50.012 Networks (2021 Term 6)

Homework 2

Hand-out: 7 Oct

Due: 19 Oct 23:59

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1. (2019 midterm exam question) Consider data communication over a link of RTT 100ms and transmission bandwidth 1Gbit/s. Assume 1G=10^9. Consider a pipelined transport protocol that uses ACKs to decide if packets were received successfully. Answer the following three questions:

1.1 After the protocol has sent a packet, what is the minimum amount of time needed for the protocol to infer that the packet was lost?

For pipelined protocols Go-Back-N and Selective Repeat, the minimum time is the timeout for the packet, which is generally about the RTT of 100ms.

1.2 If the protocol uses a window size of 6 packets (each of size 1000 bytes), what is the maximum achievable data throughput?

Max_throughput = $\frac{cwnd}{RTT} = \frac{1000}{100\times10^{-3}} = 10000 bytes/s$

1.3 To fully use the transmission bandwidth, estimate the minimum window size (in bytes) needed.

$$1 \times 10^9 = \frac{w\_min}{100 \times 10^{-3}}$$

$$w\_min = 1 \times 10^8 bytes\ (100\,000\ packets)$$

2. Consider the three 16-bit words (shown in binary) below.

01101001 11110110
11100011 00011100
10101010 10101010

What is the Internet checksum value for these three16-bit words?

Checksum: 00001000 01000010

3. (textbook chapter 3, problem P44): Consider sending a large file from a host to another over a TCP connection that has no loss.

3.1 Suppose TCP uses AIMD for its congestion control without slow start. Assuming cwnd increases by 1 MSS every time a batch of ACKs is received and assuming approximately constant round-trip times, how long does it take for cwnd increase from 6 MSS to 12 MSS (assuming no loss events)?

6 RTTs assuming no loss causing cwnd to be cut by half.

3.2 Again, assume in the first RTT 6 MSS was sent, what is the average throughout (in terms of MSS and RTT) for this connection up through time = 6 RTT?

Throughput = $\frac{\Sigma cwnd}{RTT} = \frac{\sum_{6}^{11} x}{6} = \frac{51 MSS}{6RTT} = 8.5 bytes/s$

4. (textbook Chapter 3, problem 45 and 53) Recall the macroscopic description of TCP throughput. In the period of time from when the connection's rate varies from W/(2 · RTT) to W/RTT, only one packet is lost (at the very end of the period).

4.1 Show that the loss rate (fraction of packets lost) is equal to

$$L = \text{loss rate} = \frac{1}{\frac{3}{8}W^2 + \frac{3}{4}W}$$

Loss Rate = $\frac{\#packets\ lost}{\#packets\ sent} = \frac{1}{\sum_{w/2}^{w} x} = \frac{1}{\frac{3}{8}w^2+\frac{3}{4}w}$

4.2 Use the result above to show that if a connection has loss rate L, then its average rate is approximately given by

$$\approx \frac{1.22 \cdot MSS}{RTT\sqrt{L}}$$

$$L = \frac{1}{\frac{3}{8}w^2+\frac{3}{4}w} = \frac{1}{\frac{3}{8}w(w+2)}$$

$$w^2 + 2w = \frac{8}{3L}$$

Hence, $W \approx \frac{8}{3\sqrt{L}}$

Avg rate = $\frac{3}{4}\frac{w}{RTT} = \frac{3}{4}\frac{8}{3\sqrt{L}} = \frac{1.22MSS}{RTT\sqrt{L}}$

4.3 Let's assume 1500-byte packets and a 100 ms round-trip time. If TCP needed to support a 1Gbps connection, what would the tolerable loss rate be? How about 100Gbps?

For 1 Gpbs,

1 Gbps = $\frac{1.22(1500\times8)}{100\times10^{-3}\sqrt{L}}$

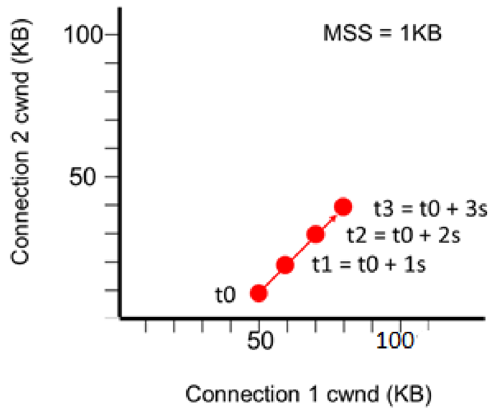
L = $\left(\frac{146400}{1\times10^{9}}\right)^{2}$ = 2.14×10^{-8}

For 10 Gbps,

10 Gbps = $\frac{1.22(1500\times8)}{100\times10^{-3}\sqrt{L}}$

L = $\left(\frac{146400}{10\times10^{9}}\right)^{2} = 2.14\times10^{-10}$

5. (2020 midterm exam question) Consider two TCP Reno connections that share one link. The figure bellow shows the evolution of the size of their respective congestion window (cwnd) over time. As shown, at time t0, connection 1's cwnd = 50KB and connection 2's cwnd=10KB. At time t1=t0+1s, connection 1's cwnd = 60KB and connection 2's cwnd=20KB. At time t2=t0+2s, connection 1's cwnd = 70KB and connection 2's cwnd=30KB. At time t3=t0+3s, connection 1's cwnd = 80KB and connection 2's cwnd=40KB. Assume the maximum segment size (MSS) for both connections is 1KB and both connections have constant round-trip time (RTT). We further assume that when the sum of the cwnd of the two connections reaches 120KB, both connections experience a packet loss event as indicated by triple duplicate ACKs. We also assume these are the only moments that the two connections experience packet losses.



5.1 From time t0 to t3, the two connections are in which state of the TCP congestion control? After the packet loss event at t3, what will be the cwnd size of connection 1 and connection 2 respectively?

For TCP Reno, after packet loss event, the cwnd will be cut by half. Connection 1's cwnd would be 40KB and connection 2's cwnd would be 20KB.

5.2 What is the RTT for the two connections respectively? What is the respective average throughput of these two connections from t0 to t3?

RTT for both connections are 1 second.

Connection 1 throughput = $\frac{50+60+70+80}{4}$ = 65 KB/s

Connection 3 throughput = $\frac{10+20+30+40}{4}$ = 25 KB/s

5.3 Assume the two connections run for a long time. What will these two connections' respective average throughput converge to?

They should converge to 3/4W per RTT.

Connection 1 Avg. throughput = $\frac{3}{4} \times 80$ = 60 KB/s

Connection 2 Avg. throughput = $\frac{3}{4} \times 40$ = 30 KB/s

5.4 Assume now connection 1's RTT reduces by 50% and connection 2's RTT remains unchanged. After a long time, what will these two connections' respective average throughput converge to?

The avg throughput of connection 2 remains at 30KB/s. The avg throughput of connection 1 doubles to 120KB/s.

Connection 1 Avg. throughput = $\frac{3}{4} \times \frac{80}{0.5}$ = 120 KB/s