# CN ASSIGNMENT 4 REPORT

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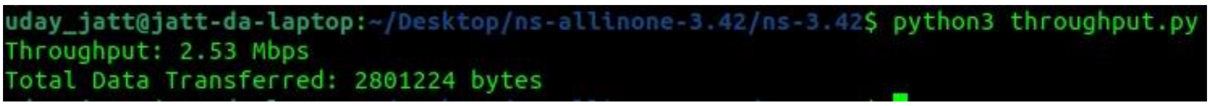
Question 1:

a. Calculation for maximum expected value of throughput in Mbps.
   It should be 7 Mbps because 7 Mbps is the bottleneck rate of the network from n0 to n2. Hence the maximum throughput cannot be higher than the bottleneck throughput rate.

b. Calculation of Bandwidth-Delay-Product.
   Theoretical bandwidth = 7 Mbps
   Round trip time = 2 * [100 ms + 10 ms + 1.66 + 1.16] = 225.64 ms.
   BDP = Bandwidth * Delay = [225.64 ms] * [7 Mbps] = 1,579,480 bits = 1.579 Megabits.
   No. of packets = 1,579,480 / 11,680 (payload = 1460 * 8) = 135.2 packets.
   Total no. of packets = 136 approx.
   [BDP in terms of packets]

c. Throughput computed through code ‘throughput.py’.



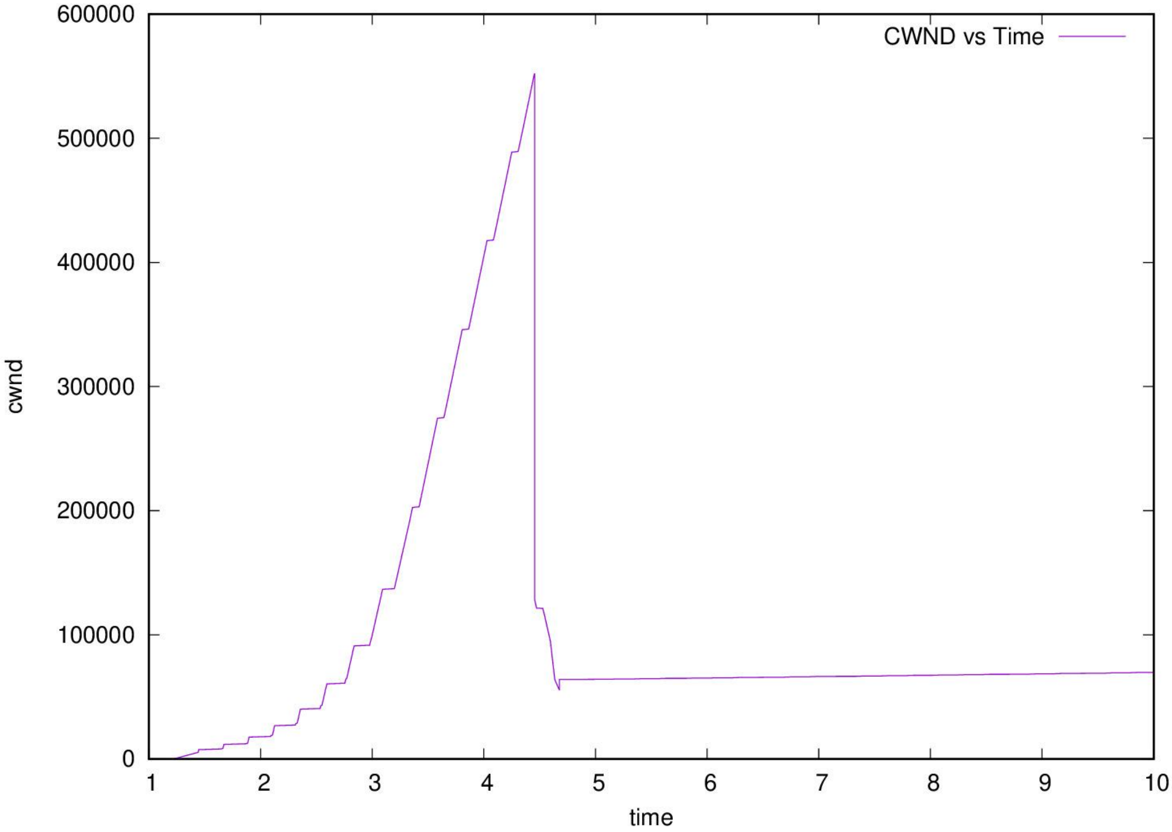

d. Expected value = 7 Mbps
   Computed value = 2.53 Mbps

   Explanation:
   - The queuing latency at node n1 significantly contributes to the discrepancy between the computed and expected bandwidth. Additionally, packet loss along the routed path further

exacerbates network performance inefficiencies.

- Moreover, the queuing delay is not accounted for when evaluating the maximum expected or theoretical bandwidth. Likewise, the additional latency caused by packet loss and retransmissions is also overlooked.

e. Plot for Congestion Window [CWND] vs time:



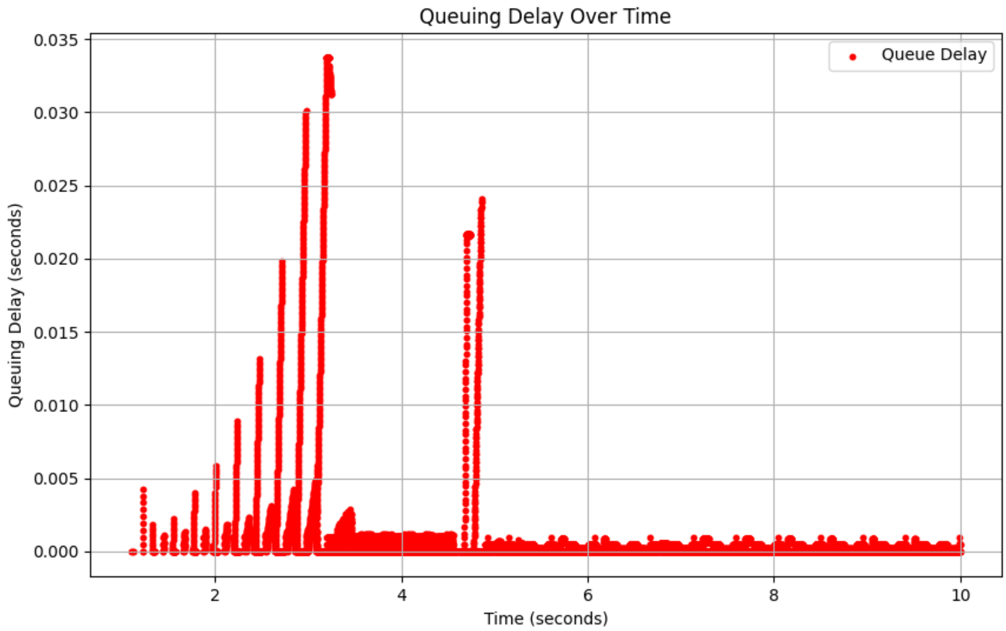

Commands:

gnuplot example.gpp [Defined as per question]

Inference from graph:

Peaks at around 4.5 seconds when the size overextends.

f. Plot for queueing delay vs time:

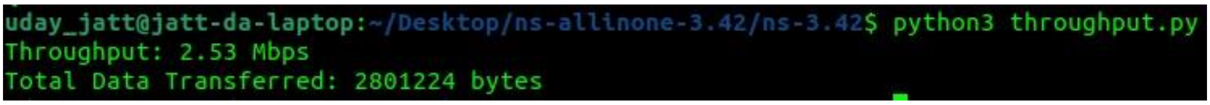



g. The plots in 1[e] and 1[f] are interconnected. From time 0 to 3.5 seconds in the CWND plot, the congestion window size grows exponentially, doubling with each RTT during the slow start phase. As the window size increases, more packets are sent per RTT, leading to higher queuing at router n1 and an increase in queuing delay. After 3.5 seconds, the window size halves, reducing queuing delay. Subsequently, the window size grows linearly during the congestion avoidance phase, stabilizing dequeuing time. This demonstrates the relationship between the congestion window and queuing delay.

# Question 2:

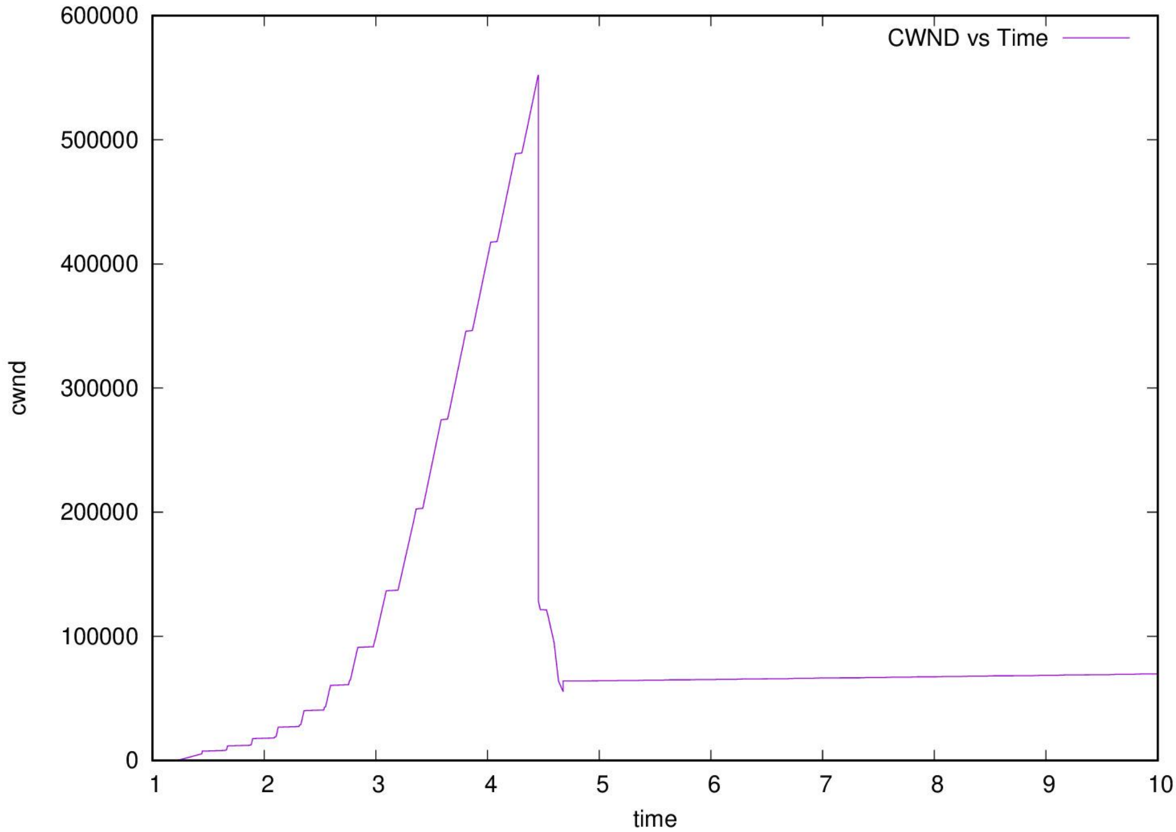
Queue size changed to 1000 [rest same]

a. Throughput computed through code 'throughput.py'.


```
uday_jatt@jatt-da-laptop:~/Desktop/ns-allinone-3.42/ns-3.42$ python3 throughput.py
Throughput: 2.53 Mbps
Total Data Transferred: 2801224 bytes
```

Computed throughput: 2.53 Mbps [same as Q1]

b. Plot for Congestion Window [CWND] vs time:



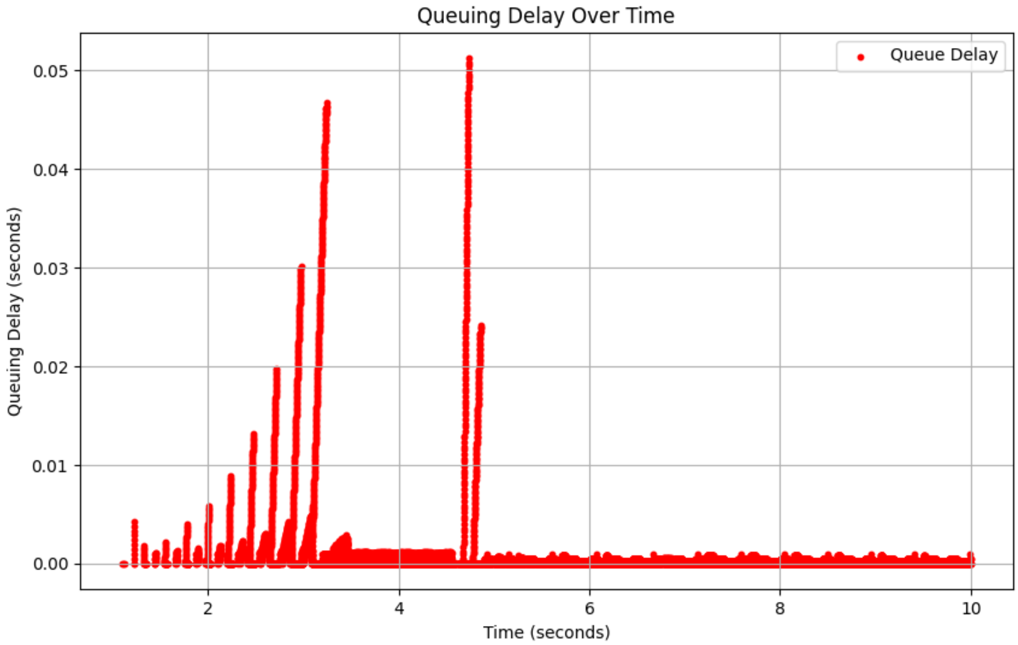

Commands:

gnuplot example.gpp [Defined as per question]

Inference from graph:

Peaks at around 4.5 seconds when the size overextends.

c. Plot for queueing delay vs time:



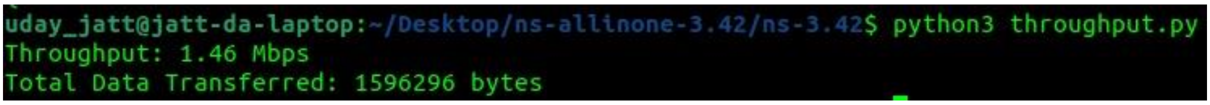

d. Comparison of Q1 CWND and Q2 CWND:

- The throughput stabilizes when the sender fully utilizes the bottleneck link's capacity. If the network reaches this capacity before queue size becomes a limiting factor, throughput and CWND behavior will remain identical for both queue sizes.
- TCP adjusts the CWND based on packet loss, not directly on queue size. If packet loss occurs due to reasons other than queue overflow (e.g., random losses or link issues), the CWND behavior and throughput will remain the same regardless of queue size.

# Question 3:

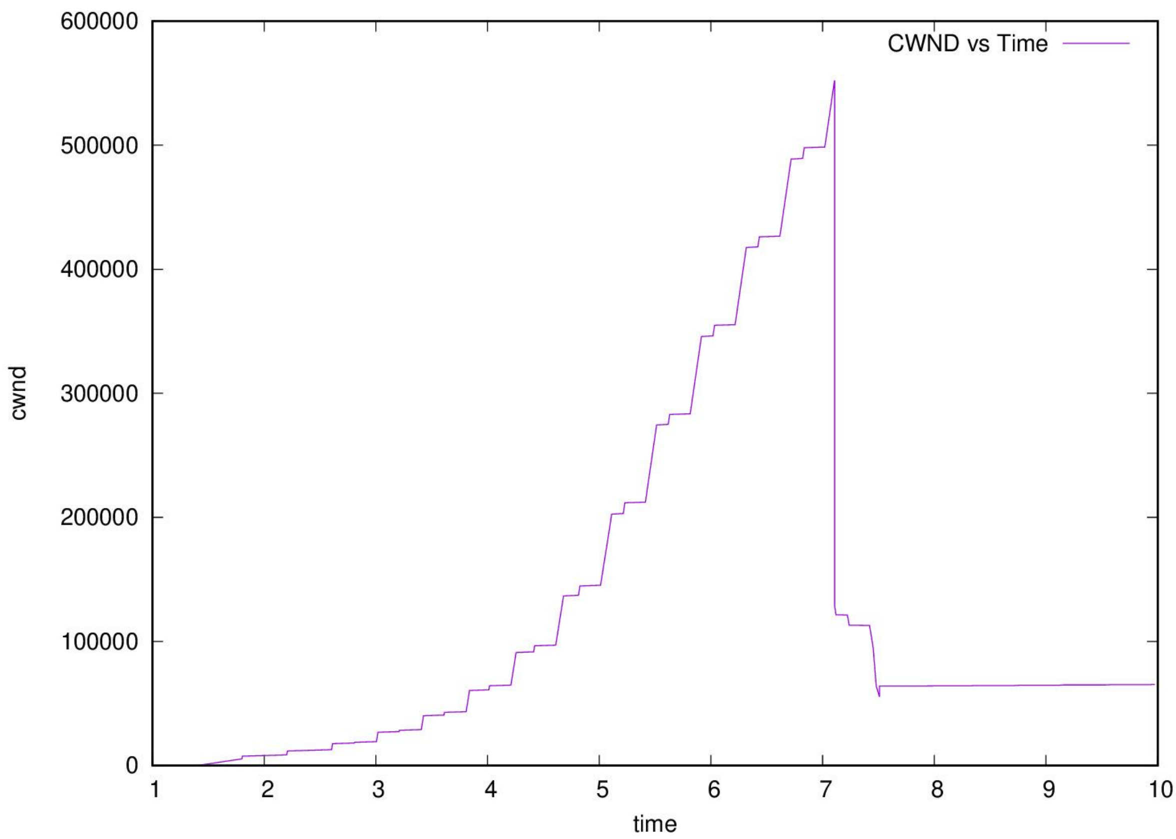
N1-N2 bandwidth changed to 10 Mbps and Delay to 100 ms.

a. Throughput computed through code 'throughput.py'.




Computed throughput: 1.46 Mbps

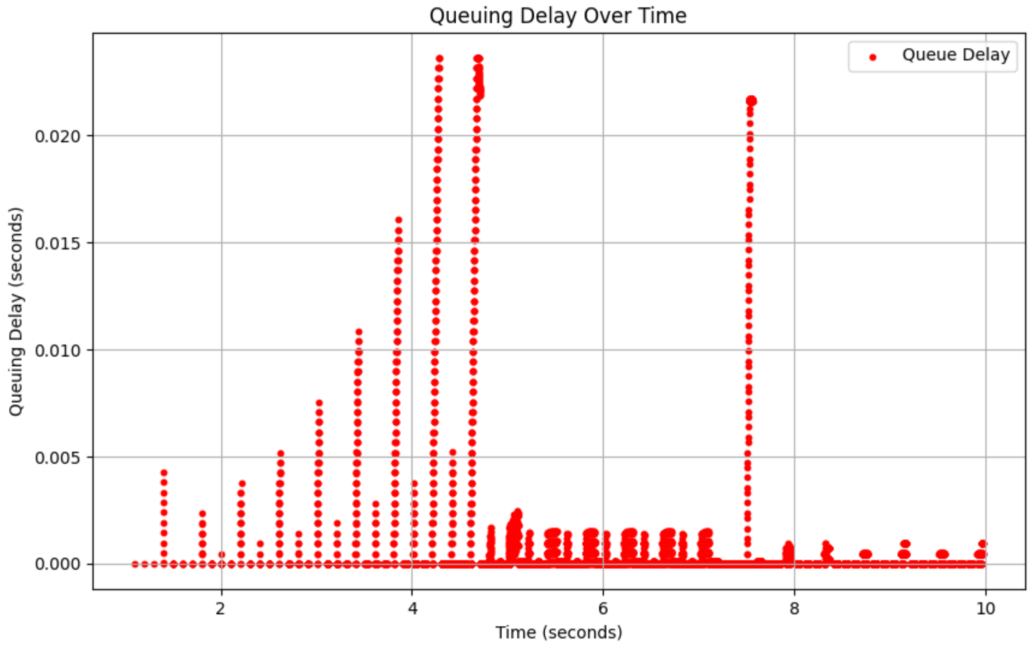
b. Plot for Congestion Window [CWND] vs time:




Commands:

gnuplot example.gpp [Defined as per question]

c. Plot for queueing delay vs time:




d. Comparison:

- Uneven bandwidth allocation [Q1] creates bottlenecks, leading to higher queuing delays. Matching bandwidth across links [Q2] ensures smoother traffic flow and reduces delay.

- Larger and more frequent fluctuations in queuing delay (Graph 1) are clear signs of congestion at a specific link. A more stable plot (Graph 2) reflects an optimized network.

- Thus, we have lesser queue size and queue time in case of question 3 which can also be verified in
from the plots.

--------------------End--------------------