CHAPTER 6

PRACTICE SET

Questions

Q6-1. *Multiplexing* is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

Q6-3. 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.

Q6-5. 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).

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

Q6-9. 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.

Q6-11 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.

Problems

P6-1. To multiplex 10 voice channels, we need nine guard bands. The required bandwidth is then $B = (4 \text{ KHz}) \times 10 + (500 \text{ Hz}) \times 9 = 44.5 \text{ KHz}$

P6-3.

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

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

c. Master group: overhead = 2520 KHz – (10 $\times$ 240 KHz) = 120 KHz.

d. Jumbo Group: overhead = 16.984 MHz – (6 $\times$ 2.52 MHz) = 1.864 MHz.

P6-5.

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

b. Each frame carries 2 bit from each source. Frame rate = 100,000/2 = 50,000 frames/s.

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

d. Data rate = (50,000 frames/s) $\times$ (41 bits/frame) = 2.05 Mbps. The output data rate here is slightly less than the one in Problem 4.

e. In each frame 40 bits out of 41 are useful. Efficiency = 40/41= 97.5%. Efficiency is better than the one in Problem 4.

P6-7. 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 $\times$ 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) $\times$ (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 $\times$ 200 + 4 $\times$ 400 = 2.8 Mbps.

P6-9. 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.

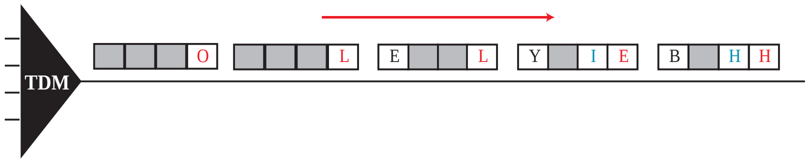
a. The frame carries 1 bit from each source. Frame size = 1 + 1 = 2 bits.

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

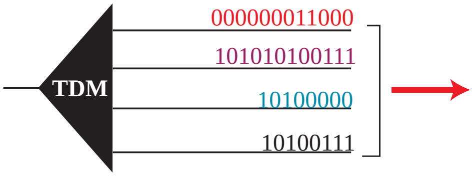
c. Frame duration = 1 /(frame rate) = 1 /190,000 = 5.3 ms.

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.

P6-11. See the following figure.



P6-13. See the following figure.



P6-15. The number of hops = 100 KHz/4 KHz = 25. So we need $\log_2 25 = 4.64 \approx 5$ bits

P6-17. Random numbers are 11, 13, 10, 6, 12, 3, 8, 9 as calculated below:

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