Multiplexing in Computer Network

Multiplexing is a technique by which different analog and digital streams of transmission can be simultaneously processed over a shared link. Multiplexing divides the high capacity medium into low capacity logical medium which is then shared by different streams.

Communication is possible over the air (radio frequency), using a physical media (cable), and light (optical fiber). All mediums are capable of multiplexing.

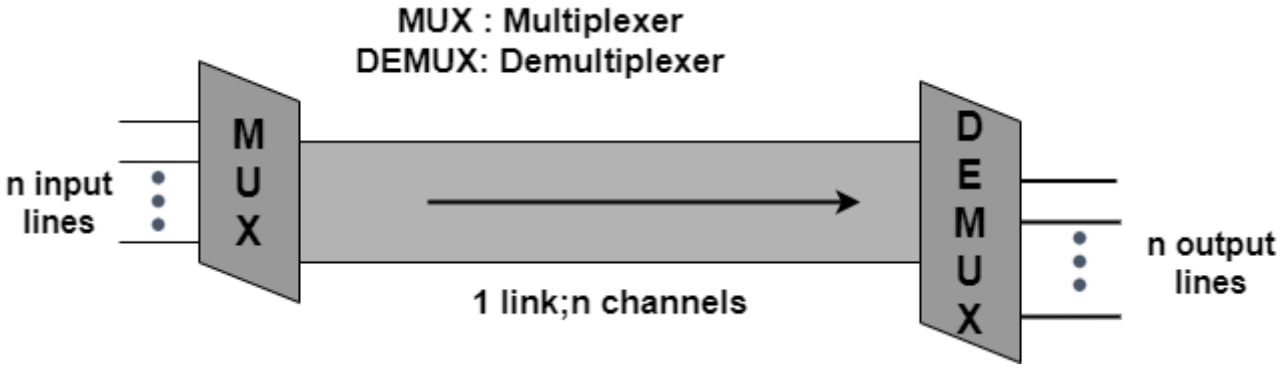
When multiple senders try to send over a single medium, a device called Multiplexer divides the physical channel and allocates one to each. On the other end of communication, a De-multiplexer receives data from a single medium, identifies each, and sends to different receivers.

The set of techniques that allows the simultaneous transmission of multiple signals across a single data link is commonly referred to as Multiplexing. Multiplexing is done by using the hardware that is called as Multiplexer(MUX).

The Multiplexer(MUX) mainly combines 'n' input lines in order to generate '1' output line(this is simply many-to-one) on the sender side. And on the receiver side, this stream is fed into the demultiplexer(DEMUX), which then separates the stream back to its component transmission (this is one-to-many) and then directs them to their corresponding lines.

The main aim of the multiplexing technique is to share scarce resources.

Let us understand with the help of a diagram given below to divide 1 link into n channels:



In the above diagram, the word link refers to the physical path, and the word channel simply refers to the portion of the link that carries a transmission between a given pair of lines. Thus 1 link can have many channels.

Categories of Multiplexing

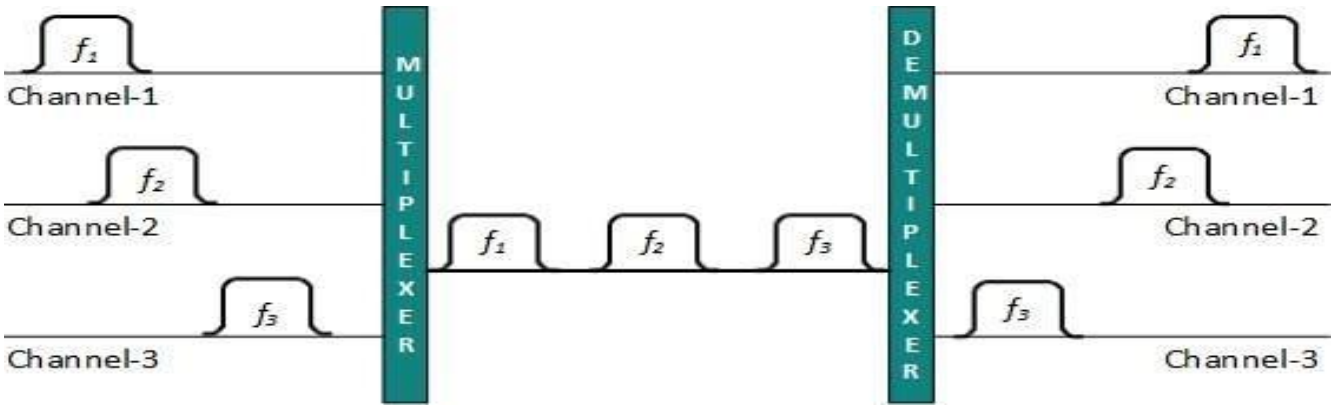
Let us take a look at the different categories of Multiplexing:

- Frequency-division multiplexing
- Wavelength-division multiplexing
- Time-division multiplexing
- Code division multiplexing

Frequency Division Multiplexing

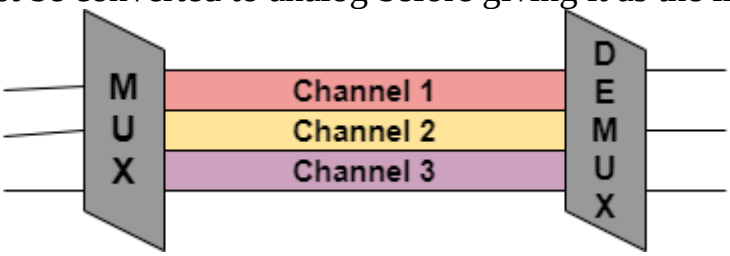
When the carrier is frequency, FDM is used. FDM is an analog technology. FDM divides the spectrum or carrier bandwidth in logical channels and allocates one user to each channel. Each user can use the channel frequency independently and has exclusive access of it. All

channels are divided in such a way that they do not overlap with each other. Channels are separated by guard bands. Guard band is a frequency which is not used by either channel.



Frequency-Divison Multiplexing i.e **FDM** is an **analog technique.**

- With this technique, signals having different frequencies are combined in a composite signal and then transmitted on the link
- It is mainly **applied at the time** when the **bandwidth of the link is greater than the combined bandwidths of the signal** to be transmitted.
- In this, each signal is of a different frequency.
- The channel is usually separated by the strips of unused bandwidth that is the **guard bands** in order to prevent the signals from overlapping.
- In the case of frequency division multiplexing, suppose the input signal is in the digital form then it must be converted to analog before giving it as the input to the modulator.



Frequency Division Multiplexing

From the above diagram, in **FDM** the transmission path is divided into **three parts** and each part mainly **represents a channel** that carries **one transmission**.

Advantages

Given below are some advantages of using FDM:

- The Simultaneous transmission of a large number of signals is done easily.
- The demodulation of FDM multiplexing is easy.
- There is no need for synchronization between the transmitter and receiver for proper operation.
- In the case of slow narrowband fading, there is only one single channel that gets affected.

Disadvantages

There are some drawbacks of using FDM:

- Communication channels must have a very large bandwidth.
- There occurs the problem of crosstalk while using FDM.
- In the case of wideband fading, all channels in the FDM gets affected.
- There is a need for a large number of filters and modulators.

Applications

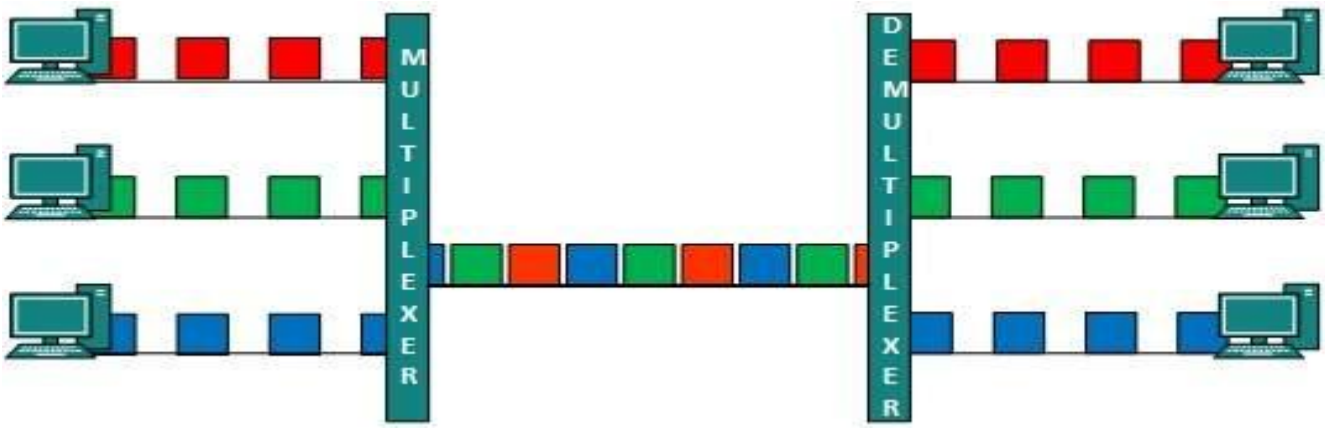
The main applications of FDM are as follows:

- One of the main applications of FDM is that it is AM and FM radio broadcasting.
- Another application of FDM is that it is used in television broadcasting.
- FDM is also used by first-generation cellular telephones.

Time Division Multiplexing

TDM is applied primarily on digital signals but can be applied on analog signals as well. In TDM the shared channel is divided among its user by means of time slot. Each user can transmit data within the provided time slot only. Digital signals are divided in frames, equivalent to time slot i.e. frame of an optimal size which can be transmitted in given time slot.

TDM works in synchronized mode. Both ends, i.e. Multiplexer and De-multiplexer are timely synchronized and both switch to next channel simultaneously.



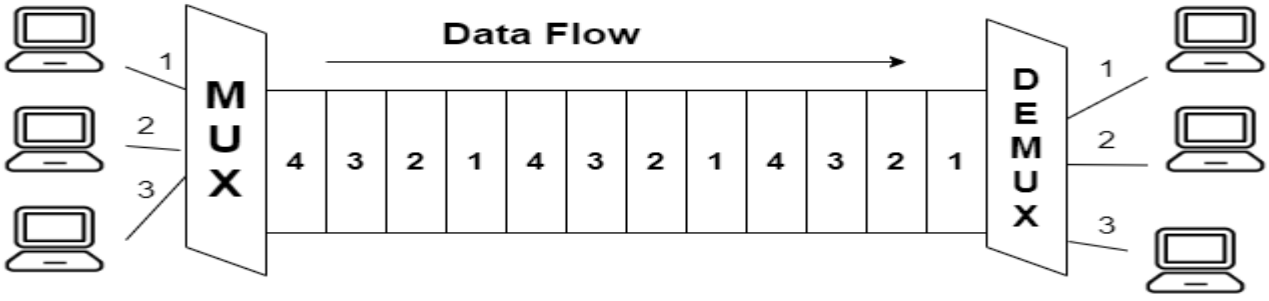
When channel A transmits its frame at one end,the De-multiplexer provides media to channel A on the other end.As soon as the channel A's time slot expires, this side switches to channel B. On the other end, the De-multiplexer works in a synchronized manner and provides media to channel B. Signals from different channels travel the path in interleaved manner.

Time-Divison multiplexing is a digital technique for multiplexing.

- In this technique, the channel/link is divided on the basis of time instead of frequency.
- The total available time on the channel is divided between the different users on the channel.
- A particular time interval is allotted to each user on the channel and it is known as time slot/slice.
- In the time-division multiplexing, the data rate capacity should be much greater than the data rate that is required by the sending and receiving device.

TDM is further categorized into two:

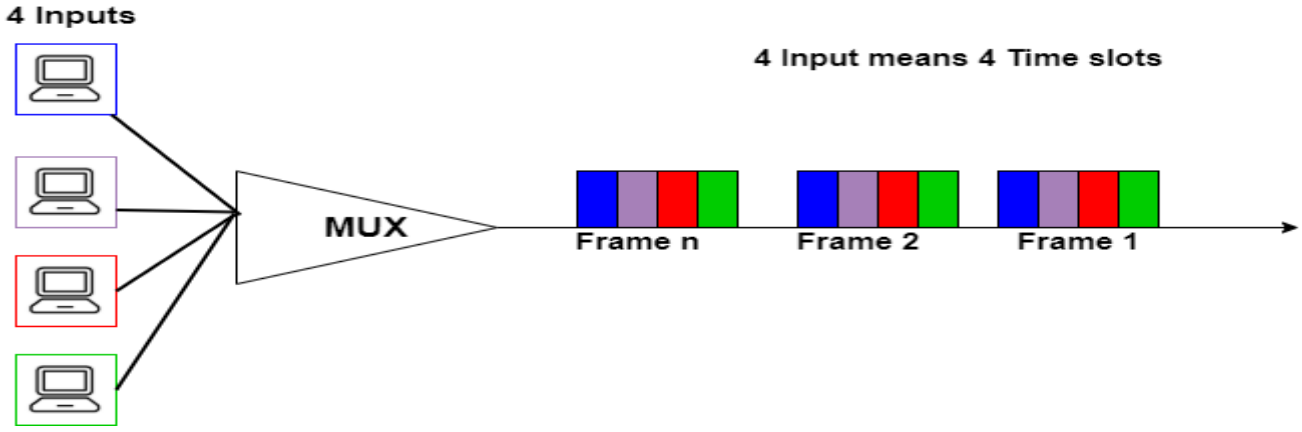
- Synchronous Time-Divison Multiplexing
- Asynchronous Time-Divison Multiplexing



1.Synchronous Time-Divison Multiplexing

In Synchronous TDM, each of the Input connection has an allotment in the output even if it is not sending the data.

- In this multiplexing, each device is given the same time slot in order to transmit data over the link whether it has to send data to the receiver or not.
- Each device places data on the link whenever its time slot arrives Thus control is given to each device turn by turn.
- In case if any devices do not have any data to send then in that case the time slot for that device remains empty.
- In this multiplexing, if there are 'n' sending devices then simultaneously there will be 'n' time slots which means one time slot for each device.
- Also, time slots are organized in the form of frames, where each frame consists of one or more time slots.



Advantages

- This technique is easy to implement.
- The performance is guaranteed in using this technique.

Disadvantages

- If a user has no data to transmit in that case time slots will get wasted.
- In this multiplexing, the capacity of the transmission link must be always higher than the total capacity of the input lines.

2.Asynchronous Time-Divison Multiplexing

Another name of Asynchronous TDM is Statical Time Divison Multiplexing. In this time slots are not fixed, rather time slots are allocated dynamically in order to improve the efficiency of bandwidth.

- The total speed of all the Input lines can be greater than the capacity of the path.
- In this Multiplexing, there are n input lines and m slots; thus always (m<n).
- There is no concept of predefined slots rather than slots are allocated dynamically on demand.
- In this multiplexing, the multiplexor mainly accepts the incoming input data and then it creates a frame that contains only data without any empty slots.
- Each slot mainly contains the address part that is used to identify the source of the input data.
- The number of frames in this multiplexing depends upon the statical analysis of the number of input lines.

Thus in the above diagram, out of 6 only 4 devices are sending data that are 1,2,4,6. In the above diagram, you can see that the data part contains the address in order to determine the source of the data. Like **A1**(data along with its source).

Advantages

- In this multiplexing, there is an efficient use of the capacity of transmission.

Disadvantages

- In this Multiplexing, frames are of different sizes.
- There is a need for the buffer address information is also needed because there are no separate slots assigned for each user.
- This technique does not provide a fixed waiting time guarantee.

Wavelength Division Multiplexing

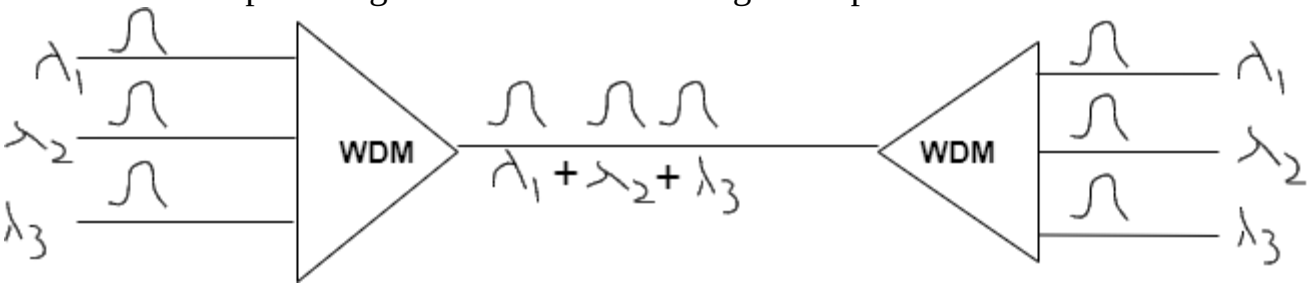
Light has different wavelength (colors). In fiber optic mode, multiple optical carrier signals are multiplexed into an optical fiber by using different wavelengths. This is an analog multiplexing technique and is done conceptually in the same manner as FDM but uses light as signals.

Further, on each wavelength time division multiplexing can be incorporated to accommodate more data signals.

Wavelength-Divison Multiplexing i.e **WDM** is an **analog technique.**

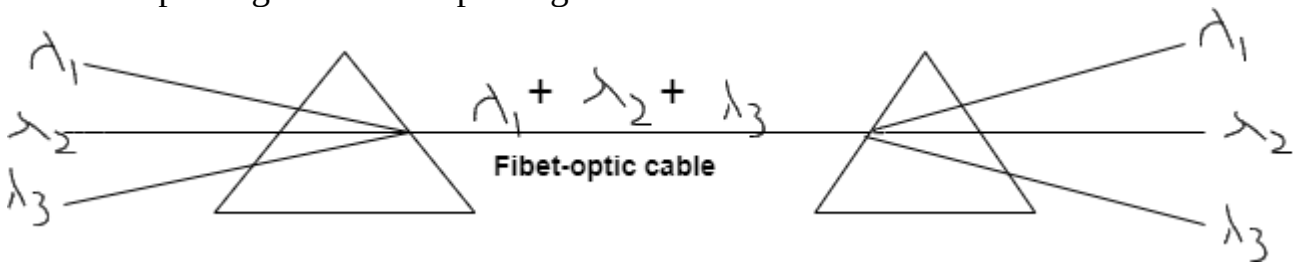
- This technique is **similar to FDM**.
- With the help of Wavelength Divison multiplexing **different signals** that include: **optical or light** signals are transmitted **through the Optical fiber.**
- With the help of the WDM technique, the high data rate capability of optical fiber cable gets utilized.
- With this technique, various light waves from different sources are combined into a composite light signal and this signal is transmitted across the channel to the receiver.
- On the receiver side, this composite light signal gets broken down into different light waves with the help of Demultiplexer.
- The process of combining and splitting the light waves is done with the help of **Prism.**

- This Prism helps to bend the beam of light on the basis of the angle of incidence and frequency of light.
- In the WDM technique mainly the role of the multiplexer is played by the Prism and it then combines the various optical signals in the order to form a composite signal after that this composite signal is transmitted through an Optical fiber cable.



The above Figure indicates Wavelength Divison Multiplexing

Let us take a look at the diagram given below where we will use prism for wavelength-division multiplexing and demultiplexing.



Advantages

Given below are some advantages of using WDM:

- With the help of WDM, the full-duplex transmission is possible.
- WDM is easy to reconfigure.
- Various Signals can be transmitted simultaneously with the help of WDM.
- This technique is less expensive and the expansion of the system is easy.
- This technique provides high security.
- As we are using an optical fiber in WDM; also Optical components are more reliable and they also provide high bandwidth.

Disadvantages

There are some drawbacks of using WDM:

- There is the use of optical equipment so cost increases.
- Utilization of bandwidth can be inefficient which causes difficulty in wavelength tuning.
- The main concern in this technique is scalability.

Code Division Multiplexing

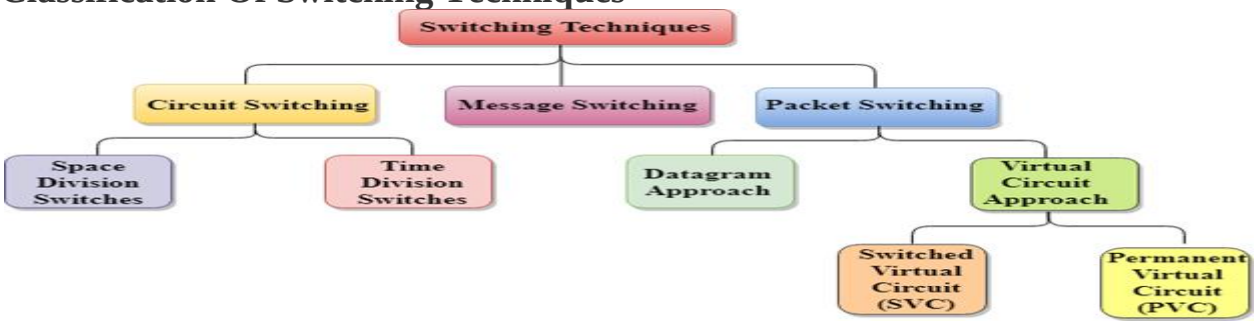
Multiple data signals can be transmitted over a single frequency by using Code Division Multiplexing. FDM divides the frequency in smaller channels but CDM allows its users to full bandwidth and transmit signals all the time using a unique code. CDM uses orthogonal codes to spread signals.

Each station is assigned with a unique code, called chip. Signals travel with these codes independently, inside the whole bandwidth.The receiver knows in advance the chip code signal it has to receive.

Switching techniques

In large networks, there can be multiple paths from sender to receiver. The switching technique will decide the best route for data transmission.
Switching technique is used to connect the systems for making one-to-one communication.

Classification Of Switching Techniques

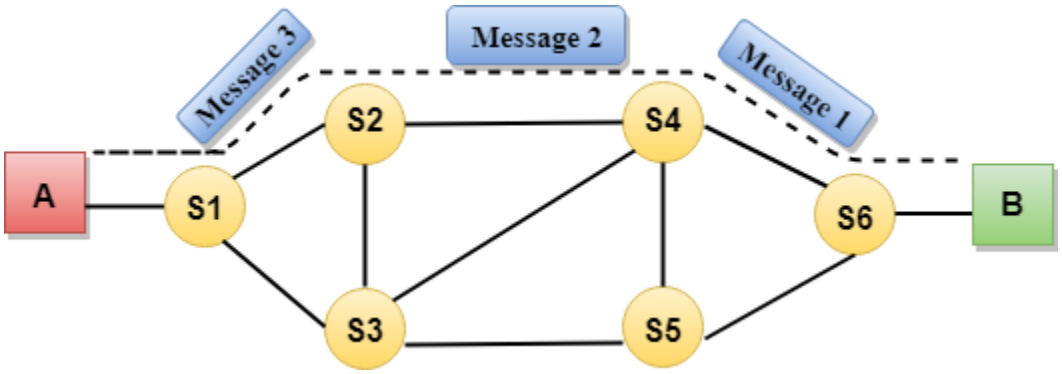


Circuit Switching

- Circuit switching is a switching technique that establishes a dedicated path between sender and receiver.
- In the Circuit Switching Technique, once the connection is established then the dedicated path will remain to exist until the connection is terminated.
- Circuit switching in a network operates in a similar way as the telephone works.
- A complete end-to-end path must exist before the communication takes place.
- In case of circuit switching technique, when any user wants to send the data, voice, video, a request signal is sent to the receiver then the receiver sends back the acknowledgment to ensure the availability of the dedicated path. After receiving the acknowledgment, dedicated path transfers the data.
- Circuit switching is used in public telephone network. It is used for voice transmission.
- Fixed data can be transferred at a time in circuit switching technology.

Communication through circuit switching has 3 phases:

- Circuit establishment
- Data transfer
- Circuit Disconnect



Advantages of Circuit Switching:

It has the following advantages :

1. The main advantage of circuit switching is that a committed transmission channel is established between the computers which give a guaranteed data rate.
2. In-circuit switching, there is no delay in data flow because of the dedicated transmission path.

3. **Reliability:** Circuit switching provides a high level of reliability since the dedicated communication path is reserved for the entire duration of the communication. This ensures that the data will be transmitted without any loss or corruption.
4. **Quality of service:** Circuit switching provides a guaranteed quality of service, which means that the network can prioritize certain types of traffic, such as voice and video, over other types of traffic, such as email and web browsing.
5. **Security:** Circuit switching provides a higher level of security compared to packet switching since the dedicated communication path is only accessible to the two communicating parties. This can help prevent unauthorized access and data breaches.
6. **Ease of management:** Circuit switching is relatively easy to manage since the communication path is pre-established and dedicated to a specific communication. This can help simplify network management and reduce the risk of errors.
7. **Compatibility:** Circuit switching is compatible with a wide range of devices and protocols, which means that it can be used with different types of networks and applications. This makes it a versatile technology for various industries and use cases.

Disadvantages of Circuit Switching:

It has the following disadvantages :

1. It takes a long time to establish a connection.
2. More bandwidth is required in setting up dedicated channels.
3. It cannot be used to transmit any other data even if the channel is free as the connection is dedicated to circuit switching.
4. **Limited Flexibility:** Circuit switching is not flexible as it requires a dedicated circuit between the communicating devices. The circuit cannot be used Waste of Resources for any other purpose until the communication is complete, which limits the flexibility of the network.
5. **Waste of Resources:** Circuit switching reserves the bandwidth and network resources for the duration of the communication, even if there is no data being transmitted. This results in the wastage of resources and inefficient use of the network.
6. **Expensive:** Circuit switching is an expensive technology as it requires dedicated communication paths, which can be costly to set up and maintain. This makes it less feasible for small-scale networks and applications.
7. **Susceptible to Failure:** Circuit switching is susceptible to failure as it relies on a dedicated communication path. If the path fails, the entire communication is disrupted. This makes it less reliable than other networking technologies, such as packet switching.
8. **Not suitable for bursty traffic:** Circuit switching is not suitable for bursty traffic, where data is transmitted intermittently at irregular intervals. This is because a dedicated circuit needs to be established for each communication, which can result in delays and inefficient use of resources.

Circuit Switching can use either of the two technologies:

Space Division Switches:

- Space Division Switching is a circuit switching technology in which a single transmission path is accomplished in a switch by using a physically separate set of crosspoints.
- Space Division Switching can be achieved by using crossbar switch. A crossbar switch is a metallic crosspoint or semiconductor gate that can be enabled or disabled by a control unit.

- The Crossbar switch is made by using the semiconductor. For example, Xilinx crossbar switch using FPGAs.
- Space Division Switching has high speed, high capacity, and nonblocking switches.

Space Division Switches can be categorized in two ways:

- **Crossbar Switch**
- **Multistage Switch**

Crossbar Switch

The Crossbar switch is a switch that has n input lines and n output lines. The crossbar switch has n^2 intersection points known as **crosspoints.**

Disadvantage of Crossbar switch:

The number of crosspoints increases as the number of stations is increased. Therefore, it becomes very expensive for a large switch. The solution to this is to use a multistage switch.

Multistage Switch

- Multistage Switch is made by splitting the crossbar switch into the smaller units and then interconnecting them.
- It reduces the number of crosspoints.
- If one path fails, then there will be an availability of another path.

Time-Division Switching

It is a digital switching technique. There is no need for crosspoints in this switching. In Time-Division Switching, the incoming signals, as well as outgoing signals, are received and re-transmitted in a different time slot.

- One of the main differences between space-division multiplexing and time-division multiplexing is the sharing of Crosspoints. There are no Crosspoints shared in space division switching, whereas crosspoints can be shared for shorter periods in time-division multiplexing.
- The Time-Division switches are used by modern devices.
- In this technique, there is the use of time-division multiplexing inside the switch and it is known as Time Slot Interchange(TSI).

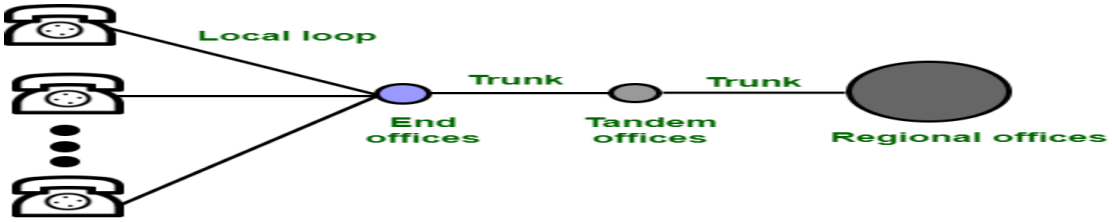
Telephone Network

Telephone Network is used to provide voice communication. Telephone Network uses Circuit Switching. Originally, the entire network was referred to as a plain old telephone system (POTS) which uses analog signals. With the advancement of technology, i.e. in the computer era, there comes a feature to carry data in addition to voice. Today's network is both analogous and digital.

Major Components of Telephone Network: There are three major components of the telephone network:

1. Local loops
2. Trunks
3. Switching Offices

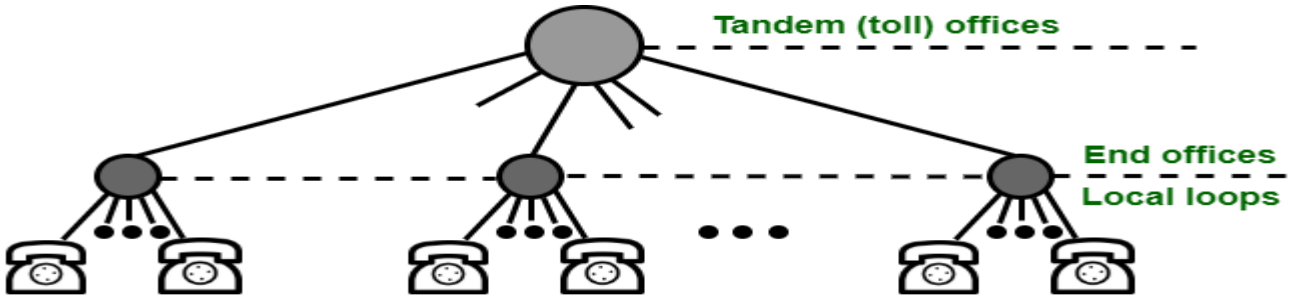
There are various levels of switching offices such as end offices, tandem offices, and regional offices. The entire telephone network is as shown in the following figure:



Local Loops: Local Loops are the twisted pair cables that are used to connect a subscriber telephone to the nearest end office or local central office. For voice purposes, its bandwidth is 4000 Hz. It is very interesting to examine the telephone number that is associated with each local loop. The office is defined by the first three digits and the local loop number is defined by the next four digits defines.

Trunks: It is a type of transmission medium used to handle the communication between offices. Through multiplexing, trunks can handle hundreds or thousands of connections. Mainly transmission is performed through optical fibers or satellite links.

Switching Offices: As there is a permanent physical link between any two subscribers. To avoid this, the telephone company uses switches that are located in switching offices. A switch is able to connect various loops or trunks and allows a connection between different subscribes.



Switching offices

Advantages of Telephone Network:

- It is a circuit-switched network.
- There is no transmission delay as any receiver can be selected.
- It is cheap in price because it is a widely spread network.

Disadvantages of Telephone Network:

- It requires a large time for connection.
- It has a low transmission speed.

Applications of Telephone Network:

- It helps to connect people.
- It is used by business organizations to advertise their products.
- It is also used around the world for recreational purposes.

Time Division Multiplexing (TDM) Bus: In digital communications and networking, Time Division Multiplexing (TDM) is a method of transmitting multiple signals or data streams over a single communication channel by dividing the channel into multiple time slots. A TDM bus, in this context, would be a communication bus or pathway that employs time division multiplexing to transmit data from different sources.

In TDM, each connected device or source is allocated a specific time slot to transmit its data. The devices take turns to send data, and the receiving end extracts and separates the data streams based on the time slots they occupy.

In computer communication, the term "TDM BUS" typically refers to a communication bus that utilizes Time Division Multiplexing (TDM) for data transmission between devices. It is a method used to share a single communication channel among multiple devices or nodes in a network.

Here's how a TDM BUS works in computer communication:

1. **Time Division Multiplexing (TDM)**: TDM is a technique where the available communication channel is divided into discrete time slots, and each device or node on the bus is allocated a specific time slot for transmitting its data. The devices take turns using the channel during their designated time slots.
2. **Data Transmission**: During each time slot, the device with the data to transmit seizes the bus and sends its information. The other devices wait until their respective time slots to send their data. This process continues in a cyclic manner, providing each device a fair opportunity to transmit data.
3. **Synchronization**: All devices on the TDM BUS must be synchronized to the same time frame to ensure proper communication. A common clock or synchronization mechanism is used to coordinate the devices' transmissions and receptions.
4. **Benefits**: TDM BUS provides a straightforward and deterministic way to share a communication channel among multiple devices. It eliminates the possibility of collisions (as in Carrier Sense Multiple Access, CSMA) and ensures that each device gets a fixed amount of time to transmit data, which can be essential for real-time applications.
5. **Drawbacks**: One limitation of TDM is that if a device has no data to send during its allocated time slot, that time slot remains unused, resulting in potential bandwidth waste. Additionally, the number of devices that can be accommodated on the bus is limited by the number of available time slots and the data rates required by each device.

   TDM Buses were commonly used in older networking technologies and some legacy systems, but with advancements in networking technologies, TDM has been largely replaced by more efficient and flexible methods such as packet switching in modern computer communication systems.