Implementação e Análise de Sistemas Distribuídos: Experiência Prática com HDFS e PySpark

Equipe

Este trabalho foi desenvolvido na disciplina de Sistemas Distribuídos por:

Autor	Matrícula	Função
Artur da Silva Oliveira	2122082008	Configuração de rede
Eduardo Costa Virmond	1922082002	Implementação HDFS
João Víctor Alves Menezes	2122082017	Configuração PySpark
Juliana Alves Pacheco	2122082026	Documentação
Natália Bastos Pereira	2212082020	Testes e validação
Rafael Dantas Boeira	2122082004	Coordenação e integração

Resumo

Este documento apresenta uma análise detalhada da implementação e configuração de um sistema distribuído baseado no ecossistema Hadoop, com foco no Sistema de Arquivos Distribuído Hadoop (HDFS) e PySpark. A pesquisa documenta os procedimentos realizados em três laboratórios práticos, abordando desde a instalação e configuração do ambiente base até a execução de tarefas de processamento distribuído. O estudo demonstra a aplicabilidade prática desses sistemas e discute os conhecimentos adquiridos durante o processo de implementação.

1. Introdução

Os sistemas distribuídos têm se tornado fundamentais para o processamento de grandes volumes de dados. O ecossistema Hadoop, especialmente com seu sistema de arquivos distribuído (HDFS) e ferramentas como PySpark, representa uma solução robusta para esse cenário. Este documento registra a experiência prática de implementação desses sistemas em um ambiente controlado, demonstrando os procedimentos necessários para sua instalação, configuração e operação.

2. Materiais e Métodos

O estudo foi conduzido realizando experimentos em três etapas laboratoriais sequenciais:

2.1 Laboratório 1: Configuração do Ambiente Base

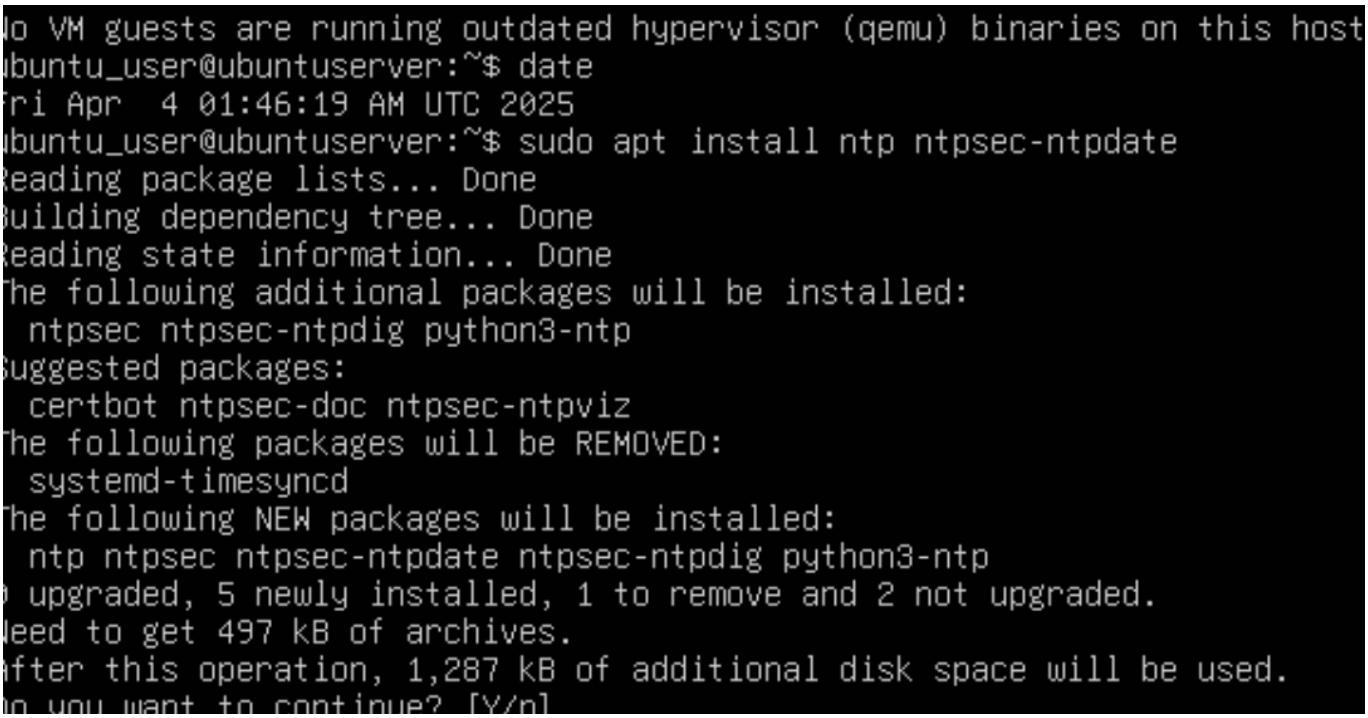
O primeiro laboratório concentrou-se na instalação e configuração do sistema operacional Ubuntu Server, que serviu como base para o sistema distribuído. Os procedimentos incluíram:

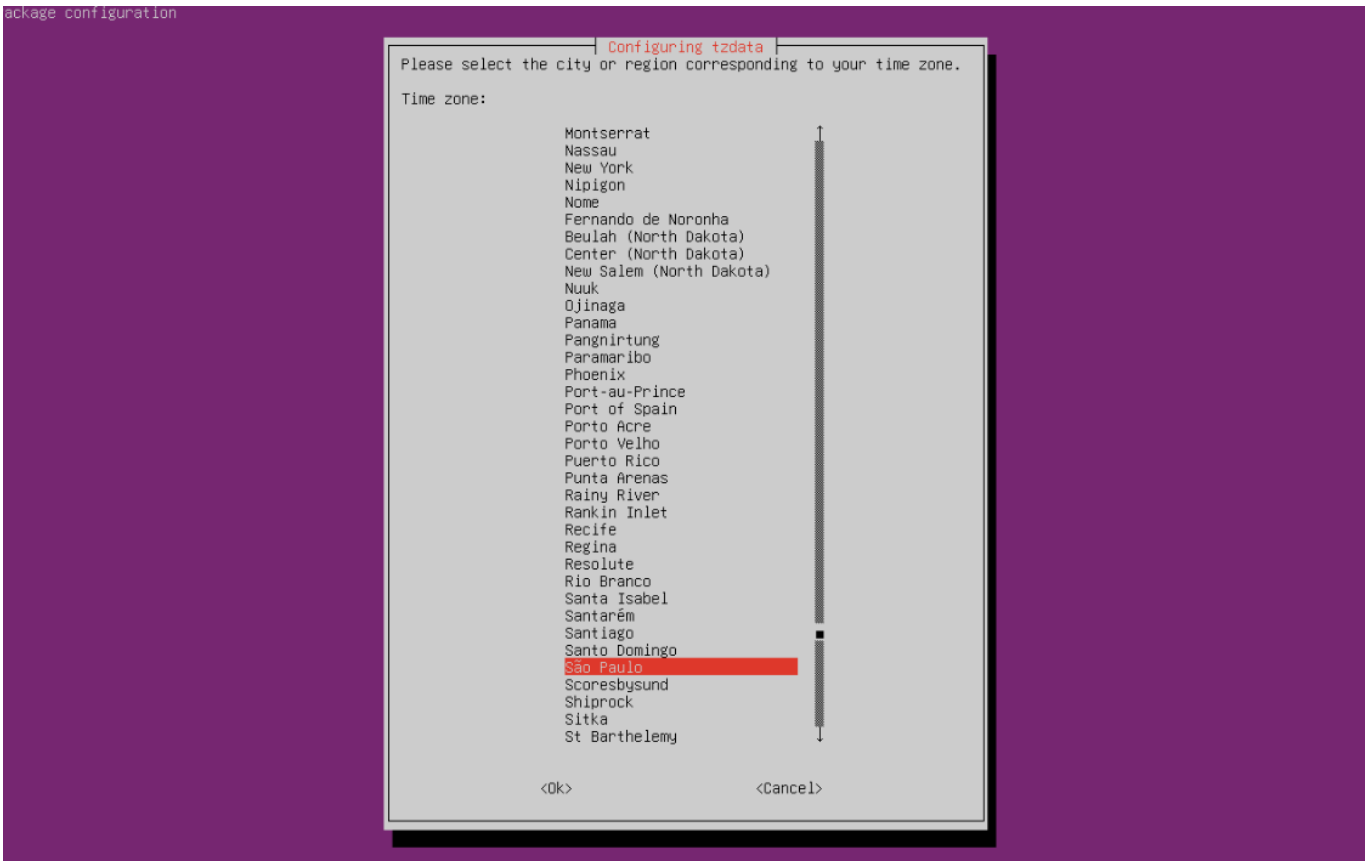
```
# Instale o sistema operacional Ubuntu Server
# Faça o update e upgrade
```

```
sudo apt update
sudo apt upgrade

# Verifique se a data e hora estão atualizadas
date

# Instale os aplicativos para sincronização de tempo
sudo apt install ntp ntpsec-ntpdate
sudo ntpq -p

# Altere o timezone
sudo dpkg-reconfigure tzdata

# Verifique a data e a hora novamente
date
```

```
Ubuntu 24.04.2 LTS ubuntuserver tty1

ubuntuserver login: ubuntu_user
Password:
Welcome to Ubuntu 24.04.2 LTS (GNU/Linux 6.8.0-57-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/pro

 System information as of Fri Apr  4 01:42:52 AM UTC 2025

  System load:             1.85
  Usage of /:              41.6% of 11.21GB
  Memory usage:            14%
  Swap usage:              0%
  Processes:               116
  Users logged in:         0
  IPv4 address for enp0s3: 10.0.2.15
  IPv6 address for enp0s3: fd00::a00:27ff:fedc:f864

Expanded Security Maintenance for Applications is not enabled.

49 updates can be applied immediately.
To see these additional updates run: apt list --upgradable

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status



The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

ubuntu_user@ubuntuserver:~$ sudo apt update
```

```
ubuntuserver login: ubuntu_user
Password:
Welcome to Ubuntu 24.04.2 LTS (GNU/Linux 6.8.0-57-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/pro

 System information as of Fri Apr  4 01:42:52 AM UTC 2025

  System load:             1.85
  Usage of /:              41.6% of 11.21GB
  Memory usage:            14%
  Swap usage:              0%
  Processes:               116
  Users logged in:         0
  IPv4 address for enp0s3: 10.0.2.15
  IPv6 address for enp0s3: fd00::a00:27ff:fedc:f864

Expanded Security Maintenance for Applications is not enabled.

49 updates can be applied immediately.
To see these additional updates run: apt list --upgradable

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status



The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

ubuntu_user@ubuntuserver:~$ sudo apt update
[sudo] password for ubuntu_user:
Hit:1 http://security.ubuntu.com/ubuntu noble-security InRelease
Hit:2 http://archive.ubuntu.com/ubuntu noble InRelease
Hit:3 http://archive.ubuntu.com/ubuntu noble-updates InRelease
Hit:4 http://archive.ubuntu.com/ubuntu noble-backports InRelease
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
51 packages can be upgraded. Run 'apt list --upgradable' to see them.
ubuntu_user@ubuntuserver:~$ sudo apt upgrade
```





2.2 Laboratório 2: Implementação do HDFS

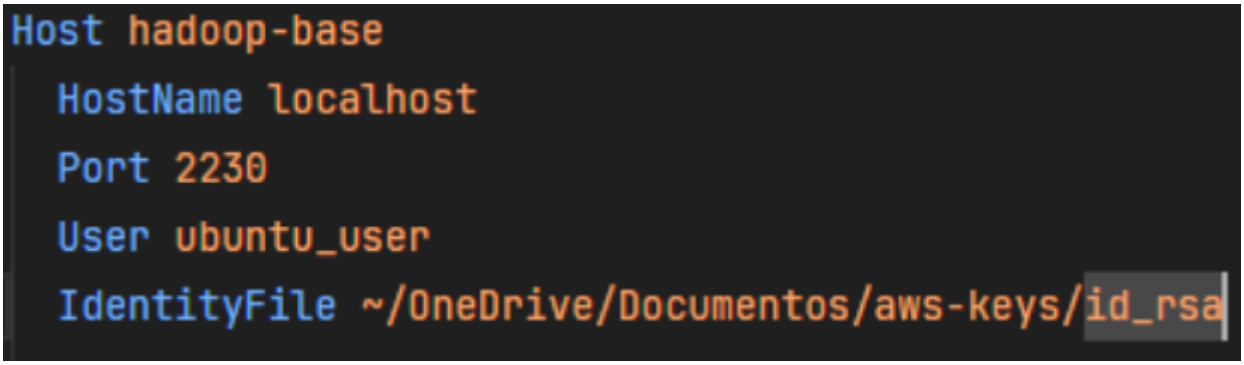
O segundo laboratório abordou a instalação e configuração do Hadoop Distributed File System, com os seguintes procedimentos:

```
sudo apt-get update
sudo apt-get upgrade
sudo apt-get install pdsh
echo "export PDSH_RCMD_TYPE=ssh" >> .bashrc
ssh-keygen -t rsa -P ""
cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
ssh localhost
sudo apt-get install openjdk-8-jdk

# Baixe do classroom ou da rede local o arquivo hadoop-3.4.0.tar.gz para a
pasta home
# Alternativamente
# wget https://archive.apache.org/dist/hadoop/common/hadoop-3.4.0/hadoop-
3.4.0.tar.gz

tar xvf hadoop-3.4.0.tar.gz
mv hadoop-3.4.0 hadoop
sudo mv hadoop /usr/local/hadoop
sudo nano /usr/local/hadoop/etc/hadoop/hadoop-env.sh
# Adicionar linha a seguir:
# export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64/

sudo nano /etc/environment
# Adicionar as linhas a seguir:
#
PATH="/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/gam
es:/usr/local/games:/usr/local/hadoop/bin:/usr/local/hadoop/sbin"
# JAVA_HOME="/usr/lib/jvm/java-8-openjdk-amd64/jre"

sudo poweroff
```

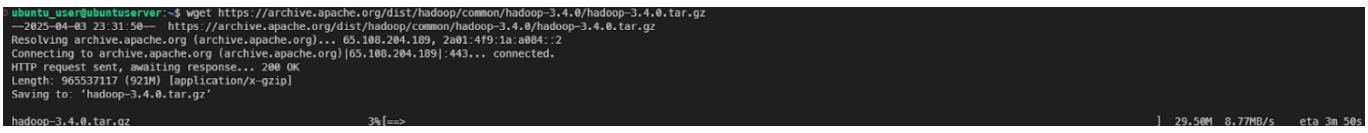
Instalação do Java e Hadoop

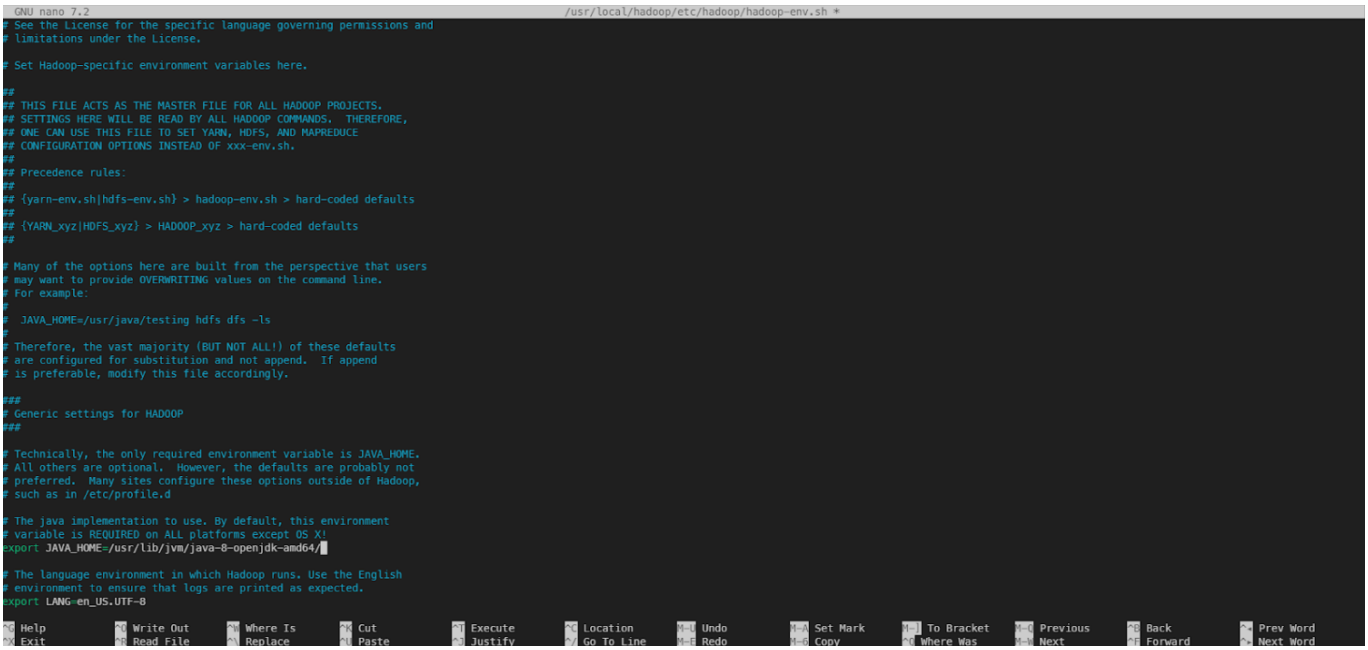
```
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  genders libgenders0 libice6 libsm6 libxt6t64 ssh-askpass x11-common
Suggested packages:
  rdist
The following NEW packages will be installed:
  genders libgenders0 libice6 libsm6 libxt6t64 pdsh ssh-askpass x11-common
0 upgraded, 8 newly installed, 0 to remove and 2 not upgraded.
Need to get 451 kB of archives.
After this operation, 1,550 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://archive.ubuntu.com/ubuntu noble/universe amd64 libgenders0 amd64 1.22-1build8 [30.8 kB]
Get:2 http://archive.ubuntu.com/ubuntu noble/universe amd64 genders amd64 1.22-1build8 [31.0 kB]
Get:3 http://archive.ubuntu.com/ubuntu noble/main amd64 x11-common all 1:7.7+23ubuntu3 [21.7 kB]
Get:4 http://archive.ubuntu.com/ubuntu noble/main amd64 libice6 amd64 2:1.0.10-1build3 [41.4 kB]
Get:5 http://archive.ubuntu.com/ubuntu noble/main amd64 libsm6 amd64 2:1.2.3-1build3 [15.7 kB]
Get:6 http://archive.ubuntu.com/ubuntu noble/main amd64 libxt6t64 amd64 1:1.2.1-1.2build1 [171 kB]
Get:7 http://archive.ubuntu.com/ubuntu noble/universe amd64 ssh-askpass amd64 1:1.2.4.1-16build2 [24.8 kB]
Get:8 http://archive.ubuntu.com/ubuntu noble/universe amd64 pdsh amd64 2.34-3build2 [115 kB]
Fetched 451 kB in 2s (224 kB/s)
Preconfiguring packages ...
Selecting previously unselected package libgenders0:amd64.
(Reading database ... 86740 files and directories currently installed.)
Preparing to unpack .../0-libgenders0_1.22-1build8_amd64.deb ...
Unpacking libgenders0:amd64 (1.22-1build8) ...
Selecting previously unselected package genders.
Preparing to unpack .../1-genders_1.22-1build8_amd64.deb ...
Unpacking genders (1.22-1build8) ...
Selecting previously unselected package x11-common.
Preparing to unpack .../2-x11-common_1%3a7.7+23ubuntu3_all.deb ...
Unpacking x11-common (1:7.7+23ubuntu3) ...
Selecting previously unselected package libice6:amd64.
Preparing to unpack .../3-libice6_2%3a1.0.10-1build3_amd64.deb ...
```

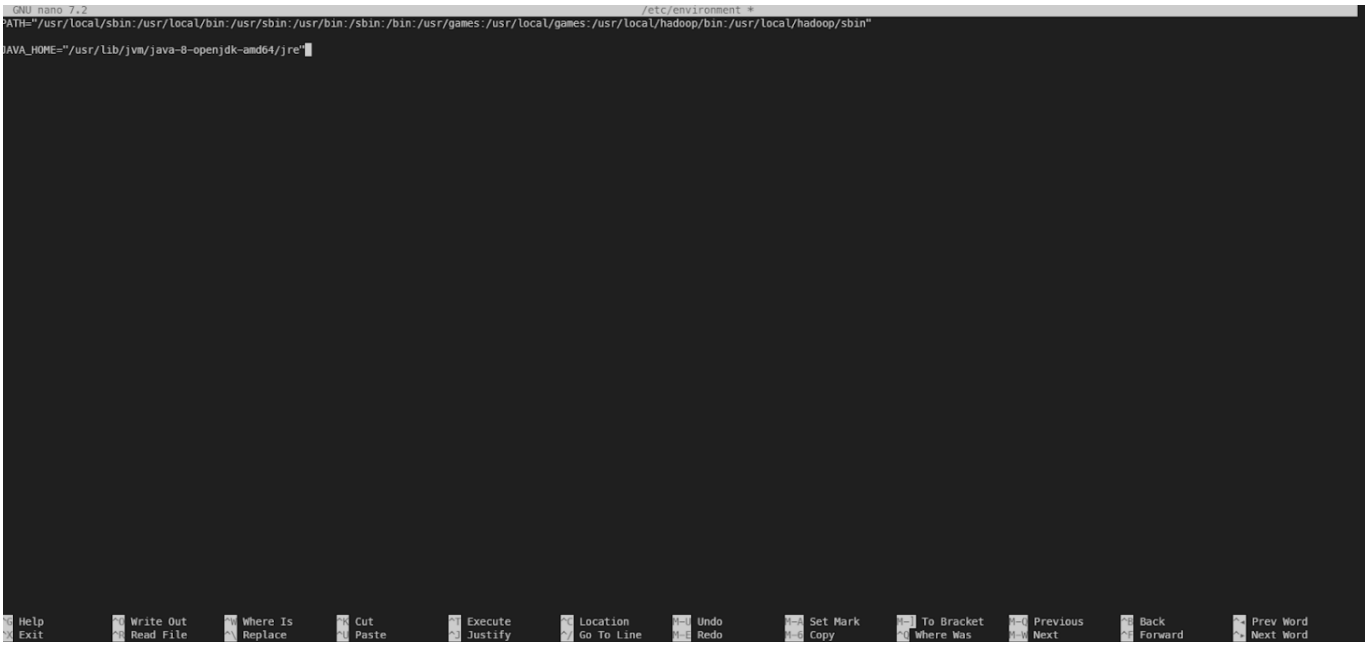
```
ubuntu_user@ubuntuserver:~$ echo " export PDSH_RCMD_TYPE=ssh" >> .bashrc
ubuntu_user@ubuntuserver:~$ ssh-keygen -t rsa -P ""
Generating public/private rsa key pair.
Enter file in which to save the key (/home/ubuntu_user/.ssh/id_rsa):
Your identification has been saved in /home/ubuntu_user/.ssh/id_rsa
Your public key has been saved in /home/ubuntu_user/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:3xNM1bU+V2ZILeLv/cMUeyuXn1ds8Adq4JI9A+RI3g4 ubuntu_user@ubuntuserver
The key's randomart image is:
+---[RSA 3072]----+
|       ...     ooo|
|      o +. . .o+.+|
```

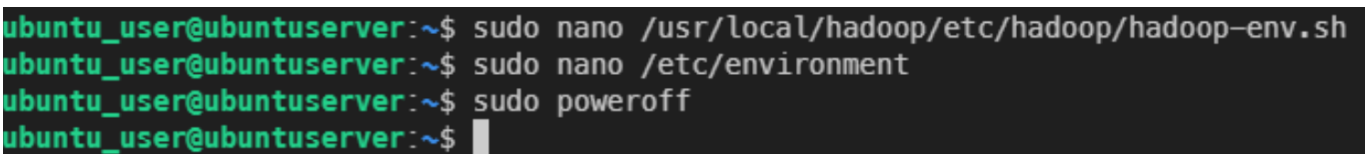


Instalação do Java e Hadoop

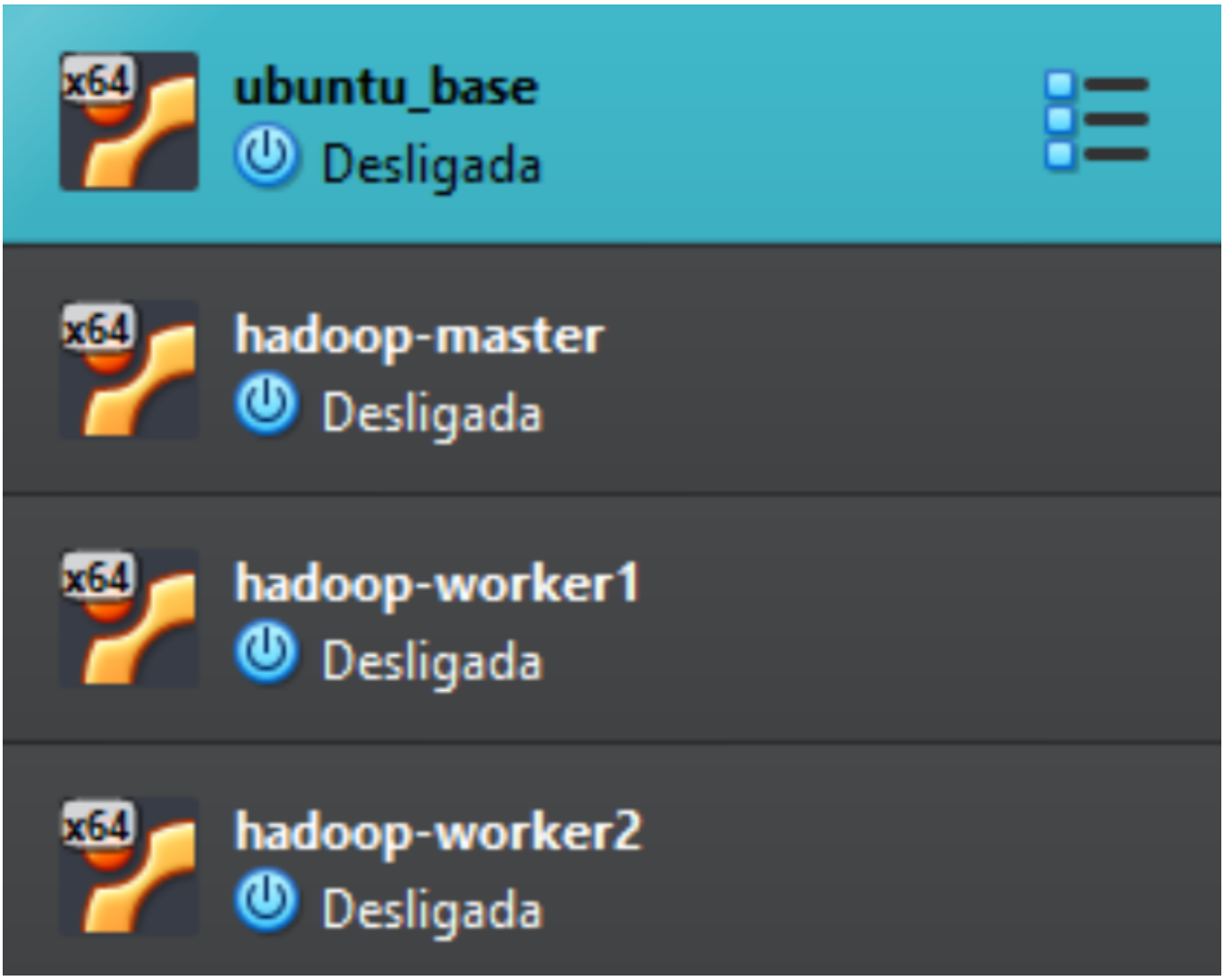




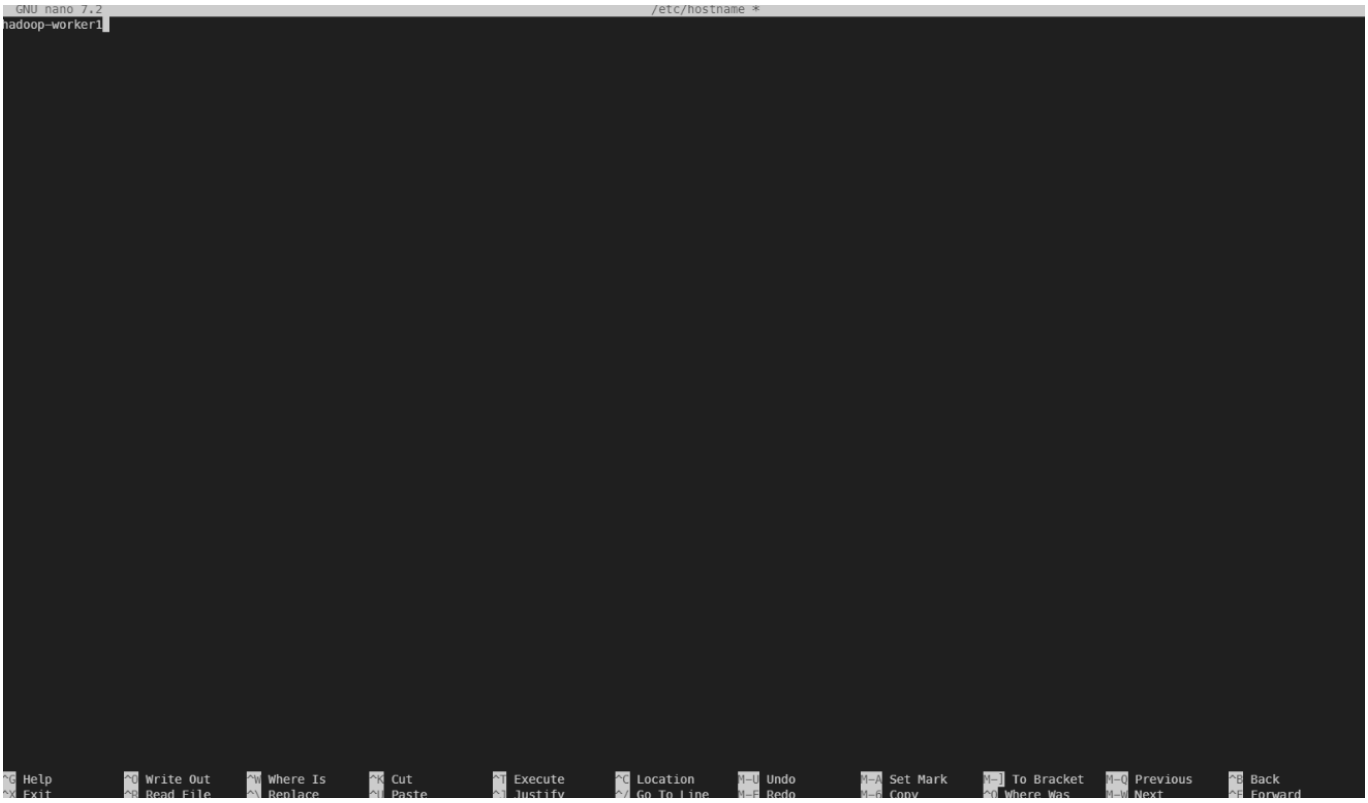


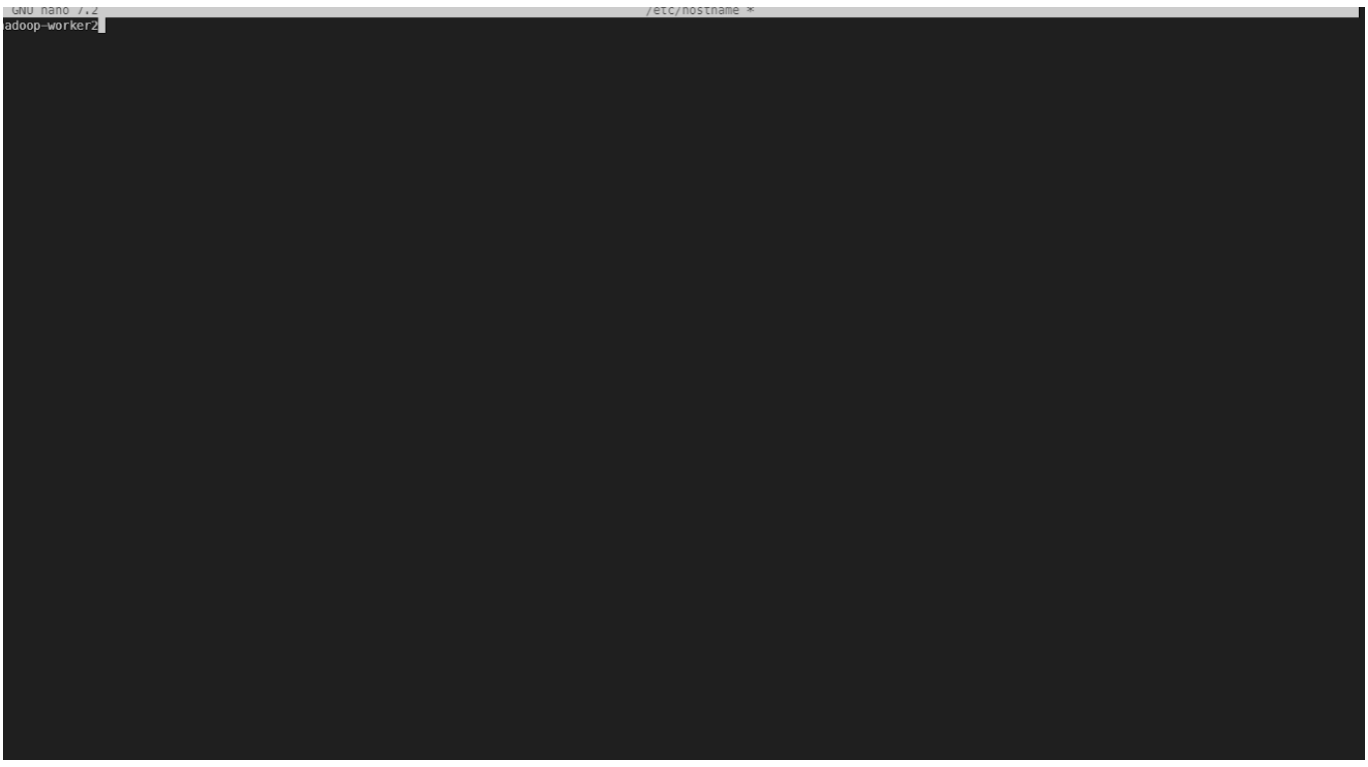


Após criar uma placa de rede HostOnly na máquina virtual, crie três clones da máquina base: 1 master e 2 workers.


ubuntu_base
Desligada
hadoop-master
Desligada
hadoop-worker1
Desligada
hadoop-worker2
Desligada


GNU nano 7.2 /etc/hostname
hadoop-master
[Wrote 1 line]
^G Help ^O Write Out ^W Where Is ^K Cut ^T Execute ^C Location M-U Undo M-A Set Mark M-] To Bracket M-Q Previous ^B Back
^X Exit ^R Read File ^\ Replace ^U Paste ^J Justify ^/ Go To Line M-E Redo M-6 Copy ^Q Where Was M-W Next ^F Forward

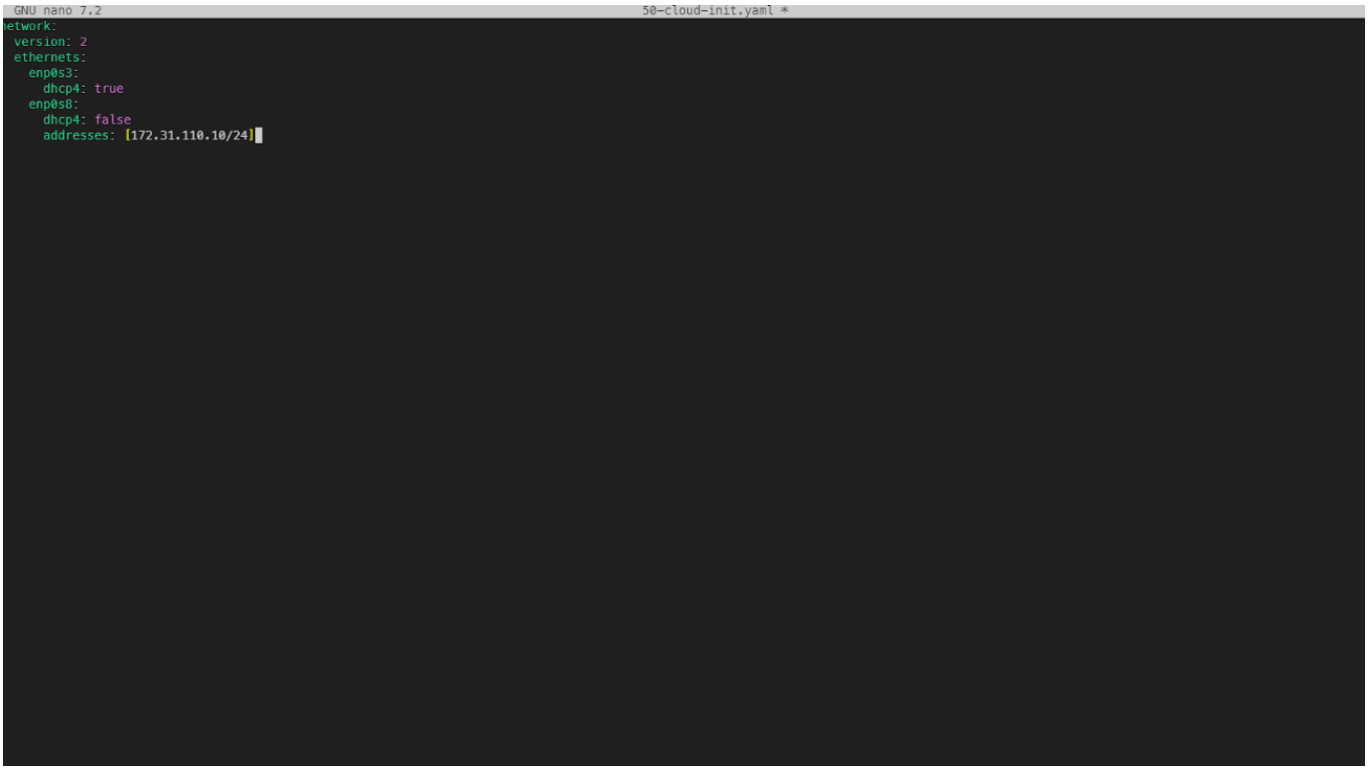


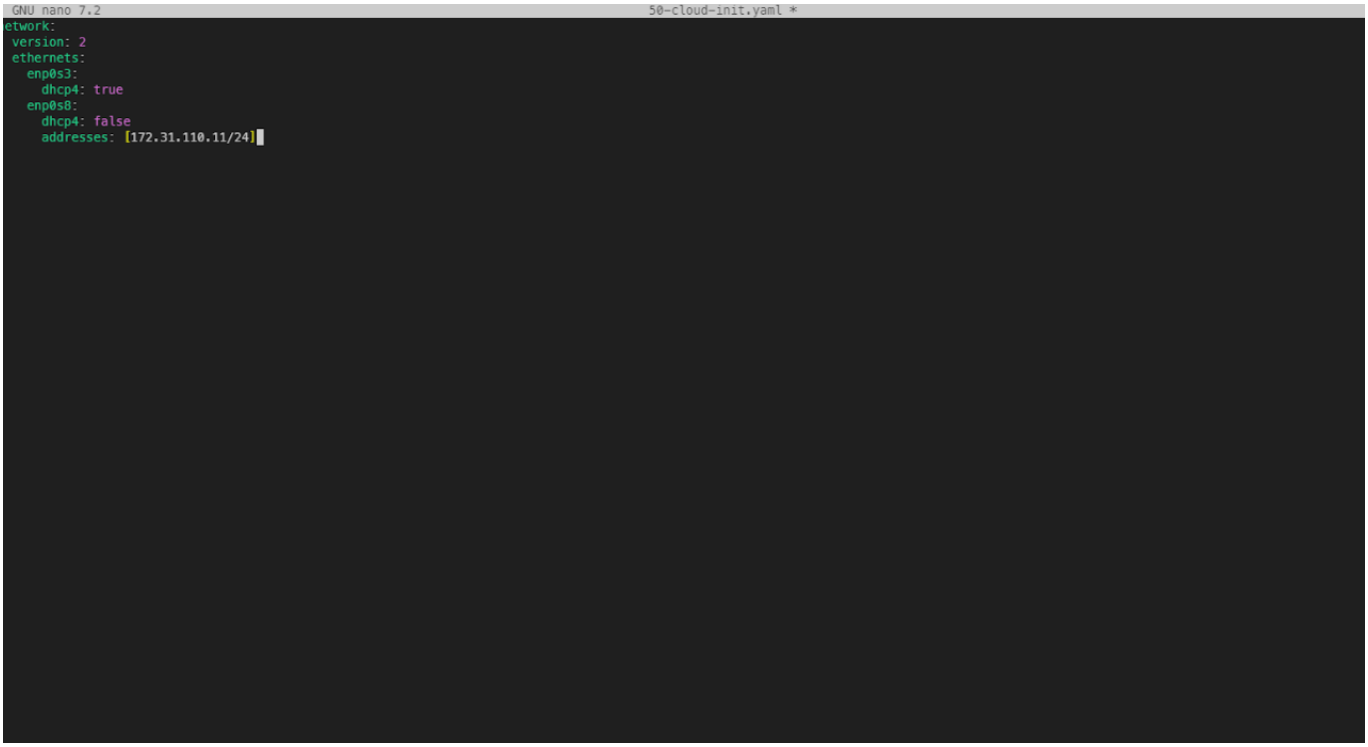


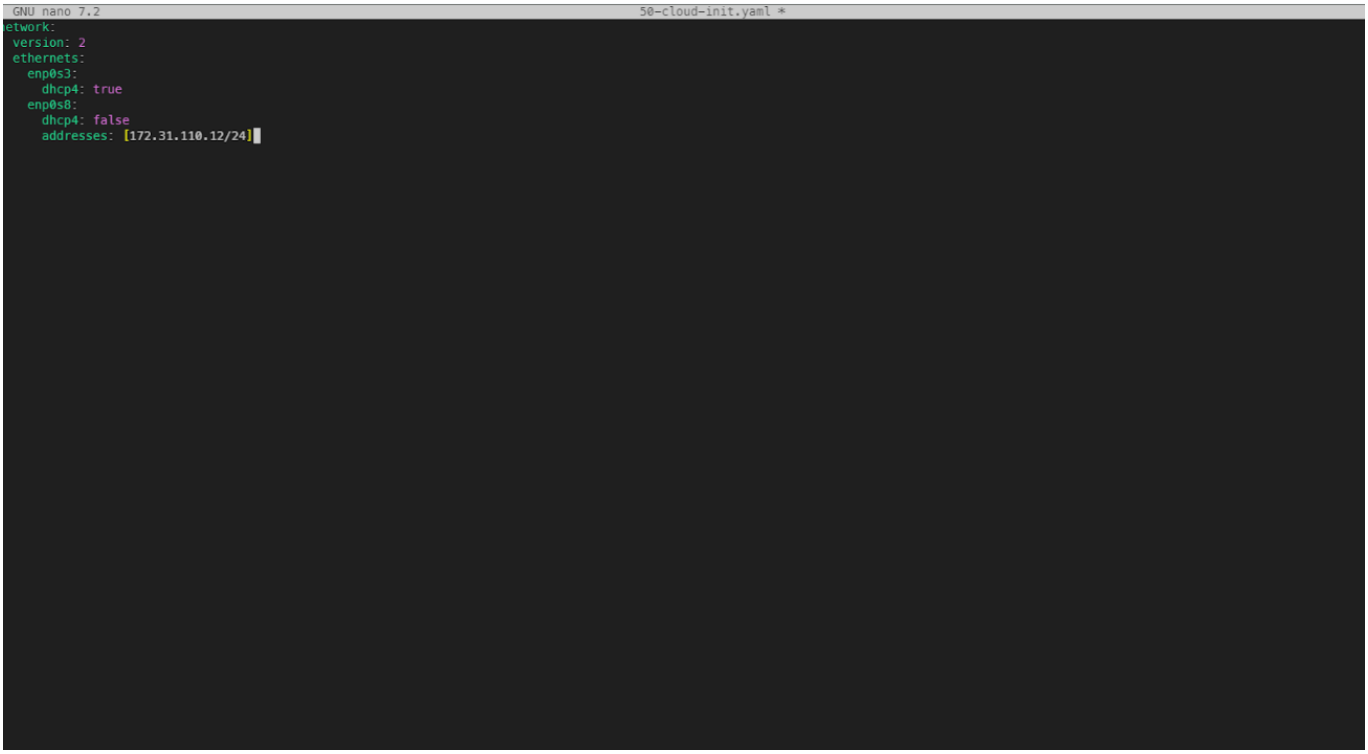

```
# Editar o arquivo hostname em cada máquina: hadoop-master, hadoop-worker1, hadoop-worker2
sudo nano /etc/hostname

# Faça o reboot dos servidores!
# Verifique o nome da placa, que no caso pode ser enp0s8
ip addr

# Editar os arquivos de rede das máquinas
# Colocar os IPs 172.31.110.10, 172.31.110.11 e 172.31.110.12 nas máquinas
```

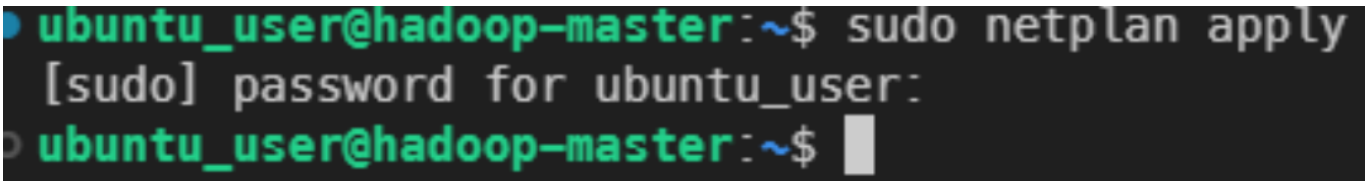
```
master e workers 1 e 2, respectivamente
cd /etc/netplan
sudo nano XXXXX.yaml

# Exemplo
# This is the network config written by 'subiquity'
network:
  version: 2
  ethernets:
    enp0s3:
      dhcp4: true
    enp0s8:
      dhcp4: false
      addresses: [172.31.110.10/24]

sudo netplan apply

# Editar o arquivo /etc/hosts incluindo os nomes e IPs
# hadoop-master, hadoop-worker1 e hadoop-worker2
# Não colocar 127.0.1.1 com o hostname
sudo nano /etc/hosts
# Adicionar:
172.31.110.10 hadoop-master
172.31.110.11 hadoop-worker1
172.31.110.12 hadoop-worker2
```

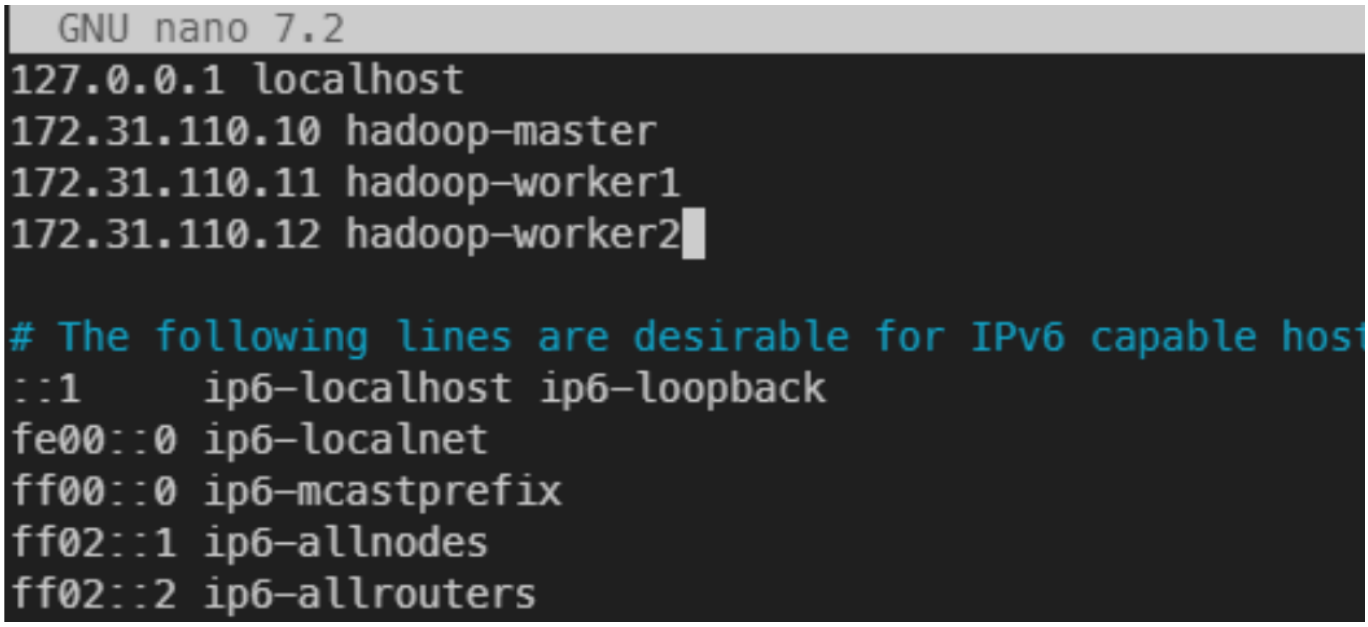
Configuração de rede e arquivo hosts

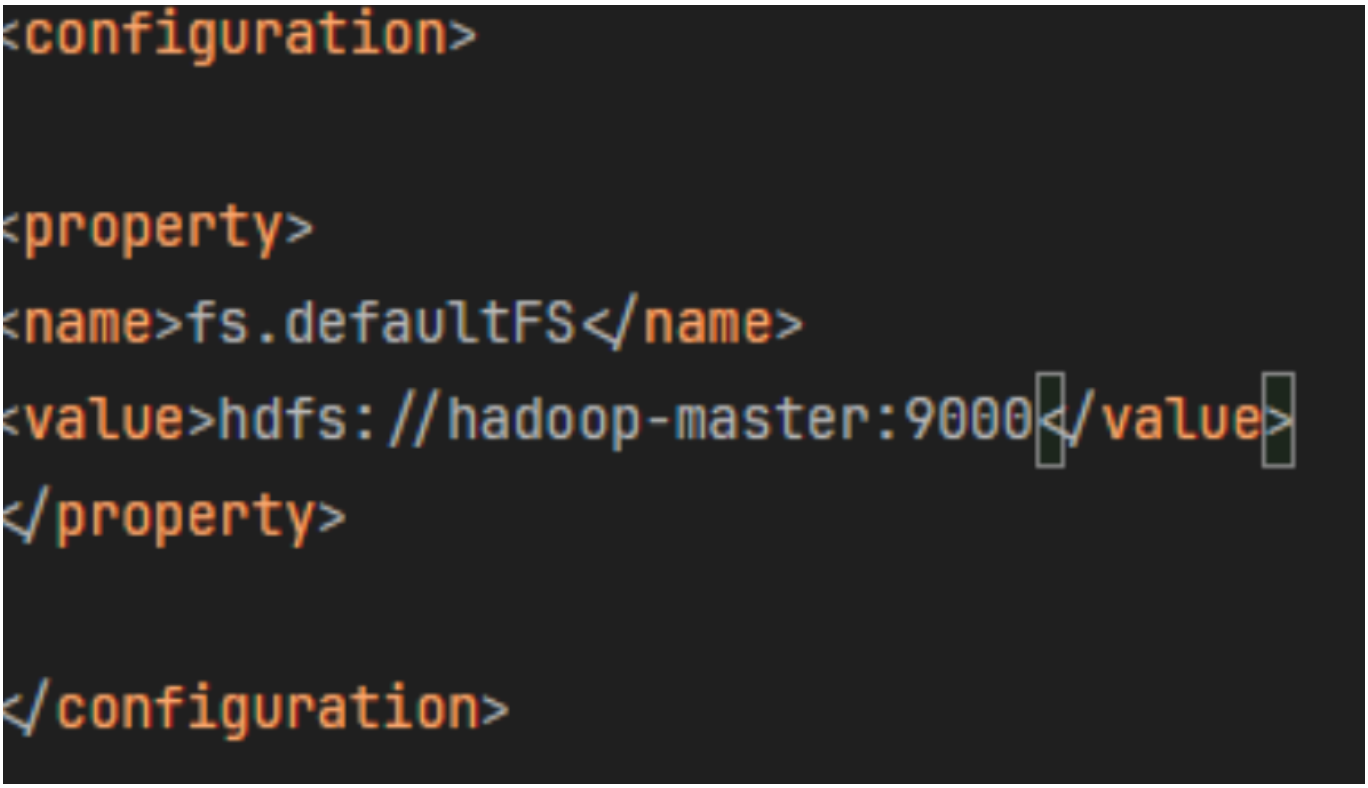

GNU nano 7.2
50-cloud-init.yaml *
network:
version: 2
ethernets:
enp0s3:
dhcp4: true
enp0s8:
dhcp4: false
addresses: [172.31.110.10/24]

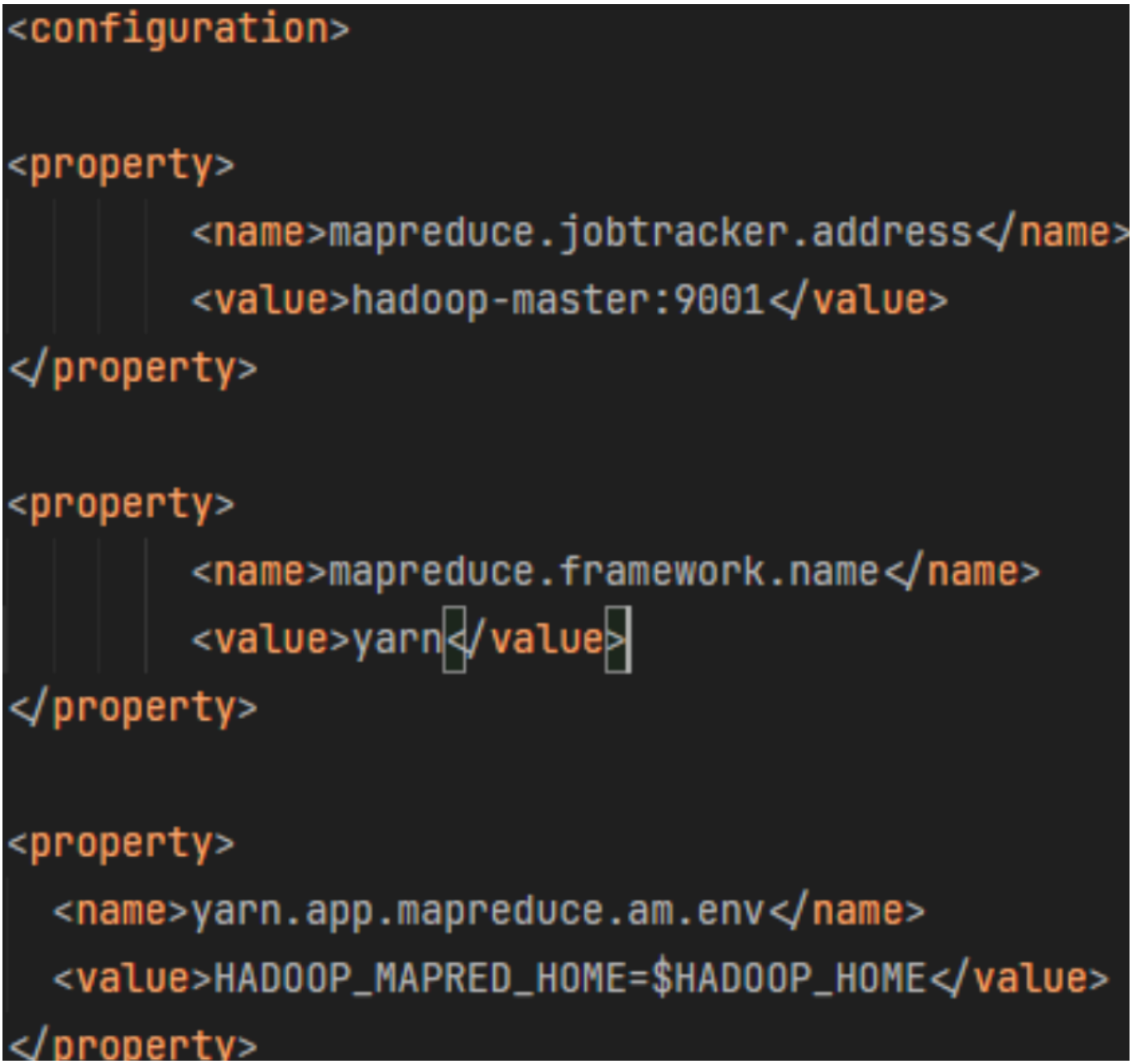

GNU nano 7.2
50-cloud-init.yaml *
network:
version: 2
ethernets:
enp0s3:
dhcp4: true
enp0s8:
dhcp4: false
addresses: [172.31.110.11/24]


GNU nano 7.2
50-cloud-init.yaml *
network:
version: 2
ethernets:
enp0s3:
dhcp4: true
enp0s8:
dhcp4: false
addresses: [172.31.110.12/24]


ubuntu_user@hadoop-master:~$ sudo netplan apply
[sudo] password for ubuntu_user:
ubuntu_user@hadoop-master:~$


GNU nano 7.2
127.0.0.1 localhost
172.31.110.10 hadoop-master
172.31.110.11 hadoop-worker1
172.31.110.12 hadoop-worker2
The following lines are desirable for IPv6 capable host
::1 ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters


<configuration>
<property>
<name>fs.defaultFS</name>
<value>hdfs://hadoop-master:9000</value>
</property>
</configuration>


<configuration>
<property>
<name>mapreduce.jobtracker.address</name>
<value>hadoop-master:9001</value>
</property>
<property>
<name>mapreduce.framework.name</name>
<value>yarn</value>
</property>
<property>
<name>yarn.app.mapreduce.am.env</name>
<value>HADOOP_MAPRED_HOME=$HADOOP_HOME</value>
</property>

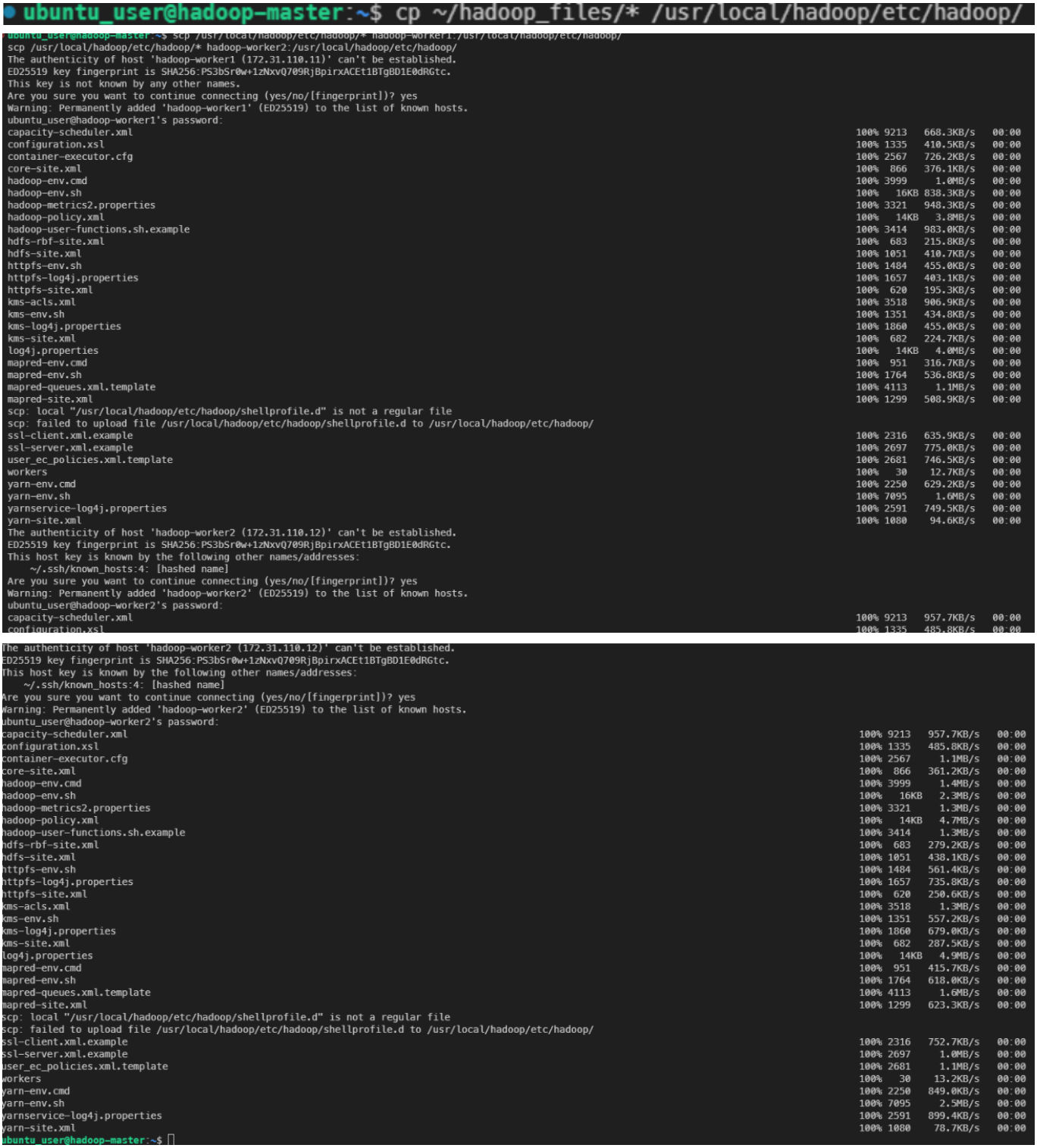
```
<configuration>

<property>
<name>yarn.resourcemanager.hostname</name>
<value>hadoop-master</value>
</property>

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

<property>
<name>yarn.nodemanager.aux-services.mapreduce_shuffle.class</name>
<value>org.apache.hadoop.mapred.ShuffleHandler</value>
</property>

<property>
<name>yarn.resourcemanager.webapp.address</name>
<value>0.0.0.0:8088</value>
</property>

</configuration>
```

```
hadoop-worker1
hadoop-worker2
```

```
# Copiar os arquivos hadoop_files que estão no Classroom ou na rede local
para /usr/local/hadoop/etc/hadoop no master
sudo apt-get install unzip
unzip hadoop_files
cp ~/hadoop_files/*.* /usr/local/hadoop/etc/hadoop

# Verifique o nome do hadoop-master e workers nos arquivos
# core-site.xml hdfs-site.xml mapred-site.xml workers yarn-site.xml
# Deve-se ajustar os arquivos para seu cluster (principalmente os nomes
hosts)
```

```
# O mesmo arquivo deve ir para os workers, lembrando que tem que certificar os nomes hosts:
scp /usr/local/hadoop/etc/hadoop/* hadoop-worker1:/usr/local/hadoop/etc/hadoop/
scp /usr/local/hadoop/etc/hadoop/* hadoop-worker2:/usr/local/hadoop/etc/hadoop/
```

Transferência de arquivos de configuração



.bashrc

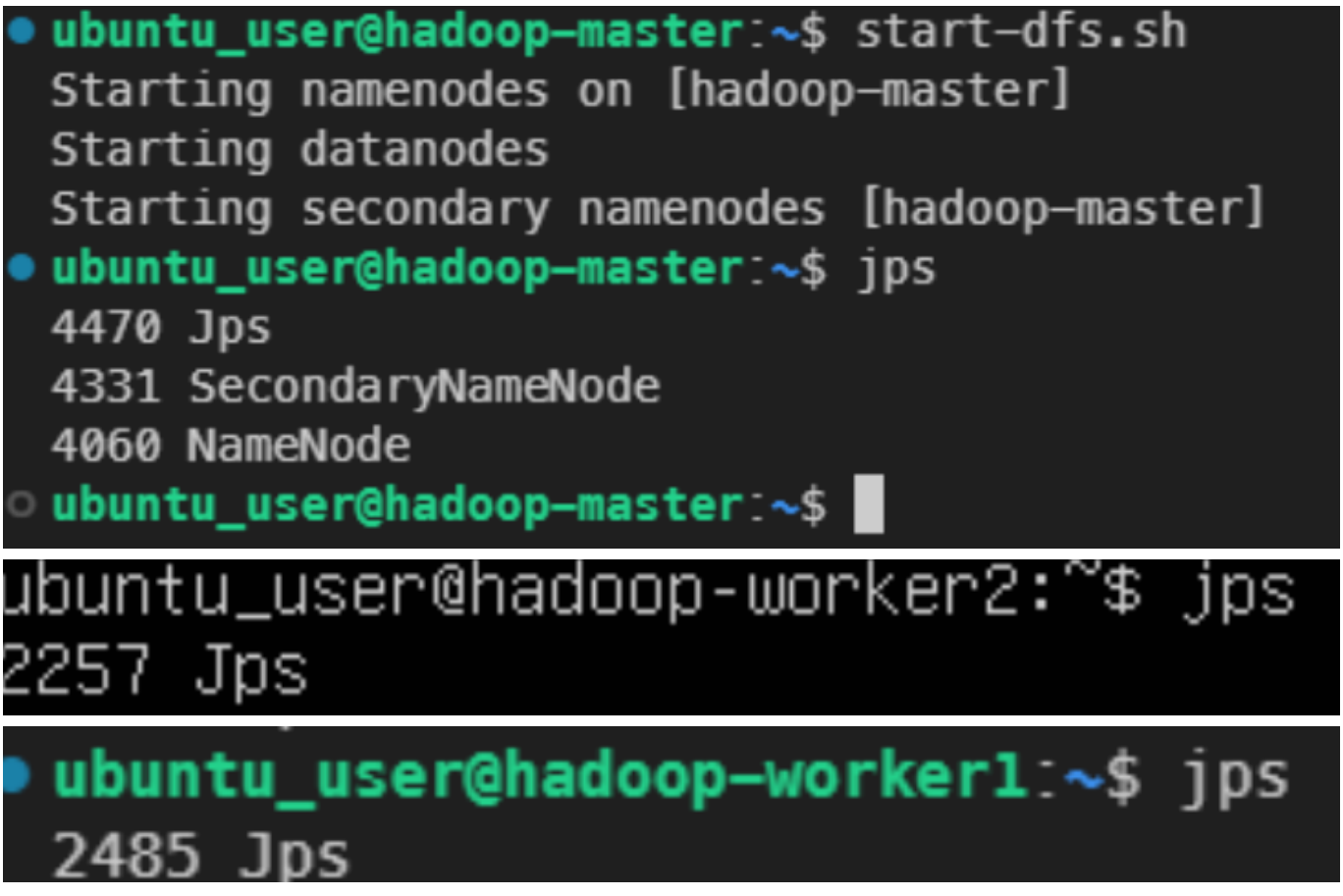
```
# enable programmable completion features (you don't need to enable
# this, if it's already enabled in /etc/bash.bashrc and /etc/profile
# sources /etc/bash.bashrc).
if ! shopt -oq posix; then
  if [ -f /usr/share/bash-completion/bash_completion ]; then
    . /usr/share/bash-completion/bash_completion
  elif [ -f /etc/bash_completion ]; then
    . /etc/bash_completion
  fi
fi
 export PDSH_RCMD_TYPE=ssh

export HADOOP_HOME="/usr/local/hadoop"
export HADOOP_COMMON_HOME=$HADOOP_HOME
export HADOOP_CONF_DIR=$HADOOP_HOME/etc/hadoop
export HADOOP_HDFS_HOME=$HADOOP_HOME
export HADOOP_MAPRED_HOME=$HADOOP_HOME
export HADOOP_YARN_HOME=$HADOOP_HOME
```

```
ubuntu_user@hadoop-master:~$ source ~/.bashrc
ubuntu_user@hadoop-master:~$ echo $HADOOP_HOME
/usr/local/hadoop
ubuntu_user@hadoop-master:~$
```

```
2025-04-04 00:12:39,054 INFO namenode.FSDirectory: GLOBAL serial map: bits=29 maxEntries=536870911
2025-04-04 00:12:39,054 INFO namenode.FSDirectory: USER serial map: bits=24 maxEntries=16777215
2025-04-04 00:12:39,054 INFO namenode.FSDirectory: GROUP serial map: bits=24 maxEntries=16777215
2025-04-04 00:12:39,054 INFO namenode.FSDirectory: XATTR serial map: bits=24 maxEntries=16777215
2025-04-04 00:12:39,081 INFO util.GSet: Computing capacity for map INodeMap
2025-04-04 00:12:39,081 INFO util.GSet: VM type       = 64-bit
2025-04-04 00:12:39,081 INFO util.GSet: 1.0% max memory 437.5 MB = 4.4 MB
2025-04-04 00:12:39,081 INFO util.GSet: capacity      = 2^19 = 524288 entries
2025-04-04 00:12:39,082 INFO namenode.FSDirectory: ACLs enabled? true
2025-04-04 00:12:39,082 INFO namenode.FSDirectory: POSIX ACL inheritance enabled? true
2025-04-04 00:12:39,082 INFO namenode.FSDirectory: XAttrs enabled? true
2025-04-04 00:12:39,083 INFO namenode.NameNode: Caching file names occurring more than 10 times
2025-04-04 00:12:39,090 INFO snapshot.SnapshotManager: Loaded config captureOpenFiles: false, skipCaptureAccessTimeOnlyChange: false, snapshotDiffAllowSnapRootDescendant: true, m
pshotFSLimit: 65536, maxSnapshotLimit: 65536
2025-04-04 00:12:39,090 INFO snapshot.SnapshotManager: dfs.namenode.snapshot.deletion.ordered = false
2025-04-04 00:12:39,092 INFO snapshot.SnapshotManager: SkipList is disabled
2025-04-04 00:12:39,097 INFO util.GSet: Computing capacity for map cachedBlocks
2025-04-04 00:12:39,097 INFO util.GSet: VM type       = 64-bit
2025-04-04 00:12:39,097 INFO util.GSet: 0.25% max memory 437.5 MB = 1.1 MB
2025-04-04 00:12:39,097 INFO util.GSet: capacity      = 2^17 = 131072 entries
2025-04-04 00:12:39,133 INFO metrics.TopMetrics: NNTop conf: dfs.namenode.top.window.num.buckets = 10
2025-04-04 00:12:39,133 INFO metrics.TopMetrics: NNTop conf: dfs.namenode.top.num.users = 10
2025-04-04 00:12:39,133 INFO metrics.TopMetrics: NNTop conf: dfs.namenode.top.windows.minutes = 1,5,25
2025-04-04 00:12:39,145 INFO namenode.FSNamesystem: Retry cache on namenode is enabled
2025-04-04 00:12:39,146 INFO namenode.FSNamesystem: Retry cache will use 0.03 of total heap and retry cache entry expiry time is 600000 millis
2025-04-04 00:12:39,155 INFO util.GSet: Computing capacity for map NameNodeRetryCache
2025-04-04 00:12:39,155 INFO util.GSet: VM type       = 64-bit
2025-04-04 00:12:39,156 INFO util.GSet: 0.029999999329447746% max memory 437.5 MB = 134.4 KB
2025-04-04 00:12:39,156 INFO util.GSet: capacity      = 2^14 = 16384 entries
2025-04-04 00:12:39,228 INFO namenode.FSImage: Allocated new BlockPoolId: BP-2057482878-172.31.110.10-1743736359209
2025-04-04 00:12:39,273 INFO common.Storage: Storage directory /usr/local/hadoop/data/nameNode has been successfully formatted.
2025-04-04 00:12:39,493 INFO namenode.FSImageFormatProtobuf: Saving image file /usr/local/hadoop/data/nameNode/current/fsimage.ckpt_0000000000000000000 using no compression
2025-04-04 00:12:39,662 INFO namenode.FSImageFormatProtobuf: Image file /usr/local/hadoop/data/nameNode/current/fsimage.ckpt_0000000000000000000 of size 403 bytes saved in 0 seco
2025-04-04 00:12:39,695 INFO namenode.NNStorageRetentionManager: Going to retain 1 images with txid >= 0
2025-04-04 00:12:39,702 INFO blockmanagement.DatanodeManager: Slow peers collection thread shutdown
2025-04-04 00:12:39,706 INFO namenode.FSNamesystem: Stopping services started for active state
2025-04-04 00:12:39,706 INFO namenode.FSNamesystem: Stopping services started for standby state
2025-04-04 00:12:39,711 INFO namenode.FSImage: FSImageSaver clean checkpoint: txid=0 when meet shutdown.
2025-04-04 00:12:39,711 INFO namenode.NameNode: SHUTDOWN_MSG:
/************************************************************
SHUTDOWN_MSG: Shutting down NameNode at hadoop-master/172.31.110.10
```

```
# Criando um ambiente virtual para o Hadoop
sudo nano ~/.bashrc
# Acrescente as seguintes variáveis em .bashrc do master
export HADOOP_HOME="/usr/local/hadoop"
export HADOOP_COMMON_HOME=$HADOOP_HOME
export HADOOP_CONF_DIR=$HADOOP_HOME/etc/hadoop
export HADOOP_HDFS_HOME=$HADOOP_HOME
export HADOOP_MAPRED_HOME=$HADOOP_HOME
export HADOOP_YARN_HOME=$HADOOP_HOME

# Recarregar as variáveis de ambiente
source ~/.bashrc

# Executar o comando para a formação do HDFS:
hdfs namenode -format

# Iniciar o HDFS
start-dfs.sh

# O comando jps serve para verificar os Datanodes e Namenodes ativos
jps
```

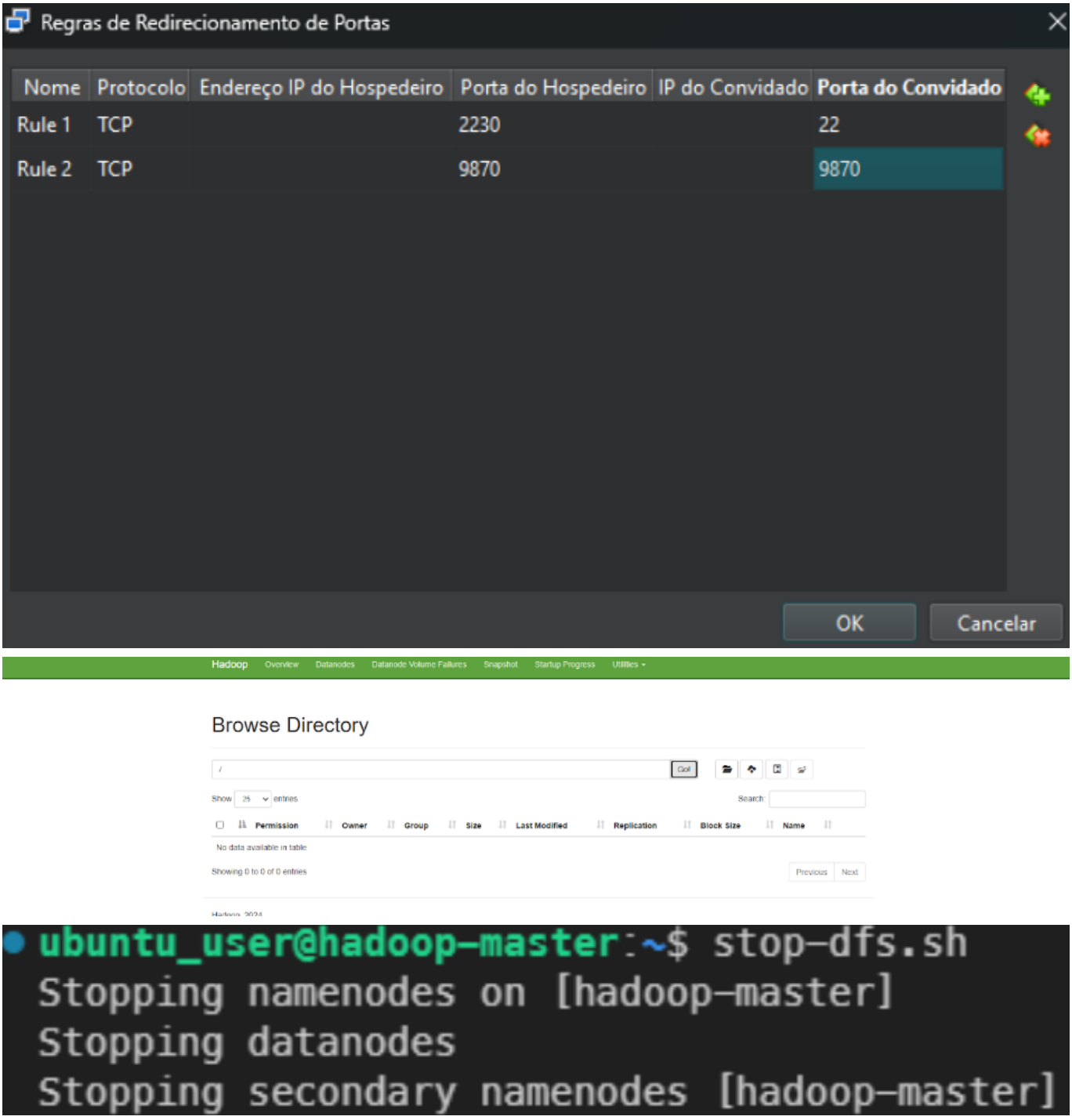
Saída do comando jps com nós ativos




```
# Crie outro redirecionamento de porta para o Master na porta 9870 para
9870
```

```
# Acesse: http://localhost:9870/
# Clique em Utilities >> Browse the file system
```

Interface web do HDFS em localhost:9870



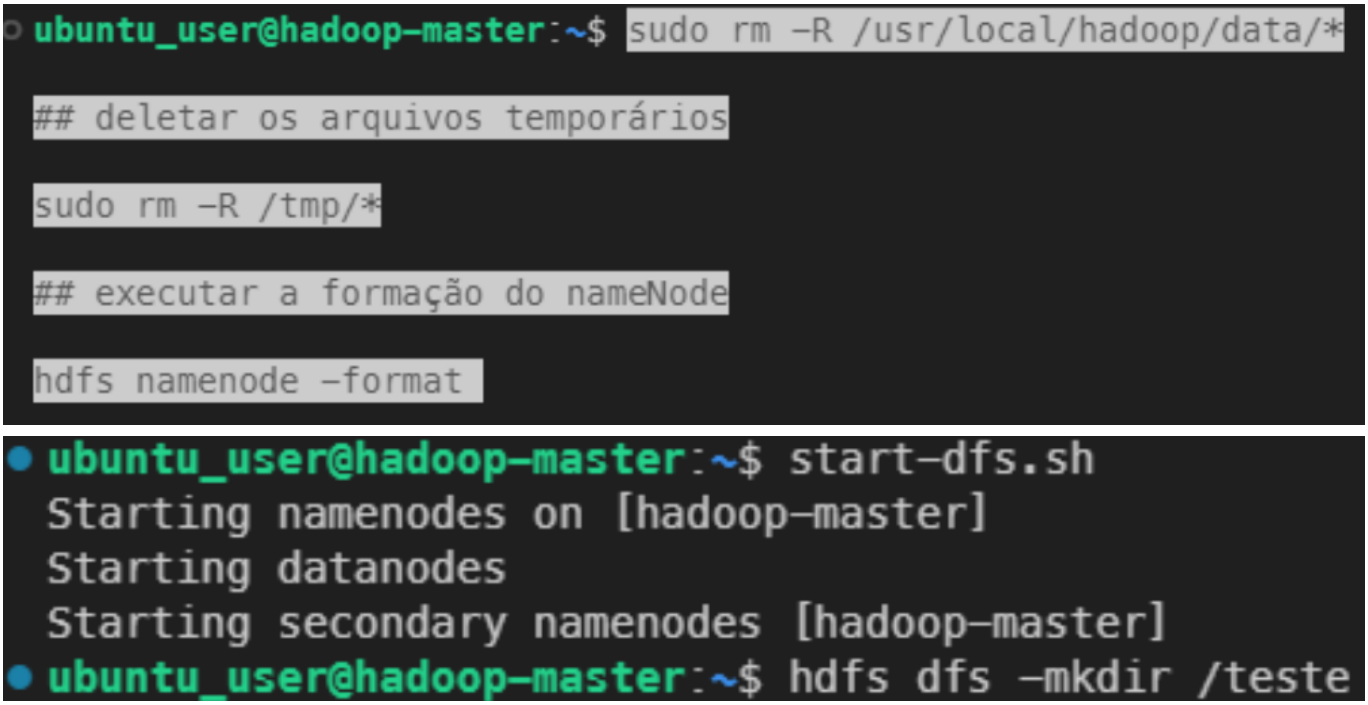
2.3 Laboratório 3: Operações HDFS e PySpark

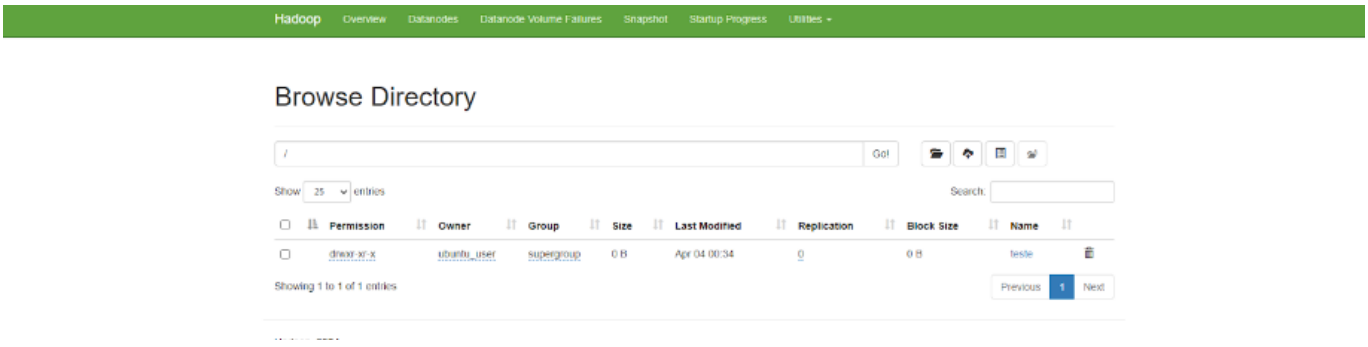
O terceiro laboratório focou na utilização prática do HDFS e implementação do PySpark para processamento de dados:

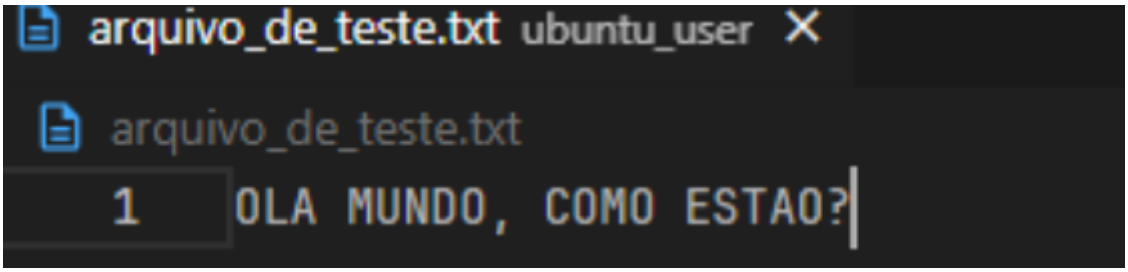
```
# Procedimentos para a limpeza e formação do HDFS, caso necessário
# Deletar todos os arquivos das pastas dataNode e nameNode (é necessário
que essas pastas existam)
```

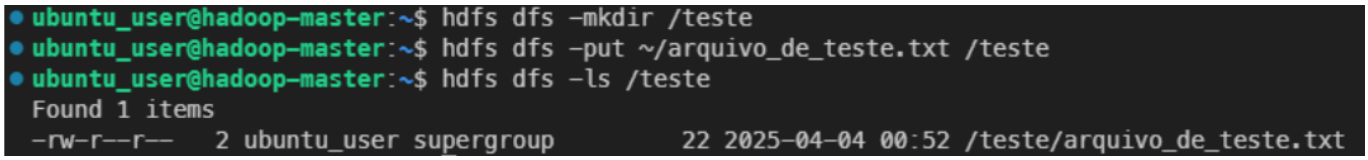
```
sudo rm -R /usr/local/hadoop/data/*

# Deletar os arquivos temporários
sudo rm -R /tmp/*

# Executar a formação do nameNode
hdfs namenode -format

# Iniciar o HDFS
start-dfs.sh

# Comandos exemplo para a operação do HDFS
hdfs dfs -mkdir /teste

# Clique em Utilities >> Browse the file system
vi ~/arquivo_de_teste.txt
hdfs dfs -put ~/arquivo_de_teste.txt /teste
hdfs dfs -ls /teste
mkdir ~/tmp
hdfs dfs -get /teste ~/tmp/
ls ~/tmp
hdfs dfs -rm /teste/arquivo_de_teste.txt
hdfs dfs -ls /teste
hdfs dfs -rm -r /teste
hdfs dfs -ls /
```

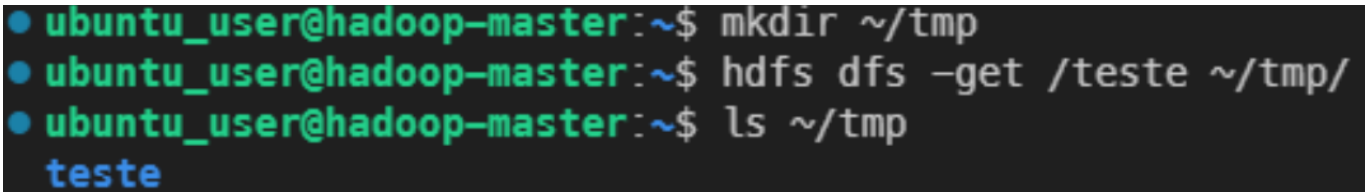
Operações de manipulação de arquivos no HDFS

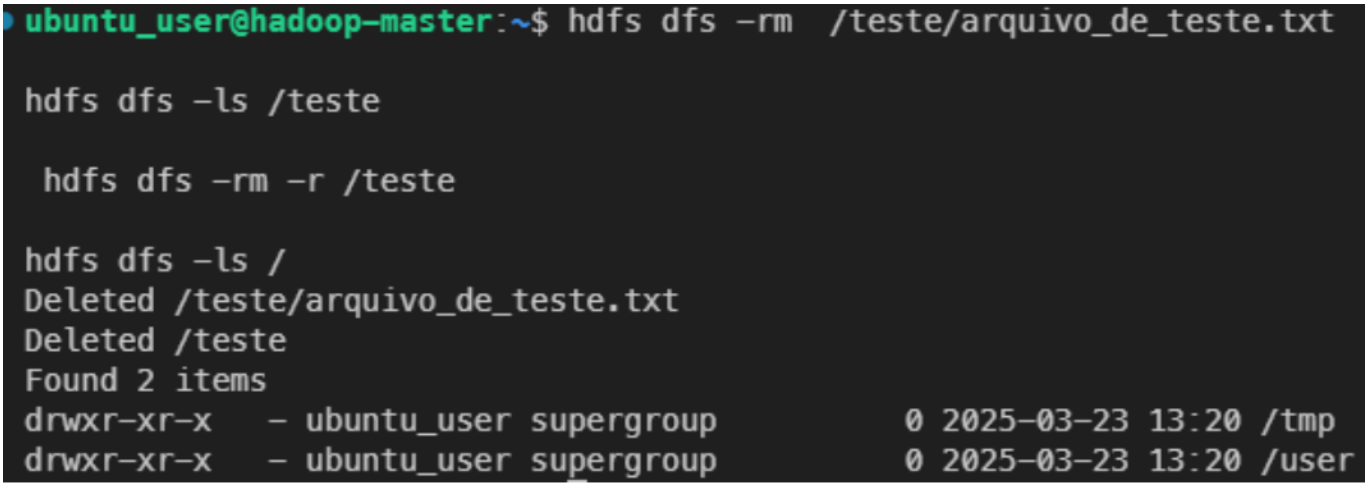






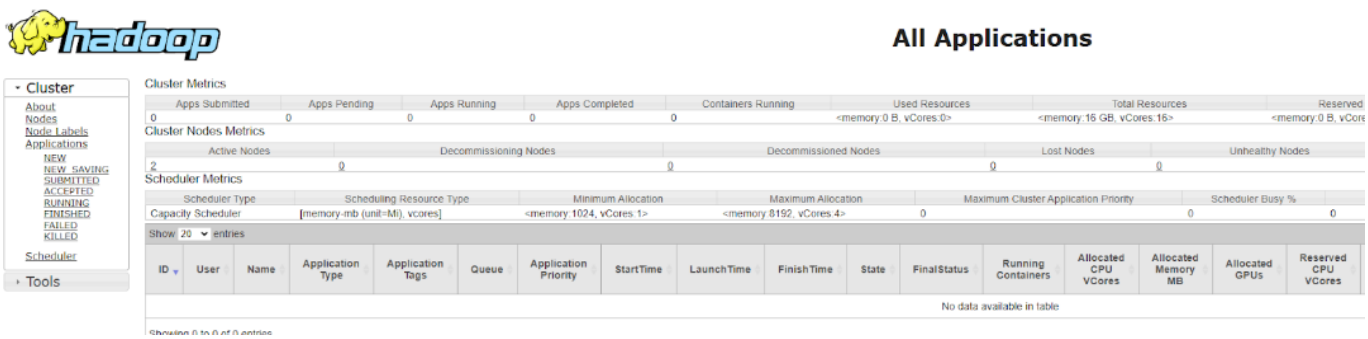






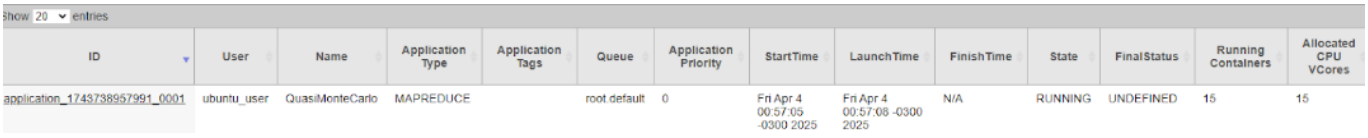

```
# Testando o YARN
start-yarn.sh  # ou /usr/local/hadoop/sbin/start-all.sh
yarn application -list
cat $HADOOP_HOME/logs/yarn-*-resourcemanager-*.log | tail -n 50

# Crie outro redirecionamento de porta para o Master no IP 172.31.110.10 na
porta 8088
# Acesse: http://localhost:8088/
hadoop jar /usr/local/hadoop/share/hadoop/mapreduce/hadoop-mapreduce-
examples-3.4.0.jar pi 30 100
```

Interface web do YARN em localhost:8088



Cálculo de π

```
ubuntu_user@hadoop-master:~$ hadoop jar /usr/local/hadoop/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.4.0.jar pi 30 100
Number of Maps  = 30
Samples per Map = 100
Wrote input for Map #0
Wrote input for Map #1
Wrote input for Map #2
Wrote input for Map #3
Wrote input for Map #4
Wrote input for Map #5
Wrote input for Map #6
Wrote input for Map #7
Wrote input for Map #8
Wrote input for Map #9
Wrote input for Map #10
Wrote input for Map #11
Wrote input for Map #12
Wrote input for Map #13
Wrote input for Map #14
Wrote input for Map #15
Wrote input for Map #16
Wrote input for Map #17
Wrote input for Map #18
Wrote input for Map #19
Wrote input for Map #20
Wrote input for Map #21
Wrote input for Map #22
Wrote input for Map #23
Wrote input for Map #24
Wrote input for Map #25
Wrote input for Map #26
Wrote input for Map #27
Wrote input for Map #28
Wrote input for Map #29
Starting Job
2025-04-04 00:57:01,709 INFO client.DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at hadoop-master/172.31.110.10:8032
2025-04-04 00:57:02,964 INFO mapreduce.JobResourceUploader: Disabling Erasure Coding for path: /tmp/hadoop-yarn/staging/ubuntu_user/.staging/job_17437389
2025-04-04 00:57:03,368 INFO input.FileInputFormat: Total input files to process : 30
2025-04-04 00:57:03,556 INFO mapreduce.JobSubmitter: number of splits:30
2025-04-04 00:57:04,436 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1743738957991_0001
2025-04-04 00:57:04,437 INFO mapreduce.JobSubmitter: Executing with tokens: []
2025-04-04 00:57:05,353 INFO conf.Configuration: resource-types.xml not found
2025-04-04 00:57:05,353 INFO resource.ResourceUtils: Unable to find 'resource-types.xml'.
2025-04-04 00:57:06,069 INFO impl.YarnClientImpl: Submitted application application_1743738957991_0001
2025-04-04 00:57:06,124 INFO mapreduce.Job: The url to track the job: http://hadoop-master:8088/proxy/application_1743738957991_0001/
2025-04-04 00:57:06,124 INFO mapreduce.Job: Running job: job_1743738957991_0001
2025-04-04 00:57:18,342 INFO mapreduce.Job: Job job_1743738957991_0001 running in uber mode : false
2025-04-04 00:57:18,343 INFO mapreduce.Job:  map 0% reduce 0%
```



```
        Map-Reduce Framework
                Map input records=30
                Map output records=60
                Map output bytes=540
                Map output materialized bytes=840
                Input split bytes=4700
                Combine input records=0
                Combine output records=0
                Reduce input groups=2
                Reduce shuffle bytes=840
                Reduce input records=60
                Reduce output records=0
                Spilled Records=120
                Shuffled Maps =30
                Failed Shuffles=0
                Merged Map outputs=30
                GC time elapsed (ms)=8452
                CPU time spent (ms)=48870
                Physical memory (bytes) snapshot=8004456448
                Virtual memory (bytes) snapshot=78907682816
                Total committed heap usage (bytes)=7669284864
                Peak Map Physical memory (bytes)=313053184
                Peak Map Virtual memory (bytes)=2552188928
                Peak Reduce Physical memory (bytes)=224133120
                Peak Reduce Virtual memory (bytes)=2553503744
        Shuffle Errors
                BAD_ID=0
                CONNECTION=0
                IO_ERROR=0
                WRONG_LENGTH=0
                WRONG_MAP=0
                WRONG_REDUCE=0
        File Input Format Counters
                Bytes Read=3540
        File Output Format Counters
                Bytes Written=97
Job Finished in 156.251 seconds
Estimated value of Pi is 3.14133333333333333333
```

```
mkdir ~/gutenberg
wget https://www.gutenberg.org/cache/epub/20417/pg20417.txt >
~/gutenberg/pg20417.txt
cd ~/gutenberg/
hdfs dfs -mkdir -p /teste
hdfs dfs -put ~/gutenberg/pg20417.txt /teste
hadoop jar /usr/local/hadoop/share/hadoop/mapreduce/hadoop-mapreduce-
examples-3.4.0.jar wordcount /teste/pg20417.txt
/user/ubuntu_user/gutenberg-output/
hdfs dfs -cat /user/ubuntu_user/gutenberg-output/part-r-00000
```

Resultado da operação wordcount

```
ubuntu_user@hadoop-master:~$ mkdir ~/gutenberg
ubuntu_user@hadoop-master:~$ wget https://www.gutenberg.org/cache/epub/20417/pg20417.txt > ~/gutenberg/pg20417.txt
--2025-04-04 01:01:21--  https://www.gutenberg.org/cache/epub/20417/pg20417.txt
Resolving www.gutenberg.org (www.gutenberg.org)... 152.19.134.47, 2610:28:3090:3000:0:bad:cafe:47
Connecting to www.gutenberg.org (www.gutenberg.org)|152.19.134.47|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 674656 (659K) [text/plain]
Saving to: ‘pg20417.txt.1’

pg20417.txt.1                       100%[===========================================================================================>] 658.84K   999KB/s    in 0.7s

2025-04-04 01:01:22 (999 KB/s) - ‘pg20417.txt.1’ saved [674656/674656]

ubuntu_user@hadoop-master:~$ cd ~/gutenberg/
ubuntu_user@hadoop-master:~/gutenberg$ hdfs dfs -mkdir -p /teste
ubuntu_user@hadoop-master:~/gutenberg$ hdfs dfs -put ~/gutenberg/pg20417.txt /teste
```

```
ubuntu_user@hadoop-master:~/gutenberg$ hadoop jar /usr/local/hadoop/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.4.0.jar wordcount /teste/pg20417.txt  /user/ubuntu_user/gutenberg-output/
2025-04-04 01:03:23,431 INFO client.DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at hadoop-master/172.31.110.10:8032
2025-04-04 01:03:23,813 INFO mapreduce.JobResourceUploader: Disabling Erasure Coding for path: /tmp/hadoop-yarn/staging/ubuntu_user/.staging/job_1743738957991_0002
2025-04-04 01:03:24,532 INFO input.FileInputFormat: Total input files to process : 1
2025-04-04 01:03:26,101 INFO mapreduce.JobSubmitter: number of splits:1
2025-04-04 01:03:27,134 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1743738957991_0002
2025-04-04 01:03:27,134 INFO mapreduce.JobSubmitter: Executing with tokens: []
2025-04-04 01:03:27,410 INFO conf.Configuration: resource-types.xml not found
2025-04-04 01:03:27,410 INFO resource.ResourceUtils: Unable to find 'resource-types.xml'.
2025-04-04 01:03:27,489 INFO impl.YarnClientImpl: Submitted application application_1743738957991_0002
2025-04-04 01:03:27,522 INFO mapreduce.Job: The url to track the job: http://hadoop-master:8088/proxy/application_1743738957991_0002/
2025-04-04 01:03:27,523 INFO mapreduce.Job: Running job: job_1743738957991_0002
2025-04-04 01:03:33,639 INFO mapreduce.Job: Job job_1743738957991_0002 running in uber mode : false
2025-04-04 01:03:33,641 INFO mapreduce.Job:  map 0% reduce 0%
2025-04-04 01:03:37,720 INFO mapreduce.Job:  map 100% reduce 0%
2025-04-04 01:03:42,775 INFO mapreduce.Job:  map 100% reduce 100%
2025-04-04 01:03:42,802 INFO mapreduce.Job: Job job_1743738957991_0002 completed successfully
2025-04-04 01:03:42,916 INFO mapreduce.Job: Counters: 54
        File System Counters
                FILE: Number of bytes read=6
                FILE: Number of bytes written=618319
                FILE: Number of read operations=0
                FILE: Number of large read operations=0
                FILE: Number of write operations=0
                HDFS: Number of bytes read=108
                HDFS: Number of bytes written=0
                HDFS: Number of read operations=8
                HDFS: Number of large read operations=0
                HDFS: Number of write operations=2
                HDFS: Number of bytes read erasure-coded=0
        Job Counters
                Launched map tasks=1
                Launched reduce tasks=1
                Other local map tasks=1
                Total time spent by all maps in occupied slots (ms)=1869
                Total time spent by all reduces in occupied slots (ms)=1792
                Total time spent by all map tasks (ms)=1869
                Total time spent by all reduce tasks (ms)=1792
                Total vcore-milliseconds taken by all map tasks=1869
                Total vcore-milliseconds taken by all reduce tasks=1792
                Total megabyte-milliseconds taken by all map tasks=1913856
                Total megabyte-milliseconds taken by all reduce tasks=1835008
        Map-Reduce Framework
                Map input records=0
                Map output records=0
                Map output bytes=0
                Map output materialized bytes=6
                Input split bytes=108
                Combine input records=0
                Combine output records=0
                Reduce input groups=0
                Reduce shuffle bytes=6
                Reduce input records=0
                Reduce output records=0
                Spilled Records=0
                Shuffled Maps =1
                Failed Shuffles=0
                Merged Map outputs=1
                GC time elapsed (ms)=83
                CPU time spent (ms)=740
                Physical memory (bytes) snapshot=520986624
                Virtual memory (bytes) snapshot=5097283584
                Total committed heap usage (bytes)=394264576
                Peak Map Physical memory (bytes)=316571648
                Peak Map Virtual memory (bytes)=2546495488
                Peak Reduce Physical memory (bytes)=204414976
                Peak Reduce Virtual memory (bytes)=2550788096
        Shuffle Errors
                BAD_ID=0
                CONNECTION=0
                IO_ERROR=0
                WRONG_LENGTH=0
                WRONG_MAP=0
                WRONG_REDUCE=0
```

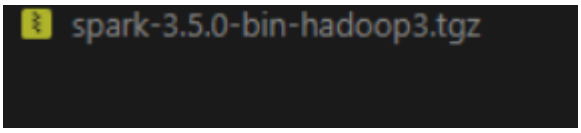
```
    Shuffle Errors
            BAD_ID=0
            CONNECTION=0
            IO_ERROR=0
            WRONG_LENGTH=0
            WRONG_MAP=0
            WRONG_REDUCE=0
    File Input Format Counters
            Bytes Read=0
    File Output Format Counters
            Bytes Written=0
```

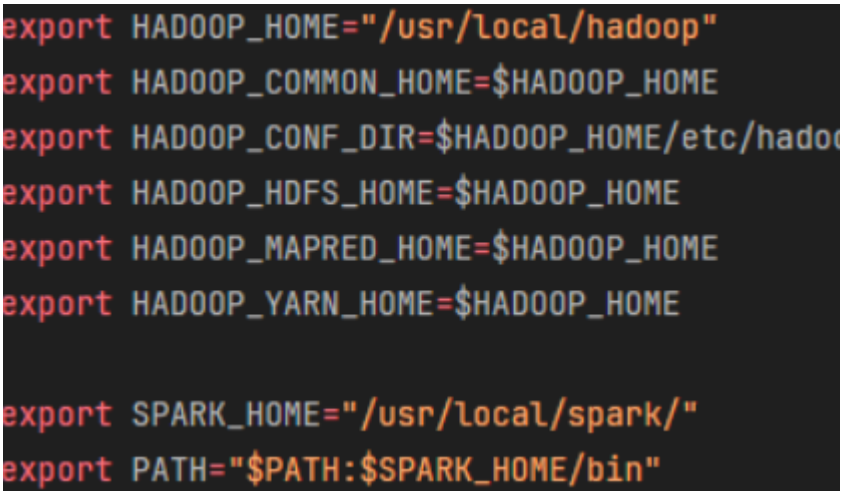
```
# Configuração e uso do PySpark
# Baixar spark do ClassRoom e colocar no diretório home
tar -xvzf spark-3.5.0-bin-hadoop3.tgz
mv spark-3.5.0-bin-hadoop3 spark
sudo mv spark /usr/local/spark
sudo nano ~/.bashrc
```

```
# Incluir essas linhas:
export SPARK_HOME="/usr/local/spark/"
export PATH="$PATH:$SPARK_HOME/bin"

# Carregar variáveis de ambiente
source ~/.bashrc
pyspark
```

Ambiente PySpark iniciado

```
# Criar um contexto de sessão do spark (cria um "programa")
sc = SparkContext.getOrCreate()

# Variável recebe o caminho que aponta para um arquivo de texto
file_path = "/teste/pg20417.txt"

# Leitura do arquivo de texto pelo programa spark
words = sc.textFile(f"{file_path}").flatMap(lambda line: line.split(" "))

# Contagem de palavras utilizando a sintaxe facilitada do pyspark
wordCounts = words.map(lambda word: (word, 1)).reduceByKey(lambda a,b:a +b)

# Salvando arquivo com resultado da execução
wordCounts.saveAsTextFile(f"{'/'.join(file_path.split('/')
[:-1])}/word_count")
wordCounts.count()
```





```
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 3.5.0
      /_/

Using Python version 3.12.3 (main, Feb  4 2025 14:48:35)
Spark context Web UI available at http://hadoop-master:4040
Spark context available as 'sc' (master = local[*], app id = local-1743739578992).
SparkSession available as 'spark'.
>>> # criar um contexto de sessão do spark (cria um "programa")
>>> sc = SparkContext.getOrCreate()
>>> # variável recebe o caminho que aponta para uma arquivo de texto
>>> file_path = "/teste/pg20417.txt"
>>> # leitura do arquivo de texto pelo programa spark
>>> words = sc.textFile(f"{file_path}").flatMap(lambda line: line.split(" "))
sintaxe facilitada do pyspark
wordCounts = words.map(lambda word: (word, 1)).reduceByKey(lambda a,b:a +b)
# salvando arquivo com resultado da execução
wordCounts.saveAsTextFile(f"{'/'.join(file_path.split('/')[:-1])}/word_count")

wordCounts.count()
```

```
>>> wordCounts.count()
18020
```

3. Resultados e Discussão

A implementação do ambiente distribuído permitiu responder diversas questões técnicas e aprofundar o conhecimento em várias áreas:

3.1 Configuração de Sistemas

Foi possível compreender os procedimentos para a instalação e configuração adequada do Ubuntu Server, incluindo a sincronização de tempo e ajuste do fuso horário, elementos críticos para o funcionamento coordenado de sistemas distribuídos.

3.2 Implementação do Hadoop

O laboratório proporcionou conhecimento prático sobre a instalação e configuração do ecossistema Hadoop, incluindo:

- Instalação de dependências como Java e ferramentas auxiliares
- Configuração de variáveis de ambiente
- Ajuste de arquivos de configuração específicos do Hadoop
- Estabelecimento de comunicação segura entre os nós através de SSH

3.3 Configuração de Rede e Cluster

Os experimentos demonstraram a importância da configuração adequada da rede para sistemas distribuídos:

- Definição de IPs estáticos para cada nó
- Configuração de nomes de host e DNS local via arquivo `/etc/hosts`
- Estratégias para comunicação eficiente entre nós

3.4 Operações no HDFS

Foram executadas e compreendidas operações fundamentais no sistema de arquivos distribuído:

- Criação de diretórios e manipulação de arquivos
- Transferência de dados entre o sistema de arquivos local e o HDFS
- Monitoramento e verificação do estado do sistema

3.5 MapReduce e Processamento Distribuído

Os laboratórios permitiram a implementação de exemplos de processamento distribuído:

- Execução de jobs MapReduce para cálculo de π
- Implementação de contagem de palavras (wordcount) em documentos
- Monitoramento de aplicações através do YARN

3.6 PySpark e Análise de Dados

A utilização do PySpark demonstrou o potencial para análise de dados em grande escala:

- Configuração e uso da API Python para o Spark
- Implementação de algoritmos para contagem de palavras em documentos
- Armazenamento e recuperação de resultados processados

3.7 Gestão do Cluster

Os procedimentos de inicialização e encerramento adequados do cluster foram compreendidos:

- Inicialização e parada coordenada dos serviços
- Utilização de ferramentas como `sshpass` para automação de tarefas
- Monitoramento do estado do cluster

4. Curiosidades e Dúvidas Respondidas

Durante os laboratórios, várias curiosidades e dúvidas foram respondidas, incluindo:

4.1 Configuração do Ubuntu Server

Durante a preparação do ambiente, aprendemos a importância crítica da sincronização de tempo em sistemas distribuídos. Sem uma sincronização precisa, os nós do cluster podem enfrentar problemas de coordenação, resultando em falhas de processamento ou inconsistência de dados.

4.2 Arquitetura do HDFS

Compreendemos como o HDFS divide e replica dados através de múltiplos nós, oferecendo tanto redundância quanto paralelismo. A divisão entre NameNode (para metadados) e DataNodes (para armazenamento) demonstra uma separação clara de responsabilidades.

4.3 Configuração e Instalação do Hadoop

Aprendemos os passos necessários para instalar e configurar o Hadoop em um cluster distribuído, incluindo a definição de variáveis de ambiente e o ajuste dos arquivos de configuração para refletir corretamente a topologia do cluster.

4.4 Operações Básicas no HDFS

Descobrimos como criar diretórios, transferir arquivos e listar dados no HDFS usando comandos como `hdfs dfs -put` e `hdfs dfs -get`, permitindo o gerenciamento eficiente dos dados no sistema distribuído.

4.5 Execução de Jobs MapReduce

Experimentamos a execução de exemplos de MapReduce, como o cálculo de π e contagem de palavras, e aprendemos a monitorar aplicações usando o YARN, obtendo insights sobre como trabalhos complexos são divididos e executados em paralelo.

4.6 Configuração e Uso do PySpark

Exploramos como instalar e configurar o PySpark em um ambiente Hadoop, e como executar scripts para processamento de dados, aproveitando a sintaxe intuitiva do Python para operações distribuídas complexas.

4.7 Gerenciamento de Cluster

Aprendemos técnicas para iniciar e parar os serviços do Hadoop de forma adequada, garantindo a integridade do sistema e dos dados durante o ciclo de vida do cluster.

4.8 Comunicação e Sincronização entre Nós

Compreendemos como configurar SSH para comunicação sem senha entre os nós do cluster e como usar ferramentas como `pdsh` para execução paralela de comandos, facilitando a administração do sistema.

4.9 Monitoramento e Depuração

Descobrimos como verificar processos em execução usando `jps` e como interpretar logs e saídas de jobs MapReduce, habilidades essenciais para manutenção e otimização do sistema.

5. Conclusões

Os laboratórios proporcionaram uma compreensão prática abrangente dos sistemas distribuídos baseados no ecossistema Hadoop. A experiência não apenas esclareceu dúvidas técnicas, mas também forneceu uma visão mais profunda de como esses sistemas funcionam na prática, desde a configuração inicial até a execução de tarefas complexas de processamento de dados.

A implementação passo a passo permitiu o desenvolvimento de habilidades técnicas essenciais para a administração e uso de sistemas distribuídos, demonstrando a viabilidade e o poder dessas tecnologias

para processamento de grandes volumes de dados.

O conhecimento adquirido sobre HDFS, MapReduce e PySpark constitui uma base sólida para aplicações futuras em ambientes de Big Data, onde o processamento distribuído é fundamental para lidar com a escala crescente dos conjuntos de dados modernos.