Data Communications and Networking Fourth Edition

Forouzan

Chapter 6

Multiplexing Techniques

Note

Bandwidth utilization is the wise use of available bandwidth to achieve specific goals.

Efficiency can be achieved by multiplexing; i.e., sharing of the bandwidth between multiple users.

6-1 MULTIPLEXING

Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared. Multiplexing is the set of techniques that allows the (simultaneous) transmission of multiple signals across a single data link. As data and telecommunications use increases, so does traffic.

Topics discussed in this section:

- Frequency-Division Multiplexing
- Wavelength-Division Multiplexing
- Synchronous Time-Division Multiplexing
- Statistical Time-Division Multiplexing

Figure 6.1 *Dividing a link into channels*

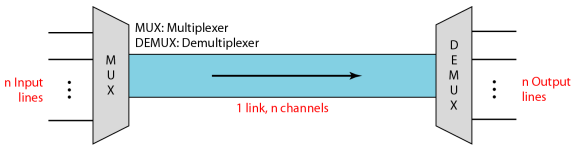
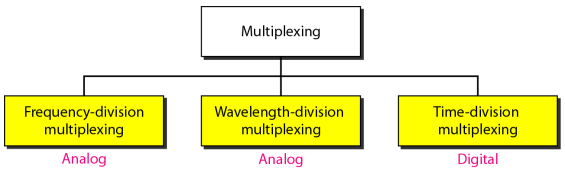


Figure 6.2 *Categories of multiplexing*



6.5

Figure 6.3 *Frequency-division multiplexing (FDM)*

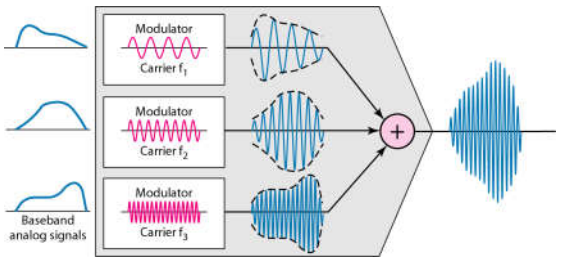
6.6

Note

FDM is an analog multiplexing technique that combines analog signals. It uses the concept of modulation

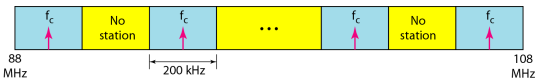
6.7

Figure 6.4 *FDM process*



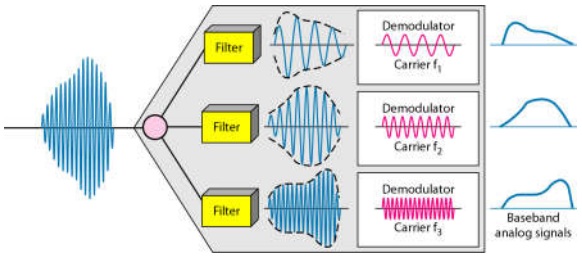
6.8

FM



6.9

Figure 6.5 *FDM demultiplexing example*



6.10

Example 6.1

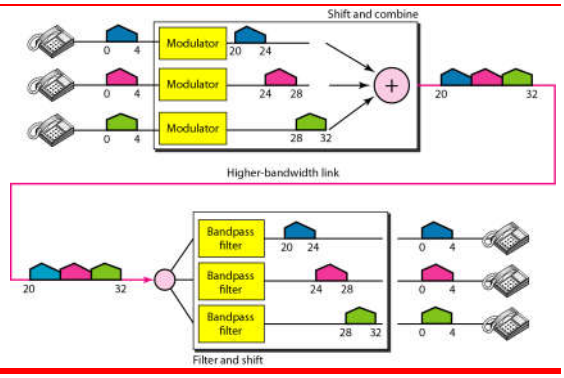
Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.

Solution

We shift (modulate) each of the three voice channels to a different bandwidth, as shown in Figure 6.6. We use the 20- to 24-kHz bandwidth for the first channel, the 24- to 28-kHz bandwidth for the second channel, and the 28- to 32-kHz bandwidth for the third one. Then we combine them as shown in Figure 6.6.

6.11

Figure 6.6 *Example 6.1*



6.12

Example 6.2

Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

Solution

For five channels, we need at least four guard bands. This means that the required bandwidth is at least

$$5 \times 100 + 4 \times 10 = 540 \text{ kHz},$$

as shown in Figure 6.7.

Figure 6.7 *Example 6.2*

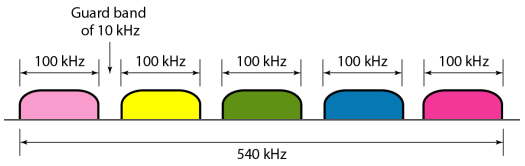


Figure 6.9 *Analog hierarchy*

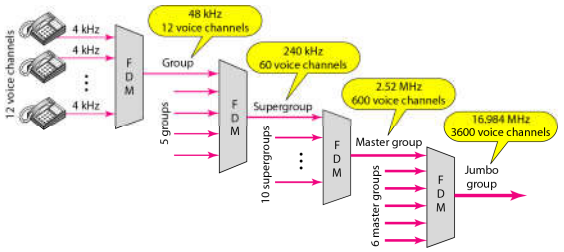
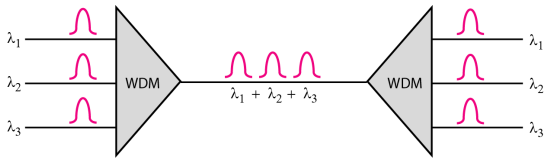


Figure 6.10 *Wavelength-division multiplexing (WDM)*

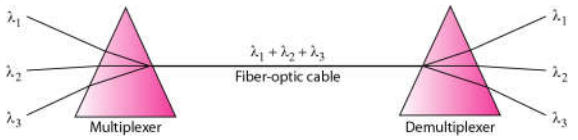


Note

WDM is an analog multiplexing technique to combine optical signals.

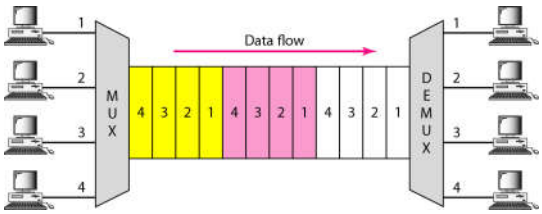
6.17

Figure 6.11 *Prisms in wavelength-division multiplexing and demultiplexing*



6.18

Figure 6.12 Time Division Multiplexing (*TDM*)



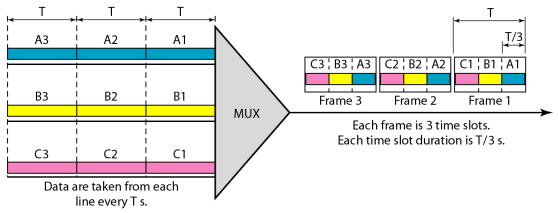
6.19

Note

TDM is a digital multiplexing technique for combining several low-rate digital channels into one high-rate one.

6.20

Figure 6.13 *Synchronous time-division multiplexing*



6.21

Note

In synchronous TDM, the data rate of the link is *n* times faster, and the unit duration is *n* times shorter.

6.22