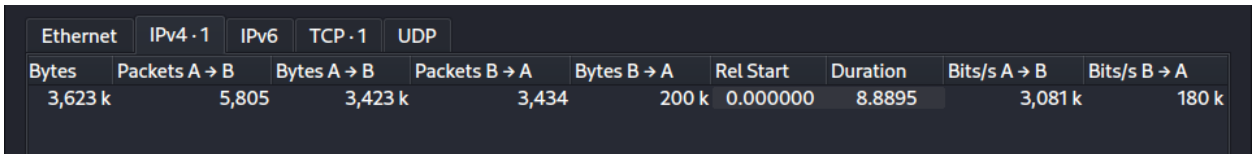
Question 1

a. The highest expected throughput is 7Mbps as it is the bottleneck in our network where bandwidth between N0-N1 is 10Mbps and that between N1-N2 is 7Mbps.

b. RTT = 2 * (total delay) = 2 * (100+10)ms = 220ms = 0.22s
BDP = Bandwidth * RTT
= (7Mbps) * (0.22s)
= 1.54 Mb
Application payload size = 1460bytes
BDP (in terms of packets) = $(1.54 * 10^6) / (1460*8)$
= 131.8 packets

c. The average throughput, as determined by Wireshark, is around (3081 + 180) = 3,261Kbps or 3.261Mbps.

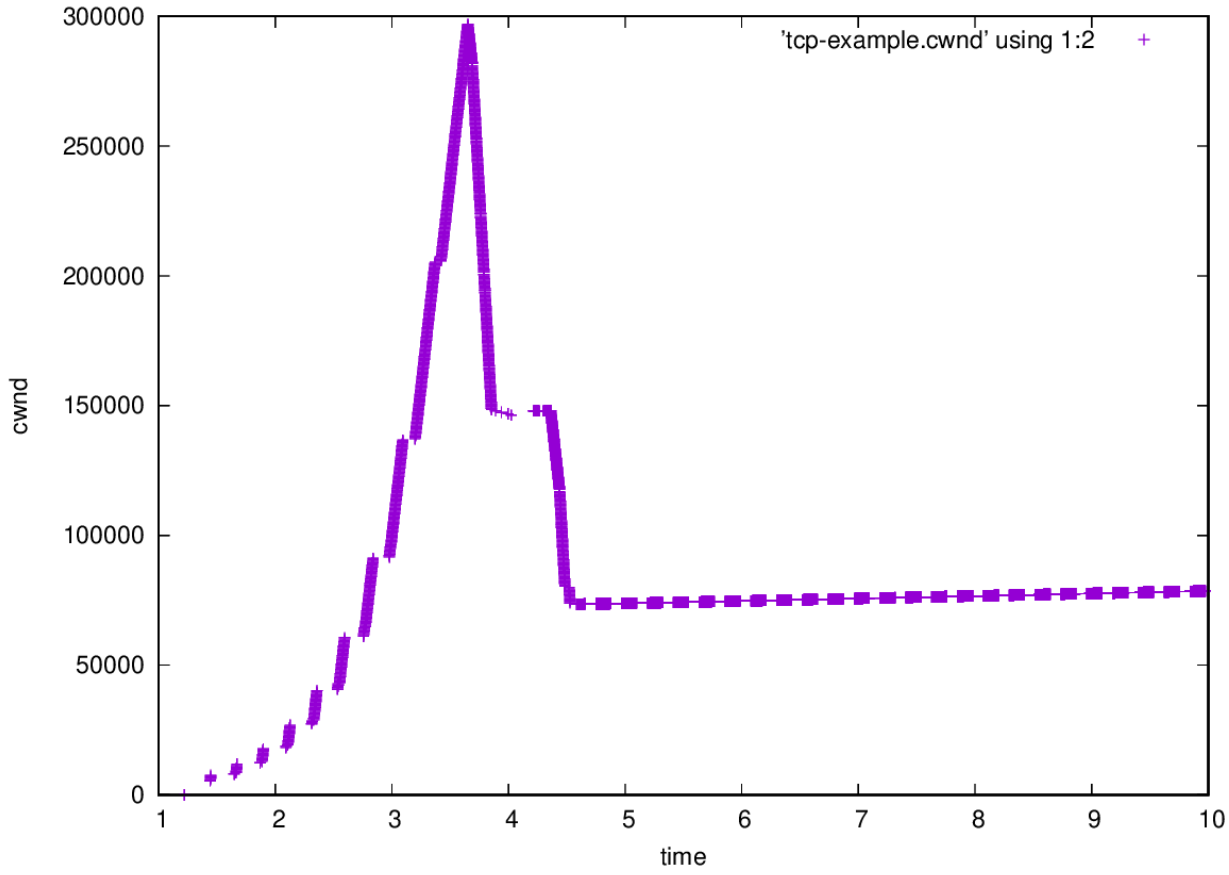


Ethernet | IPv4 · 1 | IPv6 | TCP · 1 | UDP

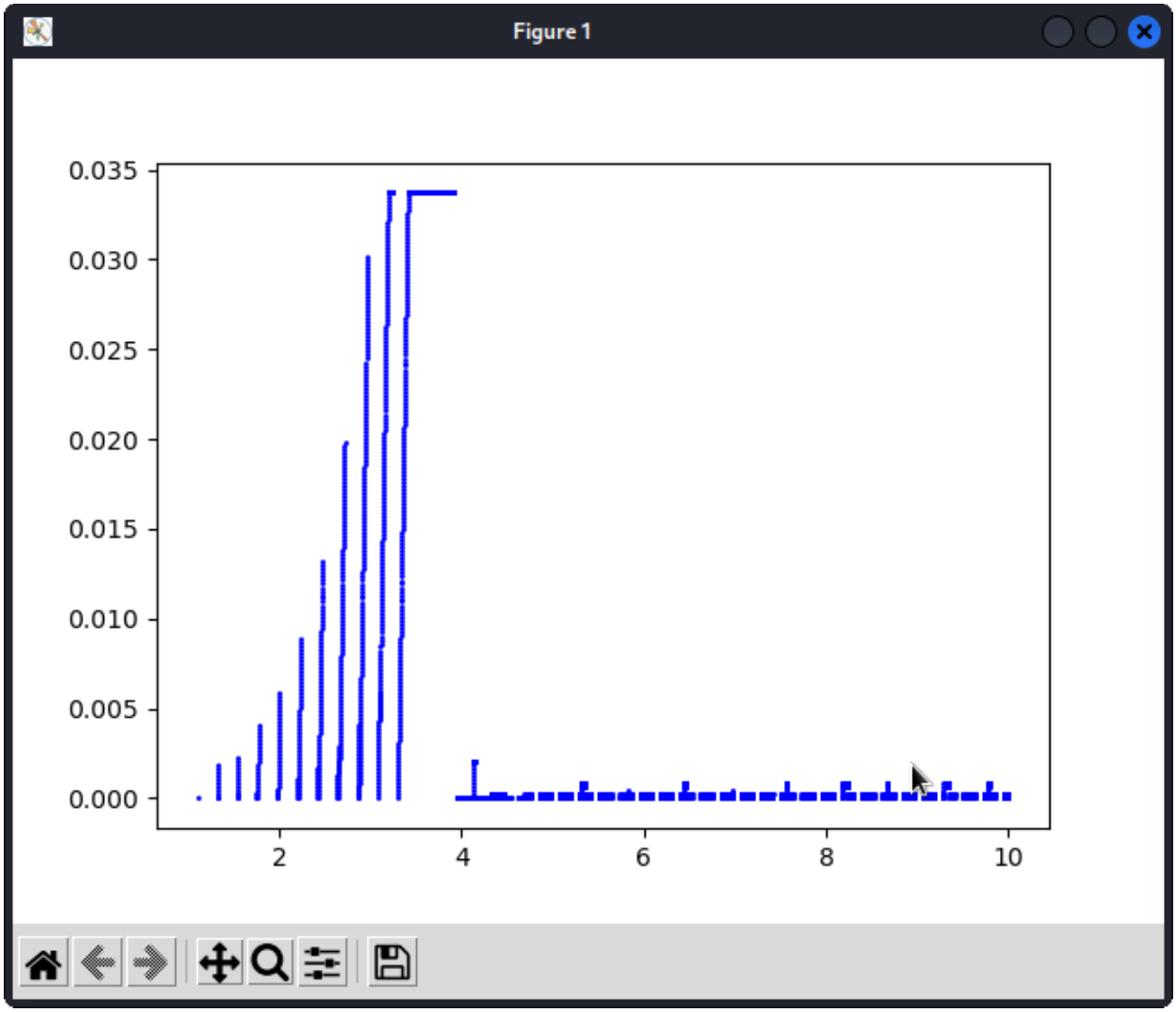
Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
3,623 k	5,805	3,423 k	3,434	200 k	0.000000	8.8895	3,081 k	180 k

d. The maximum expected throughput is not same as the average throughput achieved. It may be due to the packet loss due to congestion in network or packet drop in the queue at node 1.

e. Congestion window vs time



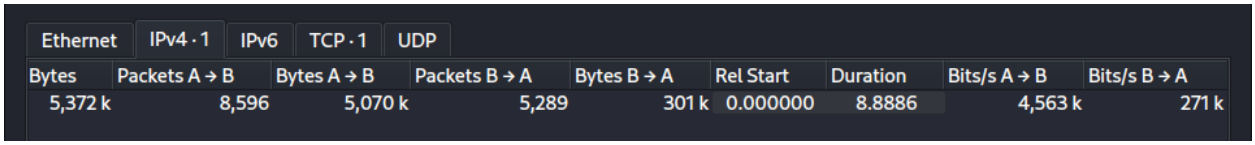
f. Queuing Delay vs Time



g. The two graphs are quite similar as spikes in both graphs are present around the same time. This similarity is present due to the fact that as the congestion window size increases, a lot of packets are pushed into the network. And these packets gets stored in the queue increasing its size. As the size of the queue increases, the queuing delay also increases.

Question 2

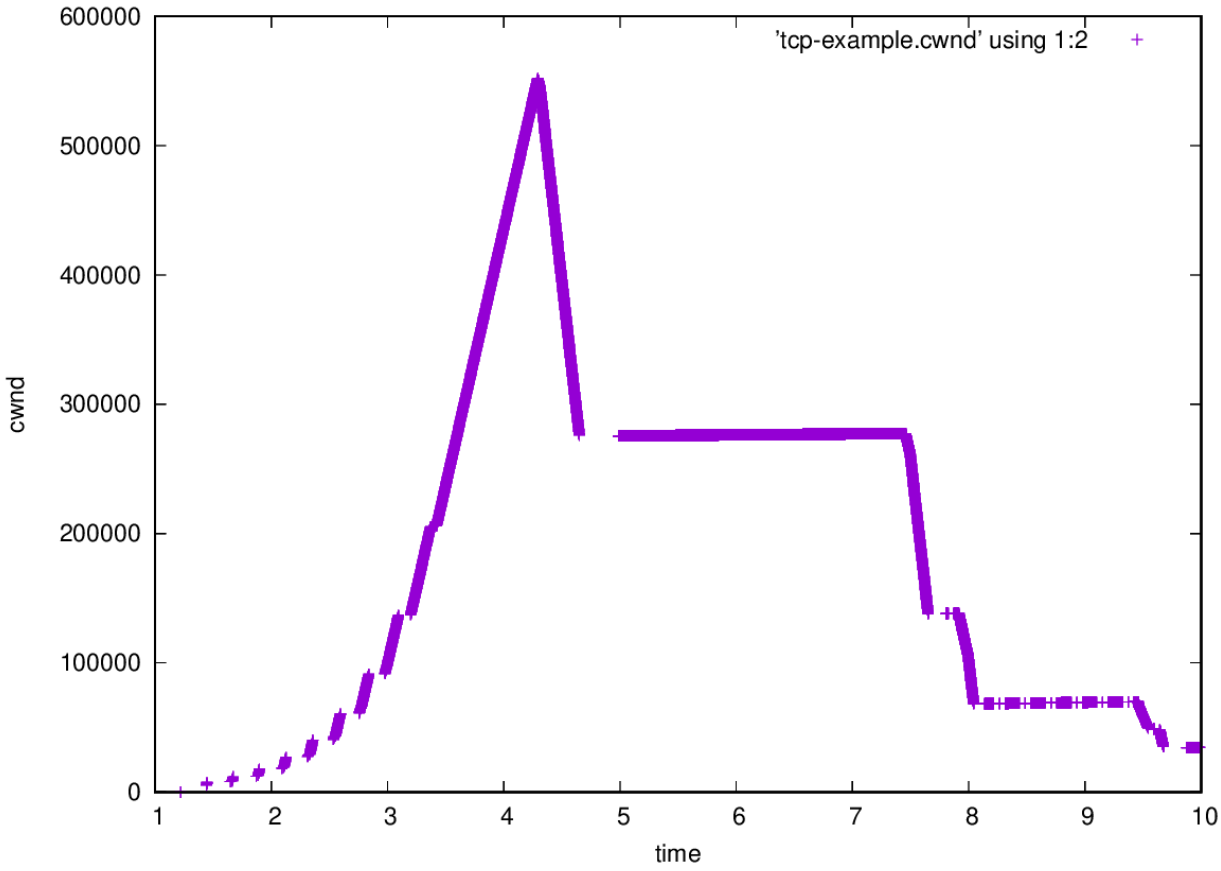
a. The average throughput is (4,563 + 271) = 4,834 Kbps or 4.834 Mbps



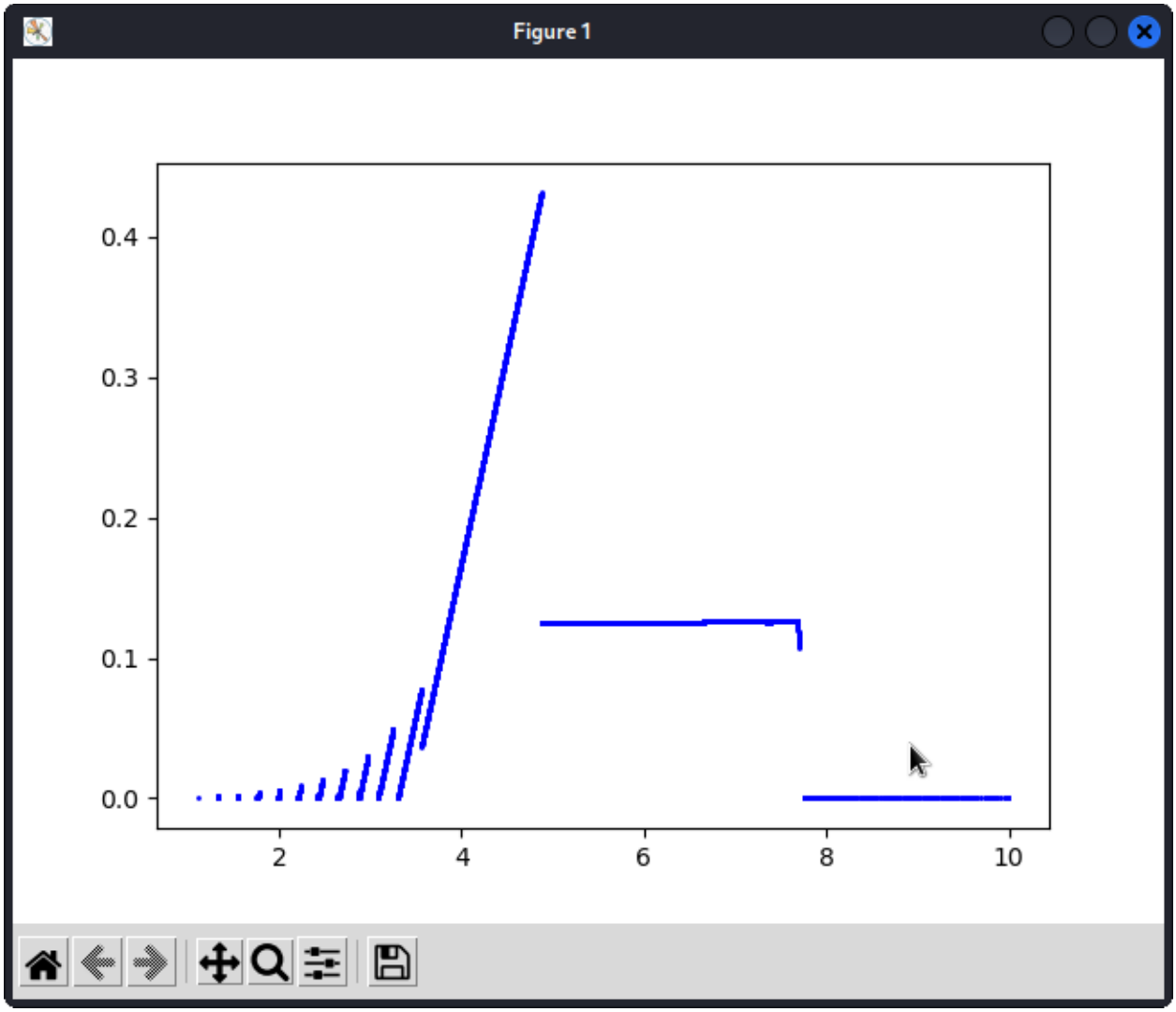
Ethernet | IPv4 · 1 | IPv6 | TCP · 1 | UDP

Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
5,372 k	8,596	5,070 k	5,289	301 k	0.000000	8.8886	4,563 k	271 k

b. CWND vs Time graph



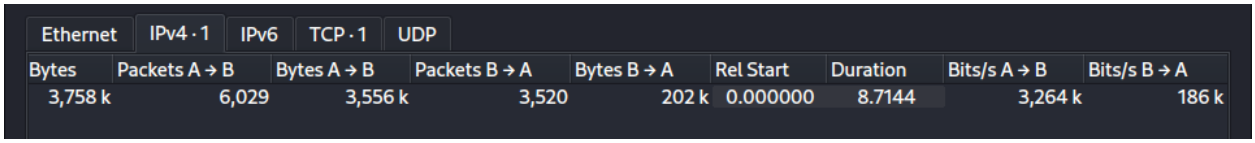
c. Delay queue vs Time



d. We can see that as the queue size increases, the cwnd also increases. So if we have a larger queue size, then we can send larger number of packets into the network resulting into higher throughput.

Question 3

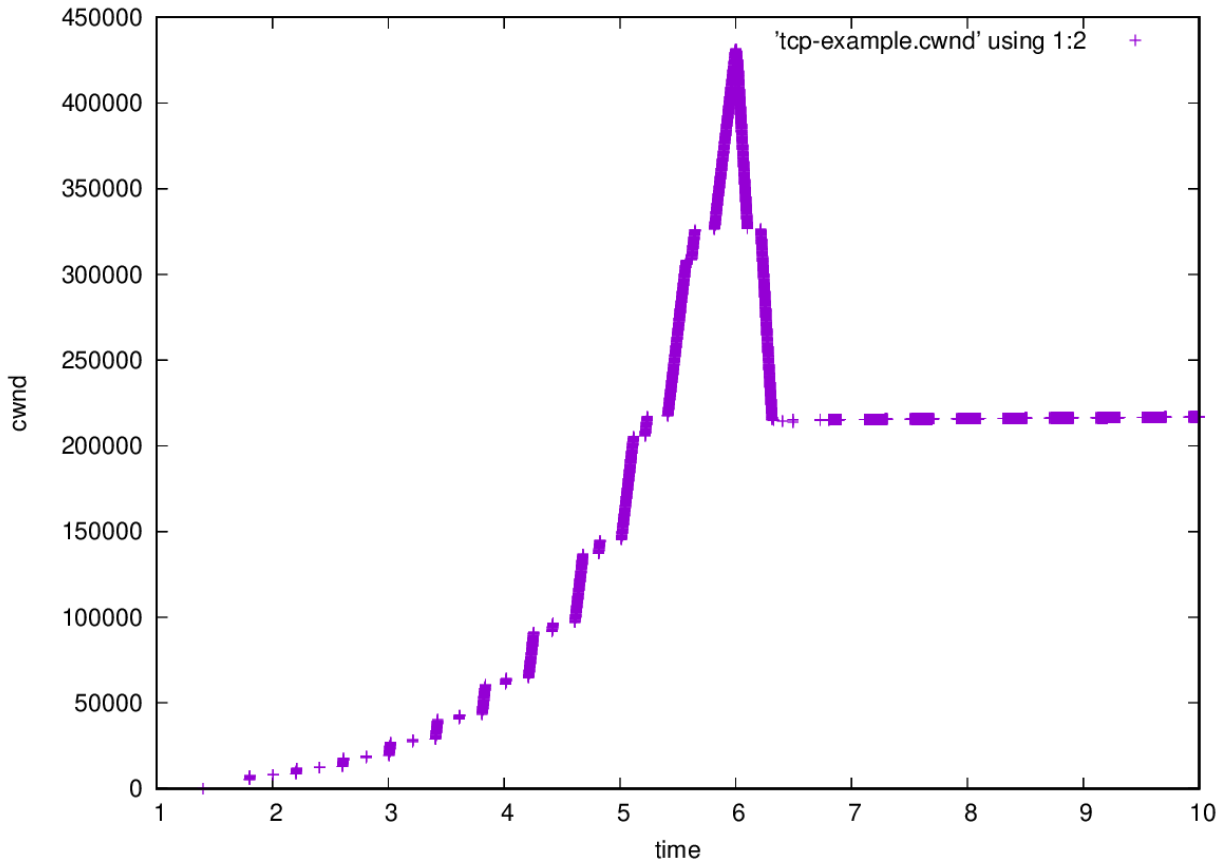
a. The average throughput is (3,264 + 186) = 3,450 Kbps or 3.45 Mbps



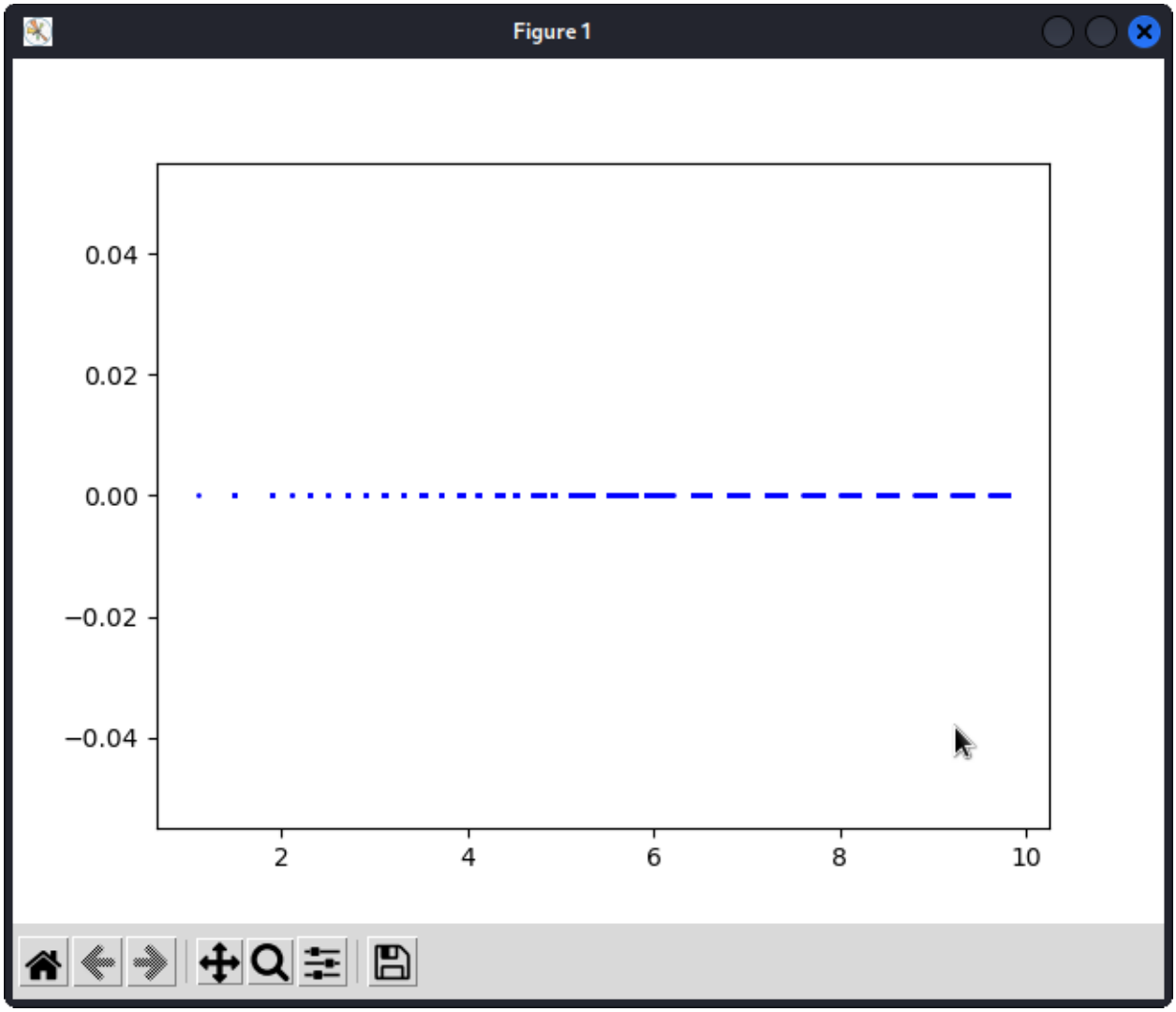
Ethernet | IPv4 · 1 | IPv6 | TCP · 1 | UDP

Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
3,758 k	6,029	3,556 k	3,520	202 k	0.000000	8.7144	3,264 k	186 k

b. CWND vs Time



c. Queuing delay vs Time



d. In the first question, the outgoing link has lesser bandwidth (7Mbps) than the incoming link (10Mbps), due to which the packets were queuing at the node causing a lot of queuing delay. But here, the bandwidth as well as the delay are same due to which the packet is released from the node as soon as it arrives causing very low queuing delay.