# MS4S21 - Big Data Engineering and Applications

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# Contents

# Apache Hadoop multi-node cluster on Ubuntu VMs

This chapter will walk you through step-wise general guidelines of creating a Apache hadoop cluster 3.2.1 at present using Ubuntu latest stable release via VMs.

## 1.1 VM creation

Please note these steps can be followed to create any OS's VM in general, however the Linux Ubuntu 19.10 is used as example here.

1. Open virtual box and click on the new icon.
2. You are about to create a Ubuntu VM, set the values of each field as shown in Fig 1.1, and then press continue. Please note that chose the machine folder based on where you want to save it on your computer. If you are using university computer, then please choose your network drive.

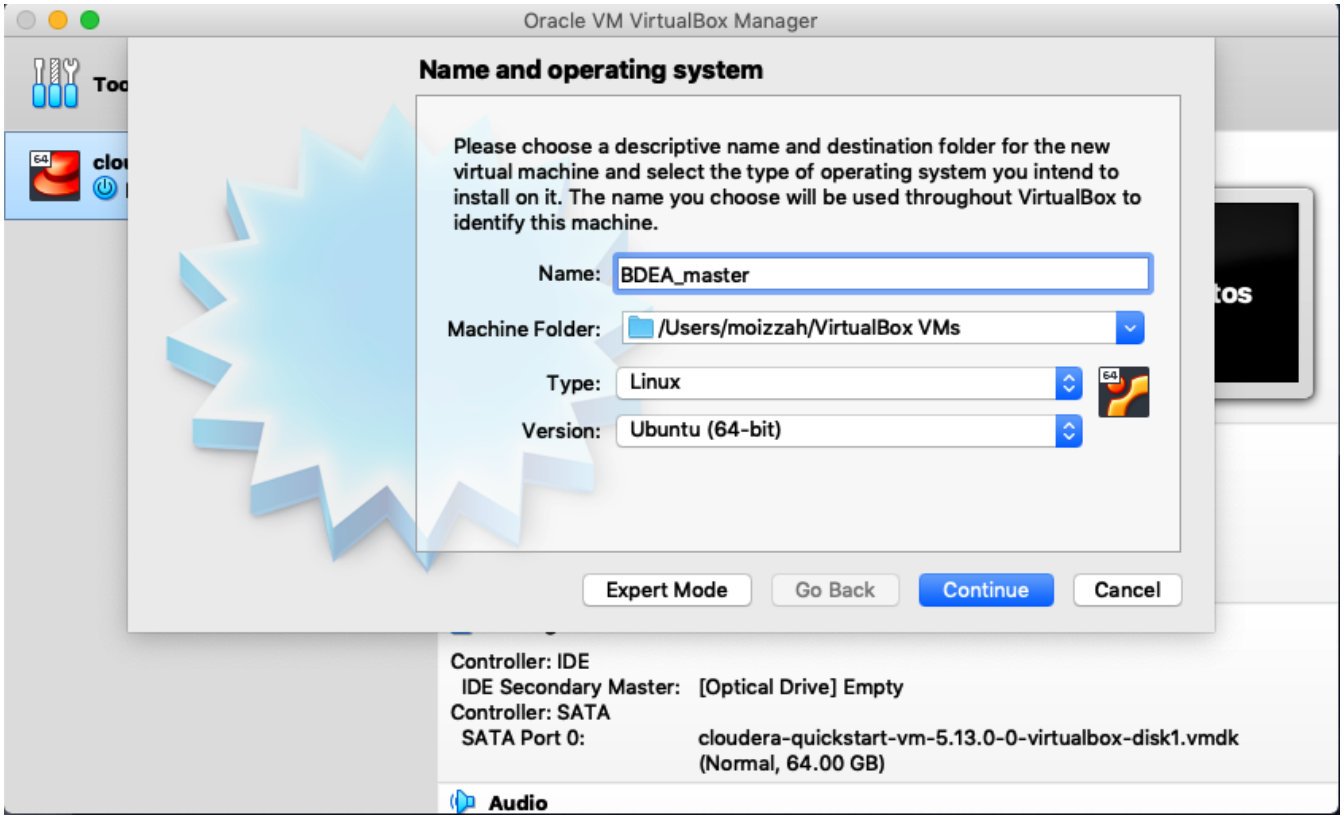



Figure 1.1: Ubuntu VM creation on virtual box - 1

3. Set RAM/memory to 12 GB/ 12288 MBs, and press continue.

4. Select the radio button which enables you to create a virtual hard disk, and then press create.

5. It will be followed by a pop up window where you can specify the hard disk file type as shown in Fig 1.2, please select VHD (virtual Hard Disk) to stay consistent with lectures, and then press continue.

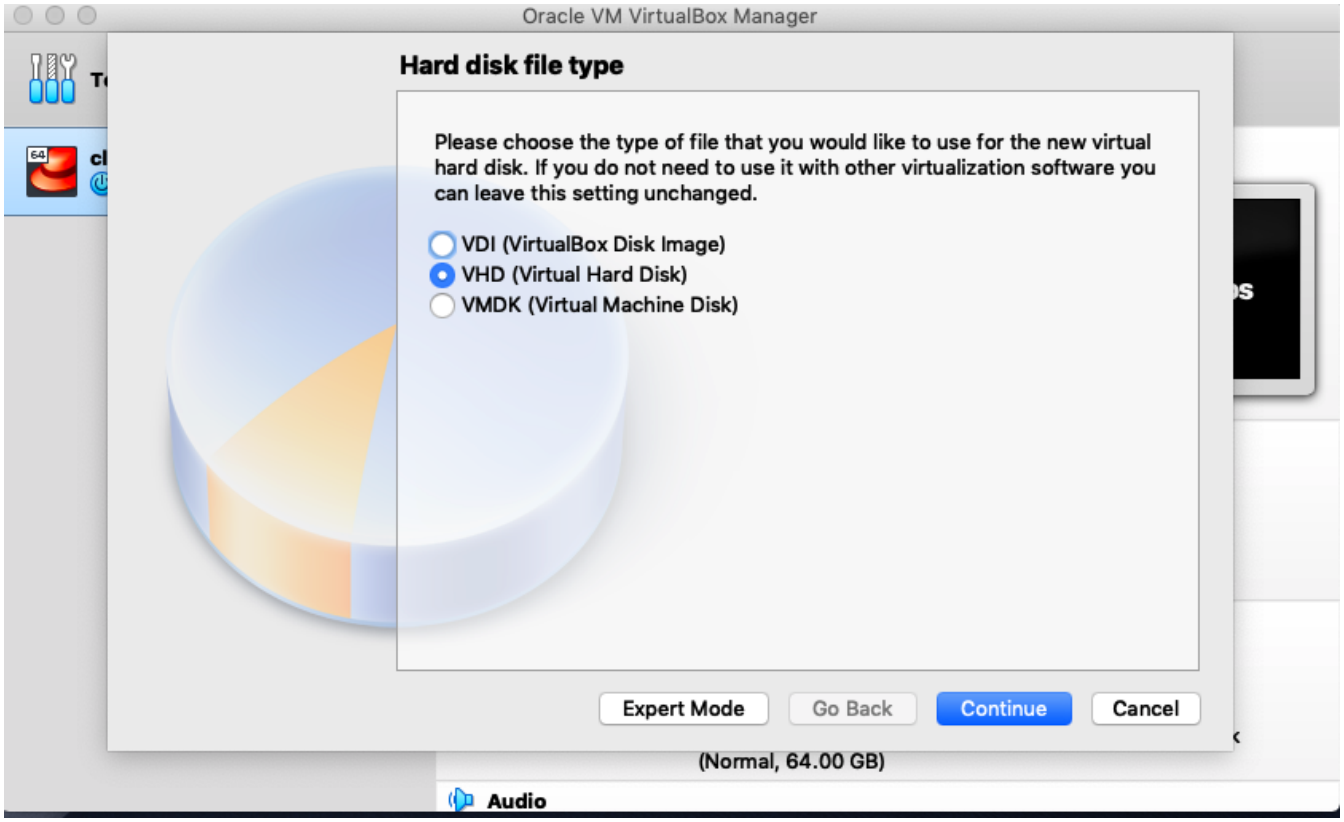



Figure 1.2: Ubuntu VM creation on virtual box - Hard disk file type

6. Select Fixed size radio button for physical storage on hard disk, press continue and then either keep or change the default value of 10 GB. This decision should be made based on your local machine's available hard drive storage, as well as the number of VMs you will have to run at once. In this case consider at least two VMS at a time to simulate the cluster. Press continue and wait for the VM to be created. Please note that you have just configured the physical and memory storage requirement until now. This is similar to brining home a computer which doesn't have any operating system installed on it.

7. You should be able to see the VM on Virtual Box left pane now. As shown in Fig 1.3 the name of this empty VM should be what you named it in the first step of creation.

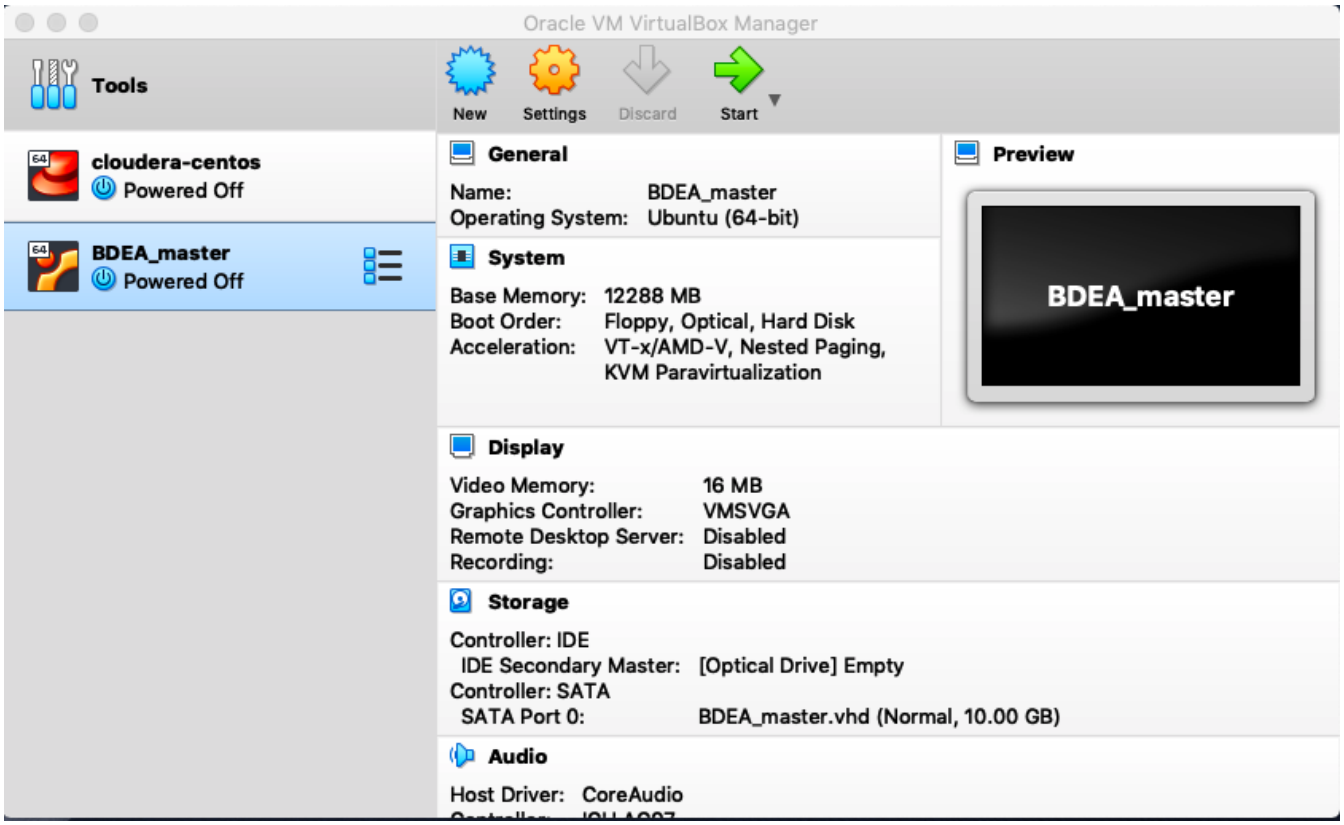



Figure 1.3: Ubuntu VM creation on virtual box - Empty VM

## 1.2 Ubuntu 20.04 installation

You will have to use the .iso image provided in BB Week 1 folder or the one you have downloaded on your computer or saved on your uni network drive.

1. Start the VM that you have just created in the previous section; click on the folder icon with a green arrow; Click on the add icon in the new pop up window;select the .iso image from the location where you have saved/downloaded it; The file should appear on the pop up windows as shown in Fig 1.4; choose this file and process with installation in the next window that pops up on your screen. The essential options in the process are listed below, please make sure that you have selected them.

   (a) install ubuntu

   (b) English UK

   (c) normal installation

   (d) erase disk an install ubuntu(it's empty already)

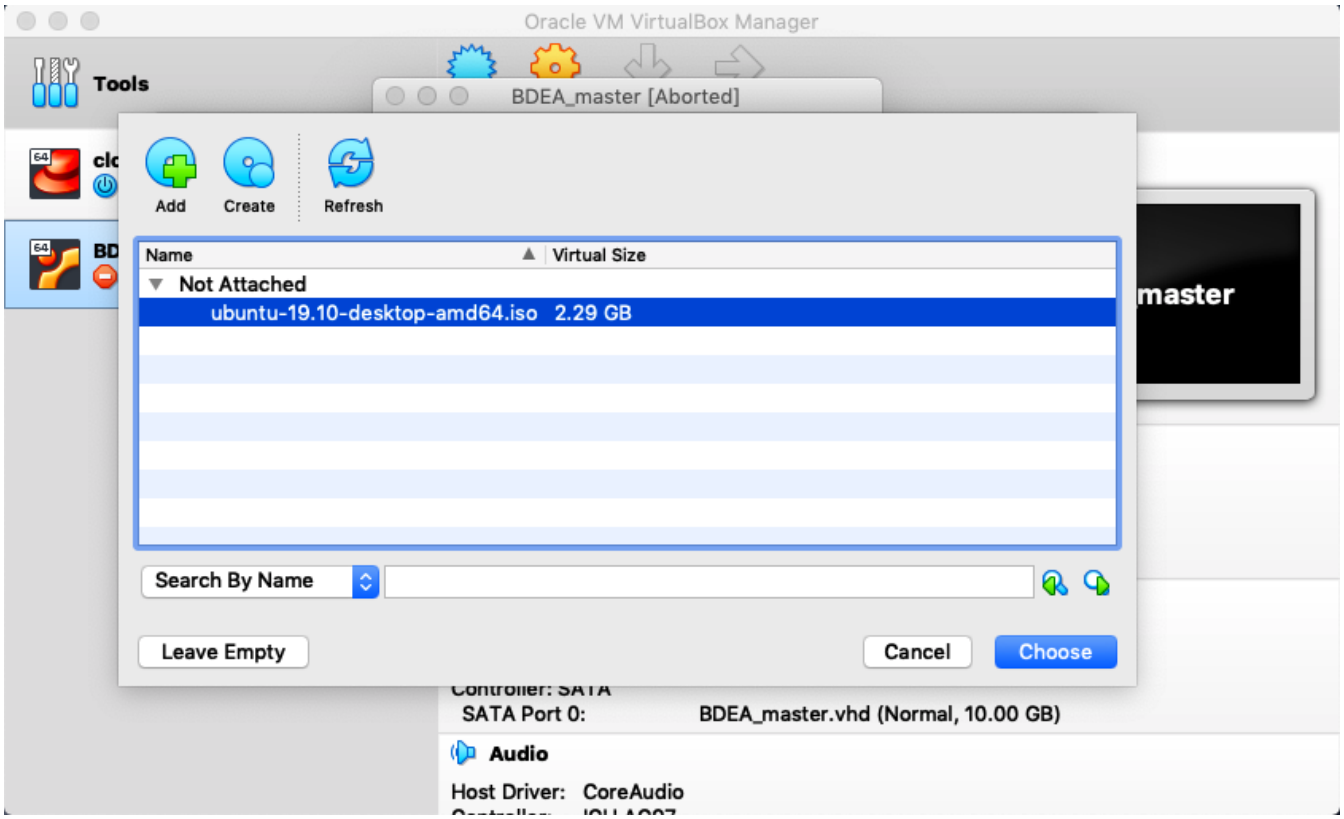



Figure 1.4: Ubuntu VM creation on virtual box - adding iso image 1

2. The screen display shown in Fig 1.5 helps you create a user profile on ubuntu. Please name the user profile intuitively. A user profile BDEA (Big Data Engineering and Applications) will be created for this tutorial's purpose.

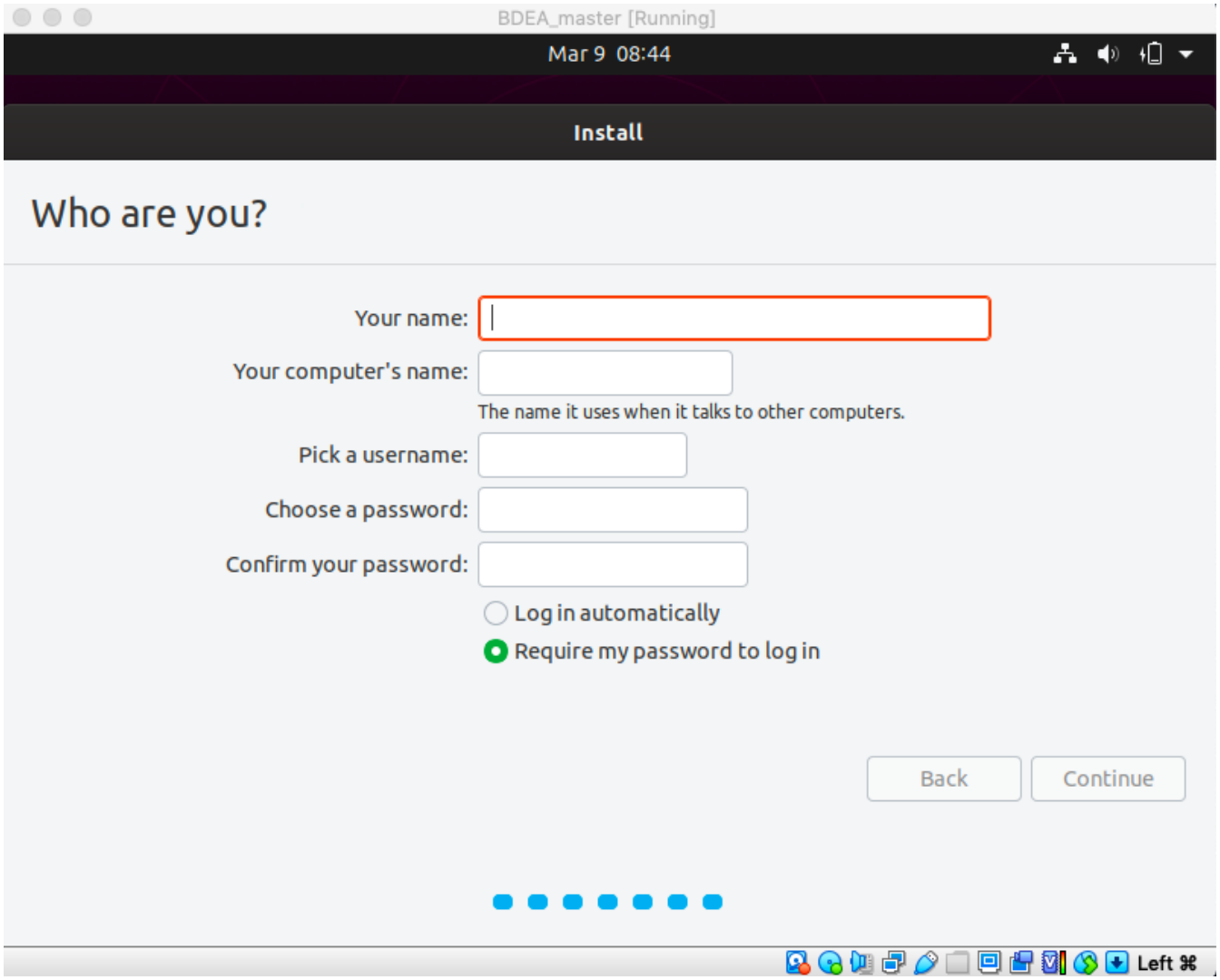



Figure 1.5: Ubuntu user creation

## 1.3 Setting up Ubuntu for Hadoop-3.2.2 hdfs cluster

Once you arrive at your Ubuntu's desktop, open Terminal so that you may set up the machine for hadoop-3.2.2 installation. Follow the guidelines listed below after opening terminal.

*For more information on linux terminal please use the forum in blackboard module.*

1. upgrade and update apt with sudo priviliges (APT - advanced packaging tool) - *sudo apt update/upgrade*
2. Install openssh server - *sudo apt install openssh-server*; verify the status now: *sudo systemctl status ssh*. You should be able to get an output similar to Fig 1.6
3. check hostname - *sudo hostname*; rename to hadoop-master - *sudo hostname hadoop-master*; verify successful renaming as shown in Fig 1.6.

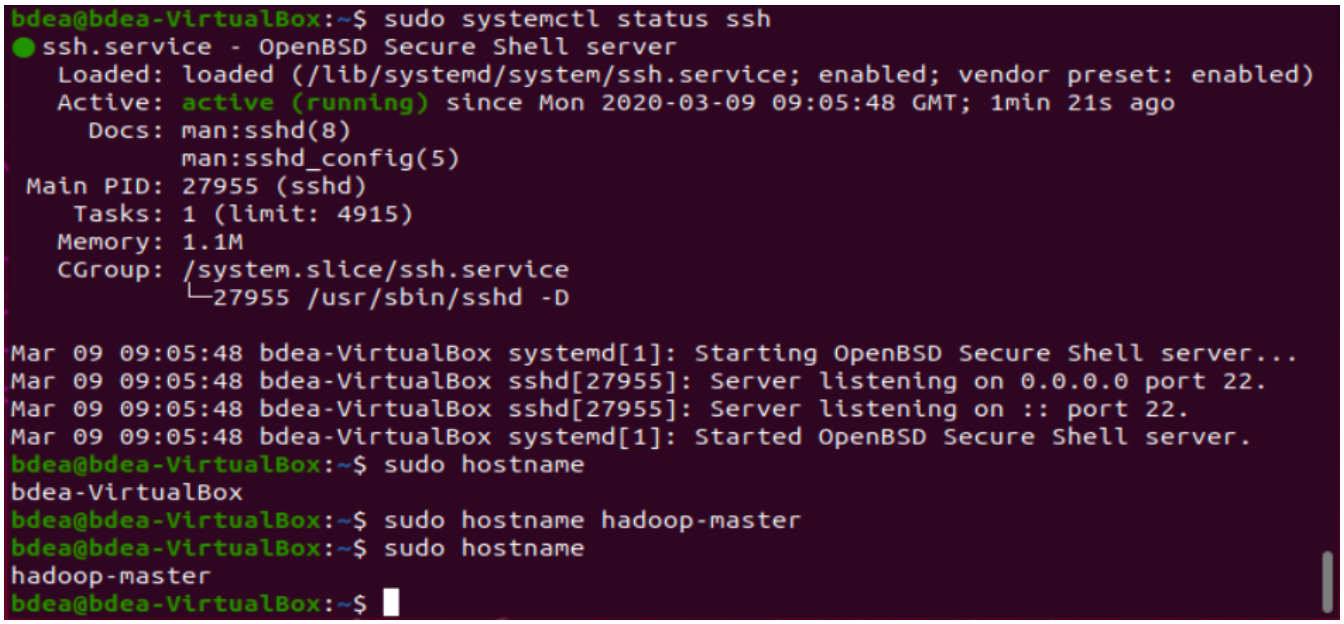



Figure 1.6: openssh-server and hostname verification

4. install gedit text editor for smooth editing - *sudo apt install gedit*. If you are working on remote hosts, this editor may not be available and you may have to work with vim. (A healthy discussion on vim had been conducted during lectures. for more info, please create a thread in the forum, or use one if it is already there.)

5. update the hosts file by adding hadoop-master as a host.

   (a) Install ifconfig to find the ip address of your machine via terminal - *sudo apt install net-tools*. Fig 1.7 shows the output and script of installing net-tools and listing the internet configurations of your machine.

   (b) Find the ip address of your vm - *ifconfig*. Fig 1.7 shows the ip address highlighted manually.

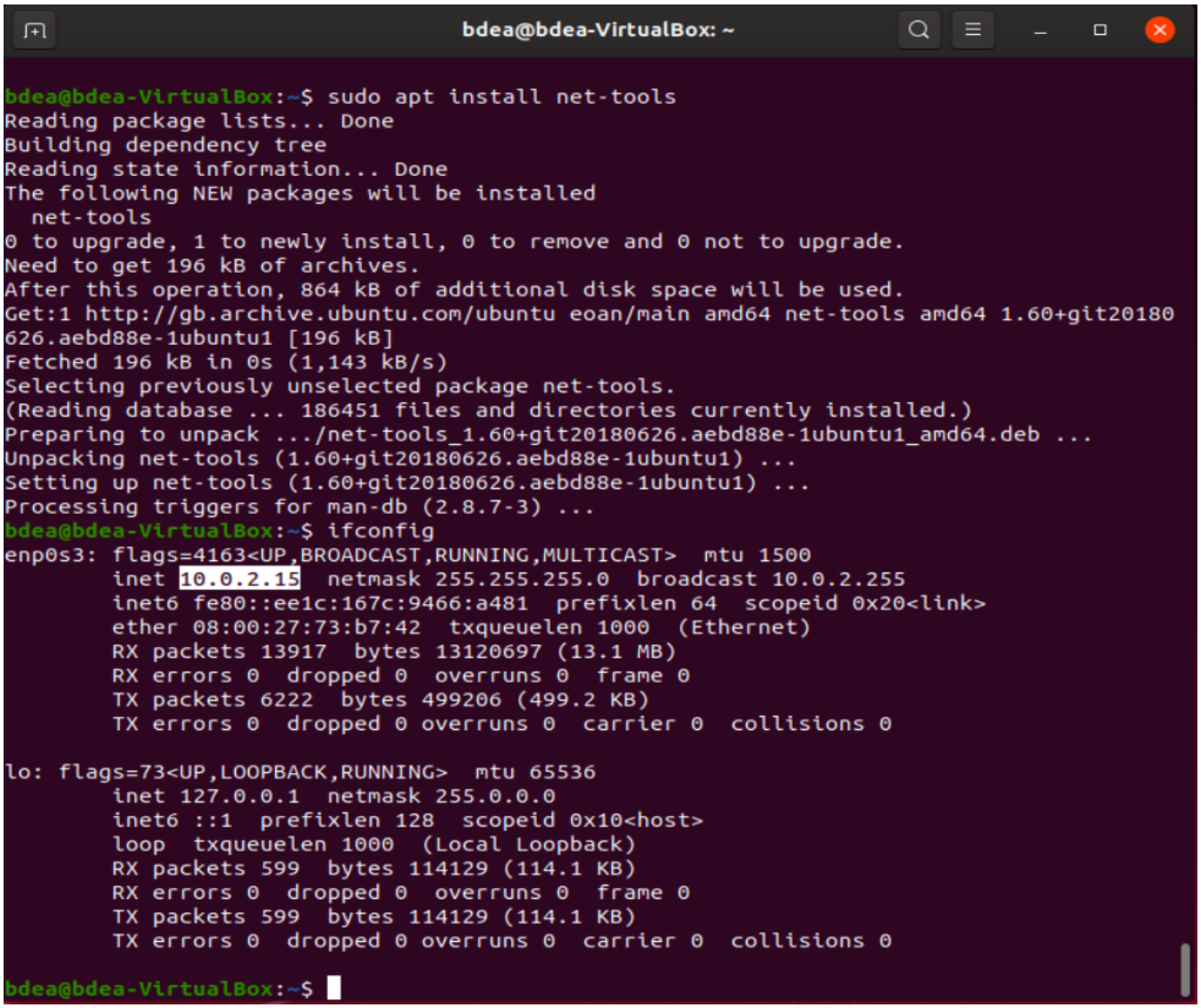



Figure 1.7: net-tools installation and ifconfig output

(c) open the hosts file for editing, to add hadoop-master as a host and map it to its ip address - *sudo gedit hosts*. The hosts file configuration shown in Fig 1.8 shows the correct format of adding a new hosts; in this example the new host is hadoop-master. Please note the highlighted line refers to a host which does not exist any more, please remove this line to avoid any carried forward errors. You may as well comment this line to keep as a reminder for future references.

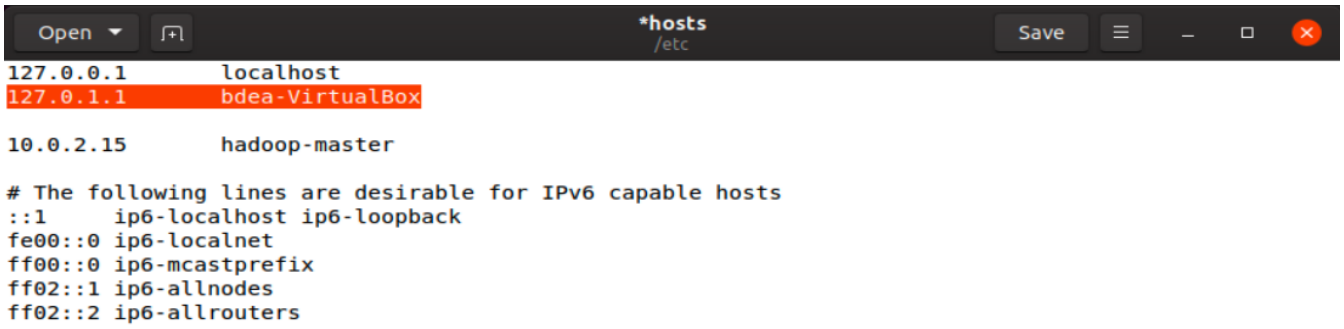



Figure 1.8: interim configuration of hosts file

6. Download, install and configure the latest stable Hadoop-3.2.2 compatible version of Java. Please follow the instructions in next section.

## 1.4 Java for Hadoop-3.2.2

Hadoop-3.2.2 is not compatible with Java 11 for development purposes. A hdfs cluster could be successfully simulated with Java 11, however, some of the big data services on hadoop cluster can not work with Java 11, such as: mapreduce framework on hadoop.

Therefore, we will work with Java 8, as it the latest stable and compatible version of Java with hadoop-3.2.2. You can follow the next set of instructions for Java 11 as well.

1. Install Java 8 JDK - *sudo apt install openjdk-8-jdk*
   The Java Development Kit (JDK) is a software development environment used for developing Java applications and applets. It includes the Java Runtime Environment (JRE), an interpreter/loader (Java), a compiler (javac), an archiver (jar), a documentation generator (Javadoc) and other tools needed in Java development

2. Configure bash file to set user variable JAVA_HOME. Setting this variable will allow the OS to locate Java directory whenever Java is called by any process/application. Either enter the absolute to path to bash file (it is located i your home directory) or open it from the home directory as follows - *sudo gedit .bashrc*

   The value of JAVA_HOME should be set as - */usr/lib/jvm/java-8-openjdk-amd64/jre*. Please refer to Fig for exact syntax of variable initialisation in bash file.


Figure 1.9: Initialising JAVA_HOME in bash file

## 1.5 Download and configure hadoop

Unlike Java, hadoop is not installed. Hadoop's directories are downloaded and configuration files are modified to ensure smooth execution and run of cluster.

1. Download hadoop-3.2.2 from apache hadoop website - *wgethttps://archive.apache.org/dist/hadoop/common/hadoop-3.2.2/hadoop-3.2.2.tar.gz*
2. unzip and delete the tar file was follows:
   - *tar -xvf hadoop-3.2.2.tar.gz*
   - *rm hadoop-3.2.2.tar.gz*
3. move hadoop to the usr local directory while renaming it to hadoop - *sudo mv hadoop-3.2.2 /usr/local/hadoop*
4. Add hadoop bin and sbin directories to the PATH variable using bash file. Please follow the syntax in Fig 1.10 to concatentae the paths to PATH variable.

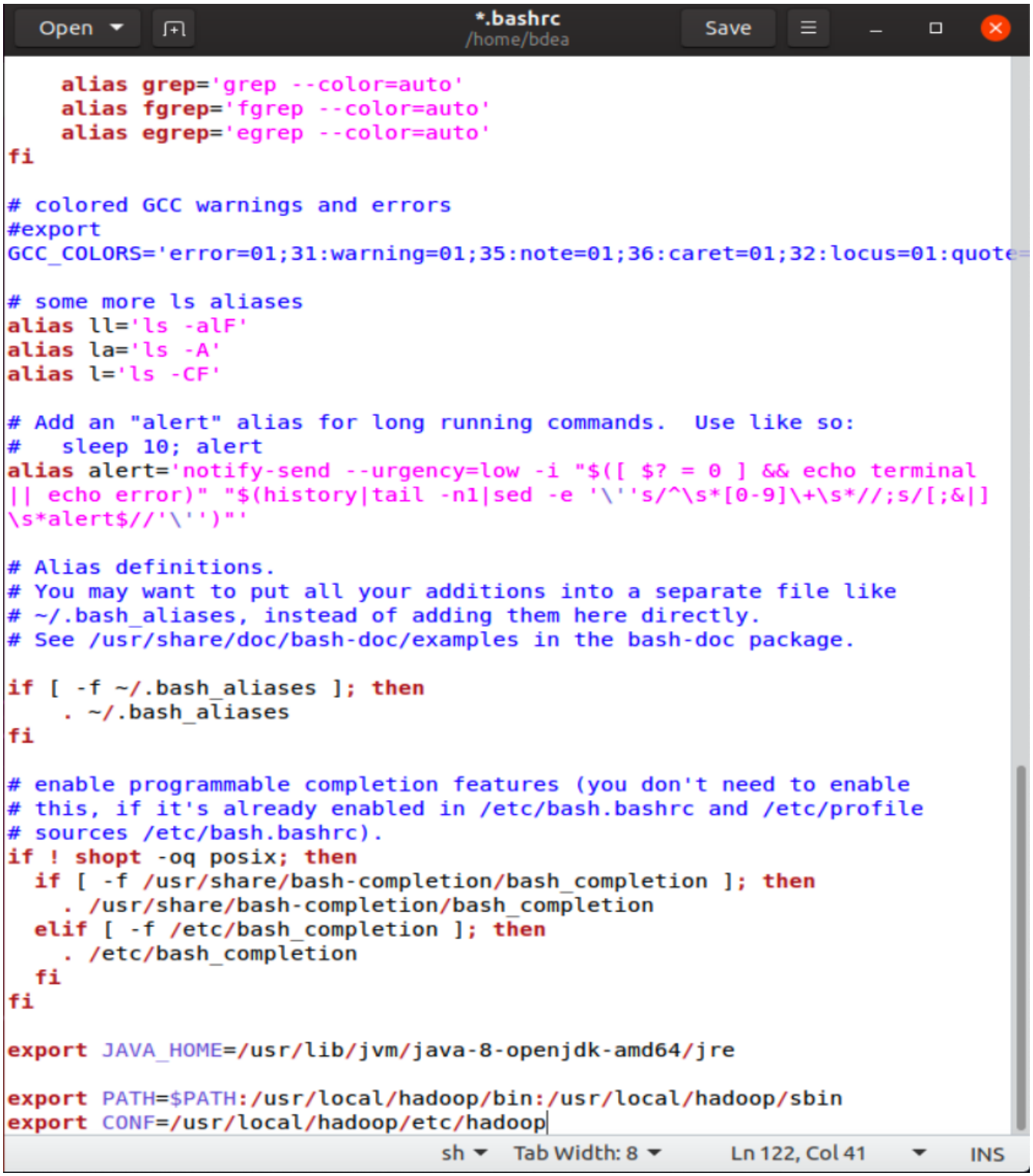



Figure 1.10: Bash file with Hadoop bin and sbin added to path

5. create another environment variable using the bash file, so that accessing the hadoop config directory becomes easier. Note the creation of CONF variable in Fig 1.10

Don't forget to source the bash file whenever you update it.

Before we start editing the hadoop configuration files, it's is essential that we clone the master VM to create a worker VM. Cloning will help save time and effort at this stage.

### 1.5.1 Cloning VM

Please follow the steps below to clone the master VM.

1. Power off the VM that you would like to clone.
2. Select the VM and right click on it in the Virtualbox interface.
3. Select the clone option as shown in Fig 1.11

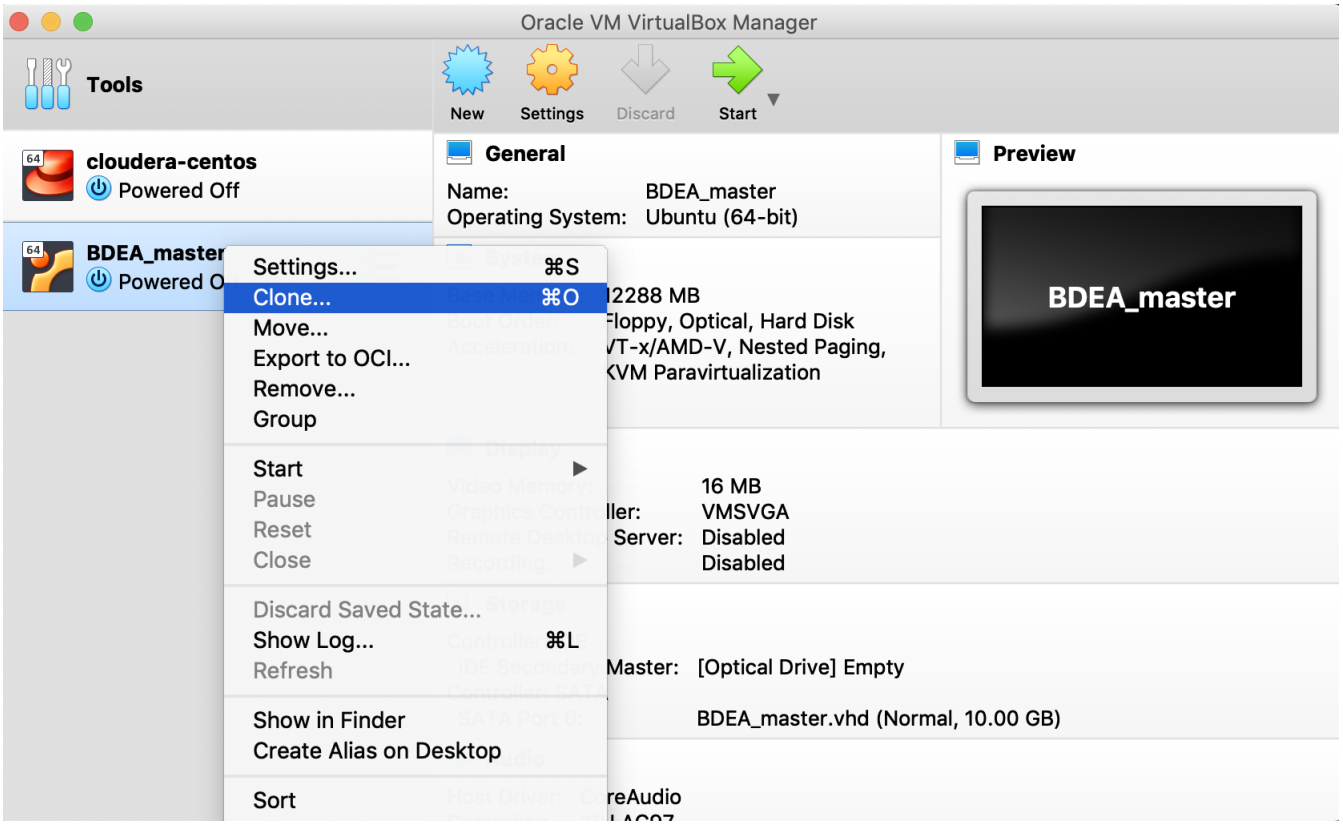



Figure 1.11: Cloning VM - 1

4. In the next pop up screen you have to very carefully choose MAC Address Policy; if you are not careful enough you may end up messing up with network adapters of both, the clone and master. Please select the option as shown in Fig 1.12; it enables you to generate new network adapters.

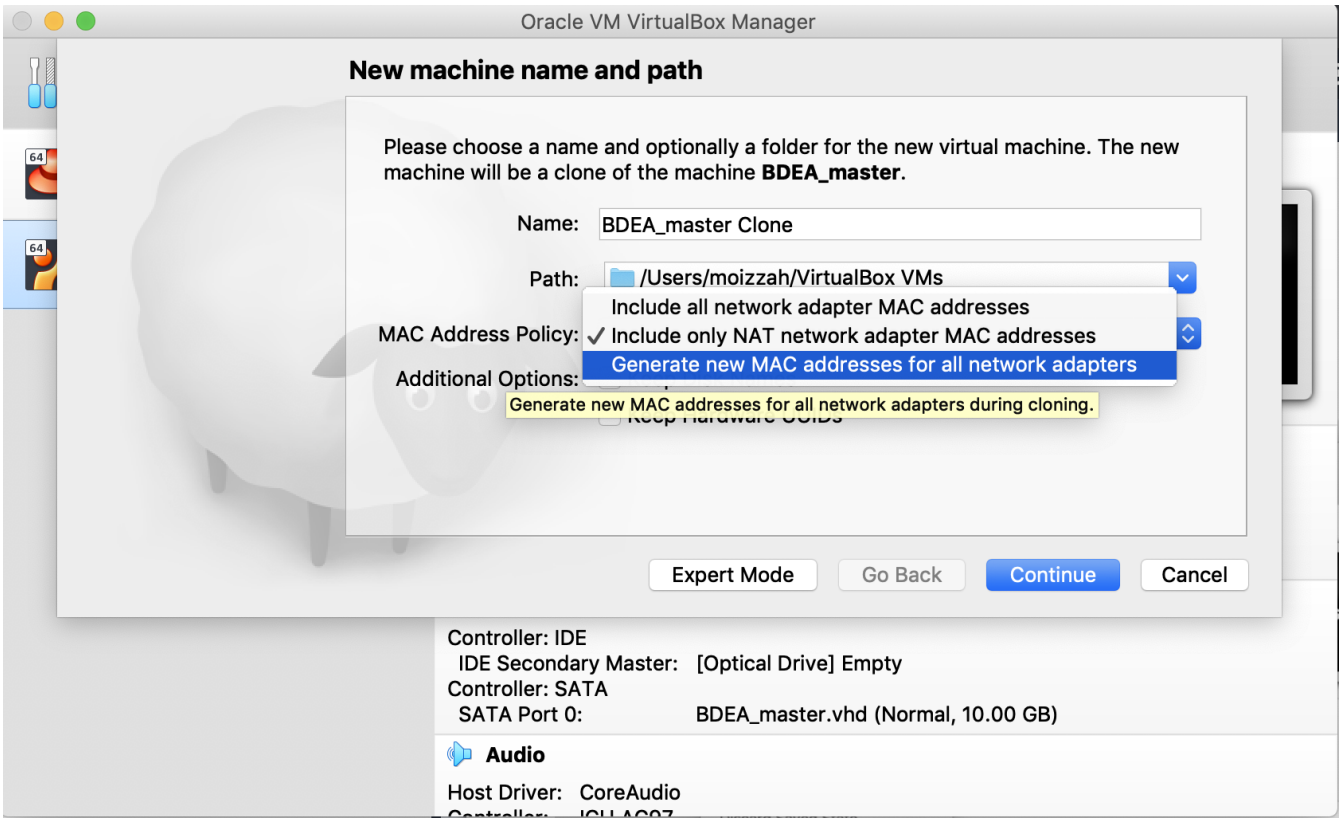



Figure 1.12: Cloning VM - Network adapter configuration

5. Create a full clone.

6. Once the cloning has successfully finished, rename the clone in a way that it indicates that this is going to be a worker node.

### 1.5.2 Virtual Box network configuration

As discussed in the lectures, there are 5 different network mode settings available on virtual box. Table 1.1 shows the list and connectivity features of each mode; you can further explore the characteristics of each networking mode following the hyperlinks in the table.

| Mode | VM→Host | VM←Host | VM1↔VM2 | VM←Net/LAN | VM→Net/LAN |
|---|---|---|---|---|---|
| Host-only | + | + | + | - | - |
| Internal | - | - | + | - | - |
| Bridged | + | + | + | + | + |
| NAT | + | Port forward | + | - | Port forward |
| NATservice | + | Port forward | + | - | Port forward |

Table 1.1: Virtual box network modes

The two suitable networking modes for communication between the hadoop nodes as well as localhost are *host-only* and *bridged* networking modes. The following subsections provide instruction on setting up these two networking modes.

#### Host-only Adapter

Here are a few selected lines from virtualbox user manual on host-only network mode.

"*When host-only networking is used, Oracle VM VirtualBox creates a new software interface on the host which then appears next to your existing network interfaces. In other words, whereas with bridged networking an existing physical interface is used to attach virtual machines to, with host-only networking a new loopback interface is created on the host. Host-only networking is particularly useful for preconfigured virtual appliances, where multiple virtual machines are shipped together and designed to cooperate. For example, one virtual machine may contain a web server and a second one a database, and since they are intended to talk to each other, the appliance can instruct Oracle VM VirtualBox to set up a host-only network for the two. A second, bridged, network would then connect the web server to the outside world to serve data to, but the outside world cannot connect to the database.*"

Before a VM can be configured to work with host-only networking mode, creating a host only interface is essential. Please take a moment here to remind yourself that you did not have to create any interfaces, instead the networking mode was simply switched to host-only network mode in the lectures. The virtual box version compatible with the windows OS installed on university lab computers automatically generates this interfaces and reduces the number of configuration steps you may have to take otherwise.

This is quite possible that the windows-OS/macOS version on your system may not support such automatic interface creation. Therefore this section covers instruction for configuring host-only adapter on macOS platorm assuming that automatic interface creation for host-only network mode is disabled, and one has to manually create it. The section also re-demonstrates switching to host-only adapter network mode on windows OS as demonstrated in lectures. The purpose of this replication is to highlight the differences between setting host-only adapter network on virtual box for a VM when an adapter is and isn't preconfigured.

**Windows**
Switching to host-only adapter network mode with a pre-configured adapter.

1. Click on the VM, the network settings need to be changed for.
2. Select network.
3. Change the selection for Attached to by selecting Host-only adapter from the drop down menu.
4. Select one the pre-configured network adapter from Name's drop down menu (You may have a choice of selecting from more than one adapters. If selecting one of them doesn't generate separate ip addresses, then select another adapter until you get unique ip addresses for of each of your VM).
5. Select Advanced.
6. Ensure that promiscous mode is set to allow all.
7. The pop up menu and configuration window should look similar to the one shown in Fig 1.13.
8. Click ok, and repeat the exercise from bullet point 1 to bullet point 7 on the rest of the VMs.

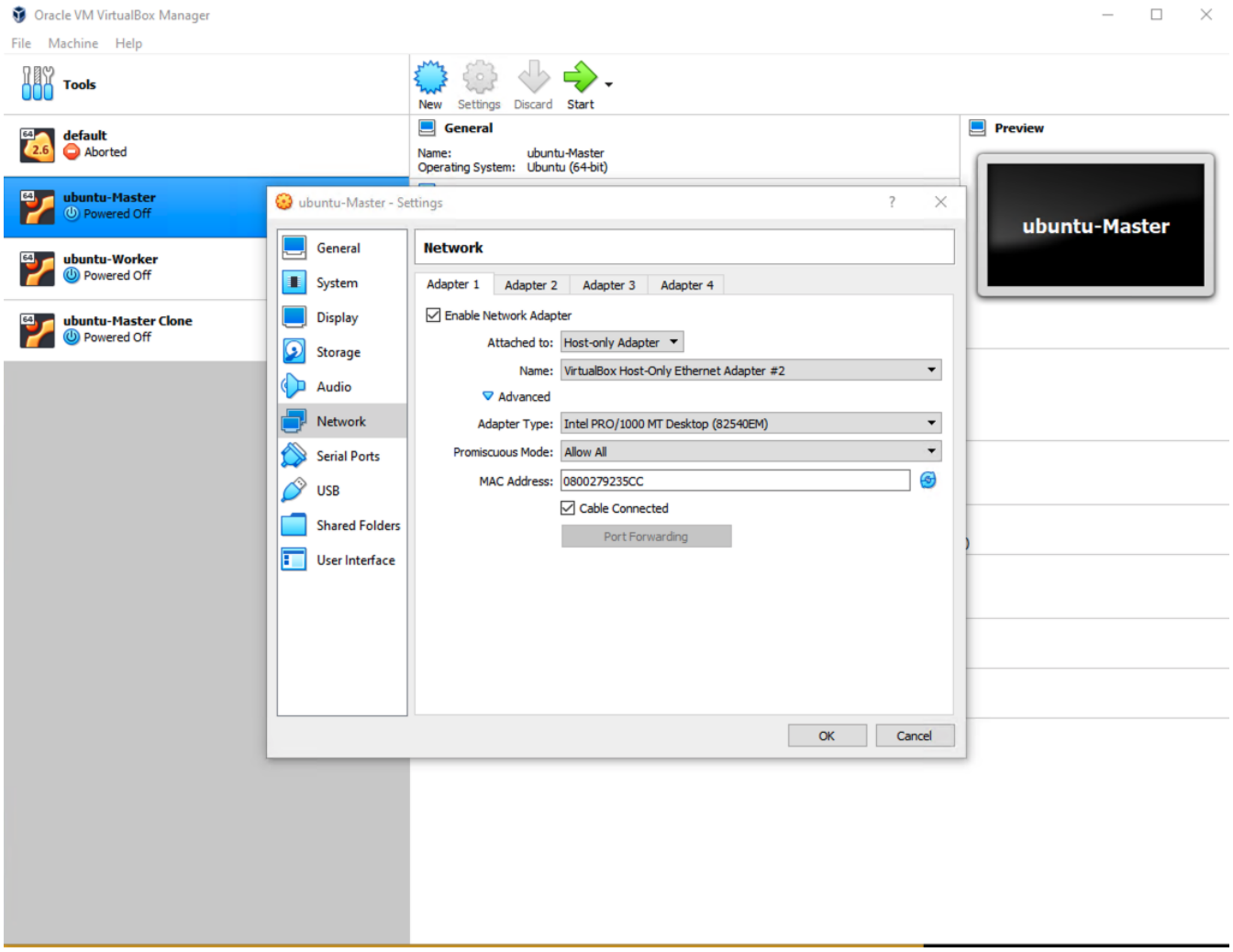



Figure 1.13: Switching to hostr-only adapter network mode on virtual box windows release

**MacOS**

Switching to host-only adapter network mode when adapter isn't preconfigured.

1. Open the menu named virtual box for virtual box.
2. Open Host network manager.
3. Click on create.
4. A new adapter named vboxnet should be created now; make sure that DHCP server is enabled. Your screen should look similar to the one shown in Fig 1.14
5. Apply the settings and close the host network manager window.

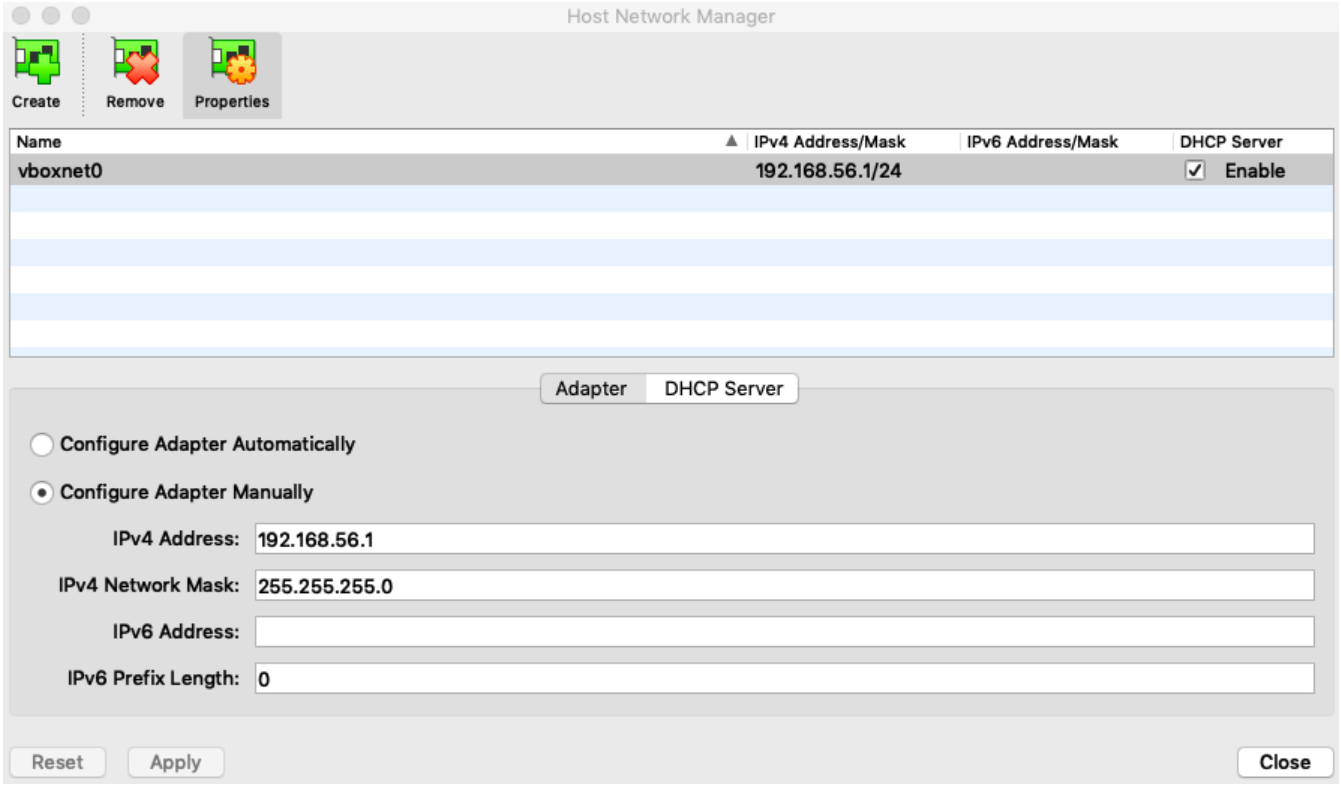



Figure 1.14: Adapter creation for host-only adapter network mode on virtual box macOS release

6. Follow the steps listed below on your master and worker VMs respectively, to switch to host-only network mode:

   (a) click on the VM, select settings;

   (b) select network mode;

   (c) change the Attached to: selection from the drop down menu to Host-only Adapter;

   (d) click on advanced;

   (e) change promiscous mode to Allow all by using the drop down menu;

   (f) the pop window should look similar to the one shown in Fig ;

   (g) click ok, and repeat the same exercise from bullet point 6a to 6f on the other VM/s.

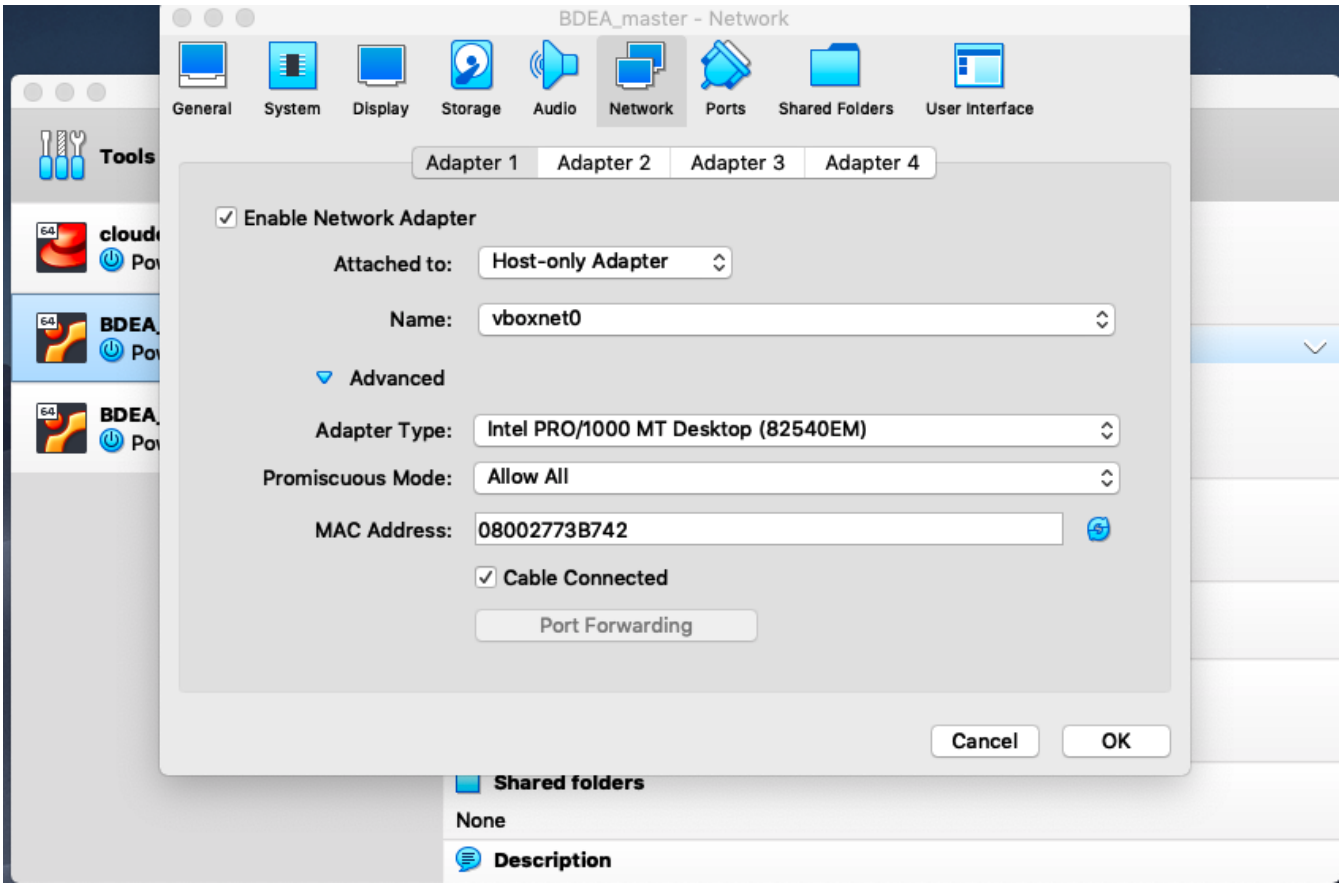



Figure 1.15: Selecting host-only adapter network mode for VMs on virtual box macOS release

### Bridged Adapter

Below are a few lines selected from virtualbox user manual on bridged adapter network mode.

*With bridged networking, Oracle VM VirtualBox uses a device driver on your host system that filters data from your physical network adapter. This driver is therefore called a net filter driver. This enables Oracle VM VirtualBox to intercept data from the physical network and inject data into it, effectively creating a new network interface in software. When a guest is using such a new software interface, it looks to the host system as though the guest were physically connected to the interface using a network cable. The host can send data to the guest through that interface and receive data from it. This means that you can set up routing or bridging between the guest and the rest of your network.*

To setup this network mode on a windows host machine, may need admin rights to configure certain settings. Therefore, we resorted to using the host-only adapter network mode during lectures. The only drawback to this mode is that the VM can not be connected to internet via the adapter the network setting is configured on. Whereas bridged adapter mode enables all possible internet and intra-machine communications.

The virtualbox release for MacOS has been used to demonstrate setting this network mode. The experience is usually smooth on MacOS for most of the network mode virtualbox has to offer as compared to windows operating system.

1. Click on the VM you want to change the network mode for.
2. Click on settings.

3. Click on Network tab.
4. Change the Attached to selection to Bridged Adapter mode from drop down menu.
5. Select either ethernet, wireless adapter, usb-c or anyother port from where internet access is possible on your machine from the drop down menu of Name.
6. Click on the Advanced option.
7. Ensure that promiscous mode is set to allow all.
8. The pop network configuration window should look similar to the one shown in Fig 1.16; click on ok to save the settings and exit.

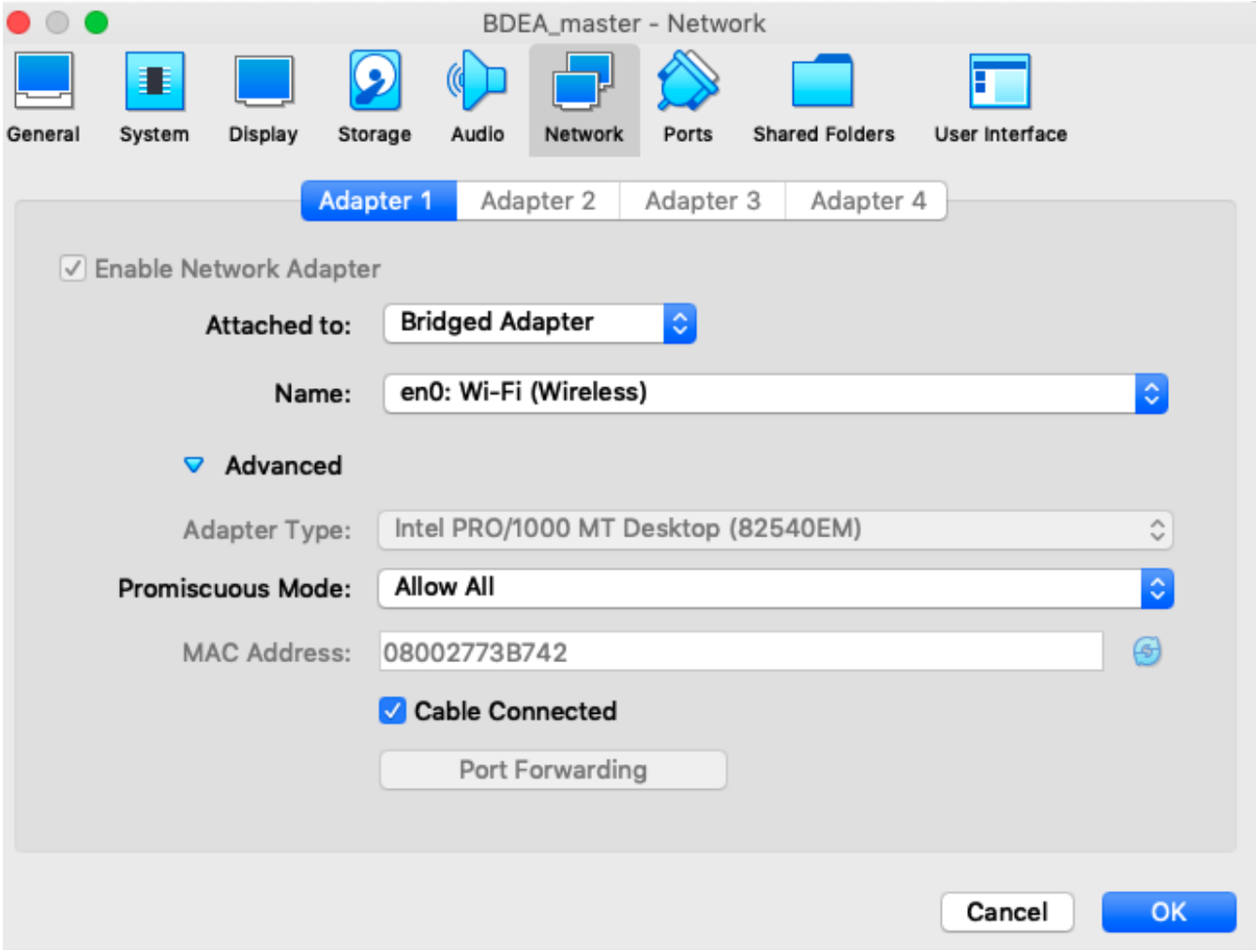



Figure 1.16: Selecting Bridged adapter network mode for VMs on virtual box macOS release

### 1.5.3 Revisiting system files

Since you have another node now and have chnaged network mode, the /etc/hosts file need to be altered accordingly on both name and data nodes respectively.

1. Copy the new ip address assigned to each VM being used as a node in hadoop cluster. Use *ifconfig* command on the terminals as shown in Fig 1.17

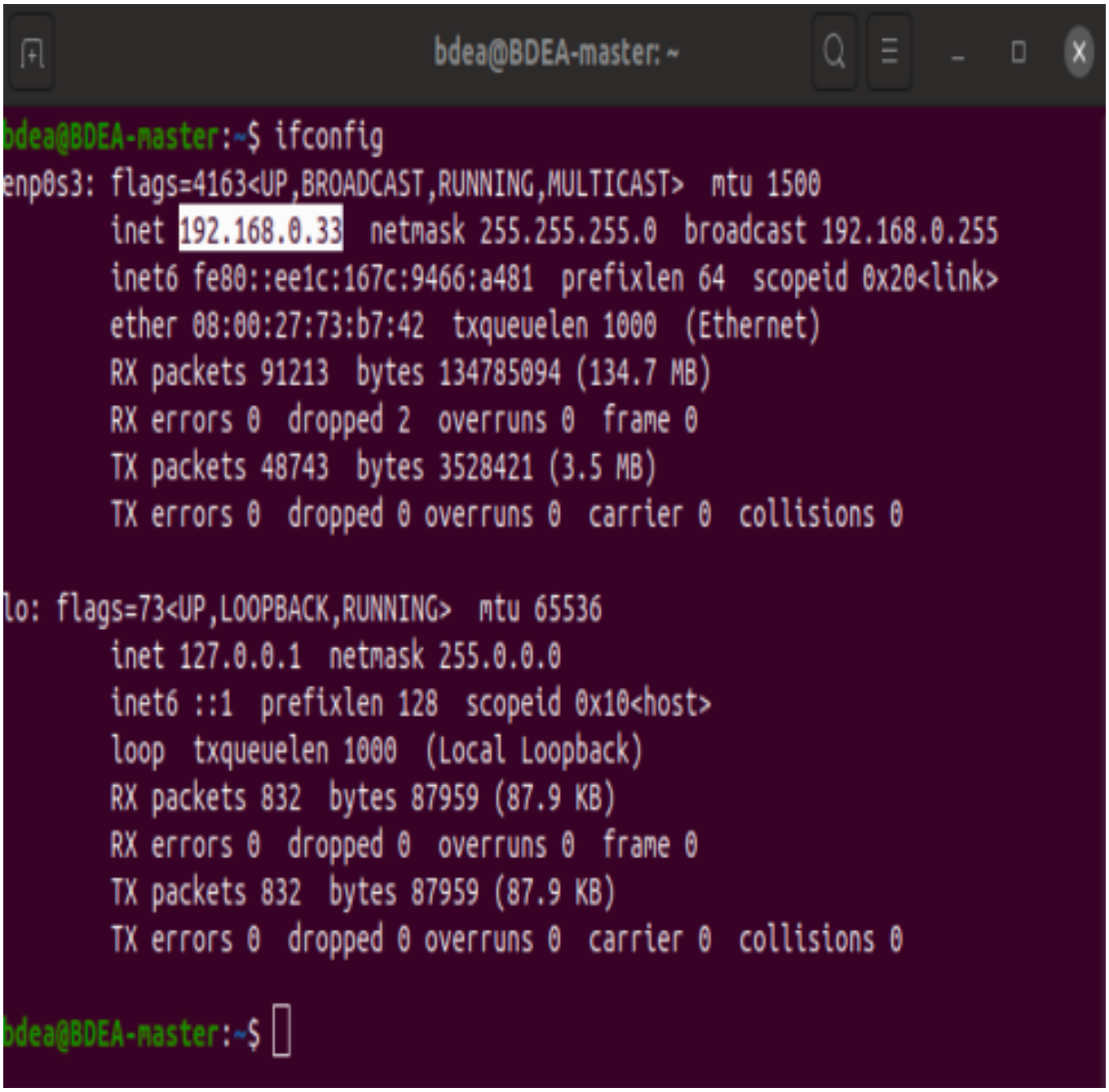



Figure 1.17: Selecting Bridged adapter network mode for VMs on virtual box macOS release

2. Update the /etc/hosts file of each VM by adding ip address and hostname mapping of all nodes - use *sudo gedit /etc/hosts* to configure the hosts files in all nodes. The hosts files on all Hadoop nodes should look similar to the one shown in Fig 1.18

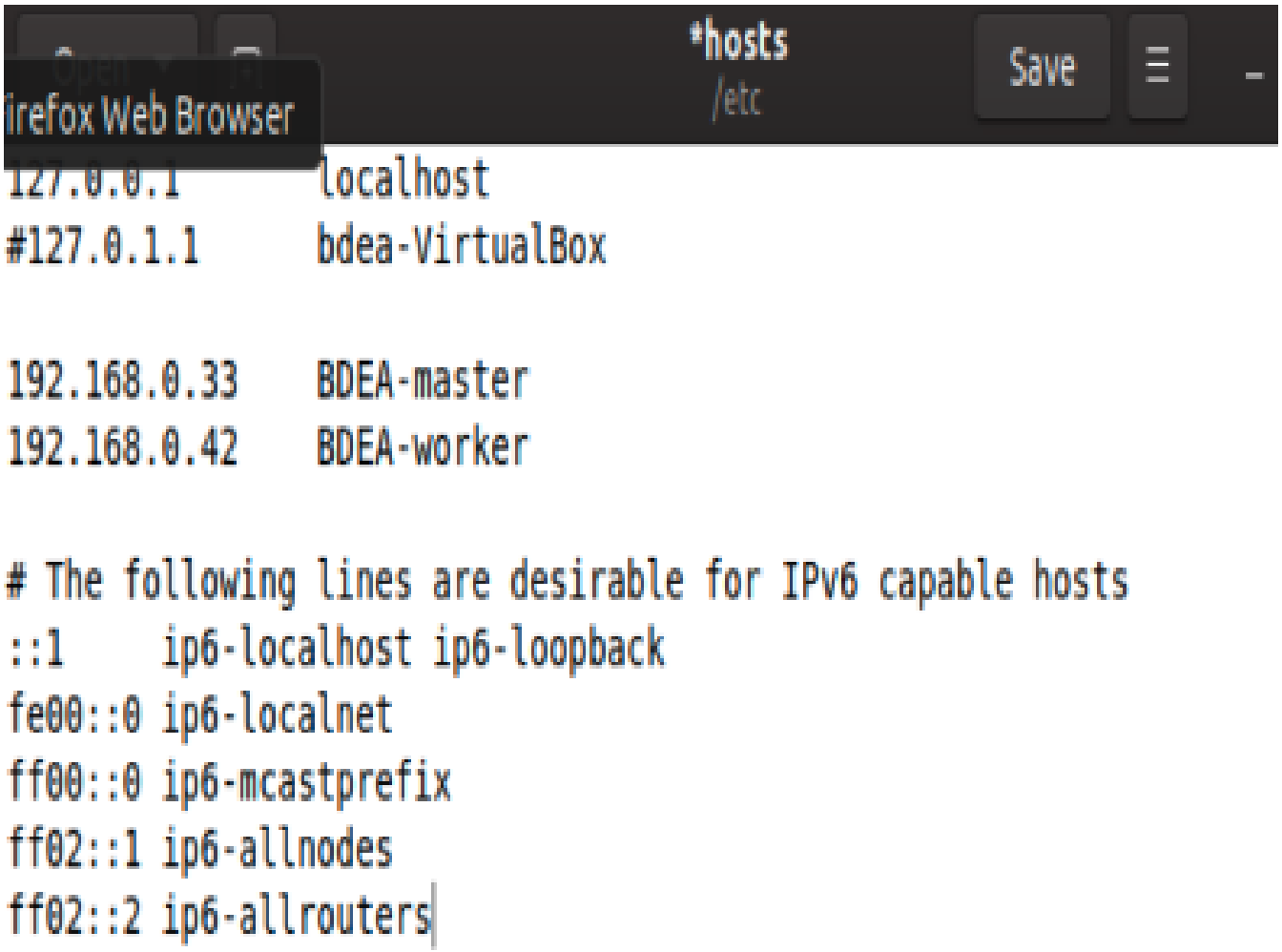



Figure 1.18: final version of /etc/hosts file for Hadoop cluster nodes

### 1.5.4 Establish Password less SSH access between hadoop nodes

We have discussed about SSH protocol in lectures; you may as well refresh your knowledge and find answers to some questions from this web-link. Similarly, we have already had a discussion around the need for establishing password less SSH access between hadoop nodes in the lectures.

Follow the steps below on name node to establish the passwordless ssh connection between all hadoop nodes. Please note that these steps can be replicated in any other context where either SSH key generation, password less access or both are required.

1. Generate a public and private SSH key pair: *ssh-keygen -t rsa.*
2. When asked for file name, press enter to apply default.
3. When asked for passphrase, press enter to use none.
4. A successful key generation terminal output should look similar to the one shown in Fig 1.19.

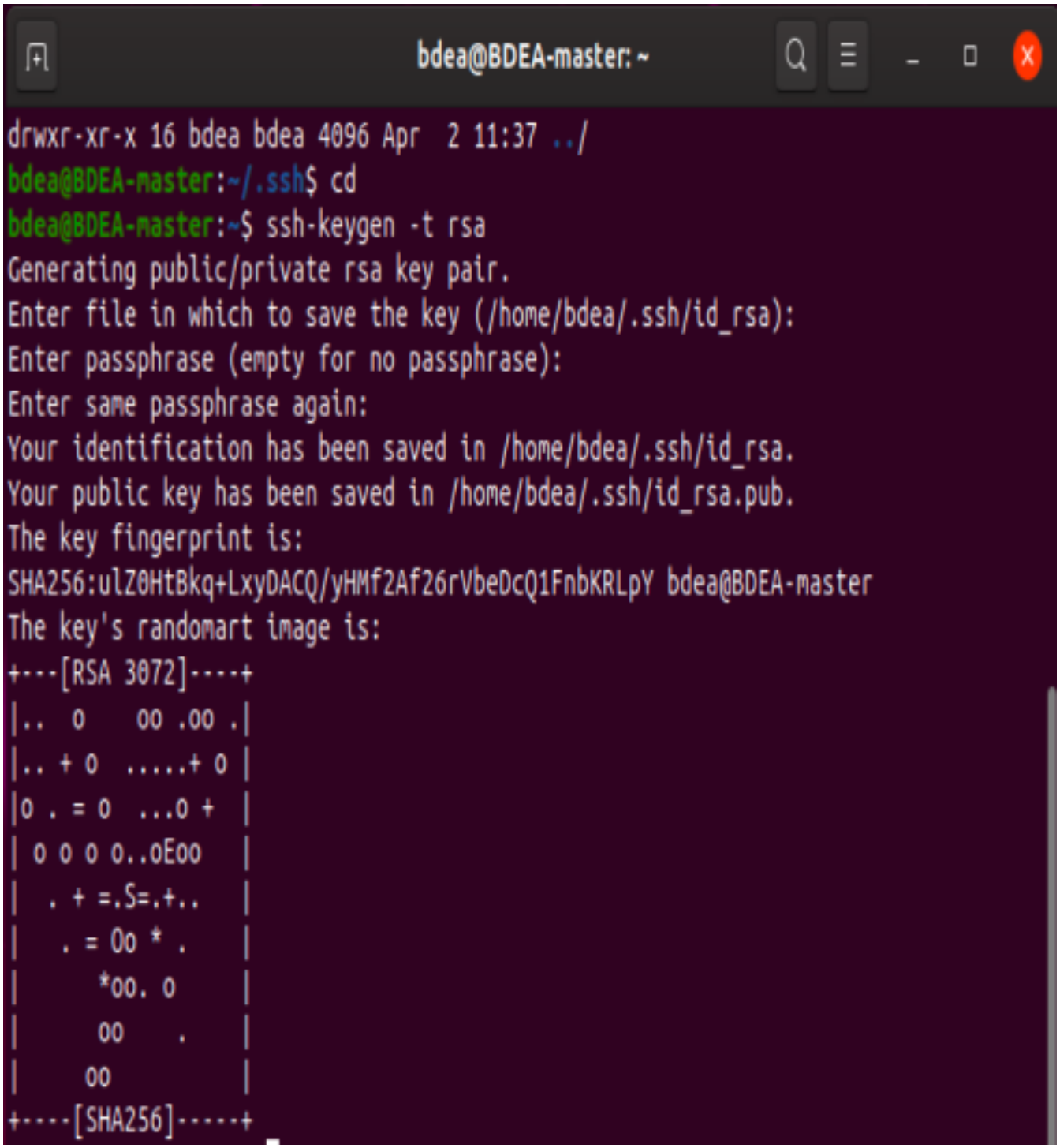



Figure 1.19: SSH key generation

5. Now copy master node's public key to the authorised users on all hadoop worker nodes. Use the following syntax to copy to all worker/data nodes respectively: ssh-copy-id <username>@<worker-hostname>.

6. When asked to continue connection, type yes and then press enter to continue.

7. Enter the password when prompted to enter the user's password on the worker node to which you are copying the keys.

8. The terminal out for a successful ssh-copy-id to a worker node should look similar to the one shown in Fig 1.20.

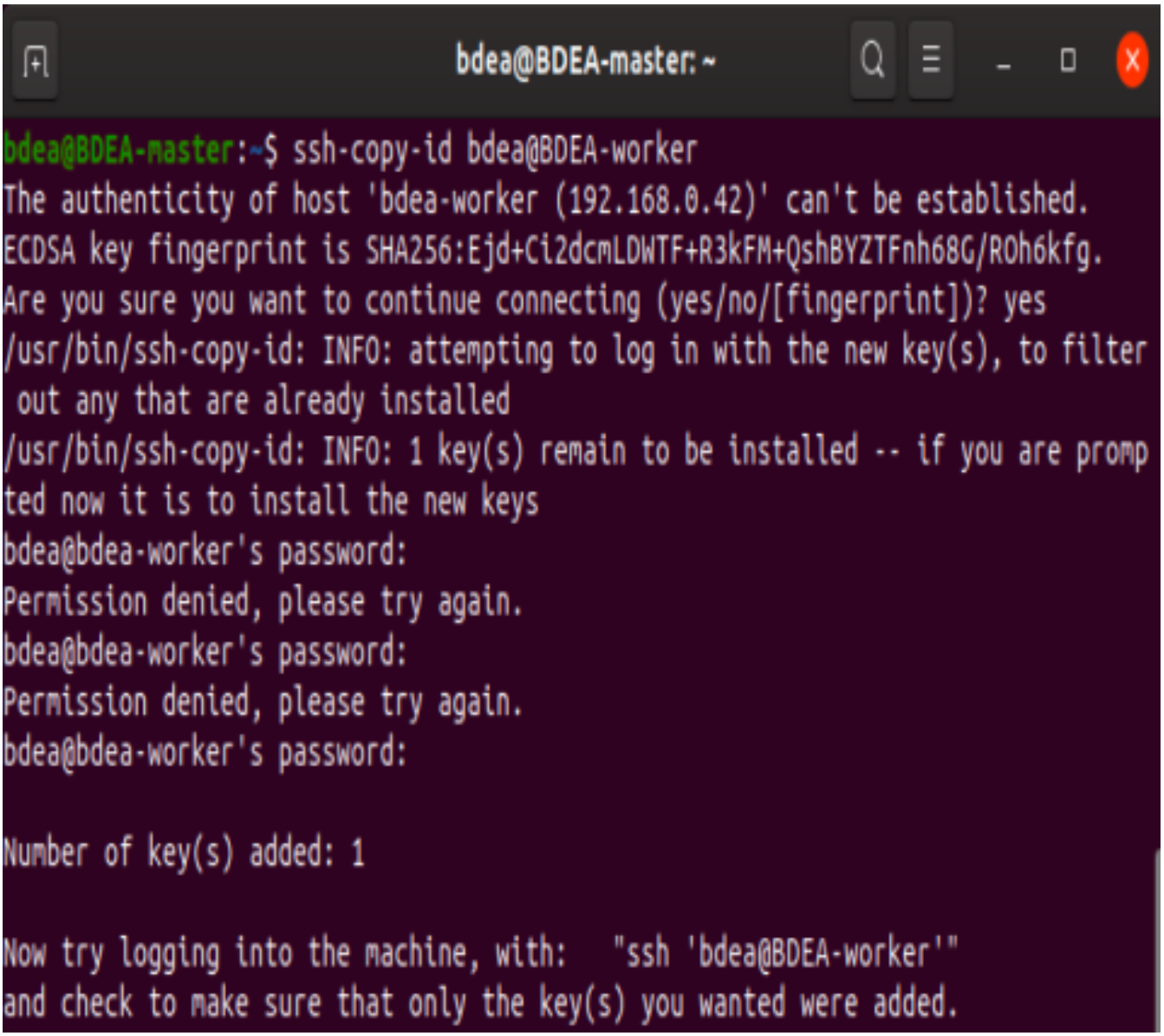



Figure 1.20: copying SSH key pairs to remote servers

9. you can ensure the successful completion of this process by logging into one of the worker nodes using SSH. The terminal syntax should be similar to the following: *ssh <username>@<worker-hostname>*.

10. After establishing the connection, you can disconnect and get back to the host's terminal by pressing 'control' and 'd' keys together. An example of logging in via SSH and logging out with this key combination is shown in Fig 1.21. Please note the change of username and host name in green colour on the terminal before and after ssh connection is established and disconnected.

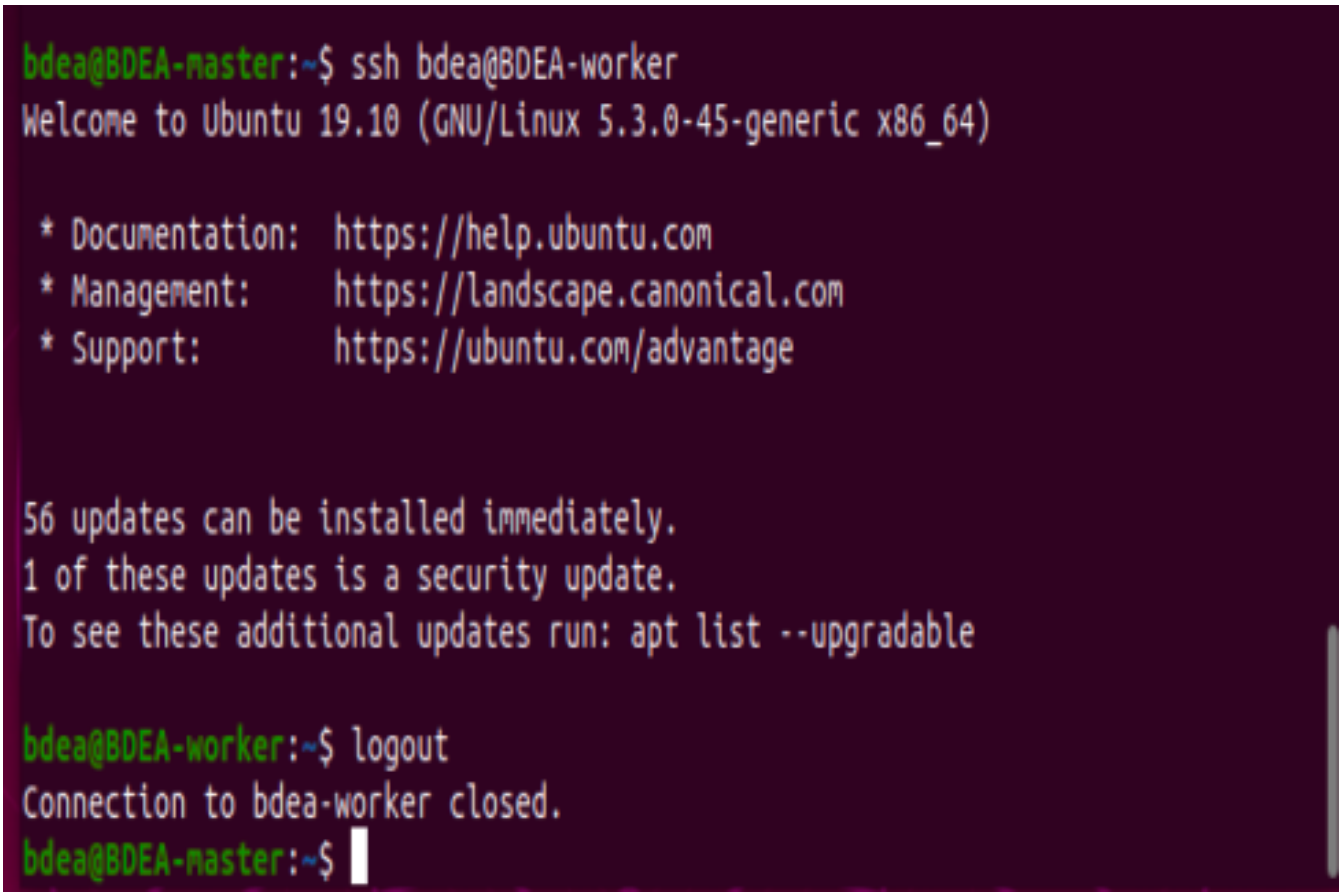



Figure 1.21: Establishing and disconnecting SSH connection to remote servers

### 1.5.5 Configuring the cluster

**Configuring hadoop files on all hadoop nodes**

Quoting Apache Hadoop's documentation:
"adoop's Java configuration is driven by two types of important configuration files:

1. Read-only default configuration -
    - core-default.xml,
    - hdfs-default.xml,
    - yarn-default.xml, and
    - mapred-default.xml.
2. Site-specific configuration -
    - etc/hadoop/core-site.xml,
    - etc/hadoop/hdfs-site.xml,
    - etc/hadoop/yarn-site.xml, and
    - etc/hadoop/mapred-site.xml.

Additionally, you can control the Hadoop scripts found in the bin/ directory of the distribution, by setting site-specific values via the etc/hadoop/hadoop-env.sh and etc/hadoop/yarn-env.sh.

To configure the Hadoop cluster you will need to configure the environment in which the Hadoop daemons execute as well as the configuration parameters for the Hadoop daemons.

HDFS daemons are NameNode, SecondaryNameNode, and DataNode. YARN daemons are ResourceManager, NodeManager, and WebAppProxy. If MapReduce is to be used, then the MapReduce Job History Server will also be running. For large installations, these are generally running on separate hosts."

Site specific configuration may vary for some file in worker and master nodes. So, the recommended approach is to configure the files with common configurations for master and worker, first in the master node and then copy them over to the worker node.

### Hadoop files on master/name and worker/data nodes

Common configuration of site specific configuration files of a hadoop cluster will be discussed n this section. You may have noticed that all the site specific configuration files are located in hadoop's etc/hadoop folder. So, based on our lab demonstrations the exact path to these files is /usr/local/hadoop/etc/hadoop/.

If you scroll back up to Fig 1.10 you will notice that we have already created a path variable to this folder, called CONF. CONF will help you to navigate and access these files with ease and quickly.
We will be editing haddop-env.sh, core-site.xml, hdfs-site.xml and workers file in this section.

The following syntax maybe used to edit each of the following files:
*gedit $CONF/<filename>*

1. **hadoop-env.sh**
   The variables set in this file are used by hadoop daemon when the hadoop start-up script is called through terminal. The start-up script is called to launch the hadoop cluster.

   Define the variable JAVA_HOME, use the same path as defined for this variable in bashfile. The final version of the file should look similar to the one shown in Fig 1.22.

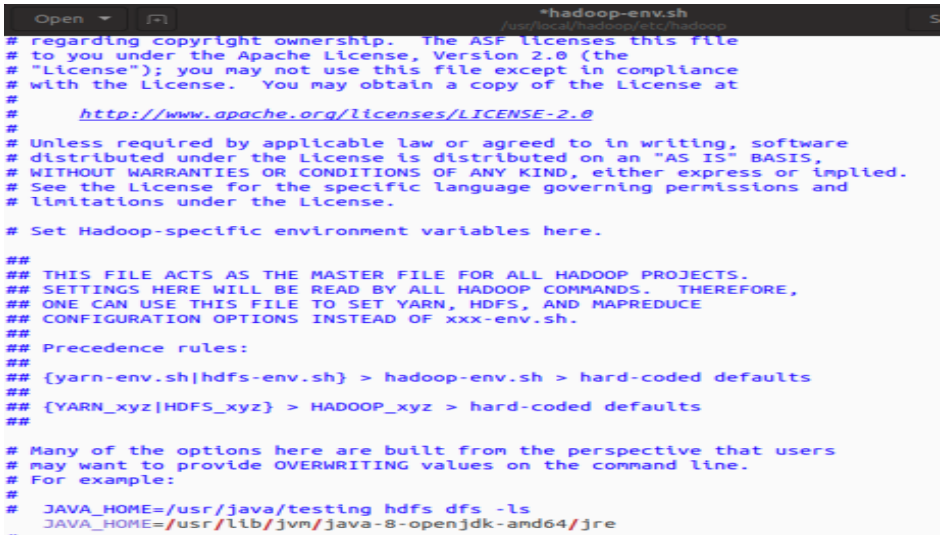



Figure 1.22: final version of hadoop-env.sh file

,

2. **core-site.xml**
   This file informs hadoop daemons about the location of namenode of the cluster. It also contains configuration settings for hadoop core such as I/O settings that are common to HDFS and mapreduce.

   The read-only version fot his file is called core-default.xml. Thsi file entails all the properties that exist in hadoop core. As this is a read-only file, so any changes that one may need to make to any of these properties should be made in core-site.xml.

   You can find the list of all properties and their default parmeters of core-default.xml in hadoop 3.2.2's documentation.

   We will modify the property called fs.defaultFS, and set the hostname of your hadoop cluster's namenode's hostname with port 9000. The final version of core-site.xml should look similar to the one shown in Fig 1.23. The uri provided as the value of the property is used to determine the host, port, etc. for a filesystem.


Figure 1.23: final version of core-site.xml file

3. **hdfs-site.xml**
   This file should contain configurations for the following hadoop daemons: namenode, secondary namenode and datanodes. This file can also be used to chnage the default data block replication behaviour. If you do not specify any property which does not requrie modification, the default values for that property would be used from hdfs-default.xml file.

   You can find the list of all properties and their default parmeters of hdfs-default.xml here in hadoop 3.2.2's documentation.

   Add the following properties and values pairs to the file: namenode dfs directory and its path; datanode directory and its path; and number of replication blocks. The final version of this file should look similar to the one shown in Fig 1.24.

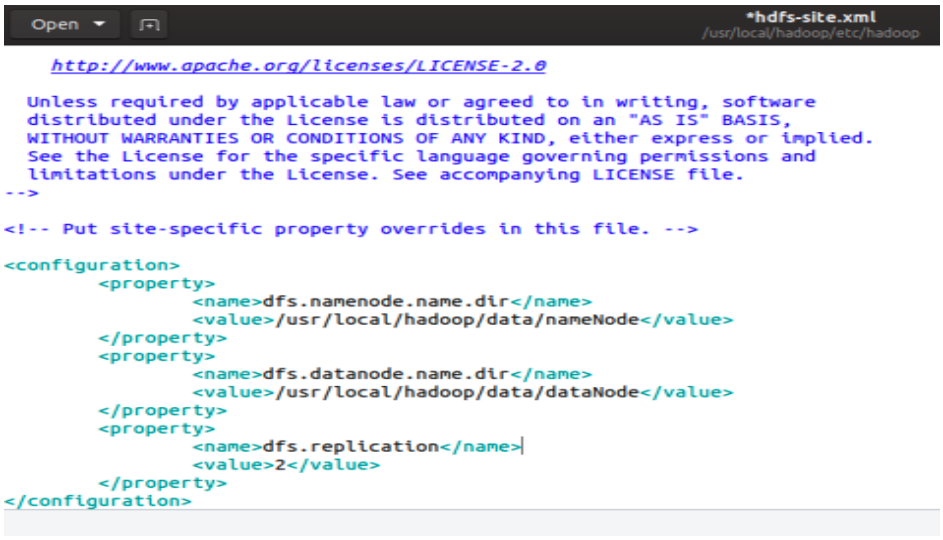



Figure 1.24: final version of core-site.xml file

4. **workers**
   Add the hostnames of all worker/data nodes of hadoop cluster in this file. Ensure that the hosts file in etc folder of the system has all the required hostnames mapped to their ip addresses. The final version of workers file should look similar to the one shown in Fig 1.25


Figure 1.25: final version of workers file

**Copying hadoop configuration files to worker nodes** :

Now that all the files which should have common configurations on name and data nodes, have been configured on name node; it is time to copy these files to all the worker/data nodes in hadoop cluster.

You will need to use the *SCP* command to move these files. As we have already established password less SSH connection between all hadoop nodes, the following syntax can be used to copy the files: *scp <absolute path to the file/s> <username>@<worker-hostname>:<path to directory where files are to be copied>* . An example is shown in Fig 1.26. The asterisk in the figure denotes 'all files'.

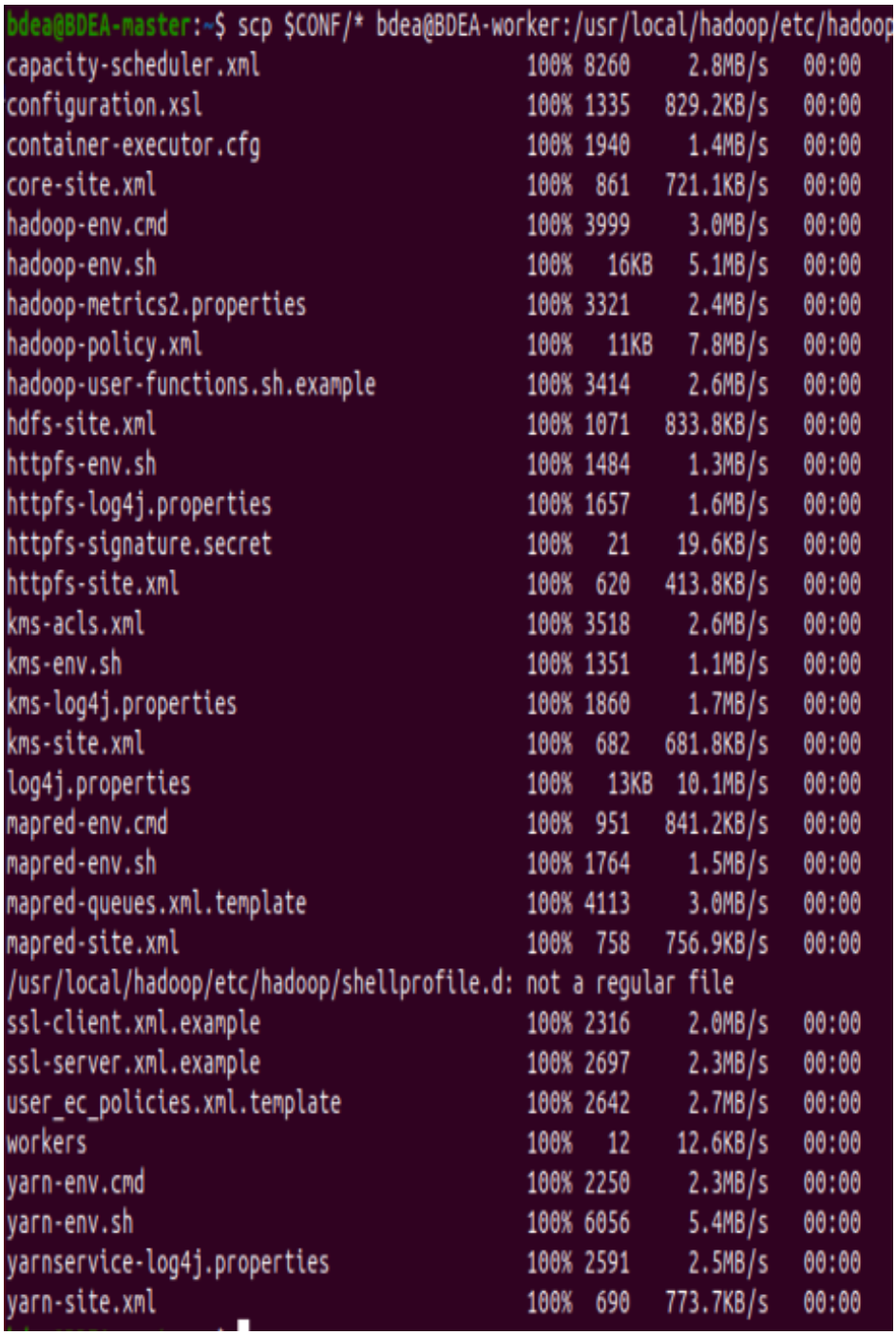



Figure 1.26: Copying files from localhost to remote servers via SCP

**Worker/s node only configuration**

Now that the configured hadoop files with common configurations are setup on all hadoop nodes, files which are supposed to be configured on worker nodes only need to be setup. Configure these files on a worker node and then copy to the any of the rest of the worker/data nodes in the cluster.

We are still editing the files in hadoop configuration directory, so use the same syntax as in previous section to navigate and edit the files.

**Yarn-site.xml** :

This file contains configuration information that overrides the default values for YARN parameters. The default values for core configuration properties are stored in the Default YARN Parameters file. We already

know from our lecture discussons that YARN stands for yet another resource negotiator and negotiates resources between the hadoop nodes. Additionally we will be executing MapReduce scripts using yarn daemons in order to make use of it's resource negotiations capabilities as required during the map reduce execution.

Add the property which tells the worker nodes the location of the yarn resource manager. For the sake of this tutorial it will be same as the master node. The final version of yarn-site.xml on worker nodes should look similar to the one shown in Fig 1.27.

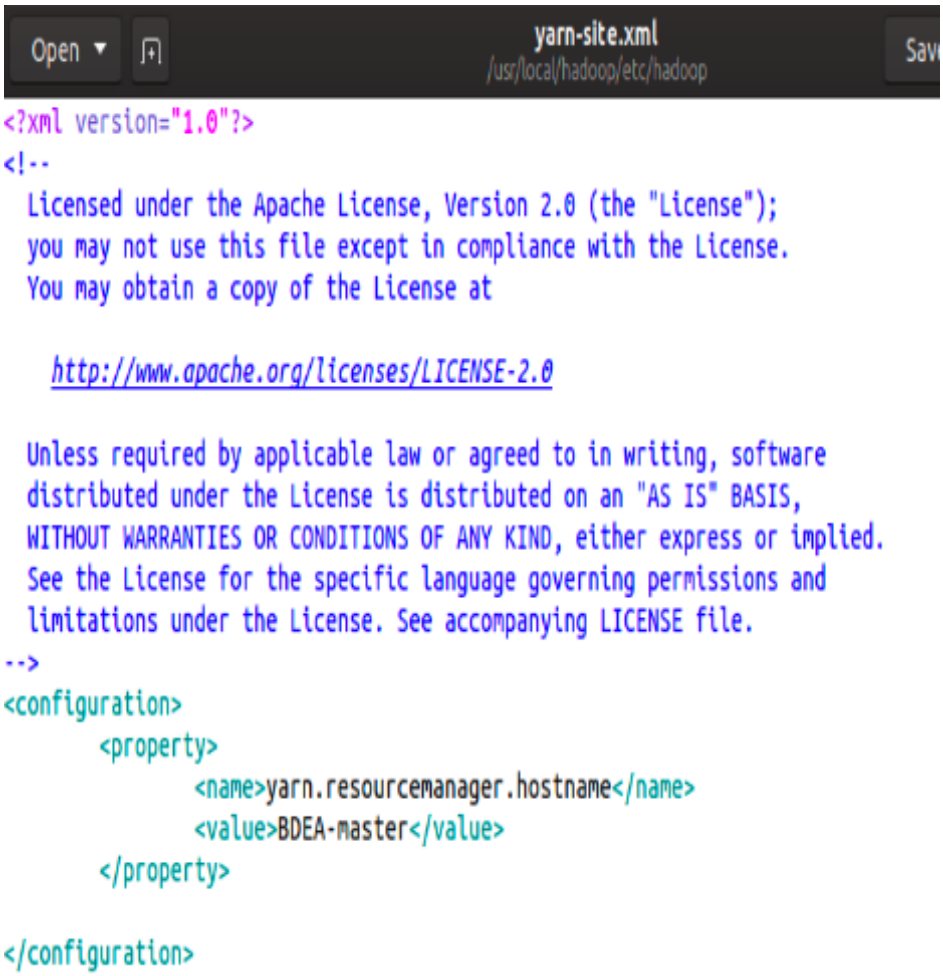



Figure 1.27: Final version of yarn-site.xml on worker/data node/s

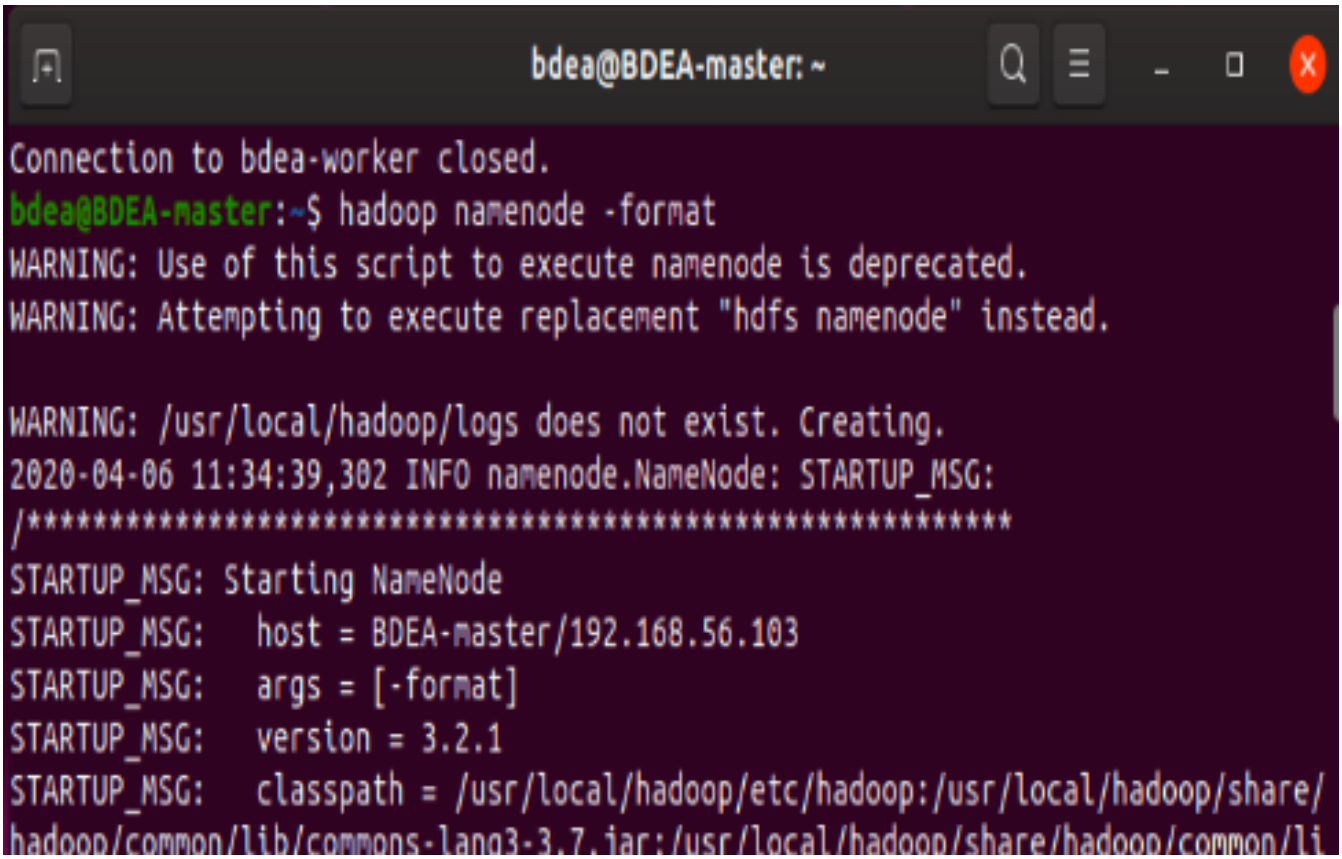
## 1.6 Starting the hadoop cluster

Before we may proceed to start the cluster by using any hadoop shell files; name/master node needs to be formated.

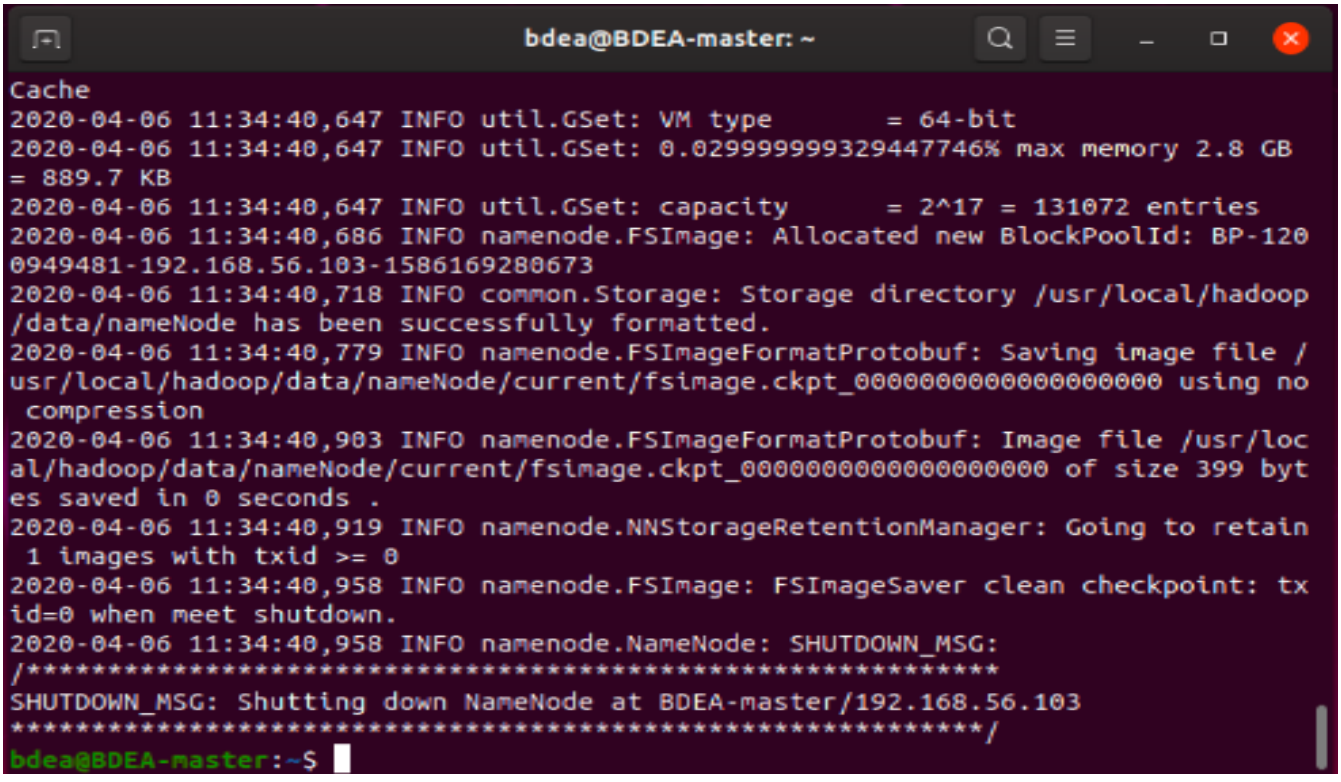
It needs to be ensured that changes made to bash file previously are in effect. If you are unsure, you can always make bashfile the source in the terminal as follows: *source .bashrc*

In order to format the master VM as namenode of the hadoop cluster; enter the following in the master VM's terminal: *hadoop namenode -format*. The beginning and end of your terminal output after executing the aforementiond command should look similar to those shown in Fig 1.28(a) and 1.28(b).

Good job, you have just simulated a bigdata cluster on a local machine using VMs. Now it would be useful




(a) output at the beginning




(b) output at the end

Figure 1.28: Terminal output after master VM is formatted as hadoop namenode

if you think on the following points:

1. how you can replicate this experiment to create an actual big data cluster with 1 tb of RAM?
2. how many PCs you may require?

3. are there any steps involved for which you may need to find alternate in actual scenario?

4. if you had admin rights on J448 machines; could you create the suggested cluster using actual computers? If not, then what needs to be changed in the cluster specifications?

# Mapreduce on Hadoop Cluster

The merits and demerits of the mapreduce paradigm have been discussed in detail in lectures, along with practical demonstrations. This chapter in the tutorial manual is provided as a reference guide on the practicalities and commands involved. Please use the material uploaded on blackboard to revisit mapreduce paradigm in detail.

## 2.1 Configuration on hadoop cluster

There are certain configurations required on all worker/data nodes and master node respectively. The following sub sections, walk through them.

### 2.1.1 Worker/data nodes configuration

**Yarn-site.xml**
It is essential that all worker nodes in the hadoop cluster should have yarn-site.xml configured as shown previously in the lecture and Section 1.5.5 of this lab-tutorial manual. Note, that yarn-site.xml file in master/name node should contain empty configuration tags.

### 2.1.2 Master/name node configuration

In order to execute a mapreduce task successfully on the cluster certain variables need to be set in your master/data node's bash file. These variables are required by different hadoop shell scripts when hadoop daemons are executed. These variables and their values are as follows:

*export HADOOP_HOME=/home/ubuntu/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*

The final outlook of the bash file should look similar to the one shown in Fig 2.1.

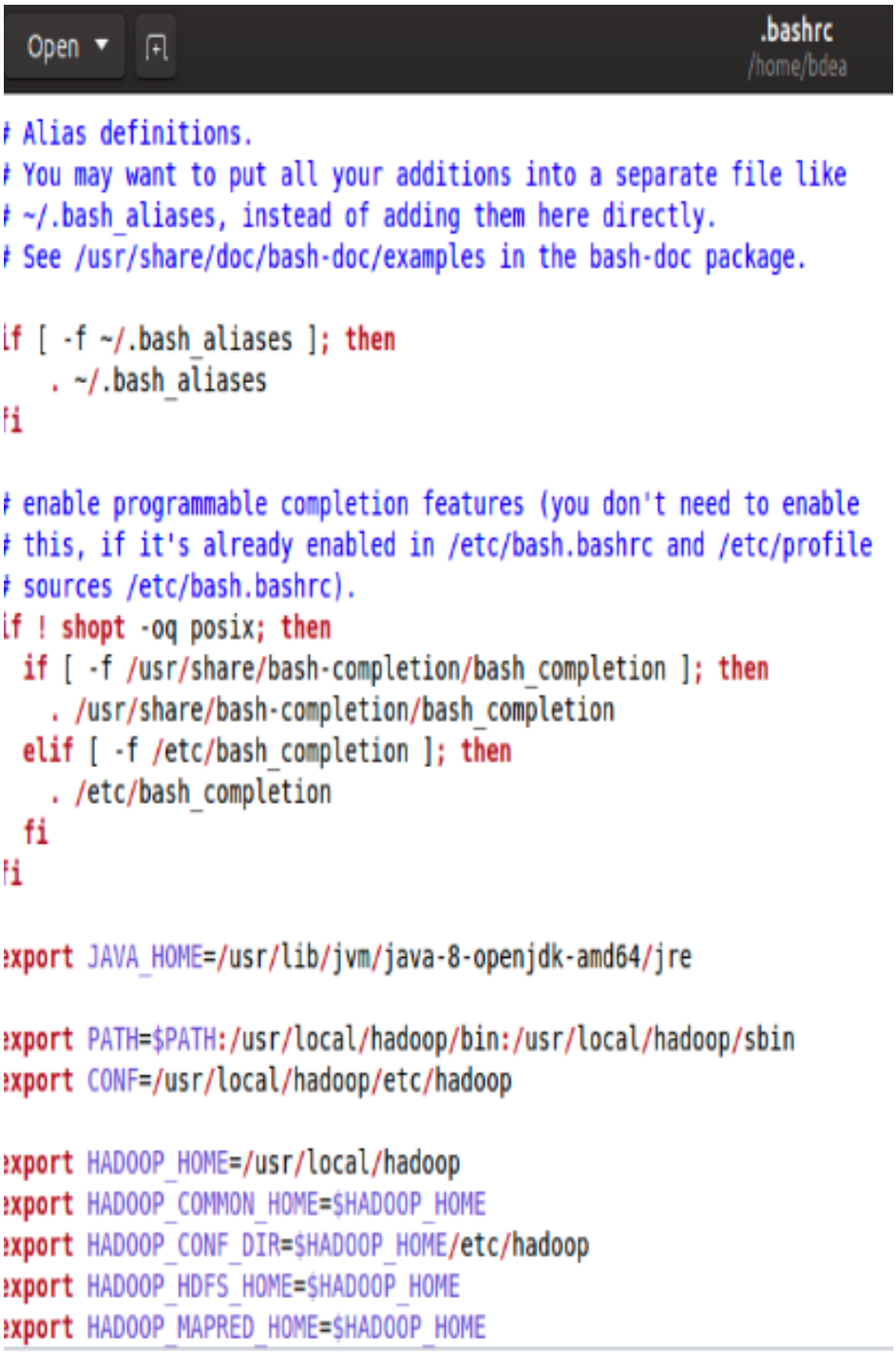
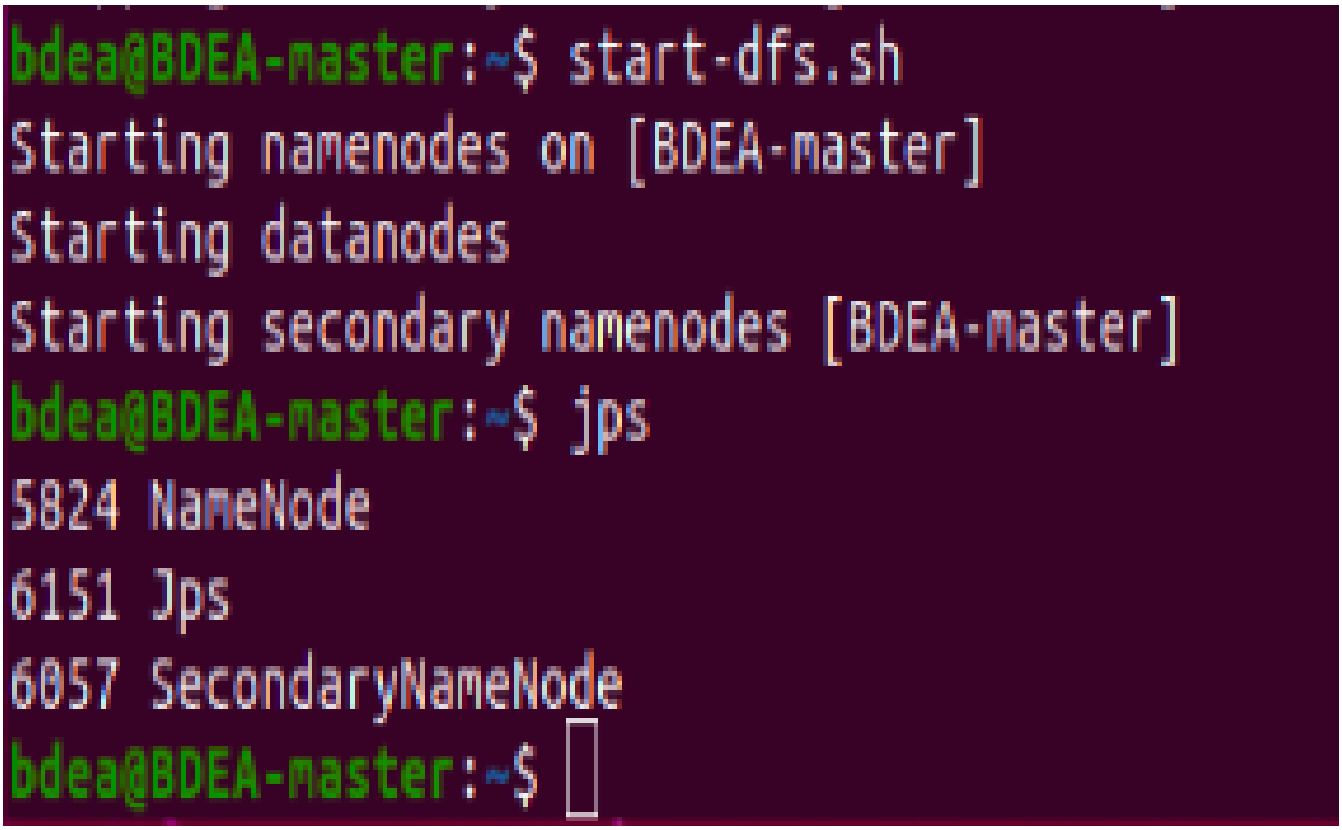



Figure 2.1: Final version of bash file on master/name node

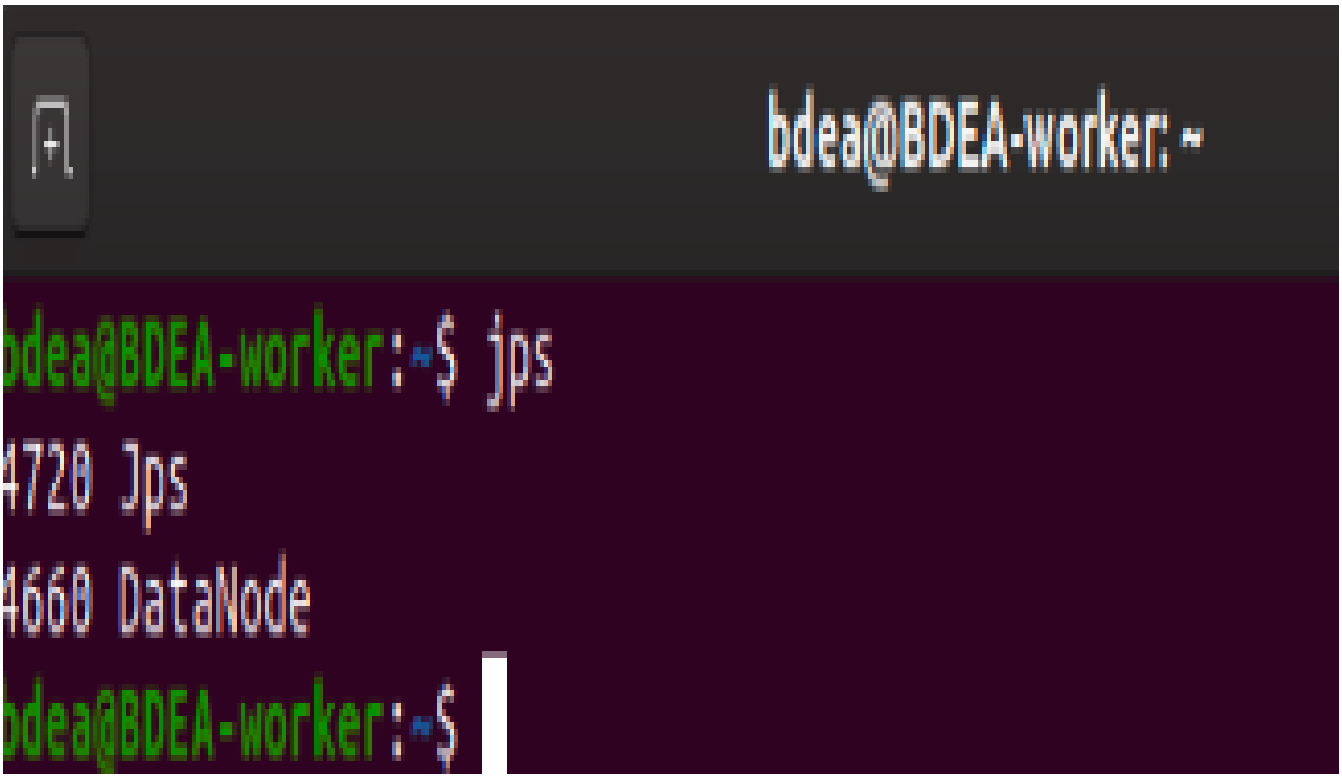
## 2.2 Executing a demo mapreduce job on the cluster

Before executing the demo job, you need to make sure that a password less ssh connection is established between all the servers in the cluster, including between localhost on master VM and master/data node on master VM. Additionally, please ensure that you format the master/name node before starting the cluster.

1. Start hadoop on master/name node - *start-dfs.sh*.
2. Type *jps* on your terminal; this commands lets you see the java processes in execution on your machine. The terminal output on name node should look similar to those shown in Fig 2.2(a) & 2.2(b).



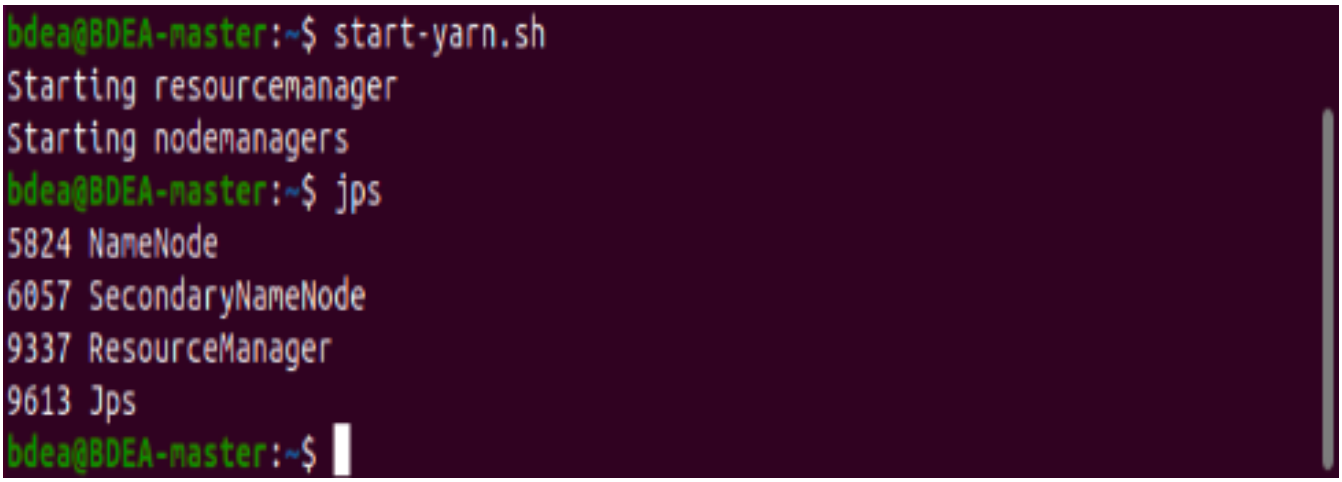

(a) jps output on master VM



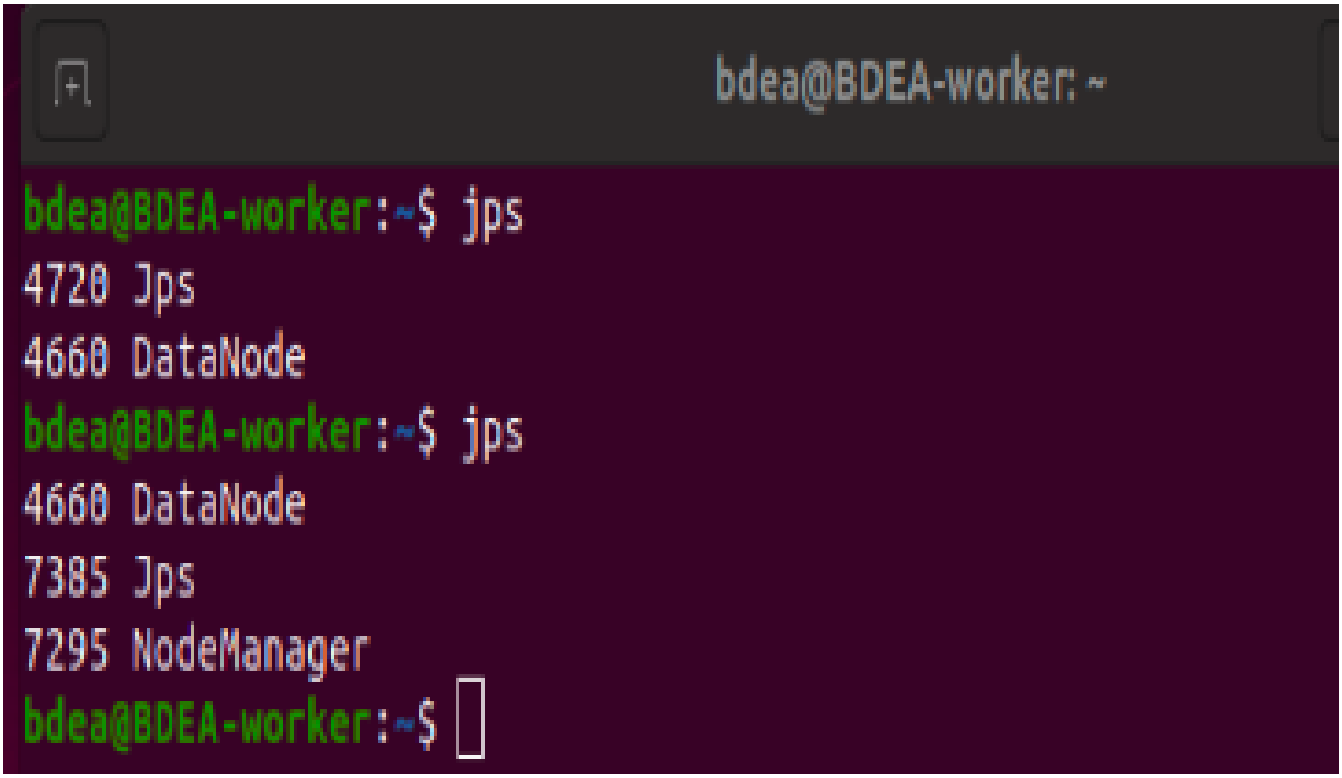

(b) jps output on worker VM

Figure 2.2: List of Java processes running on master and worker VMs of hadoop cluster after the cluster has been started.

3. It is essentially required to start Yarn before you can execute any mapreduce job. You can start yarn by executing the *start-yarn.sh* shell script from hadoop config directories. The output after calling this script and list of java processes on name and data nodes terminal should look similar to those shown in Fig




(a) jps output on master VM




(b) jps output on worker VM

Figure 2.3: List of Java processes running on master and worker VMs of hadoop cluster after starting yarn on cluster.

4. You can also view the list of yarn node manager daemons running on the worker/data nodes in your cluster by typing *yarn node -list* on the master/name node's terminal. The output list should contain details of resource managers on all the worker nodes and resemble to the one in Fig 2.4.

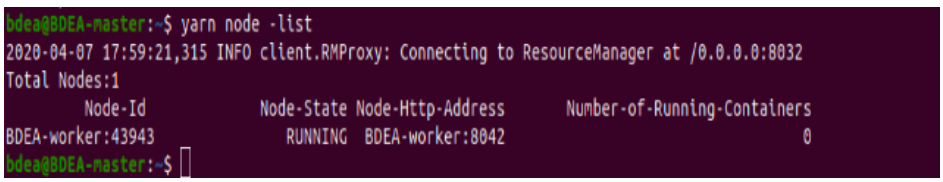



Figure 2.4: List of Resource managers running in the cluster

5. The hadoop cluster comes with an example mapreduce java programme saved in a .jar file. The

programme calculates the value of pi based on the values of points on a circle's circumference and its radius. Executing this programme can ensure that your cluster is capable of executing a simple mapreduce job.

Type the following on master VM's terminal to run the demo map reduce task:
*yarn jar hadoop/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.2.1.jar pi 16 1000*

Please watch the lecture recording to find out more about the command and its arguments. The beginning and end of this command's output in terminal should resemble to those shown in Fig

```
bdea@BDEA-master:~$ yarn jar /usr/local/hadoop/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.2.1.jar pi 16
100
Number of Maps  = 16
Samples per Map = 100
2020-04-07 18:20:58,129 INFO sasl.SaslDataTransferClient: SASL encryption trust check: localHostTrusted = false,
 remoteHostTrusted = false
Wrote input for Map #0
2020-04-07 18:20:58,229 INFO sasl.SaslDataTransferClient: SASL encryption trust check: localHostTrusted = false,
 remoteHostTrusted = false
Wrote input for Map #1
```

(a)

```
                Shuffled Maps =16
                Failed Shuffles=0
                Merged Map outputs=16
                GC time elapsed (ms)=423
                Total committed heap usage (bytes)=3242065920
        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=1888
        File Output Format Counters
                Bytes Written=97
Job Finished in 3.761 seconds
Estimated value of Pi is 3.15000000000000000000
```

(b) end

Figure 2.5: demo mapreduce job execution output

## 2.3 A word count mapreduce task locally with python

Recall, that a map step transforms the raw input data into key/value pairs and the reduce step transformsthe key/value pairs into desired output. For a word count example, a map step may take a text file and

convert it into key/value pairs. The words will be keys and each word's value will be 1.

Likewise, the reduce step will combine all duplicate keys by adding their values. Since every key has value one, so the reducer will find the unique words and sum their values.

Figure 2.6 shows python code to execute the local implementation of a map task. The map task is reading a text file line by line, stripping its whitespace, splitting it into individual words, and then assigning the word to a key and insitialising its value.

```
In [35]: txt = open('/Users/moizzah/Desktop/pg2701.txt', 'r')

In [36]: f = open('test.txt','a+')

         for line in txt:

             print(line)
             print(keys)
             for key in keys:
                 value = 1
                 print("%s\t%d" % (key, value), file = f)
```

...

```
In [37]: txt.close()
         f.close()
```

Figure 2.6: local implementation of word count mapper

If you run this implementation on the text file provided in blackboard, the output file, called test.txt should have similar initial output as shown in Figure 2.7

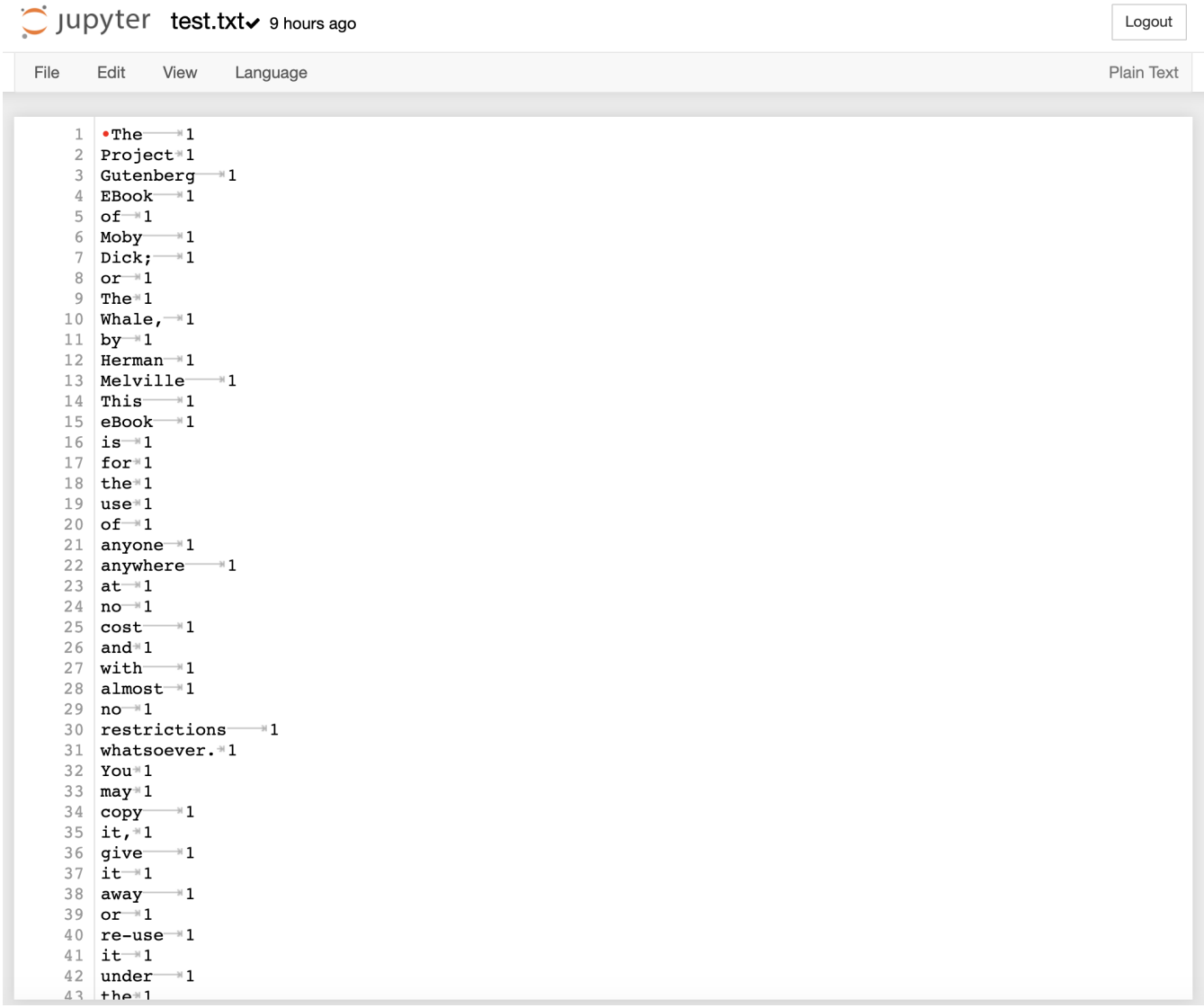



Figure 2.7: Screenshot from local mapper's output file

## 2.4 Map reduce word count task on cluster

Given that you have the text file on you local machine which you want to process using a map reduce programme, you will have to send it to the cluster, so that it can be loaded into HDFS.

Assuming that the file to be sent to the cluster is 'pg2701.txt', you will have to share it with the master node using scp as follows:

*scp -i <path to .pem file> <path to pg2701.txt> ubuntu@<master's public dns>:*

However, as we are not working on a remote cluster we can download all the files required for this task from BB, including: mapper.py, reducer.py and pg2701.txt.
The logic behind the mapper code has already been discussed in live session as well video recording.
The working of the reducer script can be summarised as follows: When it receives a key it compares the key with previous key. If the key is similar, then the value of the key is added to the previous value of the key. Whereas, if the key is not similar the script prints the previous key and its last value; and then makes the new key previous key as well as restart the counter.

This logic may seem incomplete at first as the script looses its progress with previous key as soon as it encounter a new key. However, there is a hidden step that takes place between map and reduce tasks, called shuffle. The map reduce paradigm and hadoop services transparently takes care of executing the shuffle step.

The shuffle steps involves the following:

- sorting all key/value pairs before sending them to reducer
- key/value pairs with common keys are sent to the same reducer

  Hence, as many reducer will run as many unique keys exist. So, it is very important that keys are created keeping this point in mind.

### 2.4.1 executing the map reduce task on cluster

Now you have the text file on which word count map reduce programme has to be executed on the Hadoop cluster as well as the mapper and reducer .py files which will execute this task. You need to follow the steps below to successfully execute this this map reduce job on the server:

1. load the text file into HDFS by executing the following hadoop commands on master/name node's terminal:

   *hadoop fs -mkdir wordcount_ demo* - you have created a hdfs direcotry/folder called wordcount_demo.

   *hadoop fs -copyFromLocal pg2701.txt wordcount_ demo/textfile.txt* - you are saving the file from local file system to hdfs while renaming it as textfile.txt.

   you can ensure that the file was loaded by typing the following command, user result should look similar to the output in Figure 2.8
   *hadoop fs -ls wordcount_ demo/textfile.txt*

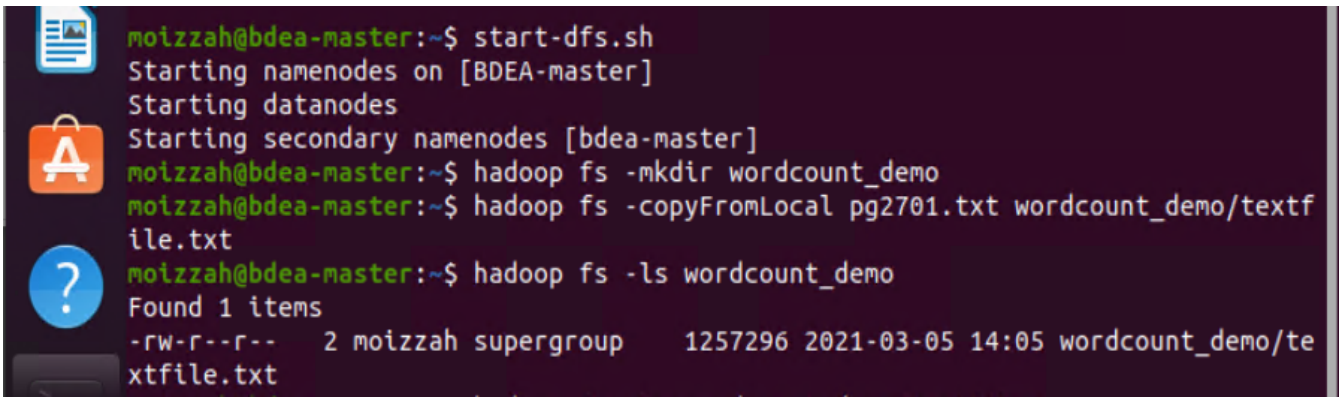



Figure 2.8: Ensuring that file has been copied to hdfs

2. execute the following command on the master's terminal to run the mapreduce job on cluster:

*yarn jar /usr/local/hadoop/share/hadoop/tools/lib/hadoop-streaming-3.2.2.jar -files ‹path to mapper.py file on master node›,‹path to reducer.py file on master node›-mapper '/path/to/mapper.py' -reducer '/path/to/reducer.py' -input 'wordcount_ demo/textfile.txt' -output 'wordcount_ demo/output_ demo'*

# Signing up for AWS educate classrooms

You would have received an e-mail on the $26^{th}$ of February 2021 about AWS Educate invitation. Before Coming to Week 4's scheduled live session you should have access to the AWS educate classroom.

The following guideline may help you to do so:

1. Click on the link provided in the e-mail with subject 'Your AWS Educate Application'.
2. Accept the invitation.
3. You will be sent a verification e-mail, get verified using the link.
4. You will need to sign in to AWS educate to access the classroom. Navigate to AWS educate home using the following link: https://aws.amazon.com/education/awseducate/.
5. Click on the 'sign in to AWS Educate' link in blue. You can find this link just below the orange 'Join Aws Educate button'.
6. Enter your e-mail address (University e-mail address as you have received invite on this address) and click on the 'Forgot password' link in blue. You will be navigated to a new page.
7. Enter your e-mail address in the 'Username' field on the new page and press the Blue 'Send Password Reset Email' button.
8. You will receive an e-mail with a subject line 'Welcome To AWS Educate'. Click on the first link provided in this e-mail.
9. You will be navigated to a sign up page, where you will be required to enter personal details such as full name, DOB and etc. Please ensure that University of South Wales and your university e-mail address appear by default and remains in-editable on this page. Once done, submit the form.
10. You should now receive an e-mail with the following subject: 'AWS Educate Application Approved'.
11. log into your AWS educate account and ensure that you can access the Big data classroom.

# NoSQL Databases: DynamoDB

## 4.1 Working from your local jupyter notebook in AWS DynamoDB

Follow this section only after you have worked the Lab manual with hands on activity to create a Dynamo Table.

This section will introduce you to setting up a python API for dynamodb in your local jupyter notebook.

You have to ensure that you are logged into you AWS educate classroom and have internet connection before going forwards with this manual.

1. The python API that we will use to work on aws dynamodb is boto3. Please ensure that you have installed boto3. You can boto3's documentation here: Boto3's documentation.
2. Now you need to configure AWS configuration on your system. We will use AWS CLI client. Please download the version suitable for your OS from this weblink: AWS CLI Version 2.
3. After successfully installing the AWS CLI, open your OS's cmd/terminal and verify successfull installtion as shown in fig 4.1

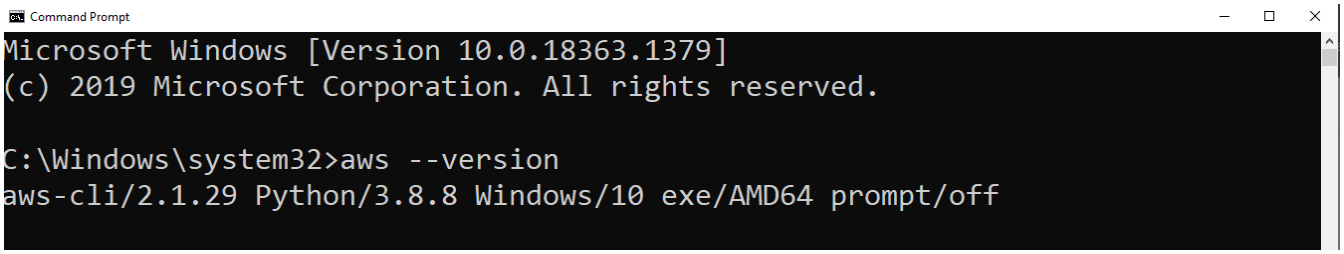



Figure 4.1: Verifying installation success for AWS CLI

4. Navigate to your AWS classroom and click on the Account Details button from homepage as shown in fig 4.2

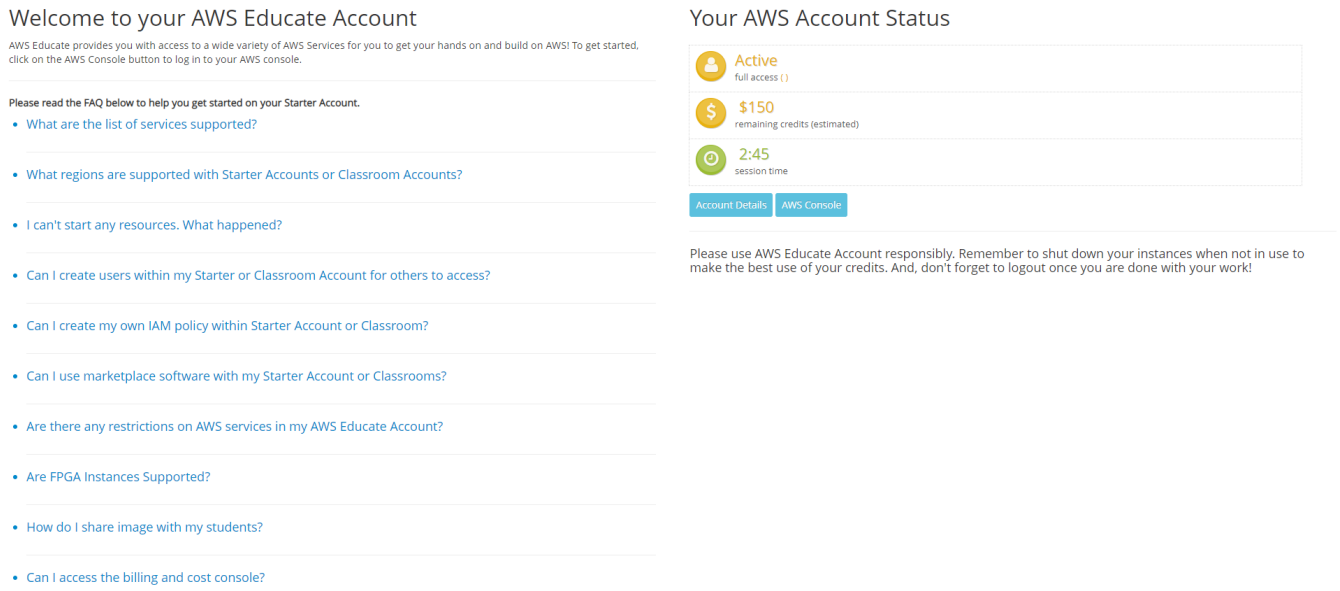



Figure 4.2: AWS educate classroom homepage

5. Click on the show button placed in front of AWS CLI as shown in fig 4.3

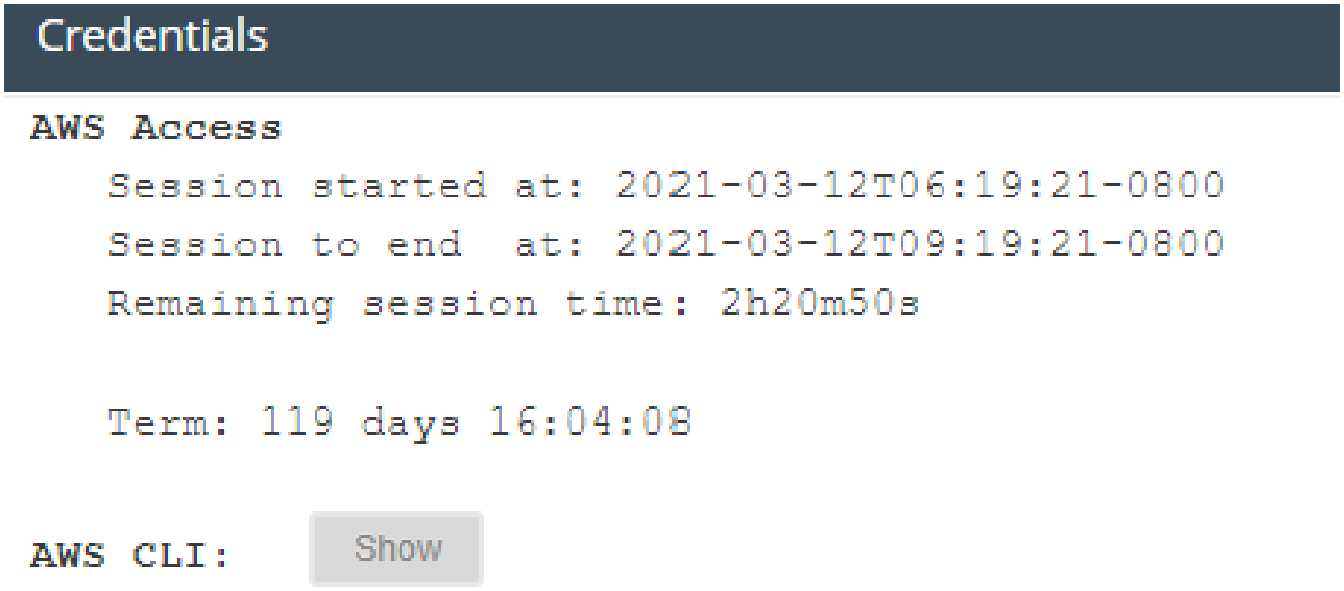



Figure 4.3: Acquiring AWS credentials for classroom console

6. Go back to your OS's cmd/terminal and type 'aws configure'. You will be able to setup the aws configuration required for boto3 to establish connection with dynamodb. Add the credentials from previous step as shown in fig 4.4. Please don't share your credentials publicly.

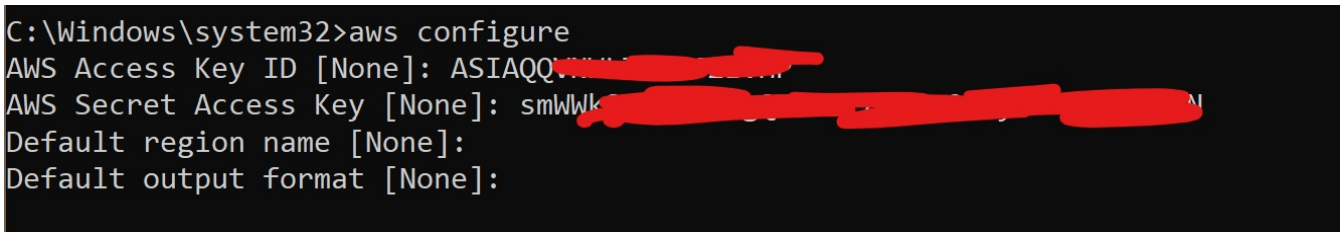



Figure 4.4: Configuring AWS credentials

7. Now copy the session token an navigate to the user folder which is logged in to your OS. For example the path to my user folder in windows is as follows: 'C:\Users\masif'.
8. You will find a folder called '.aws', open this folder
9. Open the file called credentials with any text editor and copy paste the session key here.
10. now restart the kernel in your Jupyter notebook and see if the sample python code shown in fig **??** works in your jupyter notebook without any error. We will discuss this code next week.

```
In [1]: import boto3

In [3]: client = boto3.client('dynamodb')

In [4]: client.list_tables()

Out[4]: {'TableNames': ['Music'],
 'ResponseMetadata': {'RequestId': 'IC850PITQE9F8AT7NM1DJDAA6VVV4KQNSO5AEMVJF66Q9ASUAAJG',
  'HTTPStatusCode': 200,
  'HTTPHeaders': {'server': 'Server',
   'date': 'Fri, 12 Mar 2021 14:38:47 GMT',
   'content-type': 'application/x-amz-json-1.0',
   'content-length': '24',
   'connection': 'keep-alive',
   'x-amzn-requestid': 'IC850PITQE9F8AT7NM1DJDAA6VVV4KQNSO5AEMVJF66Q9ASUAAJG',
   'x-amz-crc32': '3485585'},
  'RetryAttempts': 0}}
```

Figure 4.5: Sample boto3 code

11. You should be able to see the name of the table you have created using the dynamodb web console in the response to your query executed as shown in fig 4.5.

# Twitter App creation for the module

Please follow the steps to create a Twitter app which you will use in week4 and 5 would come handy when attempting your coursework.

## 5.1 Twitter developer account and app creation

**Required** - intended for morning asynchronous hour study

Please follow the steps to create a Twitter app which you will use in the live session.

1. Sign in to twitter.com using your twitter credentials. If you don't have a twitter account, you may need to sign up first.
2. Open Twitter developers' website https://developer.twitter.com/,Click on tab located just before your profile picture called 'Developer Portal'.
3. Go to Projects and Apps section using the left side menu, and select overview.
4. Scroll down the page, you will find a button '+create App' at the bottom of the page.
5. Give your app a meaningful name and don't forget to copy paste API key, API secret Key and Bearer token in a text document.
6. Select appropriate reason i.e. student under academic category, and switch to individual developer account.
7. Please fill the form **How will you use Twitter API or Twitter Data** as follows:
   (a) **first field**: To learn some topics of Data Science as a student of MS4S21 at the University of South Wales. The aim of using this app are as follows:
   Using python API for twitter
   Understanding the JSON format of response
   Saving the data in a NoSQL database

(b) **second field specifics**: Will download public tweets to demonstrate: the use of python API for twitter

how to save public tweets downloaded from python API in DynamoDB

finding tweets containing trending hashtags to analyse their textual content, and other response fields, such as: location.

(c) Uncheck (**NO**) the rest of the questions

8. Now you can actually start creating an app. Click apps again, create an app and fill in the form **App Details** as follows:

(a) **App name**: MS4S21_USW_Learning

(b) A**pp description**:This App will be used to learn and teach some components of programming for data analysis at the University of south wales.

This App will be used to learn and teach some module contents of Big data engineering and applications at the University of South Wales.

(c) **URL**: https://www.southwales.ac.uk/courses/msc-data-science/

(d) **callback URL**: https://www.southwales.ac.uk/courses/msc-data-science/

# Creating a simple hadoop cluster with AWS EMR

Reading and understanding the supplementary resource uploaded just before this manual in week 6 is a pre-requisite to the lab work for EMR.

## 6.1 Creating the cluster with GUI

You will create a simple EMR cluster using the AWS console provided in AWS educate classroom for MS4S21.
The following list provides you with the basic overview of how to create a cluster using the GUI. Each item from this option would be discussed in subsequent lists and subsections.

### 6.1.1 Overview of the main approach

1. Log on to aws educate with your university e-mail address.
2. Navigate to classroom for MS4S21.
3. click on the blue button which says AWS Console.
4. Scroll down through the services displayed on AWS dashboard to find the heading for Analytics services.
5. Select EMR, you should be navigated to EMR homepage which should look similar to webpage shown in Fig 6.1:

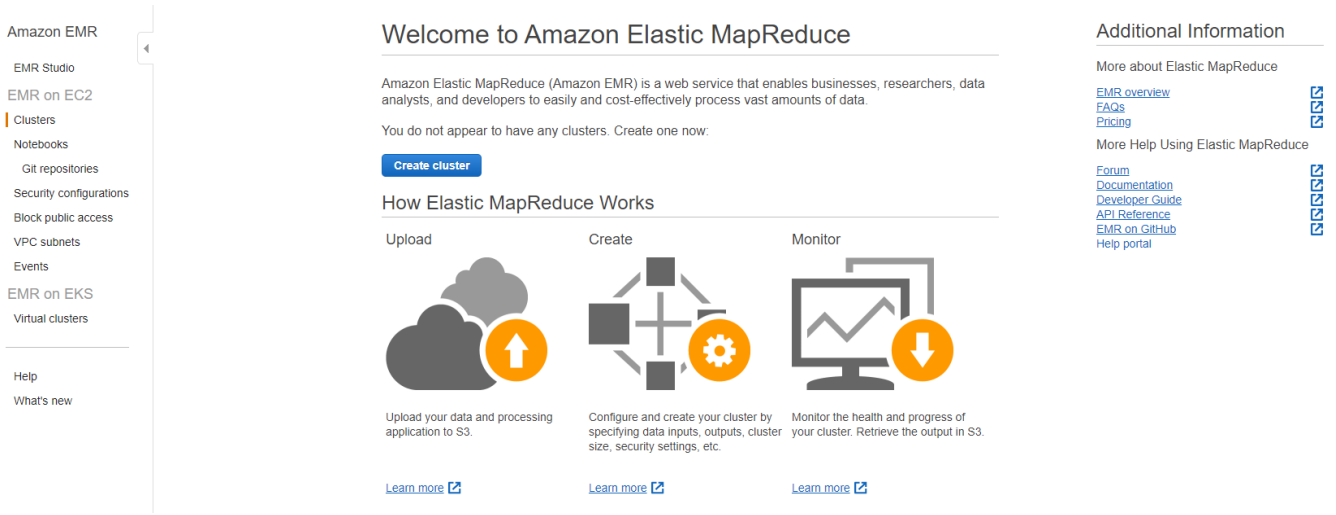



Figure 6.1: EMR AWS homepage

6. Click on the blue button which says 'Create Cluster'.

7. You will be rendered to a form which basically is a AWS GUI to create a cluster. Initially most of the fields in the form will be empty with minimal options as shown in Fig 6.2. However you should wait until next step.

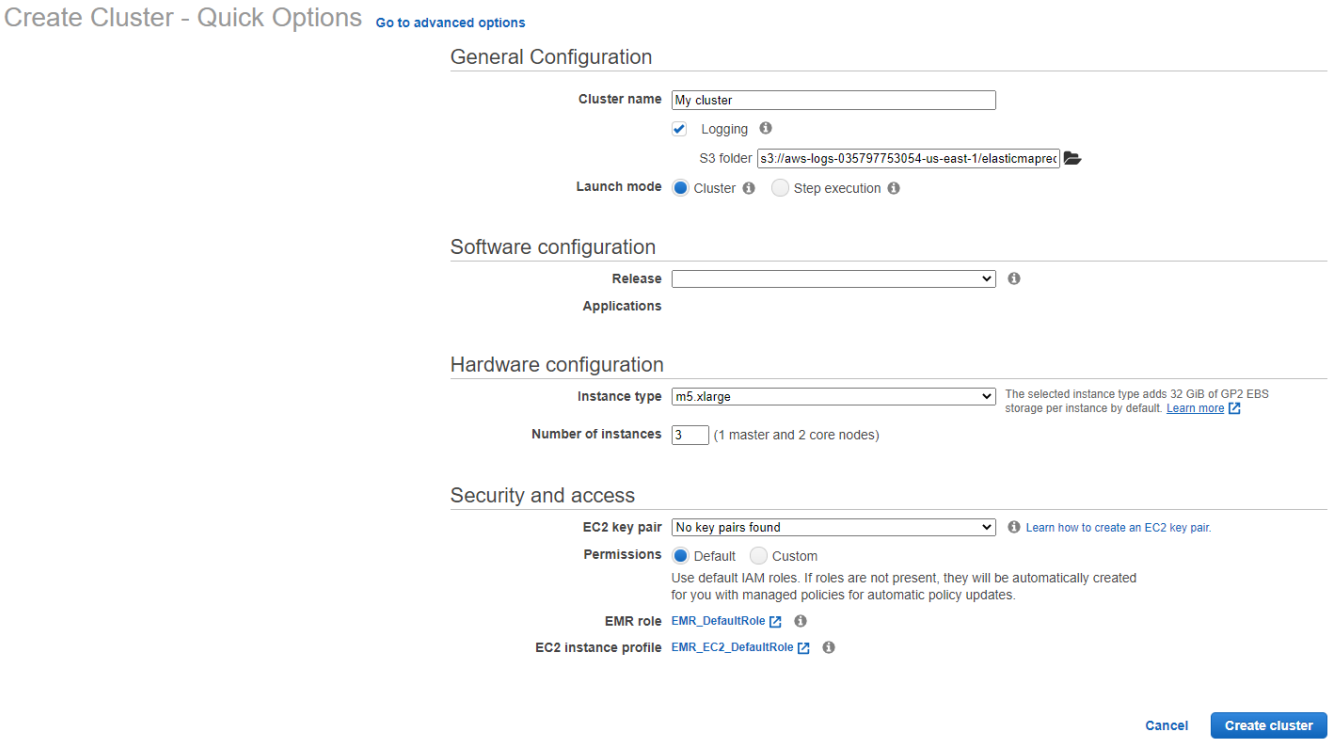



Figure 6.2: EMR Cluster creation GUI initial view

8. You will notice that after a few moments the GUI form has updated itself and had rendered more options as shown in Fig. 6.3

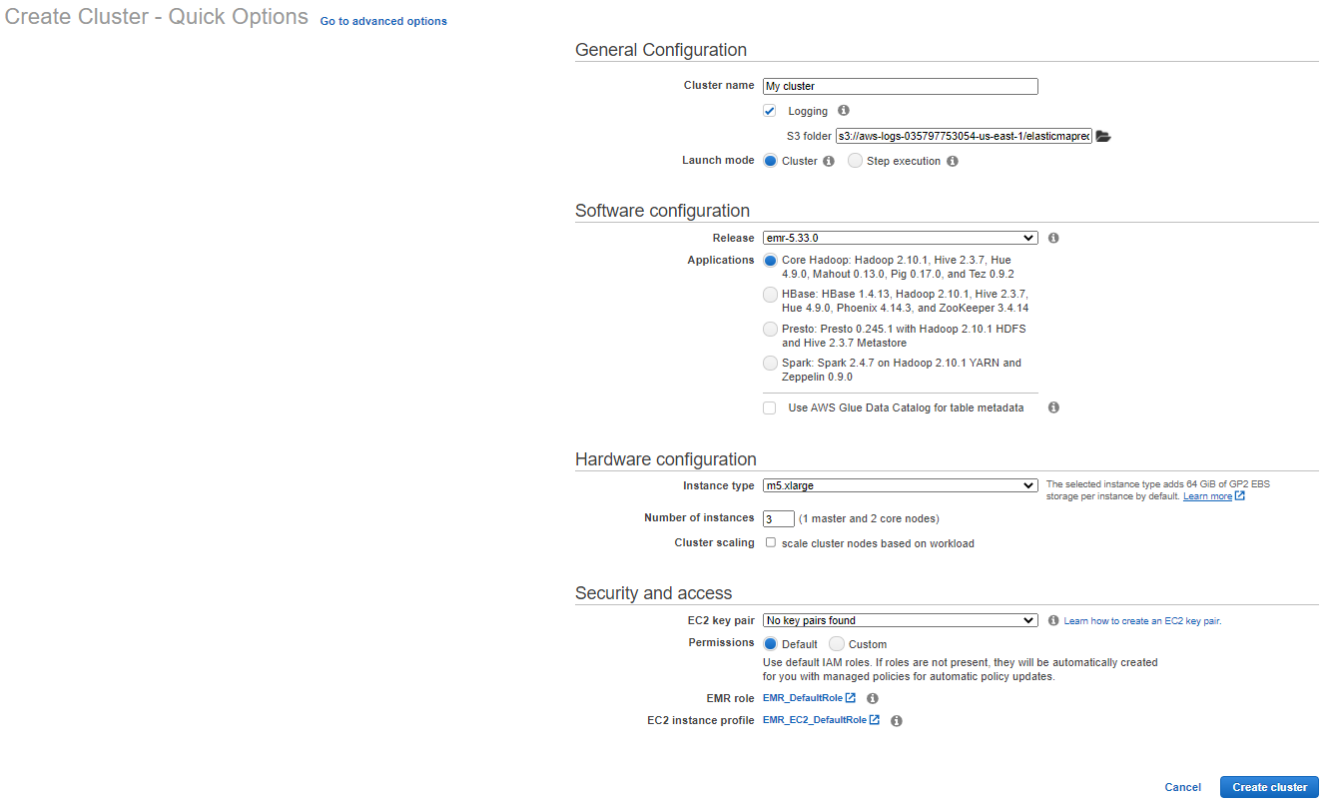



Figure 6.3: EMR Cluster creation GUI updated view

The next section will look at each section of the create cluster web page individually.

### 6.1.2 Deep dive into each section of the create cluster webpage

#### General configuration

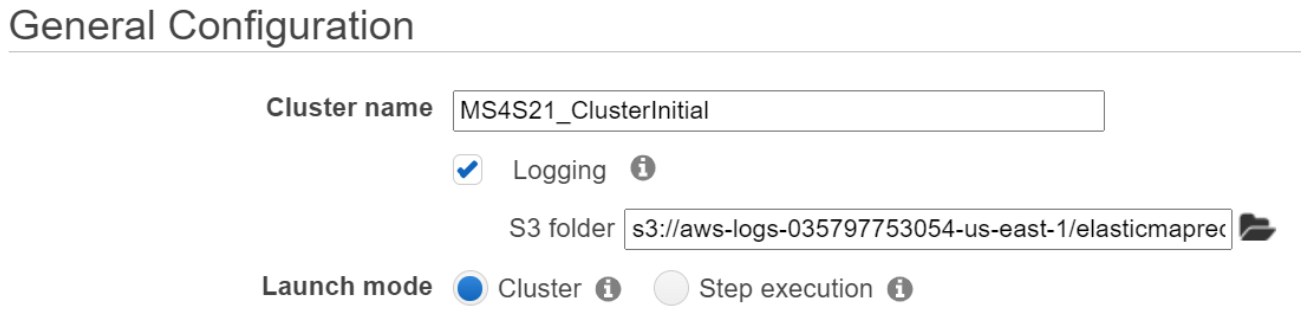



Figure 6.4: EMR cluster creation - General Configuration

1. **Cluster name** - As usual provide a meaningful and intuitive name to your cluster.

2. **Logging** - If you enable this option, a log of your cluster activities would be maintained. The log has to be maintained in an AWS S3 bucket. Enabling

this option in turn enables the S3 address field. You may have noticed that a path to a new S3 bucket is automatically provided. However, you may choose a pre-existing bucket as well.

***For this lab exercise select logging and don't edit the default S3 bucket uri.***

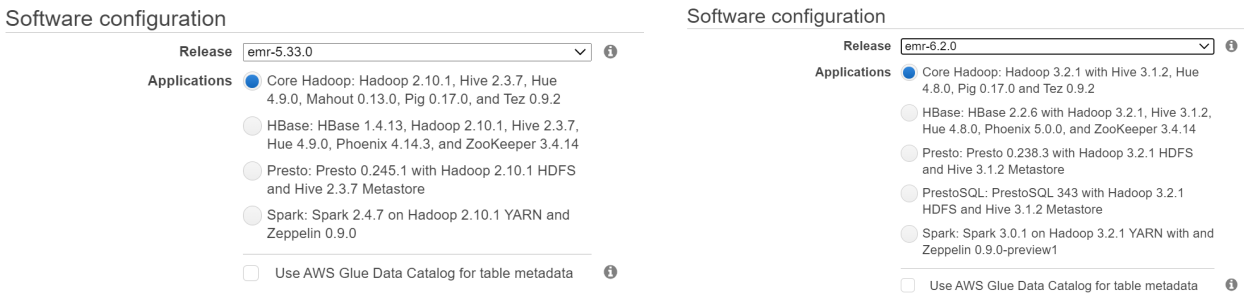
3. **Launch mode** - As evident from the form design that there are two possible modes with you can launch and EMR cluster.

   (a) ***Cluster***: This option enables you to create a cluster and add services from Apache's ecosystem on top of the cluster creation. You may use this cluster for any sort of analytics task with out any defined time frame of existence and condition to terminate. This type of cluster has to be terminated manually.

   (b) ***Step Execution***: This type of cluster is created to perform very specific tasks which are defined in a sequence of steps. As soon as the cluster finishes it pre-defined tasks, the cluster terminates automatically. We will discuss this mode of cluster creation later in detail.

***For this lab exercise select cluster as the launch mode.***

**Software configuration**




(a) default (b) custom

Figure 6.5: EMR cluster creation - Software Configuration

Since we are choosing cluster launch mode, the software configuration section of this form will give us options to choose from different releases of EMR.

In simple terms EMR releases are similar to pre-packaged Apache hadoop clusters which come with pre-installed/configured softwares of the hadoop eco system. This is similar to choosing from various apache hadoop distributions when you are not

working in a cloud environment. Such distributions may include cloudera, hortonworks and etc (we have discussed these in initial lectures).

You may have already noticed that in Fig 6.5(a) & 6.5(b) show the screenshots when the automatically rendered EMR release was left as it is and when the latest EMR release was selected instead, respectively. The list of optional hadoop eco system software that you may add in your cluster change with the selection of EMR release.

***For this lab exercise select EMR-6.20, which is the latest release and select the core hadoop option.***

**Hardware configuration**

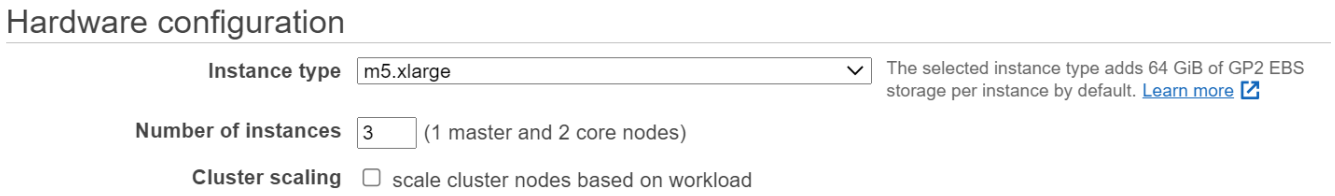



Figure 6.6: EMR cluster creation - Hardware Configuration

This section deals with picking the hardware back end that is fit for purpose in a given context for cluster creation. You may find it useful to revise the concepts about AWS EC2 compute and storage and revisit the type of compute and storage options available.

It would then be useful if you could skim through the weblink on Storage instances for EMR. Once you are back after revisiting all the concepts, you would be ready to configure this section of the cluster creation form.

***For this lab exercise leave the default options as they are in this section.***

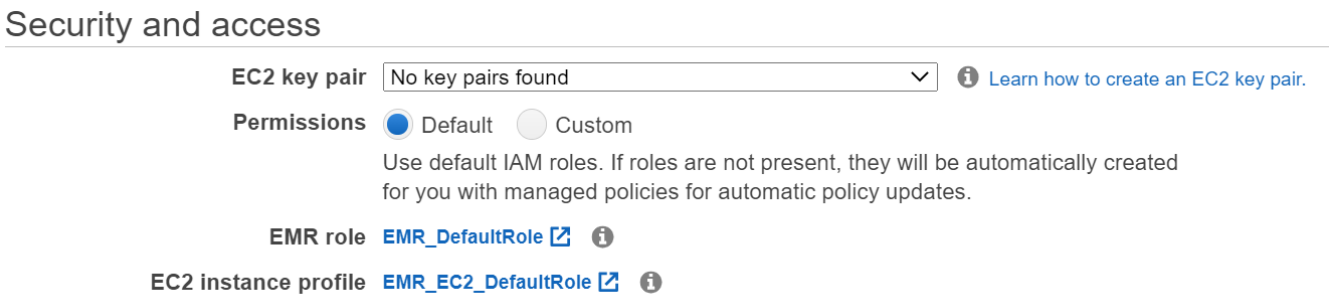
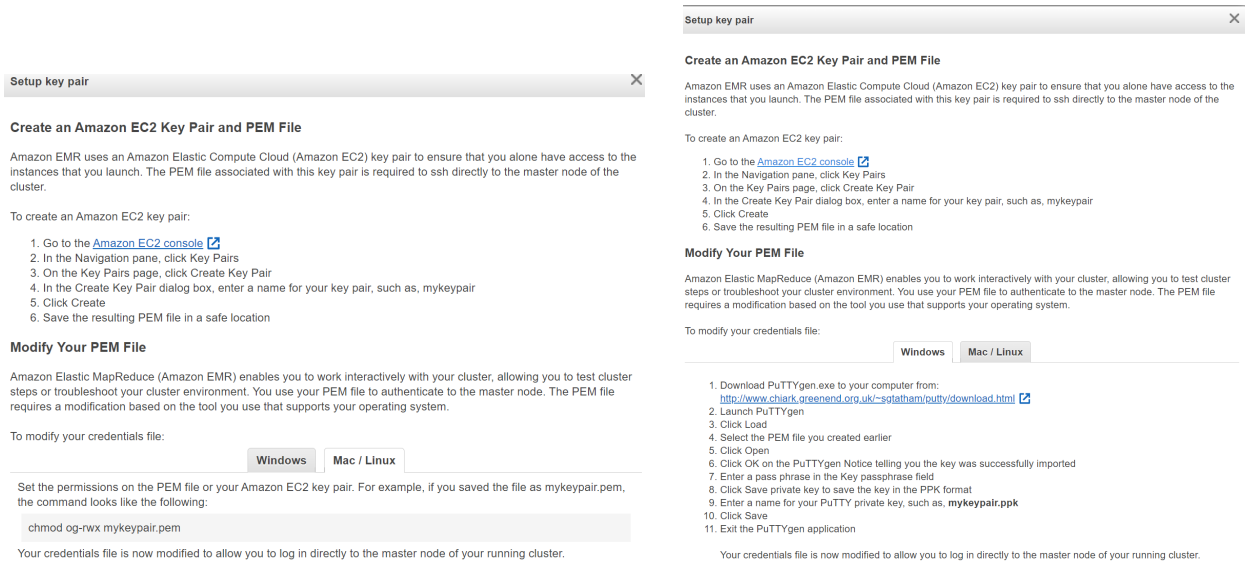



Figure 6.7: EMR cluster creation - Security and Access

Before we can go any further with this section, it is advised that you should revise your concepts on SSH and accessing remote computers from a local machine via this protocol.

In order to keep the EC2 machines secure, AWS uses EC2 key pairs which may then be used over the SSH protocol as public and private keys. It is recommended that you read through AWS's guide on EC2 before following the rest of this lab manual.




(a) iOS (b) Windows

Figure 6.8: EMR cluster creation - Creating and setting up EC2 keypairs

**Creating EC2 Keypairs** :

Since we have not created any EC2 pair in this module yet, we will have to create one. Fig 6.8 provides screenshots of the instructions that are available in the link adjacent to the EC2 key pair drop down menu in this section of the cluster creation form. Both the screenshots share instructions on how to setup an EC2 keypair for

windows and iOS platform. The instructions for iOS are also applicable on Linux distributions. Please note that you will have to access the EC2 dashboard via AWS console in MS4S21 AWS classroom.

1. Once you are in the EC2 dashboard, the dashboard web page to keypairs can be found either in the EC2 dashboard stats section or the navigation bar on the left of the EC2 dashboard web page. Both of these locations are encircled with thick ink in Fig. 6.9. Open the Keypairs dashboard.

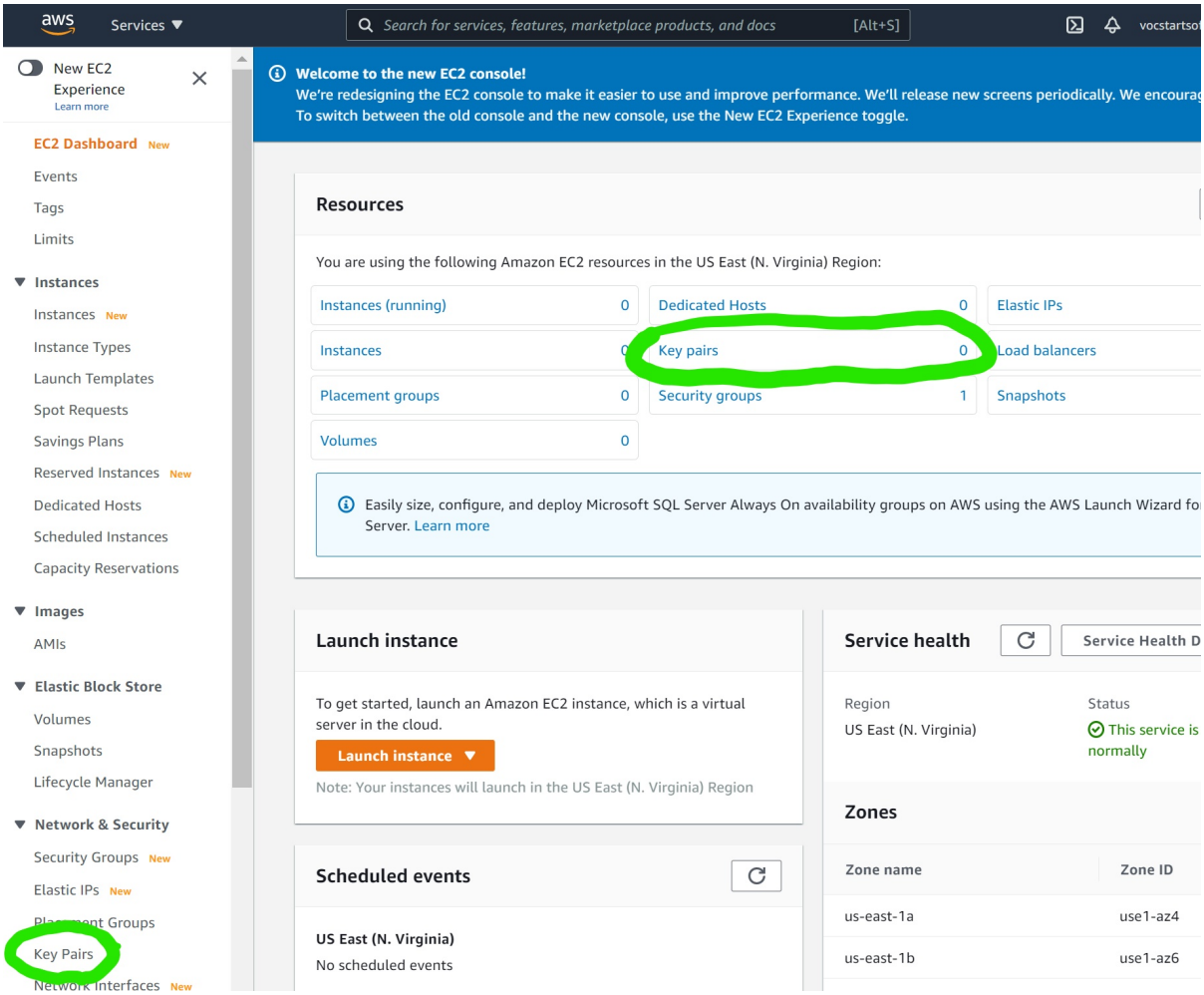



Figure 6.9: AWS Keypair Dashboard

2. Click on the orange button titled as 'create key pair' on the top right corner of keypair dashboard as shown in Fig 6.10

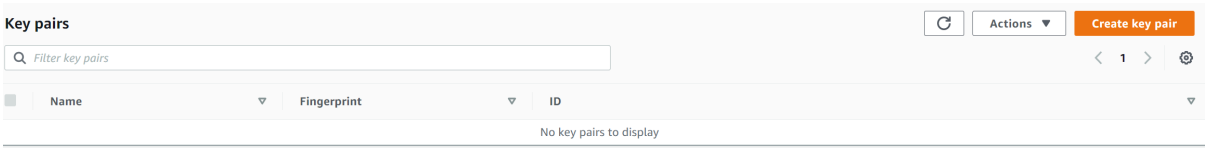



Figure 6.10: AWS Keypair dashboard

3. The create keypair button will take you to the keypair creation form. Fill the

fields and select options in this form as shown in Fig. 6.11. Note that an optional field 'Add Tag' has also been populated. This would help you recall which keypairs were created for which lab exercise or project. It is recommended that you select the .pem format as it can be converted to putty format easily while allowing you the option to use .pem or putty files of the keypair on any OS.

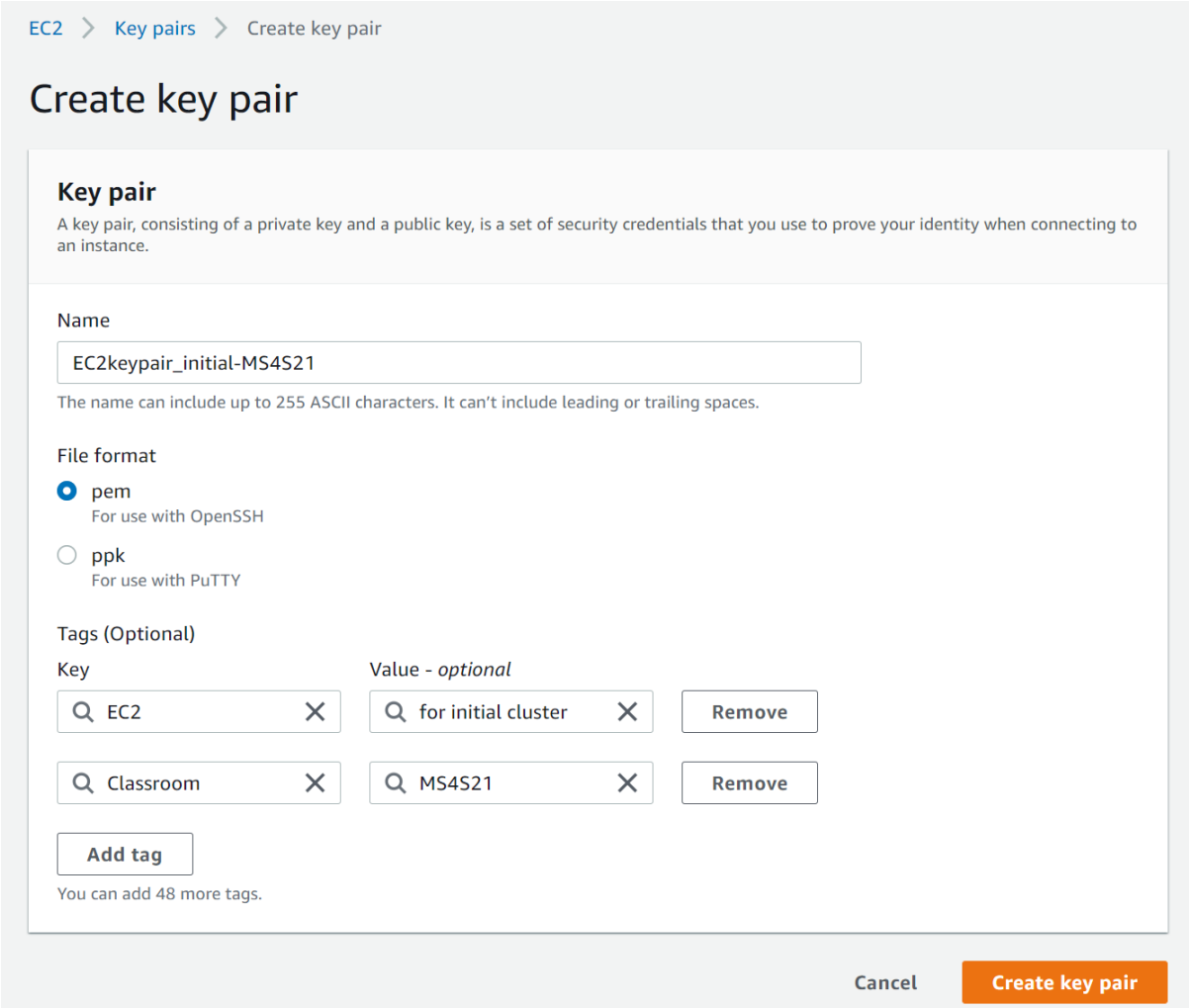



Figure 6.11: AWS Keypair dashboard

4. Don't forget to hit the 'create key pair' button once you have filled the form according to the instructions provided here.

5. You will notice that after hitting the button, you have been navigated back to the keypair dashboard as shown in Fig. 6.12 and the .pem keypair file is also downloaded. Ensure that you have saved the file to a safe location.

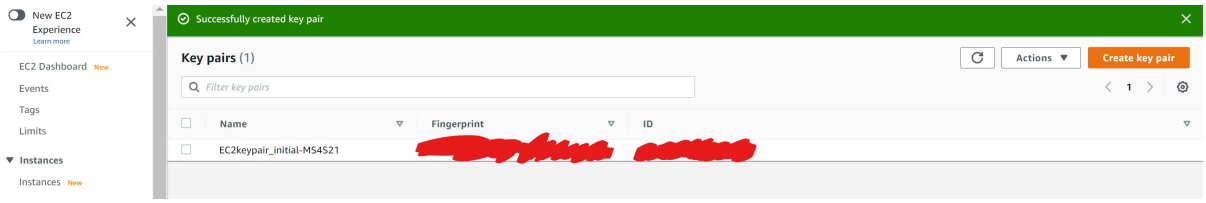



Figure 6.12: AWS Keypair dashboard

**Modifying the EC2 Keypair** :

Since we won't be using the EC2 keypair in this tutorial, the modification of the keypair won't be demonstrated unlike creation. However, if you would like you can modify the keypair following the instructions provided in Fig. 6.8 so that you have it prepared for later tutorials and courseworks.

1. **EC2 keypair** - You will notice that after the creation of keypairs, the drop down menu in cluster creation form is populated with this keypair as an option as well.

   ***For this lab tutorial select they keypair that you have just created as shown in Fig. 6.13.***

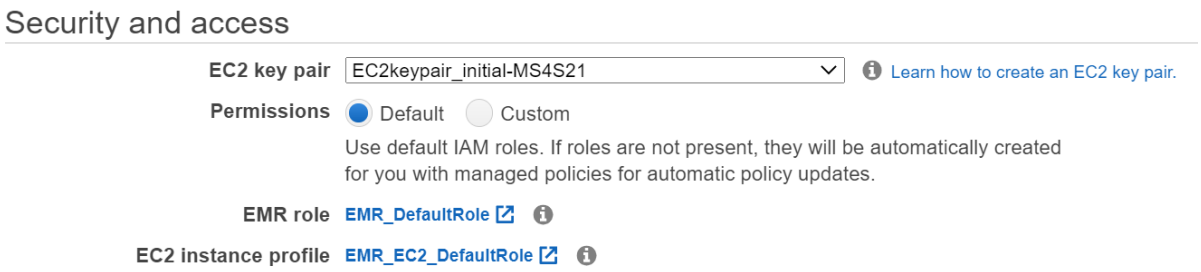



Figure 6.13: EMR Cluster creation - filled Security and Access

2. **Permissions** - leave as default.
3. **EMR Default Role** - Allows EMR to call other AWS services on your behalf as required. Open the link provide beside the field. You will be navigated to this EMR role's page under IAM dashboard as shown in Fig. 6.14.

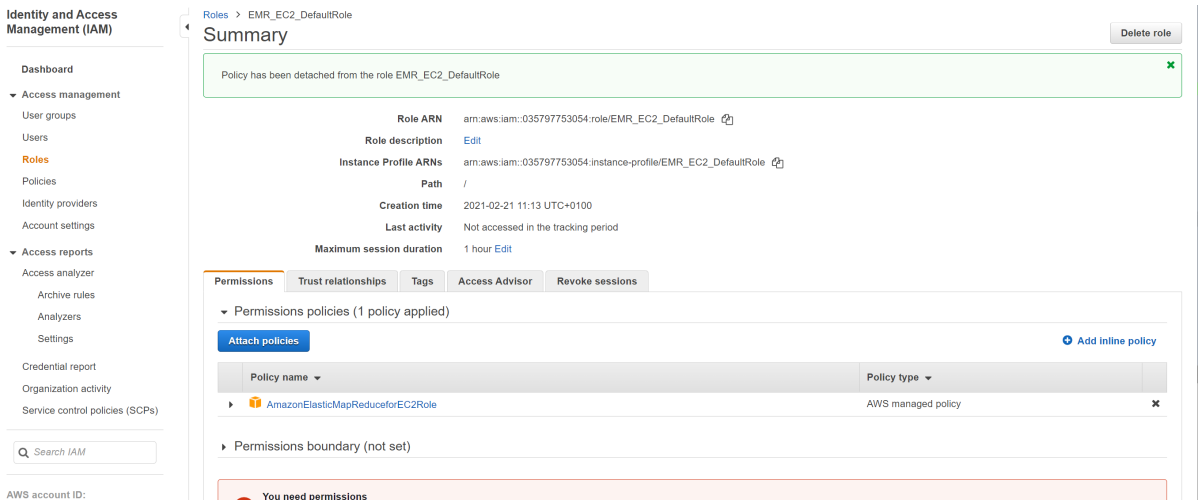



Figure 6.14: Roles webpage under IAM dashboard

You can click on the policy and find out more about the default IAM role for EMR. If you click on the policy you will be navigated to the page where all permissions with this role will be rendered on the policy summary webpage as shown in Fig. 6.15

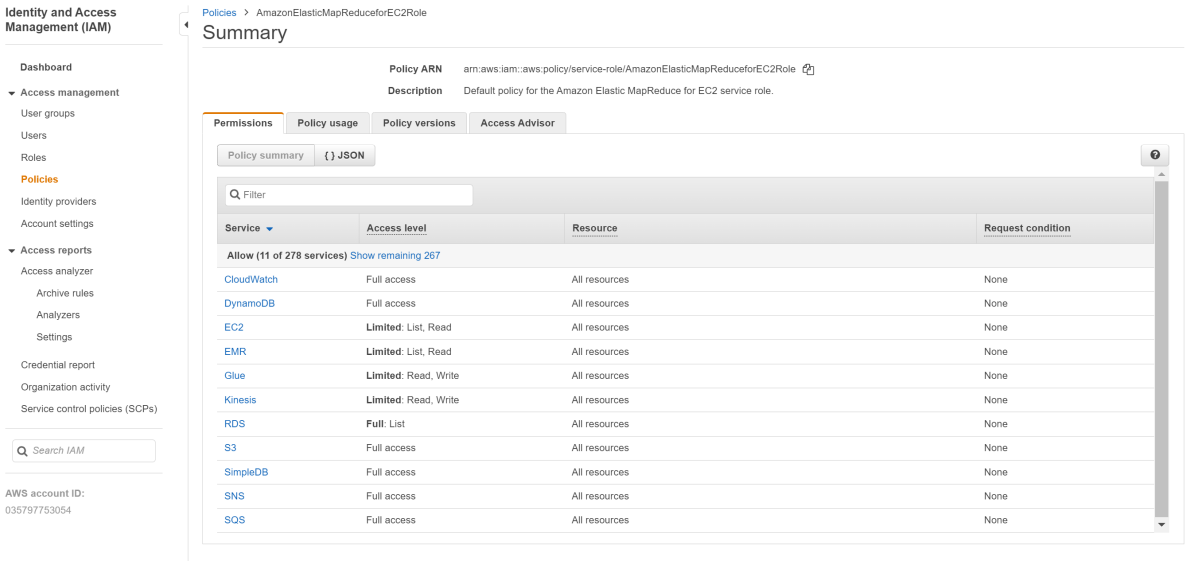



Figure 6.15: Policies for default IAM role for EMR

4. **EMR EC2 DefaultRole**: You can follow similar steps to EMR Default Role to find out more about the IAM policies and the default role here.

5. Finally don't forget to hit the create cluster button! The cluster will be discussed in the next lab tutorial manual.