Instructions:

I. You must submit your homework electronically only in .pdf format. All word processed, no handwriting.
II. Submit your homework via Blackboard no later than **11:59 pm Oct 17, 2022**.
III. Late homework is subject to 10% penalty for each day past the due date, and before the solutions are posted. No homework will be accepted after the solutions are posted.
IV. Students can discuss problems and share their ideas among themselves but MUST work out the homework problems individually. Any deviation from this policy may result in an" F" grade for the course.
V. You must start working on these problems immediately. Otherwise, you may not have enough time to submit them on time.

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1. **Two-dimensional parity**

Given below is a series of 7 7-bit items of data, with an additional bit each and an extra byte to account for parity.

1	1	1	0	1	1	0	
1	1	0	1	0	1	0	
0	1	1	1	1	1	0	
0	1	1	0	1	0	0	
1	1	0	0	0	1	0	
0	0	1	0	1	0	1	
1	1	0	0	0	0	0	

a. Fill in the parity bit for each blank, assuming even parity is followed.

1	1	1	0	1	1	0	
1	1	0	1	0	1	0	
0	1	1	1	1	1	0	
0	1	1	0	1	0	0	
1	1	0	0	0	1	0	
0	0	1	0	1	0	1	
1	1	0	0	0	0	0	

b. Will two-dimensional parity catch all 2-bit errors?

c. Will two-dimensional parity catch all 3-bit errors?

d. Will this parity check catch all 4-bit errors?

0	**0**	1	0	1	1	0	
0	**0**	1	0	1	0	0	
0	1	1	1	1	1	0	
0	1	1	0	1	0	0	
1	1	0	0	0	1	0	
0	0	1	0	1	0	1	
1	1	0	0	0	0	0	

2. Maximum Throughput

Consider a 10Mbps link with a 20-ms round-trip time (RTT). Assume that the sender can send only one frame per RTT, and that the sender has a frame size of 5 KB.

a. The Bandwidth-Delay Product of the channel

b. The maximum throughput the sender can achieve

$$\frac{5*2^{10}*8 \text{ b}}{20 \text{ ms}} = 2.048 \text{ Mbps}$$

c. The fraction (or percentage) of the capacity of the link that is being used by the sender.

3. Error-checking using CRC

Assume we have the following bit stream as the sender's message - **1011 0011 0101 0110** - and we want it to encode it with the help of the CRC-8 polynomial.

a. What does the CRC-8 polynomial look like? Write it down using the standard polynomial notation.

b. What is the sequence for the CRC-8 polynomial in binary form?

c. What does the transmitted bit-sequence look like? Highlight your steps in the calculation.

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d. Assume the 7^{th} bit in the transmitted sequence is flipped. What is the calculated remainder at the receiver?

If the received message (with 7^{th} bit flipped in red) is as follows:-

1011 00**0**1 0101 0110 1101 0101

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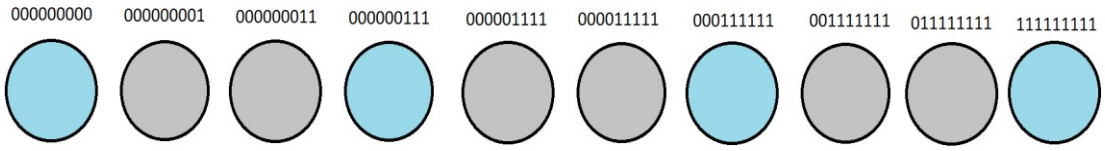
4. Hamming codes

Assume fixed-length bit-strings of length 9 where only some bit-string sequences are allowable in the encoding scheme. Assume that the bit-strings in blue are the allowed codewords and those in gray are the ones that aren't. The following diagram elucidates the assumption.



Now, calculate the following:-

a. What is the hamming distance of this encoding scheme?

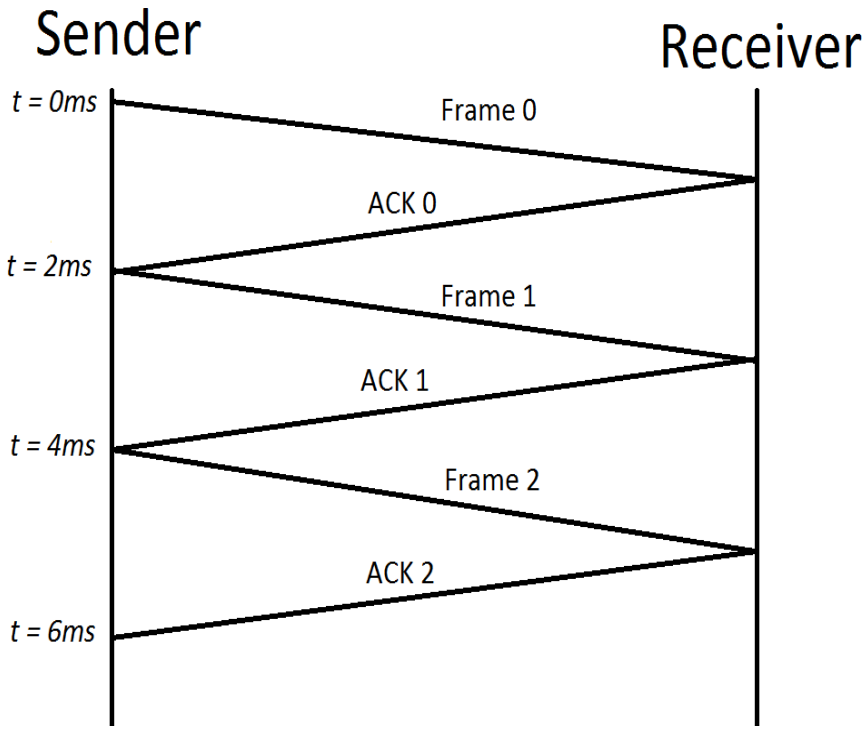
b. Is the encoding scheme efficient? Why or why not?

c. How many bit flips can be detected?

d. How many bit flips can be corrected?

5. The Automatic Repeat Request (ARQ) Protocol

Assume that two computers are communicating using the stop-and-wait ARQ protocol. Assume that the RTT for the communication channel is 2ms, and that the timeout is twice the RTT. Also assume that both parties use sequence numbers on data and ACK frames. If the sender has to send 8 frames to the receiver, draw the sequence of steps involved if the first 3 frames are sent without incident (as shown in the figure) and the following takes place:-



a. The 4th frame is lost during the first and second transmission, but is acknowledged without incident after the third transmission.

b. The 5th frame is lost during the first transmission, but acknowledged without incident after the second transmission.

c. The 6th frame is sent and acknowledged without incident.

d. The 7th frame is sent without incident but the acknowledgment is lost the first time; sent without incident during the second transmission. **(1 point)**

e. The 8th frame is sent and acknowledged without incident. **(1 point)**

Also, how much time (in *ms*) did it take for the above 8 frames to be transferred and acknowledged successfully?