CSE 232: Programming Assignment 4
Network simulation and TCP congestion control analysis using ns3

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The assignment involves analyzing the outputs of ns3 simulations with varying parameters.

Q.1.

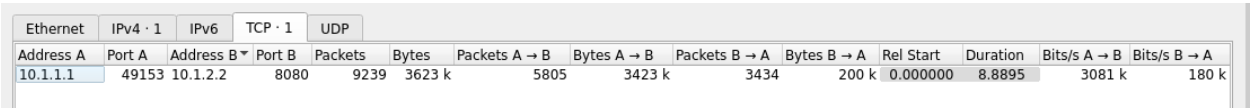
a) What is the maximum expected value (theoretical) of throughput (in Mbps)? Why?

The maximum expected throughput depends on the bottleneck bandwidth of the intermediate links between sender and receiver. We have 2 links of 10Mbps and 7Mbps. So, the maximum expected throughput is **7Mbps** theoretically.

b) How much is Bandwidth-Delay-Product (BDP)? Express your answer in terms of the number of packets.

Link 1 (N0-N1): d_trans = 1.168ms, d_prop = 100ms
Link 2 (N1-N2): d_trans = 1.669ms, d_prop = 10ms
RTT = 222.837ms
BDP = Bottleneck Bandwidth x RTT = 194982.375 Bytes
Number of packets = BDP / Payload = 133.55 packets = approx **133 packets**

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



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

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	9239	3623 k	5805	3423 k	3434	200 k	0.000000	8.8895	3081 k	180 k

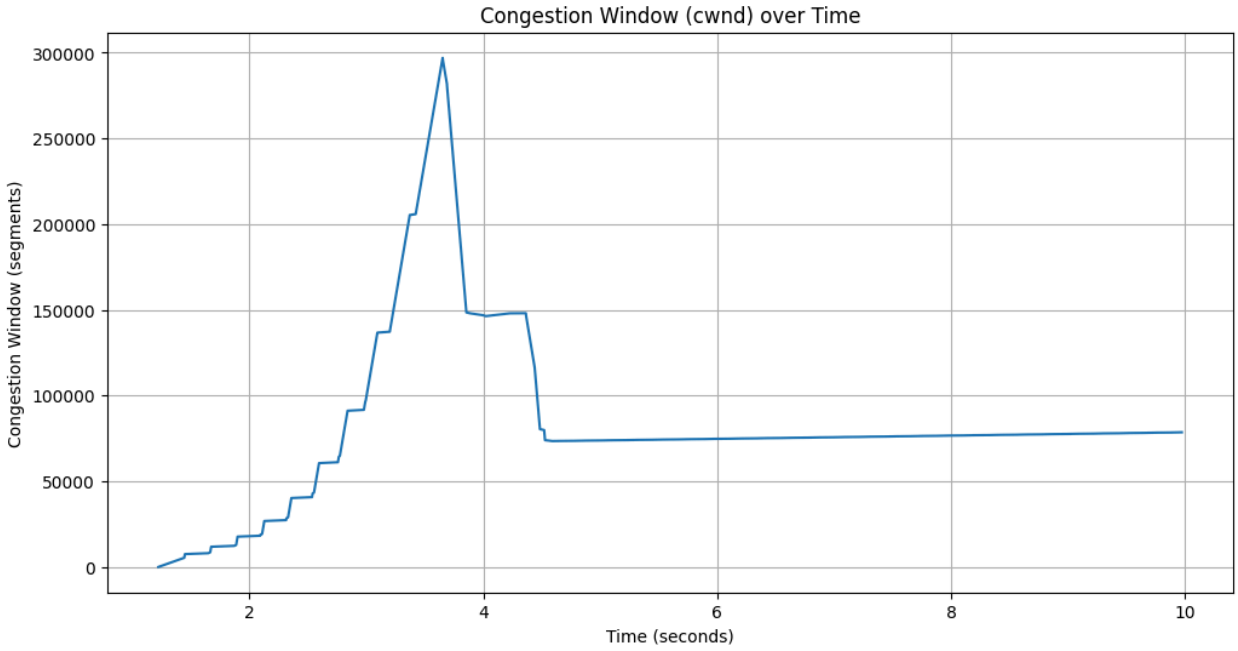
The average computed throughput of the TCP transfer is 3081kbps or **3.081Mbps**.

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

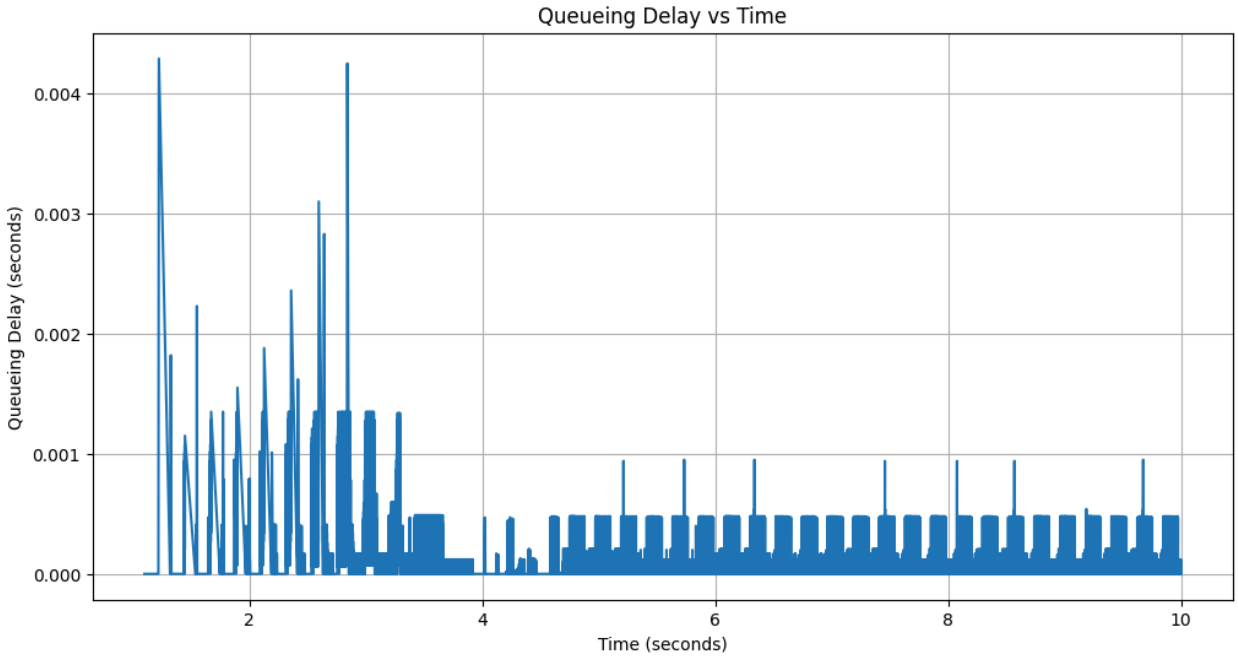
No, there is a significant difference between the achieved throughput and the maximum expected value. The theoretical approach fails to take non-deterministic delays into account which the practical simulation faces. One of these non-deterministic delays

observed is the queueing delay at node N1 which acts as an intermediate router between sender and receiver.

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, these plots are related. As the congestion window size increases, the sender window size increases, which is the minimum of the congestion window size and the receiver's window size. This allows the sender to send more packets without waiting for an acknowledgement, and the congestion in the network increases, which leads to more queueing delays. It is observed that in the first 3.5 seconds, the congestion window size increases exponentially, indicating the slow start phase. Then a timeout occurs, which reduces the congestion window size and subsequently, the value reaches an ideal value, after which it doesn't fluctuate any more. When the congestion window size reaches its ideal value, it is observed that the queuing delay is also almost constant.

Q.2.

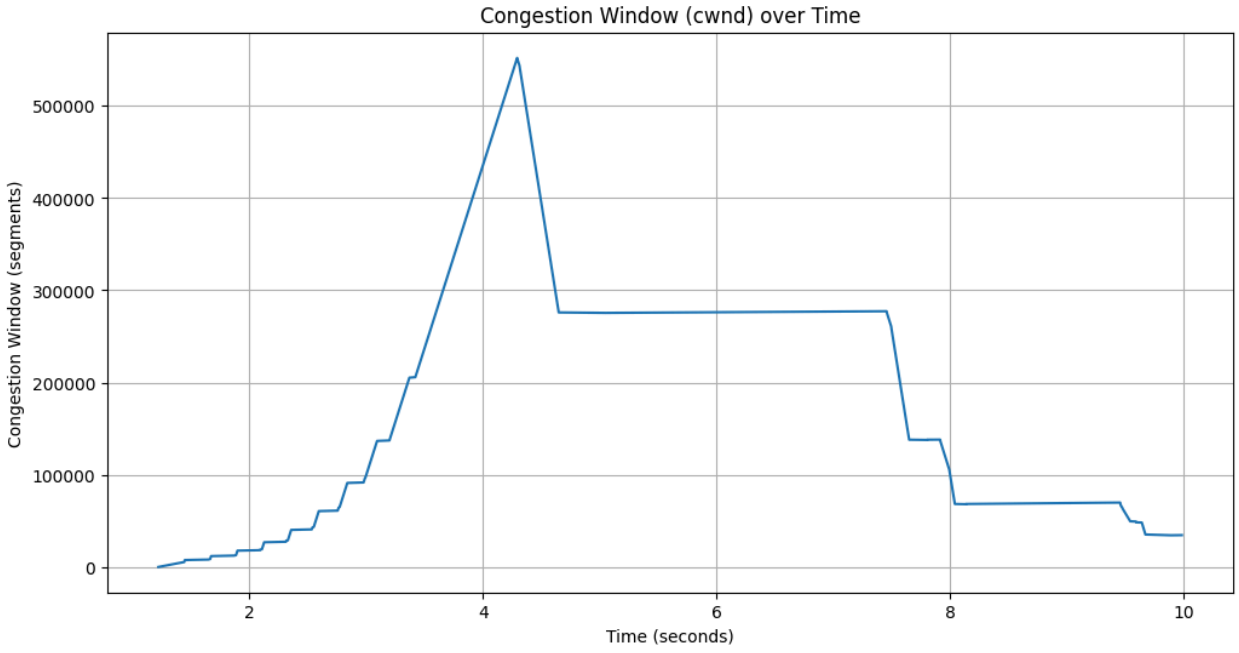
a) What is the average computed throughput of the TCP transfer?

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

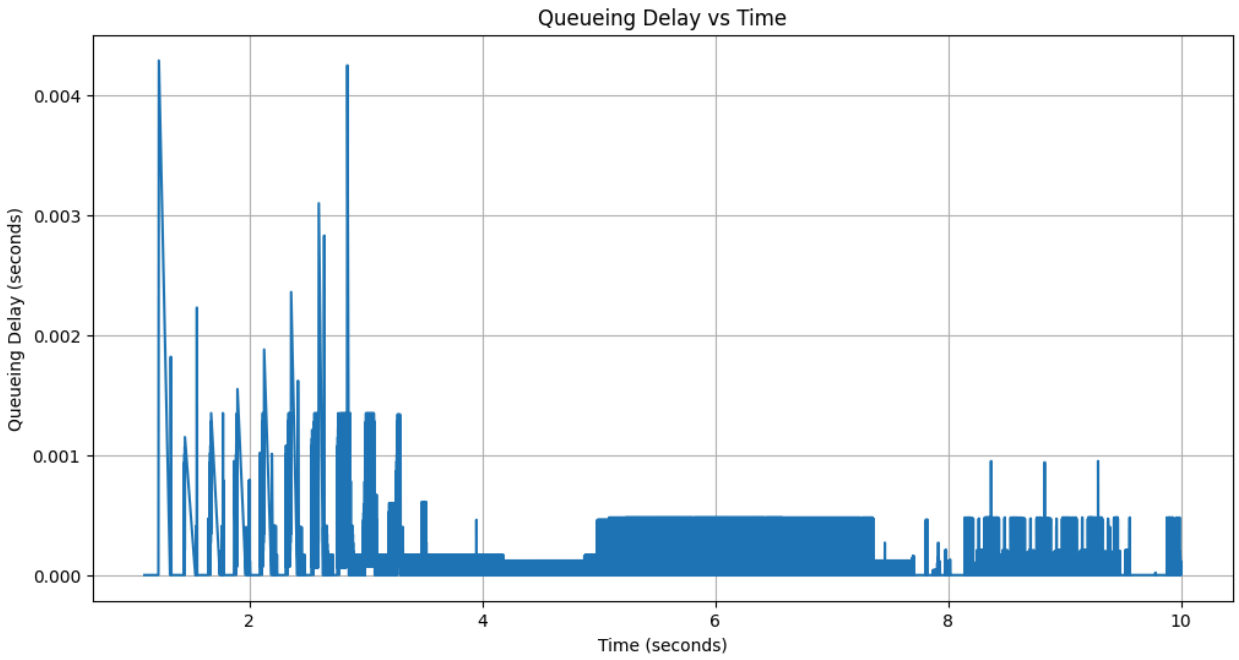
Address A	Port A	Address B	Port B	Packets	Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
10.1.1.1	49153	10.1.2.2	8080	13885	5372 k	8596	5070 k	5289	301 k	0.000000	8.8886	4563 k	271 k

The average computed throughput of the TCP transfer is 4563kbps or **4.563Mbps**.

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?

In Q.1. the first timeout occurs at around 3.5s and peak cwnd value is around 300,000 and a constant cwnd value is observed after 5 seconds. In Q.2. the first timeout occurs at around 4.5s (later than Q.1.) and peak cwnd value is around 550,000 (more than Q.1.) and no constant (more than 3 seconds) cwnd value is observed in entire 10 seconds of simulation.

Q.3.

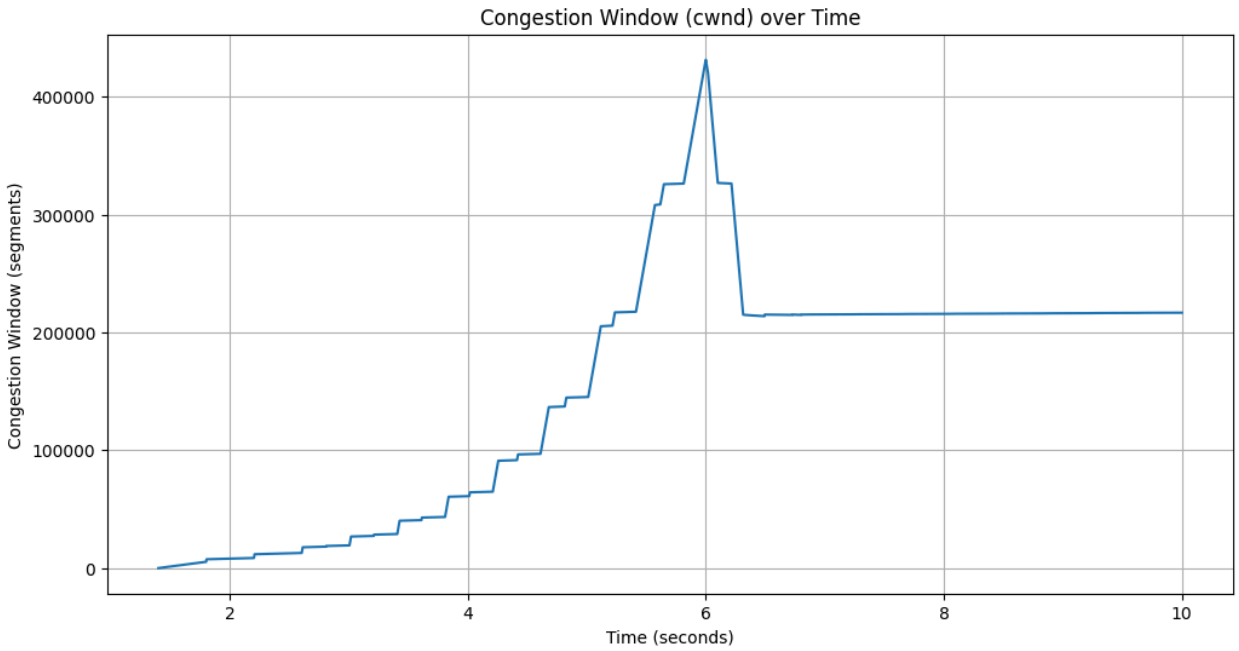
a) What is the average computed throughput of the TCP transfer?

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

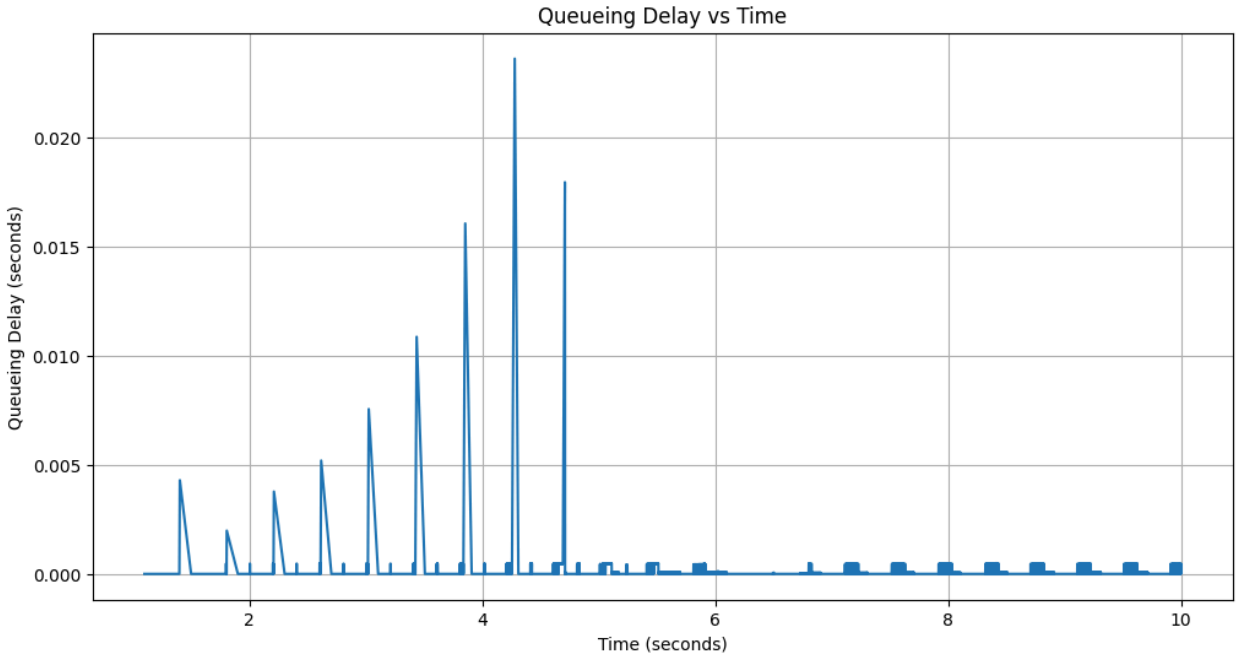
Address A	Port A	Address B	Port B	Packets	Bytes	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Rel Start	Duration	Bits/s A → B	Bits/s B → A
10.1.1.1	49153	10.1.2.2	8080	9549	3758 k	6029	3556 k	3520	202 k	0.000000	8.7144	3264 k	186 k

The average computed throughput of the TCP transfer is 3264kbps or **3.264Mbps**.

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?

In Q.1. peak value of queueing delay was about 0.004 which was only observed in first 3s, and after 3.5s queuing delay was almost constant with max of up to 0.001 seconds. In Q.3. peak value of queuing delay is about 0.025 (more than Q.1.), and an almost constant value with a max of up to 0.001 seconds is observed after 5s.