

CS447 – Networks and Data Communications

Summer 2026

Homework #4 Questions (**SOLUTIONS**)

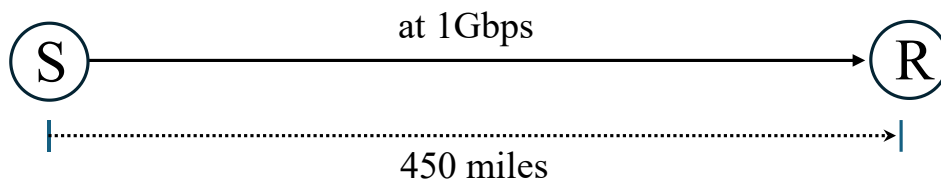
Your last-three-digits: _____

Submission Due: (each student is required to submit (by email as attached file) your solutions for this homework by **11:00AM on July 7**)

QUESTION #1:

Estimate the link-bandwidth utilization for the link (connection) from S to R using stop-and-wait flow-control with the following assumptions:

- The signal transmission rate between A and B (each direction) is 1 Gbps ($G = 10^9$)
- The propagation delay is $3\mu s/mile$ (1 second = 1,000,000 λs)
- All packets are 280-byte long; ACK messages are separate packets of negligible length.
- The link distance is 450 miles
- No error



Show all your work for full credit.

solution:

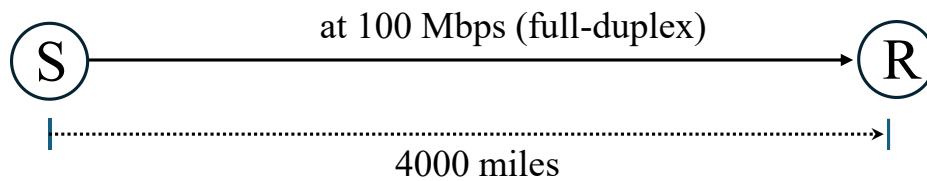
- The signal propagation delay: $450 \text{ miles} \times (3 \lambda s/mile) = 1350 \lambda s$
- The packer (signal) transmission delay: $(1/1Gbps) = 1ns \times (280 \times 8) \text{ bits}$
 $= (1 \text{ ns}) \times 2,240 \text{ bits}$
 $= 2.24 \lambda s$

$$\begin{aligned} U &= (\text{packer transmission delay}) / (2 \times (\text{signal propagation delay}) + (\text{packer transmission delay})) \\ &= (2.24 \lambda s) / ((2 \times 1350 \lambda s) + (2.24 \lambda s)) \\ &= 2.24 / (2700 + 2.24) = 2.24 / 2702.24 = \underline{0.0083 (0.083\%)} \end{aligned}$$

QUESTION #2:

Estimate the open window size to achieve at least 85% of link-bandwidth utilization for the link (connection) from S to R using sliding-window with the following assumptions:

- The signal transmission rate between S and R (each direction) is 100 Mbps ($M = 10^6$)
- The propagation delay is $0.7\mu\text{s}/\text{mile}$ for both lines
- The link (connection) is full-duplex connection
- All packets are 1,000 bits long; ACK messages are separate packets of negligible length.
- The link distance is 4000 *miles*
- No error



Show all your work for full credit.

solution:

- The signal propagation delay: $4000 \text{ miles} / (0.7 \lambda\text{s}/\text{mile}) = 2800 \lambda\text{s}$
- The packer (signal) transmission delay: $(1/100\text{Mbps}) = 0.01\lambda\text{s} \times 1000 \text{ bits} = 10 \lambda\text{s}$

$$U = (\text{window-size}) \times (\text{packer transmission delay}) / (2 \times (\text{signal propagation delay}) + (\text{packer transmission delay}))$$

$$= (w \times 10 \lambda\text{s}) / ((2 \times 2800 \lambda\text{s}) + (10 \lambda\text{s}))$$

$$= (w \times 10) / 5610 \geq 0.85$$

$$w \geq 476.85 \text{ (477.0)}$$

QUESTION #3:

Two host computers (A and B) use a sliding-window flow control with a 4-bit sequence number. Thus, the sequence numbers of 0 through 15 ($= 2^4 - 1$) are used to uniquely identify each packet between A and B. Assume that A is transmitting and B is receiving. Each packet carries a sequence number in the order of their transmissions (the first packet carries “0”) by A. If the sequence number reaches 15, then the next sequence number will be 0. Let us assume that the window size is 8. For the error control, assume GBN-ARQ.

Question: Show the window positions (where the open window starts and ends) for both A and B for each of the situations described by (a) and (b). Please take the descriptions exactly as they do (i.e., if something is not mentioned, please assume that it has not happened yet). Show all your work.

First, A establishes a connection with B. Then:

- (a) A sent frames, 0, 1, 2, 3, and 4 to B. B received 0, 1, 2, and 3 from A. B sent ACK frames for frames 0, 1, 2, and 3. A received ACK 0 and 1.
- (b) After (a), A sent frames 5, 6, 7, 8, 9, and 10 to B. A sent whichever packets A was allowed to send to B at this time. Then frame 7 got an uncorrectable bit error on the fly from A to B (and it was detected by B). B received all the frames A sent to B so far (since the very beginning) except frame 7.

Note: Dr. Fujinoki assumes it is your responsibility to present your solutions in such a way that someone else can understand your ideas in your solutions (i.e., you are expected to present your solutions neatly enough for others to understand your ideas in your solutions). If I (Fujinoki) can not understand your solutions, it is difficult for me to give credit to the solutions.

Solutions:

Since either A or B has not transmitted anything at the beginning, the positions of the open window for A (sender) and B (receiver) are as shown in Figure 1 below (the numbers inside of parenthesis stand for the current open window size).

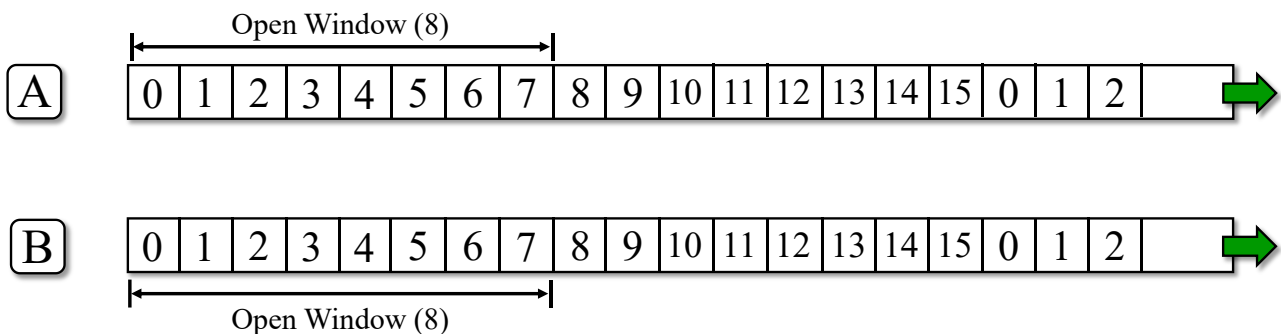


Figure 1: The open windows for the sender (A) and the receiver (B)

Then, A first sends **five** frames (0 through 4). The transmissions of the five packets shifts the LHS of A's window from '0' to '5' (meaning that the next packet A should transmit is '5'), while the RHS of A remains at the same position (i.e., '7'), as shown by Figure 2.

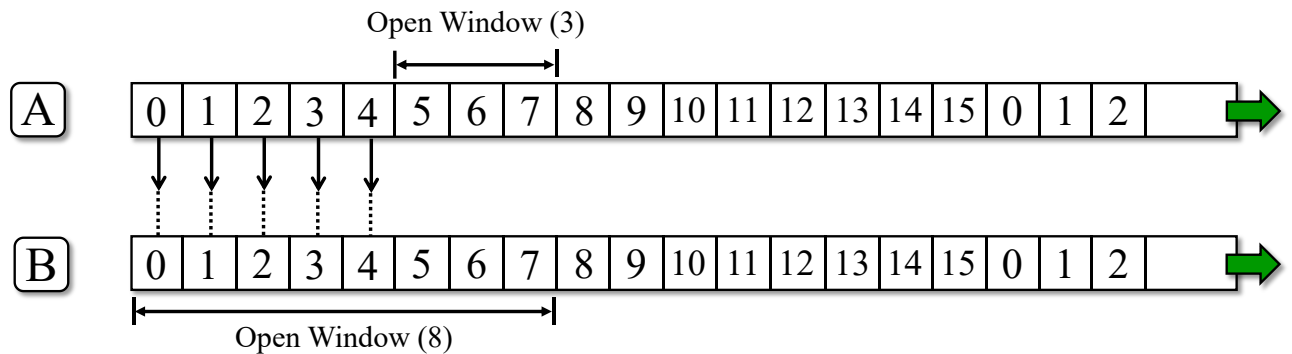


Figure 2: The open windows for A and B, when A sent the first 4, but B has not received any of the four packets transmitted by A.

Later, B receives the first two packet (0 and 1) from A, which lets B to shift the LHS of B's window by two positions to the right (to '2'). Figure 3 shows this.

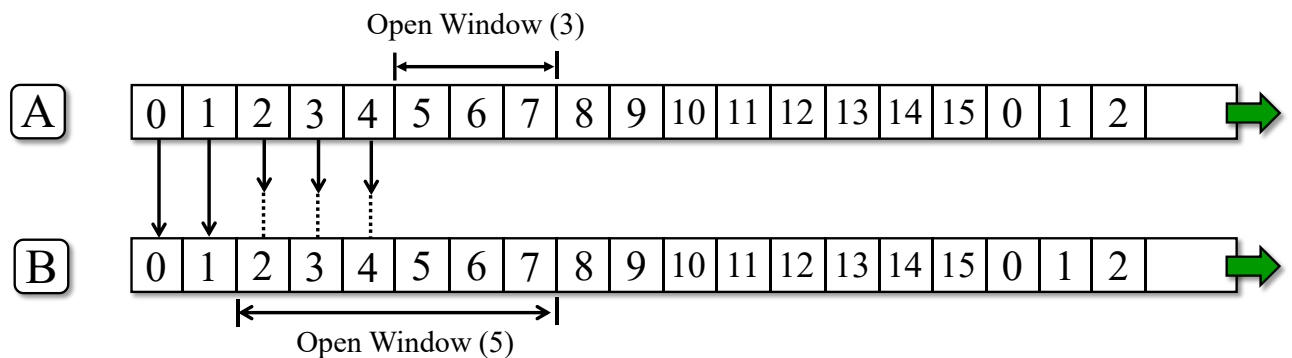


Figure 3:

Then, B transmits the ACK for packets 0, 1, 2, and 3 (this assumes packet 2 and 3 from A have successfully arrived at B – packet 4 from A is still on the fly), which lets B to shift the RHS of its window (to the right) by four positions (from 7 to 11). Note that the two ACKs (from B to A) are still on the fly and A has not received them. Thus, there is no change to A's open window (5-7). Figure 4 shows this.

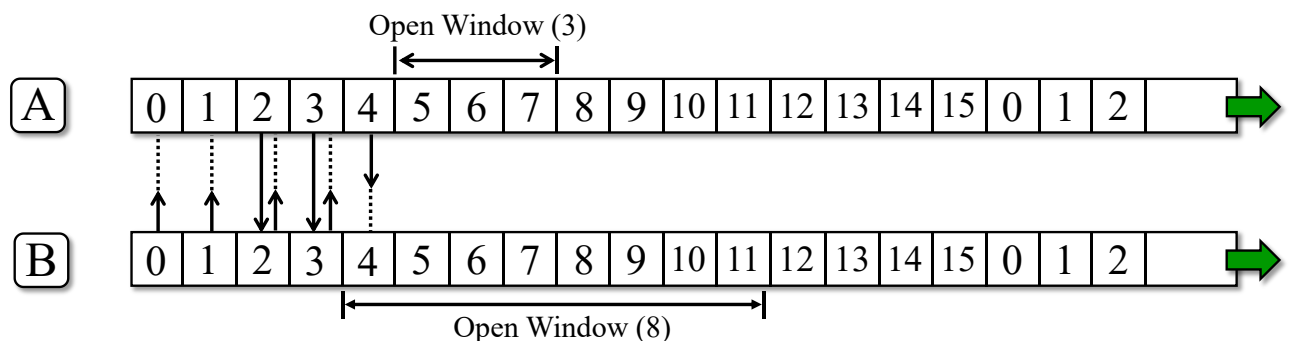


Figure 4:

Then, A receives the two ACKs (for packets 0 and 1) from B. This lets A to shift the RHS of its window to the right by two positions (from 7 to 9). Figure 5 shows this. This is the end of (a).

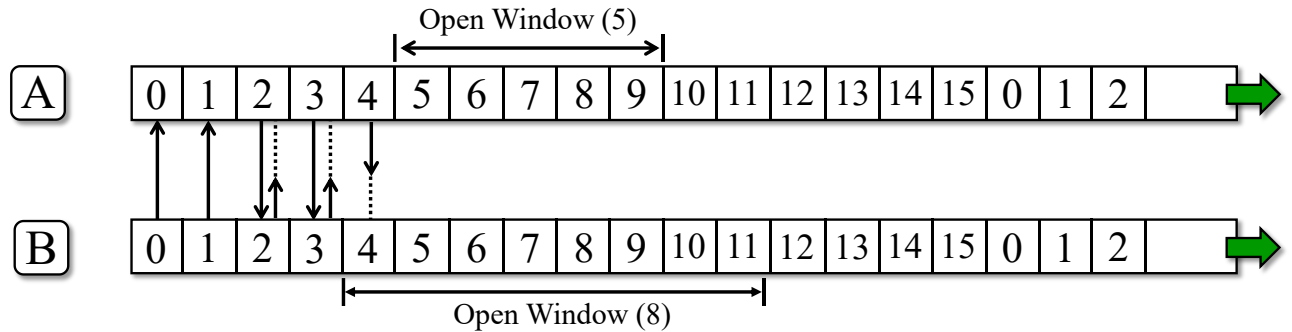


Figure 5:

After (a), as shown by Figure 5, A transmits packets 5, 6, 7, 8, and 9 (because those five packets are currently in the open window at A). This shifts the LHS of A's window to the right by five positions (from 5 to 9). Here, the LHS overlaps the RHS of A's window, meaning that A can no longer transmit any other packet (i.e., A's window size is zero). The seventh packet causes an error on the fly. There is no change to B's open window (since it is assumed that B does not receive any of packets 4, 5, 6, 7, 8, and 9). Figure 6 shows these.

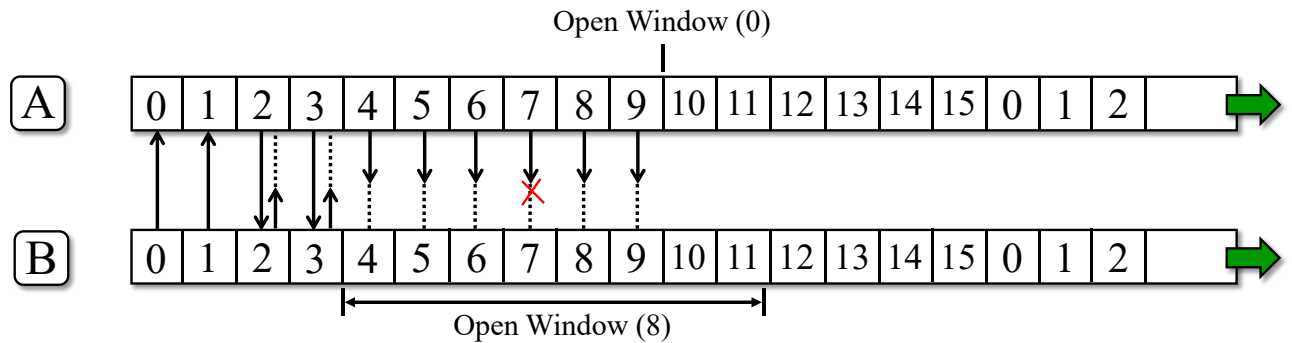


Figure 6:

Then, B receives all the packets (4, 5, 6, 8, and 9) except 7. Since GBN-ARQ ignores any packet after 7, if B successfully receives packets 4, 5, and 6, B shifts its LHS of its window to the left by three positions (from 4 to 7). Figure 7 shows this. This is end of (b).

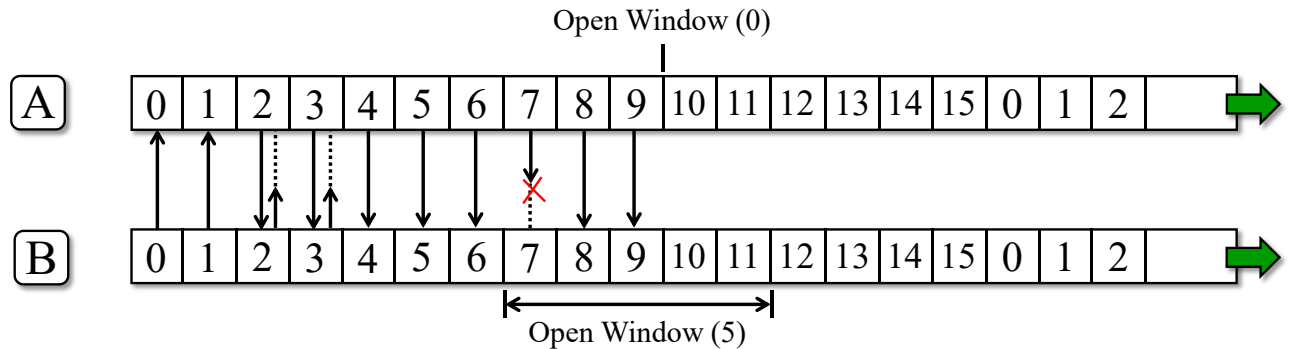


Figure 7: