CHAPTER 6 : Bandwidth Utilization

Solutions to Review Questions

Review Questions

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

2. 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.

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.

4. 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. 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.

6. 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.

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

8. 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)*.

9. ***FDM*** and ***WDM*** are used to combine ***analog signals***; the bandwidth is shared. ***TDM*** is used to combine ***digital signals***; the time is shared.

10. 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).

11. *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).*

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

Exercises

18.

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**.

22.

a. T-1 line sends 8000 frames/s. Frame duration = 1/8000 = **125 μs**.
b. Each frame carries one extra bit. Overhead = 8000 × 1 = **8 kbps**

28.

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**.