The Islamic University of Gaza
Faculty of Engineering
Department of Computer Engineering

ECOM 4314: Data Communication
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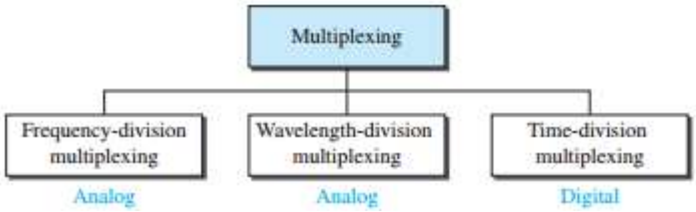
Discussion Chapter#6

Main Points in Ch#6

Multiplexing: is the set of techniques that allow the simultaneous transmission of multiple signals across a single data link.



FDM:

Used when BW of the link is greater than combined BWs of signals.

نقسم اللينك لعدد من ال channels بناء على ال frequency

WDM:

Designed to use the high data rate of fiber optic cable.

Since using fiber optic cable for one signal line wastes the available BW, so we want to combine multiple light sources onto one signal light.

TDM:

Digital process allows several connections to share high BW of link.

Link is divided into time slots.

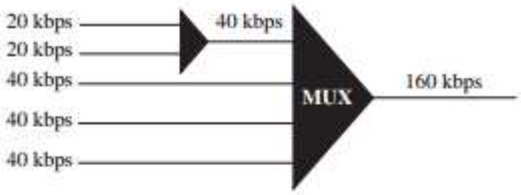
TDM can be:

- **Synchronous** : كل سجنال الها زمن محدد في اللينك سواء بعتت داتا او لا
  Each frame contains time slots of each input.
  Time slot duration at input = T
  Time slot duration at output = T/n where n is #of inputs
  Frame duration = T

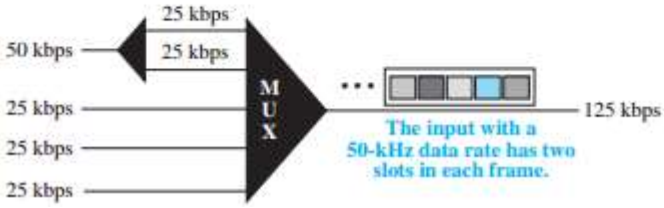
Data Rate Management:

If the data rate of the inputs are not equals, we have 3 strategies to use:

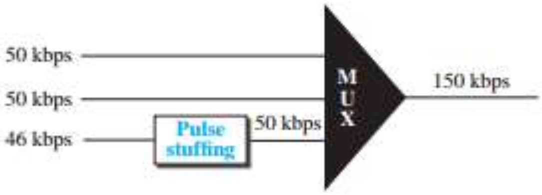
1- Multi-level Multiplexing: it's used when the data rate of an input is multiple of others.



2- Multiple-Slot Allocation Sometimes it is more efficient to allot more than one slot in a frame to a single input line.

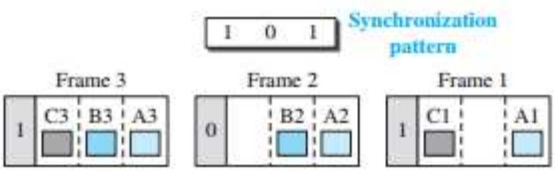


3- Pulse Stuffing: Sometimes the bit rates of sources are not multiple integers of each other. Therefore, neither of the above two techniques can be applied. One solution is to make the highest input data rate the dominant data rate and then add dummy bits to the input lines with lower rates. This will increase their rates.

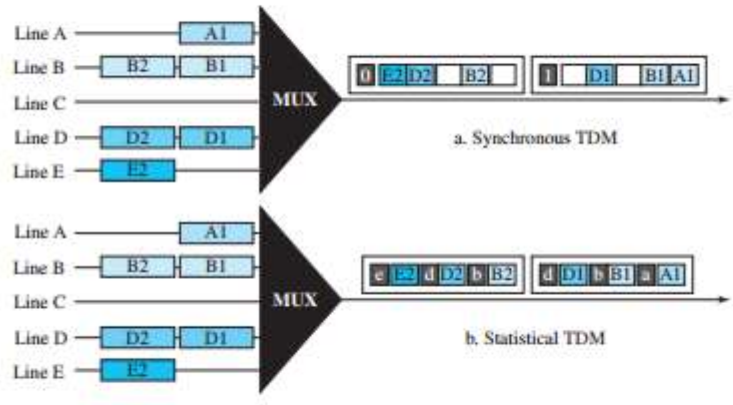


Frame Synchronizing:

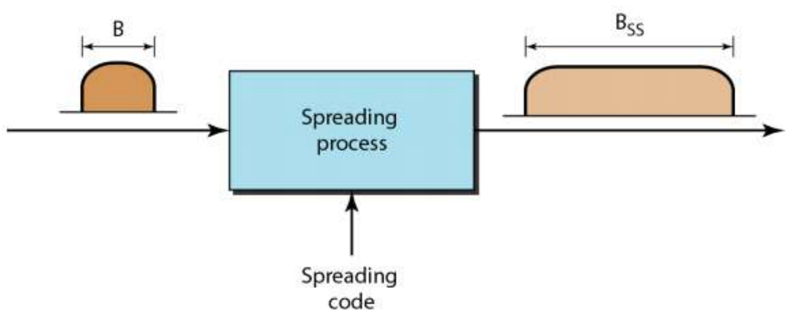
One or more synchronization bits are usually added to the beginning of each frame. These bits, called framing bits, follow a pattern, frame to frame, that allows the demultiplexer to synchronize with the incoming stream so that it can separate the time slots accurately.



- **Statistical**: slots are dynamically allocated to improve BW efficiency.
  اذا كان بدو يبعت داتا بيحجز مكان في اللينك والا ما بياخد من ال BW



Spread Spectrum: is an important form of encoding for wireless communications. In spread spectrum (SS), we combine signals from different sources to fit into a larger bandwidth, but our goals are to prevent eavesdropping and jamming.
A signal that occupies a bandwidth of B, is spread out to occupy a bandwidth of Bss. All signals are spread to occupy the same bandwidth Bss. The bandwidth is wider after the signal has been encoded using spread spectrum.(Bss >> B).



Spread Spectrum Approaches are:
1. Frequency-hopping spread spectrum (FHSS).
2. Direct sequence spread spectrum (DSSS).

Frequency-hopping spread spectrum: is a form of spread spectrum in which the signal is broadcast over a random series of frequencies, hopping from frequency to frequency at fixed intervals.

Direct sequence spread spectrum: is a form of spread spectrum in which each bit in the original signal is represented by multiple bits in the transmitted signal, using a spreading code. For an N-bit spreading code, the bit rate after spreading (usually called the chip rate) is N times the original bit rate.

Chapter's Questions:

P6-1. Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 10 voice channels with guard bands of 500 Hz using FDM. Calculate the required bandwidth.

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

P6-4. 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?

20+1 = 21 bits

b. What is the output frame rate?

Since each frame takes one bit from each input >>> #of frames = 100k frame/s

c. What is the duration of an output frame?

Duration = 1/frame rate = 1/100k = 10μs

d. What is the output data rate?

Date rate = frame rate * bits/frame = 100k * 21 = 2100kbps

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

20/21 * 100% = 95%

P6-6. We have 14 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?

Frame size = (# of slots) x (character size + slot address) = 6 x (8 bits+ 4 bits) =72 bits

b. What is the output frame rate?

We can assume that we have only 6 input lines. Each frame needs to carry one character from each of these lines. This means that the link needs to send500 frames/s

c. What is the duration of an output frame?

Frame duration = 1 / (frame rate) = 1 / 500 =2ms.

d. What is the output data rate?

Data rate = (500 frames/s) x (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?

We combine six 200-kbps sources into three 400-kbps. Now we have seven 400-kbps channel.
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?

Frame rate = **400k frames/s.**

c. What is the duration of a frame?

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

d. What is the data rate?

Data rate = (400,000 frames/s) × (7 bits/frame) = **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?

Divide all of them into 50Kbps lines => in total (200/50)*2 + (150/50) * 2 = 14, then aggregate => 14 bits/frame

b. What is the frame rate?

Frame rate = 50k frame/s

c. What is the duration of a frame?

Frame duration = 1/ (frame rate) = 1 /50k = 20μs

d. What is the data rate?

Data rate = 50k * 14 = 700kbps

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?

We need to add extra bits to the second source to make both bit rates = 190Kbps.Now we have two sources, each of 190 Kbps. Since the data unit was not specified, assume that it is one bit.

Frame size = 2 bits.

b. What is the frame rate?

Frame rate =190k frames/s

c. What is the duration of a frame?

Frame duration = 1/frame rate = 1/190k = 5.26μs

d. What is the data rate?

Data rate = 190k*2 = 380kbps

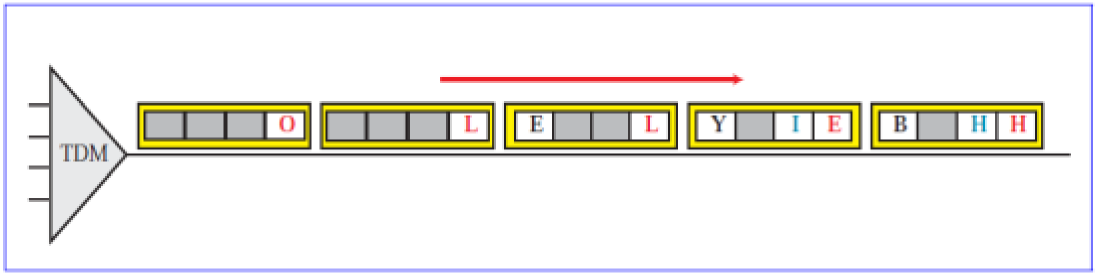
P6-11. Show the contents of the five output frames for a synchronous TDM multiplexer that combines four sources sending the following characters. Note that the characters are sent in the same order that they are typed. The third source is silent.

a. Source 1 message: HELLO

b. Source 2 message: HI

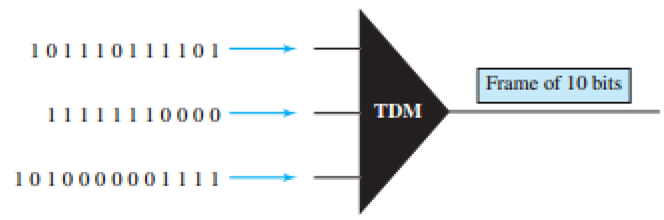
c. Source 3 message:

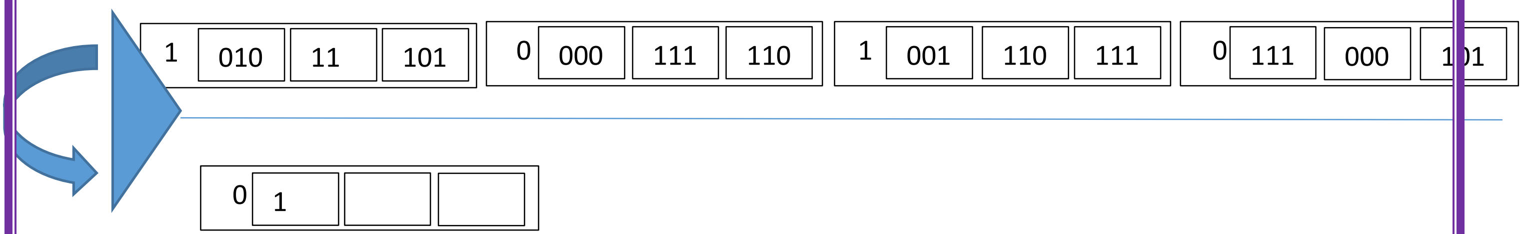
d. Source 4 message: BYE



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.

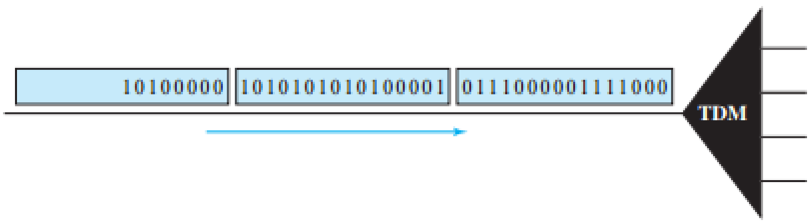
Figure 6.34 *Problem P6-12*

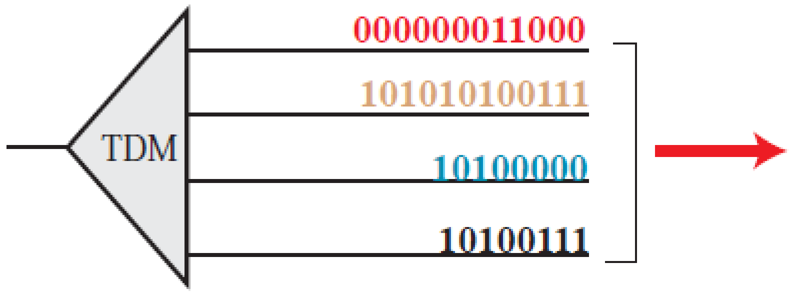




P6-13. Figure 6.35 shows a demultiplexer in a synchronous TDM. If the input slot is 16 bits long (no framing bits), what is the bit stream in each output? The bits arrive at the demultiplexer as shown by the arrows.

Figure 6.35 *Problem P6-13*





P6-15. 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?

The number of hops = 100 KHz/4 KHz = 25. So we need = $\log_2 25 \approx$ **5 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?

   2^4 = 16 channels