This exam is a closed-book and closed note exam. There are 5 questions in this exam. You have 75 minutes to finish the questions. Please write your answers on separated piece of papers. To avoid grading problems, please staple your papers in the ascending order in the question number. Calculator can be used during this exam, but you can not share a calculator with anyone else.

Your last 3 digits: ___________________

QUESTION #1 (4 points for each, 15 minutes)

#1: What is “packet encapsulation”? What is it for (i.e., what is the purpose of “packet encapsulation”)?

- The term, “packet encapsulation” means that the whole packet in the above (the next higher) protocol layer becomes the payload for this protocol layer.
- The packet encapsulation is for isolating each protocol layer from other layers.

#2: What are “virtual-circuit packet-switching networks”?

Virtual-circuit-switching networks are a type of switching networks (those networks that do not require a full-mesh network, where each switch relays (or “forwards”) network payload traffic (signals or packets) to its correct destination with the following properties*:

1. **Path set-up is required** before data transmission starts
2. Data will be transferred as a collection of packets
3. All data (as packets) follow exactly the same path (order of bits transmitted by a sender is preserved at a receiver)
4. Network resource can be shared (because data is transferred as packets) but guaranteed.

**Note 1:** the four properties about circuit-switching networks are those we agreed (to be those that should be mentioned for this question) at the end of the CS447 lecture on 8/24.

**Note 2:** if you did not earn the credit for “an example for circuit-switching networks) even if you found that example based on some research you conducted prior to Quiz #2 on 8/29, I suggest you come to see me with the source of the information (example) and the credit for your “example” will be returned to your Quiz #2 grade.

#3: What is the counter concept of “point-to-point”?

“end-to-end”

**Note:** “peer-to-peer” is not the counter concept of “point-to-point”. It is the one for “client and server”.

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#4: What are the primary disadvantages of “selective-reject ARQ” over “GBN-ARQ”?

Using the selective-reject ARQ, a receiving host computer has to keep (buffer) all packets after a packet error is detected until the packet in error is retransmitted. This is a safe design for high-speed network (by reducing the chance of eating up large memory space).

#5: What is the primary advantage of “non-persistent algorithm”? What is the primary disadvantage of “non-persistent algorithm”?

- Good (efficient) for busy networks, because the non-persistence algorithm will effectively avoid collision by randomly delaying each waiting transmitting host when more than one host is waiting for the current transmitter to finish.

- Not good for not busy networks, because the non-persistence algorithm still will let a host to wait for its transmission even if no one else is waiting for the current transmitter to finish. This will cause unnecessary wait for the only waiting host.

QUESTION #2 (20 points, 15 minutes)

Although TCP slow-start is an effective technique for dynamically adjusting the window size under various situations, it can result in long recovery times in high-speed networks.

Assume a round trip-time of 35ms and a link with an available bandwidth of 5 Gbps (1G = 10^9) and a packet size of 180 octets (1 octet = 1 byte = 8 bits). How long will it take to reach the window size that is just large enough for full (= 100%) utilization of this link? Calculate “how long” in the ms (millisecond) order (i.e., “how many milliseconds”).

Assume that no error will happen during the packet transmissions.

Show all your work (most of the credit is for showing a correct procedure to find the solution, instead of the solution itself).
QUESTION #3 (20 points, 10 minutes)

For a network system that consists of four rings and two bridges as shown below, find the probability that any two stations, selected at random, will be unable to communicate.

For this question, you do not have to complete your calculation. Establish a formula to calculate the probability with all necessary numbers in it.

- Each ring consists of 81 tapping repeaters and 81 links (for 80 host computers and 1 connection to a bridge).
- The mean failure rate for a tapping repeater is $P_R$ ($0 < P_R < 1$)
- The mean failure rate for a link is $P_L$ ($0 < P_L < 1$)
- The mean failure rate for a bridge is $P_B$ ($0 < P_B < 1$)
- Wires between a tapping repeater and a bridge will never fail
- Wires between a tapping repeater and a host computer will never fail
- Host computers will never fail
QUESTION #4 (20 points, 15 minutes)

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) cannot understand your solutions, it is difficult for me to give credit to the solutions.

QUESTION #5 (20 points, 15 minutes)

A disadvantage of the contention-based approach for medium access control, such as CSMA/CD, is the capacity wasted due to multiple stations attempting to access the transmission channel (such as an Ethernet cable) at the same time. Suppose that time is divided into discrete slots, where each discrete slot is one full round-trip time from one end of a LAN segment (using a bus-based LAN) to the other end. In each discrete slot, each of $N$ stations attempt to transmit with a probability of $p$ (0.0 ≤ $p$ ≤ 1.0). What fraction of slots will be wasted due to contentions by multiple simultaneous transmission attempts by $N$ stations (assume that ‘$p$’ is fixed – it will never be change)? If the transmission rate of the cable used for this CSMA/CD is $R$ bps, what will be the throughput achievable (ignore all other overhead)?

**Question:** Present a formula that calculates the achievable throughput.

**Note 1:** “Throughput” means the amount of work that is actually achieved (the number of bits that are actually (successfully) transmitted.

**Note 2:** I will try my best to give you partial credit to any meaningful work. However, presenting (or describing) your ideas in such a way that it is easy to follow will increase your partial credit.