CS 421: COMPUTER NETWORKS **FALL 2022**

FINAL
December 27, 2022
135 minutes

Name: ________________________________

Student No:________________________________

Q1	
Q2	
Q3	
TOT	

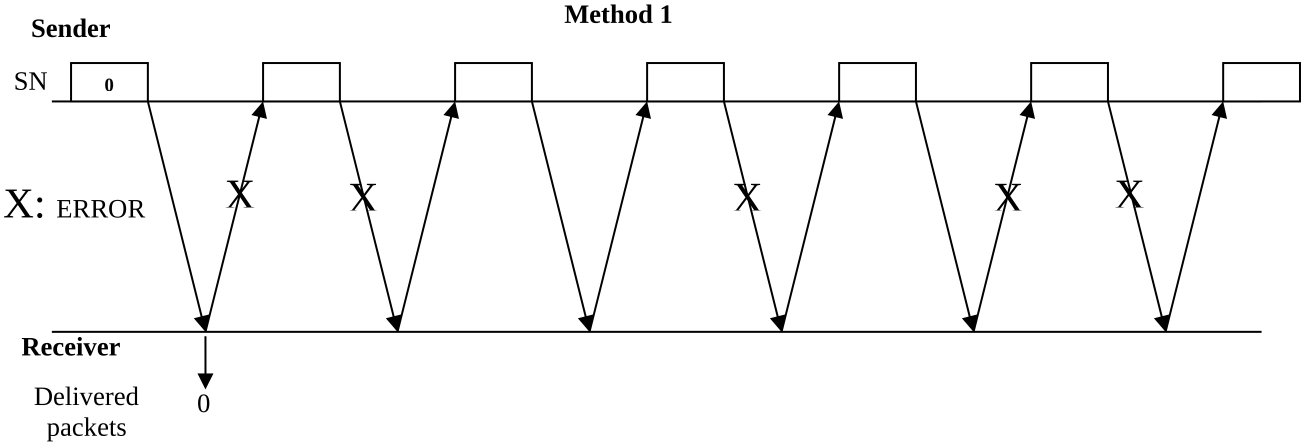
1)

a) Consider the Stop-and-Wait protocol where there are **no** lost segments, but transmission errors can occur to both data and feedback messages. Suppose that we can use the following two methods for generating the feedback information.

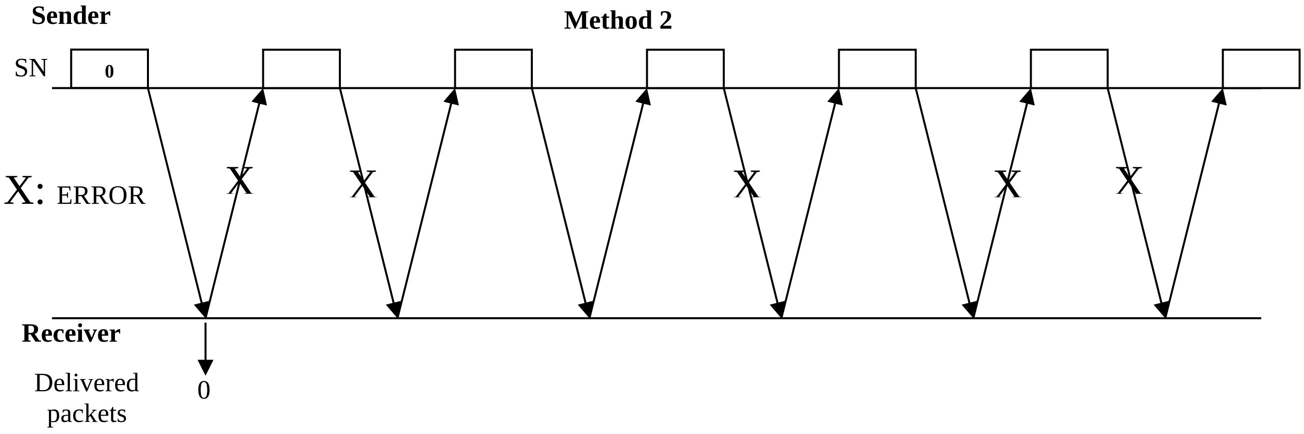
- **Method 1:** After each reception, the receiver sends an ACK or NAK message informing the sender whether the last received segment contains any detected errors (**no numbering** is used for ACKs and NAKs). The sender transmits a new segment only if it receives an error-free ACK message.
- **Method 2:** The receiver sends the sequence number of the next awaited segment (request number) after each segment is received.

i) (4 pts) Suppose a sequence of transmissions between the sender and receiver is given by the following illustration where "X" corresponds to a transmission error. For both methods, indicate the sequence number (SN) for segments sent from the sender to the receiver, type of the feedback, i.e., ACK or NAK (for Method 1), or request number (for Method 2) for segments sent from the receiver to the transmitter, the times and SNs of the packets at the receiver delivered to the application layer.

Method 1



Method 2



ii) (8 pts) In this part, we will show that Method 2 is more efficient than Method 1. Let p_1 be the probability that segments sent from the sender to the receiver will be received with errors, and let p_2 be the probability that feedback messages sent from the receiver to the sender will be received with errors. Let N_i be the average number of transmissions starting from the first transmission of a segment until the segment is successfully received for Method $i, i = 1,2$. Compute N_1 and N_2, and show that $N_2 \le N_1$. Hint: $\sum_{n=1}^{\infty} n a^{n-1} = \frac{1}{(1-a)^2}$ for $a < 1$.

b) An HTTP client and a server are communicating over a high-speed network. The distance between the client and server is 1000 km and the speed of propagation is $2x10^5$ km/s. The client wants to download a very large file from the server at a rate of 100 Mbps. You can ignore all overhead.

i) (5 pts) What is the minimum receiver buffer size, in Bytes, that is needed at the client in order to achieve a download rate of 100 Mbps?

ii) (5 pts) What is the maximum download rate that TCP can achieve if TCP window scaling is not used? Justify your answer.

c) (7 pts) Suppose that a file composed of 18 segments, each with a size of 1250 Bytes, will be transferred over a TCP connection with a round-trip delay of 10 ms and bandwidth of 10 Mbps, i.e., $10x10^6$ bps. Assume that no loss event occurs during the entire file transfer. Further assume that the slow start threshold (ssthresh) at the beginning of the TCP connection. TCP Receive Window is fixed during the entire connection at 7500 Bytes. Ignore all processing and queueing delays and assume that ACK messages have a negligibly small transmission time. How long does it take to transmit the entire file and receive the final ACK?

2)

a) (5 pts) You are given the assignment of setting subnet addresses for 5 buildings at Bilkent. The number of Internet connected PCs in each building is given in the following table. Assume that the 139.179.192.0/18 address block is given to you for this purpose. Use the following table to show the addresses of the five subnets that you created.

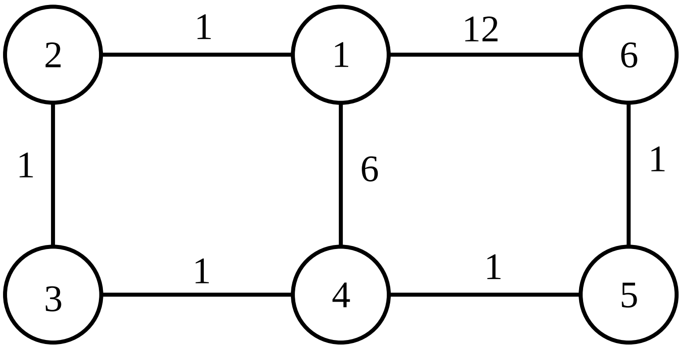
Building	# of PCs	Subnet address (CIDR format)
1	3000	
2	2200	
3	2000	
4	1500	
5	1000	

b) (5 pts) Now you have been asked to form as many as possible /24 subnets using the unassigned addresses in the original address block remaining after the assignment that you have done in a). How many /24 subnets can you form **from the unassigned addresses** in the original 139.179.192.0/18 address block after your assignments in a)?

c) (9 pts) Consider a graph $G(V,E)$, where V is the set of nodes and E is the set of edges (links). For $e \in E$, let w_e represent the weight of link e. Assume that each link weight corresponds to the probability that the link is operational and that the probability that a path is operational is given by the **product of all the weights of the links constituting the path**. Your task is to find the most reliable path between each node pair. Assume that an implementation of the Dijkstra's algorithm that computes the least cost path (path with the smallest sum of weights) between any pair of nodes in the graph is available to you as a black box. **You cannot make any changes in the given code.** Describe how you can use the implementation of the Dijkstra's algorithm provided to you to compute the most reliable paths in the network between the source node and all other nodes. Justify that your solution correctly computes the paths with the highest probability of operation as defined above.

d) (12 pts) The network below uses the distance-vector routing algorithm. Assume the following:

- Links have the same cost in both directions.
- Nodes exchange their routing info once every second, in perfect synchrony and with negligible transmission delays. Specifically, at every t = i, i = 0, 1, 2, 3,..., each node sends and receives routing info instantaneously, and updates its routing table; the update is completed by time t=i+0.1.
- At time t = 0, the link costs are as shown below and the routing tables have been stabilized. At time t = 0.5, the cost of the link (3,4) becomes 7. There are no further link cost changes.
- Route advertisements are **only exchanged periodically**, i.e., there are no immediate route advertisements after a link cost change. Hence the first route advertisement after the link cost change at t = 0.5 sec occurs at t = 1.0 sec. *Note:* However, whenever a link cost change occurs, the two nodes at the endpoints of this link immediately make corresponding changes in their distance tables.
- Assume that the distance vector algorithm **does not use poisoned reverse**.



Give the evolution of the distance tables with respect to destination 6. Specifically, give the distance table entries for destination 6 at nodes 1-5, for t = 0.1, 0.5, 1.1, 2.1, ..., **until** all distance vectors stabilize. Present your final answer in the table given below where $D^i(j)$ is the distance vector element denoting the distance from *i* to *j*.

Time, t	$D^1(6)$ via			$D^2(6)$ via		$D^3(6)$ via		$D^4(6)$ via			$D^5(6)$ via	
	2	4	6	1	3	2	4	1	3	5	4	6
0.1												
0.5												
1.1												
2.1												
3.1												
4.1												
5.1												
6.1												
7.1												
8.1												
9.1												
10.1												

3)

a) (10 pts) Suppose the data sequence 01101100110 is transmitted using the generator sequence 110101. Compute the CRC bits and the transmitted bit sequence. Determine whether the error is detectable if the highest order 4 bits of the received sequence are errored.

b) (5 pts) Consider an Ethernet LAN using CSMA/CD running at 100 Mbits/sec. The propagation speed for the signal over the cable is $2x10^8$ m/sec. The distances between the nodes in this Ethernet are given in the following table. Compute the minimum frame size **in Bytes** so that the CSMA/CD algorithm will work properly for this LAN.

Distance (m)	A	B	C	D
A	-	100	150	400
B	100	-	50	300
C	150	50	-	250
D	400	300	250	-

c) Consider three nodes A, B and C on a 100 Mbits/sec Ethernet. Suppose these three nodes are involved in a collision which is the third collision for A's frame, fourth collision for B's frame and second collision for C's frame. After the collision is detected (we assume that all nodes detect the collision exactly at the same time), nodes calculate their backoff times according to the binary exponential backoff algorithm.

i) (5 pts) What is the probability that the first transmission after the above collision will be a successful retransmission by B?

ii) (5 pts) What is the probability that the first transmission after the above collision will be a successful retransmission by C?

iii) (5 pts) What is the probability that the first transmission after the above collision will be a collision involving all three nodes?

iv) (5 pts) What is the probability that the first transmission after the above collision will be a collision involving only nodes A and B?

v) (5 pts) What is the probability that the first transmission after the above collision will be a collision involving any combination of the three nodes?