CHAPTER 8

Multiplexing

8.1 REVIEW QUESTIONS

1. FDM, WDM, and TDM.
2. In FDM each signal modulates a different carrier frequency. The modulated carriers are combined to form a new signal that is then sent across the link.
3. A guard band keeps modulated signals from overlapping and interfering with one another.
4. A demultiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals.
5. WDM is conceptually the same as FDM. Both are combining different signals of different frequencies. In WDM the frequencies are very high and the energy source is light signals transmitted through fiber optic channels.
6. Synchronous and asynchronous
7. In TDM digital signals from n devices are interleaved with one another forming a frame of data.
8. Synchronous and asynchronous. In synchronous TDM each frame contains at least one time slot dedicated to each device. The order in which each device sends its data is fixed. In asynchronous TDM the number of time slots is less than the number of devices and the slot order depends on which devices have data to send. Addressing of each time slot is necessary.
9. In synchronous TDM the demultiplexer at the receiver decomposes each frame by discarding the framing bits and extracting each data unit in turn. As a data unit is removed from the frame it is passed to the appropriate receiving device. In asynchronous TDM the multiplexer at the receiver decomposes each frame by checking the local address of each data unit. The extracted data unit is removed from the frame and passed to the appropriate receiving device.
10. Inverse multiplexing splits a data stream from one high speed line onto multiple lower speed lines.

11. Analog switched service requires dialing, while analog leased service is a permanent dedicated link between two customers; no dialing is needed.
12. Voice channels (12 x 44 KHz) are multiplexed onto a higher bandwidth line to create a group (48 KHz). Up to five groups (5 x 48 KHz) can be multiplexed to create a super group (240 KHz). Ten super groups (10 x 240 KHz) are multiplexed to create a master group (2.52 MHz). Six master groups are multiplexed to create a jumbo group with 16.984 MHz.
13. Switched/56, DDS, and DS.
14. The DSU changes the rate of the digital data created by the subscriber's device to 56 Kbps and encodes it in the format used by the service provider.
15. DS-0: single digital channel (64 Kbps)

    DS-1: 24 DS-0 channels multiplexed = 1.544 Mbps

    DS-2: 4 DS-1 channels multiplexed = 6.312 Mbps

    DS-3: 7 DS-2 channels multiplexed = 44.376 Mbps

    DS-4: 6 DS-3 channels multiplexed = 274.176 Mbps
16. DS is the name of the service, which is implemented by T-lines. The capacity of the lines precisely matches the data rate of DS-services.
17. In order to use T lines for analog transmission the analog signal needs to be sampled first.
18. ADSL divides the bandwidth of a twisted pair cable into three bands. The first band, 0-25 KHz is used for regular telephone service. The second band (925-200 KHz) is for upstream communication and the third band (250 KHz – 1 MHz) for downstream communication.
19. ADSL uses either carrierless amplitude phase (CAP) or the discrete multitone modulation technique (DMT).
20. FTTC means fiber to the curb. Optical fiber is the medium from the central office of the telephone/cable company to the curb of the users' premises.
21. Digital services are less sensitive to noise and have a wider bandwidth.
22. A DSU is used in digital services and because the service is already digital a modem is not needed to transform analog data into digital. The DSU changes the rate of the digital data created by the subscriber's device to 56 Kbps and encodes it in the format used by the service provider. A modem takes a digital signal and changes it to an analog signal and vice versa.
23. For synchronous TDM, the number of slots is the same as the number of input lines; for asynchronous TDM, the number of slots can be less than the number of input lines.
24. For DS-0 the sampling rate is 8000 samples/second; with 8 bits per sample, this means 8000 × 8 bps or 64 Kbps.

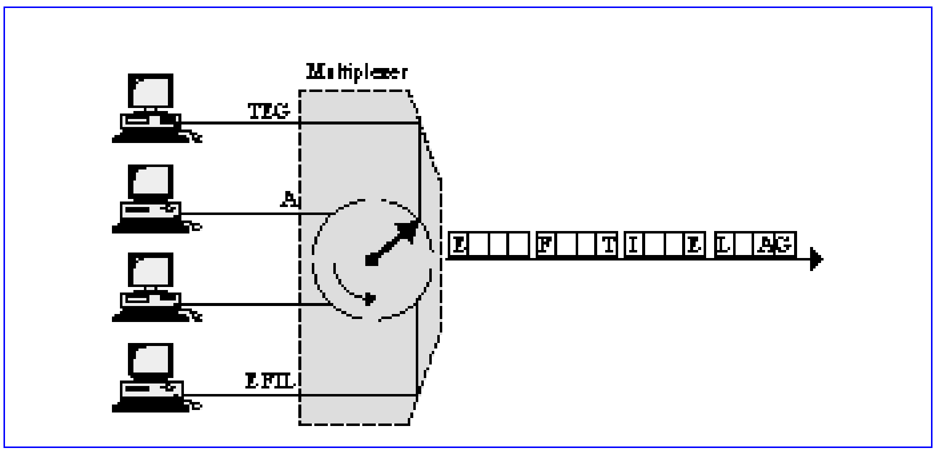
8.2 MULTIPLE CHOICE QUESTIONS

25. d	26. a	27. d	28. a	29. a	30. b	31. a	32. a	33. b	34. d
35. a	36. a	37. b	38. c	39. b	40. d	41. b	42. d	43. d	44. a
45. c	46. b	47. a	48. d	49. d	50. c	51. b	52. a	53. c	54. c
55. a	56. c	57. c	58. d						

8.3 EXERCISES

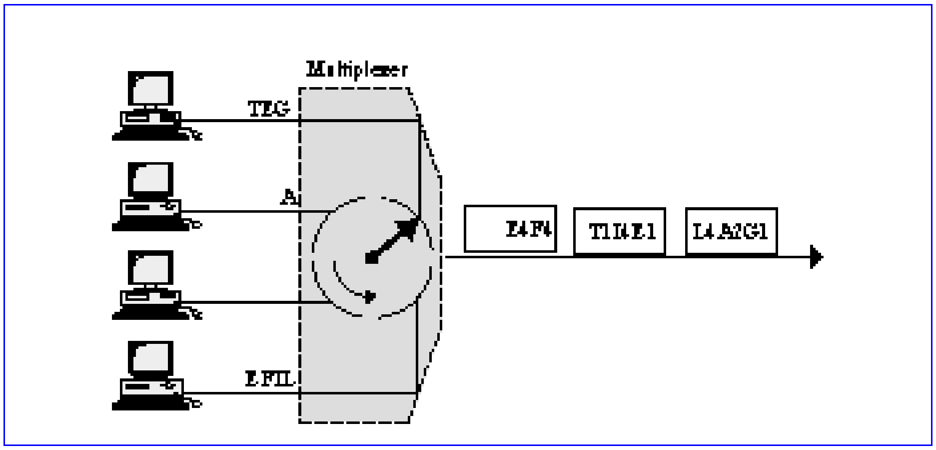
59. (4000 × 5) + (200 × 4) = 20.8 KHz
60. (7900 Hz – (200 × 2)) / 3 = 2.5 KHz
61. FDM: n is frequency of signal; TDM: n is time (s)
62. 41 bits per frame × 100 = 4.1 Kbps
63. Number of slots is derived by statistical method (analysis) of the number of input lines that are likely to be transferring at any given time.
64. See Figure 8.1.

Figur e 8.1 *Exercise 64*



65. See Figure 8.2.
66. 125 μs
67. 168 Kbps
68. n (n–1) / 2 = 500 (499)/2 = 124,750 lines; multiplexing can reduce the number of lines.
69. The original telephone lines were designed for voice (0 to 4000 Hz).

Figur e 8.2 *Exercise 65*

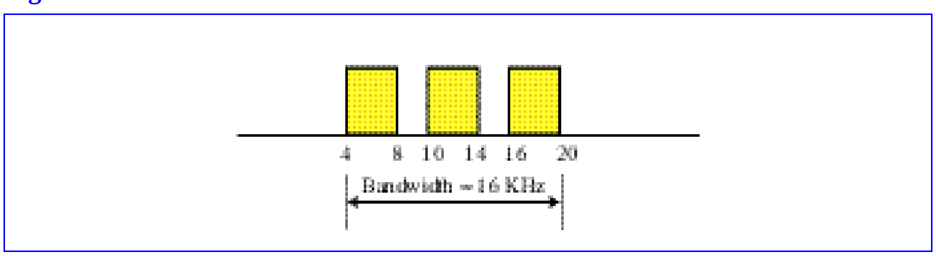


70. Nyquist theorem dictates that the sampling rate must be twice the highest frequency; 2 × 4000 Hz or 8000 Hz.
71. Theoretically, 2,000,000, 000 / 64,000 or 31250 channels. However, we need framing bits for multiplexing. Therefore, the practical number of channels is a little bit less than 31250.
72.

T1 line	(1,544,000 – 24 × 64000) / 24 = 333 bits /channel	0.5%
T2 line	(6,312,00 – 96 × 64000) / 96 = 1750 bits /channel	2.7%
T3 line	(44,736,000 – 672 × 64000) / 672 = 2571 bits /channel	4.0%
T4 line	(274,176,000 – 4032 × 64000) / 4032 = 4000 bits /channel	6.2%

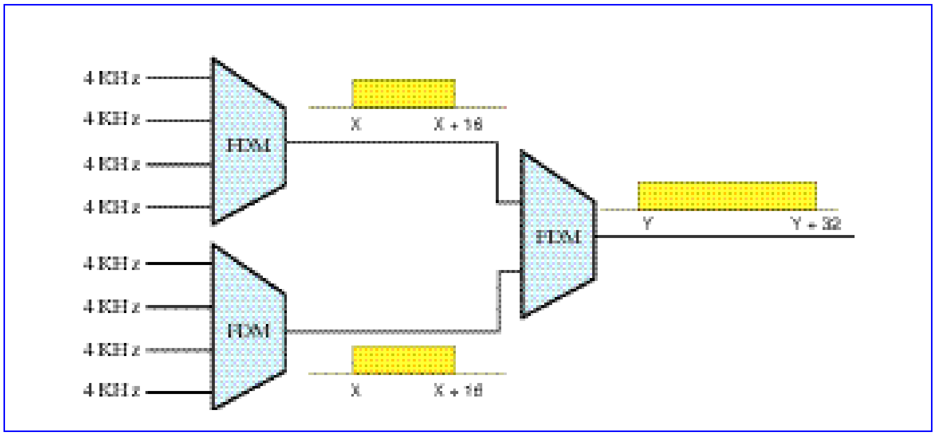
73. Bw = 20KHz – 4KHz = 16 KHz. See Figure 8.3

Figur e 8.3 *Exercise 73*

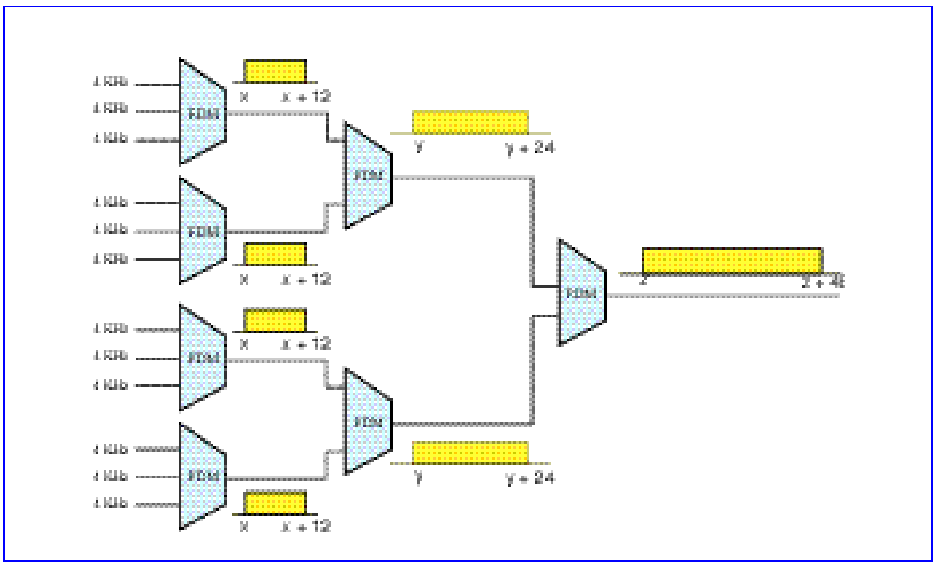


74. 19 + 4 × 20 = 99 KHz
75. See Figure 8.4.
76. See Figure 8.5.
77. 14.4 Kbps × 100 = 1.44 Mbps; assuming the overhead is not too big; a T1 line could handle the situation (1.544 Mbps)
78. Thirty percent of the bandwidth is wasted.
79. 2 × 566 Kbps = 1.132 Mbps

Figur e 8.4 *Exercise 75*



Figur e 8.5 *Exercise 76*



80. See Figure 8.6
    Output bit rate: 45 bits/second; duration; 22 ms; 45 slots per second
81. See Figure 8.7
82. 2 Mbps; T1 is not appropriate in this case (1.544 Mbps)
83. Data rate of each line: 40 Kbps; number of stations sending at full capacity: 8
84. See Figure 8.8.
85. 8 Kbps
86. See Figure 8.9.

Figure 8.6 *Exercise 80*

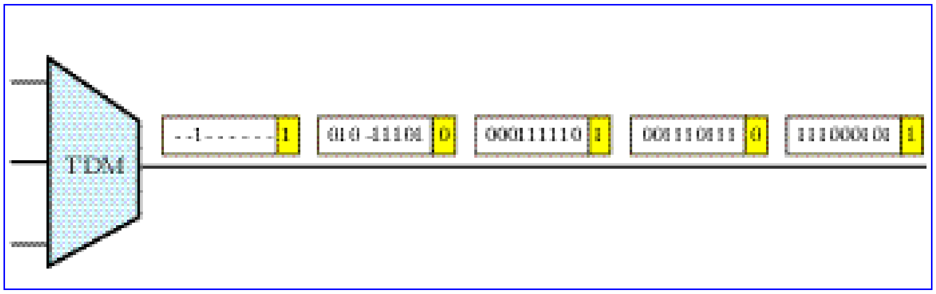


Figure 8.7 *Exercise 81*

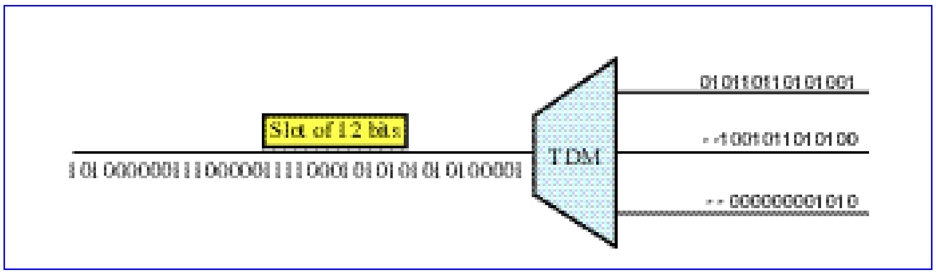


Figure 8.8 *Exercise 84*

Figure 8.9 *Exercise 86*