UNIVERSITY OF TORONTO
Faculty of Arts and Science
CSC458, Midterm Winter 2025

Examination Aids: no examination aids are allowed.

Last Name: First Name:
Student ID:

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Notes to students: There are 6 questions and 12 pages in total for this examination. There are 40 marks possible.

Question 1	4 points total
1 (a)	2 points
1 (b)	2 points
Question 2	6 points total
2 (a)	2 points
2 (b)	2 points
2 (c)	2 points
Question 3	8 points total
3 (a)	4 points
3 (b)	4 points
Question 4	7 points total
4 (a)	2 point
4 (b)	2 point
4 (c)	2 point
4 (d)	1 point
Question 4	6 points total
5 (a)	1 points
5 (b)	1 points
5 (c)	1 points
5 (d)	1 point
5 (e)	1 points
5 (f)	1 point
Question 6	9 points total
6 (a)	3 points
6 (b)	3 points
6 (c)	3 points
Total	40 points

Question 1 (4 points) 2D Parity-Check

Consider the 2D parity-check code for the data packet given in the table below, which we discussed in class.

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

(a) (2 points) Fill in the missing parity bits, assuming even parity.

(b) (2 points) Explain step by step how the 2D parity-check code detects and corrects a single-bit error. Justify why this method works.

The 2D parity-check code detects and corrects single-bit errors using the following steps:

(a) A transmitted codeword is arranged in a 2D grid of data bits and parity bits (both row and column parity bits).

(b) After the data is received, the receiver checks the parity of each row and each column.

(c) If all row and column parities are correct (even number of 1s), there is no error.

(d) If any row or column parity fails, the receiver identifies the bit in error by locating the row and column with incorrect parities. The intersection of the row and column gives the position of the error.

(e) The receiver can then correct the error by flipping the bit at the intersection.

This method works because a single-bit error will only affect one row and one column, allowing for precise identification of the error.

Question 2 (6 points) Stop-and-Wait ARQ

Consider the situation where a sender A and a receiver B communicate with each other using stop-and-wait ARQ. Suppose that A uses as the initial sequence number (ISN) 10, i.e. we have that ISN= 10. Furthermore suppose that the first packet that A sends to B consists of 200 bytes.

(a) (2 points) What is the SN number that A puts into the packet header (such as for example a TCP packet header)?

10 or 11

(b) (2 points) If B receives the first 200 bytes packet from A without an error, what is the ACK number that B uses in the packet that is sends to A in response to the packet it received?

210 or 211

(c) (2 points) If B detects an error in the first 200 bytes packet that it receives from A, what is the ACK number that B uses in the packet that is sends to A in response to the packet it received?

10 or 11

Question 3 (8 points total) IP and Packet Forwarding

This question is about the network layer.

(a) (4 points) Let the following be addresses of IP networks:

Network 1:	231.21.0.0/16
Network 2:	231.22.11.0/24
Network 3:	233.22.12.0/24

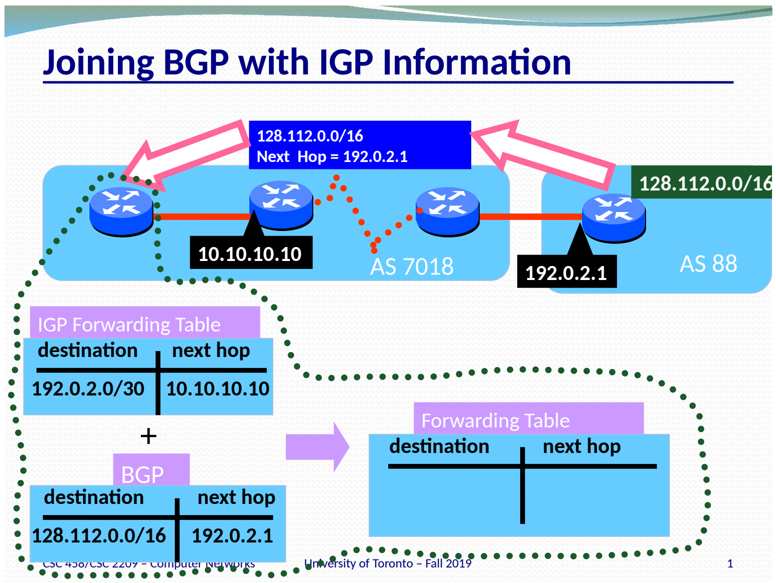
Let the IP-addresses of three hosts be given as follows:

Host A:	233.21.11.19
Host B:	231.22.12.21
Host C:	231.21.12.19
Host D:	233.21.12.19

Indicate for each how which network they belong to. If a host does not belong to any of the networks, indicate it through a "X".

Host A:	X
Host B:	X
Host C:	Network 1
Host D:	X

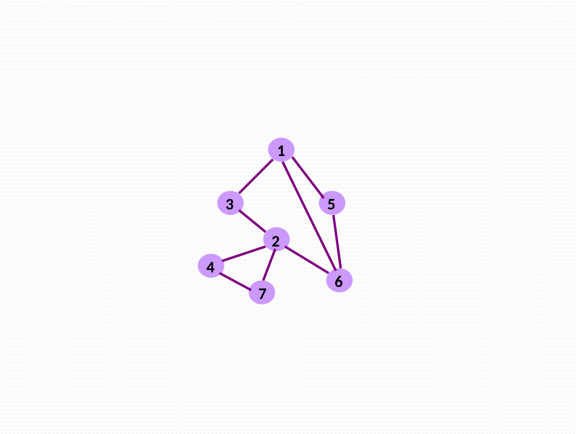
(b) (4 points) In the figure below, indicate how information from the IGP and BGP routing protocols are combined to populate the forwarding table, i.e. fill out the forwarding table based on the information obtained from the BGP and IGP protocol.



destination	next hop
192.0.2.0/30	10.10.10.10
128.112.0.0/16	10.10.10.10

Question 4 (7 points total) Spanning Tree Algorithm

In class, we discussed an algorithm to create a spanning tree for a network of switches. Answer the following questions for the network topology given below (where each node is a switch).



a) (2 points) Provide the format of the messages that the switches exchange.

- Root ID: The ID of the switch currently considered as the root.
- Cost: The cost (or number of hops) to reach the root from the sender.
- Sender ID: The ID of the switch sending the message.

b) (2 points) **Initialization:** For each node, indicate the initial state of the node, i.e. the first message the node exchanges with its neighbors.

Node	Message
1	(1, 0, 1)
2	(2, 0, 2)
3	(3, 0, 3)
4	(4, 0, 4)
5	(5, 0, 5)
6	(6, 0, 6)
7	(7, 0, 7)

c) (2 points) **Step 1:** Assume that all nodes received the messages from their neighbor during the initialization step given in b). For each node, indicate the next messages that it exchanges with its neighbors.

Node	Message
1	(1, 0, 1)
2	(2, 0, 2)
3	(1, 1, 3)
4	(2, 1, 4)
5	(1, 1, 5)
6	(1, 1, 6)
7	(2, 1, 7)

d) (1 point) **Step 2:** Assume that all nodes received the messages from their neighbor during Step 1 in c). For each node, indicate the next messages that it exchanges with its neighbors.

Node	Message
1	(1, 0, 1)
2	(1, 2, 2)
3	(1, 1, 3)
4	(2, 1, 4)
5	(1, 1, 5)
6	(1, 1, 6)
7	(2, 1, 7)

Question 5 (6 points) Hamming Distance

(a) (1 points) Provide an example of a binary code with 4 code words that has Hamming distance 2. Write down each code word.

A binary code with four code words that has a Hamming distance of 2 is:

$$C = \{0000, 0101, 1010, 1111\}$$

The Hamming distance between any two code words in this set is at least 2.

(b) (1 points) Using your example from (a), pick one code word from your code, and introduce 1 bit error into the code word. Show that this error can be detected. Recall from the lecture that a code with Hamming distance 2 is able to detect 1 bit error.

Pick the code word 1010 and introduce a 1-bit error, for example, by flipping the second bit:

$$1010 \rightarrow 1110$$

The new word 1110 does not belong to the original code C, so this error can be detected.

(c) (1 points) Using your example from (a), show that there exists a code word in your code such that if 2 bit errors are introduced into the code word, then these two errors can not be detected.

Consider the same code word 1010 and introduce 2-bit errors, for example, by flipping the second and fourth bits:

$$1010 \rightarrow 1111$$

The new word 1111 belongs to the original code C, meaning that the error is not detected. This demonstrates that a Hamming distance of 2 can detect only 1-bit errors but not 2-bit errors.

(d) (1 points) Provide an example of a binary code with 4 code words that has Hamming distance 3. Write down each code word.

A binary code with four code words that has a Hamming distance of 3 is:

$$C' = \{00000, 00111, 11001, 11110\}$$

The Hamming distance between any two code words in this set is at least 3.

(e) (1 points) Using your example from (d), pick one code word from your code, and introduce 1 bit error into the code word. Show that this error can be corrected if we assume that each code word can have at most 1 bit error. Recall from the lecture that a code with Hamming distance 3 is able to correct 1 bit error.

Pick the code word 11001 and introduce a 1-bit error, for example, by flipping the third bit:

$$11001 \rightarrow 11101$$

The new word 11101 is not in the original code C'. Since the minimum Hamming distance is 3, the closest valid code word to 11101 (with a distance of 1) is 11001, allowing us to correct the error.

(f) (1 points) Using your example from (d), show that there exists a code word in your code such that if 2 bit errors are introduced into the code word, then these two errors can not be corrected if we assume that each code word can have at most 2 bit errors.

Consider the same code word 11001 and introduce 2-bit errors, for example, by flipping the second and third bits:

$$11001 \rightarrow 10101$$

The new word 10101 is now at a Hamming distance of 2 from 11001, but it is also at a distance of 2 from another code word in C', making it ambiguous which word was originally transmitted. Since Hamming distance 3 codes can correct only 1-bit errors, this error cannot be corrected.

Question 6 (9 points) Establishing a TCP Connection

Consider a TCP connection between two applications running on two end-hosts A and B.

a) (3 points) Illustrate the sequence of packets exchanged between A and B during the TCP three-way handshake required to establish the connection. Clearly label each step in your diagram.

Host A (Client)		Host B (Server)
SYN	$\longrightarrow$	
	$\longleftarrow$	SYN ACK
ACK	$\longrightarrow$	

This handshake ensures that both hosts are synchronized before data transmission begins.

b) (3 points) For each packet in (a), specify the TCP flags (e.g., SYN, ACK) that are set and describe the key fields in the TCP header, such as sequence numbers and acknowledgement numbers.

Host A (Client)		Host B (Server)
SYN, ISN $= x$	$\longrightarrow$	
	$\longleftarrow$	SYN + ACK, INS $= y$, Ack $= x+1$
ACK, Seq $= x+1$, Ack $= y+1$	$\longrightarrow$	

- First packet: SYN is set. Initial sequence number is x.
- Second packet: SYN and ACK are set. Initial sequence number is y, and acknowledgment number is $x+1$.
- Third packet: ACK is set. Sequence number is $x+1$, and acknowledgment number is $y+1$.

c) (3 points) Provide an explanation of the purpose of each packet.

- First packet (SYN): Initiates the connection and informs Host B about the initial sequence number.
- Second packet (SYN-ACK): Confirms receipt of the SYN from Host A and informs Host A of its own sequence number.
- Third packet (ACK): Confirms receipt of the SYN-ACK, completing the handshake, and allowing data transfer to begin.