Homework 1: Transport Layer

1. [5 points] True or false?
    a. Host A is sending Host B a large file over a TCP connection. Assume Host B has no data to send Host A. Host B will not send acknowledgments to Host A because Host B cannot piggyback the acknowledgments on data.
    b. The size of the TCP `rwnd` never changes throughout the duration of the connection.
    c. Suppose Host A is sending Host B a large file over a TCP connection. The number of unacknowledged bytes that A sends cannot exceed the size of the receive buffer.
    d. Suppose Host A is sending a large file to Host B over a TCP connection. If the sequence number for a segment of this connection is m, then the sequence number for the subsequent segment will necessarily be m + 1.
    e. Suppose Host A sends one segment with sequence number 38 and 4 bytes of data over a TCP connection to Host B. In this same segment, the acknowledgment number is necessarily 42.

2. [4 points] Answer true or false to the following questions and briefly justify your answer:
    a. With the SR protocol, it is possible for the sender to receive an ACK for a packet that falls outside of its current window.
    b. The alternating-bit protocol is the same as the GBN protocol with a sender and receiver window size of 1.

3. [2 points] A sender sends a series of packets to the same destination using 5- bit sequence numbers. If the sequence numbers start with 0, what is the sequence number of the 110th packet?

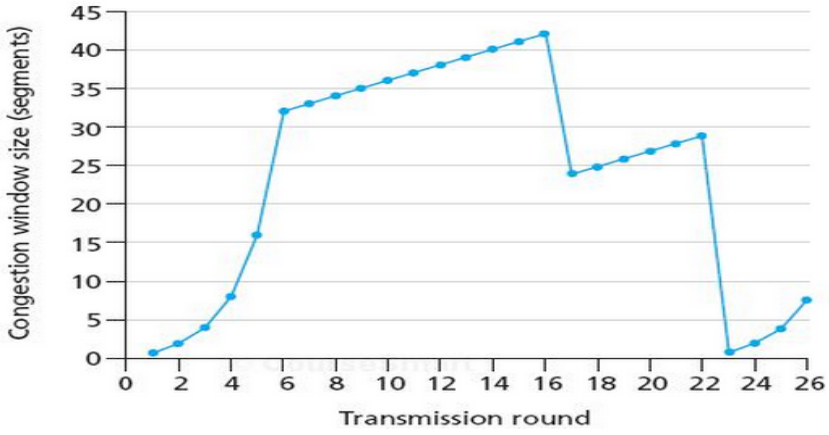
4. [3 points] Using 5- bit sequence numbers, what is the maximum size of the send and receive windows for each of the following protocols?
    a. Stop- and-Wait
    b. Go- Back- N
    c. Selective- Repeat

5. [6 points] Consider that only a single TCP (Reno) connection uses one 10Mbps link which does not buffer any data. Suppose that this link is the only congested link between the sending and receiving hosts. Assume that the TCP sender has a huge file to send to the receiver, and the receiver's receive buffer is much larger than the congestion window. We also make the following assumptions: each TCP segment size is 1,500 bytes; the two-way propagation delay of this connection is 150 msec; and this TCP connection is always in congestion avoidance phase, that is, ignore slow start.
    a. What is the maximum window size (in segments) that this TCP connection can achieve?
    b. What is the average window size (in segments) and average throughput (in bps) of this TCP connection?
    c. How long would it take for this TCP connection to reach its maximum window again after recovering from a packet loss?

6. [4 points] Recall the macroscopic description of TCP throughput. In the period of time from when the connection's rate varies from $\frac{W}{2\times RTT}$ to $\frac{W}{RTT}$, only one packet is lost (the very end of the period). Show that the loss rate, L, (fraction of packets lost) is equal to

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

7. [6 points] Assuming TCP Reno is the protocol experiencing the behavior shown above, answer the following questions. In all cases, you should provide a short discussion justifying your answer.



TCP window size as a function of time

a. Identify the intervals of time when TCP congestion avoidance is operating.
b. What is the value of ssthresh at the 18th transmission round?
c. What is the value of ssthresh at the 24th transmission round?
d. During what transmission round is the 70th segment sent?
e. Assuming a packet loss is detected after the 26th round by the receipt of a triple duplicate ACK, what will be the values of the congestion window size and of ssthresh?
f. Suppose TCP Tahoe is used (instead of TCP Reno), and there is a timeout event at 22nd round. How many packets have been sent out from 17th round till 22nd round, inclusive?