Northeastern University

EECE5155: Wireless Sensor Networks and the Internet of Things
Laboratory Assignment 3 Report

Author:

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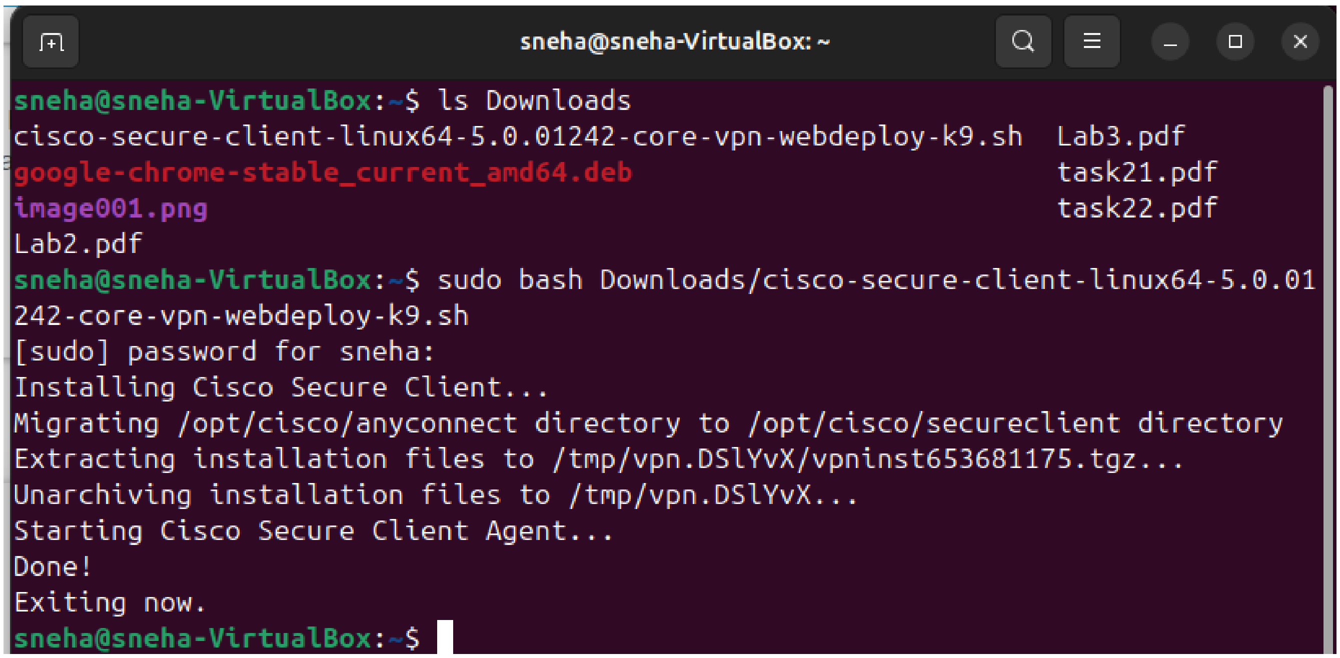
Part 1: Connect to Colosseum

A. Experimental setup

1. Connect to Colosseum VPN:

a. Follow the instructions provided in the [Cisco AnyConnect VPN setup guide] to establish a secure connection.

b. This is how I set up the Cisco AnyConnect VPN in my virtual box machine.



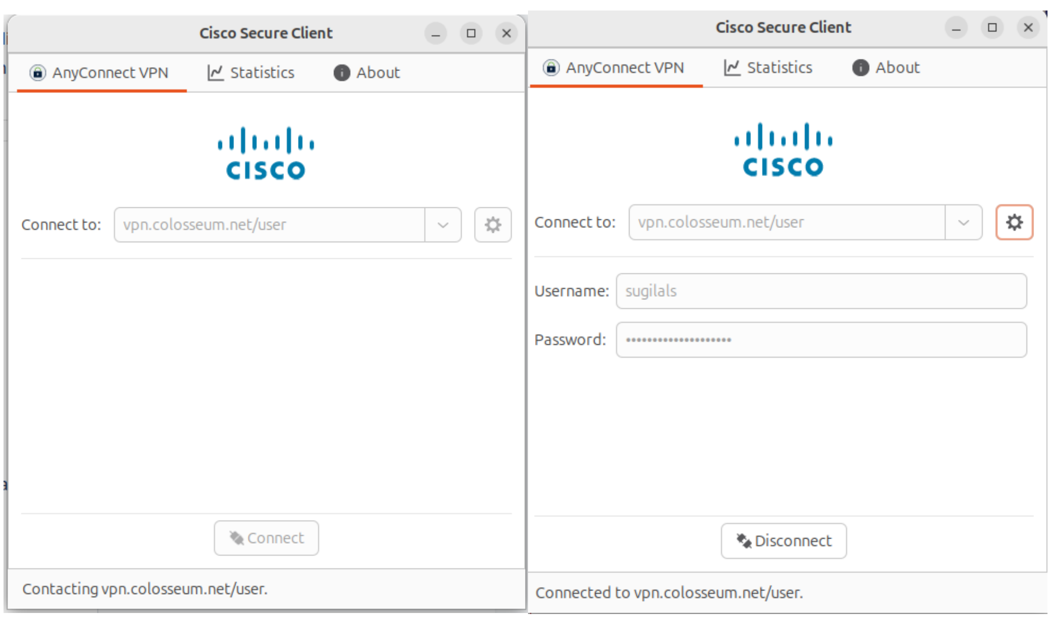
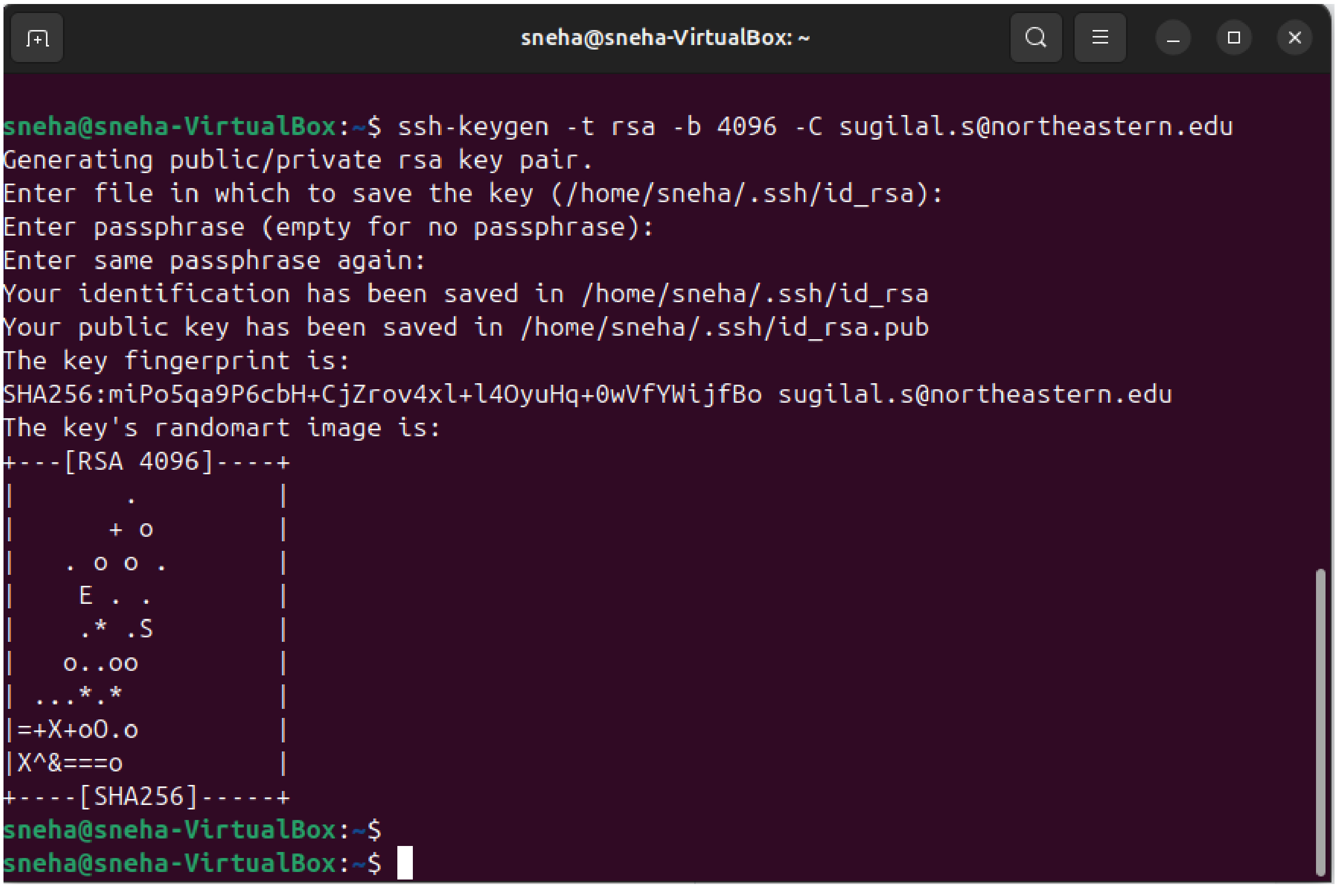
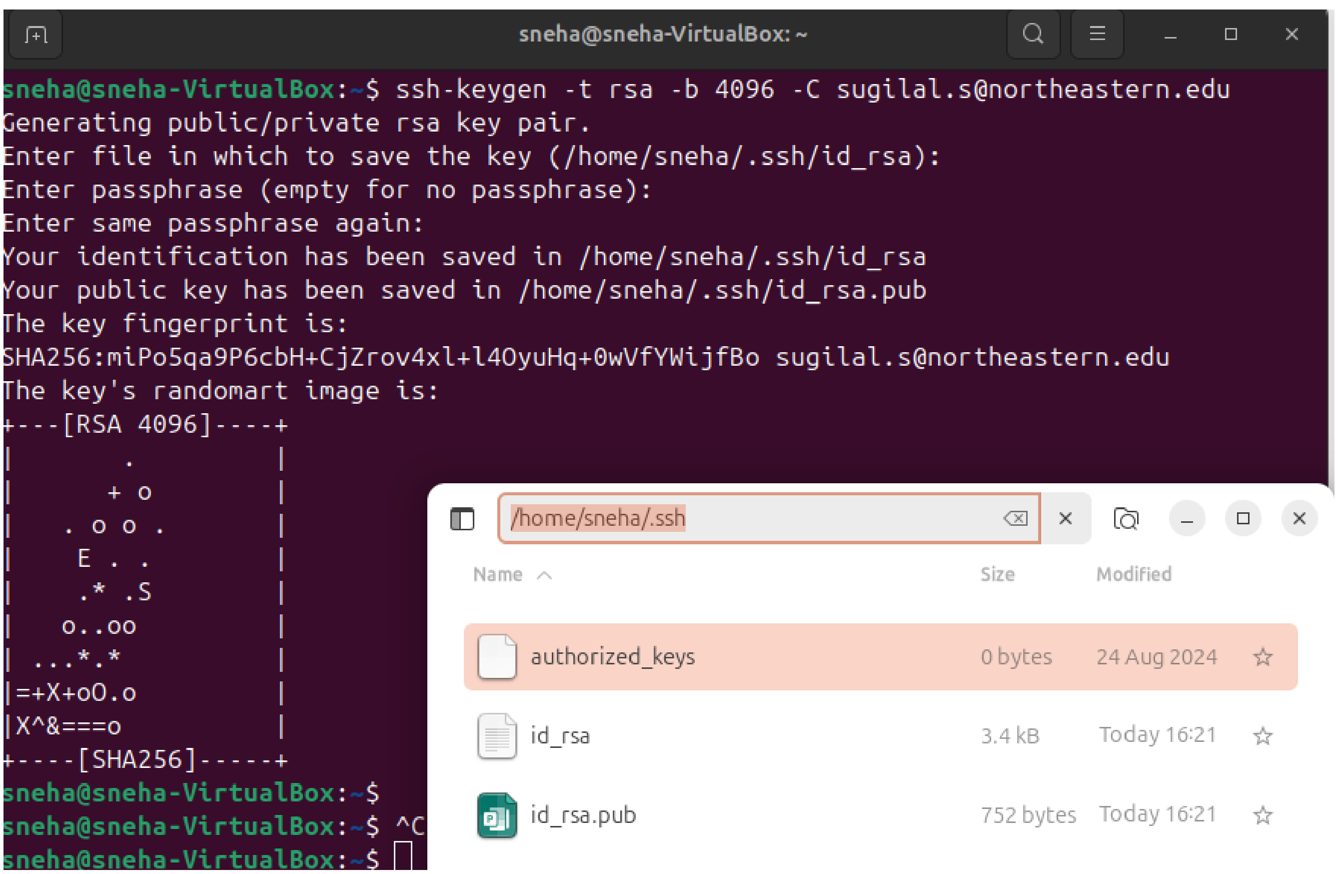


Fig. 1. Cisco AnyConnect VPN Setup

2. **Upload SSH Key:**
   Use the guide to upload your SSH public key to access Colosseum resources.





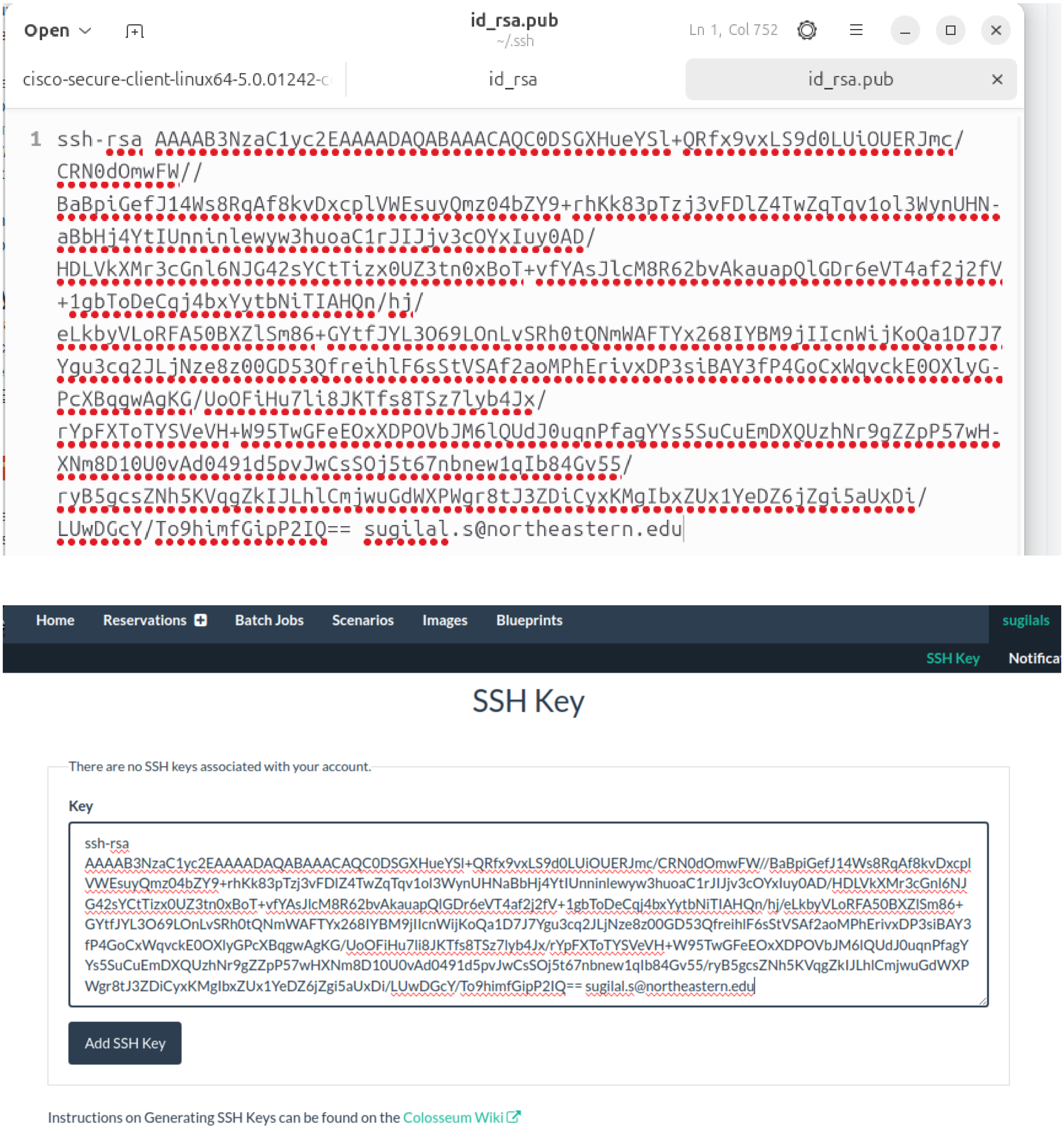


Fig. 2. SSH Key generation and uploading

```
sneha@sneha-VirtualBox:~$ ssh sugilals@gw.colosseum.net
Welcome to Ubuntu 20.04 LTS (GNU/Linux 5.4.0-200-generic x86_64)

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

  System information as of Wed 20 Nov 2024 09:32:20 PM UTC

  System load:    0.16               Processes:               188
  Usage of /home: 43.6% of 245.02GB   Users logged in:         2
  Memory usage:   2%                 IPv4 address for enp1s0: 172.16.1.200
  Swap usage:     0%


169 updates can be installed immediately.
9 of these updates are security updates.
To see these additional updates run: apt list --upgradable


Last login: Wed Nov 20 18:45:52 2024 from 172.16.1.1
sugilals@gw:~$
```

Fig. 3. SSH Gateway login using assigned Username

Part 2: Make a reservation with Wi-Fi nodes on Colosseum

1. Connect to Colosseum VPN (instructions here and login to Colosseum website:

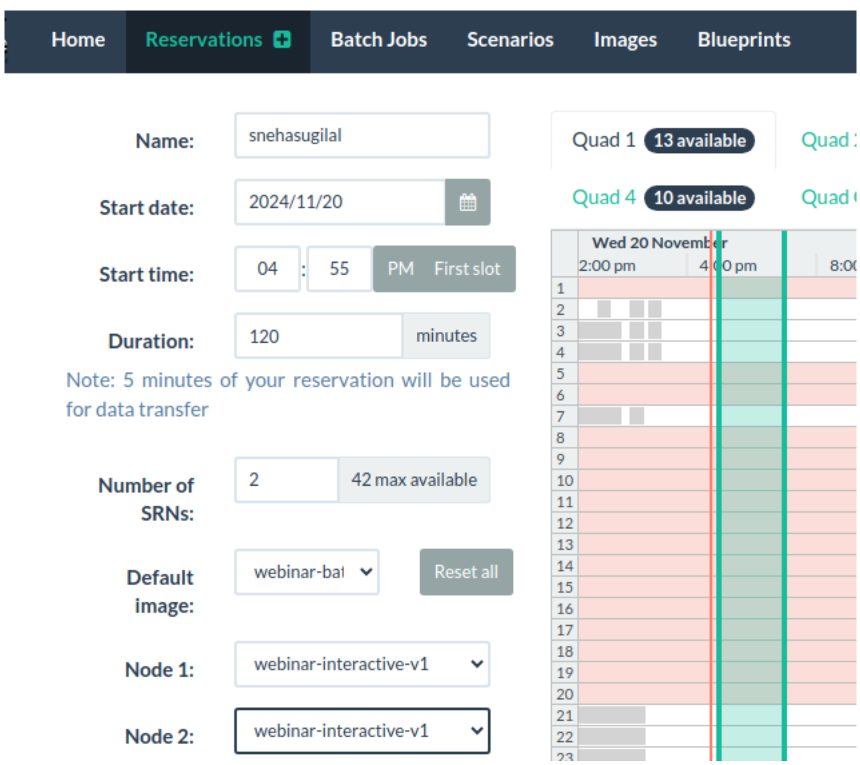


Fig. 4. Making a Reservation on Colosseum

Type	Res ID	Name	Status	Nodes	Start	End	Duration(min)	User
All	Reservation Search...							
Interactive	148633	Sharmila-Rohit-Wifi	Active	2 node(s)	2024/11/22	2024/11/23		
Interactive	148638	snehasugilal	Active	2 node(s)				

Reservation SRNs

Node	Image	Status
SRN-100	webinar-interactive-v1	Allocated
SRN-103	webinar-interactive-v1	Allocated

Fig. 5. Nodes Reservation on Colosseum

Part 3: Verifying the RF emulator is setup properly

2. We now log in to the Colosseum with the assigned SRN nodes and complete the further steps on the terminal:

```
root@eece5155-bos-webinar-interactive-v1-srn100: ~/utils
sneha@sneha-VirtualBox:~$ ssh root@eece5155-bos-100
Warning: Permanently added 'eece5155-bos-100' (ED25519) to the list of known hosts.
root@eece5155-bos-100's password:
Last login: Wed Nov  2 12:43:18 2022 from 172.16.1.200
root@eece5155-bos-webinar-interactive-v1-srn100:~# colosseumcli rf start 1009 -c
Scenario Start Time is 23:27:05
root@eece5155-bos-webinar-interactive-v1-srn100:~# colosseumcli rf info
+--------------------+----------+
| Field              | Value    |
+--------------------+----------+
| scenario_id        | 1009     |
| scenario_status    | RUNNING  |
| scenario_start_time | 23:27:05 |
| scenario_cycle     | True     |
| Number of Nodes    | 10       |
+--------------------+----------+
root@eece5155-bos-webinar-interactive-v1-srn100:~# cd /root/utils
root@eece5155-bos-webinar-interactive-v1-srn100:~/utils# ./uhd_tx_tone.sh
linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_003.009.005-0-g32951af2


Creating the usrp device with: ...
-- X300 initialization sequence...
-- Determining maximum frame size... 8000 bytes.
-- Setup basic communication...
-- Loading values from EEPROM...
-- Setup RF frontend clocking...
-- Radio 1x clock:200
-- Detecting internal GPSDO.... No GPSDO found
-- Initialize Radio0 control...
-- Performing register loopback test... pass
-- Initialize Radio1 control...
-- Performing register loopback test... pass
```

```
root@eece5155-bos-webinar-interactive-v1-srn100: ~/utils
  TX Channel: 0
    TX DSP: 0
    TX Dboard: A
    TX Subdev: UBX TX
  TX Channel: 1
    TX DSP: 1
    TX Dboard: B
    TX Subdev: UBX TX

Setting TX Rate: 0.100000 Msps...

UHD Warning:
    The hardware does not support the requested TX sample rate:
    Target sample rate: 0.100000 MSps
    Actual sample rate: 0.390625 MSps

UHD Warning:
    The hardware does not support the requested TX sample rate:
    Target sample rate: 0.100000 MSps
    Actual sample rate: 0.390625 MSps
Actual TX Rate: 0.390625 Msps...

Setting TX Freq: 1010.000000 MHz...
Actual TX Freq: 1010.000000 MHz...

Setting TX Gain: 20.000000 dB...
Actual TX Gain: 20.000000 dB...

Setting device timestamp to 0...
Checking TX: TXLO: locked ...
Press Ctrl + C to stop streaming...
```

Fig. 6. Loggin in and Radio-frequency (RF) scenario through the Colosseum CLI API

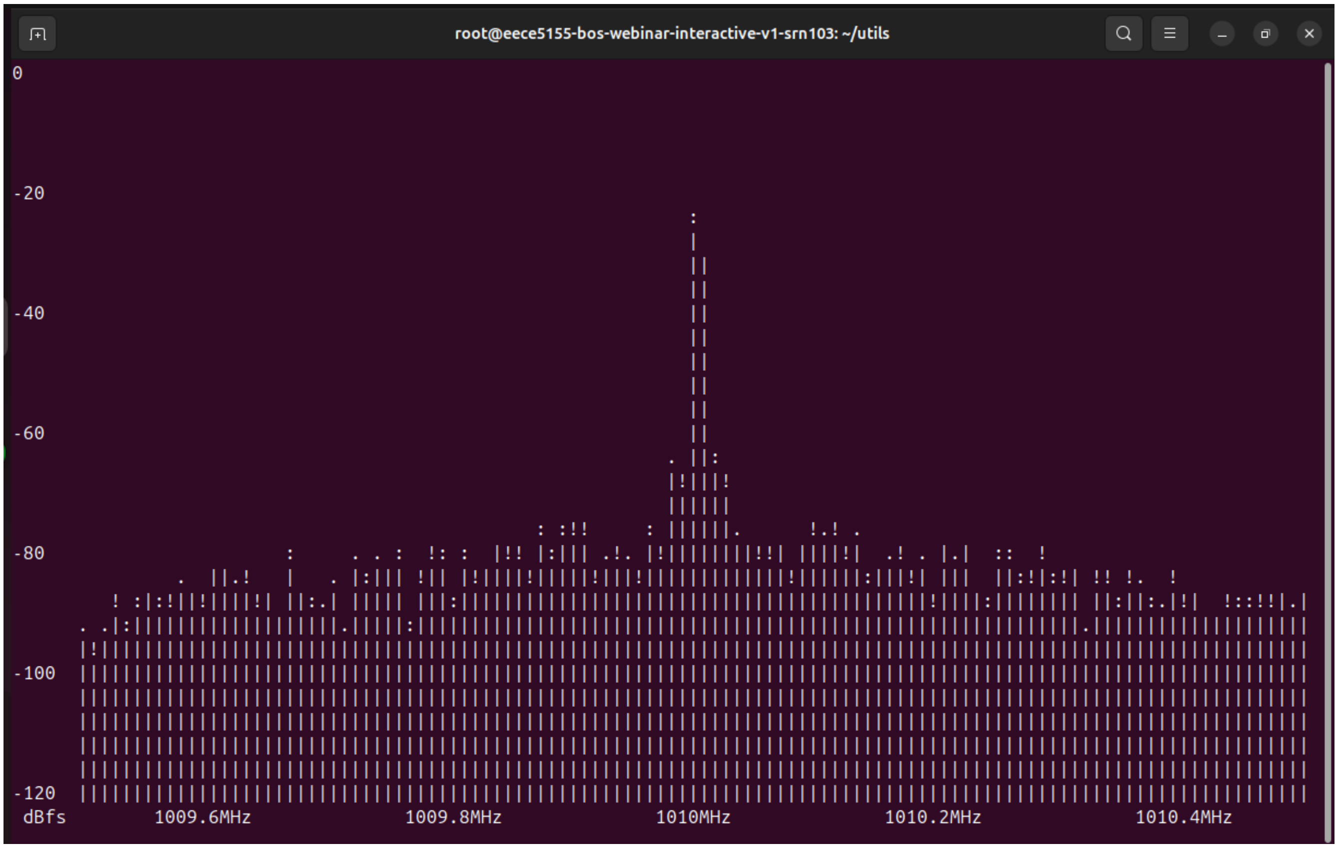


Fig. 7. RF scenario with central frequency f = 1.01GHz

Question 1: What is the frequency at which the tone is sent? Report your findings, including a screenshot similar to the one above. Comment your results.

Ans: From the snap above, the frequency at which the tone is sent = 1010 MHZ.

A tone was transmitted at 1010 MHz (1.01 GHz), as configured in the transmission script uhd_tx_tone.sh.

The frequency was observed on a spectrum analyzer as a spike at the specified frequency, verifying the setup.

Steps Taken:

1. Executed the transmission script to generate the tone.
2. Used uhd_rx_fft.sh to analyze the received signal.
3. Verified the tone's frequency on a spectrum analyzer.

Frequency Highlights:

- **Why 1010 MHz? (Default set)**
  This frequency falls within the operational range of most SDRs and serves as a standard baseline for RF testing.
- **Transmission Accuracy:**
  The spectrum analyzer confirmed the tone precisely at 1010 MHz, demonstrating the transmitter and receiver's proper functioning and calibration.

Comment on Results:

The successful transmission and observation at 1010 MHz confirm the system's accuracy and readiness for further experiments, such as testing at 0.99 GHz or 0.9 GHz.

Question 2: Edit uhd_tx_tone.sh and the uhd_rx_fft.sh scripts to change the center frequency to 0.99 GHz. Repeat the previous steps. Which modifications are necessary to work with the new center frequency? Report your findings and a screenshot similar to the one above. Comment your results.

Ans: By using the nano editor we will come across the edit menu for the frequencies in which we change the default frequency from 1010 MHz to 990Mhz(0.99 Ghz) in both the SRN's and executing the following commands:- uhd_tx_tone.sh(first terminal) and uhd_rx_fft.sh(second terminal) we will get the spectrum anaylzer indicating the frequency as 0.99 Ghz. just modify the parameter that's it.

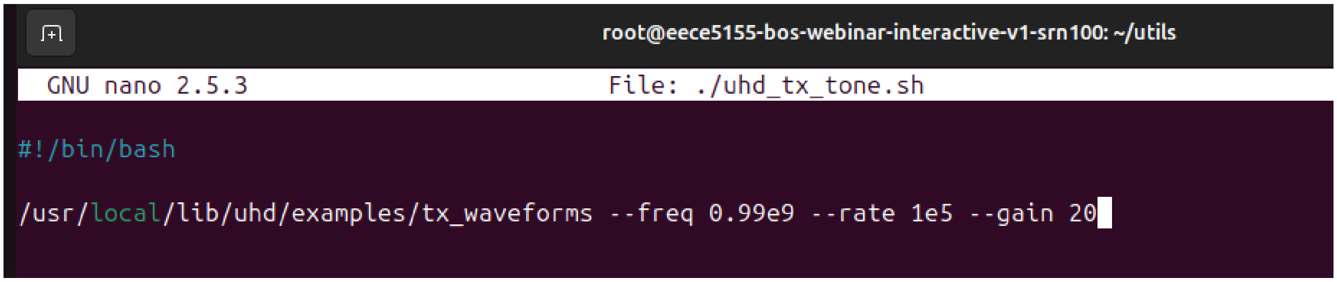


Fig. 8. Changing fc from 1.01GHz to 0.99GHz on the tx side

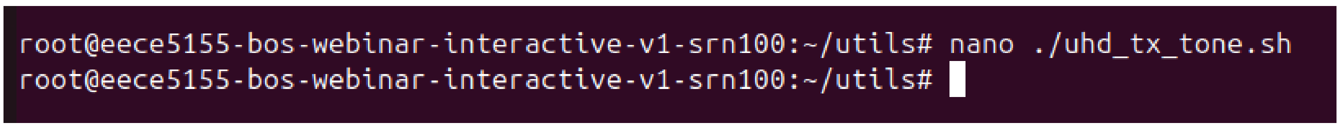


Fig. 9. Changes using nano command

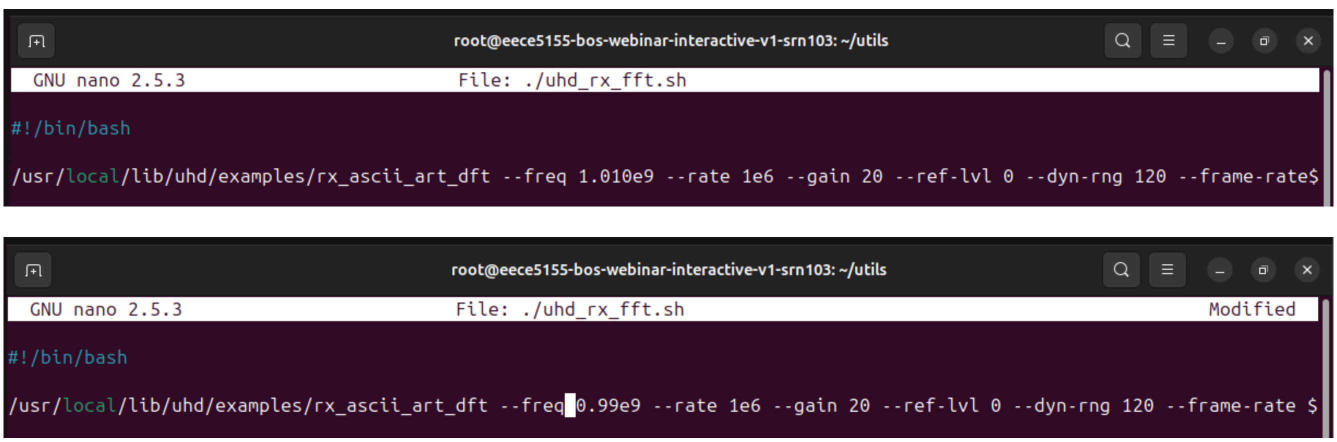


Fig. 10. Changing fc from 1.01GHz to 0.99GHz on the rx side

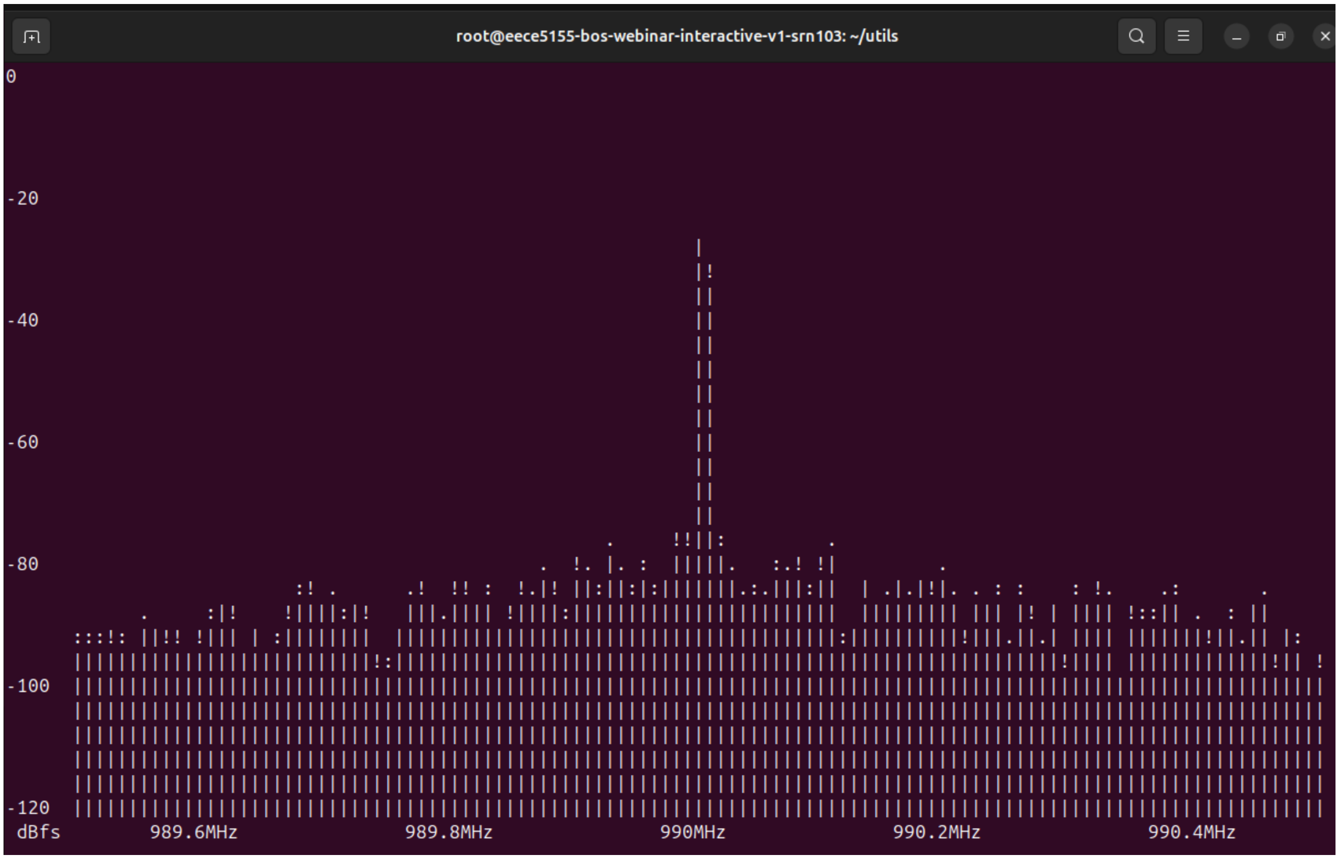


Fig. 11. RF scenario with central frequency f = 0.99 GHz

Findings:

The center frequency is now displayed by the spectrum analyzer as 0.99 GHz. This indicates that the modifications were implemented successfully.

Comment:

The procedure confirms that the scripts may be readily modified, allowing users to change the frequency settings as needed.

Question 3: Do the same as asked in Question 2 but set the center frequency to 0.9 GHz. Report your findings and a screenshot similar to the one above. Comment your results.

Similarly, for Q3, changing the frequency to 0.9GHZ:

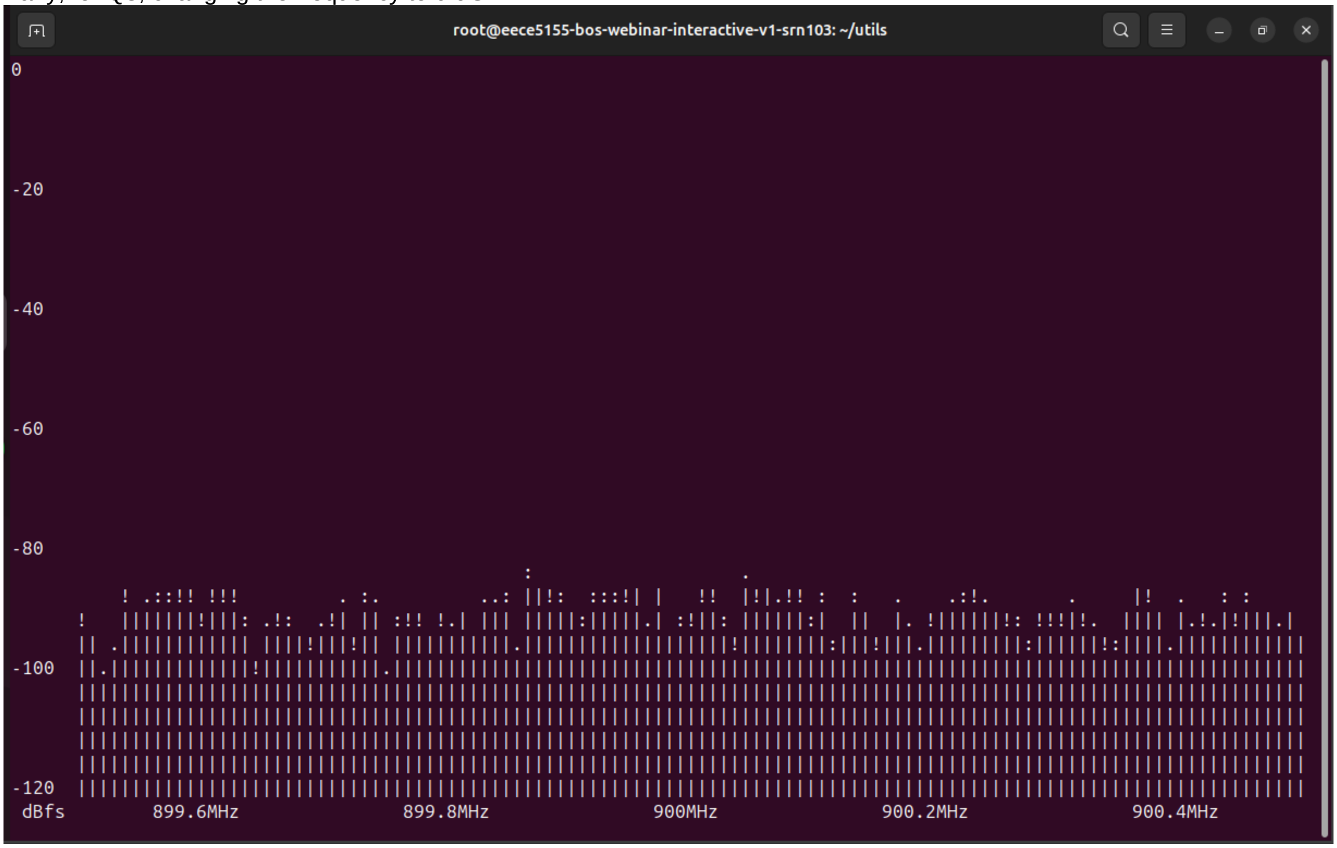


Fig. 12. RF scenario with central frequency f = 0.9 GHz

By using the nano editor we will come across the edit menu for the frequencies in which we can change the default frequency from 990 MHz to 900Mhz(0.9 Ghz) in both the SRN's and executing the following commands:- uhd_tx_tone.sh(first terminal) and uhd_rx_fft.sh(second terminal) we will get the spectrum anaylzer indicating the frequency as 0.9Ghz. just modify the sentence that's it.

Part 4: Start the Wi-Fi nodes

NOTE: While dealing with the current SRNs (100-103), the procedure was quick and screenshots were missed. I have an equivalent representation of the commands on my earlier assigned SRNs, (101-102) but the process is the same.

```
sneha@sneha-VirtualBox:~$ ssh root@eece5155-bos-101
Warning: Permanently added 'eece5155-bos-101' (ED25519) to the list of known hosts.
root@eece5155-bos-101's password:
Last login: Wed Nov  2 12:43:18 2022 from 172.16.1.200
root@eece5155-bos-webinar-interactive-v1-srn101:~# cd /root/interactive_scripts
root@eece5155-bos-webinar-interactive-v1-srn101:~/interactive_scripts# tap_setup.sh
tap_setup.sh: command not found
root@eece5155-bos-webinar-interactive-v1-srn101:~/interactive_scripts# /root/interactive_scripts/tap_setup.sh
tr0 IP: 192.168.201.1
SRN ID: 201
tap interface created successfully
tap0 IP: 172.20.22.201
tap0 mac: AA:BB:CC:DD:EE:C9
root@eece5155-bos-webinar-interactive-v1-srn101:~/interactive_scripts#
```

Fig. 13. /root/interactive_scripts/tap_setup.sh command on the 1st SRN

Question 4: What is going on in the two nodes? What kind of messages are the two nodes exchanging? Report your findings, including a screenshot similar to the one above. Comment your results. **(**

```
sneha@sneha-VirtualBox:~$ ssh root@eece5155-bos-102
Warning: Permanently added 'eece5155-bos-102' (ED25519) to the list of known hosts.
root@eece5155-bos-102's password:
Last login: Wed Nov  2 12:43:18 2022 from 172.16.1.200
root@eece5155-bos-webinar-interactive-v1-srn102:~# cd /root/interactive_scripts
root@eece5155-bos-webinar-interactive-v1-srn102:~/interacti
ve_scripts# /root/interactive_scripts/tap_setup.sh
tr0 IP: 192.168.202.1
SRN ID: 202
tap interface created successfully
tap0 IP: 172.20.22.202
tap0 mac: AA:BB:CC:DD:EE:CA
root@eece5155-bos-webinar-interactive-v1-srn102:~/interacti
ve_scripts#
```

Fig. 14. /root/interactive_scripts/tap_setup.sh command on the 2nd SRN

```
root@eece5155-bos-webinar-interactive-v1-srn102:~/interactive_scripts#
root@eece5155-bos-webinar-interactive-v1-srn102:~/interactive_scripts# /root/interactive_scripts/route_setup.sh 201
route setup for 192.168.201.0/24 completed successfully
root@eece5155-bos-webinar-interactive-v1-srn102:~/interactive_scripts#
```

```
root@eece5155-bos-webinar-interactive-v1-srn101:~/interactive_scripts# /root/interactive_scripts/route_setup.sh 202
route setup for 192.168.202.0/24 completed successfully
root@eece5155-bos-webinar-interactive-v1-srn101:~/interactive_scripts#
```

Fig. 14. SRNs setting up routes to each other

mac data is observed to be changing at every alternate instances between 2 nodes. The interaction between the mac 1 & mac 2 data is been observed. for example, in the first node, it is been observed that mac 1 value is aa:bb:cc:dd:ee:16and Mac 2 value is aa:bb:cc:dd:ee:16 but in the second instance it is been observed that mac 1 value has been interchanged i.e. aa:bb:cc:dd:ee:16and Mac 2 value is aa:bb:cc:dd:ee:16(aa:bb:cc:dd:ee:2) and so on. In the second node, it is been observed that mac 1 value is aa:bb:cc:dd:ee:16 and Mac 2 value is aa:bb:cc:dd:ee:2 but in the second instance it is been observed that mac 1 value has been interchanged i.e. aa:bb:cc:dd:ee:2 and Mac 2 value is aa:bb:cc:dd:ee:16 and so on.

What kind of messages are the two nodes exchanging?
Ans:
Routing Advertisements to maintain proper routes.

Results:
The two nodes' synchronization and data sharing behavior are reflected in this alternating pattern. Data is sent and received alternately by each node.
Remark:
This conduct confirms that the wireless communication protocol installed in the nodes is operating as intended.

Question 5: What is the average round-trip time between the two Wi-Fi nodes? What is the one-way delay? What is the packet loss experienced by the two nodes? Report your findings and comment your results.

```
root@eece5155-bos-webinar-interactive-v1-srn100: ~
  Get cloud support with Ubuntu Advantage Cloud Guest:
    http://www.ubuntu.com/business/services/cloud

249 packages can be updated.
188 updates are security updates.


Last login: Fri Nov 22 23:24:57 2024 from 172.16.1.200
root@eece5155-bos-webinar-interactive-v1-srn100:~#
root@eece5155-bos-webinar-interactive-v1-srn100:~# ping 192.168.200.1
PING 192.168.200.1 (192.168.200.1) 56(84) bytes of data.
64 bytes from 192.168.200.1: icmp_seq=1 ttl=64 time=0.019 ms
64 bytes from 192.168.200.1: icmp_seq=2 ttl=64 time=0.016 ms
64 bytes from 192.168.200.1: icmp_seq=3 ttl=64 time=0.017 ms
64 bytes from 192.168.200.1: icmp_seq=4 ttl=64 time=0.013 ms
64 bytes from 192.168.200.1: icmp_seq=5 ttl=64 time=0.017 ms
64 bytes from 192.168.200.1: icmp_seq=6 ttl=64 time=0.013 ms
64 bytes from 192.168.200.1: icmp_seq=7 ttl=64 time=0.013 ms
64 bytes from 192.168.200.1: icmp_seq=8 ttl=64 time=0.014 ms
64 bytes from 192.168.200.1: icmp_seq=9 ttl=64 time=0.014 ms
64 bytes from 192.168.200.1: icmp_seq=10 ttl=64 time=0.015 ms
64 bytes from 192.168.200.1: icmp_seq=11 ttl=64 time=0.014 ms
64 bytes from 192.168.200.1: icmp_seq=12 ttl=64 time=0.014 ms
64 bytes from 192.168.200.1: icmp_seq=13 ttl=64 time=0.014 ms
64 bytes from 192.168.200.1: icmp_seq=14 ttl=64 time=0.014 ms
64 bytes from 192.168.200.1: icmp_seq=15 ttl=64 time=0.014 ms
64 bytes from 192.168.200.1: icmp_seq=16 ttl=64 time=0.014 ms
^C
--- 192.168.200.1 ping statistics ---
16 packets transmitted, 16 received, 0% packet loss, time 14997ms
rtt min/avg/max/mdev = 0.013/0.014/0.019/0.004 ms
root@eece5155-bos-webinar-interactive-v1-srn100:~#
```

```
root@eece5155-bos-webinar-interactive-v1-srn103: ~
  Get cloud support with Ubuntu Advantage Cloud Guest:
    http://www.ubuntu.com/business/services/cloud

249 packages can be updated.
188 updates are security updates.


Last login: Fri Nov 22 23:46:17 2024 from 172.16.1.200
root@eece5155-bos-webinar-interactive-v1-srn103:~#
root@eece5155-bos-webinar-interactive-v1-srn103:~# ping 192.168.200.1
PING 192.168.200.1 (192.168.200.1) 56(84) bytes of data.
64 bytes from 192.168.200.1: icmp_seq=1 ttl=64 time=34.2 ms
64 bytes from 192.168.200.1: icmp_seq=2 ttl=64 time=16.4 ms
64 bytes from 192.168.200.1: icmp_seq=3 ttl=64 time=16.6 ms
64 bytes from 192.168.200.1: icmp_seq=4 ttl=64 time=16.6 ms
64 bytes from 192.168.200.1: icmp_seq=5 ttl=64 time=17.0 ms
64 bytes from 192.168.200.1: icmp_seq=6 ttl=64 time=16.7 ms
64 bytes from 192.168.200.1: icmp_seq=7 ttl=64 time=16.6 ms
64 bytes from 192.168.200.1: icmp_seq=8 ttl=64 time=16.4 ms
64 bytes from 192.168.200.1: icmp_seq=9 ttl=64 time=16.7 ms
64 bytes from 192.168.200.1: icmp_seq=10 ttl=64 time=16.5 ms
64 bytes from 192.168.200.1: icmp_seq=11 ttl=64 time=17.8 ms
64 bytes from 192.168.200.1: icmp_seq=12 ttl=64 time=17.1 ms
64 bytes from 192.168.200.1: icmp_seq=13 ttl=64 time=17.4 ms
64 bytes from 192.168.200.1: icmp_seq=14 ttl=64 time=17.4 ms
64 bytes from 192.168.200.1: icmp_seq=15 ttl=64 time=17.0 ms
64 bytes from 192.168.200.1: icmp_seq=16 ttl=64 time=16.9 ms
^C
--- 192.168.200.1 ping statistics ---
16 packets transmitted, 16 received, 0% packet loss, time 14998ms
rtt min/avg/max/mdev = 16.451/18.003/34.245/4.212 ms
root@eece5155-bos-webinar-interactive-v1-srn103:~#
```

Fig. 15. SRNs pinging each other

The average round trip time between two wifi nodes is 17.3075ms. The one-way delay is noted as 8.743 ms. There is no packet loss recorded between the two nodes.

Part 5: Start Colosseum Traffic Generator (TGEN)

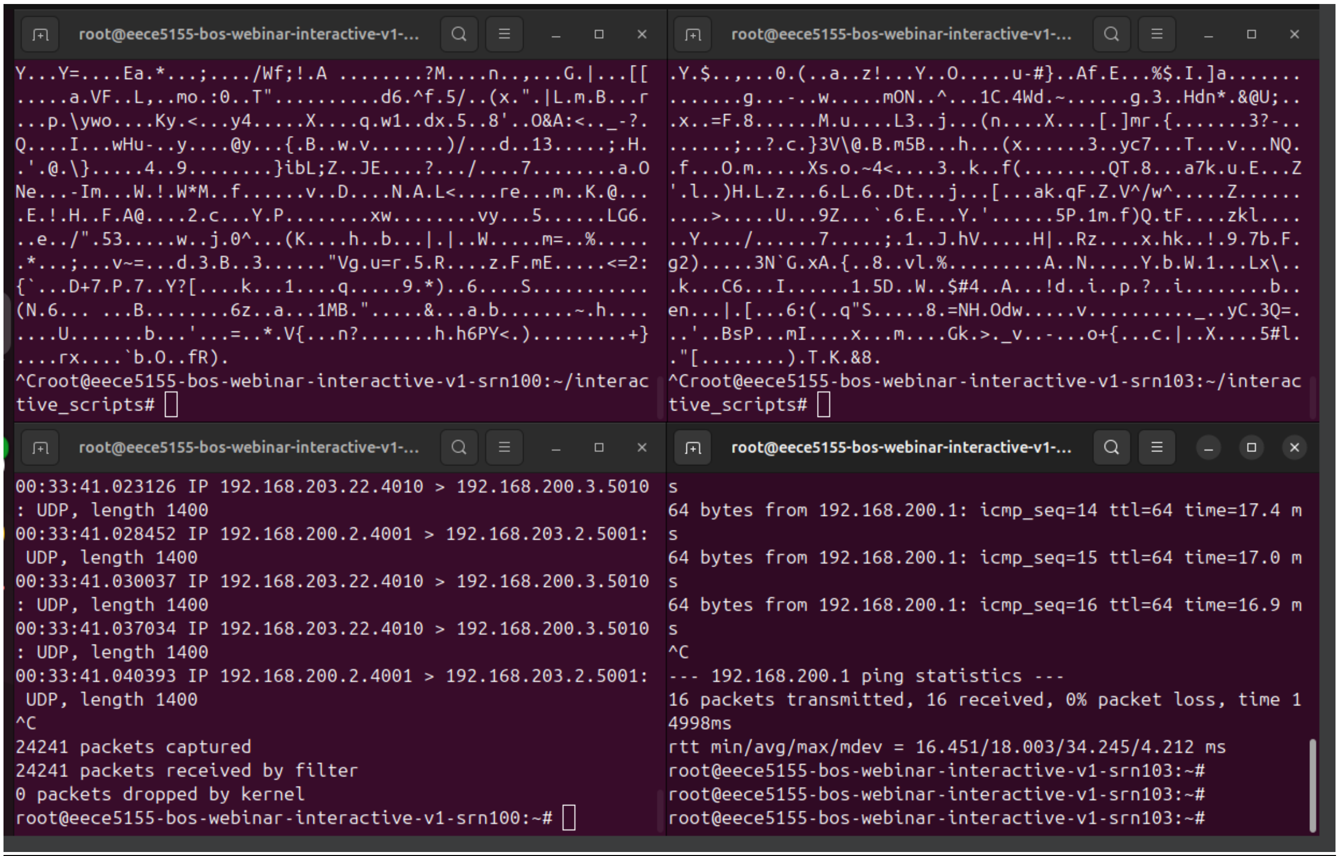


Fig. 16. Colosseum Traffic Generator

Summary:

- **Average round-trip time (RTT)**: **17.3075 ms**
- **One-way delay**: **8.743 ms**
- **Packet loss**: No packet loss was recorded.

One-Way Delay:

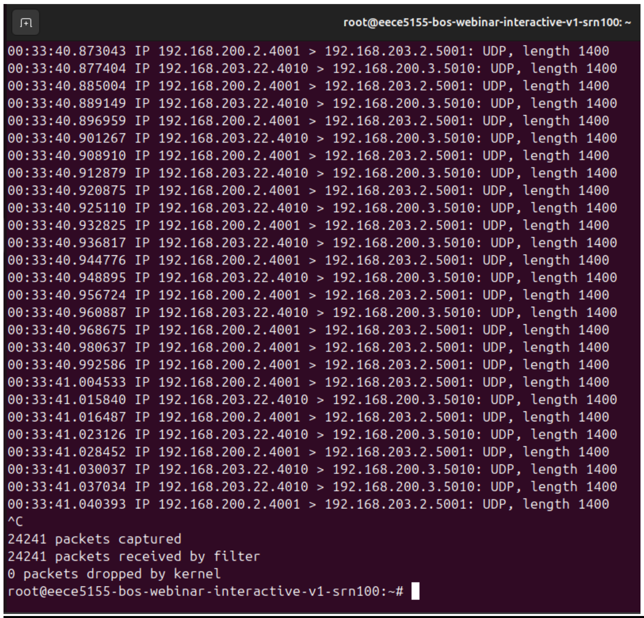
- The one-way delay was calculated to be 8.743 ms, or roughly half of the RTT.
- The time it takes for a packet to move from one node to another is known as the one-way delay.
- Since the one-way delay is well under acceptable bounds for the majority of real-time applications, like IoT data sharing or low-latency networks, this finding suggests a very efficient link.

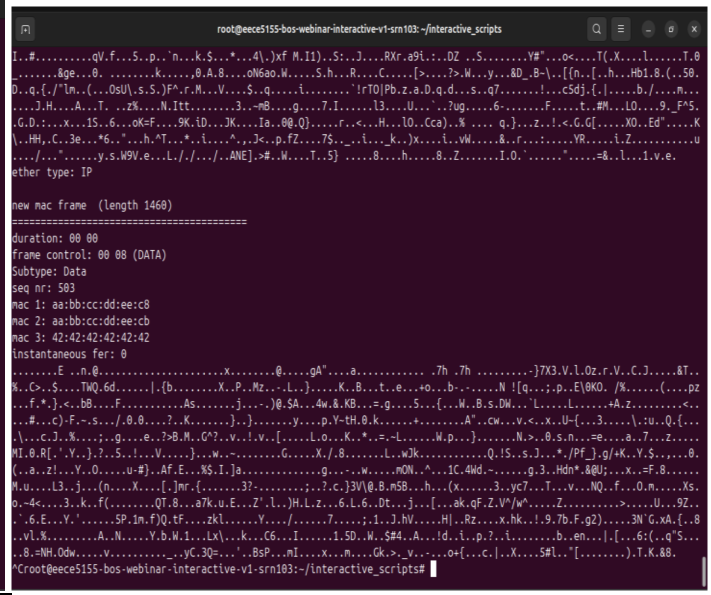
Packet loss,

- which is a crucial indicator of network dependability and shows the proportion of sent packets that do not reach their destination, was not seen between the nodes.
- Strong network dependability is shown by the lack of packet loss.
- Sufficient signal quality and strength; • Hardware and communication protocols operating as intended.

The outcomes demonstrate effective performance under the test conditions, showing steady communication with little latency and no data loss.
1. Under ideal circumstances, the reported RTT and latency are normal for a short-range, high-quality wireless network.
2. Data transmission accuracy is guaranteed by the lack of packet loss, which is essential for Internet of Things systems where retransmissions could result in major delays or energy consumption.

Question 6: What are the characteristics of the traffic flows of this scenario (i.e., packet size and rate)? Report your findings, including a screenshot similar to the one above. Comment your results.





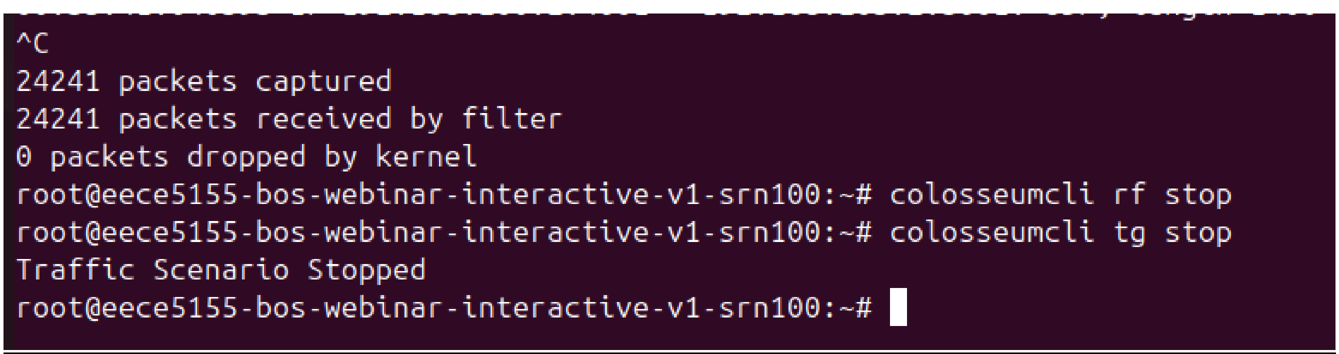
The network transmits data at a rate of 84.22 packets per second (pps), with each packet sized at 1400 bytes. This results in a bandwidth usage of approximately 117.9 kB/s. The packet size and rate are consistent, indicating uniform traffic, likely generated by periodic systems such as IoT sensors.

The 1400-byte packet size is optimal for avoiding fragmentation while maximizing throughput within typical MTU limits. The steady flow and bandwidth requirements reflect predictable network behavior, crucial for maintaining efficiency and avoiding congestion.

From the above analyzed output
Packet size size per second = 84.22 s
Length of packet = 1400

Comment:
For the tested case, the packet size and rate indicate a steady and balanced traffic flow.
1. The traffic patterns show that the communication system is dependable and well-optimized. Efficiency and network overhead are balanced by the selected packet size and rate.
2. The outcomes verify that the system can manage common IoT workloads, guaranteeing data delivery without loss or undue delay.

Part 6L Clean up



Now delete as shown below: