CSC358H5: Principles of Computer Networking — Winter 2025

Problem Set 1

Due Date: Sunday, Feb 16, 11:59 PM, on Crowdmark

Submission Instructions: You must submit your assignment electronically via Crowdmark, with each question's solution uploaded separately. For your convenience, we have provided a template file, `ps1_sol_template.tex`, which you may use to prepare your solution. However, you are free to use any other LaTeX format or any other tool of your choice (*e.g.*, Word, scanned handwritten submission, etc.). If you choose to submit a handwritten assignment, ensure your writing is legible; otherwise, TAs may have the discretion not to grade your work.

Q1 **[Layering and Encapsulation, 5 points]** In Figure 1, Host A starts sending one packet to host B at time t_0. At each time step, complete the missing sections in Figure 2 to indicate which headers are appended to the payload. For reference, the packet headers at time t_2 are provided. Under the context of OSI reference model, In Figure 1, Hypertext Transfer Protocol (HTTP) operates at L7, Transmission Control Protocol (TCP) operates at L4, Internet Protocol (IP) operates at L3, Ethernet and Optical Transport Network (OTN) operate at L2.

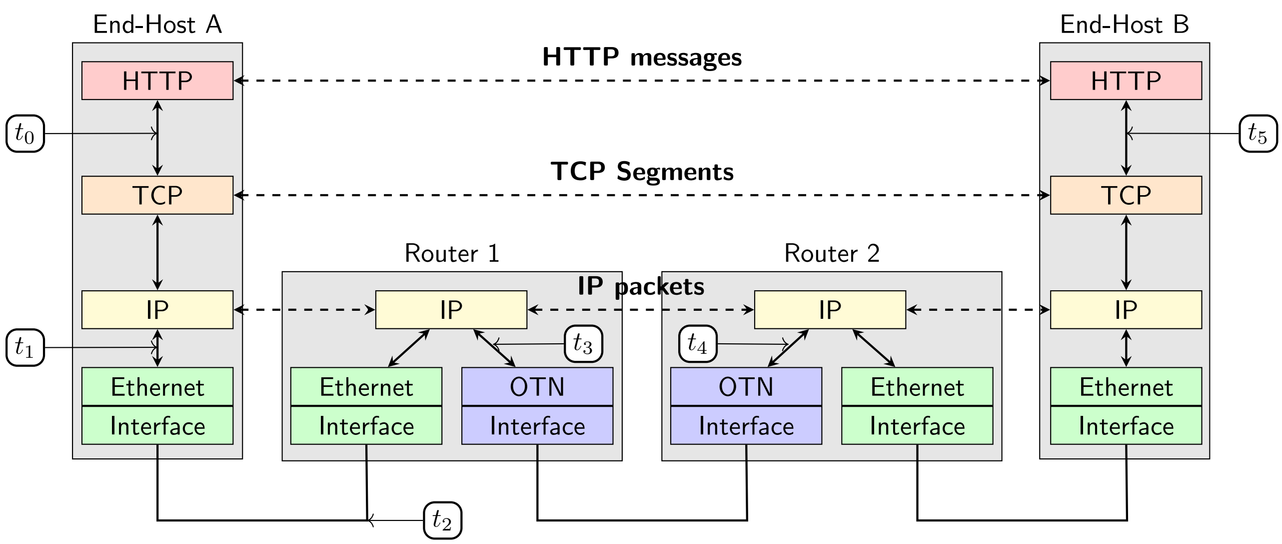


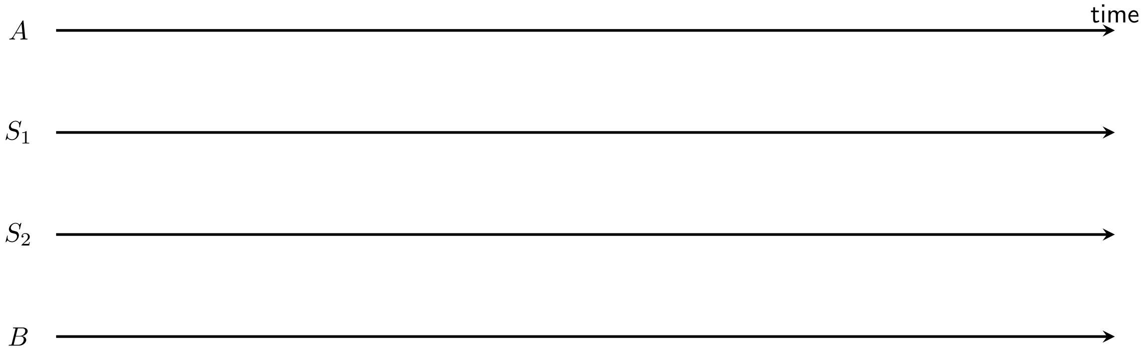
Figure 1: Host A sends one packet to host B at time t_0.

	L1/L2	L3	L4	L7	
Time $= t_0$					**Payload**
Time $= t_1$					**Payload**
Time $= t_2$	**Yes**	**Yes**	**Yes**	**Yes**	**Payload**
Time $= t_3$					**Payload**
Time $= t_4$					**Payload**
Time $= t_5$					**Payload**

Figure 2: Which headers are attached to the payload at each time? Put **Yes** if a layer's header is attached, and **No** if it is not.

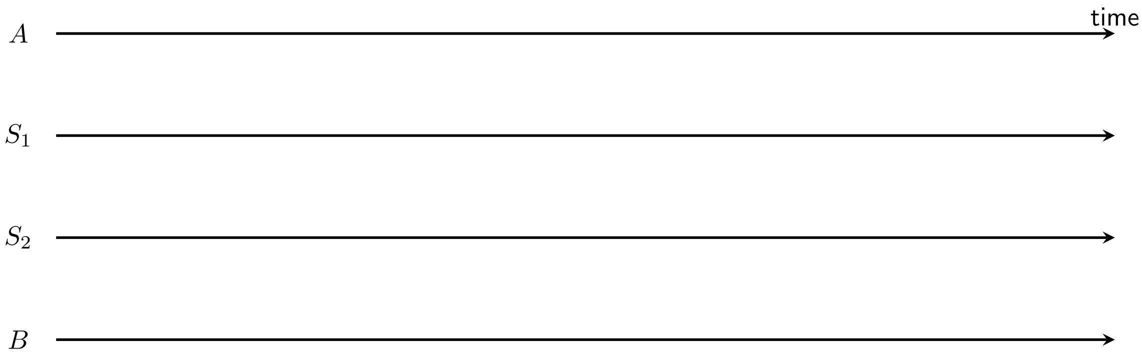
Q2 **[Message End-to-end Delay, 6 points]** A message of size 10 Kb[1] is sent from a source node A to a destination node B, passing through two switches S_1 and S_2. All three links on the path have a propagation delay of 20 ms. The link from node A to switch S_1 has a bandwidth of 100 bps, and the links from switch S_1 to S_2 and switch S_2 to node B have bandwidth of 1 Kbps. Assume the switches store-and-forward packets along the path. For simplicity, ignore the queuing delay and all header overheads as well as any time spent for initial handshake and connection termination.

2.a **[1 point]** Assume that the message is sent as a whole (*i.e.*, as one giant packet). Draw the timeline diagram of the message end-to-end delay.



2.b **[2 point]** Find the *message* end-to-end delay for part **2.a**.

2.c **[1 point]** Assume that the message is broken into packets of size 1 Kb and then transmitted to the destination. Draw the timeline diagram of the first three packets end-to-end delay.



2.d **[2 point]** Find the *message* end-to-end delay for part **2.c**.

[1] In this course, we use "b" for bits and "B" for bytes. Furthermore, we use "K", "M", and "G" in normal decimal sense. Thus, 1 Kb (kilobit), 1 Mb (megabit), and 1 Gb (gigabit) are equivalent to 10^3, 10^6, and 10^9 bits, respectively. Similarly, 1 KB (kilobyte), 1 MB (megabyte), and 1 GB (gigabyte) are equivalent to 10^3, 10^6, and 10^9 bytes, respectively. It is noteworthy that Ki, Mi, and Gi are used for binary-based units. For example, 1 Kib, 1 Mib, and 1 Gib are equivalent to 1024 bits, 1024 Kib, and 1024 Mib, respectively.

Q3 **[L2 and L3 Addressing, 8 points]** Consider the network illustrated in figure 3, which has three private networks (also called "subnets") connected to a router via Ethernet switches. The IP and MAC addresses are shown for the hosts and for the router's interfaces. Assume that Host G sends a packet to Host A. Under the context of OSI Reference Model, write the source and destination addresses in both the L2 and L3 header in Table 1 for the packet when it is crossing:

3.a [2 points] The link connecting Switch S_4 to Switch S_3.

3.b [2 points] The link connecting Switch S_3 to the router.

3.c [2 points] The link connecting the router to Switch S_1.

3.d [2 points] The link connecting Switch S_1 to Host A.

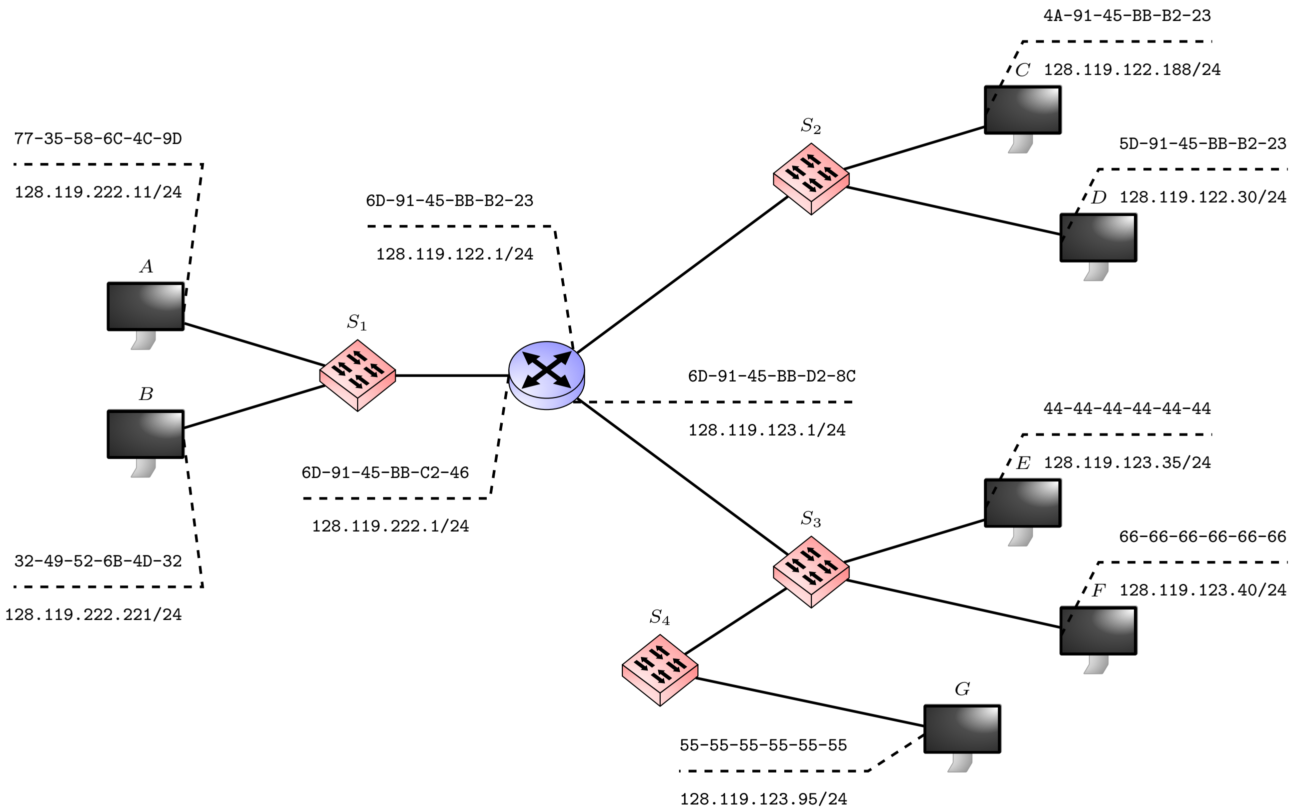


Figure 3: The IP and MAC addresses are shown for each interface.

	3.a Addresses		**3.b Addresses**		**3.c Addresses**		**3.d Addresses**	
Layer	**Source**	**Destination**	**Source**	**Destination**	**Source**	**Destination**	**Source**	**Destination**
L2								
L3								

Table 1: Specify the source and destination addresses in the L2 and L3 headers as the packet traverses from Host G to Host A.

Q4 [Error Detection and Correction, 18 points]

4.a [2D-Parity, 8 points]

4.a. i [2 points] Consider the following binary data, which we separated as chunks of 7-bits for your convenience.

1010110 0100010 1110001 0110110 0100010 1110010 1000011 1011111

Considering the 2D parity coding with even parity, fill in the parity bit for each blank in Table 2, to derive the coded version of the data.

1	0	1	0	1	1	0	__
0	1	0	0	0	1	0	__
1	1	1	0	0	0	1	__
0	1	1	0	1	1	0	__
0	1	0	0	0	1	0	__
1	1	1	0	0	1	0	__
1	0	0	0	0	1	1	__
1	0	1	1	1	1	1	__
__	__	__	__	__	__	__	__

Table 2: A series of seven 7-bit items of data.

4.a. ii [2 points] Can 2D Parity coding catch all odd number of bit errors? Justify your answer. [**NOTE:** This part is independent of part **4.a. i**]

4.a. iii [2 points] Can 2D Parity coding catch any two bits of errors? Justify your answer. [**NOTE:** This part is independent of part **4.a. i** and **4.a. ii**]

4.a. iv [2 points] Can 2D Parity coding catch any six bits of errors? Justify your answer. [**NOTE:** This part is independent of part **4.a. i**, **4.a. ii**, and **4.a. iii**.]

4.b [Internet Checksum, 4 points]

4.b. i [2 points] Compute the Internet Checksum for the following message, which is represented in hexadecimal notation.

0x4000 0xc0a8 0x31b7

4.b. ii [2 points] Verifying the Internet Checksum (*i.e.*, determine if you detect any error) for the following codeword, where the Internet Checksum is underlined. Show your process. [**NOTE:** This part is independent of part **4.b. i**]

0x0f70 0xb038 0x31b7 <u>0x0c27</u>

4.c [(N, K) Block Coding, 6 points]

The $(7,4)$ Hamming code is a specific implementation of $(7,4)$ block coding that is widely used in digital communication and data storage. It's a relatively simple yet powerful code. The $(7,4)$ notation signifies that for every 4 data bits to be encoded, the code generates a 7-bit codeword. Let us denote the 4 data bits by (d_1, d_2, d_3, d_4). The $(7,4)$ Hamming code calculates three parity bits (p_1, p_2, and p_3) based on specific combinations of the data bits explained below.

- $p_1 = d_1 \oplus d_2 \oplus d_4$.
- $p_2 = d_1 \oplus d_3 \oplus d_4$.
- $p_3 = d_2 \oplus d_3 \oplus d_4$.

The final 7-bit codeword is $(p_1, p_2, d_1, p_3, d_2, d_3, d_4)$.

4.c. i [2 points] What is the Hamming distance of this coding scheme? Justify your answer.

4.c. ii [0.25 points] What is the overhead of this coding scheme? Choose from the options below.

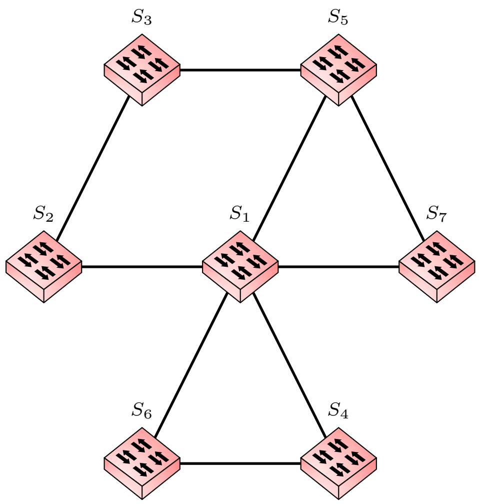


Figure 4: Switched Ethernet LAN and Spanning Tree Algorithm.

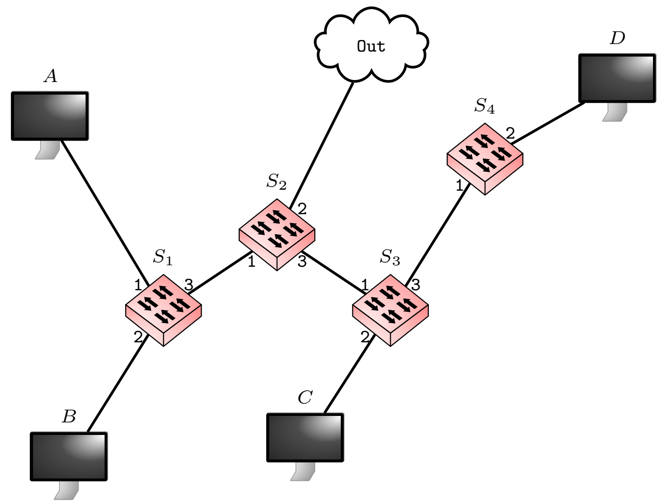


Figure 5: A switched network. Switches' port numbers are specified in the figure.

☐50% ☐75% ☐100% ☐125% ☐150% ☐175%

4.c. iii **[1.75 points]** Assume that the message to be coded is 11010100. Considering the $(7, 4)$ Hamming code described above, find the corresponding coded version of this message.

4.c. iv **[2 points]** Suppose we received 0110111 and we know that it contains exactly one bit of error. Is it possible to find which bit was flipped? If yes, which bit is it? Justify your answer. When answering this question, assume the following numbering: bit number one denotes the left most bit and bit number seven denotes the right most bit.

Q5 [Ethernet Minimum Frame Size, 3 points]

Suppose the maximum round-trip propagation delay for a 10 Mbps Ethernet with range 1500 m is 51.2 μs. This yields a minimum frame size of 512 bits.

5.a **[1 point]** Consider a new Ethernet technology in which the maximum round-trip propagation delay is held as 51.2 μs, and the bandwidth rises to 100 Mbps. What should be the minimum frame size for this new technology?

5.b **[1 point]** What are the drawbacks of having such a large minimum frame size?

5.c **[1 point]** If compatibility is not an issue, how might the specifications be written so as to permit a smaller minimum frame size? You are not allowed to change the bandwidth or propagation speed of signal in the medium.

Q6 [MAC Learning Switches, 4 points]

Give the completed forwarding tables for switches S_1 to S_4 in Figure 5. Each switch should have a *default* routing entry, chosen to forward packets with unrecognized destination addresses toward "Out". Any specific-destination table entries duplicated by the *default* entry should then be eliminated.

S_1

Destination	port
default	

S_2

Destination	port
default	

S_3

Destination	port
default	

S_4

Destination	port
default	

Q7 **[Spanning Tree Protocol, 5.5 points]** Consider the switched Ethernet network of Figure 4. Assume that each switch's ID is equal to its number (*i.e.*, switch S_k's ID is set to k).

7.a **[2 points]** For each link, specify if it will be disabled after the convergence of the spanning tree algorithm.

7.a. i Link between S_2 to S_3: ☐ Disabled ☐ Active
7.a. ii Link between S_3 to S_5: ☐ Disabled ☐ Active
7.a. iii Link between S_4 to S_6: ☐ Disabled ☐ Active
7.a. iv Link between S_5 to S_7: ☐ Disabled ☐ Active

7.b **[1.5 points]** Assume that Host A is connected to Switch S_7 and Host B is connected to Switch S_3. Assume that the spanning tree algorithm has converged and all switches' MAC address tables are empty. Assume that Host A sends a frame to Host B. Which switches will process the frame sent from Host A to Host B? Select the appropriate switches below.

☐S_1 ☐S_2 ☐S_3 ☐S_4 ☐S_5 ☐S_6

7.c **[2 points]** Consider a scenario where Switch S_1 is compromised and drops all spanning tree protocol messages during the algorithm's execution. It effectively becomes silent and does not participate in the spanning tree formation. After the spanning tree converges, which network links will be disabled as a result of this malicious behavior?
[**NOTE:** This part is independent of the previous parts.]

7.c. i Link between S_2 to S_3: ☐ Disabled ☐ Active
7.c. ii Link between S_3 to S_5: ☐ Disabled ☐ Active
7.c. iii Link between S_4 to S_6: ☐ Disabled ☐ Active
7.c. iv Link between S_5 to S_7: ☐ Disabled ☐ Active

Q8 **[Variable Length Subnet Masking (VLSM), 6 points]** Consider the router and the three subnets A, B, and C attached to it, illustrated in the figure 6. The number of hosts in subnet A, B, and C are 120, 29, and 9, respectively. The subnets share the 24 high-order bits of the address space: 38.240.108.0/24. Assign subnet addresses to each of the subnets (A, B, and C) so that the amount of address space assigned is minimal, and at the same time leaving the largest possible contiguous address space available for assignment if new subnets were to be added. Then, answer the following questions.[2]

8.a **[2 points]** What is the subnet addresses of subnet A in CIDR notation and its broadcast address?

8.b **[2 points]** What is the subnet addresses of subnet B in CIDR notation and its broadcast address?

8.c **[2 points]** What is the subnet addresses of subnet C in CIDR notation and its broadcast address?

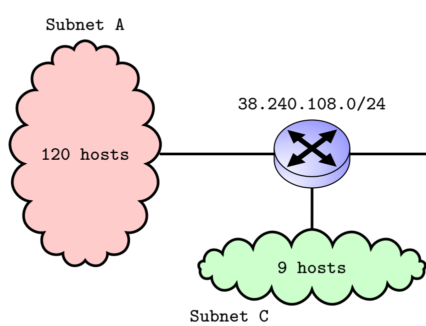


Figure 6: A Router with three subnets.

[2] The technique of using subnets of different sizes to divide an IP address space is called Variable Length Subnet Masking (VLSM).