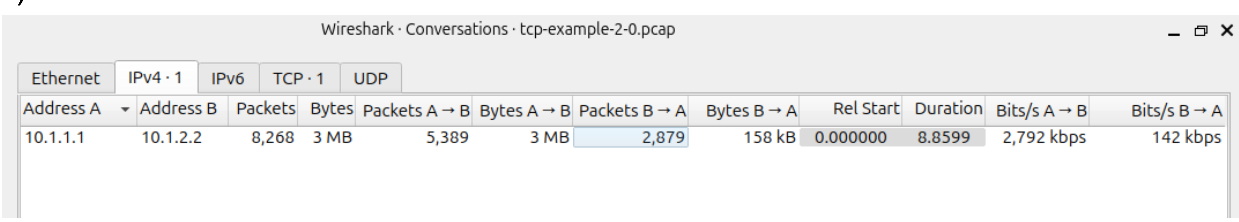
Report

1) a) The maximum expected theoretical value of the bandwidth is 7 Mbps. This is because the bandwidth will be considered as the bottleneck bandwidth between the two links; hence, it will be a minimum(10,7)=7Mbps.

b) Bandwidth delay product will be the product of max bandwidth and delay present between the two links.
Delay for one way= 100 ms + 10 ms = 110 ms
Hence Two way delay or RTT = 110 ms + 110 ms = 220 ms

Now BDP: 7Mbps*220 ms = 1540000 bits
Now, in terms of number of packets:
Size of each application packet: 1460*8=11680 bits
Hence, 1540000/11680 = 131.84
Hence, BDP is 131 or 132 packets.

c)



Address A	Address B	Packets	Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
10.1.1.1	10.1.2.2	8,268	3 MB	5,389	3 MB	2,879	158 kB	0.000000	8.8599	2,792 kbps	142 kbps

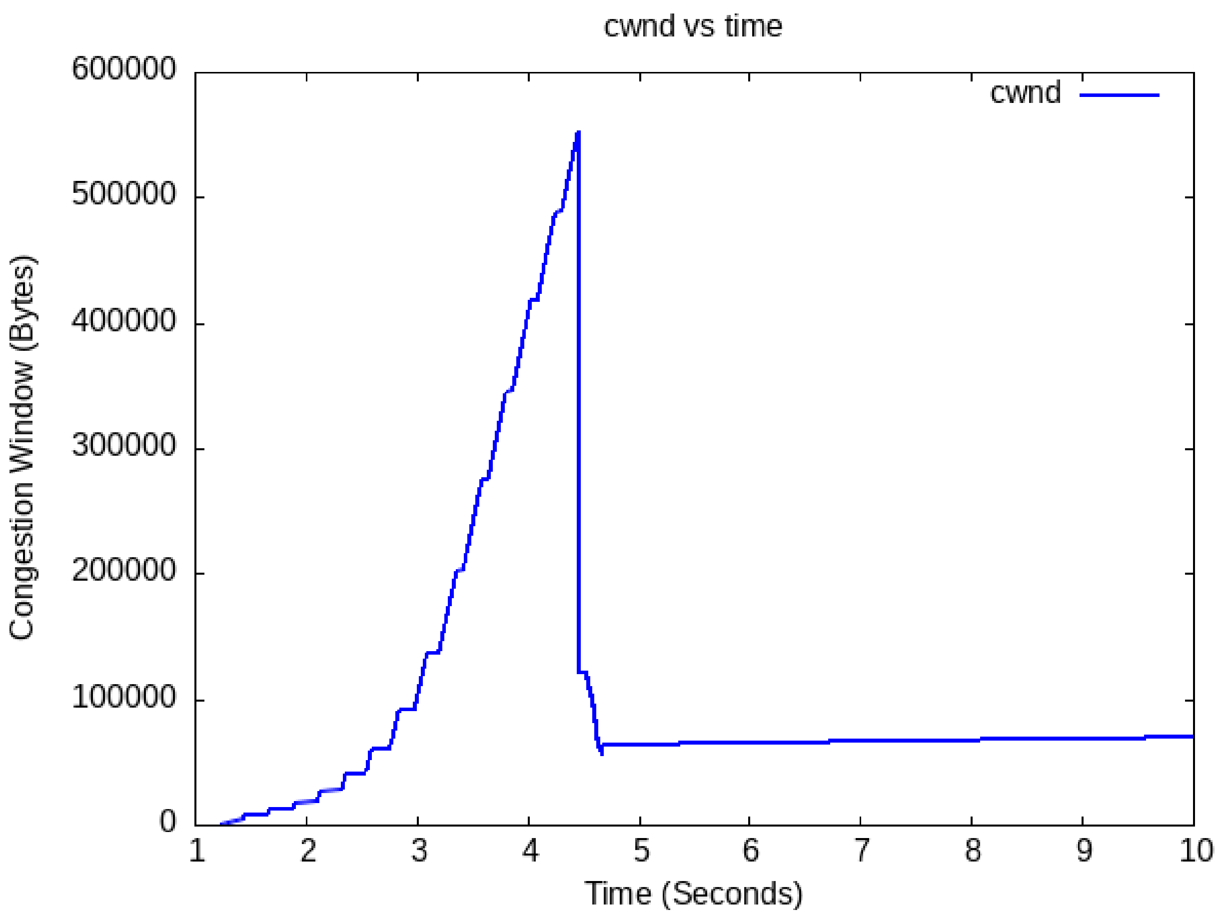
This is the pcap file of the receiver. It is clear from this that the actual throughput is 2792 kbps or 2.79 Mbps.

Also, Data From A-B: 3MB = 3000kB
Data From B-A: 158kB
Time Taken: 8.8599 seconds
Hence, Throughput: (3000kB+158kB)/8.8599 seconds
Throughput = 2.8Mbps
This is approximately equal to the throughput shown in the Wireshark interface.
BDP, in this case,
2.79Mbps*220 ms = 613800 bits
Now, in terms of number of packets:
Size of each application packet: 1460*8=11680 bits
Hence, 613800/11680 = 52.551

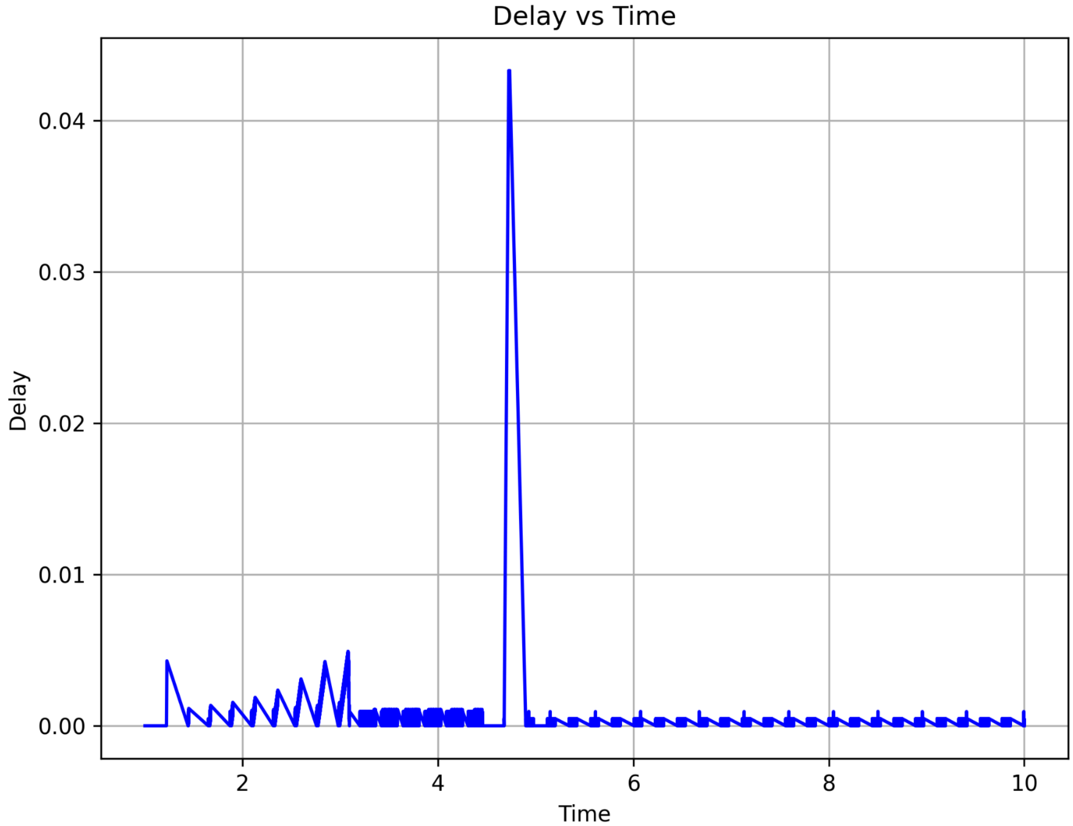
Hence, BDP is 51 or 50 packets.

d) No, the actual throughput is not the same as the maximum theoretical throughput possible. This is because of the following reasons:-
i) Protocol overheads
ii) Congestion and loss: If the queue at any intermediate node (N1) overflows due to high traffic or insufficient buffer size, packets may be dropped, reducing throughput.
iii) High link delays: Delays like- 100 ms for N0-N1 can impact the throughput.

e)

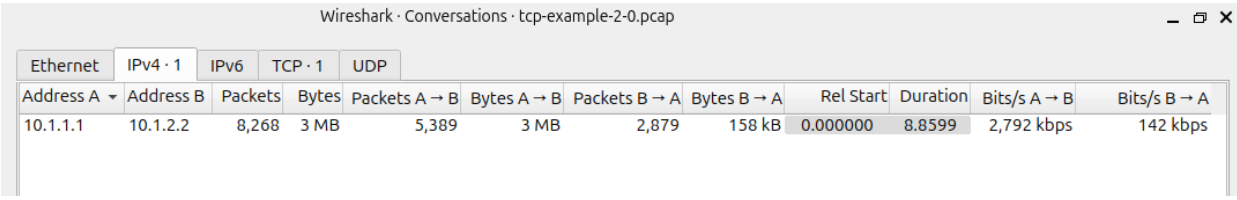


f)



g) Yes, both the plots are related.
During 2 to 4 seconds congestion window increases rapidly, and the sender pushes more packets into the network, If the outgoing link capacity is saturated, packets start to queue up in the sender's buffer, leading to an increase in queueing delay.
Now at around 4 seconds, cwnd has a sharp drop. This indicates a congestion event where packet loss or excessive delay caused TCP NewReno to invoke congestion control mechanisms. Hence, this drop in the congestion window marks the phase when the sender reduces its rate. Consequently, the queue empties quickly, causing the queue delay to decrease.
After the drop, the cwnd graph stabilizes at a lower value. TCP NewReno operates in the congestion avoidance phase, where it increases cwnd linearly rather than exponentially. In this phase, the packet sending rate matches the bottleneck link's capacity, resulting in a steady queueing delay (with smaller oscillations).

2) a)



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

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

Address A	Address B	Packets	Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
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This is the pcap file of the receiver. It is clear from this that the actual throughput is 2792 kbps or 2.79 Mbps.
Also, Data From A-B: 3MB = 3000kB
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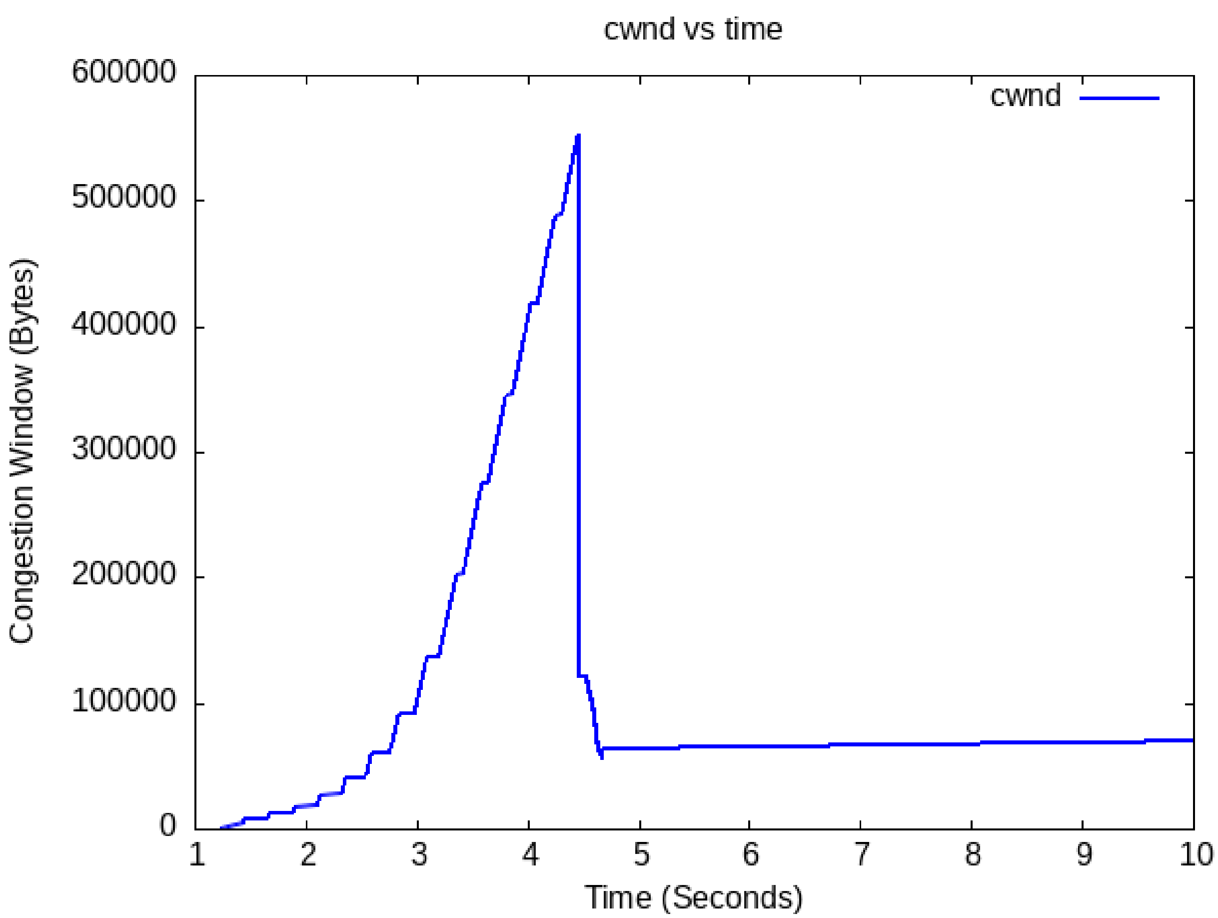
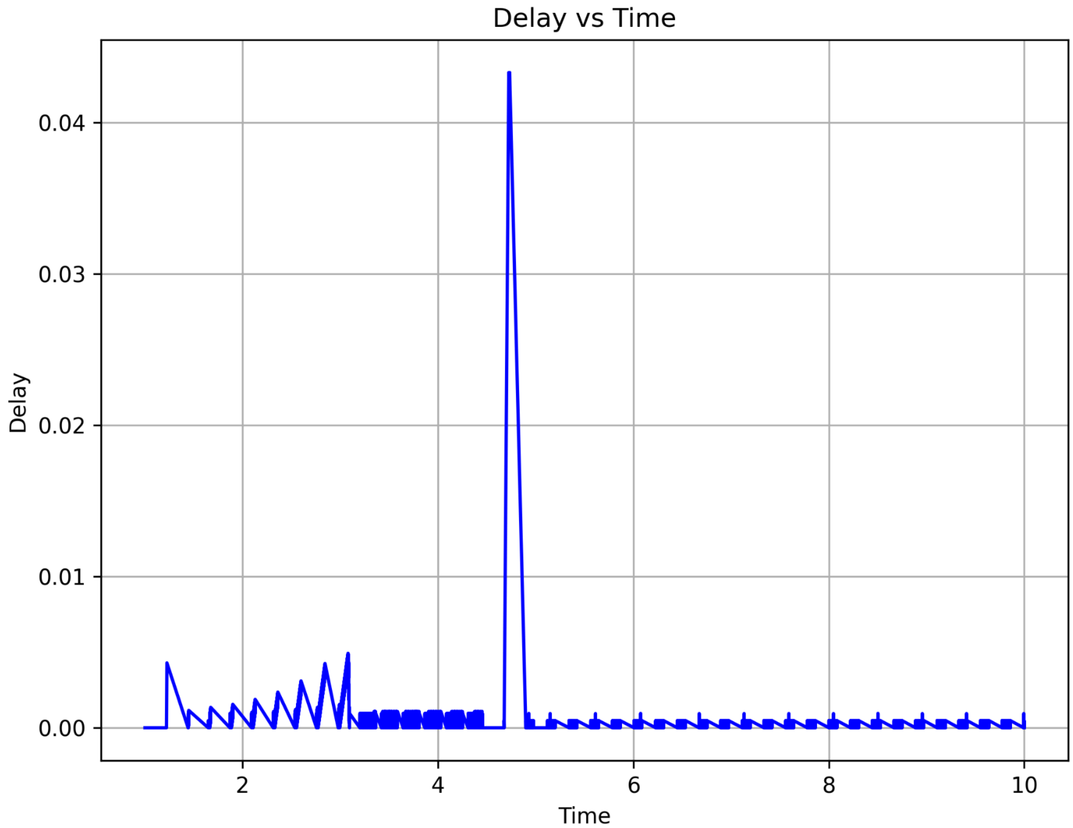
Time Taken: 8.8599 seconds
Hence, Throughput: (3000kB+158kB)/8.8599 seconds
Throughput = 2.8Mbps
This is approximately equal to the throughput shown in the Wireshark interface.

b)



c)



d) CWND plots were exactly the same, the reason for this is because the BDP is still the same, even if we increase the queue size. Hence, as Bandwidth and RTT are the same, the network's capacity to hold in-flight data is the same.
Hence, the congestion window is dictated by the BDP only.

3) a)

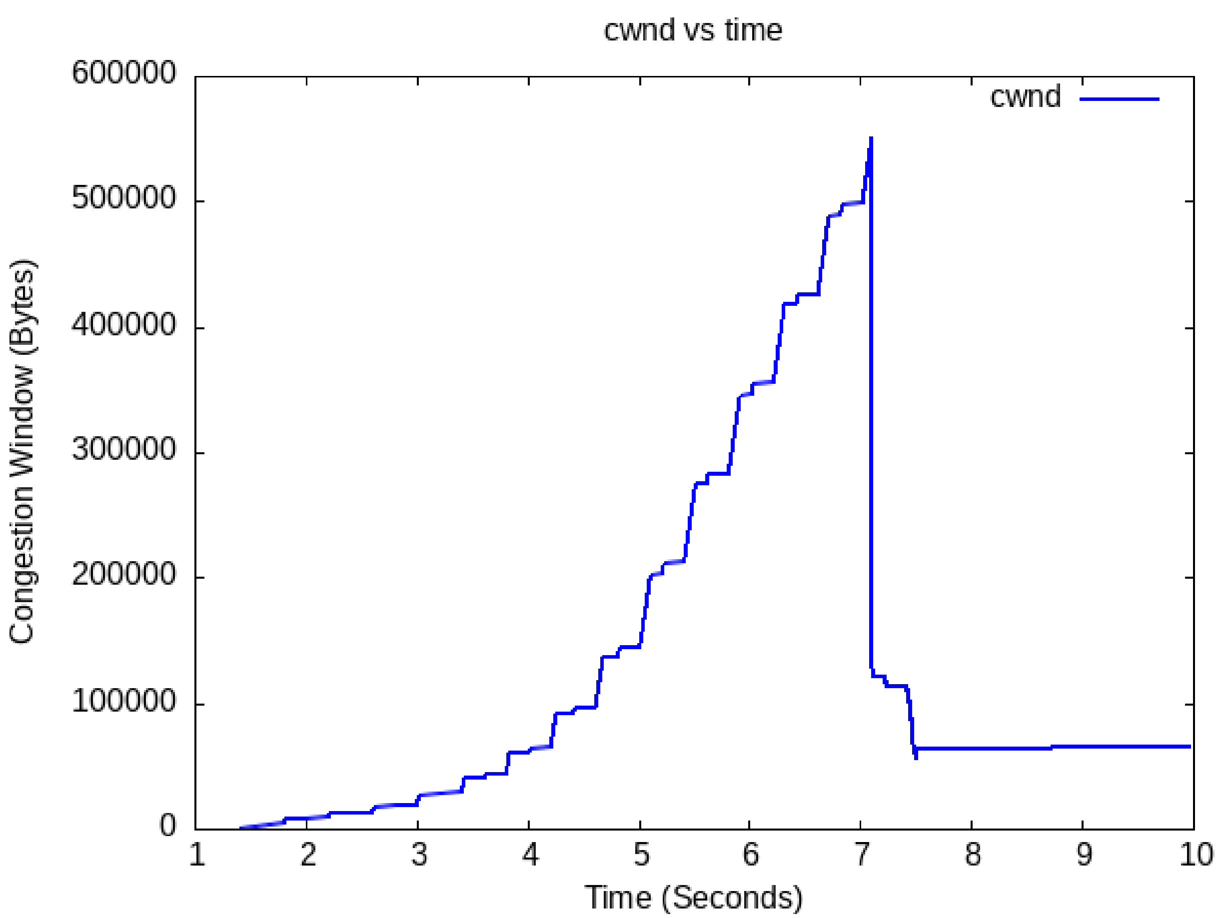
Wireshark · Conversations · tcp-example-2-0.pcap

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

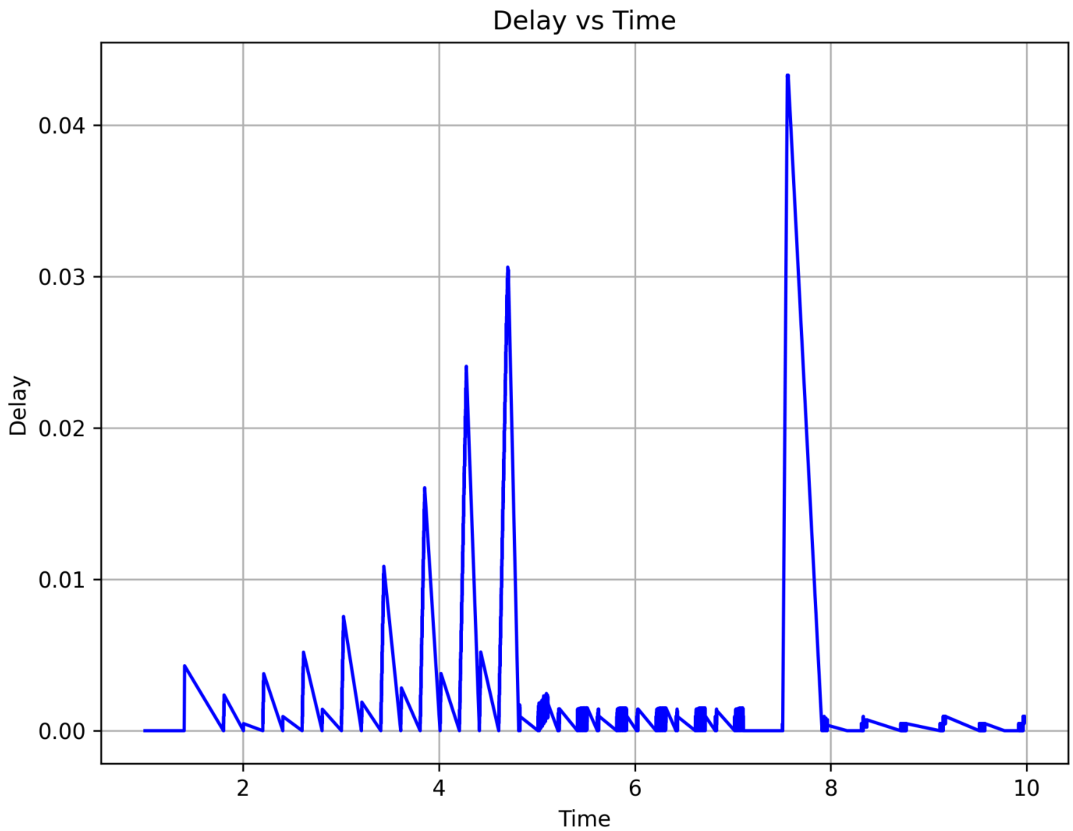
Address A	Address B	Packets	Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
10.1.1.1	10.1.2.2	4,897	2 MB	3,141	2 MB	1,756	97 kB	0.000000	8.7733	1,610 kbps	88 kbps

This is the pcap file of the receiver. It is clear from this that the actual throughput is 1610 kbps or 1.61 Mbps.
Also, Data From A-B: 2MB = 2000kB
Data From B-A: 97kB
Time Taken: 8.7733 seconds
Hence, Throughput: (2000kB+97kB)/8.7733 seconds
Throughput = 1.91 Mbps

b)



c)



d) The queuing delay graphs show variable patterns across the two; the reason for this is that BDP has changed, which has led to a change in the congestion window. Delays in the case of Q1 show the same pattern between 2 to 4 seconds, while here, from 2 to 4 seconds, delays tend to increase more and have sudden jumps and drops also, the max delay in Q1 occurs early, i-e, between around 4.5 seconds, but here it occurs around 7.8 seconds because now BDP has increased which has led to changes in congestion window overflows and hence delays occurs lately.