Problem 1

Answer True or False to the following questions and briefly justify your answer:

(a) With the Selective Repeat protocol, it is possible for the sender to receive an ACK for a packet that falls outside of its current window.

(b) With Go-Back-N, it is possible for the sender to receive an ACK for a packet that falls outside of its current window.

(c) The Stop-and-Wait protocol is the same as the SR protocol with a sender and receiver window size of 1.

(d) Selective Repeat can buffer out-of-order delivered packets, while GBN cannot. Therefore, SR saves network communication cost (by transmitting less) at the cost of additional memory.

Write your solution to Problem 1 in this box

a) True. If the timeout timer is shorter than the RTT or the packet was somehow delayed, then the sender will send the packet again. But, the original packet was not lost, so the sender will receive the first ACK for that packet. Then the window will shift. Then, the sender receives the second ACK for the same packet that was retransmitted.

b) True. If a packet was lost, and the receiver receives out of order packets, the receiver will drop those packets and send an ACK for the last ACK'd packet.
At this point, the window will have already slid past this point, so the ACK received by the send would not be in the sender's window.

c) True. While the SR protocol transmits multiple packets, up to the number of packets in its window size, the Stop-And-Wait Protocol transmits only one packet at a time. Thus, it will behave the same way as if the SR protocol had a window size of 1.

d) True. SR buffers out of order packets and thus the buffer will take up memory space. The sender only has to retransmit lost packets. On the other have, GBN does not buffer out of order packets, but instead it throws them away. While GBN does not take up memory space to save these packets, it requires the sender to retransmit packets that the receiver may have already received.

Problem 2

Host A and B are communicating over a TCP connection, and Host B has already received from A all bytes up through byte 326. 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 327, the source port number is 40200, and the destination port number is 80. Host B sends an acknowledgment whenever it receives a segment from Host A. Fill in the blanks for questions (a) – (c) directly; work out the diagram in the box for question (d).

(a) In the second segment sent from Host A to B, the sequence number is ______, source port number is ______, and destination port number is ______.

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

(c) If the second segment arrives before the first segment, in the acknowledgment of the first arriving segment, the ACK number is ______.

(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 in the box below, showing these segments and all other segments and acknowledgment sent. Assume no additional packet loss. For each segment in your diagram, provide the sequence number and the number of bytes of data; for each acknowledgment that you add, provide the ACK number.

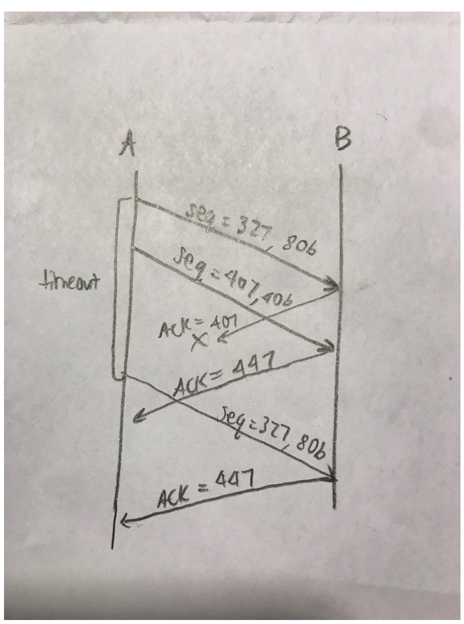
Write your solution to Problem 2 in this box

a) 407, 40200, 80

b) 407, 80, 40200

c) 327

d)



Problem 3

One of the three functions of a sliding window scheme is the orderly delivery of packets which arrive out of sequence. In Go-back-N, the receiver drops packets which arrives out of order. Assume the receiver sends an ACK for every packet it receives.

(a) What is the required buffer size (receiver's window size, RWS) at the receiver if sender's window size (SWS) = 23?

(b) In sliding window with SWS = RWS = 4, the minimum required `SeqNumSize` (the number of available sequence numbers) is 8. Calculate the minimum required `SeqNumSize` for

- (i) a sliding window scheme with SWS = 4 and RWS = 2
- (ii) a Go-back-N scheme with SWS = 4

Write your solution to Problem 3 in this box

a) In the Go-back-N protocol, there is no need for a buffer. It only accepts the packet of next in-order sequence number. In the Selective-Repeat protocol, the receiver would require a buffer size of 23, the same as the window size.

b)
i) SeqNumSize = 8
ii) SeqNumSize = 5

Problem 4

Suppose that three measured SampleRTT values are 106 ms, 120 ms, and 140 ms. Compute the EstimatedRTT after each of these SampleRTT values is obtained, assuming that the value of EstimatedRTT was 100 ms just before the first of these three samples were obtained. Compute also the DevRTT after each sample is obtained, assuming the value of DevRTT was 5 ms just before the first of these three samples was obtained. Last, compute the TCP TimeoutInterval after each of these samples is obtained.

Write your solution to Problem 4 in this box

After Sample RTT of 106ms:
Estimated RTT = (1 - alpha) * Previous Estimated RTT + alpha * SampleRTT
= (1 - 0.125) * 100 + 0.125 * 106
= 100.75ms

DevRTT = (1 - beta) * Previous Dev RTT + beta * abs(Sample RTT - Estimated RTT)
= (1 - 0.25) * 5 + 0.25 * 5.25
= 5.0625ms

Timeout Interval = Estimated RTT + 4 * Dev RTT
= 121ms

After Sample RTT of 120ms:
Estimated RTT = (1 - 0.125) * 100.75 + 0.125 * 120
= 103.156ms

Dev RTT = (1 - 0.25) * 5.0625 + 0.25 * 16.84375
= 8.0078ms

Timeout Internval
= 135.1872ms

After Sample RTT of 140ms:
Estimated RTT = (1 - 0.125) * 103.156 + 0.125 * 140
= 107.7615ms

Dev RTT = (1 - 0.25) * 8.0078 + 0.25 * 32.2385
= 14.0655ms

Timeout Interval
= 164.0234ms

Problem 5

Compare Go-Back-N, Selective Repeat, and TCP (no delayed ACK). Assume that timeout values for all three protocols are sufficiently long, such that 5 consecutive data segments and their corresponding ACKs can be received (if not lost in the channel) by the receiving host (Host B) and the sending host (Host A), respectively. Suppose Host A sends 5 data segments to Host B, and the 2nd segment (sent from A) is lost. In the end, all 5 data segments have been correctly received by Host B.

(a) How many segments has Host A sent in total and how many ACKs has Host B sent in total? What are their sequence numbers? Answer this question for all three protocols.

(b) If the timeout values for all three protocols are much longer than 5RTT, then which protocol successfully delivers all five data segments in shortest time interval?

Write your solution to Problem 5 in this box

a)
For GBN:
-initial transmission: 5 segments sent by A, seqNum 0, 1, 2, 3, 4
-ACK transmission: 4 ACKs sent by B, ACKnum 0, 0, 0, 0 (because 1 is lost)
-retransmission: 4 segments sent by A, seqNum 1, 2, 3, 4
-ACK transmission: 4 ACKs sent by B, ACKnum 1, 2, 3, 4
-Total sent: 9 segments
-Total ACKs: 8 ACKs

For SR:
-initial transmission: 5 segments sent by A, seqNum 0, 1, 2, 3, 4
-ACK transmission: 4 ACKs sent by B, ACKnum 0, 2, 3, 4
-retransmission: 1 segment sent by A, seqNum 1
-ACK transmission: 1 ACK sent by B, ACKnum 1
-Total sent: 6 segments
-Total ACKs: 5 ACKs

For TCP:
-initial transmission: 5 segments sent by A, seqNum 0, 1, 2, 3, 4
-ACK transmission: 4 ACKs sent by B, ACKnum 1, 1, 1, 1 (cumulative ACK)
-retransmission: 1 segment sent by A, seqNum 1
-ACK transmission: 1 ACK sent by B, ACKnum 5
-Total sent: 6 segments
-Total ACKs: 5 ACKs

b) TCP will deliver it fastest because it will not wait for timeout. When there are
3 duplicate ACKs, TCP will automatically retransmit the packet. Furthermore,
it only retransmits the missing packet, unlike in GBN.