PRACTICE PROBLEMS

DATA AND COMPUTER COMMUNICATIONS

TENTH EDITION

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CHAPTER 2 PROTOCOL ARCHITECTURE

2.1 Distinguish among service access point address, Internet address, and physical address.

2.2 Consider a 4-layer protocol implementation with application, TCP, IP, and Ethernet layers in that order (top to bottom). Each layer requires a header except the Ethernet layer, which requires a header and trailer. The application header is 16 bytes in length, TCP header 20 bytes, IP header 20 bytes, and let the Ethernet header be 14 bytes, and the trailer 4 bytes (ignore the preamble and gap).

- **a.** Sketch and label the layered protocol model
- **b.** Sketch a packet for this system carefully showing and labeling all headers, trailers, and data fields.
- **c.** Assume a maximum data field for an Ethernet frame of 1500 bytes. What is the overhead (in %) for a 4096-byte application message? Hint: the message must be segmented into multiple frames and be careful of how you consider the data field in the Ethernet frame.

CHAPTER 3 DATA TRANSMISSION

3.1 We specified in Chapter 3 that the general sine wave can be written as

$$s(t) = A \sin(2\pi f t + \phi)$$

We also defined the period as $T = 1/f$. The frequency in radians can be expressed as $\omega = 2\pi f$. The relative position or delay of the signal is expressed as an angular delay, and can also be expressed in units of time as a delay t_0 by writing the signal as

$$s(t) = A \sin 2\pi(ft - t_0)$$

Find the values of A, f, ω, T, ϕ, and t_0 for each of the following functions:

a. $5 \sin 6(t - 1)$

b. $5 \sin (120t + 0.75)$

c. $6 \sin (2\pi/5)(t - 3)$

d. $6 \cos (10\pi t - 0.1)$

3.2 Consider a noiseless channel of 10 kHz and devices with the ability to emit and detect 16 distinct signal levels. What is the maximum data rate of this channel?

3.3 What is the channel capacity for a teleprinter channel with a 300 Hz bandwidth and a signal-to-noise ratio of 30 dB, where the noise is white thermal noise?

3.4 What is the bandwidth of the following signal:

$m(t) = 5 \cos 1000\pi t \cos 4000\pi t$

Hint: Consult the trigonometric identities in the Math refresher document at http://www.computersciencestudent.com

3.5 Consider an asynchronous transmission system with 1 start bit, 3 data bits, 1 parity bit, and 2 stop bits (see Figure D.1 in Appendix D). Assume Pr[bit error] = 0.05 and bit errors are independent. Assume that the data bits and parity bit can be in error, but the start and stop bits are never in error.

a. What is the maximum utilization possible on this link (assuming no errors)?

b. What is the probability that a received character has no errors?

c. What is the probability that 10 characters in a row are received with no errors?

CHAPTER 4 TRANSMISSION MEDIA

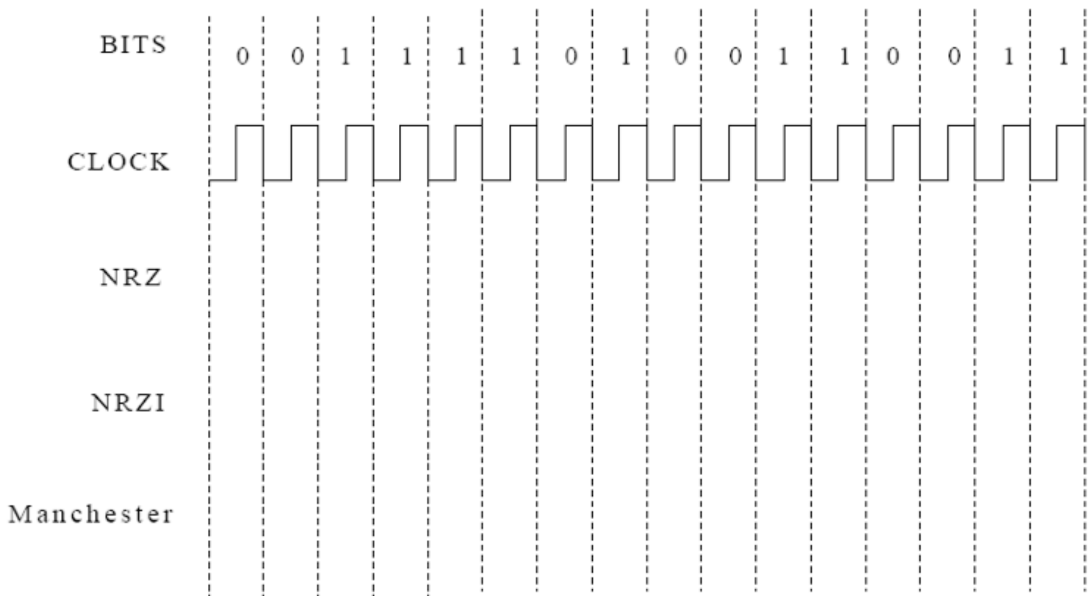
4.1 Determine the db gain of a receiving antenna that delivers a 40-μV signal to a transmission line over that of an antenna that delivers a 20-μV signal under identical circumstances.

4.2 An antenna that has a gain of 6 dB over a reference antenna is radiating 700 W. How much power must the reference antenna radiate in order to be equally effective in the most preferred direction?

4.3 An antenna is to be installed to receive a line-of-sight transmission from an antenna located at a distance of 100 km from this installation and which is 250 m in height. Determine the minimum necessary height of the receiving antenna.

CHAPTER 5 SIGNAL ENCODING TECHNIQUES

5.1 a. Show the NRZ, Manchester, and NRZI encodings for the bit pattern shown in the figure below. Assume that the NRZI signal starts out low.



b. - d. For each of these encoding schemes, identify whether the encoding can have problems with:

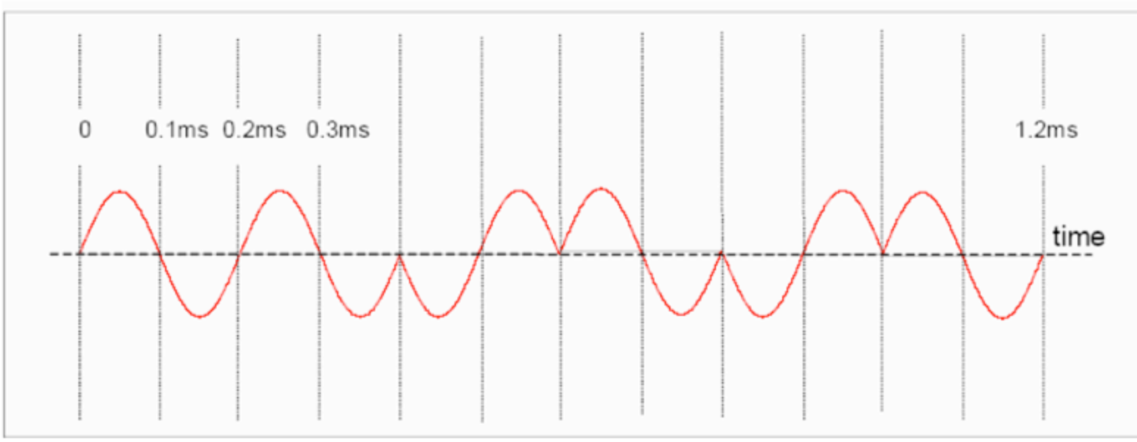
A. Long strings of 0s

B. Long strings of 1s

C. Both long strings of 1s or long strings of 0s

D. None of the above

5.2 A digital bit stream that is input to a BPSK modulator is modulated and then sent over the air. The figure below captures a pattern/portion of the transmitted signal. The rate at which data arrives at the modulator is 5000 bps. Which digital data pattern is represented with the given signal? (Namely, what is the data bit sequence encoded into the signal as shown in the figure?)



5.3 A binary channel with a bit rate R_b = 36 kbps is available for PCM voice transmission. Assume the spectrum of the channel is from 0 to 3.2 kHz, for a bandwidth of B = 3.2 kHz. Find appropriate values for:

a. The sampling rate f_s

b. The number of bits n per sample

c. The number of quantizing levels L

5.4 An analog signal is sampled at the Nyquist rate f_s and quantized into L levels. Derive an expression for the time duration τ of 1 bit of the binary-encoded signal.

5.5 In a binary PCM system, the output signal-to-quantizing noise ratio is to be held to a minimum of 40 dB.

- **a.** Determine the number of quantizing levels L.
- **b.** What is the corresponding output signal-to-quantizing noise ratio?

CHAPTER 6 ERROR DETECTION

6.1 Suppose that a synchronous serial data transmission is clocked by two clocks (one at the sender and one at the receiver) that drift one minute per day in opposite direction. Assume that a bit waveform will be good if it is sample within 40 percent of its center. How long a sequence of bits can be sent before possible clock drift could cause a problem?

6.2 We consider the transmitted sequence 0111000110. The receiver gets 1111100111. What is the Hamming distance between these 2 sequences?

6.3 Consider a linear block code where each codeword consists of three data bits and one even parity bit. Find all code words in this code. How many bit errors can the code detect? How many bit errors can the code correct?

6.4 For 32-bit messages, how many check bits are needed to provide 1-bit error correction? Justify your answer by deriving the number of check bits needed for an arbitrary m-bit message and 1-bit errors.

6.5 Consider a block of $m \times m$ bits. Suppose we have a parity-check bit for each row and a parity-check bit for each column.

- **a.** What is the data rate in terms of information bits transmitted per coded bit?
- **b.** Is there more or less redundancy in this code compared to the one-dimensional single-bit parity check code with the same number of data bits?

6.6 A sender and receiver use CRC as the means of detecting errors. The generator polynomial, P, used by both the server and the receiver is, P = $X^2 + 1$. Assume that the receiver receives a frame F = 111001. Is F without error(s)? Explain your answer carefully, that is, explain your reasoning.

6.7 The USB protocol uses a CRC with the polynomial $G(x) = x^5 + x^2 + 1$.

a. Calculate the CRC for the bit string 1100011110110001 00000.

b. Draw the shift register corresponding to G(x).

6.8 Consider the use of an even parity bit for a data block of 3 bits.

a. Show all possible code words (data plus parity bit).

b. Which error patterns can the code detect?

c. What is the probability of an undetected bit error, assuming that all bit errors are independent and that the probability of a bit error is p = 0.01?

CHAPTER 7 DATA LINK CONTROL PROTOCOLS

7.1 Consider host A communicating with host B over a 10^8 bits per sec (bps) channel of length 10,000 m. Assume a propagation speed of 2.5×10^8 m/s. For a packet of 1000 bits sent from A to B calculate the following:

a. Propagation delay (the time it takes for a bit to travel from sender to receiver)

b. Transmission delay (the time it takes for the sender to issue all of the bits of the packet)

c. Total delay

7.2 Consider two hosts, A and B (see below), connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

a. Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

b. Suppose Host A begins to transmit the packet at time t = 0. At time t = t_{trans}, where t_{trans} is the transmission time, where is the last bit of the packet?

c. Suppose the propagation delay d_{prop} is greater than t_{trans}. At time t = t_{trans}, where is the first bit of the packet?

d. Suppose $s = 2.5 \times 10^8$, L = 100bits, and R = 28 kbps. Find the distance m so that $t_{trans} = d_{prop}$

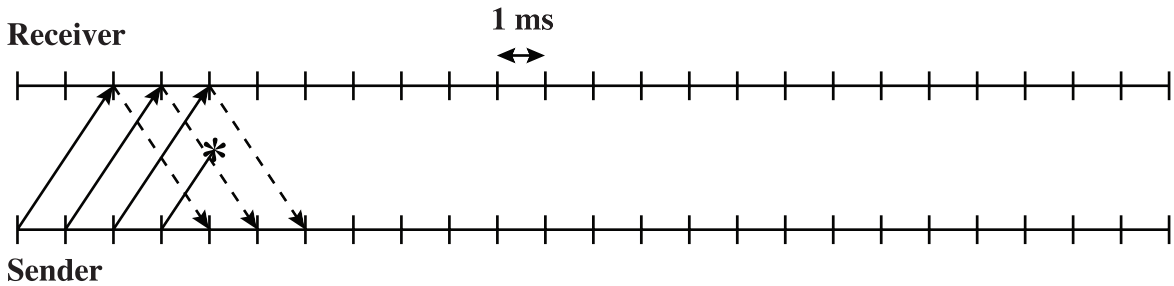
7.3 Consider the sliding window ARQ protocol. Suppose that the protocol uses a very large sequence number space that would not wrap around, and it starts from 0. And the sender always has frames to send. The receiver always sends an ACK when receiving a CRC-validated data frame. Define Send Window Size (SWS) = upper bound on number of unacknowledged frames a sender can transmit; Receive Window Size (RWS) = number of out-of-order frames a receiver will accept. Let SWS = 2 and RWS = 1. Moreover, we introduce a new retransmission scheme to the sender. In this scheme, the sender will immediately send the oldest unacknowledged frame if it receives an old ACK. An ACK is considered old if it has been received before or the value of the ACK is 0. Assume that this retransmission scheme always retransmits earlier than the case with timeout mechanism.

a. Draw a time-line diagram for the case where the first data frame (SN = 0) has bit errors and is dropped by the sender. All subsequent transmissions (data and ACK) are assumed to be error-free. Draw the diagram until the receiver’s NFE (next frame expected) = 3.

b. Draw a time-line diagram for the case where the transmissions of the first data frame (SN = 0) and its ACK are error-free, but the second data frame (SN = 1) has bit errors and is dropped by the sender. All subsequent transmissions (data and ACK) are assumed to be error-free. Draw the diagram until the receiver’s NFE (next frame expected) = 3.

7.4 A sliding window protocol is used between a sender and a receiver. The sender wants to send 10 packets with a rate 1packet/1ms. The propagation time is 2 ms for any packet, and the time out is 8 ms. The time for processing packet is negligible

a. Assume that Go-Back-N is used, window size is 5 and the packet #4 is lost. Complete the figure below that shows packets from sender to receiver and ACK packets in the reverse direction.



b. Same as (a) with Selective Reject ARQ.

c. Assume that sender wants to send 20 packets, we use selective reject protocol and the packet #4 is lost. What is the minimum window size so that the window is never full? Explain.

7.5 Draw a time line diagram for the transfer of frames on a point-to-point network from a sender node to a receiver node. The diagram should show the time period starting with the transmission of frame 0 by the sender and up to the time when the sender successfully receives an ACK for frame 7. During the transmission the third frame (frame 2) is lost. The Go-Back-N sliding window algorithm is used with SWS = 4 frames and RWS = 3 frames. The receiver uses cumulative ACKs. Assume a time out interval of 2RTT. Moreover, assume that the transmission time (insertion time) of a frame is equal to 0.25 RTT. At the receiver, assume that frames can be processed instantaneously if they arrive in order. On each data frame and ACK frame, indicate the frame number (from 0). In addition, you need to indicate what action is taken by the receiver when a frame is received, for e.g. Processed Buffered or Discarded.

CHAPTER 8 MULTIPLEXING

8.1 Suppose synchronous time-division multiplexing is used to share a link among 6 channels, and that channel 1 appears first in the frame and channel 6 appears last. If the bit string

100111000110001111100000

is sent along the data link (leftmost bit is transmitted first; rightmost transmitted last), what bit string is actually transmitted along channel 3? [Again, list the bits in order of arrival, left to right]

8.2 George wants to setup a wireless network in a reserved frequency band for his small department to use. The frequency band reserved for the department is 500MHz wide, for which Peter, Bruce, David, George, and Jacob will share. George, who did not pay attention during lecture, is trying to figure out the best way to multiplex the channel such that each member can achieve the best throughput in the network. The only method he can currently remember is time division multiplexing (TDM). To test the network the staff will each perform a 1000-kB file transfer simultaneously. Ignore propagation delay and handshaking, and assume a users transceiver is tunable to any frequency and can transmit data at a maximum rate of 2 Mbps, using 100 MHz of the channel. There is a maximum packet size of 1000 bytes, no header is used. Assume a noiseless channel (no loss will occur), such that no ACKing or collision detection scheme is needed.

In the TDM protocol that George develops, each staff member is allowed to transmit a single packet, to avoid interference 6 ms of silence is required, followed by the next staff member’s packet transmission.

Therefore, a single round of transmissions looks like this, note the order: George, 6ms, Bruce, 6ms, David, 6ms, Peter, 6ms, Jacob, 6ms. Using this protocol, how long will it take George's 1000-kB file transmission to finish?

8.3 A signal $m_1(t)$ is band-limited to 3.6 kHz, and three other signals — $m_2(t)$, $m_3(t)$, $m_4(t)$ — are bandlimited to 1.2 kHz each. These signals are to be transmitted using synchronous TDM.

- **a.** Set up a scheme similar to Figure I.1 in Appendix I for accomplishing this multiplexing requirement, with each signal sampled at its Nyquist rate.
- **b.** What must be the speed of the SCAN module, in samples per second?
- **c.** If the SCAN output is quantized with L = 1024 and the result is binary coded, what is the output bit rate?
- **d.** Determine the minimum transmission bandwidth of the TDM channel.

CHAPTER 9 WAN TECHNOLOGY AND PROTOCOLS

9.1 Draw a figure similar to Figure 9.8 for an STS switch.

9.2 Suppose that between a sending host and a receiving host there is exactly one packet switch. The transmission rates between the sending host and the switch and between the switch and the receiving host are R1 and R2, respectively. Assuming that the router uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length L? (Ignore queuing and propagation delay.)

9.3 For a link with capacity of 1Mbps, what is the maximum number of users can be supported at the same time in the following situations:

- **a.** Circuit switching
- **b.** Packet switching such that the probability of exceeding the maximum capacity is less than 0.0004

Assume that on average each user is active 10% of the time, and when active has a rate of 100 kbps. Show your solution steps and calculations

9.4 Consider sending a file of $F = M \times L$ bits over a path of Q links. Each link transmits at R bps. The network is lightly loaded so that there are no queuing delays. When a form of packet switching is used, the $M \times L$ bits are broken up into M packets, each packet with L bits. Propagation delay is negligible.

- **a.** Suppose the network is a packet-switched virtual circuit network. Denote the VC set-up time by t_s seconds. Suppose the sending layers add a total of h bits of header to each packet. How long does it take to send the file from source to destination?

b. Suppose the network is a packet-switched datagram network and a connectionless service is used. Now suppose each packet has 2h bits of header. How long does it take to send the file?

c. Finally, suppose that the network is a circuit-switched network. Further suppose that the transmission rate of the circuit between source and destination is R bps. Assuming ts set-up time and h bits of header appended to the entire file, how long does it take to send the file?

9.5 Considering a small network of four hosts and three links as depicted in the figure below. A 1,024,000 bits message is to be sent from A to D. The data rate of the first two links is 0.4 MB/second, but the link between C and D is 1.6 MB/sec. Propagation delays of the links are negligible.

$$\mathbf{A} \rightarrow \mathbf{B} \rightarrow \mathbf{C} \rightarrow \mathbf{D}$$

a. Assume that circuit switching is used and the total circuit set-up time is 100 ms, what is the time to send the message from A to D?

b. Assume that message switching is used and queuing delays are negligible, what is the time to send the message from A to D?

c. Assume that packet switching is used, packet size is 128 bytes and header size is 22 bytes (128 bytes is only payload, excluding header), what is the time to send the message from A to D? Hint: throughput of a pipeline is decided by how long it will take to pass the bottleneck step

CHAPTER 10 CELLULAR WIRELESS NETWORKS

10.1 **a.** Consider an area of 1260 square km covered by a cellular network. If each user requires 200 kHz for communication, and the total available spectrum is 40 MHz, how many users can be supported without frequency reuse?

b. If cells of area 30 square km are used, how many users can be supported with cluster sizes of 7?

10.2 Consider a wireless system using FDMA and 64-QAM modulation. Each channel is 200 KHz and the total bandwidth is 20 MHz, used symmetrically in both directions. Assume that the BS employs 120-degree beam-width antennas. Given spectral efficiency of 64-QAM is 5 bps/Hz. Find

a. The number of subscribers supported per cell

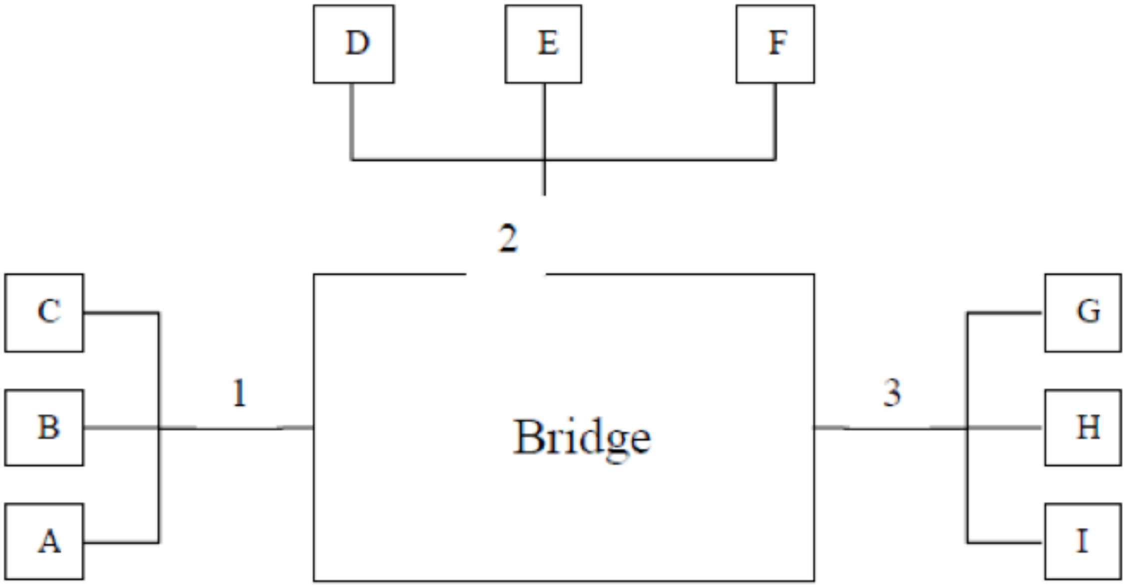
b. The total data capacity, assuming 40 cells

CHAPTER 11 LOCAL AREA NETWORKS

11.1 Bridges are self-learning (plug-and-play) devices that implement filtering/forwarding of frames on the same LAN. A bridge maintains a bridge table, which is a mapping between MAC addresses of nodes in the LAN and its (the bridge's) interfaces.

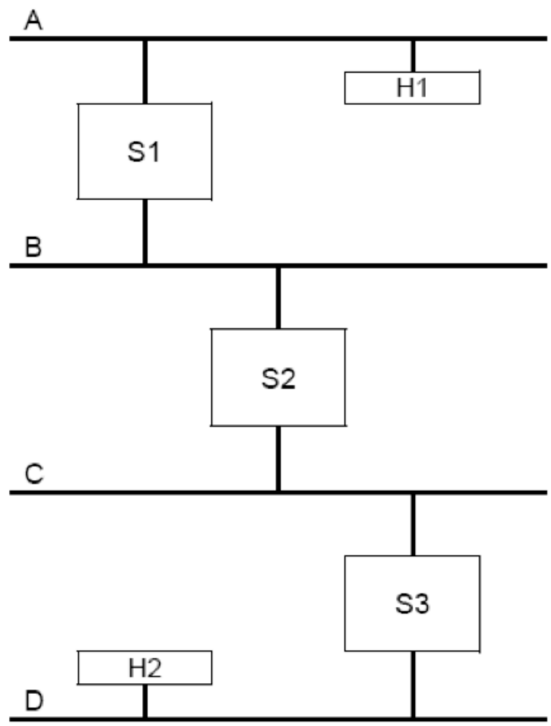
- **a.** When the bridge is first turned on, its bridge table is empty. Explain how a bridge learns the information that it uses to fill in its bridge table.
- **b.** When a bridge detects a frame on one of its interfaces it filters the frame and decides whether the frame should be forwarded to other interfaces and, if so, to which interface(s). Describe the algorithm that the bridge uses to do this filtering and forwarding.

11.2 Consider the following diagram of a LAN composed of three LAN segments connected by a bridge. Assume that the bridge table starts off empty and the given sequence of frames is sent, in the given order (frame 1, frame 2, etc.). As the bridge filters the frames it is using the standard bridge-learning algorithm to fill in its table. For each frame write down to which interfaces (if any) the Bridge forwards the frame (the answer to the first one is filled in for you) Note that it is possible that in some cases the Bridge will drop the frame and not forward it. If this happens you should say so.



Frame	Source node	Destination node	Bridge forwards frame to interfaces #
1	A	D	2,3
2	H	D	
3	C	H	
4	G	H	
5	E	D	
6	B	E	

11.3 Consider a network path, consisting of four 10-Mbps LAN bus Ethernet links (segments) A, B, C, D connected by the three store-and-forward switches S1, S2, S3 as shown in the figure below. Assume that each Ethernet link introduces a propagation latency of 10 microseconds, but the switches introduce no queuing delays.

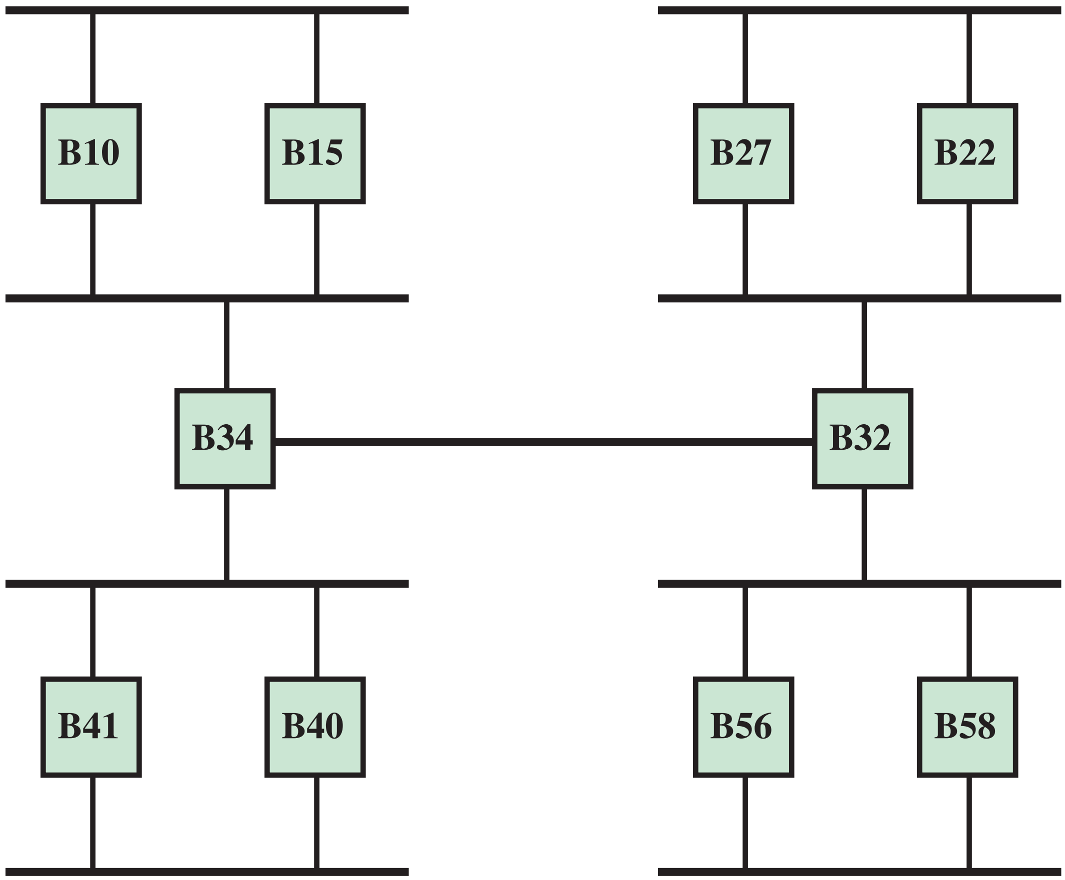


a. Calculate the path's one-way latency (total packet delay) for sending a 1-kB frame from Host H1 to Host H2

b. Calculate the effective data rate for sending a 1-kB frame across the path

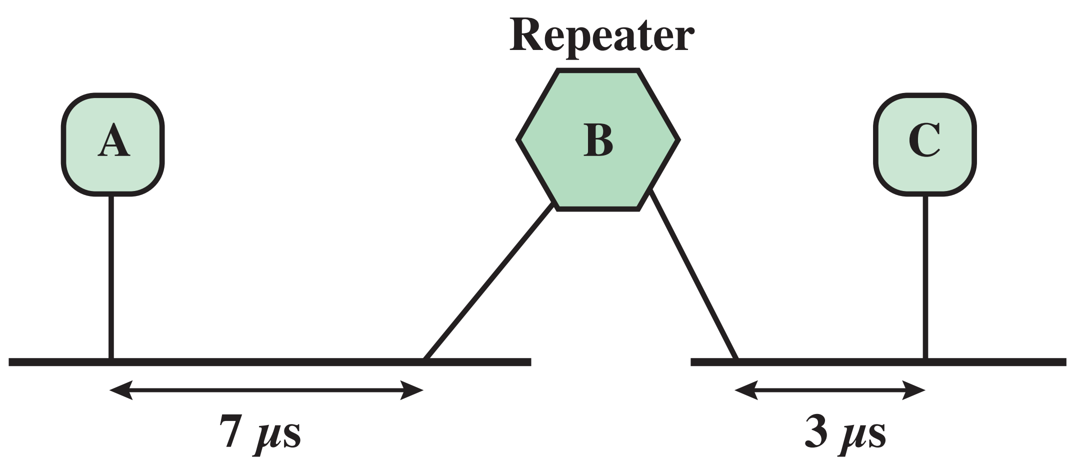
c. Calculate the effective data rate for sending a sequence of 1-kB frames if the source H1 must wait for a 20-byte ACK of the previous frame before it can send the next packet to destination H2.

11.4 Consider the following diagram of a bridged LAN. Review the material on the spanning tree algorithm in Appendix K. Which bridges would be used in forwarding packets using the spanning tree algorithm?



CHAPTER 12 ETHERNET

12.1 Consider hosts A and C connected by two Ethernet segments, with a repeater B in the middle. The segments are 10 Mbps and introduce a latency of 3 μs and 7μs respectively.



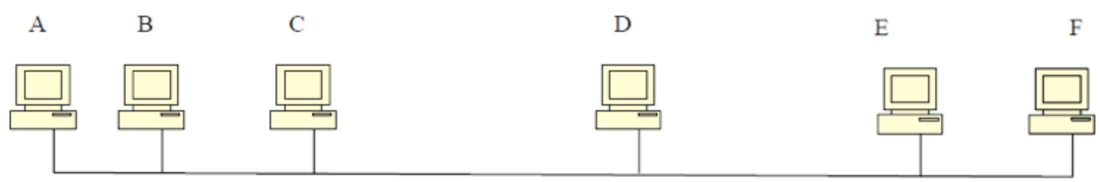
A is transferring data to C by sending Ethernet frames with a 1500-byte payload. After sending a frame, it waits for an acknowledgment from C before sending the next one. The acknowledgment has a 10-byte payload. Recalling that an Ethernet frame includes an 8-byte preamble and a 14-byte header,

- **a.** Calculate the effective data rate of the data transfer.
- **b.** Calculate the effective data rate if B were replaced by a bridge.
- **c.** Calculate the effective data rate if B were replaced by a cut-through switch.

12.2 Suppose nodes A and B are attached to opposite ends of a 100 Mbps Ethernet cable segment. Suppose A begins transmitting a frame and, before it finishes, B begins transmitting a frame. In order for A to detect collision with B, what should be the maximum length of the Ethernet cable segment?

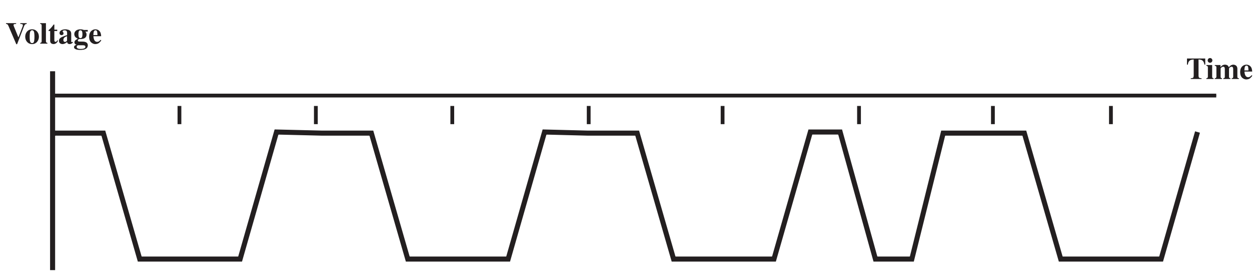
(Assume that the transmit frame size is 500 bits and signal propagation speed is 2×10^8 m/sec.

12.3 Consider the following linear network



Assume that propagation speed of electromagnetic waves sent over the medium is 2×10^8 m/s and the transmission rate of the network is 10 Mbps. Also, assume that we are using a CSMA/CD protocol with minimum frame size of 400 bits. What is the maximum length of the linear network, i.e., distance from A to F that will ensure that CSMA/CD will work properly for this network?

12.4 The waveform in the following figure shows the start of a Manchester encoded Ethernet frame. How many bits before the Start of Frame Delimiter (SFD) are shown in this figure? Note, for each octet in an Ethernet frame, the least significant bit is transmitted first.



12.5 **a.** A CSMA network with two stations A and B, has an end-to-end propagation delay of 10 μs. Station A has data to send and station B does not have any data to send. If 0.6 persistent, slotted, CSMA is being used, what is the probability that station A will send its data within 40 μs? Assume the packet fits into 1 slot.

b. Now suppose stations A and B both have data to send and are using 0.6 persistent, slotted CSMA.

12.6 Assume CSMA/CD protocol. Find the minimum frame length for a 1-Mbps bit rate and maximum network span of 10 kilometers with no repeaters. Assume a medium propagation delay of 4.5 nanoseconds per meter. Is CSMA/CD a reasonable protocol for a network of this span and bit-rate?

12.7 Two hosts, A and B, are connected to an Ethernet Network along with some other hosts. Host A wishes to send frame a and host B wants to send frame b to some other hosts on the Ethernet. Suppose that host A has had 3 collisions while trying to send frame a (with some hosts other than host B) and host B has had 5 collisions while trying to send frame (with some hosts other than host A). At time T, only hosts A and B are the ones that are ready to transmit some data. All other hosts remain idle.

a. What is the maximum slot number that A can decide to transmit packet a in?

b. What is the probability that A and B will collide in both of the next two transmissions as well?

c. Suppose that A generates random number 0.5 and B generates random number 0.6. What are the slots that A and B will transmit their packets in? (Random numbers are generated on the interval [0,1). Assume the 1st slot is the next slot)

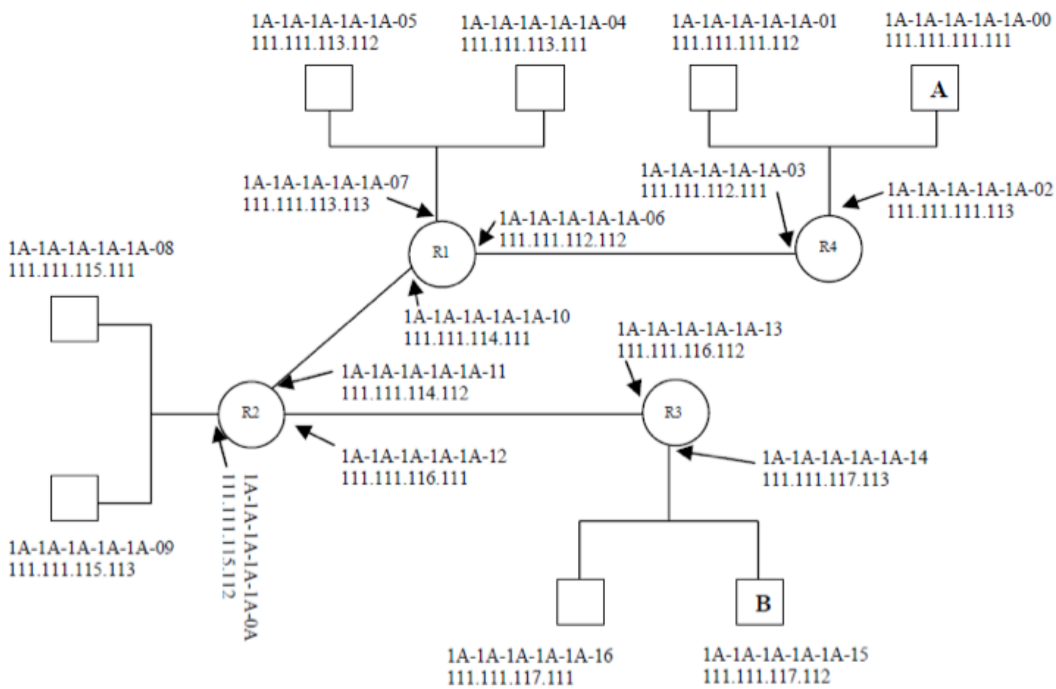
CHAPTER 13 WIRELESS LANS

13.1 Why does the 802.11 protocol not use CSMA/CD?

13.2 In wireless networking, the hidden terminal problem occurs when a node is visible from a wireless access point (AP), but not from other nodes communicating with that AP. How does the 802.11 solve the hidden terminal problem?

CHAPTER 14 THE INTERNET PROTOCOL

14.1 Consider the figure below. In the figure, for each host and for each interface on each router, the link-layer address (top line) and IP address (bottom line) is shown.



Suppose Host A sends a datagram to host B. Assume that the datagram sent is small enough to fit into one link-layer frame. During the transmission of this datagram from A to B a frame is sent from R4 to R1, a frame is sent from R1 to R2 and a frame from R2 to R3. (Other frames might be sent as well but in this question we are not concerned with them).Each of these frames contains a

(1) frame source (MAC) address,

(2) a frame destination (MAC) address and an encapsulated datagram containing a

(3) source IP address and a

(4) destination IP address.

In the table below fill in the values of these four items for each of the 3 frames indicated.

Frame sent on link from	Frame Source (MAC) Address	Frame Destination (MAC) Address	IP Datagram Source Address	IP Datagram Destination Address
R4 to R1				
R1 to R2				
R2 to R3				

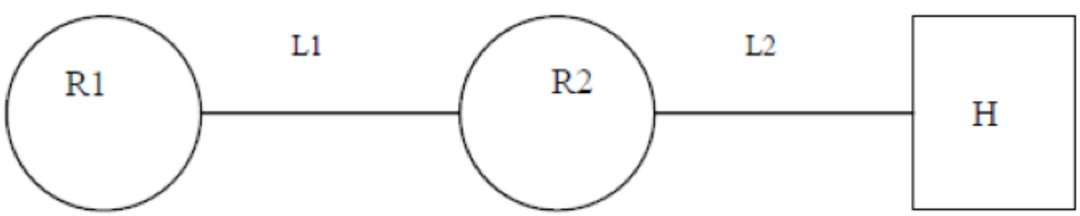
14.2 The figure below illustrates Router R1 sending a datagram to host H through Router R2. Link L1 only permits a MTU of 1000 bytes. Link L2 permits a MTU of 1500 bytes. (MTU= Maximum Transfer Unit)

A is an IP datagram which

i) Has size 4000 bytes (the size of a datagram includes its header)

ii) Is not using any of the option fields in its header.

Because A is larger than the MTU of Link L1, A is fragmented when it is sent over L1.



a. Into how many IP datagrams is A fragmented when it is sent from R1 to R2 over L1? What is the size (in bytes) of each of these smaller fragments?

b. For some fields of the IP header, the fragments created all contain the same value. For some fields, the fragments contain different values. In particular the fragmentation offset and offset-flag bit are different in different fragments. For each of the fragments described in (a) give the value of the fragmentation offset and offset-flag bit.

c. In order for Host H to receive the data in A, R2 must also send some datagrams to H. Describe the datagrams that R2 sends to H. How many are there and what are their sizes?

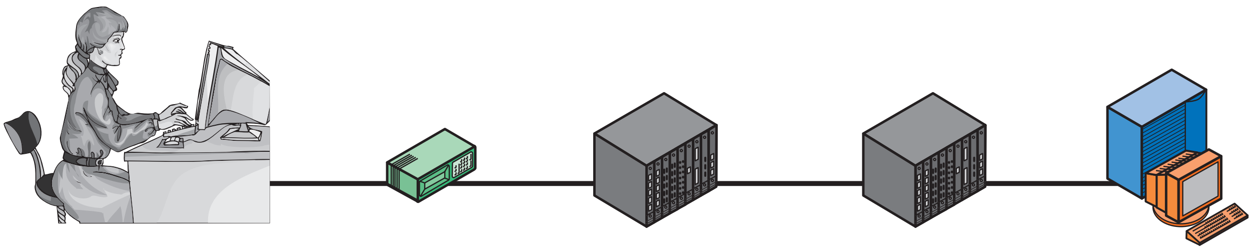
d. Explain how the fragmentation offset field and offset-flag bit are used to reconstruct datagrams.

14.3 In what cases may an IP Router not forward the packets it receives?

14.4 For this and several subsequent problems, we introduce an alternative notation to that of the subnet mask. A **routing prefix** is the sequence of leading (most-significant) bits of an IP address that precede the portion of the address used as host identifier and, if applicable, the set of bits that designate the subnet number. Routing prefixes are expressed in a notation that uses the first address of a network followed by the bit-length of the prefix, separated by a slash (/) character. For example, 192.168.1.0/24 is the prefix of the IPv4 network starting at the given address, having 24 bits allocated for the network number, and the rest (8 bits) reserved for host addressing.

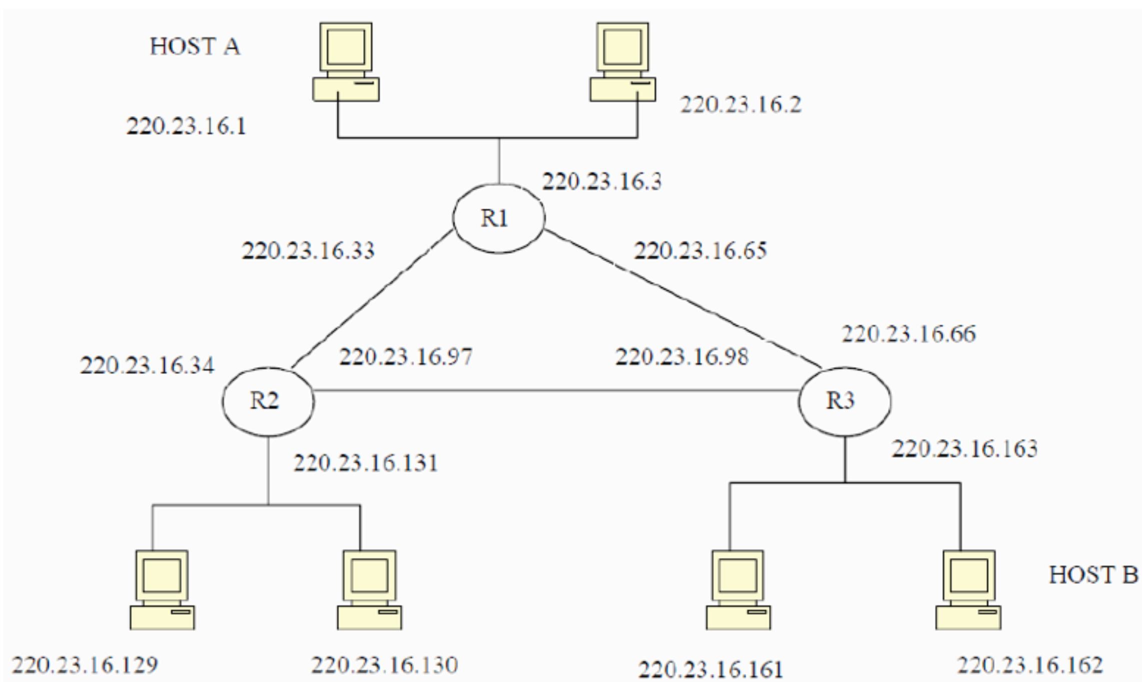
Assume that you are the address administrator at an ISP. You have a 128.20.224.0/20 address block. You have two customers with networks of size 1000 nodes each; two customers whose networks have 500 nodes each; and three customers whose networks have 250 nodes each. What are the addresses blocks (first and last address) you will assign to these customers? Use notation similar to 128.20.224.0/20 to denote the address blocks you allocate. Suppose that all your remaining customers have networks of size 50 nodes each. For how many customers can you allocate address blocks with the remaining addresses you have?

14.5 The traceroute program may be used to determine an end-to-end Internet Path through a network. Consider the following configuration. Explain the set of packets that are exchanged when Client A uses traceroute to find the path to Server B.



Client A **Switch I** **Router J** **Router K** **Server B**

14.6 Suppose that HOST A from the picture below to send an IP datagram to HOST B. Assume that A's ARP Cache is empty.

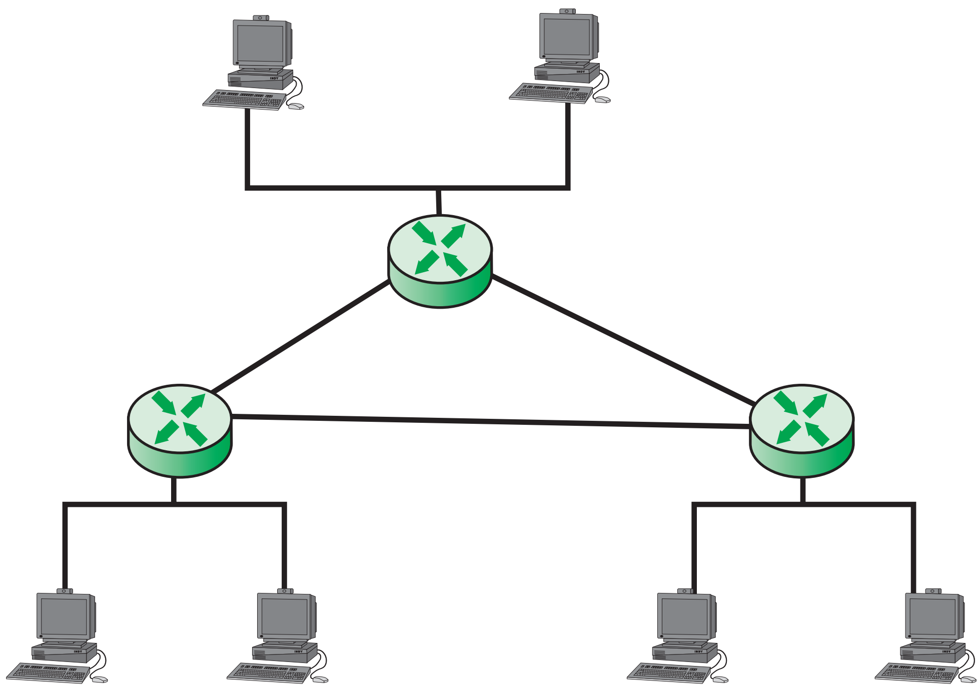


- **a.** A starts the process by sending an ARP query. What will be the reply to its ARP query?
- **b.** What will be the content of the destination-IP-address field in the header of the IP datagram sent by HOST A?
- **c.** Will routers R1 and R3 change any of the fields in the IP datagram's header? If yes, which field(s)?
- **d.** When router R3 receives the datagram, and if its ARP cache is empty, will it have to send an ARP query related to sending this datagram? If yes, what will be the reply to this query?

14.7 Consider a conventional class B network. A network administrator decides to give all subnets in the class B network a sub-net mask of 255.255.248.0.

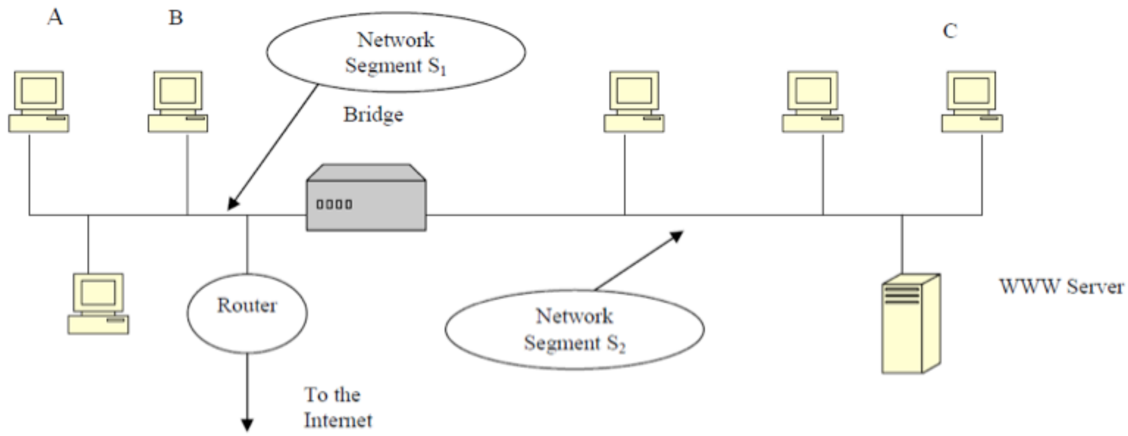
- **a.** How many sub-nets can the administrator use if all sub-nets use this mask?
- **b.** How many hosts are possible on each sub-net?
- **c.** The administrator just heard that she only needs 16 sub-nets for the class B address. What sub-net mask maximizes the number of hosts on each sub-net?

14.8 You are given a pool of 220.23.16.0/24 IP addresses to assign to hosts and routers in the system shown in the figure below.



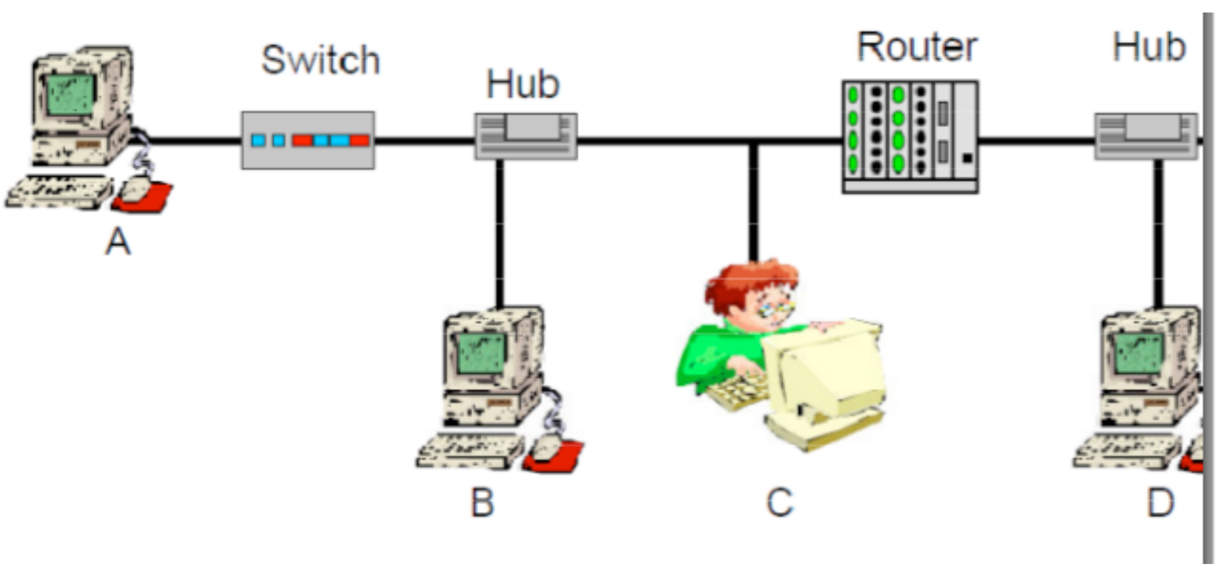
- **a.** How many separate networks are in the system?
- **b.** Partition the given address space and assign addresses to the networks. To answer this question properly you should write down the addresses of all of the networks in the A.B.C.D/x format.
- **c.** Assign addresses to components of the network. To answer this question you should label all of the interfaces in the diagram below with their assigned addresses.

14.9 Consider the following local area network:



a. Do the hosts A and C share the same network part of their IP addresses?.
b. Can host C access the WWW server at the same time as host B accesses the Internet through the router?
c. Can host A access the WWW server at the same time as host B accesses the Internet through the router?
d. What is the maximum size of the bridge's table (in the number of entries) in this configuration?
e. When host A sends an ARP query to learn the data link address of the router, can host C hear it?

14.10 In the configuration below, an Internet Protocol packet is broadcast by B. Which End Systems receive this?



CHAPTER 15 TRANSPORT PROTOCOLS

15.1 An End System sends 5 packets per second using the User Datagram Protocol (UDP) over a full duplex 100 Mbps Ethernet LAN connection. Each packet consists 1500 bytes of Ethernet frame payload data. What is the throughput, when measured at the UDP layer?

15.2 Consider the figure from Problem 18.5. End System A uses the Transmission Control Protocol (TCP) to send a packet to End System B with a payload of 100 bytes. Suppose that the link from Router K to End System B is an Ethernet link. Sketch the Ethernet frame that is sent on this. Ensure your sketch shows the addresses at both the MAC and IP layers; other details of header fields are not necessary.

15.3 For a web server, if it is supporting n simultaneous connections at a particular moment, each from a different client host, how many sockets are used?

15.4 TCP FIN is considered to occupy one byte in the sequence number space. For example, after receiving a TCP FIN segment <FIN, seq=x>, the receiver will send <ack=x+1>. One possibility is that FIN does not occupy any sequence number. Are there any issues of this approach?

15.5 Host A is sending an enormous file to Host B over a TCP connection. Over this connection there is never any packet loss and the timers never expire. Denote the transmission rate of the link connecting Host A to the internet by R bps. Suppose that the process in Host A is capable of sending data into its TCP socket at a rate S bps, where $S=10 \times R$. Further suppose that the TCP receive buffer is large enough to hold the entire file, and the send buffer can hold only one percent of file. What would prevent the process in Host A from continuously passing data to its TCP socket at rate S bps?

15.6 Consider a link of rate R kbps carrying eight identical ongoing client/server applications, with each of the applications using one TCP connection.

- **a.** If new application X comes along and opens one new TCP connection what transmission rate will it get?
- **b.** If it wants to acquire a rate of R/2, how many TCP connections does it have to open?
- **c.** Following up on (b); if the original 8 client/server applications with one TCP connection each all leave the link and 8 new UDP based applications then join the link, would application X be able to keep rate of R/2?

15.7 Suppose a UDP segment with a payload of 690 bytes is transmitted over and Ethernet link. What is the size of the Ethernet frame?

CHAPTER 16 ADVANCED DATA COMMUNICATIONS TOPICS

16.1 An audio signal: 15 sin 2π(1500t)

amplitude modulates a carrier: 60 sin 2π(100,000t)

a. Determine the modulation index and the percent modulation.

b. What are the frequencies of the audio signal and of the carrier?

c. What frequencies would show up in a spectrum analysis of the modulated signal?

16.2 A 75-MHz carrier having an amplitude of 50 V is modulated by a 3-kHz audio signal having an amplitude of 20 V. Write trigonometric equations for the carrier and modulating wave.

16.3 What is the value of the parameter a for a data link where the average packet size is 400 bytes, the data rate is 10 Mbps, the propagation delay is 120 µs.

CHAPTER 17 WIRELESS TRANSMISSION

17.1 Consider a sender A wants to send the data bit 0 with chipping code = 010011. Consider a sender B wants to send the data bit 1 with chipping code = 110101. Assume we code a binary 0 as -1, a binary 1 as +1. Both signals are transmitted at the same time. The noise to the transmitted signal is (-1, 0, +1, 0, -1, +1). Note: Noise has 3 states: -1, 0 and 1. The state 0 here means no noise meaning in this state there is no impact of noise on signal.

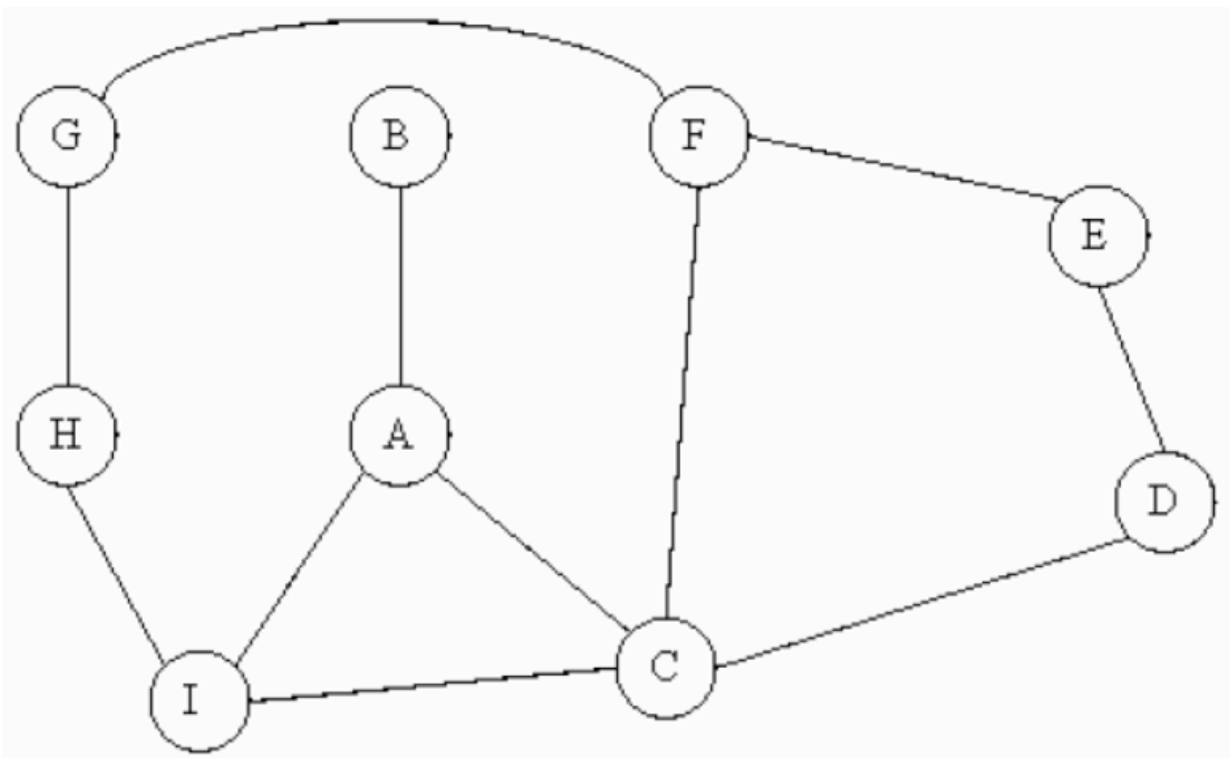
a. What signal is received by a receiver?

b. What can the receiver detect for sender A and B respectively?

17.2 Sketch or describe the Direct Sequence Spread Spectrum signal s(t)c(t) over two bit time periods assuming that s(t) is BPSK modulated with carrier frequency 8 MHz and bit time period equal to 1μs. Assume that there are four chips per bit in the spreading code c(t) and that the chips alternate between +-1, with the first chip equal to +1. Assume that the first data bit is a 1 and the second data bit is a 0.

CHAPTER 19 ROUTING

19.1 Consider the network configuration shown in figure below. Assume that each link has the same cost.

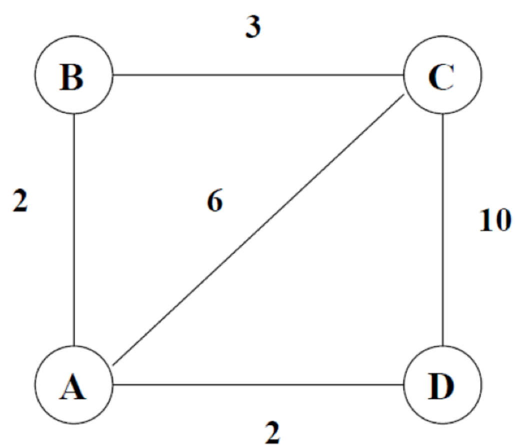


a. Run Bellman-Ford algorithm on this network to compute the routing table for the node A. Show A's distances to all other nodes at each step.

b. Suppose the link A-B goes down. As a result, A advertises a distance of infinity to B. Describe in detail a scenario where C takes a long time to learn that B is unreachable.

19.2 A technique that is sometimes used with distance vector routing algorithms is known as **poisoned reverse**, which adds the following rule: If Z routes through Y to get to X, then Z tells Y that Z's distance to X is infinity (so Y won't route to X through Z).

Consider the network below with the given link costs. Fill in the final values in B's distance table that will result after running the distance vector routing algorithm with Poisoned Reverse.



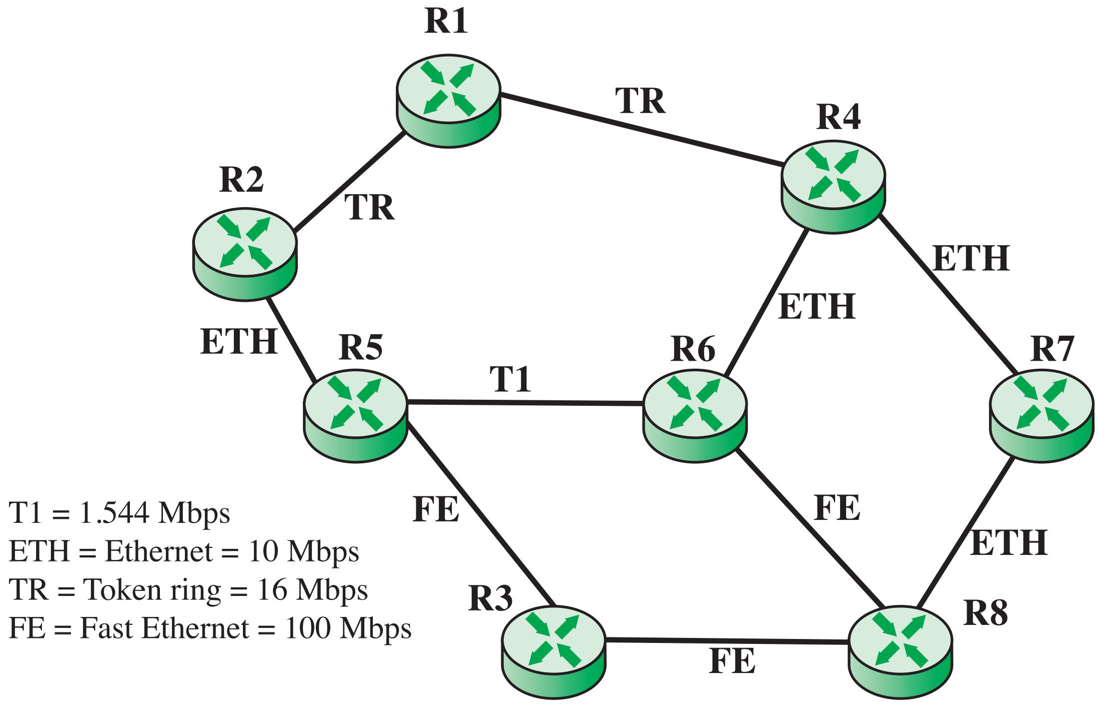
19.3 Consider the following network diagram and the use of OSPF for routing.

a. Suppose a simple hop count is used (i.e., each link is assigned a cost of 1). Which path is preferred from R6 to R2?

b. Now suppose the following common link cost algorithm is used.

$$\text{Cost} = \frac{\text{Reference data rate}}{\text{Interface data rate}}$$

Use a reference data rate of 100 Mbps. Which path is preferred from R6 to R2?


R1
TR
R4
R2
TR
ETH
ETH
ETH
R5
T1
R6
R7
T1 = 1.544 Mbps
ETH = Ethernet = 10 Mbps
TR = Token ring = 16 Mbps
FE = Fast Ethernet = 100 Mbps
FE
FE
ETH
R3
R8
FE

CHAPTER 20 CONGESTION

20.1 Consider a network in which for each link, the link capacity is greater than the sum of the input rates for all end systems in the network.

- **a.** Is congestion control needed in this scenario? Why?
- **b.** Is flow control needed in this scenario? Why?
- **c.** Would it be better to use circuit switching or packet switching in this network? Why?

20.2 Consider two TCP flows A and B: The RTT for flow A is 100 ms while the RTT for flow B is 200 ms. Recall that ssthresh denotes the threshold at which the congestion window size evolution switches over from the Slow Start phase to the Congestion Avoidance phase. Both flows have the ssthresh value of 8. At time T seconds, both flows have just had a timeout, and so their window size is set to 1. Calculate how many packets each flow is able to send in the next 1 second (including at time T+1 second). Assume that each packet can be transmitted in 0 time, and that there are no dropped packets for either flow during the interval [T, T+1] seconds.

20.3 Consider an HTTP download of a small file (an index.html) of size S from a Web server. The file is small enough so that the connection remains in slow start, and assume that no losses occur during the download. How many round-trips does this take, using TCP as the transport? Assume that the request for the file fits in one packet. Assume that the TCP does not implement delayed ACKs (i.e., it ACKs every segment) and that the maximum segment size is m.

20.4 A client in host A is making an HTTP connection to a web server C. Suppose A knows C's IP address.

- For the link between A and C, bandwidth is *b* bps (bits per second) and propagation delay is *d* second.
- Assume TCP connection setup and HTTP request/response sizes are small compared to Maximum Segment Size (MSS), so their transmission delay can be ignored.
- The client requests a webpage consisting of an HTML file and one binary file. Each file has exact size of 3 MSSes.
- Piggybacking is used whenever possible. Processing delay is negligible. Transmission delay must be considered.
- There is no error or loss in transmissions.
- Suppose non-persistent mode is applied and no parallel TCP connection is made. When HTTP uses non-persistent mode, the underlying TCP connection is closed after a single request and response. Each individual request for a Web page or HTML file requires opening and then closing a new TCP connection.

The following questions consider different TCP window cases.

a. Compute the round trip time RTT

b. Assume static TCP window size, which is fixed at 50 (segments). What is the delay required to view all the contents of the webpage?

c. Assume TCP window size changes according to the congestion control algorithm. TCP starts with slow start phase. Assume the initial threshold is very high. What is the delay required to view all the contents of the webpage?

20.5 Now assume that HTTP is using a persistent mode. That is, TCP connection used to connect to a Web server remains open for some time, allowing multiple requests and responses. Further, assume that HTTP uses pipelining, which allows the client to make multiple requests without waiting for replies to pending requests. Still assume TCP window size changes according to the congestion control algorithm at both the client and the sender. TCP starts with slow start phase. Assume the initial threshold is very high. What is the delay required to view all the contents of the webpage? (If there are back-to-back HTTP requests, they act according to the TCP states.)

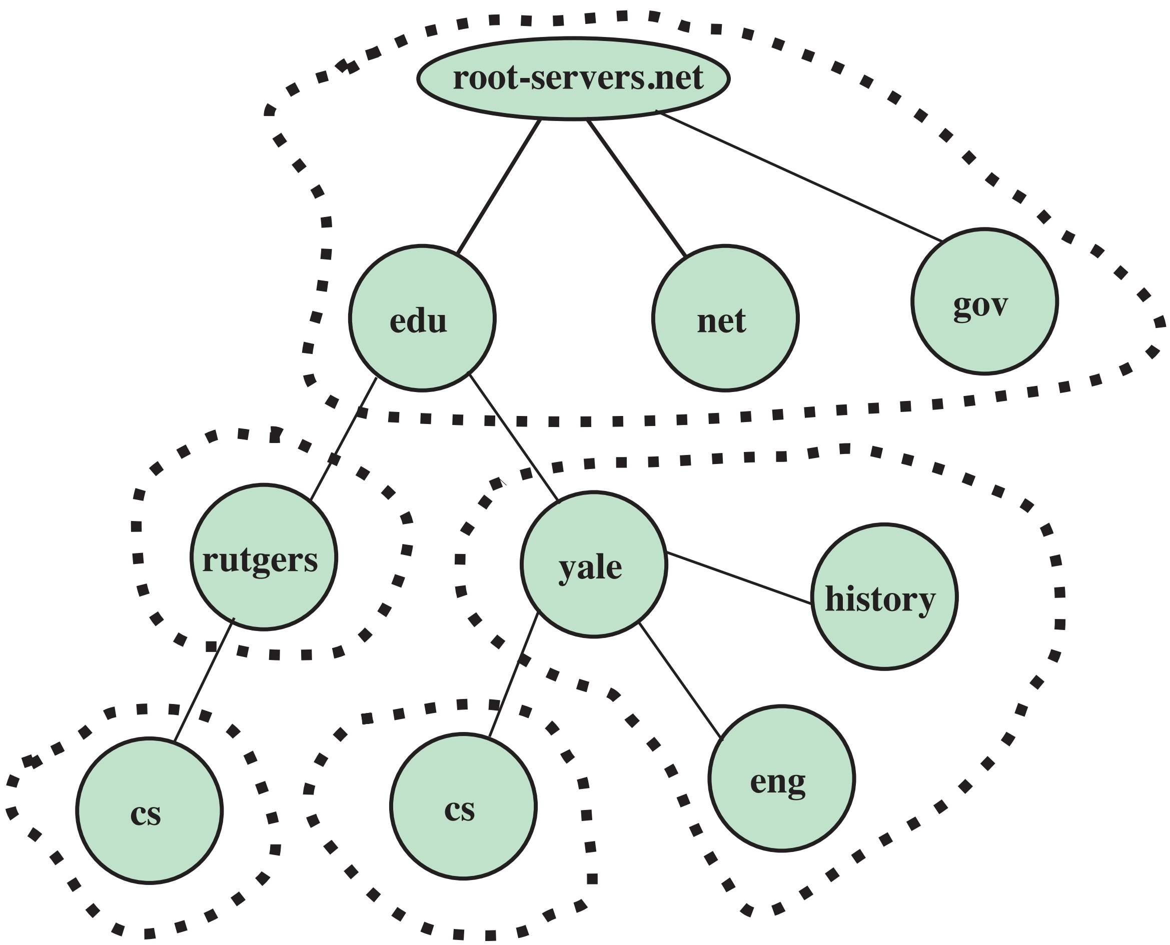
CHAPTER 21 INTERNETWORK OPERATION

21.1 When mobile IP is used and a mobile host is connected across a wireless network to an access point and from there to a host on a wired Internet, two TCP schemes have been used: indirect TCP and snooping TCP. For **indirect TCP**, the end-to-end TCP connection is broken into one connection on the wired part of route and one over wireless part of the route. The split connection results in independent flow control for the two parts. Flow/error control protocols, packet size, time-outs, may be different for each part. **Snooping TCP** is a transparent extension of TCP within the foreign agent. It buffers packets on the wireless link in both directions. Lost packets on the wireless link (both directions) will be retransmitted immediately by the mobile host or foreign agent, respectively (so called local retransmission). The foreign agent therefore "snoops" the packet flow and recognizes acknowledgements in both directions.

Suppose the latency of the wireless link is much smaller than that of the fixed portion (wired Internet) of a TCP connection but the error rate of the wireless link is high, and that the mobile host is not moving. Which of the two schemes would provide better performance in such a scenario?

CHAPTER 24 ELECTRONIC MAIL, DNS, AND HTTP

24.1 Consider the Internet in the figure below, in which zones are indicated with a dashed line. There is only one DNS server per zone and it happens to have the same name as the highest node in each zone: yale.edu, cs.yale.edu, rutgers.edu, cs.rutgers.edu and root-servers.net. The only servers supporting recursive querying are cs.yale.edu and cs.rutgers.edu. For each of the queries below, list in order all the DNS servers contacted by the resolver (located in the OS of the machine running the query). Assume there is no caching performed at any level of the hierarchy.



a. napoleon.history.yale.edu is a machine installed in the history dept at Yale, and a user on eden.rutgers.edu launches this query:

```
nslookup napoleon.history.yale.edu
```

b. At the prompt of paul.cs.rutgers.edu, somebody launches this query:

```
nslookup napoleon.history.yale.edu
```

c. Later, napoleon.history.yale.edu is assigned a new IP (but keeping the complete name) and is physically moved into the engineering building to a local Ethernet with other machines such as electron.eng.yale.edu and theorem.eng.yale.edu. At the prompt of eden.rutgers.edu a user launches this query:

```
nslookup napoleon.history.yale.edu
```

d. In engineering building, on napoleon.history.yale.edu, somebody queries:

```
nslookup paul.cs.rutgers.edu
```

e. Follow the same scenario as in (b), but this time indicating in order, all the queries involved in the process. Use this notation to represent a query:

```
rutgers.edu → rootservers.net
```

to indicate that rutgers.edu is generating/forwarding a query to rootservers.net

24.2 Consider an HTTP client that wants to retrieve a Web document at a given URL. The IP address of the HTTP server is initially unknown. The Web document at the URL has one embedded GIF image that resides at the same server as the original document. What transport and application layer protocols besides HTTP are needed in this scenario?

24.3 Suppose within your Web browser you click on a link to obtain a Web page. The IP address for the associated URL is not cached in your local host, so a DNS look-up is necessary to obtain the IP address. Suppose that n DNS servers are visited before your host receives the IP address from DNS; the successive visits incur an RTT of RTT1, …, RTTn. Further suppose that the Web page is an HTML text file and four additional objects. Let RTT0 denote a RTT between the local host and the server containing the object. Assuming zero transmission time of the object, how much time elapses from when the client clicks on the link until the client receives the entire Web page? Assume a non-persistent HTTP protocol with no parallel TCP connections

CHAPTER 26 COMPUTER AND NETWORK SECURITY THREATS

26.1 Which of the following activities might be considered a possible source of threat to a company's network, and why?

- **a.** The daily courier service personnel who drop off and pick up packages.
- **b.** Former employees who left the company because of downsizing.
- **c.** An employee traveling on company business to another city.
- **d.** The building management company where an organization has its offices has decided to install a fire sprinkler system.

26.2 Name some of the ways by which hackers compromise computers without code breaking.

26.3 What is a “Null session” problem?

26.4 How can an intrusion detection system actively respond to an attack?

26.5 Consider the following login protocol.

user knows password P
user knows Hash function H(.) and has a mobile calculator
user gives login name N to machine
machine generates random number R
machine gives R to user
user computes X := Hash(P) XOR Hash(R)
user gives X to machine
machine uses N to obtain P from password table

machine computes Y := Hash(P) XOR Hash(R)

if X=Y then machine allows login

a. Explain what is wrong with it and how can it be broken.

b. Show a simple way to strengthen this protocol against your attack.

26.6 Look at the following code snippet. You may assume that escape() argument is always non-null and points to a '\0'- terminated string. What's wrong with this code (from a security point of view)?

```
/*Escapes all newlines in the input string, replacing them
with"\n".*/
/* Requires: p != NULL; p is a valid '\0'-terminated string */
void escape(char *p)
{
while (*p != '\0')
switch (*p)
{
case '\n':
memcpy(p+2, p+1, strlen(p));
*p++ = '\\'; *p++ = 'n';
break;
default:
p++;
}
}
```

CHAPTER 27 COMPUTER AND NETWORK SECURITY TECHNIQUES

27.1 Will IPsec make firewalls obsolete?

27.2 An attacker is intent on disrupting the communication by inserting bogus packets into the communications. Discuss whether such an attack would succeed in systems protected by IPsec. Discuss whether such an attack would succeed in systems protected by SSL.