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. Suppose the sender sends package 1, get no ACK so the sender triggers timeout, and sends another package 1. After the sender receives the first ACK 1 after the timeout, the sender window will slide out of package 1. Then the second ACK 1 received by the sender is outside of its current window.

(b) True. We can use the same scenario as the one we used in the previous part. Suppose the sender sends package 1, get no ACK so the sender triggers timeout, and sends another package 1. After the sender receives the first ACK 1 after the timeout, the sender window will slide out of package 1. Then the second ACK 1 received by the sender is outside of its current window.

(c) True. When the sender and receiver window size are both 1, the sender will have to wait for one ACK before it can slide. This is exactly the behavior of stop-and wait-protocol.

(d) True. SR saves network communication lost by buffering the packages that arrive out of order. While at the same time it costs additional memory at the receiver side to storage data.

Problem 2

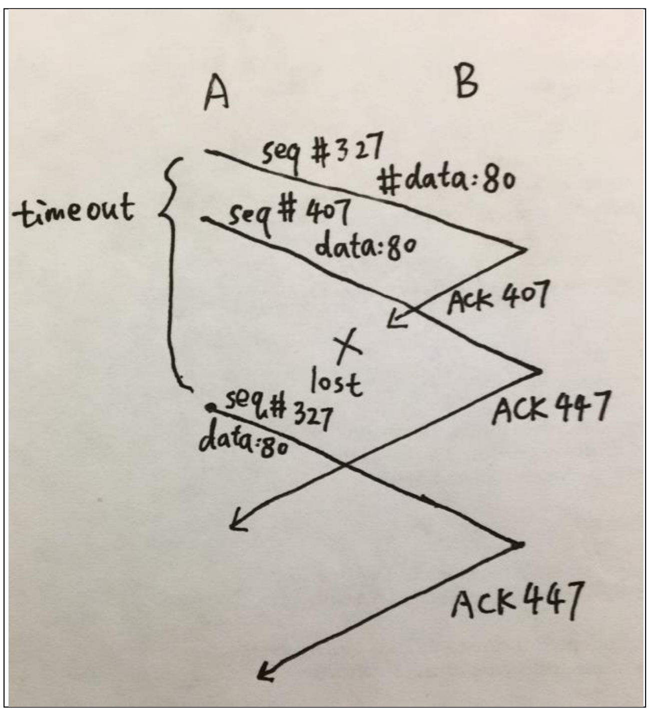
Host A and B are communicating over a TCP connection, and Host B has already received from A all bytes up through byte 326. Suppose Host A then sends two segments to Host B back-to-back. The first and second segments contain 80 and 40 bytes of data, respectively. In the first segment, the sequence number 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_407__, source port number is _40200, and destination port number is_80__.

(b) If the first segment arrives before the second segment, 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_40200_.

(c) If the second segment arrives before the first segment, in the acknowledgment of the first arriving segment, the ACK number is_327__.

(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.



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) If we are using selective repeat, RWS=SWS=23. If we are using Go-back-N, RWS=1. If we are just referring to a general sliding window scheme, RWS can be any number smaller or equal to 23.

(b) (i) the minimum size is 4+2=6. Consider the following two extreme cases. First case: package 1 is delivered to receiver. But ACK 1 from the receiver is lost and did not arrive at sender. So the sender is going resend package 1 again after the timeout. Other packages and ACKs are delivered normally. Second case: the first two packages, (package 1 and package 2) have been delivered and acknowledged. Package 3 and 4 has already been sent out from the sender. Upon receiving ACK 2, the sender is about to send the sixth package. Now if we only have 5 sequence number, the sequence number of the sixth package in the second case will have the same sequence number as the resent package 1 in the first case. And the receiver will not be able to tell the difference. Thus we need at least SeqNum Size to be 6.

(ii) the minimum size is 4+1=5. We only have to take care of wrap around in Go-back-N. Consider the two extreme cases. First case: the first package is sent, but the ACK is lost. Other packages are delivered normally. After timeout, the sender is going to resend the first package. Second case: all packages are sent, and we are about to send the fifth package. Now if we only have 4 sequence number, the sequence number of the first package in the first case will be the same as that of the fifth package in the second case. And the receiver will not be able to tell which is retransmission and which is normal transmission. Thus we need seqNumSize to be at least 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.

After first sample:
EstimatedRTT=0.875*EstimatedRTT+0.125*sampleRTT= 0.875*100+0.125*106= 100.75 ms
DevRTT=0.75*DevRTT+0.25*| sampleRTT-EstimatedRTT| =0.75*5ms+0.25* | 106-100.75|=0.75*5+0.25*5.25= 5.0625 ms
TimeoutInterval=EstimatedRTT+4* DevRTT=100.75+4*5.0625= 121 ms

After second sample:
EstimatedRTT=0.875*EstimatedRTT+0.125*sampleRTT= 0.875*100.75+0.125*120= 103.15625 ms
DevRTT=0.75*DevRTT+0.25*| sampleRTT-EstimatedRTT| =0.75*5.0625 ms+0.25* | 120-103.15625|=0.75*5.0625+0.25*16.84375= 8.0078125 ms
TimeoutInterval=EstimatedRTT+4* DevRTT=103.15625+4*8.0078125= 135.1875 ms

After third sample:
EstimatedRTT=0.875*EstimatedRTT+0.125*sampleRTT= 0.875*103.15625+0.125*140= 107.76171875 ms
DevRTT=0.75*DevRTT+0.25*| sampleRTT-EstimatedRTT| =0.75*8.0078125 ms+0.25* | 140-107.76171875|=14.0654296875 ms
TimeoutInterval=EstimatedRTT+4* DevRTT=107.76171875+4*14.0654296875= 164.0234375 ms

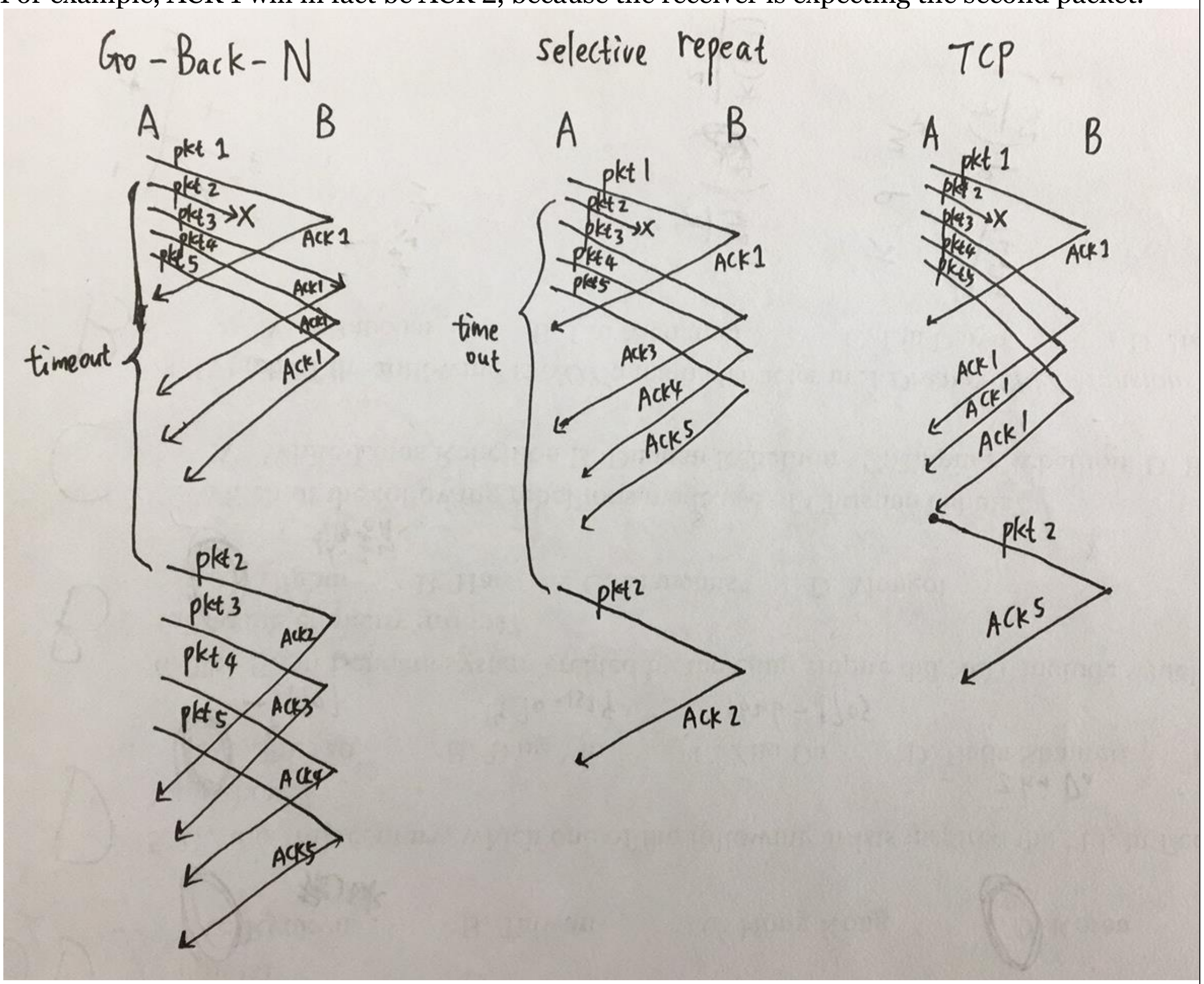
Problem 5

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) Note: based on TA's clarification email. All the ACKs for TCP in the figure below are off by 1. For example, ACK 1 will in fact be ACK 2, because the receiver is expecting the second packet.



As we can see in the picture, for Go-back-N: A send 9 segments, B send 8 segments; for selective repeat, A send 6 segments, B send 5 segments; for TCP: A send 6 segments, B send 5 segments.

(b)As we can see in the picture, both Go-back-N and selective repeat needs at least timeout+1RTT to deliver, while TCP needs less than timeout+1RTT because timeout>5RTT. Thus TCP delivers in shortest time interval.