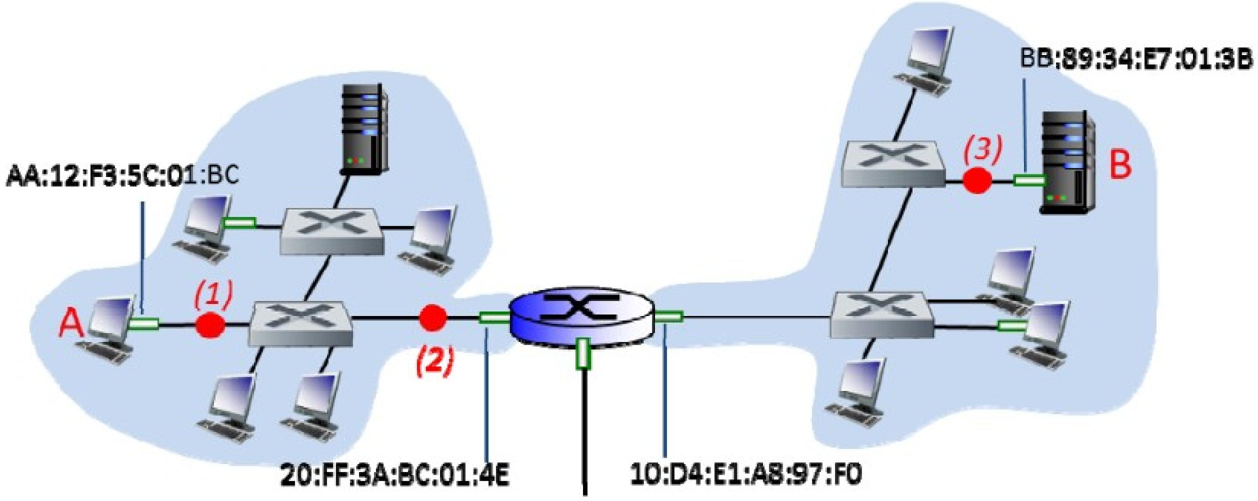
Problem 1: Network Layer – Data Plane – IP Addressing and Subnets (5 points)

Consider the network shown below:



1. (1.0 point) Assign IP address ranges to the subnets containing hosts A and B, and assign IP addresses in these ranges to hosts A and B. (You don't have to assign IP addresses to any hosts except A and B, but you do need to specify the address range being used by each subnet). Your subnet addressings should use the smallest amount of address space possible.

   Answer: Because there are less than eight but more than 4 nodes in each subnet, we'll need three address bits for each subnet. So let's assign the left subnet XX.YY.ZZ.xxxx0***/29, where the XX.YY.ZZ are 8 bit numbers. Each x is a bit and the three *'s correspond to the three address bits for this network. For the right subnet, well use XX.YY.ZZ.xxxx1***/29. A will have an IP address of XX.YY.ZZ.xxxx0000 and B will have an IP address of XX.YY.ZZ.xxxx1000.

2. (1.0 point) What IP address range can the router advertise to the outside for all of the hosts reachable in these two subnets? Again, you should choose your answer in (1) above so that the minimum-size address space is advertised here.

   Answer: XX.YY.ZZ.xxxx/28

3. (1.0 point) Does the router interface with link-layer address 20:FF:3A:BC:01:4E have an IP address? If so, what is the role of the IP address of the router's IP interface in forwarding datagrams through the router.

   Answer: Yes. That's the address that a host in the left network will use to determine the MAC address to send frames to, containing datagrams that need to be routed through the router. The router address however, won't appear in the IP datagram.

4. (1.0 point) Consider an IP datagram being sent from A to B using Ethernet as the link layer protocol in all links in the figure above. What are the (a) Ethernet source and destination addresses and (b) IP source and destination addresses of the IP datagram encapsulated within the Ethernet frame at points (1), (2), and (3) in the above example for a datagram going from A to B.

Answer: (1): ETH source: aa:12;F3:5C:01:BC, ETH dest: 20:FF:3A:BC:01:4E IP source: XX.YY.ZZ.xxxx0000; IP dest: XX.YY.ZZ.xxxx1000 see (a) above (2) same as (1) (3) ETH source: 10:D4:E1:A*:97:FO, ETH dest: BB:89:34:E7:01:3B IP source: XX.YY.ZZ.xxxx0000; IP dest: XX.YY.ZZ.xxxx1000 same as (1) above.

5. (1.0 point) Suppose all switches in the above example are learning switches. Consider the datagram being sent from A to B; neither A nor B have sent any frames or datagrams in the network before.

   - How many of the 11 hosts in the network receive the frame containing the datagram sent by A? Explain your answer briefly.

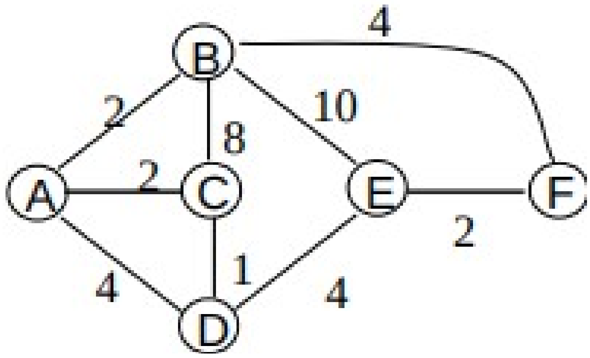
     Answer: all 11, since no switch knows where B is located (since B hasn't sent anything), all switches will broadcast the frame containing the IP datagram from A. Note that different frames are broadcast on the left and right subnets (e.g., the frames have different source and destination MAC addresses, see above), but both contain the datagram from A.

   - Suppose the server in the upper part of the left network sends a datagram to A shortly after the A-to-B datagram is sent. How many of the 11 hosts in the network receive the frame containing the datagram sent by this server? Explain your answer briefly.

     Answer: Only A will receive that, since all of the switches know the outgoing port leading to A, as a result of learning where A is, as a result of the initial A-to-B transmission.

Problem 2: Network Layer – Control Plane – Link State and Distance Vector (5 points)

Consider the network below:



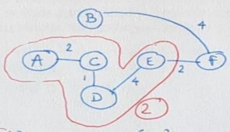
1. (2.0 points) Show the operation of Dijkstra's (Link State) algorithm for computing the least cost path from E to all destinations.
2. (0.5 points) From these results, show the least cost path from E to A, and briefly describe (in a sentence) how you got that answer from your work in part a).
3. (1.5 points) What are distance vectors in nodes E, D, and C? In one or two sentences, explain how the least cost path from E to A was determined by E based on these three distance vectors. Note: you do not have to run the distance vector algorithm; you should be able to compute distance vectors by inspection.
4. (1.0 points) Let us focus again on node E and distance vector routing. Suppose all distance vectors have been computed in all nodes and now suppose that the link from E to B goes down. Approximately how many distance vector messages will be sent by node E as a result of this link going down? Explain your answer.

Problem 2 :

(1)

	Iteration	N'	C(A), P(A)	C(B), P(B)	C(C), P(C)	C(D), P(D)	C(E), P(E)	C(F), P(F)
Init. →	0	{E}	+∞	10, E	+∞	4, E	–	2, E
	1	{E, F}	+∞	min{10, 2+4 ←} 6, F	+∞	4, E	–	–
	2	{D, E, F}	min{+∞, 4+4 ←} 8, D	6, F	min{+∞, 4+1 ←} 5, D	–	–	–
	3	{C, D, E, F}	min{8, 5+2 ←} 7, C	min{6 ←, 5+8} 6, F	–	–	–	–
	4	{B, C, D, E, F}	min{7 ←, 6+2} 7, C	–	–	–	–	–
End →	5	{A, B, C, D, E, F}	–	–	–	–	–	–

(2) Spanning Tree :



We build the Spanning Tree

(3)

$$D_E = \begin{array}{c} A \\ B \\ C \\ D \\ E \\ F \end{array}\begin{bmatrix} 7 \\ 6 \\ 5 \\ 4 \\ 0 \\ 2 \end{bmatrix} = \quad D_D = \begin{array}{c} A \\ B \\ C \\ D \\ E \\ F \end{array}\begin{bmatrix} 3 \\ 5 \\ 1 \\ 0 \\ 4 \\ 6 \end{bmatrix} = \quad D_C = \begin{array}{c} A \\ B \\ C \\ D \\ E \\ F \end{array}\begin{bmatrix} 2 \\ 4 \\ 0 \\ 1 \\ 5 \\ 7 \end{bmatrix}$$

$$D_E(A) = D_E(D) + D_D(A)$$

$$D_D(A) = D_D(C) + D_C(A)$$

(4) [redacted] No messages! Link B – E is not used in any shortest path.

Problem 3: Transport Layer – “Pipelined” Protocols (Go-Back-N and Selective Repeat)

1. Suppose that a sender is connected to a receiver over a 1 Gbps (1,000,000,000 bits per second) link, with an RTT propagation delay of 10 milliseconds. Packets are 10,000 bits long. What size window is needed to ensure that this link’s utilization is at least 50 percent?

   Answer: A packet takes 10-5 secs to transmit, so at full utilization, a sender can send 1000 packets in 10 msec. At 50% utilization, that would thus be 500 packets.

2. Consider a window of size N and the Go-Back-N protocol. Suppose the current sender window at time t starts at sequence number x (i.e., that the sender window covers sequence numbers x to x+N-1). Is it possible that the receiver window at time t start at (i) a sequence number less than x, (ii) equal to x, or (iii) greater than x? Explain your answers briefly [Hint: more than one of cases (i) – (iii) may be true].

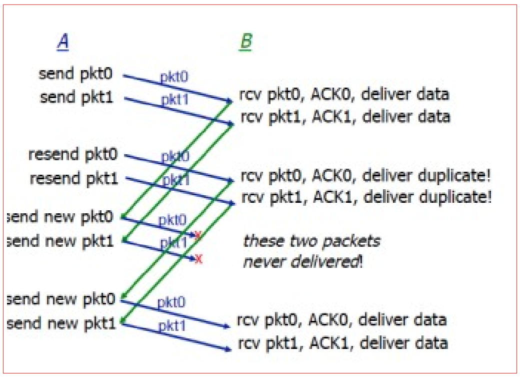
   Answer: (i) can’t happen. (ii) suppose every packet sent by the sender has been ACKed by the receiver and all ACKs have been received by the sender. In this case, the windows are aligned. (iii) Let x be the smallest sequence number of a packet sent by the sender and received and ACK by the receiver, but for which the sender has yet to receive this ACK. In this case, the sender window beings at x, and the receivers window is larger than x (since x has been ACKed).

3. Does your answer to b) change for the case of Selective Repeat?

   Answer: No. The arguments above hold in both cases.

4. Consider the GBN protocol and assume that the window size, N (which you can choose), is equal to the size of the sequence number space. Give an example (in the form of a sender/receiver timing diagram showing data and ACK messages being exchanged) showing that the receiver may deliver duplicate copies of data to the application layer above.

   Answer: see below for the case of N=2, for d) and e):

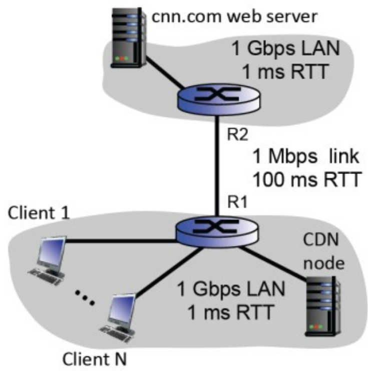


5. Again consider the GBN protocol and assume that the window size, N, is equal to the size of the sequence number space. Give an example (in the form of a sender/receiver timing diagram showing data and ACK messages being exchanged) showing that the receiver may not deliver some of the data sent by the sender to the application layer above.

   Answer: can use answer from 2d above.

Problem 4:

Consider the scenario shown in the figure to the right. N=10 clients and a CDN node (explained below) are in a local area network with a Gbps (1,000,000,000) path with a 1 msec RTT between any two hosts in the LAN. The client LAN is connected to another network containing an origin server, cnn.com, via a 1 Mbps (1,000,000 bps) link between routers R1 and R2 with a 100 ms RTT delay. All web pages being served by cnn.com are 500Kbits in size. You can assume that any other messages involved below are very short, and thus have a transmission time of zero, but do experience propagation delays.



1. a) Suppose that the 10 clients all make requests to the cnn.com server. If all clients make requests at the same rate, and ignoring web browsers and web caches, what is maximum rate that CNN content (in pages per second) can be delivered to a single client.

   Answer: 100Kbps per client

2. b) Now suppose the propagation delay of the R1-to-R2 link increases by a factor of 10. How does your answer to a) change?

   Answer: No change!

3. c) Suppose a client makes an HTTP request to the cnn.com web server. How much time is required from when the user first enters the cnn.com URL into a browser and when the page is received at that client. Ignore browser caching. You need not consider DNS delays but should take into account delays involving transport layer messages that are sent.

   Answer: 202 msec propagation delay for TCP handshake with cnn.com server. 202 msec propagation delay for HTTP GET and reply cnn.com server. 500 msec transmission delay on the 1Mbps link + .5msec transmission delay on each of the LAN links. Total delay: 904. msecs

The CDN (content distribution network) node in the client LAN contains copies of a fixed set of pages from the CNN web site (intentionally placed there by the CDN). If a client requests content from the CNN server (via a traditional HTTP GET) that is available in the CDN node, the CNN server will respond to the GET request with a short “redirection” reply that tells the requesting client to get the content from the CDN node.

1. d) Suppose that the CDN node, which can hold x pages of content, is filled with the most popular content on the cnn.com site, and the result is that 50% of the requests made to the cnn.com server are for content that is available in the CDN node. How does you answer to a) change?

   Answer: Since only half the pages need be delivered over the bottleneck link, the rate at which pages from cnn.com (and its CDN node) is twice as large as in a)

2. e) Now suppose that the CDN node is replaced by a traditional web cache that can also hold x pages (where x here is the same x as in d)). Assuming the client request characteristics are unchanged from d), would you expect that the fraction of time that content is found in the web cache is greater than, equal to, or less than 50%? Briefly explain your answer.

Answer: the fraction of time that the content would be found in the cache would be less because sometimes unpopular content would be requested, causing content that is more popular to be flushed out of the cache, causing more misses.