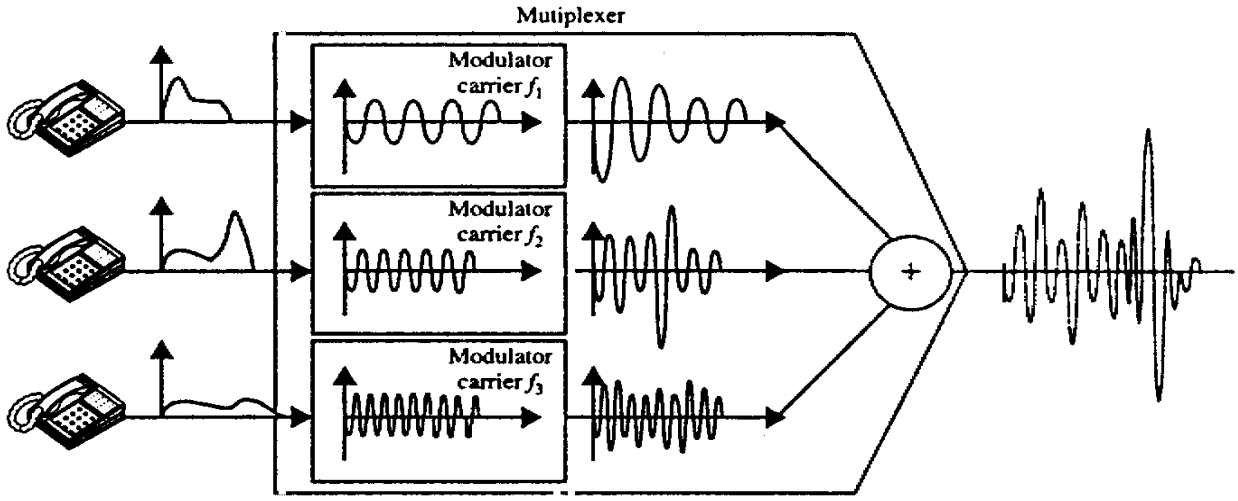
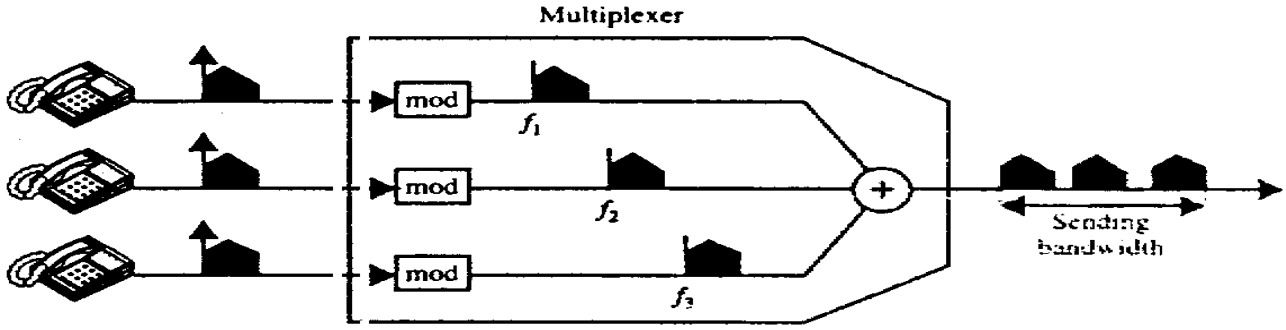
horizontal axis of this figure denotes **<u>frequency, not time</u>**. All three carrier frequencies exist at the same time within the bandwidth.) In FDM, signals are modulated onto separate carrier frequencies *(f_1, f_2* and *f_3)* using either AM or FM modulation.

FDM multiplexing process, time-domain



FDM multiplexing process, frequency-domain

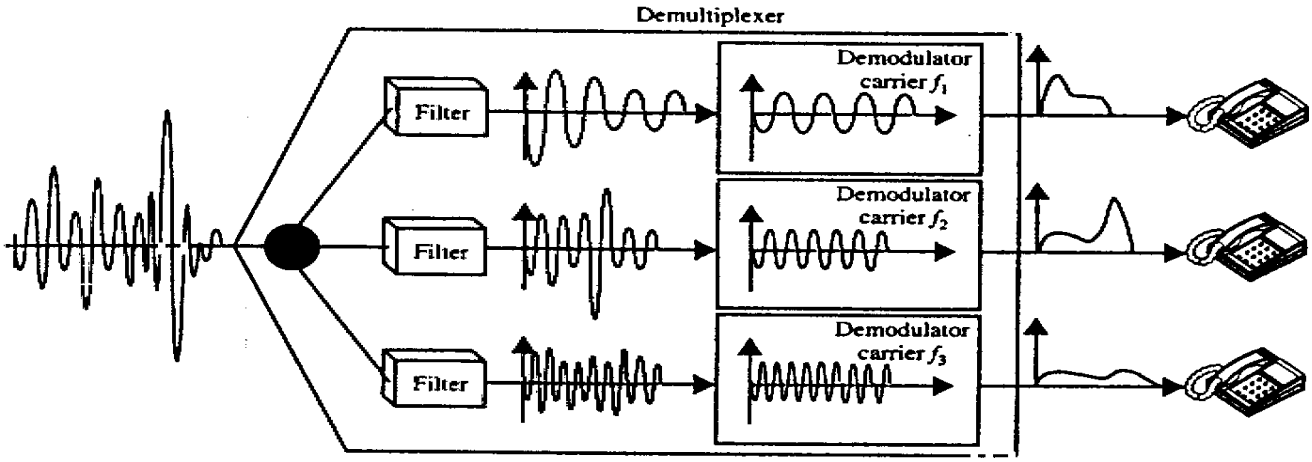


<u>Demultiplexing</u>

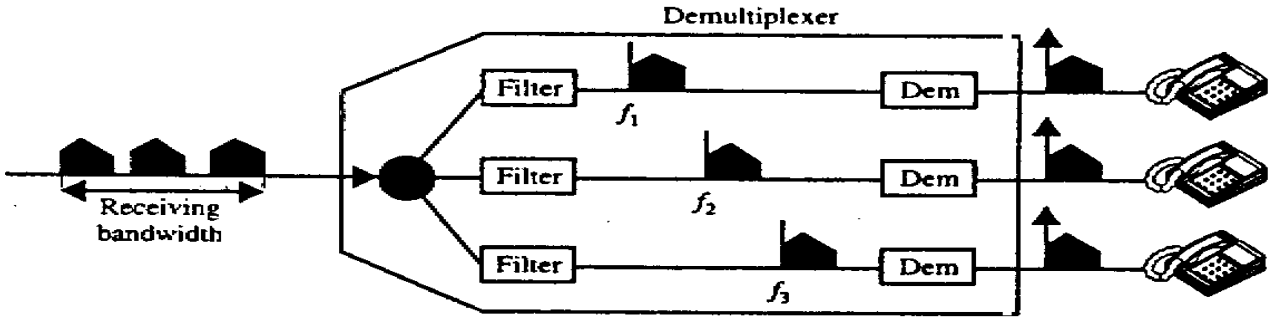
The demultiplexer ***uses*** a series of ***filters*** to decompose the multiplexed signal into its constituent component signals.

The **individual signals** are then **passed to a demodulator** that **separates them from their carriers** and passes them to the waiting receivers.

FDM demultiplexing process, time-domain



FDM demultiplexing process, frequency-domain



A familiar application of FDM is cable television. The coaxial cable used in a cable television system.

Today, a new and more efficient method is being developed to implement FDM over fiber-optic cable. Called ***wavelength division multiplexing*** ***(WDM***), it uses essentially the same concepts as FDM but incorporates the range of frequencies in the **visible light spectrum.**

2) Time-Division Multiplexing (TDM)

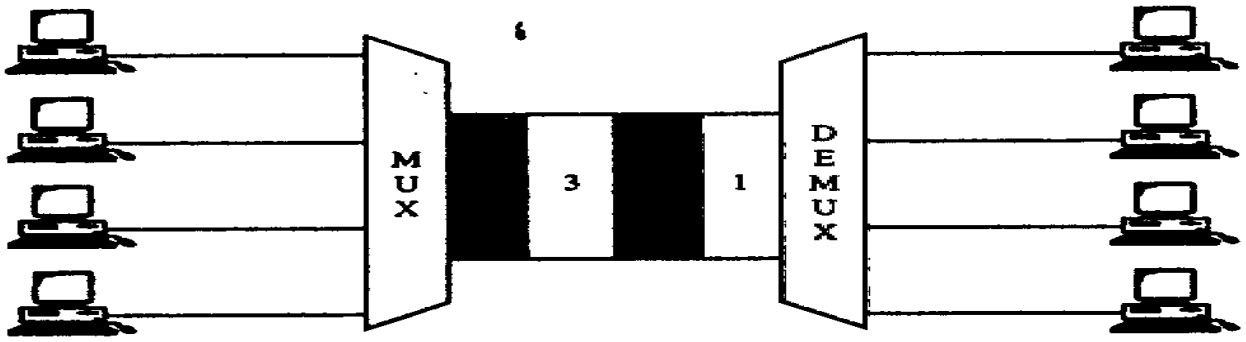
Time-division multiplexing (TDM) is a ***digital process*** that can be applied when the data rate capacity of the transmission medium is **greater than** the data rate required by the sending and receiving devices.

In such a case, multiple transmissions can occupy a single link by **subdividing** them and interleaving the portions.

In the TDM figure, **portions of** signals 1,2, 3, and 4 **occupy the link sequentially**.

TDM can be implemented in two ways: synchronous TDM and asynchronous TDM.

conceptual view of TDM



a) Synchronous TDM

In time-division multiplexing, the term ***synchronous*** has a different meaning from that used in other areas of telecommunications**.**

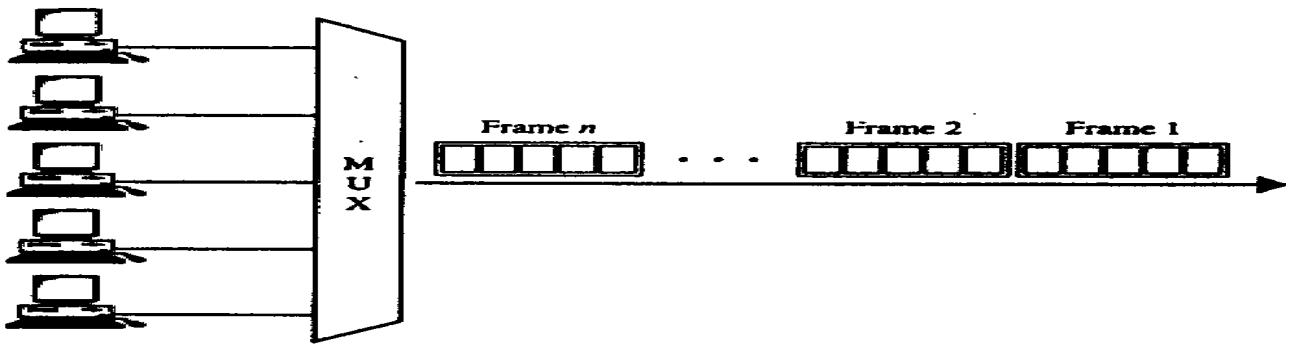
Here synchronous means that the multiplexer **allocates exactly the same time slot so each device at all times, whether or not a device has anything to transmit**.

Time slot A, ***for example***, is assigned to device A alone and cannot be used by any other device.

Each time its allocated time slot comes up, a device has the opportunity to send a portion of its data. If a device is unable to transmit or does not have data to send, its time slot remains

empty.

Figure 9, **Synchronous TDM**



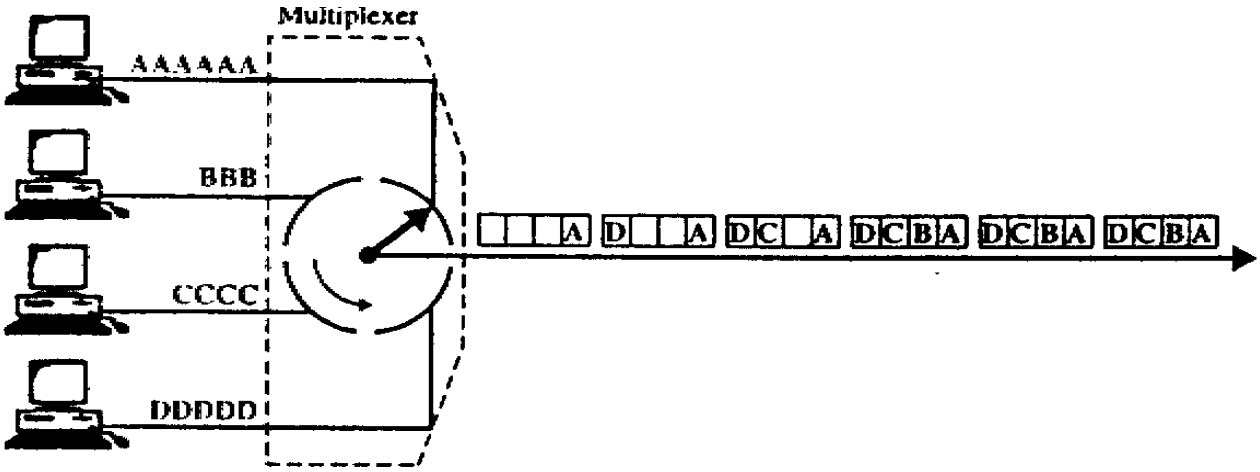
Time slots are grouped into frames.

In a system with *n* input lines, each frame has at least ***n* slots**. with each slot allocated to carry data from a specific input line.

If all the input devices sharing a link are transmitting at the same data rate, each device has **one time slot per frame**.

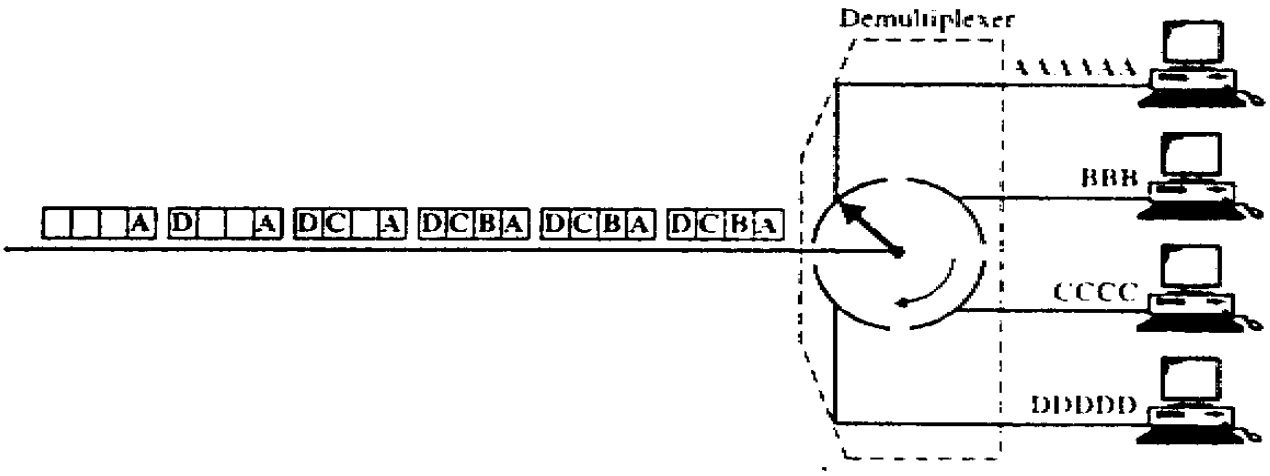
However, ***it is possible to*** accommodate **varying data rates**. A transmission with two slots per frame will arrive twice as quickly as one with one slot per frame.

number of time slots in each frame is equal to the number of input lines.



Synchronous TDM ***can be compared to*** a very fast rotating switch. As the switch opens in front of a device, that device has the opportunity to send a specified amount (x bits) of data onto the path. The switch moves from device to device at a constant rate and in a fixed order. This process is called **interleaving**. Interleaving can be done by bit, by byte, or by any other data unit.

At the receiver, the demultiplexer decomposes each frame by discarding the framing bits and extracting each character and it is passed to the appropriate receiving device .



***the major weakness* of synchronous TDM**.:By assigning each time slot to a specific input line, we end up with empty slots whenever not all the lines are active.

- synchronous TDM ***does not guarantee*** that the full capacity of a link is used
- ***Because the time*** slots fixed, whenever a connected device is not transmitting the corresponding slot is ***empty*** and that much of the path is ***wasted.***

Example

Imagine that we have four input sources on a synchronous TDM link, where transmissions are interleaved by character. If each source is creating 250 characters per second, and each frame is carrying I character front each source, the transmission path must be able to carry 250 frames per second see Figure 12 below.

If we assume that each character consists of eight bits. then each frame is 33 bits long: 32 bits for the four characters plus I framing bit. Looking at the bin relationships. we see that each device is creating 2000 bps (250 characters with 8 bits per character},
but the line is carrying 8250 bps (250 frames with 33 bits per frame): 8000 hits of data and 250 bits of overhead.

8250 bps =250 frames/second * 33 bits/frame
Or
8250 bps =4 X 2000 bps + 250 synchronization bps

b) Asynchronous *TDM*

Asynchronous time-division multiplexing, or ***statistical time-division multiplexing***, is designed to **avoid waste** in **synchronous *TDM*** .

The term ***asynchronous means*** something different in multiplexing than it means in other areas of data communications. Here it means **flexible or not fixed.**

Like synchronous TDM. asynchronous TDM allows a number of lower speed input lines to be multiplexed to a single higher speed line**.**

Unlike synchronous TDM, however, in asynchronous TDM the total speed of the input lines can be greater than the capacity of the path.

In a ***synchronous system***, if we have n input lines, the frame contains a fixed number of at least n time slots.

In an **asynchronous system**, if we have *n* input lines, the frame contains no more than in slots, with ni less than n (**based on** a statistical analysis of the number of input lines that are likely to be transmitting at any given time).

asynchronous TDM can support more devices than synchronous TDM.