43c607ce-22b2-47f9-a112-0e255b608edf
Block Pool ID:	BP-852957772-172.20.0.5-1615743781888

```
$ $HADOOP_HOME/sbin/stop-dfs.sh
```

Obtain basic filesystem information and statistics:

```
$ hdfs dfsadmin -report
```

HDFS: Datanode



Datanode Information

✓ In service ● Down ⊘ Decommissioning ⊘ Decommissioned ⏻ Decommissioned & dead
Entering Maintenance In Maintenance In Maintenance & dead

Datanode usage histogram

In operation

Show 25 entries

Search:

Node	Http Address	Last contact	Last Block Report	Capacity	Blocks	Block pool used	Version
✓0de5e9ce4956:9866 (172.23.0.4:9866)	http://0de5e9ce4956:9864	2s	32m	231.9 GB	2	52 KB (0%)	3.1.4
✓4674dad2d65c:9866 (172.23.0.2:9866)	http://4674dad2d65c:9864	155s	32m	231.9 GB	5	60.03 KB (0%)	3.1.4
✓66e5cb1c6cbb:9866 (172.23.0.3:9866)	http://66e5cb1c6cbb:9864	2s	32m	231.9 GB	1	44 KB (0%)	3.1.4

Showing 1 to 3 of 3 entries

Previous 1 Next

HDFS: Basic operations

ls: for a file ls returns stat on the file; for a directory it returns list of its direct children

```
$ hdfs dfs -ls [-d] [-h] [-R] <args>
```

-d: Directories are listed as plain files
-h: Format file sizes in a human-readable fashion
-R: Recursively list subdirectories encountered

mkdir: takes path uri's as argument and creates directories

```
$ hdfs dfs -mkdir [-p] <paths>
```

-p: creates parent directories along the path.

http://hadoop.apache.org/docs/current/hadoop-project-dist/hadoop-common/FileSystemShell.html

HDFS: Basic operations

mv: coves files from source to destination. This command allows multiple sources in which case the destination needs to be a directory. Moving files across file systems is not permitted

```
$ hdfs dfs -mv URI [URI ...] <dest>
```

put: copy single src, or multiple srcs from local file system to the destination file system

```
$ hdfs dfs -put <localsrc> ... <dst>
```

Also reads input from stdin and writes to destination file system

```
$ hdfs dfs -put - <dst>
```

HDFS: Basic operations

append: append single or multiple files from local file system to the destination file system

```
$ hdfs dfs -appendToFile <localsrc> ... <dst>
```

get: copy files to the local file system; files that fail the CRC check may be copied with the `-ignorecrc` option

```
$ hdfs dfs -get [-ignorecrc] [-crc] <src> <localdst>
```

cat: copies source paths to stdout

```
$ hdfs dfs -cat URI [URI ...]
```

HDFS: Basic operations

rm: Delete files specified as args

```
$ hdfs dfs -rm [-f] [-r |-R] [-skipTrash] URI [URI ...]
```

-f:	does not display a diagnostic message (modify the exit status to reflect an error if the file does not exist)
-R (or -r):	deletes the directory and any content under it recursively
-skipTrash:	bypasses trash, if enabled

cp: copy files from source to destination. This command allows multiple sources as well in which case the destination must be a directory

```
$ hdfs dfs -cp [-f] [-p | -p[topax]] URI [URI ...] <dest>
```

-f:	overwrites the destination if it already exists.
-p:	preserves file attributes [topx] (timestamps, ownership, permission, ACL, XAttr). If -p is specified with no arg, then preserves timestamps, ownership, permission.

HDFS: Basic operations

stat: Print statistics about the file/directory at <path> in the specified format

```
$ hadoop fs -stat [format] <path> ...
```

Format accepts

%b	Size of file in bytes
%F	Will return "file", "directory", or "symlink" depending on the type of inode
%g	Group name
%n	Filename
%o	HDFS Block size in bytes (128MB by default)
%r	Replication factor
%u	Username of owner
%y	Formatted mtime of inode
%Y	UNIX Epoch mtime of inode

An example

```
$ echo "File content" >> file
$ hdfs dfs -put file /file
$ hdfs dfs -ls /
$ hdfs dfs -mv /file /democontent
$ hdfs dfs -cat /democontent
$ hdfs dfs -appendToFile file /democontent
$ hdfs dfs -cat /democontent
$ hdfs dfs -mkdir /folder01
$ hdfs dfs -cp /democontent /folder01/text
$ hdfs dfs -ls /folder01
$ hdfs dfs -rm /democontent
$ hdfs dfs -get /folder01/text textfromhdfs
$ cat textfromhdfs
$ hdfs dfs -rm -r /folder01
```

HDFS: Snapshot

Snapshots

- read-only point-in-time copies of the file system
- can be taken on a sub-tree or the entire file system

Common use cases:
data backup, protection against user errors, and disaster recovery.

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

HDFS: Snapshot

The implementation is efficient:

- the creation is instantaneous;
- additional memory is used only when modifications are made relative to a snapshot: memory usage is *O(M)*, where *M* is the number of modified files/directories;
- blocks in datanodes are not copied: the snapshot files record the block list and the file size;
- a snapshot does not adversely affect regular HDFS operations:
  - changes are recorded in reverse chronological order so that the current data can be accessed directly;
  - the snapshot data is computed by subtracting the modifications from the current data.

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

HDFS: Snapshot

Declare a folder where snapshot operations are allowed

```
$ hdfs dfsadmin -allowSnapshot <folder>
```

Create a snapshot

```
$ hdfs dfs -createSnapshot <folder> <snapshot-name>
```

Listing the snapshots

```
$ hdfs dfs -ls <folder>/.snapshot
```

Delete a snapshot

```
$ hdfs dfs -deleteSnapshot <folder> <snapshot-name>
```

Disable snapshot operations within a folder

```
$ hdfs dfsadmin -disallowSnapshot <folder>
```

An example

```
$ hdfs dfs -mkdir /snap
$ hdfs dfs -cp /file /snap/file
$ hdfs dfsadmin -allowSnapshot /snap
$ hdfs dfs -createSnapshot /snap snap001
$ hdfs dfs -ls /snap/.snapshot
$ hdfs dfs -ls /snap/.snapshot/snap001
$ hdfs dfs -cp -ptopax /snap/.snapshot/snap001/file /test
$ hdfs dfs -deleteSnapshot /snap snap001
$ hdfs dfsadmin -disallowSnapshot /snap
$ hdfs dfs -rm -r /snap
```

HDFS: Replication

setrep: change the replication factor of a file. If path is a directory then the command recursively changes the replication factor of all files under the directory tree rooted at path.

```
$ hdfs dfs -setrep [-w] <numReplicas> <path>
```

-w:	requests that the command wait for the replication to complete; this can potentially take a very long time

An example

```
$ hdfs dfs -put file /norepl/file
$ hdfs dfs -ls /norepl
$ hdfs dfs -setrep 1 /norepl
$ hdfs dfs -ls /norepl
$ hdfs dfs -put file /norepl/file2
$ hdfs dfs -ls /norepl
$ hdfs dfs -setrep 1 /norepl/file2
# also check block availability from webUI
```

HDFS: Erasure Coding

ec subcommand performs administrative operations related to erasure coding.

```
$ hdfs ec [generic options]
     [-setPolicy -path <path> [-policy <policyName>] [-
replicate]]
     [-getPolicy -path <path>]
     [-unsetPolicy -path <path>]
     [-listPolicies]
     [-addPolicies -policyFile <file>]
     [-listCodecs]
     [-enablePolicy -policy <policyName>]
     [-disablePolicy -policy <policyName>]
     [-removePolicy -policy <policyName>]
     [-verifyClusterSetup -policy
<policyName>...<policyName>]
     [-help [cmd ...]]
```

Read more: https://hadoop.apache.org/docs/current/hadoop-project-dist/hadoop-hdfs/HDFSErasureCoding.html