MS4S21 - Big Data Engineering and Applications

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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.

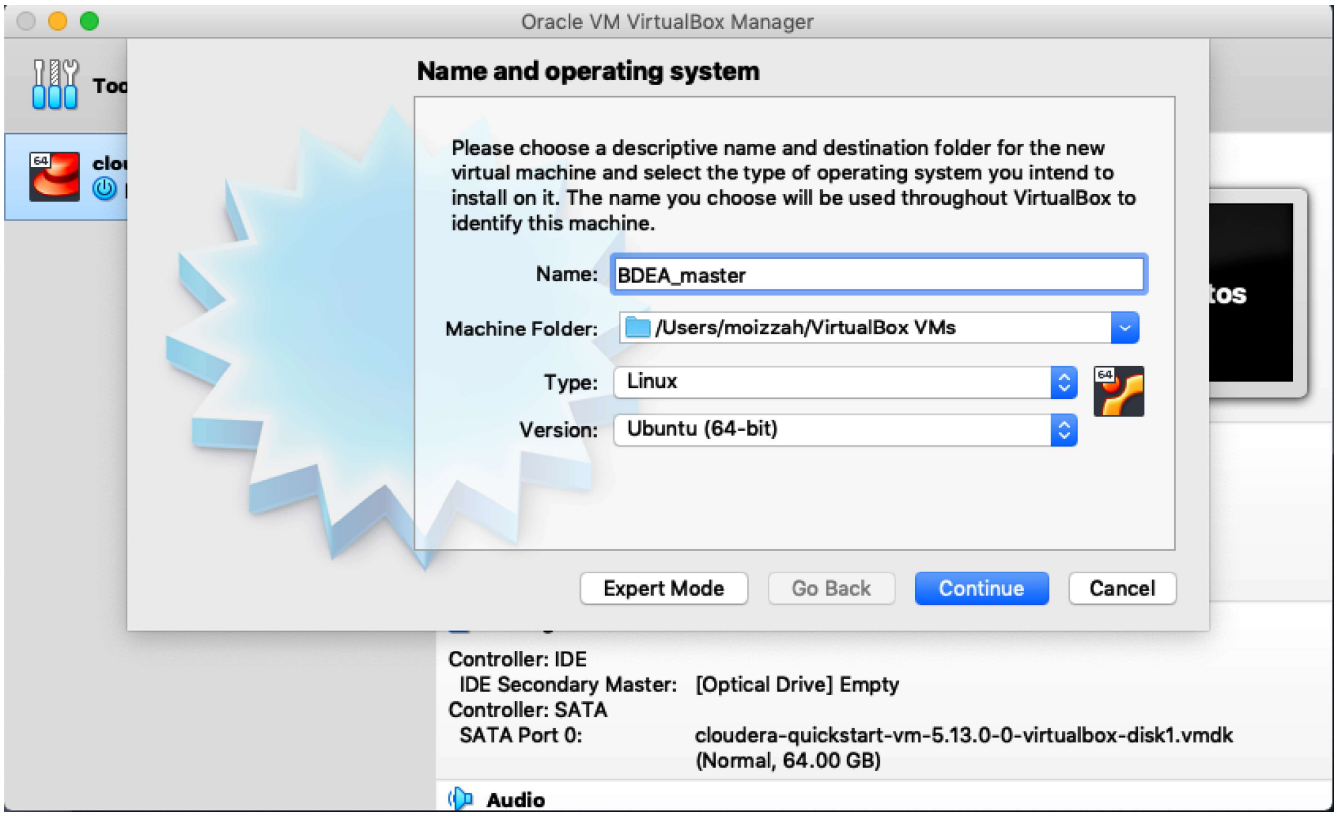


Figure 1.1: Ubuntu VM creation on virtual box - 1

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.

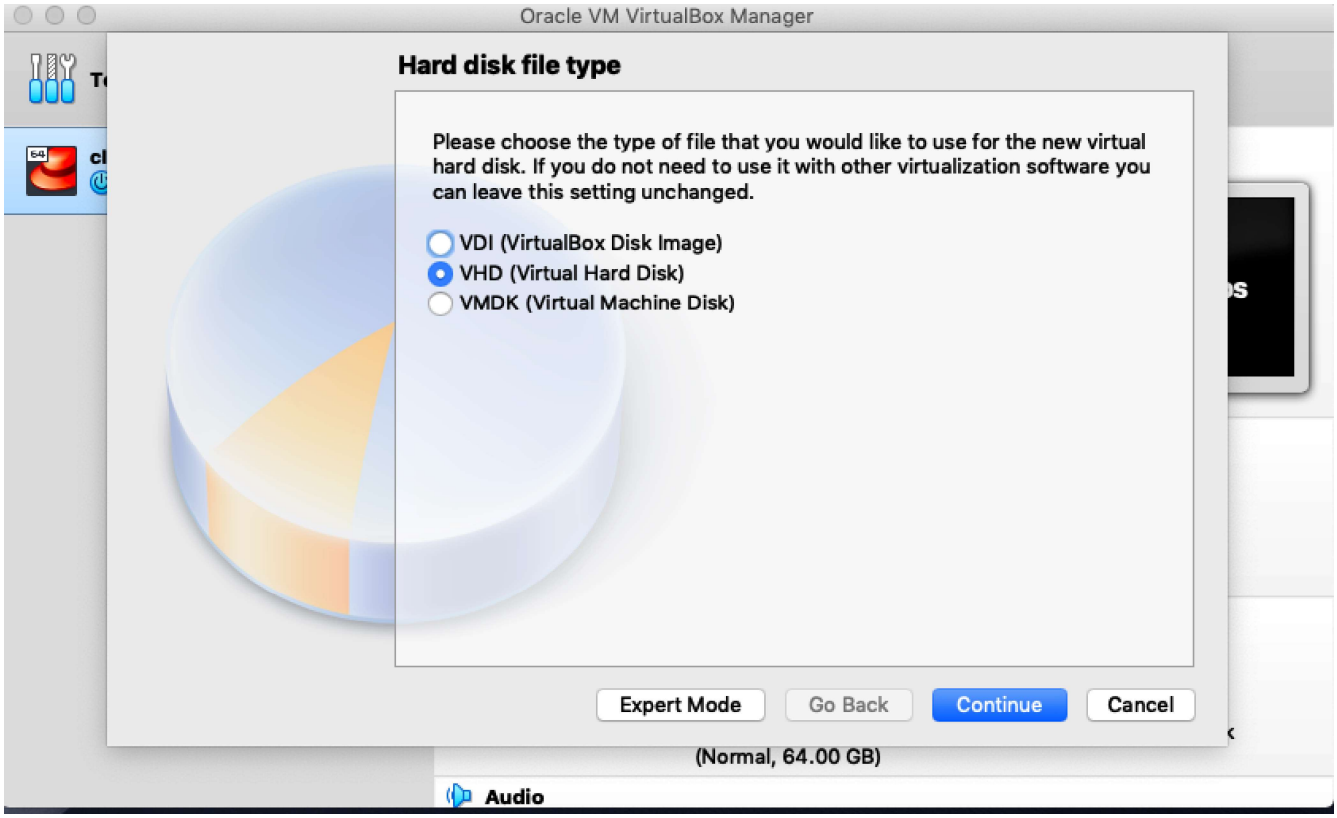


Figure 1.2: Ubuntu VM creation on virtual box - Hard disk file type

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.

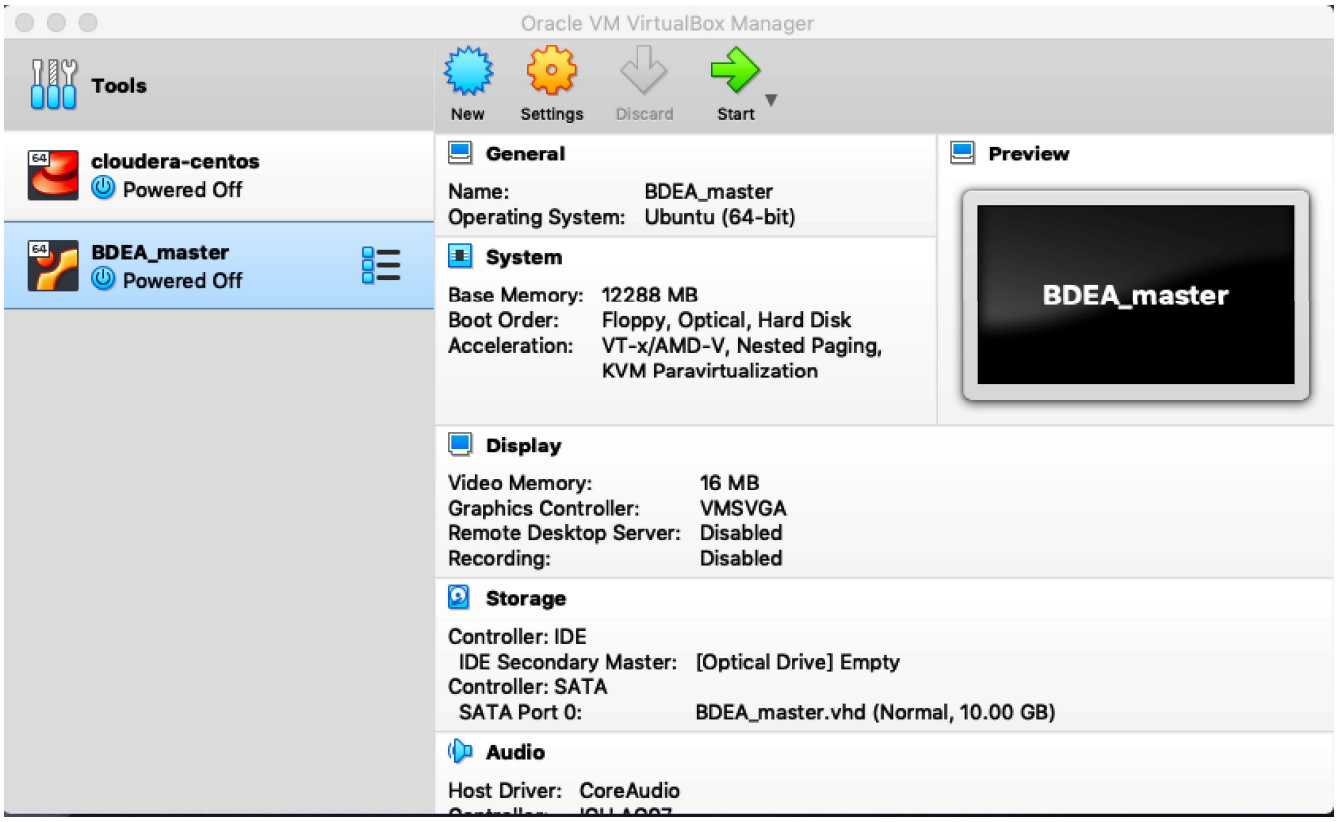


Figure 1.3: Ubuntu VM creation on virtual box - Empty VM

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)

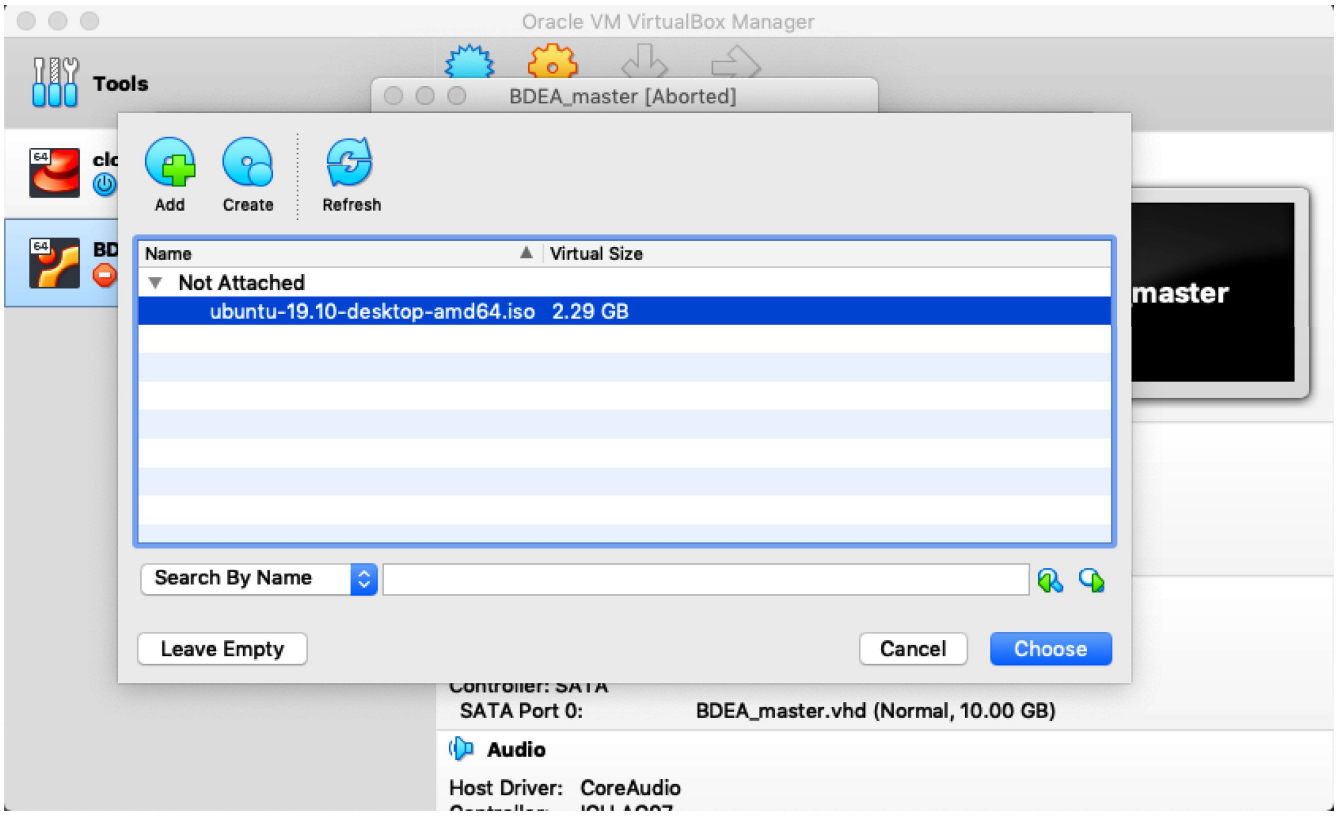


Figure 1.4: Ubuntu VM creation on virtual box - adding iso image 1

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.

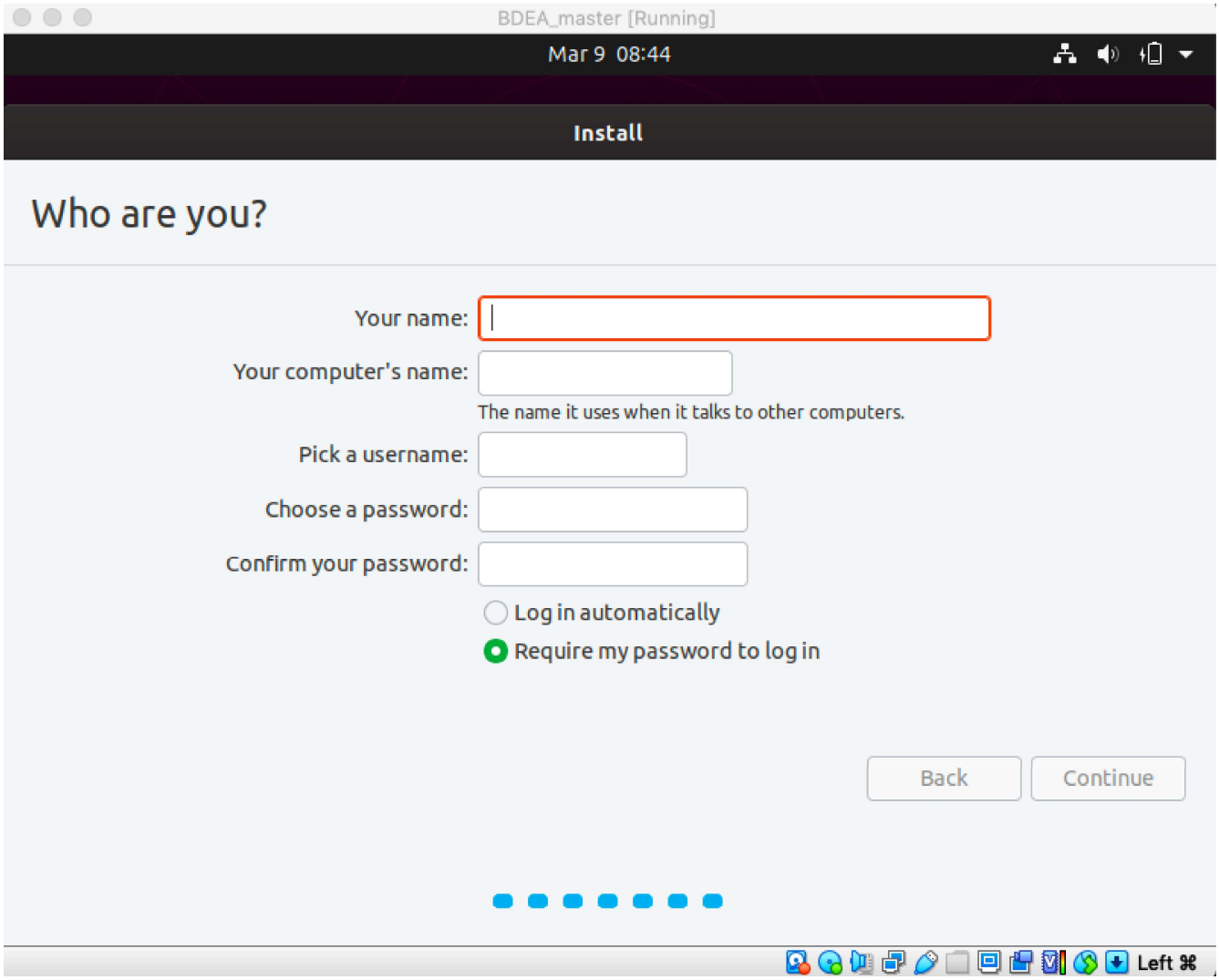


Figure 1.5: Ubuntu user creation

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.

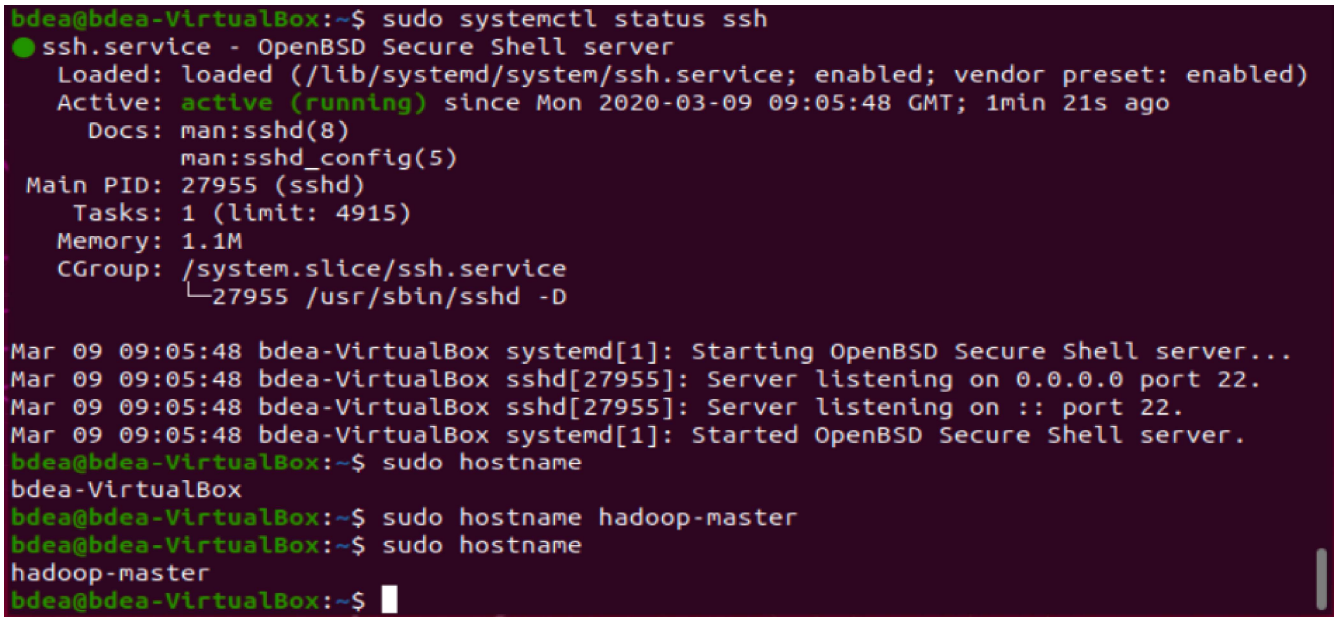


Figure 1.6: openssh-server and hostname verification

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.

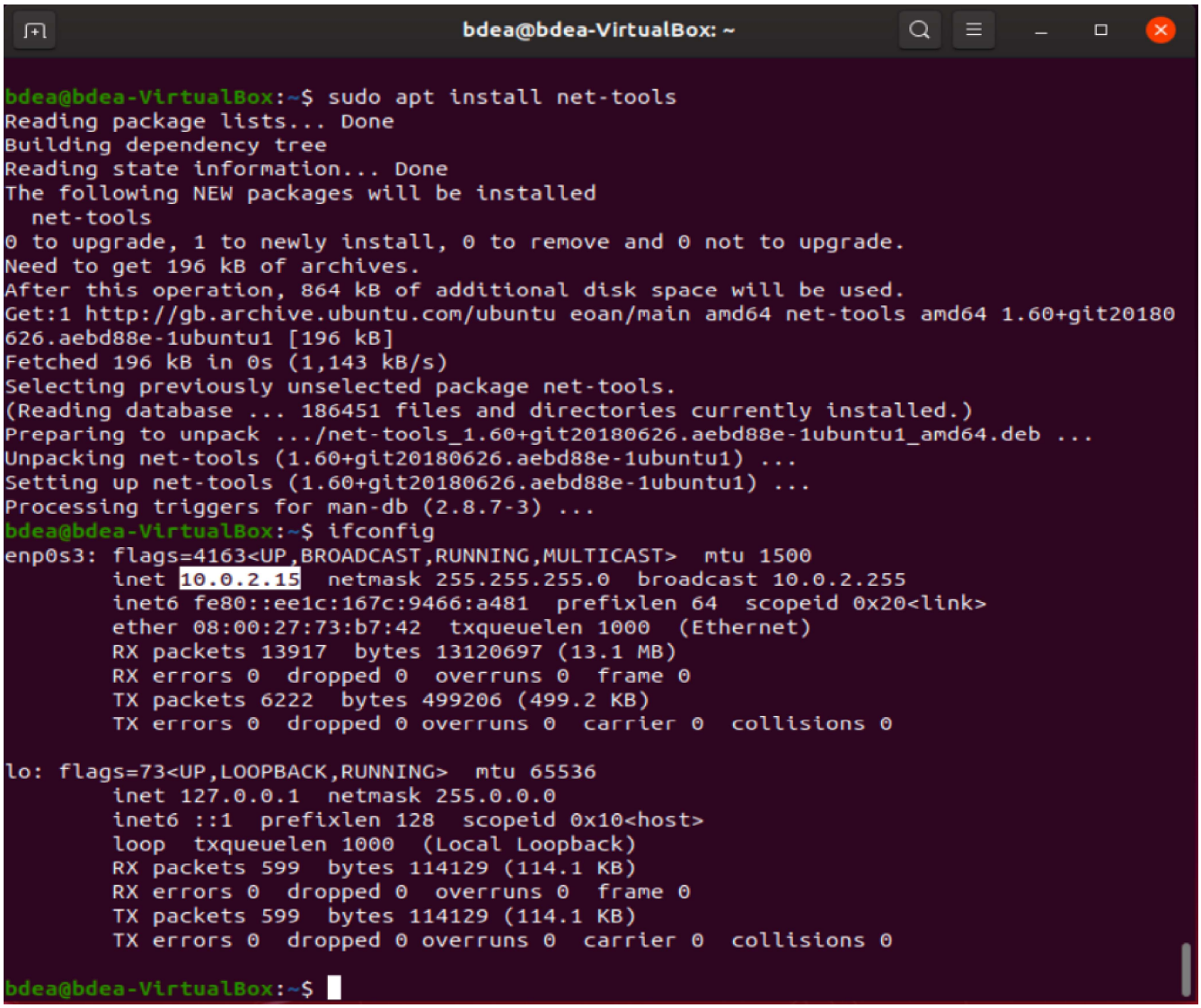


Figure 1.7: net-tools installation and ifconfig output

(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.

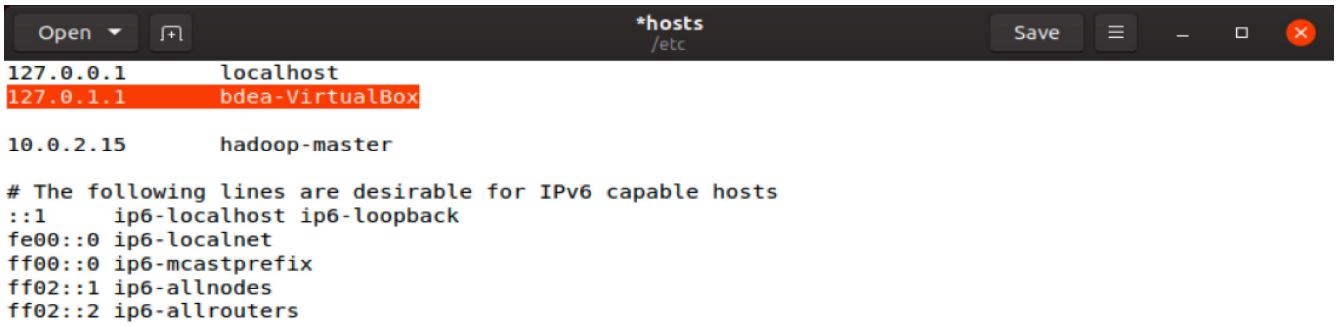


Figure 1.8: interim configuration of hosts file

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.

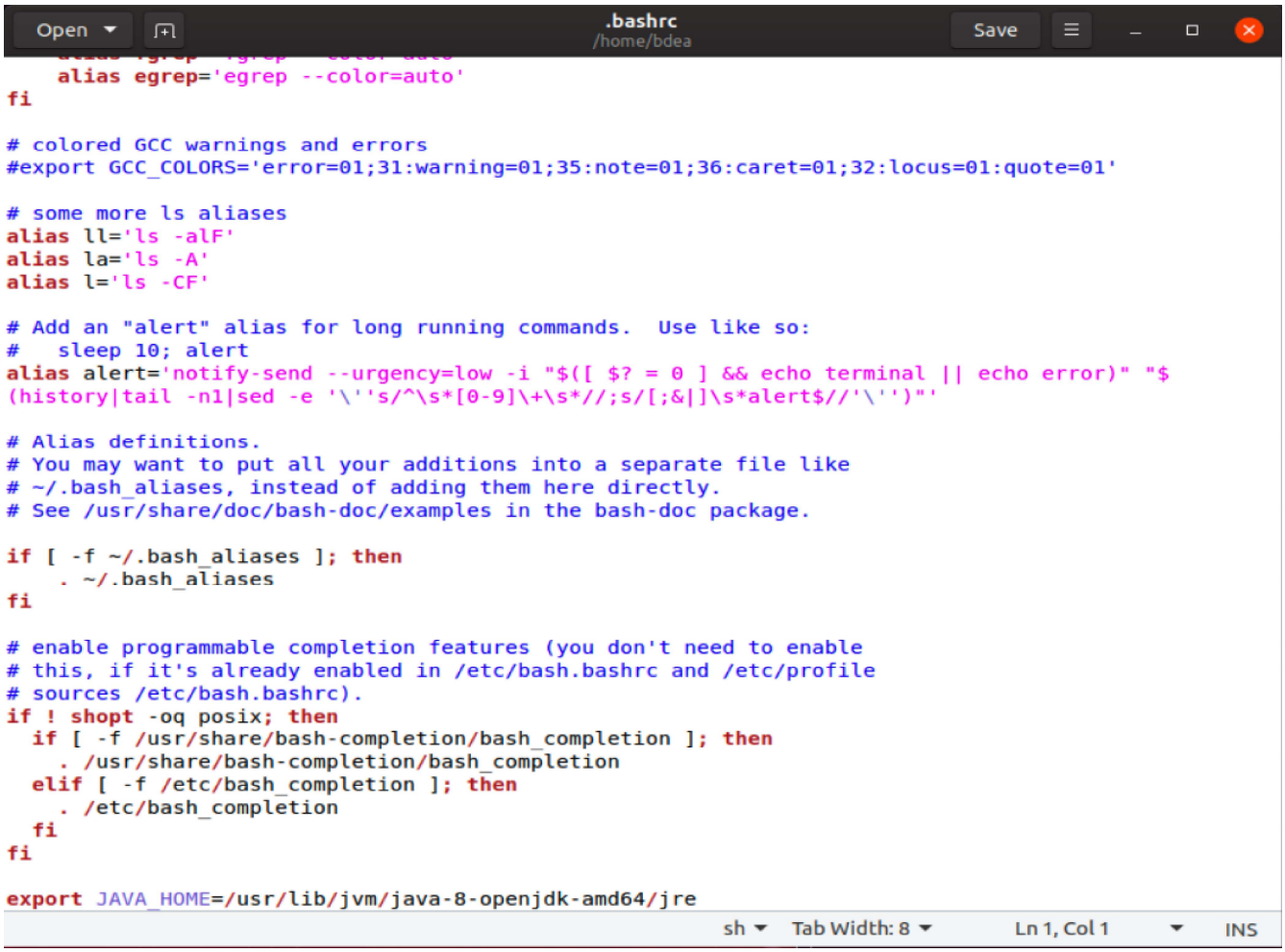


Figure 1.9: Initialising JAVA_HOME in bash file

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.

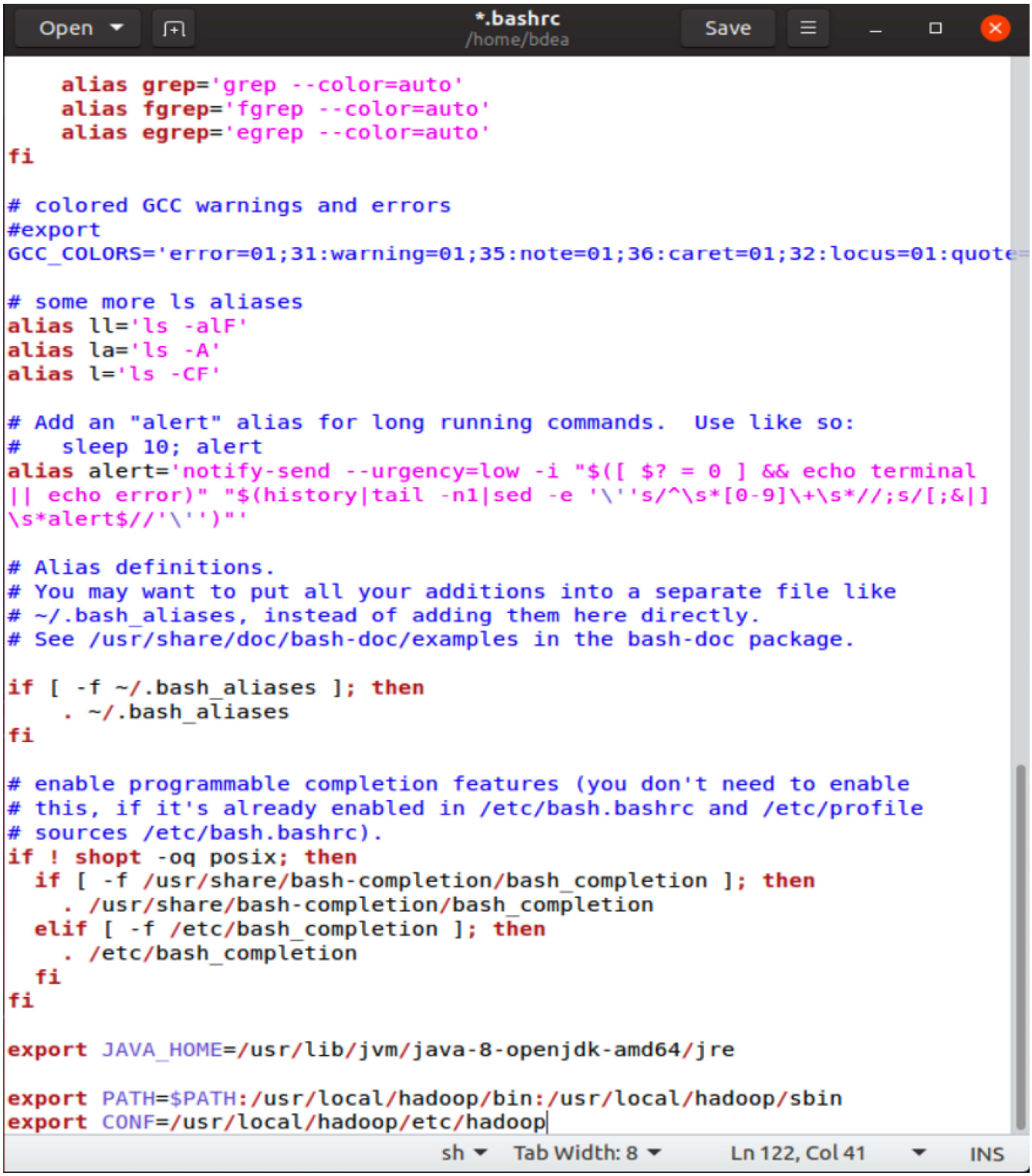


Figure 1.10: Bash file with Hadoop bin and sbin added to path

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

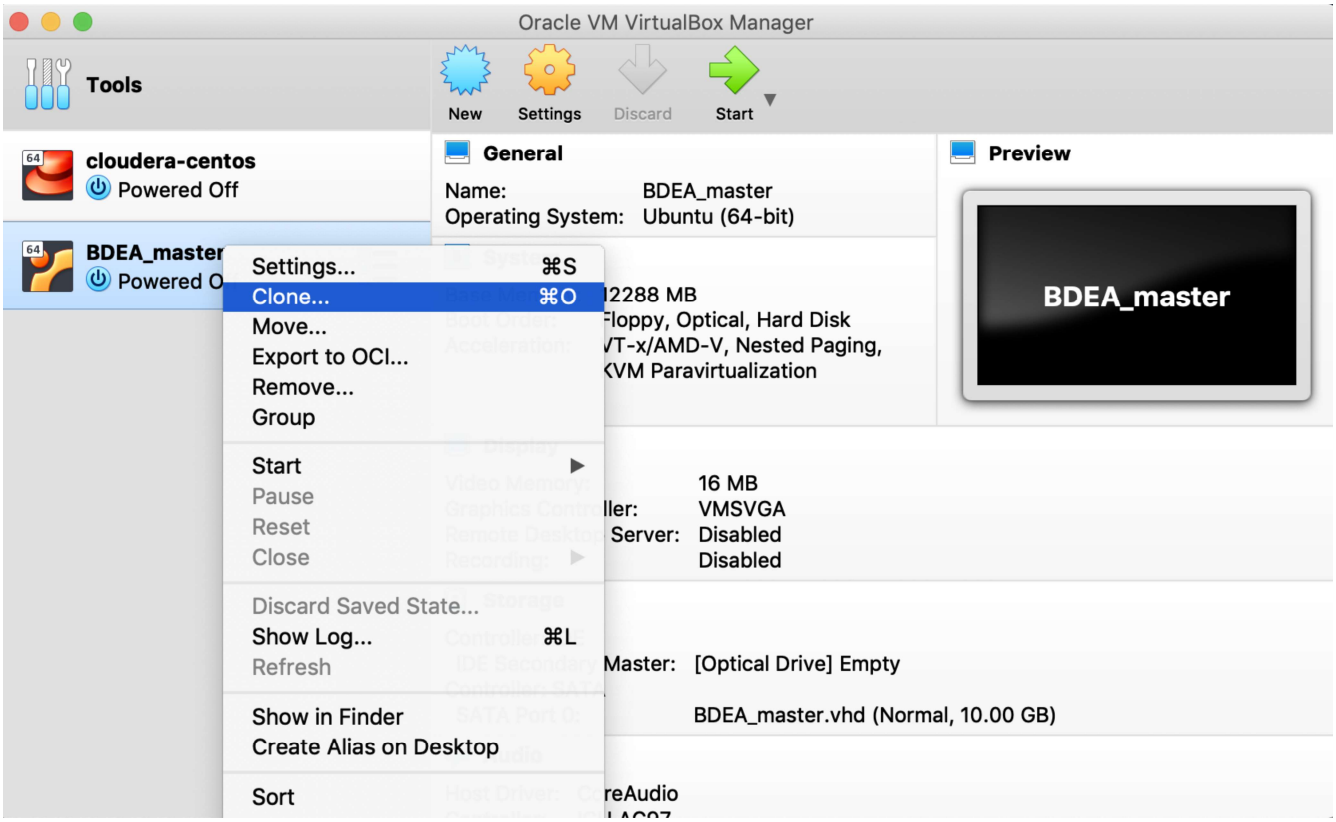


Figure 1.11: Cloning VM - 1

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.

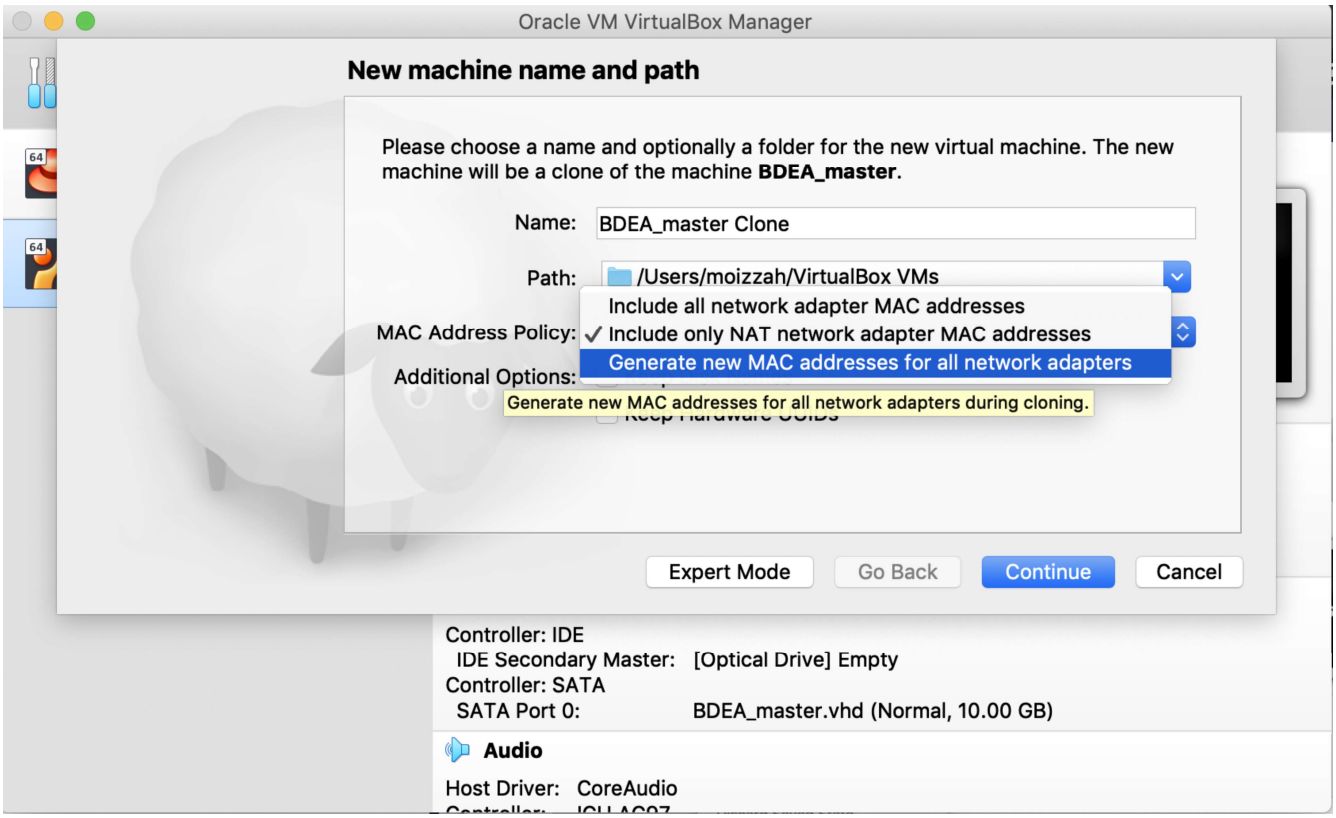


Figure 1.12: Cloning VM - Network adapter configuration

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.

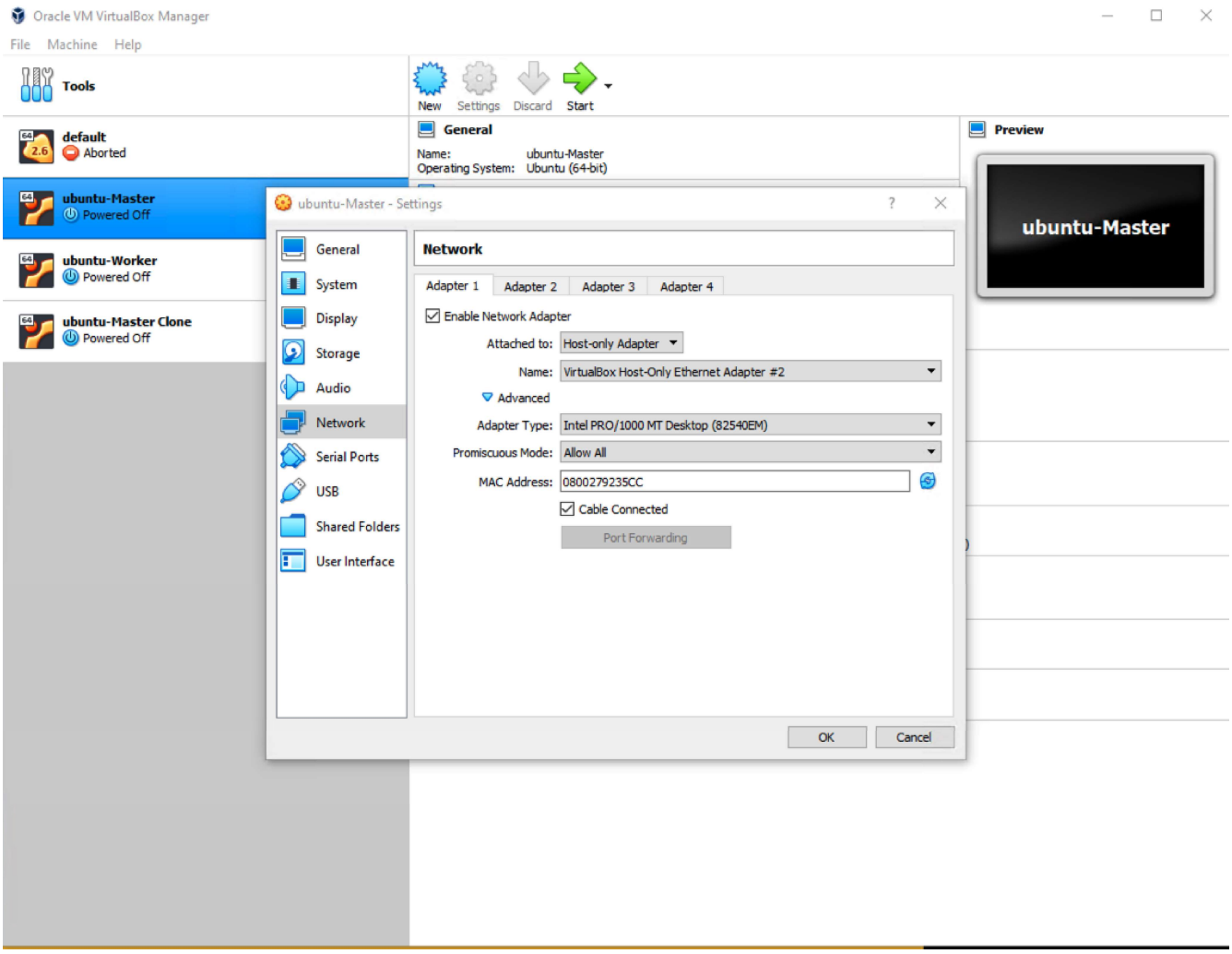


Figure 1.13: Switching to hostr-only adapter network mode on virtual box windows release

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.

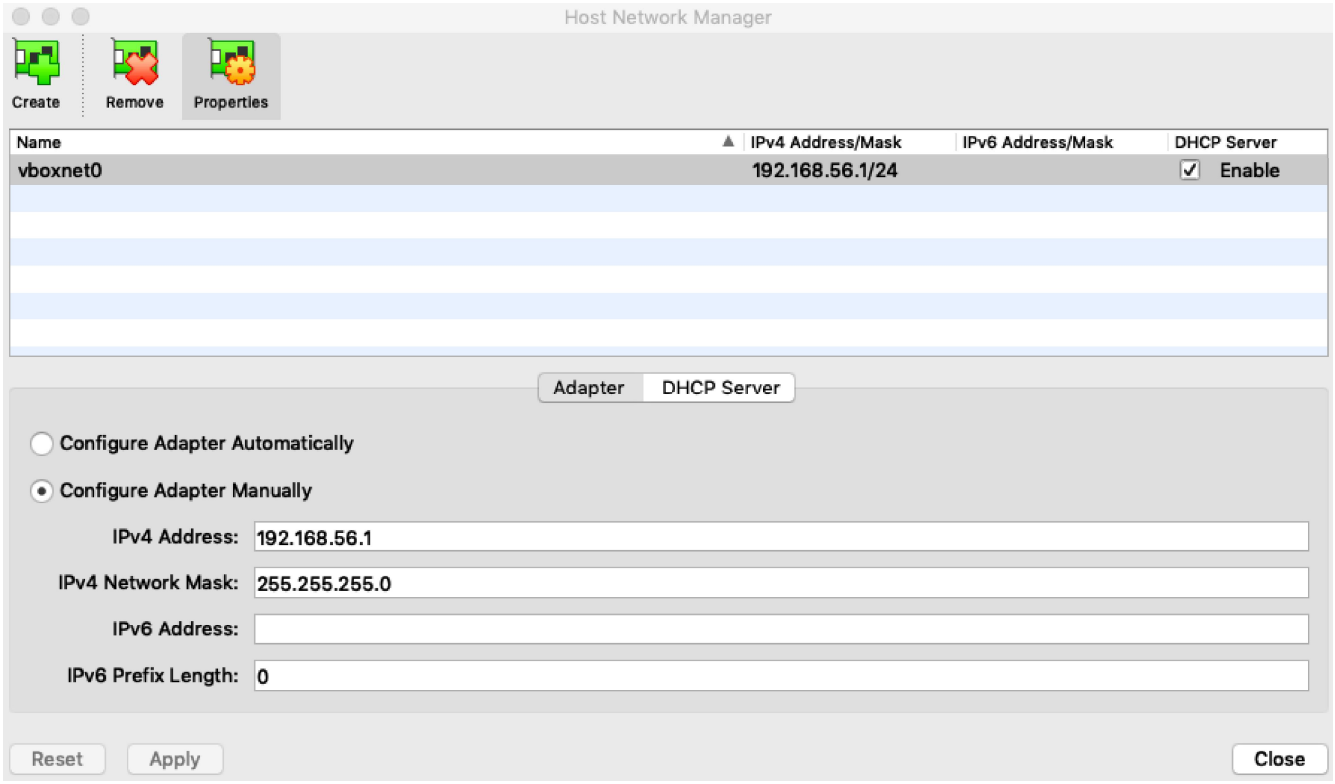


Figure 1.14: Adapter creation for host-only adapter network mode on virtual box macOS release

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.

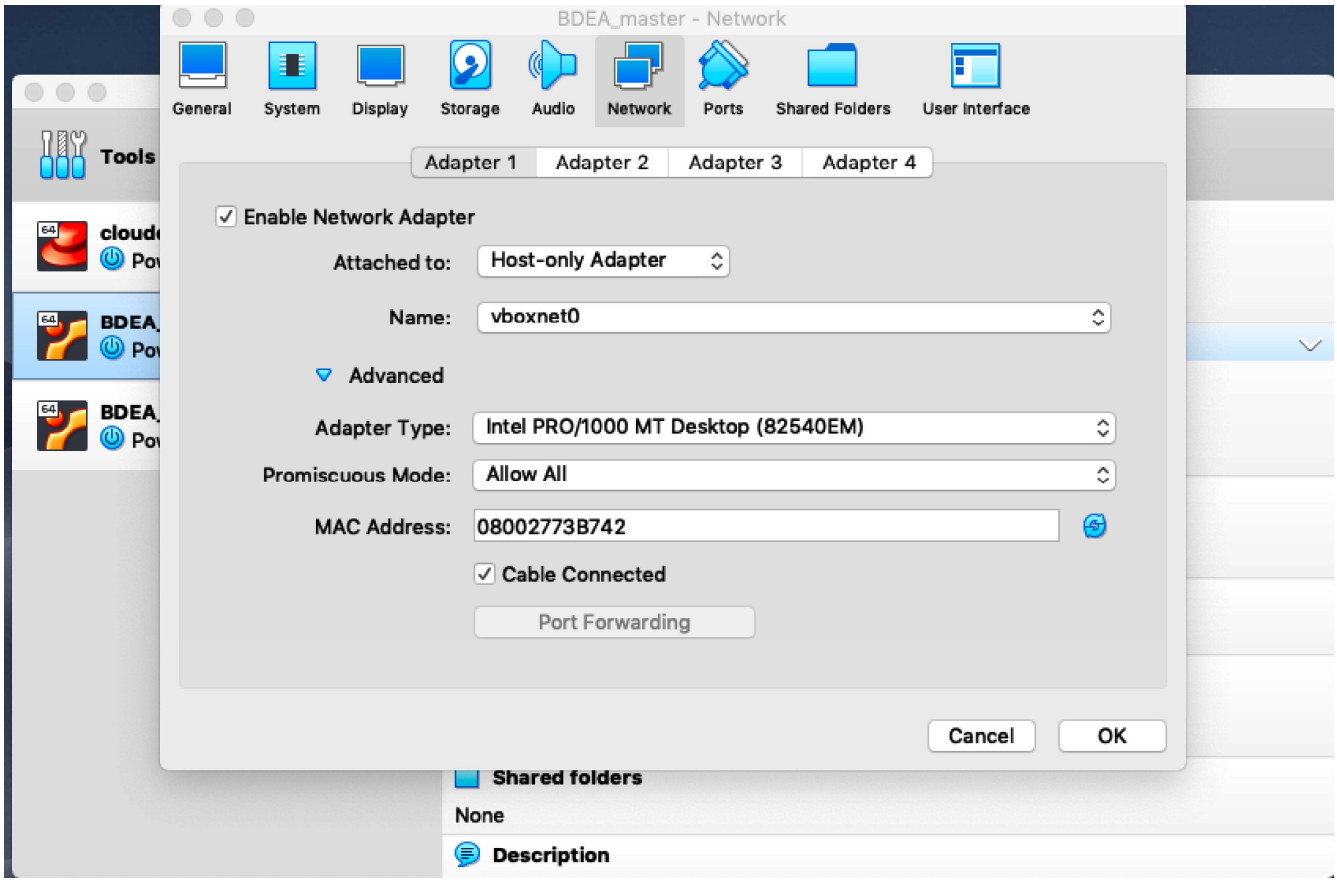


Figure 1.15: Selecting host-only adapter network mode for VMs on virtual box macOS release

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.

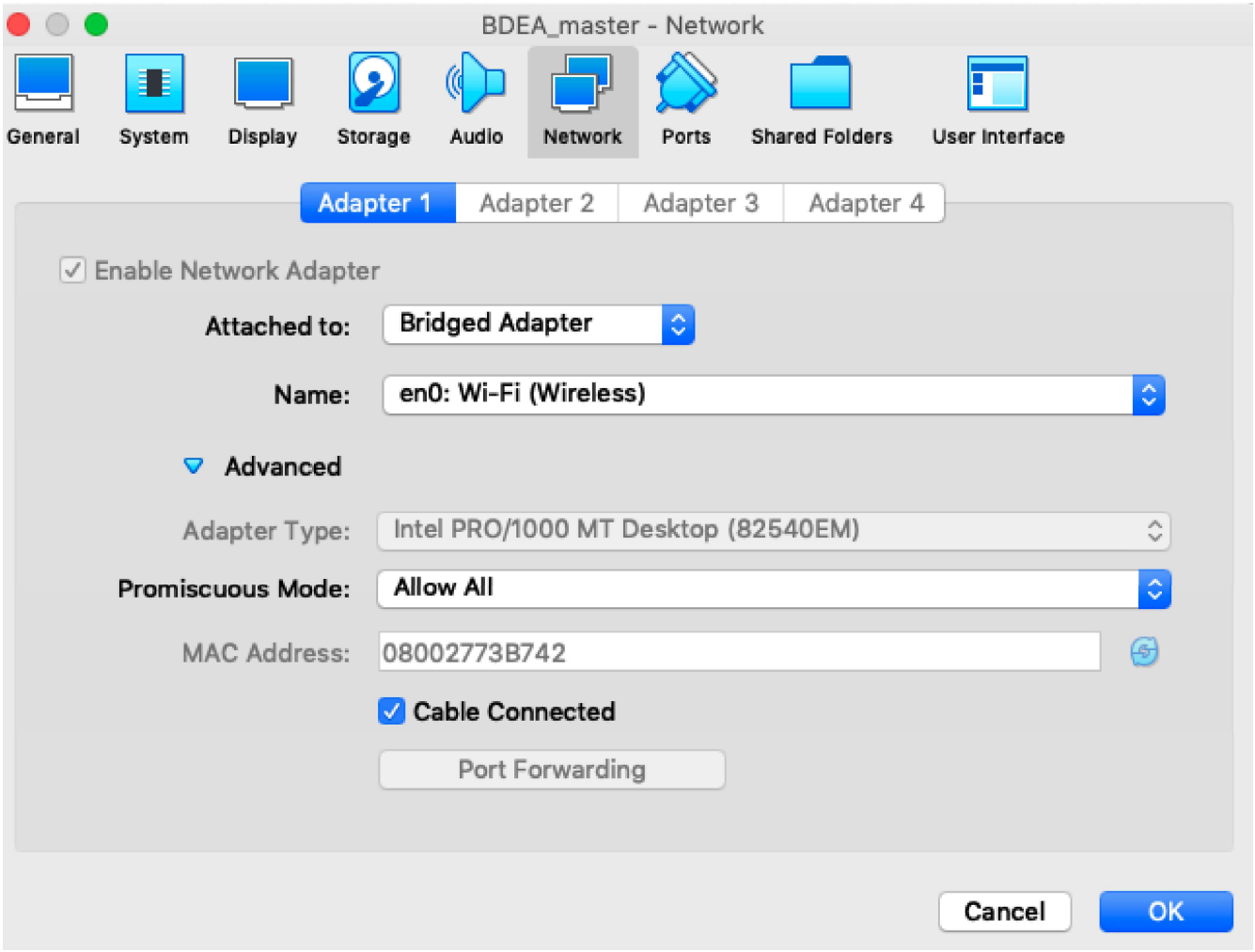


Figure 1.16: Selecting Bridged adapter network mode for VMs on virtual box macOS release

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

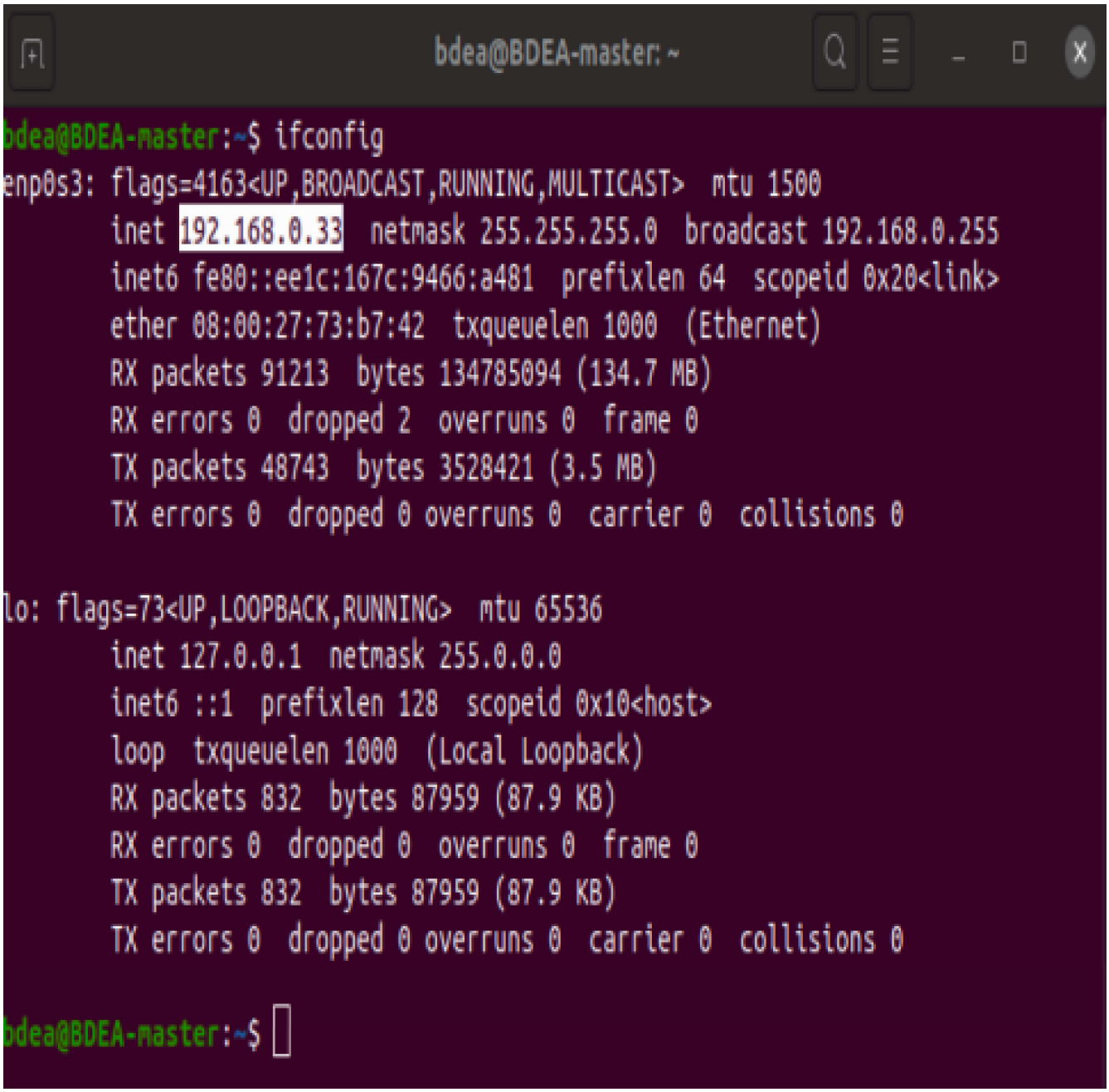


Figure 1.17: Selecting Bridged adapter network mode for VMs on virtual box macOS release

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

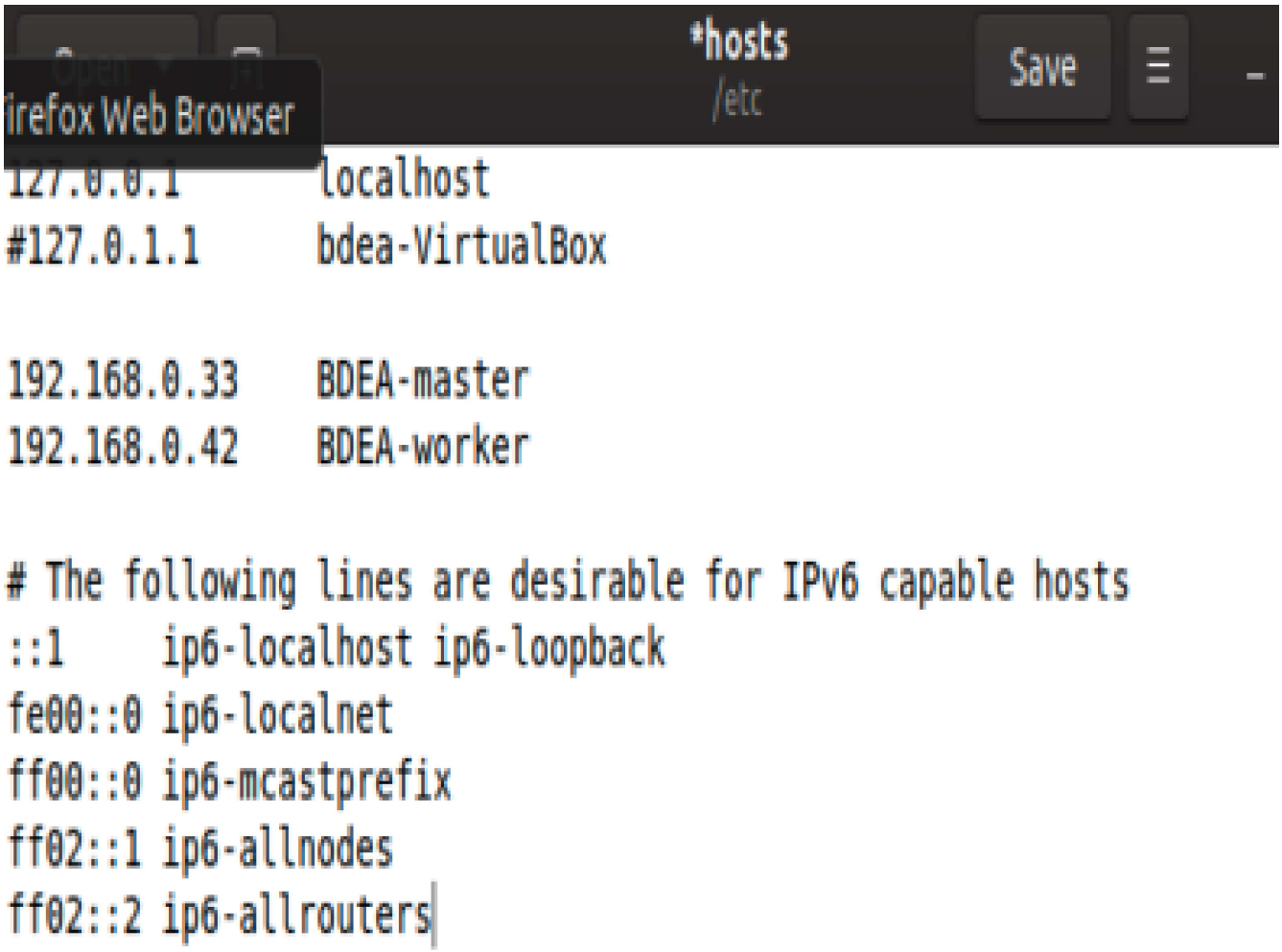


Figure 1.18: final version of /etc/hosts file for Hadoop cluster nodes

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.

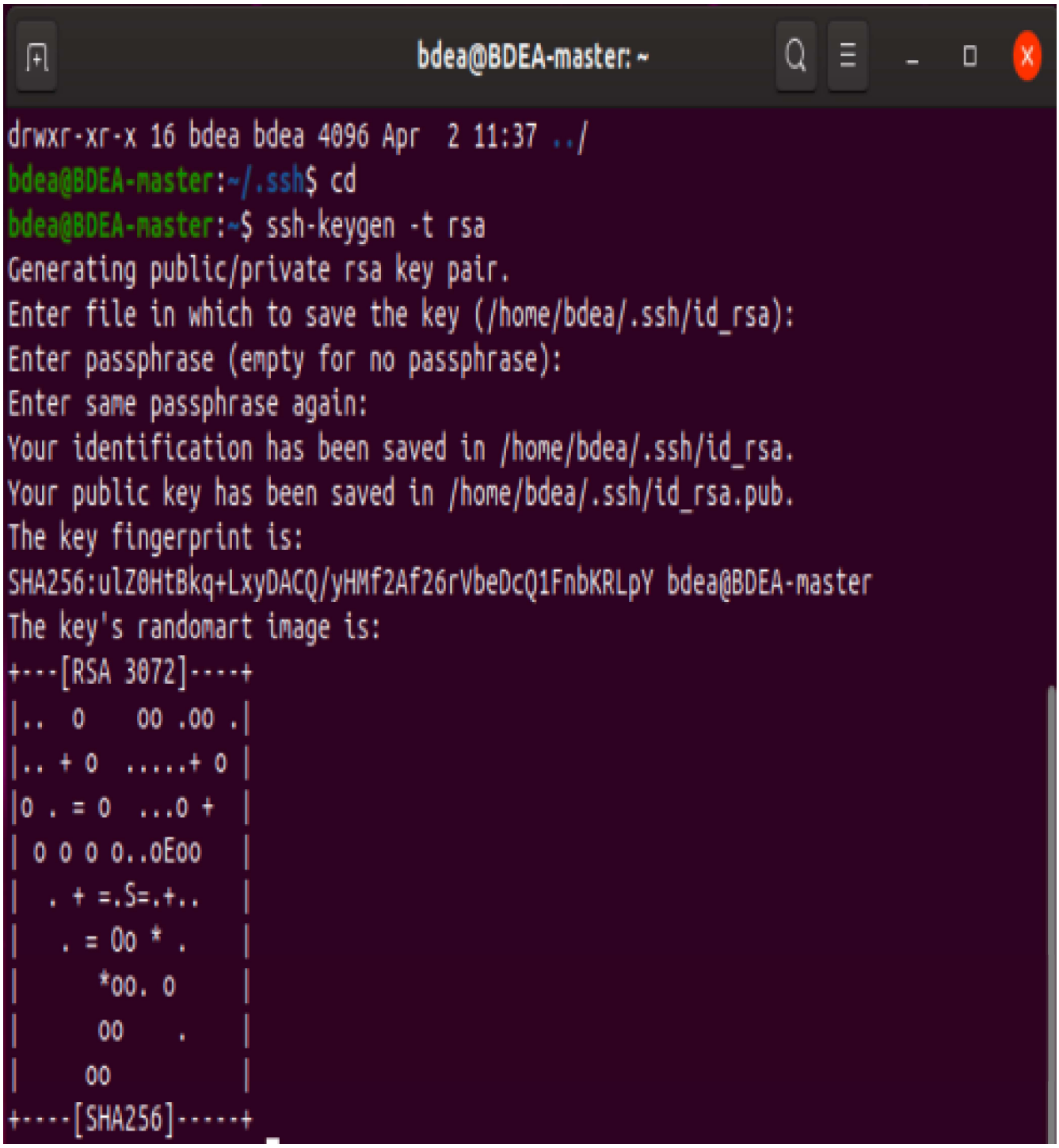


Figure 1.19: SSH key generation

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.

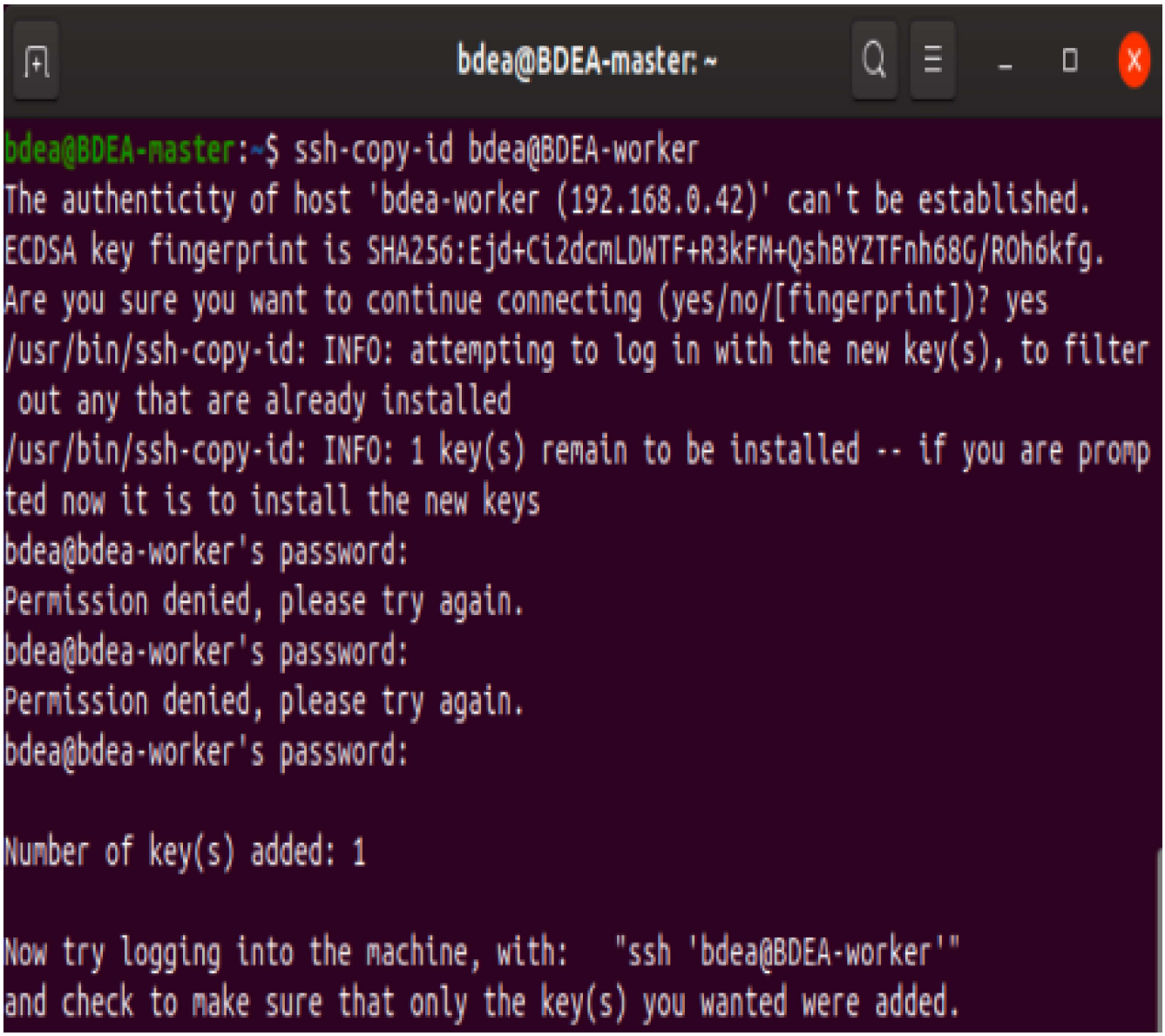


Figure 1.20: copying SSH key pairs to remote servers

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.

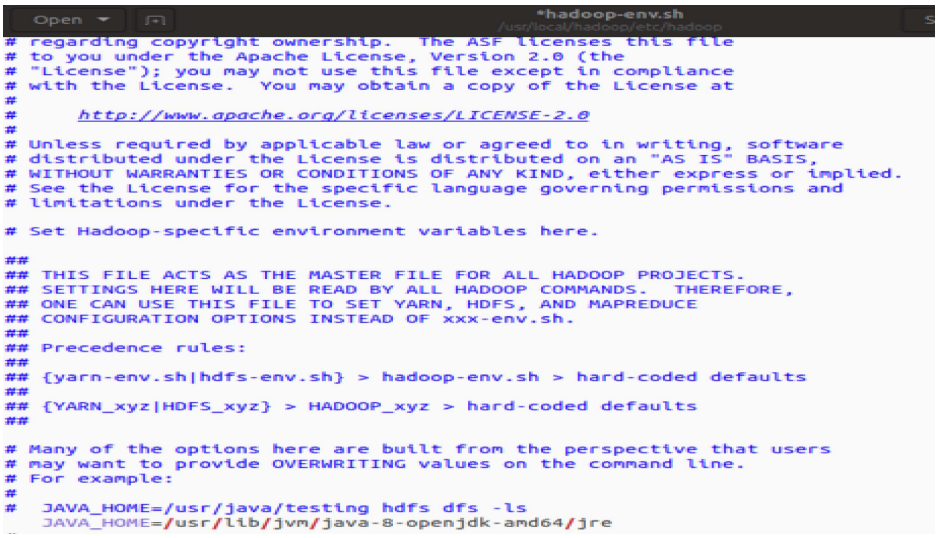


Figure 1.22: final version of hadoop-env.sh file

,

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.

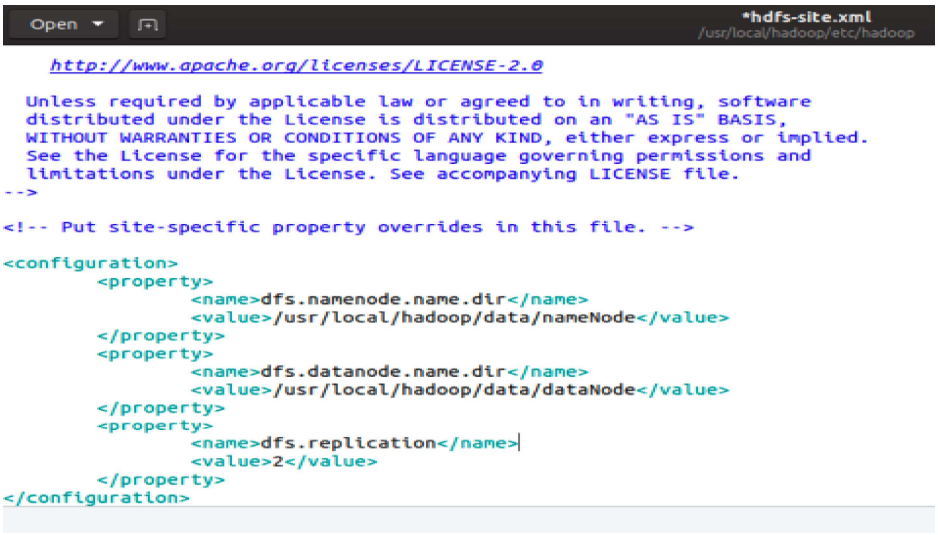


Figure 1.24: final version of core-site.xml file

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'.

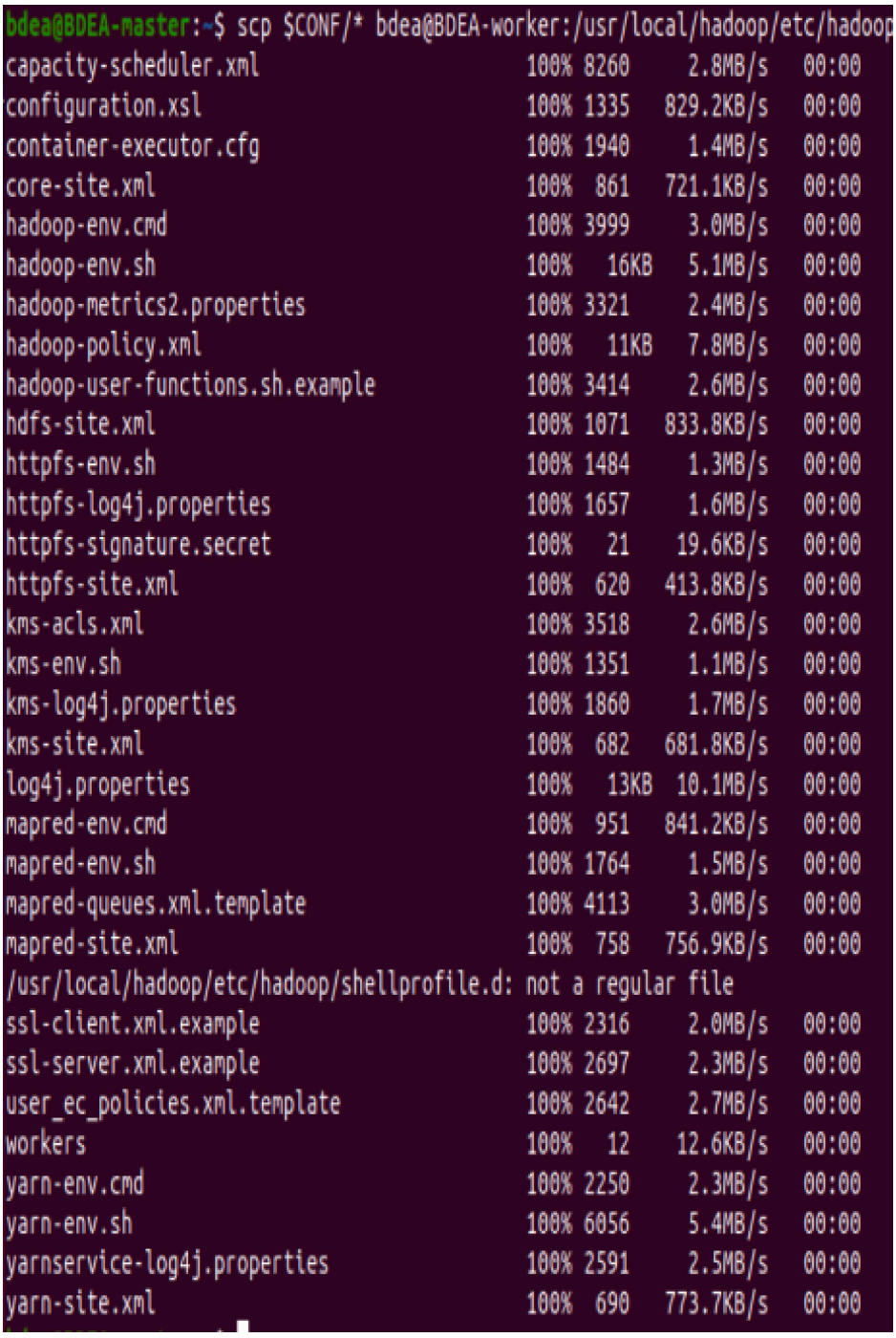


Figure 1.26: Copying files from localhost to remote servers via SCP

1.5.6 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

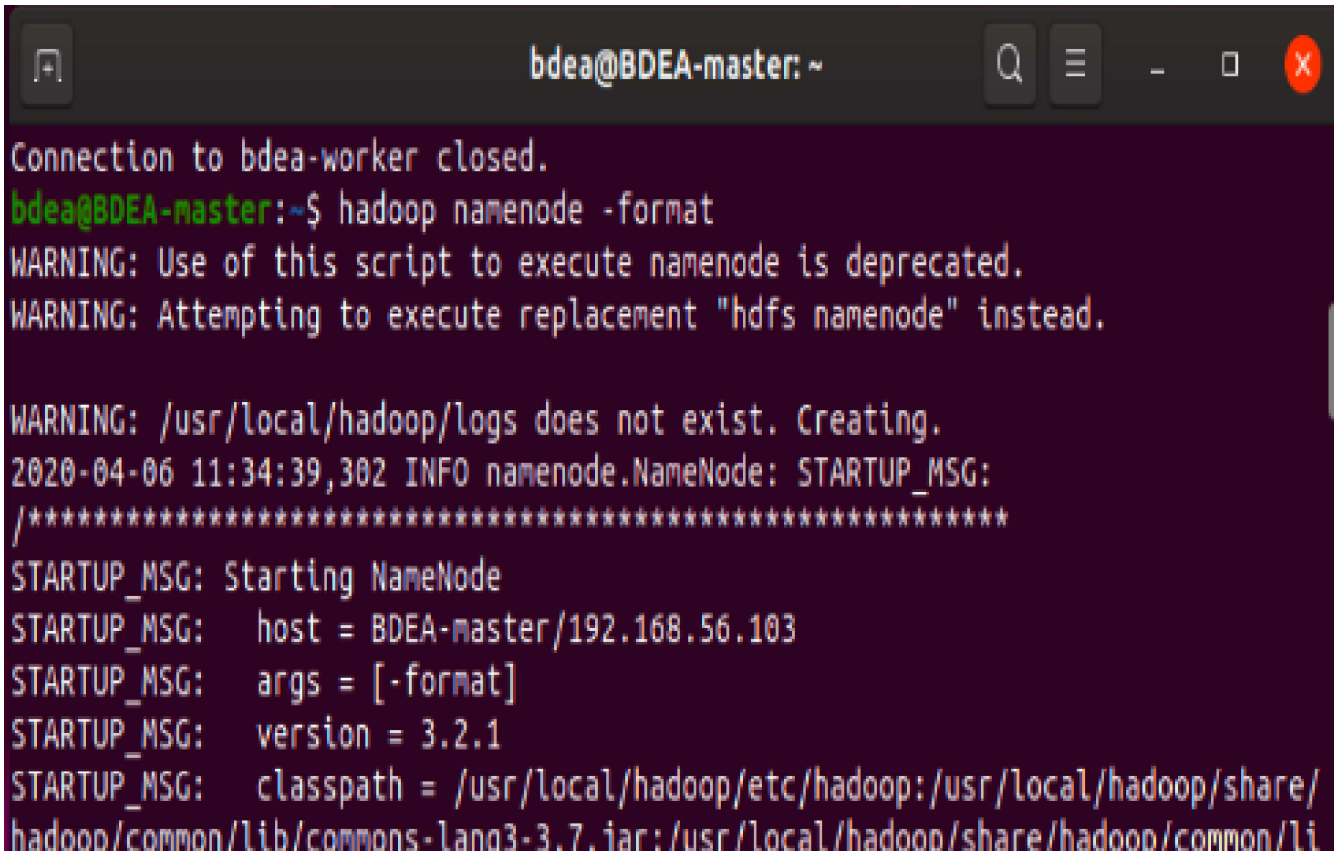
1.6 Starting the hadoop cluster

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

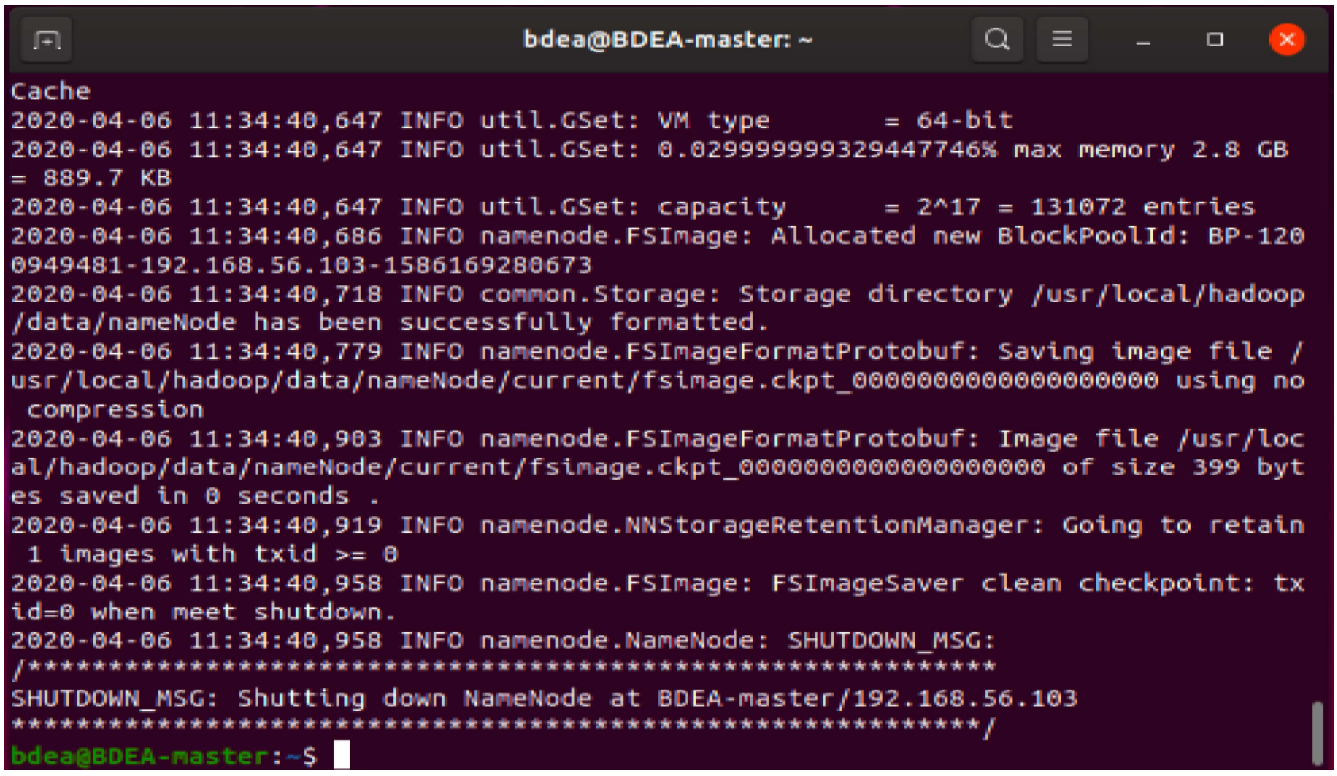
It needs to be ensured that changes made to bash file previously are in effect. If you are unsure, you can always make bashfile the source in the terminal as follows: *source .bashrc*

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?