Link to Assignment 2 files:
https://github.com/LordJatonyas/CWM-ProgNets/tree/main/assignment2

Ping

First Test (Lab to Pi 10 times, interval=0.2s)
10 packets transmitted, 10 received, 0% packet loss, time 1833ms
rtt min/avg/max/mdev = 0.368/0.474/0.521/0.044 ms

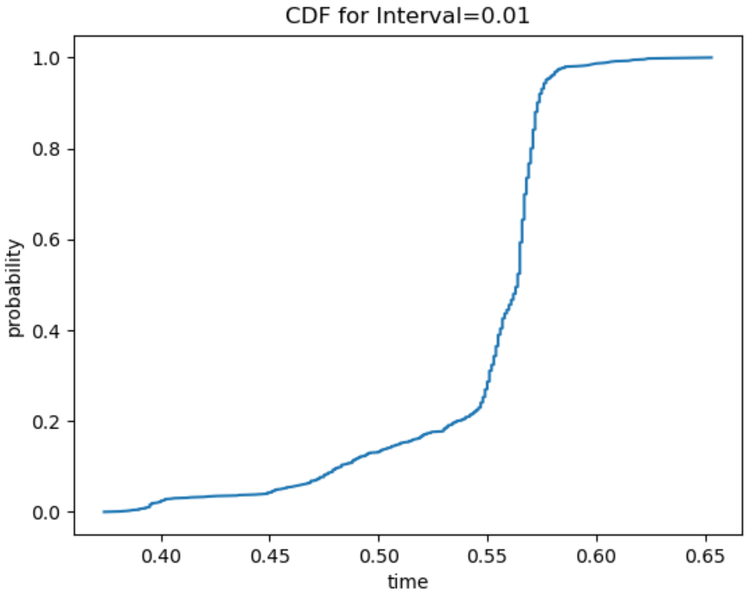
Second Test (Pi to Lab 10 times, interval=0.2s)
10 packets transmitted, 10 received, 0% packet loss, time 1836ms
rtt min/avg/max/mdev = 0.473/0.494/0.536/0.018 ms

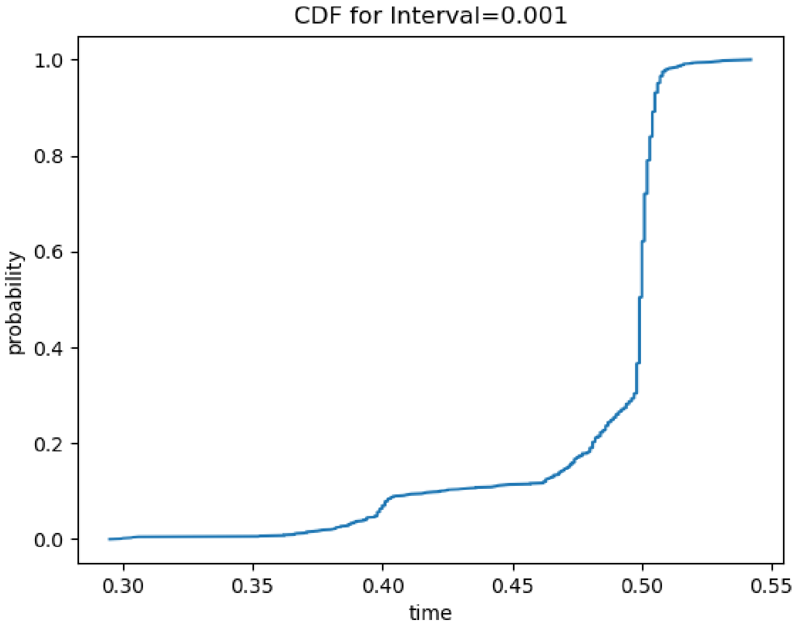
Third Test (Pi to Lab 100 times, interval=0.001s)
100 packets transmitted, 100 received, 0% packet loss, time 99ms
rtt min/avg/max/mdev = 0.365/0.486/0.595/0.036 ms

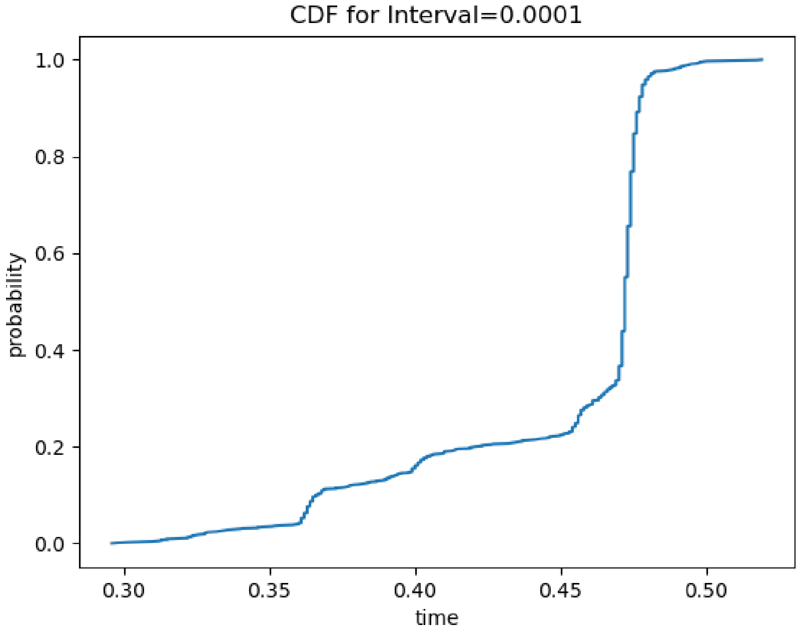
Overall, the RTT values are quite similar across the 3 tests.

Fourth Test
10000 packets transmitted, 10000 received, 0% packet loss, time 4636ms
rtt min/avg/max/mdev = 0.281/0.426/1.652/0.074 ms, ipg/ewma 0.463/0.472 ms

Fifth Test
1000 measurements were made for each of the three different intervals (0.01, 0.001, 0.0001) and CDFs were generated for each.



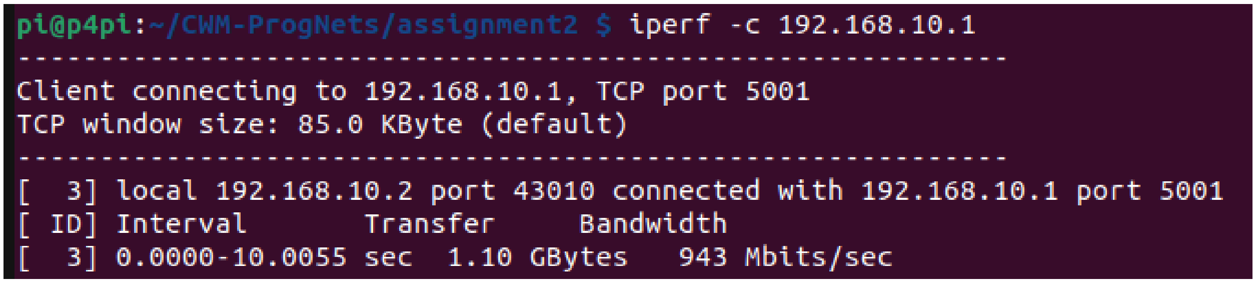




We can see that as the interval decreases, the mean RTT decreases. This is because with a larger interval, the machine tends to switch to different tasks while awaiting the next send. This introduces a startup time as a result of switching back to the task of sending packets to the Lab Machine. With a smaller interval, there is no startup time since the packets are effectively chained together. The minimum and maximum RTTs have large variance, so the most accurate estimator of propagation time is the mean RTT.

iperf

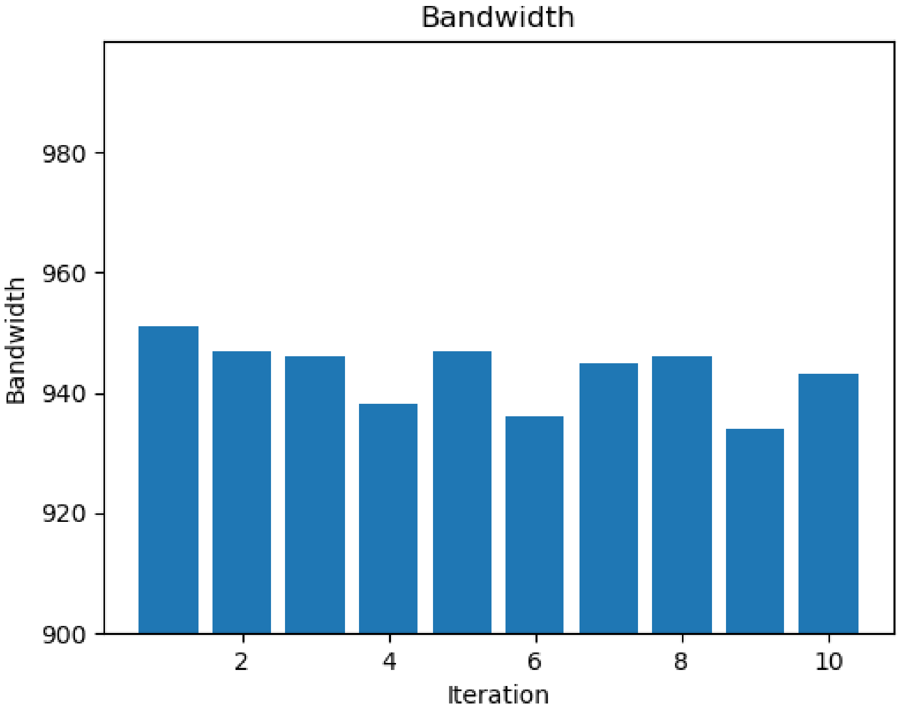
First Test (Lab Machine (server), P4Pi-9 (client), 10 sec)



```
pi@p4pi:~/CWM-ProgNets/assignment2 $ iperf -c 192.168.10.1
------------------------------------------------------------
Client connecting to 192.168.10.1, TCP port 5001
TCP window size: 85.0 KByte (default)
------------------------------------------------------------
[  3] local 192.168.10.2 port 43010 connected with 192.168.10.1 port 5001
[ ID] Interval       Transfer     Bandwidth
[  3] 0.0000-10.0055 sec  1.10 GBytes   943 Mbits/sec
```

Effective Bandwidth: 943 Mbits/sec

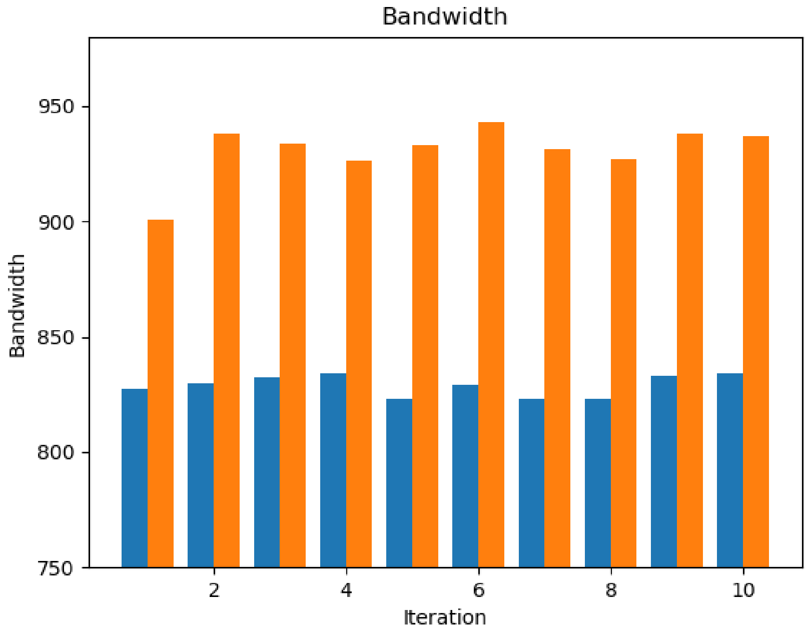
Second Test (Lab Machine (client), P4Pi-9 (server), 10 sec, interval=1 sec)



Third Test (Bi-directional Test)

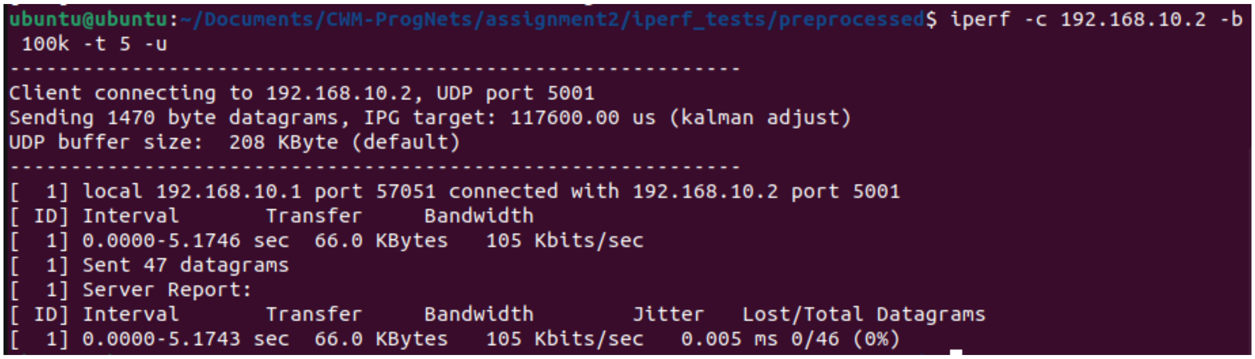
Orange - Forward

Blue - Backward



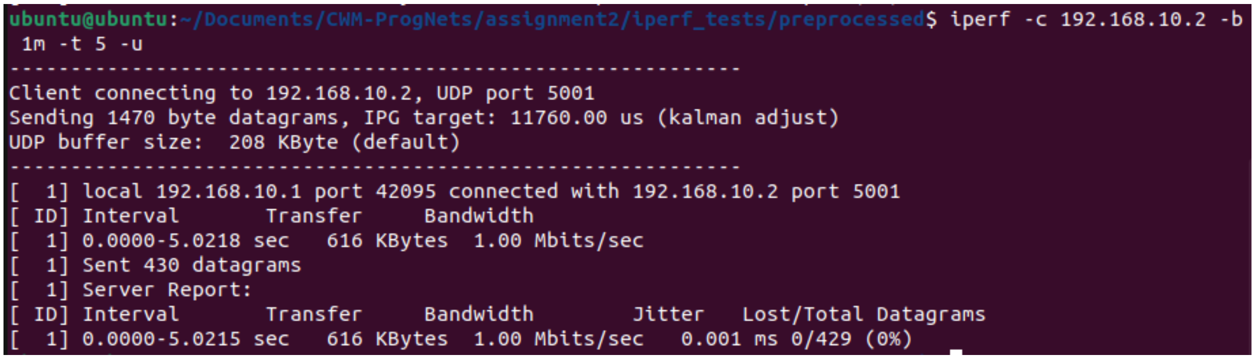
Fourth Test (UDP one-way at 100Kb/s, 1Mb/s, 100Mb/s)

100Kb/s



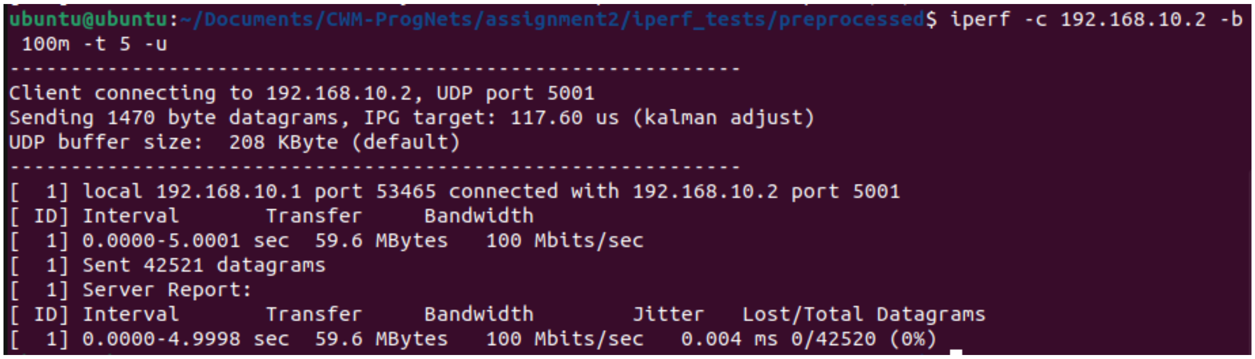
```
ubuntu@ubuntu:~/Documents/CWM-ProgNets/assignment2/iperf_tests/preprocessed$ iperf -c 192.168.10.2 -b
 100k -t 5 -u
------------------------------------------------------------
Client connecting to 192.168.10.2, UDP port 5001
Sending 1470 byte datagrams, IPG target: 117600.00 us (kalman adjust)
UDP buffer size:  208 KByte (default)
------------------------------------------------------------
[  1] local 192.168.10.1 port 57051 connected with 192.168.10.2 port 5001
[ ID] Interval       Transfer     Bandwidth
[  1] 0.0000-5.1746 sec  66.0 KBytes   105 Kbits/sec
[  1] Sent 47 datagrams
[  1] Server Report:
[ ID] Interval       Transfer     Bandwidth        Jitter   Lost/Total Datagrams
[  1] 0.0000-5.1743 sec  66.0 KBytes   105 Kbits/sec   0.005 ms 0/46 (0%)
```

1Mb/s



```
ubuntu@ubuntu:~/Documents/CWM-ProgNets/assignment2/iperf_tests/preprocessed$ iperf -c 192.168.10.2 -b
 1m -t 5 -u
------------------------------------------------------------
Client connecting to 192.168.10.2, UDP port 5001
Sending 1470 byte datagrams, IPG target: 11760.00 us (kalman adjust)
UDP buffer size:  208 KByte (default)
------------------------------------------------------------
[  1] local 192.168.10.1 port 42095 connected with 192.168.10.2 port 5001
[ ID] Interval       Transfer     Bandwidth
[  1] 0.0000-5.0218 sec   616 KBytes  1.00 Mbits/sec
[  1] Sent 430 datagrams
[  1] Server Report:
[ ID] Interval       Transfer     Bandwidth        Jitter   Lost/Total Datagrams
[  1] 0.0000-5.0215 sec   616 KBytes  1.00 Mbits/sec   0.001 ms 0/429 (0%)
```

100Mb/s

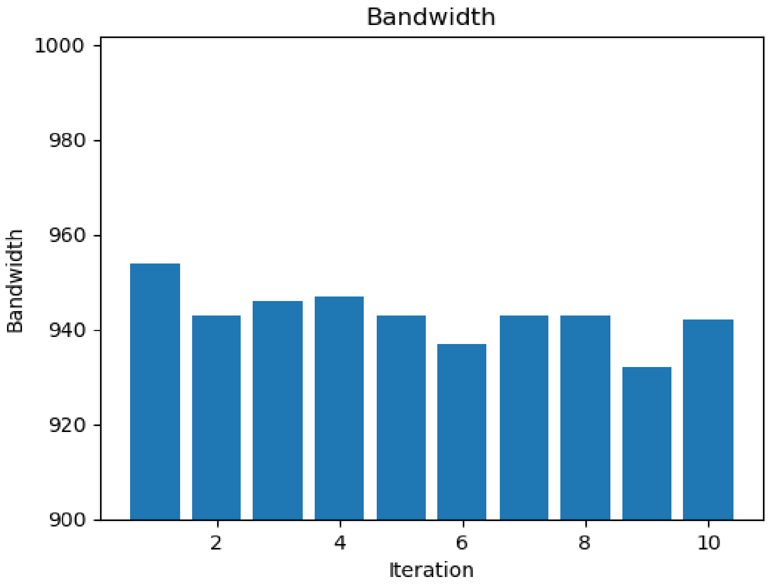


```
ubuntu@ubuntu:~/Documents/CWM-ProgNets/assignment2/iperf_tests/preprocessed$ iperf -c 192.168.10.2 -b
 100m -t 5 -u
------------------------------------------------------------
Client connecting to 192.168.10.2, UDP port 5001
Sending 1470 byte datagrams, IPG target: 117.60 us (kalman adjust)
UDP buffer size:  208 KByte (default)
------------------------------------------------------------
[  1] local 192.168.10.1 port 53465 connected with 192.168.10.2 port 5001
[ ID] Interval       Transfer     Bandwidth
[  1] 0.0000-5.0001 sec  59.6 MBytes   100 Mbits/sec
[  1] Sent 42521 datagrams
[  1] Server Report:
[ ID] Interval       Transfer     Bandwidth        Jitter   Lost/Total Datagrams
[  1] 0.0000-4.9998 sec  59.6 MBytes   100 Mbits/sec   0.004 ms 0/42520 (0%)
```

No packets dropped for each of the bandwidths tested, so no graph for packet loss is plotted.

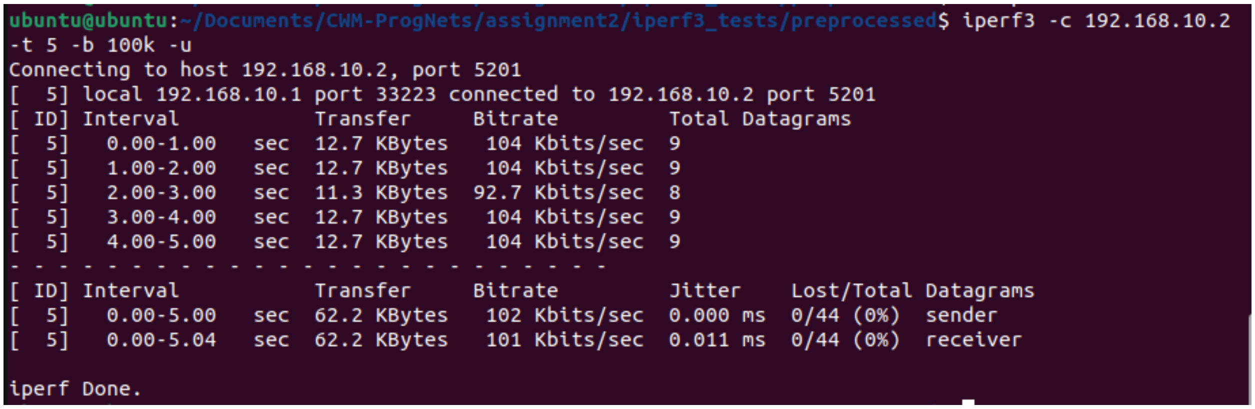
iperf3

First Test (Lab Machine (client), P4Pi-9 (server), 10 sec, interval=1 sec)



<u>Second Test</u> (UDP at 100Kb/s, 1Mb/s, 100Mb/s)

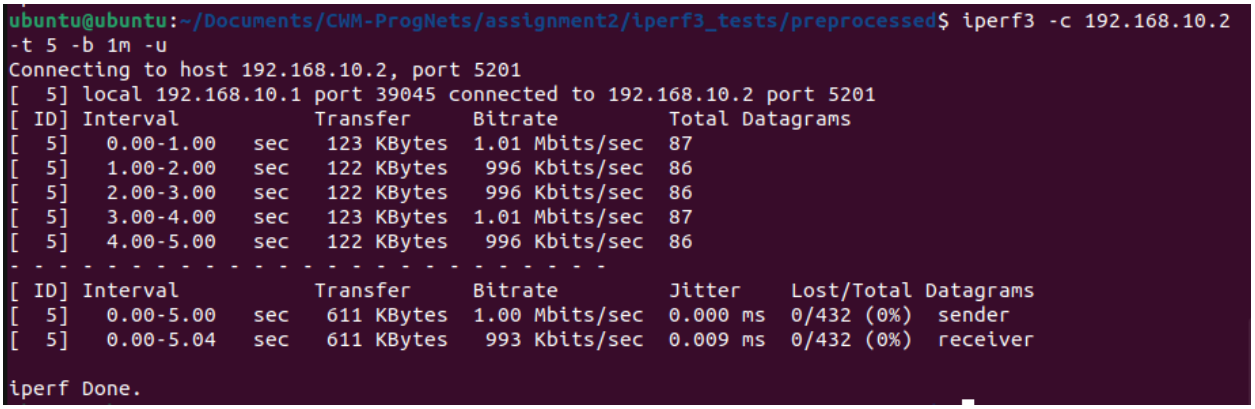
100Kb/s



```
ubuntu@ubuntu:~/Documents/CWM-ProgNets/assignment2/iperf3_tests/preprocessed$ iperf3 -c 192.168.10.2
-t 5 -b 100k -u
Connecting to host 192.168.10.2, port 5201
[  5] local 192.168.10.1 port 33223 connected to 192.168.10.2 port 5201
[ ID] Interval           Transfer     Bitrate         Total Datagrams
[  5]   0.00-1.00   sec  12.7 KBytes   104 Kbits/sec  9
[  5]   1.00-2.00   sec  12.7 KBytes   104 Kbits/sec  9
[  5]   2.00-3.00   sec  11.3 KBytes  92.7 Kbits/sec  8
[  5]   3.00-4.00   sec  12.7 KBytes   104 Kbits/sec  9
[  5]   4.00-5.00   sec  12.7 KBytes   104 Kbits/sec  9
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-5.00   sec  62.2 KBytes   102 Kbits/sec  0.000 ms  0/44 (0%)  sender
[  5]   0.00-5.04   sec  62.2 KBytes   101 Kbits/sec  0.011 ms  0/44 (0%)  receiver

iperf Done.
```

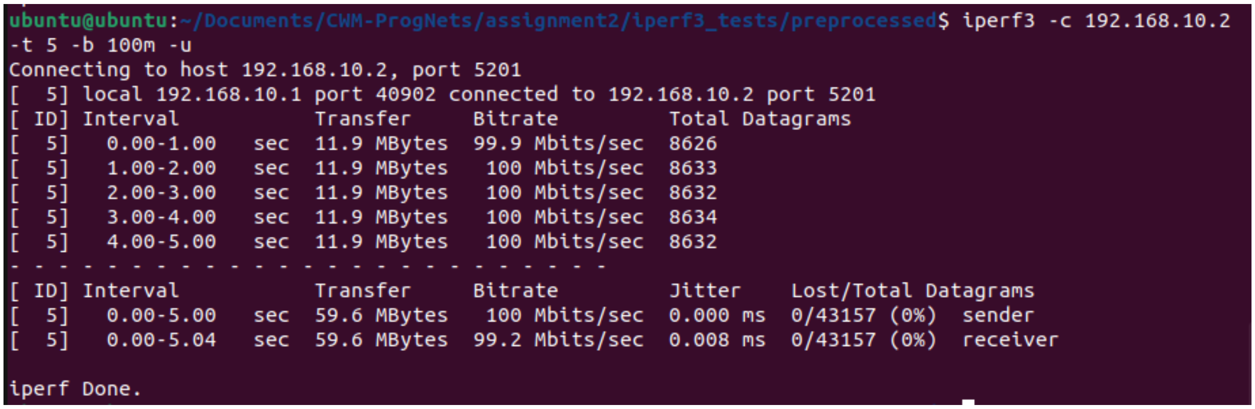
1Mb/s



```
ubuntu@ubuntu:~/Documents/CWM-ProgNets/assignment2/iperf3_tests/preprocessed$ iperf3 -c 192.168.10.2
-t 5 -b 1m -u
Connecting to host 192.168.10.2, port 5201
[  5] local 192.168.10.1 port 39045 connected to 192.168.10.2 port 5201
[ ID] Interval           Transfer     Bitrate         Total Datagrams
[  5]   0.00-1.00   sec   123 KBytes  1.01 Mbits/sec  87
[  5]   1.00-2.00   sec   122 KBytes   996 Kbits/sec  86
[  5]   2.00-3.00   sec   122 KBytes   996 Kbits/sec  86
[  5]   3.00-4.00   sec   123 KBytes  1.01 Mbits/sec  87
[  5]   4.00-5.00   sec   122 KBytes   996 Kbits/sec  86
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-5.00   sec   611 KBytes  1.00 Mbits/sec  0.000 ms  0/432 (0%)  sender
[  5]   0.00-5.04   sec   611 KBytes   993 Kbits/sec  0.009 ms  0/432 (0%)  receiver

iperf Done.
```

100Mb/s



```
ubuntu@ubuntu:~/Documents/CWM-ProgNets/assignment2/iperf3_tests/preprocessed$ iperf3 -c 192.168.10.2
-t 5 -b 100m -u
Connecting to host 192.168.10.2, port 5201
[  5] local 192.168.10.1 port 40902 connected to 192.168.10.2 port 5201
[ ID] Interval           Transfer     Bitrate         Total Datagrams
[  5]   0.00-1.00   sec  11.9 MBytes  99.9 Mbits/sec  8626
[  5]   1.00-2.00   sec  11.9 MBytes   100 Mbits/sec  8633
[  5]   2.00-3.00   sec  11.9 MBytes   100 Mbits/sec  8632
[  5]   3.00-4.00   sec  11.9 MBytes   100 Mbits/sec  8634
[  5]   4.00-5.00   sec  11.9 MBytes   100 Mbits/sec  8632
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-5.00   sec  59.6 MBytes   100 Mbits/sec  0.000 ms  0/43157 (0%)  sender
[  5]   0.00-5.04   sec  59.6 MBytes  99.2 Mbits/sec  0.008 ms  0/43157 (0%)  receiver

iperf Done.
```

Once again, no packets were lost along the way, so no plot for packet loss is made. With a large enough sample size, we expect iperf3 to outperform iperf simply because it was developed as an improvement to iperf. However, given the tests conducted here, there are no discernable differences for all 3 bandwidths.