CHAPTER 6

Bandwidth Utilization:

Solutions to Odd-Numbered Review Questions and Exercises

Review Questions

1. ***Multiplexing*** is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.
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.
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).
7. ***WDM*** is common for multiplexing ***optical signals*** because it allows the multiplexing of signals with a very high frequency.
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.
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.

Exercises

13. To multiplex 10 voice channels, we need nine guard bands. The required bandwidth is then B = (4 KHz) × 10 + (500 Hz) × 9 **= 44.5 KHz**
15.
    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**.

17.

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 = 100,000/2 **= 50,000 frames/s.**

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

d. Data rate = (50,000 frames/s) × (41 bits/frame) = **2.05 Mbps.** The output data rate here is slightly less than the one in Exercise 16.

e. In each frame 40 bits out of 41 are useful. Efficiency = 40/41= **97.5%**. Efficiency is better than the one in Exercise 16.

19. 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 μs**.

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**.

21. 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.**

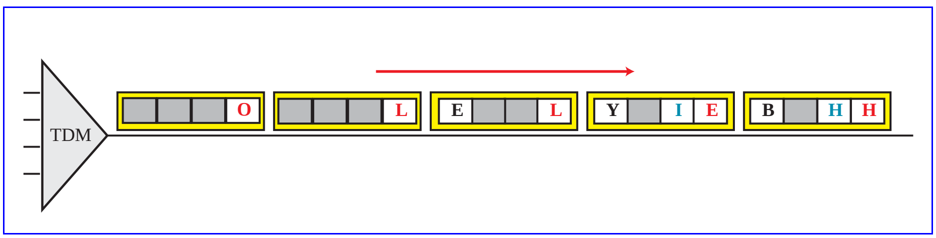
b. Each frame carries 1 bit from each 190-kbps source. Frame rate = **190,000 frames/s.**

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

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.

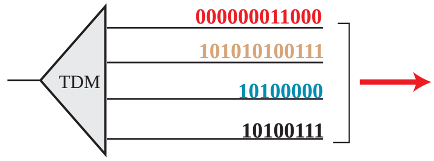
23. See Figure 6.1.

Figure 6.1 *Solution to Exercise 23*



25. See Figure 6.2.

Figure 6.2 *Solution to Exercise 25*



27. The number of hops = 100 KHz/4 KHz = 25. So we need $\log_2 25 = 4.64 \approx$ **5 bits**
29. 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**