Hadoop Architecture

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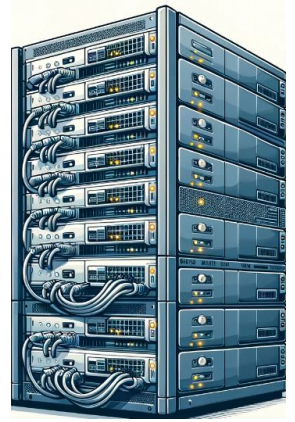
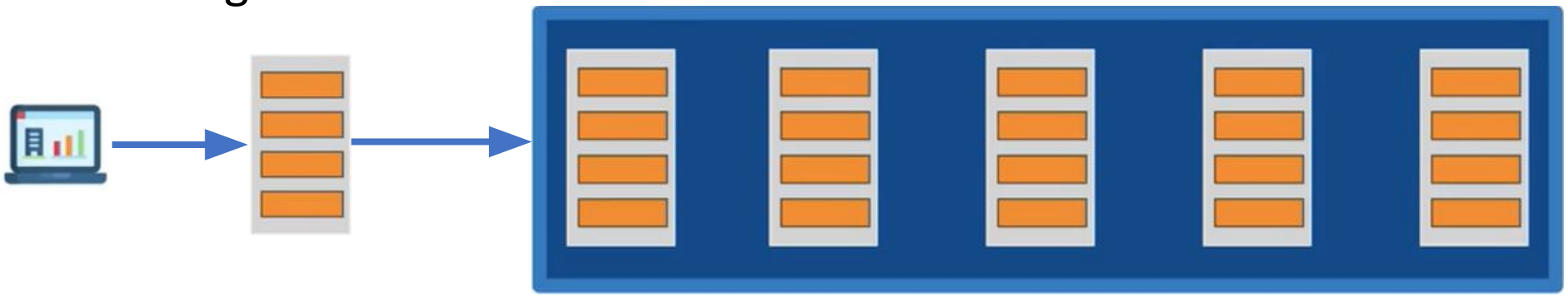
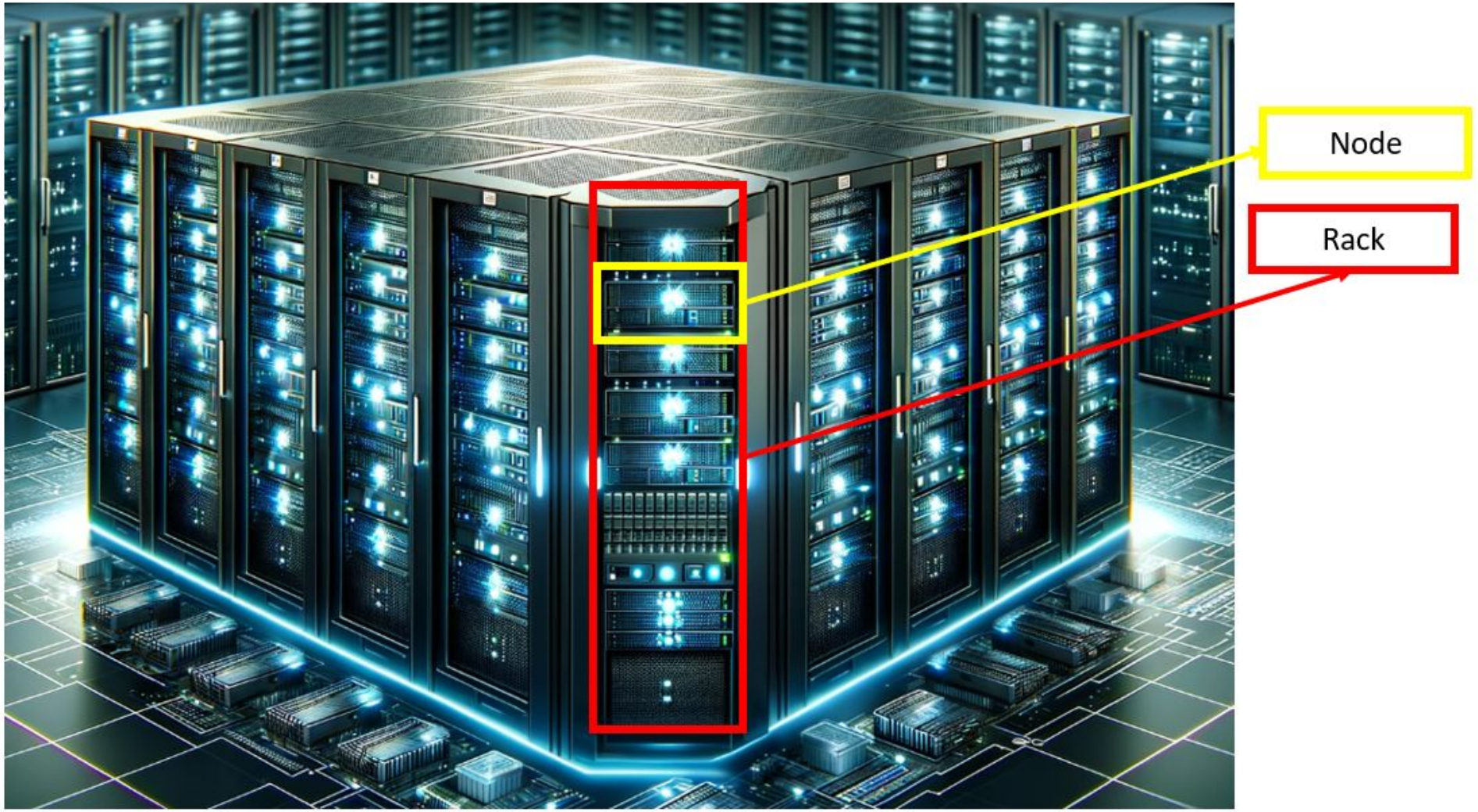
Apache Hadoop



- **Node:** Node is a single **commodity hardware** which is used to store the actual data. Node can be physical computer or virtual machine.
- **Commodity hardware:** Inexpensive, easily accessible, and interchangeable computing systems or components that are widely available in the market.
- **Rack:** Rack is the collection of nodes. Mostly 30 to 40 nodes exist in a single rack.
- **Cluster:** Cluster is the collection of racks that are networked together to preform parallel computation on big data sets

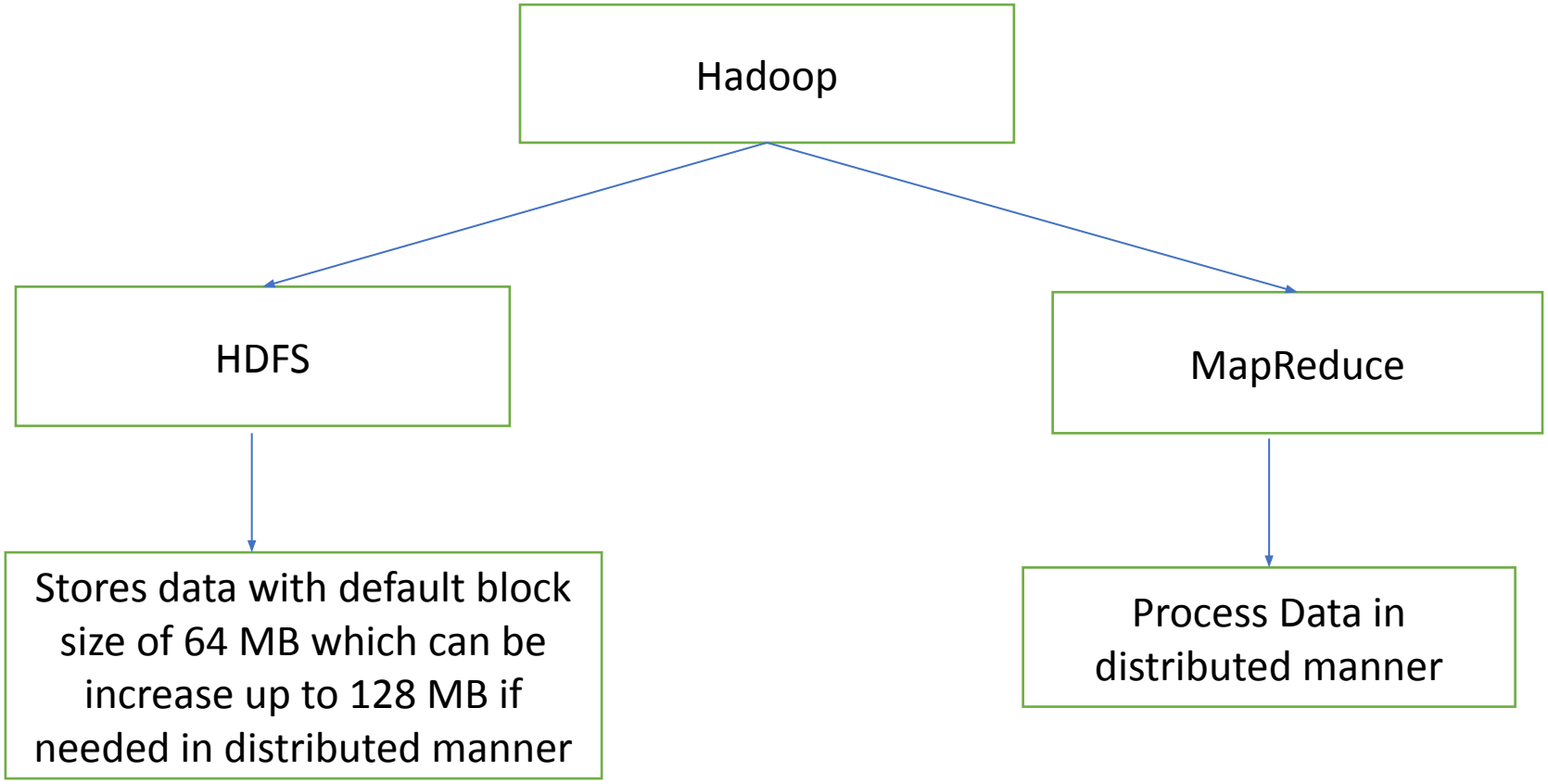


Cluster



Architecture

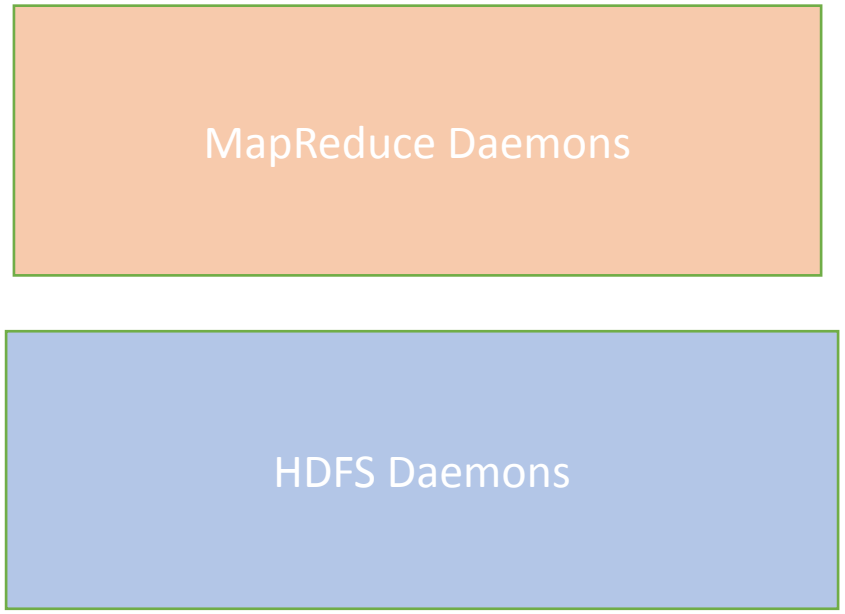
- Hadoop 1.X provides a distributed storage system called HDFS or Hadoop Distributed File System and MapReduce to tackle big data challenges.



Both components involve a set of processes

Architecture

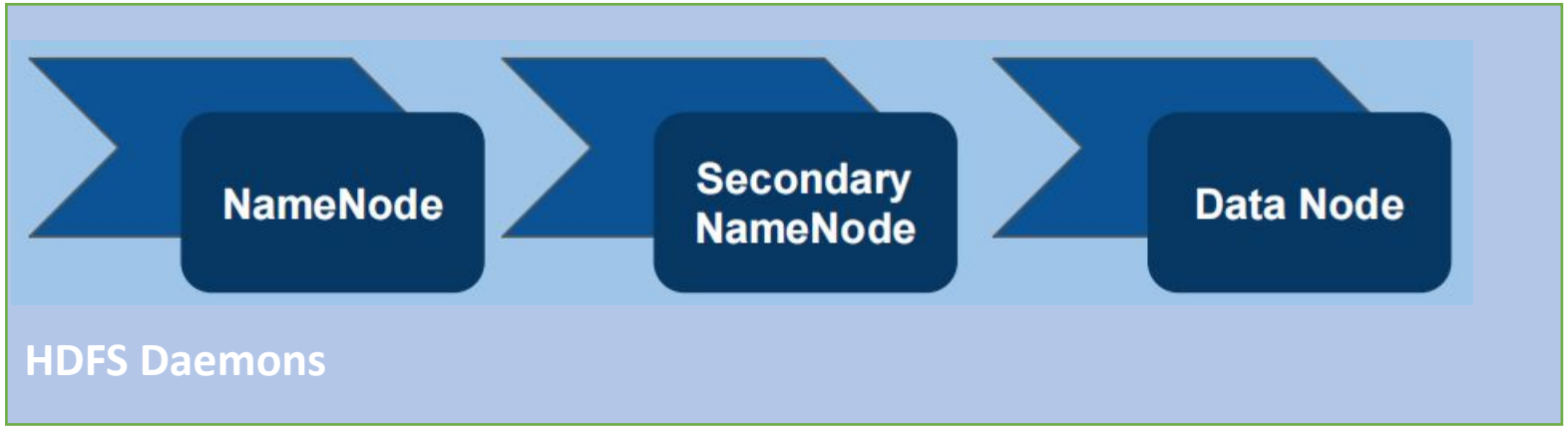
- Daemons refers to the background processes that run on the servers in a Hadoop cluster.
- These daemons are continuously running services that perform the necessary tasks to manage and process data.
- Often, a daemon waits for specific events to occur or provides certain services.



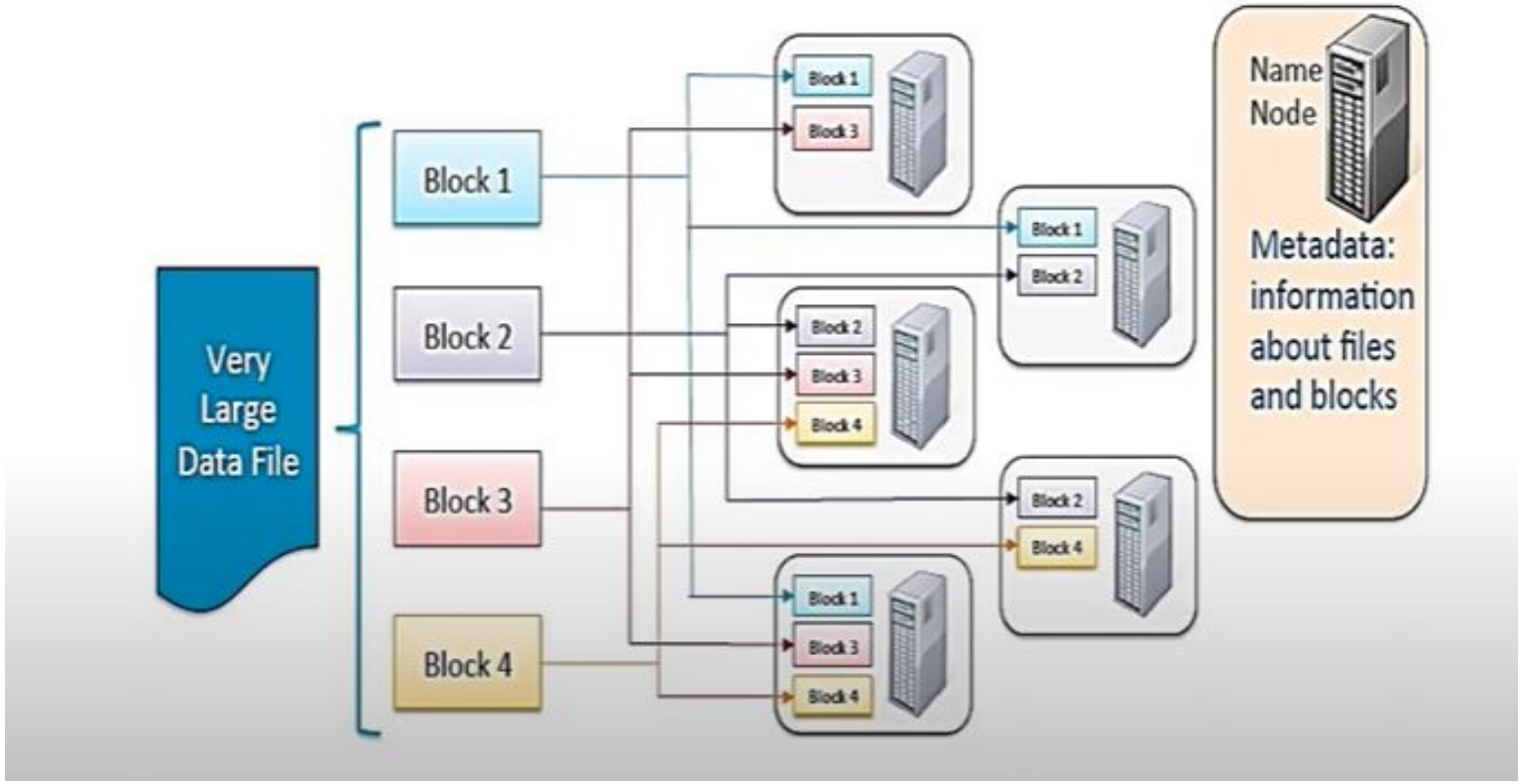
Architecture

- In Hadoop, there are three main daemons:

1. NameNode
2. Secondary NameNode
3. DataNode



How file is stored in HDFS



- A very large data file is split into four smaller blocks (Block 1, Block 2, Block 3, Block 4)
- Each block is then replicated 3 times across different data node machines
- A name node machine stores metadata about the files and their respective blocks

- When you install Hadoop it comes with configuration files, inside a file we have a property called dfs.replication with default value 3 , we can change it

Name Node

Secondary Name Node

Data Node 1

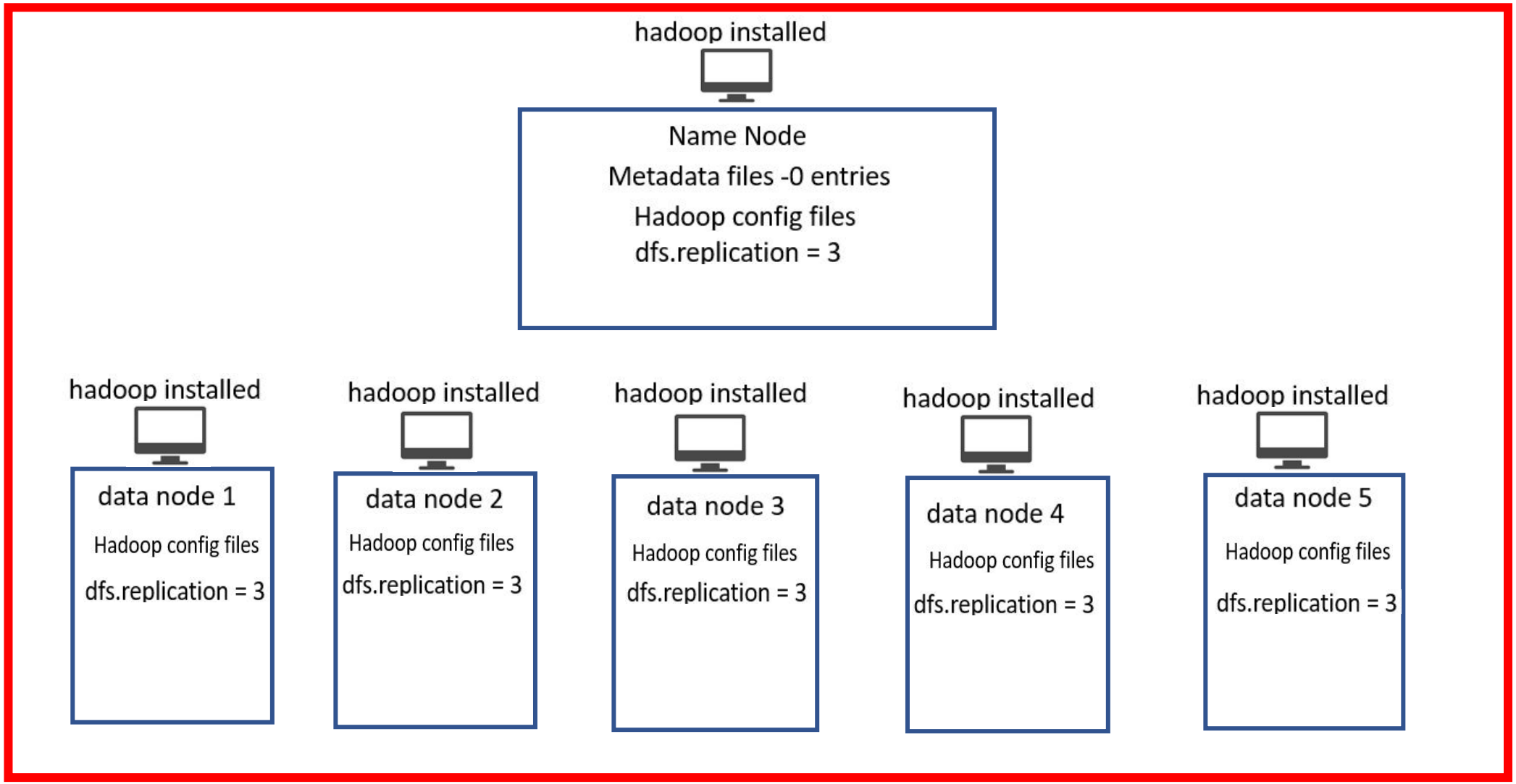
Data Node 2

Data Node 3

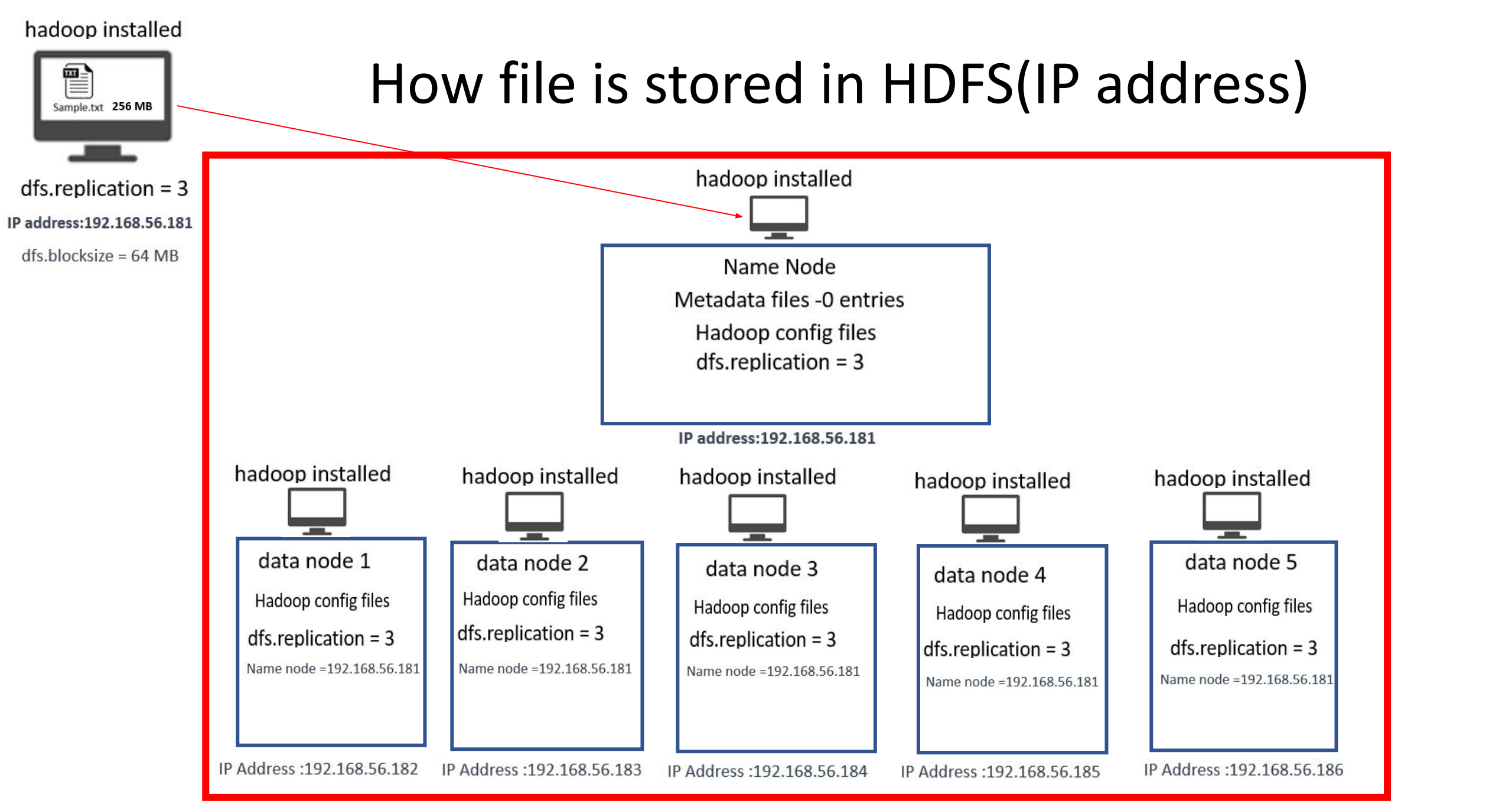
Data Node 4

Data Node 5

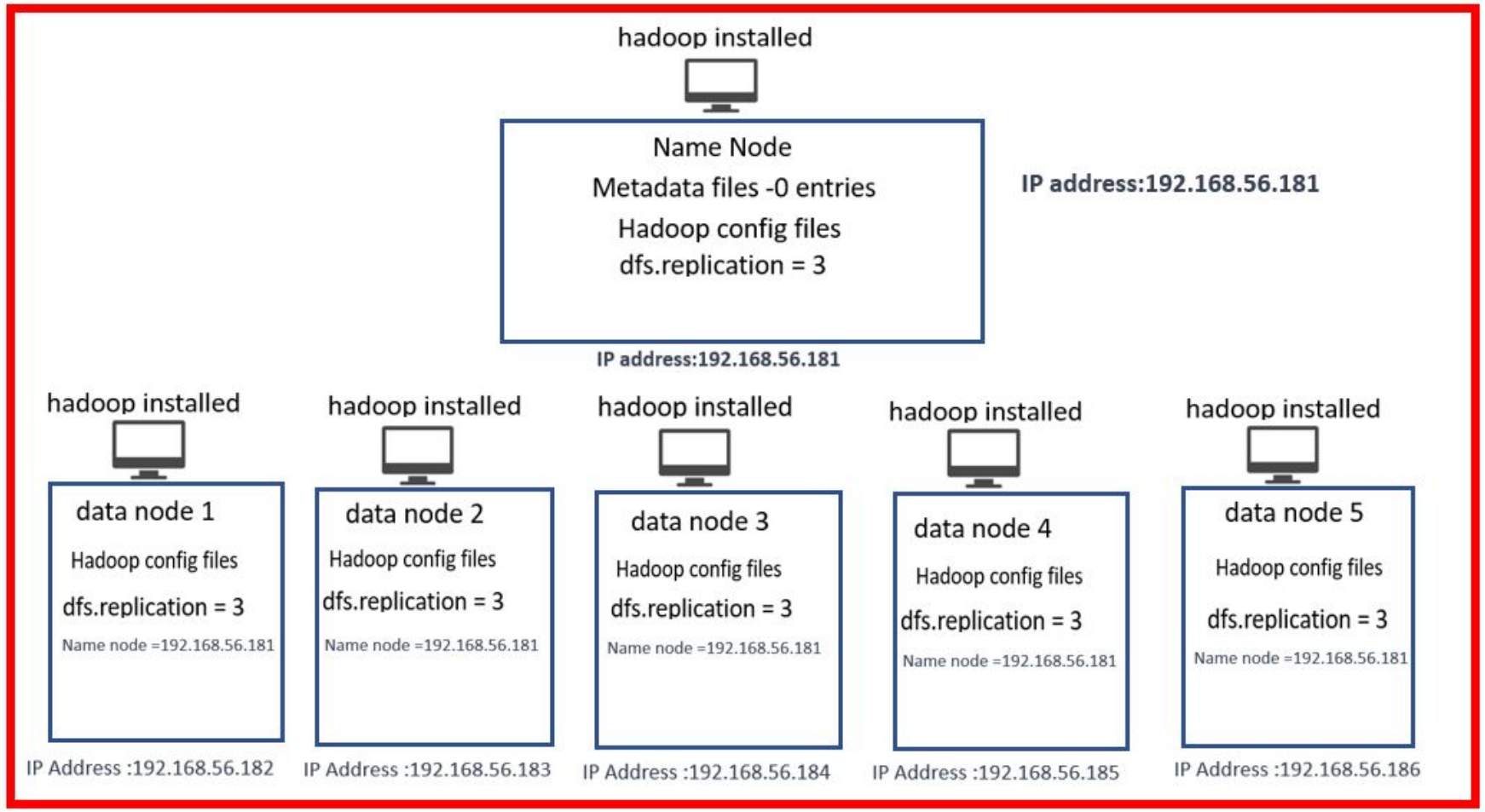
How file is stored in HDFS



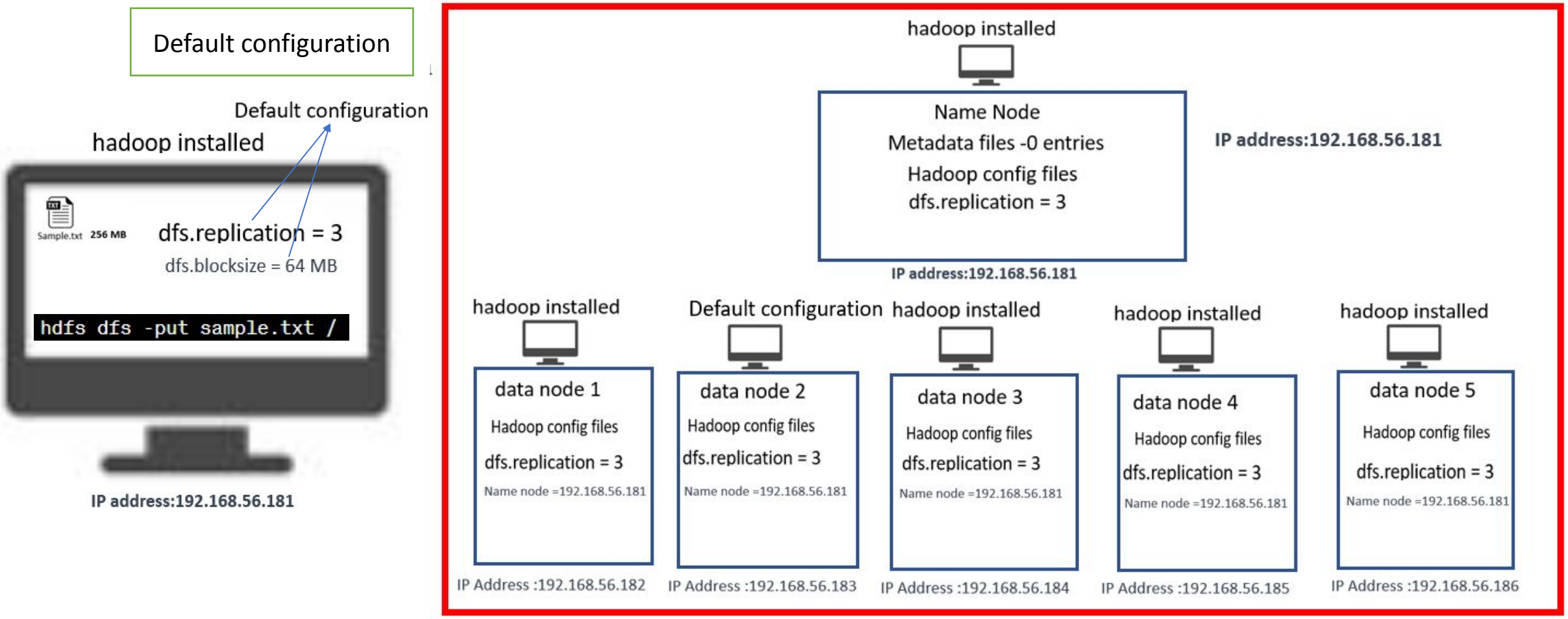
How file is stored in HDFS(IP address)



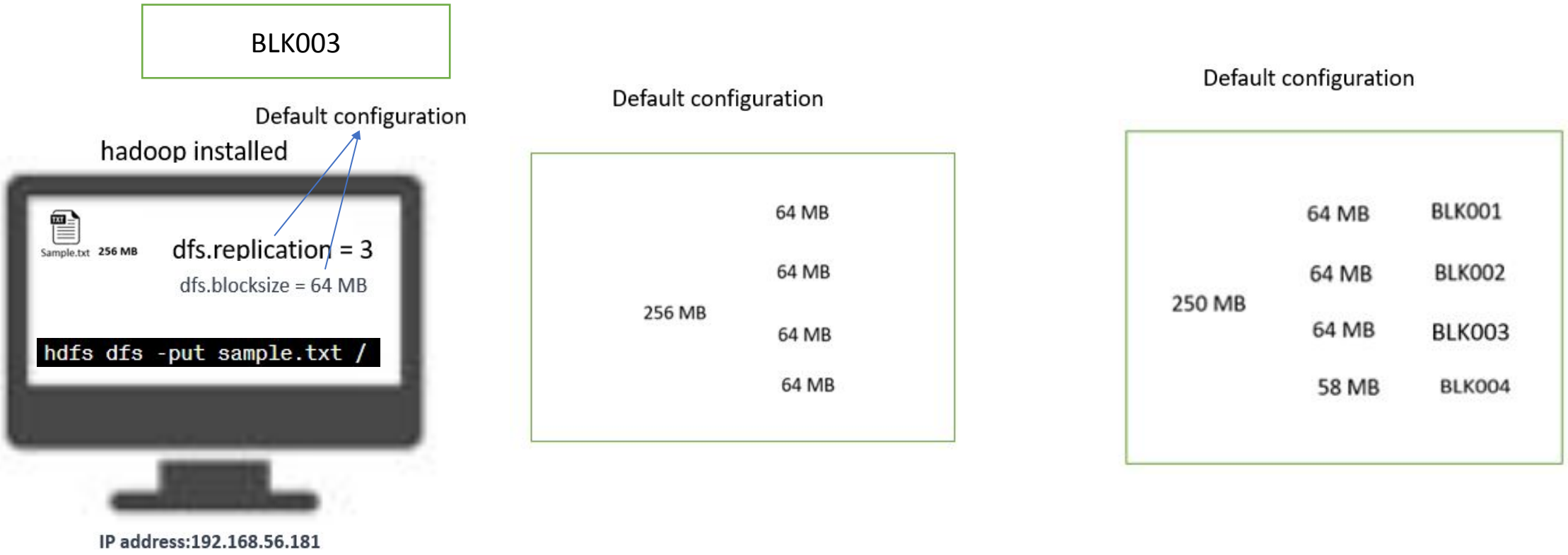
How file is stored in HDFS-Hadoop command



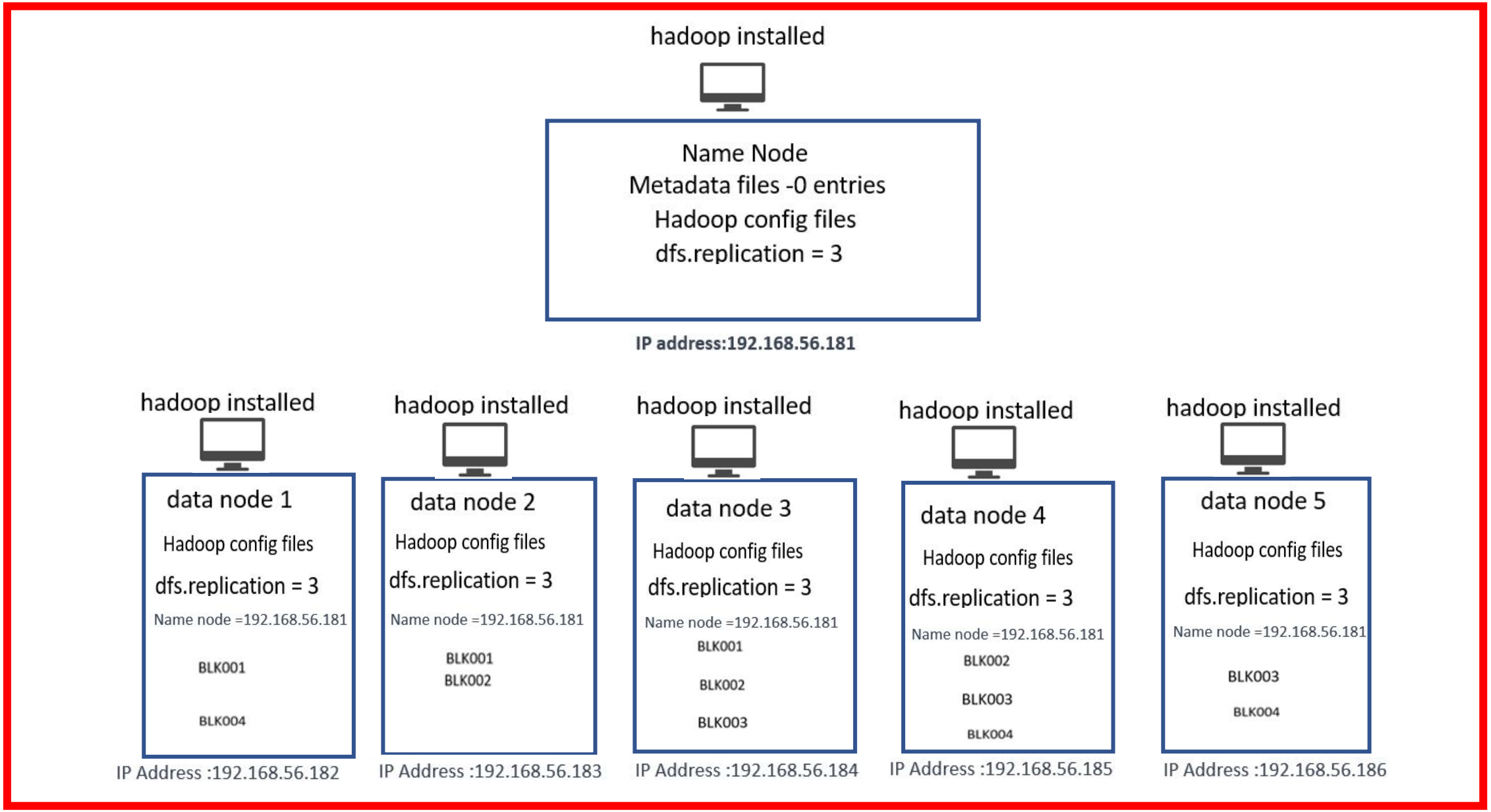
How file is stored in HDFS-default replication



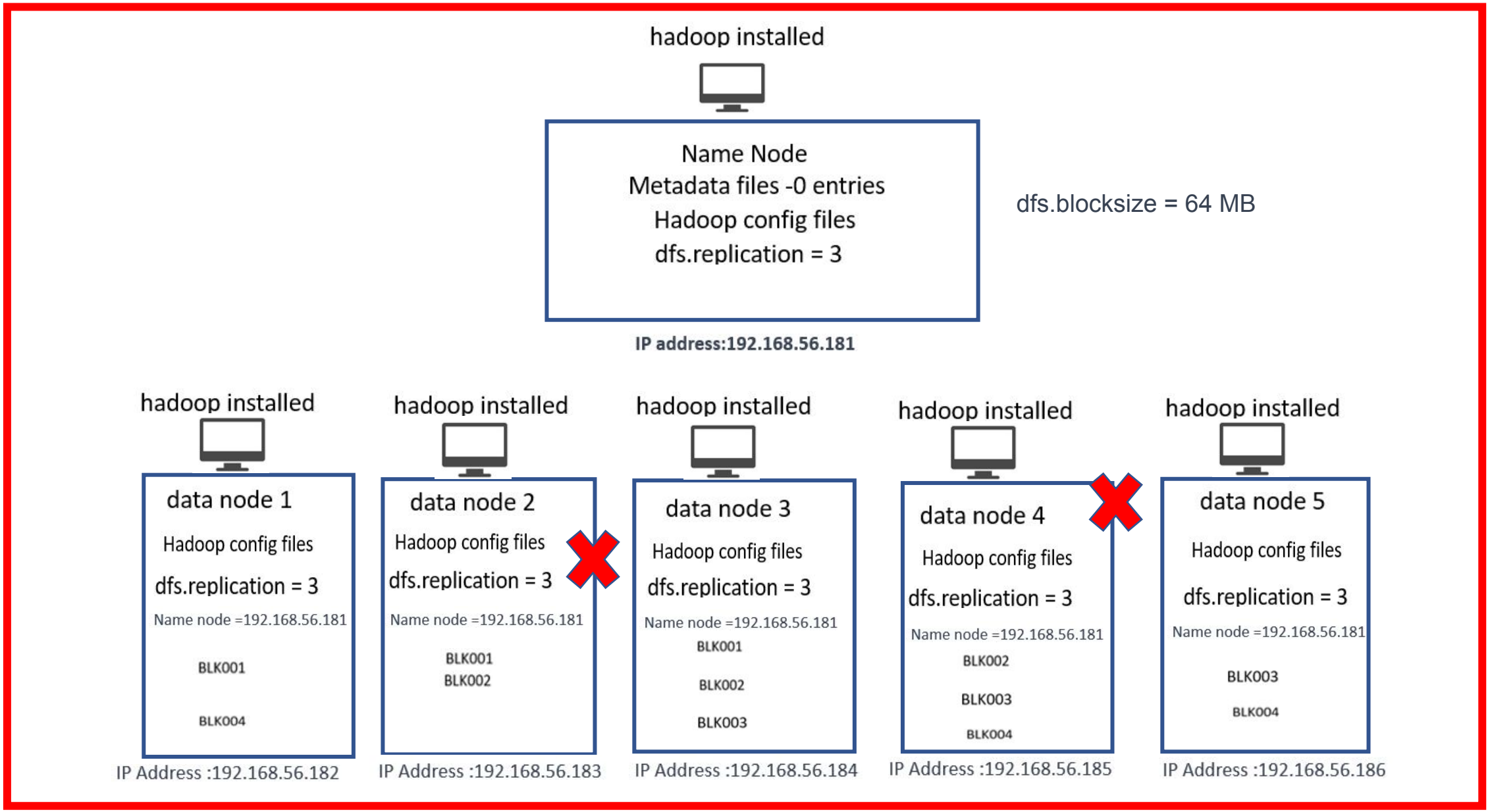
How file is stored in HDFS



How file is stored in HDFS(blocks)



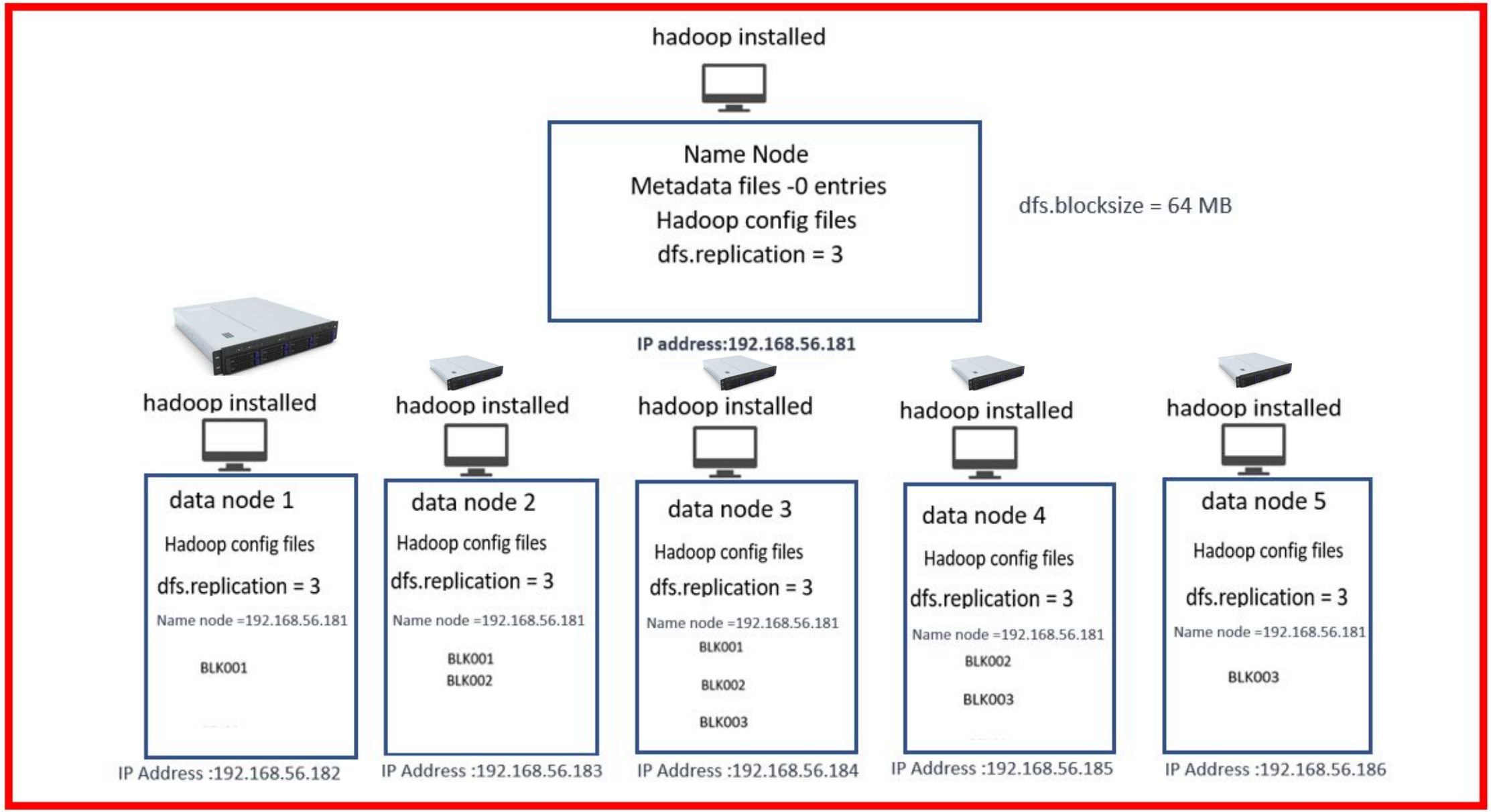
How file is stored in HDFS (why replication)



How file is stored in HDFS-custom config

Sample.txt-256 MB	100MB	BLK001
	100MB	BLK002
	50MB	BLK003

How file is stored in HDFS-blocks



How file is stored in HDFS-custom config

```
1 <= dfs.replication <= 512
```

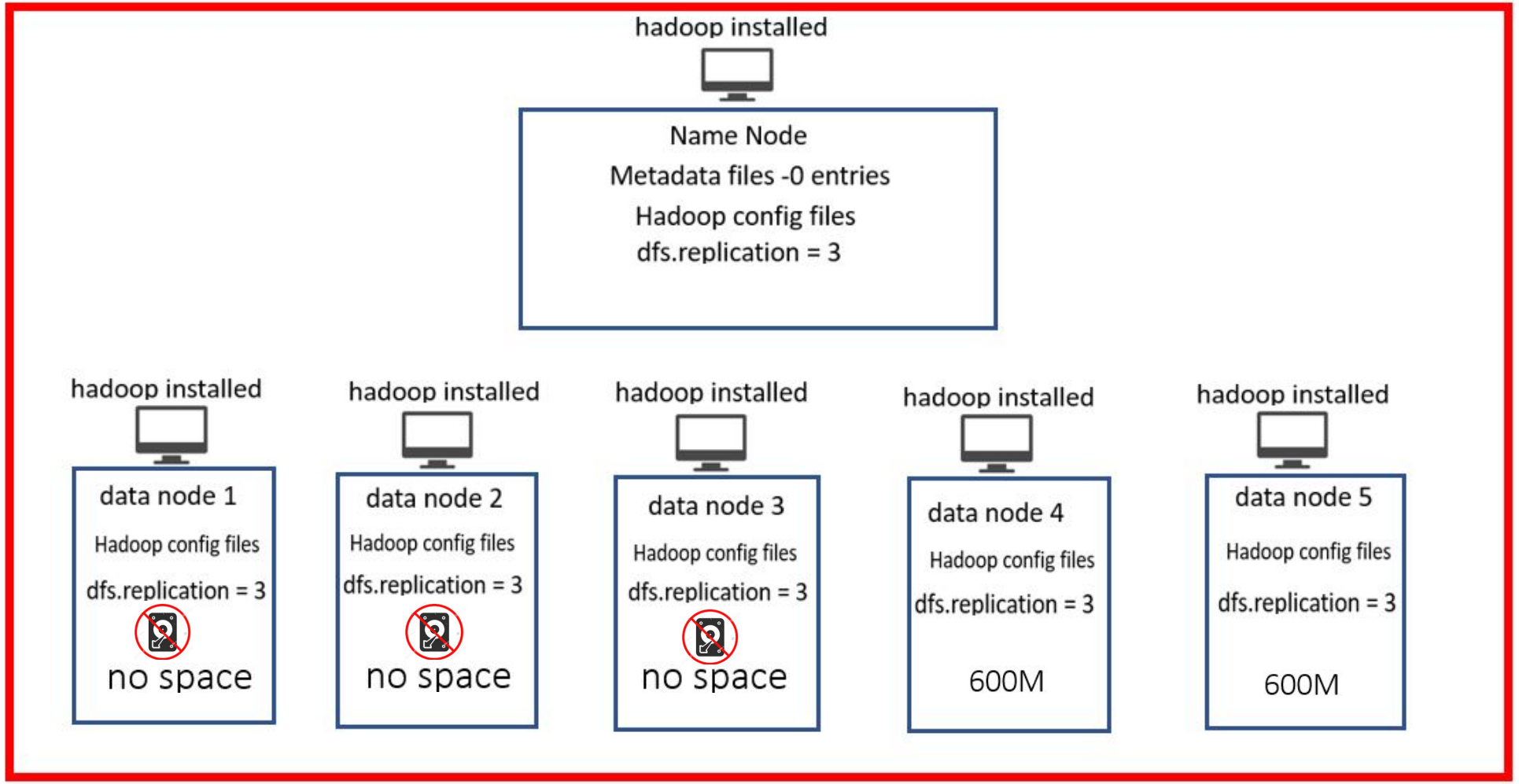
DN1	DN2	DN3	DN4	DN5
BLK001	BLK001	BLK001	BLK001	
	BLK002	BLK002	BLK002	BLK002
	BLK003	BLK003	BLK003	BLK003
BLK004	BLK004		BLK004	BLK004

How file is stored in HDFS-custom config

How file is stored in HDFS-custom config

- HDFS cannot replicate a block more times than there are nodes in the cluster.
- Therefore, in 5-node cluster, the maximum achievable replication for any block is 5, not 6.
- It will still create a 5 copies and will show you warning that it is under replicated block
- We can change any replication factor that we have set at any time ,if we feel that its too much not needed and space is getting wasted
- We can add new data node in that case
- Then automatically 6^{th} copy will be created
- It will be updated in name node

How file is stored in HDFS-custom config-no space in DN



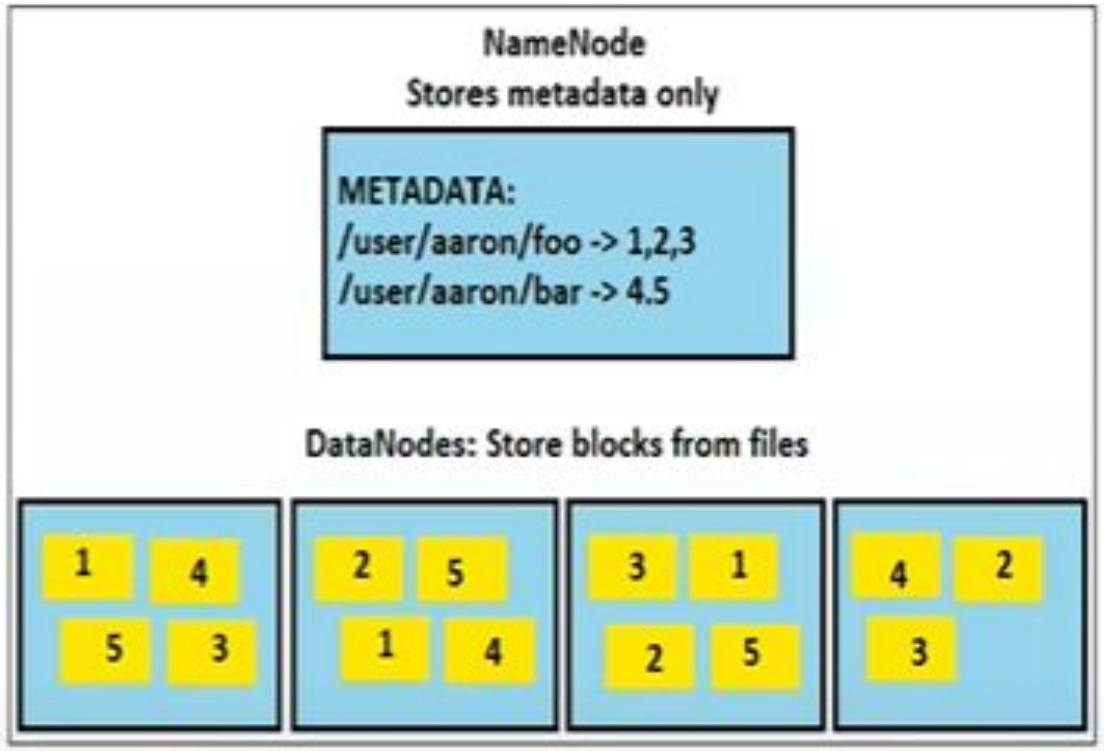
Sample.txt 256 MB

```
hdfs dfs -D dfs.replication=2 -D dfs.blocksize=300M -put sample.txt /
```

It will store 2 copies only later on it will store rest of 4 once new node is added

HDFS Key Points

- Default Block Size: *64 MB* (Hadoop 1.x)
  128 MB (Hadoop 2.x)
  256 MB (Hadoop 3.x)
- Every file is split into *Blocks*
- Every Block is *replicated 3* times by default
- Block is *never* replicated on the same Node
- Files are write-once and read-many
- Data can be appended to a file, but the file's existing contents cannot be changed



- data can be written to a storage medium (like a disk or optical storage) only once, and after that, it can only be read and not modified or deleted.
- Hadoop was meant Initially only for static data
- Example static and dynamic data (transaction / transaction date) (mobile/address)

Name Node

Hadoop Distributed File System's metadata is maintained by NameNode in various files like below

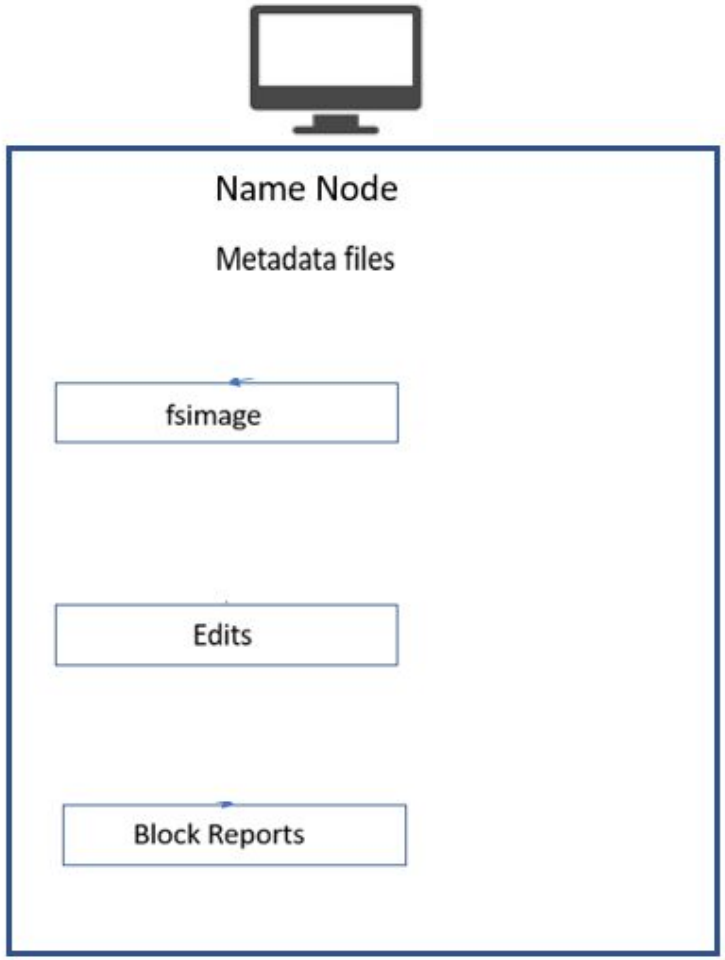
- **Fsimage:** Entire file system's metadata which includes all file properties like File Name, Ownership, Permissions, Timestamps, Size, Replication and List of Blocks is stored in a file called fsimage.

- **Edits:** Rather than modifying the existing fsimage every time for every transaction, NameNode instead records the new transactions (also called as edits) in the edit log for durability. Edit log transactions will be merged with fsimage on frequent intervals to bring fsimage content up-to-date.

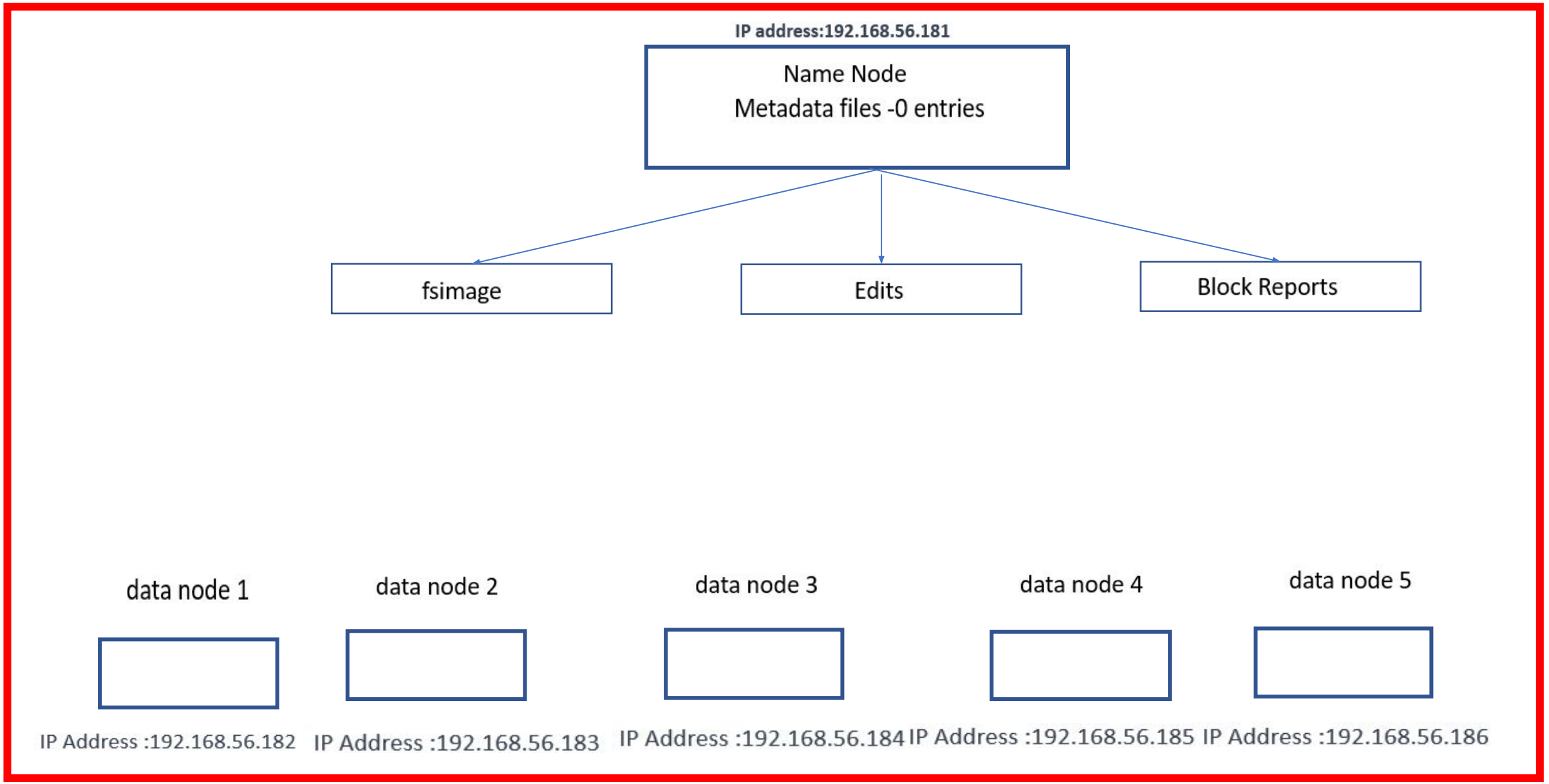
- **Block Report / Bitmap:** Whenever a DataNode service is started, it sends the list of blocks it has to NameNode through Heartbeat. NameNode receives Individual Block Report from each DataNode and merge them into a single Consolidated Block Report and maintains it into its own memory. NameNode uses this Consolidated Block Report to understand where the file blocks are actually located while reading the data from HDFS.

NOTE: Along with these metadata files, NameNode also maintains a consolidated DataNode Information file which contains info on available DataNodes, allocated capacity, used & remaining capacity, No. of blocks, etc. from each DataNode

Name Node



Name Node


IP address:192.168.56.181
Name Node
Metadata files -0 entries
fsimage
Edits
Block Reports
data node 1
data node 2
data node 3
data node 4
data node 5
IP Address :192.168.56.182
IP Address :192.168.56.183
IP Address :192.168.56.184
IP Address :192.168.56.185
IP Address :192.168.56.186

Command executed

Sample.txt-256 MB	100MB	BLK001
	100MB	BLK002
	50MB	BLK003

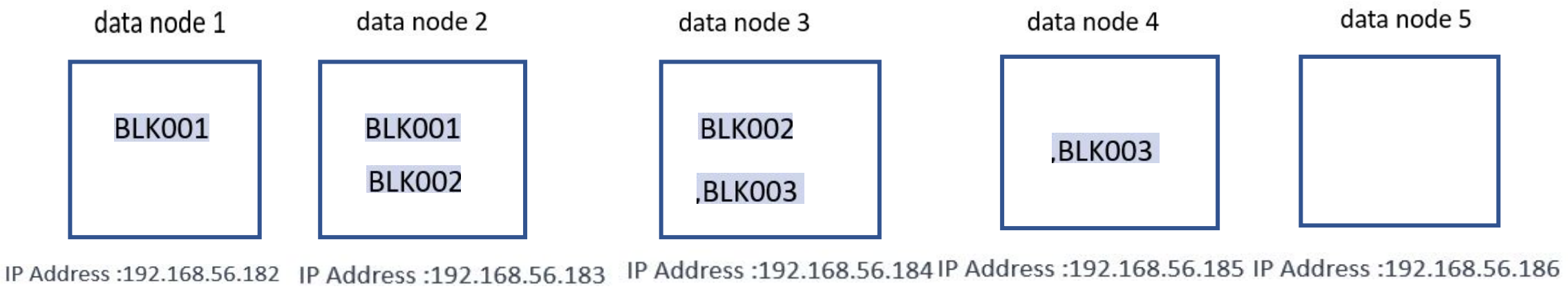
How file is stored in HDFS-Fsimage

IP address:192.168.56.181

Name Node
Metadata files -0 entries

fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003



Command executed

Now fsimage entry is updated hence name node metadata is update

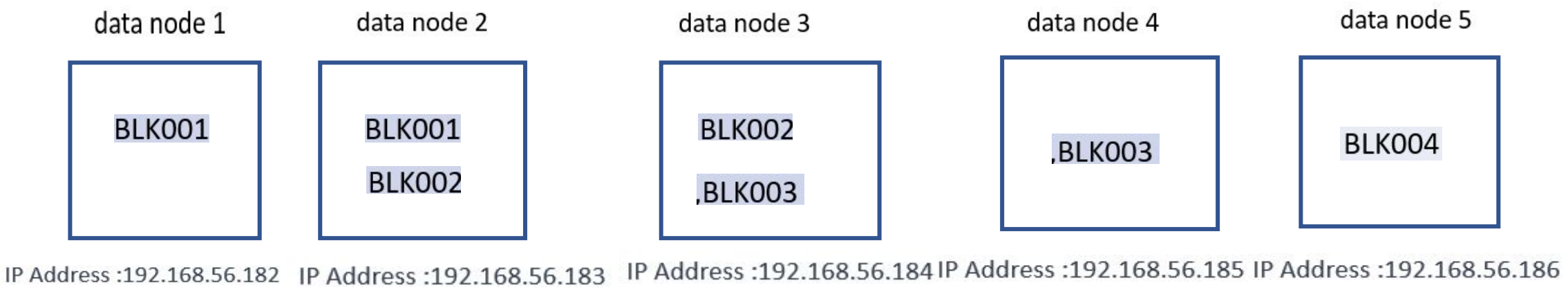
How file is stored in HDFS-Fsimage

IP address:192.168.56.181

Name Node
Metadata files -0 entries

fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./…	20M	1	64M	12/01/2024	BLK004



More transactions -Fsimage

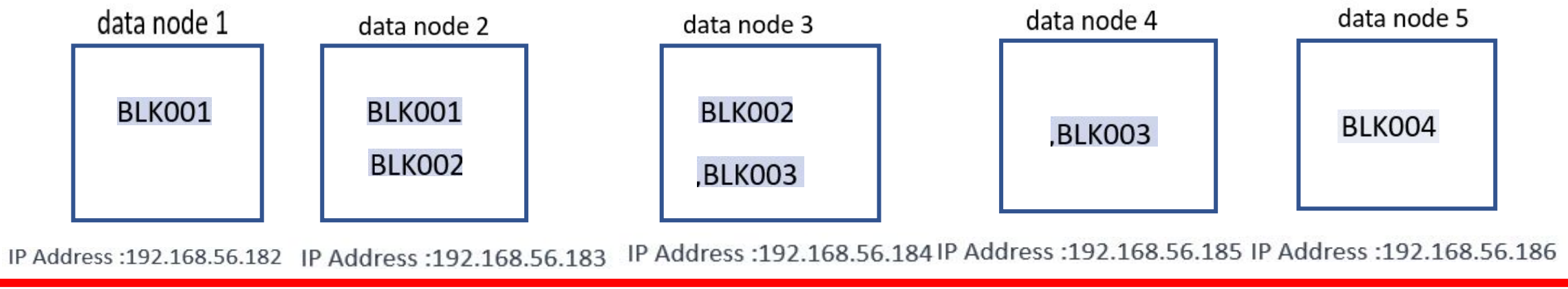
IP address:192.168.56.181

Name Node
Metadata files -0 entries

fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./…	20M	1	64M	12/01/2024	BLK004

1M	-----	-------	-------	------	------	-----	-------



More transactions -Fsimage

fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./…	20M	1	64M	12/01/2024	BLK004

1M	-----	-------	-------	------	------	-----	-------

- At the beginning lets say size of fsimage is 2MB
- After 1M transactions it will become approx. 2GB say
- In Hadoop 100s of people will be writing the file in Hadoop
- Name node has to update 100 entries in to fsimage file
- For every file entry name node will open fsimage file update metadata and save it and close it.
- 100s of people parallelly writing the file in Hadoop every time namenode is opening it, also size of file is increasing lets say its now 10GB
- Every time opening such big file and closing it parallelly is very difficult will take time as well there are chances that file will get corrupted. As we are opening and closing so many times
- Entire data will loss if fsimage is gone (persons phonebook(fsimage) is loss then)

To save this danger we they introduce edits

To save danger-edits

Edits

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003

- Name node will not write it into fsimage it will write it into edits first
- Every time you write a new file the metadata is written in edit log first

Edits after 1 hour- lets say 100 transcations

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./…	20M	1	64M	12/01/2024	BLK004

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100	----	-------	-------	------	------	-----	-------

Will merge to fsimage and it becomes empty

At the beginning

fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers

Edits

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./…	20M	1	64M	12/01/2024	BLK004

---	-----	-------	-------	------	------	-----	-------
100	----	-------	-------	------	------	-----	-------

After one hour

fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./……	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./…	20M	1	64M	12/01/2024	BLK004

---	-----	-------	-------	------	------	-----	-------
100	----	-------	-------	------	------	-----	-------

Edits

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers

- Edit file will not grow and fsimage we don’t have to open fsimage often we are opening it once in hr (default time) or we can change the interval or time duration may be in 30 minits etc
- Sometimes if too many people writing file there is a chance that edit file is corrupted but we will loose last 1 hr of data

Commands

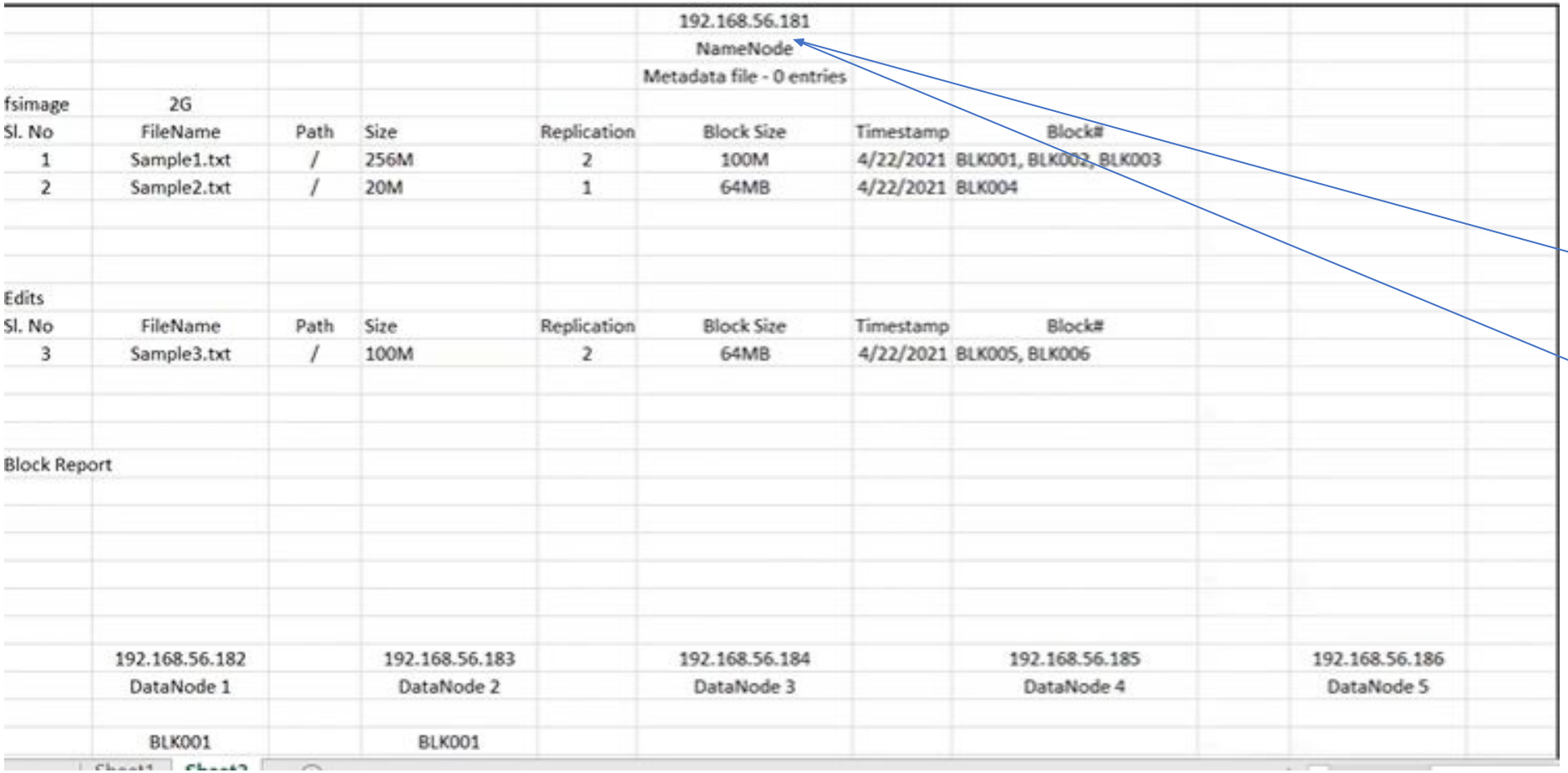
- hadoop fs -ls
- wget [URL]
- ls
- hadoop fs –ls
- **cd /hadoop/hdfs/namenode**
- ls hadoop fs -mkdir practice
- hadoop fs –ls
- mv annual-enterprise-survey-2020-financial-year-provisional-csv.csv sample.csv
- ls
- hadoop fs -copyFromLocal sample.csv practice/sample.csv
- hadoop fs -ls
- hadoop fs -ls practice
- hadoop fs -ls practice
- hadoop fs -rm practice/sample.csv
- hadoop fs -ls practice
- hadoop fs -rmdir practice
- hadoop fs -ls
- hadoop fs
- **cd current**
- **ls**
- sudo find / -name hdfs-site.xml 2>/dev/null
- cat /etc/hadoop/2.6.5.0-292/0/hdfs-site.xml

```
[maria_dev@sandbox-hdp hdfs]$ cd /hadoop/hdfs/namenode
[maria_dev@sandbox-hdp namenode]$ cd current
[maria_dev@sandbox-hdp current]$ ls
```

Process of writing a file

- Every time you write a file the meta data of the file is recorded by name node in the edit log first.
- If we have written 100 files in one hour, every one hour we are merging the content of edit log to fsimage. (we can change 1hr time-just change config file)
- Take every thing populated in edit logs and put it into fsimage and reset edit log to empty. (who does it?)
- Every one hour we are emptying edit log.
- also opening fsimage after 1 hour keeping it safe so no loss of data
- If too many people access the Hadoop edit file will be corrupted but we will not loose the complete data we will loose only one hour of data
- Fsimge is main file **to safeguard fsimage ---**we introduce edits

Reading a file(searching in edits and fsimage)



192.168.56.181
NameNode
Metadata file - 0 entries

fsimage 2G

Sl. No	FileName	Path	Size	Replication	Block Size	Timestamp	Block#
1	Sample1.txt	/	256M	2	100M	4/22/2021	BLK001, BLK002, BLK003
2	Sample2.txt	/	20M	1	64MB	4/22/2021	BLK004

Edits

Sl. No	FileName	Path	Size	Replication	Block Size	Timestamp	Block#
3	Sample3.txt	/	100M	2	64MB	4/22/2021	BLK005, BLK006

Block Report

192.168.56.182	192.168.56.183	192.168.56.184	192.168.56.185	192.168.56.186
DataNode 1	DataNode 2	DataNode 3	DataNode 4	DataNode 5
BLK001	BLK001			

Hit the name node

```
hdfs dfs -cat /path/to/sample2.txt
```

Hit the name node

```
hdfs dfs -cat /path/to/sample21
```

Name node reply

file not found

- Now metadata is available on both the files fsimage and edits
- Name node first search file in edits as it is of less size
- Then it will search in fsimage

Block Number

IP address:192.168.56.181

Name Node
Metadata files -0 entries

fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./...	20M	1	64M	12/01/2024	BLK004

Edits

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample3.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003

data node 1: BLK001

data node 2: BLK001, BLK002

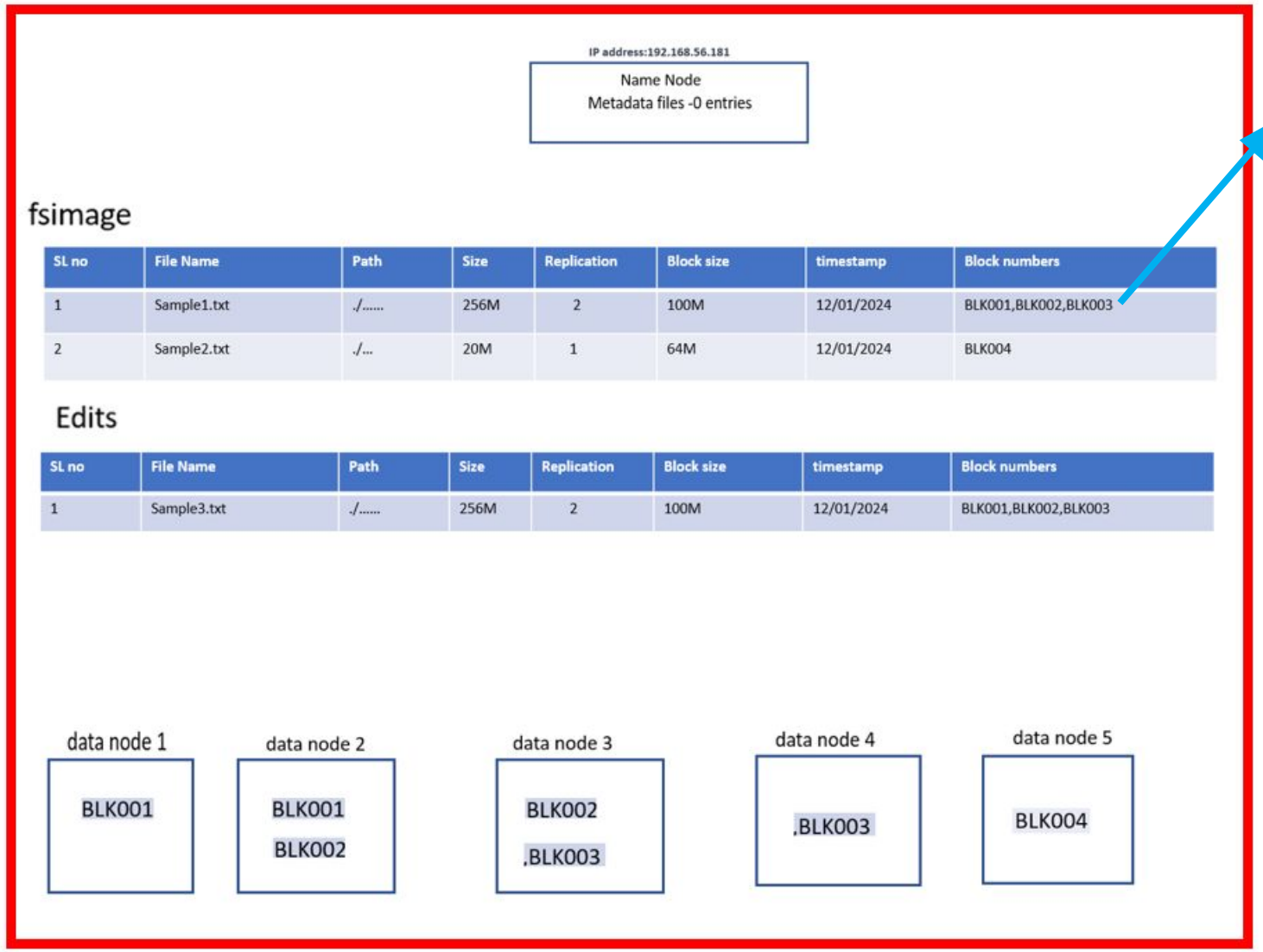
data node 3: BLK002, ,BLK003

data node 4: ,BLK003

data node 5: BLK004

- We ask for sample 2.txt , found it in fsimge we got all metadata
- Including its block number BLK004
- Does it understand where this BLK 004 is available?
- No, it doesn't understand Data node number is not there.
- When it doesn't know data node number then , it has to check all the places .
- It is a problem

Block Number



- Can we maintain data node information in fsimage or edit logs block numbers column(BLK001,DN1) etc.
- **Whenever a new data node is added, name node(master) will move some of the block from existing data node to the newly added data node, For the for the balancing purposes. It is called **data node rebalancing.** So that New data nodes and old data nodes will have equal load i.e. to make balance cluster
- Now if suppose we put for e.g (BLK001,DN1)
- Is there any guarantee that one will be available in data node one permanently?

Block Number

IP address:192.168.56.181

Name Node
Metadata files -0 entries

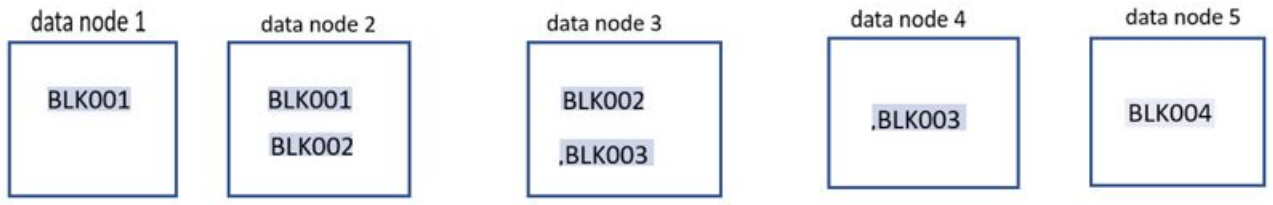
fsimage

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./...	20M	1	64M	12/01/2024	BLK004

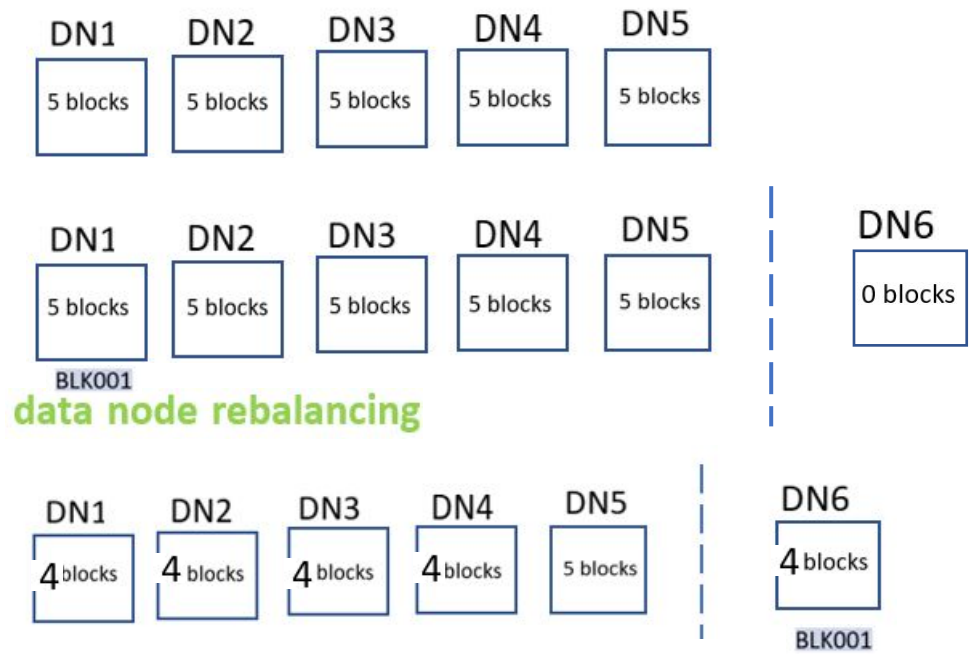
Edits

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample3.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003

Block Reports



- As there is no guarantee that BLK001 will be available in datanode1 permanently?
- So, we introduce Block report maintained by name node 4 blocks



Block Report

IP address:192.168.56.181

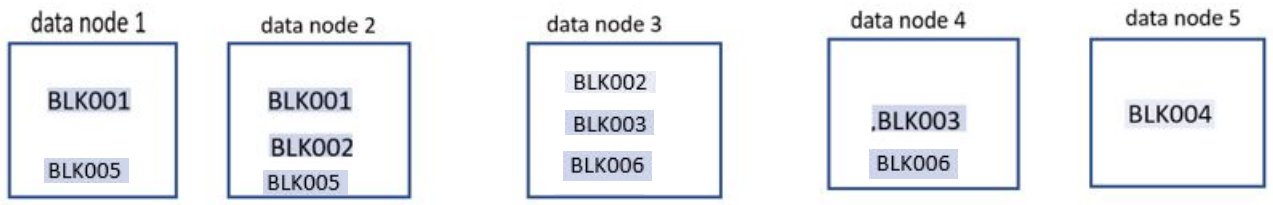
Name Node
Metadata files -0 entries

fsimage

Edits

Block Reports

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	DN3			fine
BLK003	2			DN3	DN4		fine
BLK004	1					DN4	fine
BLK005	2	DN1	DN2				fine
BLK006	2			DN3	DN4		fine



- Name Node builds metadata from Block reports
- Status of block reports is fine
- Status may change to under replication over replication valid or not valid replication

Block Report

IP address:192.168.56.181

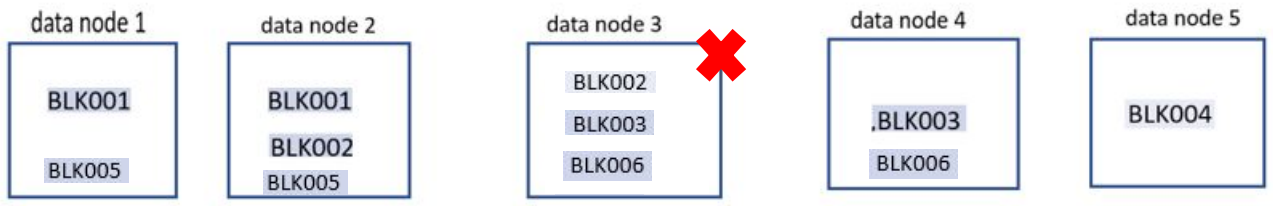
Name Node
Metadata files -0 entries

fsimage

Edits

Block Reports

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	DN3			fine
BLK003	2			DN3	DN4		fine
BLK004	1					DN4	fine
BLK005	2	DN1	DN2				fine
BLK006	2			DN3	DN4		fine



- Suppose some data node is down, how Name node will understand
- Each data Node sends Heartbeats to name node after every 3 second
- Heartbeat is proof of a data node is alive and up and running

- If any data node is not sending heart beats it will remove DN3 entries from block report

Block Report

IP address:192.168.56.181

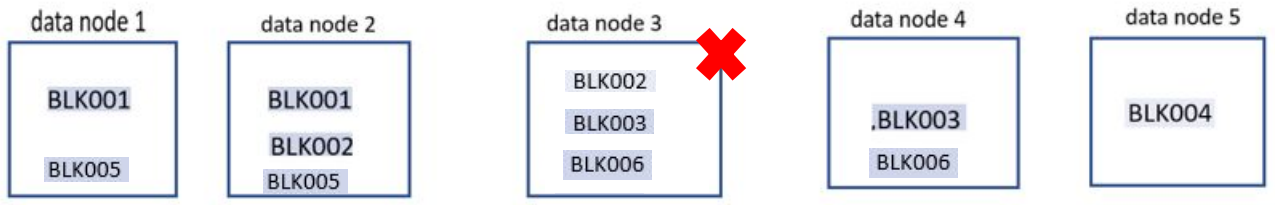
Name Node
Metadata files -0 entries

fsimage

Edits

Block Reports

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	[illegible]3			Under replicated
BLK003	2			[illegible]3	DN4		Under replicated
BLK004	1					DN5	fine
BLK005	2	DN1	DN2				fine
BLK006	2			[illegible]3	DN4		Under replicated



- If any data node is not sending heart beats it will remove DN3 entries from block report. And it will update block report
- Now Block 2 replication factor is 2 and after deletion of DN2 ,so status will change to under replicated
- Name node updated block report
- Now Name node will tell data node 2 that you have block 2 can you send it to data node 4
- Now data node 4 will talk to name node that it has block 2,so name node will update the same in block report .

- Extra blocks will result in over replication too

- Always ensure valid replication

Block Report

IP address:192.168.56.181

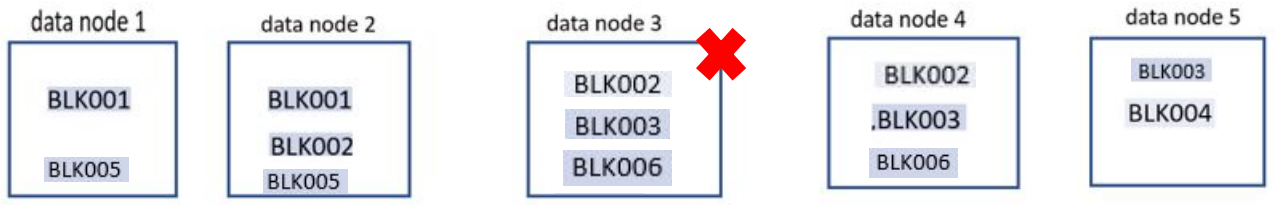
Name Node
Metadata files -0 entries

fsimage

Edits

Block Reports

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	[illegible]3	DN4		fine
BLK003	2			[illegible]3	DN4	DN5	Under replicated
BLK004	1					DN5	fine
BLK005	2	DN1	DN2				fine
BLK006	2			[illegible]3	DN4		Under replicated



- Now data node 4 will talk to name node that it has block 2,so name node will update the same in block report
- Block 2 status will update to fine.
- Same about block 3 will get replicated to data node 5
- Same about block 6 will get replicated to data node 1
- The responsibility of name node that status is valid replication always
- Name node will update block report status after every 3 seconds
- If data node is not sending any heartbeat to name node, then there is a property that name node will wait to receive a heartbeat from data node for 10.5 minits
  After that it will remove the entries from block report.

Office analogy employee did not inform to manager about his leave for one day that's ok, but…. wait for 3 weeks till then no termination same way may be due

Block Report

IP address:192.168.56.181

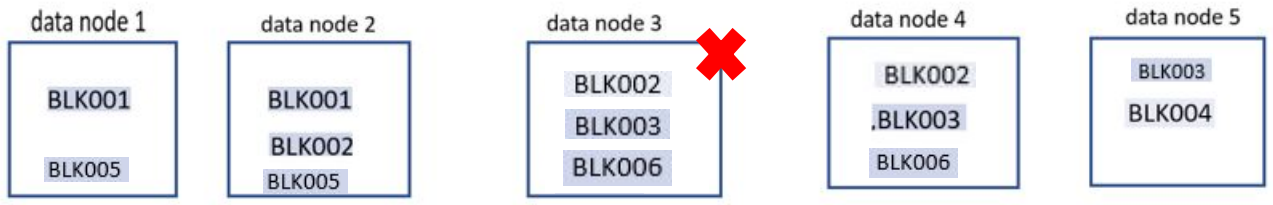
Name Node
Metadata files -0 entries

fsimage

Edits

Block Reports

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	[illegible]3	DN4		fine
BLK003	2			[illegible]3	DN4	DN5	Under replicated
BLK004	1					DN5	fine
BLK005	2	DN1	DN2				fine
BLK006	2			[illegible]3	DN4		Under replicated



- every data node is saying that I have these blocks with me.
- if there is any issue with the data node If any data node and is not sending heartbeat for to name node.
- what name node will do?
- Name node will delete the entry from the block report.
- Even if block report is corrupted it is easy to reconstruct it as it is saved in memory

IP address:192.168.56.181

Name Node
Metadata files -0 entries

```
hdfs dfs -cat /sample2.txt
```

User run the command and press enter

- Reading algorithm will contact name load.
- Name node will search for sample2.txt in edit log if not found it will search in fsimage
- Then it will search on which block it is available here it is BLK004
- Then name node will take information from consolidated block report that where BLK004 is available
- Block report will tell that BLK004 is available on data node 5
- name node will return location of block to user data node 5 it is available

fsimage Hard disk

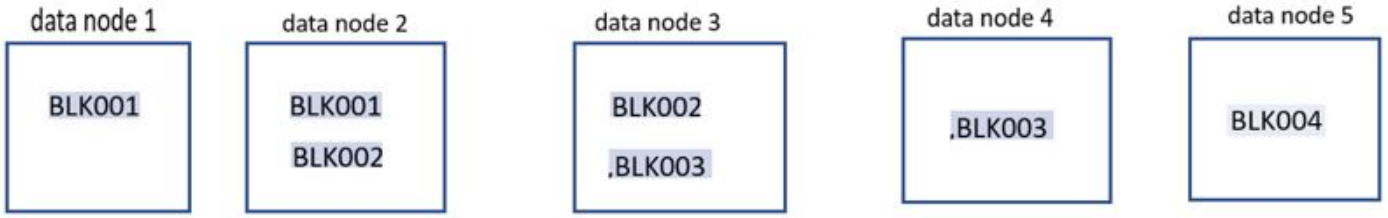
SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./...	20M	1	64M	12/01/2024	BLK004

Edits Hard disk

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample3.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003

Block Reports memory

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	DN3			fine
BLK003	2			DN3	DN4		fine



IP address:192.168.56.181

Name Node
Metadata files -0 entries

```
hdfs dfs -cat /sample3.txt
```

User run the command and press enter

fsimage Hard disk

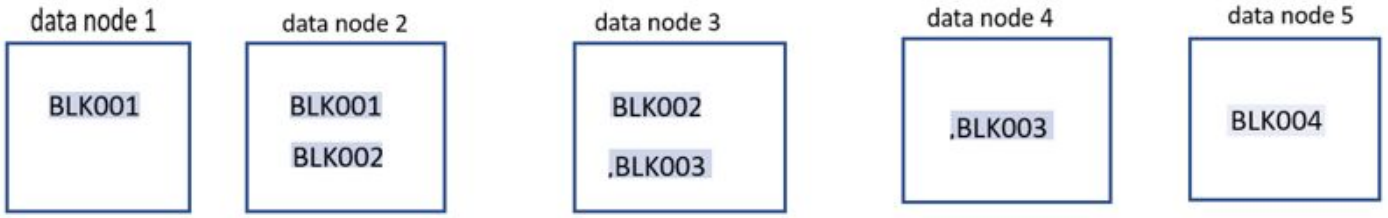
SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./...	20M	1	64M	12/01/2024	BLK004

Edits Hard disk

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample3.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003

Block Reports memory

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	DN3			fine
BLK003	2			DN3	DN4		fine



- Reading algorithm will contact name load.
- Name node will search for sample3.txt in edit log if not found it will search in fsimage
- Then it will search on which block it is available here it is BLK001 BLK002,BLK003
- Then name node will take information from consolidated block report that where BLK001 BLK002,BLK003 are available
- Block report will tell that BLK001 BLK002,BLK003 are available on data node 1 data node 2 and data node 3 data node4
-

Data Aggregation from various blocks

```
hdfs dfs -cat /sample3.txt
```

IP address:192.168.56.181

Name Node
Metadata files -0 entries

fsimage Hard disk

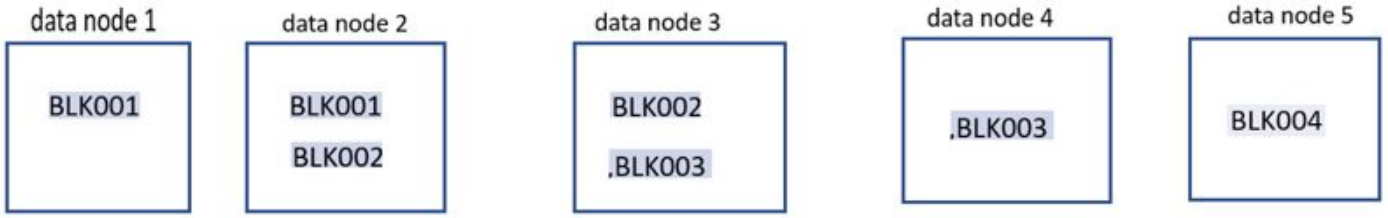
SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample1.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003
2	Sample2.txt	./...	20M	1	64M	12/01/2024	BLK004

Edits Hard disk

SL no	File Name	Path	Size	Replication	Block size	timestamp	Block numbers
1	Sample3.txt	./.....	256M	2	100M	12/01/2024	BLK001,BLK002,BLK003

Block Reports memory

Block	Replication	Data node number (On which data node which block)					Status
BLK001	2	DN1	DN2				fine
BLK002	2		DN2	DN3			fine
BLK003	2			DN3	DN4		fine



- Block report will tell that BLK001 BLK002,BLK003 are available on data node 1 data node 2 and data node 3 data node4

BLK001	DN1	DN2	
BLK002		DN2	DN3
BLK003			DN3

BLK001
BLK002
BLK003

DN1		
	DN2	
		DN3

Merge

Output

Data node information Report

IP address:192.168.56.181

Name Node
Metadata files 4 entires

fsimage

Edits

Block Reports

data node info report (in memory)

Host Name	IP Address	Total space	Used space	Available space	No of blocks	Load	Last heartbeat
DN1	192.168.56.182	10GB	184 M	9.9G	3	2%	3sec ago
DN2	192.168.56.183	20GB	284 M	19.98G	4	1.50%	3sec ago
DN3	192.168.56.184	300GB	156 M	299.99G	3	1%	15 sec ago
DN4	192.168.56.185	500GB	112 M	499.9G	3	0.50%	3 sec ago
DN5	192.168.56.186	1TB	96M	0.0000T	3	0.30%	3 sec

192.168.56.182
DN1
10GB
BLK001(100M)

BLK005(64M)

BLK007(20M)

192.168.56.183
DN2
20GB
BLK001(100M)
BLK002(100M)

BLK005(64M)

BLK007(20M)

192.168.56.185
DN3
300GB
BLK002(100M)

BLK006(36M)

BLK007(20M)

192.168.56.185
DN4
500GB
BLK003(56M)

BLK006(36M)

BLK007(20M)

192.168.56.185
DN5
1 TB
BLK003(56M)

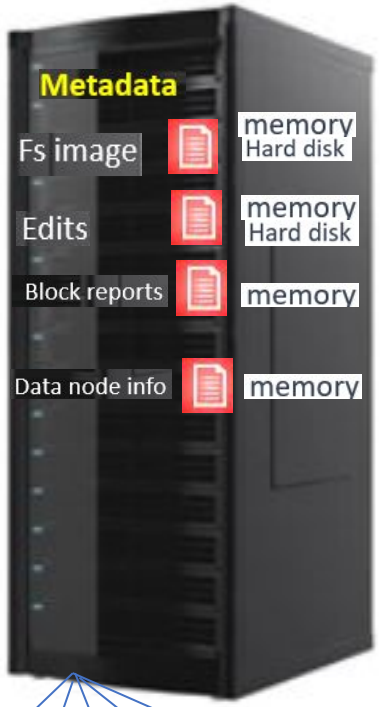
BLK00420M)

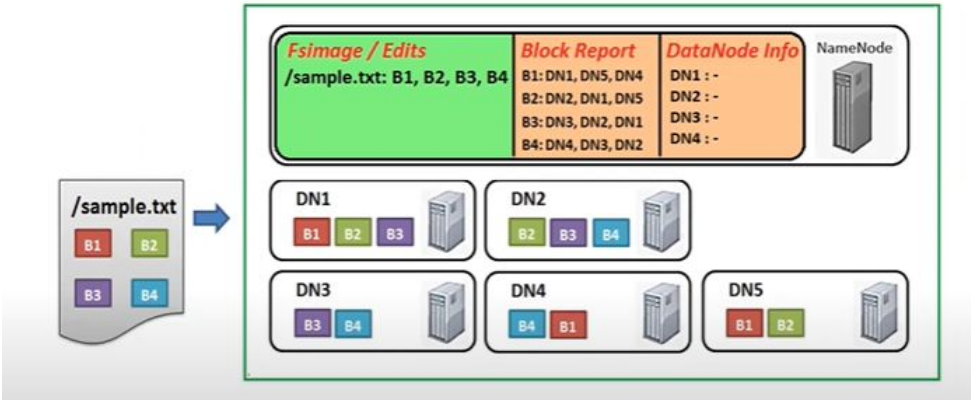
BLK007(20M)

After 630 sec it will remove that DN info

Setup

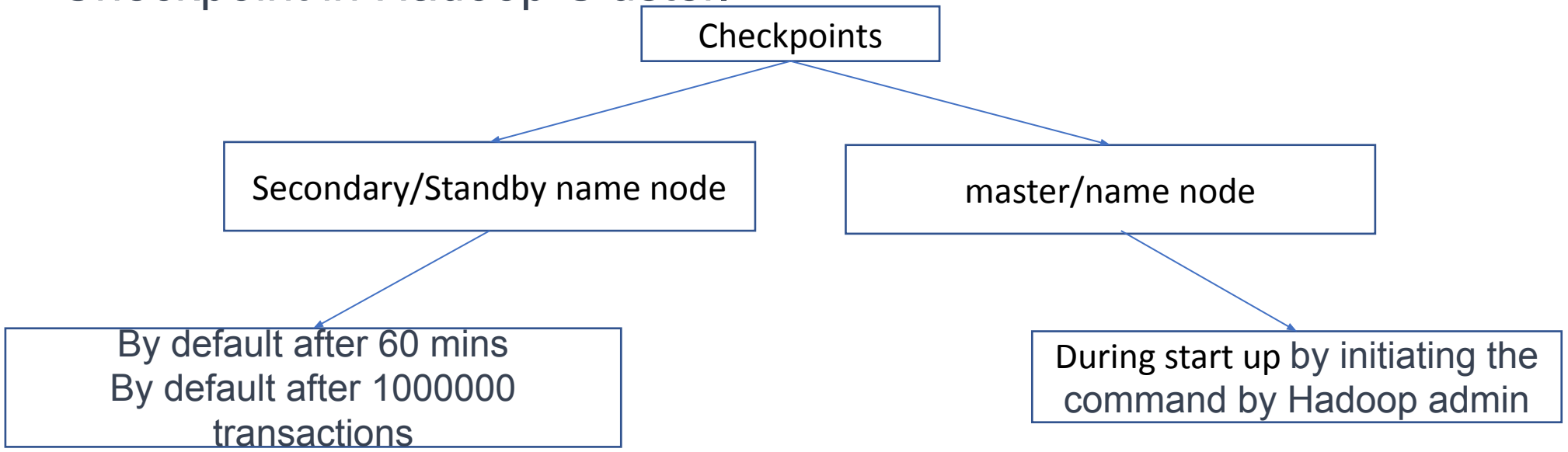

HADOOP
Hadoop
yarn
Loops


Metadata
Fs image
memory
Hard disk
Edits
memory
Hard disk
Block reports
memory
Data node info
memory


/sample.txt
B1
B2
B3
B4
Fsimage / Edits
/sample.txt: B1, B2, B3, B4
Block Report
B1: DN1, DN5, DN4
B2: DN2, DN1, DN5
B3: DN3, DN2, DN1
B4: DN4, DN3, DN2
DataNode Info
DN1 : -
DN2 : -
DN3 : -
DN4 : -
NameNode
DN1
DN2
DN3
DN4
DN5

What is Checkpoint in Hadoop?

- A process that takes fsimage & edits and combines them into a new fsimage.
- Secondary NameNode or Standby NameNode is responsible for doing Checkpoint in Hadoop Cluster.



But this operation will be performed by NameNode and NameNode should in Safemode (read-only mode) during this operation.

```
echo '<property>' >> /path/to/hdfs-site.xml
echo '  <name>dfs.namenode.checkpoint.period</name>' >> /path/to/hdfs
echo '  <value>60</value>' >> /path/to/hdfs-site.xml
echo '</property>' >> /path/to/hdfs-site.xml

echo '<property>' >> /path/to/hdfs-site.xml
echo '  <name>dfs.namenode.checkpoint.txns</name>' >> /path/to/hdfs-s
echo '  <value>1000000</value>' >> /path/to/hdfs-site.xml
echo '</property>' >> /path/to/hdfs-site.xml
```

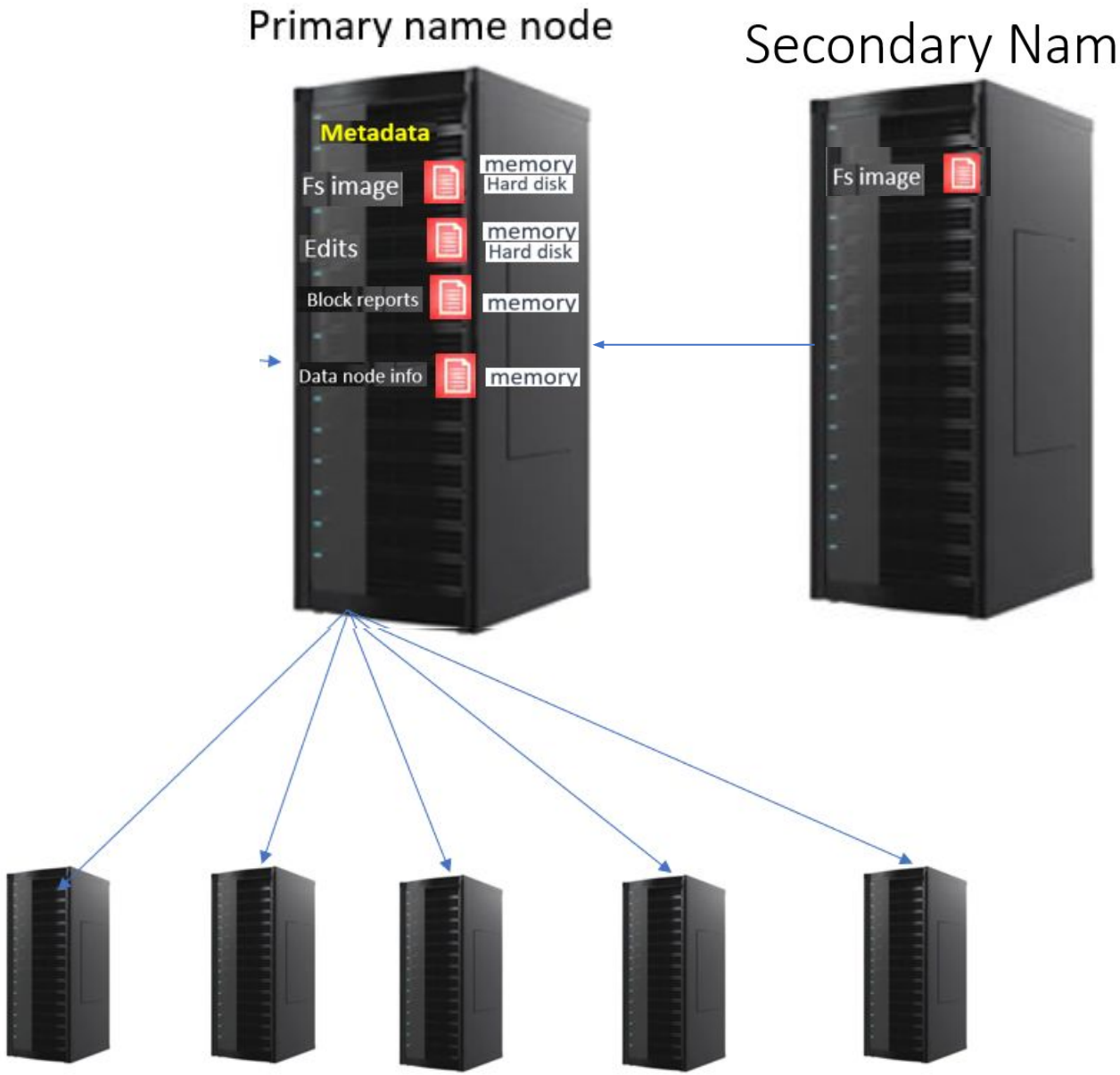
What is Checkpoint in Hadoop?

- A process that takes fsimage & edits and combines them into a new fsimage.
- Secondary NameNode or Standby NameNode is responsible for doing Checkpoint in Hadoop Cluster.

We know after every 1 hour edit logs get merge with fsimage to form new fsimage called checkpointing but now who will do this checkpointing process?

This will be taken care by secondary/standby name node

Secondary Name node check point



Secondary name node continuously monitor edit logs file and merging it to fsimage after 1 hr or after 1M transactions happened

	Time	Edits	Fsimage
		10	0
Checkpoint	8.00 AM	0	10
		5	
Checkpoint	9.00 AM	0	15
		50	
Checkpoint	10.00 AM	0	65
	10:30 AM	1Million transaction came suddenly	
Checkpoint	10:30	0	1M+65
Checkpoint	11:30		

Default settings we can change it

Checkpoint by name node

	Time	Edits	Fsimage
		10	0
Checkpoint	8.00 AM	0	10
		5	
Checkpoint	9.00 AM	0	15
		50	
Checkpoint	10.00 AM	0	65
	10:30 AM	1Million transaction came suddenly	
Checkpoint	10:30	0	1M+65
	11:30		
	12:15	1M	
Checkpoint	12:15PM	0	2M+65
	12:45PM	10	
	1:00 AM		
Checkpoint by name node	1:00 AM	0	2M+75

Entire cluster is stopped (Stop name node)

Name node start-requirement is 0 edits but

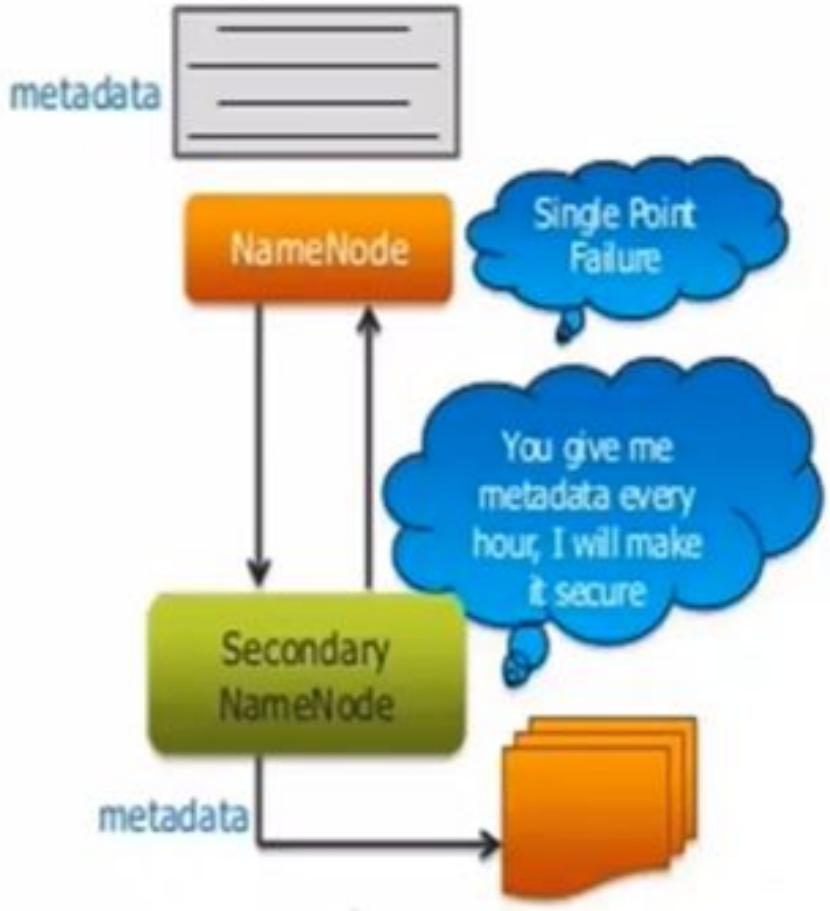
Checkpoint by Hadoop admin

	Time	Edits	Fsimage
		10	0
Checkpoint	8.00 AM	0	10
		5	
Checkpoint	9.00 AM	0	15
		50	
Checkpoint	10.00 AM	0	65
	10:30 AM	1Million transaction came suddenly	
	10:30	0	1M+65
Checkpoint	11:30		
	12:15	1M	
	12:15PM	0	2M+65
Checkpoint	12:45PM	10	
	1:00 AM		
Checkpoint by name node	1:00 AM	0	2M+75
	1:45 AM	10	
Checkpoint by Hadoop admin	1:45 AM	0	2M+85

Forcefully by giving command-Name node

Secondary name node

- Never acts like Primary NameNode in case of Primary NameNode failure
- Retrieve fsimage and edits from Primary NameNode, perform Checkpoint on regular intervals and push the latest copy of fsimage back to Primary NameNode
- Maintains a copy of fsimage as backup of Primary NameNode's metadata

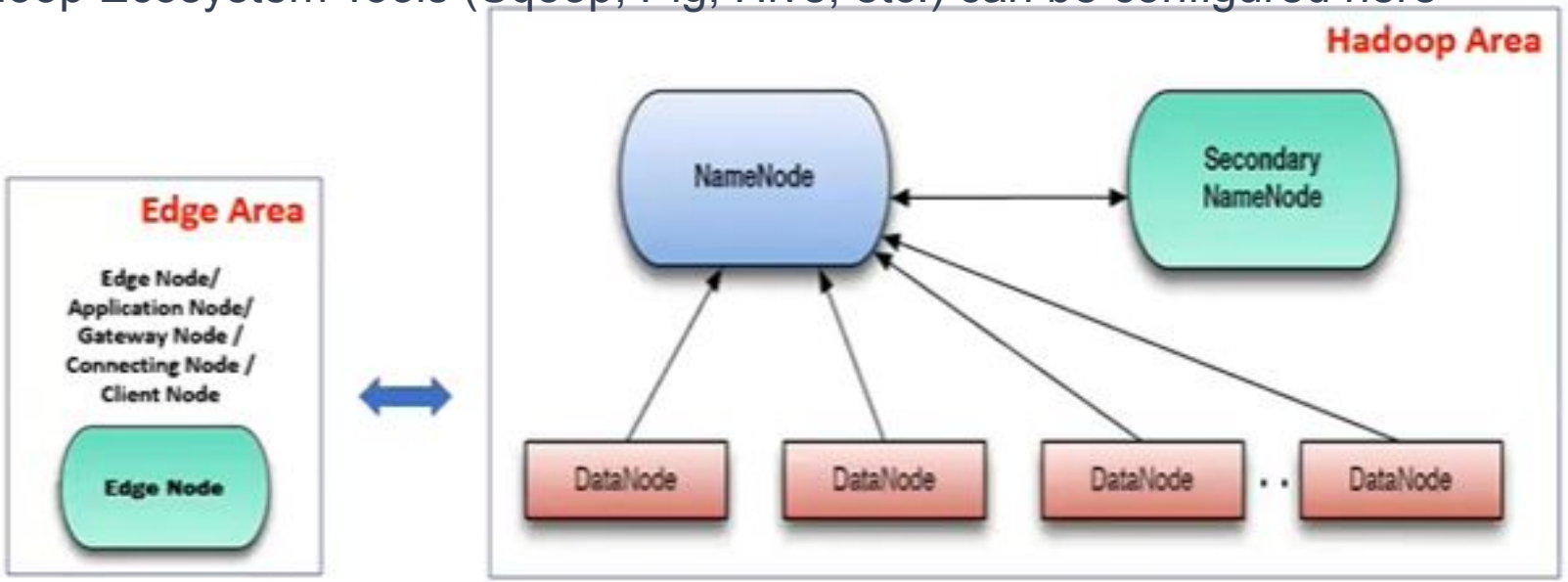


Edge Node

What is Edge Node?

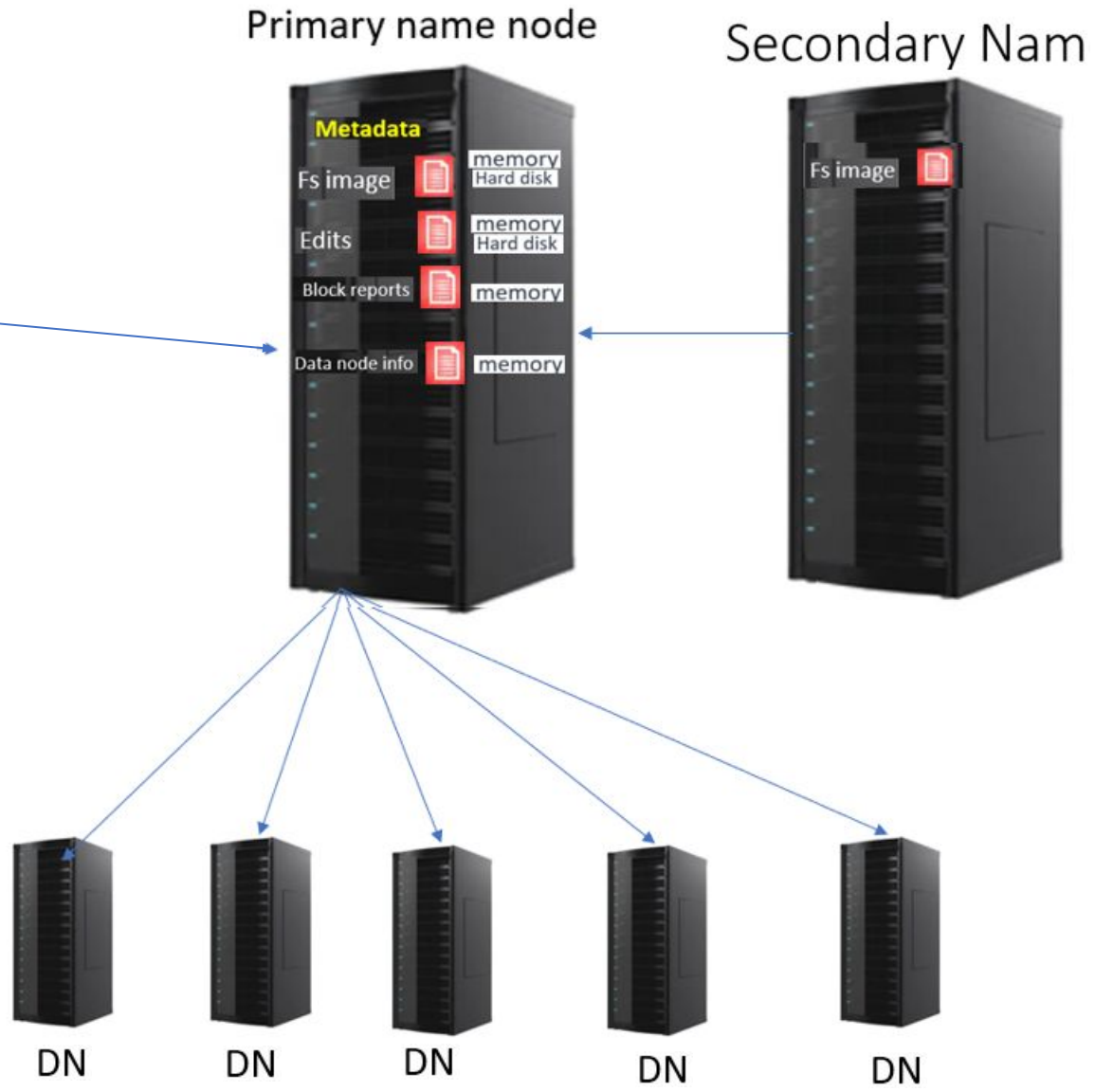
What is Edge Node?

- Can be referred as Application Node / Gateway Node / Connecting Node / Client Node
- Edge Node is the interface between Hadoop Cluster and Users/Client Applications
- Users/Developers will be given access to Edge Node to execute their Hadoop commands/jobs
- Hadoop is installed here but no Hadoop daemons will be running
- Often used as staging area for the data being transferred into Hadoop Cluster
- Hadoop Ecosystem Tools (Sqoop, Pig, Hive, etc.) can be configured here



Edge Node

- Hadoop client software installed- can type Hadoop commands
- Interface between user and Hadoop cluster
- Hadoop is installed but no daemons are running no services like data node name node at all



Installation

Installation Modes of Hadoop

Standalone Mode

All Hadoop services run in a single Java Virtual Machine (JVM) on a single machine.

Pseudo distributed Mode

Individual Hadoop services run in an individual JVM but on a single machine.

Fully distributed Mode

Hadoop services run in different JVMs but in a cluster

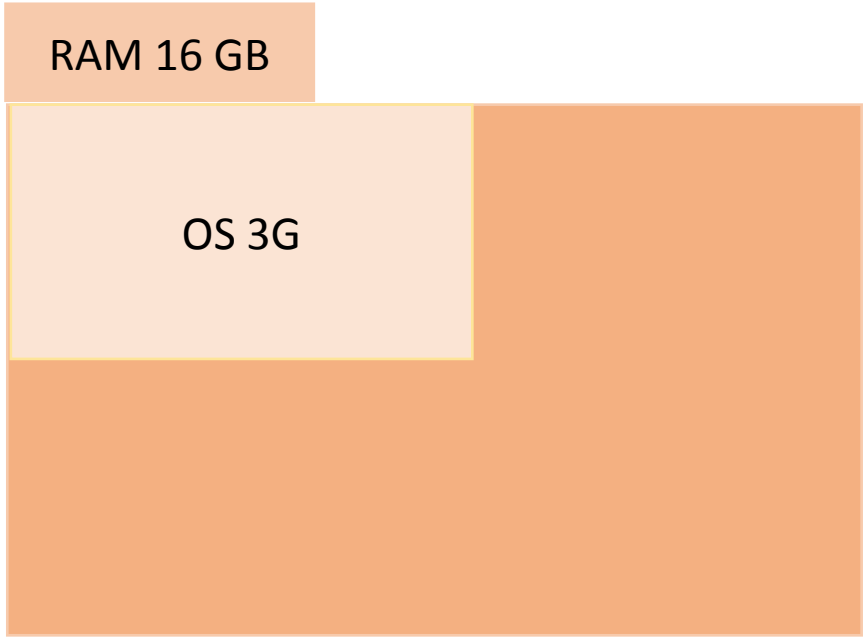
Understanding Basics

Hadoop (Java)

Services

- Name node Java program
- Secondary name node Java program
- Data node Java program

c/c++	sampleprogram1.c	3G
c/c++	sampleprogram2.c	6G
c/c++	Sampleprogram3.c	10G



Understanding Basics-JVM

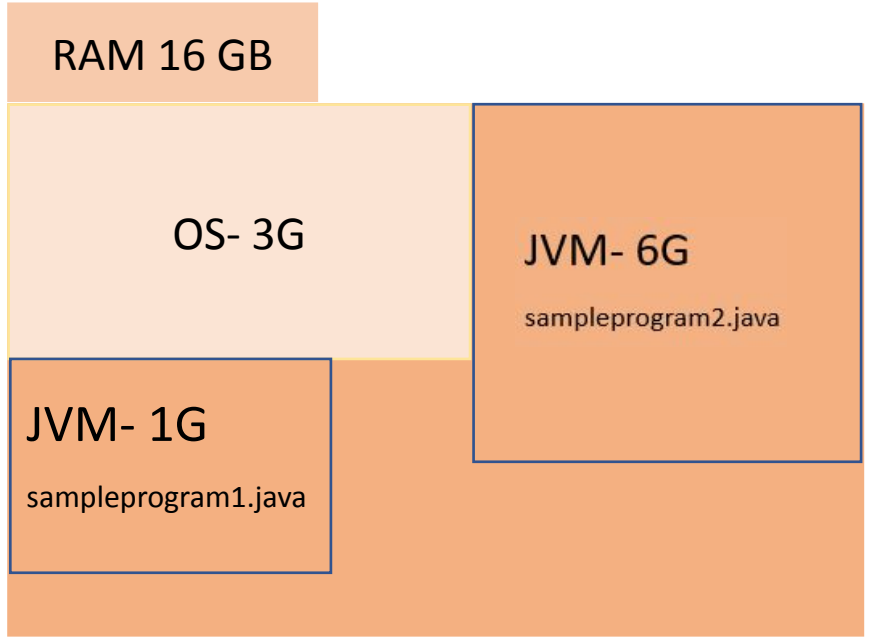
Hadoop (Java)

Services

- Name node Java program
- Secondary name node Java program
- Data node Java program

java	sampleprogram1.java	Default 1G
java	sampleprogram2.java	6G

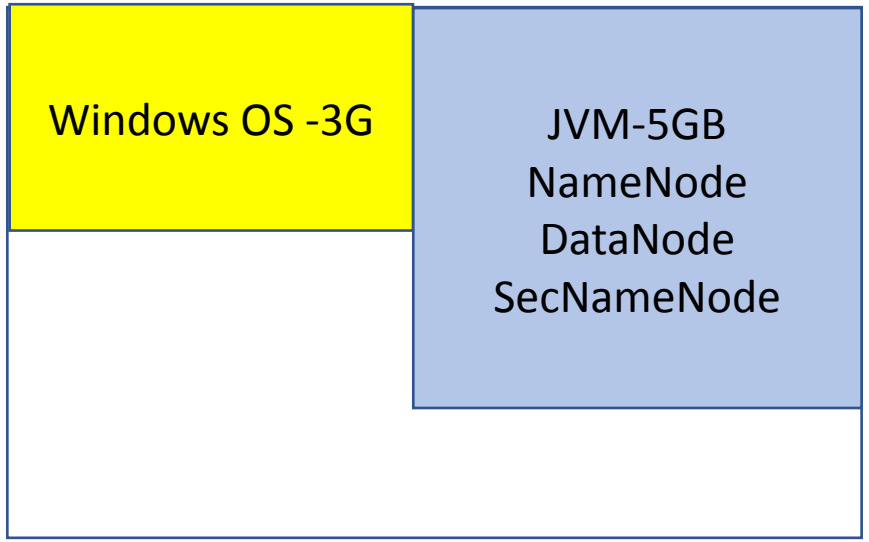
- JVM provides a controlled and specified environment in which Java programs run.
- It reserves the space for java program.
- When you run a Java application, you're running an instance of a JVM



Standalone

Services

- Name node Java program
- Secondary name node Java program
- Data node Java program

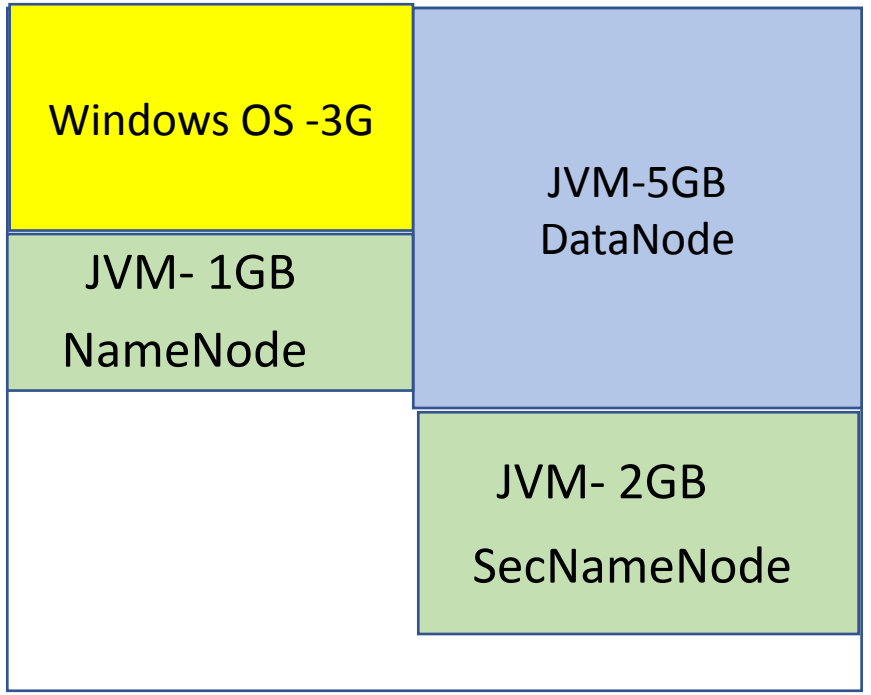


- In a standalone mode of Hadoop, all the components run as a single Java process within a single JVM on one machine

Pseudo-distributed Mode

Services

- Name node Java program
- Secondary name node Java program
- Data node Java program

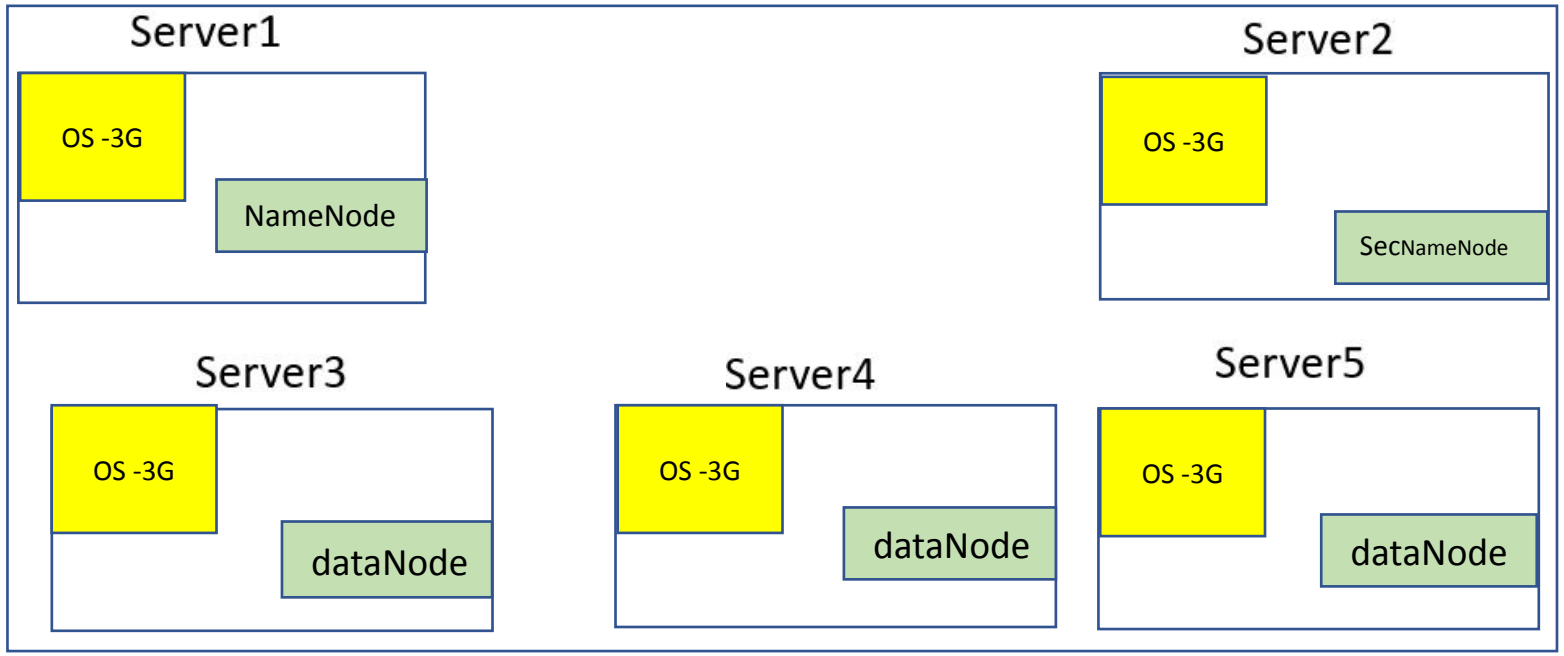


- In pseudo-distributed mode, each Hadoop daemon (NameNode, Secondary NameNode, and DataNode) runs in its own separate JVM on a single machine.
- This mode is a simulation of the distributed environment, as it acts if having multiple nodes, but it's all localized within one physical or virtual machine

Fully-distributed Mode

Services

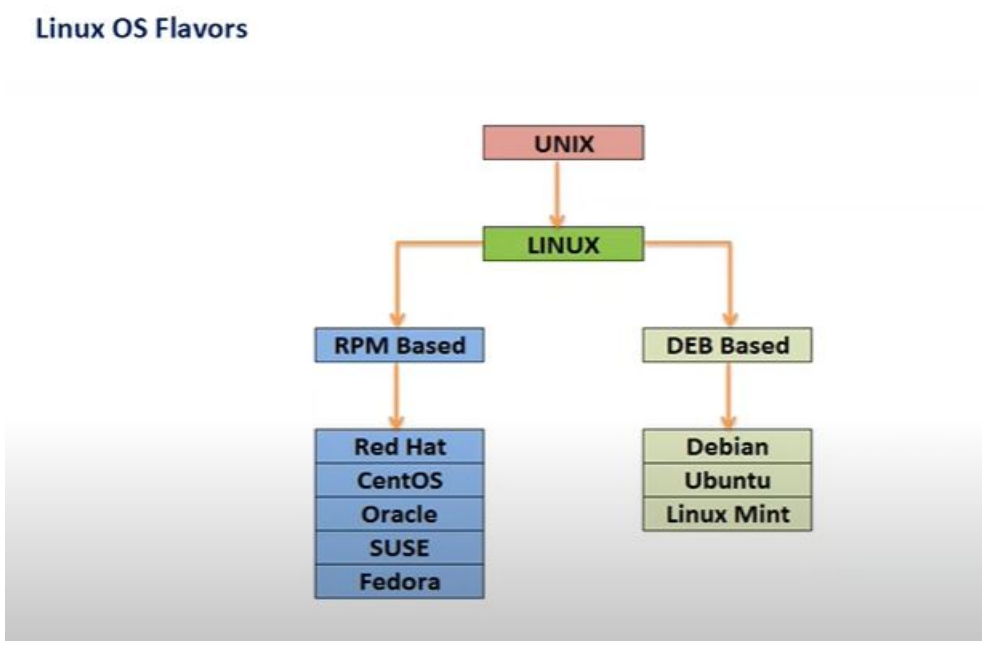
- Name node Java program
- Secondary name node Java program
- Data node Java program



- In a fully distributed mode, Hadoop runs on a cluster of machines, with each component of the Hadoop ecosystem running on its own set of dedicated hardware: (server)

Operating system

Operating systems			
Windows	GUI available	Command Prompt	licensed
Android	GUI available	Command Prompt	licensed
Macos	GUI available	Command Prompt	licensed
Unix		Command Prompt	Open source

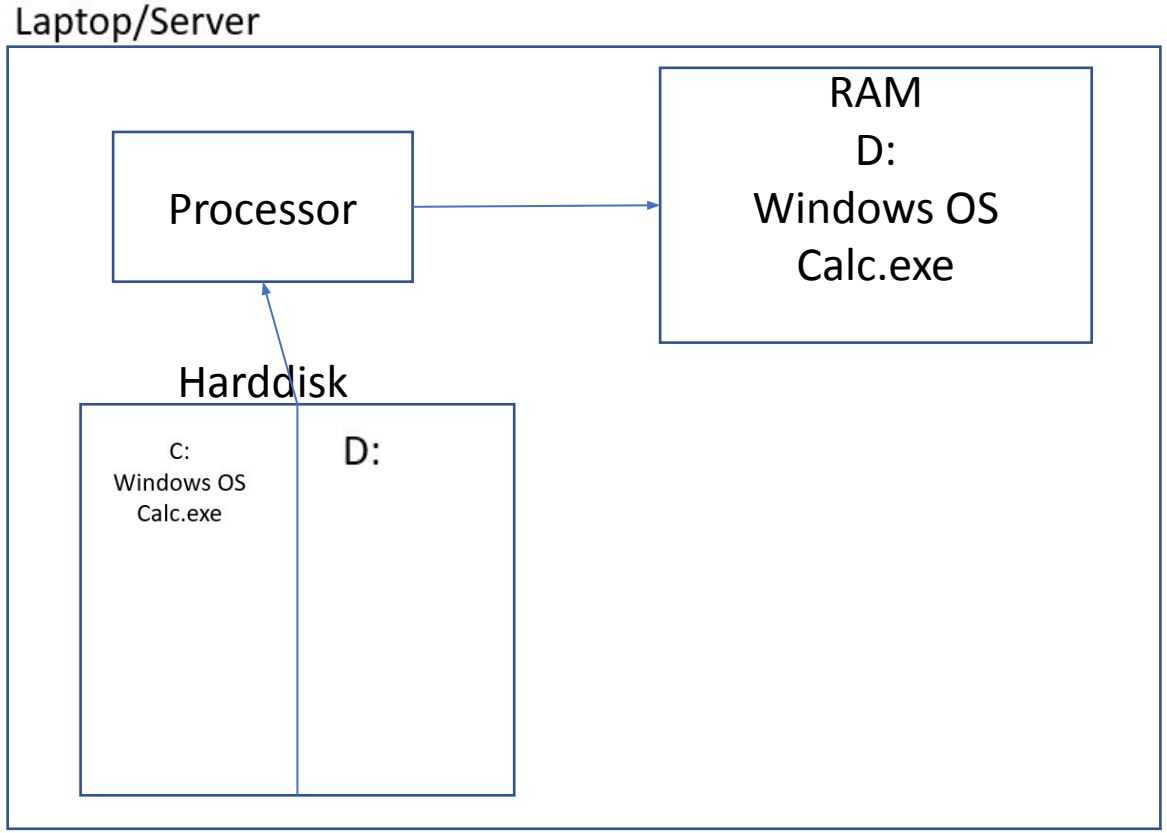


RPM (Red Hat Package Manager) and DEB (Debian Package) are two types of package management systems used by different Linux distributions to install, update, and remove software.

Processor

Pentium4
Core2duo
Corei3
Corei5
Corei7
coreo9

Double click calc.exe operating system loads calc.exe to RAM with the help of processor you use the calculator (e.g., entering numbers, performing calculations), these inputs are processed by the processor



Processor

Pentium 4 1 Physical Core Processor
Core2Duo 2 Physical Core Processor
Core i3 2 Physical Core Processor (HTE)
Core i5 4 Physical Core Processor
Core i7 4 Physical Core Processor (HTE)
Core i9 8 Physical Core Processor

PCP	LCP
6 PCP (HTE)	12 LCP
8 PCP	16 LCP
8 PCP (HTE)	16 LCP
12 PCP	24 LCP
12 PCP (HTE)	24 LCP
16 PCP	32 LCP
16 PCP (HTE)	32 LCP
24 PCP	48 LCP
24 PCP (HTE)	48 LCP
32 PCP	64 LCP
32 PCP (HTE)	64 LCP
40 PCP	80 LCP
40 PCP (HTE)	80 LCP
60 PCP	
80 PCP	
100 PCP	

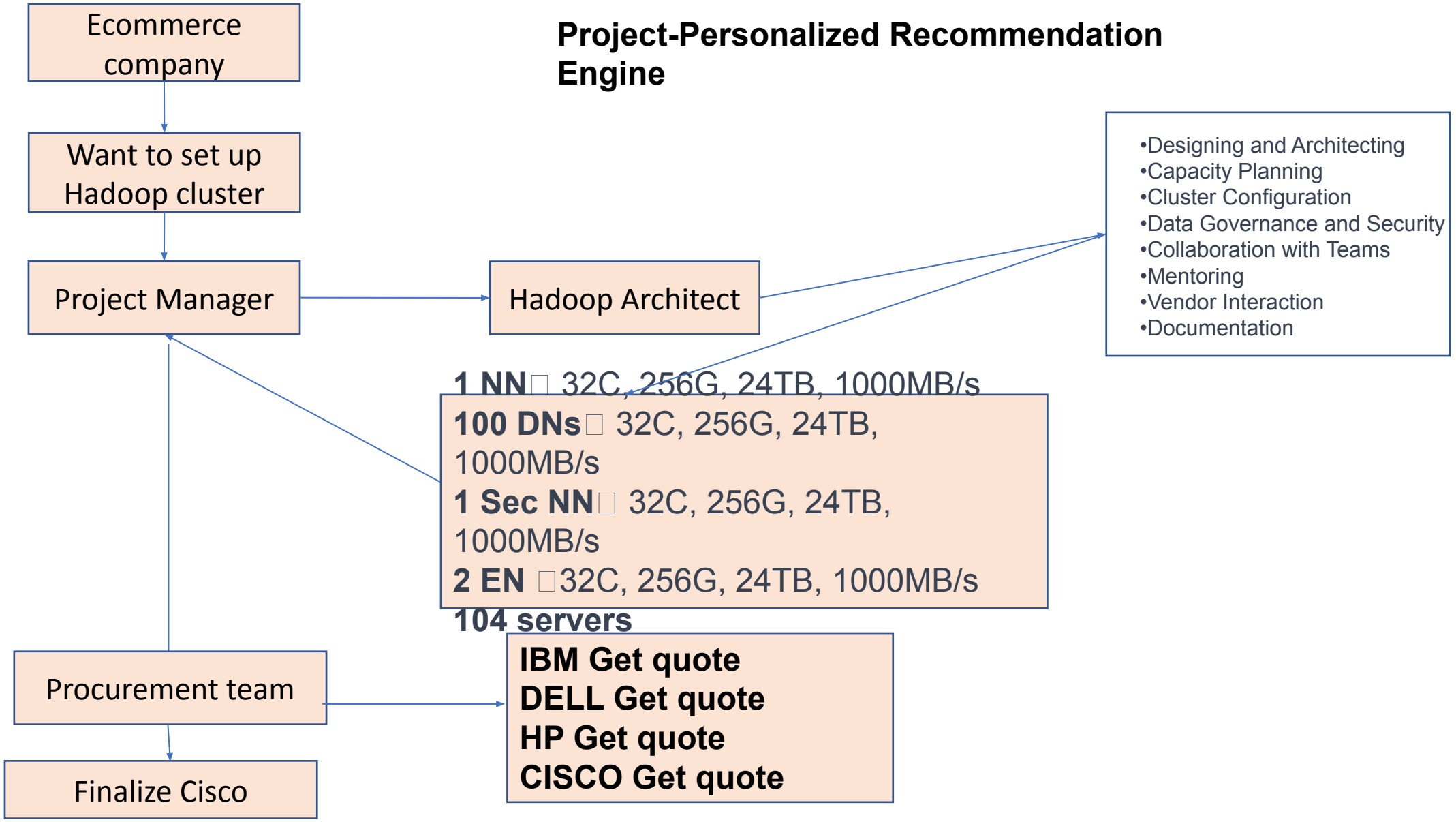
- **Physical Core Processor (PCP)**: This is the actual physical core inside a CPU. A physical core can independently execute computer instructions.
- **Logical Core Processor (LCP)**: This typically refers to logical cores created through a technology like Intel's Hyper-Threading.

IRCTC Server 400 tickets/sec
IRCTC has recently added two new high-capacity servers, bringing their total server count to a higher number to handle increased demand. These new servers have improved the ticket booking capacity significantly.
2000 tickets/sec

Laptop

Laptop	Total	OS	Free	VM1	VM2	VM3	VM4	VM5	VM6	Free_2
	Cores	16	1	15	2	2	2	2	2	2
	RAM (GB)	64	3	61	10	10	10	10	2	2
	HDD (GB)	900	300	600	30	30	30	30	30	30
	Network (MB/s)	1000	100	900	50	50	50	50	50	50
	OS	Windows			Linux	Linux	Linux	Linux	Linux (Ctrl)	Linux
	Hadoop		NN	SNN	DN1	DN2	DN3		EN	

Real time scenario

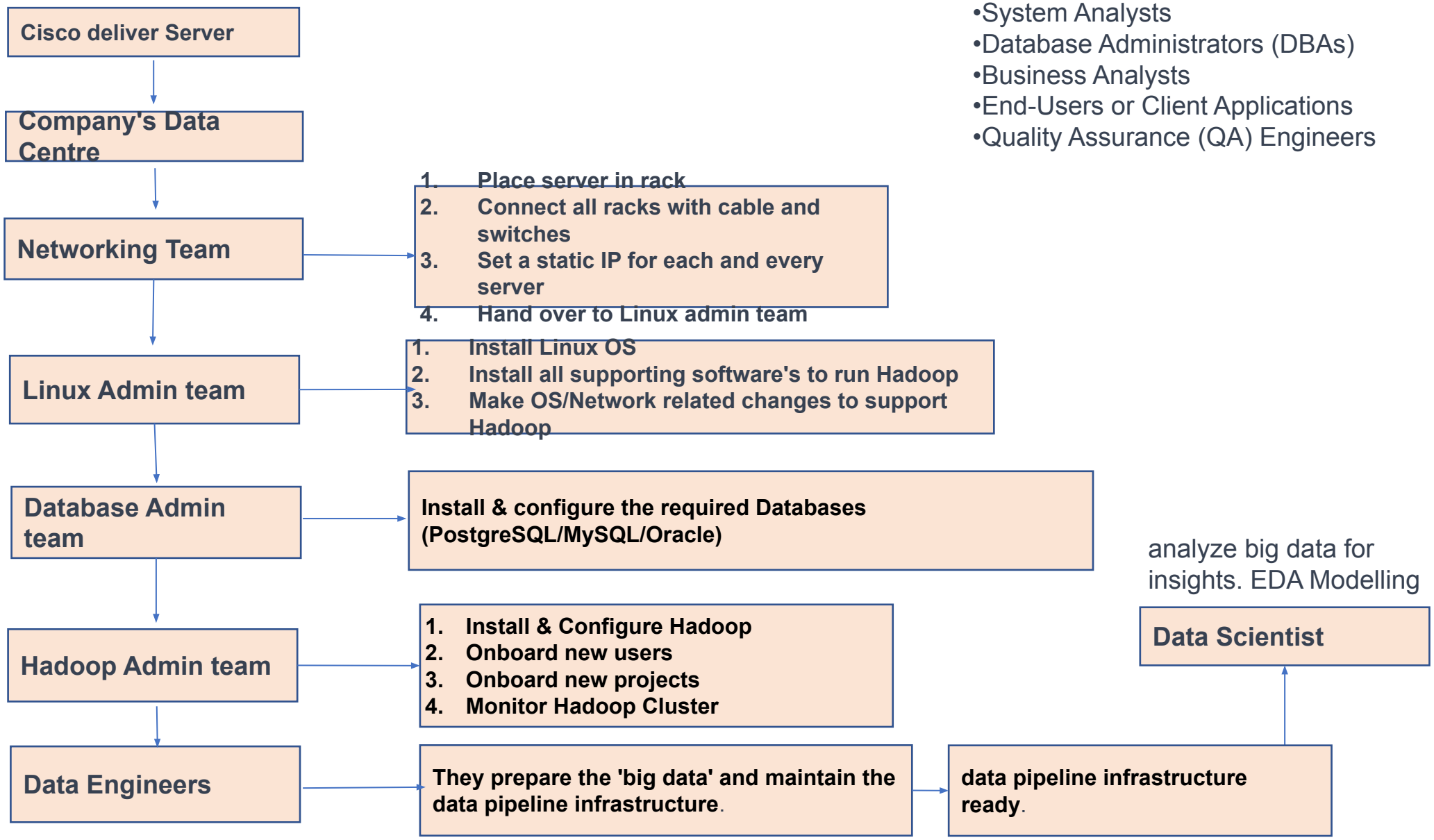


Real time scenario

1 NN 32C, 256G, 24TB, 1000MB/s
100 DNs 32C, 256G, 24TB, 1000MB/s
1 Sec NN 32C, 256G, 24TB, 1000MB/s
2 EN 32C, 256G, 24TB, 1000MB/s
104 servers

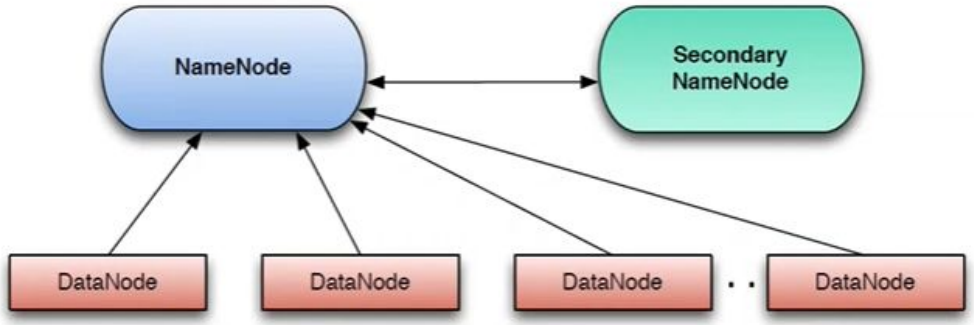
Real time scenario

- Software Developers
- System Analysts
- Database Administrators (DBAs)
- Business Analysts
- End-Users or Client Applications
- Quality Assurance (QA) Engineers



Hadoop 1.x

Hadoop Architecture with Single NameNode



Limitations of Hadoop with Single NameNode

- NameNode is Single Point of Failure as Secondary NameNode never acts like Primary NameNode in case of Primary NameNode failure
- Chances of losing data if Checkpoint doesn't happen
- Metadata files need to be copied manually in case of Primary NameNode crash.

- Sec NN is just like PA and Primary NN is like PM, sec NN cannot replace PM it will only note down PMs work.
- Sec NN only has metadata file fsimage stored nothing more than that

Solution: NameNode High Availability (Active & Standby NameNodes)

Problem

Time	Primary NN		Sec NN
	Edits	Fsimage	
8:00	0	0	
	40		
9:00	0	40	40
	20	0	
10:00	0	60	60
	10		
10:30	10	60	60
11:00			

- At 10:30 Primary NN burnt out gone down completely due to electricity problem spark happen and crashed.
- No data of last 10 transactions will be available anywhere not even in sec NN
- What if those 10 transactions of 1 lakh Rs, the Hadoop cluster will say you have not paid
- It is a big problem.
- We have to manually copy fsimage from sec NN to Pri NN but there are loss of transactions.

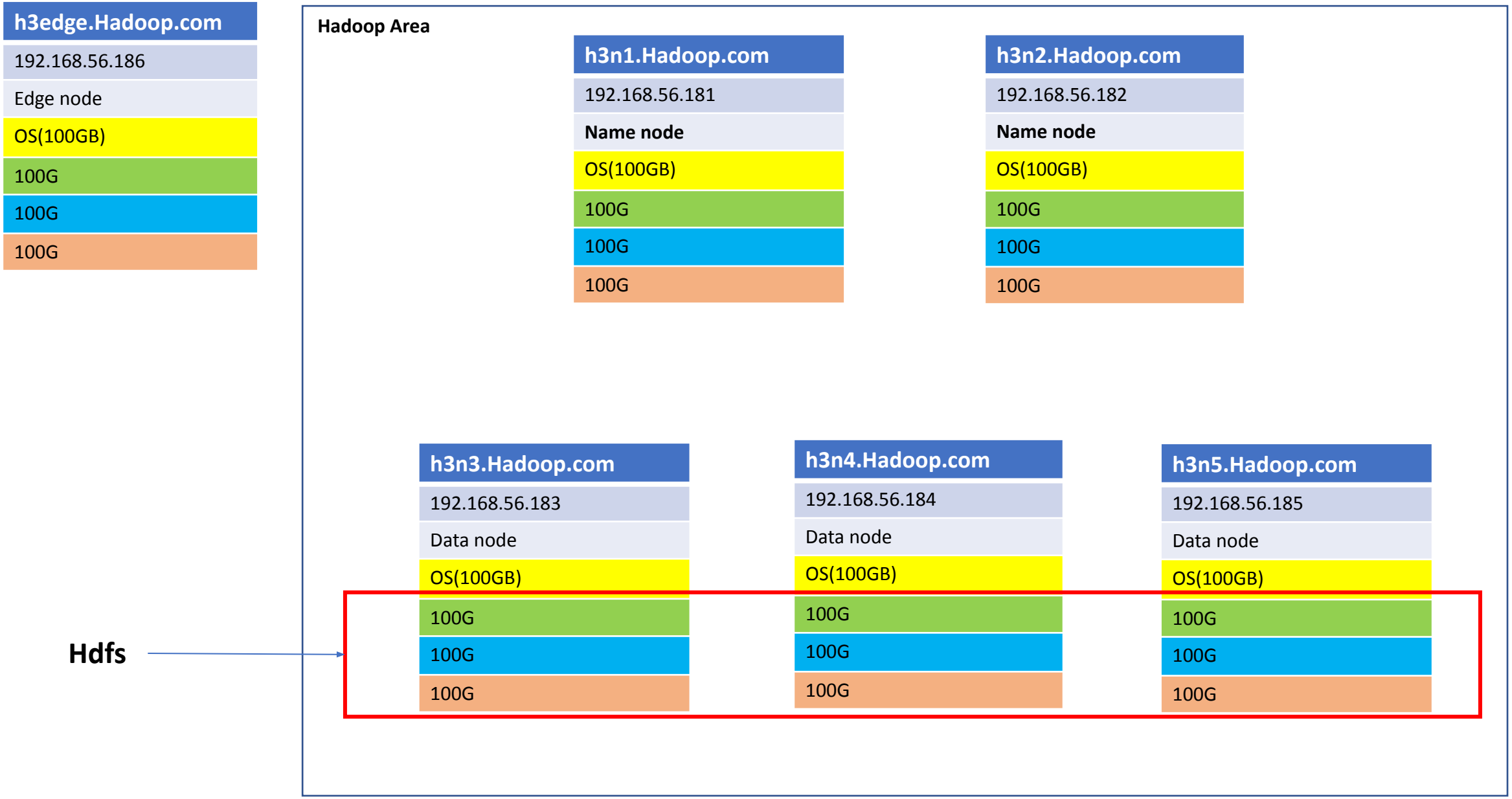
- Hadoop is good but main drawback is Name Node / master Node/Primary name node

- Hadoop people improved over this and came up with concept of name node high availability
- If one name node is not there other name node will take care of there work. (Active and standby name node)

Active and standby name node

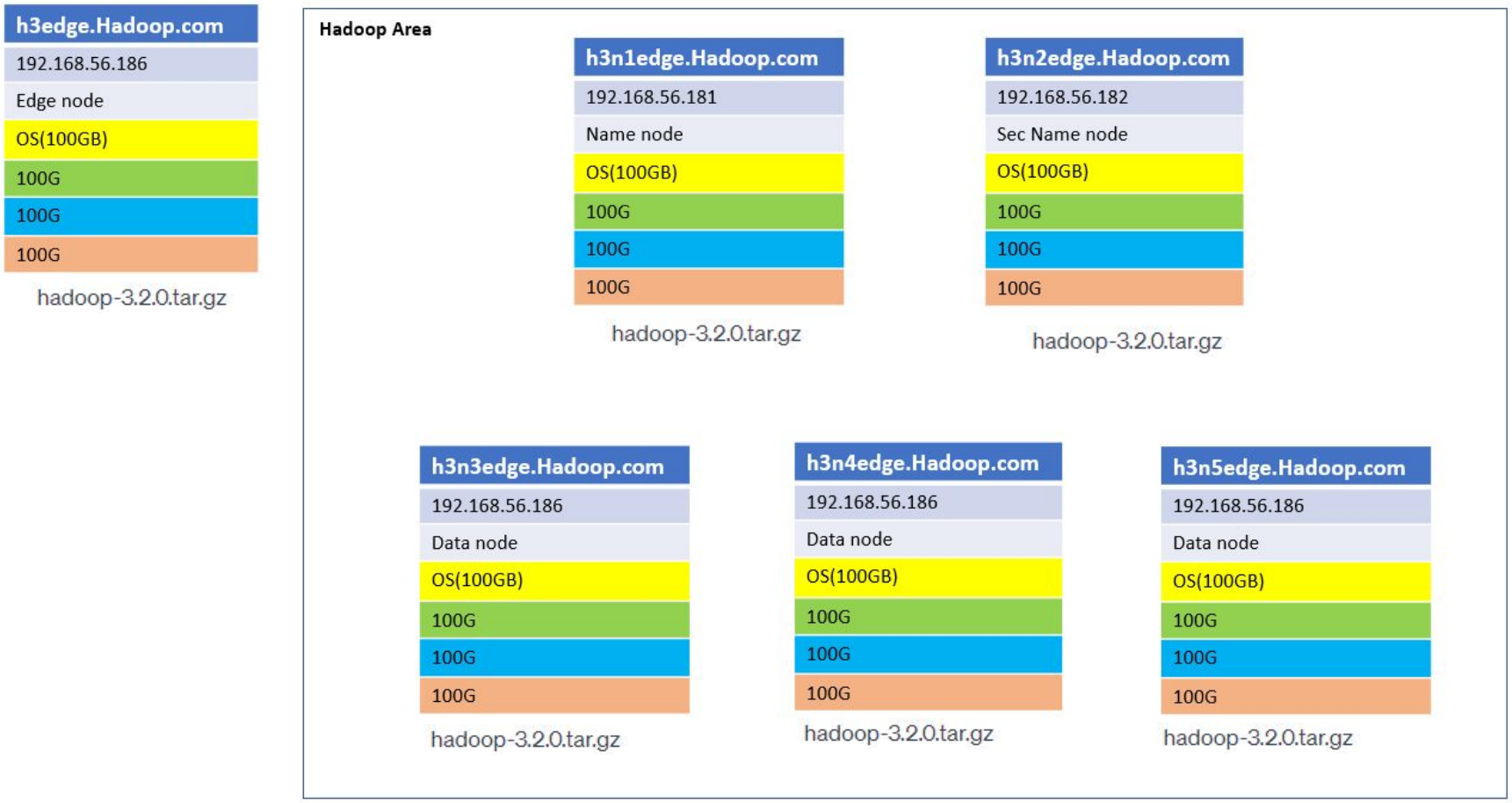
- ✔ In our clusters now we have two name nodes
- ✔ Active name node and standby name node
- ✔ If active name node is down standby name node will become active and it will take care of the work.
- ✔ manager and deputy manager

Hadoop cluster



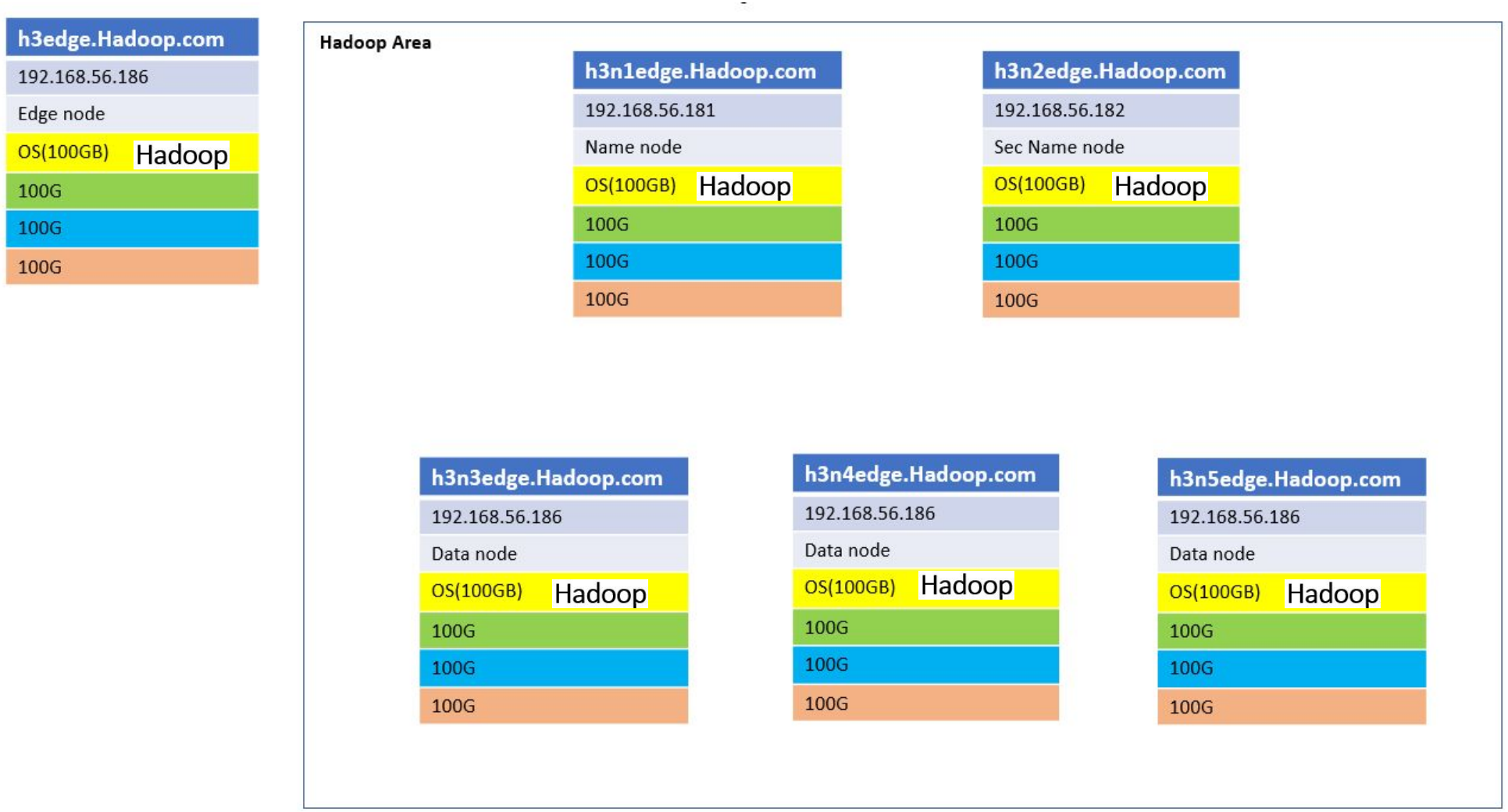
Install Hadoop on every machine

TAR Ball Name	Download Location
hadoop-3.2.0.tar.gz	https://archive.apache.org/dist/hadoop/core/hadoop-3.2.0/



Download and unzip on every machine

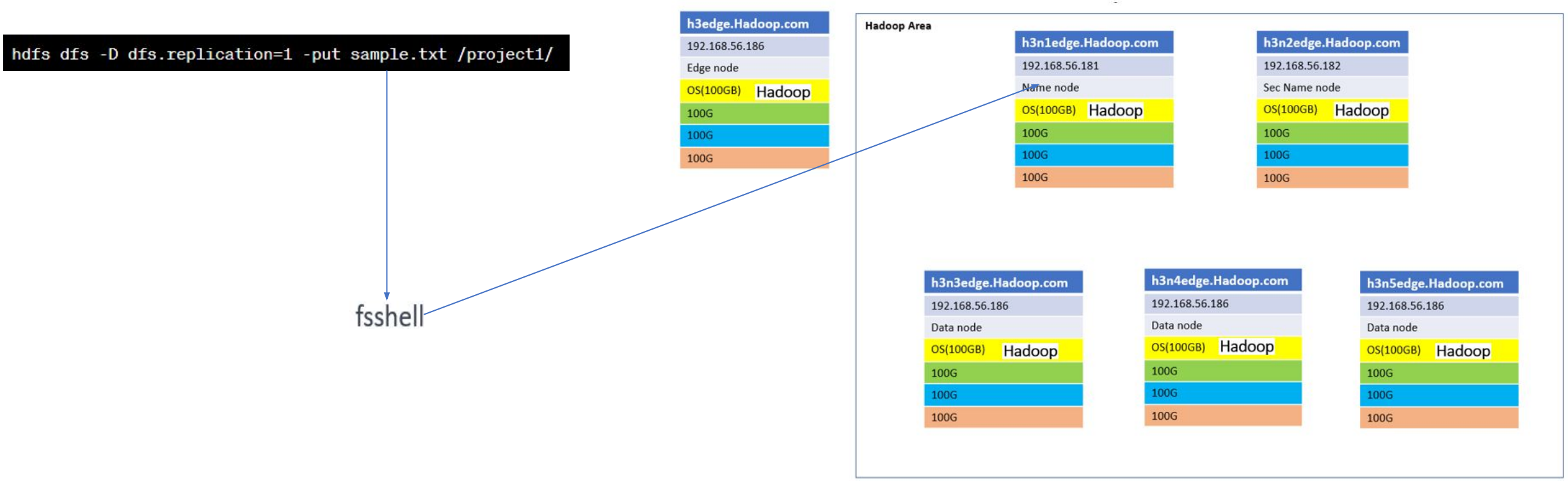
Hadoop installed on every machine



Hadoop clusters runs on configurations file

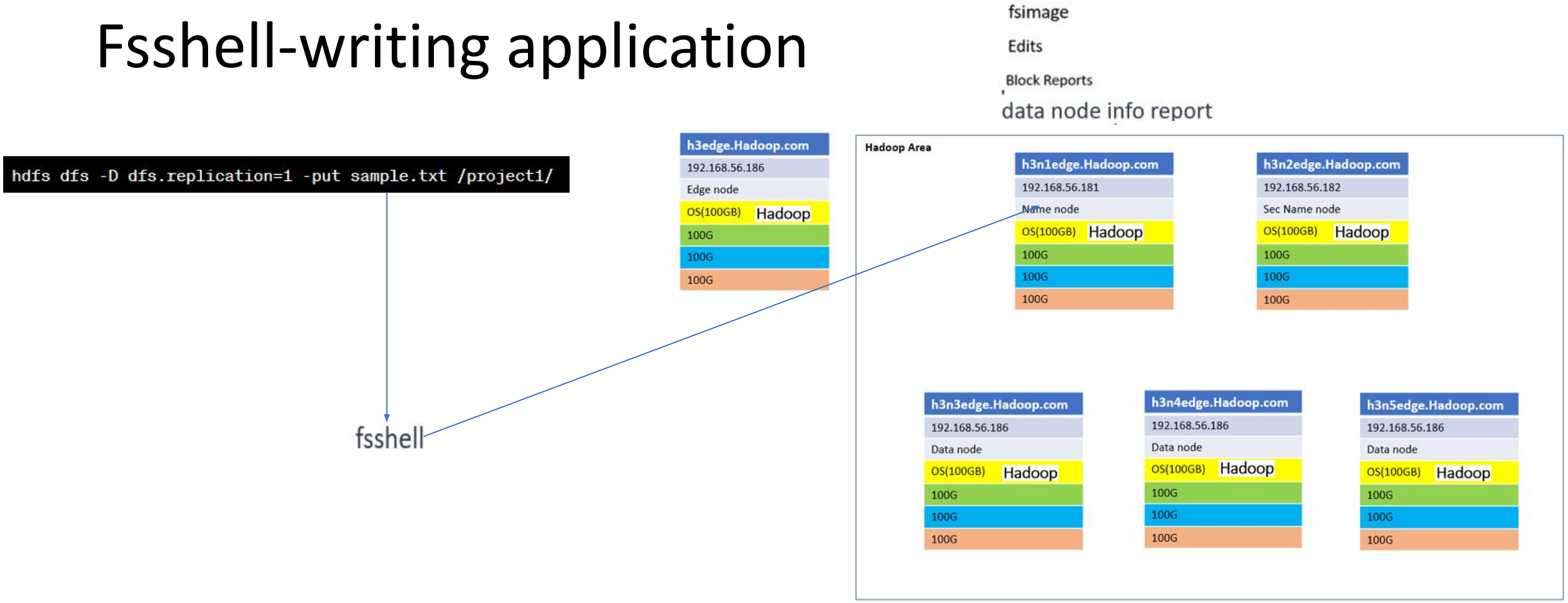
- | hadoop-env.sh | Contains Hadoop Environment Variables |
- | yarn-env.sh | Contains Hadoop Environment Variables |
- | core-site.xml | NameNode info |
- | workers | DataNode(s) info |
- | masters| SNN info|
- |hdfs-site.xml|(hdfs properties-block size replication, fsimage ,location, data block location)

Fsshell-writing application



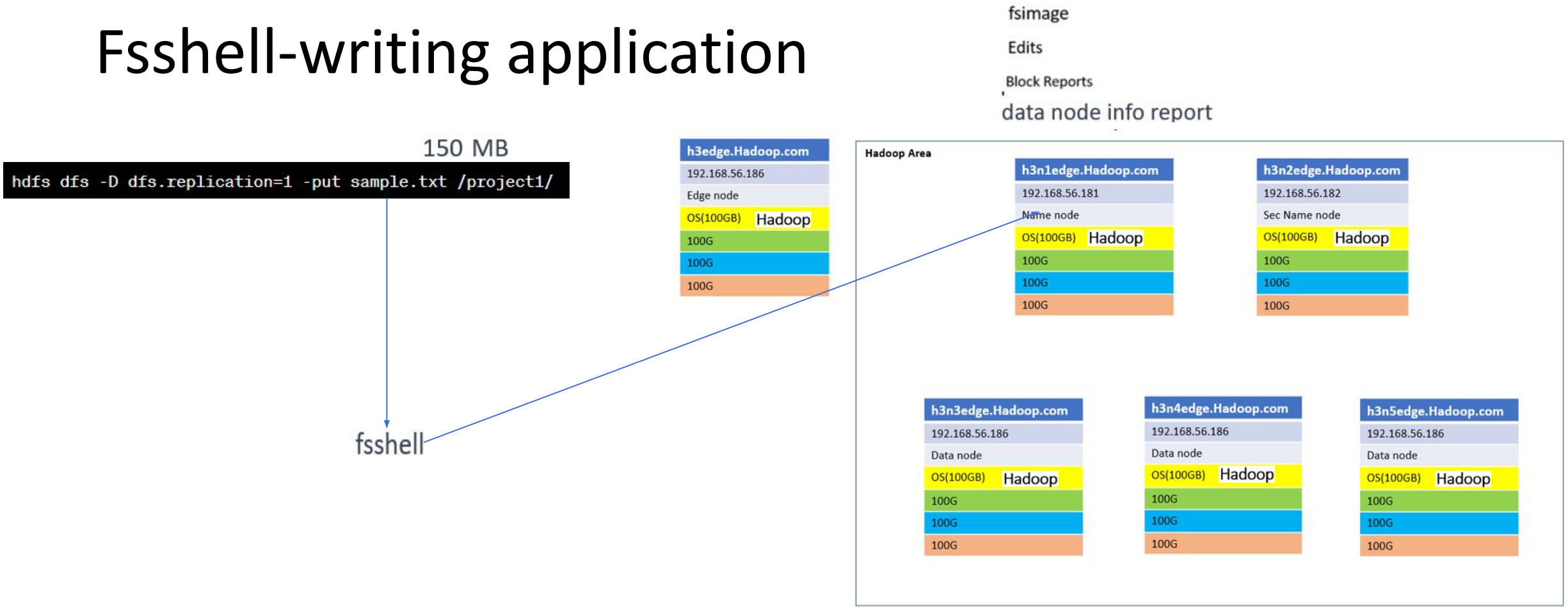
- when you type the command here and press enter (means you are invoking an algorithm) what is happening in the back end?
- Back end there is something called **fsshell(algorithm)** (client program) starting.
- It means you are Invoking fsshell who is executing your program, fsshell is executing your program.
- fsshell will contact name node

Fsshell-writing application



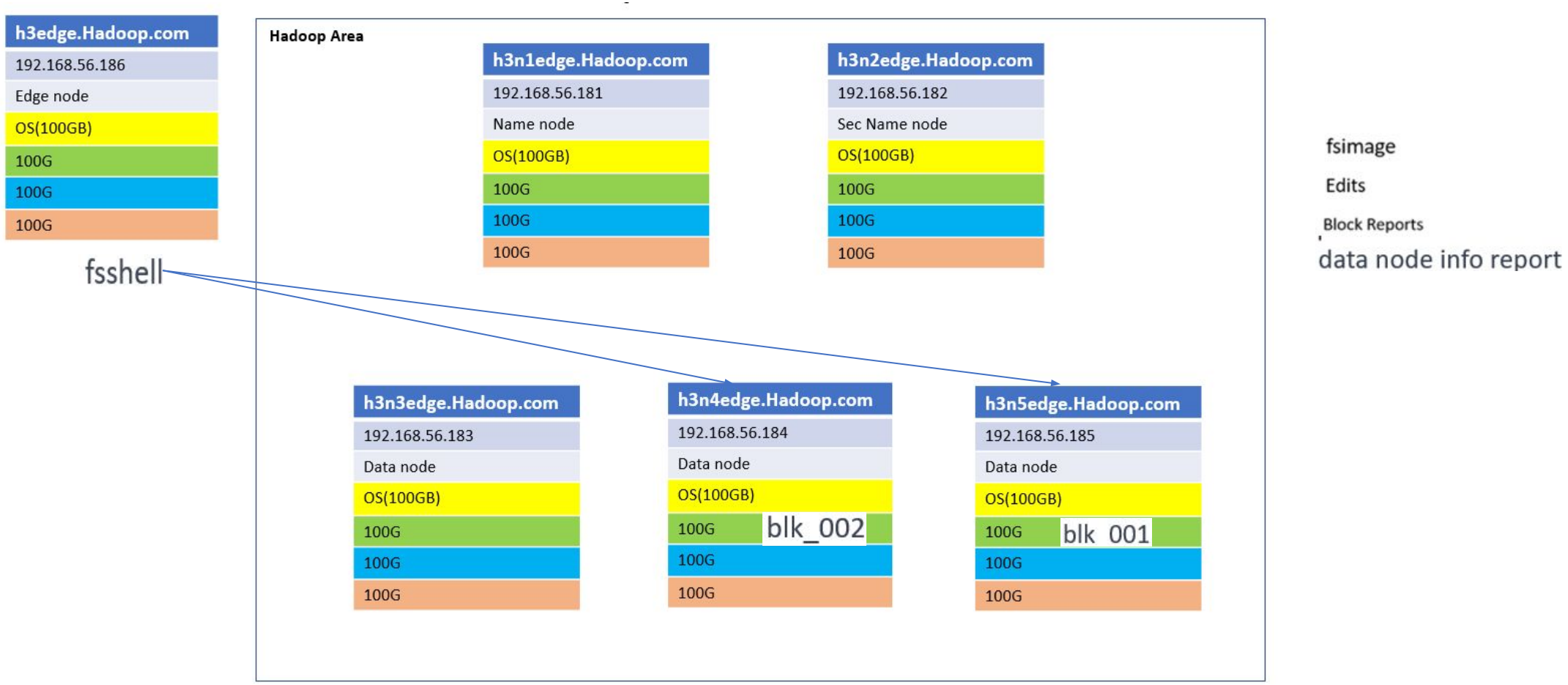
- Fsshell will understand which is name node through configuration file on edge node.
- Fsshell- Hey !!! name node I want to write sample.txt in to project 1 directory can you help me?
- Name node will check edit log first if the same entry is available or not if it is not there then it will check it in fsimage if not there too then next step
- Then it will check size of the file and will check if all its data nod has that much space using data node info

Fsshell-writing application



- Now we have 300 GB space available on each disk, so we have space to put 15o MB file
- Name node acknowledge that it has space to put the file and same name file is not available.
- Name Node- ok fsshell accepted your request now cut your data into pieces(blocks)
- fsshell will cut the data into pieces
- Default size is of piece 128MB so 150 will cut into two pieces 128 and 22

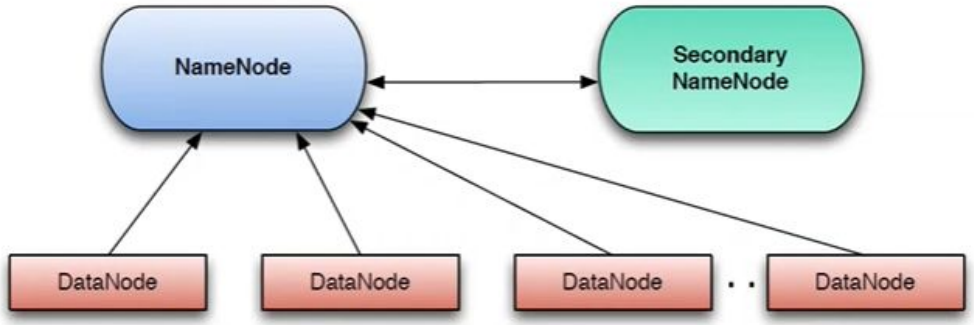
fsshell-writing application



- fsshell-hey name node I cut the file into pieces as per your suggestion Name node- put first piece in 192.158.56.184 with name it as blk_001 and second piece in 192.158.56.185 with name it as blk_002 then fsshell will contact 184 and 185 and will put it and then name node will update block report

Hadoop 1.x

Hadoop Architecture with Single NameNode



Limitations of Hadoop with Single NameNode

- NameNode is Single Point of Failure as Secondary NameNode never acts like Primary NameNode in case of Primary NameNode failure
- Chances of losing data if Checkpoint doesn't happen
- Metadata files need to be copied manually in case of Primary NameNode crash.

- Sec NN is just like PA and Primary NN is like PM, sec NN cannot replace PM it will only note down PMs work.
- Sec NN only has metadata file fsimage stored nothing more than that

Solution: NameNode High Availability (Active & Standby NameNodes)

Active Name Node Vs Standby Name Node

- In a typical HA(High Availability) cluster, two or more separate machines are configured as Name Nodes.
- At any point in time, exactly one of the Name Nodes is in an Active state, and the others are in a Standby state.
- The Active Name Node is responsible for all Client operations in the Cluster.
- The Standby Name Node is simply acting as a slave, performing checkpoint on regular intervals to provide a fast failover if necessary.

Active Name Node Vs Standby Name Node

Challenges with Name Node High Availability

- Which NN should be Active and Which NN(s) should be standby?
- Who will change the state of Standby Name Node to Active when Active Name Node is down

- **Solution:** Additional mechanism Zookeeper is required to automate this process

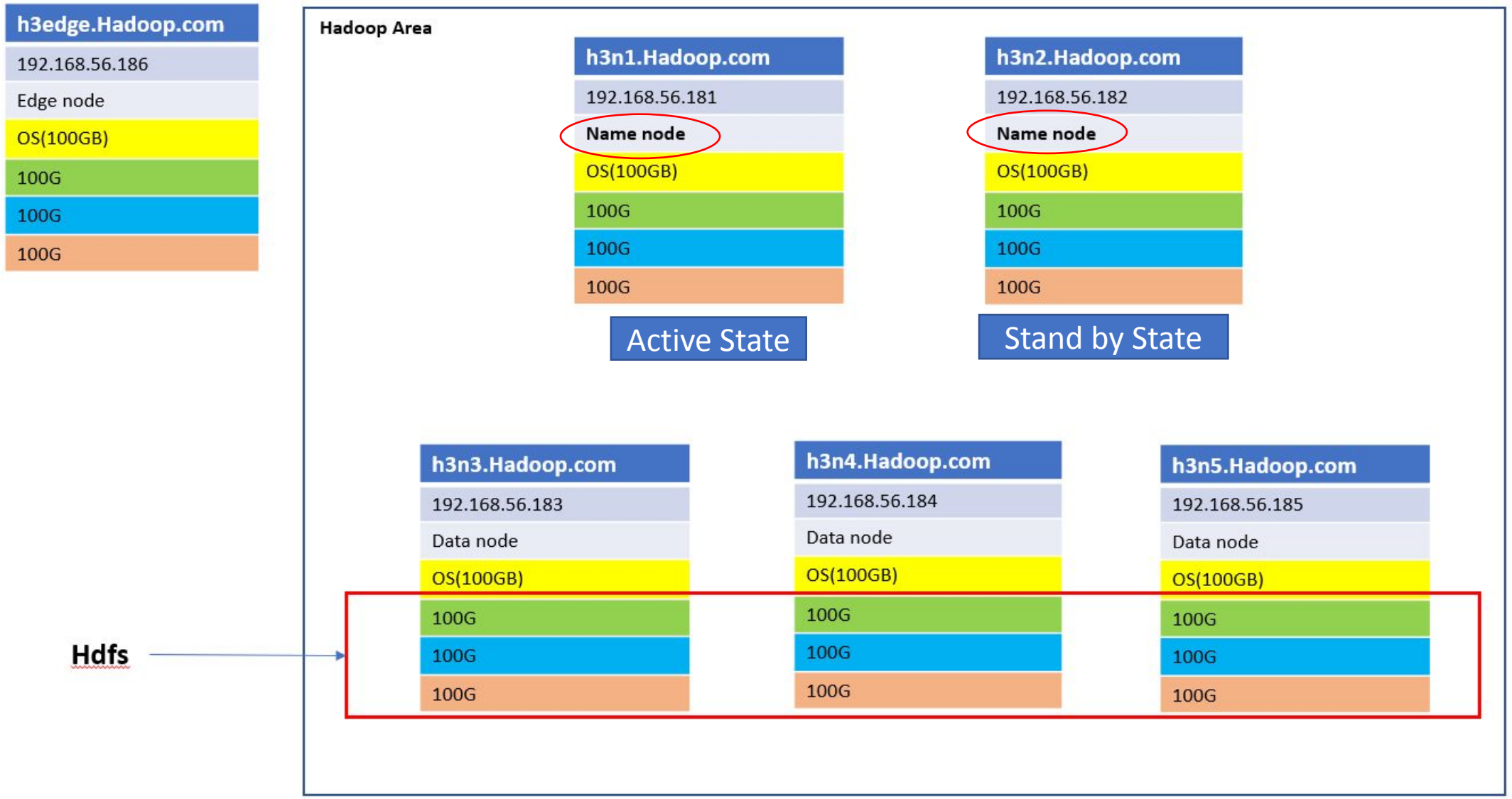
Active Name Node Vs Standby Name Node

Challenges with Name Node High Availability

- How to maintain common copy Edits when we have multiple Name Nodes?
- What in case if common copy of Edits is lost?

- Solution: Additional mechanism Quorum Journal Manager (a group of journal nodes) is required to maintain multiple copies of Edits.

Two name Nodes



High Availability

- If active is down stand by will become active

Time	NN1	NN2
9:00	Standby	Standby
9:01	Active	Standby
9:50	Down	Active
10:00	Restarted	Active
10:01	Standby	Active

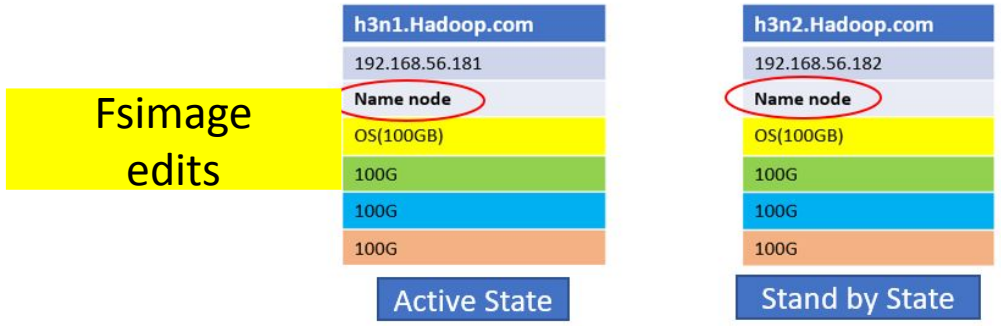
- Which name node should be active, and which should be standby
- Who will make other NN active if any one of NN1 or NN2 is down .
- It is not possible for Hadoop admin to seat and watch when NNs goes down

- Requires automatic mechanism

- The answer for first challenge is zookeeper

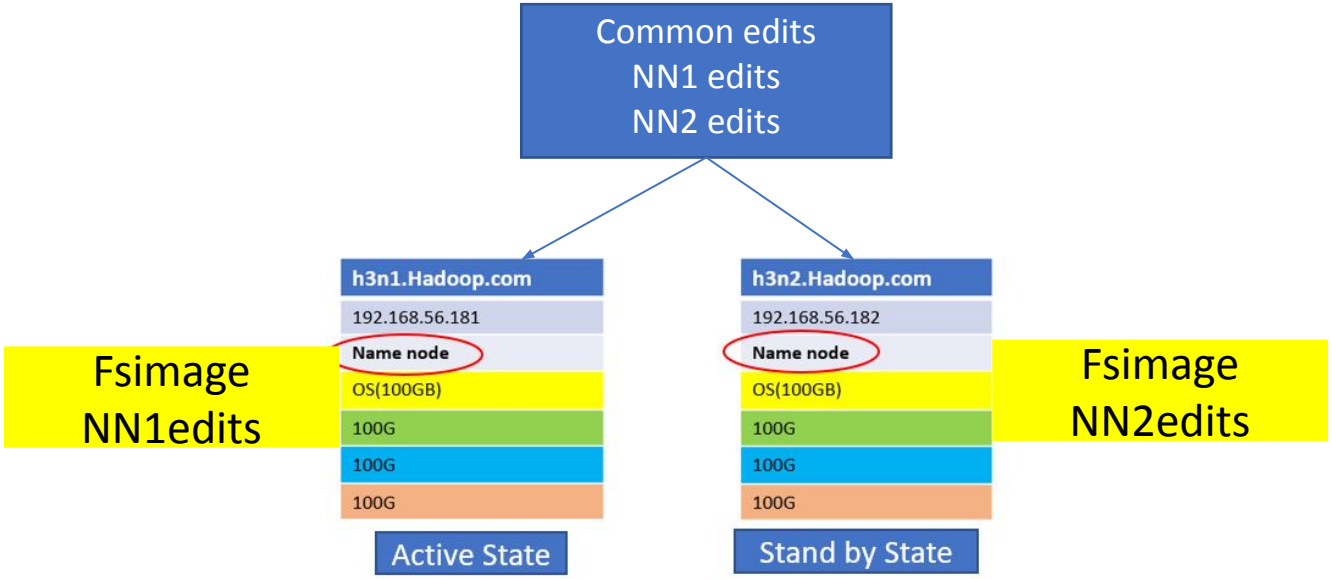
Problem 1

- If NN1 is active it will write its metadata (fsimage and edit logs) into its own hard disk .
- If NN2 is active it will write its meta data (fsimage and edit logs) into its own hard disk
- Suppose NN1 is active and at 9:00 it has written 10 edits how NN2 will understand about 10 edits
- Whatever NN1 is doing that should be known to NN2 but they are not sharing each other



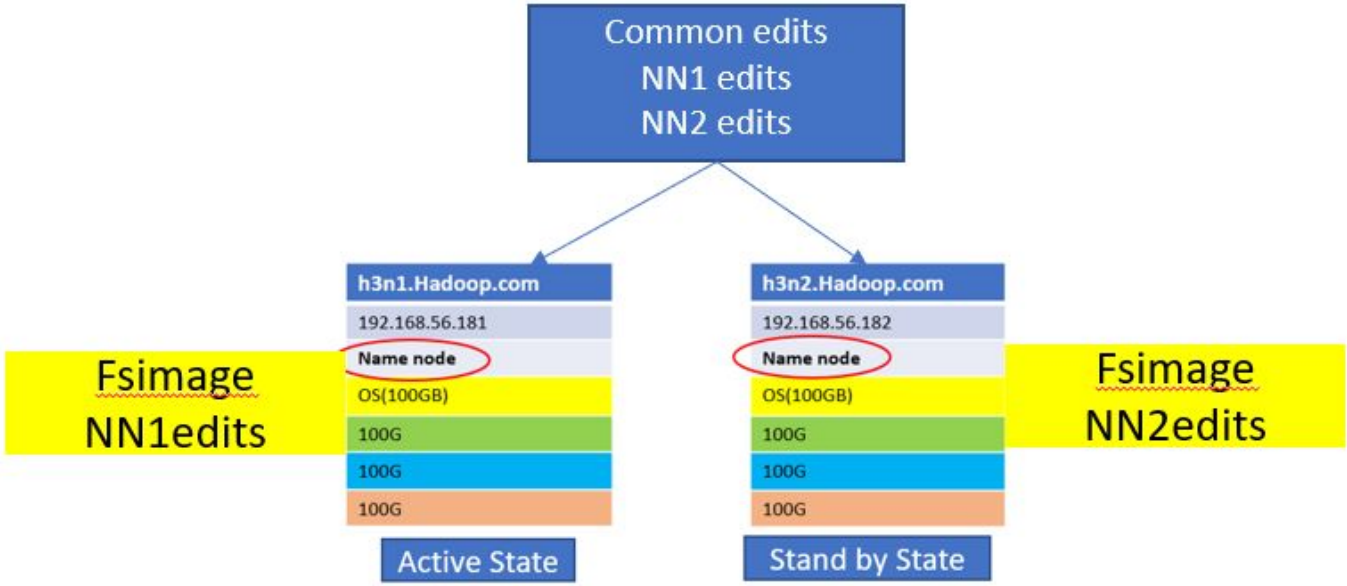
Problem 1

- If NN1 is down or crash then all its edits and fsimage is gone.
- If NN2 is down or crash then all its edits and fsimage is gone.
- It is important for us to make sure each name node should know what other name node is doing
- So we should have a common place where we put metadata for NN1 when it is active and metadata of NN2 is doing when it is active.



Problem solved

- NN1 when active will write edits in its hard disk as well as in common place also
- NN2when active will write edits in its hard disk as well as in common place also
- If NN1 written edits and it goes down then NN2 will become active and play a role of name node so it will take from common area whatever edits done by NN1
- This mechanism is called as **Journal node**



Problem 2

- When you start both NNs, both enter into Standby mode
- Challenge1: Which NN should be selected as active when we have 2 standby NNs
- Challenge2: Who will make standby as active when active NN is down

- Solution is Zookeeper we will install software called zookeeper to solve this problem

Zookeeper

- ZooKeeper (ZK) is a highly-available, highly-reliable and fault-tolerant coordination service for distributed applications.

- **Ensemble :** A group of ZooKeeper Nodes worked as a single unit rather than individual
- **Quorum :** No. of Nodes that should be up and running in the ensemble

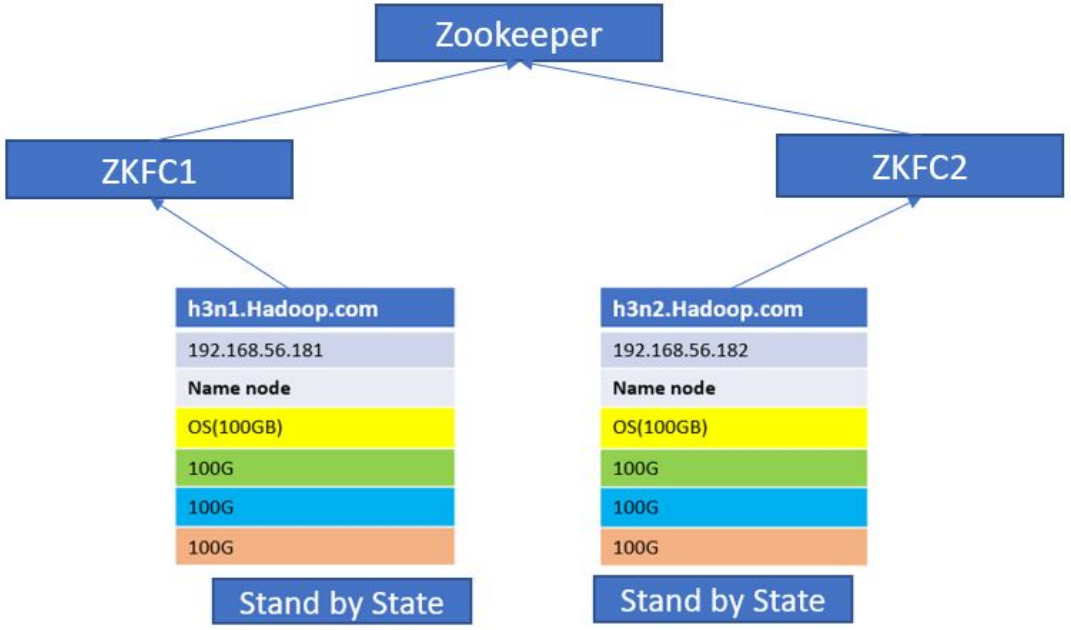
- Number of Nodes that should be up and running in the Ensemble to take a collective decision is calculated by using below formula.
- $N - (CEIL(\frac{N}{2}, 0) - 1)$
- where “N” is the number of total Nodes in Ensemble.

Zookeeper

- What is ZNode?
- ZooKeeper maintains an active connection with all its Clients using a heartbeat mechanism.
- Furthermore, ZooKeeper keeps a session for each active Client that is connected to it and assigns a key which is called ZNode.

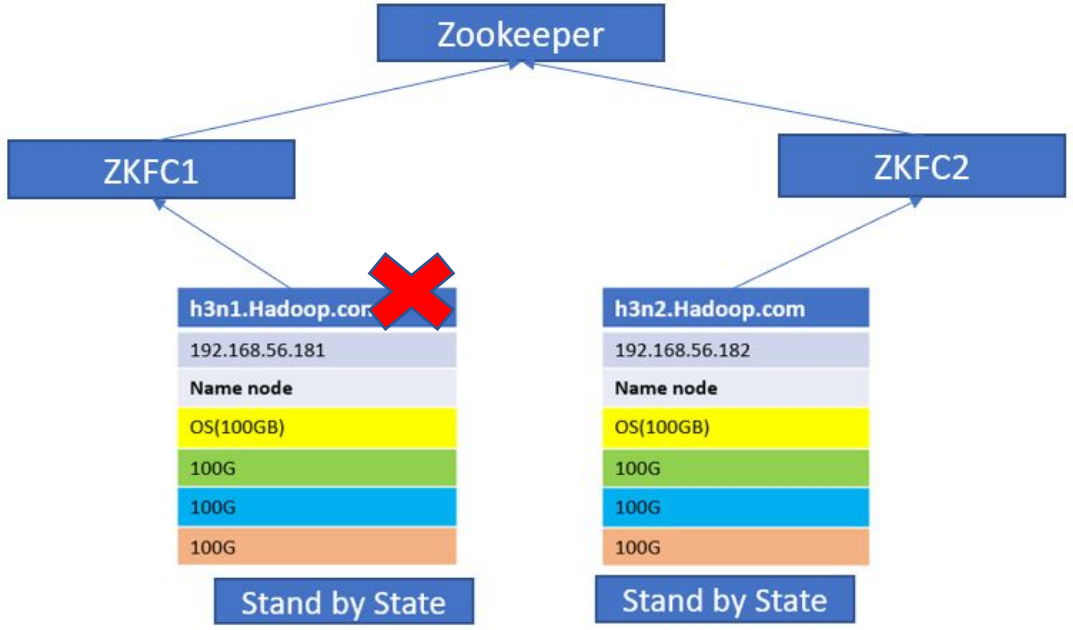
Zookeeper failure controllers (ZKFC)

- Which NN should be selected as active when we have 2 standby NNs
- NNs will send heartbeat to zookeeper, whomever heartbeat zookeeper gets first it will make that NN as active , like first come first serve
- NN send heart beats to zookeeper through zookeeper failure controller as NN are master nodes and ZKFC acts as their PA



Zookeeper failure controllers (ZKFC)

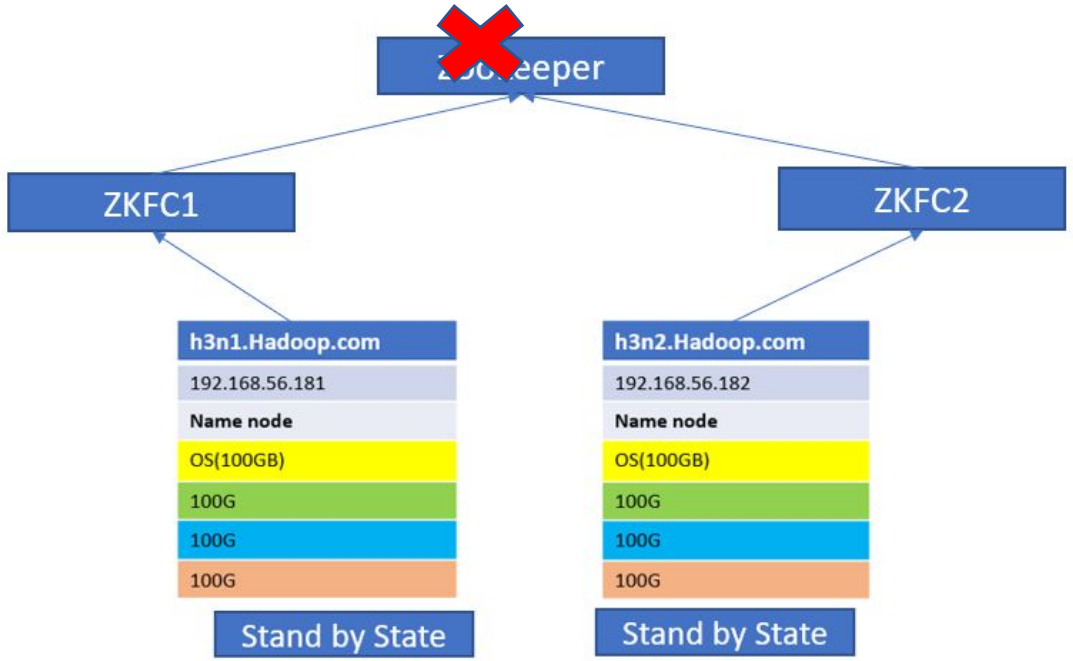
- If NN1 is down ZKFC will tell zookeeper hey my boss health is not good, please take necessary action
- Zookeeper will make NN2 active in case one NN is down
- After some time, service is started (as we assume that system is not crashed)
- ZKFC1 will report to zookeeper that my boss is back
- Zookeeper will tell ZKFC that fine let it be in standby mode NN2 is taking care now
- Now what will happen if zookeeper is down
- If NN is down and Zookeeper is down, then NN1 will never come to active state.



Zookeeper failure controllers (ZKFC)

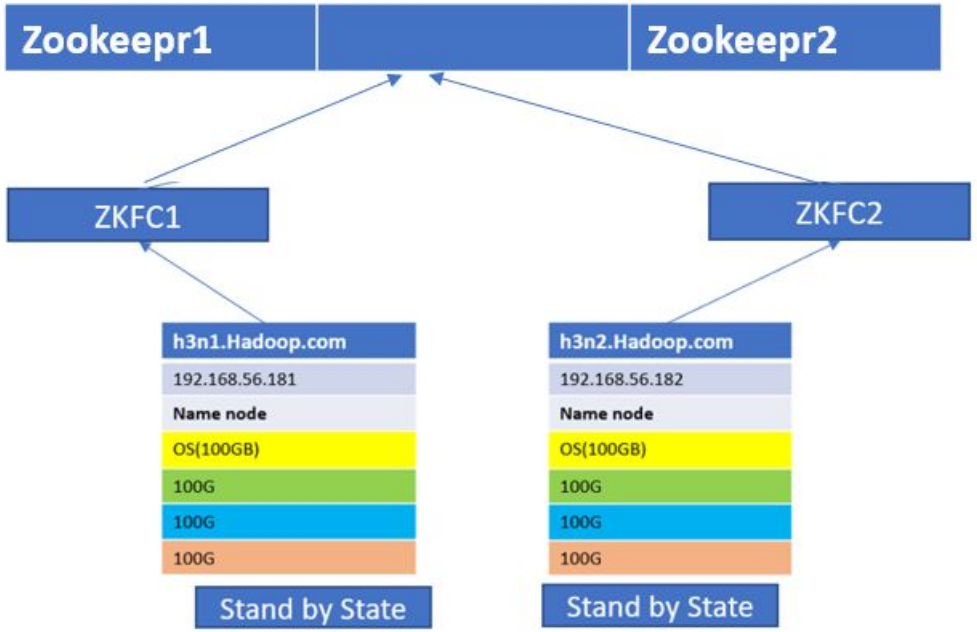
- Zookeeper is very important if its not there there won't be anyone who will monitor the health of name node if active name node is down standby name node will not become active
- First, we must start zookeeper service.
- If we start NN first, then without Zookeeper both the name node will remain in stand by mode
- We should have high availability for Zookeeper also as there are chance that any service can go down in real time

- If Zookeeper is down, we need to have a backup for Zookeeper also



Zookeeper Backup

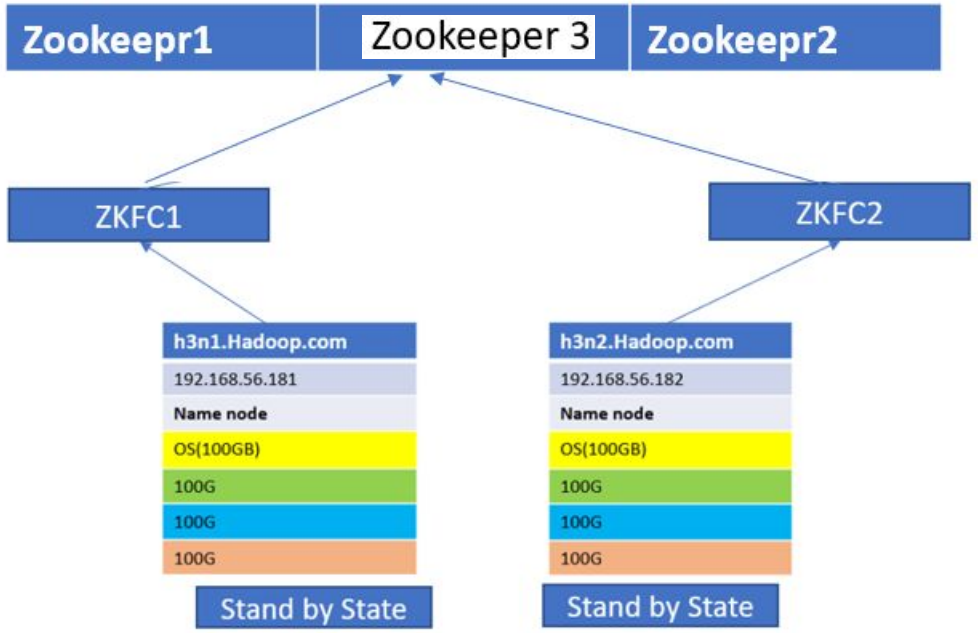
- When you have two Zookeepers or more than two Zookeepers then the concept of voting will be introduced
- In case of single Zookeeper whichever NN sends Heartbeat first Zookeeper will make that NN active
- In case of tie there is a problem, so we introduce 3 zookeepers
- If ZKFC1 sends heartbeat to ZK1 and ZK2 first so NN1 got 2 votes and NN2 got 0 in this case NN1 will become active
- If ZKFC2 sends heartbeat to ZK1 and ZK2 first so NN2 got 2 votes and NN1 got 0 in this case NN2 will become active
- If exactly at the same point of time ZKFC! Sends heartbeat to ZK1 and ZKFC2 sends heartbeat to ZKFC2 so there is tie
- It seems odd number of Zookeeper is good idea, So we nee



Zookeeper Backup

- So we need to introduce 3rd Zookeeper 3

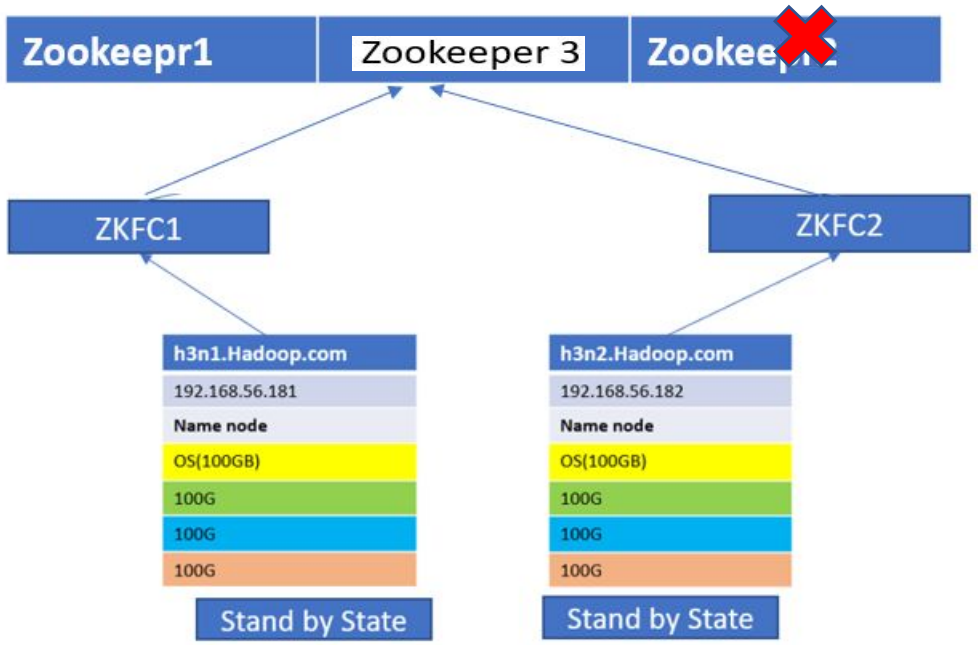
ZKFC1	ZKFC2
3	0
2	1
1	2
0	3



Zookeeper Backup

- What is ZK2 is down
- ZK internally elect leader and follower before starting any process
- Leader follower game one ZK is elected to be leader and other becomes followers
- If leader goes down other follower or immediate follower will becomes leader
- In case of tie If leader say NN1 and follower says NN2
- NN1 is selected
- Leader decision make sense only in case of tie otherwise
- Leader vote = 1.5 and followers vote=1

ZKFC1	ZKFC2
2	0
0	2
1	1

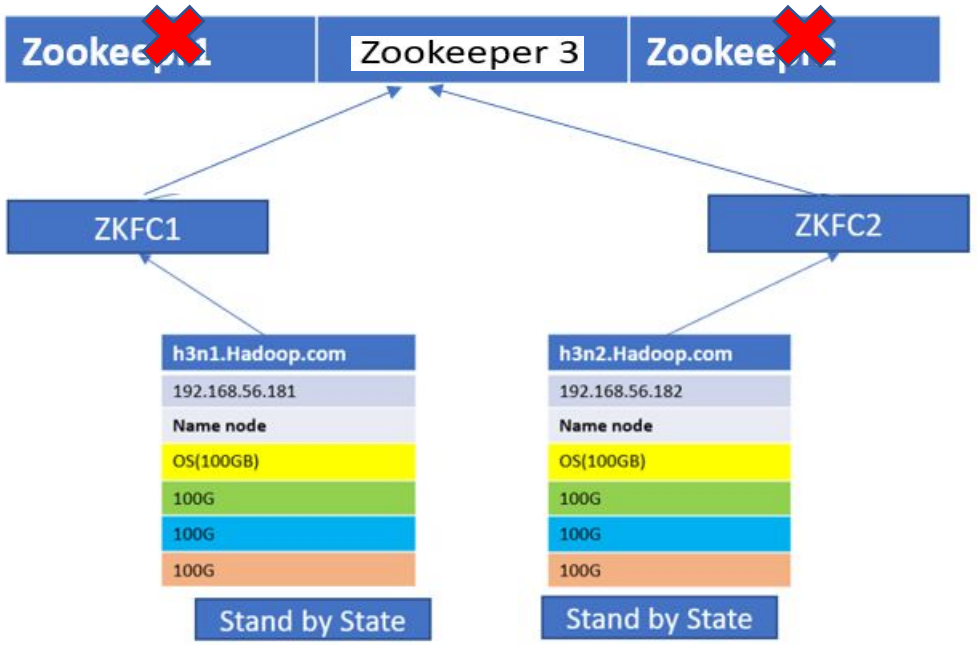


Zookeeper Backup

- What if two zookeepers are down
- Quorum based means majority of the zookeepers should be available.
- At least two Zookeepers should be available.
- With one zookeeper it can not do anything i.e. to decide which NN should me made active

  majority of Zookeepers should be present

ZKFC1	ZKFC2
2	0
0	2
1	1



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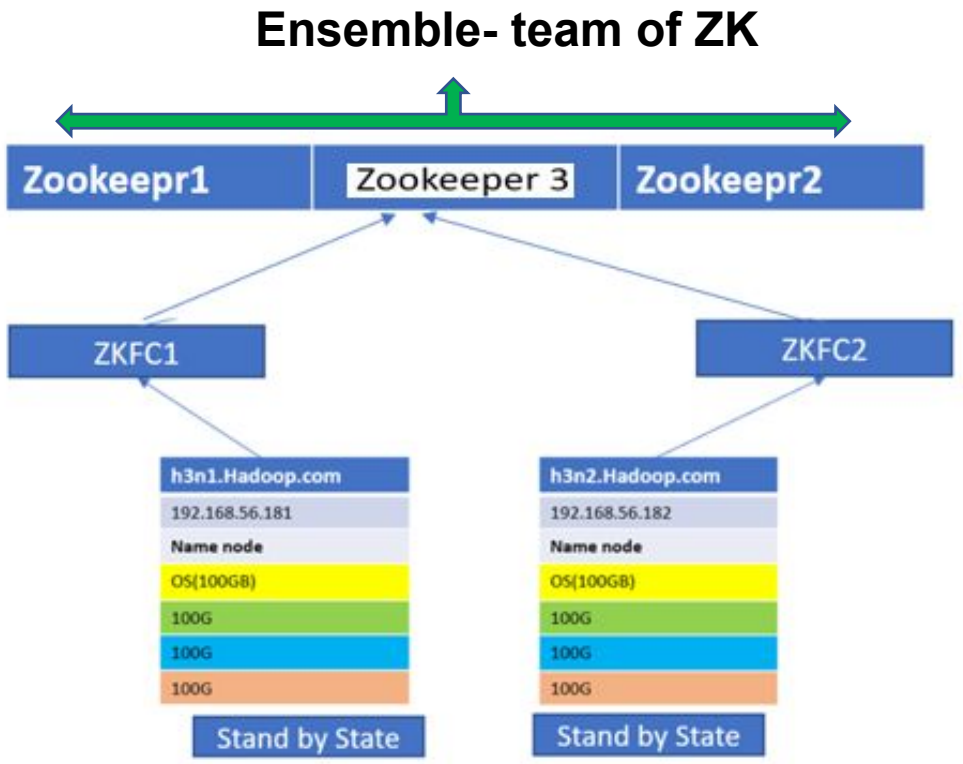
Zookeeper

- **Ensemble :** A group of ZooKeeper Nodes worked as a single unit rather than individual



Zookeeper

- **Quorum :** No. of Nodes that should be up and running in the ensemble (majority to take decision) to maintain Quorum we should have at least 3

# of ZK	Quorum (Majority)
3	2
4	3
5	3
6	4
7	4
.	.
.	.
.	.

$$N = 7 \text{ then } N - (CEIL\left(\frac{N}{2}, 0\right) - 1) = 7 - \left(CEIL\left(\frac{7}{2}, 0\right) - 1\right)$$
$$= 7 - (CEIL(3.5,0) - 1) = 4$$

Zookeeper

- What is ZNode?
- ZooKeeper maintains an active connection with all its Clients (ZKFC1,ZKFC2) using a heartbeat mechanism.
- Furthermore, ZooKeeper keeps a session for each active Client that is connected to it and assigns a key(token) which is called ZNode.
- ZKFC will send heartbeat to ZK in return ZK send token number or Znode number
- If NN1 got token no 1 and NN2 has got token 2 NN1 active
- Token number is Znode number
- NN1 will become active

Types of Znode

- **Persistent** – alive even after its Client session is disconnected and need to be deleted explicitly (Token in bank will remain valid even if you go out priority will be given to you)
- **Ephemeral** – alive only for the lifetime of its Client session and deleted automatically(Inside the bank token valid as you go out come later your token is invalid)

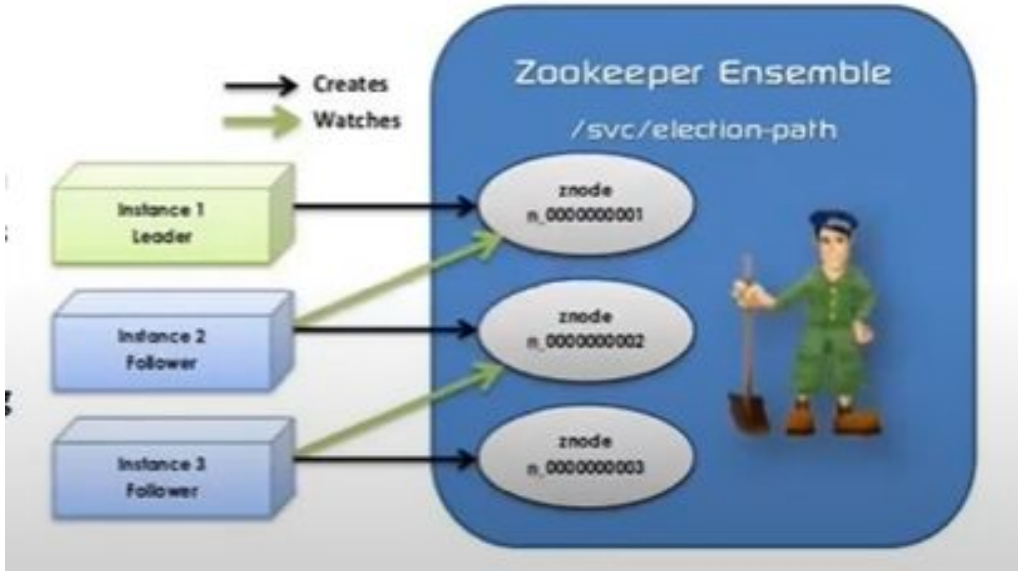
- (ZKFC has to sent heartbeat to ZK if it does not send then new Znode will be assigned)

Why odd number of Nodes in ZK Ensemble?

- In ZK Ensemble of 5 Nodes, Ceil[5/2, 0] - 1 = 2 can go down to maintain the quorum.
- In ZK Ensemble of 6 Nodes, Ceil[6/2, 0] - 1 = 2 can go down to maintain the quorum.
- In the second scenario, the extra ZooKeeper Node doesn't give any benefit to the Ensemble to maintain the quorum. So, replicating to that one extra ZooKeeper Node is just a performance overhead.

ZooKeeper Leader Election

- During ZooKeeper Leader Election process, each ZooKeeper in the ensemble creates an **ephemeral-sequential ZNode** in the election path.
- The ZooKeeper with the smallest ZNode id is the "**Leader**" and remaining ZooKeepers in the group acts like "**Follower**".
- If Leader goes down, the next follower corresponding to the Leader will become the new Leader. (Znode is ephemeral seq hence leader will get new token)

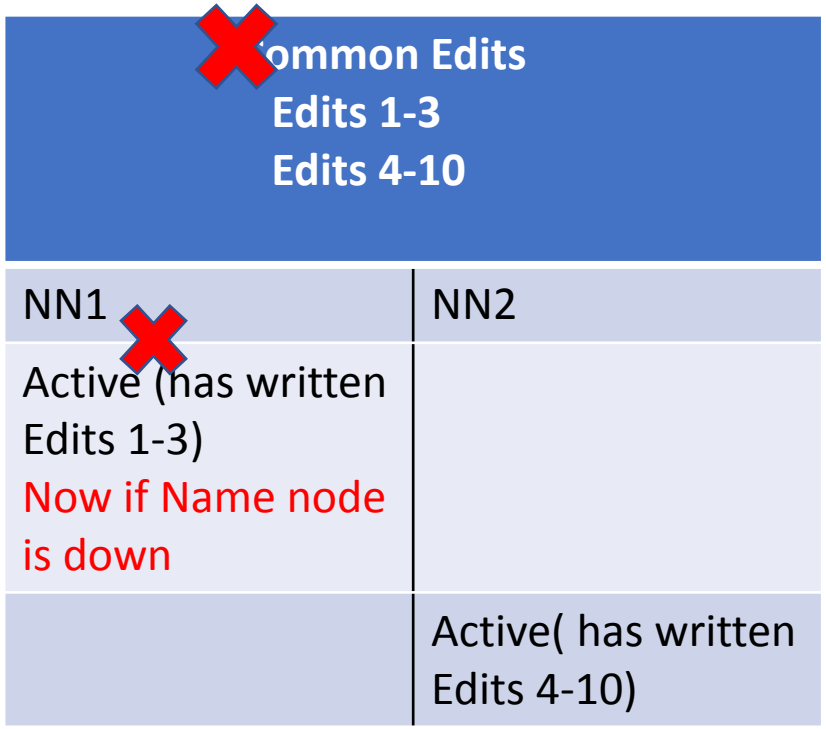


Journal Nodes

Common Edits Edits 1-3 Edits 4-10	
NN1	NN2
Active (has written Edits 1-3) Now if Name node is down	
	Active(has written Edits 4-10)

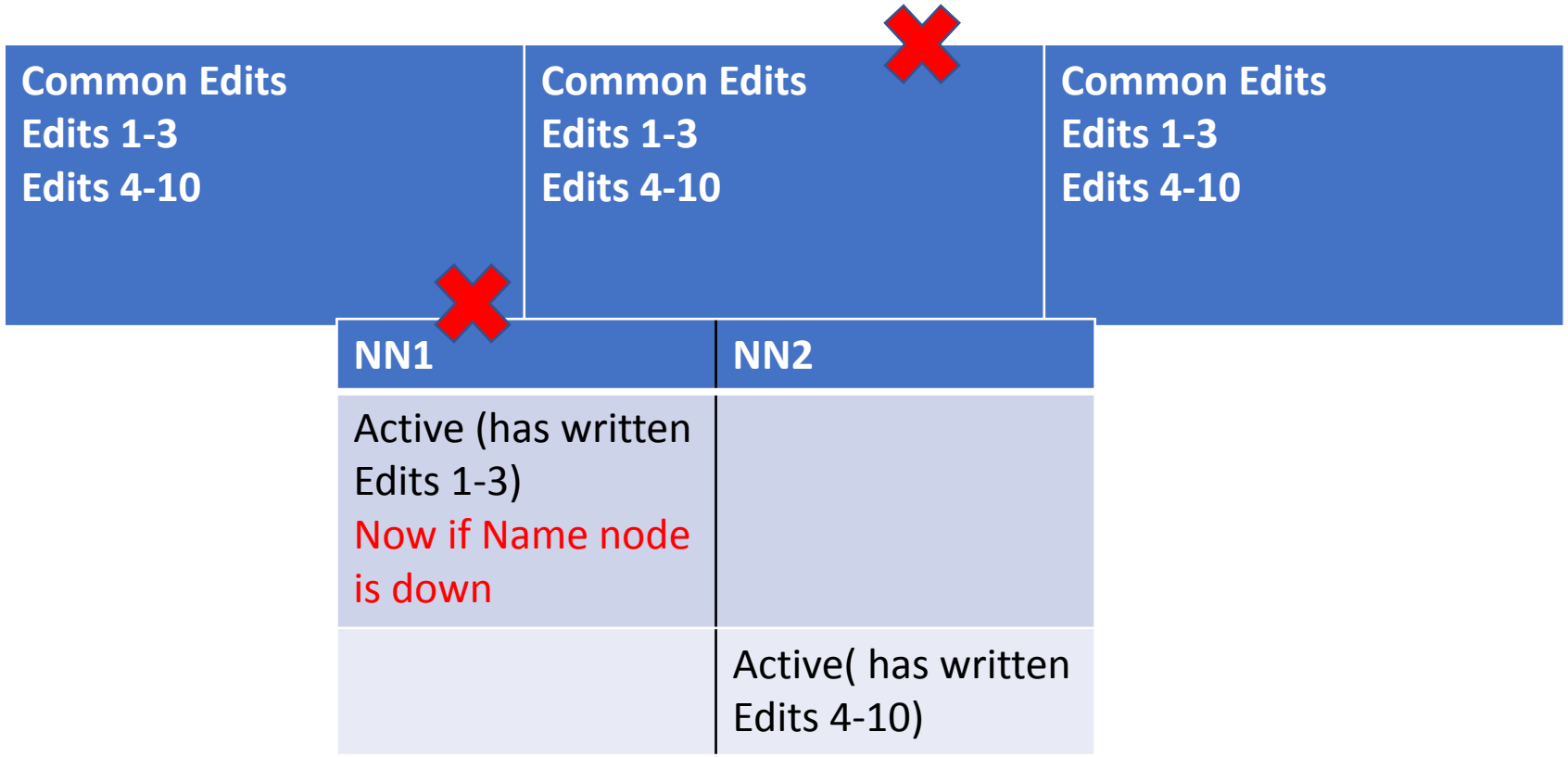
Will write one copy in common edits also

Journal Node



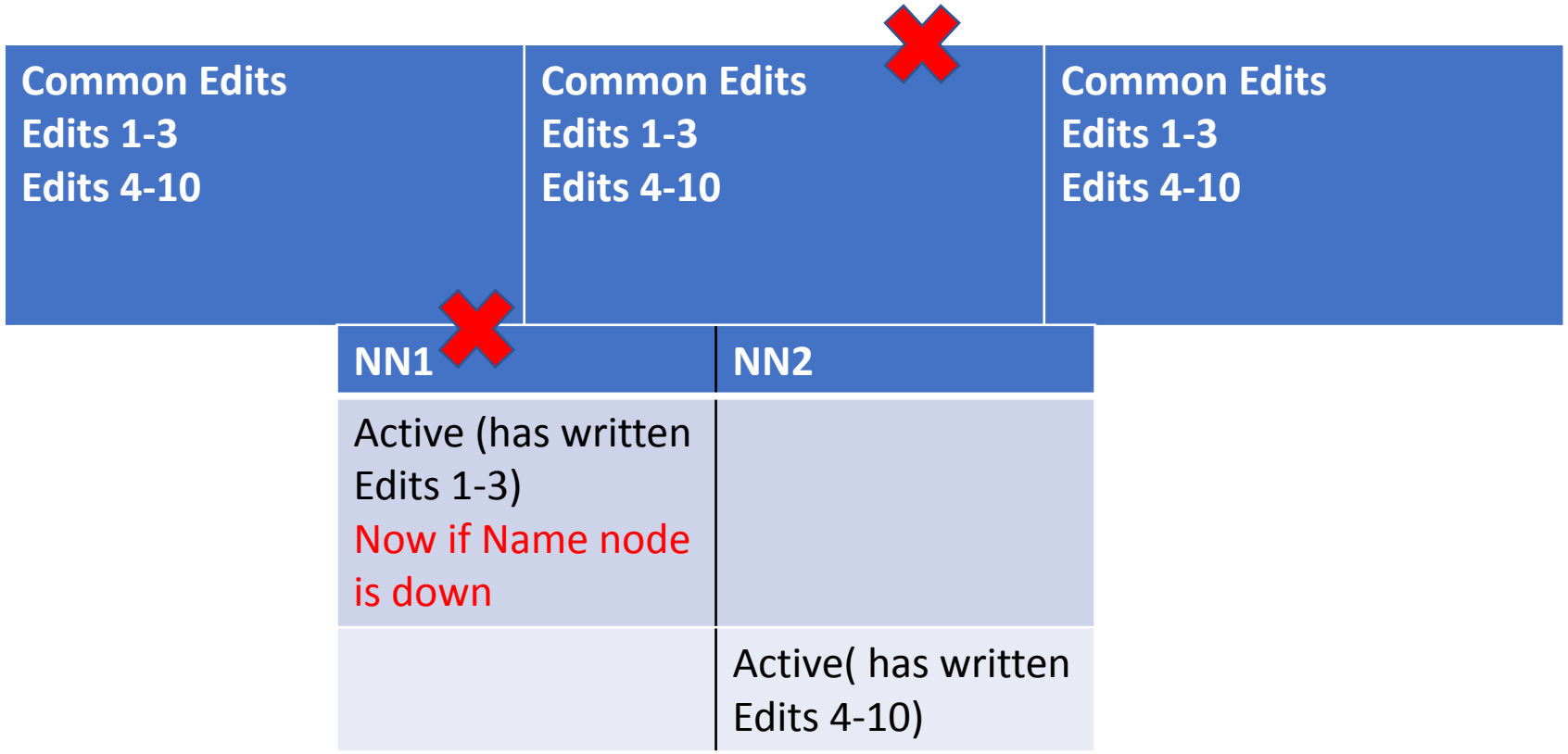
NN 2 will understand only edits 4-10 which is a big problem so we maintain common edits at three place

Journal Node



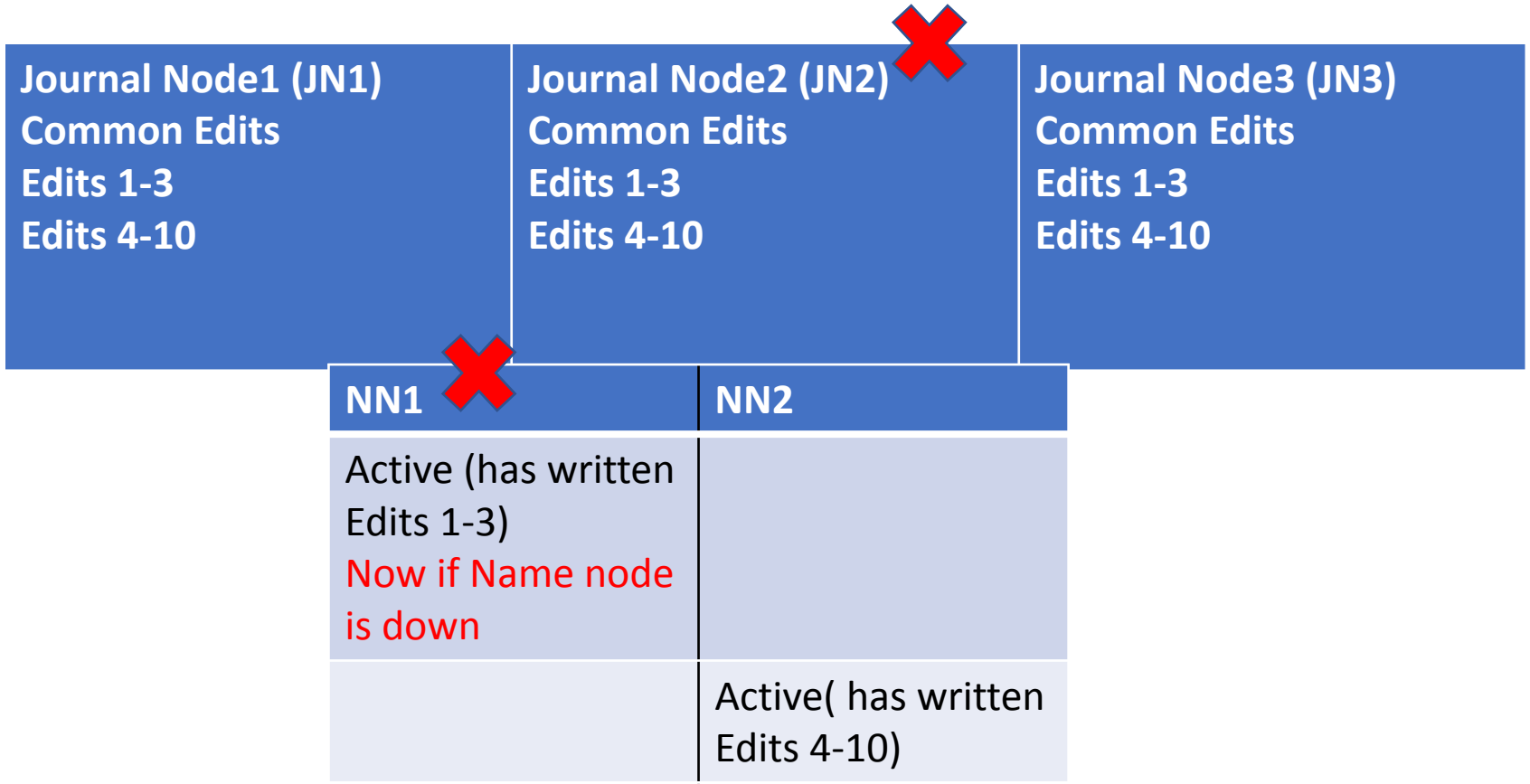
If one common edit is down NN2 can place Edits at other Common Edits

Journal node



If one common edit is down NN2 can place Edits at other Common Edits

Journal node



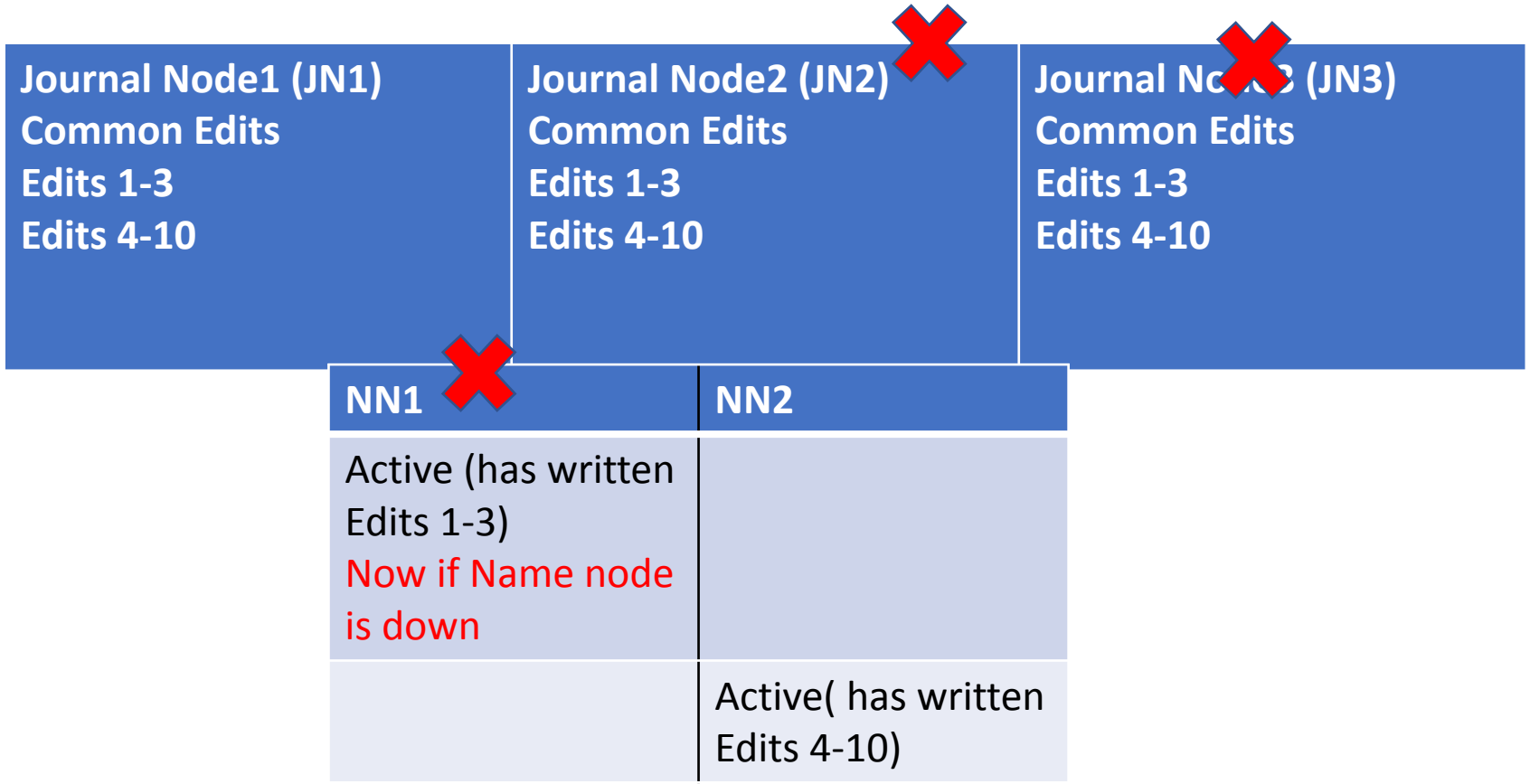
If one common edit is down NN2 can place Edits at other Common Edits JN will store all edits By NN1 and NN2

- Quorum Journal Manager

Quorum Journal Manager (a group of Journal Nodes)

- The QJM runs as a group of journal nodes, and each new transaction (also called Edit) must be written to a majority of the journal nodes.
- Typically, there are three journal nodes, so the system can tolerate the loss of one of them.
- In order for the Standby node to keep its state synchronized with Active NameNode, both NameNodes communicate with a group of separate daemons called Journal Nodes (JNs).
- When a new transaction is performed by Active NameNode, it durably logs it into a majority of these Journal Nodes.
- The Standby NameNode is capable of reading these transactions from the Journal Nodes.

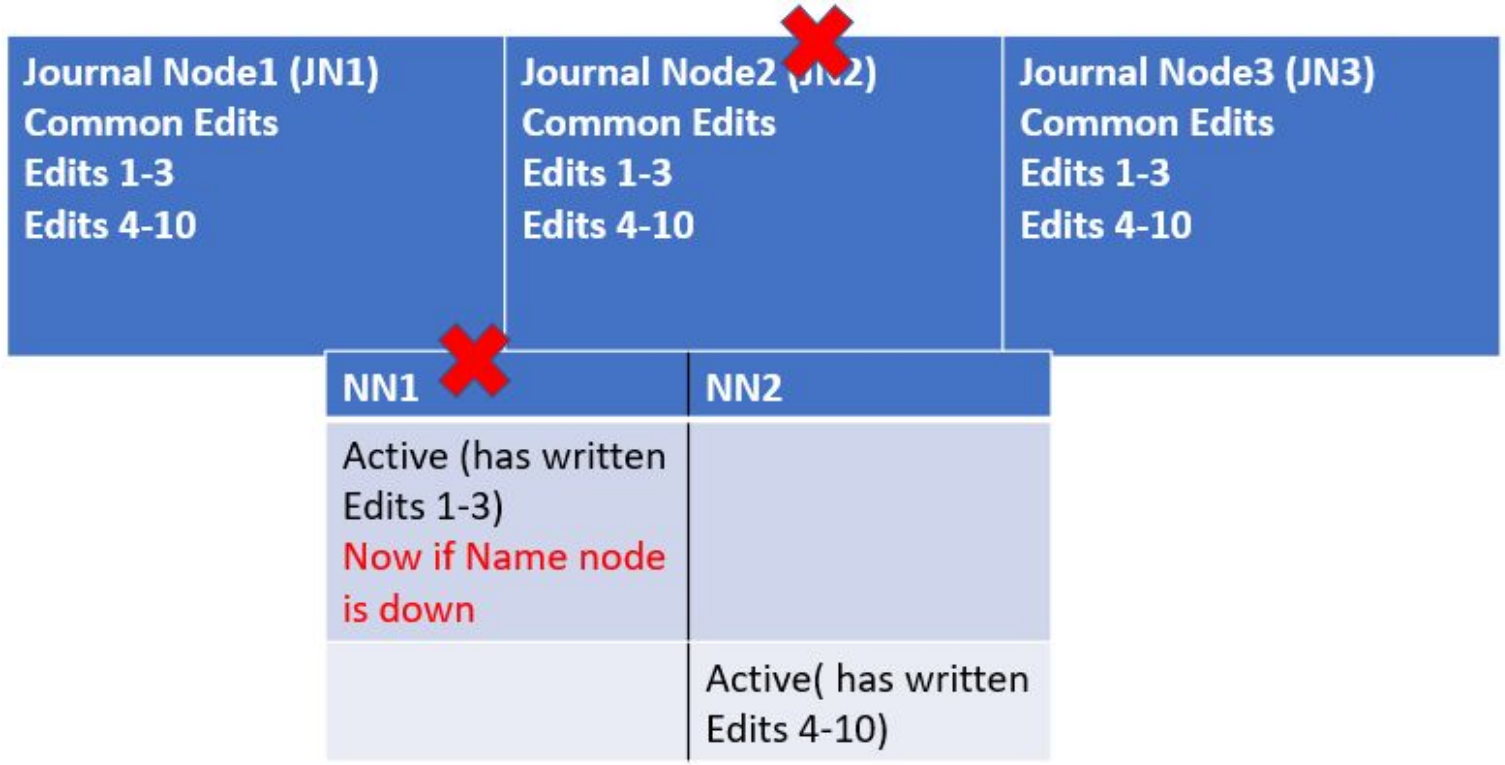
Journal node



If Two JN are down NN will not perform any Action here also concept of Quorum

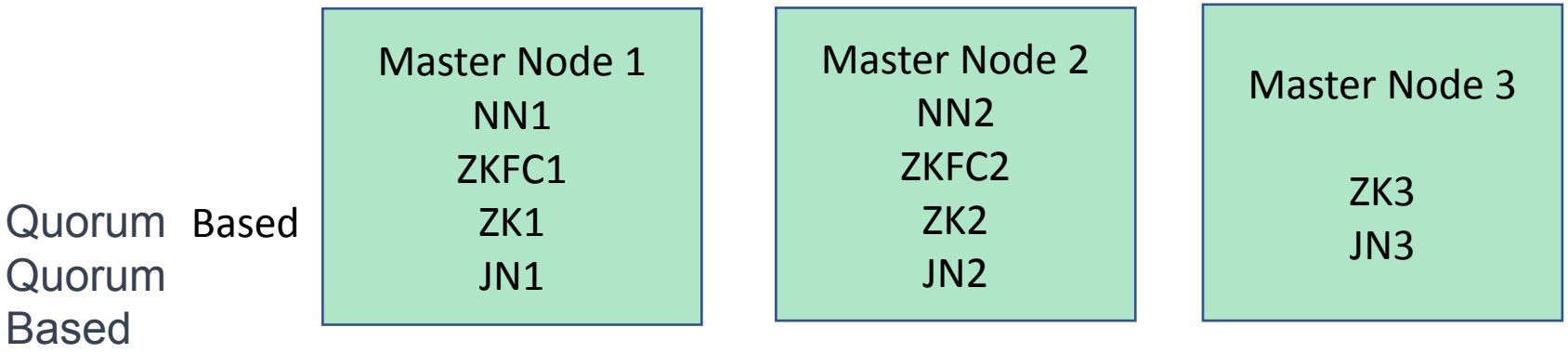
Quorum Status

Quorum - **live** (if majority of JNs available)
Quorum - Down (if majority of JNs not available)



When ever NN write Edits in to JN first it will check the quorum status if its alive or not
If Quorum is Down NN will say no JN available I will not write the transaction

Master-worker Architecture(2.x)

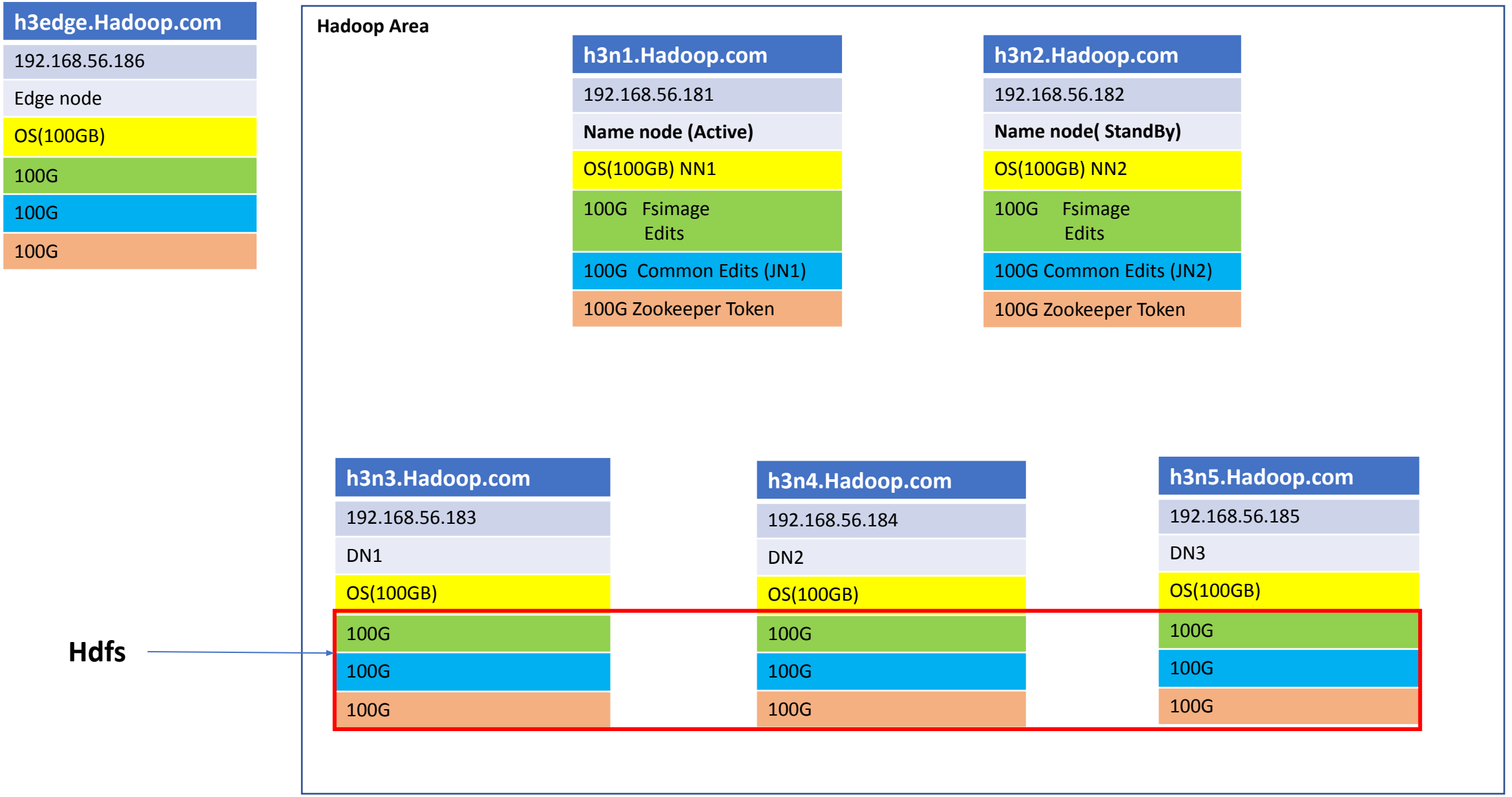


All the services Zookeeper ZKFC and JN are small Services, it does not require separate Server we install/configure them on Master Node where NN are installed We put separate hard disk on Master node to run these services

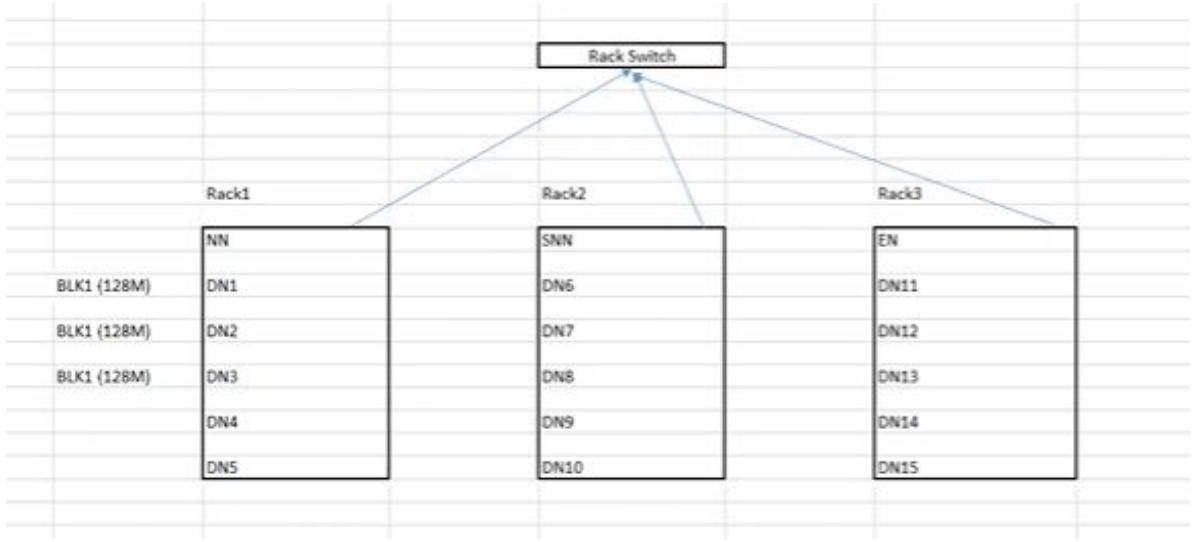
Master-worker Architecture(2.x)

IP Address	FQDN	Hostname	Role in Storage Layer
192.168.56.181	h3n1.hadoop.com	h3n1	NameNode, ZKFC, Journal Node
192.168.56.182	h3n2.hadoop.com	h3n2	NameNode, ZKFC, Journal Node
192.168.56.183	h3n3.hadoop.com	h3n3	Datanode, Journal Node
192.168.56.184	h3n4.hadoop.com	h3n4	Datanode
192.168.56.185	h3n5.hadoop.com	h3n5	Datanode
192.168.56.186	h3edge.hadoop.com	h3edge	Edge Node

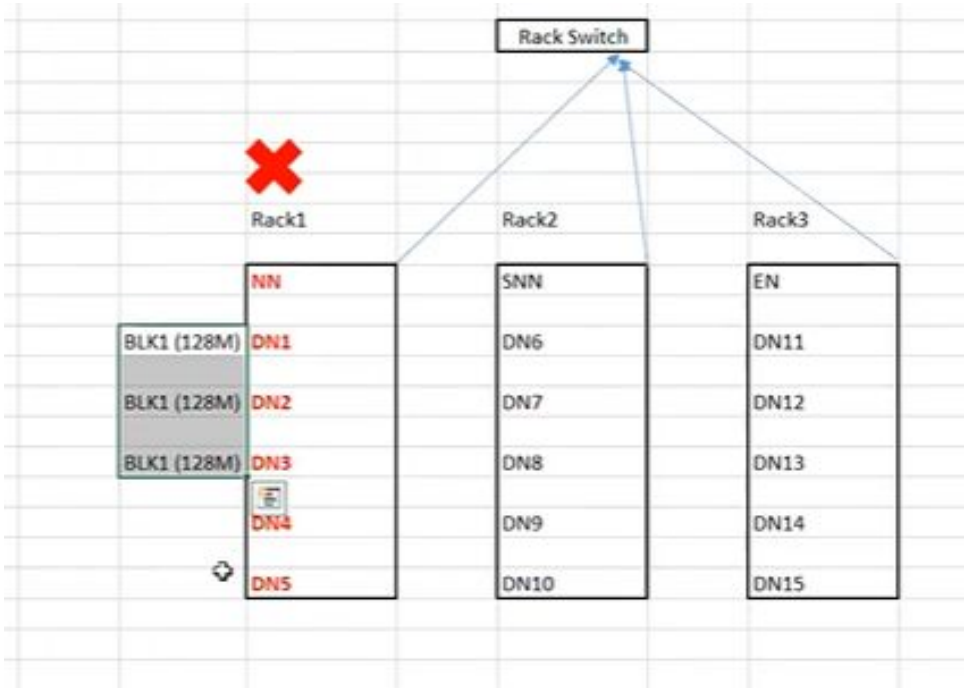
Master-worker Architecture(2.x)



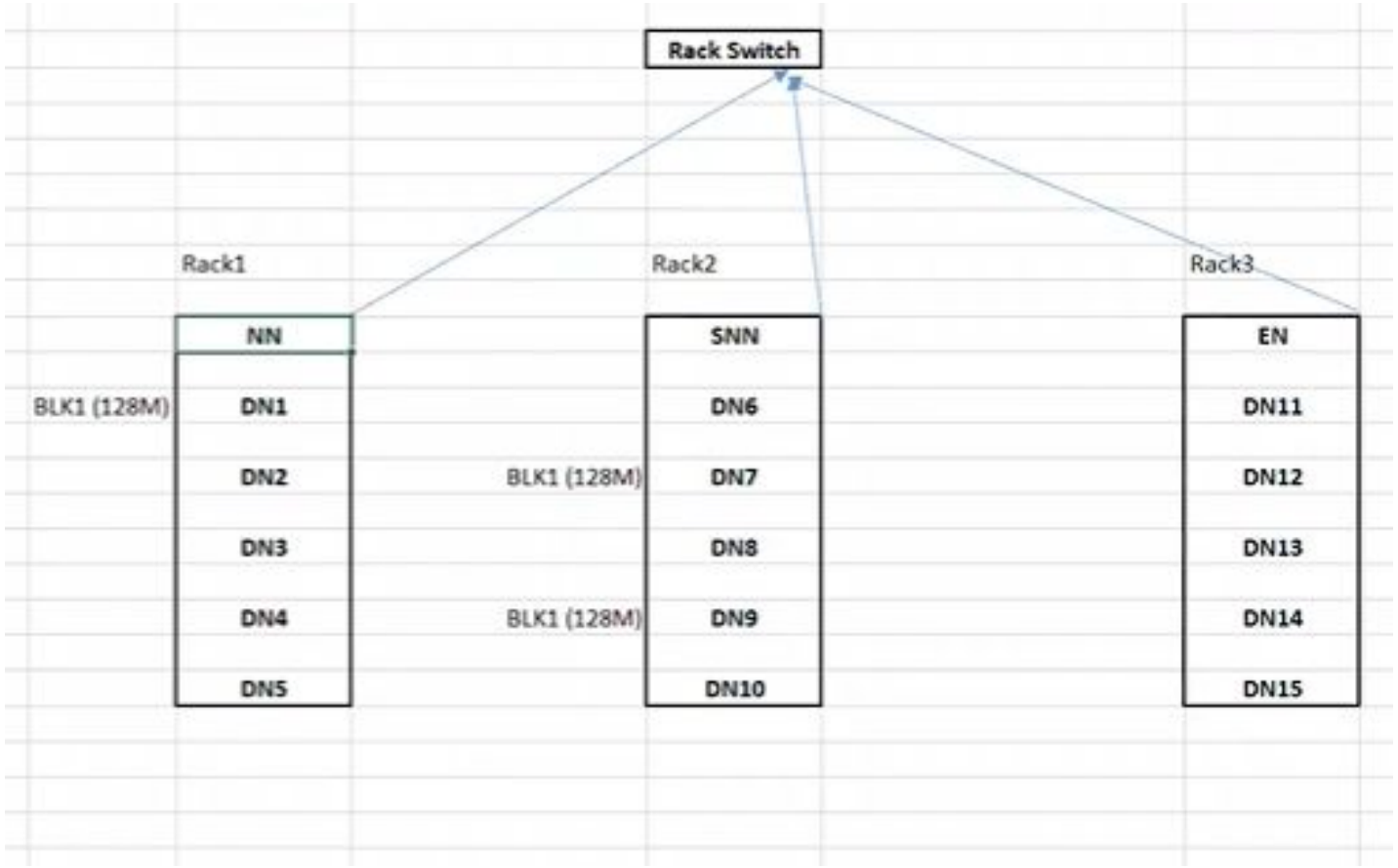
Rack awareness



Communication



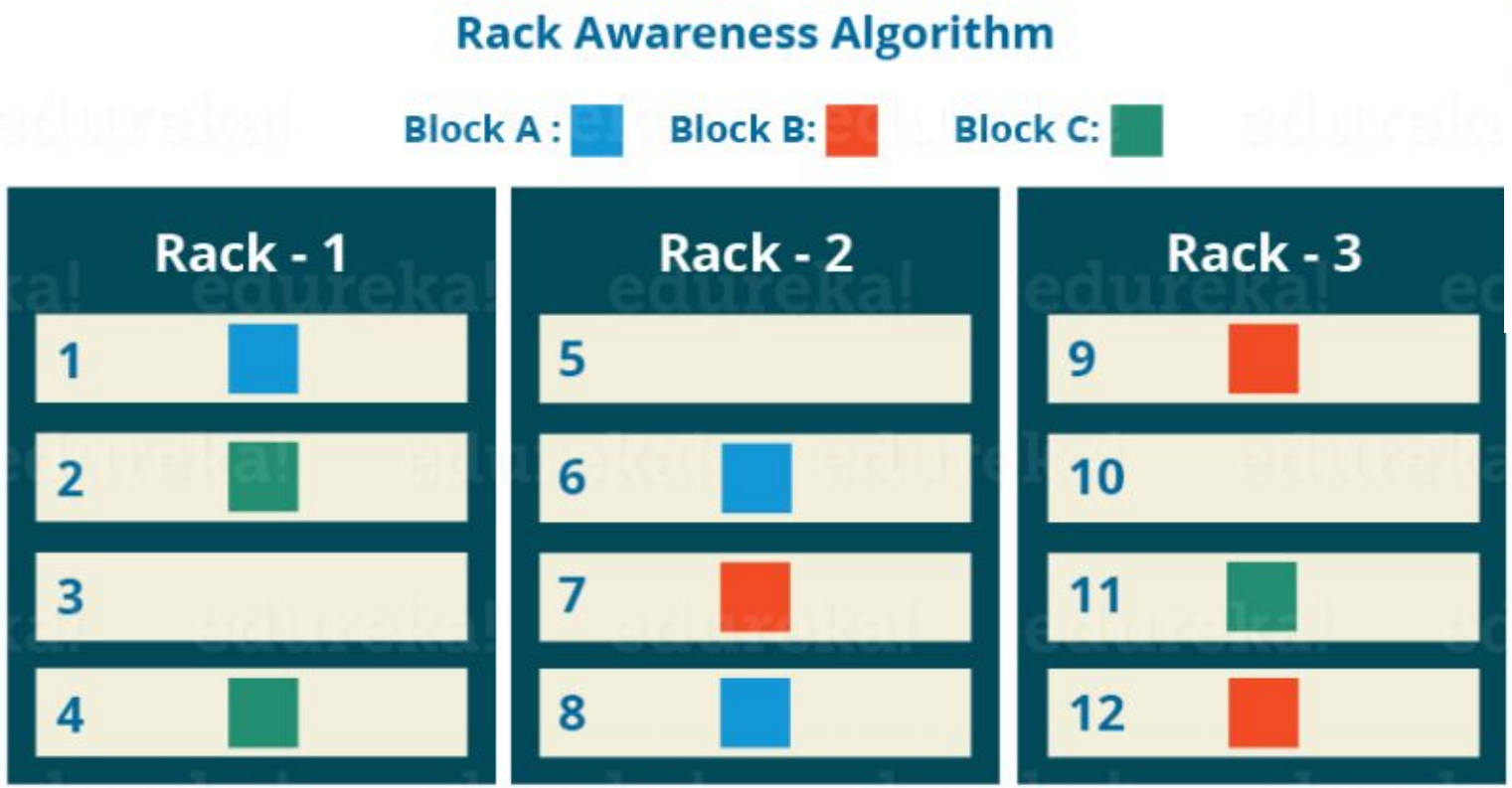
Rack awareness

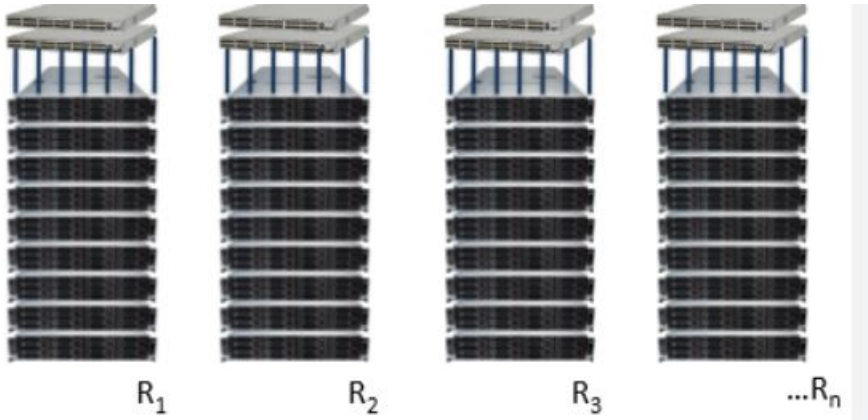


HDFS Block Replication Strategy (Rack Awareness)

- First copy of the block is placed on a random DataNode with more free space and which is not too busy
- Second copy of the block is placed on a DataNode residing on a different rack (Idea is to not to lose all the data if entire rack fails)
- Third copy of the block is placed on different DataNode in the same rack as the second copy (Assumption is that higher bandwidth and low latency in Rack)
- You are reading the data from R1 if suppose for some reason DN1 fails then you have to switch the rack and go to DN7 so if we put Blocks in different rack switching the rack will cause latency

Rack Awareness:



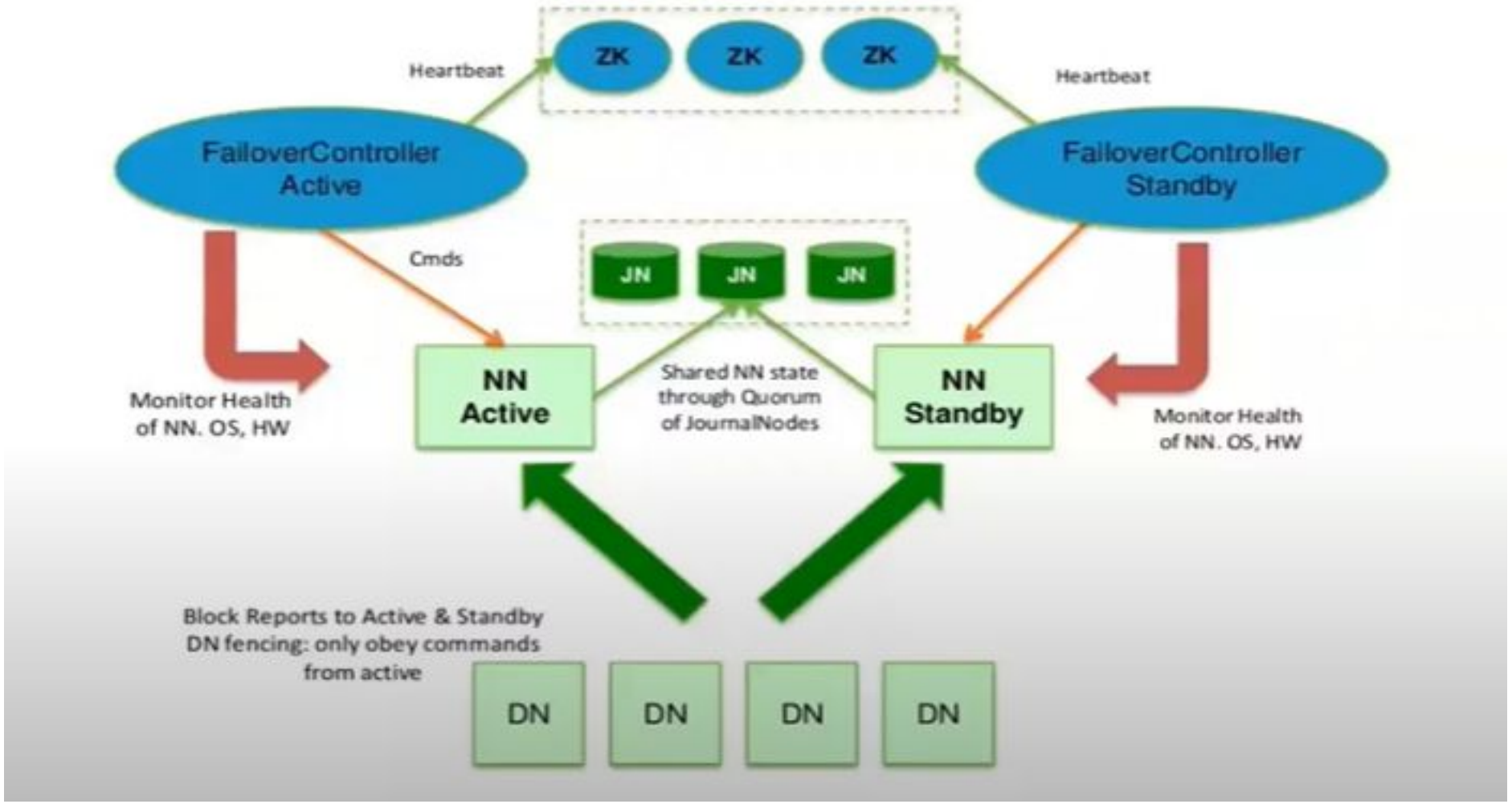


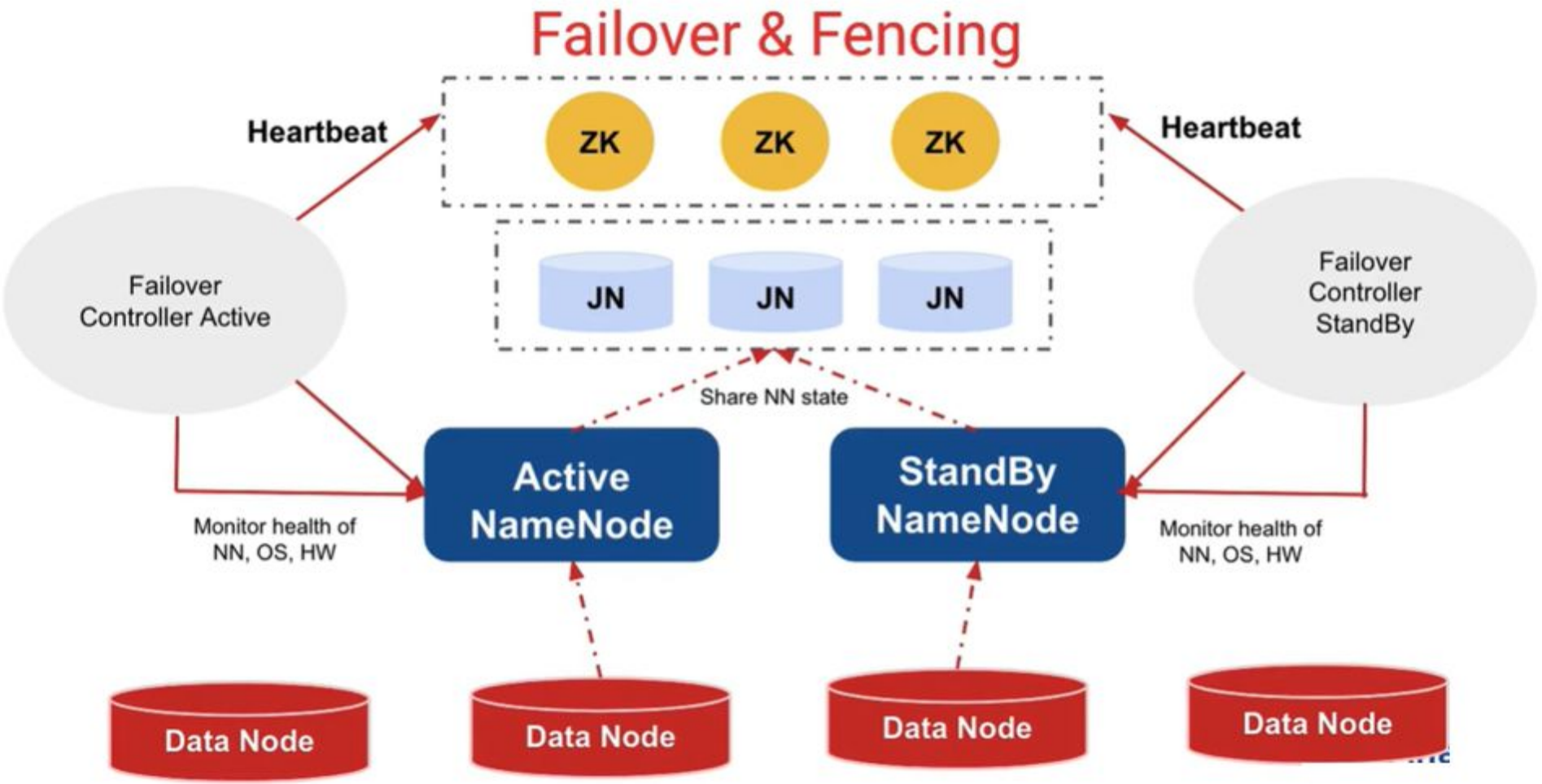
- The NameNode makes sure that copies of your data are spread out across different racks of computers. This way, if one rack has a problem, your data is still safe on another rack.
- It uses a smart rule called the "Rack Awareness Algorithm."
- Suppose the replication factor configured is 3. Now rack awareness algorithm will place the first block on a local rack.
- It will keep the other two blocks on a different rack. It does not store more than two blocks in the same rack if possible.

Hadoop Federation

- Hadoop Federation enhances the scalability and robustness of HDFS by allowing multiple NameNodes to manage separate namespace volumes within the same cluster, thereby decentralizing the metadata management and removing the single point of failure and performance bottleneck associated with a single NameNode system.

Hadoop 2.X Architecture - NameNode HA (Using Journal Nodes & ZooKeeper)




Failover & Fencing
Heartbeat
ZK
ZK
ZK
Heartbeat
Failover Controller Active
JN
JN
JN
Failover Controller StandBy
Share NN state
Active NameNode
StandBy NameNode
Monitor health of NN, OS, HW
Monitor health of NN, OS, HW
Data Node
Data Node
Data Node
Data Node

Master-worker Architecture(2.x)

Services		
Master	Active NameNode	Standby NameNode
Supporting Services	• SupS: ZKFC • SupS: JournalNode • SupS: Zookeeper	• SupS: ZKFC • SupS: JournalNode • SupS: Zookeeper
Worker Service	Data Node	
Edge Node		

Hadoop 3.X Setup differences in Storage Layer

Majorly,

- Minimum required Java version is Java 1.8
- Default Block size is 256MB
- Support for more than 2 NameNodes (1 Active & Multiple Standby NameNodes)
- Support for Erasure Encoding in HDFS (requires storage overhead up to 50% instead of 200%)
- Intra-DataNode Balancer
- Can be scaled for more than 10,000 nodes per Cluster
- Difference in default port numbers (Ex: NameNode port is 9870 instead of 50070)
- hdfs --daemon stop/start <service name> (No hadoop-daemon.sh)
- Supports Microsoft Windows & Microsoft Azure Data Lake filesystem

Erasure Encoding in HDFS

- 1GB file with replication factor 3
- 1 GB is replicated 3 times in HDFS on data nodes
- Default block size is 256
- Suppose we have 100 nodes

BLK1	256	DN1(256M)	DN2(256M)	DN3(256M)	768
BLK2	256	DN4(256M)	DN5(256M)	DN6(256M)	768
BLK3	256	DN14(256M)	DN15(256M)	DN16(256M)	768
BLK4	256	DN41(256M)	DN51(256M)	DN61(256M)	768
					3072

- To save 1GB of file with replication factor 3 it is taking 3GB space
- To save 1PB of file size with replication factor 3 it will take 3PB
- if we feel that storing 3 copies is a problem Hadoop is giving option to store the block with erasure encoding algorithm

Erasure Encoding in HDFS

- They will keep the first copy as it is and with the help of parity they will reduce the size to 64 MB

BLK1	256	DN1(256M)	DN2(64M)	DN3(64M)	384
BLK2	256	DN4(256M)	DN5(64M)	DN6(64M)	384
BLK3	256	DN14(256M)	DN15(64M)	DN16(64M)	384
BLK4	256	DN41(256M)	DN51(64M)	DN61(64M)	384
					1536MB (1.5GB)

Hadoop 3.x often uses the Reed-Solomon algorithm for erasure coding. This algorithm creates parity blocks that can be used to reconstruct the data in case of block loss. For example, in a (6,3) Reed-Solomon encoding scheme, there would be 6 data blocks and 3 parity blocks.

Erasure Encoding in HDFS

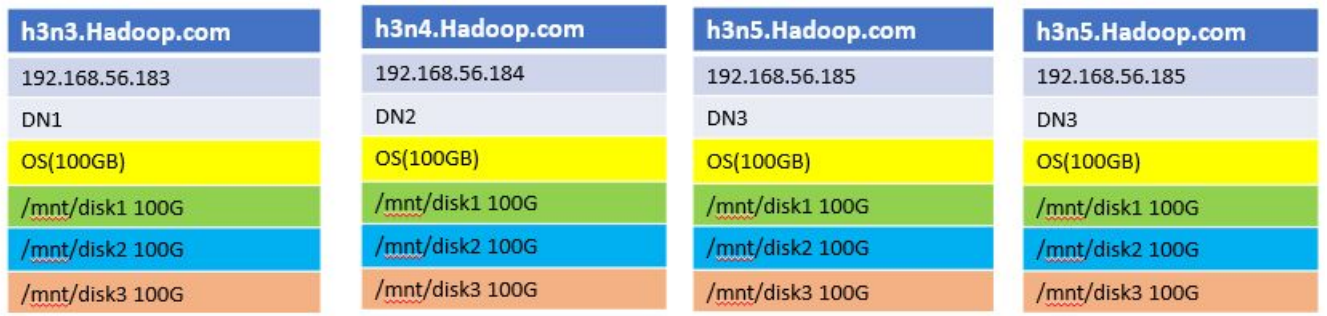
BLK1	256	DN1(256M)	DN2(64M)	DN3(64M)	384
BLK2	256	DN4(256M)	DN5(64M)	DN6(64M)	384
BLK3	256	DN14(256M)	DN15(64M)	DN16(64M)	384
BLK4	256	DN41(256M)	DN51(64M)	DN61(64M)	384
					1536MB (1.5GB)

Command executed to read file → Name Node will look at edit logs or fsimage → If found → Suppose in BLK 1 DN3 interacted first with Fs shell where encoded 64 MB is stored then first it will decode 64 MB to 256 MB

Fs shell will take time there are performance issues/ even though it will save storage cost

Intra-DataNode Balancer

Disk	DN1	DN2	DN3	DN4
/mnt/disk1	5 BLK	5BLK	5BLK	5BLK
/mnt/disk2	5BLK	5BLK	5BLK	5BLK
/mnt/disk3	5BLK	5BLK	5BLK	5BLK



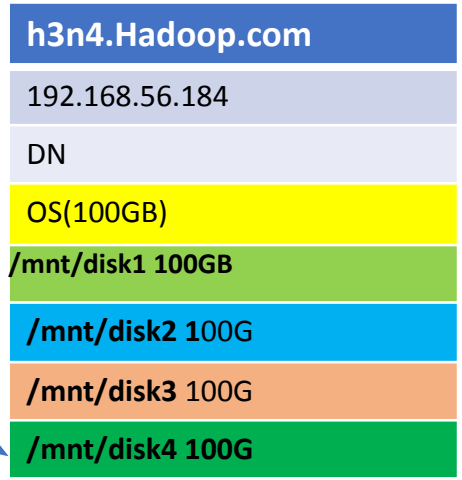
Hadoop 1.x and 2.x Add New DN and balance the data Across DNs

Disk	DN1	DN2	DN3	DN4	DN5
/mnt/disk1	4BLK	4BLK	4BLK	4BLK	4BLK
/mnt/disk2	4BLK	4BLK	4BLK	4BLK	4BLK
/mnt/disk3	4BLK	4BLK	4BLK	4BLK	4BLK

Intra-DataNode Balancer

Hadoop 3.x Add New DN as well as Disk across data nodes- **Inter data Node balancing**

Disk	DN1	DN2	DN3	DN4	DN5
/mnt/disk1	3	3	3	3	3
/mnt/disk2	3	3	3	3	3
/mnt/disk3	3	3	3	3	3
/mnt/disk4	3	3	3	3	3



Most of the clusters(90%) are migrated from Hadoop 2.x to Hadoop 3.x since 2022 though Hadoop 3.x was launched in 2018 people thought of migrating in 2019 but due to covid they started migrating little late

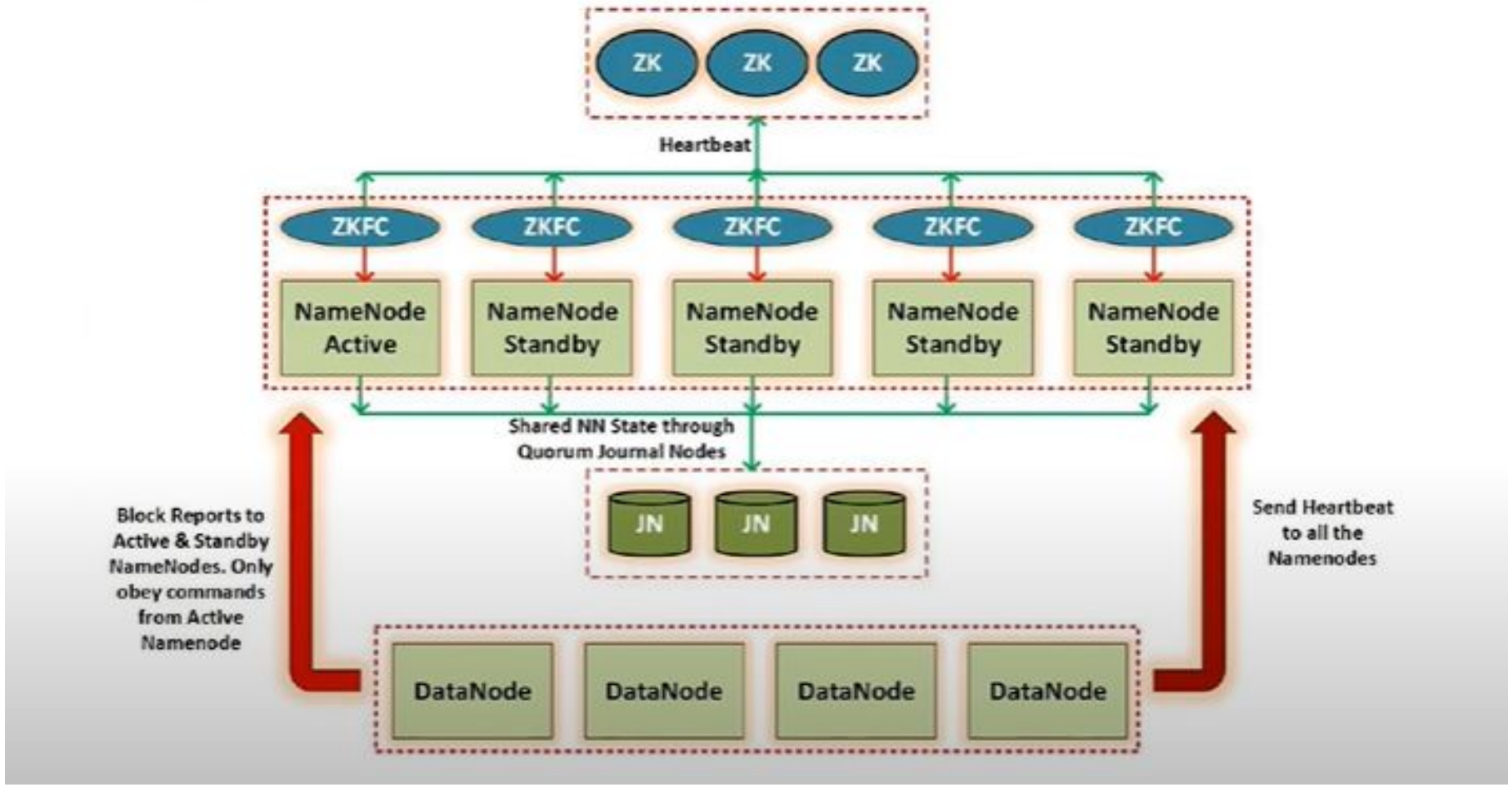
Hadoop

- Hadoop is software-dependent because it is a software framework. It is designed to work on a cluster of machines and relies on software processes to manage its distributed storage (HDFS) and distributed processing (MapReduce). Hadoop is built and run on common software systems like Java and can be installed on various operating systems that support these software requirements.
- Hadoop is not hardware dependent– it can run on commodity hardware, which means that it does not require high-end, specialized hardware. The original intent behind Hadoop was to enable distributed processing using affordable and readily available hardware. Hadoop's architecture is designed to handle failures at the application layer, thus not relying on high-reliability or high-availability hardware features.

Can be scaled for more than 10,000 nodes per Cluster

- Hadoop 1.x Maximum datanode you can add is 4000
- Hadoop 2.x Maximum datanode you can add is 10000
- World biggest cluster capacity is approaching 10000 nodes(linkedin) , people are not even reached maximum capacity of Hadoop.
- Hadoop 3.x you can go up to 25000 data nodes

Hadoop 3.X Architecture



Advantages of NameNode HA with Journal Nodes & ZooKeeper

- ✔ Multiple copies of Edits for both the NameNodes by using JNs
- ✔ Automatic failover of Active and Standby NameNodes by using ZooKeeper

Failover

- The transition from NameNode's active state to the standby is managed by a new entity in the system called the Failover Controller.
- Each NameNode runs with a lightweight ZooKeeper Failover Controller (ZKFailoverController / ZKFC), whose job is to monitor its NameNode for failures (using a simple heartbeat mechanism) and triggers a failover.

- Graceful failover: Failover may also be initiated manually by an administrator (Example: In case of routine maintenance).

Failover

Types of Failover

Types of Failovers:

- **Graceful**
  - Initiated by the administrator
  - Mostly done in case of a routine maintenance
  - Failover Controller arranges an orderly transition

- **UnGraceful**
  - Not possible to make sure if NodeNode has failed
  - Slow network can trigger a Failover transition

Scenario 1	NN1: Active NN2: Standby	NN1 is down/Stopped ZKFC1 is running	ZKFC1 will inform ZKs ZKs will inform ZKFC2 ZKFC2 will make NN2 active	
Scenario 2	NN1: Standby NN2: Active	NN2 is down/Stopped ZKFC2 is running	ZKFC1 will inform ZKs ZKs will inform ZKFC1 ZKFC2 will make NN1 active	
Scenario 3	NN1: Active NN2: Standby	NN1running ZKFC1 is down	ZKFC1 will stop sending heartbeat ZKs will inform ZKFC2 ZKFC2 will make NN2 Active	NN1 will be active but ZKFc down no heartbeat to ZK ,ZKFC will make NN2 active but NN1 is also Active ZKFC2 will make NN1 Standby
Scenario 4	NN1: Standby NN2: Active	NN2 is running ZKFC2 is down/stopped	ZKFC2 will stop sending heartbeat ZKs will inform ZKFC1 ZKFC1 will make NN1 Active	ZKFC1 will make NN2 Standby
Scenario 5	NN1: Active NN2: Standby	NN1 is down/Stopped ZKFC1 is down/stopped	ZKFC1 will stop sending heartbeat ZKs will inform ZKFC2 ZKFC2 will make NN2 Active	
Scenario 6	NN2: Active NN1 : Satanby	NN2 is down/Stopped ZKFC2 is down/stopped	ZKFC2 will stop sending heartbeat ZKs will inform ZKFC1 ZKFC1 will make NN1 Active	

Fencing

- Fencing: In case of an ungraceful failover, however, it is impossible to be sure that the failed NameNode has stopped running (Example: A slow network or a network partition can trigger a failover transition).
- In this case, the previously active NameNode will be still in Active state and try to write the Edits in Journal Nodes.
- With the help of Fencing mechanism, HA implementation will ensure that the previously active NameNode is prevented from doing any damage and causing corruption.
- **SSH Fencing** is a method to kill the previously active NameNode's state using SSH Private Key. This requires a passwordless ssh access between both the NameNodes.
- **SHELL Fencing** is a method to kill the previously active NameNode's state using script. This will be used where the primary NameNode machine is inaccessible and the ssh method is failed.

What if we make both the NameNodes ACTIVE?

- If both the NameNodes are active, they think that they are in control and both try to write to the same Edit Log. There are chances of corruption of metadata in this case.
- This is like “split-brain” syndrome issue.
- Fencing in ZKFC will take care of this issue by killing one of the NameNode’s Active state.

Command	Description
ls	Directory Listing
cd dir	Change directory to dir
pwd	Show current working directory
mkdir dir	Create a directory dir
rm file	Delete file
rm -r dir	Delete directory dir
rm -f file	Delete file
rm -rf dir	Force remove directory dir
cp file1 file2	Copy file1 to file2
cp -r dir1 dir2	Copy dir1 to dir2; Create dir2 if it doesn't exist
scp	Copy from one server to another server
mv file1 file2	Rename or Move file1 to file2
ln -s file link	Create symbolic link to file
cat file	Print file content
more file	Output the contents of file by page wise

Command	Description
head file	Output the first 10 lines of file
tail file	Output the last 10 lines of file
tail -f file	Output the contents of file as it grows, starting with the last 10 lines
dos2unix	Convert Windows file format to Unix file format
md5sum file	Print checksum value of a file
chmod octal file	Change the permissions of file to octal, which can be found separately for user, group, and world by adding: 4 – read (r), 2 – write (w), 1 – execute (x)
chmod 777	Read, Write, Execute for all
chown file	Change owner for the particular file
chown -R dir	Change owner for all files in the dir

Commands

- # Lists all files and directories in the root of the HDFS
- hdfs dfs -ls

- # Downloads a file from the given URL to the local file system of the machine where the command is executed
- wget https://www.stats.govt.nz/assets/Uploads/Annual-enterprise-survey/Annual-enterprise-survey-2020-financial-year-provisional-csv.csv

- # Creates a new directory named 'practice' in the HDFS under the current user's home directory
- hadoop fs -mkdir practice

- # Lists all files and directories in the current local directory of the Linux shell (not HDFS)
- ls

- # Renames the file 'annual-enterprise-survey-2020-financial-year-provisional-csv.csv' to 'sample.csv' on the local file system
- mv annual-enterprise-survey-2020-financial-year-provisional-csv.csv sample.csv

- # Copies the file 'sample.csv' from the local file system to the 'practice' directory in HDFS
- hadoop fs -copyFromLocal sample.csv practice/sample.csv

What is a Container?

On a specific server/host, Container is a logical construct that represents a specific amount of CPU and RAM to run the tasks from your job/application

Resource Manager (RM)

- *Master* Service in YARN Framework
- First point of contact for all processing layer requests
- Keeps track of all NodeManager(s) using simple heartbeat mechanism
- Maintains *Cluster State Store* to understand the total resources, allocated resources & free resources (COREs & RAM) that each running NodeManager has
- Maintains *Application State Store* to understand the list of applications submitted, submission context, application-attempt level (AMa) information and credentials about each application
- Instructs NodeManager(s) to launch Application Master container when a new application is submitted
- Handles Application Masters' requests either to launch new containers (to run map/reduce tasks) or to release existing containers and instructs NodeManager(s) on the same
- Determines how the resources are allocated with the help of YARN Schedulers
- Manages Cluster level security (who can submit/kill the jobs) with the help of ACLs

RM preforms multiple activities based on its role:

- App Manager (AMg) – Manage Application Masters across the Cluster
- Job Scheduler – Responsible for allocating containers to the submitted jobs

Application Master (AMa)

- One Application Master for each job/application
- Kind of a leader container in the application
- Responsible for analyzing the application requirements & creating Job configuration XML file (contains properties used in job submission/execution)
- Responsible for negotiating the containers with RM and allocating the tasks in each container
- Monitors the progress of the tasks and tracks the status of the application in Job history JSON file (contains job, task and attempt events and their stats)
- Responsible for end to end execution of application

Node Manager (NM)

- *Slave* Service in YARN Framework and runs on each DataNode
- Provides information to RM through heartbeat on total / allocated / available resources (CPU & RAM) and status of running containers
- Takes care of launching/releasing/execution of containers based on the instructions from RM
- Kills runaway containers when required