Computer Networks
Assignment-4

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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 7 Mbps is the bottleneck rate of the network between no to n1 and n1 to n2.

Bottleneck bandwidth: min(bandwidths of links throughout the network)

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

BDP= Throughput * RTT

Throughput = 7Mbps

RTT = 2 * (100ms + 10ms) = 220ms

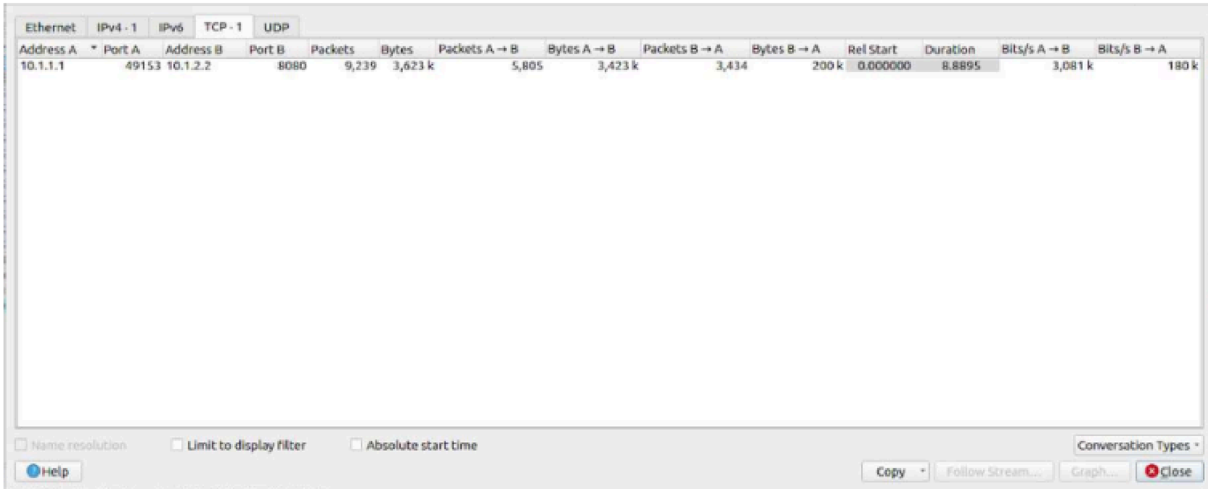
BDP = 7Mbps * 220ms = 1,540,000 bits = 1.54 Mb

Payload size = 1 packet size=1460 bytes = 11680 bits

Therefore, BDP (in packets) = BDP (in bits) / Packet size = 1,540,000 / 11680

BDP = 131.85 packets 131 packets or 132 packets

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

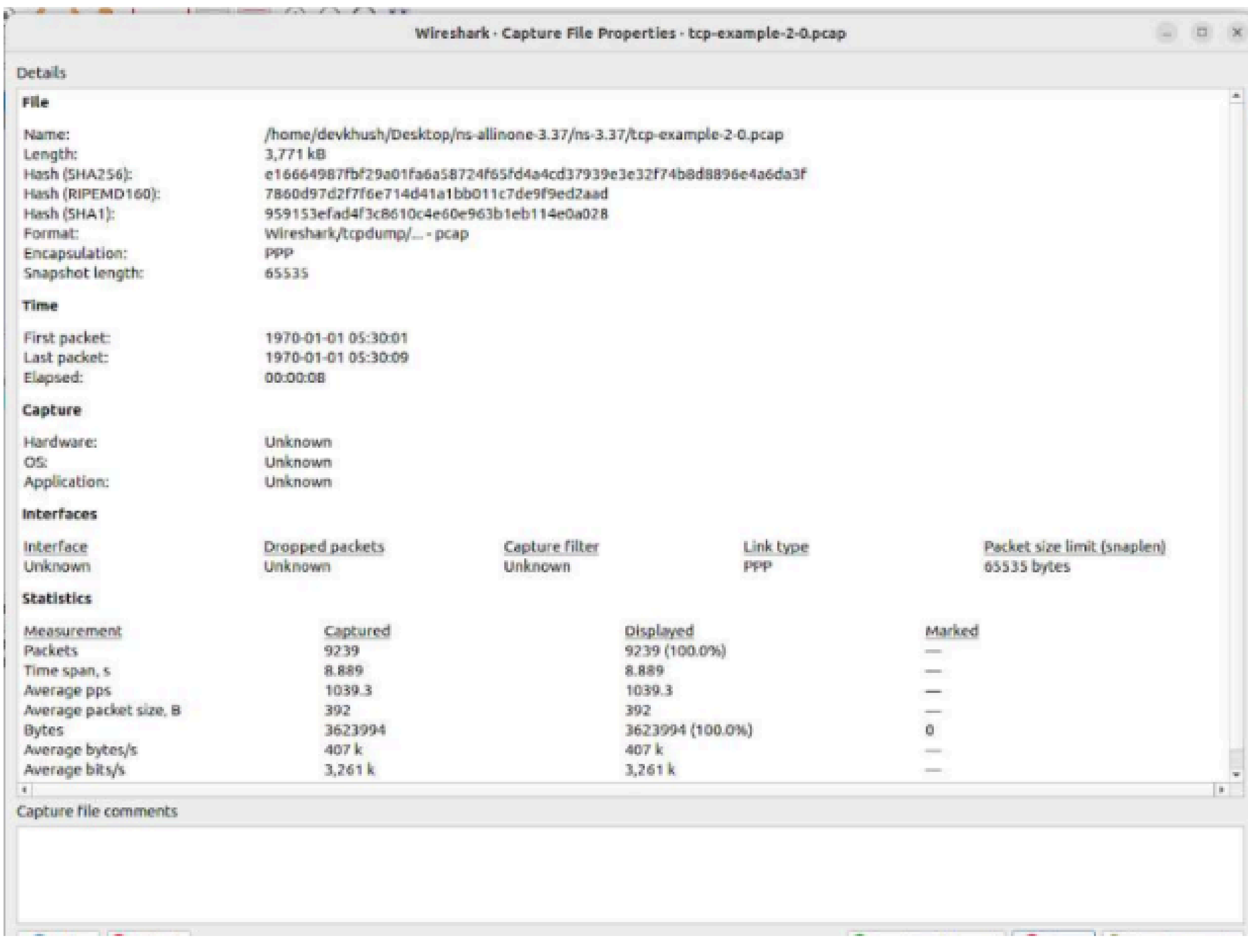


Ethernet | IPv4 · 1 | IPv6 | TCP · 1 | UDP

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	9,239	3,623 k	5,805	3,423 k	3,434	200 k	0.000000	8.8895	3,081 k	180 k

Name resolution | Limit to display filter | Absolute start time | Conversation Types

Help | Copy | Follow Stream... | Graph... | Close



Wireshark · Capture File Properties · tcp-example-2-0.pcap

Details

File

Name:	/home/devkhush/Desktop/ns-allinone-3.37/ns-3.37/tcp-example-2-0.pcap
Length:	3,771 kB
Hash (SHA256):	e16664987fbf29a01fa6a58724f65fd4a4cd37939e3e32f74b8d8896e4a6da3f
Hash (RIPEMD160):	7860d97d2f7f6e714d41a1bb011c7de9f9ed2aad
Hash (SHA1):	959153efad4f3c8610c4e60e963b1eb114e0a028
Format:	Wireshark/tcpdump/... - pcap
Encapsulation:	PPP
Snapshot length:	65535

Time

First packet:	1970-01-01 05:30:01
Last packet:	1970-01-01 05:30:09
Elapsed:	00:00:08

Capture

Hardware:	Unknown
OS:	Unknown
Application:	Unknown

Interfaces

Interface	Dropped packets	Capture filter	Link type	Packet size limit (snaplen)
Unknown	Unknown	Unknown	PPP	65535 bytes

Statistics

Measurement	Captured	Displayed	Marked
Packets	9239	9239 (100.0%)	—
Time span, s	8.889	8.889	—
Average pps	1039.3	1039.3	—
Average packet size, B	392	392	—
Bytes	3623994	3623994 (100.0%)	0
Average bytes/s	407 k	407 k	—
Average bits/s	3,261 k	3,261 k	—

Capture file comments

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

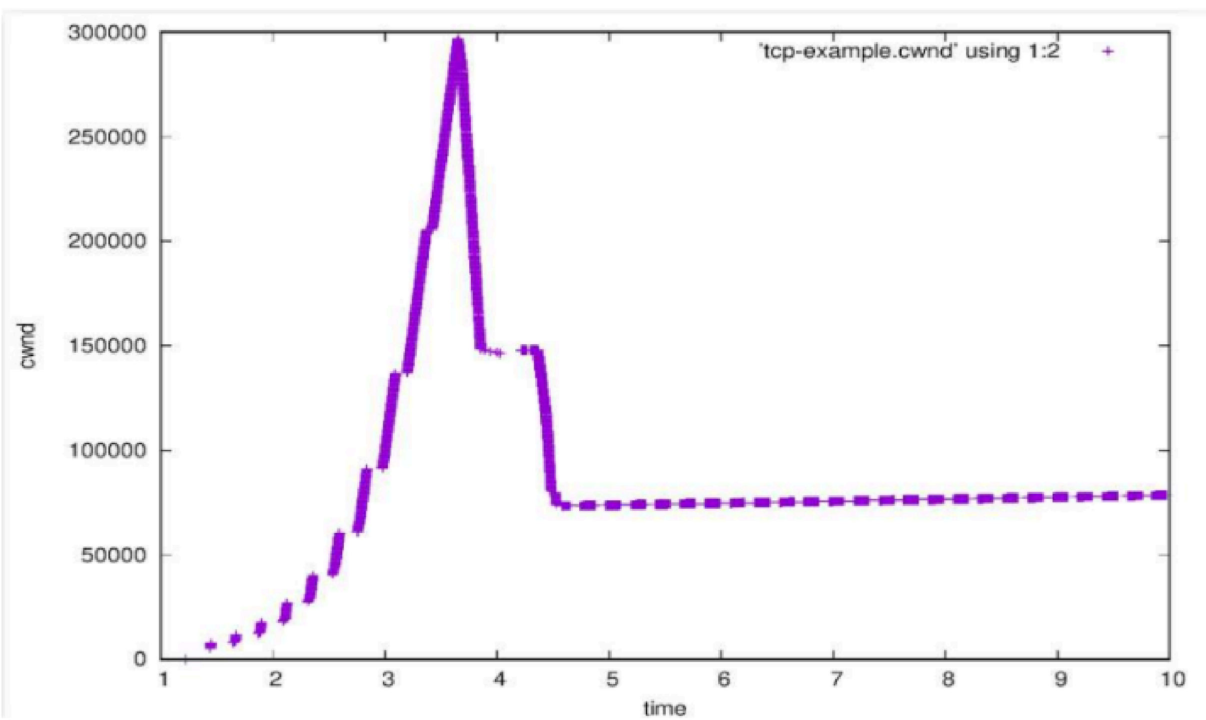
d) Is the achieved throughput approximately equal to the maximum expected value? If it is not, explain the reason for the difference.

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

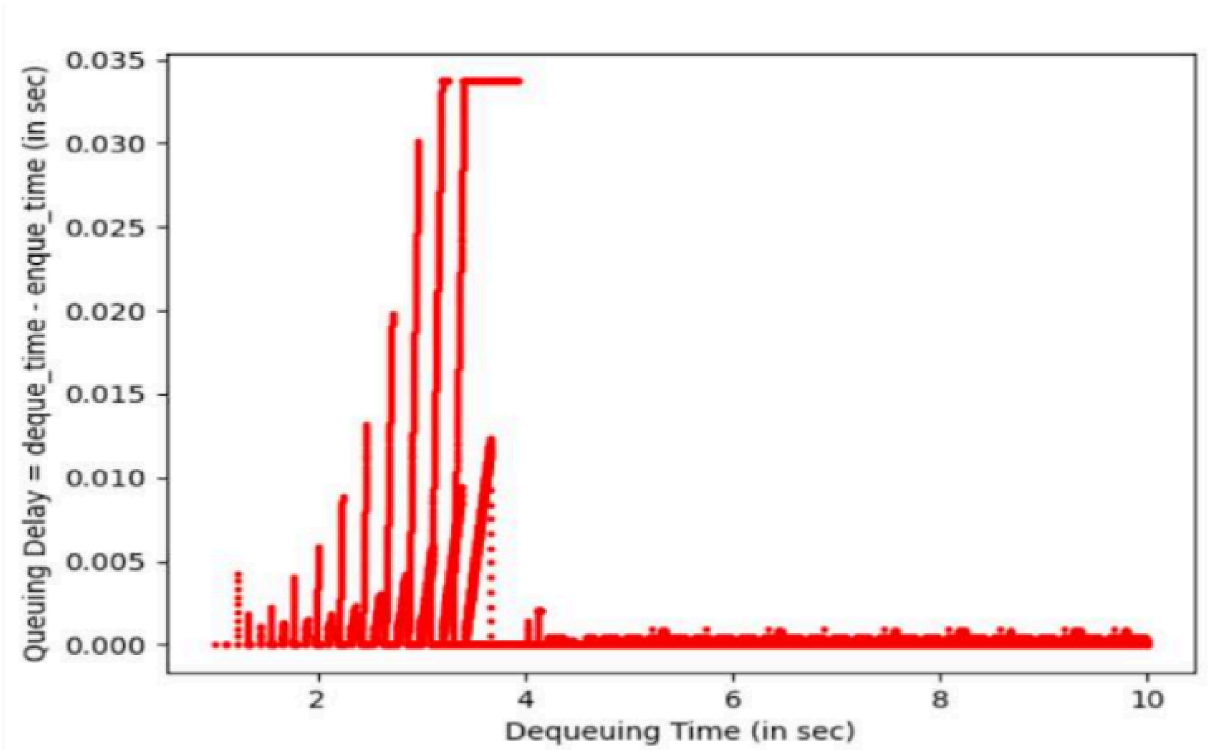
This is because of the queuing delay through the n1 node and possible packet loss in the routed path which occurred in the network.

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?*

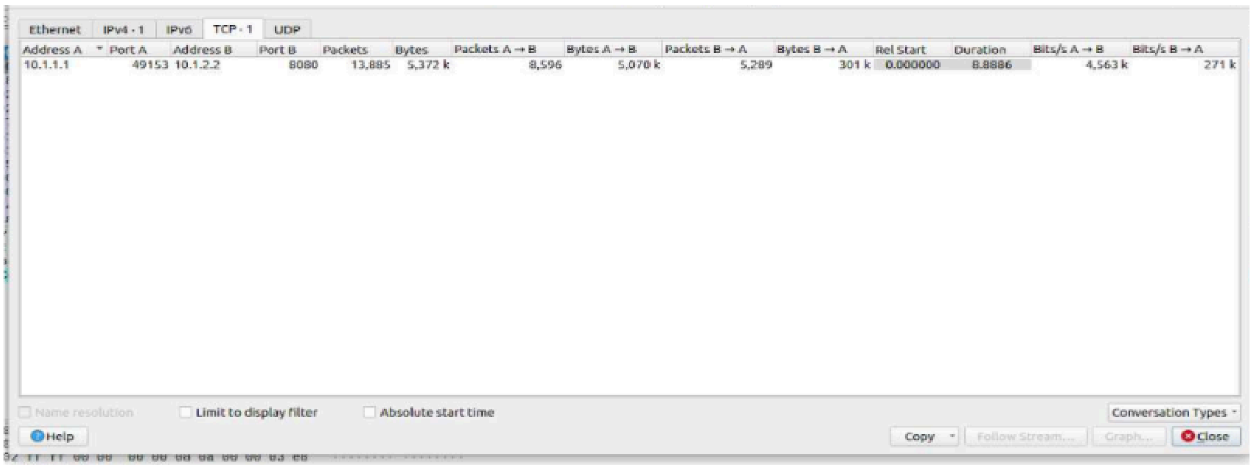
Yes, the CWND plot and Queueing delay plot are related.

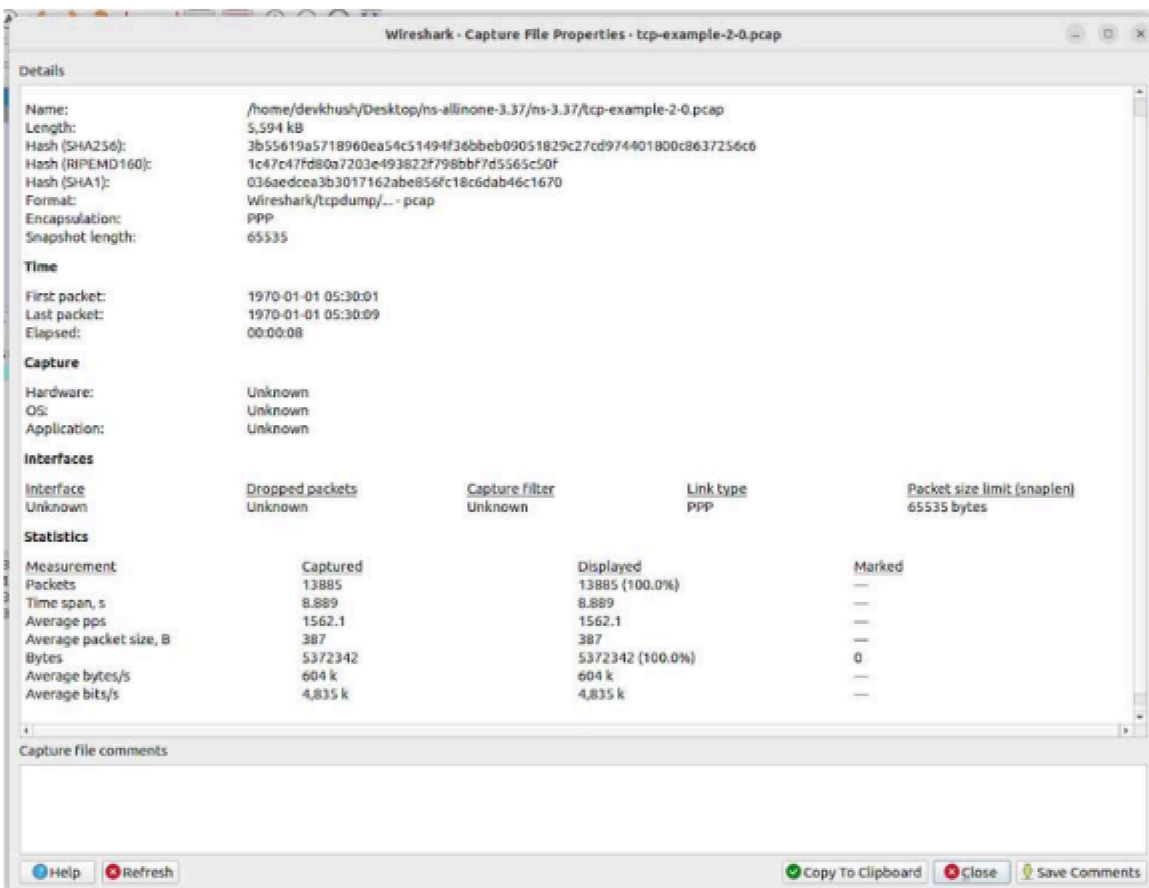
In the CWND plot, it is observed that from time = 0 to 3.5 seconds, the congestion window size doubles per RTT. This marks the slow start phase of packet transmission. As the congestion window size grows, the sender can transmit more packets per RTT. Consequently, the number of incoming packets received per RTT at the router increases, leading to the router's buffer filling up more quickly. As a result, packets are queued at the router, causing an increase in the queueing delay, as evident from the Queueing delay plot for the time period 0s - 3.5s.

In the CWND plot, timeouts occur at time = 3.5 seconds and 4.5 seconds, causing the congestion window size to drop to half of its value. Following the timeout at 4.5 seconds, the congestion window size stabilizes, and the queueing delay also remains roughly constant. This corresponds to the congestion avoidance phase. Therefore, the congestion window (CWND) and queueing delay are directly proportional to each other.

Question 2)

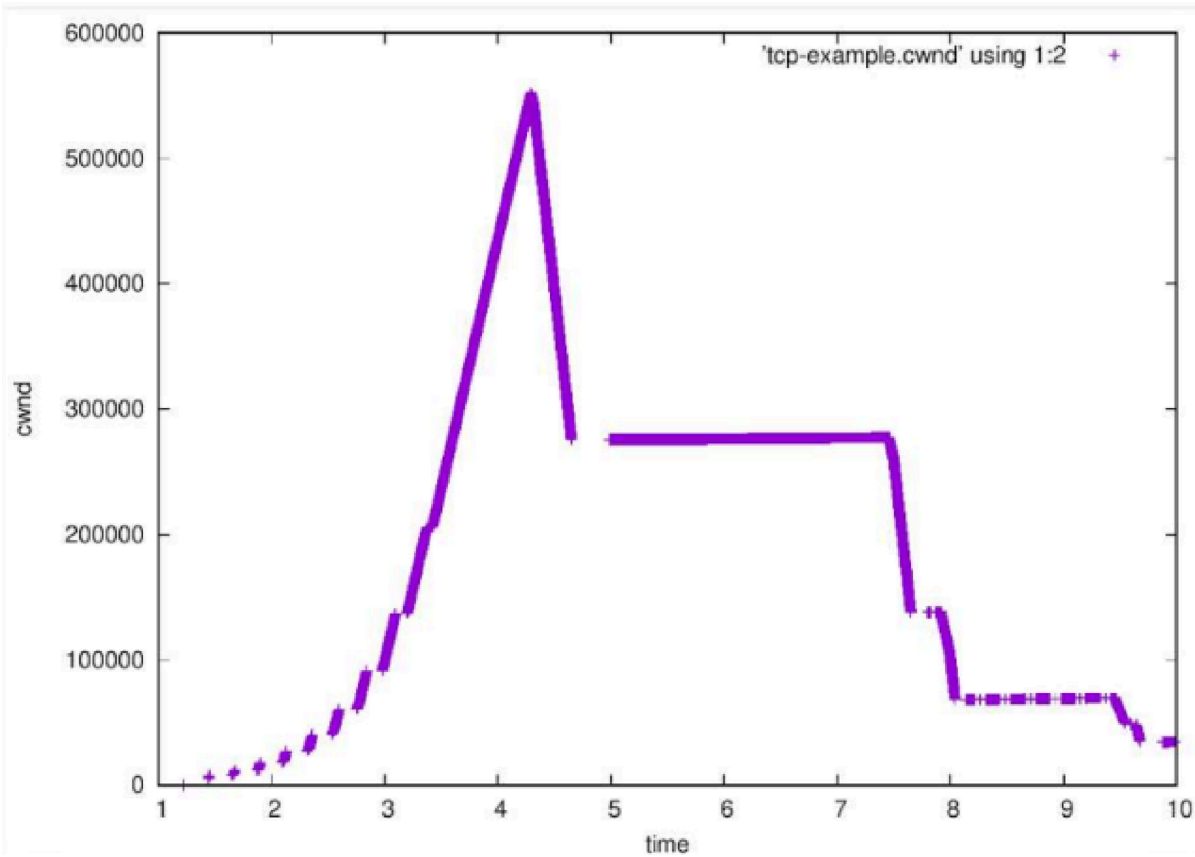
a) What is the average computed throughput of the TCP transfer?



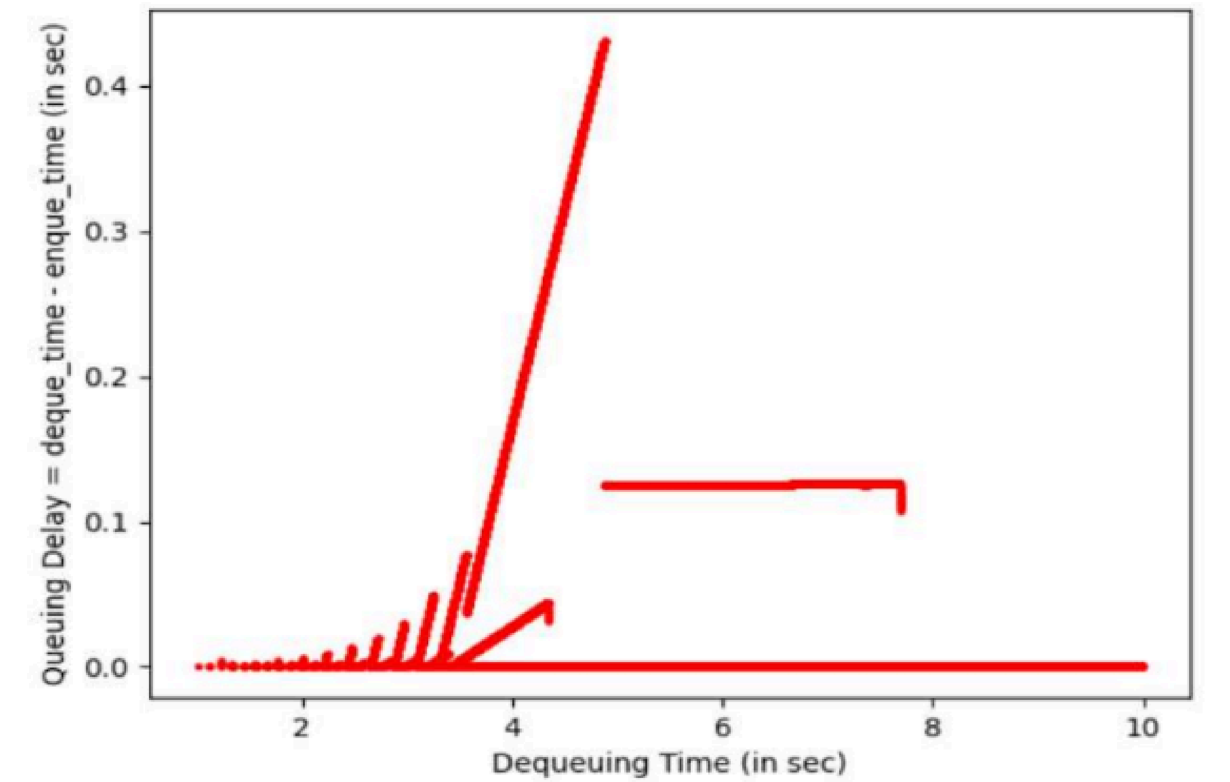


Average computed throughput = 4563k bits/s + 271k bits/s = 4.834 Mb/s.

b) Plot CWND with time.



c) Plot queueing delay with time



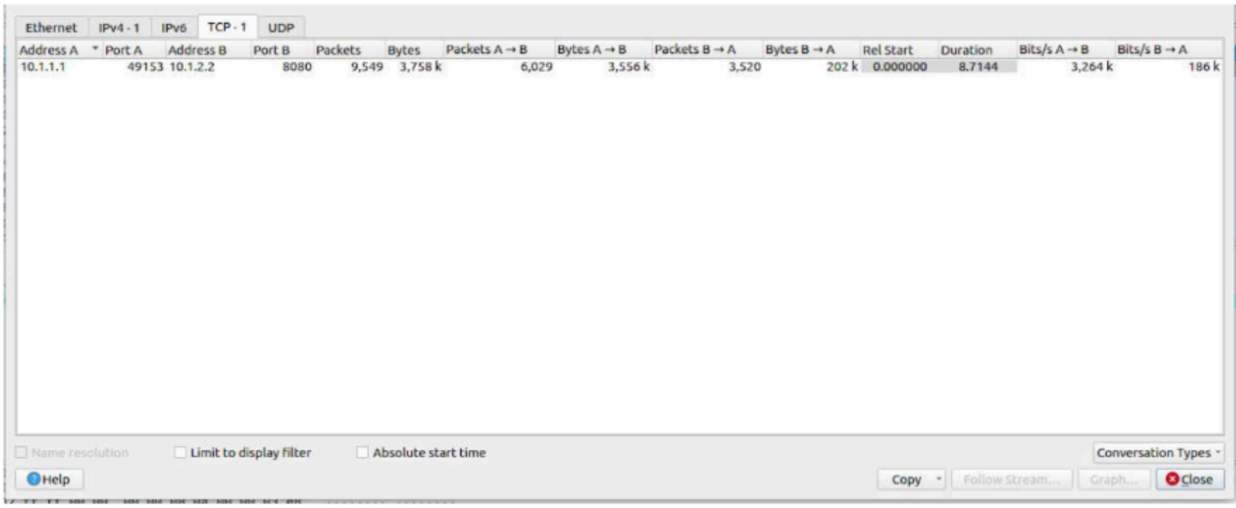
d) Compare CWND plots of Q.1. and Q.2. what insights did you gain?

The buffer size at the router node (n1) is increased by enlarging the queue size. This means more packets can be buffered at the router node. Comparing the CWND plots of Q1 and Q2, it is evident that the congestion window spans greater ranges of values with larger queue sizes. The maximum value of the congestion window increases from 300,000 to 550,000 with a larger queue size. This indicates that the congestion window can reach a higher value before entering the timeout or congestion avoidance phase because more packets can be buffered at the router. Consequently, more packets can be transmitted in a single RTT since they can be buffered or queued at the router with a larger queue size.

However, increasing the queue size also leads to longer waiting times for packets in the queue or buffer. This results in packets spending a longer duration in the queue compared to Q1. Therefore, the queuing delay per packet transmitted increases with an increase in the router’s queue size. This observation is also supported by the queuing delay plot, where the queuing delay values for packets are higher in Q2 than in Q1.

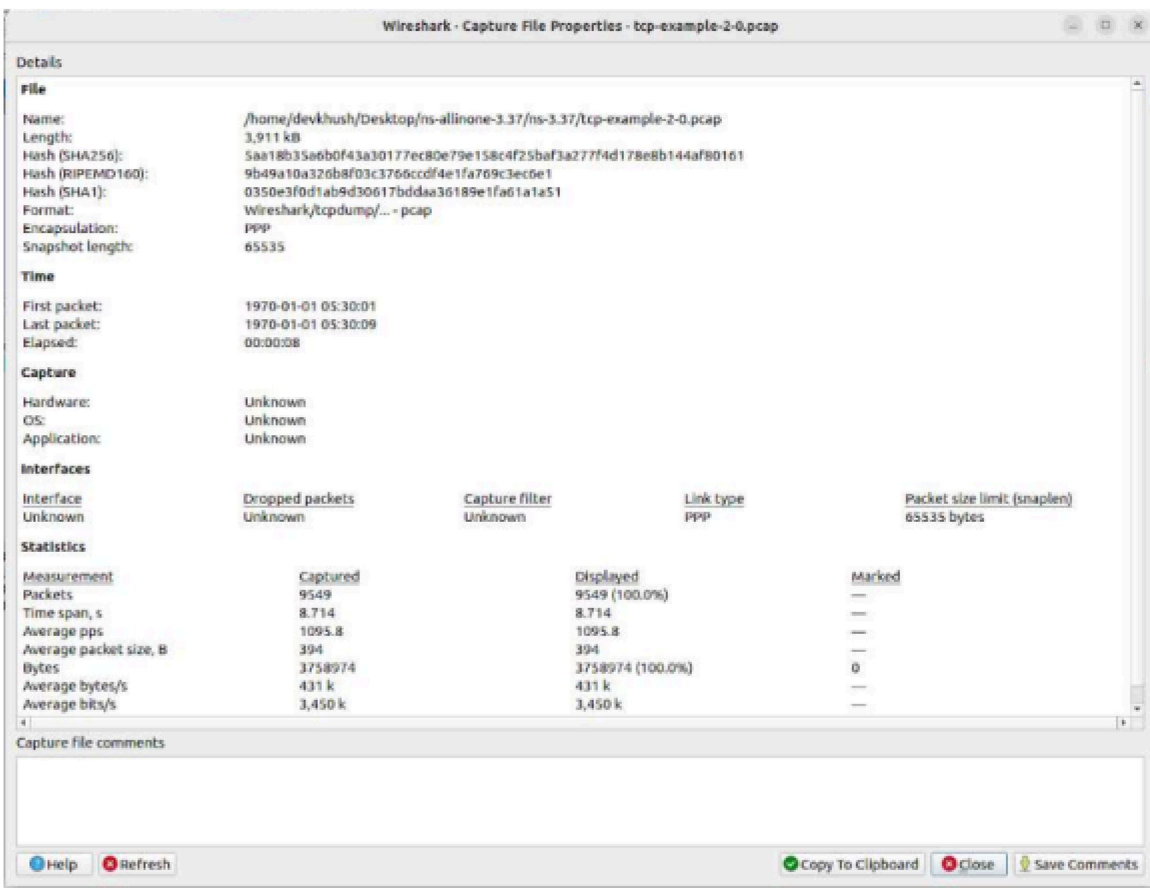
Question 3)

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	9,549	3,758 k	6,029	3,556 k	3,520	202 k	0.000000	8.7144	3,264 k	186 k



Wireshark · Capture File Properties · tcp-example-2-0.pcap

Details

File

Name:	/home/devkhush/Desktop/ns-allinone-3.37/ns-3.37/tcp-example-2-0.pcap
Length:	3,911 kB
Hash (SHA256):	5aa18b35a6b0f43a30177ec80e79e158c4f25baf3a277f4d178e8b144af80161
Hash (RIPEMD160):	9b49a10a326b8f03c3766ccdf4e1fa769c3ec6e1
Hash (SHA1):	0350e3f0d1ab9d30617bddaa36189e1fa61a1a51
Format:	Wireshark/tcpdump/... - pcap
Encapsulation:	PPP
Snapshot length:	65535

Time

First packet:	1970-01-01 05:30:01
Last packet:	1970-01-01 05:30:09
Elapsed:	00:00:08

Capture

Hardware:	Unknown
OS:	Unknown
Application:	Unknown

Interfaces

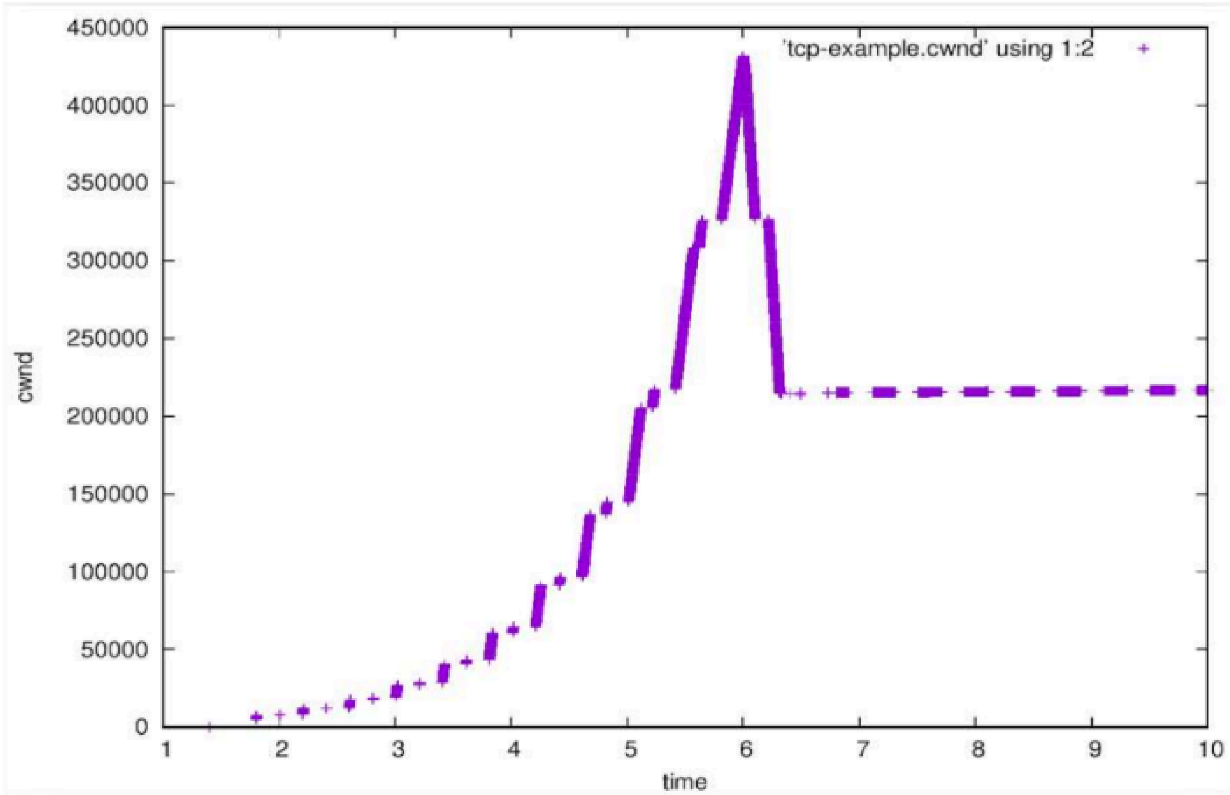
Interface	Dropped packets	Capture filter	Link type	Packet size limit (snaplen)
Unknown	Unknown	Unknown	PPP	65535 bytes

Statistics

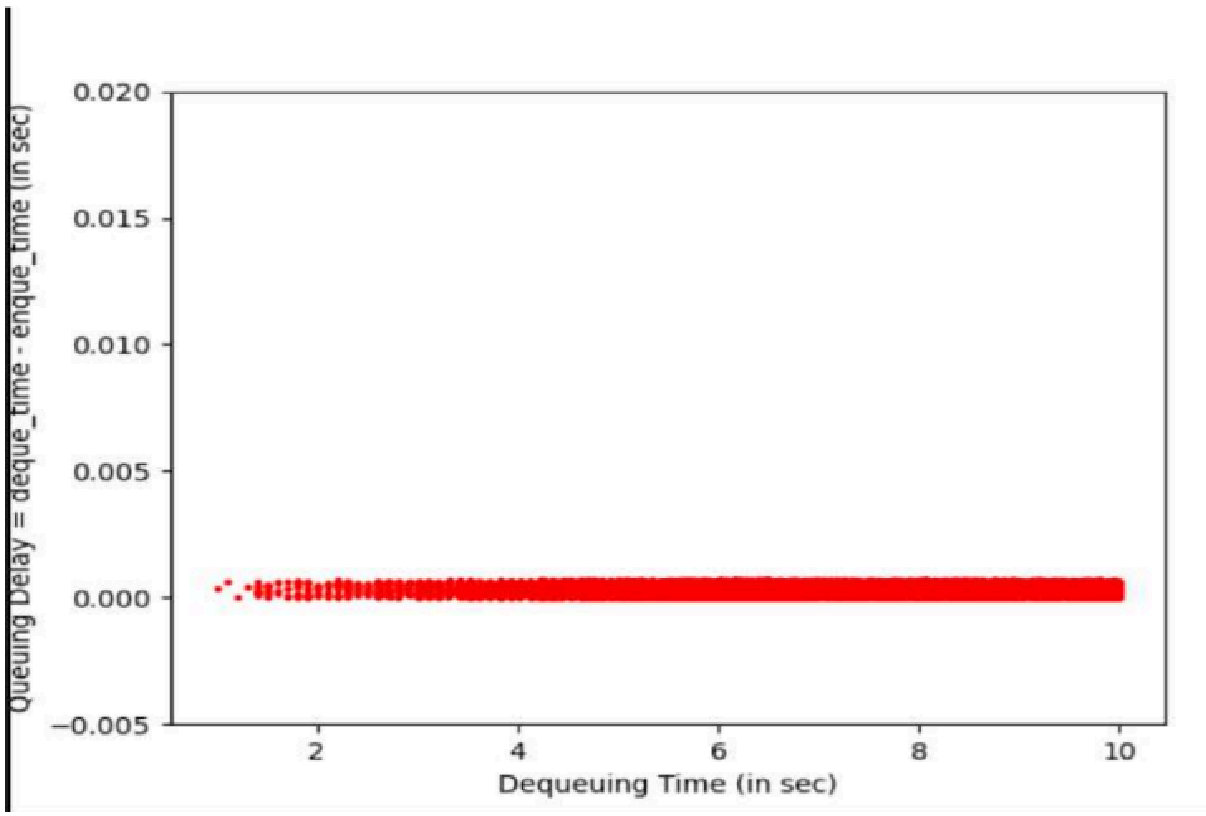
Measurement	Captured	Displayed	Marked
Packets	9549	9549 (100.0%)	—
Time span, s	8.714	8.714	—
Average pps	1095.8	1095.8	—
Average packet size, B	394	394	—
Bytes	3758974	3758974 (100.0%)	0
Average bytes/s	431 k	431 k	—
Average bits/s	3,450 k	3,450 k	—

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?

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

The bandwidth of the links from n0 to n1 and from n1 to n2 is now 10 Mbps each. This means both n0 and n1 can transmit packets at equal rates. As a result, there will be no buffering or queuing of packets at router n1, and packets will not accumulate in the queue at node n1.

In Q1, the outgoing transmission bandwidth at node n1 was lower, leading to a significant queuing delay at the router. By increasing the bandwidth, the queue size and queuing delay at router n1 are reduced compared to Q1, as the outgoing transmission rate has been enhanced.

This is evident from the Queueing delay plot for Q1 and the updated plot. The updated plot shows nearly zero queuing delay values, in contrast to the higher queuing delay values observed in Q1