

# PROJECT 1

## Group 3



**San José State**  
UNIVERSITY

## EE286- Mobile and Wireless Networks

### Prof. Pedro SantaCruz

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# 1. Point to Point Communication

## 1. What is the distance between the two nodes in the network?

```
using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("ProjectOneTemplate");

int main (int argc, char *argv[])
{
    uint32_t packetSize = 1000;
    uint32_t n=2;
    double dist = 100;

    CommandLine cmd;
    cmd.AddValue ("packetSize", "size of application packet sent", packetSize);
    cmd.AddValue ("n", "number of nodes", n);
    cmd.AddValue ("dist", "distance between nodes", dist);

    cmd.Parse (argc, argv);
```

As per the above code, double dist = 100;

Which implies the distance between the codes is 100. We can change this value as needed.

## 2. How many seconds of this simulation are we running?

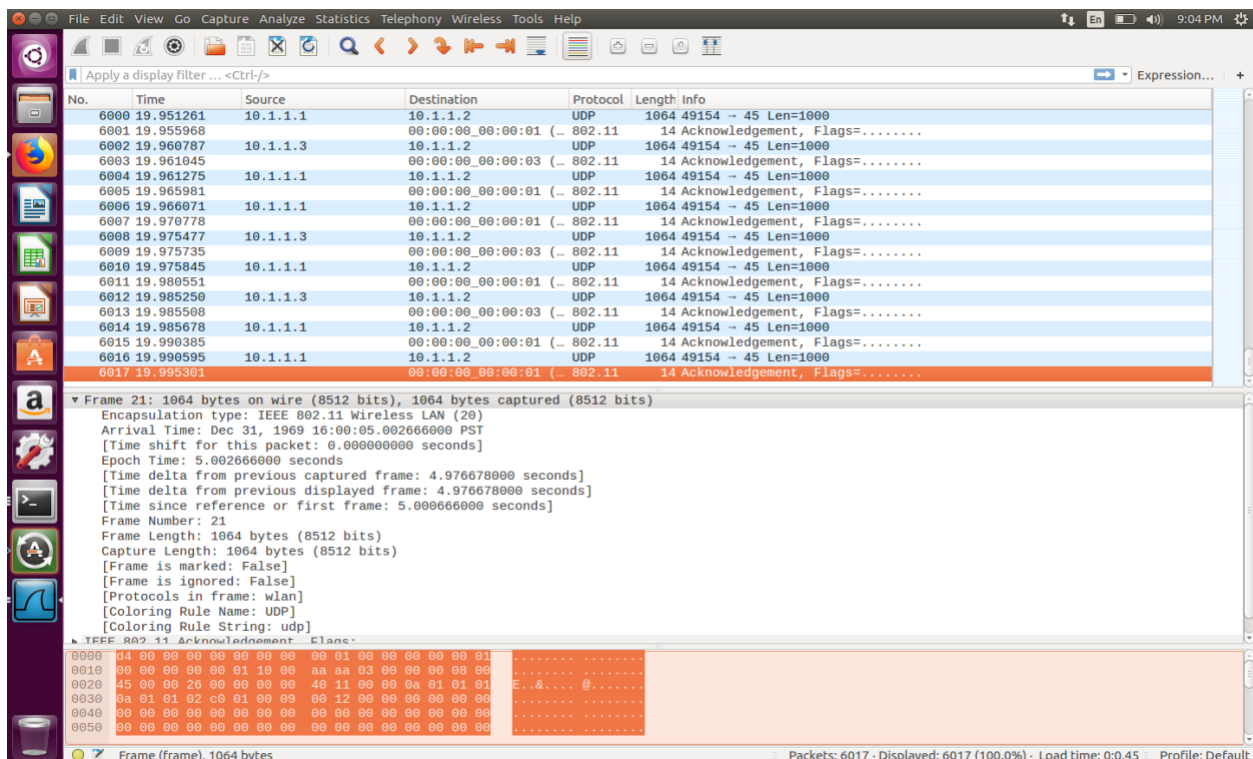
```
//////Setup Simulator
Simulator::Stop (Seconds (20.0));

Simulator::Run ();
Simulator::Destroy ();

//////Count number of packets received
uint32_t totalPacketsThrough = DynamicCast<UdpServer> (serverApp.Get (0))->GetReceived ();

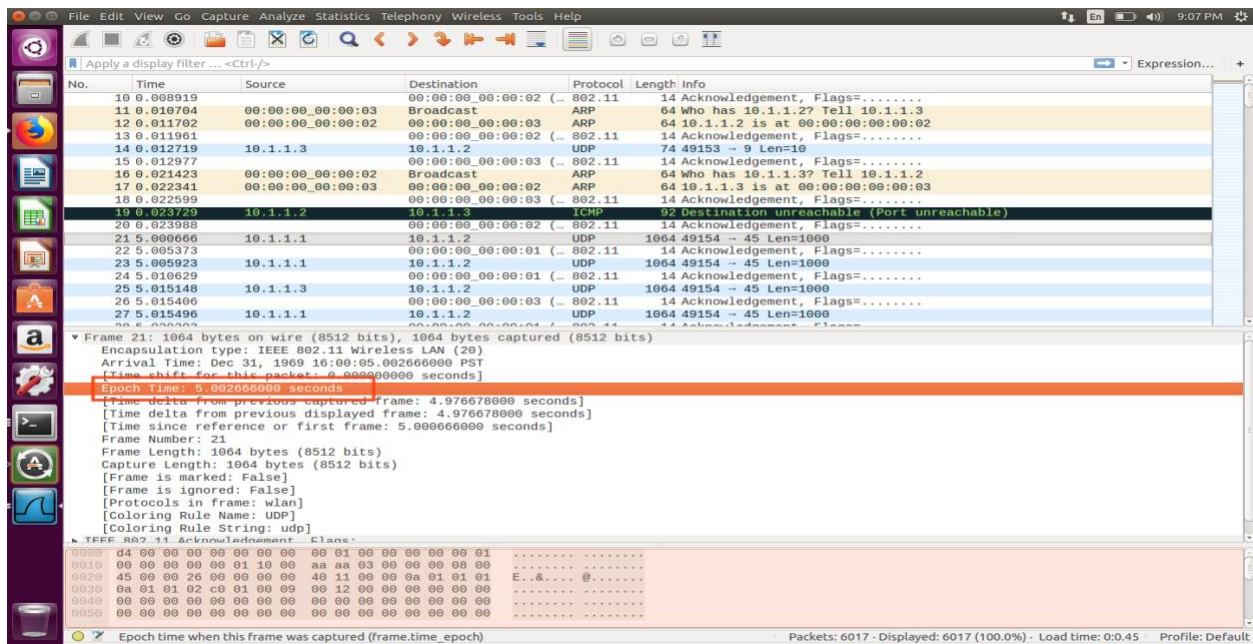
std::cout << "Total Packets Received: " << totalPacketsThrough << '\n';

return 0;
}
```



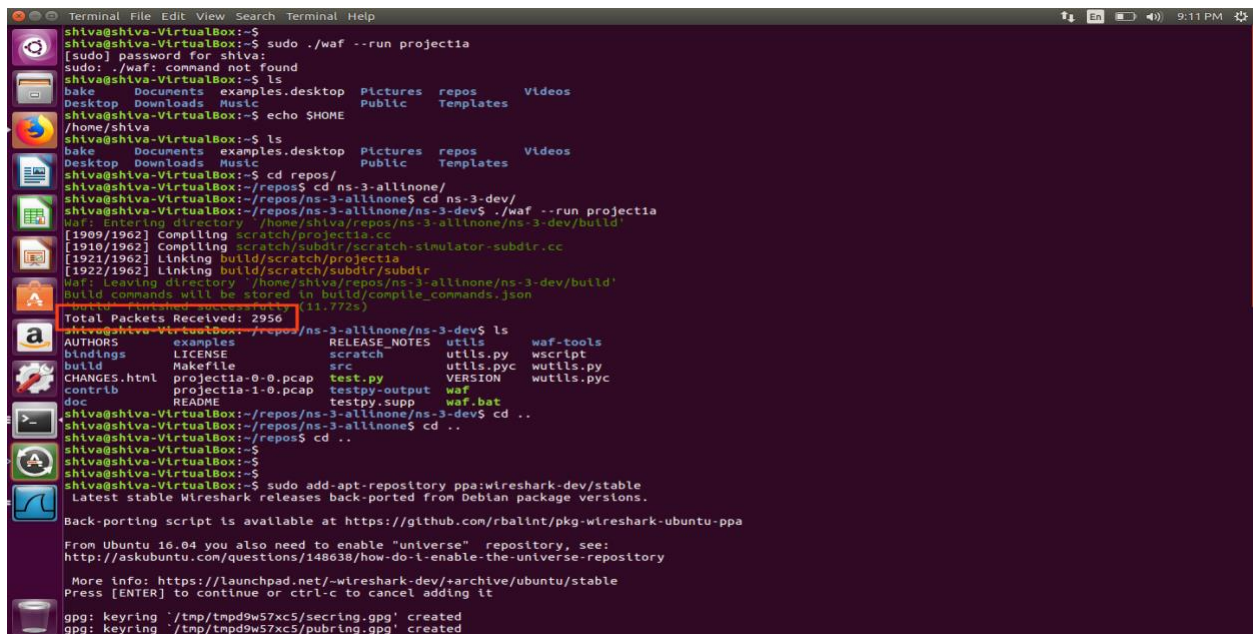
As per the code above, the total time (seconds) for the simulation is 20 seconds. Also, on wireshark, we are able to capture packets only up to 19.995 seconds.

### 3. When does the transmitter start transmitting data packets?



As per the Wireshark snapshot above, the transmitter starts transmitting data packets at 5.0026 seconds.

### 4. What is the throughput of the network, that is, how many bytes per second are being exchanged in the network?



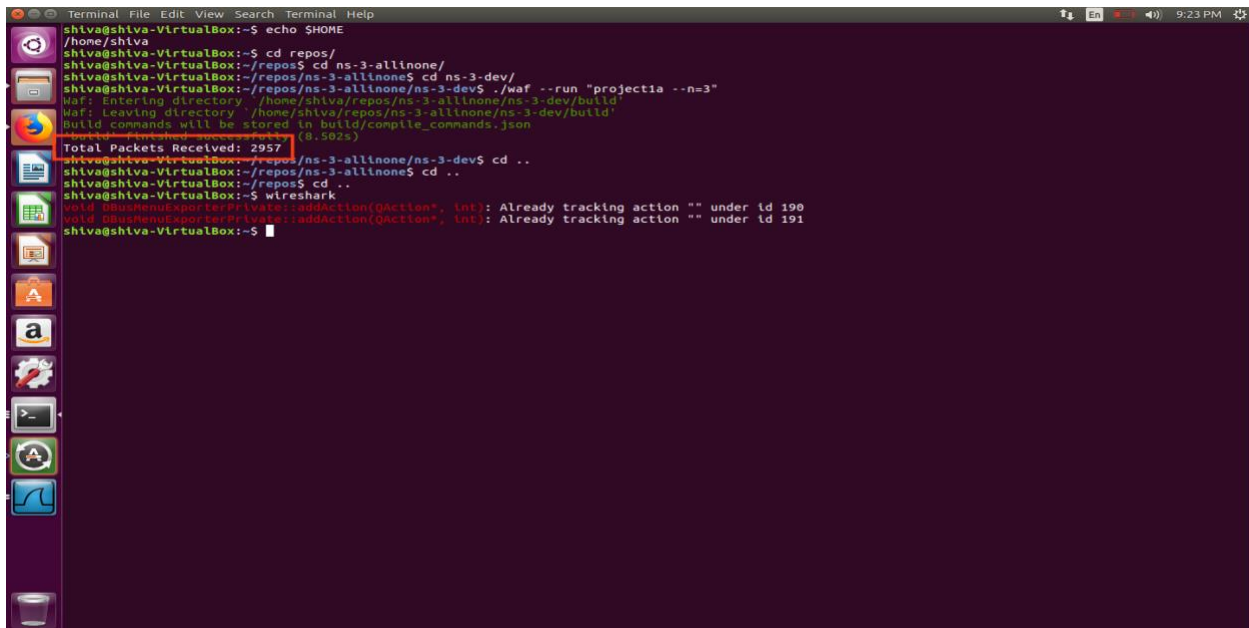
Total Packets received as per the above snapshot = 2956; Length of each packet = 1000;  
 Start time of transmission = 5.0026 seconds (As per question 3);  
 End time of transmission = 20 seconds (As per question 2);

Therefore, Total Transmission time = (20 – 5.0026) seconds  
 No. of bytes = (2956\*1000)

Throughput of the Network =  $(2956 * 1000 * 8) / (20 - 5.0026)$   
 = 1.577 Mbps

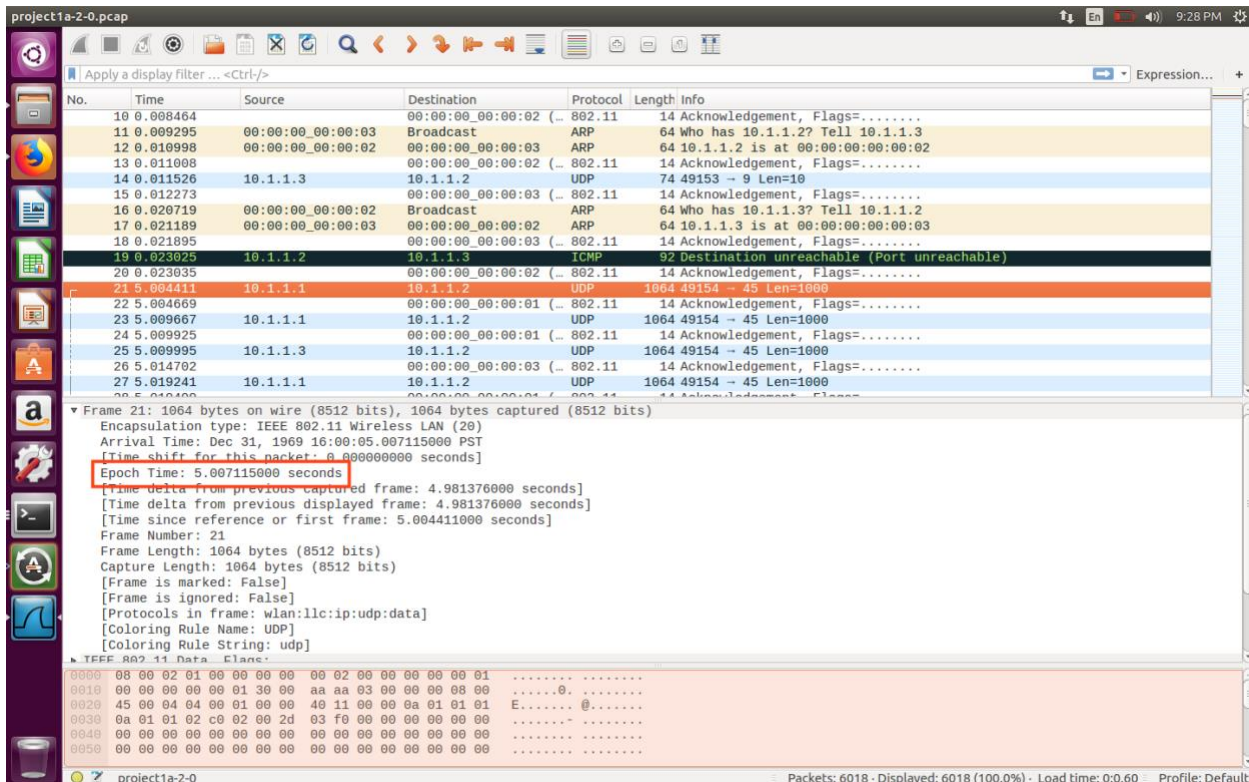
## 2. Three Node Network

### 1. What is the throughput of the network?



A terminal window showing the setup of a three-node network. The user is in a virtual machine named 'shiva'. They navigate through directories: `/home/shiva`, `/repos`, `ns-3-allinone`, and `ns-3-dev`. They run `waf --run "project1a --n=3"` to build and run the project. The output shows the build directory and the number of packets received (2957). They also run `wireshark` to capture traffic.

```
shiva@shiva-VirtualBox:~$ echo $HOME
/home/shiva
shiva@shiva-VirtualBox:~$ cd repos/
shiva@shiva-VirtualBox:~/repos$ cd ns-3-allinone/
shiva@shiva-VirtualBox:~/repos/ns-3-allinone$ cd ns-3-dev/
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$ ./waf --run "project1a --n=3"
waf: Entering directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev/build$
Total Packets Received: 2957
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$ cd ..
shiva@shiva-VirtualBox:~/repos$ cd ..
shiva@shiva-VirtualBox:~$ wireshark
void dbusMenuExporterPrivate::addAction(QAction*, int): Already tracking action "" under id 190
void dbusMenuExporterPrivate::addAction(QAction*, int): Already tracking action "" under id 191
shiva@shiva-VirtualBox:~$
```



A Wireshark packet capture window showing a list of network packets. The table has columns for No., Time, Source, Destination, Protocol, and Length. The packets are captured on the interface 'eth0'. The time range is from 5.007115000 to 20.000000000 seconds. The total number of packets is 6018, and 6018 are displayed (100.0%).

No.	Time	Source	Destination	Protocol	Length	Info
10	0.008464	00:00:00:00:00:03	00:00:00:00:00:02	ARP	64	14 Acknowledgement, Flags=.....
11	0.009295	00:00:00:00:00:03	Broadcast	ARP	64	Who has 10.1.1.2? Tell 10.1.1.3
12	0.010998	00:00:00:00:00:02	00:00:00:00:00:03	ARP	64	10.1.1.2 is at 00:00:00:00:00:02
13	0.011008	00:00:00:00:00:02	00:00:00:00:00:02	ARP	64	14 Acknowledgement, Flags=.....
14	0.011526	10.1.1.3	10.1.1.2	UDP	74	49153 → 9 Len=10
15	0.012273	00:00:00:00:00:03	00:00:00:00:00:03	ARP	64	14 Acknowledgement, Flags=.....
16	0.020719	00:00:00:00:00:02	Broadcast	ARP	64	Who has 10.1.1.3? Tell 10.1.1.2
17	0.021189	00:00:00:00:00:03	00:00:00:00:00:02	ARP	64	10.1.1.3 is at 00:00:00:00:00:03
18	0.021895	00:00:00:00:00:03	00:00:00:00:00:03	ARP	64	14 Acknowledgement, Flags=.....
19	0.023025	10.1.1.2	10.1.1.3	ICMP	92	Destination unreachable (Port unreachable)
20	0.023035	00:00:00:00:00:02	00:00:00:00:00:02	ARP	64	14 Acknowledgement, Flags=.....
21	5.007115	10.1.1.1	10.1.1.2	UDP	1064	49154 → 45 Len=1000
22	5.004669	00:00:00:00:00:01	00:00:00:00:00:01	ARP	64	14 Acknowledgement, Flags=.....
23	5.009667	10.1.1.1	10.1.1.2	UDP	1064	49154 → 45 Len=1000
24	5.009925	00:00:00:00:00:01	00:00:00:00:00:01	ARP	64	14 Acknowledgement, Flags=.....
25	5.009995	10.1.1.3	10.1.1.2	UDP	1064	49154 → 45 Len=1000
26	5.014702	00:00:00:00:00:03	00:00:00:00:00:03	ARP	64	14 Acknowledgement, Flags=.....
27	5.019241	10.1.1.1	10.1.1.2	UDP	1064	49154 → 45 Len=1000

Total Packets received as per the above snapshot = 2957; Length of each packet = 1000;  
Start time of transmission = 5.0071 seconds (As per the snapshot on wireshark);  
End time of transmission = 20 seconds;

Therefore, Total Transmission time = (20 – 5.0071) seconds  
No. of bytes = (2957\*1000)

Throughput of the Network =  $(2957 \times 1000 \times 8) / (20 - 5.0071)$



= 1.578 Mbps

## 2. We now have two users offering traffic at the same time, are we receiving more packets?

We are receiving more packets i.e. 2957 as per the snapshot in question 1 in comparison to 2956 packets received in Task 1 where there was only 1 user.

## 3. How long does it take for a packet sent by a transmitter to be received by receiver? What factors determine how long it takes?

Wireshark packet capture screenshot showing network traffic. The packet list shows a sequence of packets including ARP requests, acknowledgements, and a destination unreachable message. The packet details pane for packet 21 shows it is a UDP packet from 10.1.1.1 to 10.1.1.2, length 1064 bytes. The packet bytes pane shows the raw data in hexadecimal and ASCII.

Wireshark packet capture screenshot showing network traffic. The packet list shows a sequence of packets including ARP requests, acknowledgements, and a destination unreachable message. The packet details pane for packet 21 shows it is a UDP packet from 10.1.1.1 to 10.1.1.2, length 1064 bytes. The packet bytes pane shows the raw data in hexadecimal and ASCII.

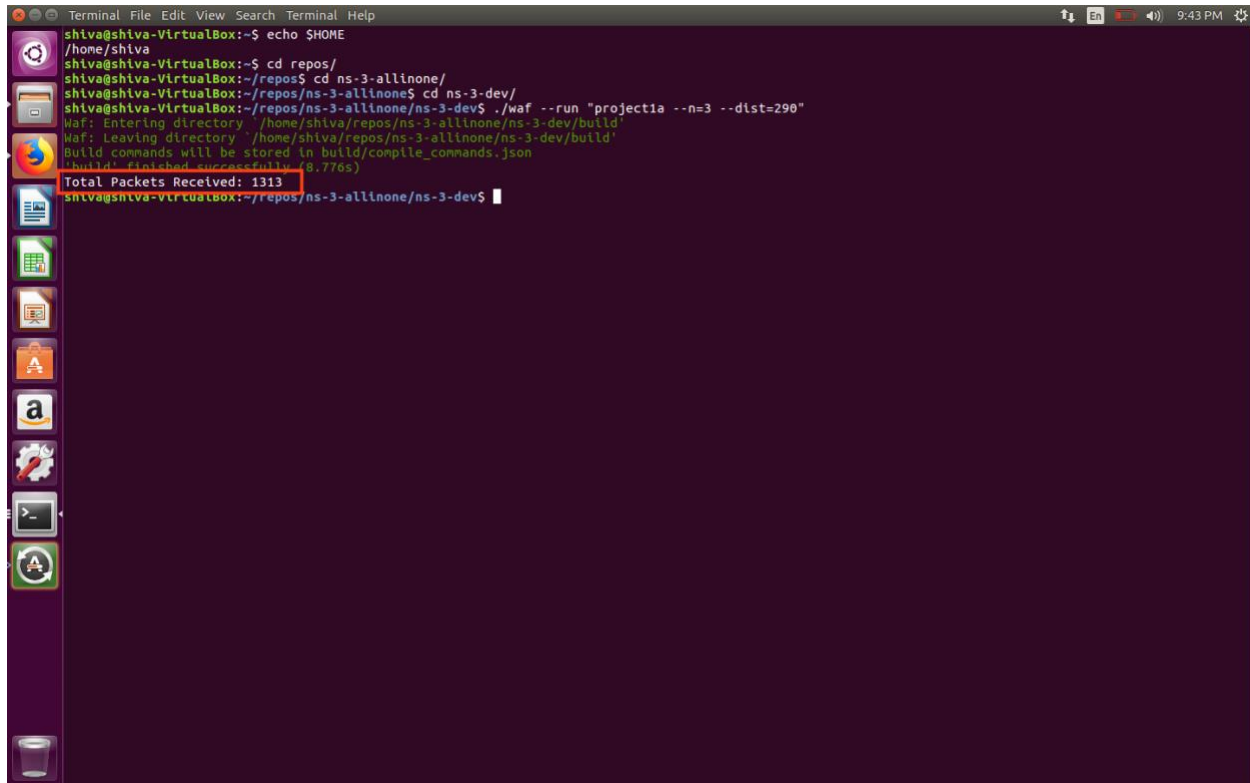
By looking at the snapshots above,  
The transmitter sends the packet at 5.0026 seconds and receiver receives the packet at 5.0071 seconds.

Therefore, total time taken for transmission = 5.0071 – 5.0026 seconds

= 0.00448 seconds  
= 4.48 milliseconds

### 3. Increasing the Distance

#### 1. How many packets are received in the network this time?

A terminal window titled 'Terminal File Edit View Search Terminal Help' showing a series of commands and their outputs. The user is in a directory structure: /home/shiva, then /repos, then /repos/ns-3-allinnone, and finally /repos/ns-3-allinnone/ns-3-dev. They run the command 'waf --run "project1a --n=3 --dist=290"'. The output shows 'Waf: Entering directory "/home/shiva/repos/ns-3-allinnone/ns-3-dev/build"', 'Waf: Leaving directory "/home/shiva/repos/ns-3-allinnone/ns-3-dev/build"', and 'Build commands will be stored in build/compile\_commands.json'. The final line of output is 'Total Packets Received: 1313', which is highlighted with a red box. The prompt 'shiva@shiva-VirtualBox:~/repos/ns-3-allinnone/ns-3-dev\$' is visible at the bottom.

```
shiva@shiva-VirtualBox:~$ echo $HOME
/home/shiva
shiva@shiva-VirtualBox:~$ cd repos/
shiva@shiva-VirtualBox:~/repos$ cd ns-3-allinnone/
shiva@shiva-VirtualBox:~/repos/ns-3-allinnone$ cd ns-3-dev/
shiva@shiva-VirtualBox:~/repos/ns-3-allinnone/ns-3-dev$ ./waf --run "project1a --n=3 --dist=290"
Waf: Entering directory "/home/shiva/repos/ns-3-allinnone/ns-3-dev/build"
Waf: Leaving directory "/home/shiva/repos/ns-3-allinnone/ns-3-dev/build"
Build commands will be stored in build/compile_commands.json
Build finished successfully (8.776s)
Total Packets Received: 1313
shiva@shiva-VirtualBox:~/repos/ns-3-allinnone/ns-3-dev$
```

On increasing the distance between two nodes to 290, we receive 1313 packets as shown in the snapshot above.

#### 2. Provide an explanation to the observed behavior?

On increasing the distance between the nodes, transmission time for the packet also increases, which results in packet taking more time to reach the destination. Also, there are chances of collisions. Therefore, for the above reasons, we receive less packets in comparison to the previous tasks.

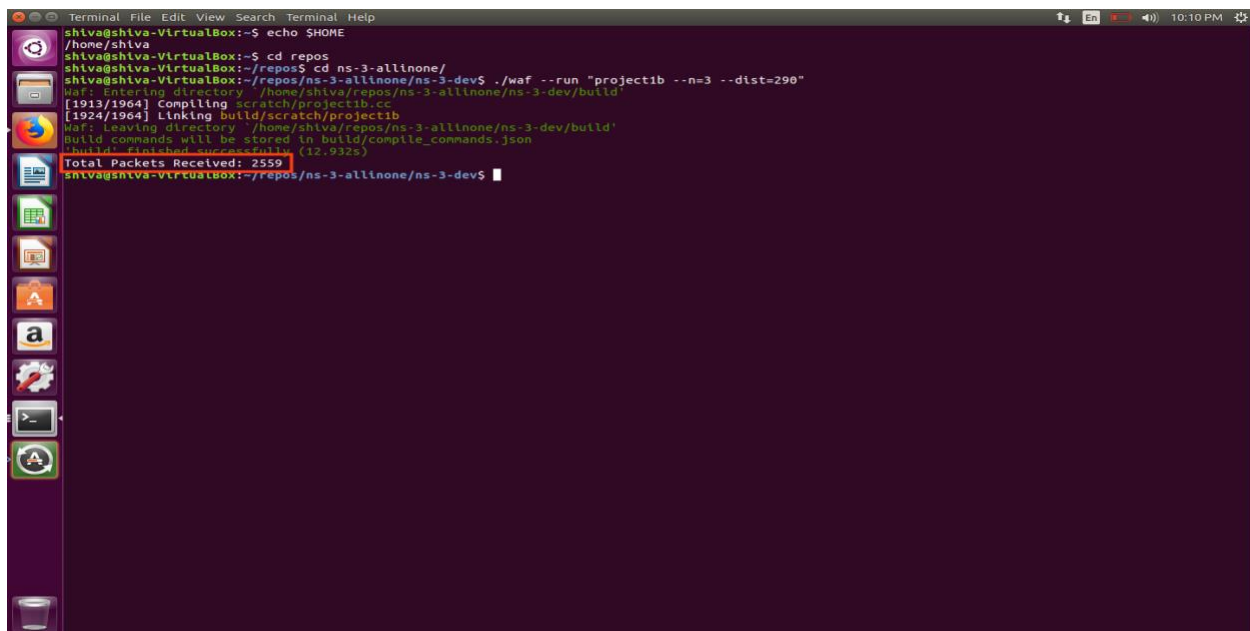
## 4. RTS/CTS

### 1. What lines of code did you change and why?

```
//////Fragmentation and RTS/CTS properties
Config::SetDefault ("ns3::WifiRemoteStationManager::FragmentationThreshold", StringValue ("2200"));
Config::SetDefault ("ns3::WifiRemoteStationManager::RtsCtsThreshold", StringValue ("0"));
```

To have RTS/CTS handshake before Transmitter sends the data packet, packet size should be greater than the RTS/CTS Threshold function. Hence, we changed the value from 2200 to 0.

### 2. How many packets are received in the network this time? Compare the result to the one in part 3?



```
shiva@shiva-VirtualBox:~$ echo $HOME
/home/shiva
shiva@shiva-VirtualBox:~$ cd repos
shiva@shiva-VirtualBox:~/repos$ cd ns-3-allinone/
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$ ./waf --run "project1b --n=3 --dist=290"
[1913/1964] Compiling scratch/project1b.cc
[1924/1964] Linking build/scratch/project1b
Waf: Leaving directory "/home/shiva/repos/ns-3-allinone/ns-3-dev/build"
Build commands will be stored in build/compile_commands.json
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev/build$
Total Packets Received: 2559
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$
```

Total Number of packets received in this part using RTS/CTS = 2559 in comparison to  
Total Number of packets received in the part 3 without RTS/CTS = 1313.

### 3. Provide an explanation for the observed behavior?

By enabling RTS/CTS, number of collisions in the network decreases, thereby increasing the total number of successful transmission of packets to the receiver.

### 4. What is the throughput of the network? Compare this result to the one in part 2?

Total Packets received as per the above snapshot = 2559; Length of each packet = 1000;  
Start time of transmission = 5.0089 seconds (As per the snapshot on wireshark);  
End time of transmission = 20 seconds;

Therefore, Total Transmission time = (20 – 5.0089) seconds  
No. of bytes = (2559\*1000)

Throughput of the Network =  $(2559 * 1000 * 8) / (20 - 5.0089)$   
= 1.365 Mbps

### **5. Provide an explanation for the observed behavior?**

Throughput obtained here is lesser than what is observed in Part 2, since, even though the number of collisions decreases, the overall time taken including data transmitting time, RTS, CTS time increase and therefore reduce the throughput of the network.

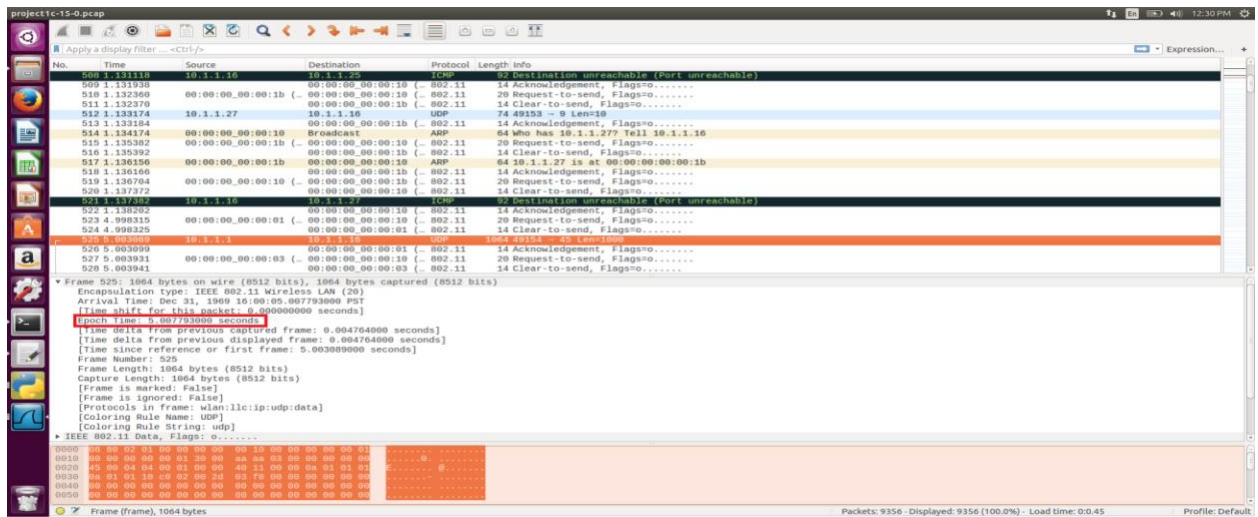
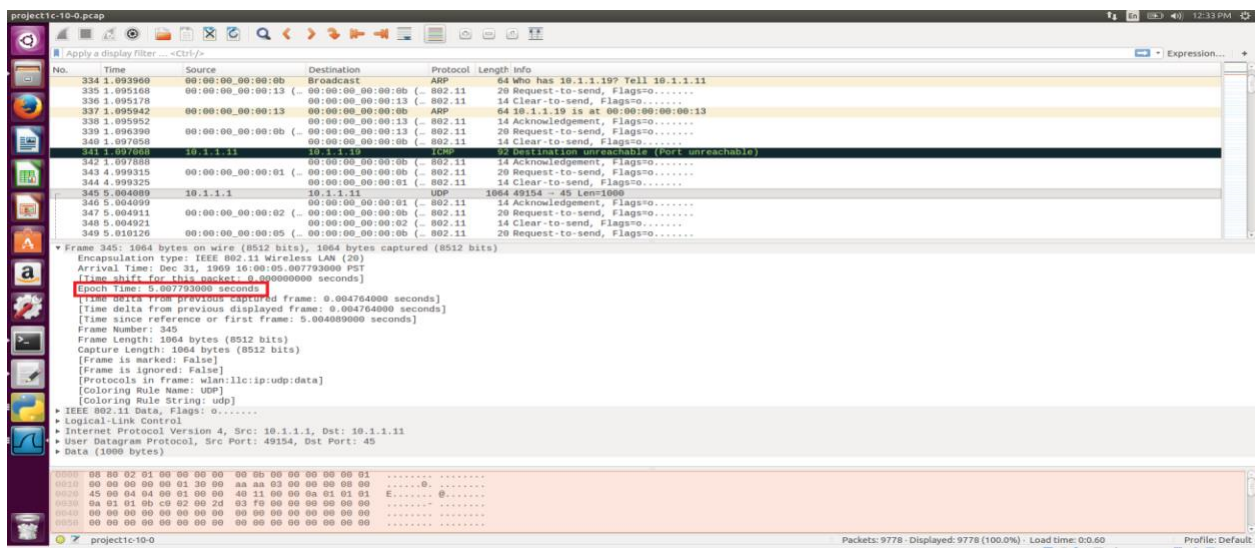


## 5. Throughput as a Function of Number of Users

### 1. With RTS/CTS Enabled:

```
Terminal File Edit View Search Terminal Help
shiva@shiva-VirtualBox:~$ cd repos
shiva@shiva-VirtualBox:~/repos$ cd ns-3-allnone/
shiva@shiva-VirtualBox:~/repos/ns-3-allnone$ cd ns-3-dev/
shiva@shiva-VirtualBox:~/repos/ns-3-allnone/ns-3-dev$ ./waf --run "projectic --n=3 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
[1907/1966] Compiling scratch/projectic.cc
[1908/1966] Compiling scratch/scratch-simulator.cc
[1909/1966] Compiling scratch/projectia.cc
[1910/1966] Compiling scratch/subdir/scratch-simulator-subdir.cc
[1911/1966] Compiling scratch/projectib.cc
[1922/1966] Linking build/scratch/projectic
[1923/1966] Linking build/scratch/scratch-simulator
[1924/1966] Linking build/scratch/projectia
[1925/1966] Linking build/scratch/subdir/subdir
[1926/1966] Linking build/scratch/projectib
Waf: Leaving directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
Build finished successfully (22.699s)
Total Packets Received: 2565
shiva@shiva-VirtualBox:~/repos/ns-3-allnone/ns-3-dev$ ./waf --run "projectic --n=10 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
Waf: Leaving directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
Build finished successfully (8.235s)
Total Packets Received: 2403
shiva@shiva-VirtualBox:~/repos/ns-3-allnone/ns-3-dev$ ./waf --run "projectic --n=20 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
Waf: Leaving directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
Build finished successfully (8.460s)
Total Packets Received: 2178
shiva@shiva-VirtualBox:~/repos/ns-3-allnone/ns-3-dev$ ./waf --run "projectic --n=30 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
Waf: Leaving directory '/home/shiva/repos/ns-3-allnone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
Build finished successfully (8.581s)
Total Packets Received: 1987
shiva@shiva-VirtualBox:~/repos/ns-3-allnone/ns-3-dev$
```

```
projectic-5-0.pcap
Apply a display filter (Ctrl+F)
Expression:
No. Time Source Destination Protocol Length Info
160 1.041690 00:00:00_00:00:00 00:00:00_00:00:00 802.11 20 Request-to-send, Flags=0.....
161 1.042358 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Clear-to-send, Flags=0.....
162 1.042950 10.1.1.0 10.1.1.0 UDP 1064 49154 -> 45 Len=1000 (port unreachable)
163 1.043108 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Acknowledgement, Flags=0.....
164 4.996315 00:00:00_00:00:00 00:00:00_00:00:00 802.11 20 Request-to-send, Flags=0.....
165 4.996325 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Clear-to-send, Flags=0.....
166 5.001089 10.1.1.1 10.1.1.0 UDP 1064 49154 -> 45 Len=1000
167 5.001099 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Acknowledgement, Flags=0.....
168 5.001811 00:00:00_00:00:00 00:00:00_00:00:00 802.11 20 Request-to-send, Flags=0.....
169 5.001821 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Clear-to-send, Flags=0.....
170 5.006585 10.1.1.1 10.1.1.0 UDP 1064 49154 -> 45 Len=1000
171 5.006595 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Acknowledgement, Flags=0.....
172 5.007287 00:00:00_00:00:00 00:00:00_00:00:00 802.11 20 Request-to-send, Flags=0.....
173 5.007297 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Clear-to-send, Flags=0.....
174 5.012761 00:00:00_00:00:00 00:00:00_00:00:00 802.11 20 Request-to-send, Flags=0.....
175 5.012771 00:00:00_00:00:00 00:00:00_00:00:00 802.11 14 Clear-to-send, Flags=0.....
* Frame 166: 1064 bytes on wire (8512 bits), 1064 bytes captured (8512 bits)
Encapsulation type: IEEE 802.11 Wireless LAN (20)
Arrival Time: Dec 31, 1969 10:00:05.007793000 PST
[Time shift for this packet: 0.000000000 seconds]
Epoch time: 5.007793000 seconds
[Time delta from previous capture frame: 0.004764000 seconds]
[Time delta from previous displayed frame: 0.004764000 seconds]
[Time since reference or first frame: 5.001089000 seconds]
Frame Number: 166
Frame Length: 1064 bytes (8512 bits)
Capture Length: 1064 bytes (8512 bits)
[Frame is marked: False]
[Frame is ignored: False]
[Protocols in frame: wlan:llc:ip:udp:data]
[Coloring Rule Name: UDP]
[Coloring Rule String: udp]
IEEE 802.11 Data, Flags: 0.....
Logical-Link Control
Internet Protocol Version 4, Src: 10.1.1.1, Dst: 10.1.1.0
User Datagram Protocol, Src Port: 49154, Dst Port: 45
Data (1000 bytes)
0000 00 00 02 01 00 00 00 00 00 00 00 00 00 00 01 .....
0010 00 00 00 00 00 01 30 00 aa aa 03 00 00 00 00 .....0.....
0020 45 00 04 04 00 01 00 00 40 11 00 00 0a 01 01 01 .....@.....
0030 0a 01 01 00 c0 02 00 2d 03 f0 00 00 00 00 00 .....
0040 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
0050 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
```



No. Of Users	No. of Packets	Throughput (Mbps)	Throughput/user (Mbps)
3	2565	1.368	0.456
10	2403	1.282	0.128
20	2178	1.162	0.058
30	1987	1.060	0.035

## 2. With RTS/CTS Disabled:

```
Terminal File Edit View Search Terminal Help
shiva@shiva-VirtualBox:~$ cd repos
shiva@shiva-VirtualBox:~/repos$ cd ns-3-allinone/
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$ ./waf --run "projectic --n=3 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
[1907/1966] Compiling scratch/projectic.cc
[1926/1966] Linking build/scratch/projectic
Waf: Leaving directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
!build: finished successfully (12.907s)
Total Packets Received: 1313
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$ ./waf --run "projectic --n=10 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Waf: Leaving directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
!build: finished successfully (8.363s)
Total Packets Received: 417
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$ ./waf --run "projectic --n=20 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Waf: Leaving directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
!build: finished successfully (8.388s)
Total Packets Received: 143
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$ ./waf --run "projectic --n=30 --dist=290"
Waf: Entering directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Waf: Leaving directory '/home/shiva/repos/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
!build: finished successfully (8.391s)
Total Packets Received: 56
shiva@shiva-VirtualBox:~/repos/ns-3-allinone/ns-3-dev$
```

No. Of Users	No. of Packets	Throughput (Mbps)	Throughput/user (Mbps)
3	1313	0.700	0.233
10	417	0.222	0.022
20	143	0.076	0.003
30	56	0.029	0.0009

