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.

(a) True. It could happen if premature timeout is triggered, so that the sender resends the packets, and then receives the ACKs for the original packets. Thus, it would move on to another window; however, the ACKs for duplicated packets will be outside of its current window.

(b) True. By essentially the same scenario as in (a).

(c) True. With a window size of 1, SR, GBN, and the alternating bit protocol are functionally equivalent.

(d) True. Reason same as (c).

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 ______.

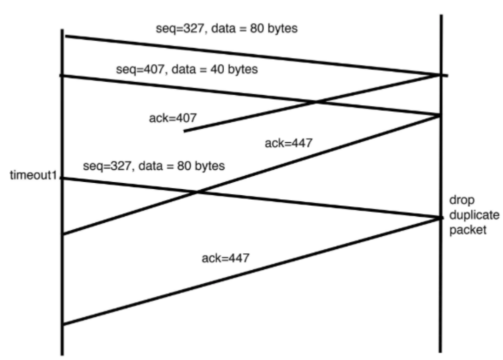
(d) Suppose the two segments sent by A arrive in order at B. The first acknowledgment is lost and the second acknowledgment arrives after the first timeout interval. Draw a timing diagram in the box below, showing these segments and all other segments and acknowledgment sent. Assume no additional packet 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.

(a) In the second segment from Host A to B, the sequence number is 407, source port number is 40002 and destination port number is 80.

(b) If the first segment arrives before the second, in the acknowledgment of the first arriving segment, the ACK number is 407, the source port number is 80 and the destination port number is 40002.

(c) If the second segment arrives before the first segment, in the acknowledgment of the first arriving segment, the ACK number is 327, indicating that it is still waiting for bytes 327 and onwards.

(d) **Note**: it is also fine to assume the second ACK arrives after second timeout (since two segments shall be sent back-to-back and transmission delay is small here.) Then the TCP would retransmit segment 1 and 2 together.



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

(a) For Go-Back-N, RWS = 1. For selective repeat and TCP, RWS = 23. In general the RWS should be ¡= SWS to avoid waste of memory. (**Note**: it is fine to just assume we are using Go-Back-N and answer with 1.)
(b) the minimum required sequence size for a sliding window is (SWS + RWS). If SWS=N and RWS=M, consider the following worst-case scenario: The sender sends N packets. All are received in order at the receiver, but all of its ACKs are corrupted. The receiver is expecting packets from (N+1) to (N+M). After time-out, the sender repeats the same packets, but the receiver is expecting new ones. For RWS=M, the confusion is avoided if the (minimum) total number of SeqNum is (N+M).
i) 6 ii) 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.

$$\text{EstimatedRTT} = \alpha\text{SampleRTT} + (1-\alpha)\text{EstimatedRTT}$$

$$\text{DevRTT} = \beta\text{SampleRTT} - \text{EstimatedRTT} + (1-\beta)\text{DevRTT}$$

$$\text{TimeoutInterval} = \text{EstimatedRTT} + 4\text{DevRTT}$$

(a) After obtaining first sampleRTT = 106 ms:

$$\text{EstimatedRTT} = 0.125 \times 106 + 0.875 \times 100 = 100.75 \text{ ms},$$

$$\text{DevRTT} = 0.25 \times 106 - 100.75 + 0.75 \times 5 = 5.06 \text{ ms},$$

$$\text{TimeoutInterval} = 100.75 + 4 \times 5.06 = 120.99 \text{ ms};$$

(b) After obtaining second sampleRTT = 120 ms:

$$\text{EstimatedRTT} = 0.125 \times 120 + 0.875 \times 100.75 = 103.15 \text{ ms},$$

$$\text{DevRTT} = 0.25 \times 120 - 103.15 + 0.75 \times 5.06 = 8 \text{ ms},$$

$$\text{TimeoutInterval} = 103.15 + 4 \times 8 = 135.15 \text{ ms};$$

(c) After obtaining third sampleRTT = 140 ms:

$$\text{EstimatedRTT} = 0.125 \times 140 + 0.875 \times 103.15 = 107.76 \text{ ms},$$

$$\text{DevRTT} = 0.25 \times 140 - 107.76 + 0.75 \times 8 = 14.06 \text{ ms},$$

$$\text{TimeoutInterval} = 107.76 + 4 \times 14.06 = 164 \text{ ms}.$$

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?

(a) Go-Back-N:

- A sends 9 segments in total. They are initially sent segments 1, 2, 3, 4, 5 and later re-sent segments 2, 3, 4, and 5.
- B sends 8 ACKs. They are 4 ACKS with sequence number 1, and 4 ACKs with sequence numbers 2, 3, 4, and 5.

Selective Repeat:

- A sends 6 segments in total. They are initially sent segments 1, 2, 3, 4, 5 and later re-sent segments 2.
- B sends 5 ACKs. They are 4 ACKS with sequence number 1, 3, 4, 5. And there is one ACK with sequence number 2.

TCP:

- A sends 6 segments in total. They are initially sent segments 1, 2, 3, 4, 5 and later re-sent segments 2.
- B sends 5 ACKs. They are 4 ACKS with sequence number 2. There is one ACK with sequence numbers 6. Note that TCP always send an ACK with expected sequence number.

(b) TCP. This is because TCP uses fast retransmit without waiting until time out.