

Hadoop & its Components

What is Hadoop?

Lots of data + clusters

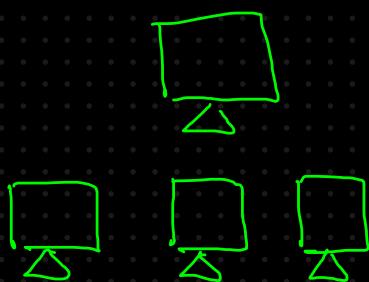
Hadoop is an open source framework designed to handle massive amount of data in a distributed and scalable way.

data started increasing exponentially

2008

GFS → Storing
MapReduce → Processing

2 task → 1. Massive data storage
2. faster parallel processing



Properties of Hadoop

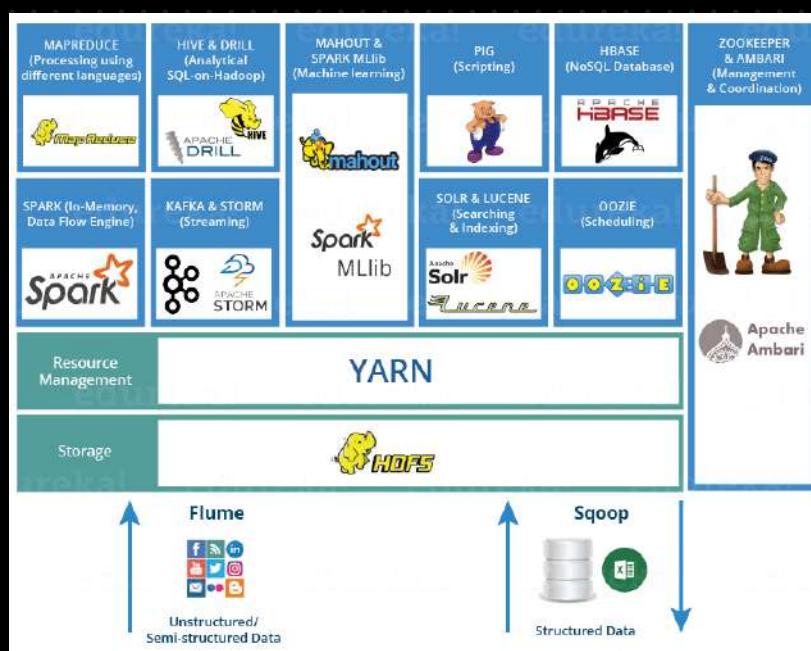
1. Scalability : Hadoop can scale horizontally
2. Fault tolerance: Hadoop maintains copy/replicas to avoid failure if any single m/c
3. Distributed processing : Hadoop can process the data where it is stored
4. Cost effectiveness : inexpensive hardware / commodity machines can be used
5. Open Source : Free to use and modify.

Hadoop solving a real world Problem



Hadoop Ecosystem

Hadoop ecosystem is a collection of open-source projects and tool that work together to store, process and analyze large amount of data.



Storage: HDFS, Hbase

Processing: MR, Pig, Hive, Spark

Data ingestion: Flume, Swoop

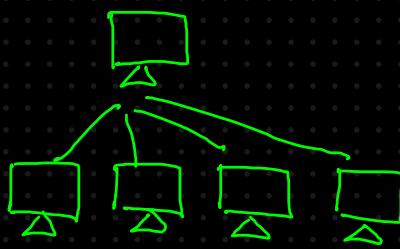
Co-ordination: Zookeeper

Workflow mgmt: Oozie

1. HDFS (hadoop distributed file system)

distributed storage for large datasets

20 node → 20 machines



2. Map Reduce

helps in processing of data by dividing it into smaller task which can run parallelly

3. YARN

decouples the resource management from application execution

4. Hive

Query engine and not a DB

Avoid Java interaction & wanted SQL performance of MR

Hive rocks MR by translating SQL

queries into MR jobs

5. Pig

abstraction of your MR.

MR performance but no JAVA/SQL

high-level scripting language for MR

6. Sqoop

Facilitates import/export between

Hadoop & Relational databases

7. Oozie

automation of MR, XML files for scheduling and automating our work

essential for scheduling complex workflows in our ETL process

8. Hbase

Columnar

NoSQL database which allows real time read and writes on HDFS

9. Mahout

data science component
provides ML libraries

implement algorithm for clustering, classification etc.

10. Flume

Messaging Queue

Collect logs or event data from various sources and deliver them to Hadoop or Hbase

ingesting streaming data

real time analytics for monitoring

11. Zookeeper

Coordinated distributed system to maintain consistency

Critical for ensuring reliability in Hadoop cluster.

2 properties about Hadoop framework

1. Loosely coupled framework

We can remove elements/components and it's still going to work

2. Integration

can be connected with spark or
any other big data frameworks

Same for non-big data

like MySQL, RDBMS

HDFS (Hadoop Distributed file system)

HDFS is a key component of the Hadoop ecosystem. It is designed to store and manage large scale dataset across a distributed environment, making it highly scalable and fault tolerant.

Unlike traditional file system, HDFS is optimized for Big Data, where files are massive and need to be processed efficiently.

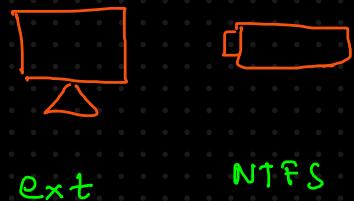
Terminologies

1. File system :

Layer between our Software and hardware



- Linux (ext)
- Windows (NTFS, FAT32)
- Mac OS (APPS)
- Hadoop (HDFS) → distributed

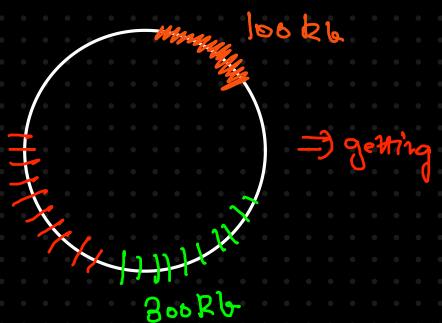


2. Block

Smallest unit of data storage in a file system.

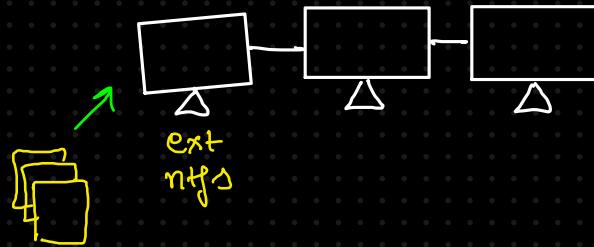
NTFS 4 Kb 10 Kb → 3 blocks

HDFS 128 mb



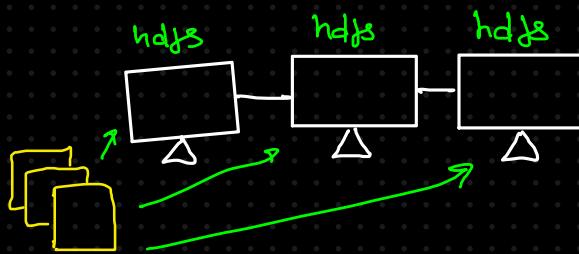
Types of File system

1. Standalone



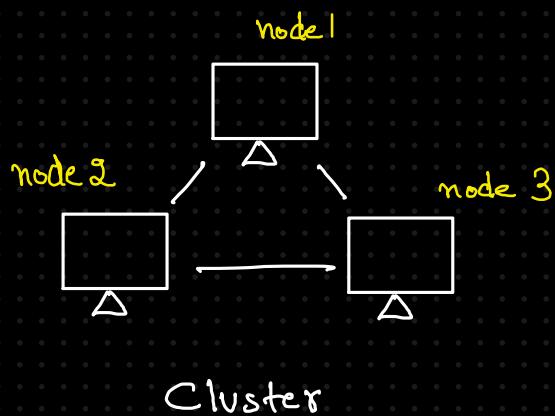
files are stored and managed
in a single machine

2. Distributed



files are stored across multiple
machines in a cluster

4. Cluster and node



5. Process and Daemon process

↓
program in
execution

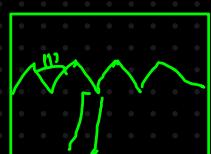
↓
a background
process that
runs without
any user's
intervention

A screenshot of the Windows Task Manager showing the Processes tab. The table lists processes with their names, statuses, and resource usage. A red arrow points to the "FontClient Logging daemon" row, which is highlighted in orange and shows 21.4% CPU usage and 9,285.0 MB memory usage.

Name	Status	100% CPU	96% Memory	8% Disk	0% Network	Power usage
FontClient Logging daemon	Running	21.4%	9,285.0 MB	0.1 MB/s	0 Mbps	High
Microsoft Teams (2)	Running	17.7%	477.9 MB	0.1 MB/s	0 Mbps	High
Google Chrome (19)	Running	1.4%	382.4 MB	0 MB/s	0.1 Mbps	Very low
Firefox (4)	Running	0%	138.3 MB	0 MB/s	0 Mbps	Very low

6. Metadata

Data about data
'index page'



size
created
modified
perm
Quality

7. Replication

process of making copies of our data

it is needed to achieve fault tolerance

Why HDFS?

Relocation



essence of HDFS

1. Distributes data across multiple nodes / machine
2. Replicates data to ensure fault tolerance
3. Provides efficient access for Big Data Processing

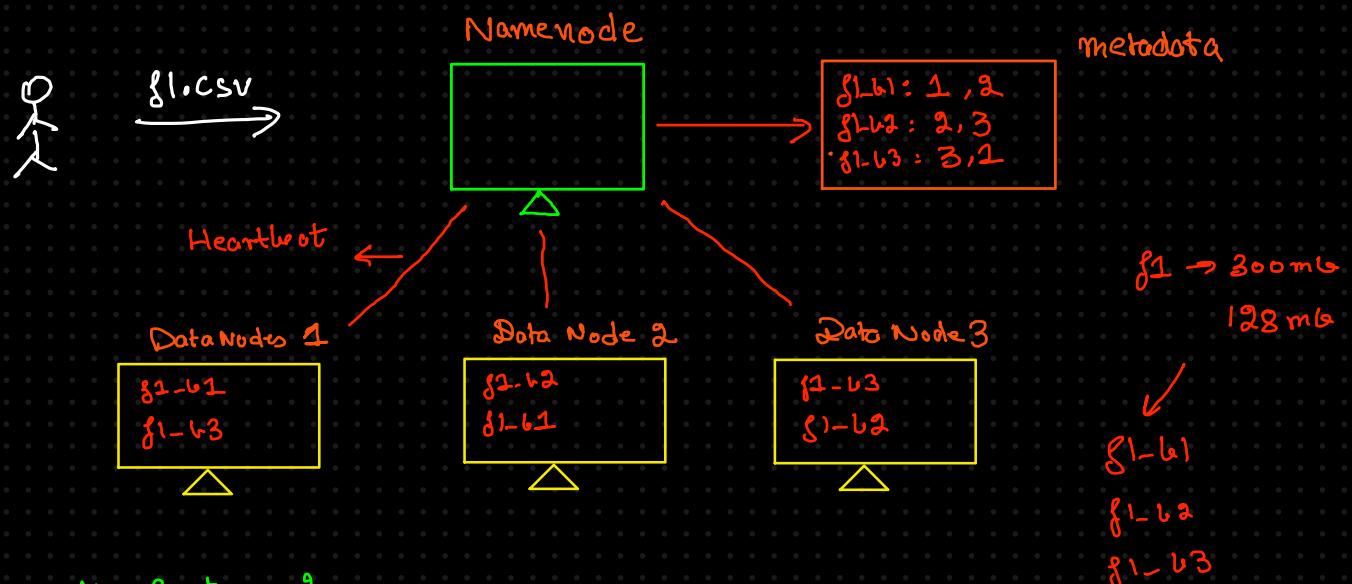
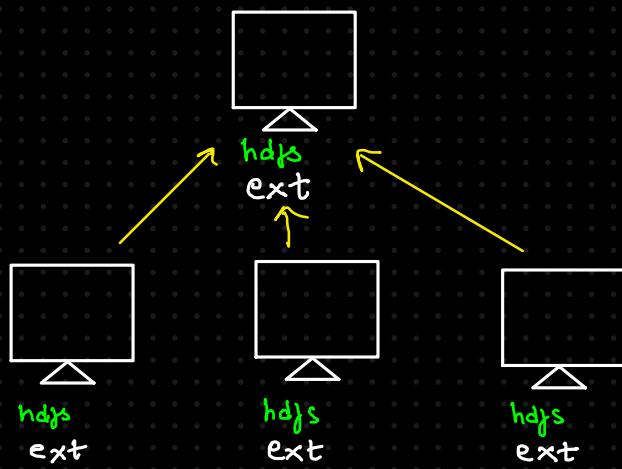
HD**F**S architecture

Master - Worker architecture

machine cluster

Hadoop

dataproc



Name node → librarian

Data nodes → shelves

Data blocks → books

Aspect	NameNode	DataNode
Definition	The master node in the HDFS architecture. It manages metadata and file system namespace.	The worker nodes in HDFS. They store the actual file data in blocks.
Purpose	Keeps track of file locations, file metadata, and directory structure (but does not store data).	Responsible for storing, retrieving, and replicating data blocks.
Role	Coordinator – directs how files are stored and accessed across DataNodes.	Executor – performs read and write operations as instructed by the NameNode.
Data Stored	Metadata (e.g., file names, permissions, and locations of data blocks).	Actual data split into blocks.
Dependency	HDFS cannot function without a NameNode. It is the single point of failure in non-HA setups.	HDFS can function with one or more DataNodes, and their failure does not stop the system.
Communication	Communicates with clients for file operations and with DataNodes to track block statuses.	Communicates with the NameNode for block operations and periodically sends heartbeat signals.
Fault Tolerance	Does not store redundant copies (replication is for data blocks only).	Handles fault tolerance through block replication across multiple DataNodes.
Processes	Maintains and updates the file system namespace dynamically.	Regularly reports to the NameNode with block reports and health checks.
Example Role	Acts like a manager in a library , knowing the exact shelf (DataNode) where a book (block) is stored.	Acts like the shelves in the library , holding and managing the physical books (blocks).

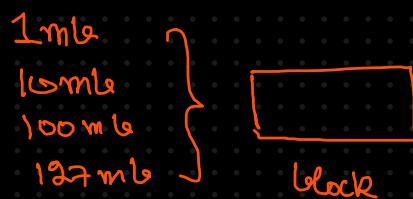
Blocks in HDFS

- a block is the smallest unit of storage in HDFS
- Each file stored in HDFS is divided into blocks, which are then distributed across multiple data nodes.

default size - 128 mb



Name node has less metadata to manage.



1. efficient for large files
2. Distributed storage and computation

Q. Can we change the block size in our Hadoop cluster?

Yes.

1. Decreasing the block size

128mb → 1mb

500mb → 5 * 50



help in increasing parallelism but also metadata will increase

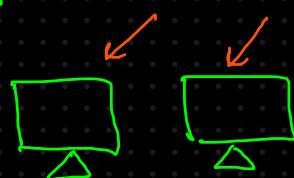
2. increase the block size:

128mb → 512mb

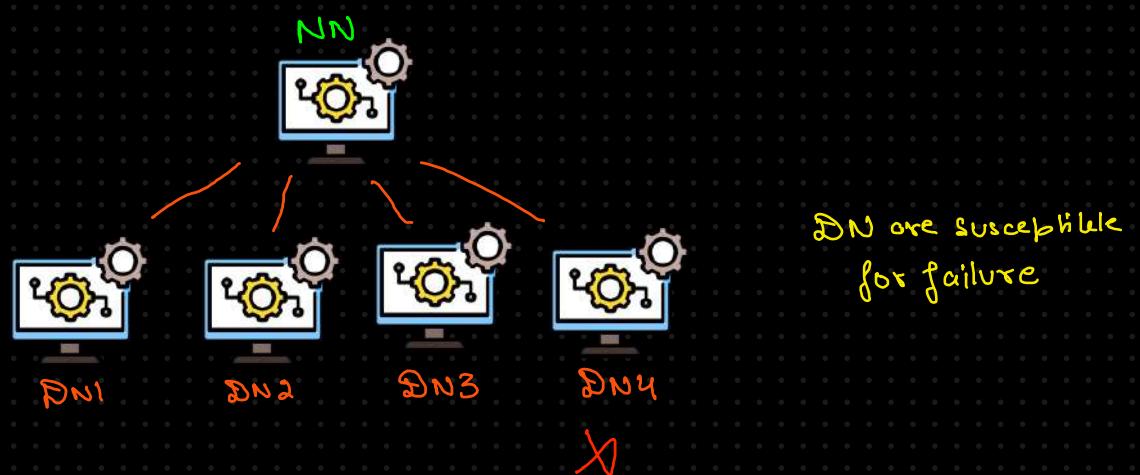
less parallelism

⇒ less metadata

1gb file → 2 squares



Data Node (worker) failure in HDFS



Replication in hdfs

default RF = 3 1 original
2 copies Log → 3gle

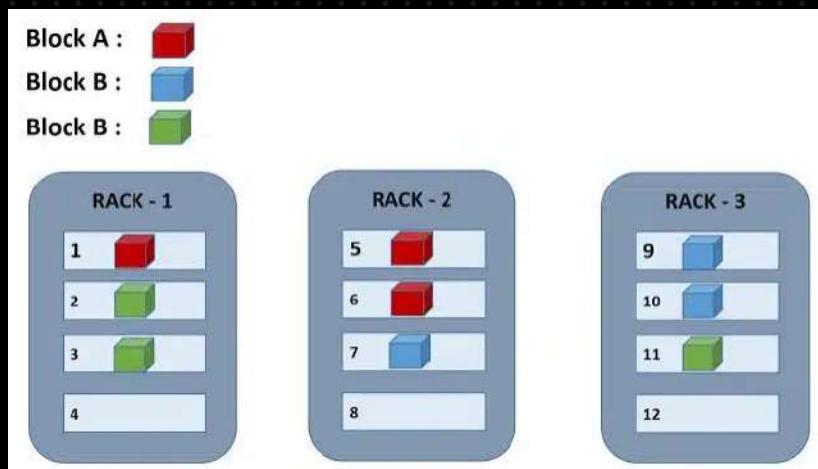
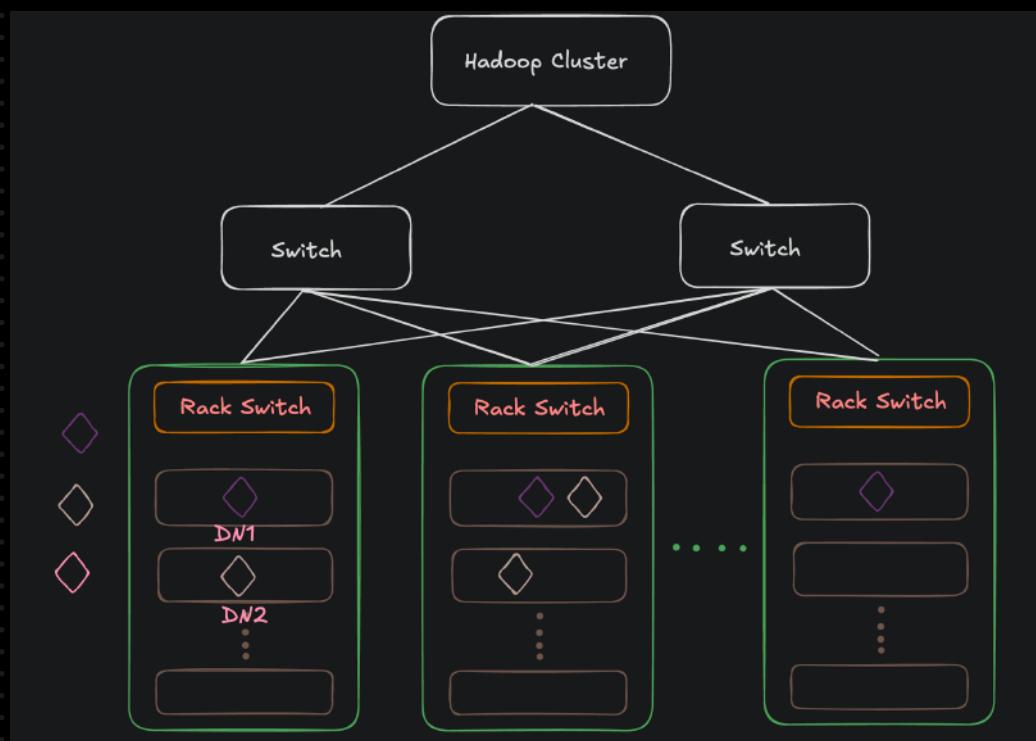


Rack awareness in HDFS

A rack is a collection of DataNodes that are physically close together, often in the same network switch.



Rack awareness algorithm ensures that replicas are distributed across different racks and not just different DataNodes.

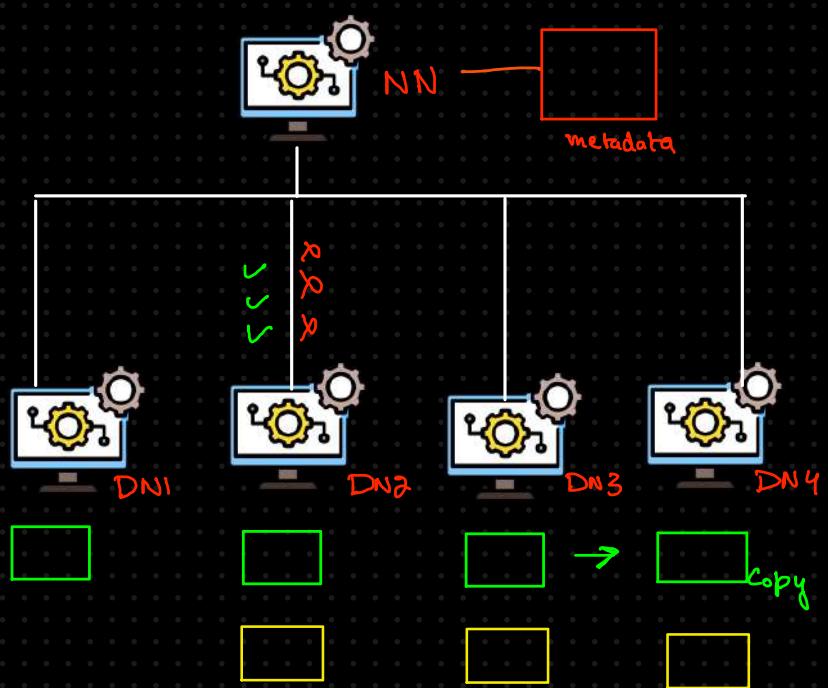


Data Node Failures in Hadoop Cluster

Temporary failure

DN is unavailable due to some transient issue.

1. Network outage
2. Software crashes
3. Node reboot maintenance



→ heartbeat
→ block report

1. Detection 10.5 minutes

2. Replication

1 green block

1 yellow

Under-replicated

3. When DN recovers

Metadata is updated

to ensure consistency

after the excess
replicas are deleted

library

book → block

DN → block



Cleaning

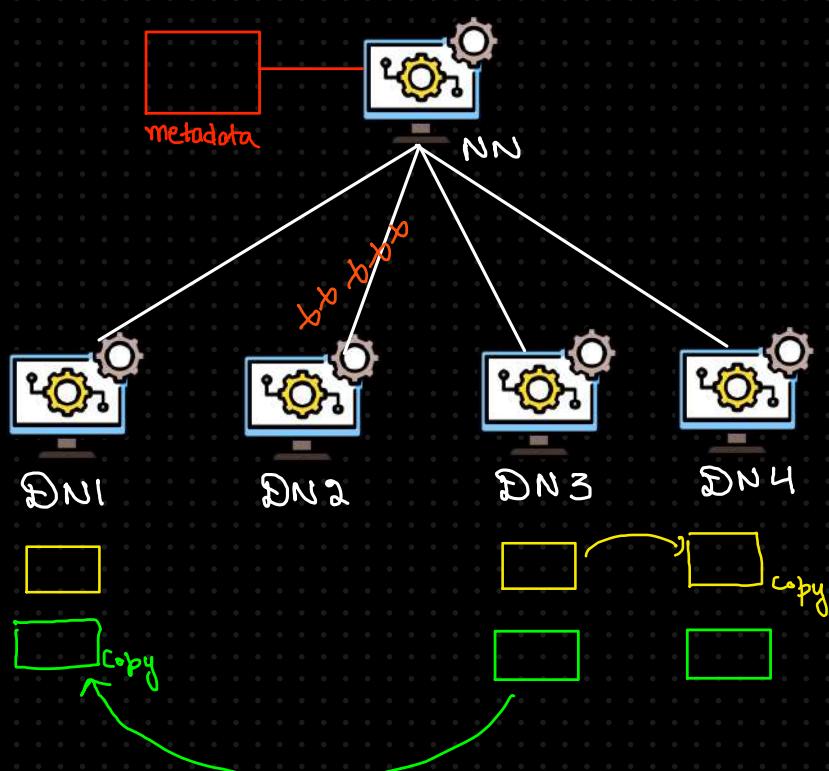


Permanent Failure

when a data node is permanently lost.

1. Hardware failure
2. Disk corruption
3. Decommissioning of a node

> 10.5 minutes



1. Detection

2. Replication

Blocks on **DN2** are marked lost

3. Machine comes back

The m/c is not trusted

Data node can get reintegrated
in our system as a fresh
node i.e. blocks are ignored
and cleaned up to avoid
data inconsistency.

Library



Liu



fire

Aspect	Temporary Failure	Permanent Failure
Failure Cause	Network issues, software crashes, or reboots.	Hardware failures, disk corruption, or decommissioning.
Detection	DataNode stops sending heartbeat signals; marked as temporarily unavailable.	DataNode stops sending heartbeat signals for an extended period; marked as dead.
Replication Trigger	Blocks on the failed DataNode are marked as "under-replicated," and new replicas are created.	Blocks on the failed DataNode are treated as lost, and new replicas are created.
Returning DataNode Behavior	Sends a block report to the NameNode. Excess replicas are deleted to restore the replication factor.	Returning DataNode is not trusted. Its blocks are treated as stale and eventually cleaned up.
Metadata Updates	Metadata dynamically updates to include new replicas and remove excess copies.	Metadata permanently removes blocks from the failed DataNode and updates mappings for new replicas.
Library Analogy	A locked bookshelf temporarily restricts access. Extra copies are reconciled when it becomes available.	A destroyed bookshelf is permanently removed from the catalog, and its books are replaced elsewhere.

1. HDFS handles failures gracefully
2. Metadata is the backbone of HDFS
3. Replication factor is strictly maintained.

Name Node failure

The name node is the most critical component in the HDFS as it manages the metadata and namespace of the filesystem.



Single point of failure (SPOF)

Secondary Name node

it helps in checkpointing & size management of our primary datanode.

Standby NN



register



Edit logs

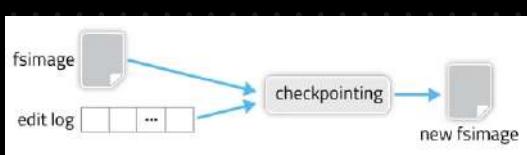
new block addition
replication
deletion etc.



Secondary Name Node

← 1. checkpointing
2. size mgmt

Combining → new fsimage'



Secondary NN is not a failover mechanism



Works fine if we can afford downtimes.

Standby Name node

Hadoop 2.x

it is a hot backup for your NN

High availability

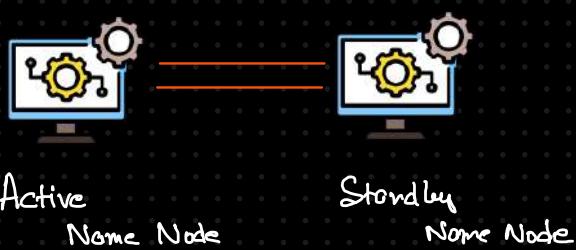
→ Constant connection with master

→ makes the copy of namespace image in memory

Secondary NN

1. Checkpointing
2. Size management

⇒ still our NN/master is the SPOF



1. High availability: it can take the role of Active NN when required.

2. failover mechanism: Seamless takeover ensuring no data loss and minimum downtime.

3. Synchronization : all edit logs are applied & Standby NN always up-to date

Primary



active

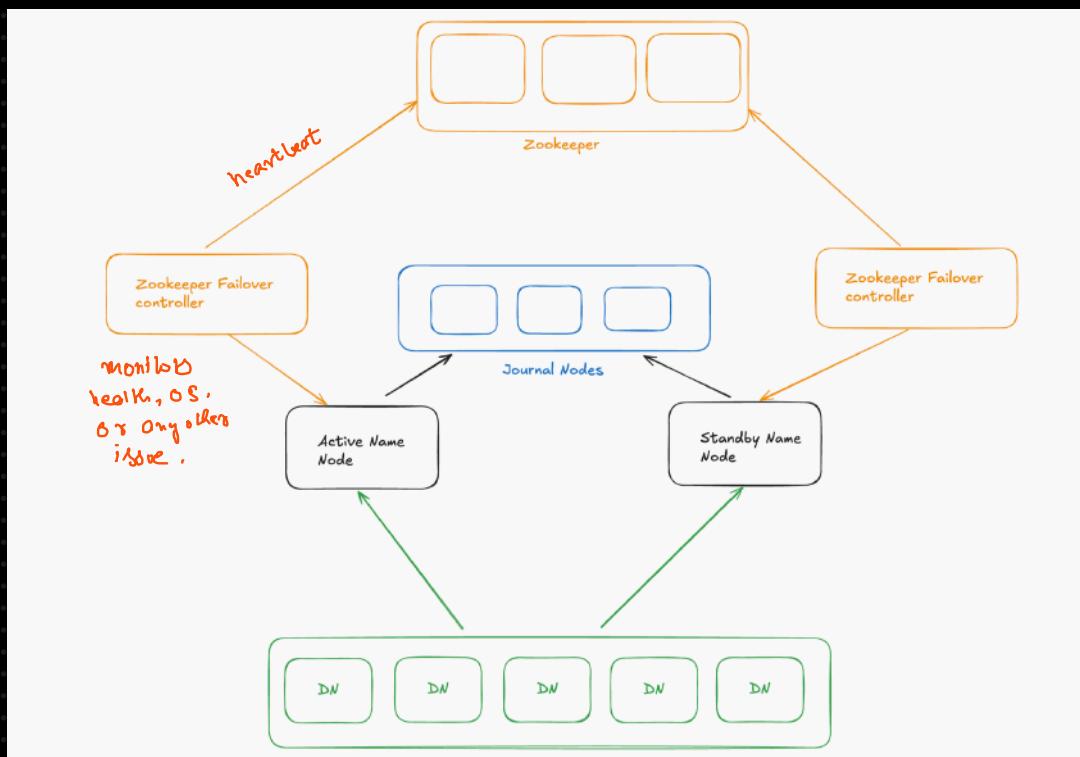


Standby NN

Aspect	Secondary NameNode	Standby NameNode
Role	Helper for checkpointing and edits log management.	Hot backup for Active NameNode, enabling seamless failover.
High Availability	Does not provide HA; cannot replace the NameNode.  NN is SPOF	Ensures HA by taking over the Active NameNode's role on failure.
Synchronization	No continuous synchronization; works periodically.	Continuously synchronized with the Active NameNode.
Failover Capability	Not capable of failover; only provides updated fsimage.	Fully capable of taking over in case of Active NameNode failure.
Introduced In	Hadoop 1.x	Hadoop 2.x

Hadoop High Availability (HA) Architecture

High availability architecture ensures the continuous operation of the hadoop cluster even if the active Name node fails.



→ high availability
→ minimal downtime

Critical for a production grade cluster

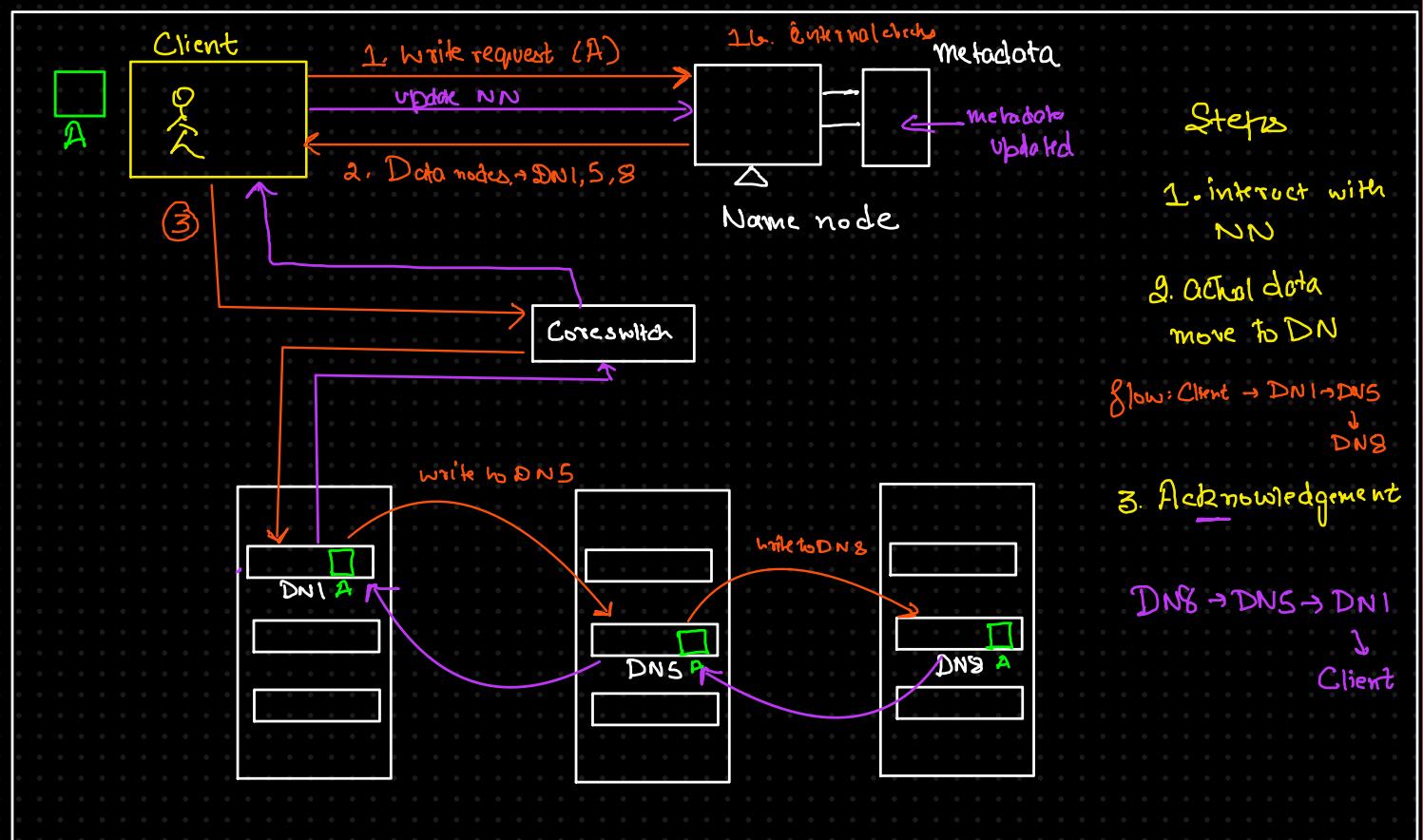
Component	Role	Explanation
Active NameNode	Main controller managing HDFS namespace and block information.	Handles all client operations like file creation, deletion, and metadata management.
Standby NameNode	Hot backup of the Active NameNode, ready to take over during failure.	Synchronizes its state with the Active NameNode using edit logs stored in JournalNodes.
DataNodes (DN)	Store actual data blocks and handle data read/write operations.	Send regular block reports to both Active and Standby NameNodes.
JournalNodes (JN)	Maintain a shared edit log that keeps both NameNodes synchronized.	Facilitate consistent updates to the Standby NameNode to ensure it has the latest changes in the HDFS namespace.
Zookeeper (ZK)	Coordinates failover and prevents split-brain scenarios.	Monitors NameNode states and triggers leader election during failover.
FailoverController	Monitors the health of NameNodes and initiates failover.	Works with Zookeeper to perform automatic failover when the Active NameNode is unresponsive.
Heartbeat Mechanism	Periodic signals exchanged between components to check health.	Ensures timely detection of failures in NameNodes or DataNodes.
Block Reports	Periodic reports from DataNodes to NameNodes about stored blocks.	Ensures both Active and Standby NameNodes have accurate information about the location of data blocks in the cluster.
Clients	Users or applications interacting with the Hadoop cluster.	Access HDFS files through the Active NameNode. Failover is transparent to clients, ensuring uninterrupted service.

We can also use
NFS (Network File Storage)

Split-brain scenario →
ensuring only one active
NN thus preventing
conflict.

Write operation in HDFS

using HDFS as a distributed data storage



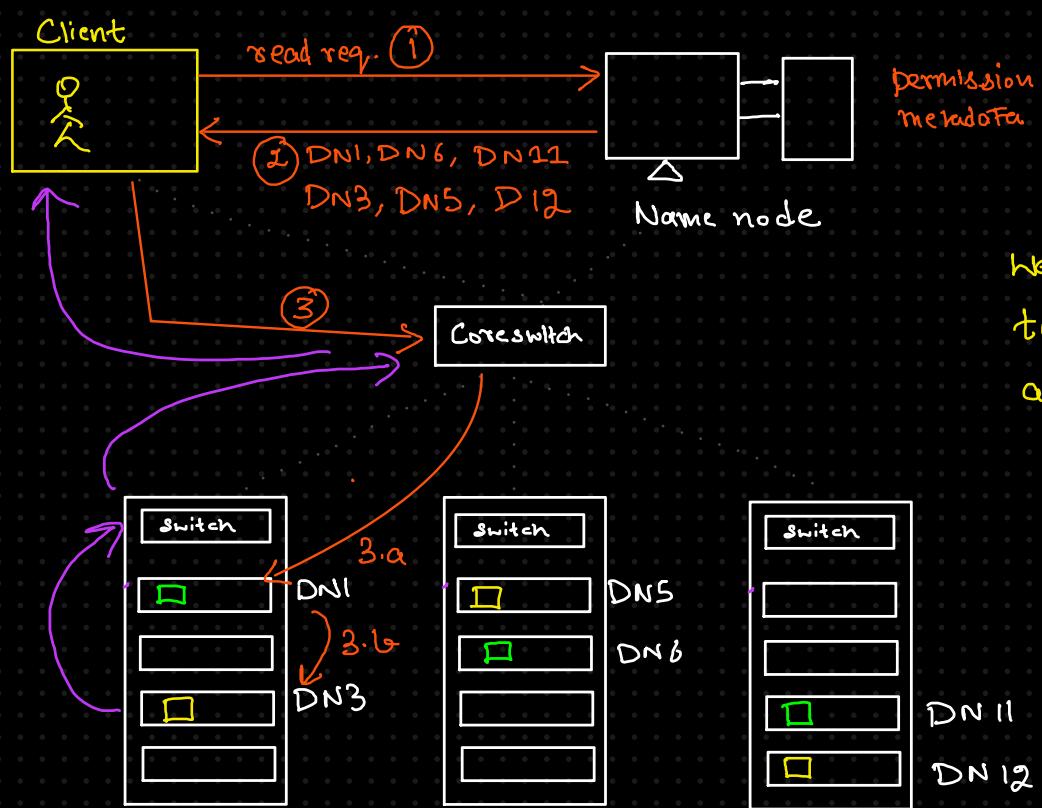
Fault tolerance & failure handling

1. DN fails during the write.
2. Client fail
3. Network / Rack failure
4. Name node failure
5. DN failure

Read operation in HDFS

The process of reading the data kept on the HDFS cluster

Read request does not require an acknowledgement



We don't need
to read data from
all the copies.

Google cloud platform

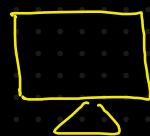
cloud.google.com

Please make sure to first focus on getting the service we want work perfectly.

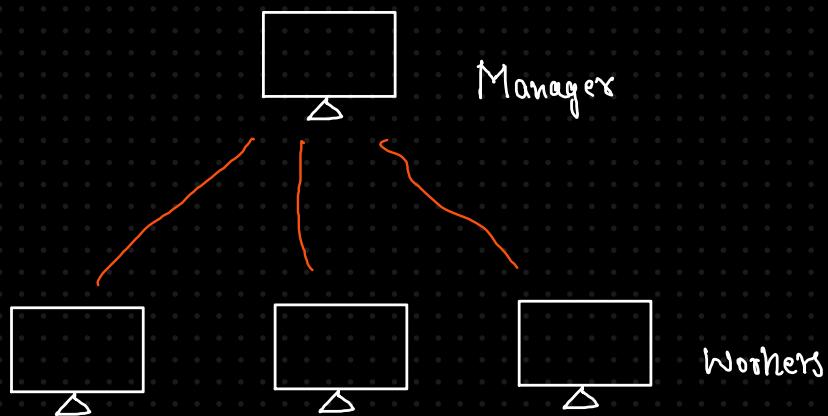
Cluster type

- Standard (1 master, N workers)
- Single Node (1 master, 0 workers)
Provides one node that acts as both master and worker. Good for proof-of-concept or small-scale processing
- High Availability (3 masters, N workers)
Hadoop High Availability mode provides uninterrupted YARN and HDFS operations despite single-node failures or reboots

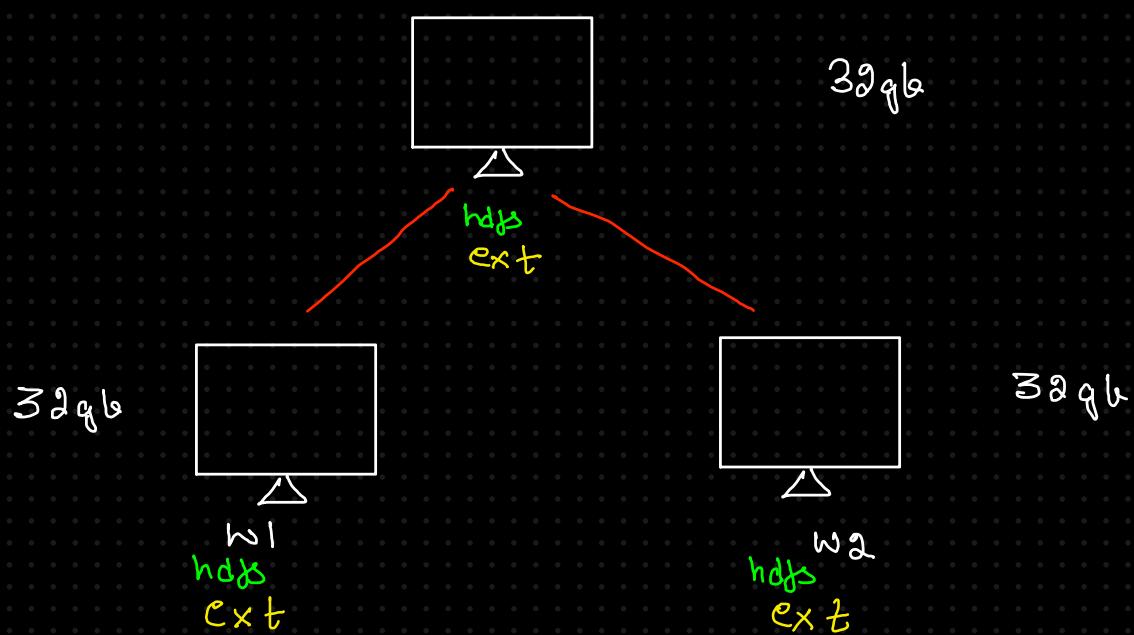
⇒ Pseudo distributed cluster



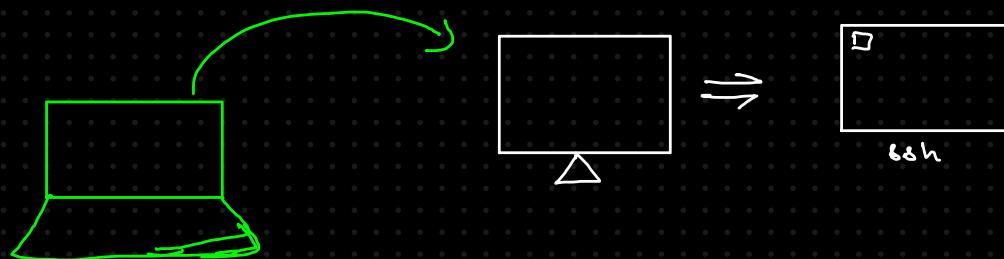
Autoscaling



More on Google dataproc Hadoop cluster



Some internal space will be used by machine for OS, drivers.



linux] → terminal
mac

windows → cmd / powershell

Linux Commands

As a data engineer, proficiency in linux command is crucial for

- managing data pipelines
- handling files
- working with distributed systems

Windows

Linux

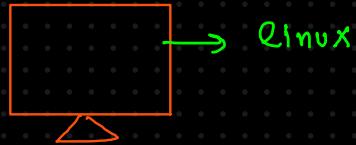
MacOS

gcp → 3 machines

1M 2W

debian OS

→ very lightweight
→ easy to install & maintain



cli

terminal → linux & macos

Windows terminal / Ubuntu subsystem / Github cli

Clear

1. Navigation Command

(a) `pwd` → print working directory

(b) `cd` → change directory

absolute vs relative path

tab helps to

auto complete

Wordcount
 home → mayank → localfile
 ↓
 test-dir

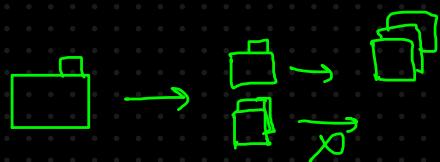
(c) directory listing

`ls`

blue → folder/dir

green → executable files

black → normal files



```
drwxr-xr-x 2 mayank0953 mayank0953 4.0K Jan 11 05:12 wordcount
-rw-r--r-- 1 mayank0953 mayank0953 231M Jan 11 15:27 logfile.txt
drwxr-xr-x 2 mayank0953 mayank0953 4.0K Jan 12 03:35 wordcount_twoReducers
drwxr-xr-x 2 mayank0953 mayank0953 4.0K Jan 12 04:09 wordcount_noReducer
drwxr-xr-x 3 mayank0953 mayank0953 4.0K Jan 13 09:57 localFile
-rw-r--r-- 1 mayank0953 mayank0953 0 Jan 13 10:04 test.bat
-rwxr-xr-x 1 mayank0953 mayank0953 0 Jan 13 10:07 test.exe
```

↓

d

-

rwx r-x r-x

owner

group

others

r → read (4)

w → write (2)

x → execute (1)

chmod

More linux Commands

File operations

Move

`mv` filename finallocation

Remove

`rm` filename
`rm -r` dir

Copy

`cp` source destination

File → create and view content

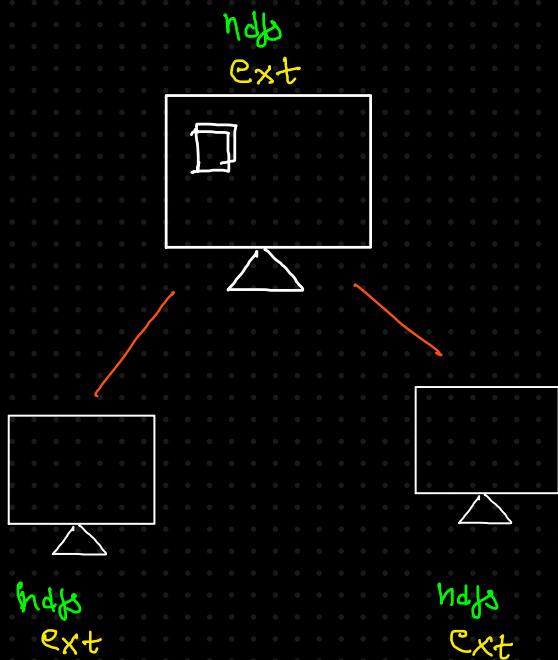
→ please refer here for complete details on command discussed

<https://allthingdata.substack.com/p/essential-linux-commands-for-data>

HDFS commands

hadoop fs _____

hdfs dfs _____



Copy data from local to hdfs

hadoop fs -put
-copy from local

file name

destination

<https://allthingdata.substack.com/p/essential-hdfs-commands-for-data>

