

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.

- DS-1 overhead = $1.544 \text{ Mbps} - (24 \times 64 \text{ kbps}) = \mathbf{8 \text{ kbps}}$.
- DS-2 overhead = $6.312 \text{ Mbps} - (4 \times 1.544 \text{ Mbps}) = \mathbf{136 \text{ kbps}}$.
- DS-3 overhead = $44.376 \text{ Mbps} - (7 \times 6.312 \text{ Mbps}) = \mathbf{192 \text{ kbps}}$.
- DS-4 overhead = $274.176 \text{ Mbps} - (6 \times 44.376 \text{ Mbps}) = \mathbf{7.92 \text{ Mbps}}$.

22.

- T-1 line sends 8000 frames/s. Frame duration = $1/8000 = \mathbf{125 \mu\text{s}}$.
- Each frame carries one extra bit. Overhead = $8000 \times 1 = \mathbf{8 \text{ kbps}}$

28.

- Group level: overhead = $48 \text{ KHz} - (12 \times 4 \text{ KHz}) = \mathbf{0 \text{ Hz}}$.
- Supergroup level: overhead = $240 \text{ KHz} - (5 \times 48 \text{ KHz}) = \mathbf{0 \text{ Hz}}$.
- Master group: overhead = $2520 \text{ KHz} - (10 \times 240 \text{ KHz}) = \mathbf{120 \text{ KHz}}$.
- Jumbo Group: overhead = $16.984 \text{ MHz} - (6 \times 2.52 \text{ MHz}) = \mathbf{1.864 \text{ MHz}}$.