Networks lab 4

1. What is the normal time required to download the webpage on h1 from h2?

Normal time required is 1 second.

```
Length: 177669 (174K) [text/html]
Saving to: ‘index.html.1’

     0K .......... .......... .......... .......... .......... 28%  182K 1s
    50K .......... .......... .......... .......... .......... 57%  177K 0s
   100K .......... .......... .......... .......... .......... 86%  171K 0s
   150K .......... .......... ...                              100%  182K=1.0s

2021-10-28 20:04:24 (177 KB/s) - ‘index.html.1’ saved [177669/177669]
```

2. What was your initial expectation for the congestion window size over time?

My initial expectation follows that of theory. The congestion window size (cwnd) will start out at 1 MSS then increase exponentially by a scale factor of 2 for each transmission round. This happens at the slow start phase. Eventually, after hitting ssthresh, the cwnd increases linearly. From the results, that the first 28% took 1s due to smaller cwnd at the slow start phase. Upon reaching the congestion avoidance phase, we can see that the timing of the download decreased significantly from 1s and then the timing increases back to 1s between 86% and 100% because there are three duplicate ACKs. This implies the decrease in cwnd size.

3. After starting iperf on h1, did you observe something interesting in the ping RTT?

There is an additive increase multiplicative decrease effect. The screenshots below show that for every packet sent, from sequence 1 to sequence 23, there is an eventual increase from 499 ms for each round trip to 751ms for each round trip. After sequence 23, the timing dropped to 387ms for each round trip as the congestion window gets jammed. We can see the aggressive drop in the round trip times. Then the round trip time increases gradually.

```
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=524 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=542 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=560 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=572 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=581 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=600 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=610 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=627 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=645 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=648 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=665 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=675 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=693 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=695 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=705 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=724 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=735 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=745 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=761 ms
64 bytes from 10.0.0.2: icmp_seq=22 ttl=64 time=765 ms
64 bytes from 10.0.0.2: icmp_seq=23 ttl=64 time=751 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=387 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=404 ms
64 bytes from 10.0.0.2: icmp_seq=26 ttl=64 time=424 ms
64 bytes from 10.0.0.2: icmp_seq=27 ttl=64 time=449 ms
64 bytes from 10.0.0.2: icmp_seq=28 ttl=64 time=466 ms
64 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=475 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=496 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=514 ms
```

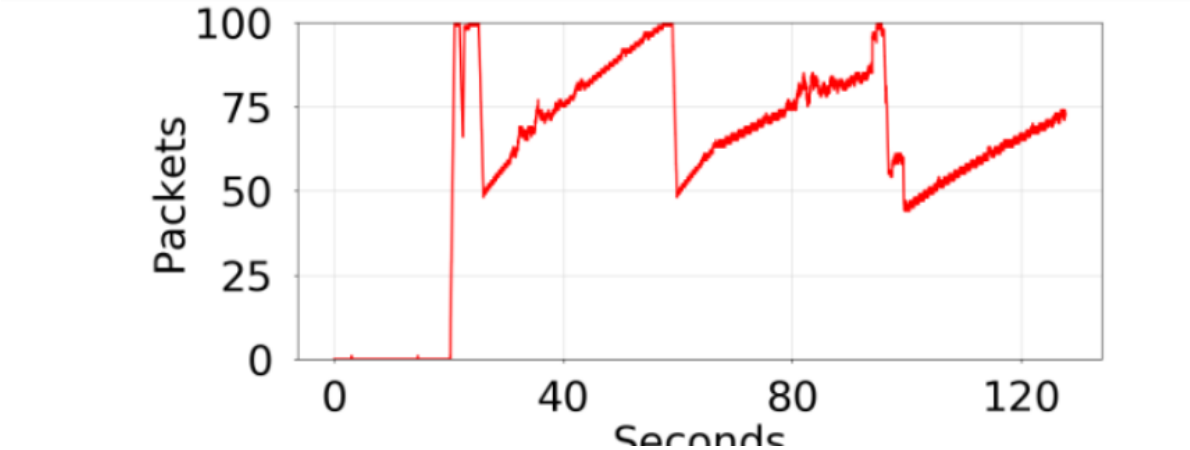
```
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=532 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=542 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=553 ms
64 bytes from 10.0.0.2: icmp_seq=35 ttl=64 time=571 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=588 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=598 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=602 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=612 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=621 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=624 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=633 ms
64 bytes from 10.0.0.2: icmp_seq=43 ttl=64 time=642 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=652 ms
64 bytes from 10.0.0.2: icmp_seq=45 ttl=64 time=661 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=647 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=656 ms
```

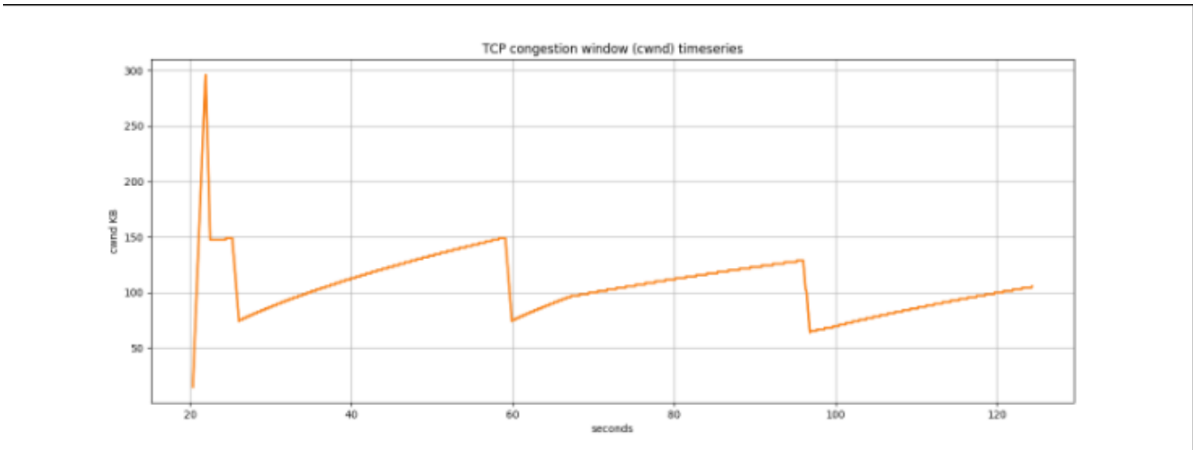
The linear increase of ping is due to the linear increase in the cwnd size during the congestional avoidance phase. More data packets sent over due to queueing delay at the buffer. Due to triple duplicate ACK, the cwnd size decreases by half so that the fast recovery state is done, causing the ping rtt to decrease by half.

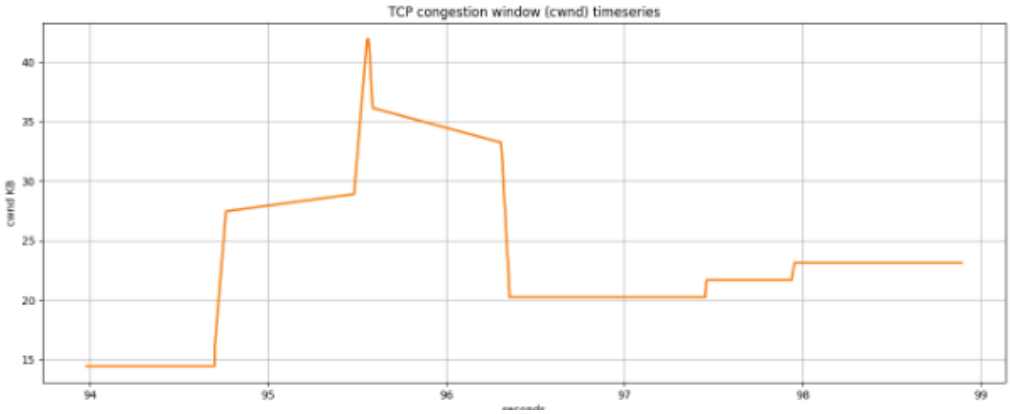
5. After starting iperf on h1, why does the web page take so much longer to download?

The webpage takes a longer time to download because of the fact that there may be higher transmission delay even though the bandwidth is almost the same due to the sharing of bandwidth with iperf1. Hence, the effective bandwidth to download the files is smaller. Hence longer time.

6. Please provide the figures for the first experiment (with qlen 100).



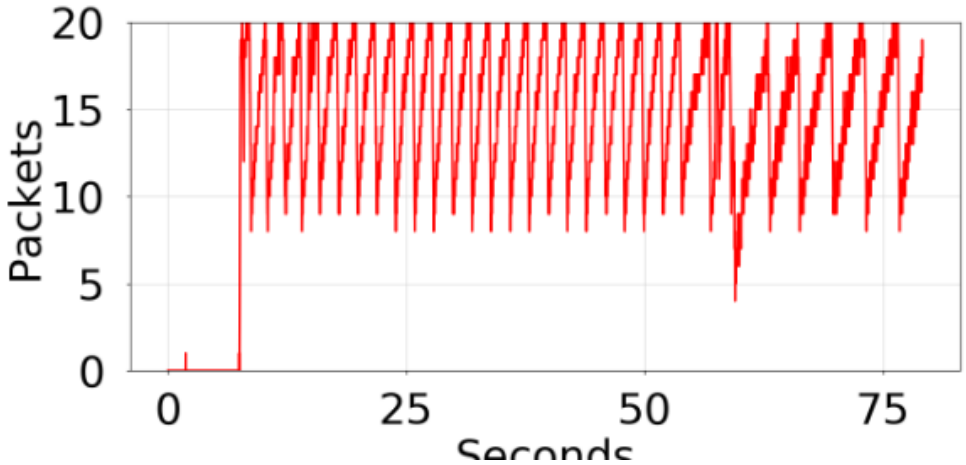


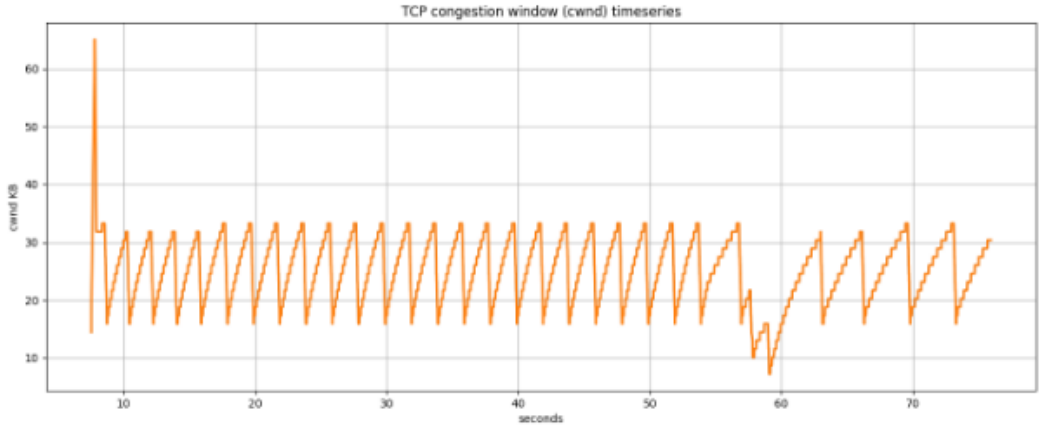


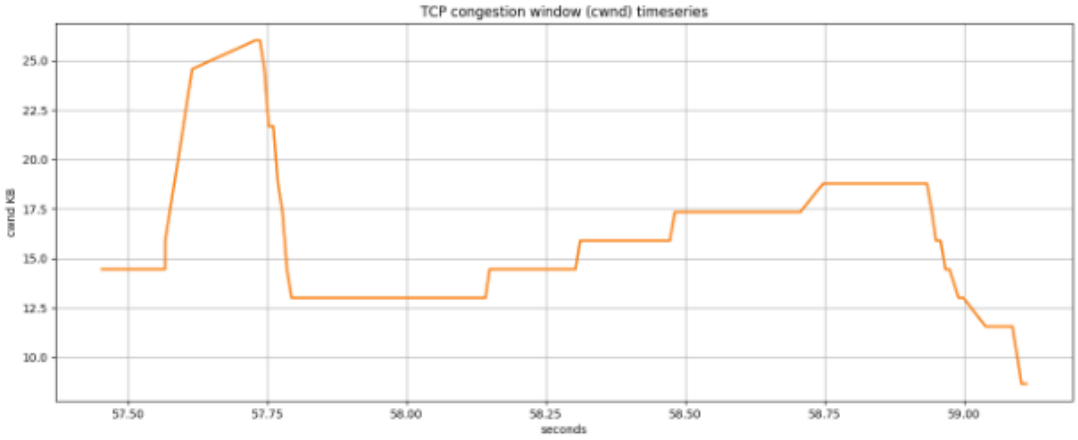
a. Please comment on what you can see in the figures.

Normal sawtooth pattern in the second figure corresponds to the staircase pattern from 97 to 99 packet. When wget runs, we see the at around 97.5 seconds on the second figure, the cwnd experiences a packet loss even at a marginally smaller value than before. at around 147 KB as compared to 150 KB previously. wget run at around 95 seconds in last figure means thatpacket loss event. cwnd decreases at about half from 42 KB to 21 KB. This means fast recovery phase.

7. Please provide the figures for the second experiment (with qlen 20).
   * Please comment on what you can see in the figures and what is different from the previous experiment. Explain the reason behind the difference.







One major difference between the figures of qlen = 20, as compared to qlen = 100, is the average time is takes for a packet loss event to occur, as observed in the second figure of this part. We observe about 5-6 packet loss events in about 10 seconds in the second figure of this question, as compared to 20-40s in the second figure of the previous question. For qlen = 20, the cwnd follows a sawtooth pattern between approx. 13KB to 26KB, whereas for qlen = 100, the cwnd is between approx. 21KB to 42KB.

Since the cwnd increases by 1MSS every RTT during congestion avoidance, larger amount of time taken for a larger raw increase of cwnd.