1.7.3 Problems

P1-1. What is the maximum number of characters or symbols that can be represented by Unicode?

P1-2. A color image uses 16 bits to represent a pixel. What is the maximum number of different colors that can be represented?

P1-3. Assume six devices are arranged in a mesh topology. How many cables are needed? How many ports are needed for each device?

P1-4. For each of the following four networks, discuss the consequences if a connection fails.

- **a.** Five devices arranged in a mesh topology
- **b.** Five devices arranged in a star topology (not counting the hub)
- **c.** Five devices arranged in a bus topology
- **d.** Five devices arranged in a ring topology

P1-5. We have two computers connected by an Ethernet hub at home. Is this a LAN or a WAN? Explain the reason.

P1-6. In the ring topology in Figure 1.7, what happens if one of the stations is unplugged?

P1-7. In the bus topology in Figure 1.6, what happens if one of the stations is unplugged?

P1-8. Performance is inversely related to delay. When we use the Internet, which of the following applications are more sensitive to delay?

- **a.** Sending an e-mail
- **b.** Copying a file
- **c.** Surfing the Internet

P1-9. When a party makes a local telephone call to another party, is this a point-to-point or multipoint connection? Explain the answer.

P1-10. Compare the telephone network and the Internet. What are the similarities? What are the differences?

1.8 SIMULATION EXPERIMENTS

1.8.1 Applets

One of the ways to show the network protocols in action or visually see the solution to some examples is through the use of interactive animation. We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action. However, note that applets have been created only for some chapters, not all (see the book website).

1.8.2 Lab Assignments

Experiments with networks and network equipment can be done using at least two methods. In the first method, we can create an isolated networking laboratory and use

Q2-12. When we say that the transport layer multiplexes and demultiplexes application-layer messages, do we mean that a transport-layer protocol can combine several messages from the application layer in one packet? Explain.

Q2-13. Can you explain why we did not mention multiplexing/demultiplexing services for the application layer?

Q2-14. Assume we want to connect two isolated hosts together to let each host communicate with the other. Do we need a link-layer switch between the two? Explain.

Q2-15. If there is a single path between the source host and the destination host, do we need a router between the two hosts?

2.5.3 Problems

P2-1. Answer the following questions about Figure 2.2 when the communication is from Maria to Ann:

a. What is the service provided by layer 1 to layer 2 at Maria's site?

b. What is the service provided by layer 1 to layer 2 at Ann's site?

P2-2. Answer the following questions about Figure 2.2 when the communication is from Maria to Ann:

a. What is the service provided by layer 2 to layer 3 at Maria's site?

b. What is the service provided by layer 2 to layer 3 at Ann's site?

P2-3. Assume that the number of hosts connected to the Internet at year 2010 is five hundred million. If the number of hosts increases only 20 percent per year, what is the number of hosts in year 2020?

P2-4. Assume a system uses five protocol layers. If the application program creates a message of 100 bytes and each layer (including the fifth and the first) adds a header of 10 bytes to the data unit, what is the efficiency (the ratio of application-layer bytes to the number of bytes transmitted) of the system?

P2-5. Assume we have created a packet-switched internet. Using the TCP/IP protocol suite, we need to transfer a huge file. What are the advantage and disadvantage of sending large packets?

P2-6. Match the following to one or more layers of the TCP/IP protocol suite:

a. route determination

b. connection to transmission media

c. providing services for the end user

P2-7. Match the following to one or more layers of the TCP/IP protocol suite:

a. creating user datagrams

b. responsibility for handling frames between adjacent nodes

c. transforming bits to electromagnetic signals

P2-8. In Figure 2.10, when the IP protocol decapsulates the transport-layer packet, how does it know to which upper-layer protocol (UDP or TCP) the packet should be delivered?

P2-9. Assume a private internet uses three different protocols at the data-link layer (L1, L2, and L3). Redraw Figure 2.10 with this assumption. Can we say that, in the data-link layer, we have demultiplexing at the source node and multiplexing at the destination node?

P2-10. Assume that a private internet requires that the messages at the application layer be encrypted and decrypted for security purposes. If we need to add some information about the encryption/decryption process (such as the algorithms used in the process), does it mean that we are adding one layer to the TCP/IP protocol suite? Redraw the TCP/IP layers (Figure 2.4 part b) if you think so.

P2-11. Protocol layering can be found in many aspects of our lives such as air travelling. Imagine you make a round-trip to spend some time on vacation at a resort. You need to go through some processes at your city airport before flying. You also need to go through some processes when you arrive at the resort airport. Show the protocol layering for the round trip using some layers such as baggage checking/claiming, boarding/unboarding, takeoff/landing.

P2-12. The presentation of data is becoming more and more important in today's Internet. Some people argue that the TCP/IP protocol suite needs to add a new layer to take care of the presentation of data. If this new layer is added in the future, where should its position be in the suite? Redraw Figure 2.4 to include this layer.

P2-13. In an internet, we change the LAN technology to a new one. Which layers in the TCP/IP protocol suite need to be changed?

P2-14. Assume that an application-layer protocol is written to use the services of UDP. Can the application-layer protocol uses the services of TCP without change?

P2-15. Using the internet in Figure 1.11 (Chapter 1) in the text, show the layers of the TCP/IP protocol suite and the flow of data when two hosts, one on the west coast and the other on the east coast, exchange messages.

Q3-10. Can we say whether a signal is periodic or nonperiodic by just looking at its frequency domain plot? How?

Q3-11. Is the frequency domain plot of a voice signal discrete or continuous?

Q3-12. Is the frequency domain plot of an alarm system discrete or continuous?

Q3-13. We send a voice signal from a microphone to a recorder. Is this baseband or broadband transmission?

Q3-14. We send a digital signal from one station on a LAN to another station. Is this baseband or broadband transmission?

Q3-15. We modulate several voice signals and send them through the air. Is this baseband or broadband transmission?

3.8.3 Problems

P3-1. Given the frequencies listed below, calculate the corresponding periods.

a. 24 Hz **b.** 8 MHz **c.** 140 KHz

P3-2. Given the following periods, calculate the corresponding frequencies.

a. 5 s **b.** 12 μs **c.** 220 ns

P3-3. What is the phase shift for the following?

a. A sine wave with the maximum amplitude at time zero

b. A sine wave with maximum amplitude after 1/4 cycle

c. A sine wave with zero amplitude after 3/4 cycle and increasing

P3-4. What is the bandwidth of a signal that can be decomposed into five sine waves with frequencies at 0, 20, 50, 100, and 200 Hz? All peak amplitudes are the same. Draw the bandwidth.

P3-5. A periodic composite signal with a bandwidth of 2000 Hz is composed of two sine waves. The first one has a frequency of 100 Hz with a maximum amplitude of 20 V; the second one has a maximum amplitude of 5 V. Draw the bandwidth.

P3-6. Which signal has a wider bandwidth, a sine wave with a frequency of 100 Hz or a sine wave with a frequency of 200 Hz?

P3-7. What is the bit rate for each of the following signals?

a. A signal in which 1 bit lasts 0.001 s

b. A signal in which 1 bit lasts 2 ms

c. A signal in which 10 bits last 20 μs

P3-8. A device is sending out data at the rate of 1000 bps.

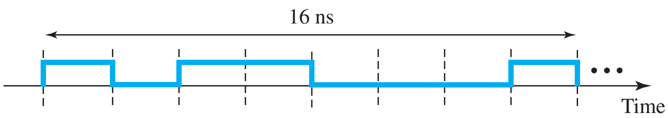
a. How long does it take to send out 10 bits?

b. How long does it take to send out a single character (8 bits)?

c. How long does it take to send a file of 100,000 characters?

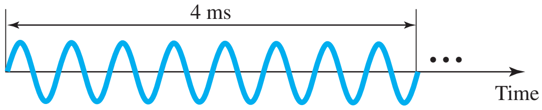
P3-9. What is the bit rate for the signal in Figure 3.35?

Figure 3.35 *Problem P3-9*



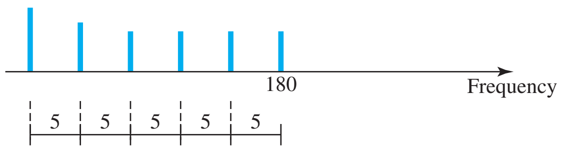
P3-10. What is the frequency of the signal in Figure 3.36?

Figure 3.36 *Problem P3-10*



P3-11. What is the bandwidth of the composite signal shown in Figure 3.37?

Figure 3.37 *Problem P3-11*



P3-12. A periodic composite signal contains frequencies from 10 to 30 KHz, each with an amplitude of 10 V. Draw the frequency spectrum.

P3-13. A nonperiodic composite signal contains frequencies from 10 to 30 KHz. The peak amplitude is 10 V for the lowest and the highest signals and is 30 V for the 20-KHz signal. Assuming that the amplitudes change gradually from the minimum to the maximum, draw the frequency spectrum.

P3-14. A TV channel has a bandwidth of 6 MHz. If we send a digital signal using one channel, what are the data rates if we use one harmonic, three harmonics, and five harmonics?

P3-15. A signal travels from point A to point B. At point A, the signal power is 100 W. At point B, the power is 90 W. What is the attenuation in decibels?

P3-16. The attenuation of a signal is −10 dB. What is the final signal power if it was originally 5 W?

P3-17. A signal has passed through three cascaded amplifiers, each with a 4 dB gain. What is the total gain? How much is the signal amplified?

P3-18. If the bandwidth of the channel is 5 Kbps, how long does it take to send a frame of 100,000 bits out of this device?

P3-19. The light of the sun takes approximately eight minutes to reach the earth. What is the distance between the sun and the earth?

P3-20. A signal has a wavelength of 1 μm in air. How far can the front of the wave travel during 1000 periods?

P3-21. A line has a signal-to-noise ratio of 1000 and a bandwidth of 4000 KHz. What is the maximum data rate supported by this line?

P3-22. We measure the performance of a telephone line (4 KHz of bandwidth). When the signal is 10 V, the noise is 5 mV. What is the maximum data rate supported by this telephone line?

P3-23. A file contains 2 million bytes. How long does it take to download this file using a 56-Kbps channel? 1-Mbps channel?

P3-24. A computer monitor has a resolution of 1200 by 1000 pixels. If each pixel uses 1024 colors, how many bits are needed to send the complete contents of a screen?

P3-25. A signal with 200 milliwatts power passes through 10 devices, each with an average noise of 2 microwatts. What is the SNR? What is the SNRdB?

P3-26. If the peak voltage value of a signal is 20 times the peak voltage value of the noise, what is the SNR? What is the SNR_{dB}?

P3-27. What is the theoretical capacity of a channel in each of the following cases?

a. Bandwidth: 20 KHz $SNR_{dB} = 40$

b. Bandwidth: 200 KHz $SNR_{dB} = 4$

c. Bandwidth: 1 MHz $SNR_{dB} = 20$

P3-28. We need to upgrade a channel to a higher bandwidth. Answer the following questions:

a. How is the rate improved if we double the bandwidth?

b. How is the rate improved if we double the SNR?

P3-29. We have a channel with 4 KHz bandwidth. If we want to send data at 100 Kbps, what is the minimum SNR_{dB}? What is the SNR?

P3-30. What is the transmission time of a packet sent by a station if the length of the packet is 1 million bytes and the bandwidth of the channel is 200 Kbps?

P3-31. What is the length of a bit in a channel with a propagation speed of 2×10^8 m/s if the channel bandwidth is

a. 1 Mbps? **b.** 10 Mbps? **c.** 100 Mbps?

P3-32. How many bits can fit on a link with a 2 ms delay if the bandwidth of the link is

a. 1 Mbps? **b.** 10 Mbps? **c.** 100 Mbps?

P3-33. What is the total delay (latency) for a frame of size 5 million bits that is being sent on a link with 10 routers each having a queuing time of 2 μs and a processing time of 1 μs. The length of the link is 2000 Km. The speed of light inside the link is 2×10^8 m/s. The link has a bandwidth of 5 Mbps. Which component of the total delay is dominant? Which one is negligible?

3.9 SIMULATION EXPERIMENTS

3.9.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.

in the signal level. Compare your guess with the corresponding entry in Table 4.1.

a. 00000000 **b.** 11111111 **c.** 01010101 **d.** 00110011

P4-4. Repeat Problem P4-3 for the NRZ-I scheme.

P4-5. Repeat Problem P4-3 for the Manchester scheme.

P4-6. Repeat Problem P4-3 for the differential Manchester scheme.

P4-7. Repeat Problem P4-3 for the 2B1Q scheme, but use the following data streams.

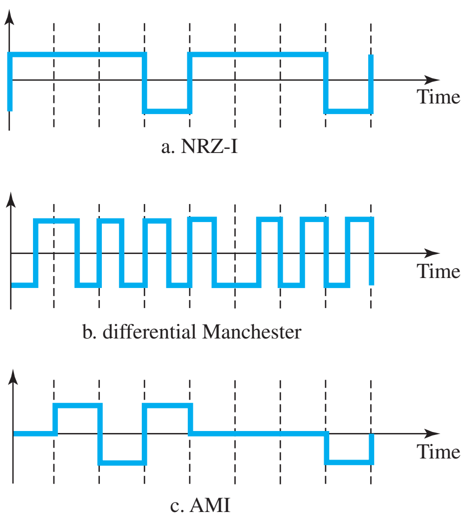
a. 0000000000000000
b. 1111111111111111
c. 0101010101010101
d. 0011001100110011

P4-8. Repeat Problem P4-3 for the MLT-3 scheme, but use the following data streams.

a. 00000000 **b.** 11111111 **c.** 01010101 **d.** 00011000

P4-9. Find the 8-bit data stream for each case depicted in Figure 4.36.

Figure 4.36 *Problem P4-9*



P4-10. An NRZ-I signal has a data rate of 100 Kbps. Using Figure 4.6, calculate the value of the normalized energy (P) for frequencies at 0 Hz, 50 KHz, and 100 KHz.

P4-11. A Manchester signal has a data rate of 100 Kbps. Using Figure 4.8, calculate the value of the normalized energy (P) for frequencies at 0 Hz, 50 KHz, 100 KHz.

P4-12. The input stream to a 4B/5B block encoder is

0100 0000 0000 0000 0000 0001

Answer the following questions:

a. What is the output stream?

b. What is the length of the longest consecutive sequence of 0s in the input?

c. What is the length of the longest consecutive sequence of 0s in the output?

P4-13. How many invalid (unused) code sequences can we have in 5B/6B encoding? How many in 3B/4B encoding?

P4-14. What is the result of scrambling the sequence 11100000000000 using each of the following scrambling techniques? Assume that the last non-zero signal level has been positive.

a. B8ZS

b. HDB3 (The number of nonzero pulses is odd after the last substitution.)

P4-15. What is the Nyquist sampling rate for each of the following signals?

a. A low-pass signal with bandwidth of 200 KHz?

b. A band-pass signal with bandwidth of 200 KHz if the lowest frequency is 100 KHz?

P4-16. We have sampled a low-pass signal with a bandwidth of 200 KHz using 1024 levels of quantization.

a. Calculate the bit rate of the digitized signal.

b. Calculate the SNR_{dB} for this signal.

c. Calculate the PCM bandwidth of this signal.

P4-17. What is the maximum data rate of a channel with a bandwidth of 200 KHz if we use four levels of digital signaling.

P4-18. An analog signal has a bandwidth of 20 KHz. If we sample this signal and send it through a 30 Kbps channel, what is the SNR_{dB}?

P4-19. We have a baseband channel with a 1-MHz bandwidth. What is the data rate for this channel if we use each of the following line coding schemes?

a. NRZ-L **b.** Manchester **c.** MLT-3 **d.** 2B1Q

P4-20. We want to transmit 1000 characters with each character encoded as 8 bits.

a. Find the number of transmitted bits for synchronous transmission.

b. Find the number of transmitted bits for asynchronous transmission.

c. Find the redundancy percent in each case.

4.6 SIMULATION EXPERIMENTS

4.6.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.

5.4.3 Problems

P5-1. Calculate the baud rate for the given bit rate and type of modulation.

a. 2000 bps, FSK
b. 4000 bps, ASK
c. 6000 bps, QPSK
d. 36,000 bps, 64-QAM

P5-2. Calculate the bit rate for the given baud rate and type of modulation.

a. 1000 baud, FSK
b. 1000 baud, ASK
c. 1000 baud, BPSK
d. 1000 baud, 16-QAM

P5-3. What is the number of bits per baud for the following techniques?

a. ASK with four different amplitudes
b. FSK with eight different frequencies
c. PSK with four different phases
d. QAM with a constellation of 128 points

P5-4. Draw the constellation diagram for the following:

a. ASK, with peak amplitude values of 1 and 3
b. BPSK, with a peak amplitude value of 2
c. QPSK, with a peak amplitude value of 3
d. 8-QAM with two different peak amplitude values, 1 and 3, and four different phases

P5-5. Draw the constellation diagram for the following cases. Find the peak amplitude value for each case and define the type of modulation (ASK, FSK, PSK, or QAM).The numbers in parentheses define the values of I and Q respectively.

a. Two points at (2, 0) and (3, 0)
b. Two points at (3, 0) and (–3, 0)
c. Four points at (2, 2), (–2, 2), (–2, –2), and (2, –2)
d. Two points at (0, 2) and (0, –2)

P5-6. How many bits per baud can we send in each of the following cases if the signal constellation has one of the following number of points?

a. 2 **b.** 4 **c.** 16 **d.** 1024

P5-7. What is the required bandwidth for the following cases if we need to send 4000 bps? Let d = 1.

a. ASK
b. FSK with $2\Delta f = 4$ KHz
c. QPSK
d. 16-QAM

P5-8. The telephone line has 4 KHz bandwidth. What is the maximum number of bits we can send using each of the following techniques? Let d = 0.

a. ASK **b.** QPSK **c.** 16-QAM **d.** 64-QAM

P5-9. A corporation has a medium with a 1-MHz bandwidth (lowpass). The corporation needs to create 10 separate independent channels each capable of sending at least 10 Mbps. The company has decided to use QAM technology. What is the minimum number of bits per baud for each channel? What is the number of points in the constellation diagram for each channel? Let d = 0.

P5-10. A cable company uses one of the cable TV channels (with a bandwidth of 6 MHz) to provide digital communication for each resident. What is the available data rate for each resident if the company uses a 64-QAM technique?

P5-11. Find the bandwidth for the following situations if we need to modulate a 5-KHz voice.

a. AM **b.** FM ($\beta = 5$) **c.** PM ($\beta = 1$)

P5-12. Find the total number of channels in the corresponding band allocated by FCC.

a. AM **b.** FM

5.5 SIMULATION EXPERIMENTS

5.5.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.

Q6-8. Distinguish between multilevel TDM, multiple-slot TDM, and pulse-stuffed TDM.

Q6-9. Distinguish between synchronous and statistical TDM.

Q6-10. Define spread spectrum and its goal. List the two spread spectrum techniques discussed in this chapter.

Q6-11. Define FHSS and explain how it achieves bandwidth spreading.

Q6-12. Define DSSS and explain how it achieves bandwidth spreading.

6.4.3 Problems

P6-1. Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 10 voice channels with guard bands of 500 Hz using FDM. Calculate the required bandwidth.

P6-2. We need to transmit 100 digitized voice channels using a passband channel of 20 KHz. What should be the ratio of bits/Hz if we use no guard band?

P6-3. In the analog hierarchy of Figure 6.9, find the overhead (extra bandwidth for guard band or control) in each hierarchy level (group, supergroup, master group, and jumbo group).

P6-4. We need to use synchronous TDM and combine 20 digital sources, each of 100 Kbps. Each output slot carries 1 bit from each digital source, but one extra bit is added to each frame for synchronization. Answer the following questions:

- **a.** What is the size of an output frame in bits?
- **b.** What is the output frame rate?
- **c.** What is the duration of an output frame?
- **d.** What is the output data rate?
- **e.** What is the efficiency of the system (ratio of useful bits to the total bits)?

P6-5. Repeat Problem 6-4 if each output slot carries 2 bits from each source.

P6-6. We have 14 sources, each creating 500 8-bit characters per second. Since only some of these sources are active at any moment, we use statistical TDM to combine these sources using character interleaving. Each frame carries 6 slots at a time, but we need to add 4-bit addresses to each slot. Answer the following questions:

- **a.** What is the size of an output frame in bits?
- **b.** What is the output frame rate?
- **c.** What is the duration of an output frame?
- **d.** What is the output data rate?

P6-7. Ten sources, six with a bit rate of 200 kbps and four with a bit rate of 400 kbps, are to be combined using multilevel TDM with no synchronizing bits. Answer the following questions about the final stage of the multiplexing:

- **a.** What is the size of a frame in bits?
- **b.** What is the frame rate?
- **c.** What is the duration of a frame?
- **d.** What is the data rate?

P6-8. Four channels, two with a bit rate of 200 kbps and two with a bit rate of 150 kbps, are to be multiplexed using multiple-slot TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?

b. What is the frame rate?

c. What is the duration of a frame?

d. What is the data rate?

P6-9. Two channels, one with a bit rate of 190 kbps and another with a bit rate of 180 kbps, are to be multiplexed using pulse-stuffing TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?

b. What is the frame rate?

c. What is the duration of a frame?

d. What is the data rate?

P6-10. Answer the following questions about a T-1 line:

a. What is the duration of a frame?

b. What is the overhead (number of extra bits per second)?

P6-11. Show the contents of the five output frames for a synchronous TDM multiplexer that combines four sources sending the following characters. Note that the characters are sent in the same order that they are typed. The third source is silent.

a. Source 1 message: HELLO

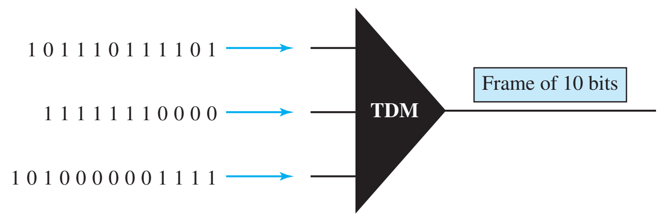
b. Source 2 message: HI

c. Source 3 message:

d. Source 4 message: BYE

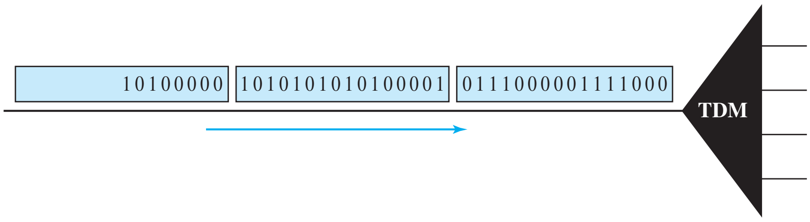
P6-12. Figure 6.34 shows a multiplexer in a synchronous TDM system. Each output slot is only 10 bits long (3 bits taken from each input plus 1 framing bit). What is the output stream? The bits arrive at the multiplexer as shown by the arrows.

Figure 6.34 *Problem P6-12*



P6-13. Figure 6.35 shows a demultiplexer in a synchronous TDM. If the input slot is 16 bits long (no framing bits), what is the bit stream in each output? The bits arrive at the demultiplexer as shown by the arrows.

Figure 6.35 *Problem P6-13*



P6-14. Answer the following questions about the digital hierarchy in Figure 6.23:

a. What is the overhead (number of extra bits) in the DS-1 service?

b. What is the overhead (number of extra bits) in the DS-2 service?

c. What is the overhead (number of extra bits) in the DS-3 service?

d. What is the overhead (number of extra bits) in the DS-4 service?

P6-15. What is the minimum number of bits in a PN sequence if we use FHSS with a channel bandwidth of $B = 4$ KHz and $B_{SS} = 100$ KHz?

P6-16. An FHSS system uses a 4-bit PN sequence. If the bit rate of the PN is 64 bits per second, answer the following questions:

a. What is the total number of possible channels?

b. What is the time needed to finish a complete cycle of PN?

P6-17. A pseudorandom number generator uses the following formula to create a random series:

$$N_{i+1} = (5 + 7N_i) \bmod 17 - 1$$

In which N_i defines the current random number and N_{i+1} defines the next random number. The term *mod* means the value of the remainder when dividing $(5 + 7N_i)$ by 17. Show the sequence created by this generator to be used for spread spectrum.

P6-18. We have a digital medium with a data rate of 10 Mbps. How many 64-kbps voice channels can be carried by this medium if we use DSSS with the Barker sequence?

6.5 SIMULATION EXPERIMENTS

6.5.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.

7.5.3 Problems

P7-1. Using Figure 7.6, tabulate the attenuation (in dB) of a 18-gauge UTP for the indicated frequencies and distances.

Table 7.5 *Attenuation for 18-gauge UTP*

Distance	*dB at 1 KHz*	*dB at 10 KHz*	*dB at 100 KHz*
1 Km			
10 Km			
15 Km			
20 Km			

P7-2. Use the results of Problem P7-1 to infer that the bandwidth of a UTP cable decreases with an increase in distance.

P7-3. If the power at the beginning of a 1 Km 18-gauge UTP is 200 mw, what is the power at the end for frequencies 1 KHz, 10 KHz, and 100 KHz? Use the results of Problem P7-1.

P7-4. Using Figure 7.9, tabulate the attenuation (in dB) of a 2.6/9.5 mm coaxial cable for the indicated frequencies and distances.

Table 7.6 *Attenuation for 2.6/9.5 mm coaxial cable*

Distance	*dB at 1 KHz*	*dB at 10 KHz*	*dB at 100 KHz*
1 Km			
10 Km			
15 Km			
20 Km			

P7-5. Use the results of Problem P7-4 to infer that the bandwidth of a coaxial cable decreases with the increase in distance.

P7-6. If the power at the beginning of a 1 Km 2.6/9.5 mm coaxial cable is 200 mw, what is the power at the end for frequencies 1 KHz, 10 KHz, and 100 KHz? Use the results of Problem P7-4.

P7-7. Calculate the bandwidth of the light for the following wavelength ranges (assume a propagation speed of 2×10^8 m):

a. 1000 to 1200 nm **b.** 1000 to 1400 nm

P7-8. The horizontal axes in Figures 7.6 and 7.9 represent frequencies. The horizontal axis in Figure 7.16 represents wavelength. Can you explain the reason? If the propagation speed in an optical fiber is 2×10^8 m, can you change the units in the horizontal axis to frequency? Should the vertical-axis units be changed too? Should the curve be changed too?

P7-9. Using Figure 7.16, tabulate the attenuation (in dB) of an optical fiber for the indicated wavelength and distances.

Table 7.7 *Attenuation for optical fiber*

Distance	*dB at 800 nm*	*dB at 1000 nm*	*dB at 1200 nm*
1 Km			
10 Km			
15 Km			
20 Km			

P7-10. A light signal is travelling through a fiber. What is the delay in the signal if the length of the fiber-optic cable is 10 m, 100 m, and 1 Km (assume a propagation speed of 2×10^8 m)?

P7-11. A beam of light moves from one medium to another medium with less density. The critical angle is 60°. Do we have refraction or reflection for each of the following incident angles? Show the bending of the light ray in each case.

a. 40° **b.** 60° **c.** 80°

circuit-switched network and a datagram network. It has some characteristics of both. Circuit switching uses either of two technologies: the space-division switch or the time-division switch. A switch in a packet-switched network has a different structure from a switch used in a circuit-switched network. We can say that a packet switch has four types of components: input ports, output ports, a routing processor, and switching fabric.

8.6 PRACTICE SET

8.6.1 Quizzes

A set of interactive quizzes for this chapter can be found on the book website. It is strongly recommended that the student take the quizzes to check his/her understanding of the materials before continuing with the practice set.

8.6.2 Questions

Q8-1. Describe the need for switching and define a switch.

Q8-2. List the three traditional switching methods. Which are the most common today?

Q8-3. What are the two approaches to packet switching?

Q8-4. Compare and contrast a circuit-switched network and a packet-switched network.

Q8-5. What is the role of the address field in a packet traveling through a datagram network?

Q8-6. What is the role of the address field in a packet traveling through a virtual-circuit network?

Q8-7. Compare space-division and time-division switches.

Q8-8. What is TSI and what is its role in time-division switching?

Q8-9. Compare and contrast the two major categories of circuit switches.

Q8-10. List four major components of a packet switch and their functions.

8.6.3 Problems

P8-1. A path in a digital circuit-switched network has a data rate of 1 Mbps. The exchange of 1000 bits is required for the setup and teardown phases. The distance between two parties is 5000 km. Answer the following questions if the propagation speed is 2×10^8 m:

a. What is the total delay if 1000 bits of data are exchanged during the data-transfer phase?

b. What is the total delay if 100,000 bits of data are exchanged during the data-transfer phase?

c. What is the total delay if 1,000,000 bits of data are exchanged during the data-transfer phase?

d. Find the delay per 1000 bits of data for each of the above cases and compare them. What can you infer?

P8-2. Five equal-size datagrams belonging to the same message leave for the destination one after another. However, they travel through different paths as shown in Table 8.1.

Table 8.1 *P8-2*

Datagram	*Path Length*	*Visited Switches*
1	3200 km	1, 3, 5
2	11,700 km	1, 2, 5
3	12,200 km	1, 2, 3, 5
4	10,200 km	1, 4, 5
5	10,700 km	1, 4, 3, 5

We assume that the delay for each switch (including waiting and processing) is 3, 10, 20, 7, and 20 ms respectively. Assuming that the propagation speed is 2×10^8 m, find the order the datagrams arrive at the destination and the delay for each. Ignore any other delays in transmission.

P8-3. Transmission of information in any network involves end-to-end addressing and sometimes local addressing (such as VCI). Table 8.2 shows the types of networks and the addressing mechanism used in each of them.

Table 8.2 *P8-3*

Network	*Setup*	*Data Transfer*	*Teardown*
Circuit-switched	End-to-end		End-to-end
Datagram		End-to-end	
Virtual-circuit	End-to-end	Local	End-to-end

Answer the following questions:

a. Why does a circuit-switched network need end-to-end addressing during the setup and teardown phases? Why are no addresses needed during the data transfer phase for this type of network?

b. Why does a datagram network need only end-to-end addressing during the data transfer phase, but no addressing during the setup and teardown phases?

c. Why does a virtual-circuit network need addresses during all three phases?

P8-4. We mentioned that two types of networks, datagram and virtual-circuit, need a routing or switching table to find the output port from which the information belonging to a destination should be sent out, but a circuit-switched network has no need for such a table. Give the reason for this difference.

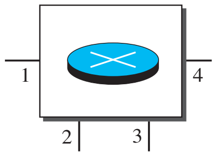
P8-5. An entry in the switching table of a virtual-circuit network is normally created during the setup phase and deleted during the teardown phase. In other words, the entries in this type of network reflect the current connections, the activity in the network. In contrast, the entries in a routing table of a datagram network do not depend on the current connections; they show the configuration of the network and how any packet should be routed to a final destination. The entries may remain the same even if there is no activity in the network. The routing tables, however, are updated if there are changes in the network. Can you explain the reason for these two different characteristics? Can we say that a virtual-circuit is a *connection-oriented* network and a datagram network is a *connectionless* network because of the above characteristics?

P8-6. The minimum number of columns in a datagram network is two; the minimum number of columns in a virtual-circuit network is four. Can you explain the reason? Is the difference related to the type of addresses carried in the packets of each network?

P8-7. Figure 8.27 shows a switch (router) in a datagram network.

Figure 8.27 *Problem P8-7*

Destination address	Output port
1233	3
1456	2
3255	1
4470	4
7176	2
8766	3
9144	2



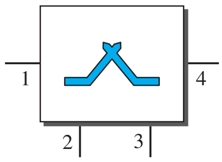
Find the output port for packets with the following destination addresses:

a. Packet 1: 7176
b. Packet 2: 1233
c. Packet 3: 8766
d. Packet 4: 9144

P8-8. Figure 8.28 shows a switch in a virtual-circuit network.

Figure 8.28 *Problem P8-8*

Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	22
2	71	4	41
2	92	1	45
3	58	2	43
3	78	2	70
4	56	3	11



Find the output port and the output VCI for packets with the following input port and input VCI addresses:

a. Packet 1: 3, 78
b. Packet 2: 2, 92
c. Packet 3: 4, 56
d. Packet 4: 2, 71

P8-9. Answer the following questions:

a. Can a routing table in a datagram network have two entries with the same destination address? Explain.

b. Can a switching table in a virtual-circuit network have two entries with the same input port number? With the same output port number? With the same incoming VCIs? With the same outgoing VCIs? With the same incoming values (port, VCI)? With the same outgoing values (port, VCI)?

P8-10. It is obvious that a router or a switch needs to search to find information in the corresponding table. The searching in a routing table for a datagram network is based on the destination address; the searching in a switching table in a virtual-circuit network is based on the combination of incoming port and incoming VCI. Explain the reason and define how these tables must be ordered (sorted) based on these values.

P8-11. Consider an $n \times k$ crossbar switch with n inputs and k outputs.

a. Can we say that the switch acts as a multiplexer if $n > k$?

b. Can we say that the switch acts as a demultiplexer if $n < k$?

P8-12. We need a three-stage space-division switch with $N = 100$. We use 10 crossbars at the first and third stages and 4 crossbars at the middle stage.

a. Draw the configuration diagram.

b. Calculate the total number of crosspoints.

c. Find the possible number of simultaneous connections.

d. Find the possible number of simultaneous connections if we use a single crossbar (100×100).

e. Find the blocking factor, the ratio of the number of connections in part c and in part d.

P8-13. Repeat Problem 8-12 if we use 6 crossbars at the middle stage.

P8-14. Redesign the configuration of Problem 8-12 using the Clos criteria.

P8-15. We need to have a space-division switch with 1000 inputs and outputs. What is the total number of crosspoints in each of the following cases?

a. Using a single crossbar.

b. Using a multi-stage switch based on the Clos criteria.

P8-16. We need a three-stage time-space-time switch with $N = 100$. We use 10 TSIs at the first and third stages and 4 crossbars at the middle stage.

a. Draw the configuration diagram.

b. Calculate the total number of crosspoints.

c. Calculate the total number of memory locations we need for the TSIs.

8.7 SIMULATION EXPERIMENTS

8.7.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.

Q9-11. Why does a host or a router need to run the ARP program all of the time in the background?

Q9-12. Why does a router normally have more than one interface?

Q9-13. Why is it better not to change an end-to-end address from the source to the destination?

Q9-14. How many IP addresses and how many link-layer addresses should a router have when it is connected to five links?

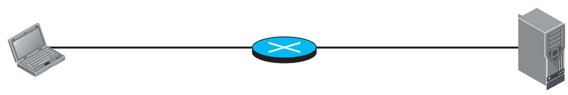
9.4.3 Problems

P9-1. Assume we have an internet (a private small internet) in which all hosts are connected in a mesh topology. Do we need routers in this internet? Explain.

P9-2. In the previous problem, do we need both network and data-link layers?

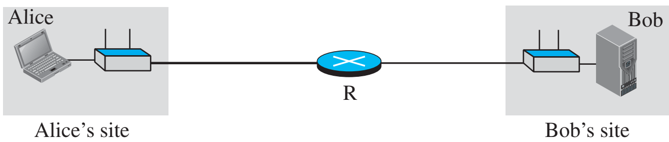
P9-3. Explain why we do not need the router in Figure 9.15.

Figure 9.15 *Problem 9-3*



P9-4. Explain why we may need a router in Figure 9.16.

Figure 9.16 *Problem 9-4*



P9-5. Is the current Internet using circuit-switching or packet-switching at the data-link layer? Explain.

P9-6. Assume Alice is travelling from 2020 Main Street in Los Angeles to 1432 American Boulevard in Chicago. If she is travelling by air from Los Angeles Airport to Chicago Airport,

a. find the end-to-end addresses in this scenario.

b. find the link-layer addresses in this scenario.

P9-7. In the previous problem, assume Alice cannot find a direct flight from the Los Angeles to the Chicago. If she needs to change flights in Denver,

a. find the end-to-end addresses in this scenario.

b. find the link-layer addresses in this scenario.

P9-8. When we send a letter using the services provided by the post office, do we use an end-to-end address? Does the post office necessarily use an end-to-end address to deliver the mail? Explain.

P9-9. In Figure 9.5, assume Link 2 is broken. How can Alice communicate with Bob?

P9-10. In Figure 9.5, show the process of frame change in routers R1 and R2.

P9-11. In Figure 9.7, assume system B is not running the ARP program. What would happen?

P9-12. In Figure 9.7, do you think that system A should first check its cache for mapping from N2 to L2 before even broadcasting the ARP request?

P9-13. Assume the network in Figure 9.7 does not support broadcasting. What do you suggest for sending the ARP request in this network?

P9-14. In Figures 9.11 to 9.13, both the forwarding table and ARP are doing a kind of mapping. Show the difference between them by listing the input and output of mapping for a forwarding table and ARP.

P9-15. Figure 9.7 shows a system as either a host or a router. What would be the actual entity (host or router) of system A and B in each of the following cases:

a. If the link is the first one in the path?

b. If the link is the middle one in the path?

c. If the link is the last one in the path?

d. If there is only one link in the path (local communication)?

Q10-11. In CRC, we have chosen the generator 1100101. What is the probability of detecting a burst error of length

a. 5? **b.** 7? **c.** 10?

Q10-12. Assume we are sending data items of 16-bit length. If two data items are swapped during transmission, can the traditional checksum detect this error? Explain.

Q10-13. Can the value of a traditional checksum be all 0s (in binary)? Defend your answer.

Q10-14. Show how the Fletcher algorithm (Figure 10.18) attaches weights to the data items when calculating the checksum.

Q10-15. Show how the Adler algorithm (Figure 10.19) attaches weights to the data items when calculating the checksum.

10.7.3 Problems

P10-1. What is the maximum effect of a 2-ms burst of noise on data transmitted at the following rates?

a. 1500 bps **b.** 12 kbps **c.** 100 kbps **d.** 100 Mbps

P10-2. Assume that the probability that a bit in a data unit is corrupted during transmission is p. Find the probability that x number of bits are corrupted in an n-bit data unit for each of the following cases.

a. $n = 8, x = 1, p = 0.2$

b. $n = 16, x = 3, p = 0.3$

c. $n = 32, x = 10, p = 0.4$

P10-3. Exclusive-OR (XOR) is one of the most used operations in the calculation of codewords. Apply the exclusive-OR operation on the following pairs of patterns. Interpret the results.

a. (10001) ⊕ (10001) **b.** (11100) ⊕ (00000) **c.** (10011) ⊕ (11111)

P10-4. In Table 10.1, the sender sends dataword 10. A 3-bit burst error corrupts the codeword. Can the receiver detect the error? Defend your answer.

P10-5. Using the code in Table 10.2, what is the dataword if each of the following codewords is received?

a. 01011 **b.** 11111 **c.** 00000 **d.** 11011

P10-6. Prove that the code represented by the following codewords is not linear. You need to find only one case that violates the linearity.

{**(00000), (01011), (10111), (11111)**}

P10-7. What is the Hamming distance for each of the following codewords?

a. *d* (10000, 00000) **b.** *d* (10101, 10000)

c. *d* (00000, 11111) **d.** *d* (00000, 00000)

P10-8. Although it can be formally proved that the code in Table 10.3 is both linear and cyclic, use only two tests to partially prove the fact:

a. Test the cyclic property on codeword 0101100.

b. Test the linear property on codewords 0010110 and 1111111.

P10-9. Referring to the CRC-8 in Table 5.4, answer the following questions:

a. Does it detect a single error? Defend your answer.

b. Does it detect a burst error of size 6? Defend your answer.

c. What is the probability of detecting a burst error of size 9?

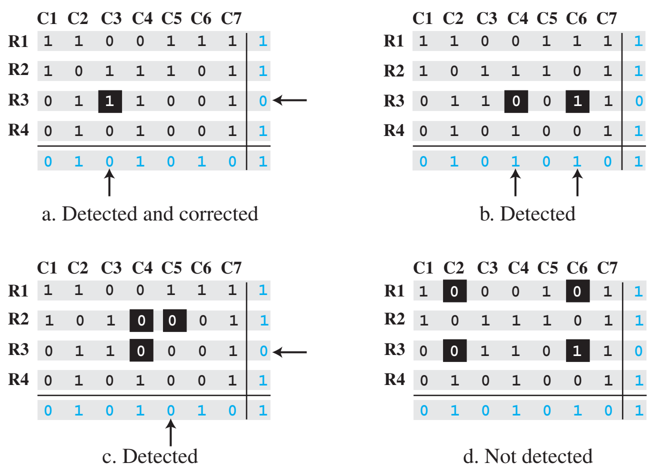
d. What is the probability of detecting a burst error of size 15?

P10-10. Assuming even parity, find the parity bit for each of the following data units.

a. 1001011 **b.** 0001100 **c.** 1000000 **d.** 1110111

P10-11. A simple parity-check bit, which is normally added at the end of the word (changing a 7-bit ASCII character to a byte), cannot detect even numbers of errors. For example, two, four, six, or eight errors cannot be detected in this way. A better solution is to organize the characters in a table and create row and column parities. The bit in the row parity is sent with the byte, the column parity is sent as an extra byte (Figure 10.23).

Figure 10.23 *P10-11*



Show how the following errors can be detected:

a. An error at (R3, C3).

b. Two errors at (R3, C4) and (R3, C6).

c. Three errors at (R2, C4), (R2, C5), and (R3, C4).

d. Four errors at (R1, C2), (R1, C6), (R3, C2), and (R3, C6).

P10-12. Given the dataword 101001111 and the divisor 10111, show the generation of the CRC codeword at the sender site (using binary division).

P10-13. Apply the following operations on the corresponding polynomials:

a. $(x^3 + x^2 + x + 1) + (x^4 + x^2 + x + 1)$

b. $(x^3 + x^2 + x + 1) - (x^4 + x^2 + x + 1)$

c. $(x^3 + x^2) \times (x^4 + x^2 + x + 1)$

d. $(x^3 + x^2 + x + 1) / (x^2 + 1)$

P10-14. Answer the following questions:

a. What is the polynomial representation of 101110?

b. What is the result of shifting 101110 three bits to the left?

c. Repeat part b using polynomials.

d. What is the result of shifting 101110 four bits to the right?

e. Repeat part d using polynomials.

P10-15. Which of the following CRC generators guarantee the detection of a single bit error?

a. $x^3 + x + 1$ **b.** $x^4 + x^2$ **c.** 1 **d.** $x^2 + 1$

P10-16. Referring to the CRC-8 polynomial in Table 10.7, answer the following questions:

a. Does it detect a single error? Defend your answer.

b. Does it detect a burst error of size 6? Defend your answer.

c. What is the probability of detecting a burst error of size 9?

d. What is the probability of detecting a burst error of size 15?

P10-17. Referring to the CRC-32 polynomial in Table 10.4, answer the following questions:

a. Does it detect a single error? Defend your answer.

b. Does it detect a burst error of size 16? Defend your answer.

c. What is the probability of detecting a burst error of size 33?

d. What is the probability of detecting a burst error of size 55?

P10-18. Assume a packet is made only of four 16-bit words $(A7A2)_{16}$, $(CABF)_{16}$, $(903A)_{16}$, and $(A123)_{16}$. Manually simulate the algorithm in Figure 10.17 to find the checksum.

P10-19. Traditional checksum calculation needs to be done in one's complement arithmetic. Computers and calculators today are designed to do calculations in two's complement arithmetic. One way to calculate the traditional checksum is to add the numbers in two's complement arithmetic, find the quotient and remainder of dividing the result by 2^{16}, and add the quotient and the remainder to get the sum in one's complement. The checksum can be found by subtracting the sum from $2^{16} - 1$. Use the above method to find the checksum of the following four numbers: 43,689, 64,463, 45,112, and 59,683.

P10-20. This problem shows a special case in checksum handling. A sender has two data items to send: $(4567)_{16}$ and $(BA98)_{16}$. What is the value of the checksum?

P10-21. Manually simulate the Fletcher algorithm (Figure 10.18) to calculate the checksum of the following bytes: $(2B)_{16}$, $(3F)_{16}$, $(6A)_{16}$, and $(AF)_{16}$. Also show that the result is a weighted checksum.

P10-22. Manually simulate the Adler algorithm (Figure 10.19) to calculate the checksum of the following words: $(FBFF)_{16}$ and $(EFAA)_{16}$. Also show that the result is a weighted checksum.

P10-23. One of the examples of a weighted checksum is the ISBN-10 code we see printed on the back cover of some books. In ISBN-10, there are 9 decimal digits that define the country, the publisher, and the book. The tenth (rightmost) digit is a checksum digit. The code, $D_1D_2D_3D_4D_5D_6D_7D_8D_9C$, satisfies the following.

$$[(10 \times D_1) + (9 \times D_2) + (8 \times D_3) + \ldots + (2 \times D_9) + (1 \times C)] \bmod 11 = 0$$

In other words, the weights are 10, 9, . . .,1. If the calculated value for C is 10, one uses the letter X instead. By replacing each weight *w* with its complement in modulo 11 arithmetic $(11 - w)$, it can be shown that the check digit can be calculated as shown below.

$$C = [(1 \times D_1) + (2 \times D_2) + (3 \times D_3) + \ldots + (9 \times D_9)] \bmod 11$$

Calculate the check digit for ISBN-10: **0-07-296775-C**.

P10-24. An ISBN-13 code, a new version of ISBN-10, is another example of a weighted checksum with 13 digits, in which there are 12 decimal digits defining the book and the last digit is the checksum digit. The code, $D_1D_2D_3D_4D_5D_6D_7D_8D_9D_{10}D_{11}D_{12}C$, satisfies the following.

$$[(1 \times D_1) + (3 \times D_2) + (1 \times D_3) + \ldots + (3 \times D_{12}) + (1 \times C)] \bmod 10 = 0$$

In other words, the weights are 1 and 3 alternately. Using the above description, calculate the check digit for ISBN-13: **978-0-07-296775-C**.

P10-25. In the interleaving approach to FEC, assume each packet contains 10 samples from a sampled piece of music. Instead of loading the first packet with the first 10 samples, the second packet with the second 10 samples, and so on, the sender loads the first packet with the odd-numbered samples of the first 20 samples, the second packet with the even-numbered samples of the first 20 samples, and so on. The receiver reorders the samples and plays them. Now assume that the third packet is lost in transmission. What will be missed at the receiver site?

P10-26. Assume we want to send a dataword of two bits using FEC based on the Hamming distance. Show how the following list of datawords/codewords can automatically correct up to a one-bit error in transmission.

$00 \rightarrow 00000 \qquad 01 \rightarrow 01011 \qquad 10 \rightarrow 10101 \qquad 11 \rightarrow 11110$

P10-27. Assume we need to create codewords that can automatically correct a one-bit error. What should the number of redundant bits (r) be, given the number of bits in the dataword (k)? Remember that the codeword needs to be $n = k + r$ bits, called $C(n, k)$. After finding the relationship, find the number of bits in r if k is 1, 2, 5, 50, or 1000.

P10-28. In the previous problem we tried to find the number of bits to be added to a dataword to correct a single-bit error. If we need to correct more than one bit, the number of redundant bits increases. What should the number of redundant bits (r) be to automatically correct one or two bits (not necessarily contiguous) in a dataword of size k? After finding the relationship, find the number of bits in r if k is 1, 2, 5, 50, or 1000.

P10-29. Using the ideas in the previous two problems, we can create a general formula for correcting any number of errors (m) in a codeword of size (n). Develop such a formula. Use the combination of n objects taking x objects at a time.

P10-30. In Figure 10.22, assume we have 100 packets. We have created two sets of packets with high and low resolutions. Each high-resolution packet carries on average 700 bits. Each low-resolution packet carries on average 400 bits. How many extra bits are we sending in this scheme for the sake of FEC? What is the percentage of overhead?

10.8 SIMULATION EXPERIMENTS

10.8.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.

10.9 PROGRAMMING ASSIGNMENTS

For each of the following assignments, write a program in the programming language you are familiar with.

Prg10-1. A program to simulate the calculation of CRC.

Prg10-2. A program to simulate the calculation of traditional checksum.

Prg10-3. A program to simulate the calculation of Fletcher checksum.

Prg10-4. A program to simulate the calculation of Adler checksum.

Data-link protocols have been designed to handle communication between two nodes. We discussed two protocols in this chapter. In the Simple Protocol, there is no flow and error control. In the Stop-and-Wait Protocol, there are both flow and error controls, but communication is a frame at a time.

High-level Data Link Control (HDLC) is a bit-oriented protocol for communication over point-to-point and multipoint links. It implements the Stop-and-Wait protocol. It is the basis of many protocols in practice today. HDLC defines three types of frames: information frames, supervisory frames, and unnumbered frames. The informational frames are used to carry data frames. Supervisory frames are used only to transport control information for flow and error control. Unnumbered frames are reserved for system management and provide connection-oriented service.

One of the most common protocols for point-to-point access is the Point-to-Point Protocol (PPP). PPP uses only one type of frame, but allows multiplexing of different payloads to achieve a kind of connection-oriented service authentication. Encapsulating different packets in a frame allows PPP to move to different states to provide necessary services.

11.6 PRACTICE SET

11.6.1 Quizzes

A set of interactive quizzes for this chapter can be found on the book website. It is strongly recommended that the student take the quizzes to check his/her understanding of the materials before continuing with the practice set.

11.6.2 Questions

Q11-1. Define *framing* and give the reason it is needed.

Q11-2. Explain why flags are needed when we use variable-size frames.

Q11-3. Assume a new character-oriented protocol is using the 16-bit Unicode as the character set. What should the size of the flag be in this protocol?

Q11-4. Compare and contrast byte-oriented and bit-oriented protocols.

Q11-5. Compare and contrast byte-stuffing and bit-stuffing.

Q11-6. In a byte-oriented protocol, should we first unstuff the extra bytes and then remove the flags or reverse the process?

Q11-7. In a bit-oriented protocol, should we first unstuff the extra bits and then remove the flags or reverse the process?

Q11-8. Compare and contrast flow control and error control.

Q11-9. In the Stop-and-Wait Protocol, assume that the sender has only one slot in which to keep the frame to send or the copy of the sent frame. What happens if the network layer delivers a packet to the data-link layer at this moment?

Q11-10. In Example 11.3 (Figure 11.12) how many frames are in transit at the same time?

Q11-11. In Example 11.4 (Figure 11.13) how many frames are in transit at the same time?

Q11-12. In the traditional Ethernet protocol (Chapter 13), the frames are sent with the CRC. If the frame is corrupted, the receiving node just discards it. Is this an example of a Simple Protocol or the Stop-and-Wait Protocol? Explain.

Q11-13. In Figure 11.11, do the ready and blocking states use the same timer? Explain.

Q11-14. Explain why there is no need for CRC in the Simple Protocol.

Q11-15. In Figure 11.9, we show the packet path as a horizontal line, but the frame path as a diagonal line. Can you explain the reason?

Q11-16. In Figure 11.12, explain why we need a timer at the sending site, but none at the receiving site.

Q11-17. Does the duplex communication in Figure 11.10 necessarily mean we need two separate media between the two nodes? Explain.

Q11-18. Define *piggybacking* and its benefit.

Q11-19. In Figure 11.16, which frame type can be used for acknowledgment?

Q11-20. Compare Figure 11.6 and Figure 11.21. If both are FSMs, why are there no event/action pairs in the second?

Q11-21. In PPP, we normally talk about *user* and *system* instead of *sending and receiving nodes;* explain the reason.

Q11-22. Compare and contrast HDLC with PPP.

Q11-23. Compare the flag byte and the escape byte in PPP. Are they are the same? Explain.

Q11-24. In Figure 11.20, explain why we need only one address field. Explain why the address is set to the predefined value of $(11111111)_2$.

11.6.3 Problems

P11-1. Byte-stuff the following frame payload in which E is the escape byte, F is the flag byte, and D is a data byte other than an escape or a flag character.

D	**E**	D	D	**F**	D	D	**E**	**E**	D	**F**	D

P11-2. Unstuff the following frame payload in which E is the escape byte, F is the flag byte, and D is a data byte other than an escape or a flag character.

E	**E**	D	**E**	**F**	D	D	**E**	**F**	**E**	**E**	D	D	D	

P11-3. Bit-stuff the following frame payload:

0001111111001111101000111111111110000111

P11-4. Unstuff the following frame payload:

00011111000001111101110100111011111000001111

P11-5. Assume we change the Stop-and-Wait Protocol to include a NAK (negative feedback), which is used only when a corrupted frame arrives and is discarded. Redraw Figure 11.9 to show this change.

P11-6. In Example 11.4 (Figure 11.13), assume the round trip time for a frame is 40 milliseconds. Explain what will happen if we set the time-out in each of the following cases.

a. 35 milliseconds **b.** 45 milliseconds **c.** 40 milliseconds

P11-7. Redraw Figure 11.12 using the following scenario:

a. The first frame is sent and acknowledged.

b. The second frame is sent and acknowledged, but the acknowledgment is lost.

c. The second frame is resent, but it is timed-out.

d. The second frame is resent and acknowledged.

P11-8. Redraw Figure 11.2 using the following scenario:

a. Frame 0 is sent, but lost.

b. Frame 0 is resent and acknowledged.

c. Frame 1 is sent and acknowledged, but the acknowledgment is lost.

d. Frame 1 is resent and acknowledged.

P11-9. In Figure 11.11, show what happens in each of the following cases:

a. The sender is at the ready state and an error-free ACK arrives.

b. The sender is at the blocking state and a time-out occurs.

c. The sender is at the ready state and a time-out occurs.

P11-10. In Figure 11.11, show what happens in each of the following cases:

a. The receiver is in the ready state and a packet comes from the network layer.

b. The receiver is in the ready state and a corrupted frame arrives.

c. The receiver is in the ready state and an acknowledgment arrives.

P11-11. Using the following specifications, draw a finite state machine with three states (I, II, and III), five events, and six actions:

a. If the machine is in state I, two events can occur. If event 1 occurs, the machine moves to state II. If event 2 occurs, the machine performs actions 1 and 2 and moves to state III.

b. If the machine is in state II, two events can occur. If event 3 occurs, the machine remains in state II. If event 4 occurs, the machine moves to state III.

c. If the machine is in state III, three events can occur. If event 2 occurs, the machine remains in state III. If event 3 occurs, the machine performs actions 1, 2, 4, and 5 moves to state II. If event 5 occurs, the machine performs actions 1, 2, and 6 and moves to state I.

P11-12. Using the following specifications, draw a finite state machine with three states (I, II, and III), six events, and four actions:

a. If the machine is in state I, two events can occur. If event 1 occurs, the machine moves to state III. If event 3 occurs, the machine performs actions 2 and 4 and moves to state II.

b. If the machine is in state II, two events can occur. If event 4 occurs, the machine remains in state II. If event 6 occurs, the machine performs actions 1 and 2 and moves to state III.

c. If the machine is in state III, three events can occur. If event 2 occurs, the machine remains in state III. If event 6 occurs, the machine performs actions 2, 3, 4, and 5 moves to state I. If event 4 occurs, the machine performs actions 1 and 2 and moves to state I.

P11-13. Redraw Figure 11.11 using a variable to hold the one-bit sequence number and a variable to hold the one-bit acknowledgment number.

P11-14. Redraw Figure 11.10 using piggybacking.

P11-15. Assume PPP is in the established phase; show payload encapsulated in the frame.

P11-16. Redraw Figure 11.21 with the system not using authentication.

P11-17. Assume PPP is in the authentication phase, show payload exchanged between the nodes if PPP is using

a. PAP

b. CHAP

P11-18. Assume the only computer in the residence uses PPP to communicate with the ISP. If the user sends 10 network-layer packets to ISP, how many frames are exchanged in each of the following cases:

a. Using no authentication?

b. Using PAP for authentication?

c. Using CHAP for authentication?

11.7 SIMULATION EXPERIMENTS

11.7.1 Applets

We have created some Java applets to show some of the main concepts discussed in this chapter. It is strongly recommended that the students activate these applets on the book website and carefully examine the protocols in action.

11.8 PROGRAMMING ASSIGNMENTS

For each of the following assignments, write a program in the programming language you are familiar with.

Prg11-1. Write and test a program that simulates the byte stuffing and byte unstuffing as shown in Figure 11.2.

Prg11-2. Write and test a program that simulates the bit stuffing and bit unstuffing as shown in Figure 11.4.