Project Report

CSE – 5344 Computer Networks

UNIVERSITY OF
TEXAS
ARLINGTON

Project: **Network Environment Simulation**
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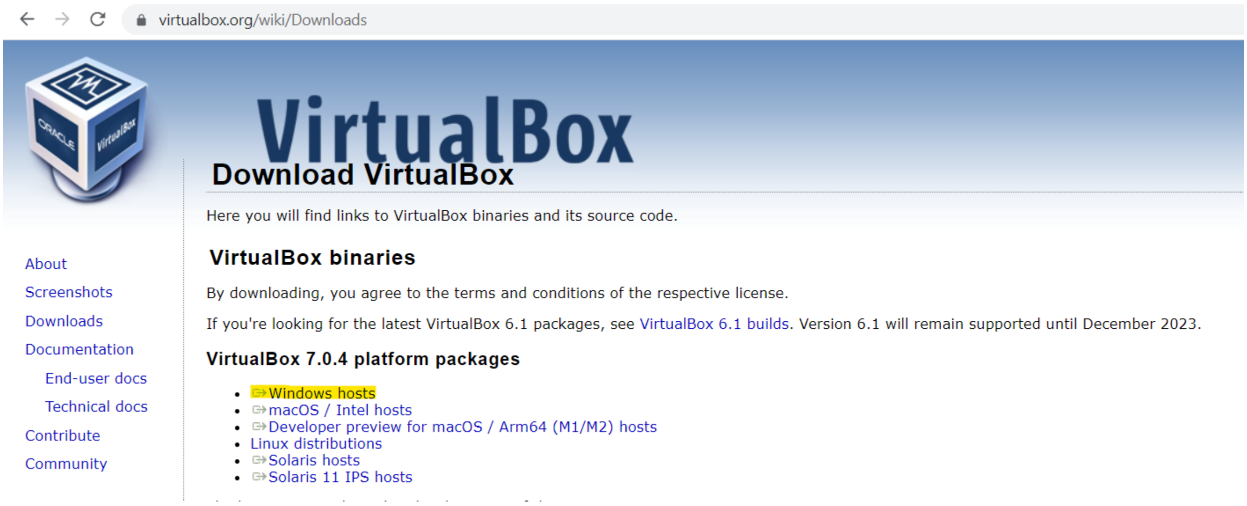
OBJECTIVE

Build a simple topology by ns-3. You need to write a script file by c. You will use ns-3 library. This is a very useful simulation tool which support all kinds of networks and network device, not just fabric and host, but also wifi and SDN-enable switches.

Installation Steps

Installation of ns-3 in Ubuntu:

Step 1: Download and install VirtualBox via https://www.virtualbox.org/



virtualbox.org/wiki/Downloads

Download VirtualBox

Here you will find links to VirtualBox binaries and its source code.

VirtualBox binaries

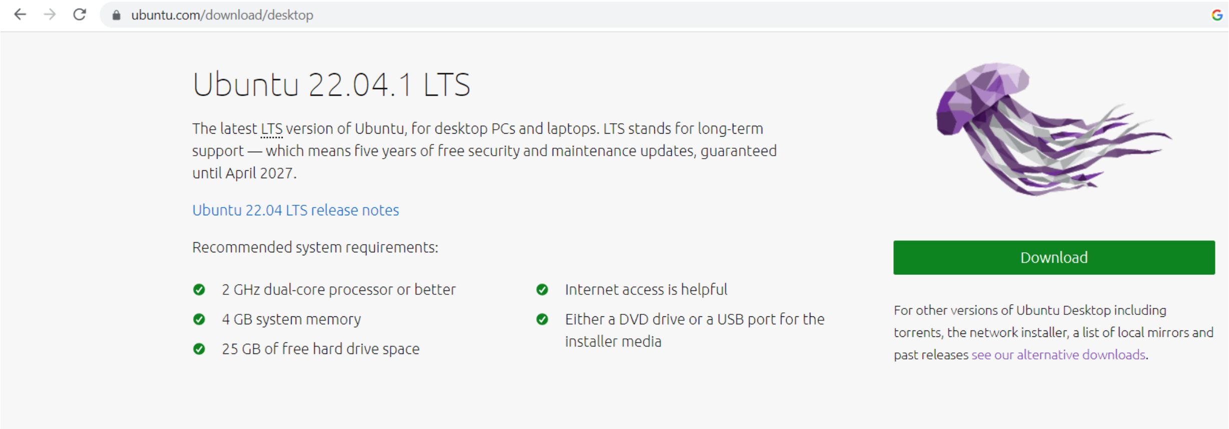
By downloading, you agree to the terms and conditions of the respective license.

If you're looking for the latest VirtualBox 6.1 packages, see VirtualBox 6.1 builds. Version 6.1 will remain supported until December 2023.

VirtualBox 7.0.4 platform packages

- Windows hosts
- macOS / Intel hosts
- Developer preview for macOS / Arm64 (M1/M2) hosts
- Linux distributions
- Solaris hosts
- Solaris 11 IPS hosts

Step 2: Download Ubuntu via https://ubuntu.com/download/desktop



ubuntu.com/download/desktop

Ubuntu 22.04.1 LTS

The latest LTS version of Ubuntu, for desktop PCs and laptops. LTS stands for long-term support — which means five years of free security and maintenance updates, guaranteed until April 2027.

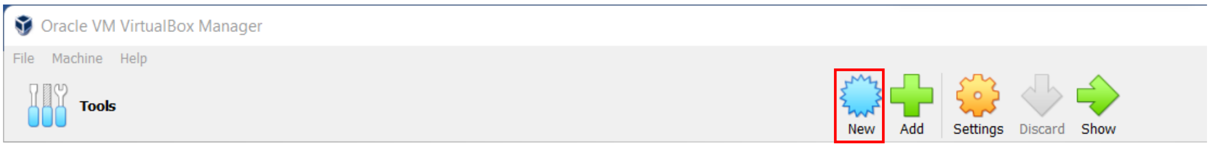
Ubuntu 22.04 LTS release notes

Recommended system requirements:

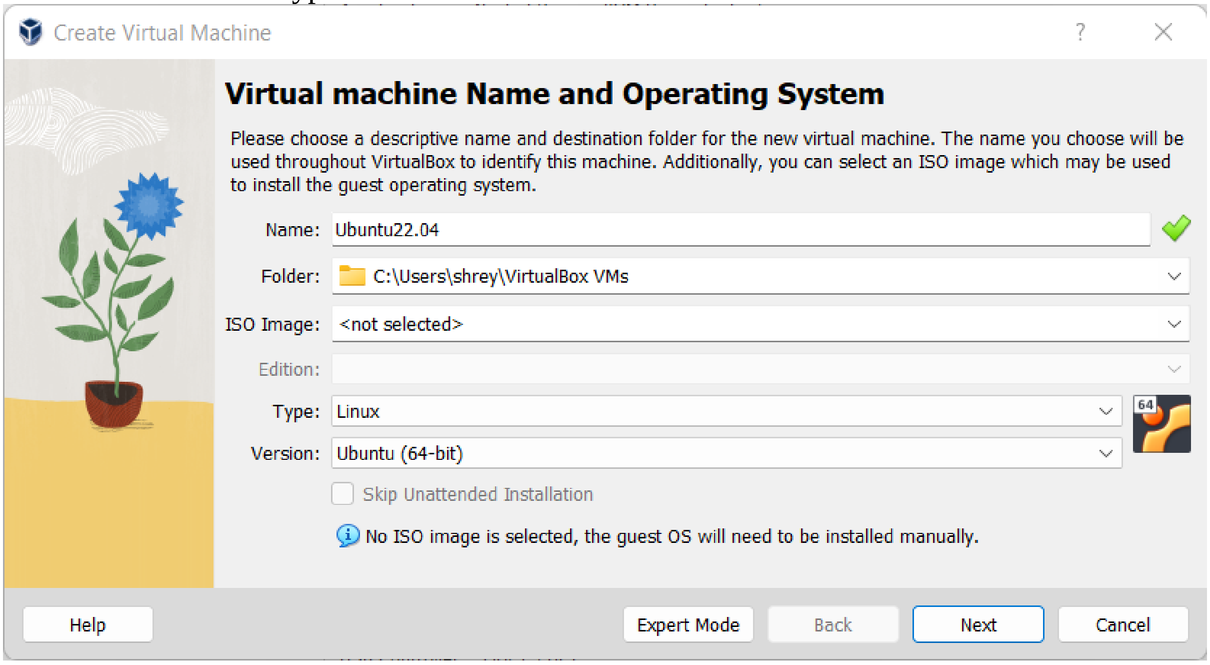
- 2 GHz dual-core processor or better
- 4 GB system memory
- 25 GB of free hard drive space
- Internet access is helpful
- Either a DVD drive or a USB port for the installer media

For other versions of Ubuntu Desktop including torrents, the network installer, a list of local mirrors and past releases see our alternative downloads.

Step 3: Create New Virtual Machine Instance



Step 4: Name your virtual machine, choose a folder your file would be stored. Select Linux and Ubuntu-64bit as Type and Version. Then click Next



Virtual machine Name and Operating System

Please choose a descriptive name and destination folder for the new virtual machine. The name you choose will be used throughout VirtualBox to identify this machine. Additionally, you can select an ISO image which may be used to install the guest operating system.

Name: Ubuntu22.04

Folder: C:\Users\shrey\VirtualBox VMs

ISO Image: <not selected>

Edition:

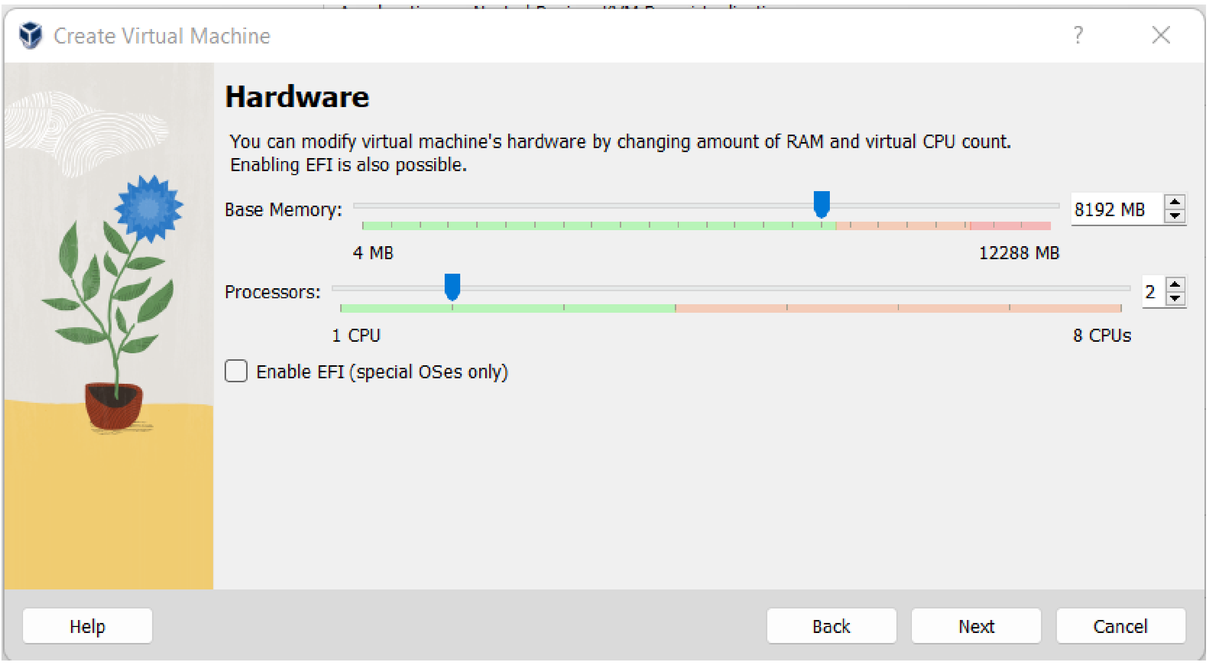
Type: Linux

Version: Ubuntu (64-bit)

□ Skip Unattended Installation

No ISO image is selected, the guest OS will need to be installed manually.

Select appropriate Base Memory and Processors and click Next again



Hardware

You can modify virtual machine's hardware by changing amount of RAM and virtual CPU count. Enabling EFI is also possible.

Base Memory: 8192 MB

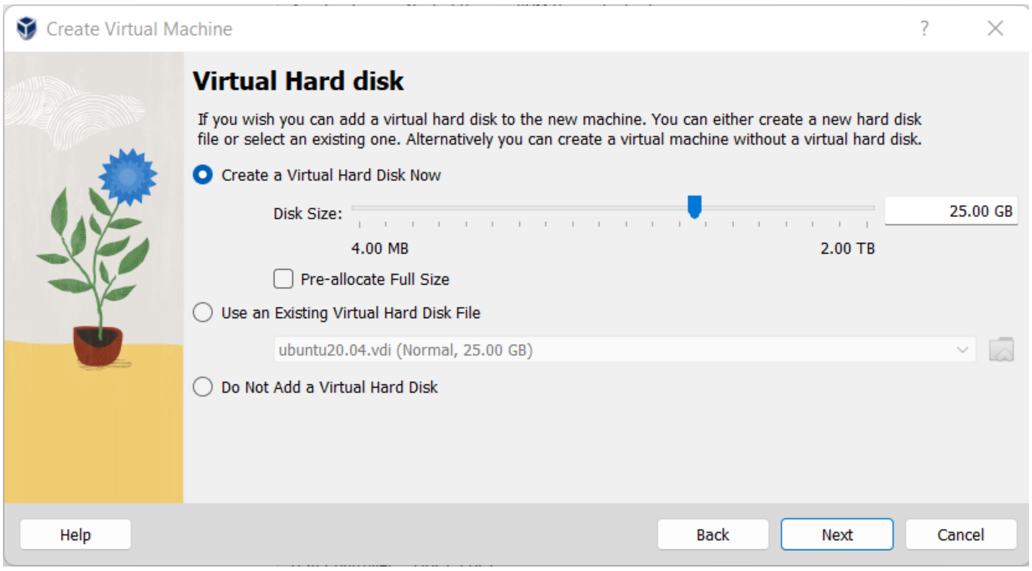
4 MB 12288 MB

Processors: 2

1 CPU 8 CPUs

□ Enable EFI (special OSes only)

Click Next



Virtual Hard disk

If you wish you can add a virtual hard disk to the new machine. You can either create a new hard disk file or select an existing one. Alternatively you can create a virtual machine without a virtual hard disk.

● Create a Virtual Hard Disk Now

Disk Size: 25.00 GB

4.00 MB 2.00 TB

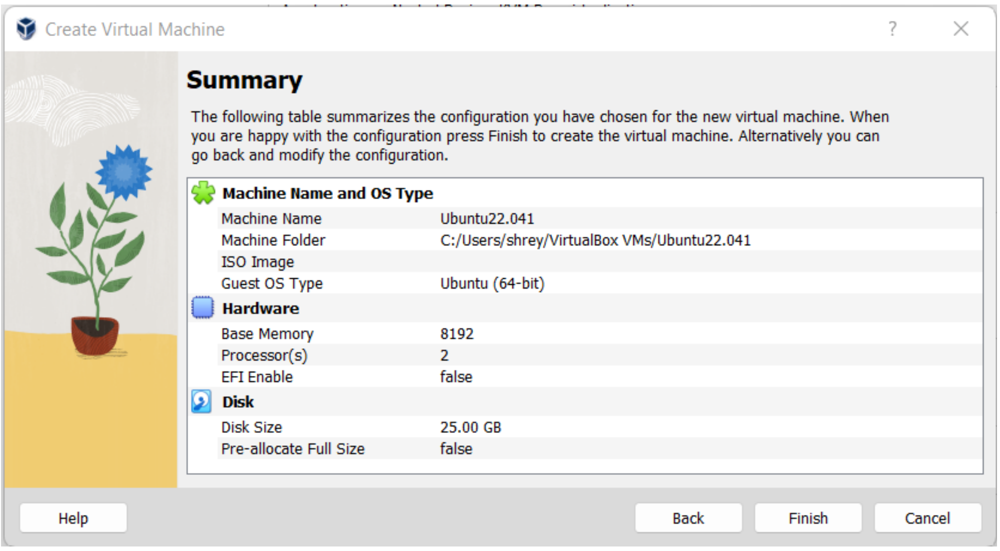
□ Pre-allocate Full Size

○ Use an Existing Virtual Hard Disk File

ubuntu20.04.vdi (Normal, 25.00 GB)

○ Do Not Add a Virtual Hard Disk

Click Finish

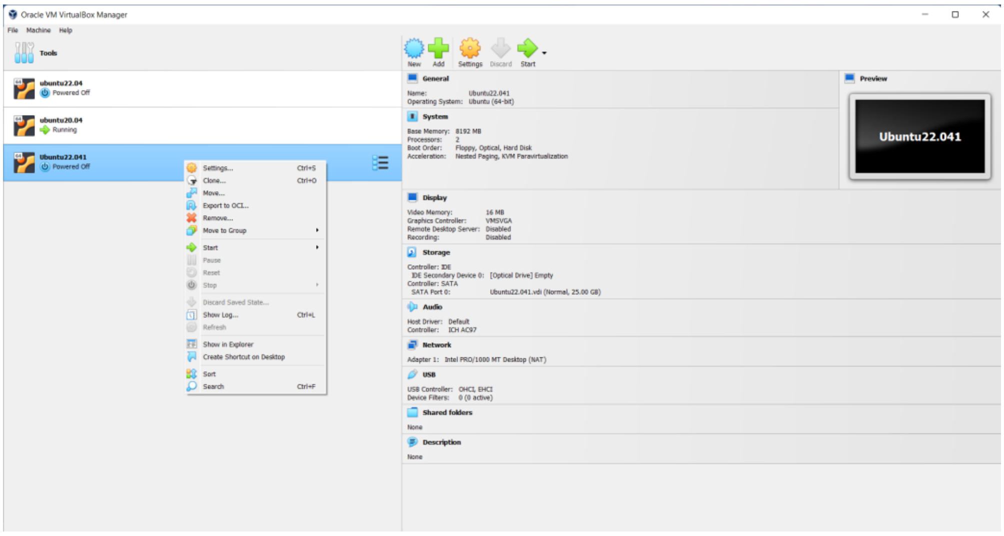


Summary

The following table summarizes the configuration you have chosen for the new virtual machine. When you are happy with the configuration press Finish to create the virtual machine. Alternatively you can go back and modify the configuration.

Machine Name and OS Type	
Machine Name	Ubuntu22.041
Machine Folder	C:/Users/shrey/VirtualBox VMs/Ubuntu22.041
ISO Image	
Guest OS Type	Ubuntu (64-bit)
Hardware	
Base Memory	8192
Processor(s)	2
EFI Enable	false
Disk	
Disk Size	25.00 GB
Pre-allocate Full Size	false

Step 5: Right Click on the Virtual Machine created and click on Settings



ubuntu22.04
Powered Off

ubuntu20.04
Running

Ubuntu22.041
Powered Off

General

Name: Ubuntu22.041
Operating System: Ubuntu (64-bit)

System

Base Memory: 8192 MB
Processors: 2
Boot Order: Floppy, Optical, Hard Disk
Acceleration: Nested Paging, KVM Paravirtualization

Display

Video Memory: 16 MB
Graphics Controller: VMSVGA
Remote Desktop Server: Disabled
Recording: Disabled

Storage

Controller: IDE
IDE Secondary Device 0: [Optical Drive] Empty
Controller: SATA
SATA Port 0: Ubuntu22.041.vdi (Normal, 25.00 GB)

Audio

Host Driver: Default
Controller: ICH AC97

Network

Adapter 1: Intel PRO/1000 MT Desktop (NAT)

USB

USB Controller: OHCI, EHCI
Device Filters: 0 (0 active)

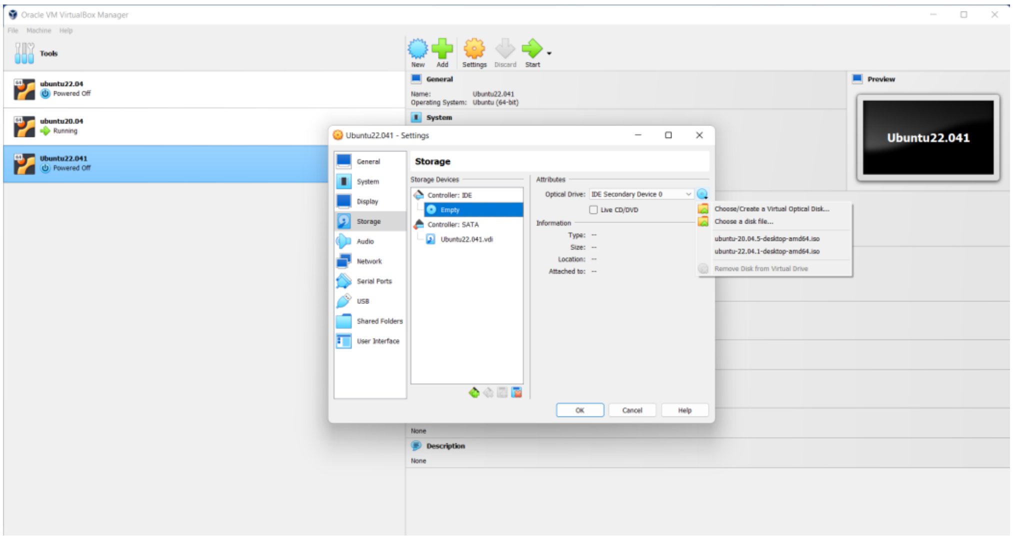
Shared folders

None

Description

None

Step 6: Under Storage, click on the disk and choose downloaded Ubuntu file and click Ok



Name: Ubuntu22.041
Operating System: Ubuntu (64-bit)

Controller: IDE
Empty
Controller: SATA
Ubuntu22.041.vdi

Optical Drive: IDE Secondary Device 0

□ Live CD/DVD

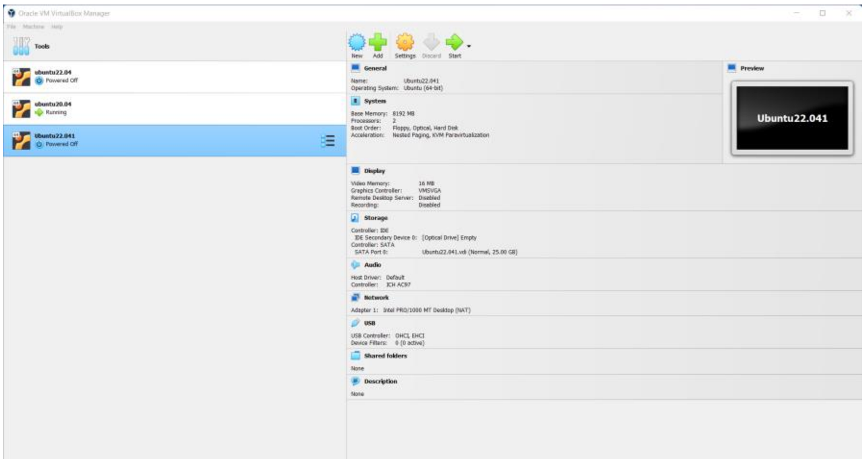
Type: --
Size: --
Location: --
Attached to: --

None

Description

None

Step 7: Select the Virtual Machine you created and click on Start



General

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Base Memory: 8192 MB
Processors: 2
Boot Order: Floppy, Optical, Hard Disk
Acceleration: Nested Paging, KVM Paravirtualization

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IDE Secondary Device 0: [Optical Drive] Empty
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Host Driver: Default
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Network

Adapter 1: Intel PRO/1000 MT Desktop (NAT)

USB

USB Controller: OHCI, EHCI
Device Filters: 0 (0 active)

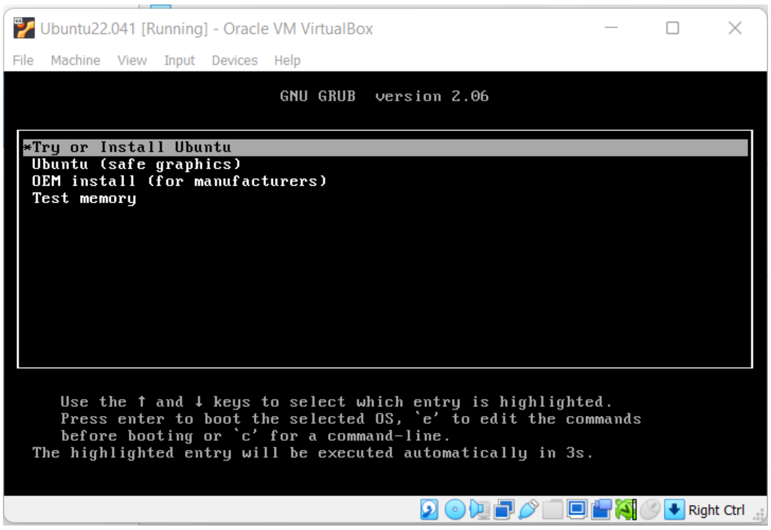
Shared folders

None

Description

None

Step 8: Click on Try and Install Ubuntu


Ubuntu22.041 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Right Ctrl

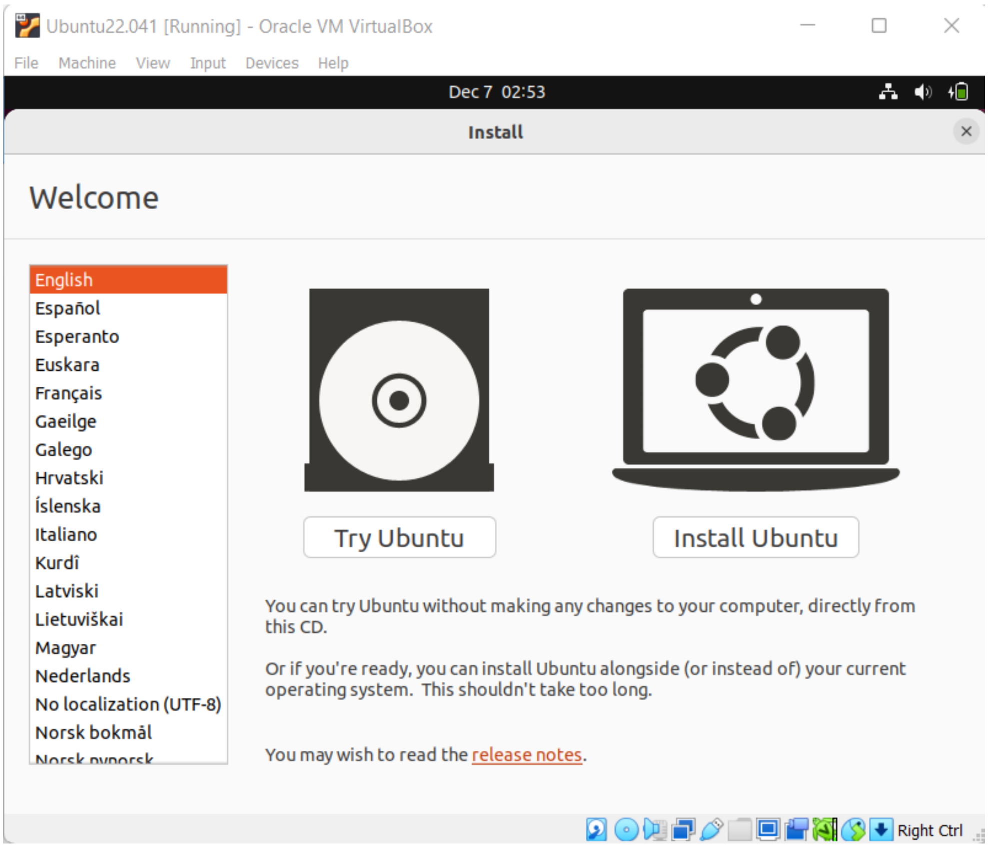
```
                          GNU GRUB  version 2.06

*Try or Install Ubuntu
 Ubuntu (safe graphics)
 OEM install (for manufacturers)
 Test memory




     Use the ↑ and ↓ keys to select which entry is highlighted.
     Press enter to boot the selected OS, `e' to edit the commands
     before booting or `c' for a command-line.
 The highlighted entry will be executed automatically in 3s.
```

Step 9: Click on Install Ubuntu



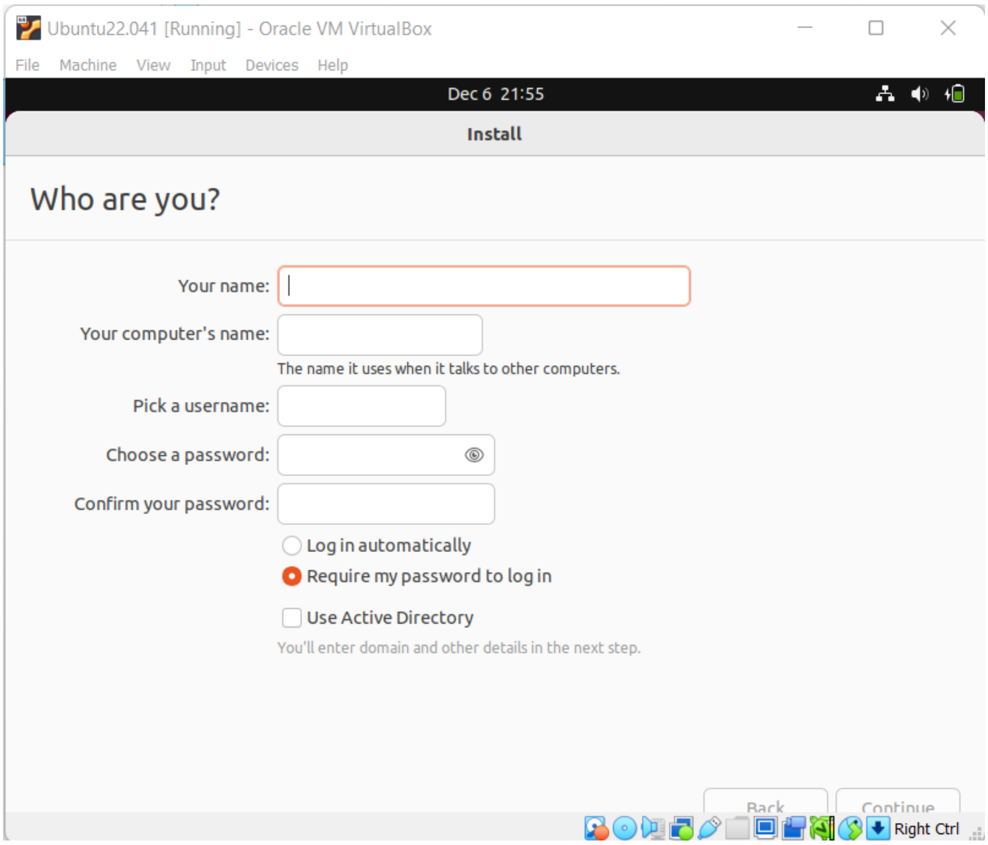
Welcome

You can try Ubuntu without making any changes to your computer, directly from this CD.

Or if you're ready, you can install Ubuntu alongside (or instead of) your current operating system. This shouldn't take too long.

You may wish to read the release notes.

Step 10: Enter the details and click Continue which install ubuntu


Ubuntu22.041 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Dec 6 21:55
Install
Back
Continue
Right Ctrl

Who are you?

Your name:

Your computer's name:

The name it uses when it talks to other computers.

Pick a username:

Choose a password:

Confirm your password:

○ Log in automatically

● Require my password to log in

□ Use Active Directory

You'll enter domain and other details in the next step.

Step 11: Open the Terminal and run following commands to install ns-3 (version is 3.33)

Make sure that you are on the Home Directory

```
cd ~
```

Update the Ubuntu Repo and Existing Applications

```
sudo apt update

sudo apt -y upgrade
```

Install Core Dependencies for Build and Compilation

```
sudo apt install build-essential libsqlite3-dev libboost-all-dev
libssl-dev git python3-setuptools castxml
```

Install Dependencies for NS-3 Python bindings

```
sudo apt install gir1.2-goocanvas-2.0 gir1.2-gtk-3.0
libgirepository1.0-dev python3-dev python3-gi python3-gi-cairo
python3-pip python3-pygraphviz python3-pygccxml
```

Install Dependencies for NS-3

```
sudo apt install g++ pkg-config sqlite3 qt5-default mercurial
ipython3 openmpi-bin openmpi-common openmpi-doc libopenmpi-dev
autoconf cvs bzr unrar gdb valgrind uncrustify doxygen graphviz
imagemagick python3-sphinx dia tcpdump libxml2 libxml2-dev cmake
libc6-dev libc6-dev-i386 libclang-6.0-dev llvm-6.0-dev automake
```

Install Additional Python Packages

```
sudo su
cd
pip3 install kiwi
exit
cd
```

Download and Install NS-3 and NetAnim

```
# download from ns-3 server
wget -c https://www.nsnam.org/releases/ns-allinone-3.33.tar.bz2
# extract tar.bz2
tar -xvjf ns-allinone-3.33.tar.bz2
# go back to home folder
cd

# navigate to ns-3 directory (not the NS-3 all in one)
cd ns-allinone-3.33/ns-3.33/
# Configure the installation
./waf configure --enable-examples
# Build ns-3 installation
./waf
# to check whether installation was a success
./waf --run hello-simulator

# navigate to netanim dir.
cd ns-allinone-3.33/netanim-3.108/
# configure the build
make clean
# compile the build
```

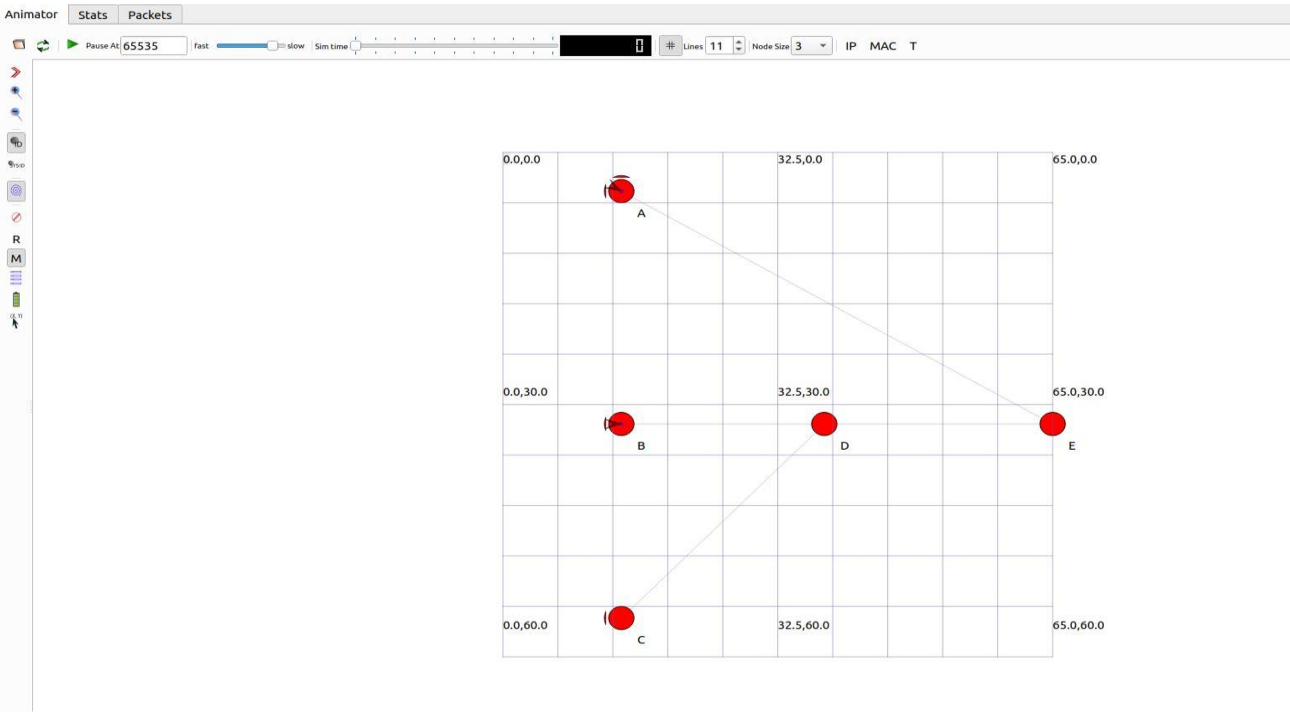
```
qmake NetAnim.pro
# build netanim installation
make
# to execute NetAnim
./NetAnim
```

Code Overview

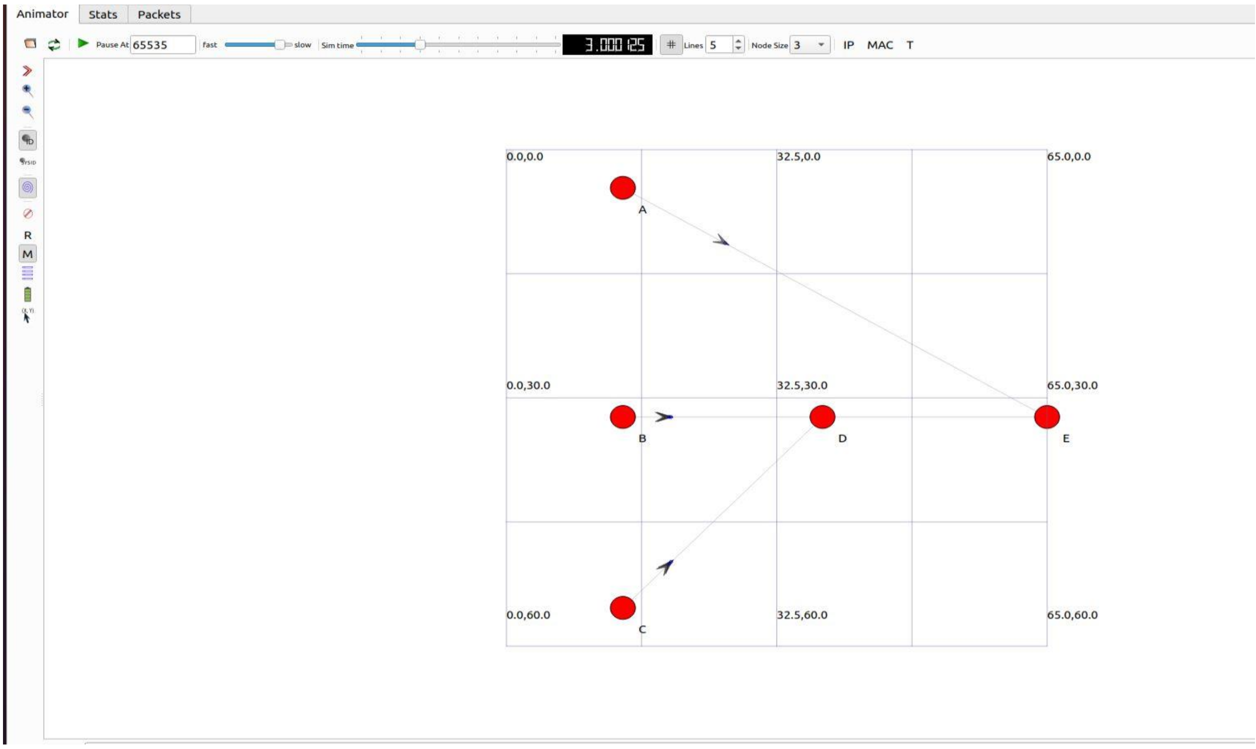
1. Firstly, we create Network Topology
2. Where, we write code to Simulate the Network
3. After that we build topology by generating the nodes and connecting them
4. We assign IPv4 address to each side of the connection
5. Populate the routing table using the helper function provided by ns-3 and apply them to all the nodes
6. We will configure the servers and clients within the topology after topology construction. In ns-3, as a server, we may use sink helper to set a sink on a node at a certain port. Additionally, we will employ flow helpers like bulk send helpers for each client, which create applications using source node IP and destination node IP information together with port numbers to establish connections.
7. We will calculate the throughput
8. We will calculate the average throughput
9. Gnuplot generated to see the visual effect of the throughput

RESULTS

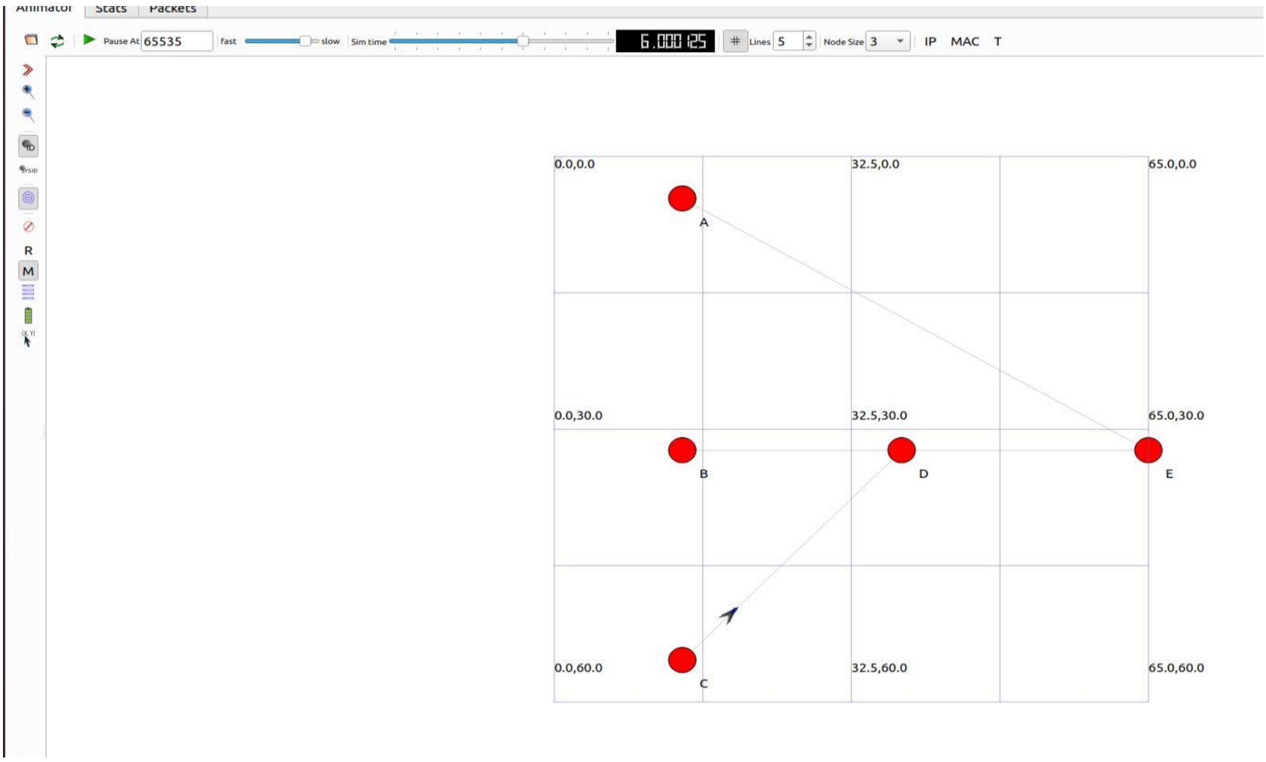
Topology node generated output at 0 second is as follows:



Topology node generated output after 1 second is as follows:

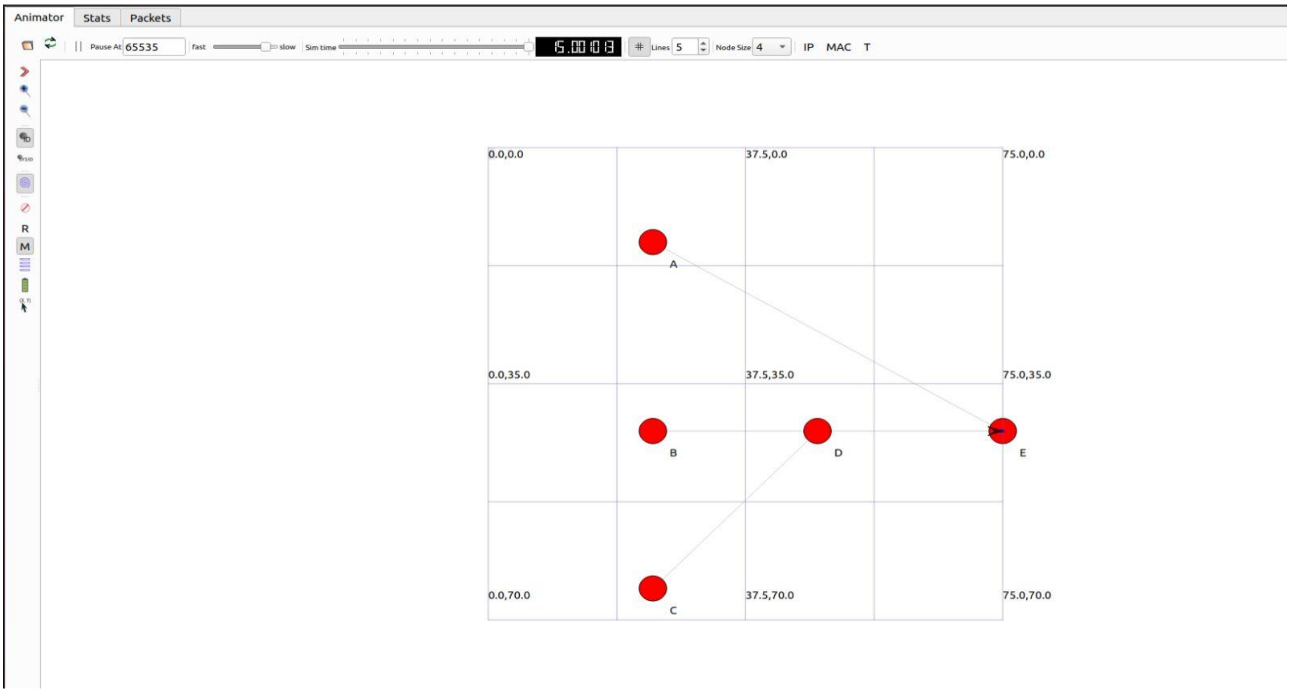


Topology node generated output after 2 second is as follows:



Pause At 65535
Sim time 6.000125
Lines 5
Node Size 3

Topology node generated output after 3 second is as follows:

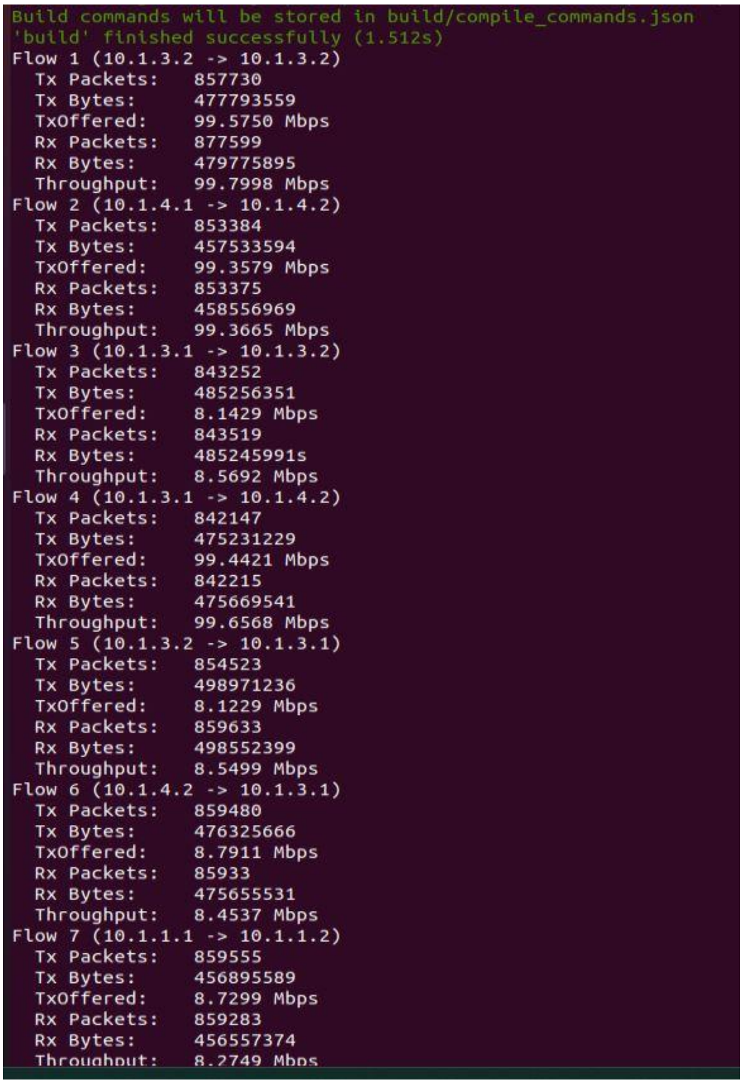


Pause At 65535
Sim time 15.001013
Lines 5
Node Size 4

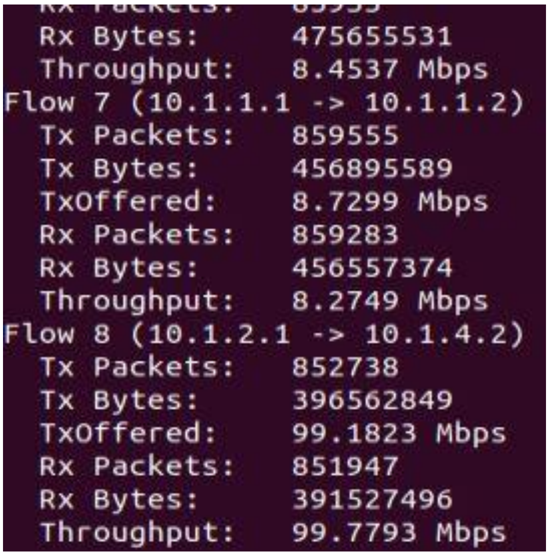
<u>XML file generated</u>: 1001888859_shreyas.xml

<u>META file generated:</u> **1001888859_Meta.data**

Final OUTPUT

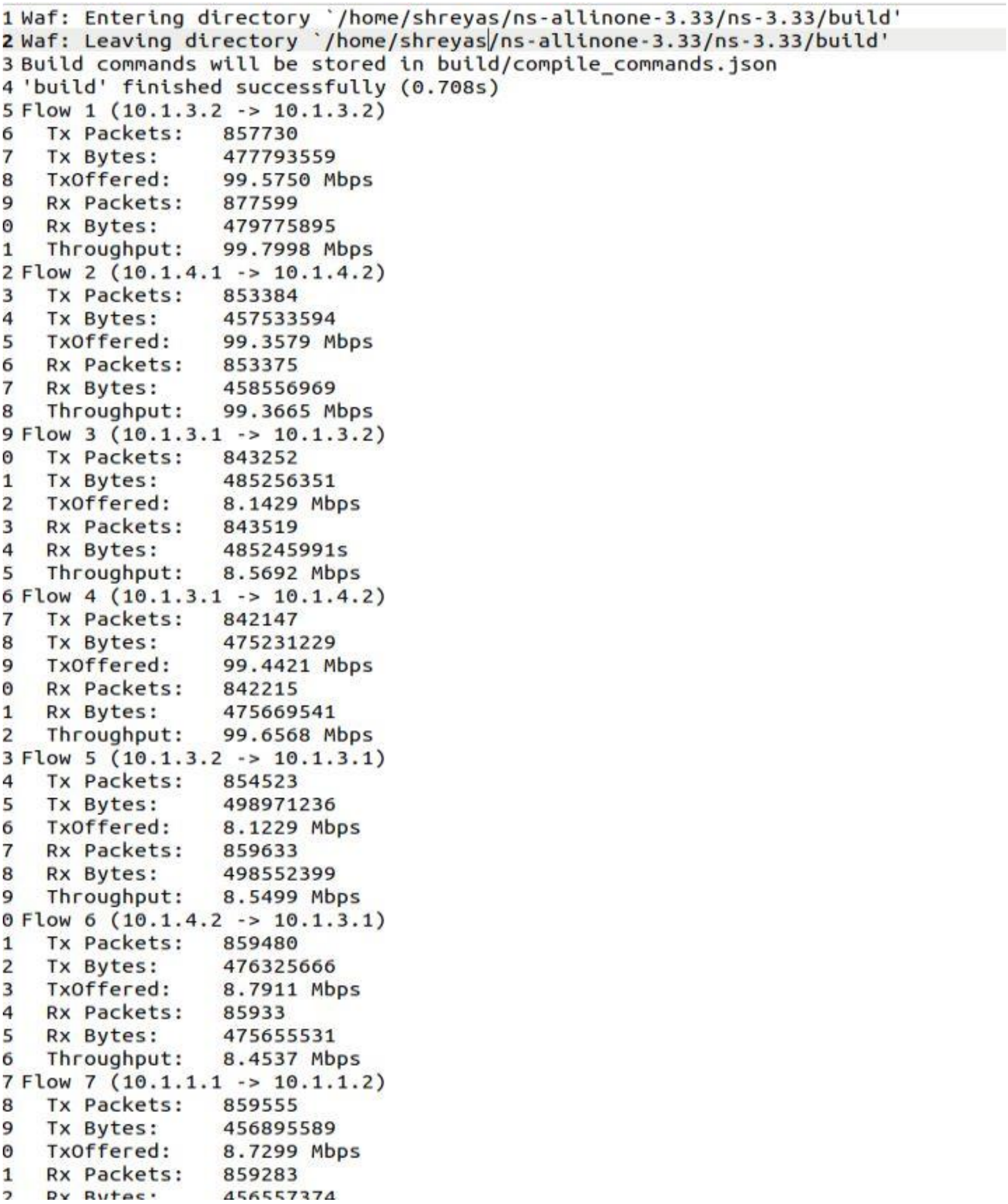


```
Build commands will be stored in build/compile_commands.json
'build' finished successfully (1.512s)
Flow 1 (10.1.3.2 -> 10.1.3.2)
  Tx Packets:   857730
  Tx Bytes:     477793559
  TxOffered:    99.5750 Mbps
  Rx Packets:   877599
  Rx Bytes:     479775895
  Throughput:   99.7998 Mbps
Flow 2 (10.1.4.1 -> 10.1.4.2)
  Tx Packets:   853384
  Tx Bytes:     457533594
  TxOffered:    99.3579 Mbps
  Rx Packets:   853375
  Rx Bytes:     458556969
  Throughput:   99.3665 Mbps
Flow 3 (10.1.3.1 -> 10.1.3.2)
  Tx Packets:   843252
  Tx Bytes:     485256351
  TxOffered:    8.1429 Mbps
  Rx Packets:   843519
  Rx Bytes:     485245991s
  Throughput:   8.5692 Mbps
Flow 4 (10.1.3.1 -> 10.1.4.2)
  Tx Packets:   842147
  Tx Bytes:     475231229
  TxOffered:    99.4421 Mbps
  Rx Packets:   842215
  Rx Bytes:     475669541
  Throughput:   99.6568 Mbps
Flow 5 (10.1.3.2 -> 10.1.3.1)
  Tx Packets:   854523
  Tx Bytes:     498971236
  TxOffered:    8.1229 Mbps
  Rx Packets:   859633
  Rx Bytes:     498552399
  Throughput:   8.5499 Mbps
Flow 6 (10.1.4.2 -> 10.1.3.1)
  Tx Packets:   859480
  Tx Bytes:     476325666
  TxOffered:    8.7911 Mbps
  Rx Packets:   85933
  Rx Bytes:     475655531
  Throughput:   8.4537 Mbps
Flow 7 (10.1.1.1 -> 10.1.1.2)
  Tx Packets:   859555
  Tx Bytes:     456895589
  TxOffered:    8.7299 Mbps
  Rx Packets:   859283
  Rx Bytes:     456557374
  Throughput:   8.2749 Mbps
```



```
  Rx Packets:   85933
  Rx Bytes:     475655531
  Throughput:   8.4537 Mbps
Flow 7 (10.1.1.1 -> 10.1.1.2)
  Tx Packets:   859555
  Tx Bytes:     456895589
  TxOffered:    8.7299 Mbps
  Rx Packets:   859283
  Rx Bytes:     456557374
  Throughput:   8.2749 Mbps
```

```
Flow 8 (10.1.2.1 -> 10.1.4.2)
  Tx Packets:   852738
  Tx Bytes:     396562849
  TxOffered:    99.1823 Mbps
  Rx Packets:   851947
  Rx Bytes:     391527496
  Throughput:   99.7793 Mbps
```



```
Waf: Entering directory `/home/shreyas/ns-allinone-3.33/ns-3.33/build'
Waf: Leaving directory `/home/shreyas/ns-allinone-3.33/ns-3.33/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (0.708s)
Flow 1 (10.1.3.2 -> 10.1.3.2)
  Tx Packets:   857730
  Tx Bytes:     477793559
  TxOffered:    99.5750 Mbps
  Rx Packets:   877599
  Rx Bytes:     479775895
  Throughput:   99.7998 Mbps
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  Rx Bytes:     458556969
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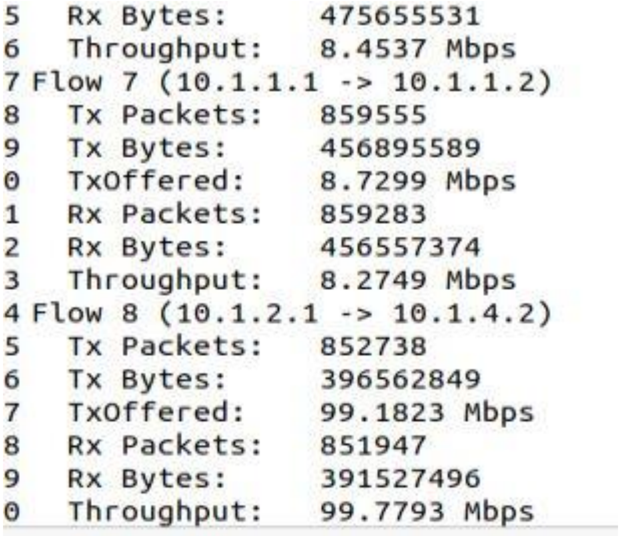
  Tx Packets:   859555
  Tx Bytes:     456895589
  TxOffered:    8.7299 Mbps
  Rx Packets:   859283
  Rx Bytes:     456557374
```



```
  Rx Bytes:     475655531
  Throughput:   8.4537 Mbps
Flow 7 (10.1.1.1 -> 10.1.1.2)
  Tx Packets:   859555
  Tx Bytes:     456895589
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  Rx Packets:   859283
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  Throughput:   8.2749 Mbps
Flow 8 (10.1.2.1 -> 10.1.4.2)
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  Rx Packets:   851947
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References

1. https://www.nsnam.org/docs/release/3.28/doxygen/tcp-pacing_8cc_source.html
2. https://groups.google.com/g/ns-3-users/c/lVYMLGy1TKU?pli=1
3. https://www.nsnam.org/docs/doxygen-bak/first_8cc_source.html
4. https://www.nsnam.org/docs/release/3.18/doxygen/first_8cc_source.html
5. https://www.nsnam.org/docs/release/3.7/tutorial/tutorial_18.html
6. https://www.nsnam.org/docs/tutorial/html/building-topologies.html
7. https://groups.google.com/g/ns-3-users/c/VoEDC1IqoEk/m/B3lmZPCrI_MJ
8. https://www.nsnam.org/docs/models/html/flow-monitor.html
9. https://coe.northeastern.edu/Research/krclab/crens3-doc/flow-monitor_8cc_source.html
10. https://www.youtube.com/watch?v=timruVmsOxI