CHAPTER - 5

PHYSICAL LAYERS AND ITS DESIGN ISSUES

TRANSMISSION MEDIUMS IN COMPUTER NETWORKS:

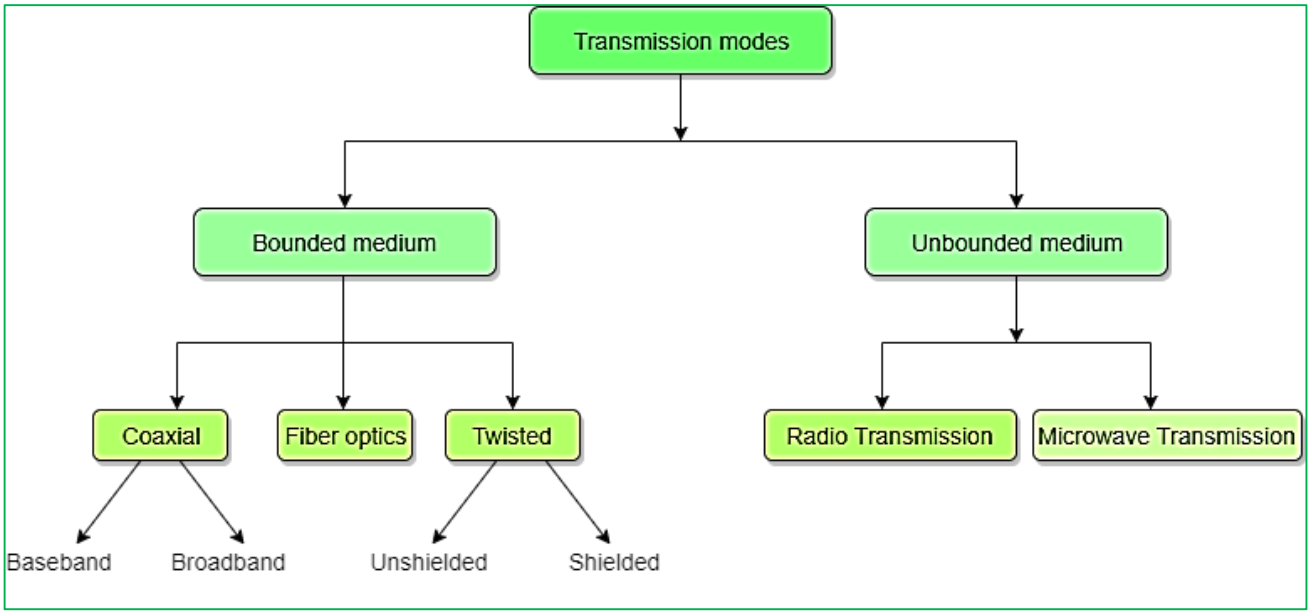
Data is represented by computers and other telecommunication devices using signals. Signals are transmitted in the form of electromagnetic energy from one device to another. Electromagnetic signals travel through vacuum, air or other transmission mediums to move from one point to another (from sender to receiver).

Electromagnetic energy (includes electrical and magnetic fields) consists of power, voice, visible light, radio waves, ultraviolet light, gamma rays etc.

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.

Factors to be considered while selecting a Transmission Medium

- Transmission Rate
- Cost and Ease of Installation
- Resistance to Environmental Conditions
- Distances



BOUNDED TRANSMISSION MEDIA:

Bound Transmission Media in Communication Networks are the cables that are tangible or have physical existence and are limited by the physical geography. Also known as Conducted systems, wired media generally employ a metallic or glass conductor which serves to conduct, some form

of electromagnetic energy. Popular bound transmission media in use are twisted pair cable, co-axial cable and fiber optical cable.

1. **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 @ 1 kHz.
- Typical delay is 50 μs/km.
- Repeater spacing is 2km.

Twisted Pair is of two types:

1. **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 color plastic insulator. Identification is the reason behind colored 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.

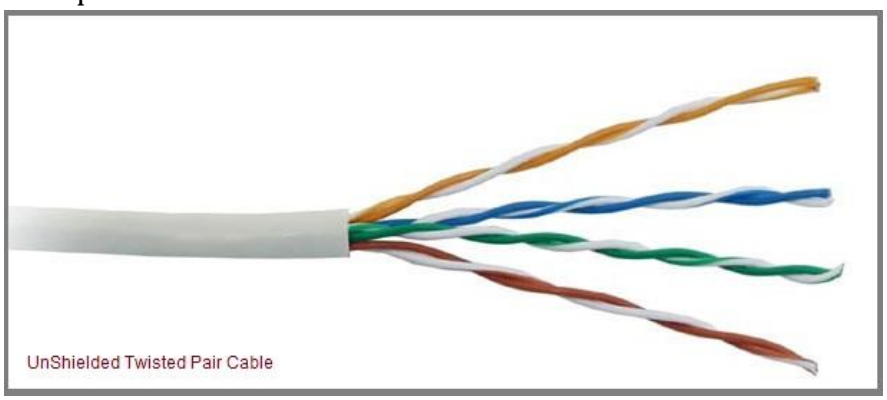
Advantages:

- 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.


UnShielded Twisted Pair Cable

2. 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 (explained in KEY TERMS Chapter). It has same attenuation as unshielded twisted pair. It is faster the 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

2. 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:

1. **BaseBand:**

This is a 50 ohm (Ω) 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.

2. BroadBand:

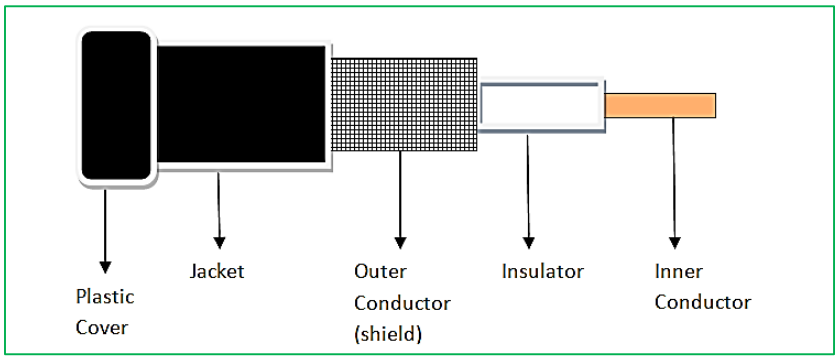
This uses analog transmission on standard cable television cabling. It transmits several simultaneous signal using different frequencies. It covers large area when compared with Baseband Coaxial Cable.

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.



3. 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.

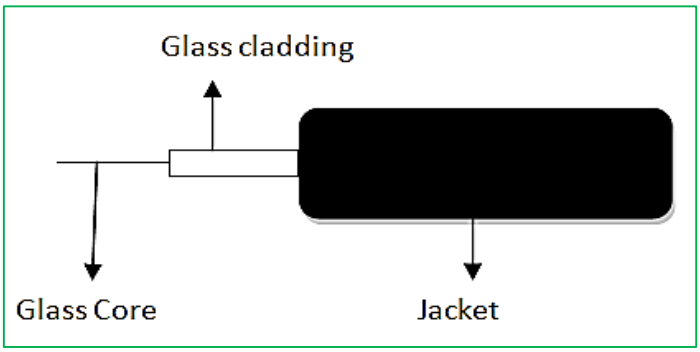
The core in fiber optic cable is surrounded by glass cladding with lower index of refraction as compared to core to keep all the light in core. This is covered with a thin plastic jacket to protect the cladding. The fibers are grouped together in bundles protected by an outer shield. Fiber optic cable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

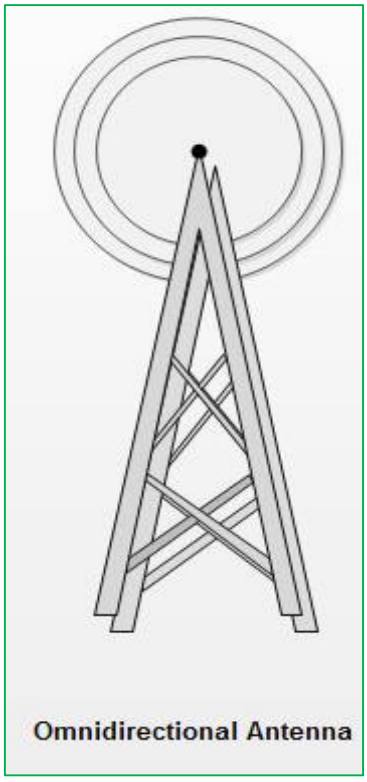
- It is expensive
- Difficult to install.
- Maintenance is expensive and difficult.
- Do not allow complete routing of light signals.



Unbound Transmission Media:

Unbound transmission media extend beyond the limiting confines of cabling. They provide an excellent Communication Networks alternative for WANS. The lack of physical restrictions provides larger bandwidth as well as wide area capabilities. Unbound media typically operate at **very high frequencies**. The three types of unbound transmission media are: **Radio wave, Micro wave, Infrared.**

1. Radiowaves Transmission:



Although Radio waves are prevalent and well understood, we are just beginning to realize their enormous potential as a networking medium. Radio waves can operate on a **single or multiple frequency bands**. Its frequency is between 10 kHz to 1GHz. It is simple to install and has high attenuation. These waves are used for multicast communications.

Radiowaves are omni directional i.e. they travel in all the directions from the source. Because of this property, transmitter and receiver need not to be aligned. Radiowaves can penetrate buildings easily, so they are widely used for communication both indoors outdoors. At high frequencies, radiowaves tends to travel in straight line and bounce off the obstacles. They are also absorbed by rain. Radiowaves widely used for AM and FM radio, television, cordless telephone, cellular phones, paging and wireless LAN.

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.

2. Microwave Transmission:

Microwaves have been used in data communications for a long time. They have a higher frequency than radio waves and therefore can handle larger amounts of data.

Microwave transmission is line of sight transmission. The transmit station must be in visible contact with the receive station. This sets a limit on the distance between stations depending on the local geography. Typically the line of sight due to the Earth's curvature is only 50 km to the horizon! Repeater stations must be placed so the data signal can hop, skip and jump across the country. Microwave circuits considered a broad band communication channel.

Microwaves operate at high operating frequencies of 3 to 10 GHz. This allows them to carry large quantities of data due to their large bandwidth.

Advantages:

- Used for long distance telephone communication
- Carries 1000's of voice channels at the same time
- They require no right of way acquisition between towers.
- They can carry high quantities of information due to their high operating frequencies.
- Low cost land purchase: each tower occupies only a small area.
- High frequency/short wavelength signals require small antennae.

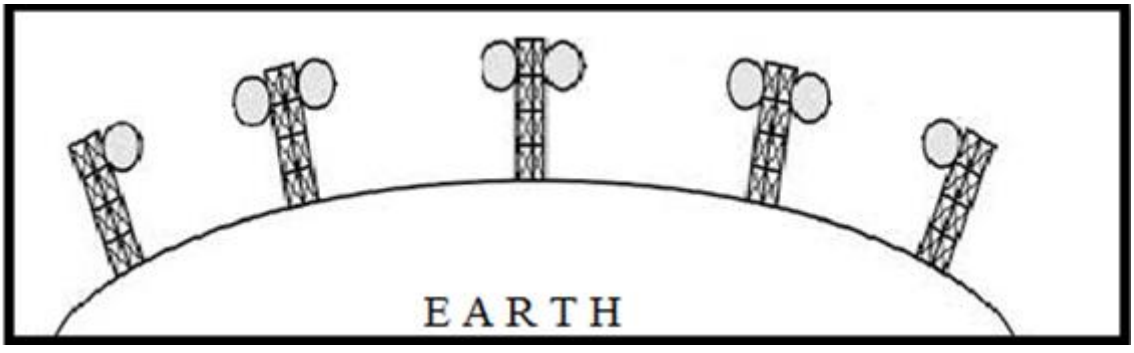
Disadvantages:

- It is Very costly
- Attenuation by solid objects: birds, rain, snow and fog.
- Reflected from flat surfaces like water and metal.
- Diffracted (split) around solid objects.
- Refracted by atmosphere, thus causing beam to be projected away from receiver.

There are 2 types of Microwave Transmission:

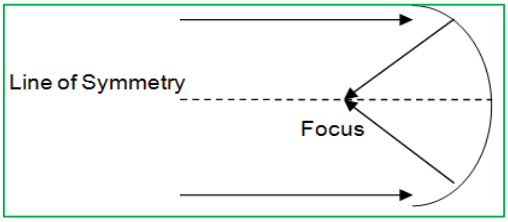
a. Terrestrial Microwave:

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.



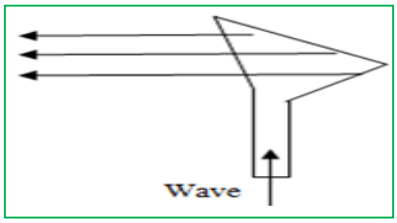
There are two types of antennas used for terrestrial microwave communication:

a. 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.

b. Horn Antenna:

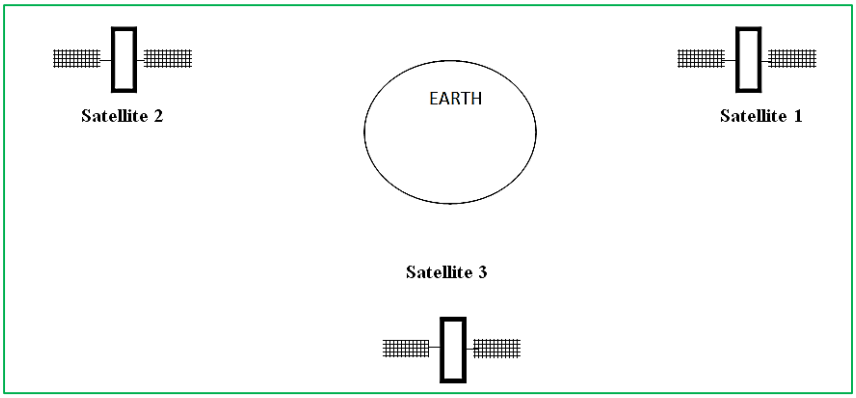


It is a like gigantic scoop. The outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by curved head.

B. 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 36000KM 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 stationery 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.



Features:

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

Advantages:

- 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:

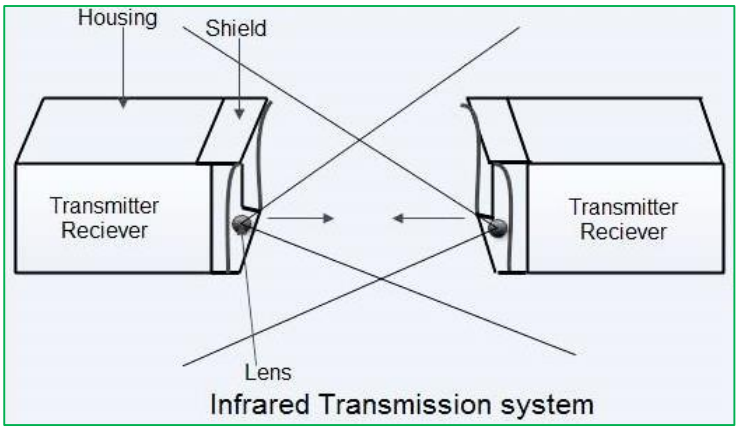
- Satellite manufacturing cost is very high
- Cost of launching satellite is very expensive

- Transmission highly depends on whether conditions, it can go down in bad weather

3. Infra-Red:

Infrared offers a great unbound photonic solution. Like fiber-optic cabling, **infrared communications use light**, so they are not bound by the limitations of electricity.

Infrared light transmissions have existed for many years and their use having been limited to TV remote controls and wireless slide projector remote controls. However, they now are assuming a position of some, if still limited, importance. Infrared systems use the infrared light spectrum to send a focused light beam to a receiver, much, as would a microwave system, although no reflective dish is used. Rather, pair of lenses is used, with a focused lens employed in the transmitting device and a collective lens in the receiving device as shown in Figure. Infrared is an airwave, rather than a conducted transmission system. Although generally used in short-haul transmission, they do offer substantial bandwidth, but with risks of interference.



Infrared Transmission system

Advantages include rapid deployment, especially as there are no licensing requirements as typically is the cue with microwave. Additionally, infrared offers fairly substantial bandwidth at relatively low Cost. However, infrared systems require line-or-sight and suffer from environmental interference, as do microwave system. Error performance is also satisfactory. Additionally, infrared is distance limited. However, infrared often is an attractive alternative to leased lines or private cabled systems for building.

The forward cell can reuse frequencies used in the previous cell. This helps in sharing the same frequency band. Many calls can be handled by one frequency especially where digital phones are used.

Introduction of ISDN and PSTN:

1. ISDN (Integrated Services Digital Network):

Stands for "Integrated Services Digital Network." ISDN is a telecommunications technology that enables the transmission of digital data over standard phone lines. It can be used for voice calls as well as data transfers.

The first ISDN standard was defined in 1988 by the CCITT organization, which is now the ITU-T (International Telegraph and Telephone Consultative Committee). However, it wasn't until the

1990s that the service became widely used. Since the introduction of ISDN, several variants have been standardized, including the following:

- **Basic Rate Interface (BRI):** supports two 64 kbps bearer channels (or B channels) for a data transfer rate of 128 kbps.
- **Primary Rate Interface (PRI):** supports 30 B channels and two additional channels in a single E1 connection, providing a data transfer rate of 2,048 kbps.
- **Always on Dynamic ISDN (AODI):** consistent ISDN connection that uses the X.25 protocol and supports speeds up to 2 Mbps.

ISDN was a common high-end Internet service in the 1990s and early 2000s and was offered by many ISPs as faster alternative to dial-up Internet access. Many businesses and organizations used ISDN service for both Internet access and network connections between locations. In the mid-2000s, DSL and cable serviced began to replace ISDN connections because of their faster speed and lower cost. Today, ISDN is still used in some network connections, but it is rarely used for Internet access.

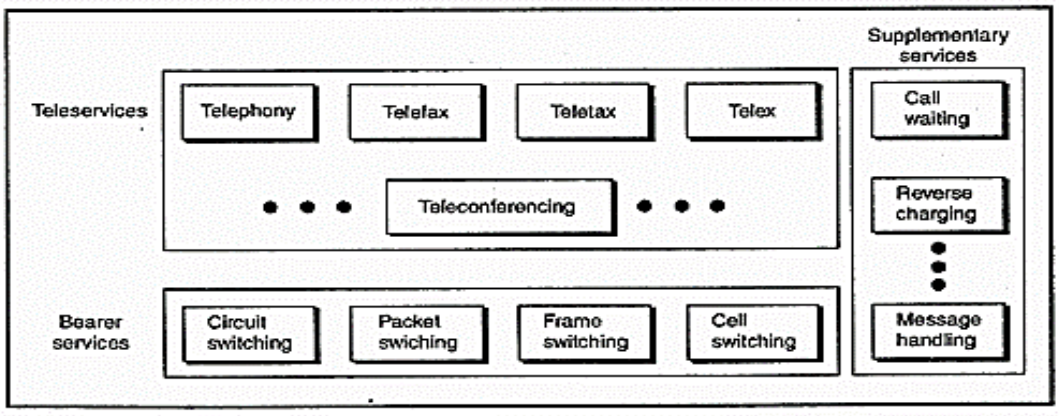


Fig: ISDN Services

2. PSTN (Public Switched Telephone Network):

PSTN is the abbreviated term used for landline telephone system. Another term commonly used for it is POTS, which stands for Plain Old Telephone System, a non-geek way of naming the landline that is now old and quite plain and flat when compared to new competitors on the market. This network was created mainly for analog voice communication over cables that covered countries and continents. It is an improvement over the basic telephone system discovered by Alexander Graham Bell. It brought to the system better management and hauled it to the level of being an industry, and a very lucrative and revolutionary one at that.

The PSTN and Other Communication Systems:

PSTN is now very often expressed and referred to, especially in the media, in contrast with other emerging communication technologies. Mobile telephony emerged as the first alternative to PSTN when it comes to voice communication. Cellular communication (2G) allowed people to communicate on the go while the PSTN allowed people to make and receive calls only within the reach of the wires, that is at home or in the office.

Nevertheless, the PSTN has still been able to keep its place in modern telephony as it remained the so far unchallenged leader in call quality, with a Mean Opinion Score (MOS) of 4 to 5, 5 being

the ceiling value. It has also kept its place at home and in businesses for several reasons. Until the recent past, many people (including people who are not digital natives or digital immigrants) had still not adopted mobile telephony and could therefore only be reached through their plain old landline phone number.

Also, the PSTN is the main carrier for Internet connectivity is most parts of the world. Subsequently, being able to use alternative means of communication like VoIP and other OTT technologies often required the PSTN line for there to be Internet connectivity, through an ADSL line for instance. Speaking of VoIP, which is the very topic of this site, it has been a more serious competitor to PSTN operators than any other technology by allowing people to communicate locally and worldwide for free or cheaper. Think of Skype, WhatsApp and all the other VoIP services and apps, which are even banned in some countries as a means to protect the local and often government-owned telcos.

How the PSTN Works:

In the early days of telephony, establishing a voice communication line two parties required stretching wires between them. This meant higher cost for longer distances. The PSTN came to level the cost despite the distance. As the name suggests, it consists of switches at centralized points on the networks. These switches act as nodes for communication between any point and any other on the network. This way, one person can talk to another on the other side of the country-wide network, by being on the end of a circuit that consists of a number of switches between them.

This circuit is dedicated to the two corresponding parties throughout the length of the call, hence the rate you pay for each minute of call. This type of switching is called circuit-switching. IP networks like the Internet brought around packet switching, which used the same underlying network but without reserving any portion of the line. The voice (and data) messages were split into small parcels called packets which were disseminated through the switches independent of each other and reassembled on the other end. This made voice communication free on the Internet through VoIP.

Difference between ISDN and PSTN:

ISDN	PSTN
☑ "ISDN" means "Integrated Services Digital Network."	☑ "PSTN" means "Public Switched Telephone Network,"
☑ ISDN lines are digital.	☑ PSTN lines are analogue.
☑ ISDL are used for bigger companies.	☑ PSTN lines are used for small companies.
☑ The ISDN provides 128 kbit/s, which is really good for the Internet.	☑ PSTN has a disadvantage that it does not make the most possible use of the broadband.
☑ ISDN allow two simultaneous connections.	☑ PSTN does not allow two simultaneous connections.
☑ ISDN can make faster calls than PSTN.	☑ PSTN are slower than ISDN.
☑ ISDN are designed for transmission of Data as well as voice.	☑ PSTN are designed for the transmission of voice only.
☑ ISDN provides better voice quality than PSTN.	☑ PSTN is not as better as ISDN.