COMMUNICATION TECHNOLOGIES

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About the Tutorial

Exchange of information through the use of speech, signs or symbols is called communication. When early humans started speaking, some 5,00,000 years ago, that was the first mode of communication. Communication over a long distance when people who are communicating are not in direct line of each other's site is called telecommunication.

Invention of telephone and establishment of commercial telephony in 1878 marked a turnaround in communication systems and real telecommunication was born. Telephones slowly gave way to television, videophone, satellite and finally computer networks. Computer networks have revolutionized modern day communication and communication technologies.

In this tutorial, we will discuss in detail how networks have evolved since the first network known as ARPANET. We will also discuss the hardware and software components of networking and the concept of global communication via Internet.

Audience

This tutorial is designed for anyone who wants to understand the basic concepts of networking and how a network functions.

Prerequisites

There are no prerequisites for this course except an appetite for learning how networks in general and Internet in particular operate.

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1. Communication Technologies – Introduction

Exchange of information through the use of speech, signs or symbols is called communication. When early humans started speaking, some 5,00,000 years ago, that was the first mode of communication. Before we dive into modern technologies that drive communication in contemporary world, we need to know how humans developed better communication techniques to share knowledge with each other.

History of Communication

Communicating with people over a distance is known as **telecommunication**. The first forms of telecommunication were **smoke signals**, **drums** or fire **torches**. The major disadvantage with these communication systems was that only a set of pre-determined messages could be transmitted. This was overcome in the 18th and 19th century through development of **telegraphy** and **Morse code**.

Invention of telephone and establishment of commercial telephony in 1878 marked a turnaround in communication systems and real telecommunication was born. International Telecommunication Union (ITU) defines telecommunication as transmission, emission and reception of any signs, signals or messages by electromagnetic systems. Now we had the

communication technology to connect with people physically located thousands of kilometers away.

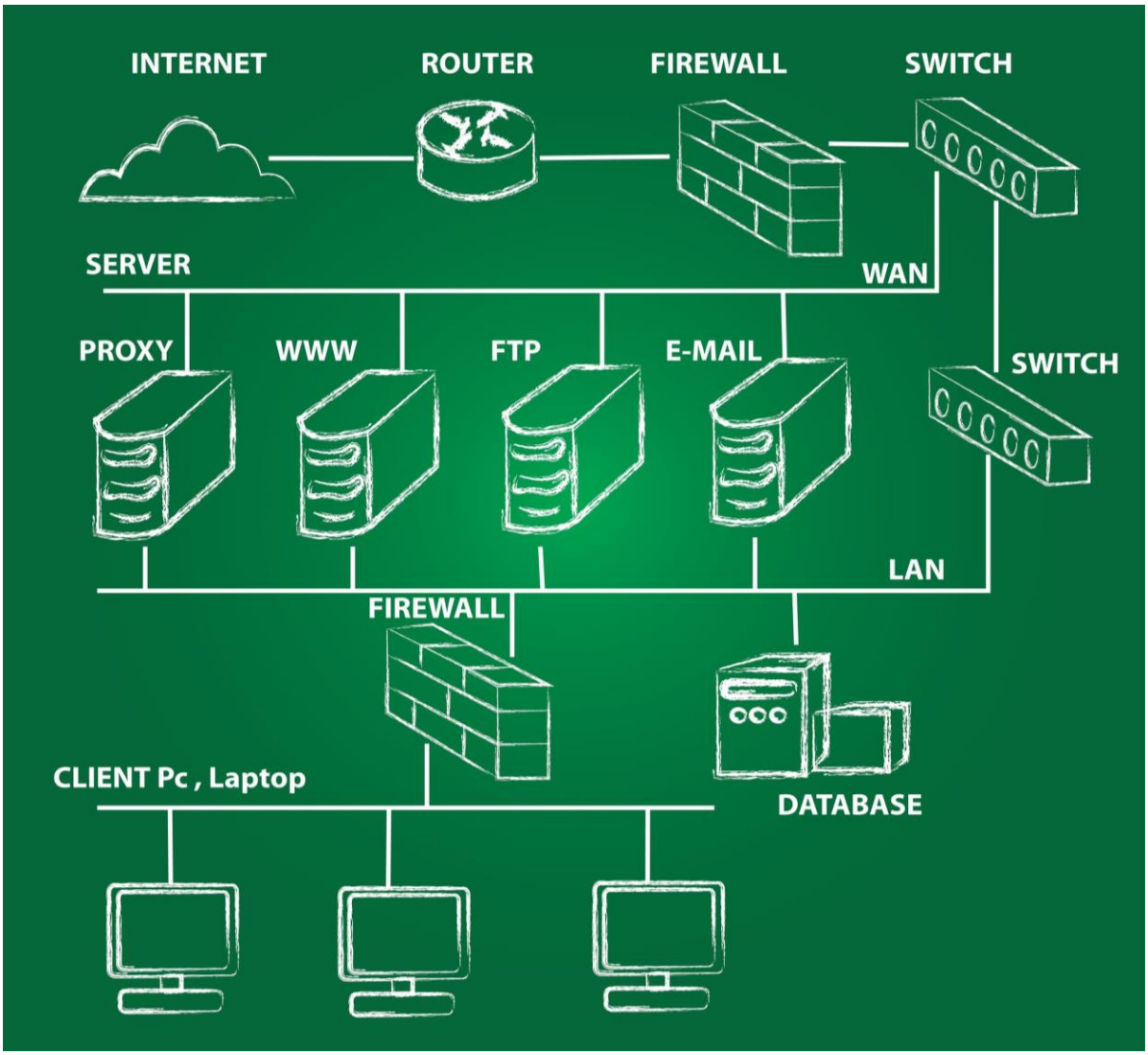
Telephones slowly gave way to television, videophone, satellite and finally computer networks. Computer networks have revolutionized modern day communication and communication technologies. That will be the subject of our in-depth study in subsequent chapters.

2. Communication Technologies – History of Networking

ARPANET – the First Network

ARPANET – **Advanced Research Projects Agency Network** – the granddad of Internet was a network established by the US Department of Defense (DOD). The work for establishing the network started in the early 1960s and DOD sponsored major research work, which resulted in development on initial protocols, languages and frameworks for network communication.

It had four nodes at University of California at Los Angeles (UCLA), Stanford Research Institute (SRI), University of California at Santa Barbara (UCSB) and University of Utah. On October 29, 1969, the first message was exchanged between UCLA and SRI. E-mail was created by Roy Tomlinson in 1972 at Bolt Beranek and Newman, Inc. (BBN) after UCLA was connected to BBN.



Internet

ARPANET expanded to connect DOD with those universities of the US that were carrying out defense-related research. It covered most of the major universities across the country. The concept of networking got a boost when University College of London (UK) and Royal Radar Network (Norway) connected to the ARPANET and a network of networks was formed.

The term Internet was coined by Vinton Cerf, Yogen Dalal and Carl Sunshine of Stanford University to describe this network of networks. Together they also developed protocols to facilitate information exchange over the Internet. Transmission Control Protocol (TCP) still forms the backbone of networking.

Telenet

Telenet was the first commercial adaptation of ARPANET introduced in 1974. With this the concept of Internet Service Provider (ISP) was also introduced. The main function of an ISP is to provide uninterrupted Internet connection to its customers at affordable rates.

World Wide Web

With commercialization of internet, more and more networks were developed in different part of the world. Each network used different protocols for communicating over the network. This prevented different networks from connecting together seamlessly. In the 1980s, Tim Berners-Lee led a group of Computer scientists at CERN, Switzerland, to create a seamless network of varied networks, called the World Wide Web (WWW).

World Wide Web is a complex web of websites and web pages connected together through hypertexts. Hypertext is a word or group of words linking to another web page of the same or different website. When the hypertext is clicked, another web page opens.

The evolution from ARPANET to WWW was possible due to many new achievements by researchers and computer scientists all over the world. Here are some of those developments:

Year	Milestone
1957	Advanced Research Project Agency formed by US

1969	ARPANET became functional
1970	ARPANET connected to BBN
1972	Roy Tomlinson develops network messaging or E-mail. Symbol @ comes to mean "at"
1973	APRANET connected to Royal Radar Network of Norway
1974	Term Internet coined First commercial use of ARPANET, Telenet, is approved
1982	TCP/IP introduced as standard protocol on ARPANET
1983	Domain Name System introduced
1986	National Science Foundation brings connectivity to more people with its NSFNET program
1990	ARPANET decommissioned First web browser Nexus developed HTML developed
2002-2004	Web 2.0 is born

3. Communication Technologies – Terminologies

Before we dive into details of networking, let us discuss some common terms associated with data communication.

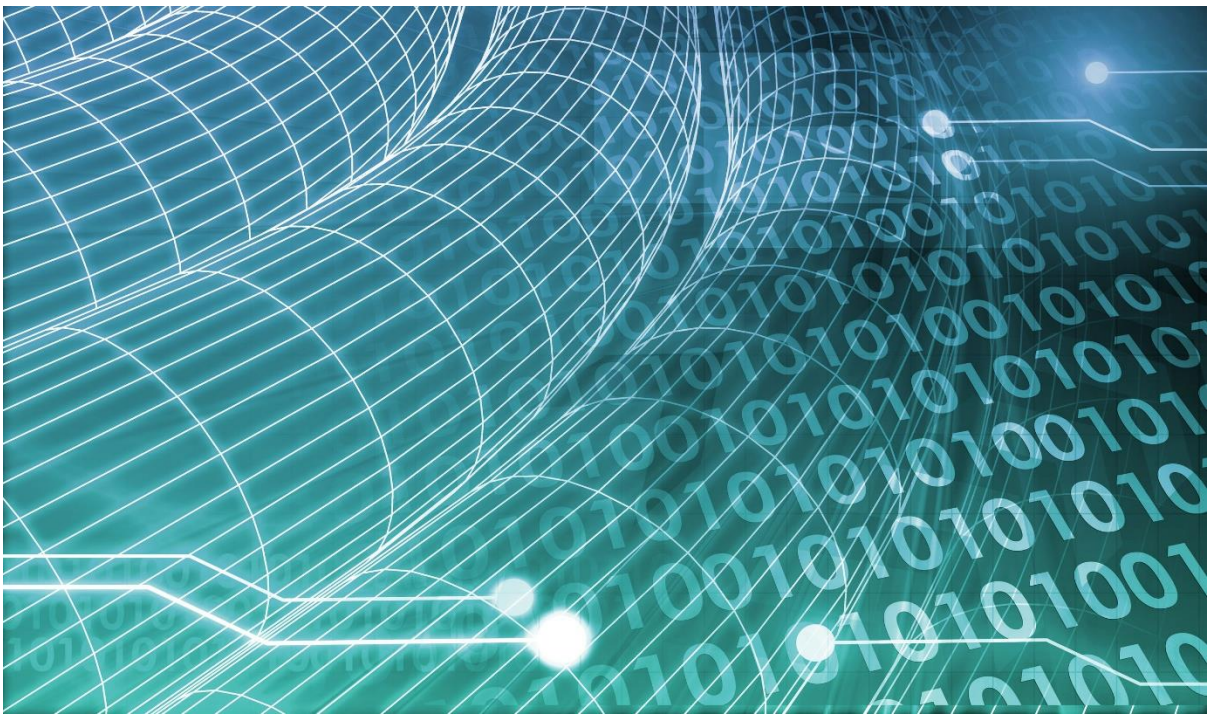
Channel

Physical medium like cables over which information is exchanged is called **channel**. Transmission channel may be **analog** or **digital**. As the name suggests, analog channels transmit data using **analog signals** while digital channels transmit data using **digital signals**.

In popular network terminology, path over which data is sent or received is called **data channel**. This data channel may be a tangible medium like **copper wire cables** or broadcast medium like **radio waves**.

Data Transfer Rate

The speed of data transferred or received over transmission channel, measured per unit time, is called data transfer rate. The smallest unit of measurement is bits per second (bps). 1 bps means 1 bit (0 or 1) of data is transferred in 1 second.



Here are some commonly used data transfer rates:

- 1 Bps = 1 Byte per second = 8 bits per second
- 1 kbps = 1 kilobit per second = 1024 bits per second
- 1Mbps = 1 Megabit per second = 1024 Kbps
- 1 Gbps = 1 Gigabit per second = 1024 Mbps

Bandwidth

Data transfer rates that can be supported by a network is called its bandwidth. It is measured in bits per second (bps). Modern day networks provide bandwidth in Kbps, Mbps and Gbps. Some of the factors affecting a network's bandwidth include:

- Network devices used
- Protocols used
- Number of users connected
- Network overheads like collision, errors, etc.

Throughput

Throughput is the actual speed with which data gets transferred over the network. Besides transmitting the actual data, network bandwidth is used for transmitting error messages, acknowledgement frames, etc.

Throughput is a better measurement of network speed, efficiency and capacity utilization rather than bandwidth.

Protocol

Protocol is a set of rules and regulations used by devices to communicate over the network. Just like humans, computers also need rules to ensure successful communication. If two people start speaking at the same time or in different languages when no interpreter is present, no meaningful exchange of information can occur.

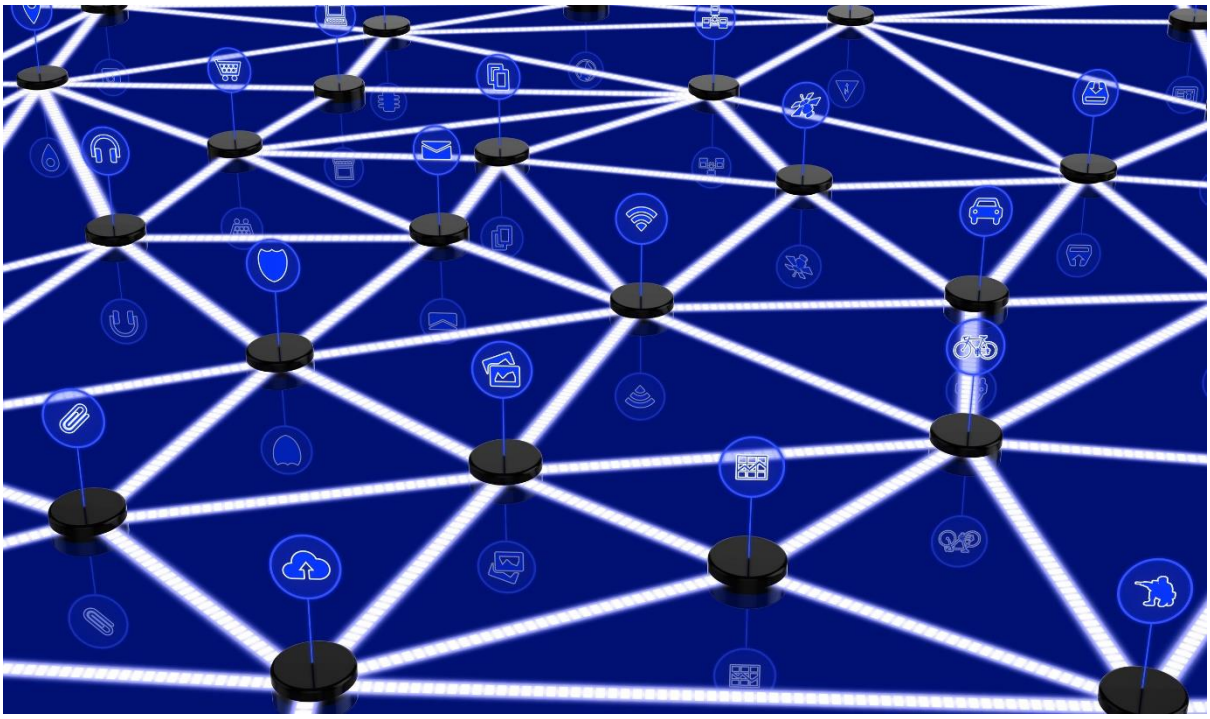
Similarly, devices connected on the network need to follow rules defining situations like when and how to transmit data, when to receive data, how to give error-free message, etc.

Some common protocols used over the Internet are:

- Transmission Control Protocol
- Internet Protocol
- Point to Point Protocol
- File Transfer Protocol
- Hypertext Transfer Protocol
- Internet Message Access Protocol

4. Communication Technologies – Switching Techniques

In large networks, there may be more than one paths for transmitting data from **sender** to **receiver**. Selecting a path that data must take out of the available options is called **switching**. There are two popular switching techniques – circuit switching and packet switching.



Circuit Switching

When a dedicated path is established for data transmission between sender and receiver, it is called circuit switching. When any network node wants to send data, be it audio, video, text or any other type of information, a **call request signal** is sent to the receiver and acknowledged back to ensure availability of dedicated path. This dedicated path is then used to send data. ARPANET used circuit switching for communication over the network.

Advantages of Circuit Switching

Circuit switching provides these advantages over other switching techniques:

- Once path is set up, the only delay is in data transmission speed
- No problem of congestion or garbled message

Disadvantages of Circuit Switching

Circuit switching has its disadvantages too:

- Long set up time is required
- A request token must travel to the receiver and then acknowledged before any transmission can happen
- Line may be held up for a long time

Packet Switching

As we discussed, the major problem with circuit switching is that it needs a dedicated line for transmission. In packet switching, data is broken down into small packets with each packet having source and destination addresses, travelling from one router to the next router.

5. Communication Technologies – Transmission Media

For any networking to be effective, raw stream of data is to be transported from one device to other over some medium. Various transmission media can be used for transfer of data. These transmission media may be of two types:

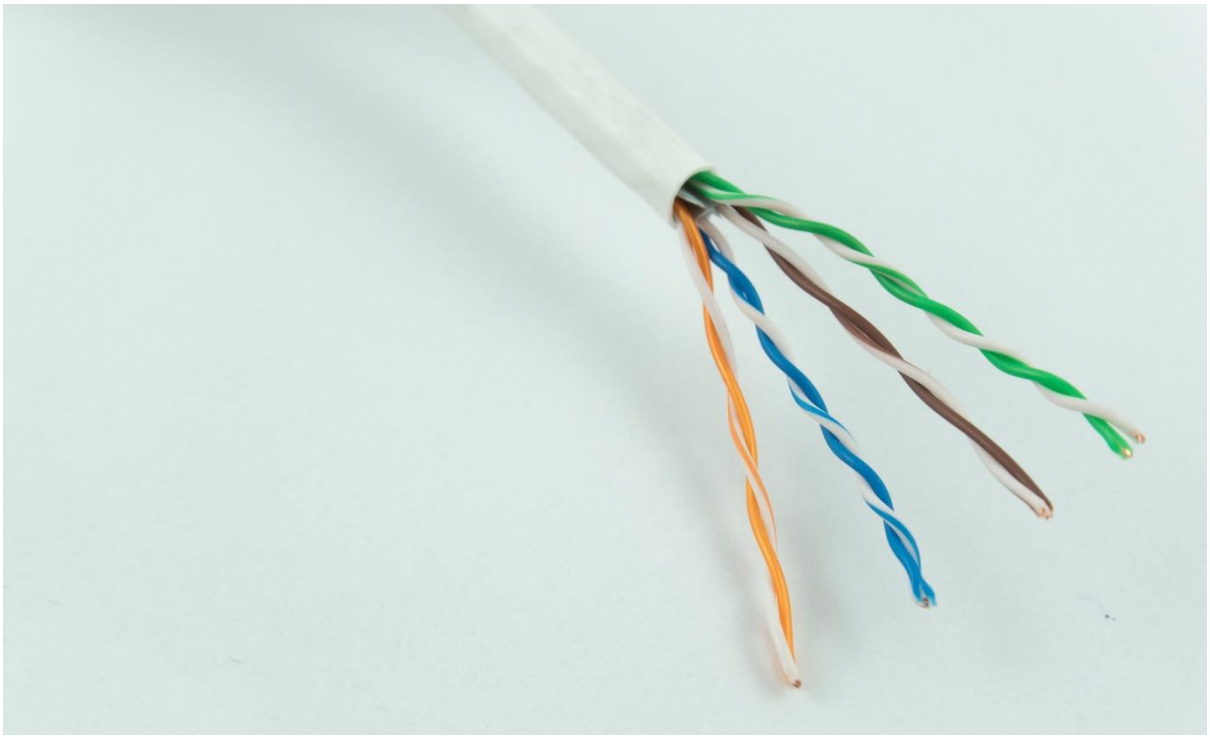
- **Guided**: In guided media, transmitted data travels through cabling system that has a fixed path. For example, copper wires, fibre optic wires, etc.

- **Unguided**: In unguided media, transmitted data travels through free space in form of electromagnetic signal. For example, radio waves, lasers, etc.

Each transmission media has its own advantages and disadvantages in terms of bandwidth, speed, delay, cost per bit, ease of installation and maintenance, etc. Let's discuss some of the most commonly used media in detail.

Twisted Pair Cable

Copper wires are the most common wires used for transmitting signals because of good performance at low costs. They are most commonly used in telephone lines. However, if two or more wires are lying together, they can interfere with each other's signals. To reduce this electromagnetic interference, pair of copper wires are twisted together in helical shape like a DNA molecule. Such twisted copper wires are called **twisted pair**. To reduce interference between nearby twisted pairs, the twist rates are different for each pair.



Up to 25 twisted pair are put together in a protective covering to form twisted pair cables that are the backbone of telephone systems and Ethernet networks.

Advantages of twisted pair cable

Twisted pair cable are the oldest and most popular cables all over the world. This is due to the many advantages that they offer:

- Trained personnel easily available due to shallow learning curve
- Can be used for both analog and digital transmissions
- Least expensive for short distances
- Entire network does not go down if a part of network is damaged

Disadvantages of twisted pair cable

With its many advantages, twisted pair cables offer some disadvantages too:

- Signal cannot travel long distances without repeaters
- High error rate for distances greater than 100m
- Very thin and hence breaks easily
- Not suitable for broadband connections

Shielding twisted pair cable

To counter the tendency of twisted pair cables to pick up noise signals, wires are shielded in the following three ways:

- Each twisted pair is shielded.
- Set of multiple twisted pairs in the cable is shielded.
- Each twisted pair and then all the pairs are shielded.

Such twisted pairs are called **shielded twisted pair (STP) cables**. The wires that are not shielded but simply bundled together in a protective sheath are called **unshielded twisted pair (UTP) cables**. These cables can have maximum length of 100 metres.

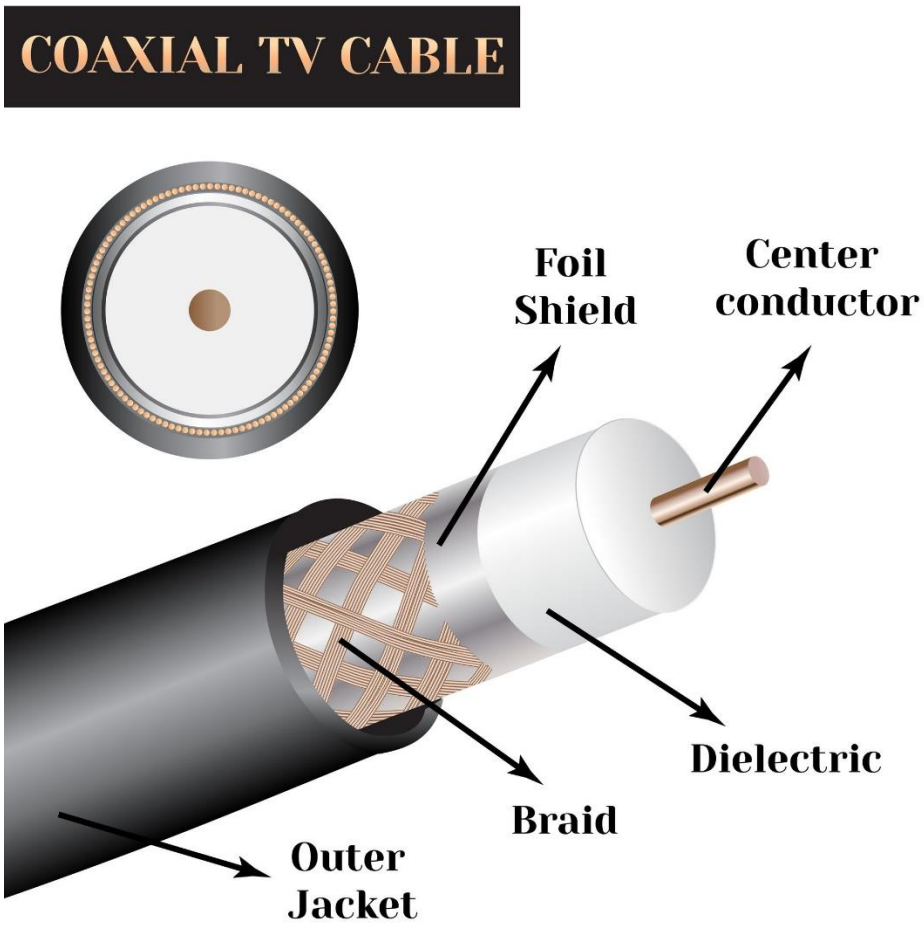
Shielding makes the cable bulky, so UTP are more popular than STP. UTP cables are used as the last mile network connection in homes and offices.

Coaxial Cable

Coaxial cables are copper cables with better **shielding** than twisted pair cables, so that transmitted signals may travel longer distances at higher speeds. A coaxial cable consists of these layers, starting from the innermost:

- Stiff copper wire as **core**
- **Insulating material** surrounding the core
- Closely woven braided mesh of **conducting material** surrounding the **insulator**
- Protective **plastic sheath** encasing the wire

Coaxial cables are widely used for **cable TV** connections and **LANs**.



Advantages of Coaxial Cables

These are the advantages of coaxial cables:

- Excellent noise immunity
- Signals can travel longer distances at higher speeds, e.g. 1 to 2 Gbps for 1 Km cable
- Can be used for both analog and digital signals
- Inexpensive as compared to fibre optic cables
- Easy to install and maintain

Disadvantages of Coaxial Cables

These are some of the disadvantages of coaxial cables:

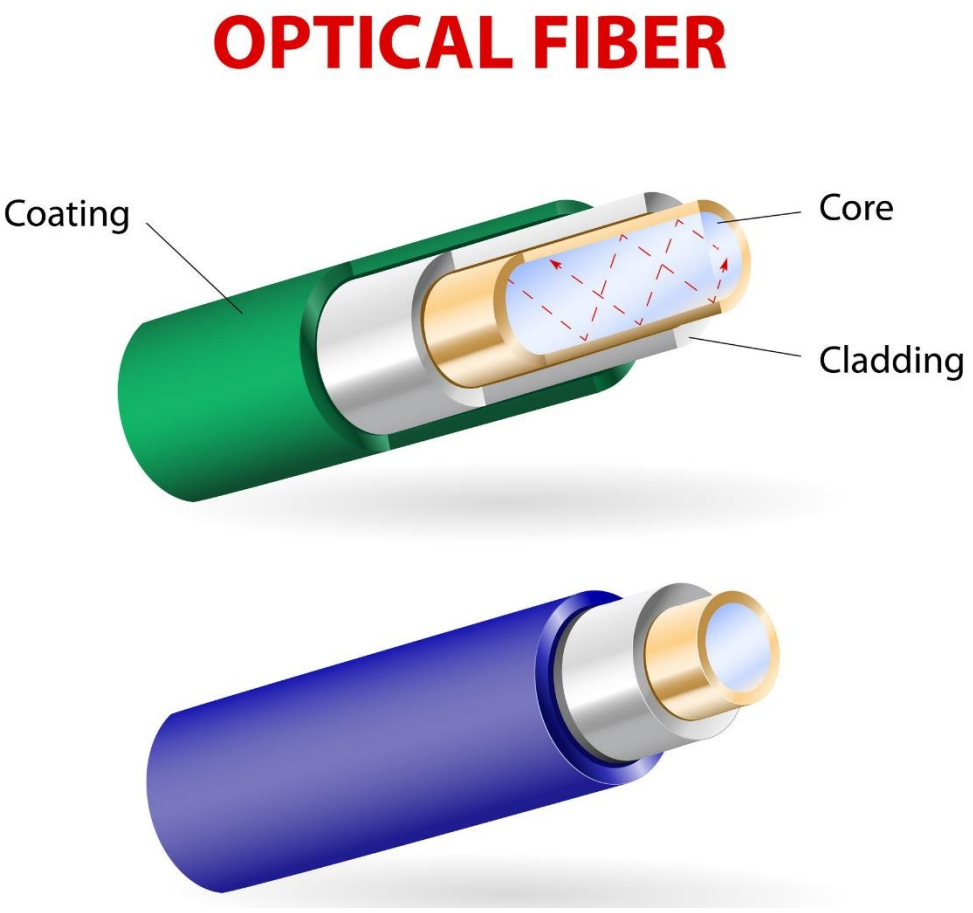
- Expensive as compared to twisted pair cables
- Not compatible with twisted pair cables

Optical Fibre

Thin glass or plastic threads used to transmit data using light waves are called **optical fibre**. Light Emitting Diodes (LEDs) or Laser Diodes (LDs) emit light waves at the **source**, which is read by a **detector** at the other end. **Optical fibre cable** has a bundle of such threads or fibres bundled together in a protective covering. Each fibre is made up of these three layers, starting with the innermost layer:

- **Core** made of high quality **silica glass** or **plastic**
- **Cladding** made of high quality **silica glass** or **plastic**, with a lower refractive index than the core
- Protective outer covering called **buffer**

Note that both core and cladding are made of similar material. However, as **refractive index** of the cladding is lower, any stray light wave trying to escape the core is reflected back due to **total internal reflection**.



Optical fibre is rapidly replacing copper wires in telephone lines, internet communication and even cable TV connections because transmitted data can travel very long distances without

weakening. **Single node** fibre optic cable can have maximum segment length of 2 kms and bandwidth of up to 100 Mbps. **Multi-node** fibre optic cable can have maximum segment length of 100 kms and bandwidth up to 2 Gbps.

Advantages of Optical Fibre

Optical fibre is fast replacing copper wires because of these advantages that it offers:

- High bandwidth
- Immune to electromagnetic interference
- Suitable for industrial and noisy areas
- Signals carrying data can travel long distances without weakening

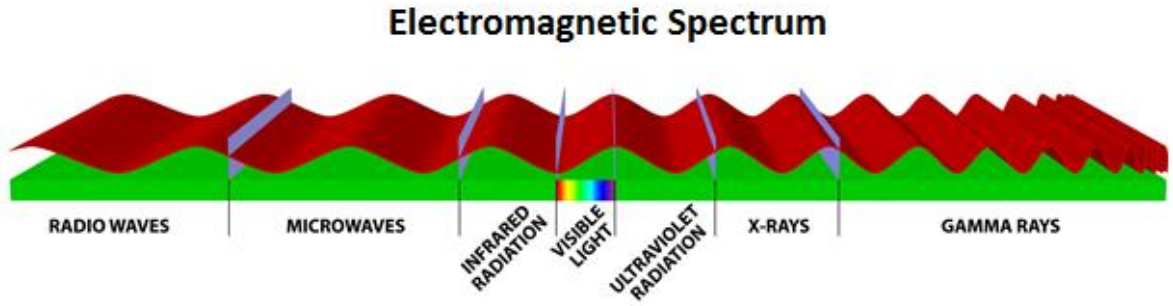
Disadvantages of Optical Fibre

Despite long segment lengths and high bandwidth, using optical fibre may not be a viable option for every one due to these disadvantages:

- Optical fibre cables are expensive
- Sophisticated technology required for manufacturing, installing and maintaining optical fibre cables
- Light waves are unidirectional, so two frequencies are required for **full duplex** transmission

Infrared

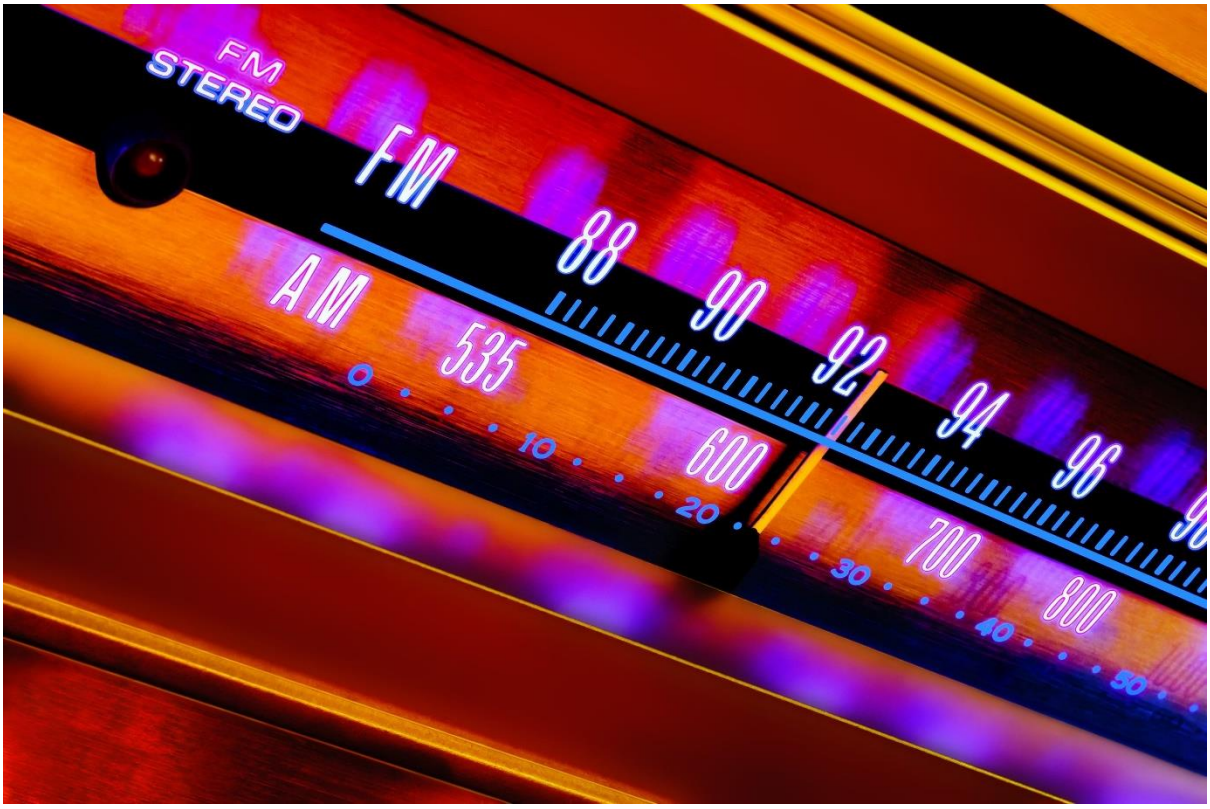
Low frequency infrared waves are used for very short distance communication like TV remote, wireless speakers, automatic doors, hand held devices etc. Infrared signals can propagate within a room but cannot penetrate walls. However, due to such short range, it is considered to be one of the most secure transmission modes.



Radio Wave

Transmission of data using radio frequencies is called **radio-wave transmission**. We all are familiar with radio channels that broadcast entertainment programs. Radio stations transmit radio waves using **transmitters,** which are received by the receiver installed in our devices.

Both transmitters and receivers use antennas to radiate or capture radio signals. These radio frequencies can also be used for **direct voice communication** within the **allocated range**. This range is usually 10 miles.



Advantages of Radio Wave

These are some of the advantages of radio wave transmissions:

- Inexpensive mode of information exchange
- No land needs to be acquired for laying cables
- Installation and maintenance of devices is cheap

Disadvantages of Radio Wave

These are some of the disadvantages of radio wave transmissions:

- Insecure communication medium

- Prone to weather changes like rain, thunderstorms, etc.

6. Communication Technologies – Network Devices

Hardware devices that are used to connect computers, printers, fax machines and other electronic devices to a network are called **network devices**. These devices transfer data in a fast, secure and correct way over same or different networks. Network devices may be inter-network or intra-network. Some devices are installed on the device, like NIC card or RJ45 connector, whereas some are part of the network, like router, switch, etc. Let us explore some of these devices in greater detail.

Modem

Modem is a device that enables a computer to send or receive data over telephone or cable lines. The data stored on the computer is digital whereas a telephone line or cable wire can transmit only analog data.

Digital Data Waveform

Analog Data Waveform

The main function of the modem is to convert digital signal into analog and vice versa. Modem is a combination of two devices – **modulator** and **demodulator.** The **modulator** converts digital data into analog data when the data is being sent by the computer. The **demodulator** converts analog data signals into digital data when it is being received by the computer.

Types of Modem

Modem can be categorized in several ways like direction in which it can transmit data, type of connection to the transmission line, transmission mode, etc.

Depending on direction of data transmission, modem can be of these types:

1. **Simplex**: A simplex modem can transfer data in only one direction, from digital device to network (modulator) or network to digital device (demodulator).

2. **Half duplex**: A half-duplex modem has the capacity to transfer data in both the directions but only one at a time.