Questions

Q6-1. Describe the goals of multiplexing.

Ans:

Efficiently utilize transmission resources by combining multiple signals onto a single medium.

Q6-2. List three main multiplexing techniques mentioned in this chapter.

Ans:

Time Division Multiplexing (TDM), Frequency Division Multiplexing (FDM), and Wavelength Division Multiplexing (WDM).

Q6-3. Distinguish between a link and a channel in multiplexing.

Ans:

A link refers to the physical connection between two devices, while a channel refers to the medium through which signals are transmitted.

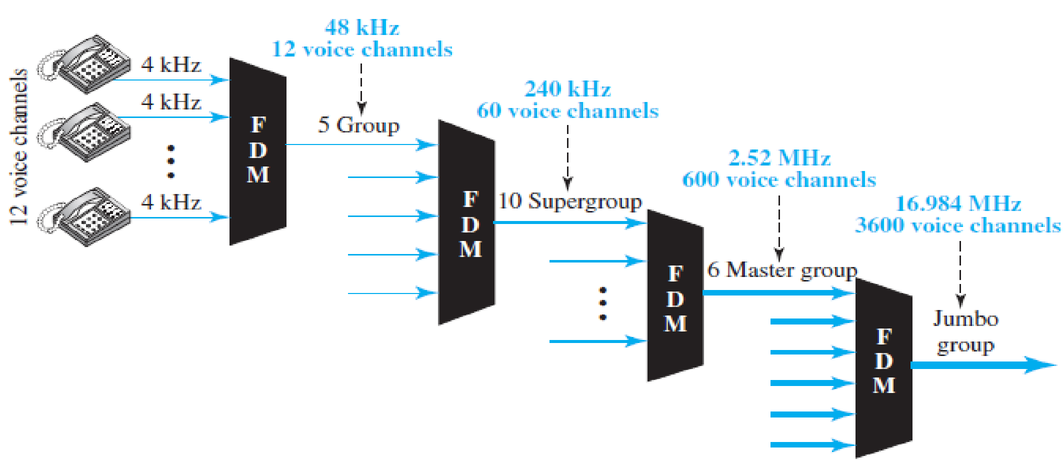
Q6-4. Which of the three multiplexing techniques is (are) used to combine analog signals? Which of the three multiplexing techniques is (are) used to combine digital signals?

Ans: FDM, WDM for analog TDM for digital.

Q6-5. Define the analog hierarchy used by telephone companies and list different levels of the hierarchy.

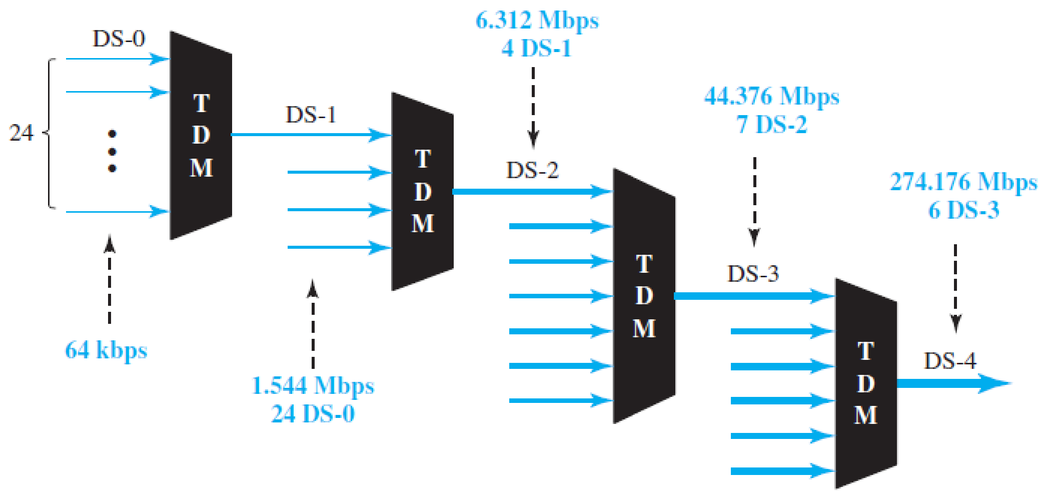
Ans: We use analog hierarchy for analog data transmission like telephone. There are groups, super groups, master groups and jumbo groups.

Figure 6.9 *Analog hierarchy*



Q6-6. Define the digital hierarchy used by telephone companies and list different levels of the hierarchy.
Ans:There are DS-0,DS-1,DS-2,DS-3 levels.

Figure 6.23 *Digital hierarchy*



Q6-7. Which of the three multiplexing techniques is common for fiber-optic links? Explain the reason.
Ans:

Wavelength Division Multiplexing (WDM) is common for fiber-optic links because it allows multiple signals to be transmitted simultaneously over a single fiber by using different wavelengths of light. This maximizes the utilization of the available bandwidth in the fiber-optic cable. With WDM, each signal occupies a unique wavelength, enabling high data transmission rates and efficient use of the optical spectrum.WDM is cost-effective as it eliminates the need for laying down multiple fiber cables for each signal.

Q6-8. Distinguish between multilevel TDM, multiple-slot TDM, and pulse-stuffed TDM.
Ans:
Multilevel TDM-In this method we use multiple multiplexer to increase the bandwidth. Then finally we use another multiplexer to make a single link.

Multiple-slot TDM- In this method we use multiple demultiplexer to decrease the bandwidth. Then finally we use multiplexer to make a single link.

Pulse stuffed TDM- If the above techniques don't work, then we use pulse stuffed TDM. By using it we can easily add dummy bits in main bandwidth.

Q6-9. Distinguish between synchronous and statistical TDM.
Ans:
Synchronous TDM allocates fixed time slots regardless of data activity, while statistical TDM dynamically allocates slots based on data traffic.

Q6-10. Define spread spectrum and its goal. List the two spread spectrum techniques discussed in this chapter.
Ans:
Spread spectrum is a technique used in telecommunications and signal processing where the bandwidth of a signal is intentionally spread over a larger frequency range than the minimum necessary. The primary goal of spread spectrum techniques is to enhance the security, robustness, and privacy of communication systems.
Techniques include Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS).

Q6-11. Define FHSS and explain how it achieves bandwidth spreading.
Ans:

Frequency Hopping Spread Spectrum (FHSS) rapidly switches among predetermined frequencies within a band. It transmits data in short bursts on different frequencies, spreading the signal's energy.
FHSS achieves bandwidth spreading by rapidly switching between different frequencies within a designated frequency band. Each frequency hop is synchronized between the transmitter and receiver. By transmitting data in short bursts on different frequencies, FHSS spreads the signal's energy over a wide range. This spreading makes the signal more resilient to interference and interception. FHSS effectively increases the bandwidth utilization and enhances communication reliability.
Q6-12. Define DSSS and explain how it achieves bandwidth spreading.
Ans:
Direct Sequence Spread Spectrum (DSSS) is a spread spectrum modulation technique where the data signal is multiplied with a higher-rate spreading code.

DSSS achieves bandwidth spreading by multiplying the data signal with a spreading code sequence. This spreading code sequence has a higher data rate than the original signal. The resulting spread signal occupies a wider bandwidth. At the receiver, the spread signal is multiplied again by the same spreading code, effectively "despreading" it to recover the original data. DSSS spreads the signal's energy over a larger frequency range, enhancing resistance to interference and improving security.

6.4.3 Problems

P6-1. Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 12 voice channels with guard bands of 500 Hz using FDM. Calculate the required bandwidth.

Ans:

Voice channel Bandwidth = 4 KHz

Number of voice channels to be multiplexed = 12

guard band bandwidth = 500 Hz

To multiplex 12 channels we will need 11 guard bands. Required bandwidth will be

$$(4 \text{ KHz} * 12) + (11 * 0.5 \text{ KHz}) = 53.5 \text{ KHz}$$

P6-2. We need to transmit 100 digitized voice channels using a passband channel of 30 KHz. What should be the ratio of bits/Hz if we use no guard band?

Ans:

The desired bandwidth apportions to each and every voice channel is 30,000Hz/ 100 = 300 Hz, each compute voice channel has a data rate of 64 Kbps (8000 sample x 8 bit/sample). This medium that our modulation style uses 64,000/300 = 213.34 bits/Hz.

P6-3. In the analog hierarchy of Figure 6.9, find the overhead (extra bandwidth for guard band or control) in each hierarchy level (group, supergroup, master group, and jumbo group).

Ans:

Group level:

From the given figure:

The number of voice channel =12

Voice channel occupied bandwidth = 4 KHz

The overhead=48 KHz-(12*4)
=0 Hz

Super group level:
From the given figure:
The number of groups = 5
The overhead=240 KHz-(5*48)
=0 Hz

Master group level:
From the given figure:
The number of super groups =10
The overhead=2520 KHz-(10*240)
= 2520-2400
= 120 KHz

Jumbo group level:
The number of master groups = 6
The over head = 16.984MHz-(6*2.52)
= 16.984MHz-(15.12MHz)
= 1.864MHz

P6-4. We need to use synchronous TDM and combine 20 digital sources, each of 200 Kbps. Each output slot carries 2 bit from each digital source, but one extra bit is added to each frame for synchronization. Answer the following questions:

a. What is the size of an output frame in bits?

ans: The total number of digital sources=20
Each frame output slot carries 1 bit from each digital source, but one extra bit is added to each frame for synchronization.
Then, the size of the an output frame in bits = 20 *2+1
= 41 bits

b. What is the output frame rate?

ans: Each frame carries 1 bit from each source.
Then, the frame rate=200Kbps
=200,000 frames/s

c. What is the duration of an output frame?

ans: The duration of an output frame=1/frame rate
=1/200000

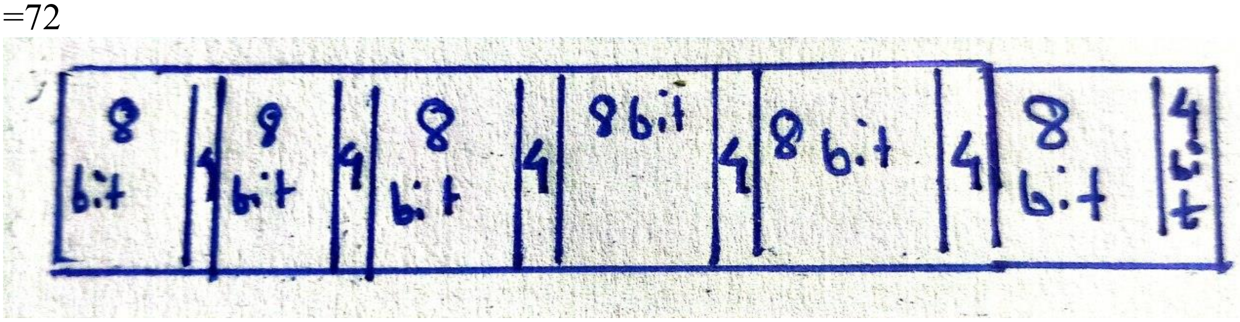
=5 μs

d. What is the output data rate?
ans: Output data rate= size of an output frame * frame rate
= (200000 frames/s) (41 bits/frame)
=41* 10^5 bits/s
=4.1 10^6 bits/s
=4.1 Mbps (since, 1Mbps=10^6 bits/s)

e. What is the efficiency of the system (ratio of useful bits to the total bits)?
Ans: In each frame 20 digital sources out of 21 are useful.
Therefore, the efficiency of the system=20/41
=48% (not sure)

P6-5. Repeat Problem 6-4 if each output slot carries 2 bits from each source.
Ans: same as question 4

P6-6. We have 12 sources, each creating 500 8-bit characters per second. Since only some of these sources are active at any moment, we use statistical TDM to combine these sources using character interleaving. Each frame carries 6 slots at a time, but we need to add 4-bit addresses to each slot. Answer the following questions:
a. What is the size of an output frame in bits?
ans: Every frame acquires 6 slots at a time, but we require to add a 4-bit address to each slot and 8-bit characters per second.
We know that the output frame size is:
Frame size = no of slots * (char size + slot address)
= 6 * (8 + 4)
=72



b. What is the output frame rate?
Ans: As we have only 6 input lines.

Each frame can carry one character from each lines. That means that the link should send 500 frames/s.

c. What is the duration of an output frame?
ans: frame duration = 1/500 = 2 ms

d. What is the output data rate?
ans: data rate = 500 frames/sec * 72 bits/frame = 36 kbps
P6-7. Ten sources, six with a bit rate of 200 kbps and four with a bit rate of 400 kbps, are to be combined using multilevel TDM with no synchronizing bits. Answer the following questions about the final stage of the multiplexing:

a. What is the size of a frame in bits?
ans: 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. What is the frame rate?
Ans: Each frame carries 1 bit from each 400-kbps source. Frame rate = 400,000 frames/s.

c. What is the duration of a frame?
Ans: Frame duration = 1 /(frame rate) = 1 /400,000 = 2.5 μs.

d. What is the data rate?

Ans: Output data rate = (400,000 frames/s) × (7 bits/frame) = 2.8 Mbps. We can likewise figure the output data rate as the entirety of info data rate in light of the fact that there is no synchronizing bits. Output data rate = 6 × 200 + 4 × 400 = 2.8 Mbps

P6-8. Four channels, two with a bit rate of 200 kbps and two with a bit rate of 150 kbps, are to be multiplexed using multiple-slot TDM with no synchronization bits. Answer the following questions:
a. What is the size of a frame in bits?
Ans: Since the frame carries 1 bit from each source , the frame size = 1 + 1 +1 + 1 = 4bits

b. What is the frame rate?

Ans: Since the frame carries 1 bit from each 200 kbps source , the frame rate = 200000 frames/sec

c. What is the duration of a frame?
ans: Frame duration = 1/ frame rate , therefore, 1/ 200000 = 5 $* 10^{-6}$ sec

d. What is the data rate?
ans: The output data rate is calculated as, frame rate * frame size = 200000 * 4 = 800 kbps
P6-9. Two channels, one with a bit rate of 190 kbps and another with a bit rate of 180 kbps, are to be multiplexed using pulse-stuffing TDM with no synchronization bits. Answer the following questions:
a. What is the size of a frame in bits?
Ans: Since the frame carries 1 bit from each source , the frame size = 1 + 1 = 2bits

b. What is the frame rate?
Ans: Since the frame carries 1 bit from each 190 kbps source , the frame rate = 190000 frames/sec

c. What is the duration of a frame?
ans: Frame duration = 1/ frame rate , therefore, 1/ 190000 = 5.3 $* 10^{-6}$ sec

d. What is the data rate?
ans: The output data rate is calculated as, frame rate * frame size = 190000 * 2 = 380 kbps

P6-10. Answer the following questions about a T-1 line:
a. What is the duration of a frame?
ans: A T-1 line frame would havr 193 bits which would be send at 8KHZ, hence the duration will be time period which is given by 1/ frequency, hence duration is 1/8KHZ= 0.000125s= 125 microsecond.

b. What is the overhead (number of extra bits per second)?
ans: . A T-1 line consists of 24 channels each of 8 bits and 1 for framing. Hence total number of bits per frame is 8*24+1=193bits/frame. As in T-1 line it is sent at 8KHZ hence it would be 8000 frames per second. Hence to get the overhead, the overhead bits is the number of control bits i.e 24*1+1=25 bits/ frame. To get the overhead in bits per second we multiply it with frames per second, i.e 25* 8000= 200000bits per second= 200Kbps.(not sure)

P6-11. Show the contents of the five output frames for a synchronous TDM multiplexer that combines four sources sending the following characters. Note that the characters are sent in the same order that they are typed. The third source is silent.

a. Source 1 message: HELLO

b. Source 2 message: HI

c. Source 3 message:

d. Source 4 message: BYE

ans:

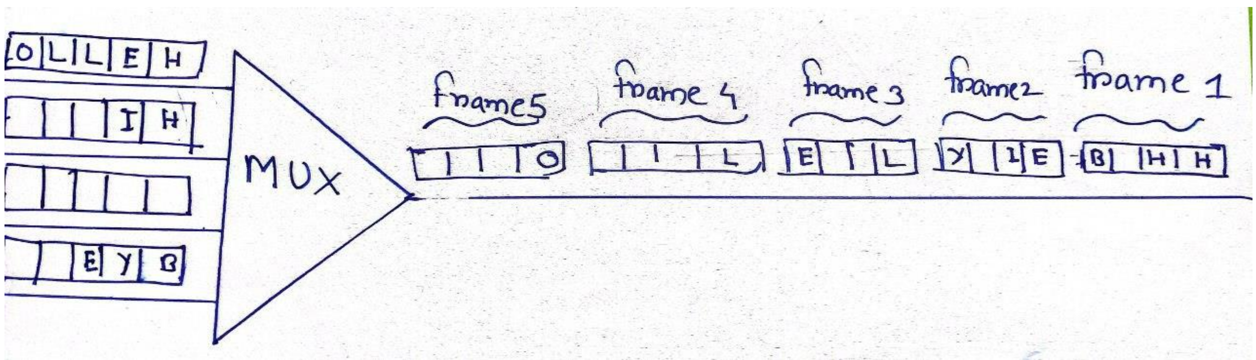
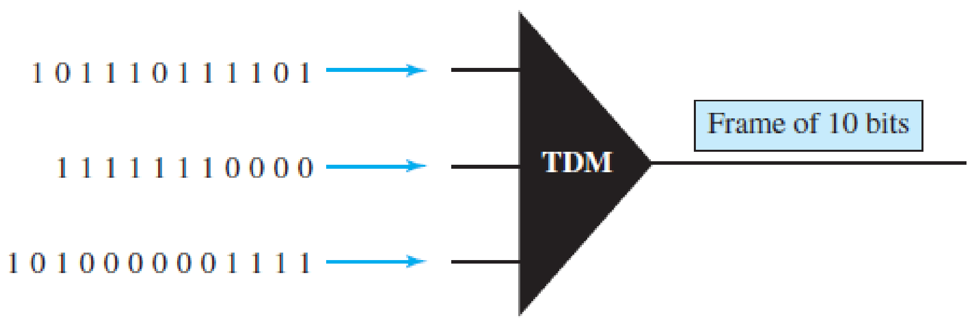
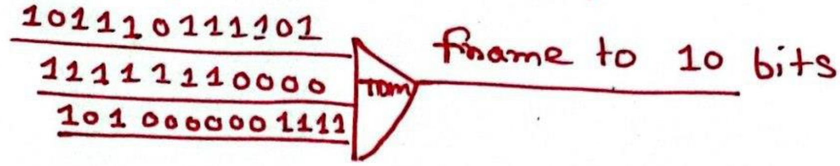


Figure 6.34 *Problem P6-12*



P6-12. Figure 6.34 shows a multiplexer in a synchronous TDM system. Each output slot is only 10 bits long (3 bits taken from each input plus 1 framing bit). What is the output stream? The bits arrive at the multiplexer as shown by the arrows.

Ans:



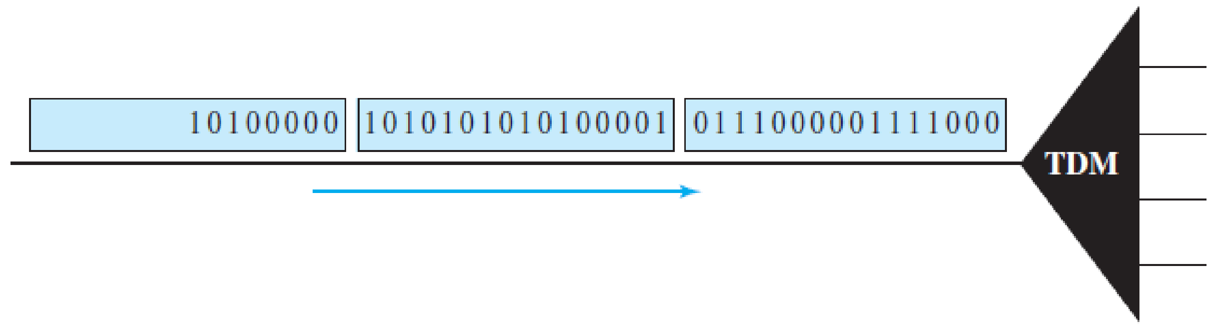
We need to use bits per input and one extra bit for framing bit. There are 3 inputs. So number of bits per frame $3 \times 3 + 1 = 10$ bits.

	frame 5	frame 4	frame 3	frame 2	frame 1
Input 1 ⇒		101	110	111	101
Input 2 ⇒		11	111	110	000
Input 3 ⇒	1	010	000	001	111

So frames of 10 bits ⇒

frame 5	frame 4	frame 3	frame 2	frame 1
1 | 1 | |	0 | 010 | 11 | 101	1 | 000 | 111 | 110	0 | 001 | 110 | 111	1 | 111 | 000 | 101

Figure 6.35 *Problem P6-13*



P6-13. Figure 6.35 shows a demultiplexer in a synchronous TDM. If the input slot is 16 bits long (no framing bits), what is the bit stream in each output? The bits arrive at the demultiplexer as shown by the arrows.

Ans:

frame 1 ⇒ 0111 00000 1111 000

frame 2 ⇒ 1010 1010101010 0001

frame 3 ⇒ 10 100000

There are 3 frames and 4 bits per frame.

4	3	2	1
0111	0000	0111	1000
1010	1010	1010	000 1
1010	0000		

Signal 1 ⇒ 1000 0001

Signal 2 ⇒ 0111 1010

Signal 3 ⇒ 0000 1010 0000

Signal 4 ⇒ 0111 1010 1010

P6-14. Answer the following questions about the digital hierarchy in Figure 6.23:
a. What is the overhead (number of extra bits) in the DS-1 service?
ans:DS-1 overhead=1544-(24*64)=8kbps

b. What is the overhead (number of extra bits) in the DS-2 service?
ans: DS-2 overhead=6312-(64*24*4)=168kbps

c. What is the overhead (number of extra bits) in the DS-3 service?
ans: DS-3 overhead=44376-(64*24*4*7)=1368 kbps

d. What is the overhead (number of extra bits) in the DS-4 service?
ans:DS-4 overhead=274176-(4*24*4*7*6)=16128 kbps

P6-15. What is the minimum number of bits in a PN sequence if we use FHSS with a channel bandwidth of *B* = 8 KHz and *B*ss = 100 KHz?
ans: If s the minimum number of bits in a PN sequence if we use FHSS with a channel bandwidth of B =8 KHz and Bss =100 KHz;
The number of hops = 100 KHz/8 KHz = 12.5 . So we need $\log_2 12.5 = 3.64 \approx 4$ bits

P6-16. An FHSS system uses a 4-bit PN sequence. If the bit rate of the PN is 64 bits per second, answer the following questions:
a. What is the total number of possible channels?
b. What is the time needed to finish a complete cycle of PN?
Ans:

(a) No. of bits, $n = 4$

number of channel $= 2^n = 2^4 = 16$ Channels.

(b) Total bit required $\Rightarrow$ $4 \times$ no. of channel

$\Rightarrow 4 \times 16$

$\Rightarrow 64$ bits

Time needed $\Rightarrow \dfrac{64 \text{ bits}}{PN} = \dfrac{64 \text{ bits}}{64 \text{ bits/S}}$

$\Rightarrow 1S$

P6-17. A pseudorandom number generator uses the following formula to create a random Series:

$$N_{i+1} = (5 + 7N_i) \bmod 17 - 1$$

In which *N*i defines the current random number and *N*i+1 defines the next random number. The term *mod* means the value of the remainder when dividing (5 + 7*N*i) by 17. Show the sequence created by this generator to be used for spread spectrum.

P6-18. We have a digital medium with a data rate of 10 Mbps. How many 64-kbps voice channels can be carried by this medium if we use DSSS with the Barker sequence?

Ans:

In DSSS (Direct Sequence Spread Spectrum) with the Barker sequence, each voice channel requires a data rate of 64 kbps. The digital medium has a data rate of 10 Mbps (10,000,000 bps). To calculate how many voice channels can be carried, we divide the data rate of the medium by the data rate per voice channel:

Number of voice channels = Data rate of medium / Data rate per voice channel

Number of voice channels = 10,000,000 bps / 64,000 bps = 156.25

Since we cannot have a fractional number of channels, we round down to get the maximum number of voice channels:

Number of voice channels = 156