UNIT : 2 Physical Layer

Transmission Media – Guided and Unguided Media

What is Transmission Media in Computer Networks?

A transmission media is a physical path between the transmitter and the receiver i.e. it is the path along which data is sent from one device to another. Transmission Media is broadly classified into the following types:

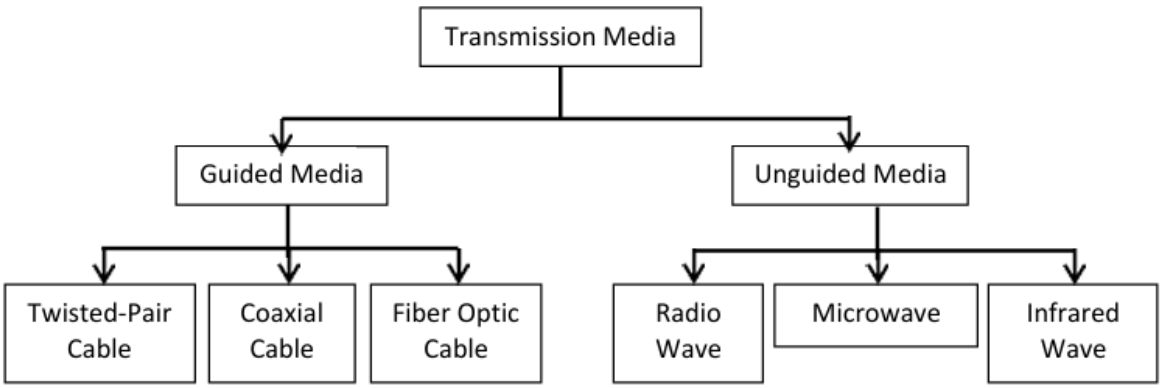


Figure 8: Classification Transmission Media

1. Guided Media

Guided Media is also referred to as Wired or Bounded transmission media. Signals being transmitted are directed and confined in a narrow pathway by using physical links.

Features:

- High Speed
- Secure
- Used for comparatively shorter distances

There are 3 major types of Guided Media:

Twisted Pair Cable

It consists of 2 separately insulated conductor wires twisted about each other. Generally, several such pairs are bundled together in a protective sheath. They are the most widely used Transmission Media. Twisted Pair is of two types:

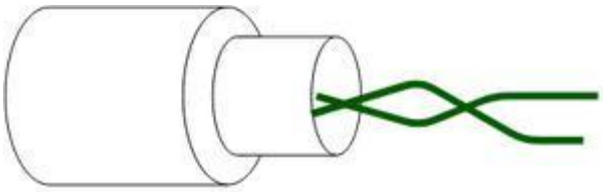
- **Unshielded Twisted Pair (UTP):**UTP consists of two insulated copper wires twisted around one another. This type of cable has the ability to block interference and does not depend on a physical shield for this purpose. It is used for telephonic applications.

Advantages of Unshielded Twisted Pair

- Least expensive
- Easy to install
- High-speed capacity

Disadvantages of Unshielded Twisted Pair

- Lower capacity and performance in comparison to STP
- Short distance transmission due to attenuation



Shielded Twisted Pair

Shielded Twisted Pair (STP): Shielded Twisted Pair (STP) cable consists of a special jacket (a copper braid covering or a foil shield) to block external interference. It is used in fast data rate Ethernet and in voice and data channels of telephone lines.

Advantages of Shielded Twisted Pair

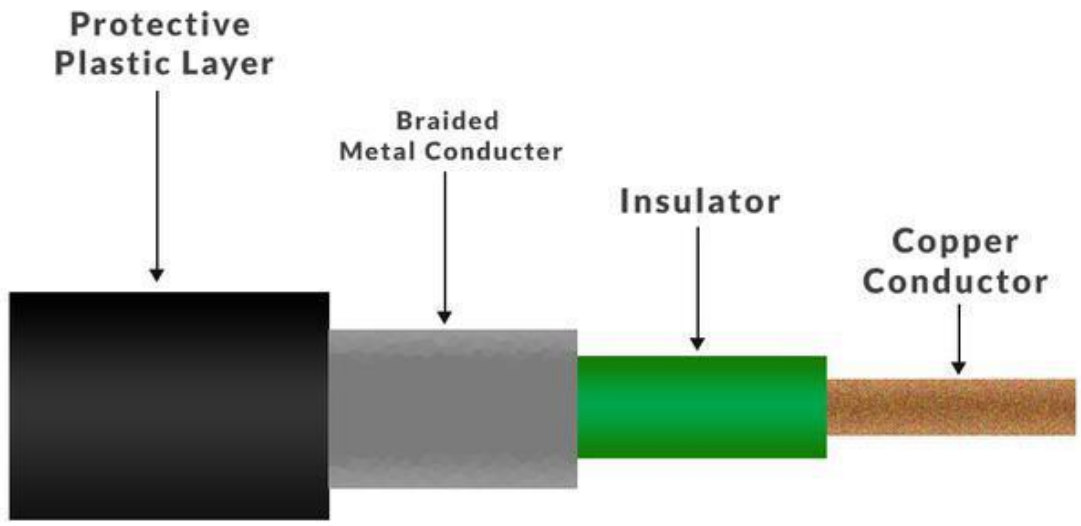
- Better performance at a higher data rate in comparison to UTP
- Eliminates crosstalk
- Comparatively faster

Disadvantages of Shielded Twisted Pair

- Comparatively difficult to install and manufacture
- More expensive
- Bulky

Coaxial Cable

Coaxial cable has an outer plastic covering containing an insulation layer made of PVC or Teflon and 2 parallel conductors each having a separate insulated protection cover. The coaxial cable transmits information in two modes: Baseband mode(dedicated cable bandwidth) and Broadband mode(cable bandwidth is split into separate ranges). Cable TVs and analog television networks widely use Coaxial cables.



Advantages of Coaxial Cable

- Coaxial cables has high bandwidth .
- It is easy to install.
- Coaxial cables are more reliable and durable.
- Less affected by noise or cross-talk or electromagnetic inference.
- Coaxial cables support multiple channels

Disadvantages of Coaxial Cable

- Coaxial cables are expensive.
- The coaxial cable must be grounded in order to prevent any crosstalk.
- As a Coaxial cable has multiple layers it is very bulky.
- There is a chance of breaking the coaxial cable and attaching a “t-joint” by hackers, this compromises the security of the data.

Optical Fiber Cable

Optical Fibre Cable uses the concept of total internal reflection of light through a core made up of glass. The core is surrounded by a less dense glass or plastic covering called the coating. It is used for the transmission of large volumes of data. The cable can be unidirectional or bidirectional. The WDM (Wavelength Division Multiplexer) supports two modes, namely unidirectional and bidirectional mode.

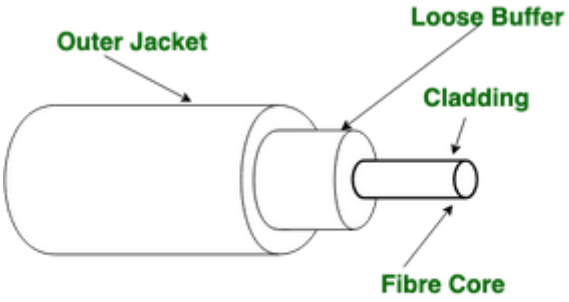


Figure of Optical Fibre Cable

Advantages of Optical Fibre Cable

- Increased capacity and bandwidth
- Lightweight
- Less signal attenuation
- Immunity to electromagnetic interference
- Resistance to corrosive materials

Disadvantages of Optical Fibre Cable

- Difficult to install and maintain
- High cost

Applications of Optical Fibre Cable

- **Medical Purpose:** Used in several types of medical instruments.
- **Defence Purpose:** Used in transmission of data in aerospace.
- **For Communication:** This is largely used in formation of internet cables.
- **Industrial Purpose:** Used for lighting purposes and safety measures in designing the interior and exterior of automobiles.

2. Unguided Media

It is also referred to as Wireless or Unbounded transmission media . No physical medium is required for the transmission of electromagnetic signals.

Features of Unguided Media

- The signal is broadcasted through air
- Less Secure
- Used for larger distances

There are 3 types of Signals transmited through unguided media:

Radio Waves

Radio waves are easy to generate and can through buildings. The sending and receiving antennas need not be aligned. Frequency Range:3KHz - 1GHz. FM radios and cordless phones use Radio waves for transmission.

Types of Radio Waves:

- **VHF (Very High Frequency):** FM Radio/TV
- **UHF (Ultra High Frequency):** TV

Radio Wave Components:

- **Transmitter:** Responsible for encoding the signal.
- **Receiver:** Responsible for decoding the signal.

Microwaves

It is a line of sight transmission i.e. the sending and receiving antennas need to be properly aligned with each other. The distance covered by the signal is directly proportional to the height of the antenna. Frequency Range:1GHz - 300GHz. **Micro waves** are majorly used for mobile phone communication and television distribution.

Advantages:

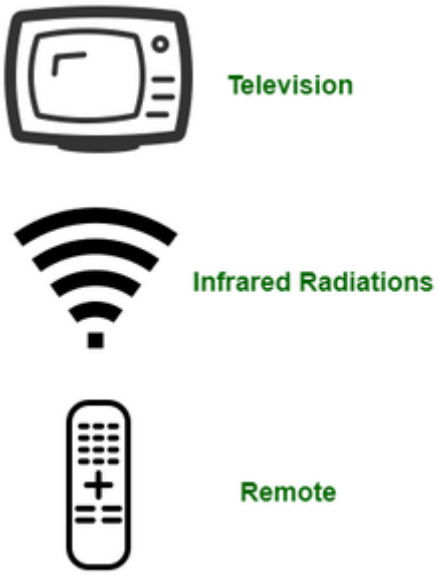
- Cheaper than using cables
- Ease of communication
- Communication

Disadvantages:

- Insecure communication.
- Out of phase signal.
- Susceptible to weather conditions.
- Bandwidth is limited.
- High cost of design, implementation, and maintenance.

Infrared

Infrared waves are used for very short distance communication. They cannot penetrate through obstacles. This prevents interference between systems. Frequency Range:300GHz - 400THz. It is used in TV remotes, wireless mouse, keyboard, printer, etc.



Analog and Digital Signals – Concepts and Differences

What is an Analog Signal?

Analog signal is a type of signal that represents continuous data using a continuous range of values. In other words, it can take on any value within a certain range. Analog signals are characterized by their smooth and continuous nature.

What is Digital Signal?

Digital signal is a type of signal that represents data as a sequence of discrete values, typically using binary numbers, it also contain different voltage values. Unlike analog signals, which vary continuously over time, digital signals are discrete and quantized, meaning they only take on specific, distinct values.

Difference Between Analog And Digital Signal

The difference between analog signal and digital signal could be understood from the table given below:

Basis	Analog Signal	Digital Signal
Definition	Analog signals represent continuous variations in magnitude over time.	Digital signals are Discrete and quantized, with specific values.
Signal Type	Continuous waveforms	Discrete Signals
Processing	Requires complex processing for manipulation.	Easier to process and manipulate digitally.
Storage	Less efficient for storage due to continuous nature.	More efficient for storage due to discrete values.
Bandwidth	Typically requires more bandwidth.	Requires less bandwidth for transmission.
Examples	Analog audio signals, analog radio waves, Human voice, etc.	Digital audio signals, digital data streams, computers, etc.
Errors	Susceptible to noise and distortion	More resistant to noise and distortion
Circuit Component	Amplifiers, filters, continuous-wave oscillators	Microprocessors, binary counters, logic gates

Basis	Analog Signal	Digital Signal
Signal Values	Infinite range of values	Limited to discrete values
Conversion	No conversion required	Analog-to-digital conversion (ADC) required
Applications	Analog signals are used in electric fan, landlines, radio frequency communications, etc.	Digital signals are used in computers, smartphones, digital sensors, digital imagining, etc.

Encoding Techniques – Line Coding (NRZ and Manchester)

Data Encoding

Encoding is the process of using various patterns of voltage or current levels to represent 1s and 0s of the digital signals on the transmission link.

Encoding Techniques

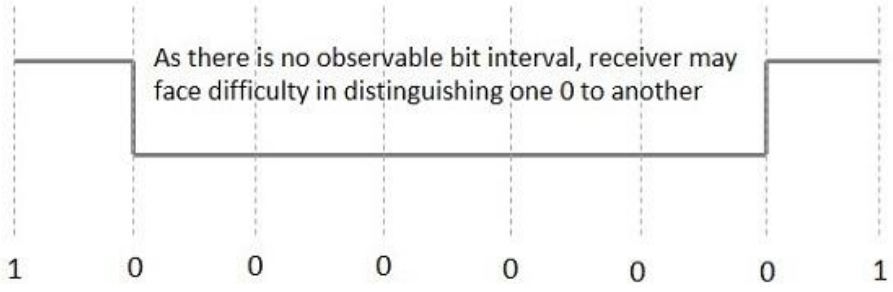
The data encoding technique is divided into the following types, depending upon the type of data conversion.

- Analog data to Analog signals − The modulation techniques such as Modulation, Frequency Modulation and Phase Modulation of analog signals, fall under this category.
- Analog data to Digital signals − This process can be termed as digitization, which is done by Pulse Code Modulation (PCM). Hence, it is nothing but digital modulation. As we have already discussed, sampling and quantization are the important factors in this. Delta Modulation gives a better output than PCM.
- Digital data to Analog signals − The modulation techniques such as Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), etc., fall under this category. These will be discussed in subsequent chapters.

- Digital data to Digital signals − These are in this section. There are several ways to map digital data to digital signals.

Non Return to Zero (NRZ)

NRZ Codes has 1 for High voltage level and 0 for Low voltage level. The main behavior of NRZ codes is that the voltage level remains constant during bit interval. The end or start of a bit will not be indicated and it will maintain the same voltage state, if the value of the previous bit and the value of the present bit are same.



NRZ Coding

Manchester Encoding

- **Definition:** A line coding scheme where **each bit has a** transmission **in the middle** of the time slot.
- Combines **clock signal + data signal** → helps with networking.

Rules (IEEE 802.3 Standard):

- 0 → High-to-Low transition.
- 1 → Low-to-High transition.
  (Transition always occurs at the middle of the bit period).

Advantages of Manchester:

- receiver can extract clock from transmission
- Easy to detect errors (missing transitions indicate errors).

- Reliable for long-distance transmission.

Disadvantages of Manchester:

- Requires **double the bandwidth** of NRZ.
- More complex to encode and decode.

Signal Conversion – Digital-to-Analog and Analog-to-Digital

- In computer networks and communication systems, **data exists in both digital and analog forms**.
- To transmit data effectively, sometimes we need to **convert digital data into analog signals** (for telephone lines, radio, etc.) or **convert analog signals into digital data** (for computers, digital storage).

Digital-to-Analog Conversion (DAC)

- **Definition:** Process of converting digital data (0s and 1s) into an **analog signal** (continuous waveform) so that it can travel over analog transmission mediums (like telephone networks, radio waves).

Applications of DAC:

- Modems (convert computer data → telephone line signals).
- Broadcasting digital TV/radio.
- Wireless communication (Wi-Fi, 4G/5G)

Analog-to-Digital Conversion (ADC)

- **Definition:** Process of converting analog signals (like voice, sound, temperature) into **digital data** (binary) that computers and digital devices can process, store, or transmit.

Applications of ADC:

- Voice over IP (VoIP).
- Digital audio (MP3, CDs).
- Digital video streaming.
- Sensors in IoT (temperature, pressure converted to digital).

Multiplexing Techniques – FDM, TDM, and WDM

What is Multiplexing?

- **Multiplexing** = Technique that allows **multiple signals** (voice, data, video) to share the **same transmission medium** (cable, fiber, radio channel).
- Purpose: Efficient utilization of bandwidth.
- A special device called a **Multiplexer (MUX)** combines signals, and a **Demultiplexer (DEMUX)** separates them at the receiver side.

Types of Multiplexing

A) Frequency Division Multiplexing (FDM)

- **Concept:** Entire bandwidth of a channel is divided into smaller **frequency bands**, each carrying one signal.
- Each user is assigned a **unique frequency range** within the channel.

Example:

- Radio broadcasting: FM 93.5 MHz, 98.3 MHz, 104.8 MHz (different stations).
- Cable TV channels.

Advantages:

- Simple and widely used.
- All users can transmit **at the same time**.

Disadvantages:

- Wastage of bandwidth due to **guard bands** (space between channels to prevent overlap).
- Susceptible to interference and crosstalk.

B) Time Division Multiplexing (TDM)

- **Concept:** Available time is divided into **time slots**; each user is assigned a slot in a **round-robin**(time slots) **manner**.
- Signals share the same channel but only one transmits at a time.
- Two Types:

1. **TDM** – Each user gets a **fixed time slot**, even if idle.
2. **Statistical TDM** – Slots are allocated dynamically to active users only (more efficient).

Example:

- Telephone networks (digital switching).
- Computer networks.

Advantages:

- More efficient use of bandwidth (especially Statistical TDM).
- No interference between users (only one transmits per slot).

Disadvantages:

- Synchronization needed between sender and receiver.
- Delay possible if many users are active.

C) Wavelength Division Multiplexing (WDM)

- **Concept:** Special type of FDM used in **optical fiber communication**.
- Different **wavelengths (colors of light)** are used to transmit multiple signals simultaneously through the same fiber.
- Each wavelength carries separate data.

Example:

- Internet backbone (optical fiber networks).
- Submarine cables connecting continents.

Advantages:

- Very high capacity (Tbps range).
- Efficient use of fiber optic cables.
- Easy to expand by adding more wavelengths.

Disadvantages:

- Expensive equipment (lasers, optical filters).
- Complex to implement.

Switching Techniques – Circuit Switching, Packet Switching, and Message Switching

What is Switching?

- In computer networks, switching is the technique of transferring data from a source to a destination across a network.
- Since direct connections between all devices are not practical, switching allows data to travel via intermediate nodes (switches/routers).
- Types of Switching:
    1. Circuit Switching
    2. Packet Switching
    3. Message Switching

1. Circuit Switching

- Concept: A dedicated communication path (circuit) is established between sender and receiver before data transfer begins.
- Once the circuit is set up, all data follows the same path.
- Connection-oriented method.

Example:

- Traditional telephone networks.

2. Packet Switching

- Concept: Data is divided into small packets, and each packet is transmitted independently across the network.
- Each packet may take different routes and is reassembled at the destination.
- Connectionless method (no fixed path).

Types:

1. Datagram Packet Switching:
    - Each packet treated independently, may take different routes.
    - Example: Internet (IP protocol).

2. Virtual Circuit Packet Switching:
    - A logical path is established, but packets still sent individually.
    - Example: Frame Relay, ATM.

Example:

- Internet communication (TCP/IP, Email, Web browsing).

3. Message Switching

- Concept: Entire message is treated as a single unit.
- The message is stored at intermediate nodes (store-and-forward) and then forwarded to the next node.
- No dedicated path, and no splitting into smaller packets.

Example:

- Early telegraph systems.

Transmission Modes – Simplex, Half-Duplex, and Full-Duplex.

What is Transmission Mode?

- Transmission mode refers to the way data is transmitted between two devices in a communication system.
- It defines the direction of signal flow between sender and receiver.
- The three modes are:
    1. Simplex
    2. Half-Duplex
    3. Full-Duplex

1. Simplex Mode

- Definition: Communication is unidirectional → data flows in only one direction.
- One device = always sender, the other = always receiver.
- Example:
    - Keyboard → Computer (keyboard only sends input).

    - Monitor → User (only displays output).
    - Radio/TV broadcasting (station transmits, listeners only receive).

2. Half-Duplex Mode

- Definition: Communication is bidirectional, but only one direction at a time.
- Devices take turns in sending and receiving.
- Example:
    - Walkie-Talkies (one person speaks, the other listens; then roles reverse).
    - Traditional Ethernet using hubs (old networks).

3. Full-Duplex Mode

- Definition: Communication is bidirectional and simultaneous → both devices can transmit and receive data at the same time.
- Requires two separate channels (or one channel with echo cancellation).
- Example:
    - Telephone conversation (both people can talk and listen simultaneously).
    - Modern Ethernet, Wi-Fi.