UNIVERSITY OF ALBERTA

DEPT. OF ELECTRICAL AND COMPUTER ENGINEERING

ECE 487 B1 – Data Communications Networks

Midterm Examination

Instructor: Hai Jiang
Exam date: Thursday Feb. 13, 2020
Exam duration: 65 minutes (9:40 – 10:45am)

Instructions:

1. Verify that this booklet contains 9 pages (including ARQ summary sheet).
2. Sign on Page 1
3. Place your I.D. card on your table.
4. Neatly enter your answers in the spaces provided.
5. Use the reverse sides of the pages for rough work. Answers written on the reverse sides of the pages will **NOT** be marked.

Last name: ____

First name: ____

Student I.D.: ____

Signature: ____

Question	Worth	Mark
1.	18	
2.	18	
3.	10	
4.	14	
Total	**60**	

GOOD LUCK!!!

1. Network Topology, Switching, and Network Model (**18 points**)

(1) Recall that there are four network topologies: mesh, star, bus, and ring topology. Consider a WiFi network in which multiple computers are supported by a wireless router. Which topology is used in this network? Does the topology provide privacy? (**2 points**)

Star topology. It provides privacy.

(2) When you use your cell phone to call one of your friends, which switching mode (circuit switching or packet switching) is used? Is there potential waste of resources in your talking with your friend? If your answer is "yes", when does the waste happen? If your answer is "no", please explain why there is no potential waste. (**2 points**)

Circuit switching. There is waste when only one person is talking and the other person is listening.

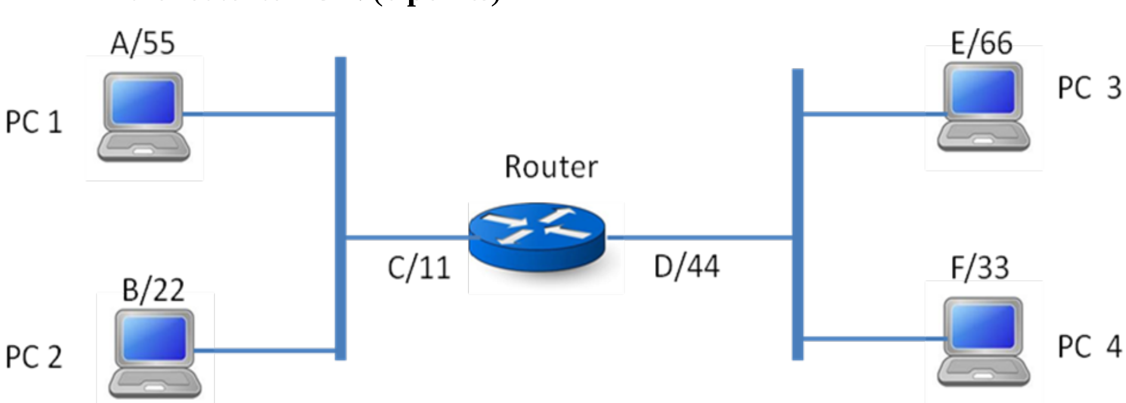
(3) Match the following to one or multiple layers of the Open Systems Interconnection (OSI) model. In your answer, please give names of the layers. For example, for Layer 1, you should answer "physical layer." (**3 points**)

	Name(s) of the layer(s)
Reliable process-to-process message delivery	Transport layer
Interface to transmission medium	Physical layer
log-in and log-out procedure	Session layer

(4) In the following figure, four PCs (with indices 1, 2, 3, and 4) are connected through two bus-topology local area networks (LANs). The address configuration is also shown in the figure, where a capital-case letter means an IP address and a number means a physical address. Any data frame in the network has the following format:

Layer 2 header	Layer 3 header	Layer 4 header	Layer 4 data	Layer 2 trailer

Assume a process with port address 't' on PC 1 sends a message to a process with port address 'h' on PC 4. In the following table, please indicate the source & destination addresses used by the Layer 2, 3, and 4 headers in the data frame from PC 1 to the router and the data frame from the router to PC 4. (**6 points**)



Question 1 (continued)

	Data frame from PC 1 to the router		Data frame from the router to PC 4	
	Source address	Destination address	Source address	Destination address
Layer 2 header	55	11	44	33
Layer 3 header	A	F	A	F
Layer 4 header	t	h	t	h

(5) In TCP (Transmission Control Protocol)/IP (Internet Protocol), we know that IP addresses are used in routing. Why not use physical addresses in routing? (**2 points**)

Physical addresses are NOT universal (different layer-2 protocols may have different physical address format)

(6) Among the four network topologies (mesh, star, bus, and ring topologies), we know that a token-passing access method can be applied in three network topologies. Please indicate the other topology's name. Please also explain your answer. (**3 points**)

Mesh topology does not use token-passing access method. In mesh topology, each station has a dedicated link to any other station. There is no shared link. Thus, mesh topology does not need the token-passing access method.

2. Error Detection and Correction (**18 points**)

(1) Consider the encoder and decoder for a Hamming code. Denote the 4-bit dataword at the sender as $a_3a_2a_1a_0$, and the 7-bit codeword at the sender as $a_3a_2a_1a_0r_2r_1r_0$. The three parity check bits are given as follows:

$r_2 = a_2 + a_1 + a_0$ modulo-2 (so r_2 is parity check for a_2, a_1, and a_0)

$r_1 = a_3 + a_1 + a_0$ modulo-2 (so r_1 is parity check for a_3, a_1, and a_0)

$r_0 = a_3 + a_2 + a_1$ modulo-2 (so r_0 is parity check for a_3, a_2, and a_1)

The received codeword at the receiver is denoted as $b_3b_2b_1b_0q_2q_1q_0$.

(a) How does the receiver calculate the three syndrome bits? (**2 points**)

$S_2 = b_2 + b_1 + b_0 + q_2$ modulo-2

$S_1 = b_3 + b_1 + b_0 + q_1$ modulo-2

$S_0 = b_3 + b_2 + b_1 + q_0$ modulo-2

Question 2 (continued)

(b) The receiver assumes there is at most one bit error in the received codeword. The three-bit syndrome creates eight different bit patterns ("000" to "111"). For each bit pattern, please indicate which bit (among the seven bits in the received codeword) the receiver considers corrupted. (**4 points**)

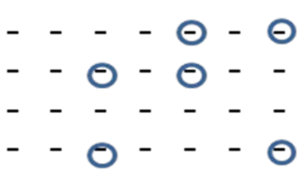
Syndrome $S_2S_1S_0$	000	001	010	011	100	101	110	111
Corrupted bit	none	q_0	q_1	b_3	q_2	b_2	b_0	b_1

(c) Consider the above Hamming code. For transmission of the 7-bit codeword $a_3a_2a_1a_0r_2r_1r_0$, define 7-bit error pattern as follows: for each bit in the error pattern, if the bit is '0', it means that the corresponding bit in the codeword is correctly received; if the bit in the error pattern is '1', it means that the corresponding bit in the codeword is corrupted. For example, if the 7-bit error pattern is 1000010, it means that bits a_3 and r_1 are corrupted, while other bits are correctly received. We have totally 2^7=128 error patterns (from 0000000 to 1111111). All the error patterns except 0000000 are for cases with bit error(s). Among those 127 error patterns for cases with bit error(s), how many error patterns **cannot** be detected by the receiver? Please explain how you get your answer. (**4 points**)

If an error pattern is in the form of a valid codeword, the error pattern cannot be detected.

We have 2^4=16 valid codewords. Note that '0000000' is also a valid codeword. Thus, 15 error patterns cannot be detected.

(2) Give an example for the case that a two-dimensional parity-check code **cannot** detect six bit errors. (**2 points**)



Question 2 (Continued)

(3) Consider the encoder for a Cyclic Redundancy Check (CRC) code. The divisor at the sender and receiver is $d_3d_2d_1d_0$=1011. Please give the codeword for dataword '1101'. Show your steps. (**4 points**)

Division of 1101000 by 1011: the remainder is 001.

So the codeword is: 1101001

(4) Recall that we may use a checksum method for error detection. If we want to add a checksum for five numbers (7, 11, 12, 0, 6), what should the checksum be? (**2 points**)

Checksum = - (7 + 11 + 12 + 0 + 6) = -36

3. Data Link Control (**10 points**)

(1) Consider that a communication system uses an automatic repeat request (ARQ) protocol. The distance between the sender and receiver is 3,000,000 meters, and the propagation speed is 3×10^8 meters per second. We only consider propagation delay and ignore all other delay (and therefore, the transmission time of a frame can be infinitely small). The time-out value of a timer is 1 second. At the sender side, there are an infinite number of packets in Layer 3 to be sent. The size of a data frame is 1000 bits.

(a) Assume stop-and-wait ARQ is used and no frame is corrupted. What is the throughput of the system? Here throughput means for a long duration (for example, a day), on average how many bits of information per second can be delivered successfully from the sender to the receiver. (**2 points**)

(b) Assume stop-and-wait ARQ is used. The channel from the sender to the receiver is noisy in such a manner that for each particular data frame, its first transmission attempt is always corrupted, while its subsequent transmission attempts are always successful. The channel from the receiver to the sender is noisy in such a manner that, for each particular data frame, its first ACK is always corrupted, while its second ACK is always successfully received by the sender. Then what is the throughput of the system? (**3 points**)

(c) Assume Selective Repeat ARQ with m=3 bits for the sequence number is used. The channel from the sender to the receiver is noisy in such a manner that for each particular data frame, its first transmission attempt is always corrupted, while its subsequent transmission attempts are always successful. The channel from the receiver to the sender is noiseless. What is the throughput of the system? (**3 points**)

Question 3 (Continued)

One-way propagation time = $3 \times 10^6 / 3 \times 10^8$ = 0.01 second. Round-trip propagation time is 0.02 second.

(a) 1 successful frame per round-trip propagation time. So throughput is:

1000 bits / 0.02 second = 50,000 bits/second

(b) 1 successful frame per (2 time-out + round-trip propagation time). So throughput is:

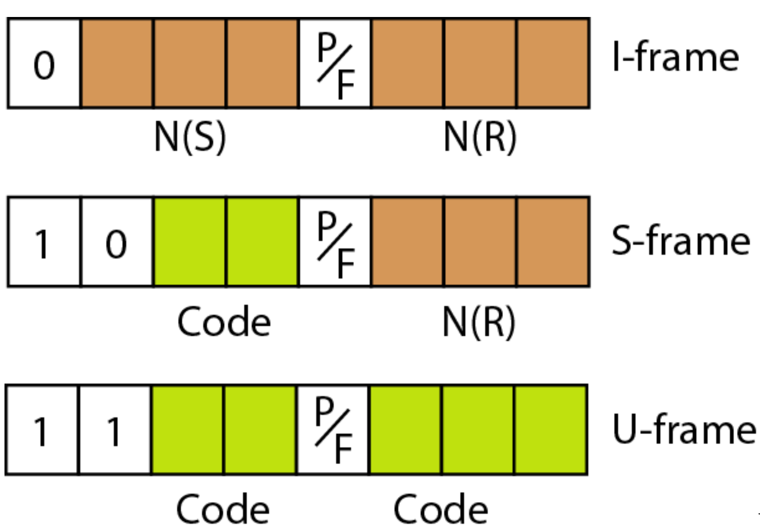
1000 bits / (2 + 0.02) second = 495 bits/second

(c) Send window size is 2^{3-1}=4.

4 successful frames per (1 time-out + round-trip propagation time). So throughput is

4000 bits / (1 + 0.2) second = 3,922 bits/second.

(2) In High-level Data Link Control (HDLC) Protocol, the "Control" field in a frame is shown as follows. Consider that Station A and Station B communicate by using HDLC. At a time instant, Station A successfully receives an I-frame from Station B. In the I-frame, N(S) is "010" (binary) and N(R) is "001" (binary). After that, Station A sends back an I-frame to Station B. Please indicate the values of N(S) and N(R) in the I-frame sent by Station A. (**2 points**)



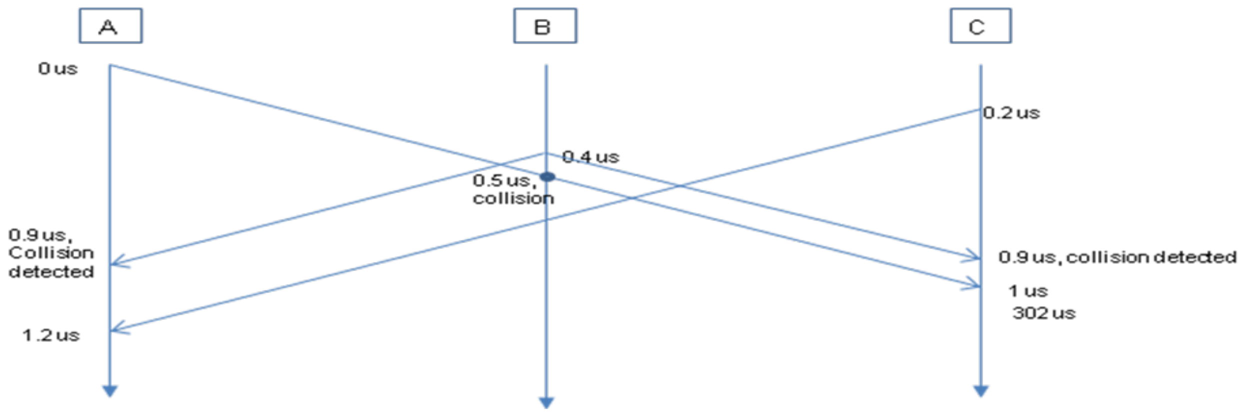
N(S) = 001, N(R) = 011

4. Multiple Access and Ethernet (**14 points**)

(1) A pure ALOHA network transmits 400-bit frames on a shared channel of 200 kbps (note that 1 kbps = 10^3 bits per second). How long is the vulnerable time? What is the throughput (**in unit of frames per second**) if the system (all stations together) produces 1000 frames per second? Recall that the throughput for pure ALOHA is $S = G \times e^{-2G}$, in which G is average number of frames generated by the system during one frame transmission time, and S is average number of successful frames during one frame transmission time. (**4 points**)

Frame transmission time is 400 bits/200kbps = 2ms. Vulnerable time is 4ms (double frame transmission time).
G=2. $S= G \times e^{-2G}$ = 0.0366 frames/(2 ms) = 18.3 frames/second.

(2) Consider a standard Ethernet (which implements CSMA/CD [carrier sense multiple access with collision detection] and 1-persistent method) with only three stations in a line: the distance between Station A and Station B and between Station B and Station C are both 150 meters. The propagation speed is the speed of light (3×10^8 meters per second). The data rate is 10^7 bits/seconds. At time instant t_1=0 microsecond, Station A has a frame with size 2,000 bits to be sent. At time instant t_2=0.2 microsecond, **Station C** has a frame with size 3,000 bits to be sent. At time instant t_3=0.4 microsecond, **Station B** has a frame with size 4,000 bits to be sent. Please determine the number of bits each station can send during its first transmission attempt. Note that 1 microsecond = 10^{-6} second. (**6 points**)



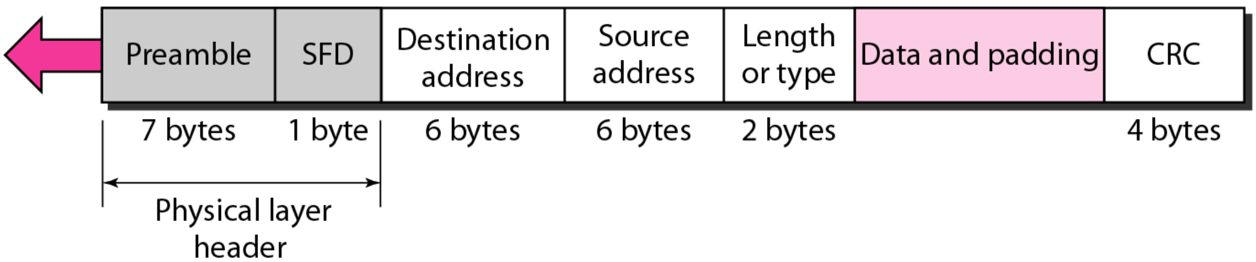
So A transmits 0.9 microsecond, with 9 bits;
B transmits 0.1 microsecond, with 1 bit;
C transmits 0.7 microsecond, with 7 bits.

Question 4 (Continued)

(3) Recall that in our lecture for "Framing", we introduced a method that adds two flags for each frame, one at the beginning of the frame and the other at the end of the frame. Below is the frame structure of IEEE 802.3 (a medium access control [MAC] protocol for Ethernet). We can see that only one flag (SFD in the frame structure) is used at the beginning of a frame. Please explain why only one flag is used. Also explain when we should use "padding" in a frame. (**4 points**)

Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)



We use only one flag because the length of the frame is specified in the frame header. The length can serve as a delimiter.

In Ethernet, there is a minimum frame size requirement (for collision detection). We should use padding when we do not have sufficient data to meet the minimum frame size requirement.

The end