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CSE 232 - Computer Networks Assignment - 3

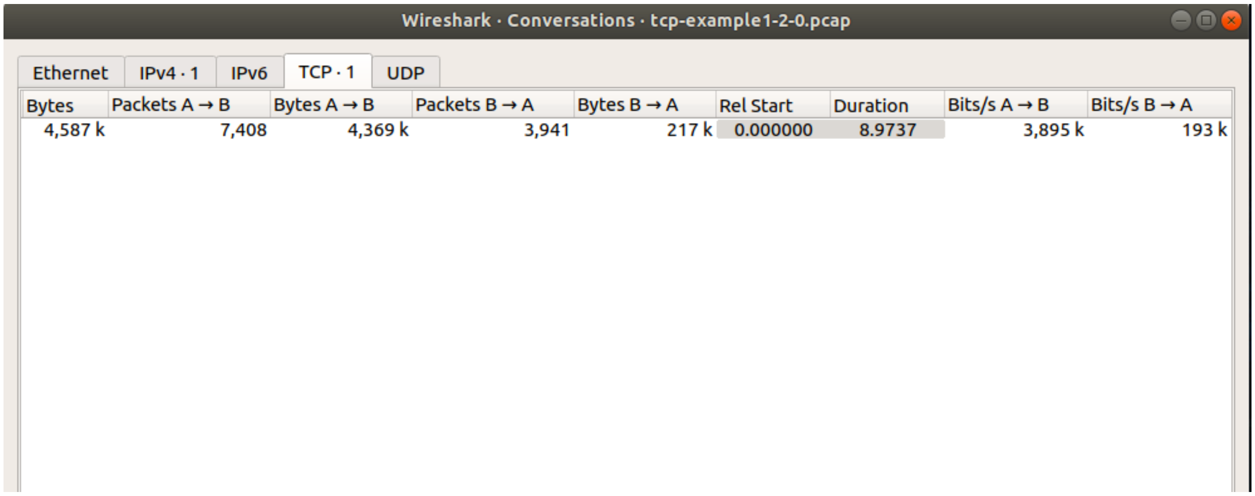
Q1)

a) Since the bottleneck bandwidth is 5Mbps, the maximum expected value of throughput (theoretically) is 5Mbps since this is the minimum bandwidth of the link.

Note: If we consider the delay too:
Total number of packets N2 receives = 10^5
Size of 1 packet = 1460 x 8 = 11680 bits.
Total data received, TD = 1168Mb
Delay = 0.01+0.015 = 0.025s
Total time taken = TD/5 + 0.025 (Packets are received faster at N1 than they are transferred since the link between N0 and N1 is 10Mbps, between N1 and N2 is 5Mbps)
Therefore, maximum value of throughput = TD/(Total time taken) = 1168/(1168/5+0.025) = 4.9994 Mbps

b) Bandwidth-Delay-Product (BDP) = (Data link capacity x RTT)/ (size of 1 packet)
Data link capacity = 5Mbps = 5*10^6 bps(bottleneck-capacity)
RTT = 2* (10+15) ms = 0.05 s
Size of 1 packet = 1460 x 8 bits
Putting in the formula, BDP = 21.404 packets

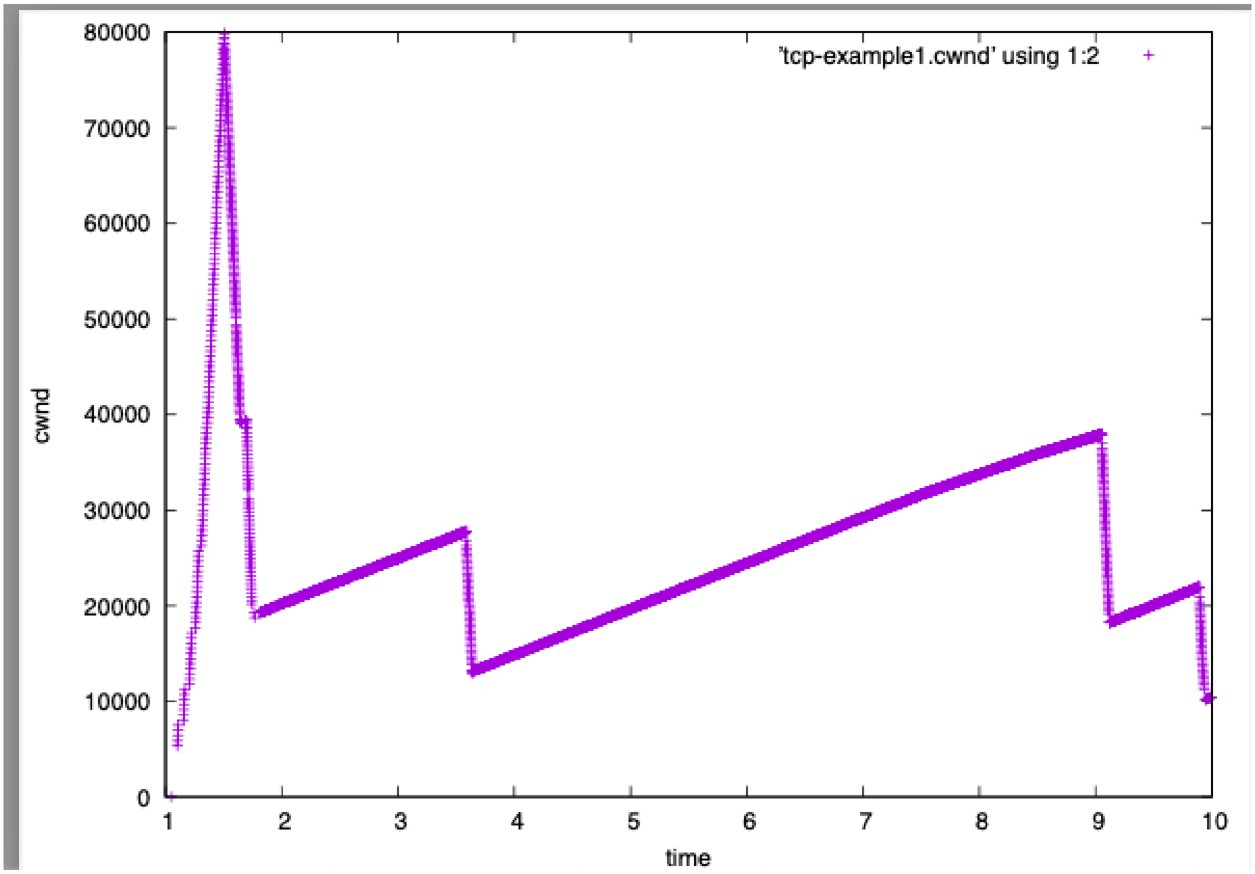
c) The average throughput is 3.895 Mbps.



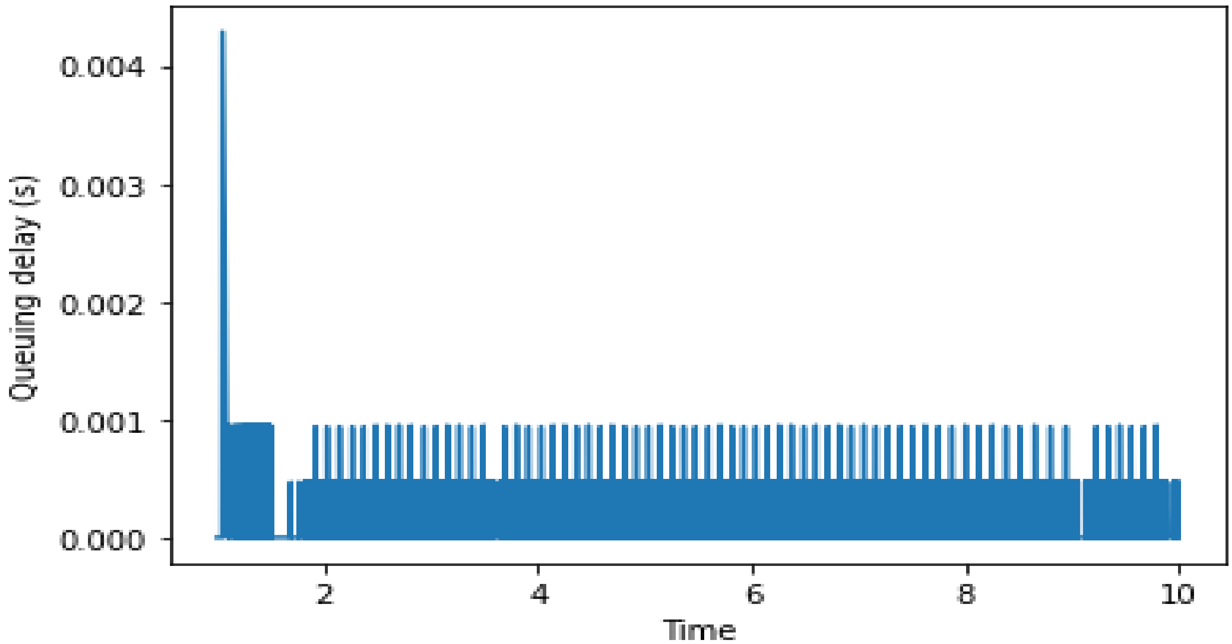
Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
4,587 k	7,408	4,369 k	3,941	217 k	0.000000	8.9737	3,895 k	193 k

d)No, the maximum expected value of throughput is 5Mbps. The average throughput observed is 3.895Mbps. This is due to the queuing delays, delays in the link as well as error rate of the simulation. The packets get dropped as a result of limited queue size and high congestion rates.

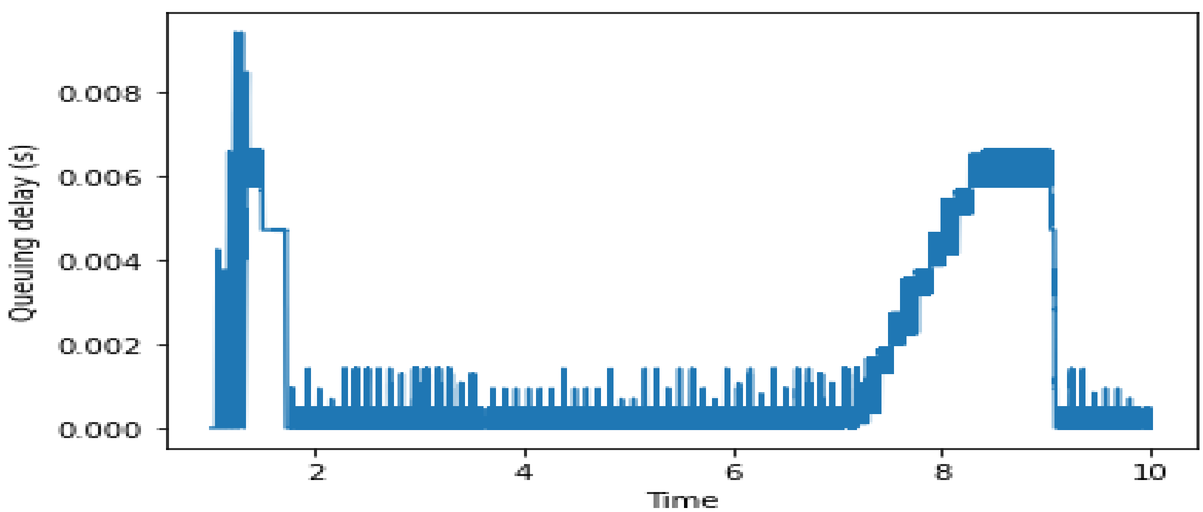
e)


'tcp-example1.cwnd' using 1:2
cwnd
time
80000
70000
60000
50000
40000
30000
20000
10000
0
1
2
3
4
5
6
7
8
9
10

f) For N0:



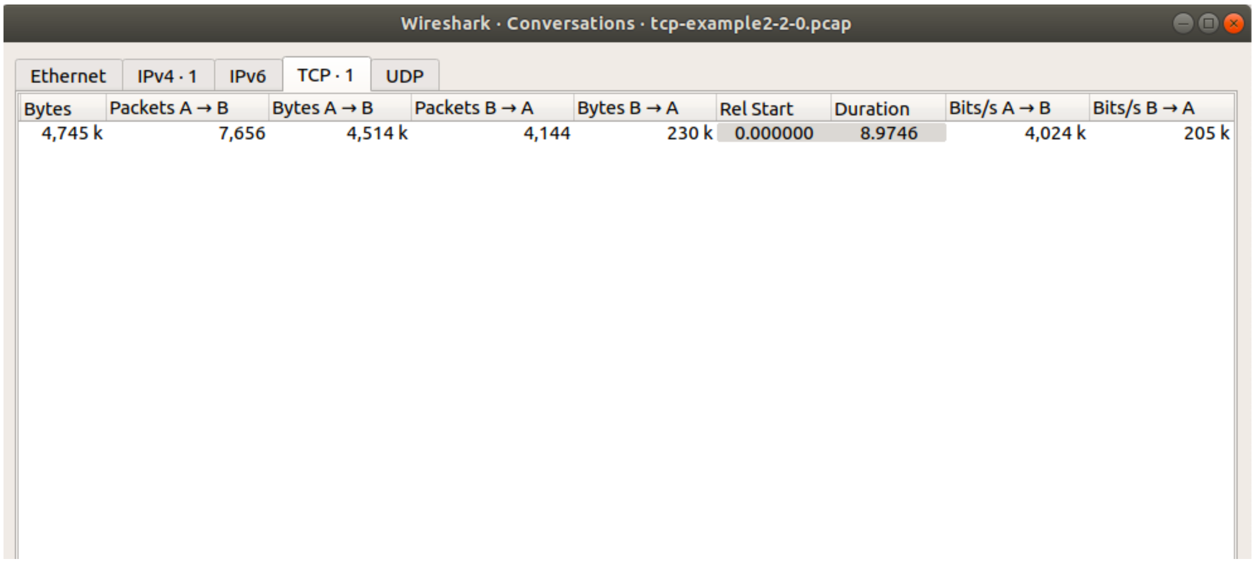
For N1:



g) Yes, the plots are related. They are proportional. As transmission rates increase, the congestion window and queuing delay grow in size linearly. The congestion window size increases , and the queueing delay also increases. However, once the transmission rate reaches the threshold level, the congestion window is reduced to half to decrease congestion (transmission rate decreases) and queue time. They begin to increase linearly once more, and the process is repeated.

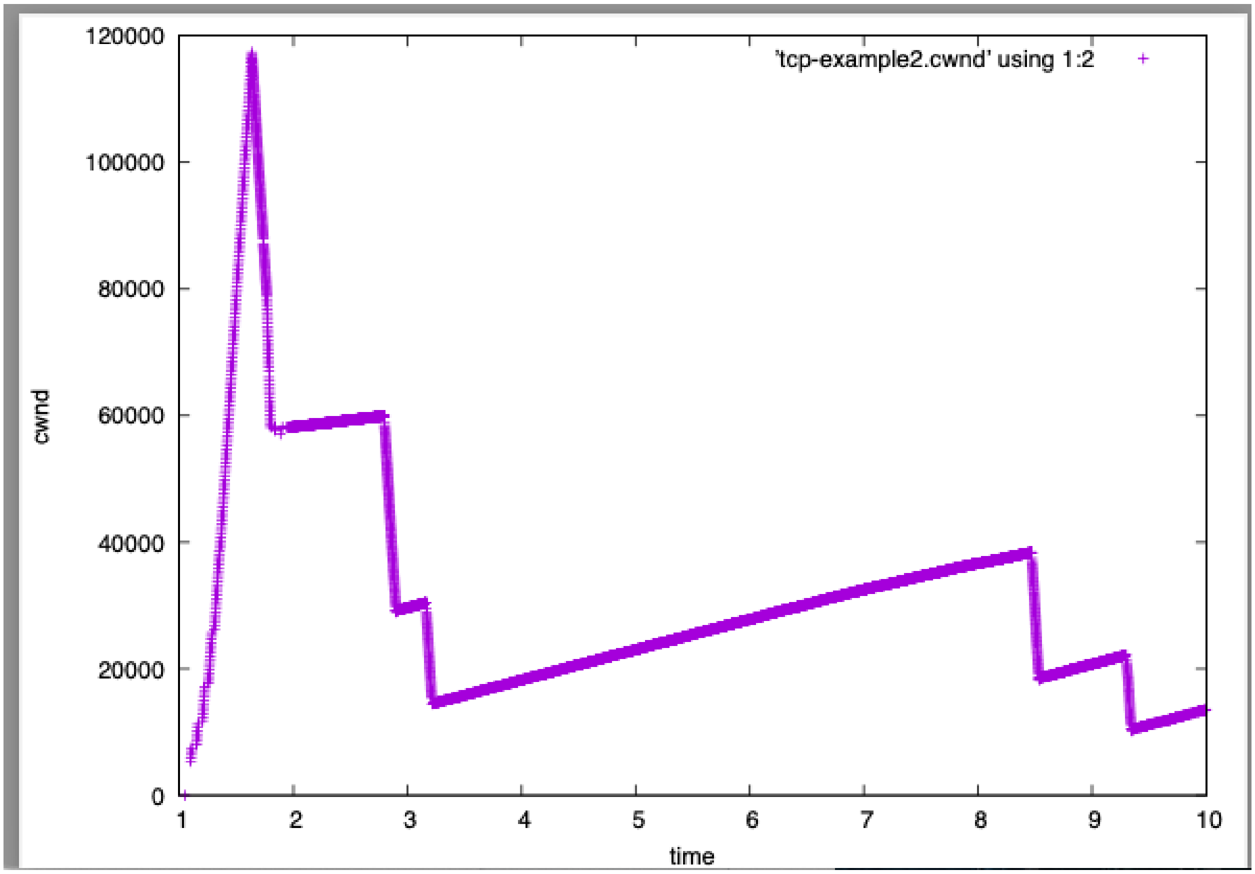
Q2)

a) The average throughput is 4.024 Mbps.



Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
4,745 k	7,656	4,514 k	4,144	230 k	0.000000	8.9746	4,024 k	205 k

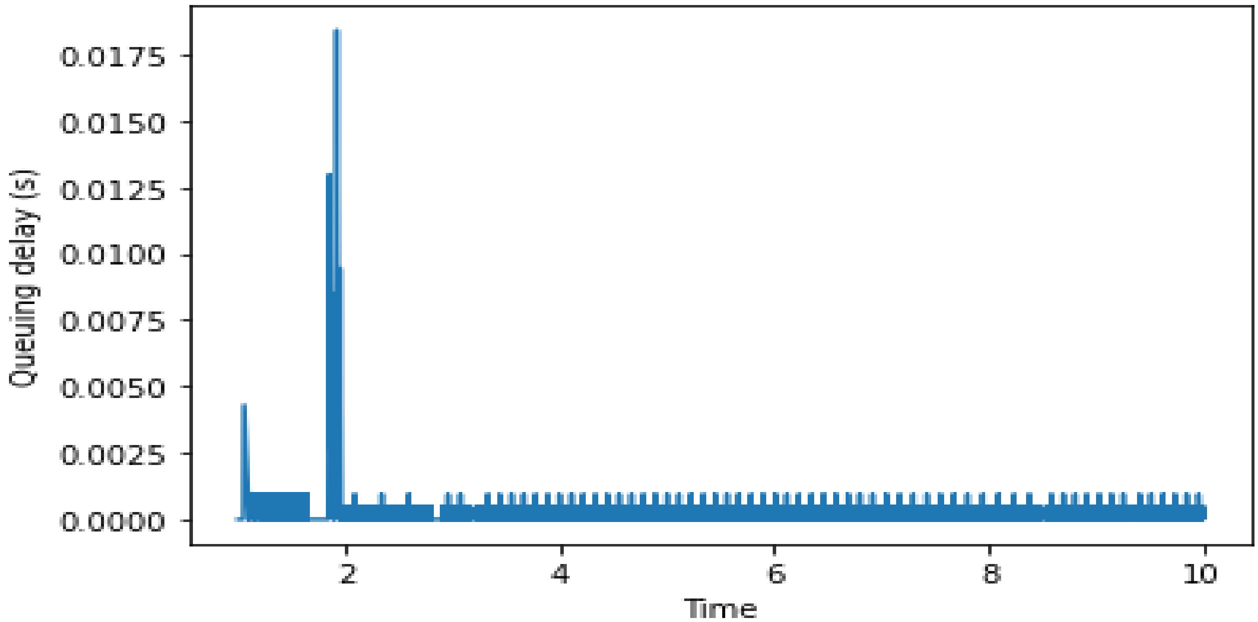
b)



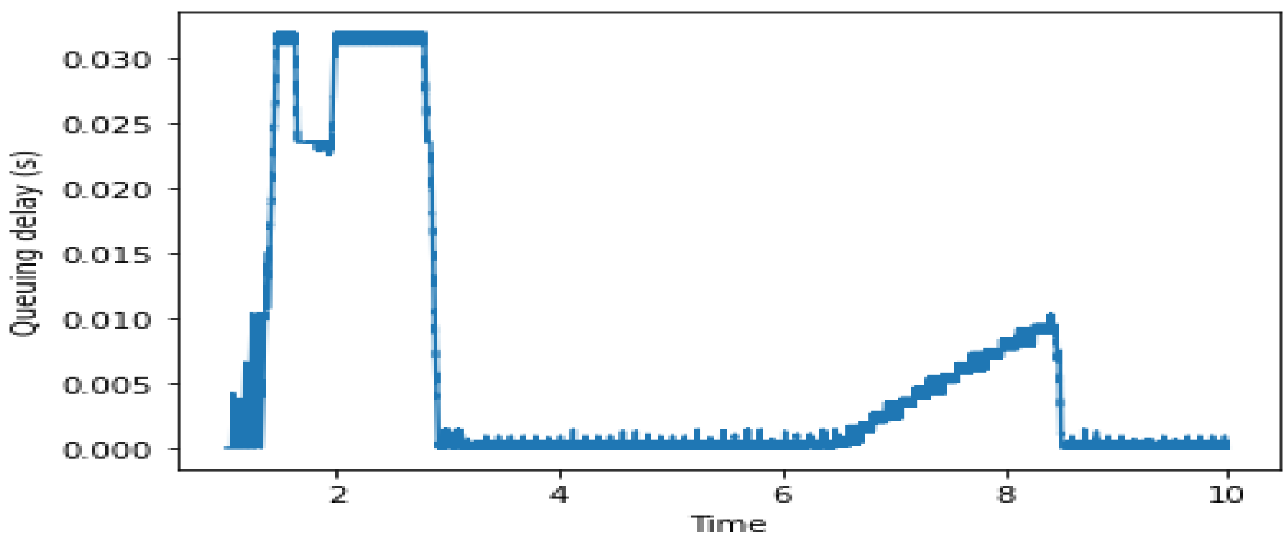
'tcp-example2.cwnd' using 1:2
cwnd
time
120000
100000
80000
60000
40000
20000
0
1
2
3
4
5
6
7
8
9
10

c)

For N0:



For N1:



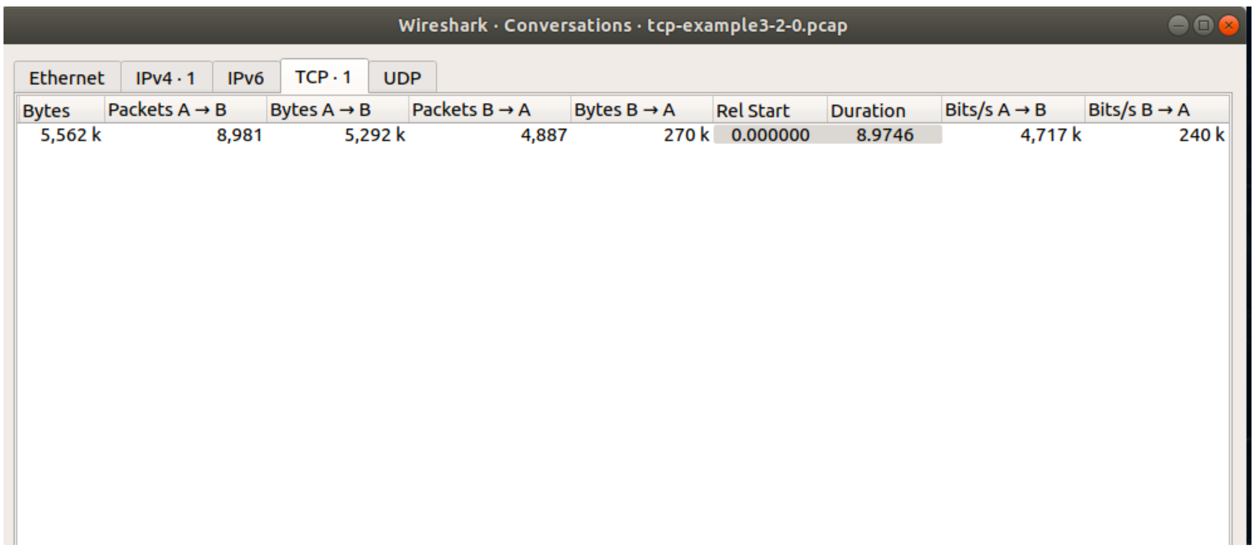
d) Comparing the CWND plots of Q1 and Q2- The queue size in Q2 is greater than that of Q1. Thus greater queue size in Q2 will allow more packets in the queue buffer. Due to this, the CWND value can be increased more as the queue size is large which prevents packet loss. Thus, the maximum value of tCWND in Q1 is around 80000 while in Q2, it is about 120000. Higher queue sizes lead to greater congestion tolerance. As a result, we see that the reduction in congestion window size because of congestion is less abrupt for queue size 50 than for queue size 10.

The slow start thresholds which follow are higher for Q2 than Q1. This is due to the fact that the initialisation of the slow start threshold is CWND/2 if we consider timeout and

packet losses. Owing to higher CWND in Q2, higher are the values of slow start thresholds.
Due to the small queue size in Q1, the CWND is dropped abruptly to 20000 directly to prevent packet loss. The CWND takes small drops in case of Q2 since higher queue size ensures more packets in the queue buffer.

Q3)

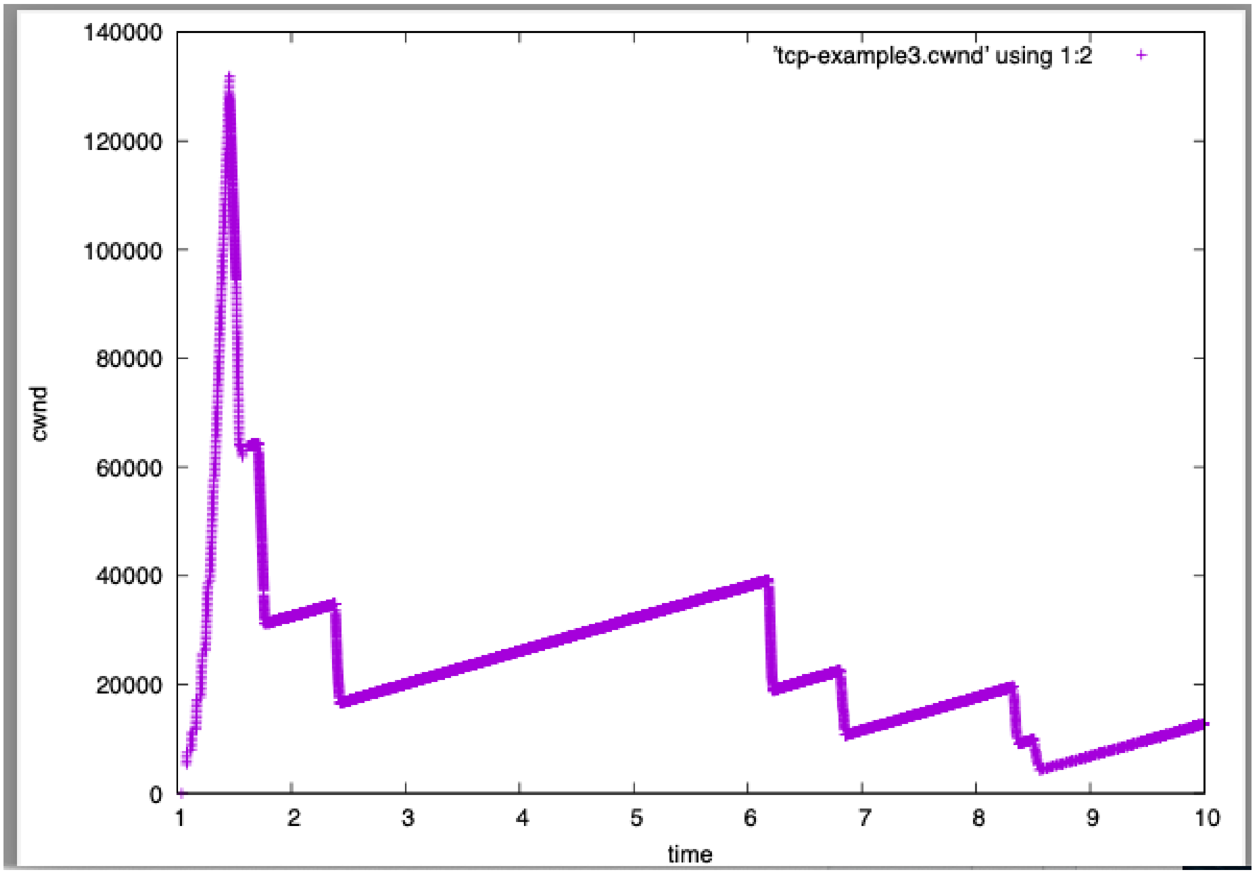
The average throughput is 4.717 Mbps.



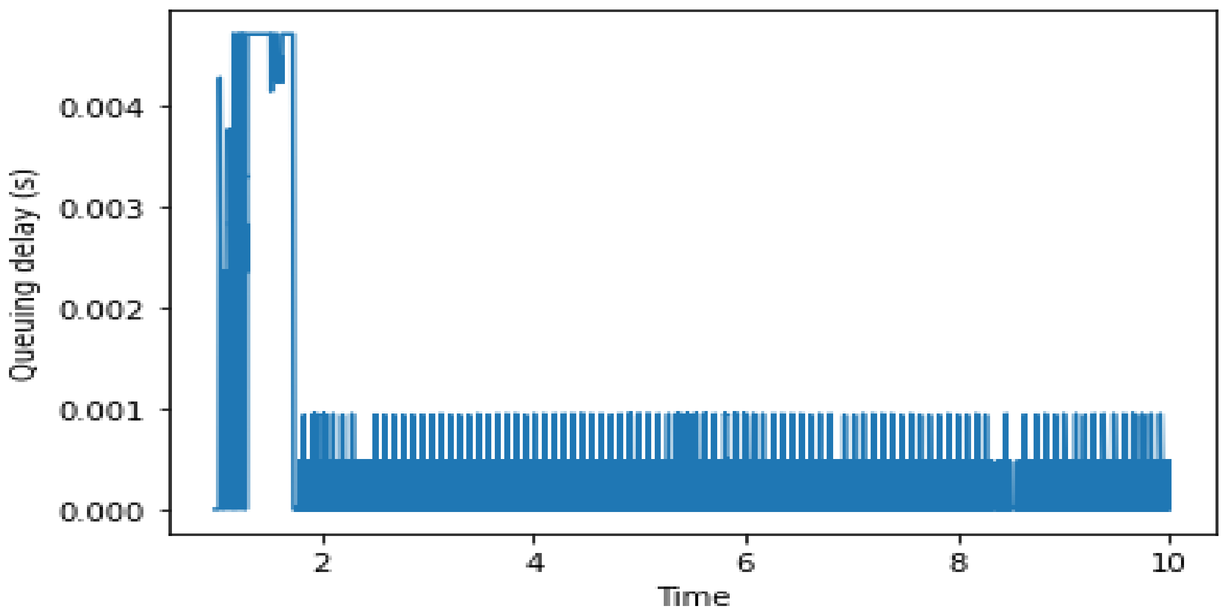
Wireshark · Conversations · tcp-example3-2-0.pcap

Ethernet | IPv4 · 1 | IPv6 | TCP · 1 | UDP

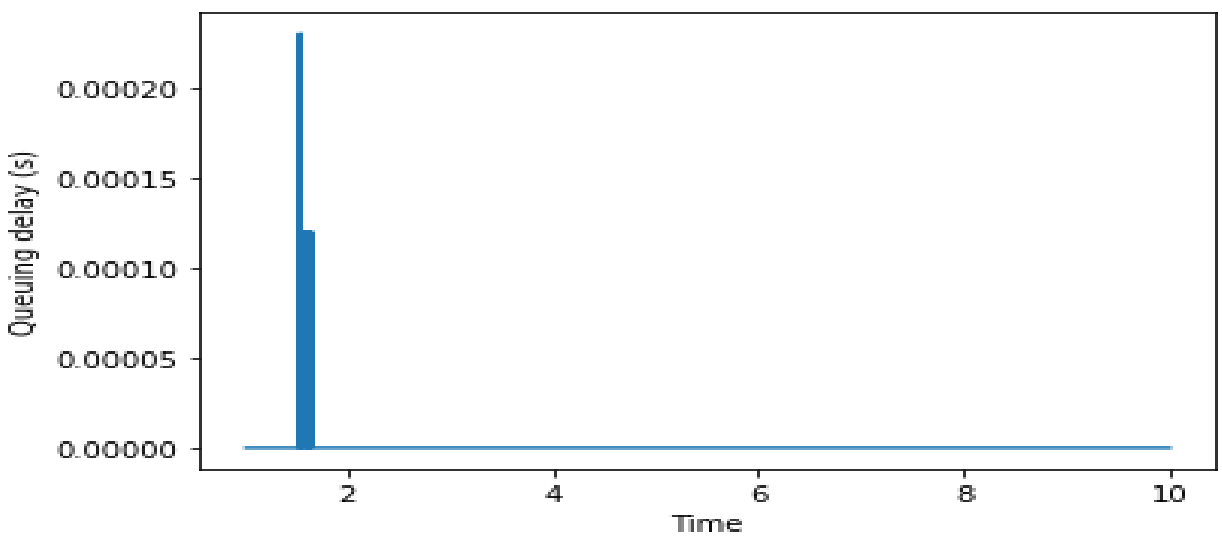
Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
5,562 k	8,981	5,292 k	4,887	270 k	0.000000	8.9746	4,717 k	240 k


'tcp-example3.cwnd' using 1:2
cwnd
time
140000
120000
100000
80000
60000
40000
20000
0
1
2
3
4
5
6
7
8
9
10

For N0:



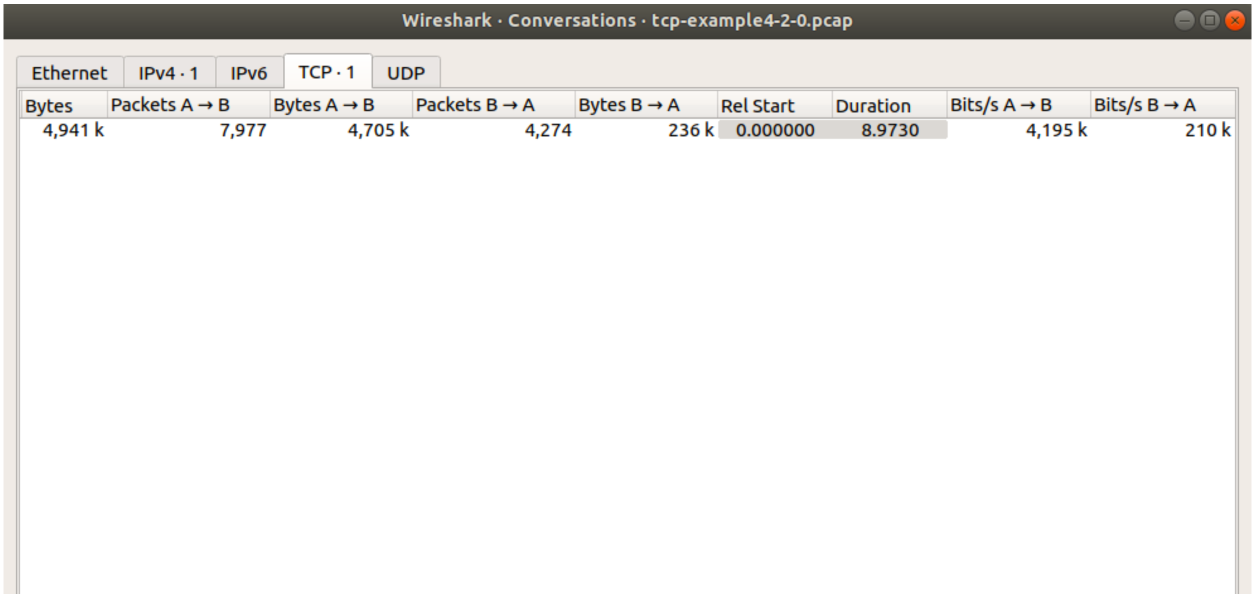
For N1:



d) The bandwidth and delays are same for both the links in Q3 , thus queuing delay hardly happens as there is no congestion and no queue gets formed at n1. However in Q1, there is a spike in the queueing delay owing to the fact that the bandwidth is greater between n0 and n1 compared to n1,n2 and the delays are different. Thus, a queue gets formed at n1.

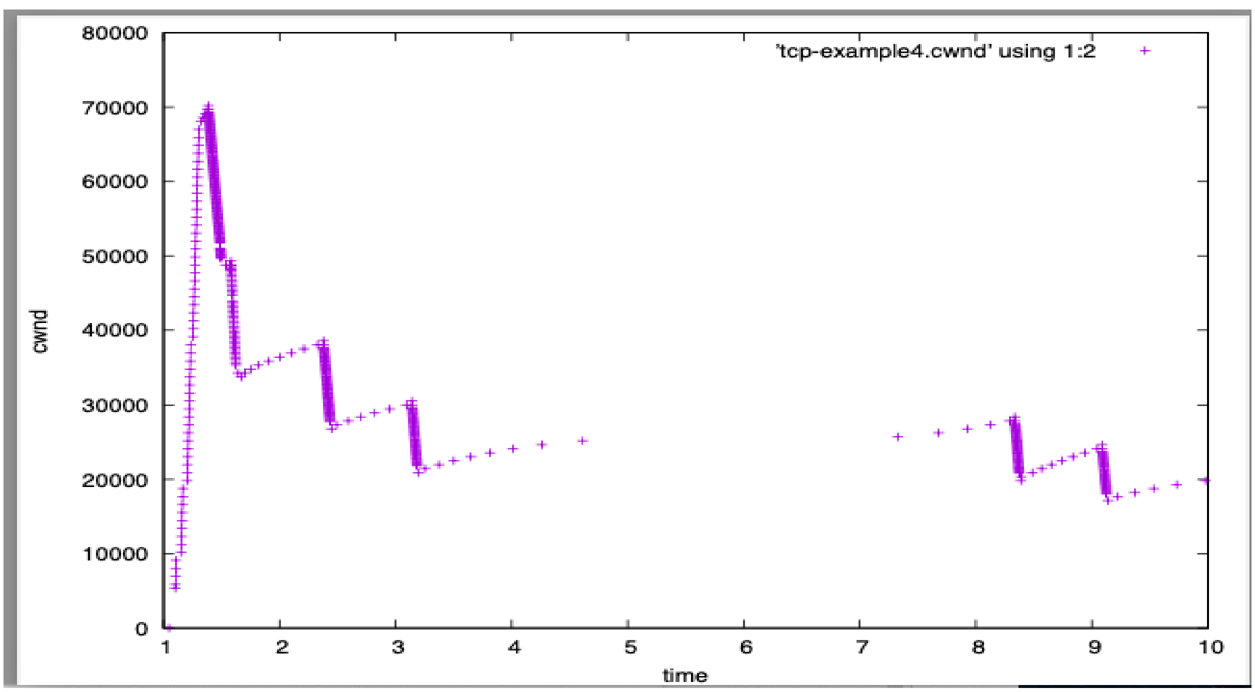
Q4)

a) The average throughput is 4.195 Mbps.



Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
4,941 k	7,977	4,705 k	4,274	236 k	0.000000	8.9730	4,195 k	210 k

b)



c) Comparing the CWND plots in Q1 and Q4:
The slow start stages are similar in both Q1 and Q4.
In the congestion avoidance phase,

TCP Reno's window growth function is AIMD (Additive Increase Multiplicative Decrease), whereas TCP Cubic's is the cubic function. Thus, in Q1, there is a linear increase in the CWND size.TCP's bandwidth probing approach offers a higher throughput because TCP Reno still probes linearly with the rise in the bottleneck bandwidth, but TCP Cubic probes cubically. TCP Cubic increases quite fast initially, but slows down the increase in the size of CWND as it reaches the maximum value. Thus it remains close to the maximum value mostly. In the fast recovery phase, iI TCP New Reno, the congestion window reduces by a factor of around 0.5, while hand, in TCP Cubic, the congestion factor dynamically changes.