Computer Networks
Problem Set 2

Instructor: Shashi Prabh

Chapter 2 - The Physical Layer

2.1 How much bandwidth is there in 0.1 microns of spectrum at a wavelength of 1 micron.

2.2 It is desired to send a sequence of computer screen images over an optical fiber. The screen is 3840 $\times$ 2160 pixels, each pixel being 24 bits. There are 50 screen images per second. What data rate is needed?

2.3 Radio antennas often work best when the diameter of the antenna is equal to the wavelength of the radio wave. Reasonable antennas range from 1 cm to 1 meter in diameter. What frequency range does this cover?

2.4 Multipath fading is maximized when the two beams arrive 180 degrees out of phase. How much of a path difference is required to maximize the fading for a 100-km-long 1-GHz microwave link?

2.5 A laser beam 1 mm wide is aimed at a detector 1 mm wide 100 m away on the roof of a building. How much of an angular diversion (in degrees) does the laser have to have before it misses the detector?

2.6 Compute the Fourier coefficients for the function $f(t) = t, 0 \leq t \leq 1$.

2.7 A noiseless 10-kHz channel is sampled every 1 msec. What is the maximum data rate?

2.8 Television channels are 6 MHz wide. How many bits/sec can be sent if four-level digital signals are used? Assume a noiseless channel.

2.9 If a binary signal is sent over a 3-kHz channel whose signal-to-noise ratio is 20 dB, what is the maximum achievable data rate?

2.10 You need to select a line code that will only be used to send the bit sequences 10101010 and 00111100. Which of the lines codes shown in Fig. 1 is not a good candidate? Consider both bandwidth efficiency and clock recovery.

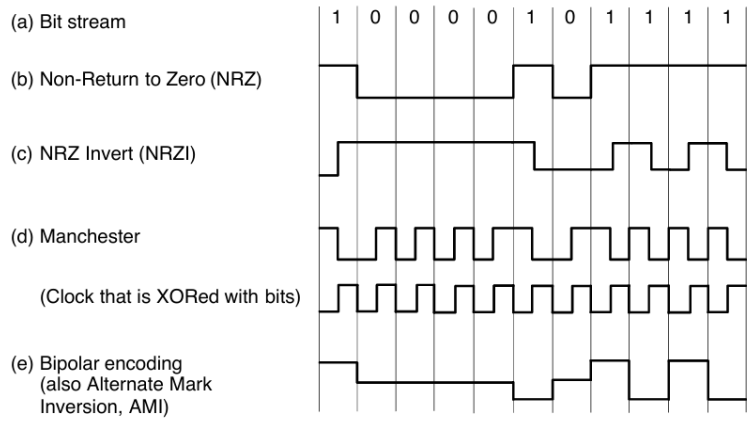

Figure 2-14. Line codes: (a) Bits, (b) NRZ, (c) NRZI, (d) Manchester, (e) Bipolar or AMI.

Figure 1: Exercise 2.10

2.11 Draw NRZ , NRZI, Manchester and bipolar encodings for the following data streams:

a. 01010101

b. 01001100111

2.12 Prove that in 4B/5B mapped data with the NRZI encoding, a signal transition will occur at least every four bit times.

2.13 Ten signals, each requiring 4000 Hz, are multiplexed onto a single channel using FDM.What is the minimum bandwidth required for the multiplexed channel? Assume that the guard bands are 400 Hz wide.

2.14 Suppose that A, B, and C are simultaneously transmitting 0 bits, using a CDMA system with the chip sequences of Fig. 2. What is the resulting chip sequence?

A = (−1 −1 −1 +1 +1 −1 +1 +1)

B = (−1 −1 +1 −1 +1 +1 +1 −1)

C = (−1 +1 −1 +1 +1 +1 −1 −1)

D = (−1 +1 −1 −1 −1 −1 +1 −1)

(a)

Figure 2: Exercise 2.14

2.15 In the discussion about orthogonality of CDMA chip sequences, it was stated that if S•T = 0 then S•T is also 0. Prove this.

2.16 Consider a different way of looking at the orthogonality property of CDMA chip sequences. Each bit in a pair of sequences can match or not match. Express the orthogonality property in terms of matches and mismatches.

2.17 A base station schedules a single slot for devices A and B to send data using their corresponding chip sequences from Fig. 3. During this time, other stations remain silent. Due to noise, some of the chips are lost. The base station receives the following sequence: (0, 0, ?, 2, ?, ?, 0,-2). What are the bit values transmitted by stations A and B?

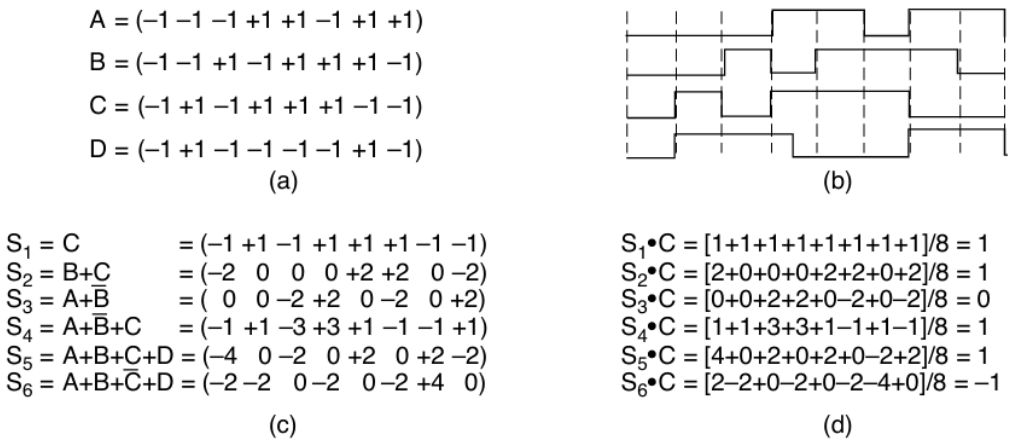

Figure 2-22. (a) Chip sequences for four stations. (b) Signals the sequences represent (c) Six examples of transmissions. (d) Recovery of station C's signal.

Figure 3: Exercise 2.17

2.18 How many end office codes were there pre-1984, when each end office was named by its three-digit area code and the first three digits of the local number? Area codes started with a digit in the range 2–9, had a 0 or 1 as the second digit, and ended with any digit. The first two digits of a local number were always in the range 2–9. The third digit could be any digit.

2.19 28. A simple telephone system consists of two end offices and a single toll office to which each end office is connected by a 1-MHz full-duplex trunk. The average telephone is used to makefour calls per 8-hour workday. The mean call duration is 6 min. Ten percent of the calls are long distance (i.e., pass through the toll office). What is the maximum number of telephones an end office can support? (Assume 4 kHz per circuit.) Explain why a telephone company may decide to support a lesser number of telephones than this maximum number at the end-office.

2.20 What is the maximum bit rate achievable in a V.32 standard modem if the baud rate is 9600 and no error correction is used?

2.21 Why has the PCM sampling time been set at 125 μ s?

2.22 SONET clocks have a drift rate of about 1 part in 109. How long does it take for the drift to equal the width of 1 bit? Do you see any practical implications of this calculation? If so, what?

2.23 In Fig. 4, the user data rate for OC-3 is stated to be 148.608 Mbps. Show how this number can be derived from the SONET OC-3 parameters. What will be the gross, SPE, and user data rates of an OC-3072 line?

SONET		SDH	Data rate (Mbps)		
Electrical	Optical	Optical	Gross	SPE	User
STS-1	OC-1		51.84	50.112	49.536
STS-3	OC-3	STM-1	155.52	150.336	148.608
STS-12	OC-12	STM-4	622.08	601.344	594.432
STS-48	OC-48	STM-16	2488.32	2405.376	2377.728
STS-192	OC-192	STM-64	9953.28	9621.504	9510.912
STS-768	OC-768	STM-256	39813.12	38486.016	38043.648

Figure 2-35. SONET and SDH multiplex rates.

Figure 4: Exercise 2.14

2.24 Three packet-switching networks each contain n nodes. The first network has a star topology with a central switch, the second is a (bidirectional) ring, and the third is fully interconnected, with a wire from every node to every other node. What are the best-, average-, and worst-case transmission paths in hops?

2.25 Compare the delay in sending an x-bit message over a k-hop path in a circuit-switched network and in a (lightly loaded) packet-switched network. The circuit setup time is s sec, the propagation delay is d sec per hop, the packet size is p bits, and the data rate is b bps. Under what conditions does the packet network have a lower delay? Also, explain the conditions under which a packet-switched network is preferable to a circuit-switched network.

2.26 Suppose that x bits of user data are to be transmitted over a k-hop path in a packet-switched network as a series of packets, each containing p data bits and h header bits, with $x \gg p + h$. The bit rate of the lines is b bps and the propagation delay is negligible. What value of p minimizes the total delay?

2.27 In a typical mobile phone system with hexagonal cells, it is forbidden to reuse a frequency band in an adjacent cell. If 840 frequencies are available, how many can be used in a given cell?

2.28 The 66 low-orbit satellites in the Iridium project are divided into six necklaces around the earth. At the altitude they are using, the period is 90 minutes. What is the average interval for handoffs for a stationary transmitter?

2.29 Consider a satellite at the altitude of geostationary satellites but whose orbital plane is inclined to the equatorial plane by an angle ϕ. To a stationary user on the earth's surface at north latitude ϕ, does this satellite appear motionless in the sky? If not, describe its motion.

2.30 Calculate the end-to-end transit time for a packet for both GEO (altitude: 35,800 km), MEO (altitude: 18,000 km), and LEO (altitude: 750 km) satellites.

2.31 What is the latency of a call originating at the North Pole to reach the South Pole if the call is routed via Iridium satellites? Assume that the switching time at the satellites is 10 μ s and earth's radius is 6371 km.

2.32 How long will it take to transmit a 1-GB file from one VSAT to another using a hub as shown in Fig. 5? Assume that the uplink is 1 Mbps, the downlink is 7 Mbps, and circuit switching is used with 1.2 sec circuit setup time.

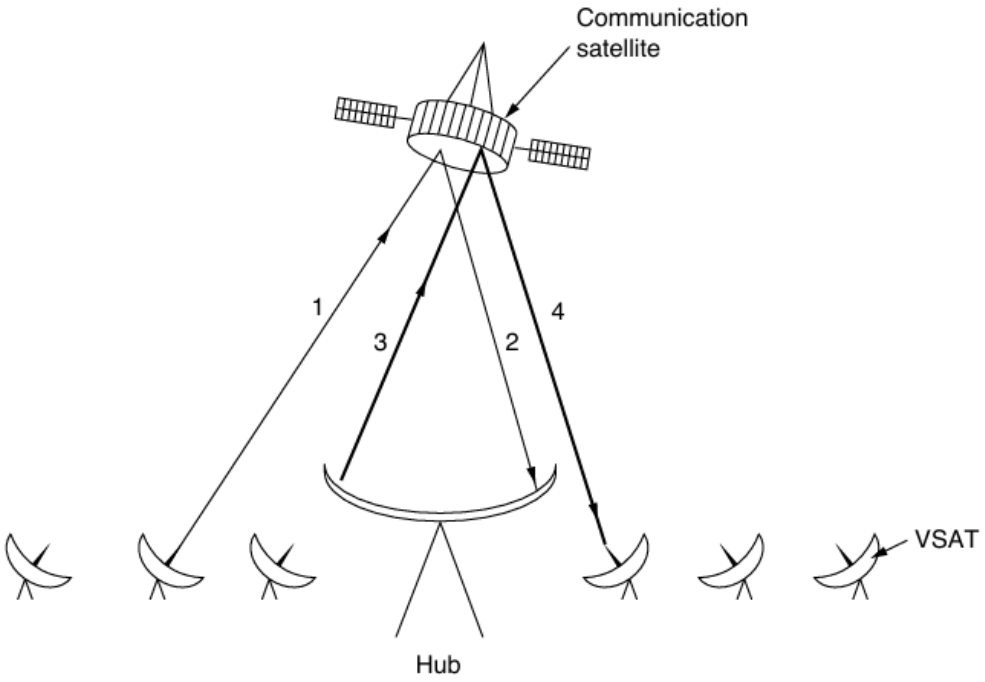

Figure 2-50. VSATs using a hub.

Figure 5: Exercise 2.17

2.33 Calculate the transmit time in the previous problem if packet switching is used instead.

2.34 Write a program to implement CDMA. Assume that the length of a chip sequence is eight and the number of stations transmitting is four. Your program consists of three sets of processes: four transmitter processes (t0, t1, t2, and t3), one joiner process, and four receiver processes (r0, r1, r2, and r3). The main program, which also acts as the joiner process first reads four chip sequences (bipolar notation) from the standard input and a sequence of 4 bits (1 bit per transmitter process to be transmitted), and forks off four pairs of transmitter and receiver processes. Each pair of transmitter/receiver processes (t0,r0; t1,r1; t2, r2; t3, r3) is assigned one chip sequence and each transmitter process is assigned 1 bit (first bit to t0, second bit to t1, and so on). Next, each transmitter process computes the signal to be transmitted (a sequence of 8 bits) and sends it to the joiner process. After receiving signals from all four transmitter processes, the joiner process combines the signals and sends the combined signal to the four receiver processes. Each receiver process then computes the bit it has received and prints it to standard output. U se pipes for communication between processes.