CHAPTER 6

PRACTICE SET

Questions

Q6-1. In *synchronous TDM*, each input has a reserved slot in the output frame. This can be inefficient if some input lines have no data to send. In *statistical TDM*, slots are dynamically allocated to improve bandwidth efficiency. Only when an input line has a slot's worth of data to send is it given a slot in the output frame.

Q6-2. In *spread spectrum*, we spread the bandwidth of a signal into a larger bandwidth. Spread spectrum techniques add redundancy; they spread the original spectrum needed for each station. The expanded bandwidth allows the source to wrap its message in a protective envelope for a more secure transmission. We discussed frequency hopping spread spectrum (FHSS) and direct sequence spread spectrum (DSSS).

Q6-3. The *frequency hopping spread spectrum* (FHSS) technique uses M different carrier frequencies that are modulated by the source signal. At one moment, the signal modulates one carrier frequency; at the next moment, the signal modulates another carrier frequency.

Q6-4. To maximize the efficiency of their infrastructure, telephone companies have traditionally multiplexed digital signals from lower data rate lines onto higher data rate lines. The *digital hierarchy* uses DS-0 (64 Kbps), DS-1 (1.544 Mbps), DS-2 (6.312 Mbps), DS-3 (44.376 Mbps), and DS-4 (274.176 Mbps).

Q6-5. *Multiplexing* is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

Q6-6. FDM and WDM are used to combine analog signals; the bandwidth is shared. TDM is used to combine digital signals; the time is shared.

Q6-7. WDM is common for multiplexing *optical signals* because it allows the multiplexing of signals with a very high frequency.

Q6-8. In *multilevel TDM*, some lower-rate lines are combined to make a new line with the same data rate as the other lines. *Multiple slot TDM*, on the other hand, uses multiple slots for higher data rate lines to make them compatible with the lower data rate line. *Pulse stuffing TDM* is used when the data rates of some lines are not an integral multiple of other lines.

Q6-9. In *multiplexing*, the word *link* refers to the physical path. The word *channel* refers to the portion of a link that carries a transmission between a given pair of lines. One link can have many (n) channels.

Q6-10. We discussed *frequency-division multiplexing* (FDM), *wave-division multiplexing* (WDM), and *time-division multiplexing* (TDM).

Q6-11. To maximize the efficiency of their infrastructure, telephone companies have traditionally multiplexed analog signals from lower-bandwidth lines onto higher-bandwidth lines. The *analog hierarchy* uses voice channels (4 KHz), *groups* (48 KHz), *supergroups* (240 KHz), *master groups* (2.4 MHz), and *jumbo groups* (15.12 MHz).

Q6-12. The *direct sequence spread spectrum* (DSSS) technique expands the bandwidth of the original signal. It replaces each data bit with n bits using a spreading code.

Problems

P6-1.

a. Each output frame carries 2 bits from each source plus one extra bit for synchronization. Frame size = 20 × 2 + 1 = 41 bits.

b. Each frame carries 2 bit from each source. Frame rate = 200,000/2 = 100,000 frames/s.

c. Frame duration = 1 /(frame rate) = 1 /100,000 = 10 ms.

d. Data rate = (100,000 frames/s) × (41 bits/frame) = 41 Mbps.

e. In each frame 40 bits out of 41 are useful. Efficiency = 40/41= 97.5%.

P6-2.

a. The frame carries 6 bits from each of the first two sources and 3 bits from each of the second two sources. Frame size = 6 × 2 + 3 × 2 = 18 bits.

b. Each frame carries 6 bit from each 300-kbps source or 3 bits from each 150 kbps. Frame rate = 300,000 / 6 = 150,000 /3 = 50,000 frames/s.

c. Frame duration = 1 /(frame rate) = 1 /50,000 = 20 ms.

d. Output data rate = (50,000 frames/s) × (18 bits/frame) = 900 kbps. We can also calculate the output data rate as the sum of input data rates because there are no synchronization bits. Output data rate = 2 × 300 + 2 × 150 = 900 kbps.

P6-3.

a. Group level: overhead = 48 KHz – (12 × 4 KHz) = 0 Hz.

b. Supergroup level: overhead = 240 KHz – (5 × 48 KHz) = 0 Hz.

c. Master group: overhead = 2520 KHz – (10 × 240 KHz) = 120 KHz.

d. Jumbo Group: overhead = 16.984 MHz – (6 × 2.52 MHz) = 1.864 MHz.

P6-4.

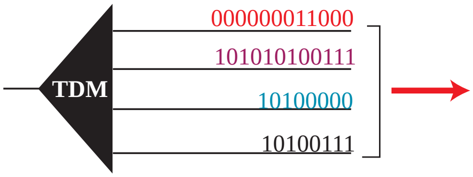
a. Frame size = 6 × (8 + 4) = 72 bits.

b. We can assume that we have only 6 input lines. Each frame needs to carry one character from each of these lines. This means that the frame rate is 500 frames/s.

c. Frame duration = 1 /(frame rate) = 1 /500 = 2 ms.

d. Data rate = (500 frames/s) × (72 bits/frame) = 36 kbps.

P6-5. See the following figure.



P6-6.

a. 2^4 = 16 hops

b. (64 bits/s) / 4 bits = 16 cycles

P6-7. Random numbers are 11, 13, 10, 6, 12, 3, 8, 9 as calculated below:

$$
\begin{aligned}
&N_1 && = && 11 \\
&N_2 = (5 + 7 \times 11) \bmod 17 - 1 && = && 13 \\
&N_3 = (5 + 7 \times 13) \bmod 17 - 1 && = && 10 \\
&N_4 = (5 + 7 \times 10) \bmod 17 - 1 && = && 6 \\
&N_5 = (5 + 7 \times 6) \bmod 17 - 1 && = && 12 \\
&N_6 = (5 + 7 \times 12) \bmod 17 - 1 && = && 3 \\
&N_7 = (5 + 7 \times 3) \bmod 17 - 1 && = && 8 \\
&N_8 = (5 + 7 \times 8) \bmod 17 - 1 && = && 9
\end{aligned}
$$

P6-8.

a. DS-1 overhead = 1.544 Mbps – (24 × 64 kbps) = 8 kbps.

b. DS-2 overhead = 6.312 Mbps – (4 × 1.544 Mbps) = 136 kbps.

c. DS-3 overhead = 44.376 Mbps – (7 × 6.312 Mbps) = 192 kbps.

d. DS-4 overhead = 274.176 Mbps – (6 × 44.376 Mbps) = 7.92 Mbps.

P6-9. The number of hops = 100 KHz/8 KHz = 12.5. So we need $\log_2 12.5 = 3.64 \approx$ 4 bits

P6-10.

a. Each output frame carries 1 bit from each source plus one extra bit for synchronization. Frame size = 40 × 1 + 1 = 41 bits.

b. Each frame carries 1 bit from each source. Frame rate = 100,000 frames/s.

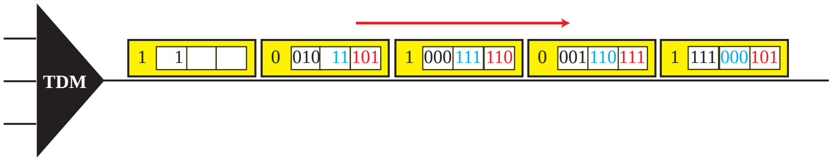
c. Frame duration = 1 /(frame rate) = 1 /100,000 = 10 ms.

d. Data rate = (100,000 frames/s) × (41 bits/frame) = 4.1 Mbps

e. In each frame 40 bits out of 41 are useful. Efficiency = 40/41= 97.5%

P6-11. To multiplex 12 voice channels, we need eleven guard bands. The required bandwidth is then B = (4 KHz) × 12 + (500 Hz) × 11 = 53.5 KHz

P6-12. See the following figure.



P6-13. We combine six 200-kbps sources into three 400-kbps. Now we have seven 400-kbps channel.

a. Each output frame carries 1 bit from each of the seven 400-kbps line. Frame size = 7 × 1 = 7 bits.

b. Each frame carries 1 bit from each 400-kbps source. Frame rate = 400,000 frames/s.

c. Frame duration = 1 /(frame rate) = 1 /400,000 = 2.5 ms.

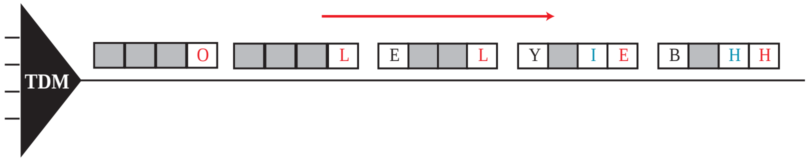
d. Output data rate = (400,000 frames/s) × (7 bits/frame) = 2.8 Mbps. We can also calculate the output data rate as the sum of input data rate because there is no synchronizing bits. Output data rate = 6 × 200 + 4 × 400 = 2.8 Mbps.

P6-14.

a. T-1 line sends 8000 frames/s. Frame duration = 1/8000 = 125 ms.

b. Each frame carries one extra bit. Overhead = 8000 × 1 = 8 kbps

P6-15. See the following figure.



P6-16. The bandwidth allocated to each voice channel is 30 KHz / 100 = 300 Hz. As we saw in the previous chapters, each digitized voice channel has a data rate of 64 Kbps (8000 sample × 8 bit/sample). This means that our modulation technique uses 64,000/300 ≈ 214 bits/Hz.

P6-17. We need to add extra bits to the second source to make both rates = 190 kbps. Now we have two sources, each of 190 Kbps.

a. The frame carries 1 bit from each source. Frame size = 1 + 1 = 2 bits.

b. Each frame carries 1 bit from each 190-kbps source. Frame rate = 190,000 frames/s.

c. Frame duration = 1 /(frame rate) = 1 /190,000 = 5.3 ms.

d. Output data rate = (190,000 frames/s) × (2 bits/frame) = 380 kbps. Here the output bit rate is greater than the sum of the input rates (370 kbps) because of extra bits added to the second source.

P6-18. The Barker chip is 11 bits, which means that it increases the bit rate 11 times. A voice channel of 64 kbps needs 11×64 kbps = 704 kbps. This means that the bandpass channel can carry (20 Mbps) / (704 kbps) or approximately 28 channels.