Computer Communication Networks

Introduction, Communication link, Multiplexing

Dr. Raja Vara Prasad

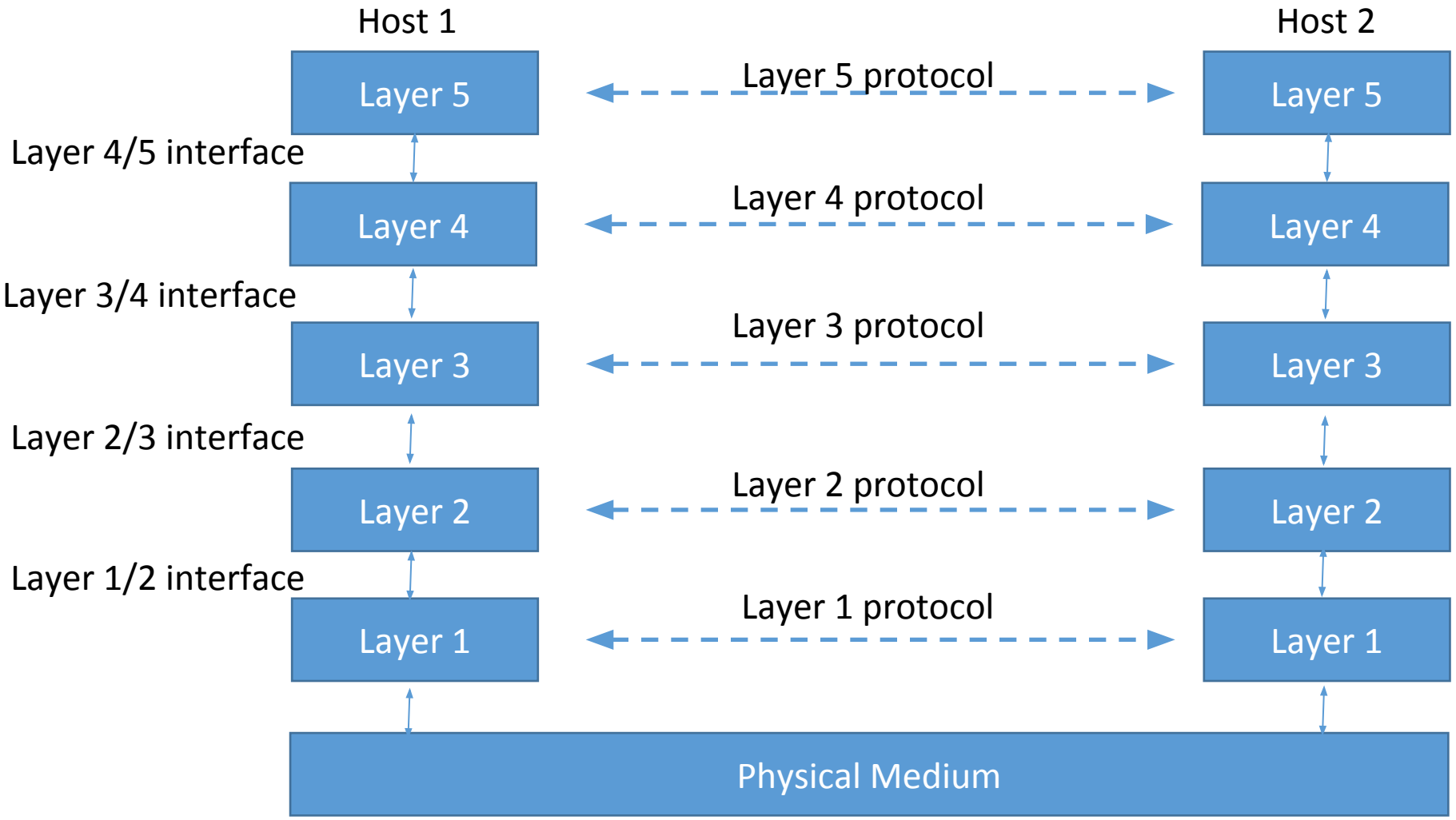
Assistant Professor

IIIT Sri City

Network Software

- Protocol
  - Is an agreement between the communicating parties on how communication is to proceed.
  - Violation of protocol will make communication more difficult, if not completely impossible.

Layers, protocols, and interfaces

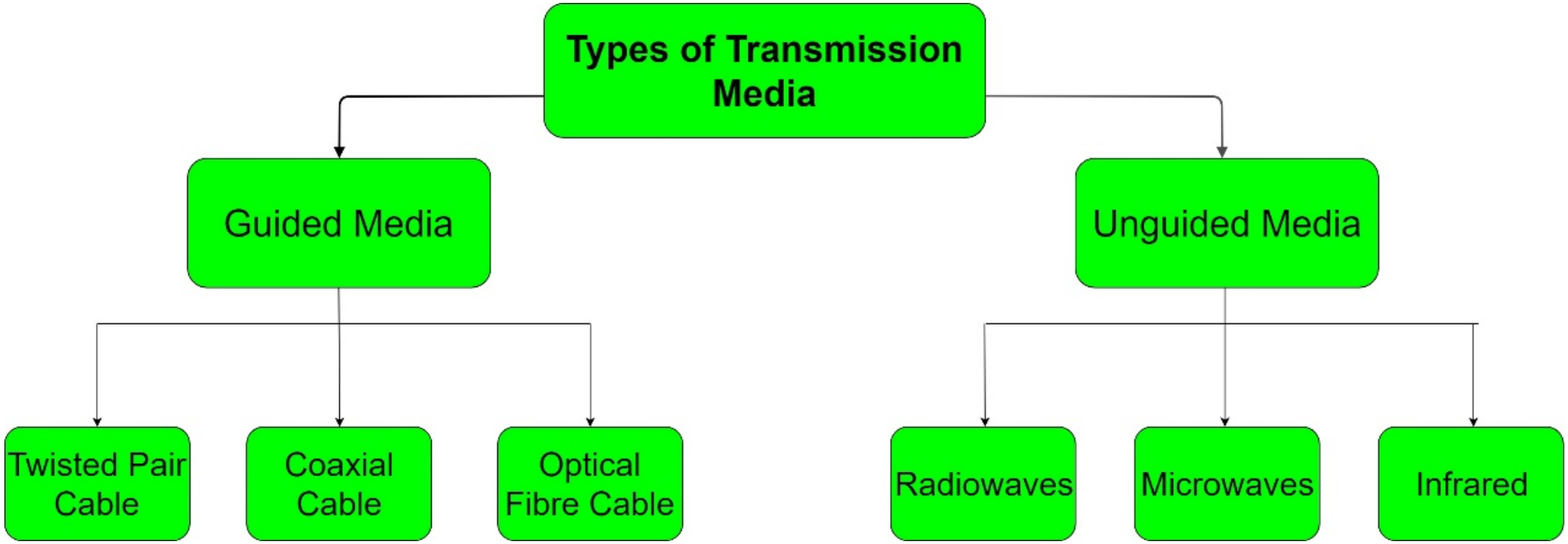


The Physical Layer

- Lowest of our protocol model
- Defines the electrical, timing and other interfaces by which bits are sent as signals over channels.
- The properties of different kinds of physical channels determine the performance.
- Kinds of transmission media: Guided and Unguided.

Communication Link?

Communication link : provides a way for information to move between physically separated components



Magnetic Media

- One of the most common ways to transport data from one computer to another is to write them onto magnetic tape or removable media.
- It is often more cost effective, especially for applications in which high bandwidth or cost per bit transported is the key factor.

Floppy disc.

Hard Disc

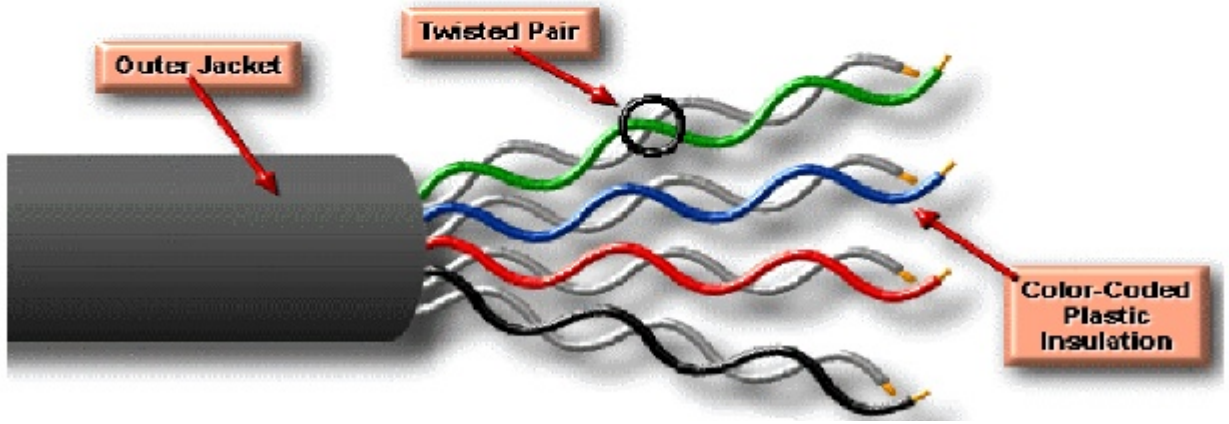
External hard Disc

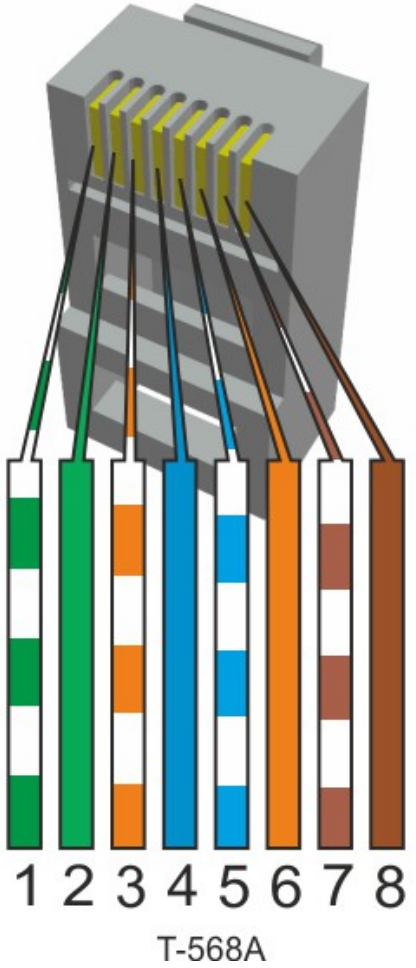
Twisted pair

- Used for telephone communications and most modern Ethernet networks.
- A pair of wires forms a circuit that can transmit data.
- The pairs are twisted to provide protection against *crosstalk*, the noise generated by adjacent pairs.
- When electrical current flows through a wire, it creates a small, circular magnetic field around the wire (Ampere's Law).
- When two wires in an electrical circuit are placed close together, their magnetic fields are the exact opposite of each other. Thus, the two magnetic fields cancel each other out.
- Twisting the wires can enhance this *cancellation effect.*
- *Two types: Unshielded, and shielded.*

UTP (unshielded)

- is a medium that is composed of pairs of wires (4 pairs for network medium)
- UTP cable often is installed using a Registered Jack 45 (RJ-45) connector





Pin	Description	10base-T	100Base-T	1000Base-T
1	Transmit Data+ or BiDirectional	TX+	TX+	BI_DA+
2	Transmit Data- or BiDirectional	TX-	TX-	BI_DA-
3	Receive Data+ or BiDirectional	RX+	RX+	BI_DB+
4	Not connected or BiDirectional	n/c	n/c	BI_DC+
5	Not connected or BiDirectional	n/c	n/c	BI_DC-
6	Receive Data- or BiDirectional	RX-	RX-	BI_DB-
7	Not connected or BiDirectional	n/c	n/c	BI_DD+
8	Not connected or BiDirectional	n/c	n/c	BI_DD-

PinoutsGuide.com

UTP

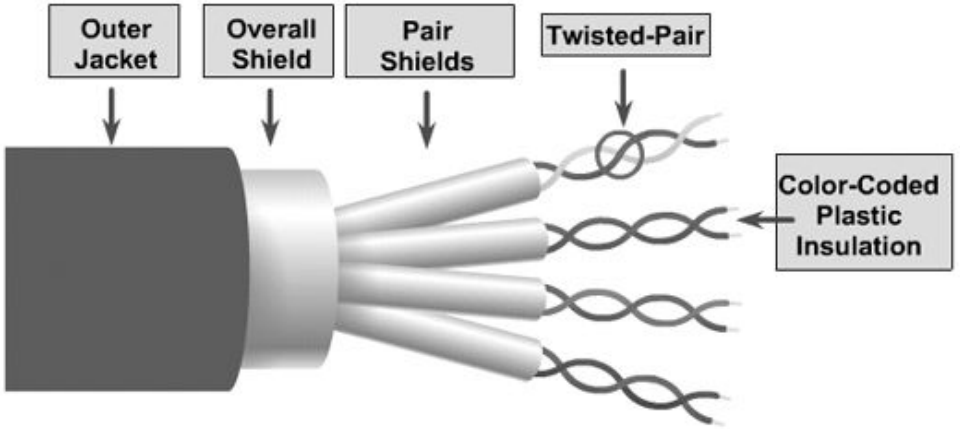
- Advantages: Smaller size (external diameter), easy to install and less expensive.
- Disadvantages: UTP cable is more prone to electrical noise and interference than other types of networking media, and the distance between signal boosts is shorter for UTP .
- The following summarizes the features of UTP cable:
  - Speed and throughput—10 to 1000 Mbps
  - Average cost per node—Least expensive
  - Media and connector size—Small
  - Maximum cable length—100 m (short)

UTP cabling

- **Category 1 (1 pair)**—Used for telephone communications. Not suitable for transmitting data.
- **Category 2 (2 pairs)**—Capable of transmitting data at speeds up to 4 megabits per second (Mbps).
- **Category 3 (4 pairs)**—Used in 10BASE-T networks, Can transmit data at speeds up to 10 Mbps.
- **Category 4 (4 pairs)**—Used in Token Ring networks, Can transmit data at speeds up to 16 Mbps.
- **Category 5 (4 pairs)**—Can transmit data at speeds up to 100 Mbps.
- **Category 5e (4 pairs)** —Used in networks running at speeds up to 1000 Mbps (1 gigabit per second [Gbps]).
- **Category 6 (4 pairs)**—Typically, Category 6 cable consists of four pairs of 24 American Wire Gauge (AWG) copper wires. Category 6 cable is currently the fastest standard for UTP.

STP (Shielded Twisted Pair)

- Combines the techniques of shielding, cancellation, and wire twisting.
- Each pair of wires is wrapped in a metallic foil. The four pairs of wires then are wrapped in an overall metallic braid or foil.
- Reduces electrical noise both within the cable (pair-to-pair coupling, or crosstalk) and from outside the cable (EMI and RFI)



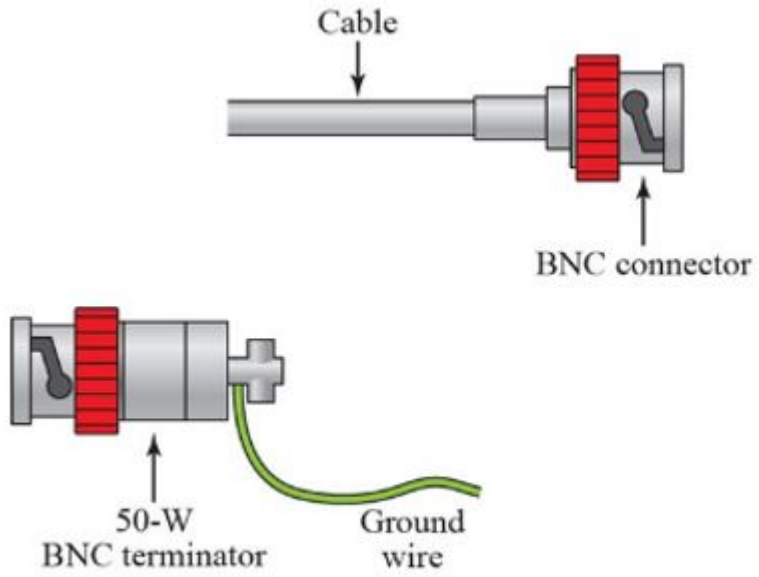
- Speed and throughput: 10-100 Mbps
- Cost per node: Moderately expensive
- Media and connector size: Medium to Large
- Maximum cable length: 100m (short)

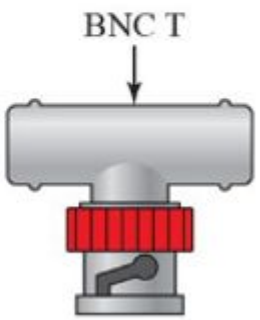
STP comparison with UTP

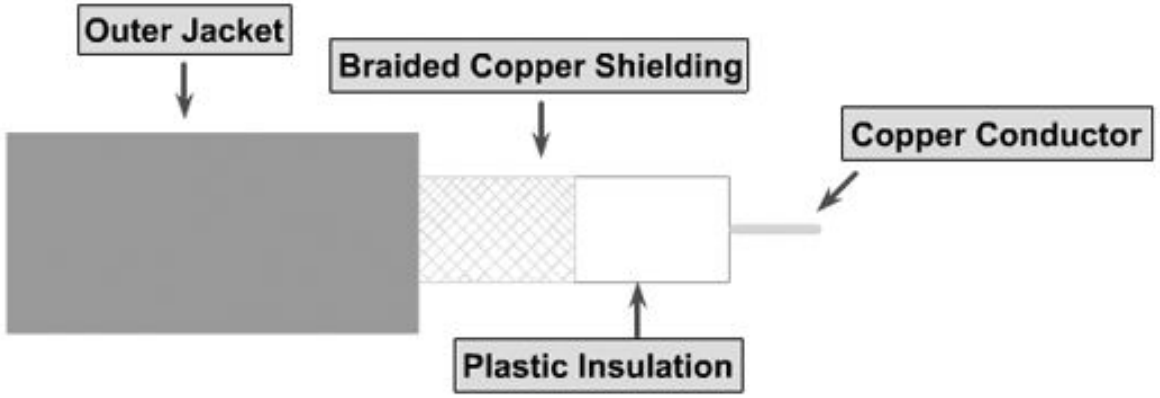
- Although STP prevents interference better than UTP, it is more expensive and difficult to install.
- the metallic shielding must be grounded at both ends. If it is improperly grounded, the shield acts like an antenna and picks up unwanted signals.
- Because of its cost and difficulty with termination, STP is rarely used in Ethernet networks.
- The speed of both types of cable is usually satisfactory for local-area distances.

Coaxial Cable

- Coaxial cabling has a single copper conductor at its center. A plastic layer provides insulation between the center conductor and a braided metal shield.
- The metal shield helps to block any outside interference from fluorescent lights, motors, and other computers.
- The most common type of connector used the Bayonet Neill-Concelman (BNC) connector







Categories of Coax.

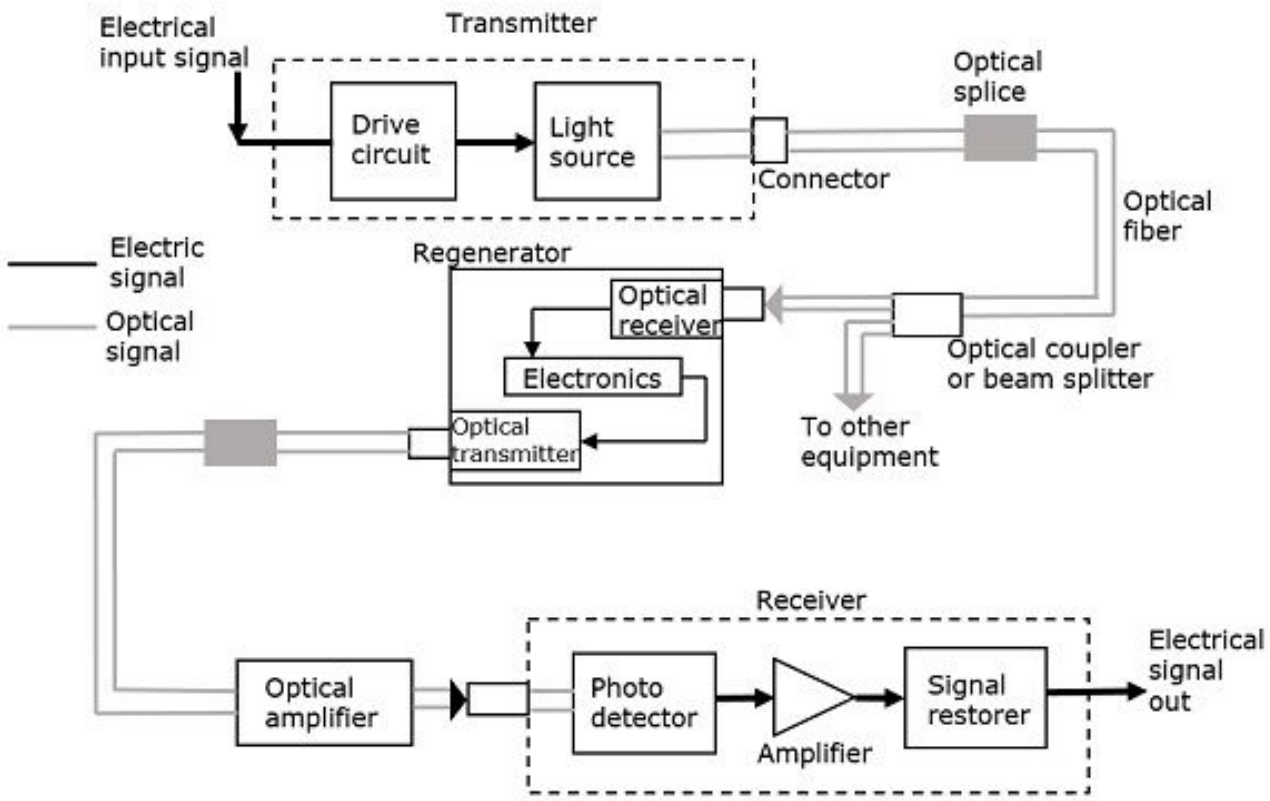
- Base band
- For digital transmission, a 50 ohm (Ω) coaxial cable is used. It defines a process of transmitting a single signal at a time with a very high speed. It is generally used for LAN's.
- Broadband
- Analog transmission on standard cable television 75 ohm (Ω) cabling is used by this. It defines a process of transmitting multiple signals simultaneously with very high speed. It covers a large area as compared to Baseband Coaxial Cable.

Advantages and Disadvantages

- It can be used for both analog and digital transmission.
- It offers higher bandwidth as compared to twisted pair cable and can span longer distances.
- Because of better shielding in coaxial cable, loss of signal or attenuation is less.
- Better shielding also offers good noise immunity.
- It is relatively inexpensive as compared to optical fibers.
- It has lower error rates as compared to twisted pair.
- It is not as easy to tap as twisted pair because copper wire is contained in plastic jacket.
- It is usually more expensive than twisted pair.

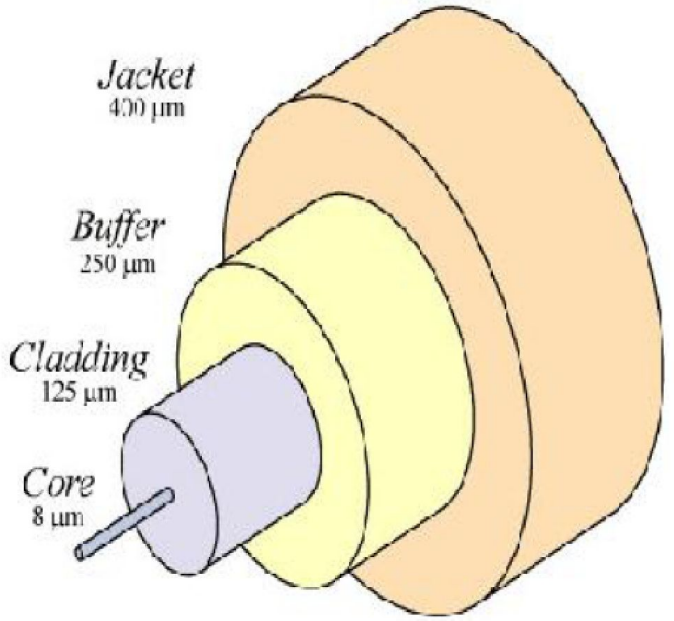
Fiber optics

- An optical transmission system has three key components:
- the light source,
- the transmission medium, and
- the detector



Fiber Optics: Construction

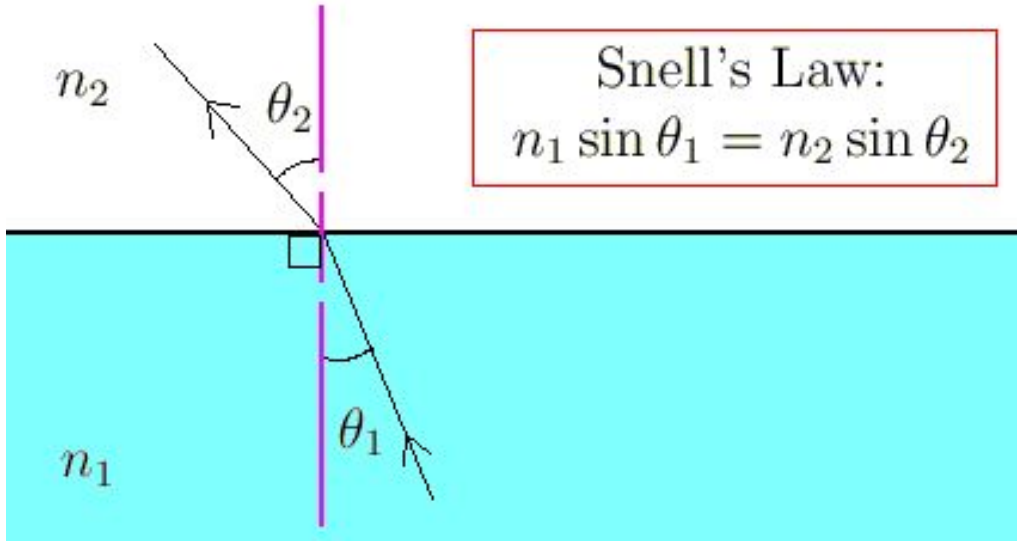
- Core: The core of a fiber cable is a cylinder of plastic that runs all along the fiber cable's length. The diameter of the core depends on the application used.
- Cladding: Cladding is an outer optical material that protects the core. The main function of the cladding is that it reflects the light back into the core.
- Buffer: The main function of the buffer is to protect the fiber from damage and thousands of optical fibers arranged in hundreds of optical cables.
- Jacket: These bundles are protected by the cable's outer covering that is called jacket.



Fiber Optics: Working Principle

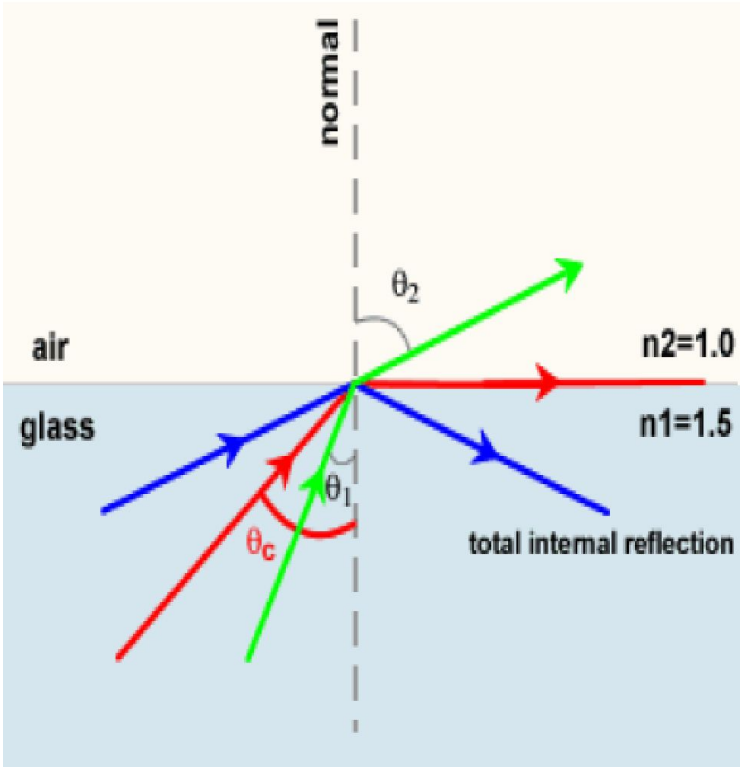
- A hair-thin Fiber consist of two concentric layers of high-purity silica glass the core and the cladding, which are enclosed by a protective sheath.
- Core and cladding have different refractive indices, with the core having a refractive index, n1, which is slightly higher than that of the cladding, n2.
- When light enters the fiber made of material with higher refractive index than the cladding surrounding it, it stays inside the material due to total internal reflection and is thus transmitted forward.
- **Index of refraction:** Index of refraction is a measurement of speed of light in material.

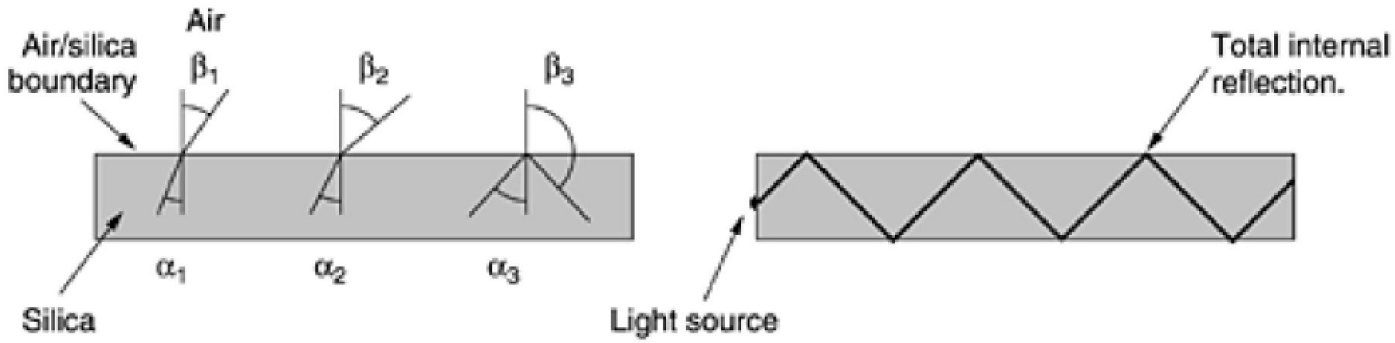
Snell's Law: Law of Refraction, Critical Angle, total internal Reflection



Snell's Law:

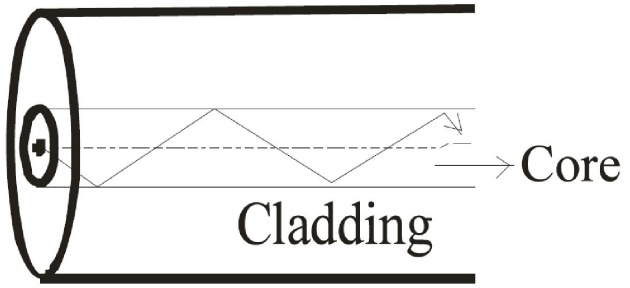
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

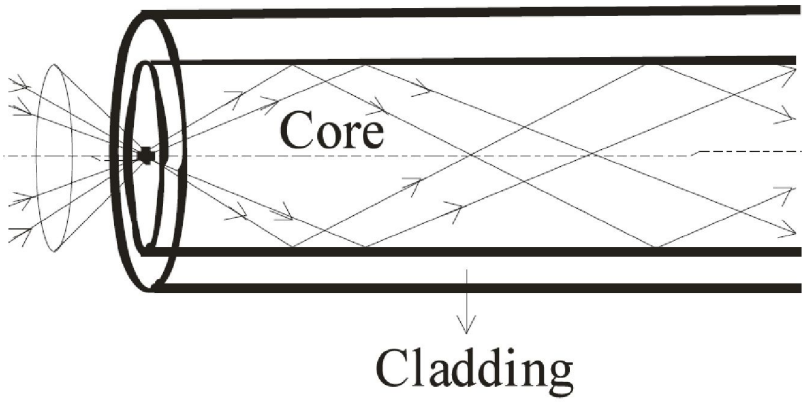




Fiber Optics: Modes

- Mode is the one which describes the nature of propagation of electromagnetic waves (light) in a wave guide (Fiber).
- Single mode fiber: In a fiber, if only one mode is transmitted through it, then it is said to be a single mode fiber.
- If more than one mode is transmitted through optical fiber, then it is said to be a multimode fiber.
- The larger core radii of multimode fibers make it easier to launch optical power into the fiber and facilitate the end to end connection of similar powers.





Types of Fibers

- **Step-index fiber** – The refractive index of the core is uniform throughout and undergoes an abrupt change (or step) at the cladding boundary.
- **Graded-index fiber** – The core refractive index is made to vary as a function of the radial distance from the center of the fiber.
- Further divided into:
- **Single-mode fiber** – These are excited with laser.
- **Multi-mode fiber** – These are excited with LED.

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

Fiber Optics: Advantages and Disadvantages

- **Advantages:**
- The transmission bandwidth of the fiber optic cables is higher than the metal cables.
- The amount of data transmission is higher in fiber optic cables.
- The power loss is very low and hence helpful in long-distance transmissions.
- Fiber optic cables provide high security and cannot be tapped.
- Fiber optic cables are the most secure way for data transmission.
- Fiber optic cables are immune to electromagnetic interference.
- These are not affected by electrical noise.
- **Disadvantages:**
- Though fiber optic cables last longer, the installation cost is high.
- The number of repeaters are to be increased with distance.
- They are fragile if not enclosed in a plastic sheath. Hence, more protection is needed than copper ones

Media Type	Maximum Segment Length	Speed	Cost	Advantages	Disadvantages
UTP	100 m	10 Mbps to 1000 Mbps	Least expensive	Easy to install; widely available and widely used	Susceptible to interference; can cover only a limited distance
STP	100 m	10 Mbps to 100 Mbps	More expensive than UTP	Reduced crosstalk; more resistant to EMI than Thinnet or UTP	Difficult to work with; can cover only a limited distance
Coaxial	500 m (Thicknet) 185 m (Thinnet)	10 Mbps to 100 Mbps	Relatively inexpensive, but more costly than UTP	Less susceptible to EMI interference than other types of copper media	Difficult to work with (Thicknet); limited bandwidth; limited application (Thinnet); damage to cable can bring down entire network
Fiber-Optic	10 km and farther (single-mode) 2 km and farther (multimode)	100 Mbps to 100 Gbps (single mode) 100 Mbps to 9.92 Gbps (multimode)	Expensive	Cannot be tapped, so security is better; can be used over great distances; is not susceptible to EMI; has a higher data rate than coaxial and twisted-pair cable	Difficult to terminate

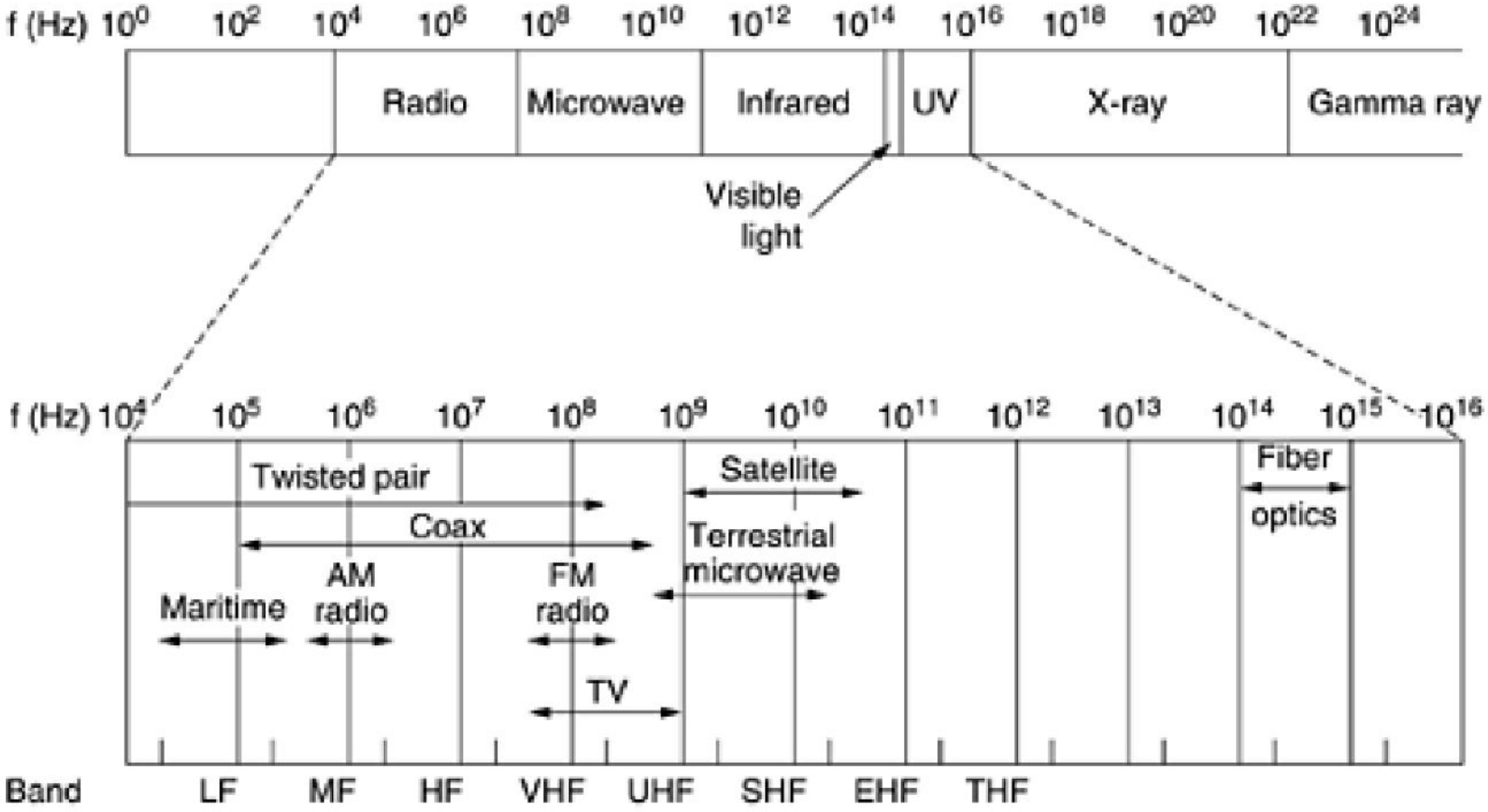
Unguided Media: Wireless Transmission

- Electromagnetic Spectrum
- Radio transmission
- Microwave Transmission
- Infrared Transmission
- Light Transmission

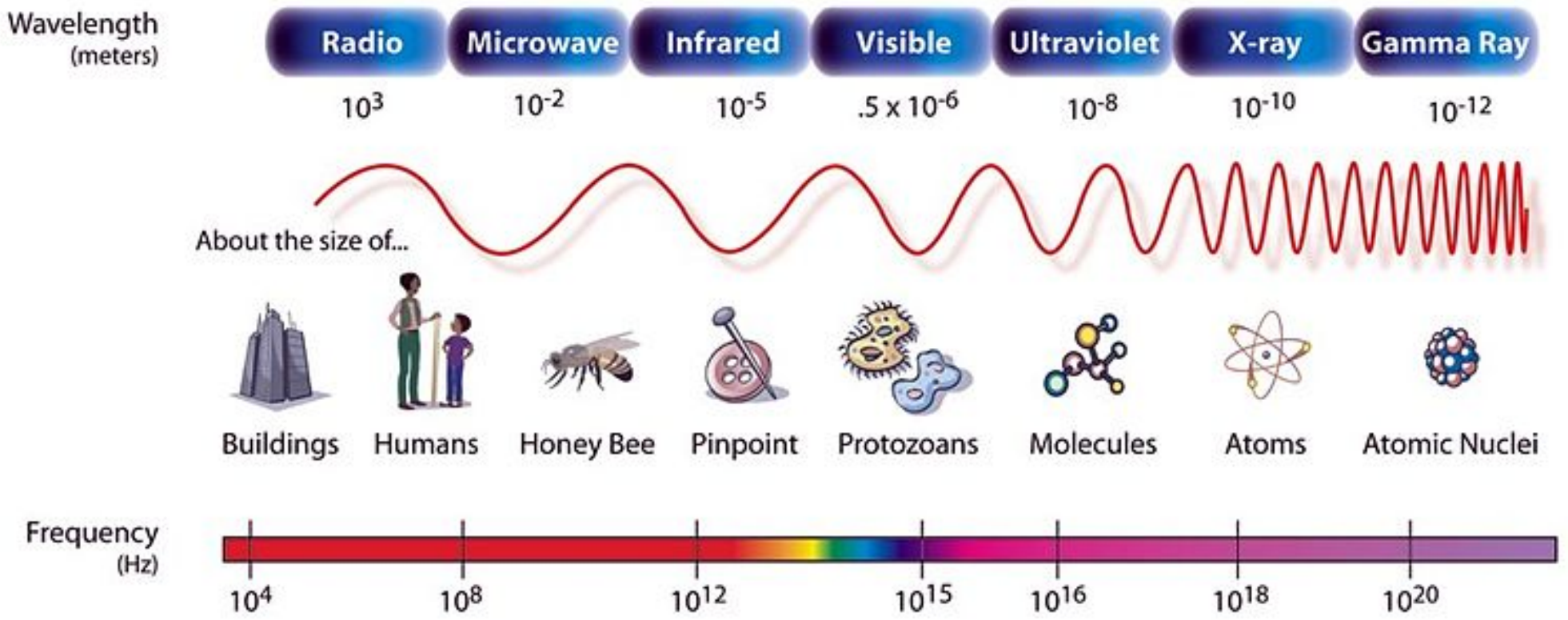
Electromagnetic Spectrum

- Electromagnetic waves, can propagate through space, were predicted by J C Maxwell in 1865 and observed by Heinrich Hertz in 1887.
- When an antenna of the appropriate size is attached to an electrical circuit, the electromagnetic waves can be broadcast efficiently and received by a receiver some distance away.
- In vacuum, all electromagnetic waves travel at the same speed, no matter what their frequency.
- In copper or fiber the speed slows to about 2/3 of this value and becomes slightly frequency dependent.

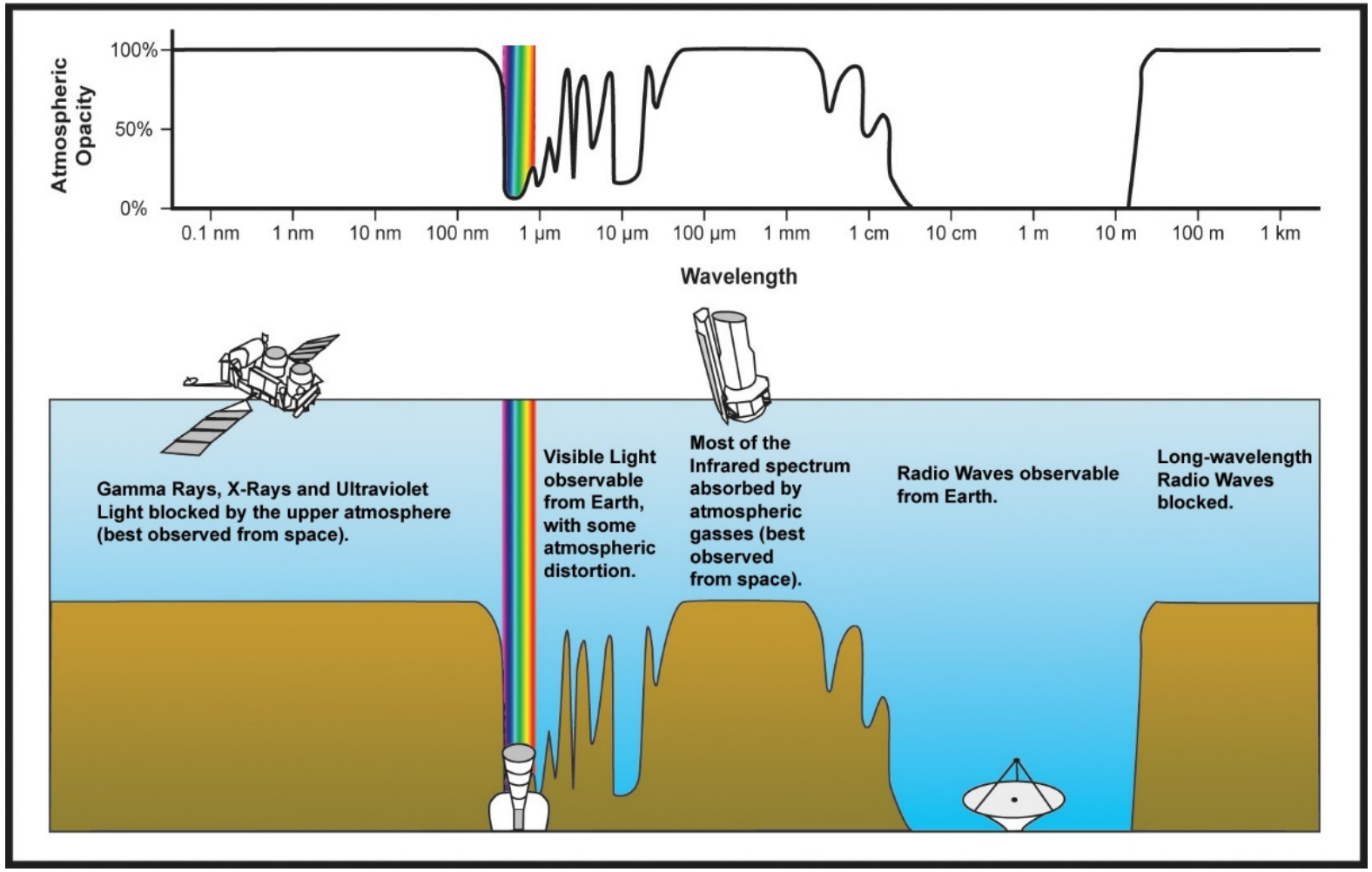
Electromagnetic spectrum and its uses for communication



Electromagnetic spectrum and its uses for communication



Electromagnetic spectrum and its uses for communication



Electromagnetic spectrum and its uses for communication

- The radio, microwave, infrared, and visible light portions of the spectrum can all be used for transmitting information
- by modulating the amplitude, frequency, or phase of the waves.
- Ultraviolet light, X-rays, and gamma rays would be even better, due to their higher frequencies.
- but they are hard to produce and modulate, do not propagate well through buildings, and are dangerous to living things.

Radio Transmission (10 kHz – 300 MHz)

- easy to generate, can travel long distances, and can penetrate buildings easily, so they are widely used for communication, both indoors and outdoors.
- Radio waves also are omnidirectional, meaning that they travel in all directions from the source, so the transmitter and receiver do not have to be carefully aligned physically.
- Due to radio's ability to travel long distances, interference between users is a problem. For this reason, all governments tightly license the use of radio transmitters.
- There is a wide range of subcategories contained within radio including AM and FM radio

Radio Transmission

- **AM radio waves**: commercial radio signals (540 and 1600 kHz), information is carried by amplitude variation, while the frequency remains constant.
- **FM radio waves**: commercial radio signals (88 and 108 MHz), information is carried by frequency modulation, while the signal amplitude remains constant.
- TV broadcast: (174 – 216 MHz).

Microwave Transmission (300 MHz – 300 GHz)

- Microwaves are “small” compared to waves used in typical radio broadcasting.
- The microwave portion of the electromagnetic spectrum can be subdivided into:
  - **Extremely High Frequency (30 to 300 GHz):** wavelength range of 10 to 1 mm, so it is sometimes called the millimeter band.
  - **Super High Frequency (3 to 30 GHz):** ten to one centimeters, used for wireless LANs, cell phones, satellite communication, microwave radio relay links, and numerous short range terrestrial data links
  - **Ultra-High Frequency (300 MHz to 3 GHz):** 10 centimeters to 1 meter, used for television broadcasting, cordless phones, walkie-talkies, satellite communication, and numerous other applications

Infrared and Millimeter Wave

- Unguided infrared and millimeter waves are widely used for short-range communication (The remote controls used on televisions, VCRs, and stereos all use infrared communication).
- They are relatively directional, cheap, and easy to build but have a major drawback: they do not pass through solid objects.
- In general, as we go from long-wave radio toward visible light, the waves behave more and more like light and less and less like radio.
- On the other hand, infrared system in one room of a building will not interfere with a similar system in adjacent rooms or buildings.
- Infrared communication has a limited use on the desktop, for example, connecting notebook computers and printers, it is not a major player in the communication.

Light Wave Transmission

- A more modern application is to connect the LANs in two buildings lasers mounted on their rooftops.
- Coherent optical signaling using lasers is inherently unidirectional, so each building needs its own laser and its own photodetector. This scheme offers very high bandwidth and very low cost.
- It is also relatively easy to install and, unlike microwave, does not require an FCC license.

Multiplexing

- **Definition**: Multiplexing is a technique which combines multiple signals into one signal, suitable for transmission over a communication channel such as coaxial cable or optical fiber.

- **By doing multiplexing**, large amount bandwidth can be saved, cost can be reduced, circuit complexity can be reduced and multiple signals can be sent simultaneously over a single communication channel.

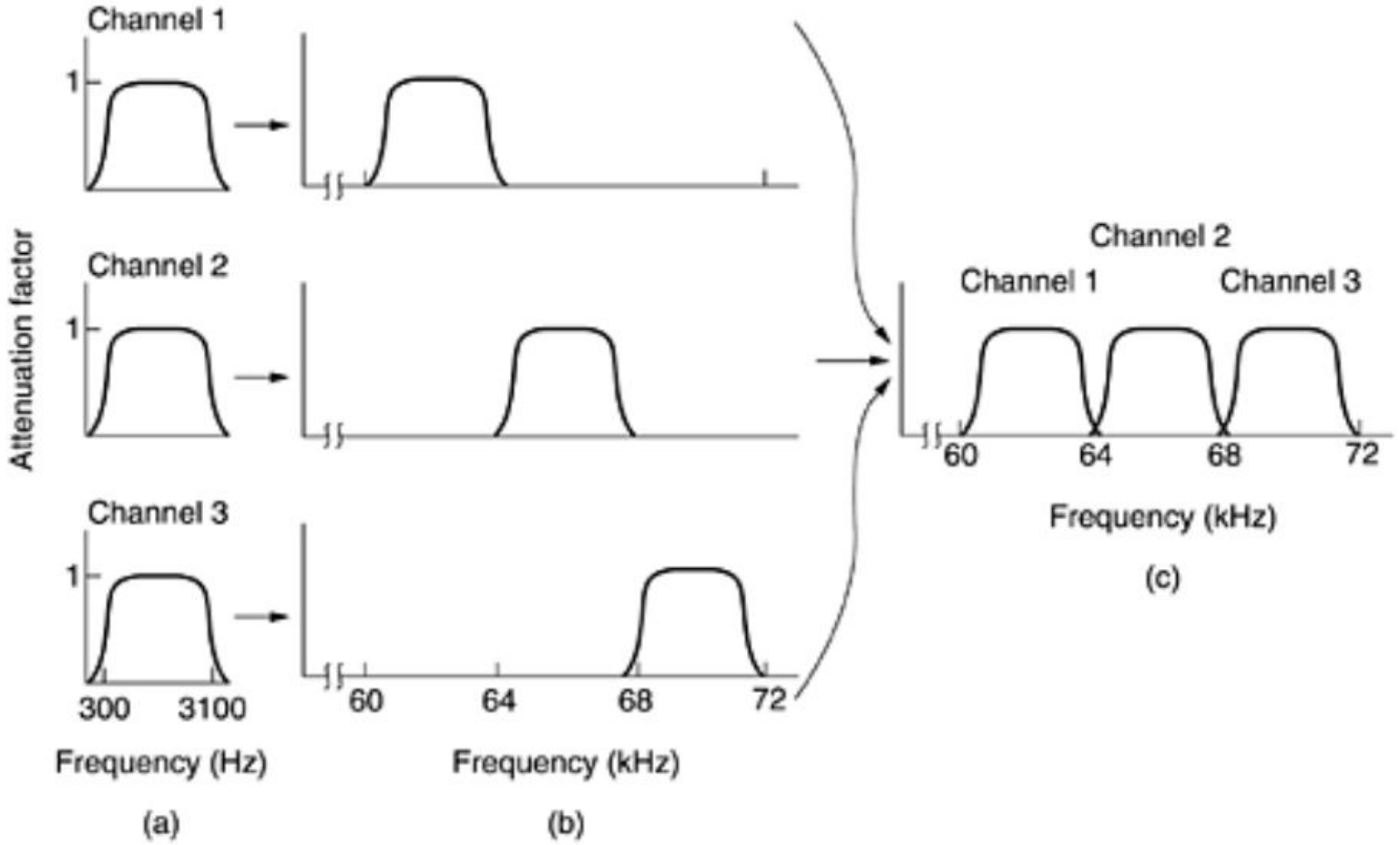
- **Analog**: Frequency Division Multiplexing and Wavelength Division Multiplexing

- **Digital**: Time Division Multiplexing

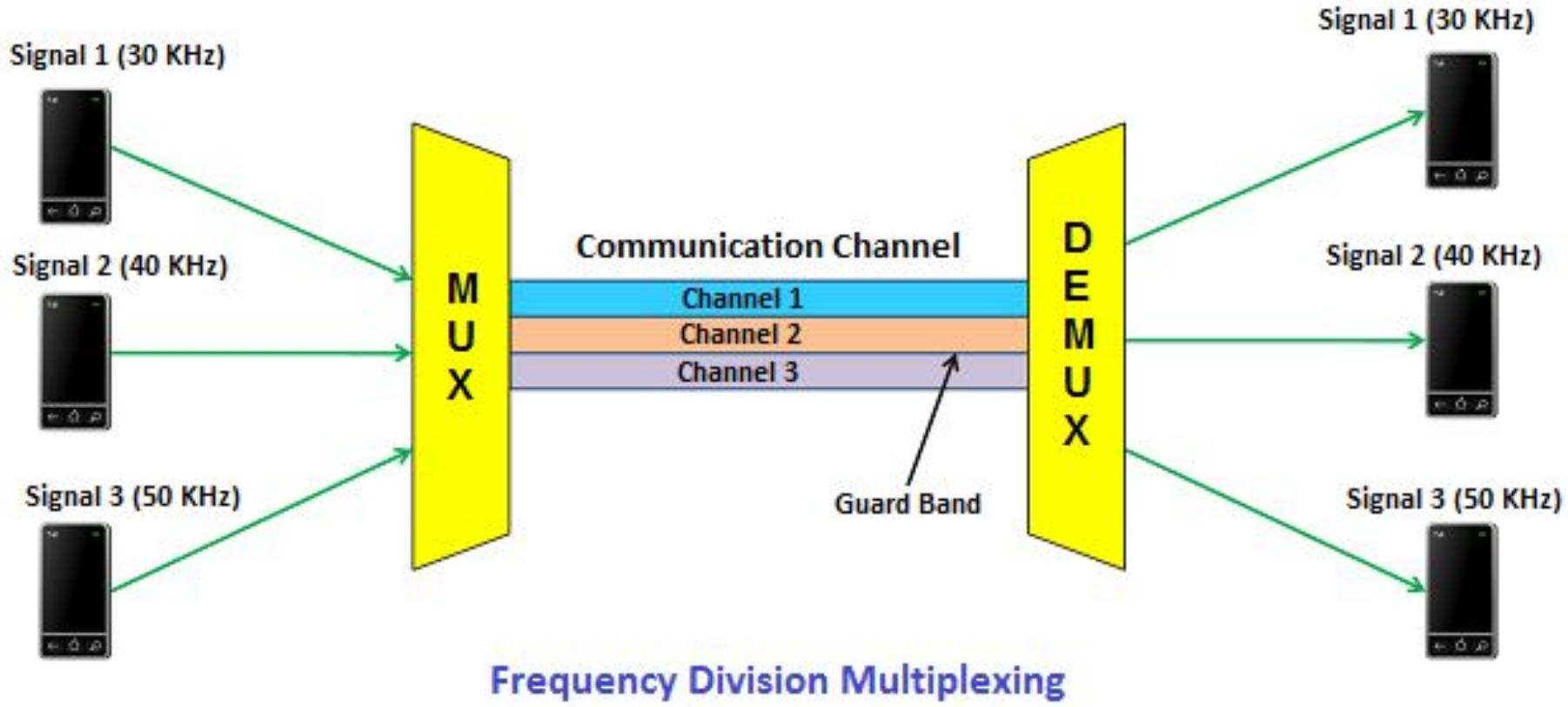
Frequency Division Multiplexing (FDM)

- popular multiplexing technique in TV and radio.
- combines multiple signals into one signal transmitted over the communication channel.
- bandwidth of the communication channel should be greater than the combined bandwidth of individual signals.
- divides the bandwidth of a channel into several logical sub-channels and each logical sub-channel is separated by an unused bandwidth called Guard Band to prevent overlapping of signals.
- A guard band is a narrow frequency range that separates two signal frequencies.

FDM Operation



FDM Operation



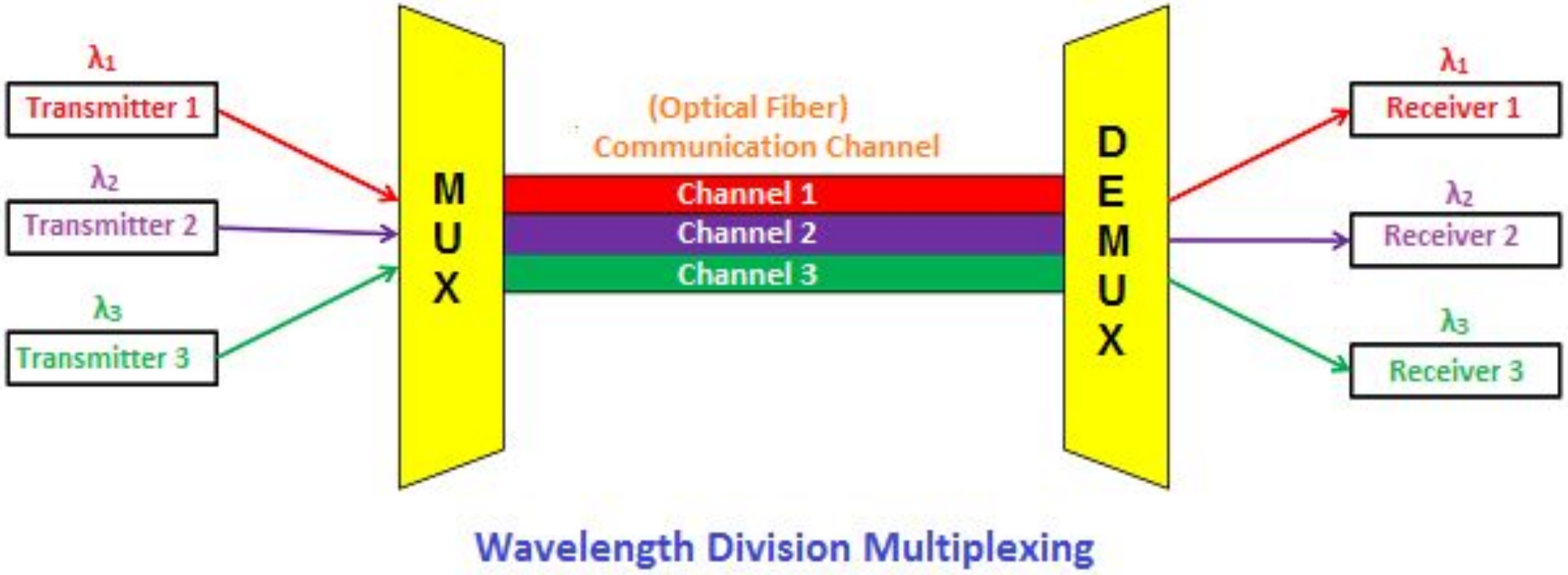
FDM

- **Advantages of Frequency Division Multiplexing (FDM)**
  - It transmits multiple signals simultaneously.
  - In frequency division multiplexing, the demodulation process is easy.
  - It does not need Synchronization between transmitter and receiver.
- **Disadvantages of Frequency Division Multiplexing (FDM)**
  - It needs a large bandwidth communication channel.
- **Applications of Frequency Division Multiplexing (FDM)**
  - Frequency division multiplexing is used for FM and AM radio broadcasting.
  - It is used in first generation cellular telephone.
  - It is used in television broadcasting.

Wavelength Division Multiplexing (WDM)

- Wavelength division multiplexing is a technology that increases the bandwidth of a communication channel (optical fiber) by simultaneously allowing multiple optical signals through it.
- the working principle of wavelength division multiplexing is similar to frequency division multiplexing. The only difference is in wavelength division multiplexing optical signals are used instead of electrical signals.
- The main advantage of WDM system is that only need to upgrade the multiplexer and demultiplexer at each end; no need to buy more fibers which are more expensive.

WDM


λ1
Transmitter 1
λ2
Transmitter 2
λ3
Transmitter 3
MUX
(Optical Fiber)
Communication Channel
Channel 1
Channel 2
Channel 3
DEMUX
λ1
Receiver 1
λ2
Receiver 2
λ3
Receiver 3
Wavelength Division Multiplexing

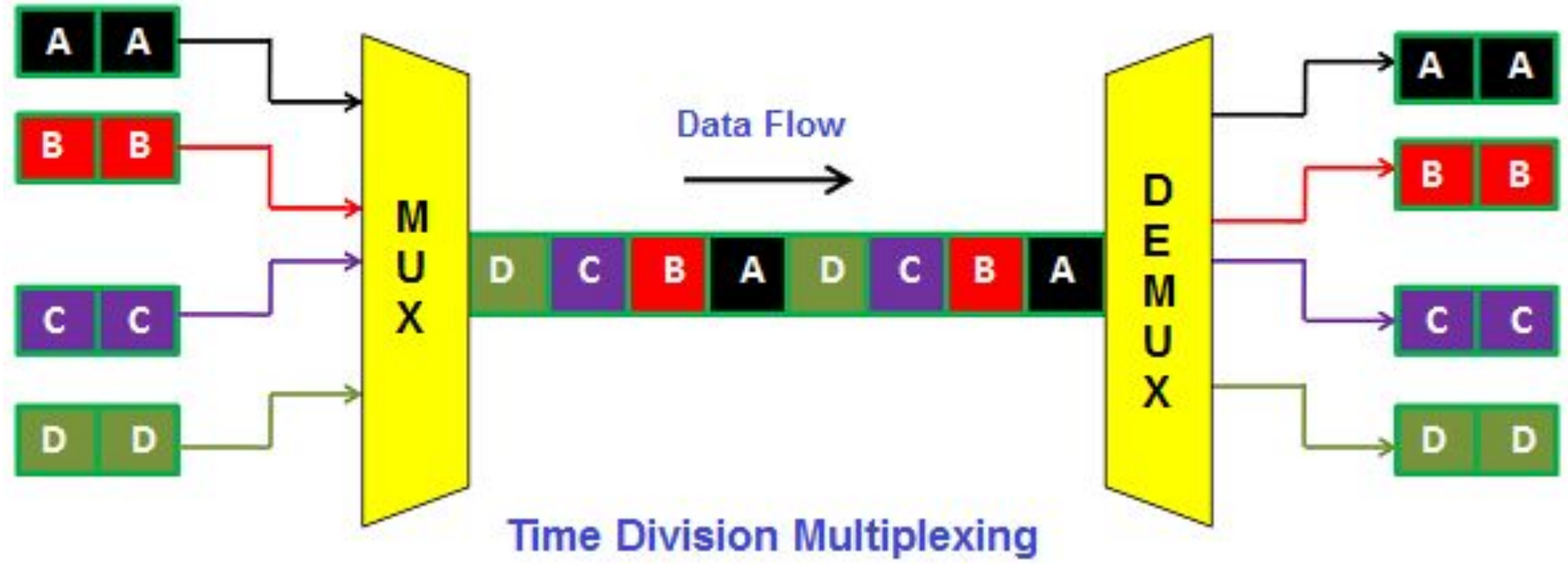
WDM

- WDM techniques are of two types:
  - Dense Wavelength Division Multiplexing (longer distances)
  - Coarse Wavelength Division Multiplexing (Shorter distances)
- **Advantages of Wavelength Division Multiplexing (WDM)**
  - WDM allows transmission of data in two directions simultaneously
  - Low cost
  - Greater transmission capacity
  - High security
  - Long distance communication with low signal loss

Time Division Multiplexing (digital)

- multiple signals are combined and transmitted one after another on the same communication channel.
- in time division multiplexing, all signals operate with the same frequency are transmitted at different times.

TDM

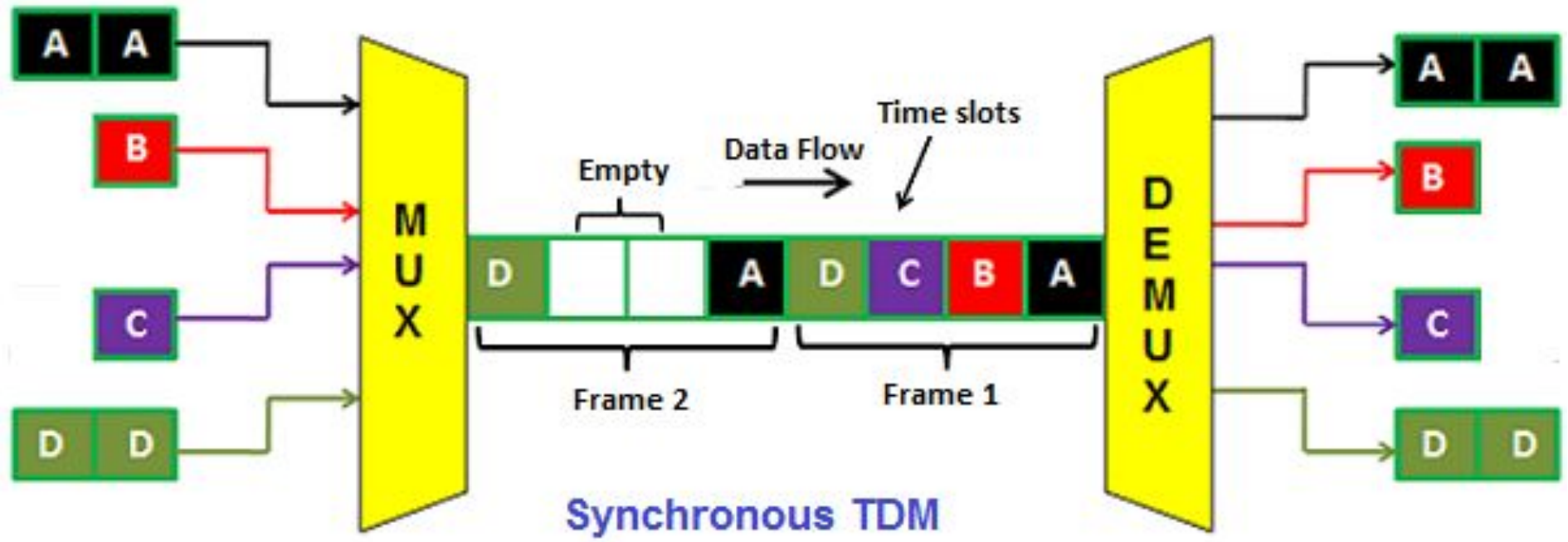

A A
B B
C C
D D
MUX
Data Flow
D C B A D C B A
DEMUX
A A
B B
C C
D D
Time Division Multiplexing

TDM

- Time Division Multiplexing is mainly classified into two types:
  - Synchronous TDM (fixed time slots)
  - Asynchronous TDM (no fixed time slots they are flexible).
- **Advantages of Time Division Multiplexing (TDM)**
  - Full bandwidth is utilized by a user at a particular time.
  - The time division multiplexing technique is more flexible than frequency division multiplexing.
  - In time division multiplexing, the problem of crosstalk is very less.
- **Disadvantages of Time Division Multiplexing (TDM)**
  - In time division multiplexing, synchronization is required.

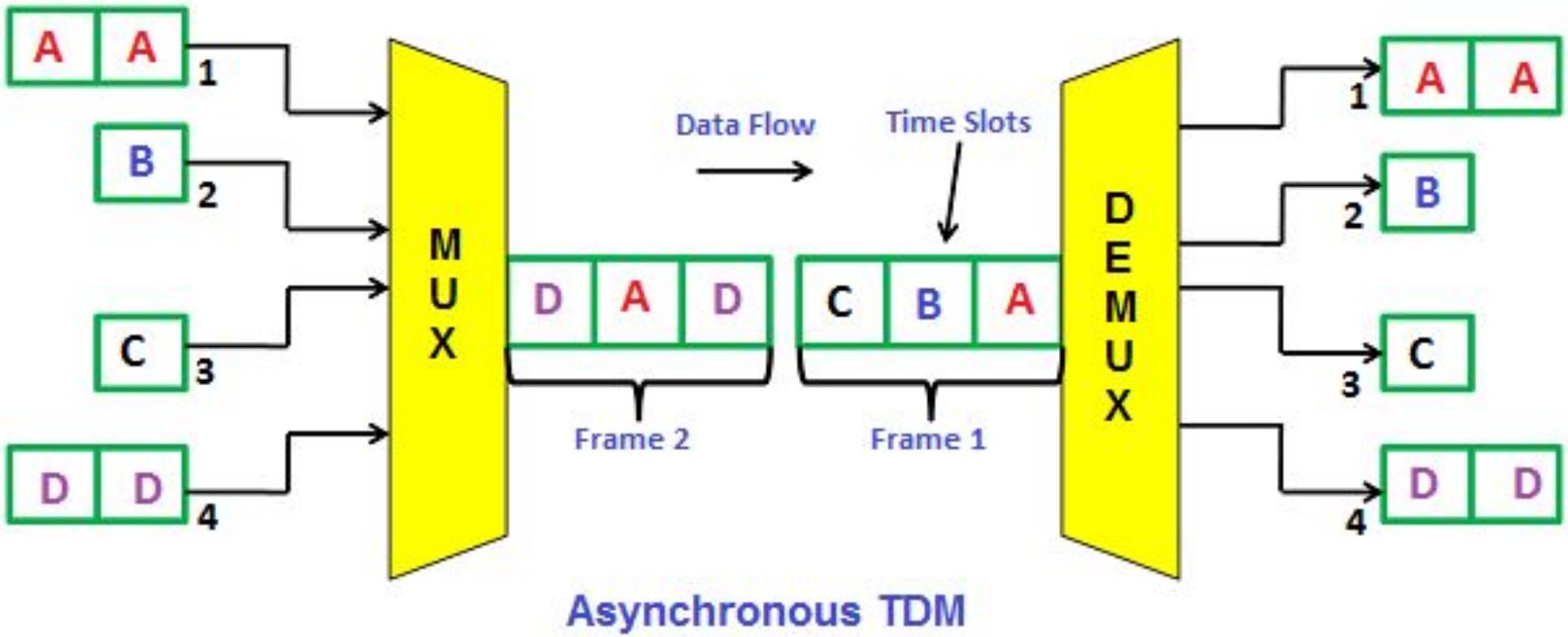
Synchronous TDM

synchronous TDM, the number of time slots is equal to the number of transmitters.



Asynchronous TDM

in Asynchronous TDM, the number of time slots is not equal to the number of devices (transmitters). The time slots in asynchronous TDM are always less than the number of devices (transmitter)



Asynchronous TDM