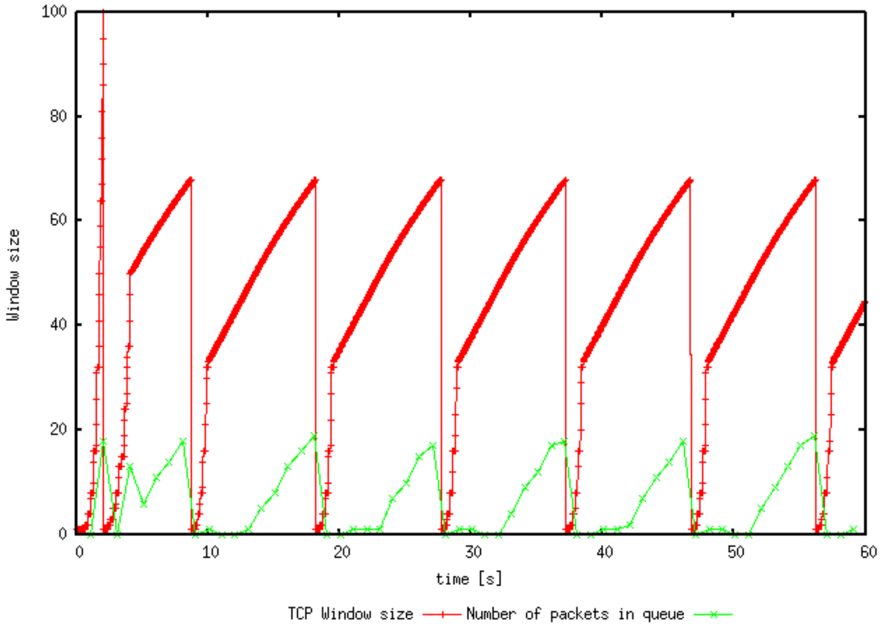
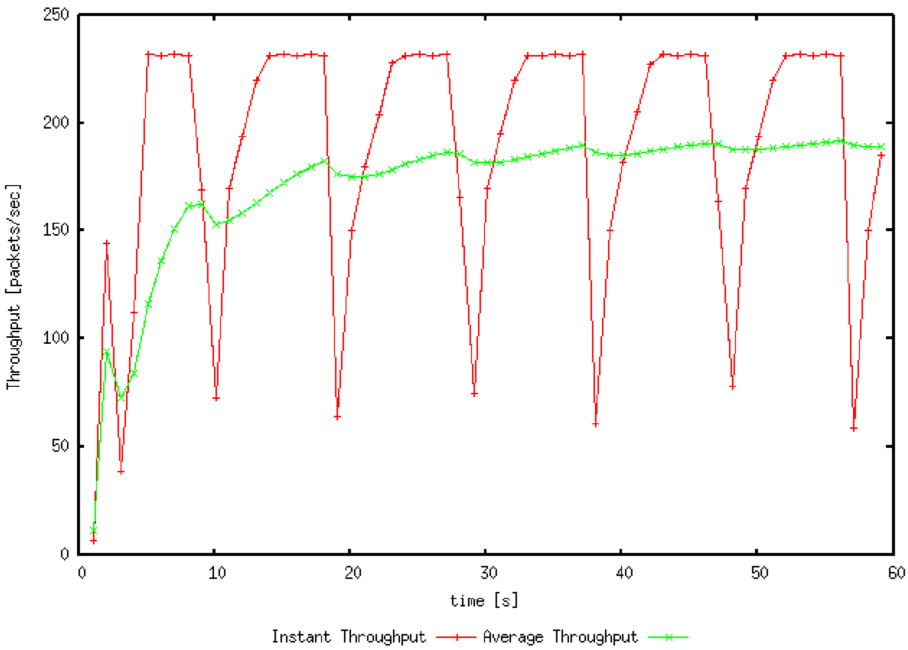
Exercise 1

1. Maximum size of the congestion window TCP reaches: 100.
   When it reaches 100, it drops to 0. This is because there was a loss event (timeout or there were 3 duplicate acks) – and after this, TCP tahoe drops the congestion window to 0. Now it will go into slow start until it reaches the slow start threshold (which is set at half of 100 (50)).

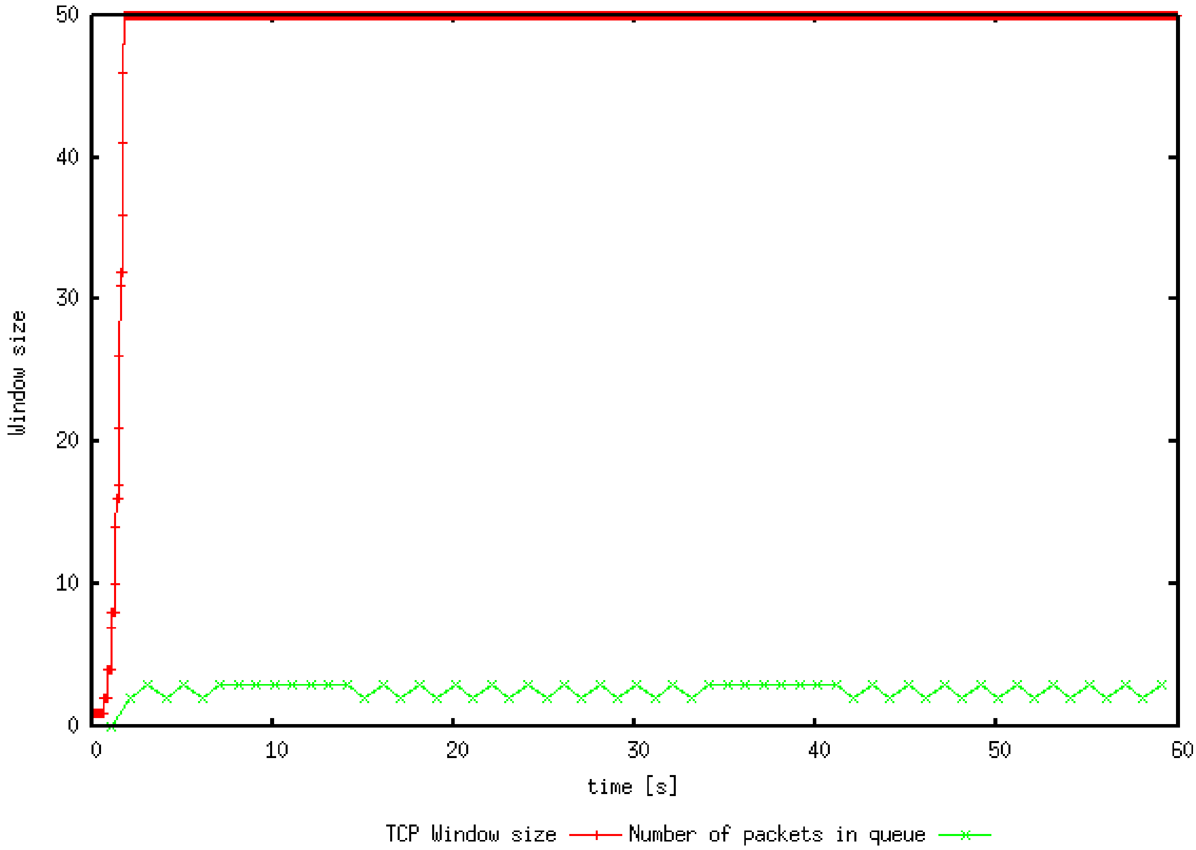


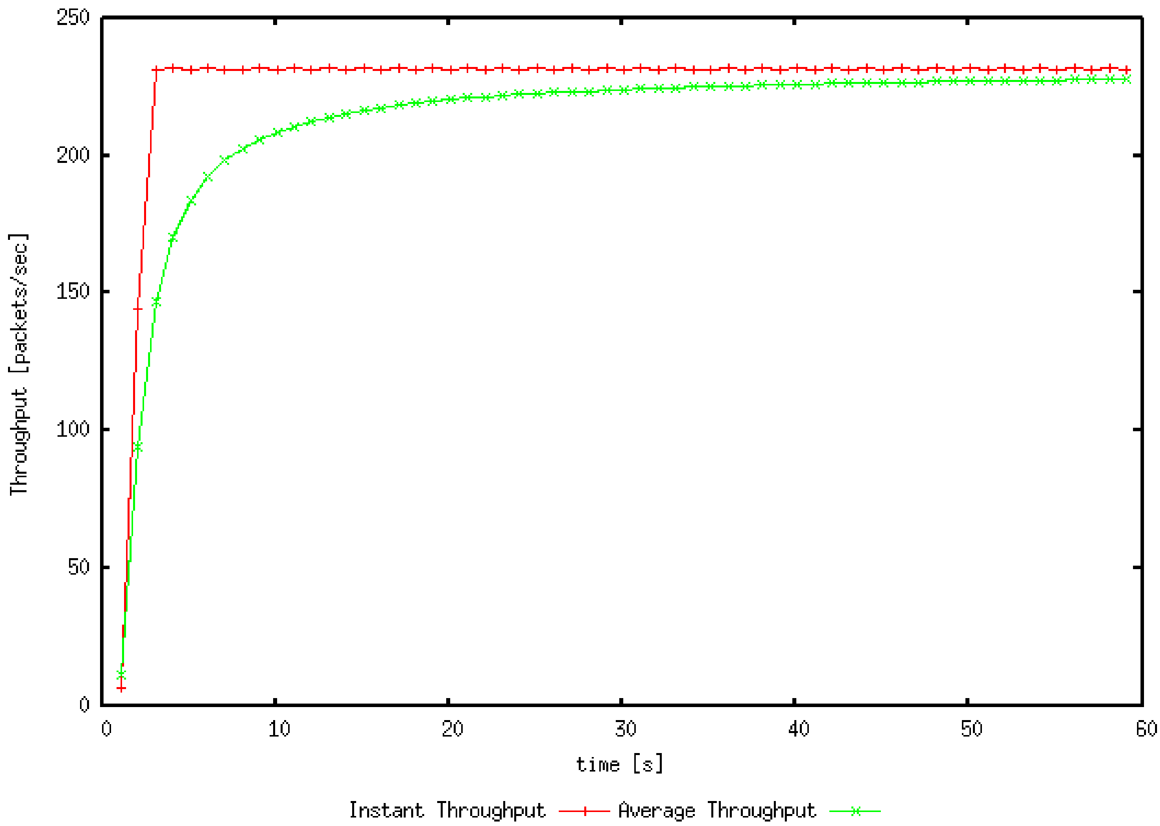
2. Throughput: 189 packets/second.

   500 - 40 = 460 bytes per packet * 189 packets = 86940 bps



3. The lower the window size, the less oscillations until it is a flat line



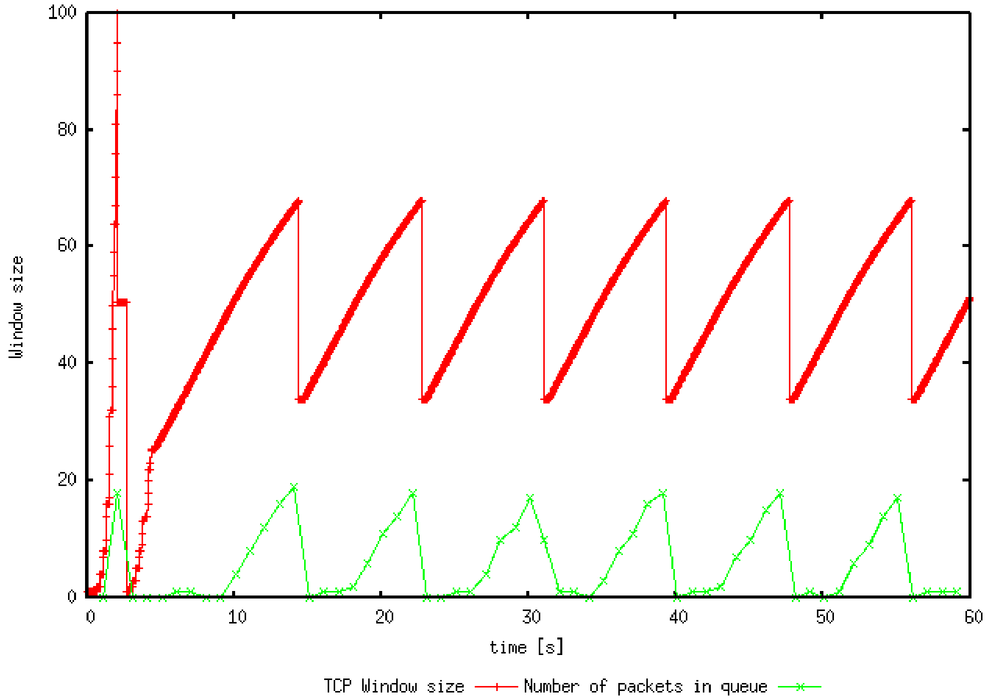


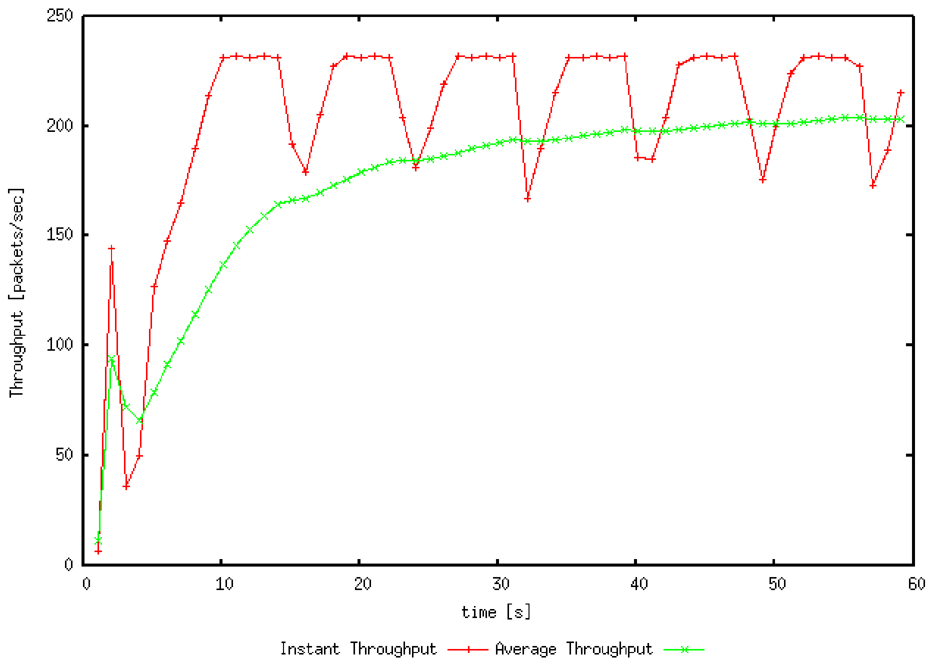
At window size 50, TCP stops oscillating as shown by the above graphs

The average throughput at this point is: 227 packets/second, 104420 bps. This is lower than the link capacity (1Mbps)

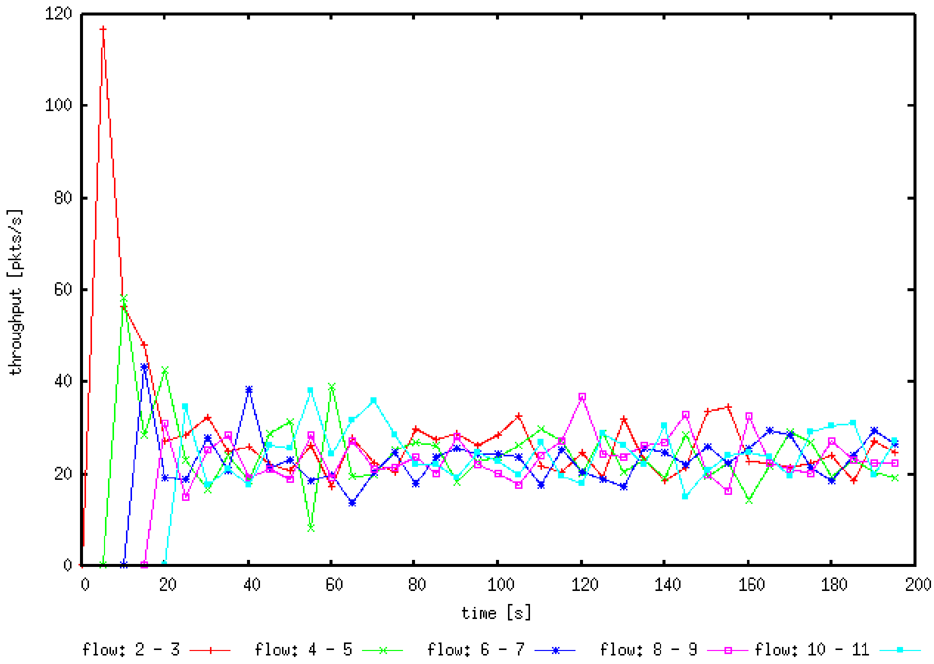
4. The loss events in the graph are 3 duplicate acks and in TCP reno, that means the window is set as half of the current congestion window size instead of zero in TCP tahoe.

The average throughput is 201 packets/second: 500 – 40 = 460 bytes per packet, 201 packets so 460 * 201 = 92460 bps





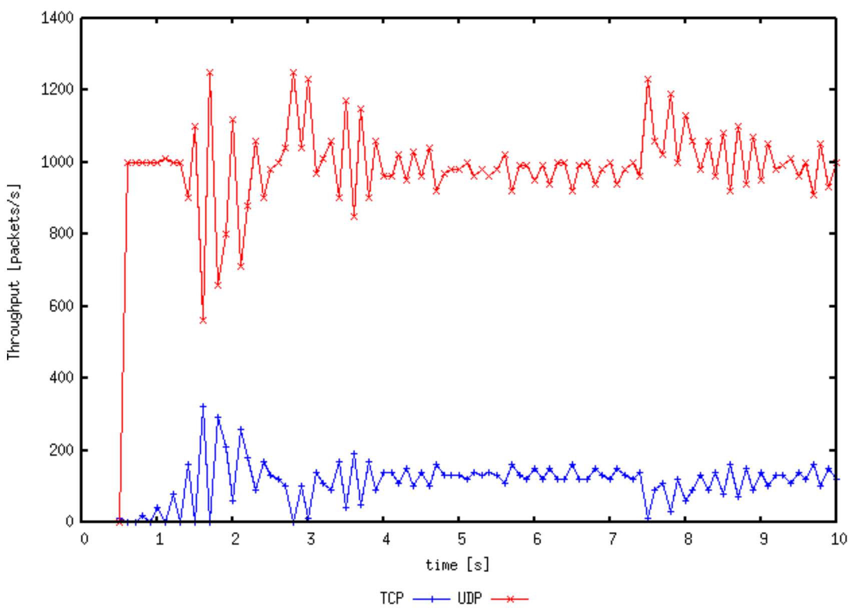
Exercise 2



1. Yes, each flow gets an equal share of the capacity. All links oscillating around 20 packets/s indicates that all flows are getting an equal share (around 20packets/s)

2. The throughput of all existing flows will decrease if a new flow is added. They will oscillate around a lower throughput value. Mechanisms that create flows to decrease are how after loss (which will happen after another flow joins as it is using bandwidth that existing flows were using), the segments size is decreased by TCP (either to half or zero depending on whether this is TCP tahoe or TCP reno. All existing flows will have their segment size decreased allowing the new flow to use some of the link bandwidth. This behaviour is fair as all flows get roughly equal share of the link bandwidth

Exercise 3



1. UDP will use as much of the link bandwidth as it can (wants) and TCP will use the remaining capacity of the link. TCP is blue, UDP is red

2. UDP has no congestion avoidance mechanisms so will send as much as it can down the link. TCP does have congestion avoidance so it starts with slow start and then slowly backs off and uses the remaining amount on the link that UDP doesn't use.

3. Advantages of UDP over TCP:

- no congestion avoidance, will send files as fast as it can
- will send files faster than TCP over the same link if bandwidth is restricted

Disadvantages:

- If UDP sending exceeds link bandwidth, it will lose packets

If everyone starts using UDP, no one will be using congestion control, and the internet would become very congested and eventually become unusable