ECE/CS 372–Introduction to Computer Networks

Assignment # 2

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(Textbook Version 7)

1. **(P22, Page294)**
Consider the GBN protocol with a sender window size of 4 and a sequence number range of 1,024. Suppose that at time t, the next in-order packet that the receiver is expecting has a sequence number of k. Assume that the medium does not reorder messages. Answer the following questions:

   (a) What are the possible sets of sequence numbers inside the senders window at time t? Justify your answer.

   (b) What are all possible values of the ACK field in all possible messages currently propagating back to the sender at time t? Justify your answer.

2. **(P27, Page294)**
Host A and B are communicating over a TCP connection, and Host B has already received from A all bytes up through byte 126. Suppose Host A then sends two segments to Host B back-to-back. The first and second segments contain 80 and 40 bytes of data, respectively. In the first segment, the sequence number is 127, the source port number is 302, and the destination port number is 80. Host B sends an acknowledgment whenever it receives a segment from Host A.

   (a) In the second segment sent from Host A to B, what are the sequence number, source port number, and destination port number?

   (b) If the first segment arrives before the second segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number, the source port number, and the destination port number?

   (c) If the second segment arrives before the first segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number?

   (d) Suppose the two segments sent by A arrive in order at B. The first acknowledgment is lost and the second acknowledgment arrives after the first timeout interval. Draw a timing diagram, showing these segments and all other segments and acknowledgments sent. (Assume there is no additional packet loss.) For each segment in your figure, provide the sequence number and the number of bytes of data; for each acknowledgment that you add, provide the acknowledgment number.

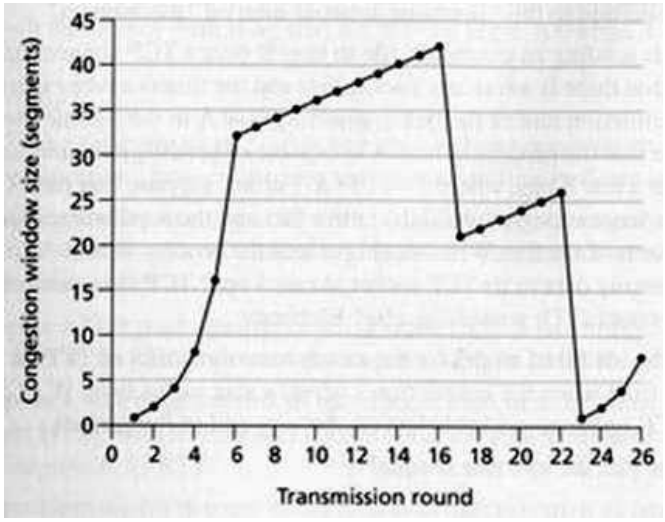
3. **(P32, Page296)**
Consider the TCP procedure for estimating RTT. Suppose that $\alpha = 0.1$. Let $\texttt{SampleRTT}_1$ be the most recent sample RTT, let $\texttt{SampleRTT}_2$ be the next most recent sample RTT, and so on.

   (a) For a given TCP connection, suppose four acknowledgments have been returned with corresponding sample RTTs: $\texttt{SampleRTT}_4$, $\texttt{SampleRTT}_3$, $\texttt{SampleRTT}_2$, and $\texttt{SampleRTT}_1$. Express `EstimatedRTT` in terms of the four sample RTTs.

   (b) Generalize your formula for n sample RTTs.

(c) For the formula in part (b) let n approach infinity. Comment on why this averaging procedure is called an exponential moving average.

4. **(P40, Page297)**
Consider the following figure. Assuming TCP Reno is the protocol experiencing the behavior shown in the figure, answer the following questions. In all cases, you should provide a short discussion justifying your answer.



(a) Identify the intervals of time when TCP slow start is operating.

(b) Identify the intervals of time when TCP congestion avoidance is operating.

(c) After the 16th transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?

(d) After the 22nd transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?

(e) What is the initial value of ssthresh at the first transmission round?

(f) What is the value of ssthresh at the 18th transmission round?

(g) What is the value of ssthresh at the 24th transmission round?

(h) During what transmission round is the 70th segment sent?

(i) 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 ?

(j) Suppose TCP Tahoe is used (instead of TCP Reno), and assume that triple duplicate ACKs are received at the 16th round. What are the ssthresh and the congestion window size at the 19th round?

(k) Again suppose TCP Tahoe is used, and there is a timeout event at 22nd round. How many packets have been sent out from 17th round till 22nd round, inclusive?

5. **(P44, Page298) (BONUS)**
Consider sending a large file from a host to another over a TCP connection that has no loss.

(a) 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)?

(b) What is the average throughout (in terms of MSS and RTT) for this connection up through time=6 RTT?

6. **(P45, Page299) (BONUS)**
Recall the macroscopic description of TCP throughput. In the period of time from when the connections rate varies from W/(2 RTT) to W/RTT, only one packet is lost (at the very end of the period).

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

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

   (b) Use the result above to show that if a connection has loss rate L, then its average rate is approximately given by $\approx \frac{1.22 \cdot MSS}{RTT\sqrt{L}}$. Hint: For large W, $\frac{3}{8}W^2 >> \frac{3}{4}W$, meaning that $\frac{3}{8}W^2 + \frac{3}{4}W \approx \frac{3}{8}W^2$.

7. **(P46, Page299)**
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 receivers 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?