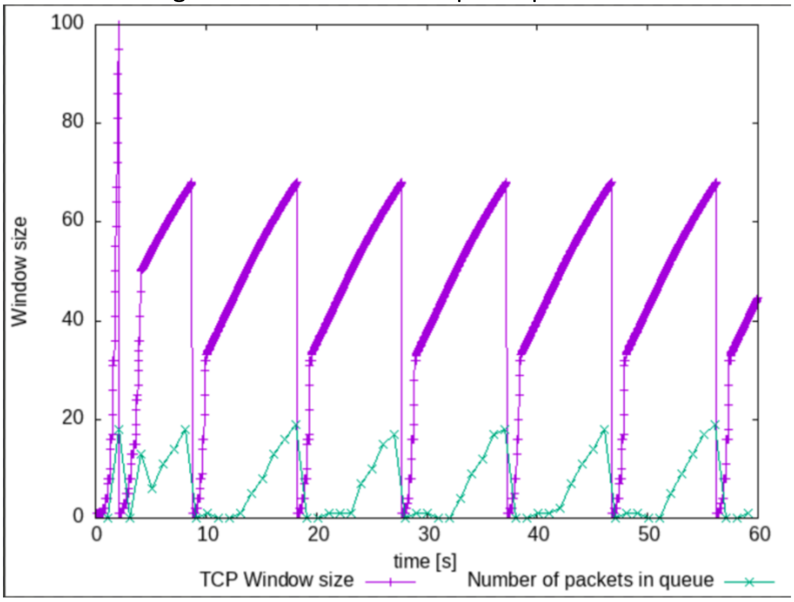
<u>**Lab05**</u>

Exercise 1: Understanding TCP Congestion Control using ns-2

1. The maximum size of the congestion window that the TCP reaches in this case is 100 packets. When this value is reached, the congestion window will experience packet loss, hence the congestion window will drop to 1 packet.



2. Through inspecting the graph, we can estimate that the average throughput is around 185 packets/sec.

$\text{Throughput}_{\text{Packet only}}$ = data (bytes) / transmission time (sec)

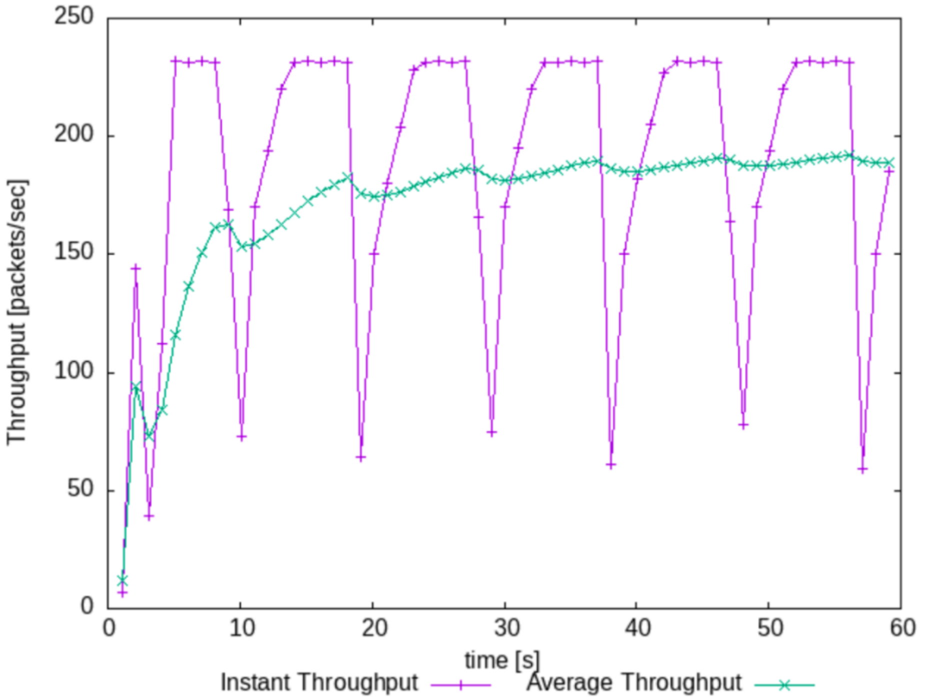
= (packet size) * (throughput packets/sec)

= 500 * 185 bytes/sec = 92500 bytes/sec = 740000 bits/sec

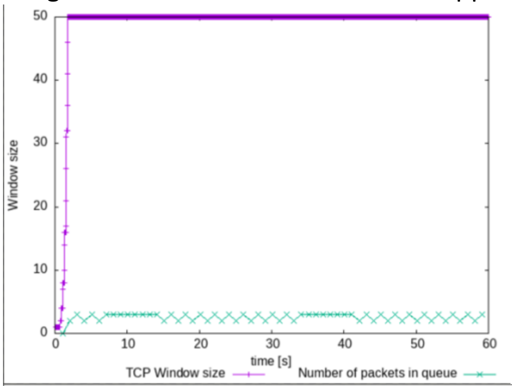
$\text{Throughput}_{\text{Packet including IP and TCP}}$ = data (bytes) / transmission time (sec)

= (packet size) * (throughput packets/sec)

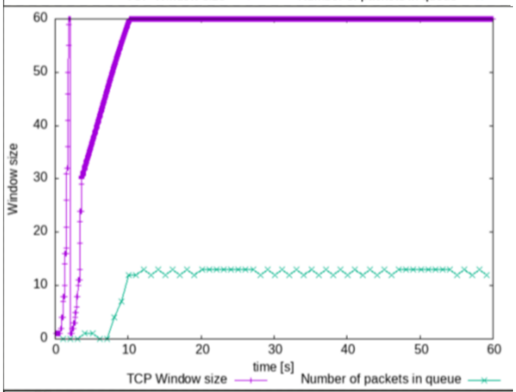
= (500 + 20 + 20) * 185 bytes/sec = 99900 bytes/sec = 799200 bits/sec



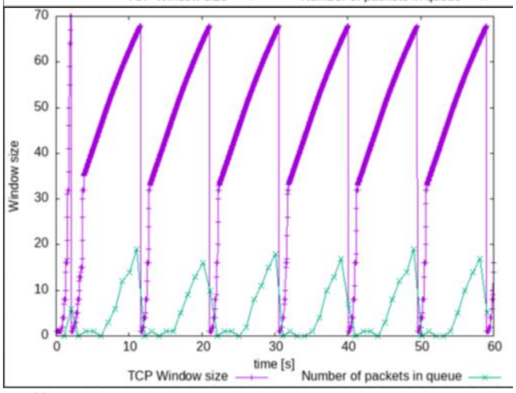
3. Through inspecting the graphs, we can conclude that number of oscillations increase as the congestion window size increases. It appears to stop oscillating at 50 packets.



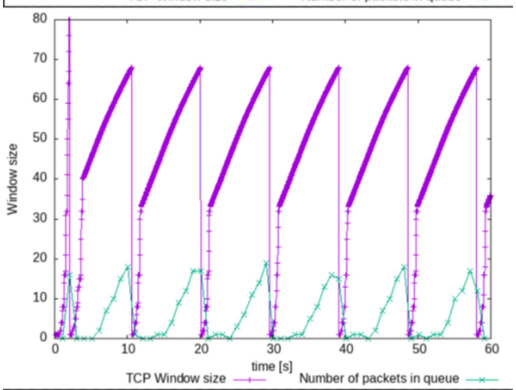
ns tpWindow.tcl 50 100ms



ns tpWindow.tcl 60 100ms



ns tpWindow.tcl 70 100ms

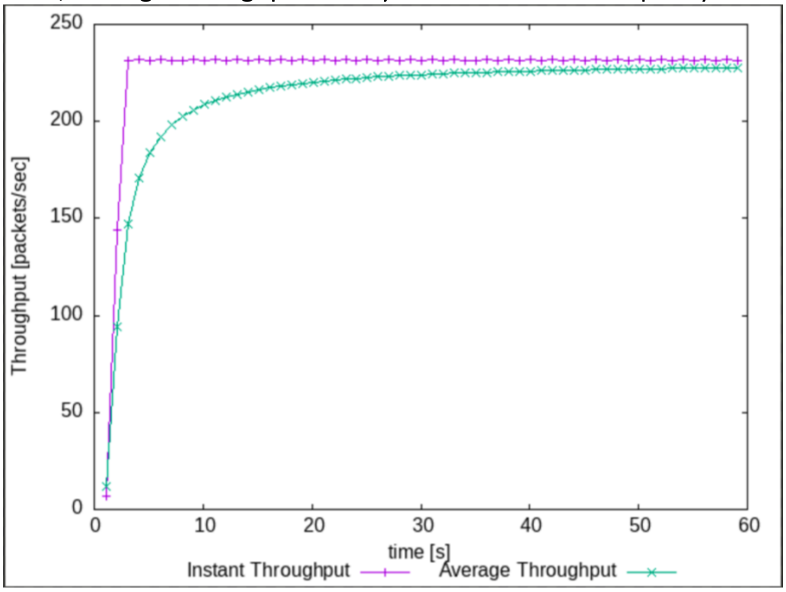


ns tpWindow.tcl 80 100ms

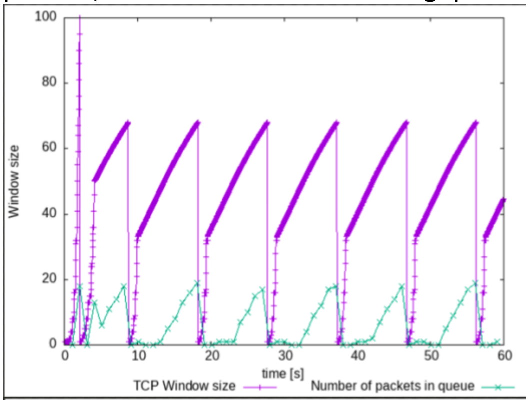
Also, we can see that the maximum throughput is at 220 packets/sec and approaching 230 packets/sec.
$Throughput_{Packet\ only}$ = data (bytes) / transmission time (sec)
= (packet size) * (throughput packets/sec)
= 500 * 230 bytes/sec = 115000 bytes/sec

$Throughput_{Packet\ including\ IP\ and\ TCP}$ = data (bytes) / transmission time (sec)
= (packet size) * (throughput packets/sec)
= (500 + 20 + 20) * 230 bytes/sec = 124200 bytes/sec = 993600 bits/sec ≈ 1000000 bits/sec
= 1 Mbps

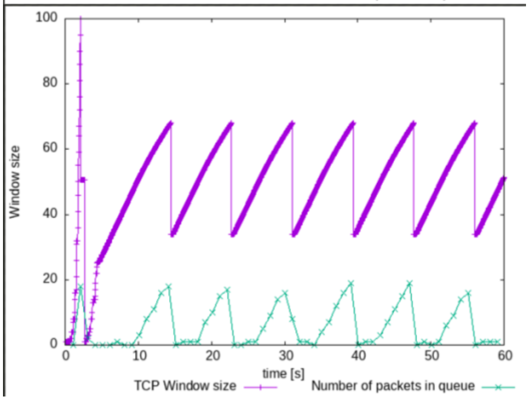
Thus, average throughput is very similar to the link capacity.



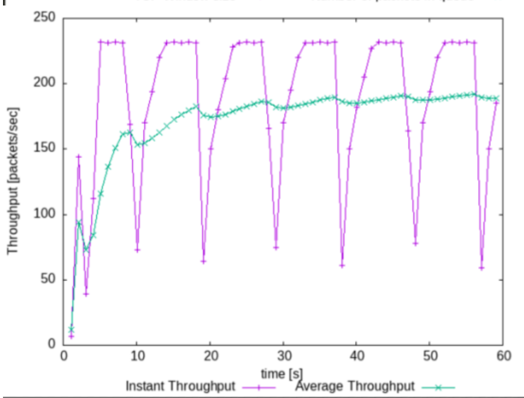
4. In the Window.png files, we can see that the Tahoe window size drops to 1 packet after the packet loss while Reno drops to half the max window size after the packet loss.
In the WindowTPut.png files, we can see that Tahoe has a throughput of approximately 185 packets/sec while Reno has a throughput of slightly more than 200 packets/sec.



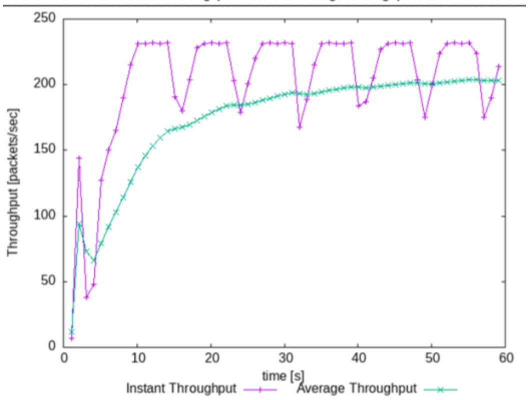
TCP Tahoe Window



TCP Reno Window



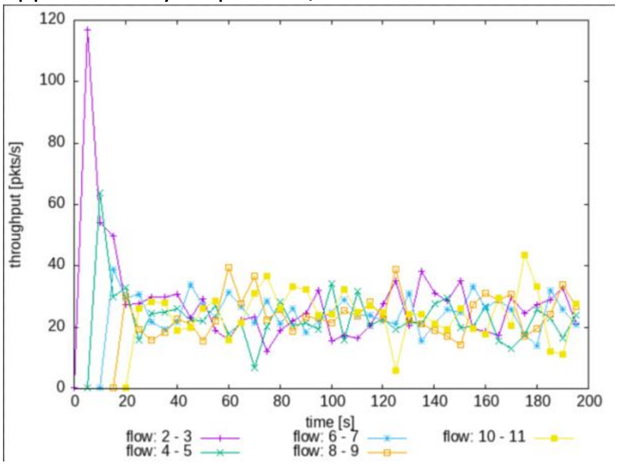
TCP Tahoe WindowTPut



TCP Reno WindowTPut

Exercise 2: Flow Fairness with TCP

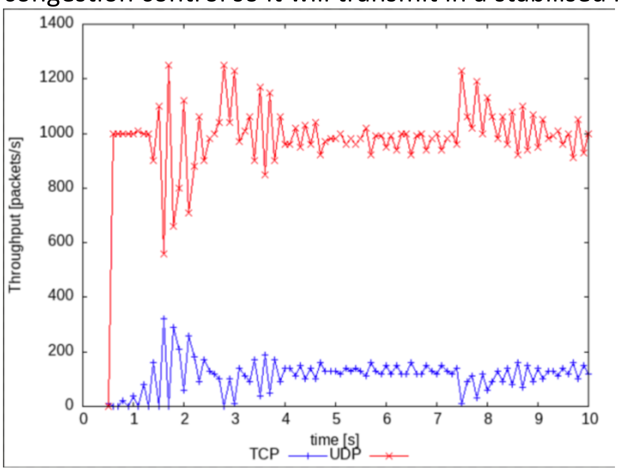
1. Yes, each flow gets an equal share of the capacity of the common link. During the 0-20 second stage, flow 2-3 clearly had a much higher throughput than the others but by the end of the 200 seconds, with some expected fluctuations, all flows ended with a throughput of approximately 20 packets/sec .



2. When a new flow is created, the flows equal out as when they converge their throughputs by the additive-increase/multiplicative-decrease (AIMD) mechanism, which combines the linear growth of the congestion window when there is no congestion with an exponential reduction when congestion is detected. Therefore, I consider this behaviour to be fair as all flows receive an equal share of throughput.

Exercise 3: TCP competing with UDP

1. I would expect that UDP flow would have a higher throughput than TCP flow. This is because UDP does not have congestion control thus, it will send many packets at once while TCP has congestion control so it will transmit in a stabilised manner.



2. Like the previous answer, the UDP flow has a higher throughput as it does not have congestion control while TCP flow has congestion control so it will send less packets to stabilise flow.

3. UDP instead of TCP:

Advantages	Disadvantages
Higher rates of transmission	No congestion control
Less packet and header size requirement	Increased packet loss in poor network conditions
Constant rate of data flow	No connection establishment

If everyone started using UDP instead of TCP, where our connection had to compete with other flows for the same link, the network would be overwhelmed. As UDP has no congestion control, it will send as many packets as possible at once, leading to increased congestion. This would result in great amounts of packet loss and an unreliable and unusable network.