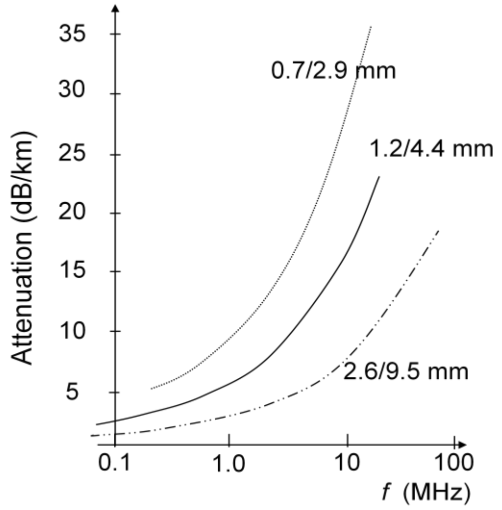
1. Use Figure 3.47 and Figure 3.50 to explain why the bandwidth of twisted-wire pairs and coaxial cable decreases with distance.



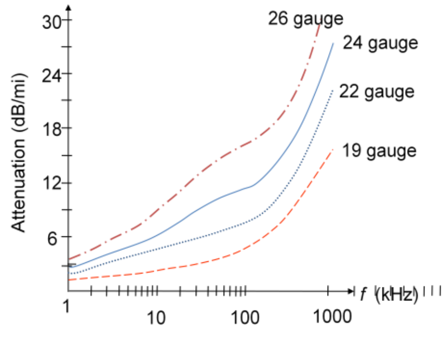


Figure 3.47

figure 3.50

sol:

The bandwidth is the range of frequencies where the channel passes a significant proportion of the power in the input signal. Both figures show that the attenuation when measured in dB/km <u>increases</u> with higher frequency. For example, the attenuation for 19-gauge wire at 100 kHz is about 5 dB/km and at 1MHz it is about 15 dB/km. This implies that the <u>relative</u> attenuation between a lower frequency and a higher frequency increases with distance. Using the same example, we have that at 1 km and at 10 km, the attenuation at 100 kHz is 5 dB and 50 dB respectively, but at 1 MHz it is 15 dB and 150 dB respectively. Thus at longer distances higher frequencies are attenuated much more severely and consequently the bandwidth decreases with increasing distance.

3. Suppose that WDM wavelengths in the 1550 nm band are separated by 0.8 nm. What is the frequency separation in Hz? What is an appropriate bit rate for signals carried on these wavelengths?

Sol: Optical range from λ_1 to $\lambda_1 + \Delta\lambda$ contains bandwidth

$$B = f_1 - f_2 = \frac{v}{\lambda_1} - \frac{v}{\lambda_1 + \Delta\lambda}$$

$$= \frac{v}{\lambda_1}\left\{\frac{\Delta\lambda / \lambda_1}{1 + \Delta\lambda / \lambda 1}\right\} \approx \frac{v\,\Delta\lambda}{\lambda_1^{2}}$$

For $\Delta\lambda = 0.8$ nm: $B = (v.\Delta\lambda)/\lambda_1^2 = (2\text{x}10^8 \text{ x } 0.8\text{x}10^{-9}) / (1550\text{x}10^{-9})^2 = 66.6\text{x}10^9$ Hz = 66.6 GHz

Bit rates up to 66 Gbps can be carried on these wavelengths. An appropriate bit rate could be 40 Gbps or 10 Gbps.

4. Can WDM be used for simultaneous transmission of optical signals in opposite directions?

Solution:

WDM can be used for simultaneous transmission in opposite directions, however the regenerators and amplifiers along the path should support both directions.

5. Consider a crossbar switch with *n* inputs and *k* outputs.

a. Explain why the switch is called a concentrator when *n* > *k*. Under what traffic conditions is this switch appropriate?
b. Explain why the switch is called an expander when *n* > *k*. Under what traffic conditions is this switch appropriate?
c. Suppose an *N* x *N* switch consists of three stages: an *N* x *k* concentration stage; a *k* x *k* crossbar stage; and a *k* x *N* expansion stage. Under what conditions is this arrangement appropriate?
d. When does the three-stage switch in part (c) fail to provide a connection between an idle input and an idle output line?

Sol:

a. Explain why the switch is called a concentrator when $n > k$. Under what traffic conditions is this switch appropriate?

This switch is a concentrator because traffic comes in on *n* lines and is concentrated onto *k* lines. Traffic on the output lines is higher than that of the input lines by a factor of *n/k* on average. The switch has inherent multiplexing functionality.

b. Explain why the switch is called an expander when $n > k$. Under what traffic conditions is this switch appropriate?

This switch is an expander because the number of lines is expanded from *n* to *k*. This switch is appropriate when the outgoing lines carry less traffic than the incoming lines. One such example is at the egress of a backbone network to an access network. The switch has inherent demultiplexing functionality.

c. Suppose an N x N switch consists of three stages: an N x k concentration stage; a k x k crossbar stage; and a k x N expansion stage. Under what conditions is this arrangement appropriate?

The number of crosspoints in an N x N crossbar switch is N^2. If the traffic load on the inputs is relatively low, this configuration may save on hardware costs. The number of crosspoints needed in the three-stage switch described is:

$$k^2 + 2kN$$

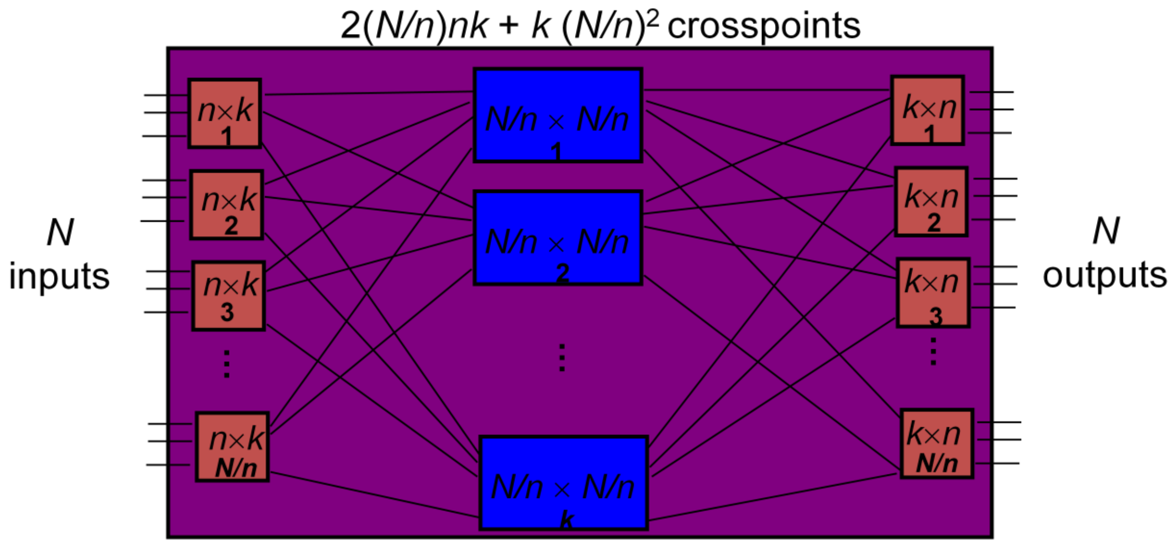
Depending on the values of N and k, $k^2 + 2kN$ may be less than N^2, especially if N is much greater than k.

d. When does the three-stage switch in part (c) fail to provide a connection between an idle input and an idle output line?

Assuming unicast traffic, if more than *k* inputs require a path to one of the third stage's *n* outputs at the same time, blocking will occur in the first stage, since it only has *k* outputs.

6. Consider the multistage switch in Figure 4.35 with $N = 16$, $n = 4$, $k = 2$.

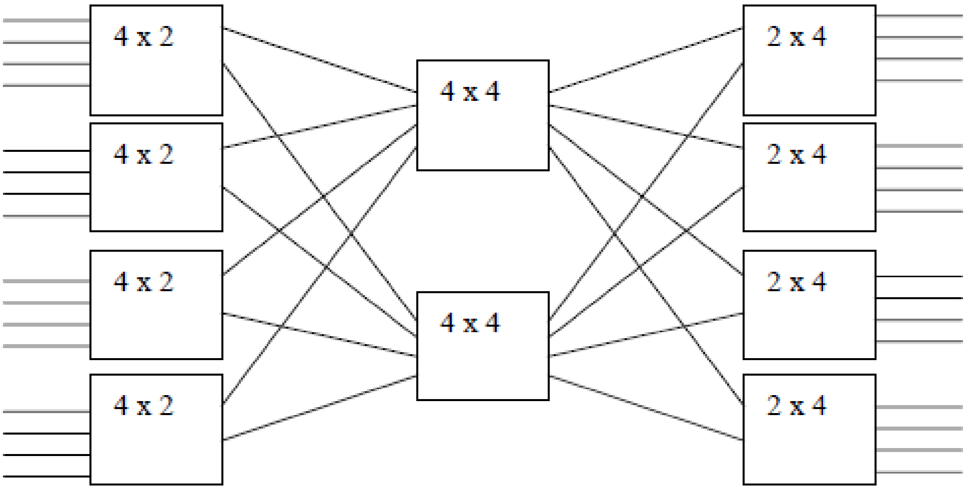
a. What is the maximum number of connections that can be supported at any given time?



Sol:

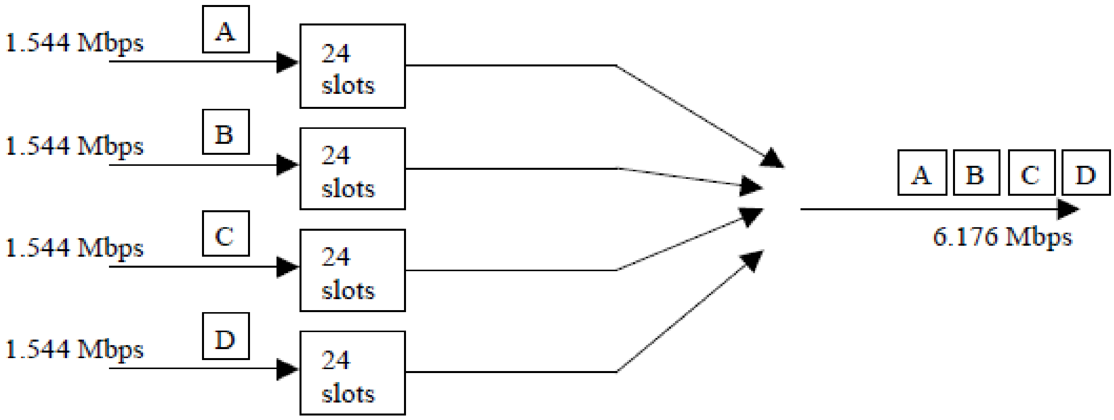
For *N* = 16, *n* = 4 and *k* = 2, we have the following switch architecture:
The number of switches for the first stage: N/n = 16/4 = 4
The number of switches for the 2^{nd} stage: k = 2.
The number of switches for the 3rd stage: N/n = 16/4 = 4

nxk=4x2 , N/n x N/n = 16/4 x 16/4 = 4x4 , kxn = 2x4



7. Explain how the TSI method can be used to build a time-division multiplexer that takes four T-1
lines and combines them into a single time-division multiplexed signal. Be specific in terms of the
number of registers required and the speeds of the lines involved.

Sol:
Each input line carries T-1 traffic. The input frame size is *n = 24* slots. Each frame that is output
is of length 4*n* = *96* slots. After a full set of 96 slots is written into the 4 registers, the slots are
read out in the outgoing line.



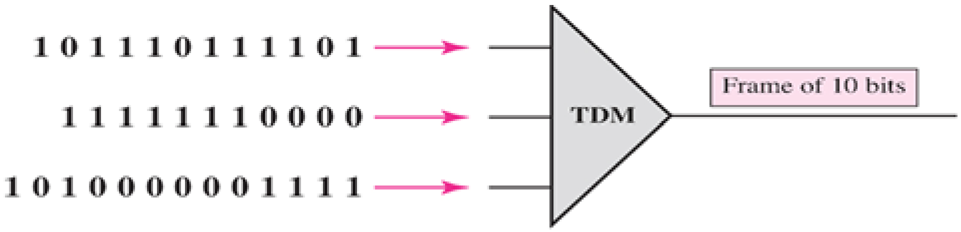
9. Two channels , one with a bit rate of 190kbps and another with a bit rate 180 kbps are to be multiplexed using g pulse stuffing TDM with no synchronization bits. Answer the following questions:

i. What is the size of a frame in bits?
ii. What is the frame rate?
iii. What is the duration of a frame?
iv. What is the date rate?

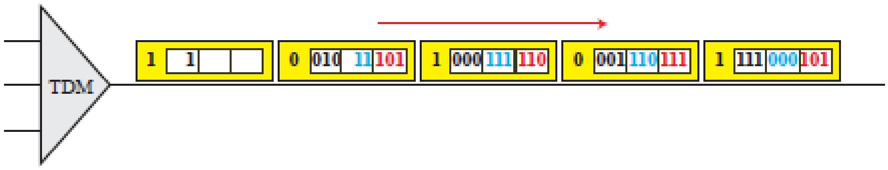
Sol:

We need to add extra bits to the second source to make both rates = 190 kbps. Now
we have two sources, each of 190 Kbps.
a. The frame carries 1 bit from each source. Frame size = 1 + 1 = **2 bits.**
b. Each frame carries 1 bit from each 190-kbps source. Frame rate = **190,000 frames/s.**
c. Frame duration = 1 /(frame rate) = 1 /190,000 = **5.3 μ s.**
d. Output data rate = (190,000 frames/s) $\times$ (2 bits/frame) = **380 kbps.** Here the output bit rate is greater than the sum of the input rates (370 kbps) because of extra bits added to the second source.

10. Figure 6.64 shows a multiplexer in a synchronous TDM system. Each O/p slot is only 10 bits long (3 bits taken from each input plus 2 framing bit). What is the output stream? The bits arrive at the multiplexer as shown by the arrows.



Sol:



11. Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 10 voice channels with gaurd bands of 500 Hz using FDM. Calculate the required bandwidth.

Sol:

To multiplex 10 voice channels, we need nine guard bands. The required bandwidth is then

B = (4 KHz) × 10 + (500 Hz) × 9 = **44.5 KHz**

12. four channels , two with a bit rate of 200kbps and two with a bit rate 150 kbps are to be multiplexed using multiple slots TDM with no synchronization bits. Answer the following questions: assume 4 bits from the first 2 sources and 3 bits from the second 2 sources.

i. What is the size of a frame in bits?
ii. What is the frame rate?
iii. What is the duration of a frame?
iv. What is the date rate?

sol: . The frame carries 4 bits from each of the first two sources and 3 bits from each of the second two sources. Frame size = 4 × 2 + 3 × 2 = **14 bits.**

b. Each frame carries 4 bit from each 200-kbps source or 3 bits from each 150 kbps. Frame rate = 200,000 / 4 = 150,000 /3 = **50,000 frames/s.**

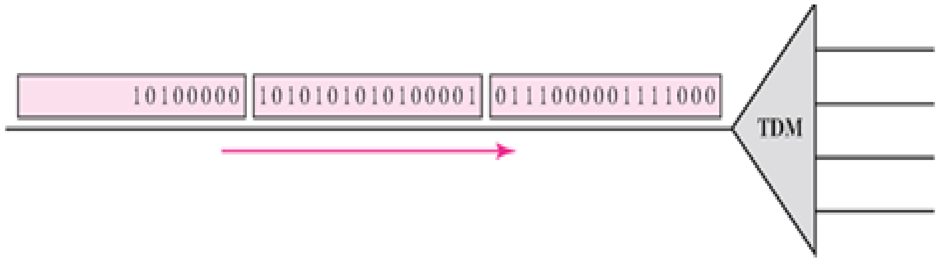
c. Frame duration = 1 /(frame rate) = 1 /50,000 = **20 μ s**.

d. Output data rate = (50,000 frames/s) × (14 bits/frame) = **700 kbps.** We can also

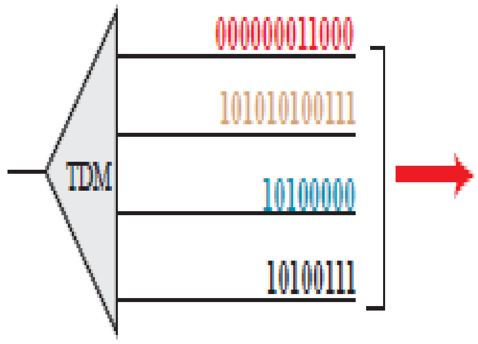
calculate the output data rate as the sum of input data rates because there are no synchronization bits. Output data rate = 2 × 200 + 2 × 150 = 700 kbps.

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 demultiplxer as shown by the arrows.


10100000
1010101010100001
0111000001111000
TDM

Sol:


000000011000
101010100111
10100000
10100111
TDM