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Assignment 3**

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**Example 6.2**

**Five channels, each with a lOa-kHz bandwidth, are to be multiplexed together. What is the mini-**

**mum bandwidth of the link if there is a need for a guard band of 10kHz 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 x 100 + 4 x 10 =540 kHz

**Example 6.4**

**The Advanced Mobile Phone System (AMPS) uses two bands. The first band of 824 to 849 MHz**

**is used for sending, and 869 to 894 MHz is used for receiving. Each user has a bandwidth of**

**30 kHz in each direction. The 3-kHz voice is modulated using FM, creating 30 kHz of modulated**

**signal. How many people can use their cellular phones simultaneously?**

Solution:

Each band is 25 MHz. If we divide 25 MHz by 30 kHz, we get 833.33. In reality, the band is divided

into 832 channels. Of these, 42 channels are used for control, which means only 790 channels are

available for cellular phone users.

**Example 6.5**

**In Figure 6.13, the data rate for each input connection is 3 kbps. If 1 bit at a time is multiplexed (a**

**unit is 1 bit), what is the duration of (a) each input slot, (b) each output slot, and (c) each frame?**

Solution:

We can answer the questions as follows:

a. The data rate of each input connection is 1 kbps. This means that the bit duration is 111000 s

or 1 ms. The duration of the input time slot is 1 ms (same as bit duration).

b. The duration of each output time slot is one-third of the input time slot. This means that the

duration of the output time slot is 1/3 ms.

c. Each frame carries three output time slots. So the duration of a frame is 3 x 113 ms, or 1 ms.

The duration of a frame is the same as the duration of an input unit.

**Example 6.6**

**Figure 6.14 shows synchronous TOM with a data stream for each input and one data stream for**

**the output. The unit of data is 1 bit. Find (a) the input bit duration, (b) the output bit duration,**

**(c) the output bit rate, and (d) the output frame rate.**

Solution:

We can answer the questions as follows:

a. The input bit duration is the inverse of the bit rate: 1/1 Mbps = 1 lls.

b. The output bit duration is one-fourth of the input bit duration, or 1/411s.

c. The output bit rate is the inverse of the output bit duration or 1/4 lls, or 4 Mbps. This can also

be deduced from the fact that the output rate is 4 times as fast as any input rate; so the output

rate =4 x 1 Mbps =4 Mbps.

d. The frame rate is always the same as any input rate. So the frame rate is 1,000,000 frames per

second. Because we are sending 4 bits in each frame, we can verify the result of the previous

question by multiplying the frame rate by the number of bits per frame.

**Example 6.7**

**Four l-kbps connections are multiplexed together. A unit is I bit. Find (a) the duration of I bit**

**before multiplexing, (b) the transmission rate of the link, (c) the duration of a time slot, and**

**(d) the duration of a frame.**

Solution

We can answer the questions as follows:

a. The duration of 1 bit before multiplexing is 1/1 kbps, or 0.001 s (l ms).

b. The rate of the link is 4 times the rate of a connection, or 4 kbps.

c. The duration of each time slot is one-fourth of the duration of each bit before multiplexing,

or 1/4 ms or 250 I.ls. Note that we can also calculate this from the data rate of the link, 4 kbps.

The bit duration is the inverse of the data rate, or 1/4 kbps or 250 I.ls.

d. The duration of a frame is always the same as the duration of a unit before multiplexing, or

I ms. We can also calculate this in another way. Each frame in this case has fouf time slots.

So the duration of a frame is 4 times 250 I.ls, or I ms.

**Example 6.8**

**Four channels are multiplexed using TDM. If each channel sends 100 bytesis and we multiplex**

**1 byte per channel, show the frame traveling on the link, the size of the frame, the duration of a**

**frame, the frame rate, and the bit rate for the link.**

Solution

The multiplexer is shown in Figure 6.16. Each frame carries 1 byte from each channel; the size of

each frame, therefore, is 4 bytes, or 32 bits. Because each channel is sending 100 bytes/s and a

frame carries 1 byte from each channel, the frame rate must be 100 frames per second. The dura-

tion of a frame is therefore 11100 s. The link is carrying 100 frames per second, and since each

frame contains 32 bits, the bit rate is 100 x 32, or 3200 bps. This is actually 4 times the bit rate of

each channel, which is 100 x 8 =800 bps.

**Example 6.9**

**A multiplexer combines four 100-kbps channels using a time slot of 2 bits. Show the output with**

**four arbitrary inputs. What is the frame rate? What is the frame duration? What is the bit rate?**

**What is the bit duration?**

Solution

Figure 6.17 shows the output for four arbitrary inputs. The link carries 50,000 frames per second

since each frame contains 2 bits per channel. The frame duration is therefore 1/50,000 s or 20 ~s.

The frame rate is 50,000 frames per second, and each frame carries 8 bits; the bit rate is 50,000 x

8 =400,000 bits or 400 kbps. The bit duration is 1/400,000 s, or 2.5 IJ.s. Note that the frame duration is 8

times the bit duration because each frame is carrying 8 bits.

**Example 6.10**

**We have four sources, each creating 250 characters per second. If the interleaved unit is a character**

**and 1 synchronizing bit is added to each frame, find (a) the data rate of each source, (b) the duration**

**of each character in each source, (c) the frame rate, (d) the duration of each frame, (e) the number of**

**bits in each frame, and (f) the data rate of the link.**

Solution:

We can answer the questions as follows:

a. The data rate of each source is 250 x 8 = 2000 bps = 2 kbps.

b. Each source sends 250 characters per second; therefore, the duration of a character is 1/250 s,

or4 ms.

c. Each frame has one character from each source, which means the link needs to send

250 frames per second to keep the transmission rate of each source.

d. The duration of each frame is 11250 s, or 4 ms. Note that the duration of each frame is the

same as the duration of each character coming from each source.

e. Each frame carries 4 characters and I extra synchronizing bit. This means that each frame is

4 x 8 + 1 =33 bits.

f. The link sends 250 frames per second, and each frame contains 33 bits. This means that the

data rate of the link is 250 x 33, or 8250 bps. Note that the bit rate of the link is greater than

the combined bit rates of the four channels. If we add the bit rates of four channels, we get

8000 bps. Because 250 frames are traveling per second and each contains 1 extra bit for

synchronizing, we need to add 250 to the sum to get 8250 bps.

**Example 6.11**

**Two channels, one with a bit rate of 100 kbps and another with a bit rate of 200 kbps, are to be**

**multiplexed. How this can be achieved? What is the frame rate? What is the frame duration?**

**What is the bit rate of the link?**

Solution:

We can allocate one slot to the first channel and two slots to the second channel. Each frame carries 3

bits. The frame rate is 100,000 frames per second because it carries 1 bit from the first

channel. The frame duration is 1/100,000 s, or 10 ms. The bit rate is 100,000 frames/s x 3 bits per

frame, or 300 kbps. Note that because each frame carries 1 bit from the first channel, the bit rate

for the first channel is preserved. The bit rate for the second channel is also preserved because

each frame carries 2 bits from the second channel.

**16. We need to use synchronous TDM and combine 20 digital sources, each of 100 Kbps.**

**Each output slot carries 1 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?**

**b. What is the output frame rate?**

**c. What is the duration of an output frame?**

**d. What is the output data rate?**

**e. What is the efficiency of the system (ratio of useful bits to the total bits).**

Answer:

a. Each output frame carries 1 bit from each source plus one extra bit for synchronization.

Frame size = 20 × 1 + 1 = 21 bits.

b. Each frame carries 1 bit from each source. Frame rate = 100,000 frames/s.

c. Frame duration = 1 / (frame rate) = 1 /100,000 = 10 μs.

d. Data rate = (100,000 frames/s) × (21 bits/frame) = 2.1 Mbps

e. In each frame 20 bits out of 21 are useful. Efficiency = 20/21= 95%

**19. 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?**

**b. What is the frame rate?**

**c. What is the duration of a frame?**

**d. What is the data rate?**

Answer:

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. Each frame carries 1 bit from each 400-kbps source. Frame rate = 400,000 frames/s.

c. Frame duration = 1 / (frame rate) = 1 /400,000 = 2.5 μs.

d. Output data rate = (400,000 frames/s) × (7 bits/frame) = 2.8 Mbps. We can also

calculate the output data rate as the sum of input data rate because there is no

synchronizing bits. Output data rate = 6 × 200 + 4 × 400 = 2.8 Mbps.

**20. 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?**

**b. What is the frame rate?**

**c. What is the duration of a frame?**

**d. What is the data rate?**

Answer:

a. 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 μs.

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.

**21. 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?**

**b. What is the frame rate?**

**c. What is the duration of a frame?**

**d. What is the data rate?**

Answer:

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 μs.

d. Output data rate = (190,000 frames/s) × (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.

**22. Answer the following questions about a T-1 line:**

**a. What is the duration of a frame?**

**b. What is the overhead (number of extra bits per second)?**

Answer:

a. T-1 line sends 8000 frames/s. Frame duration = 1/8000 = 125 μs.

b. Each frame carries one extra bit. Overhead = 8000 × 1 = 8 kbps

**27. What is the minimum number of bits in a PN sequence if we use FHSS with a**

**channel bandwidth of B =4 KHz and Bss =100 KHz?**

Answer:

The number of hops = 100 KHz/4 KHz = 25. So we need log225 = 4.64 ≈ 5 bits

**28. 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 hops?**

**b. What is the time needed to finish a complete cycle of PN?**

Answer:

a. Total number of possible 2^4= 16 hops

b. Complete cycle of (64 bits/s) / 4 bits = 16 cycles