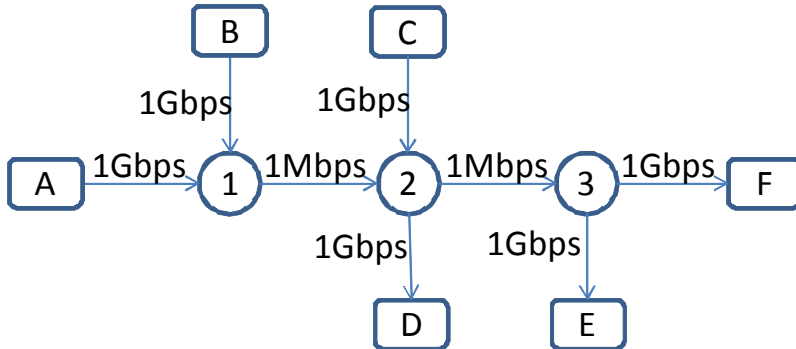


1. Page 285: R4, R6, R14 (note: f is true. Show why it is true), R15, R17
2. Page 288: P15, P26, P27, P29 (syn cookies), P30a, P32, P36, P39 (Now consider Figure 3.46(c). If $\%in$ increases beyond $R/2$, can $\%out$ increase beyond $R/4$ under the assumption that a packet will be forwarded twice on average from the router to the receiver? Explain.), P40 a-i, P41, P43, P45 (see class notes for this problem), P46, P49, P53, P56
3. Draw a detailed timing diagram that shows the beginning of the file transfer (including connection establishment) until $cwnd = 7000B$. By timing diagram, we mean a diagram with two vertical lines showing time going down with one line for the source and one line for the destination. Also, assume the following.
 - The client begins the transfer of a very large file after the connection is established
 - $MSS = 1000B$
 - The initial size of $cwnd = 1000B$
 - $SSThresh = 6000B$
 - Receiver Window = 100000B (and is always available)
 - $RTT = 100ms$
 - Link speed = 1Gbps
4. Suppose that a host sends a TCP packets and each packet has exactly one byte of data. Now suppose that the host sent a packet with sequence number equal to 10. When this packet reaches the destination, the destination generates an ACK. Which of the following ACK numbers might the destination generate. Make a timing diagram for each case.
 - (a) ACK Number = 9
 - (b) ACK Number = 10
 - (c) ACK Number = 11
 - (d) ACK Number = 12
5. We can define the average data rate to be the size of the file transferred divided by the time it takes to transfer the file. Of course, this data rate will depend on the size of the file. Suppose that a client connects to a server and uploads data to the server, where the upload occurs as soon as the connection is established. Also, assume that $MSS=1500B$, the initial window size is 1MSS, the maximum receiver window size is 20KB (and the buffer is always emptied as soon as data arrives), RTT is 100ms, $SSThresh=40KB$, and there is a single 100Mbps link between the source and destination.
 - (a) What is the data rate when transferring a file of size 1500B?
 - (b) What is the data rate when transferring a file of size 15000B?
 - (c) What is the data rate when transferring a file of size 150000B?Don't forget connection establishment. However, the closing of the connection should not be included, since the file transfer is complete before the connection is closed.
6. SYN Attack. How large must be server's memory be to withstand a SYN attack when the following are true?
 - Suppose that the initial value of RTO is 3 sec., and RTO is multiplied by two if a packet loss occurs.
 - Suppose that a TCP server will only resend a SYN-ACK four times if an ACK does not arrive before RTO after the previous SYN-ACK was sent.

- Suppose that the server reserves 100KB of memory when a SYN arrives, and frees the memory after the connection ends, the connection is reset, or the connection fails (e.g., if no response for the SYN-ACK arrives after four retries).
- Finally, suppose that the server is connected via 10 Mbps link and SYN packets are 40B.

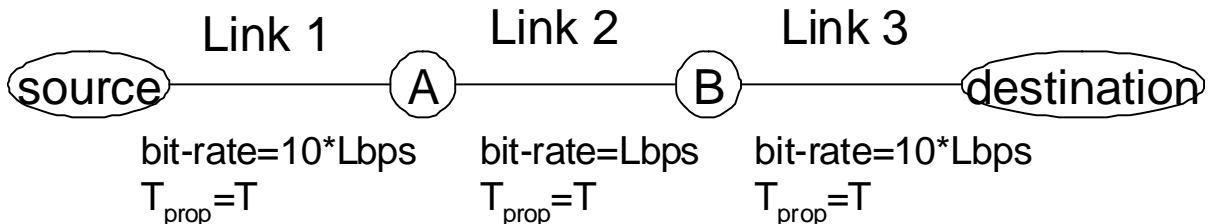
7. Consider the topology below



Suppose that each link as a 100ms propagation delay, queues are equal or greater than the bandwidth delay product, MSS=1000B, and rwnd is always very large.

- Suppose that there is only one flow where host A is the source and host F is the destination. What is the loss probability that router 1? Use the formula that relates lost probability, RTT, and throughput, where we assume that the throughput is the same as the bottleneck link rate.
- Suppose that there are three flows, one from source A to destination F, one with source B and destination D, and one with source C and destination E. Compute the throughput of each flow and the loss probability at each interface (or link). More specifically, compute the loss probability for link 1->2, and 2->3.

8. (optional) Consider the topology below



Suppose that there is a single TCP connection from the source to the destination and that this TCP connection is being used to send an infinite number of bytes to the destination (i.e., the connection never stops).

- (optional)
 - Show that if $cwnd = \text{bandwidth-delay product}$, then there are no packets in any buffer. To do this, account for all packets would be located.
 - Show that if $cwnd = 2 \times \text{bandwidth-delay product}$, then the number of packets in the buffer of the bottleneck link is exactly equal to the bandwidth-delay product.
 - Show that if the size of the queue at in node A for the interface of link 2 is equal to the bandwidth-delay product, then link 2 is fully utilized.
- (optional) Suppose the receiver window is exactly the same size as the bandwidth delay product. And suppose that delayed ACKs is used. A long time after the connection has started (i.e., after the network has stabilized), does the queue in router A ever have packets? Describe the

behavior.(As something to consider: what would happen if the source was a busy machine, and so it could allocate processor time to TCP once every 6T seconds?)

9. Wireshark

- Download the pcap file <http://www.eecis.udel.edu/~bohacek/TCP1.pcap>
- Scroll down to packet number 1700. Right click and select follow TCP stream. the question below are about this TCP connection
- What is the IP address of the host that initiated the connection? What ports are used. What application layer protocol is used?
- This TCP connection is a file download from youtube. Explain the what is happening during the period from 6.269 to 7.89 where 6 packets are exchanged. Explain what each packet exchange is accomplishing.
- Estimate the throughput. To do this, select a packet where the source is 74.125.167.21 and the destination is 128.4.35.56. From the menu, select Statistics -> TCP Stream Graph -> Time Sequence Graph (Stevens). Note that two windows open. One window is a dialog box. In that window select the "Origin" tab and select the "beginning of capture" option (DO NOT SKIP SETTING Origin. IF YOU DO, THEN YOUR ANSWER BELOW WILL NOT MAKE SENSE). Now, from the plot in the other window, estimate the throughput from 8 seconds to 16 seconds (throughput is the total data sent divided by the time to send the data).
- What is the value of TCP's congestion window at time 11.735, 11.77, 11.81, 11.84, 11.88? What phase of TCP congestion control is TCP in?
- What is the value of RTT around 11.77?
- How many packets do you think were sent at time 8.62?
- How many packets do you think were sent at time 8.65?
- How many packets were sent at time 8.70?
- Explain what happened at time 8.62 and 8.65 and what happened to the congestion window.