Computer Networks
Assignment 3

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Question 1)

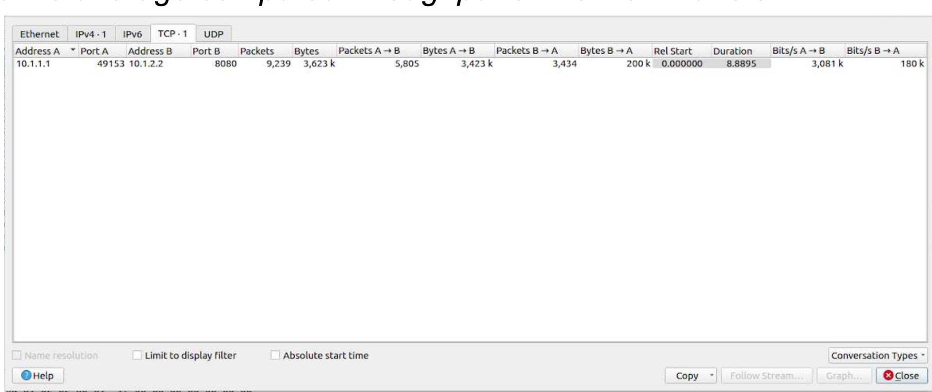
a) *What is the maximum expected value (theoretical) of throughput (in Mbps)? Why?*
The maximum expected throughput is 7Mbps. It is because 7Mpbs is the bottleneck rate of the network between n0 to n1 and n1 to n2.
Bottleneck bandwidth is the minimum bandwidth of all the links throughout the network.
So, the maximum expected throughput can't be higher than the bottleneck throughput rate.

b) *How much is Bandwidth-Delay-Product (BDP)? Express your answer in terms of the number of packets.*
Bandwidth Delay Product, BDP = Throughput * RTT
Throughput = 7Mbps
RTT = 2 * (100ms + 10ms) = 220ms

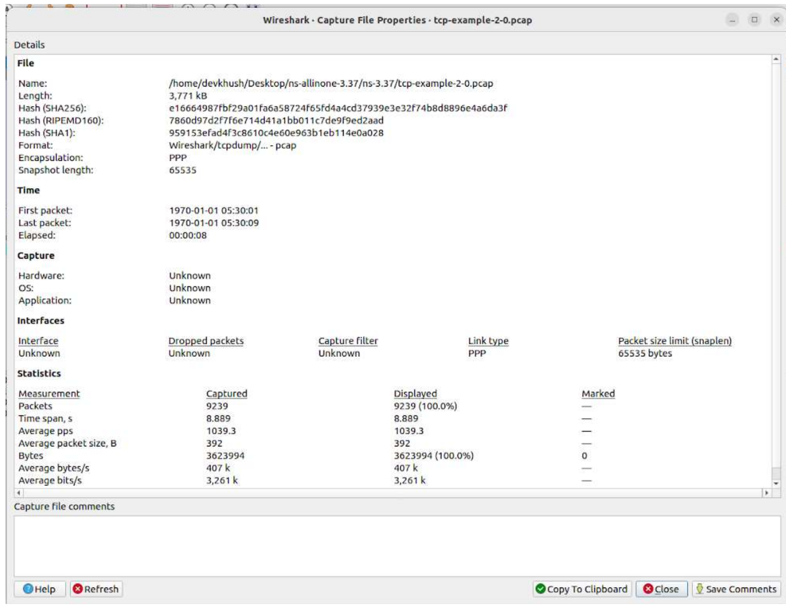
BDP = 7Mbps * 220ms = 1,540,000 bits = 1.54 Mb

Payload size = 1 packet size = 1460 bytes = 11680 bits
Therefore, BDP (in packets) = BDP (in bits) / Packet size = 1,540,000 / 11680
BDP = 131.849 packets ~ 131 packets or 132 packets

c) *What is the average computed throughput of the TCP transfer?*



Address A	Port A	Address B	Port 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	49153	10.1.2.2	8080	9,239	3,623 k	5,805	3,423 k	3,434	200 k	0.000000	8.8895	3,081 k	180 k



Average computed throughput = 3081k bits/s + 180k bits/s = 3.261 Mb/s.

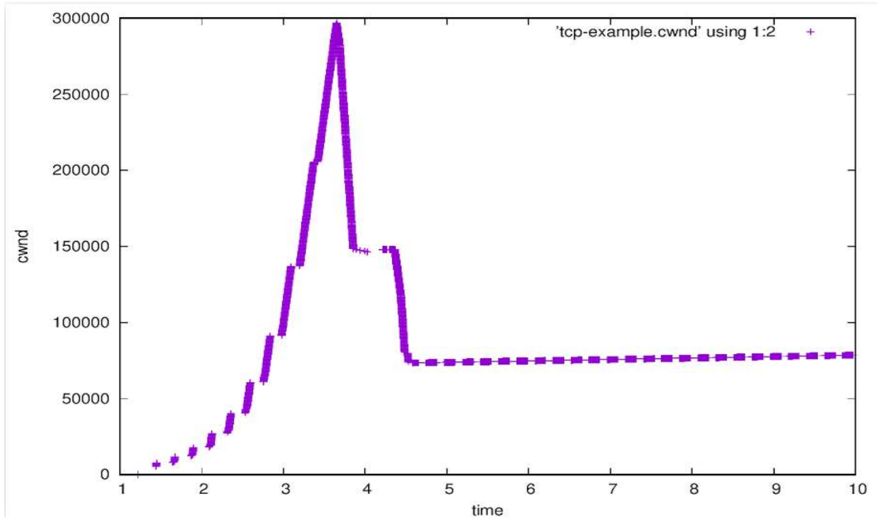
d) *Is the achieved throughput approximately equal to the maximum expected value? If it is not, explain the reason for the difference.*

No, the achieved throughput is not approximately equal to the maximum expected value. The achievable throughput is less than the maximum throughput.

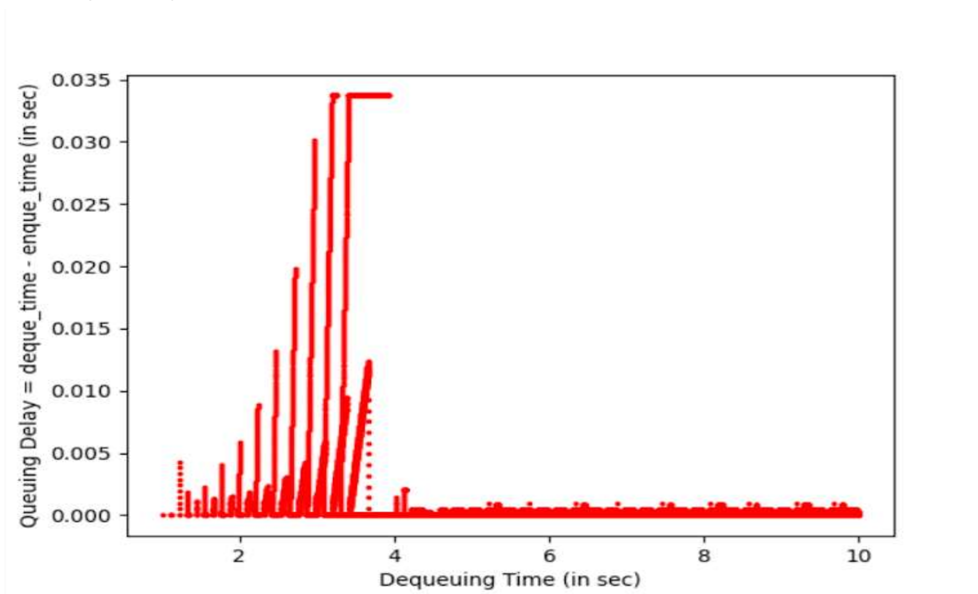
This is because of the queuing delay through the n1 node and possible packet loss in the routed path which occurred in the network.

In the maximum throughput calculation, we didn't consider the queueing delay of packets and packet loss in packet transmission. But these occur in the packet transmission in practical scenarios. Hence, the achievable throughput is less than the maximum throughput.

e) Plot Congestion Window (CWND) with time



f) Plot queueing delay with time



g) *Are the plots in 1(e) and 1(f) related?*

Yes, the CWND plot and Queueing delay plot are related to each other.

In the CWND plot, we can see that from time = 0 to 3.5 seconds, the congestion window size increases by double the amount per RTT. This is the slow start phase of packet transmission. When the congestion window size increases, the sender can send more packets per RTT. This will increase the number of incoming packets received per RTT at the router and will fill up the buffer size at the router faster. Hence, packets will be queued at the router, thus increasing the queueing delay of packets. This can be inferred from the plot of Queueing delay for time period 0s - 3.5s.

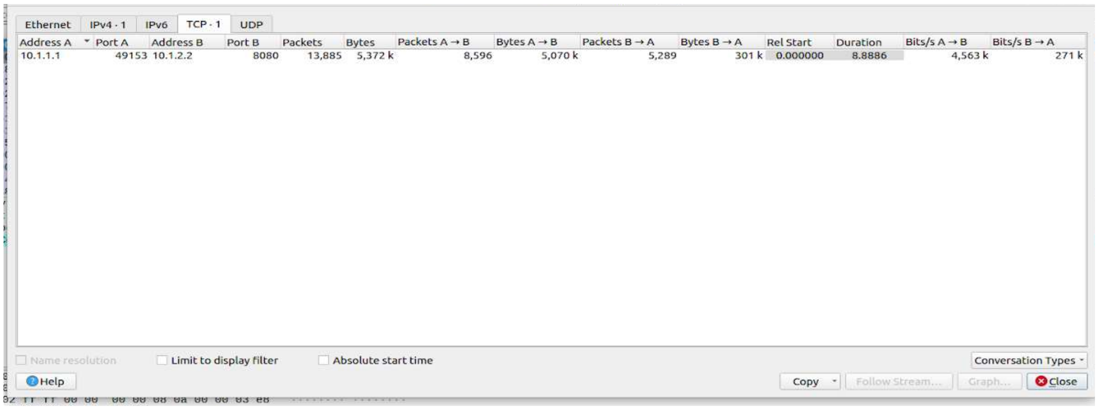
In the CWND plot, a timeout occurs at time=3.5 sec and 4.5 sec, and the congestion window size reduces to half of its value.

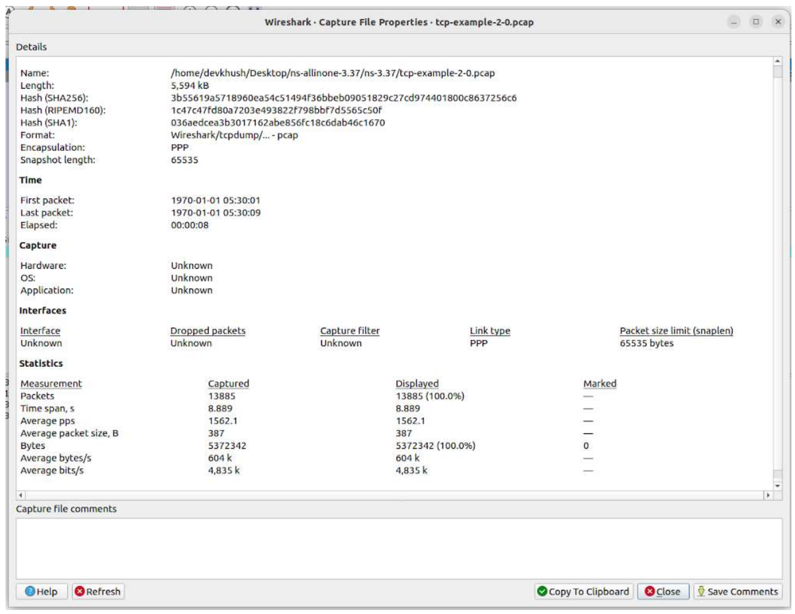
When the congestion window size is constant for the time after 4.5 sec, the queueing delay is also roughly constant. This is the congestion avoidance stage.

So, the congestion window (cwnd) and the queueing delay are directly (proportional) related to each other.

Question 2)

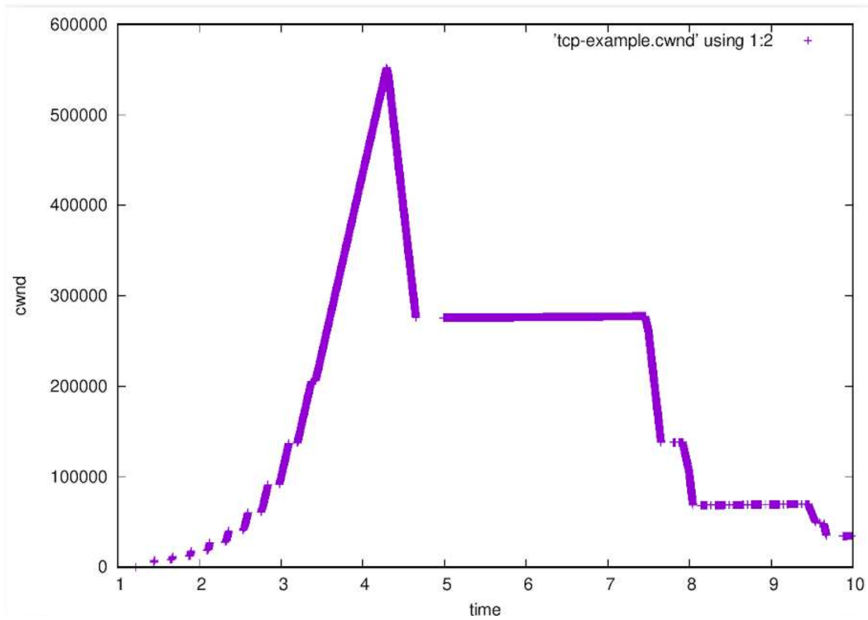
a) *What is the average computed throughput of the TCP transfer?*



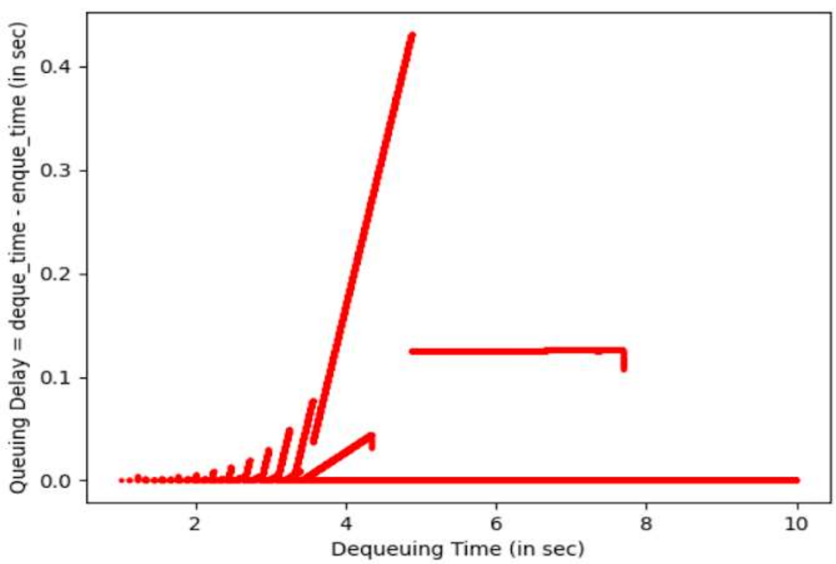


Average computed throughput = 4563k bits/s + 271k bits/s = 4.834 Mb/s.

b) Plot CWND with time.



c) Plot queueing delay with time



d) *Compare CWND plots of Q.1. and Q.2. what insights did you gain?*

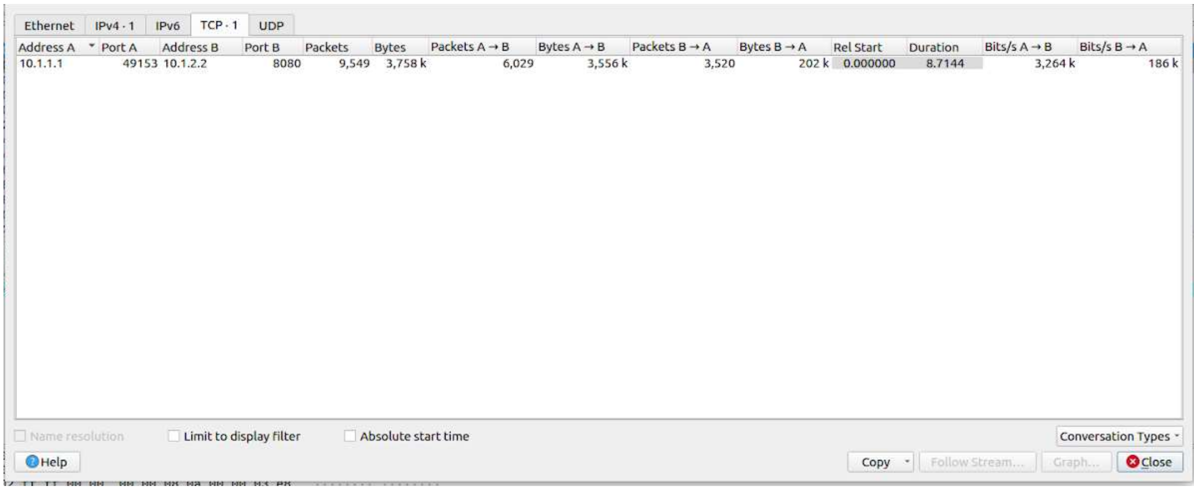
The buffer size at the router node (n1) is increased by increasing the queue size. This simply implies that more packets can be buffered at the router node.

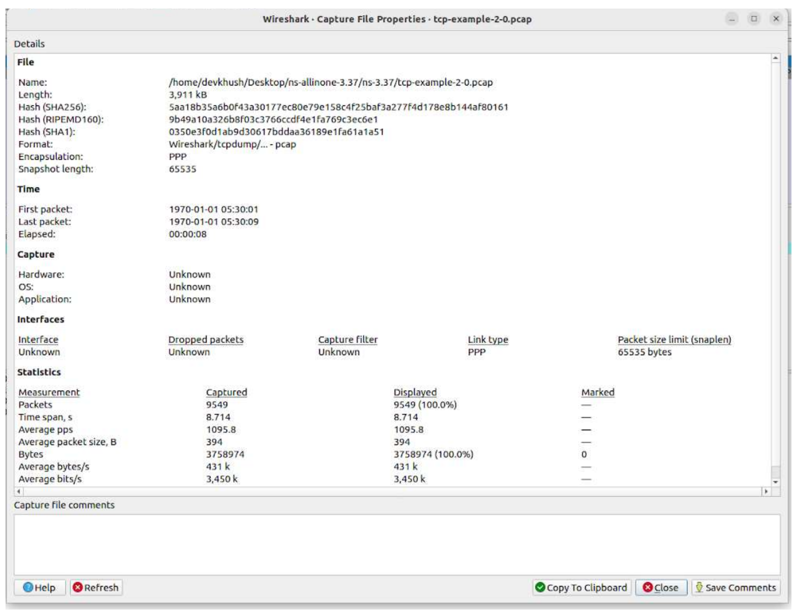
Comparing the CWND plots of Q1 and Q2, we can see that the congestion windows take greater ranges of values with larger queue sizes. The maximum value of the congestion window jumps from 300000 to 550000 with a greater queue size. This implies congestion window can now take greater value before the timeout or congestion avoidance phase because more no. of packets can be buffered at the router. Hence, more packets can be sent in a single RTT because they can be buffered/queued at the router (of greater queue size).

Increasing the queue size also implies a long waiting time for the packets in the queue/buffer. So, the packets will wait for a longer duration in the queue as compared to Q1. Hence, the queuing delay per packet transmitted increases by increasing the queue size at the router. This insight can also be inferred from the queuing delay plot, as the queuing delay values for packets are greater in Q2 than in Q1.

Question 3)

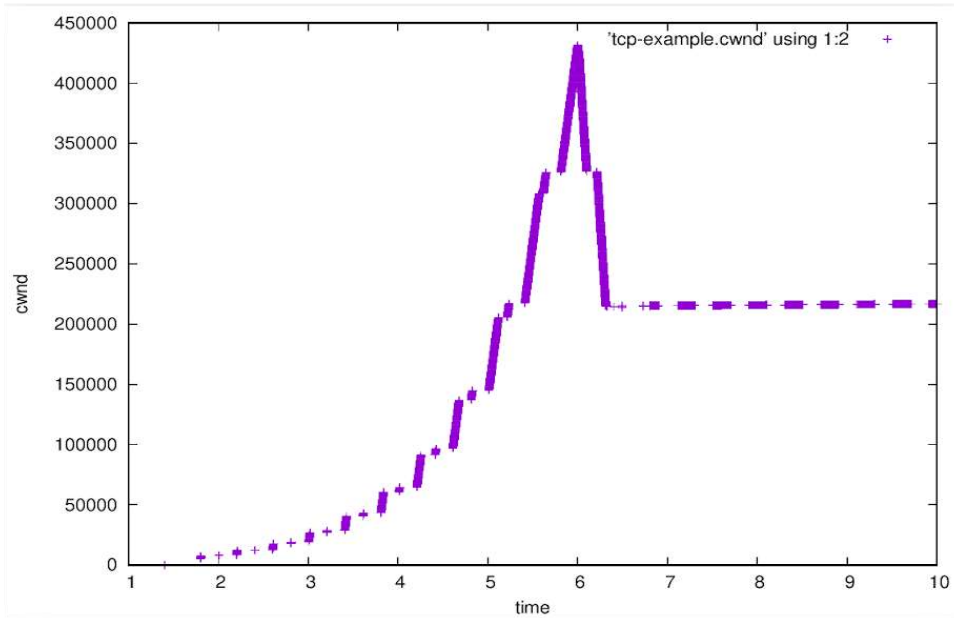
a) *What is the average computed throughput of the TCP transfer?*



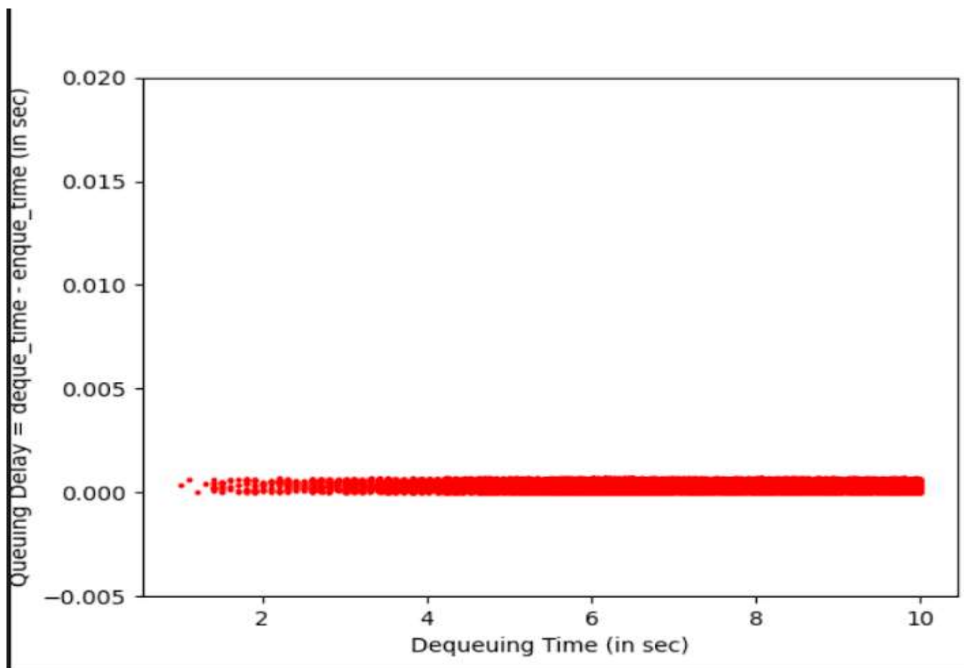


Average computed throughput = 3264k bits/s + 186k bits/s = 3.450 Mb/s.

b) Plot CWND with time



c) Plot queueing delay with time



d) *Compare queuing delay plots of Q.1. and Q.3. what insights did you gain?*

On increasing the bandwidth on the transmission link of n1 to n2, we have increased the rate at which packets can be sent from n1 to n2. In Q1, the bandwidth of this link was 7Mbps.

The bandwidth link from n0 to n1 and n1 to n2 is 10Mbps each.

So, both n0 and n1 can send the packets at equal transmission rates.

Due to this, there will be no buffering and queuing of packets at the router n1, and hence packets will not get queued at node n1.

In Q1, the outgoing transmission bandwidth at node n1 was low. Hence there was a long queuing delay at the router n1.

So, by increasing the bandwidth, the queue size and queuing will be reduced at the router ‘n1’ as compared to Q1 because the outgoing transmission rate is increased.

This can be inferred from the plot of Queueing delay of Q1 and the above plot.

The above queueing delay plot takes nearly zeros queue delay values than queuing delay plot of Q1.