

1. Network monitoring: delay, latency, throughput

2. Transmission media: Twisted pair, Coaxial, Fiber optic, Line-of-site, Satellite

3. Multiplexing, Circuit switching, Packet switching, VC Switching, Telecommunication switching system (Networking of Telephone exchanges)

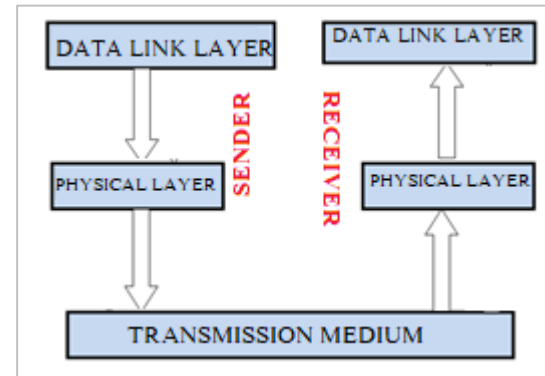
4. ISDN: Architecture, Interface, and Signaling

Physical layer is the **lowest layer** of all. It is responsible for **sending bits** from one computer to another. This layer is not concerned with the meaning of the bits and deals with the **physical connection** to the network and with **transmission and reception** of signals.

This layer defines electrical and physical details represented as 0 or a 1. How many pins a network will contain? When the data can be transmitted or not? and How the data would be synchronized?

#### FEATURES OF PHYSICAL LAYER:

- It is the **lowest layer** of the OSI Model.
- It activates, maintains and deactivates the **physical connection**.
- It is responsible for transmission and reception of the unstructured raw data over network.
- **Voltages and data rates** needed for transmission is defined in the physical layer.
- It **converts** the digital/analog bits into electrical signal or optical signals.
- **Data encoding** is also done in this layer.
- **Representation of Bits**: Data in this layer consists of stream of bits. The bits must be encoded into signals for transmission. It defines the type of encoding i.e. how 0's and 1's are changed to signal.
- **Data Rate**: This layer defines the rate of transmission which is the number of bits per second.
- **Synchronization**: It deals with the synchronization of the transmitter and receiver. The sender and receiver are synchronized at bit level.
- **Encoding and Signaling**: The physical layer is responsible for various encoding and signaling functions that transform the data from bits that reside within a computer or other device into signals that can be sent over the network.
- **Definition of Hardware Specifications**: The details of operation of cables, connectors, wireless radio transceivers, network interface cards and other hardware devices are generally a function of the physical layer (although also partially the data link layer; see below).
- **Interface**: The physical layer defines the transmission interface between devices and transmission medium.
- **Line Configuration**: This layer connects devices with the medium: Point to Point configuration and Multipoint configuration.
- **Topologies and Physical Network Design**: Devices must be connected using the following topologies: Mesh, Star, Ring and Bus.
- **Data Transmission and Reception Modes**: Physical Layer defines the direction of transmission between two devices: Simplex, Half Duplex, Full Duplex.
- Deals with **baseband and broadband** transmission.



### 2.1 Network Monitoring : delay, latency, throughput

- these are the **factor affecting in network performance**

\***Bandwidth**: Bandwidth determines **how fast data** can be transferred over time. Bandwidth is the amount of data that can be transferred per second.

\***Throughput**: Throughput is the **average rate of successful message** that, a communication channel can delivery over a communication period. Its measuring unit is bits/second.

**Throughput** is the **number of messages successfully delivered per unit time**. Throughput is **controlled by available bandwidth**, as well as the available signal-to-noise ratio and hardware limitations.

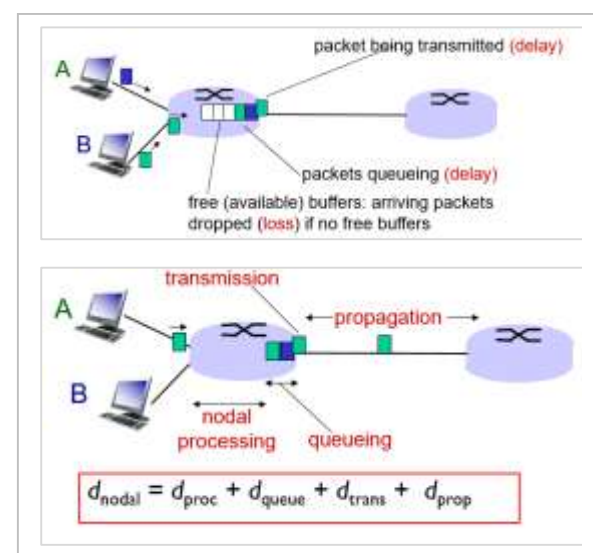
\***Delay** : The delay of a network specifies **how long it takes for a bit of data to travel across the network from one node ( host or router ) or endpoint to another**. When a packet travels from one node to the subsequent node along the path, it suffers from four sources of delays at each and every node along the paths like (i)Nodal processing delays /Processing Delays, (ii)delay in Queuing, (iii)Transmission delay and (iv)delay in Propagation.

$d_{proc}$ : nodal processing – processing in a node

- check bit errors
- determine output link
- typically < msec

$d_{queue}$ : queueing delay - packets *queue* in router buffers

- time waiting at output link for transmission
- depends on congestion level of router



$d_{trans}$ : transmission delay:

- $L$ : packet length (bits)
- $R$ : link bandwidth (bps)
- $d_{trans} = L/R$

$d_{prop}$ : propagation delay:

- $d$ : length of physical link
- $s$ : propagation speed in medium ( $\sim 2 \times 10^8$  m/sec)
- $d_{prop} = d/s$

Delay is the one way trip of a packet crossing a network. Latency is the round-trip of a packet over the network. The time is calculated by adding the time it takes for the packet to go from the source to destination and back.

\***Latency**: Latency is a part of delay. Latency is **how long it takes data** to travel between its source and destination, measured in milliseconds.

Latency is an expression of how much time it takes for a packet of data to travel from one node to another.

**Total latency of a network = one-way latency from source to destination + one-way latency from the destination back to the source.**

Think of latency as the speed limit on a highway. Traffic speed on a motorway is affected by many variables such as weather, other traffic, and highway signs. Likewise, data packets traversing a network are affected by many variables as well. The first step in mitigating latency is to break down the overall latency into that **due to the network and that due to the application and its associated servers**. With that determination made, visually graph both the application and network latency to help identify patterns and anomalies that deserve closer attention so that you can later drill down and figure out exactly what is causing the bottleneck.

The factors affecting in network latency are:

- **Propagation**: This is simply the time it takes for a packet to travel between one place and another at the speed of light.
- **Transmission**: The medium itself (whether optical fiber, wireless, or some other) introduces some delay, which varies from one medium to another. The size of the packet introduces delay in a round trip since a larger packet will take longer to receive and return than a short one. Also, when signals must be boosted by a repeater, this too introduces additional latency.
- **Router and other processing**: Each gateway node takes time to examine and possibly change the header in a packet (for example, changing the hop count in the time-to-live field).
- **Other computer and storage delays**: Within networks at each end of the journey, a packet may be subject to storage and hard disk access delays at intermediate devices such as switches and bridges. (In backbone statistics, however, this kind of latency is probably not considered.)

### Measuring Latency

You can measure the latency between your computer and a web address with [the ping command](#).

In example, it takes 11 milliseconds for traffic to go between our computer and Google's servers. If we had a satellite Internet connection, this could be as high as 700ms.

```

C:\Users\Chris>ping google.com

Pinging google.com [173.194.33.7] with 32 bytes of data:
Reply from 173.194.33.7: bytes=32 time=13ms TTL=55
Reply from 173.194.33.7: bytes=32 time=11ms TTL=55
Reply from 173.194.33.7: bytes=32 time=11ms TTL=55
Reply from 173.194.33.7: bytes=32 time=11ms TTL=55

Ping statistics for 173.194.33.7:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 11ms, Maximum = 13ms, Average = 11ms
  
```

\***Packet Loss**: Glitches, errors, or network overloading might result in the loss of data packets. Sometimes routers or switches might shed traffic intentionally to maintain overall network performance or to enforce a particular service level. In a well-tuned network intentional packet loss is hopefully a rare occurrence, though packet loss is still something that happens regularly due to a host of other reasons, and must be monitored closely to ensure overall network performance.

\***Retransmission**: When packet loss does occur, those lost packets are retransmitted. This retransmission process can cause two delays; one from re-sending the data and the second delay resulting from waiting until the data is received in the correct order before forwarding it up the protocol stack.

\* **Jitter**: Jitter is a variance in latency over time. If every packet takes exactly the same amount of time to travel from A to B, there is no jitter.

## 2.2 Transmission Mediums in Computer Networks

Transmission medium is the means through which we send our data from one place to another. The first layer (physical layer) of Communication Networks OSI Seven layer model is dedicated to the transmission media, we will study the OSI Model later.

### Factors to be considered while choosing Transmission Medium

1. Transmission Rate
2. Cost and Ease of Installation
3. Resistance to Environmental Conditions
4. Distances

### Bounded/Guided Transmission Media

It is the [transmission media](#) in which signals are confined to a specific path using wire or cable. The types of [Bounded](#)/ Guided are discussed below.

#### Twisted Pair Cable

This cable is the most commonly used and is cheaper than others. It is lightweight, cheap, can be installed easily, and they support many different types of network. Some important points :

- Its [frequency range](#) is 0 to 3.5 kHz.
- Typical [attenuation](#) is 0.2 dB/Km @ 1kHz.
- Typical [delay](#) is 50  $\mu$ s/km.
- Repeater [spacing](#) is 2km.

Twisted Pair is of two types :

- **Unshielded Twisted Pair (UTP)**
- **Shielded Twisted Pair (STP)**

**\*Unshielded Twisted Pair Cable :** It is the most common type of telecommunication when compared with Shielded Twisted Pair Cable which consists of [two conductors usually copper](#), each with its own [colour plastic insulator](#). Identification is the reason behind coloured plastic insulation.

UTP cables consist of 2 or 4 pairs of twisted cable. Cable with 2 pair use **RJ-11** connector and 4 pair cable use **RJ-45** connector.

#### Advantages :

- Installation is easy
- Flexible
- Cheap
- It has high speed capacity,
- 100 meter limit
- Higher grades of UTP are used in LAN technologies like Ethernet.

It consists of two insulating copper wires (1mm thick). The wires are twisted together in a helical form to reduce electrical interference from similar pair.

#### Disadvantages :

- Bandwidth is low when compared with Coaxial Cable
- Provides less protection from interference.

**\*Shielded Twisted Pair Cable :** This cable has a [metal foil or braided-mesh covering](#) which encases each pair of insulated conductors.

[Electromagnetic noise penetration](#) is prevented by metal casing. Shielding also [eliminates crosstalk](#)

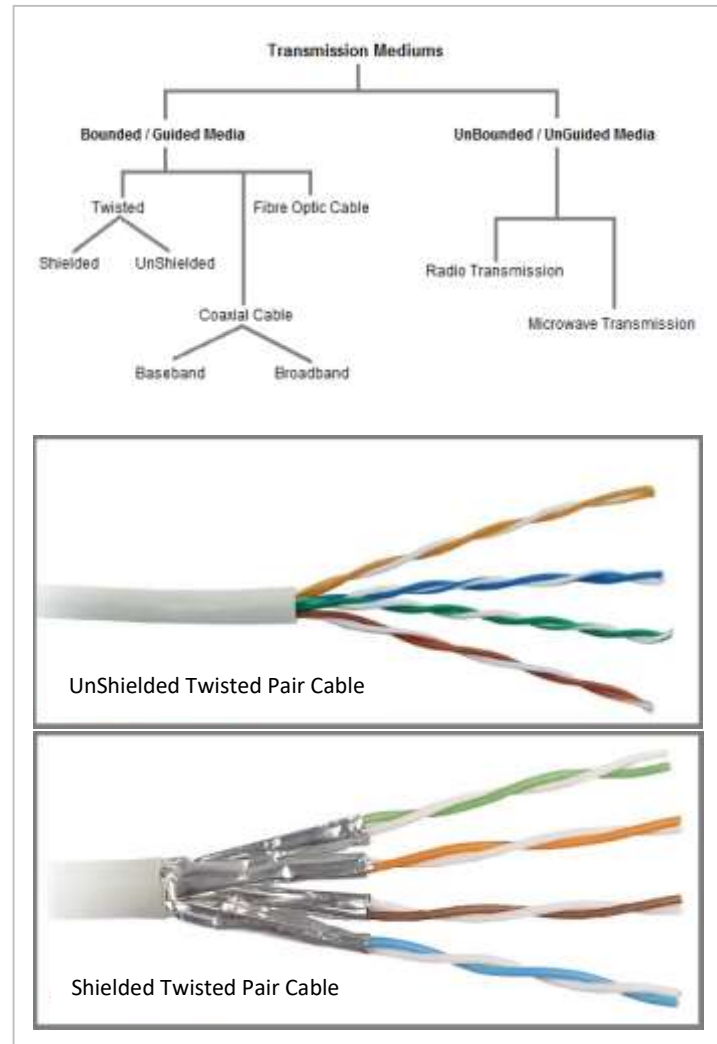
It has same attenuation as unshielded twisted pair. It is [faster](#) than unshielded and coaxial cable. It is [more expensive](#) than coaxial and unshielded twisted pair.

#### Advantages :

- Easy to install
- Performance is adequate
- Can be used for Analog or [Digital transmission](#)
- Increases the signaling rate
- Higher capacity than unshielded twisted pair
- Eliminates crosstalk

#### Disadvantages :

- Difficult to manufacture
- Heavy



**Coaxial Cable**

Coaxial is called by this name because it contains **two conductors that are parallel to each other**. Copper is used in this as center conductor which can be a solid wire or a standard one. It is surrounded by **PVC installation**, a sheath which is encased in an outer conductor of metal foil, braid or both.

**Outer metallic** wrapping is used as a shield against noise and as the second conductor which completes the circuit. The outer conductor is also encased in an insulating sheath. The outermost part is the plastic cover which protects the whole cable.

Here the most common coaxial standards.

- 50-Ohm RG-7 or RG-11 : used with thick Ethernet.
- 50-Ohm RG-58 : used with thin Ethernet
- 75-Ohm RG-59 : used with cable television
- 93-Ohm RG-62 : used with ARCNET.

There are two **types** of Coaxial cables :

**BaseBand** : This is a 50 ohm ( $\Omega$ ) coaxial cable which is used for **digital transmission**. It is mostly used for LAN's. Baseband transmits a single signal at a time with very high speed. The major drawback is that it needs amplification after every 1000 feet.

**BroadBand** : This uses **analog transmission** on standard cable television cabling. It transmits several simultaneous signal using different frequencies. It covers large area when compared with Baseband Coaxial Cable.

**Advantages :**

- Bandwidth is high
- Used in long distance telephone lines.
- Transmits digital signals at a very high rate of 10Mbps.
- Much higher noise immunity
- Data transmission without distortion.
- The can span to longer distance at higher speeds as they have better shielding when compared to twisted pair cable

**Disadvantages :**

- Single cable failure can fail the entire network.
- Difficult to install and expensive when compared with twisted pair.
- If the shield is imperfect, it can lead to grounded loop.

**Fiber Optic Cable**

These are similar to coaxial cable. It uses **electric signals** to transmit data. At the center is the glass core through which **light propagates**.

In **multimode fibers**, the core is 50microns, and In **single mode fibers**, the thickness is 8 to 10 microns.

The core in fiber optic cable is surrounded by **glass cladding** with lower index of refraction as compared to core to keep all the light in core. This is covered with a thin plastic jacket to protect the **cladding**. The fibers are grouped together in bundles protected by an outer shield.

Fiber optic cable has bandwidth more than **2 gbps (Gigabytes per Second)**

**Advantages :**

- Provides high quality transmission of signals at very high speed.
- These are not affected by electromagnetic interference, so noise and distortion is very less.
- Used for both analog and digital signals.

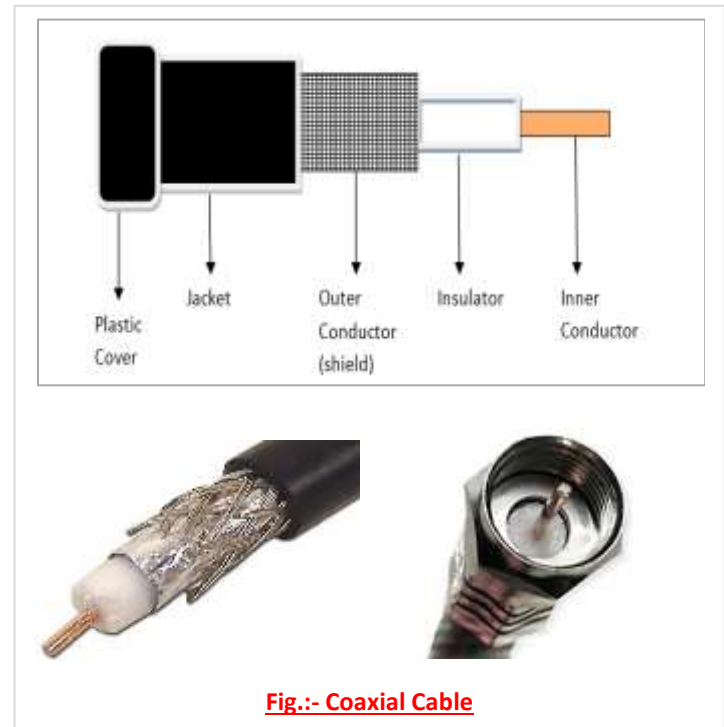
**Disadvantages :**

- It is expensive
- Difficult to install.
- Maintenance is expensive and difficult.
- Do not allow complete routing of light signals.

**UnBounded/UnGuided Transmission Media**

Unguided or **wireless** media sends the **data through air (or water)**, which is available to anyone who has a device capable of receiving them. Types of unguided/ unbounded media are discussed below :

- Radio Transmission
- MicroWave Transmission



**Fig.:- Coaxial Cable**



**Fig. Fiber Optic Cable**

**Radio Transmission**

Its frequency is between **3 kHz to 300GHz**. It is simple to install and has high attenuation. These waves are used for **multicast communications**. The prime purpose of radio is to convey information from one place to another through the intervening media (i.e., air, space, nonconducting materials) without wires.

**Applications: Radios, Televisions**

**Types of Propagation**

Radio Transmission utilizes different types of propagation :

- **Troposphere** : The **lowest portion** of earth's atmosphere extending outward approximately 30 miles from the earth's surface. **Clouds, jet planes, wind is found here.**
- **Ionosphere** : The **layer** of the atmosphere **above** troposphere, but **below** space. **Contains electrically charged particles.**

**Microwave Transmission**

It travels at **high frequency 300MHz – 300 GHz** than the radio waves. It requires the sender to be inside of the receiver. It operates in a system with a **low gigahertz range**. It is mostly used for **unicast communication**.

There are 2 types of Microwave Transmission :

1. Terrestrial Microwave
2. Satellite Microwave

**Advantages of Microwave Transmission**

- Used for long distance telephone communication
- Carries 1000's of voice channels at the same time

**Disadvantages of Microwave Transmission**

- It is Very costly

**Applications: Telecom, Radar, GPS, Satellite**

**Terrestrial Microwave**

For increasing the distance served by terrestrial microwave, **repeaters can be installed with each antenna**. The signal received by an antenna can be converted into transmittable form and relayed to next antenna as shown in below figure. It is an example of telephone systems all over the world

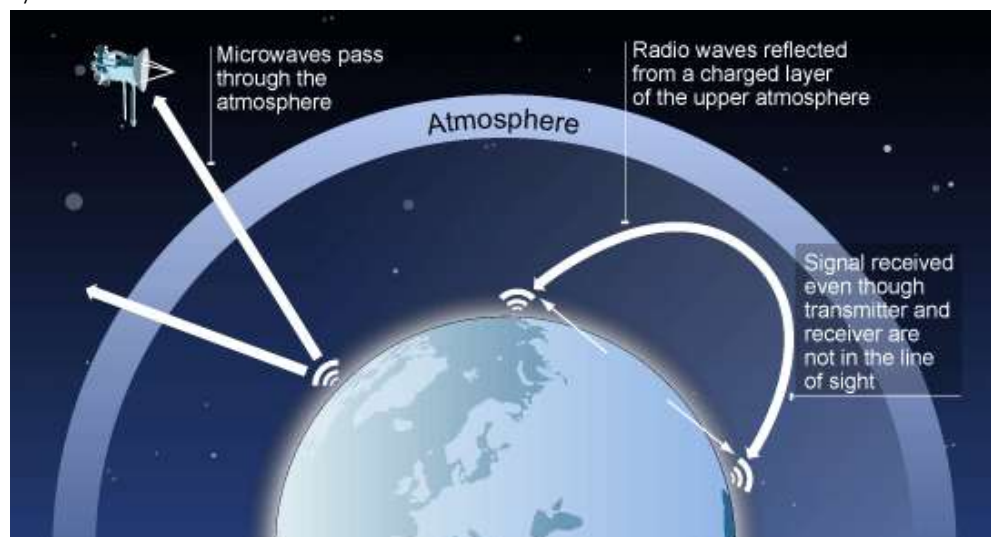
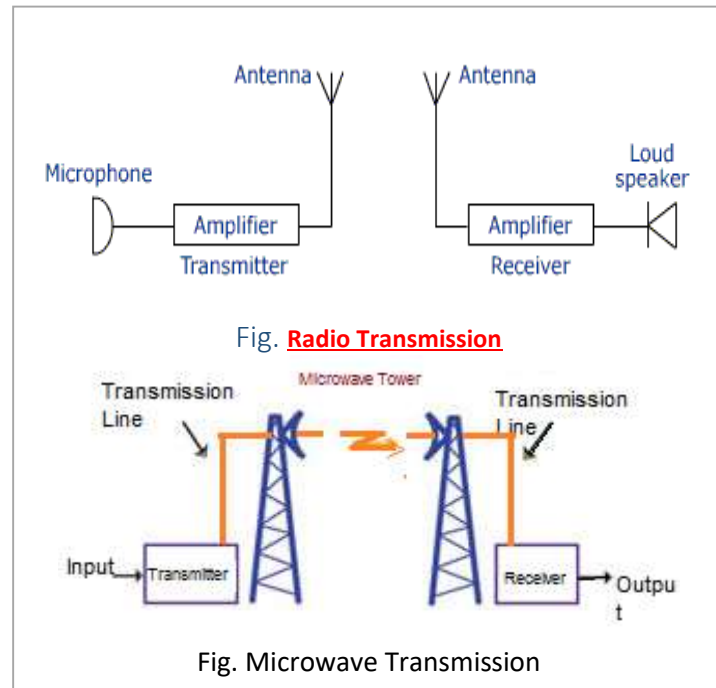
There are two types of antennas used for terrestrial microwave communication :

**1. Parabolic Dish Antenna**

In this every line parallel to the line of symmetry reflects off the curve at angles in a way that they intersect at a common point called focus. This antenna is based on geometry of parabola.

**2. Horn Antenna**

It is a like gigantic scoop. The outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by curved head.



(a) Microwaves and radio waves in the atmosphere



(b) A mobile phone mast - an example of a microwave transmitter

Satellite Microwave

This is a microwave relay station which is **placed in outer space**. The satellites are launched either by rockets or space shuttles carry them.

These are positioned **3600KM above the equator** with an orbit speed that exactly matches the rotation speed of the earth. As the satellite is **positioned in a geo-synchronous orbit**, it is stationary relative to earth and always stays over the same point on the ground. This is usually done to allow ground stations to aim antenna at a fixed point in the sky.

*If two users on the opposite side of the world want to communicate, the radio wave cannot use line of sight propagation, because it travels in a straight line and will not go around the curve of the earth. So, the solution for contacting somebody who's over the curved horizon is to put a satellite up, and the satellite will receive the signal from the radio caller, and then transmit it in another straight line, line of sight, to the person receiving it at the other end.*

Features of Satellite Microwave :

- ✓ Bandwidth capacity depends on the frequency used.
- ✓ Satellite microwave deployment for orbiting satellite is difficult.

Communications satellites usually have one of three primary types of **orbit**, while other **orbital classifications** are used to further specify orbital details.

- Geostationary satellites have a **geostationary orbit (GEO)**, which is **35,786 KM (22,236 mi)** from Earth's surface. This orbit has the special characteristic that the apparent position of the satellite in the sky when viewed by a ground observer does not change, the satellite appears to "stand still" in the sky. This is because the satellite's orbital period is the same as the rotation rate of the Earth. The advantage of this orbit is that ground antennas do not have to track the satellite across the sky, they can be fixed to point at the location in the sky the satellite appears.
- **Medium Earth orbit (MEO)** satellites are closer to Earth. **Orbital altitudes** range from **2,000 to 35,786 KM (1,243 to 22,236 mi)** above Earth.
- The region below medium orbits is referred to as **low Earth orbit (LEO)**, and is about **160 to 2,000 KM (99 to 1,243 mi)** above Earth.

Advantages of Satellite Microwave :

- Transmitting station can receive back its own transmission and check whether the satellite has transmitted information correctly.
- A single microwave relay station which is visible from any point.

Disadvantages of Satellite Microwave :

- Satellite manufacturing cost is very high
- Cost of launching satellite is very expensive
- Transmission highly depends on whether conditions, it can go down in bad weather

**What is the difference between Radio Waves and Microwaves?**

- **Microwaves** are a **sub-class of radio waves**.
- The frequency of **radio waves** can take values **from 3 KHz - to - 300 GHz**, but **microwaves** are defined to have frequencies ranging from **300 MHz – to - 300 GHz**.
- **Radio waves** in general have **long distance communication capabilities**, but **microwaves** do not have these abilities.
- **Radio waves** are mostly used in the **communication field** whereas **microwaves** are used in **industries and astronomy**.

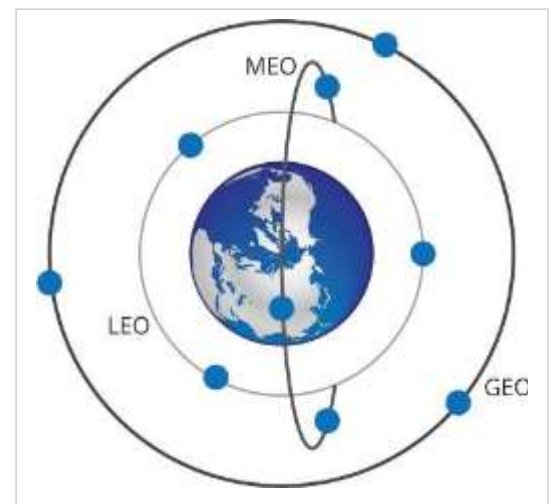
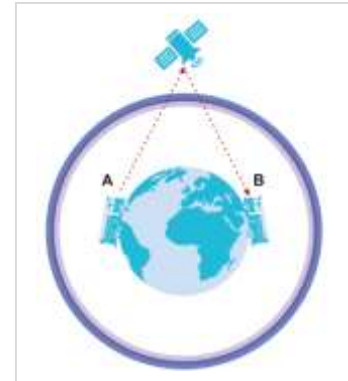
Line of sight (LoS)

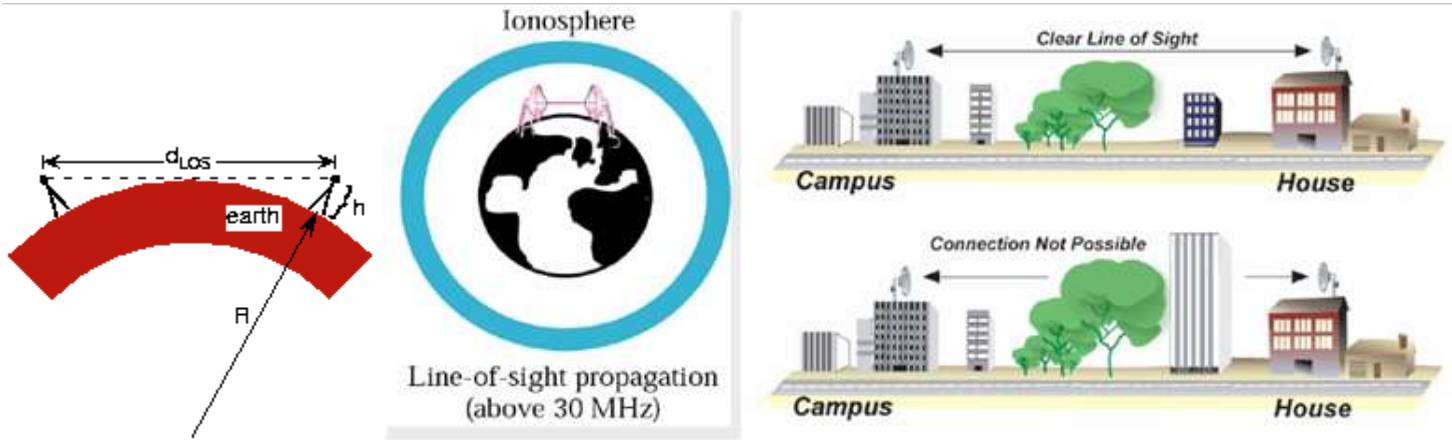
LoS is a type of **propagation** that can transmit and receive data only where transmit and receive stations are in view of each other without any sort of an obstacle between them. FM radio, microwave and satellite transmission are examples of line-of-sight communication.

Line-of-sight propagation refers to **electromagnetic radiation or acoustic wave propagation**. The rays or waves travel in a straight line which is diffracted, refracted, reflected, or absorbed by atmosphere and obstructions with material and generally cannot travel over the horizon or behind obstacles. The two-communicating antenna must be placed such a way that they see each other in earth's curvature.

**Long-distance transmission** over either kind of channel **encounters attenuation** problems. Losses in wire line channels are explored in the Circuit Models module, where repeaters can extend the distance between transmitter and receiver beyond what passive losses the wire line channel imposes. In wireless channels, not only does radiation loss occur, but also one antenna may not "see" another because of the earth's curvature.

Two antennae are shown each having the same height. Line-of-sight transmission means the transmitting and receiving antennae can "see" each other as shown. The maximum distance at which they can see each other, **d<sub>LoS</sub>**, occurs when the sighting line just grazes the earth's surface.





At the usual **radio frequencies**, propagating electromagnetic energy does not follow the earth's surface. Line-of-sight communication has the transmitter and receiver antennas in visual contact with each other. In line of sight propagation, **higher frequency signals are transmitted in straight line from antenna to antenna.**

**Comparison of Transmission Medias**

BASIS FOR COMPARISON	GUIDED MEDIA	UNGUIDED MEDIA
Basic	The signal requires a physical path for transmission.	The signal is broadcasted through air or sometimes water.
Alternative name	It is called wired communication or bounded transmission media.	It is called wireless communication or unbounded transmission media.
Direction	It provides direction to signal for travelling.	It does not provide any direction.
Types	Twisted pair cable, coaxial cable and fibre optic cable.	Radio wave, microwave and infrared.

Medium	Attenuation	Electromagnetic Interface	Security	Cost
Unshielded Twisted Pair	High	High	Low	Low
Shielded Twisted Pair	High	Moderate	Low	Moderate
Coaxial Cable	Moderate	Moderate	Low	Moderate
Fibre Optic Cable	Low	Low	High	High
Radio Waves	Low to High	High	Low	Moderate
Microwave Transmission	Can be higher or lower or moderate	High	Moderate	High
Satellite Communication	Can be higher or lower or moderate	High	Moderate	Very High

### 2.3 Multiplexing

Multiplexing is a method by which multiple analog or digital signals (information streams) are **combined into one signal over a shared medium** such as a cable. The aim is to share an expensive resource.

For example, in telecommunications, several telephone calls may be carried using one wire.

#### Importance of Multiplexing

- Shared medium
- Cost effective
- Reduce extra resources, infrastructures
- Increase capacity and bandwidth

#### Types

- Space-division multiplexing (SDM)
- Frequency-division multiplexing (FDM) – **Analog Technique**
- Time-division multiplexing(TDM) – **Digital Technique**
- Code-division multiplexing

**Space-division multiplexing:** It involves **grouping many separate wires into a common cable enclosure**. In wired communication, **space-division multiplexing**, also known as Space-division multiple access is the use of **separate point-to-point electrical conductors** for each transmitted channel. *Examples: a switched star network such as a telephone access network (although inside the telephone exchange or between the exchanges, other multiplexing techniques are typically employed).*

**Frequency-division multiplexing (FDM):** The spectrum of each input signal is shifted to a **distinct frequency range**. **Frequency-division multiplexing (FDM)** is inherently an analog technology. FDM achieves the combining of several signals into one medium by sending signals in several distinct frequency ranges over a single medium. In FDM the **signals are electrical signals**. One of the most common applications for FDM is **traditional radio and television broadcasting** from terrestrial, mobile or satellite stations, or cable television. *Only one cable reaches a customer's residential area, but the service provider can send multiple television channels or signals simultaneously over that cable to all subscribers without interference. Receivers must tune to the appropriate frequency (channel) to access the desired signal.*

A variant technology, called **wavelength-division multiplexing (WDM)** is used in optical communications.

**Time-division multiplexing (TDM):** Time-division multiplexing (TDM) is a **digital (or in rare cases, analog) technology** which uses time, instead of space or frequency, to separate the different data streams. TDM involves sequencing groups of a few bits or bytes from each individual input stream, one after the other, and in such a way that they can be associated with the appropriate receiver. If done sufficiently quickly, the receiving devices will not detect that some of the circuit time was used to serve another logical communication path.

*Example:- Consider requiring four terminals at an airport to reach a central computer. Each terminal communicated at 2400 baud, so rather than acquire four individual circuits to carry such a low-speed transmission, the airline has installed a pair of multiplexers. A pair of 9600 baud modems and one dedicated analog communications circuit from the airport ticket desk back to the airline data center are also installed.<sup>[1]</sup> Some web proxy servers (e.g. polipo) use TDM in HTTP pipelining of multiple HTTP transactions onto the same TCP/IP connection.*

**Code-division multiplexing :** Each signal carries a code and then send received accordingly this code. Code are generated by mathematically algorithm and finds own signal by this code. Code division multiplexing (CDM), Code division multiple access (CDMA) or spread spectrum is a class of techniques where several channels simultaneously **share the same frequency spectrum, and this spectral bandwidth is much higher than the bit rate or symbol rate**. One form is frequency hopping, another is direct sequence spread spectrum. In the latter case, each channel transmits its bits as a coded channel-specific sequence of pulses called chips. Number of chips per bit, or chips per symbol, is the **spreading factor**. This coded transmission typically is accomplished by transmitting a unique time-dependent series of short pulses, which are placed within chip times within the larger bit time. **All channels, each with a different code, can be transmitted on the same fiber or radio channel or other medium, and asynchronously demultiplexed.**

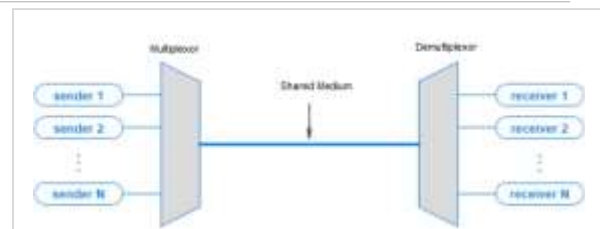


Fig. Concept of Multiplexing



Fig. FDM

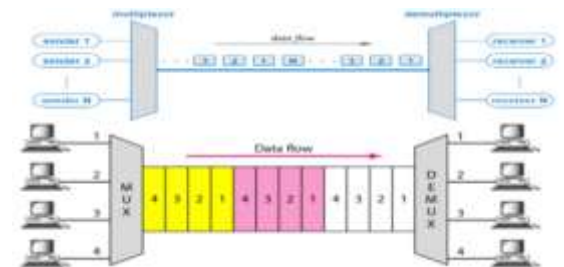
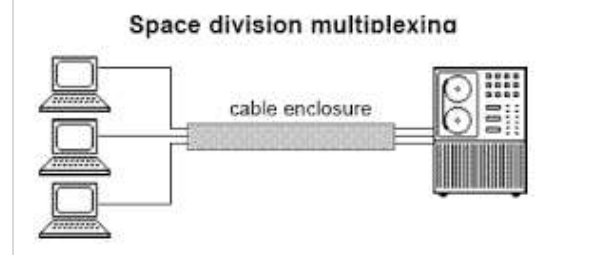
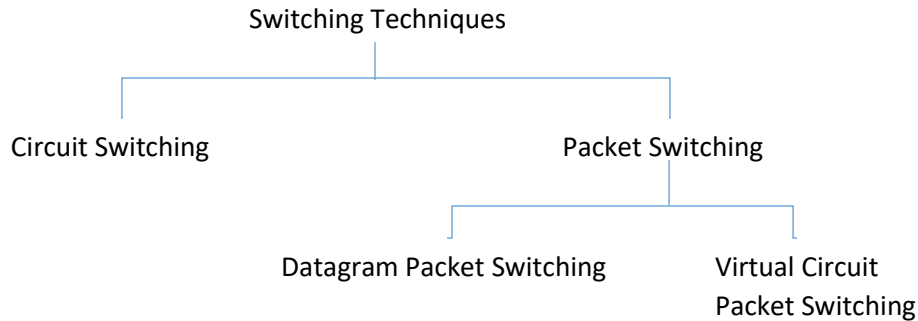


Fig. TDM



**Switching Process**

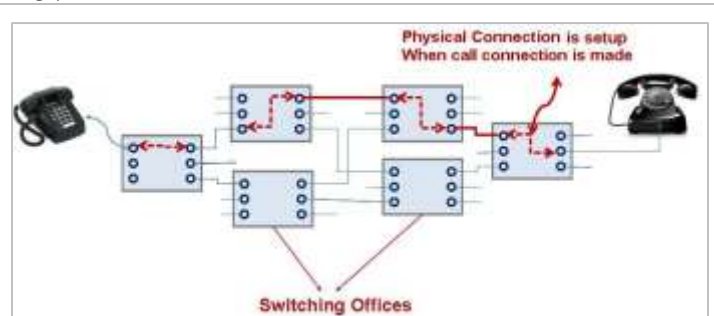
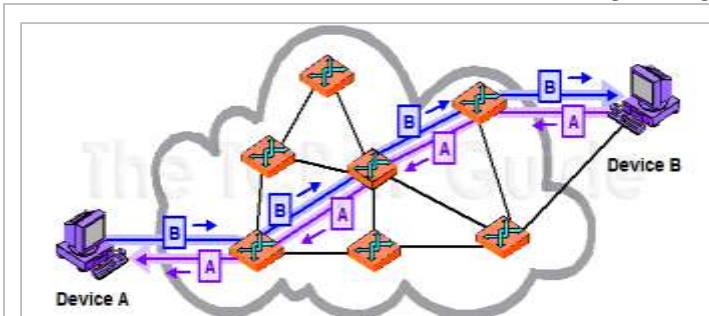
Switching is the method by which data is transferred from an input port to an output port of an intermediate exchange switch. The most popular methods of switching are Circuit Switching and Packet Switching (Virtual Circuit (VC) switching, Datagram based packet switching)



**\* Circuit Switching: Path is dedicated**

Circuit switching is primarily used in Telephone networks and not in Computer networks. In circuit switching,

- An End to end circuit (path) is first reserved using a separate signaling protocol
- Data transfer proceeds only after the circuit establishment phase
- All data of that session passes through the same circuit
- No other user can use this circuit till this session is completed
- No signaling information is sent along with the data
- Circuit is released after data transfer using the signaling protocol



**An example: - during a telephone call setup.**

You pick up your land phone and dial your friend. At that point, the telco provider creates a dedicated circuit for that session and connects you to your friend's telephone. No matter how long you keep the line open with your friend, the circuit will remain, and packets flowing between both telephones will always follow the same path.

**\* Datagram Packet Switching:**

Packet switching is the process of transmitting data in small units called as packets. In packet switching, data that is to be transmitted is split into smaller units. A small header containing signaling/addressing information about the source and destination nodes is added to each such small data unit, to form packets. Each packet is then routed from the source to the destination by intermediate data exchange devices, using the signaling information present in each packet. Example :- data networks for computer communication.

The diagram given below illustrates basic packet switching between a sender and a receiver through a packet switched data network.

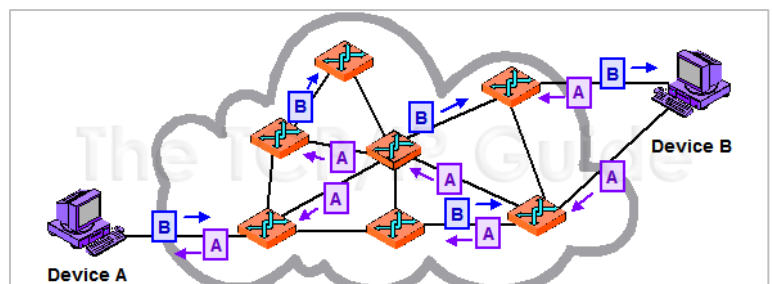
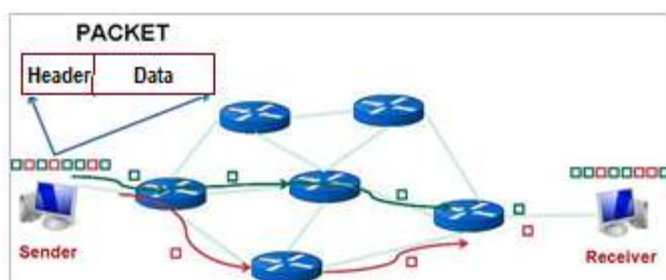


Fig. A typical packet switching process where each packet of the same session may take different routes Fig. Packet Switching: In a packet-switched network, no circuit is set up prior to sending data between devices. Blocks of data, even from the same file or communication, may take any number of paths as it journeys from one device to another.

### In packet switching,

- There is **no** end to end circuit reservation
- A packet **consists** of a header and data
- Each packet **has** signaling information in the form of source and destination addresses in the packet header.
- Signaling information is **used** by intermediate data exchange devices to route packets.
- **Exchange** devices like routers and switches use a **store and forward** approach for transmitting packets from an input port to an output port
- **Link utilization** is efficient because there is no end to end reservation of telecommunication links and multiple connections can simultaneously share the link.
- **Virtual Circuit and Datagram** are two types of packet switching, both of which are used in Computer Communication at different layers. While VC based packet, switching is used primarily at the data link layer, datagram based packet switching is used both at the data link and network layers.

**Example** of packet-switching: In the second example, you switch on your PC and connect to your favorite site that offers a number of applications you can download from, so you begin downloading one application at a time. Each packet has to find its own route to the destination, i.e., your computer. **Each packet finds its way using the information it carries**, such as the source and destination IP address. **If network congestion occurs, the routers responsible for routing packets between networks will automatically select different paths** to ensure data is transferred as required.

### \* Virtual Circuit (VC) Switching

Virtual circuit switching is a **packet switching methodology** where a path is established between the source and the destination nodes through which all the packets will be **transmitted or send or routed during a call**. As the **connection appears as a dedicated physical circuit**, but not in real, it is called a virtual circuit.

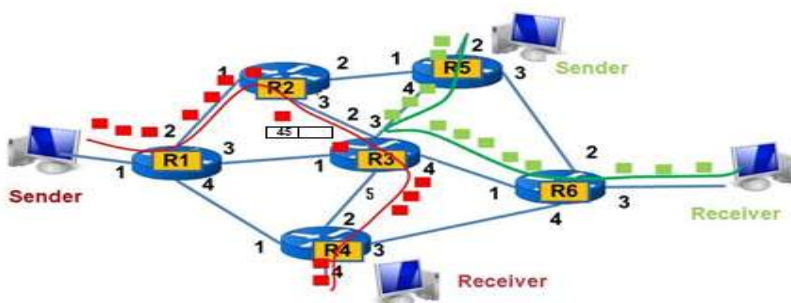
VC (Virtual Circuit) based switching is a method widely used in computer communication, especially at the **data link layer**, to switch packets inside **switched WAN** networks. Popular protocols using VC based switching include **X.25, Frame-Relay, ATM and MPLS**.

VC based switching is also called as **connection-oriented packet switching** because a logical (not physical) connection is first established between sender and receiver, before data transfer starts.

### In VC based switching,

- Whenever a new **session/flow of data transfer** needs to happen between a source and a destination node, a **connection establishment phase is executed** in the switched WAN network, using a **signaling protocol**.
- The signaling protocol (e.g. Label Distribution Protocol (LDP) in MPLS) is first used to **identify an end to end path between the source and destination nodes**. Once such a path is identified, all packets of the data session/flow **MUST** follow the same path. **But this path is not reserved for this session alone and multiple sessions can share the links in this path**.
- After identifying the path, packet switches/routers allocate a set of **VC IDs or labels** to uniquely identify this connection. **These labels do not have end-to-end significance and only have local significance at each intermediate device**.
- Data is **split** into small units and **appended** with a packet header (containing labels) to form packets.
- Packets **are switched within the WAN network through labels**. Usually the length of the label is shorter than IP and layer 2 addresses **thereby enabling faster lookup**.
- At each intermediate device/packet switch, the device **looks at the incoming label and link**. Based on this, **it identifies a suitable outgoing link and an outgoing label, by consulting a local VC table**. The label inside the packet header is modified accordingly and the packet is switched out of the outgoing link.
- At the end of the data transfer phase, the labels are **released from the VC table**.

The diagram given below illustrates a sample VC based switched WAN topology involving **six routers (R1 to R6)**, with **two different flows**. The first flow is shown in **red** colour and is through the path **R1-R2-R3-R4**. The second flow is shown in **green** colour and is through the path **R5-R3-R6**.



Incoming Link/ Port	Incoming Label (VCI)	Outgoing Link/ Port	Outgoing Label (VCI)
2 ■	45 ■	5 ■	33 ■
3 ■	22 ■	4 ■	24 ■

Fig.(a) VC based switching

Fig. (b) Sample VC table at Router R3

Note that all packets of the same flow follow the same path. A sample VC table at Router R3 is shown in fig(b).

A sample VC table at R3 containing labels for both the flows. As shown in the above VC table, the first entry is for the flow shown in red colour. It states that if a packet comes to R3 via. link 2 and with label 45, then R3 has to change the label in the packet to value 33 and send it via. its link 5. Similarly, the second entry in the table is for the flow shown in green colour. It states that if a packet comes to R3 via. link 3 and with label 22, then R3 has to change the label in the packet to value 24 and send it via. its link 4.

Since all packets of the same flow follow the same path, prioritized treatment could be given to packets belonging to specific flows, inside packet switches, for the purpose of better Quality Of Service (QOS).

	CIRCUIT SWITCHING	PACKET SWITCHING
Link Established	i. In circuit switching there are 3 phases i) Connection Establishment. ii) Data Transfer. iii) Connection Released.	In Packet switching directly data transfer takes place. Do not need to be sequence in network, reassemble by destination.
Path Address	In circuit switching, each data unit know the entire path address which is provided by the source	In Packet switching, each data unit just know the final destination address, intermediate path is decided by the routers.
Data Processing	In Circuit switching, data is processed at source system only	In Packet switching, data is processed at all intermediate node including source system.
Delay	Delay between data units in circuit switching is uniform.	Delay between data units in packet switching is not uniform.
Resource reservation	Resource reservation is the feature of circuit switching because path is fixed for data transmission.	There is no resource reservation because bandwidth is shared among users.
Reliable	Circuit switching is more reliable.	Packet switching is less reliable.
Wastage of Resources	Wastage of resources are more in Circuit Switching	More resource utilization, Less wastage of resources as compared to Circuit Switching

Attribute	Circuit Switching	Datagram Packet Switching	VC Switching
Path type	Dedicated path	No Dedicated path	No Dedicated path
Path established	Path established for entire conversion	Route established for each packet	Route established for entire conversion
Delay	Call Setup Delay	Packet Transmission Delay	Both Call Setup and Transmission Delay
Overload	Overload may block call setup	Overload increases packet delay	Overload increases call setup and packet delay
speed and code conversion	No speed and code conversion	Speed and Code conversion	Speed and Code conversion
Bandwidth	Fixed Bandwidth	Dynamic Bandwidth	Dynamic Bandwidth
Overhead bits	No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet
Resource reservation	Yes	No	Yes
Reliability	More	Less	More than Datagram
Wastage of Resources	More	Less	More than Datagram

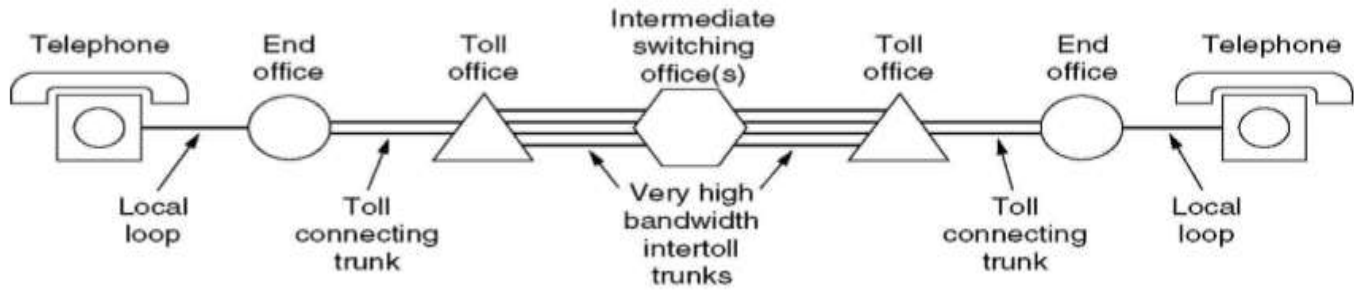
### \* Telecommunication Switching System

In the telecommunications industry, switching is used to connect two nodes that are not in direct proximity to each other. Telephone Exchange is termed as switches.

Telecommunication is the electronic transmission of sound, data, facsimiles, pictures, voice, video, and other information between systems using either analog or digital signaling techniques. Transmissions may take place over guided media (copper cables and fiber-optic cables) or unguided media (wireless radio, microwave, and infrared).

The voice telephone systems are generally referred to as the PSTN (public-switched telephone network). You will also hear the phone system referred to as POTS (plain old telephone system). The system was designed from the ground up for voice. It is a circuit-switching system that sets up voice circuits across a hierarchy of digital switching systems connected by copper and optical cables.

Telecommunication switching system consists of electronic components. In older version of these systems, human operators did the interconnection (switching) of telephone subscriber lines to establish telephone calls between subscribers.



- **Local Loop:** a local loop is the **wired connection** from a telephone company's central office in a locality to its customers' telephones at homes and businesses. This connection is usually on a pair of **copper wires called twisted pair**.
- A **local office (or end office)** was a **switching center that connected directly** to the customers' telephone devices.
- A **toll office** was involved in **switching traffic over long-distance (or toll)** circuits.

### Types of Service

- **Local Exchange Service** provides calling within your exchange. An exchange is a specified area usually encompassing a city, town or village and its environs.
- **Local Toll (intraLATA) Service (also called local long distance or regional toll service)** provides calling within a geographic area known as a **Local Access and Transport Area (LATA)**. Per-minute toll charges usually apply to these calls.

Local toll calls may be made within your area code or to a different area code across town, in the next county or, in some cases, an adjoining state. You must dial "1" before making a local toll call, even if the area code is the same as yours. These calls can be carried by your local exchange telephone company or your long distance company.

Some local telephone companies offer an optional bundle of local exchange and local toll service for a single monthly fee.

- **Expanded Local Exchange Service** extends a local exchange calling area and eliminates local toll costs. However, you may see expanded local exchange service as a surcharge on your telephone bill.

The aforementioned services usually cover calls within a state, and are usually regulated by your state public service commission. If you have a problem regarding these services, you can find contact information for your state's commission at [www.naruc.org/about-naruc/regulatory-commissions/](http://www.naruc.org/about-naruc/regulatory-commissions/). You may also contact your state consumer protection agency, Better Business Bureau, or state attorney general's office to learn about protections and remedies available to you as a consumer. You can also find contact information for these organizations in the blue pages or government section of your local telephone directory.

- **Long Distance Toll (interLATA) Service** includes all calls outside the local exchange and local toll service areas, calls that originate in one LATA and terminate in another, and international calls. Long-distance toll calls can be between two LATAs in the same state, such as a call from San Diego to San Francisco, or between LATAs in different states. Long-distance toll service includes international service (except in Hawaii where international service is separate from long distance service). When purchasing long-distance toll service, remember to ask whether international calls are included in monthly long-distance calling plans.

### 4. ISDN (Integrated Services Digital Network)

ISDN is a set of communication standards for **simultaneous digital transmission** of voice, video, data, and other network services *over the traditional circuits of the public switched telephone network*

ISDN is a **network** that provides **end-to-end digital connectivity** to support a **wide range of services including voice and data services**. ISDN allows multiple **digital channels** to operate simultaneously through the **same regular phone wiring** used for analog lines, but ISDN **transmits a digital signal rather than analog**. **Latency is much lower** on an ISDN line than on an analog line.

ISDN is a circuit-switched telephone network system, which also provides access to packet switched networks, designed to allow digital transmission of voice and data over ordinary telephone copper wires, resulting in potentially better voice quality than an analog phone can provide. It offers circuit-switched connections (for either voice or data), and packet-switched connections (for data),

#### ISDN Architecture

The traditional PSTN used an analog connection for communicating between the customer premises and the local exchange, also known as the local loop. The analog circuits cause the limitations on the bandwidth in the local loop. So, ISDN was developed with the intention of creating a totally **digital network**. ISDN technology allows **digital signals to be sent** over existing telephone line. It can transfer many types of network traffics like **voice, data, video, graphic**, etc.

ISDN system architecture is shown in **Figure 27.2**. If the subscriber has an ISDN telephone, an ISDN terminal, and an ISDN PBX, they are connected to the Network Termination-1 (**NT1**), and NT1 is in turn connected to the ISDN switch. Non-ISDN equipment such as a PSTN telephone, or **a normal computer can be connected to the ISDN interfaces through a Terminal Adapter (TA)**.

To ensure that the ISDN-compliant equipment as well as the legacy equipment can be connected through standard interfaces, various interfaces are defined as shown in Figure 27.2. R, S, T, and U interfaces are called the reference points between various equipment. These reference points are conceptual points to describe the interfaces between various equipment. The advantages of this approach are:

- Interface standards can be developed at each reference point.
- Improvements/modifications on one piece of equipment do not have an effect on the other equipment.
- The subscriber is free to obtain equipment from different suppliers.

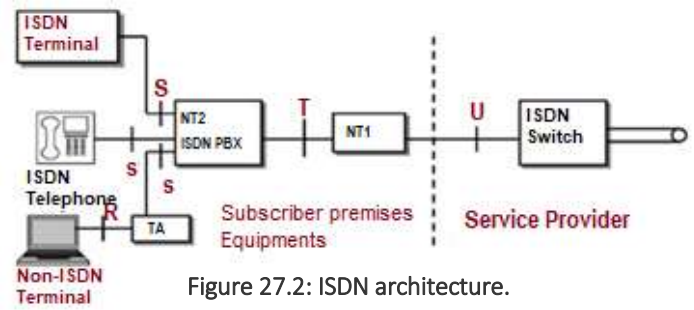
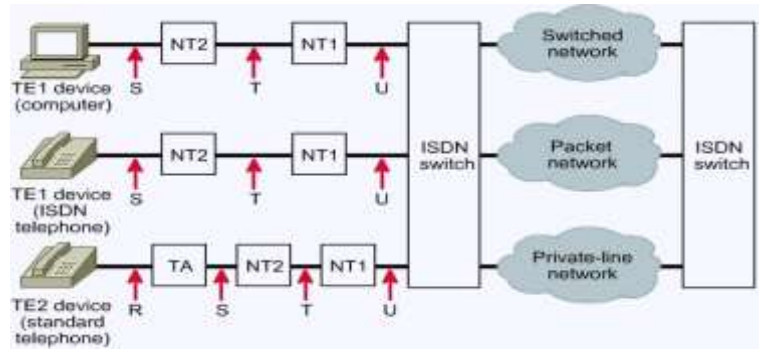


Figure 27.2: ISDN architecture.

**Terminal Equipment(TE):** Terminal equipment is of two types—TE1 and TE2. TE1 devices support standard ISDN interfaces such as a digital telephone, integrated voice/data terminals, and digital fax machines. TE2 devices are the present non-ISDN equipment such as PC with RS232 interface computer with an X.25 interface. A terminal adapter (TA) is required to interface the TE2 devices with the ISDN network.

Three types of Network Terminations (NT) are defined in the ISDN architecture: -

- NT1 forms the boundary to the network and is controlled by an ISDN service provider. NT1 includes functions associated with physical and electrical terminations, performs line maintenance functions such as loop-back testing and performance monitoring of ISDN at user premises. This corresponds to OSI layer 1.
- NT2 is an intelligent device that can be connected to the ISDN switch, perform switching functions and is owned by the subscriber; e.g. Digital PBX and a Local Area Network (LAN). It includes functionality up to layer 3 of the OSI model.
- NT12 combines the functions of NT1 and NT2 and is owned by the service provider.



**ISDN Components**

- TE1 - Device compatible with ISDN network, connects to NT2
- TE2 - Device not compatible with ISDN requires TA
- TA - (terminal Adapter) Converts signals so, non-ISDN devices can use ISDN
- NT1 - Connects 4-wire ISDN to 2-wire local loop
- NT2 - Directs traffic to and from different subscriber devices and NT1

**ISDN Reference Points**

- Reference point T (terminal):** This reference point corresponds to a minimal ISDN network termination at the subscriber premises. It separates the ISDN service provider's equipment from the user's equipment.
- Reference point S (system):** This reference point corresponds to the interface of individual ISDN terminals and separates the user terminal equipment from network-related communication functions.
- Reference point R (rate):** This reference point provides a non-ISDN interface between user equipment that is not ISDN compatible and adapter equipment (such as an RS232 interface to connect an existing PC to ISDN through a terminal adapter).
- Reference point U:** This reference point provides the interface between the ISDN switch and the network termination-1(NT1).



Figure 27.2: ISDN Phone.

**ISDN SERVICES**

Each B-channel carries data, voice, and other services. The D-channel carries control and signaling information.

- BRI:** The ISDN Basic Rate Interface (BRI) service offers two B channels and one D channel (2B+D). Each BRI B channel operates at 64 kbps and is meant to carry user data. The BRI D channel operates at 16 kbps and is meant to carry control and signaling information, although it can support user data transmission under certain circumstances. The capacity of the BRI = (Two voice or Two high-speed data or One voice and One high-speed data) + 16kbps packet data.

BRI can carry a wide and flexible range of communications. A single BRI, for example, can carry two simultaneous voice or data conversations (to the same or different locations). intended for small enterprises and residential service.

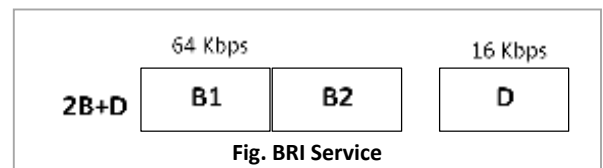


Fig. BRI Service

- **PRI: Primary Rate Interface** for large organizations. Larger connections are possible using PRI pairing. The bandwidth is divided into 24 64KB channels. The ISDN PRI services used 23 B channel accesses and used the 24<sup>th</sup> one 64 Kbps D channel for signaling purpose.

The interfaces at the reference points are well defined in the standards, so it is possible to integrate equipment supplied by different vendors.

