1. (20pt in total) Networking Architecture

   (a) (6pt) Name two layers of the OSI model that performs flow control.

   Answer: Data link layer and transport layer.

   (b) (6pt) Name two functions of the Session layer according to the OSI model.

   Answer: checkpoint and error recovery

   Hint: any two functions from the handout or textbook will do. The answer above is not the only one.

   (c) (8pt) Give two advantages and one disadvantage of network standards.

   Answer: advantages: interoperability and economy of scale. disadvantages: could be obsolete.

   Discussion: The answers above are not the only one.

2. (40pt in total) Physical Layer

   (a) (6pt) Consider a periodic signal $x(t)$ whose period is 5 millisecond. It has been determined that harmonics up to $8f$ are required to represent the signal. Calculate the effective bandwidth of $x(t)$.

   Answer: frequency f =1/period = 1/0.005=200 Hz (1 millisecond = 0.001 second). Effective bandwidth $8f - 1f = 7f = 1400$ Hz.

   Hint: don't forget the units to answers

   (b) Consider a communication link with bandwidth H=4000 Hz and S/N=30dB.

      i. (10pt) Calculate its maximum data rate according Shannon's theorem.
      Answer: First to compute the straight S/N ratio:

$$30 = 10 \log_{10} \frac{S}{N} \Longrightarrow \frac{S}{N} = 1000$$

      According Shannon's theorem,

$$\text{max data rate} = 4000 \times \log_2(1 + 1000) \approx 40,000\text{bits/second}$$

      ii. (4pt) Nyquist's theorem cannot be applied here because a factor is unknown. Point out that factor.
      Answer: Variable V, the number of signaling elements.

   (c) (8pt) Define *multiplexing* in one sentence. What is the multiplexing method of T1 line ?

   Answer: A multiplexing technique allows several low bandwidth signals to share a high capacity link. The multiplexing method of T1 lines is time division multiplexing.

(d) (8pt) Show the delay modulation encoding of the bit sequence $(1, 1, 1, 0, 0, 0, 1, 0)$, assuming that the the signal starts with the high voltage.

(e) (4pt) Give an 8-bit sequence that results in the *fastest* modulation rate with Manchester encoding.

Answer: 11111111 or 00000000 (one of either will do)

3. (30pt in total) Medium Access Control

   (a) (10pt) Describe the purpose and the operations (how it works) of CSMA/CD in three sentences.

      Answer: The purpose of CSMA/CD is to allow multiple users to share a communication medium and resolve the conflicts of concurrent transmissions. It operates as follows: before transmission a station listens to the channel to make sure it is quite; during transmissions it also listens to check for collisions of transmissions.

      Hints: Be clear, precise and unambiguous. A *bad* example: a user pays attention to the channel when sending data. Points are lost because expressions like "pay attention" do not have a well-defined technical meaning.

   (b) (6pt) Give two advantages of token-based MAC over CSMA/CD.

      Answer: fairness and bounded delays.

      Hint: When "pointing out" or "giving" advantages, disadvantages, functions, features, etc, just *name* the answers. No need to elaborate.

(c) (14pt) Consider a hypothetic Ethernet standard 5BaseX with the following specifications.

i. 3 segments of 500 meter cables can be cascaded by 2 repeaters to form networks diameters up to 1,500 meters.

ii. Signal propagation speed is 2×10^8 meters per second.

iii. Per repeater delay is 0.5 μsec.

iv. Minimum frame length is 20 bytes.

v. Data rate is 5 Mbps.

Determine whether collision detection would work with 5BaseX. Calculations are mandatory.

Answer: to compute round trip times (RTT):

$$\text{Signal propagation delay} = \frac{3000}{2 \times 10^8}\text{seconds} = 15\mu\text{sec}$$

$$\text{Repeater delay} = 0.5 \times 4 = 2\mu\text{sec}$$

$$\text{RTT} = 15 + 2 = 17\mu\text{sec}$$

The minimum frame transmission time (MFT) is

$$\text{MFT} = \frac{20 \times 8}{5 \times 10^6} = 32\mu\text{sec}$$

We have MFT < RTT and collision detection will work.

4. (20pt in total) Hamming Distance and Hamming Code

   (a) (5pt) We define a coding scheme as follows. For every 14 bits of data, two parity bits are added. The first parity bit is determined by even bit positions and the second by odd ones. The results are 16-bits codewords. Give the minimum Hamming Distance between any pair of valid codewords.

      Answer: The use of two parity bits is not effective. If two error bits are both in even positions (or both in odd ones), then they will not be caught. The minimum hamming distance is still 2 (the same with single-bit parity).

   (b) (15pt) Calculate the Hamming code of 1110101011.

      Answer: $\underline{1}$ $\underline{0}$ 1 $\underline{0}$ 1 1 0 $\underline{0}$ 1 0 1 0 1 1

      Underlined bits are check bits.

5. (35pt in total) Cyclic Redundancy Codes
Given the generator polynomial 1101111 and data frame 11011000011, answer the following questions.

   (a) (20pt) Compute the CRC checksum.

   Answer: 1 0 1 1 0 1

(b) (5pt) Show that the given generator can catch all errors involving odd numbers of bits.

Discussion: please discard this question. Relevant materials are not covered in this semester.

(c) (10pt) Let $T(x) = 11000101110$ be the bit stream transmitted by a communication source. Due to transmission errors, it is received as $R(x) = 11010011111$. Give the error polynomial $E(x)$ of this transmission in the form of a bit stream and show that the error will not be caught by CRC using the generator 1101111.

Answer: $E(x) = 00010110001$ For the second part, divide 10110001 by 1101111 and show that the remainder is all zeros.

6. (20pt in total) Sliding Window Protocols

(a) A sliding window protocol needs a sufficiently large window to avoid "stop and wait." We have decided that a window size of 200 is needed for a given communication link. Determine the (minimum) number of bits in sequence numbers with

i. (4pt) go-back-n protocol
Answer: with go-back-n, window size is limitted to $2^n - 1$ where n is the number of bits in sequence numbers. To have $2^n - 1 \geq 200$, n must be at least 8.

ii. (4pt) selective repeat protocol
Answer: with selective repeat, window size is limitted to 2^{n-1}. To have $2^{n-1} \geq 200$, n must be at least 9.

(b) (12pt) In this question, you demonstrate the reason why the selective repeat protocol has the window size restriction of $2^n - 1$, where n is the length of sequence numbers. Specifically, we assume the use of the selective repeat protocol with 2-bit sequence numbers and a window of size 3. The receiver sees the following sequence of frames:

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0 1 2          0
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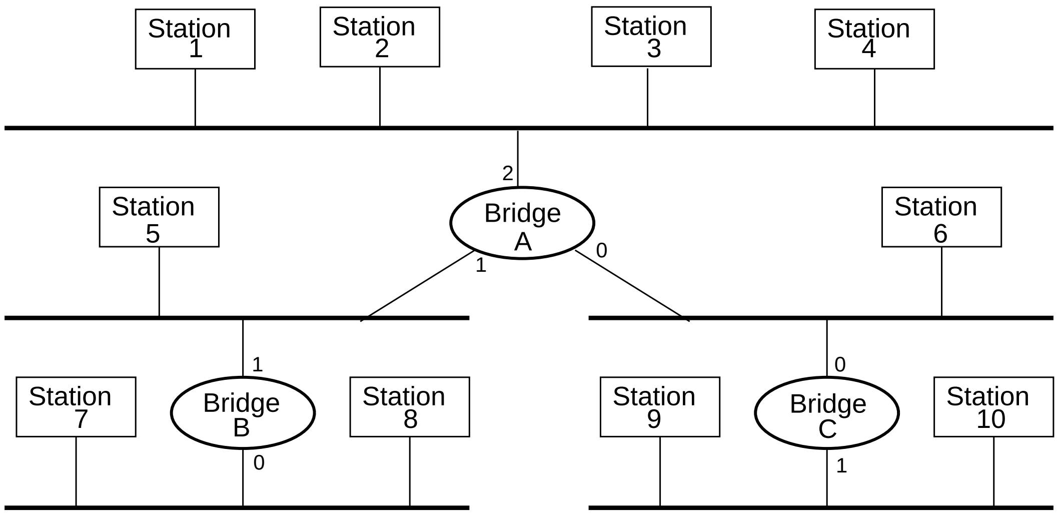
Give two plausible interpretations of the second frame 0.

Answer: The second frame 0 could be the retransmission of the first frame, due to the loss of its acknowledgment and subsequent timeout. Without the ack of first 0, frame 3 cannot be transmitted (the window would be filled by 0, 1, and 2); hence its absence. The second frame 0 could also be a new frame (the fifth). In this scenario, the first 0 was acknowledged successfully and frame 3 was lost.

7. (15pt in total) Bridges
Consider a bridged network depicted below where all bridges are transparent bridges. Starting with empty routing caches at all bridges, show the contents of caches of Bridges A, B, and C, after Station 9 sends a frame to Station 6, Station 2 sends a frame to Station 6, and Station 10 sends a frame to Station 9.



Answer:
After 9 to 6,

Bridge A: (9,0)
Bridge B: (9,1)
Bridge C: (9,1)

After 2 to 6,

Bridge A: (9,0) (2,2)
Bridge B: (9,1) (2,1)
Bridge C: (9,1) (2,0)

After 10 to 9,

Bridge A: (9,0) (2,2)
Bridge B: (9,1) (2,1)
Bridge C: (9,1) (2,0) (10,1)