CS/ECE 438: Computer Networks	Spring 2026

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Homework 2

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Handed Out: February 14, 2026   *Due: 11:59pm, March 6, 2026*

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- Homework assignments must be submitted online through GradeScope. No handwritten solutions will be accepted. LaTeX formatting is recommended, but not enforced.

- Each question is worth the same number of points (e.g., 10 points). Show your work for full credit. You will not receive points for a correct answer with no work shown. Partial credit may be awarded for correct reasoning even if the final answer is incorrect.

- Please come to office hours if you have questions about the homework.

- While we encourage discussion within and outside of the class, cheating and copying is strictly prohibited. Copied solutions will result in the entire assignment being discarded from grading at the very least and a report filed in the FAIR system.

1 Framing

Consider the data bit sequence 0111 1110 1111 1110 0000 1000 0000 0011 0001 0000 1110 0101.

In this problem, you will frame these bits in three ways.

a. First, frame the bits with byte stuffing as used in the BISYNC protocol. You need to show the body (including stuffed bytes) and the sentinel bits. DLE is ASCII character 16 (decimal), STX is 2, and ETX is 3.

b. Second, frame the bits using bit stuffing as defined by the HDLC protocol. Again, you need to show the body, the (stuffed) data bits and the sentinel bits.

c. Third, frame the bits into 8-bit RS-232 characters. Use "0" to represent start bits and "1" to represent stop bits.

d. Now, counting only the bits that you wrote, calculate the efficiency (as a percentage of real data per bit sent) of your answers to (a), (b), and (c).

2 Error Detection

Note: we will allow hand written long division as long it's legible.

a. A CRC is constructed to generate a 4-bit checksum for an 11-bit message. The generator polynomial is
$$x^4 + x^3 + 1.$$

Encode the data bit sequence `10111101100`. Now assume that bit 4 (counting from the right) in the received code word is in error and show how the error is detected.

b. The bit sequence `10100110101` corresponds to the polynomial

$$x^{10} + x^8 + x^5 + x^4 + x^2 + 1.$$

Divide this polynomial by the CRC generator polynomial

$$x^3 + x^2 + 1$$

and report the remainder as a polynomial. Is the bit sequence correctly encoded with the given generator (i.e., is the remainder 0)?

c. Suppose a 4-bit CRC is appended to an n-bit message according to the CRC polynomial

$$x^4 + x + 1.$$

The encoded message thus has $n + 4$ bits. What is the largest value of n such that every double-bit error can be detected? (Hint: any error sequence corresponds to a polynomial that is the product of $C(x)$ and some other polynomial. We first seek the shortest nonzero sequence that when multiplied by 10011 using no carries (i.e., polynomial multiplication) produces a sequence with only two 1's. The sequence should start and end with a 1. The idea is to select the other bits of the multiplier so that the product also has 1's for the first and last bits, and all other bits 0.)

3 Networking Utilities

(a) The Unix utility `ping` can be used to find the round-trip time (RTT) to various Internet hosts. See the man page for `ping` to see how to use it and the `-s` option with other options to see how you can control the time between ICMP packet transmissions, and to display the resulting round trip times. Upon interrupting execution of `ping`, the min, average and maximum RTT will also be displayed. Here is what you turn in:

Report the average (average over ten pings) round trip times for pings to the following domains:

- `www.illinois.edu`
- `www.google.com`
- `www.apple.com`
- `www.sydney.edu.au`
- `www.bbc.co.uk`
- `www.harvard.edu`

(b) The Unix utility `traceroute` is like `ping`, but it sends packets that are limited to go one hop, then two hops, then three hops, and so on, towards a given destination, and the intermediate routers are reported. Read the man page for `traceroute` and experiment with it. Try `traceroute` on the servers that you just pinged. Report the

number of routers that are encountered along the way. Answer these questions: what is the relation between this number and the RTT? Is the number of hops the only factor affecting the RTT?

4   Delay-Bandwidth Product for Links in Series

Consider three nodes in series. Node A is connected to node B via a 400 Mbps fiber optic link, 5000 km in length. Node B is connected to node C via a 4 Mbps link, 4 km in length. The links are full duplex. The rate of transmission errors on the links, the time to switch a packet at node B, and the time to transmit an ACK are all negligible. A large file is to be sent from node A to node C, and there is no other traffic on the links. Packets are 1200 B, including headers.

(Use Speed of Light $= 3 \times 10^8$ m/s)

a. Ignoring reliability and packet headers, what is the maximum throughput that can be achieved (in Mbps)? Explain.

b. What is the round trip time from A to C?

c. What is the roundtrip bandwidth delay product for the path from A to C? (Specify the units you use).

5   Spanning Tree Algorithm for Intelligent Bridges

Figure 1: Spanning Tree Algorithm

Note: we will allow drawing on the diagram as long it's legible.

Suppose the Perlman spanning tree algorithm and the bridge learning algorithm for forwarding are used for the network shown in Fig.1.

a. Indicate which bridge is root, which ports are root ports (i.e. the preferred port for reaching the root bridge), which bridge is the designated bridge for each LAN, and which ports are designated ports (i.e. the ports that connect some LAN to its given designated bridge). Hint: bridges that are not designated bridges for any LAN, and ports that are not either root ports or designated ports do not play a role in the routing of packets. The remaining bridges together with the LANs form a spanning tree.

b. Suppose after the configuration is complete, Venus sends a message to Jupiter, then Jupiter sends a message to Venus, then Mars sends a message to Jupiter. For each of the three messages, indicate which LANs the message is heard on.

6 Switch Fabrics

Banyan and Batcher networks are two types of self-routing fabrics often used to construct large switches from simpler components. A single stage of a $n \times n$ Banyan network consists of $n/2$ switches of dimension 2×2. An $n \times n$ Batcher network can be made from two Batcher networks of size $n/2 \times n/2$ plus a merge network with $n/2 \log_2(n)$ switches.

a. For $n = 512$, how many stages are required to route packets from the inputs to the outputs of a Banyan Network?

b. How many 2×2 switches are required for the network in part (a)?

c. Write down a recurrence relation $T(n)$ for the number of switches in a Batcher network of size $n \times n$.

d. Give the number of switches required for $n = 32$ in a Batcher network.

7 Server Bandwidth

Consider a server with direct memory access (DMA) in and out of main memory. Assume the server's I/O bus speed is 450Mbps and the memory bandwidth is 800Mbps.

a. How many switched 8Mbps links could be supported by the server?

b. Suppose the server switching time is such that it can forward packets at the rate of 2056 packets per second. Determine the throughput as a function of the packet size.

c. At what packet size does the memory bandwidth become the limiting factor?

8 Ethernet Timing

This problem is about the Ethernet/IEEE 802.11 access protocol. To be definite, suppose that if a host detects a transmission while it is transmitting a frame, then:

(i) if the host has already transmitted the 128 bit preamble, the host stops transmitting the frame and sends a 64 bit jamming sequence;

(ii) Else the host finishes transmitting the 128 bit preamble and then sends a 64 bit jamming sequence. For simplicity, assume a collision is detected as soon as an interfering signal first begins to reach a host and ignore the 9.72 ms waiting period after successful frames.

Suppose the packets are 1024 bits long, which is the minimum length allowed. Hosts A and B are the only active hosts on a 10 Mbps Ethernet and the propagation time between them is 0.05ms, or 500 bit durations. Suppose A begins transmitting a frame at time $t = 0$, and just before the beginning of the frame reaches B, B begins sending a frame, and then almost immediately B detects a collision.

   a. Does A finish transmitting the frame before it detects that there was a collision? Explain.

   b. What time does A finish sending a jamming signal? What time does B finish sending a jamming signal?

   c. What time does A first hear an idle channel again? What time does B first hear an idle channel again?

   d. Suppose each host next decides to retransmit immediately after hearing the channel idle. After the resulting (second) collision: When does A next hear the channel idle? When does B next hear the channel idle?

   e. Suppose after the second collision, A decides to wait 1024 bit durations to retransmit (if it hears silence after that long) and B decides to retransmit immediately after hearing a silent channel. Is the transmission of host B successful?

   f. At the time A was planning to send its second retransmission, it senses a carrier present. Suppose at that particular time A decides to wait $2 \times 1024\mu s$ more until its next retransmission. What time does host A finish sending its packet?

9   Virtual Circuits

Consider the use of virtual circuits with the network shown in Fig.2. Assume that each switch port has an associated variable, NextVCIOut, initially set to 0. When an outgoing connection is made through a port, it is assigned VCI = NextVCIOut. NextVCIOut is then incremented.

The following connections are made, in order:

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A connects to G

A connects to C

E connects to I
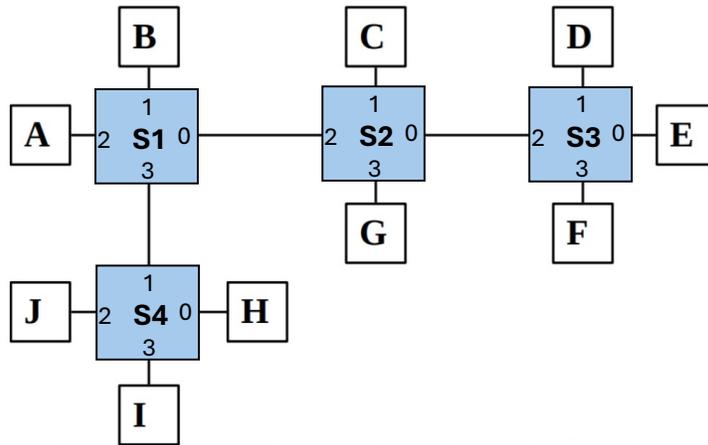
D connects to E

G connects to H

B connects to D

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Figure 2: Virtual Circuit

a. After the connections are made, what is the Virtual Circuit table (fill in the table in Fig. 3) at each switch? Report your answer (Append rows to each switch as needed).

In Port	In VCI	Out Port	Out VCI
S1			
S2			
S3			
S4			

Figure 3: Table for Virtual Circuit sub-problem a.

b. What is NextVCIOut for each port at each switch (fill in the table in Fig. 4)?

c. What sequence of VCIs does a packet from E to I get?

d. What sequence of VCIs does a packet from B to D get?

	S1	S2	S3	S4
0				
1				
2				
3				

Figure 4: Table for Virtual Circuit subproblem b.

10 Wireshark

Install Wireshark on your laptop and use it to monitor your Internet traffic. Record a session that includes you opening YouTube in your browser and watching a video for 40 seconds. Answer the questions below.

1. How much data in total was received by your computer during this time?

2. What are the top 2 IPs that sent traffic to your computer (by number of bytes sent)

3. What ports were used to communicate with these two IPs? What protocol was it using (full name instead of acronym)?

4. Try to find out a bit about where these IPs are located and who owns them

5. List the full name of 2 other protocols.

11 Link-State Routing

Show how the link-state algorithm builds the routing table for node B in the network (Fig. 5) by completing the Table 1 (similar to the format used in class). If you need more rows, just simply add the rows into the table.
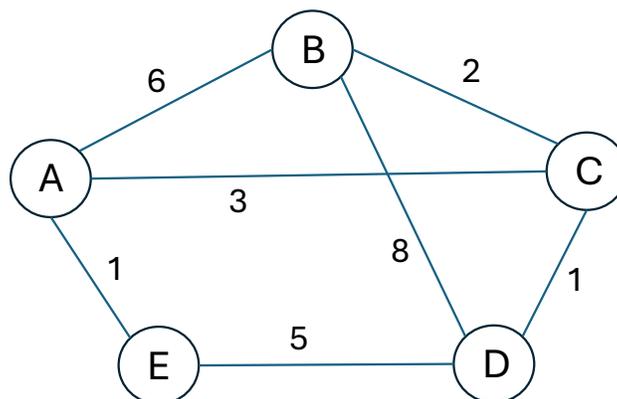

Figure 5: Link-State routing

Table 1: Link State Routing Table

Step	Confirmed	Tentative
1	(B, 0, -)	
2		
3		
4		
5		
6		

12 Distance-Vector Routing

Consider the network configuration in Fig. 6 where the routers calculate shortest routes using the Distance Vector Routing Protocol.
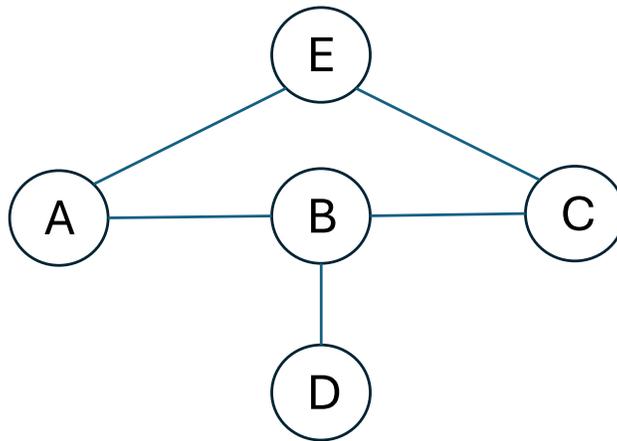

Figure 6: Graph for Distance-Vector Routing Problem

Initially, the router tables for routes to node D look like Table. 2:

Table 2: Router table for node D

B		C		A		E	
Cost	Next Hop	Cost	Next Hop	Cost	Next Hop	Cost	Next Hop
1	D	2	B	2	B	3	A

Now, assume node D goes down.

Given the sequence of routing update messages in Table. 3, fill in the table for the routing entries for reaching D at each event, where the notation $B \rightarrow C$ indicates that node B sent a routing update to node C.

Analyze this carefully and try to see what's happening compared to what should happen ideally. So what, according to you, is the problem here? Why is it a problem?

Table 3: Sequence of routing update messages

	B		C		A		E	
Event	Cost	Next Hop	Cost	Next Hop	Cost	Next Hop	Cost	Next Hop
	1	D	2	B	2	B	3	A
Node D goes down								
$B \rightarrow C$								
$E \rightarrow C$								
$C \rightarrow B$								
$B \rightarrow A$								
$A \rightarrow E$								
$E \rightarrow C$								
$C \rightarrow B$								
$B \rightarrow A$								