Data Communication TDM

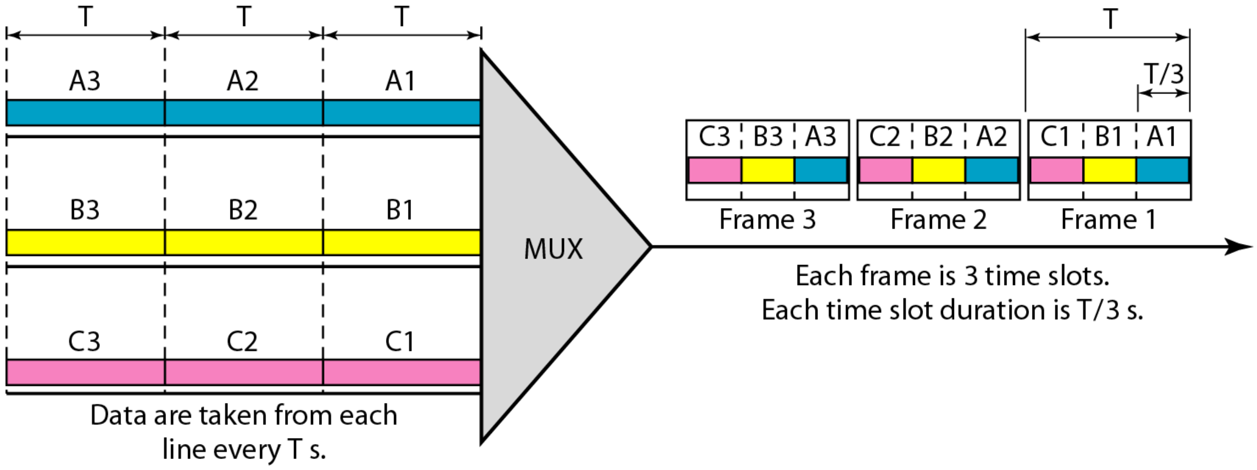

Figure 1

Time Division Multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link. Instead of sharing a portion of the bandwidth as in FDM, time is shared. Each connection occupies a portion of time in the link. Figure 1 gives a conceptual view of TDM. Note that the same link is used as in FDM; here, however, the link is shown sectioned by time rather than by frequency. In the figure, portions of signals A, B, and C occupy the link sequentially.

In this figure (Figure 1), A1 (or B1 or C1) is transmission unit. For example, when it is said that a channel is transmitting 2 bits at a time, it means unit size is 2 bits (size of A2, or C1, or B3). This can be mentioned in a lot of different ways. We have to be aware about that. For example, output slot carries 3 bits from each source means the same thing, unit size is 3 bits. Again if it is said that, a multiplexer combines four 100-kbps channels using **a time slot of 5 bits** means the same thing, unit size is 5 bits.

So before going into TDM we need to understand when it is wise to use a communication link for multiple digital channels. For example, assume we have a communication link **AB** with 12 MHz bandwidth and 15 SNR. That means it has a capacity ($B*\log_2(1+SNR)$) of 48 Mbps. So, if we are using digital channels of 6 Mbps, it is possible to combine 8 similar channels using TDM and transmit the combined digital signal through communication link **AB**.

We will mainly focus on synchronous TDM in our course. For solving problems related to TDM we need to familiarize ourselves with 10 common terminologies. They are: **a.** Input Bit Duration. **b.** Input Unit/Slot Size and Duration. **c.** Input Data/Bit Rate **d.** Output Data/Bit Rate (commonly known as Link Data/Bit Rate or only Data/Bit Rate). **e.** Output Bit Duration. **f.** Output Unit/Slot Size and Duration. **g.** Frame Size. **h.** Frame Duration. **i.** Frame Rate. **j.** Efficiency.

Let us consider scenario here:

Example scenario: We have five sources, each creating 400 characters per second. If the interleaved unit is a character, find (1) the data rate of each source, (2) the duration of each character in each source, (3) the frame rate, (4) the duration of each frame, (5) the number of bits in each frame, and (6) the data rate of the link.

In this example, form the sentence "the interleaved unit is a character" we have to figure out the input unit size is **1 character** or **8 bits**. So, let's find out the values of those 10 terms we learnt earlier with respect to the example given here. Remember we may or may not have a figure provided with the problem we have to solve. If we are given a figure, we have to look for information in the figure.

Information we already have: Number of input sources is **5**, each input source is transmitting data with a rate of **400 characters per second**, and each input is transmitting **1 character (or 8 bits)** at a time.

a. **Input Bit Duration** denotes how much time 1 bit takes to be transmitted from each input. To find this out we need to know the input bit rate of each source. In this example, the input bit rate is not given directly. It is given as 400 characters per second. And we know each character is comprised of 8 bits. That means input bit rate of each source is (400*8) bps or 3200 bps. So, Input bit duration is 1/3200 second or 312.5 μs. [Input Bit Duration = 1/(Input Bit Rate)]

b. **Input Unit/Slot Size** denotes number of bits a unit/slot carries in input sources. In this example, Input Unit/Slot Size is 1 character (8 bits).
Input Unit/Slot Duration denotes the time a unit takes to be transmitted from each source. In this example, we know Input Unit/Slot Size is 8 bits (from **b.**) and it takes 312.5 μs for one bit to be transmitted from input sources (from **a.**). So, Input Unit/Slot Duration is 8*312.5 μs or 2.5 ms. [Input Unit Duration = (Input Unit Size)*(Input Bit Duration)]

c. **Input Data/Bit Rate** denotes with what bit rate or data rate each source is transmitting data. In this example, Input Data/Bit Rate is 3200 bps (we have already solved that in **a.**).

d. **Output Data/Bit Rate** denotes the bit rate or data rate of the output communication link. In this example, Output Data/Bit Rate is 5*3200 bps or 16 kbps. [Output Data/Bit Rate = (Number of Input Sources)*(Input Data Rate)], [Output Data/Bit Rate = (Frame Size)*(Frame Rate)]

e. **Output Bit Duration** denotes how much time 1 bit takes to be transmitted in the communication link. To find this out we need to know the output bit rate. From **d.** we know output bit rate is 16 kbps. So, Output Bit Duration is 1/16000 second or 62.5 μs. [Output Bit Duration = 1/(Output Bit Rate)]

f. **Output Unit/Slot Size** denotes number of bits a unit/slot carries in the communication link. It is same as Input Unit/Slot Size. In this example, Output Unit/Slot Size is 8 bits (from **b.**) **Output Unit/Slot Duration** denotes the time a unit takes to be transmitted in output communication link. In this example, we know Output Unit/Slot Size is 8 bits (from **f.**) and it takes 62.5 μs for one bit to be transmitted in output communication link (from **e.**). So, Output Unit/Slot Duration is 8*62.5 μs or 500 μs. [Output Unit Duration = (Output Unit Size)*(Output Bit Duration)], [Output Unit Duration = (Input Unit Duration)/(Number of Input Sources)]

g. **Frame Size** denotes number of bits in one frame in output communication link. Frame is a combination of units coming from all the input sources. In this example we know number of input sources is 5 and Input Unit/Slot Size is 8 bits (from **b.**). So, Frame Size is 5*8 bits or 40 bits. [Frame Size = (Number of Input Sources)* (Input Unit Size)]

h. **Frame Duration** denotes how much time one frame takes to be transmitted in output communication link. In this example, we know Output Bit Duration is 62.5 μs (from **e.**), and Frame Size is 40 bits (from **g.**). So transmitting a frame means transmitting 40 bits. So, the time we need to transmit one frame (or 40 bits) is 40*62.5 μs or 2.5 ms. [Frame Duration = (Frame Size)*(Output Bit Duration)], [Frame Duration = (Output Unit Duration)*(Number of Input Sources)], [Frame Duration = Input Unit Duration]

i. **Frame Rate** denotes number of frames we transmit each second in output communication link. In this example, we need 2.5 ms to transmit one Frame. So, number of frames we transmit each second or Frame Rate is $1/(2.5*10^{-3})$ or 400 Fps. [Frame Rate = 1/(Frame Duration)], [Frame Rate = (Output Data Rate)/(Frame Size)]

j. **Efficiency** denotes ratio of information bits and total bits transmitted in output communication link. In this example, we are not using any synchronizing bits. So, all the output bits are information bits, which in turn means, here Efficiency is 100%.

So, the answers of the given example are **1.** 3200 bps (from **c.**), **2.** 2.5 ms (from **b.**), **3.** 400 Fps (from **i.**), **4.** 2.5 ms (from **h.**), **5.** 40 bits (from **g.**), and **6.** 16 kbps (from **d.**).

Now consider we do have synchronizing bits while transmission. Let's rephrase the previous example.

Updated Example scenario: We have five sources, each creating 400 characters per second. If the interleaved unit is a character and 4 synchronizing bits are added to each frame, find (1) the data rate of each source, (2) the duration of each character in each source, (3) the frame rate, (4) the duration of each frame, (5) the number of bits in each frame, and (6) the data rate of the link.

First of all remember, if we have synchronizing bits. It will directly impact the calculations in **d. Output Data/Bit Rate, g. Frame Size, j. Efficiency**.

g. Frame Size denotes number of bits in one frame in output communication link. Here, Frame is a combination of units coming from all the input sources and synchronizing bits. In this example Frame Size is (5*8+4) bits or 44 bits.

d. Output Data/Bit Rate. First we have to find out Frame Size which is 44 bits in this example. Then we need to figure out Frame Rate (Frame Rate will not be affected by synchronizing bits), which is 400 Fps from previous example. So, Output Data/Bit Rate is 44*400 bps 17.6 kbps. [Output Data/Bit Rate = (Frame Size)*(Frame Rate)]

j. Efficiency. Here Frame Size is 44 bits. Frame Size would be 40 bits if there were no synchronizing bits. So, efficiency is (40/44*100)% or 90.91%.