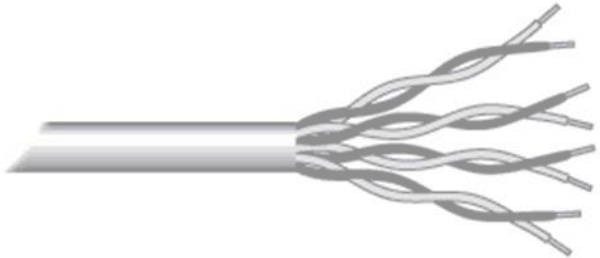
ICT 4010 Data and Communication Networks



Data Transmission Media

Lecture 5

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Data Transmission Introduction

- Transmission is the process of sending or propagating an information signal over a physical **point to point** or **point to multi point** transmission medium.
  - Between transmitter and receiver
  - Transmission can either be analog or digital
  - Mainly deals with **Physical Layer** of OSI Model

Data Transmission Introduction

- Transmission can occur through guided or unguided (wireless) medium

- Guided media has boundaries
  - e.g. physical cable, fiber optics, twisted pair and coaxial

Some Criteria For Selecting The Right Media

- Electromagnetic Interference (EMI)
  - or Radio Frequency Interference (RFI).
- Corners and Small Spaces
- Security
- Existing Infrastructure
- Speed
- Anticipated Growth
- Flexibility and Ease of Use
- Cost
- Distance of coverage

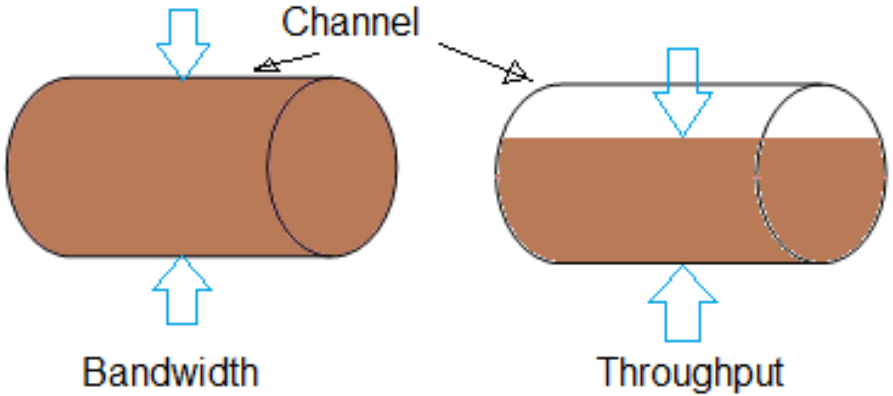
Bandwidth and Speed

- Speed refers to amount of information that can be transmitted through a channel in one second
  - Measured in bits per second (bps)

Bandwidth and Speed

- **Bandwidth** is the measure of how much data **can be** transferred from a source to a destination at any given time.

- **Throughput** is the measure of how much data **was actually** transferred from a source at any given time



Bandwidth and Speed

- Bandwidth is the range of frequencies that a channel (such as a cable) can support (the differences between the highest and lowest frequency within the channel)
  - Greater range means greater bandwidth
  - Greater bandwidth means greater transmission capacity

Bandwidth and Speed

- Bandwidth is also defined as the amount of data that can be transmitted in a fixed amount of time.
  - It is expressed in **cycles per second (Hertz)** for Analogue devices
  - and **bits per second (bps)** for Digital Devices.

Carrier Sense Multiple Access (CSMA)

- In networking, a single transmission channel can be used to transmit multiple signals

- CSMA is a Media Access Control (MAC) protocol
  - Used to control the flow of data in a transmission media so that packets do not get lost and data integrity is maintained

Carrier Sense Multiple Access (CSMA)

- CSMA senses the state of medium in order to prevent or recover from a collision
  - Collision happens when two transmitters transmit at the same time
  - Data gets scrambled and receivers would not be able to discern one from another causing information to get lost
- Two general categories of CSMA
  - CSMA/CD
  - CSMA/CA

Carrier Sense Multiple Access (CSMA)

- **CSMA/CD (CSMA with Collision Detection)**
  - Listens for collisions in the media
  - Immediately terminates transmission once a collision is detected
  - Minimizes recovery time
  - Transmits bits which are assembled at the receiver
  - Used mostly in wired installations

Carrier Sense Multiple Access (CSMA)

- **CSMA/CA (with Collision Avoidance)**
  - Does not deal with recovery
  - Checks whether the channel is in use
    - If in use, the transmitter waits until it is idle before it starts transmitting
  - Effectively minimises possibility of collisions and makes more efficient use of the medium
  - Transmits entire frame
  - Mostly used in wireless connections

CSMA/CD - Analogy

- This can be likened to what happens in a meeting, where all the participants can talk to each other through a common medium (the air).
  - Before speaking, each participant politely waits for the current speaker to finish. If two speakers somehow start speaking at the same time, this creates a collision.
  - In this case, both stop and wait for short, random periods of time. The hope is that by each choosing a random period of time, both speakers will not choose the same time to try to speak again, thus avoiding another collision.

Collision Domain

- Part of network where a packet collision can occur
- A collision occurs when two devices send a packet at the same time on the shared network segment
- If packets collide, both devices must send the packets again, which reduces network efficiency

Collision Domain

- Network regions in which collisions are propagated (increased/spread)
  - Repeaters and hubs propagate collisions
  - Bridges, switches and routers do not

- Reduce collision frequency by breaking the network into segments bounded by:
  - Bridges
  - Switches
  - Router

Broadcast Domain

- A broadcast domain is a set of devices whereby a broadcast frame sent on one device will be received by all other devices
- Broadcast frames used for:
  - finding services: ie a PC searching for a network printer
  - Advertising services: ie. a network printer indicating it's availability

  - 192.168.10.0 (.1 - .254) 192.168.10.255

- Network region in which broadcast frames are propagated
  - Repeaters, hubs, bridges, & switches propagate broadcasts
  - Routers do not propagate broadcasts

Broadcast Domain

- Broadcasts are necessary for a network function.

- Some devices and protocols produce lots of broadcasts;
  - However, high occurrences of broadcasts should be avoided
  - The frequency of broadcasts can be kept manageable by limiting the LAN size.
  - LANs can then be cross-connected by **routers** to make a larger internetwork.

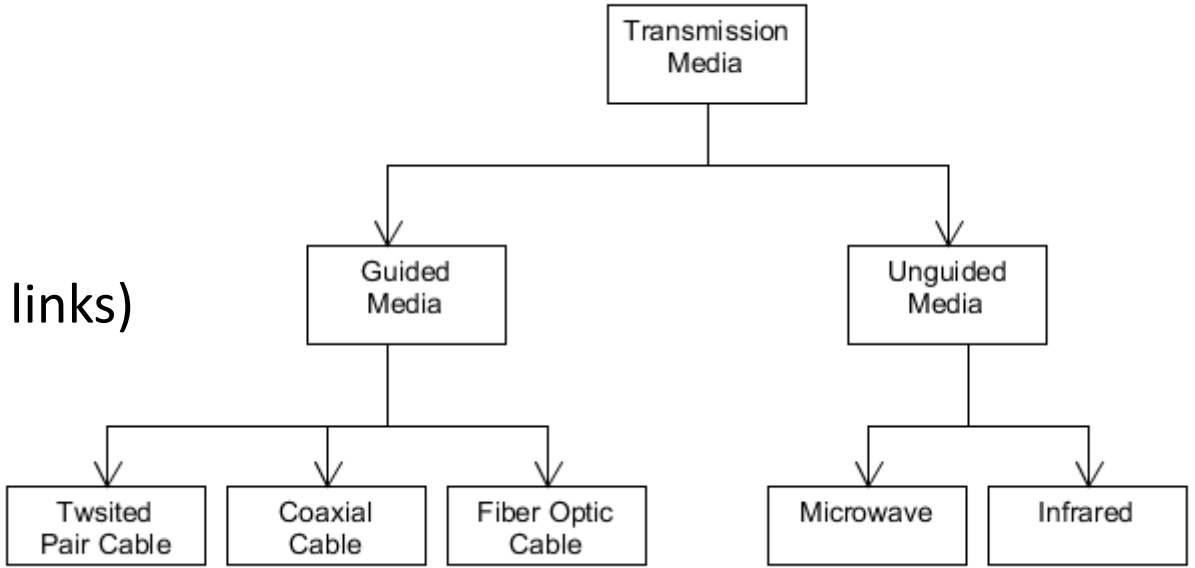
Broadcast and Collision Domains Recap

- Collisions
  - spread throughout a LAN segment
  - spread across hubs & repeaters
  - are stopped by **switches**, **bridges & routers**

- Broadcasts
  - spread throughout an entire LAN
  - spread across hubs, switches, bridges
  - are stopped only by **routers**

Classification of Transmission Media

- **Guided Media**
  - Copper Cables
    - Twisted Pair Cable
    - Coaxial Cable
  - Fiber Optic Cable
- **Unguided Media**
  - Microwave (or Radio links)
  - Infrared



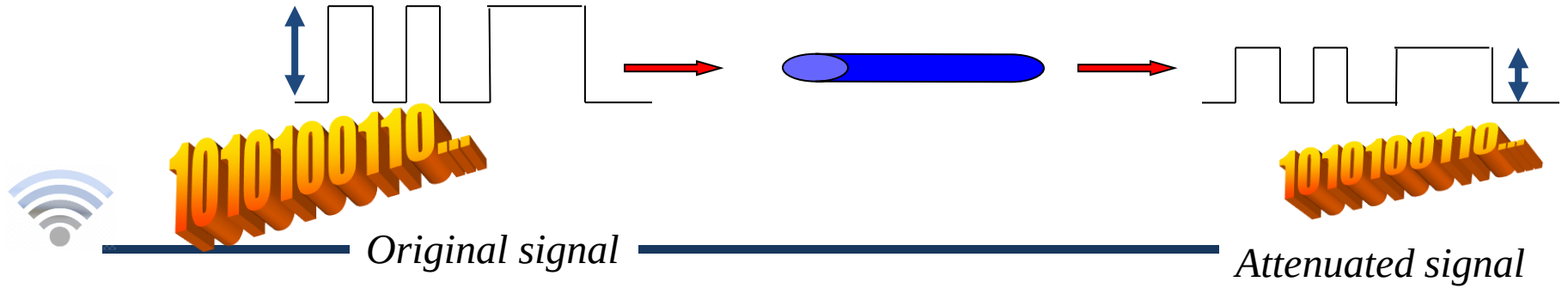
Guided Media

- **Copper cable** is the oldest, cheapest and the most common form of transmission medium currently
- Types of Copper Cables
  - Coaxial Cable
  - Unshielded Twisted Pair (UTP)
  - Shielded Twisted Pair (STP)

- **Optical fiber** is increasingly being used for high speed applications

Cable characteristics

- A cable moves electromagnetic (EM) waves by providing a channel in which the pair of conductors act like mirrors between which the wave bounces back and forth
- While traversing through the cable however, the wave loses energy and the intensity of the wave diminishes due to physical effects
- This results in a decrease in signal amplitude at the receiving end called ***attenuation***
  - ie, the magnitude of the signal diminishes as it reaches the end of the cable



Cable Characteristics

- ***The longer the cable, the larger the attenuation***
  - It is desirable to use larger, more expensive cables in situations that require high transmission quality over long distances
  - High transmission quality means that the receiver is able to detect correctly if a 1 or a 0 is transmitted
  - If a signal is highly attenuated at the receiving end, the receiver will not be able to distinguish between the levels of 1 and 0, and this will lead to erroneous transmission of information

Attenuation

- Reduction of signal strength during transmission
- Attenuation is the opposite of amplification, and is normal when a signal is sent from one point to another
- If the signal attenuates too much, it becomes unintelligible, which is why most networks require repeaters at regular intervals
- Attenuation is measured in decibels

Factors that Influence Attenuation

- Attenuation varies with:
  - Frequency
  - EMI (Electro-Magnetic Interference)
  - Impedance
  - Echo
  - Resistance

Factors that Influence Attenuation

Frequency

- Attenuation increases with frequency
- higher frequencies attenuate more than lower frequencies.

Factors that Influence Attenuation

Electromagnetic Interference (EMI)

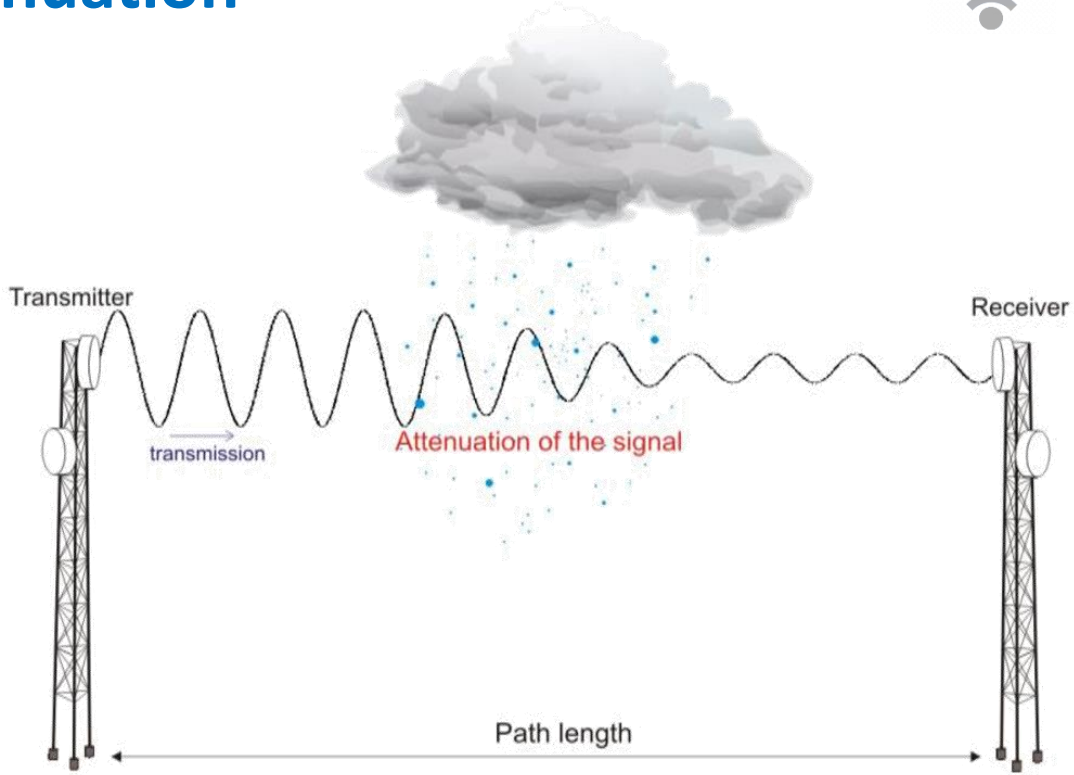
- EMI is a result of electromagnetic emissions
  - Every piece of electrically powered equipment transmits and receives electromagnetic energy

- Since LANs operate at very high speeds, there can be problems / loss of signal strength due to EMI

Factors that Influence Attenuation

Impedance

- Expressed in ohms, defined as opposition to alternating current as a result of resistance and inductance in a component



Unguided attenuation example

Factors that Influence Attenuation

Echo

- Echo or return loss is a reflection, that occurs when an electrical signal encounters an impedance irregularity.
- The greater the distance from a source to an irregularity, the greater the time-delay in the reflected signal.

Factors that Influence Attenuation

Resistance

- Cable resistance depends upon the specific resistivity of the material, the length, and the cross-sectional area of the cable.

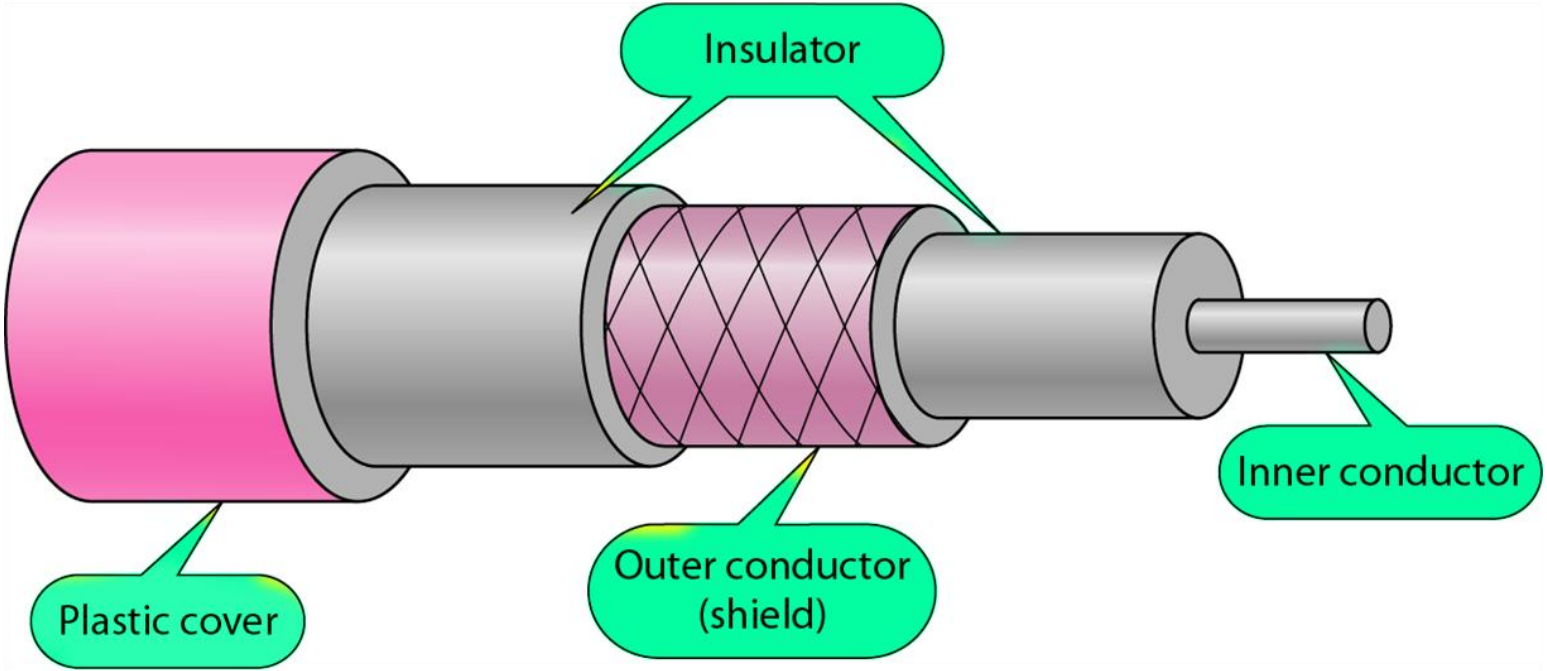
Coaxial Cable

- Consist of a centre wire (inner conductor) surrounded by insulation and then a grounded shield of braided wire (outer conductor) which together from an electromagnetic field
- Shield or outer conductor minimizes electrical and radio frequency interference (stray signals from the air)
- High bandwidth but lossy channel
- Repeater is used to regenerate weakened signals.

Coaxial Cable

- Networking coaxial cable has 50 ohms resistance
- Television coaxial cable has 75 ohms resistance
- Two types of Coaxial cable
  - Thick Coaxial (10Base5)
  - Thin Coaxial (10Base2)

Coaxial Cable

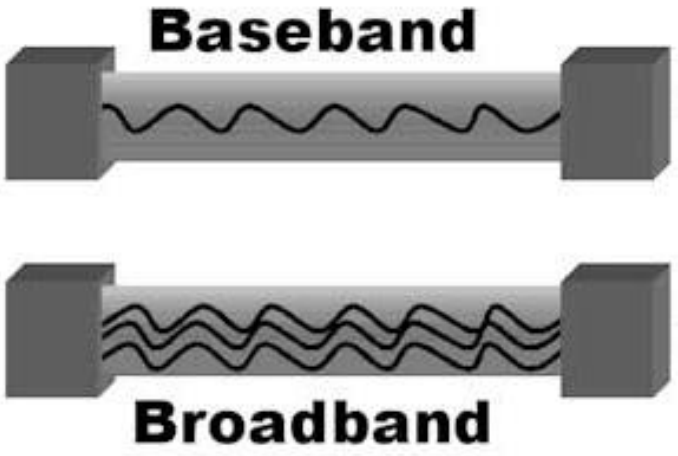


10Base5 Cable

- Also known as: **Thick Ethernet** or **Thicknet** or **Thick Coax**
  - Maximum data transfer is 10Mbps
  - Maximum cable length is 500 meters
  - Solid inner conductor that is rigid and difficult to bend
  - Mostly used as a backbone where flexibility isn't really needed

10Base5 Cable

- **Thick Ethernet cable (cont.)**
  - Uses baseband transmission
  - Can connect maximum 100 devices per segment
  - Transmits electrical signals better over longer distances
  - Lower cost



10Base2 Cable

- Also known as: **Thin Ethernet** or **Thinnet**
- Thinner with stranded inner conductor thus more flexible and used mostly as patch cords
- Operates at 10Mbps
- Uses baseband transmission
- Maximum cable length 200 meters

10Base2 Cable [2]

- Connect maximum 30 devices per segment
- Shorter transmission distances
- Higher attenuation (resistance)
- More expensive

Unshielded Twisted Pair (UTP)

- Pair of wires twisted together and protected by a thin jacket
- Colour coded pairs of insulated copper wires twisted around each other and encased in plastic coating or jacket
- Cable can be made with variety of materials, sizes of conductors and numbers of pairs inside a single cable
- Comes in both solid or stranded filament
  - Solid usually intended for trunk cabling
  - Stranded intended for patch cables because of flexibility

Unshielded Twisted Pair

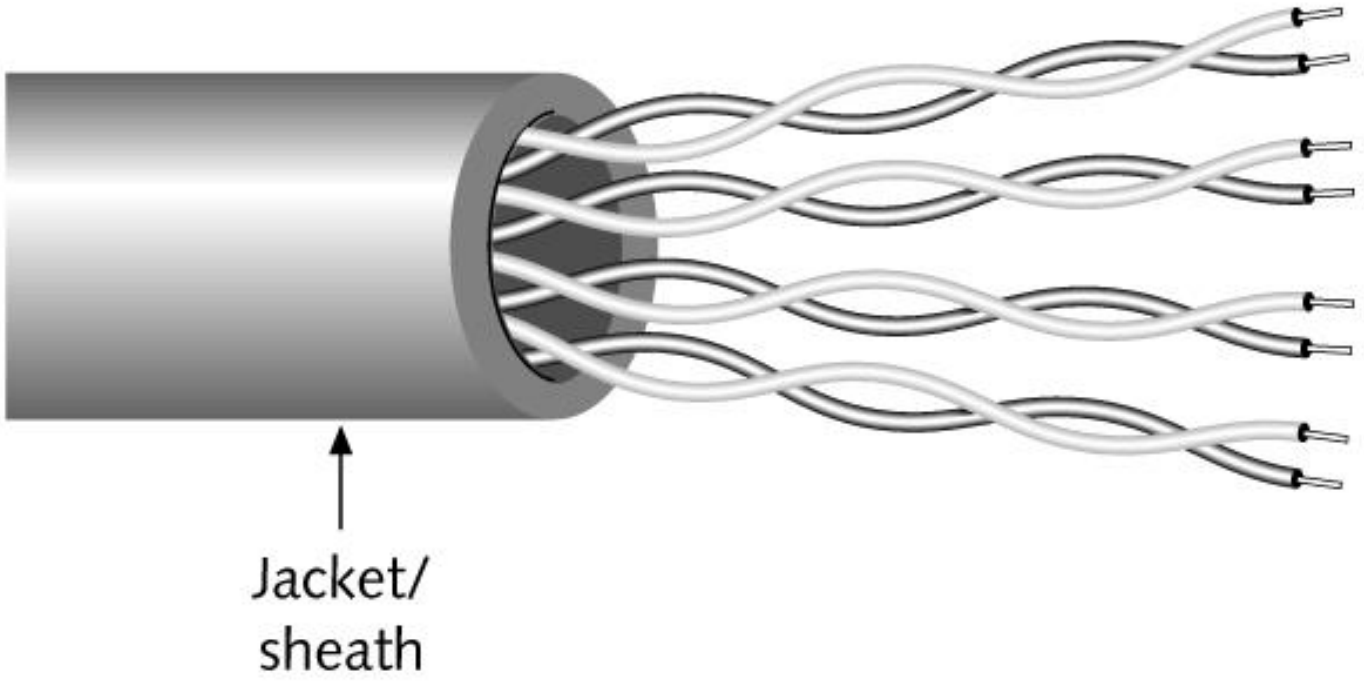
- **CAT 5 (Category 5 cable)**
  - 100Mbps data rate; Used in 100BaseT Ethernet and 155 Mbps ATM
- **CAT 5E and CAT 6**
  - Electrically backwards compatible with CAT 5
  - CAT 6 assures at least double the channel bandwidth of CAT 5
  - The bi-directional dual duplex transmission scheme employed by 1000Base-T actually requires each end of a CAT 6 cable to transmit on one conductor of each of the four pairs simultaneously

Unshielded Twisted Pair

- Differences between CAT 5e and CAT 6 cables
  - CAT 6 offers higher signal to noise ratio
    - ratio of the strength of an electrical (or other) signal carrying information to that of unwanted interference
  - CAT 6 is compatible with 10GBaseT (10 Gigabit Ethernet)

- **CAT 6 cable is better suited to handle faster connection speeds**

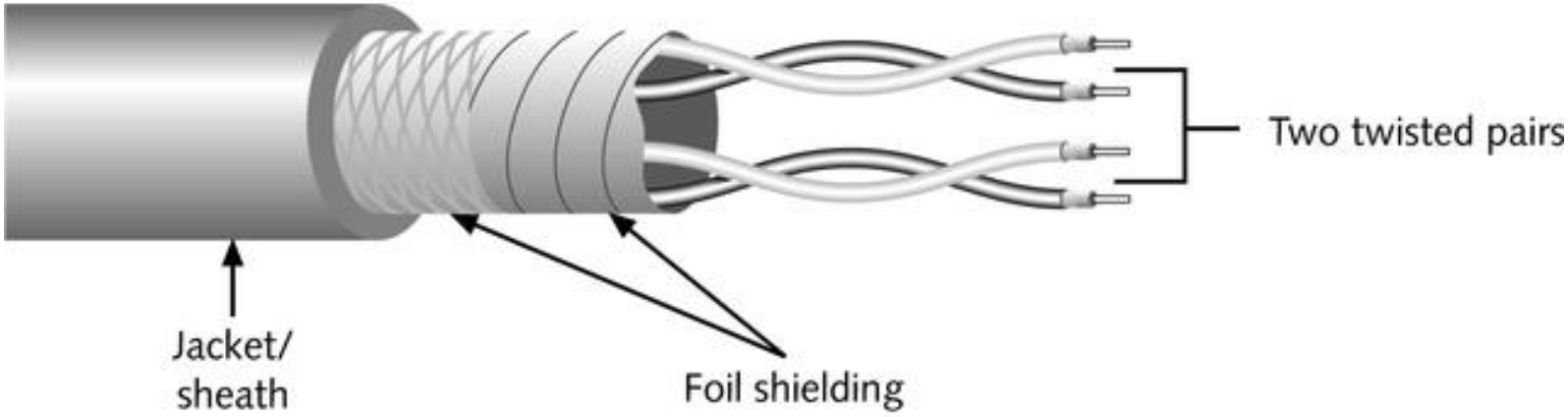
Unshielded Twisted Pair



Shielded Twisted Pair (STP)

- STP cable consists of twisted wire pairs that are individually insulated and surrounded by shielding made of metallic substance
  - Shielding absorbs radiation and reduces EMI therefore STP can handle higher data speeds than UTP
- 150 ohm cable composed of two copper pairs

Shielded Twisted Pair (STP)



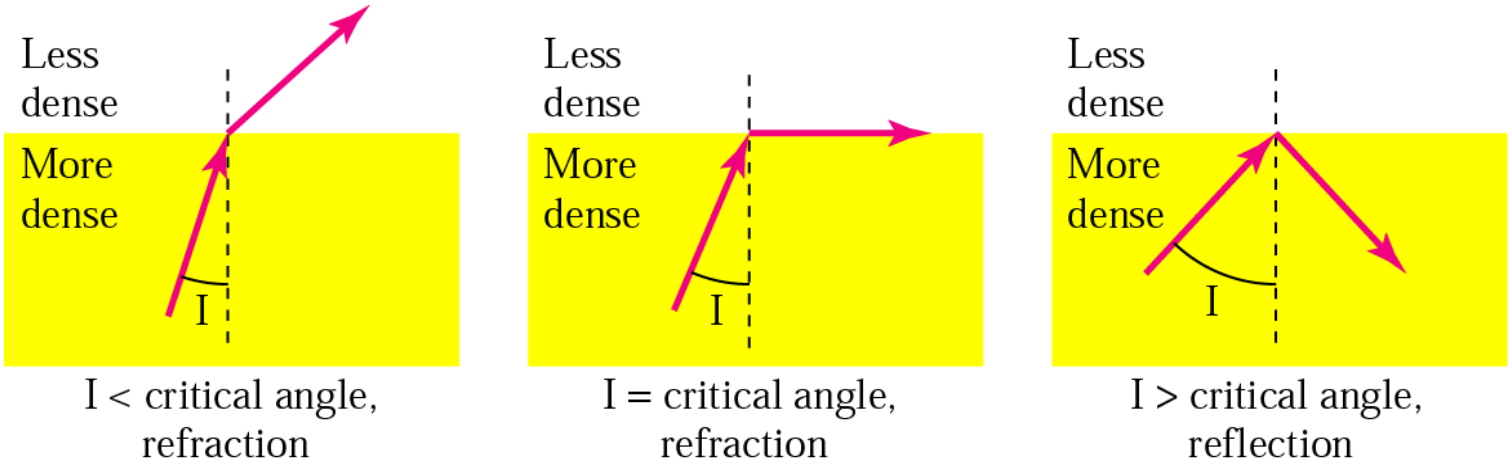
UTP VS STP CABLE

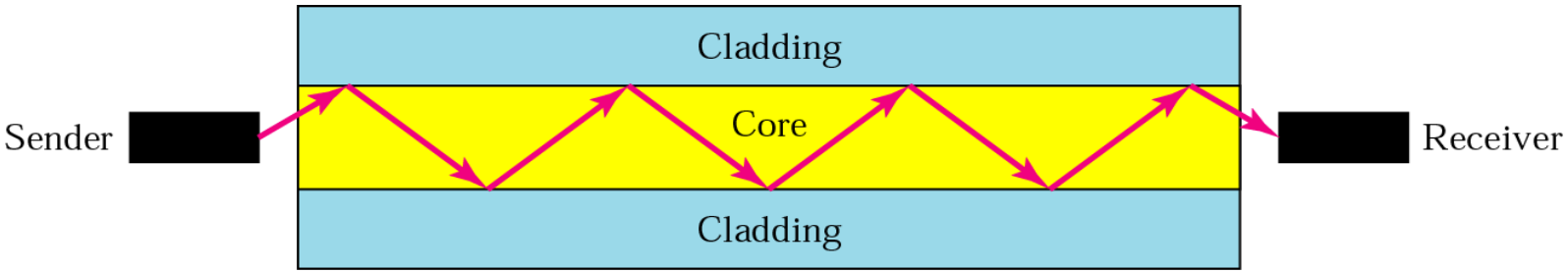
- **Cost**
  - Typically STP is more expensive
- **Connector**
  - Both use RJ-45 connectors
- **Noise immunity**
  - STP is more noise-resistant
- **Size and scalability**
  - Maximum segment length for both is 100 meters

Fiber-Optic Cable

- Use light to send information through optical medium instead of electrical pulses
- Uses total internal reflection principal
  - When the angle of incidence exceeds a critical value, light cannot get out of the glass; instead, the light bounces back inside
- Modulated light transmissions are used to transmit the signal

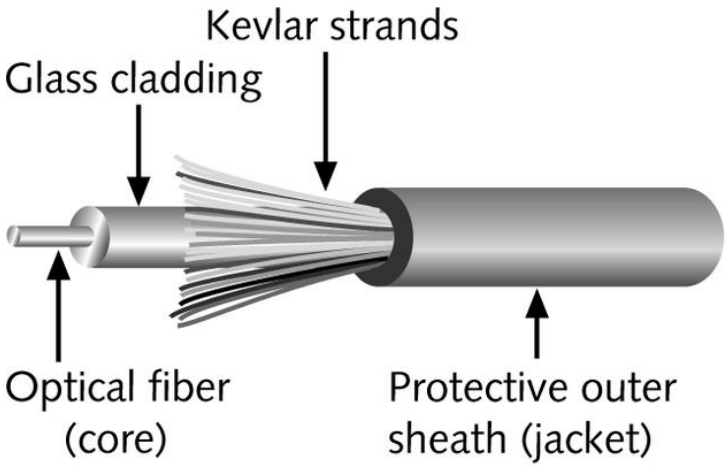
Fiber-Optic Cable





Fiber-Optic Cable

- Contains one or several glass fibers at its core Optical fiber consists three parts
  - Core
  - Cladding
  - Coating or buffer
- Core is cylindrical rod of dielectric material
  - Dielectric material does not conduct electricity
- Light propagates through the core of the fiber which is made of silica glass



Fiber-Optic Cable

- Functions of cladding
  - Reduces loss of light from core into surrounding air
  - Reduces scattering loss at the surface of the core
  - Protects fiber from absorbing surface contaminants e.g. moisture
  - Adds mechanical strength

Fiber-Optic Cable

- For extra protection cladding is enclosed in an additional layer called the coating or buffer
  - Used to protect from physical damage
  - Material used is a type of plastic
  - Elastic in nature and prevents abrasions
  - Also prevents optical fibre from scattering losses caused by micro-bends which occur when an optical fibre is placed on a rough and distorted surface

Fiber-Optic Cable

- Light emitting diode (LED) or injection laser diode (ILD) used to generate the light pulses

- Light is often 850nm wavelength for shorter distances and 1,300nm for longer distances on **multimode fiber**
- Light is often 1300nm wavelength for shorter distances and 1,500nm for longer distances on **single mode fiber**

Fiber Media

- Two types of Fiber media
  - Single Mode
  - Multimode

- **Single Mode**
  - Has a very small core
  - Carry only one beam of light
  - Supports Gbps data rates over long distances without using repeaters

Fiber Media – Single Mode

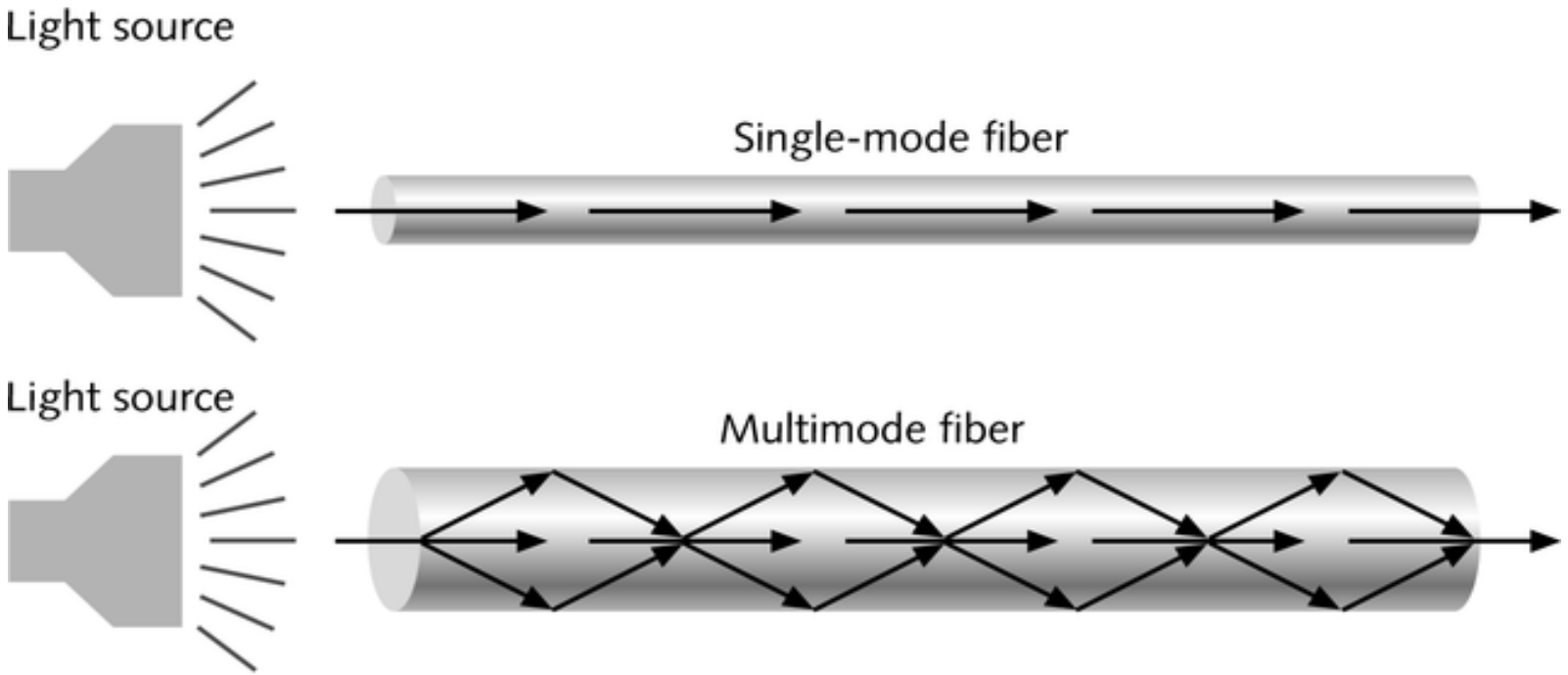
- **Single Mode (cont.)**
  - Carries light pulses along single path
  - Uses Laser Light Source
- Higher transmission rates and up to 50 times more distance than multi mode
  - Costs more
- Small core and single wavelength virtually eliminate any distortion that may result from overlapping light pulses
  - Provides least attenuation

Fiber Media – Multimode

- **Multimode**
- Many pulses of light generated by LED travel at different angles
- Has large diametrical core that allows multiple modes of light to propagate

- Quality of signal is reduced over long distances
  - Use for **short distances**
  - support less **bandwidth** than single mode fiber

Fiber Media


Light source
Single-mode fiber
Light source
Multimode fiber

Single Vs Multi Mode Fiber

Single Mode Fiber	Multimode Fiber
Core radius is small 9/125 microns	Core radius is large 50/125 microns
Supports one mode of propagation (around 1300nm wavelength)	Supports hundreds of modes (up to 4 modes: TE0, TE1, TE2, TE3)
Optical source – Laser	Optical source – LED
Lower signal loss	Higher signal loss
Higher bandwidth	Lower bandwidth

Single Vs Multi Mode Fiber

Single Mode Fiber	Multimode Fiber
Higher cost of connectors and Accessories	Lower cost of connectors and Accessories
Higher installation cost	Lower installation cost
Best for WAN, MAN, CAMPUS	Best for LAN, SAN, DATACENTER
Distance of approximately 60km +	Distance up to 2km

Unguided Media

- Wireless signals spread over in the air and received and interpreted by appropriate antennas
- Antenna convert digital data into wireless and spread it all over within its frequency and vice versa

Unguided Media (Wireless)

- Useful in difficult terrain where cable laying is not possible
- Provides mobility to communicating nodes
- Right of way and cable laying costs can be reduced
- Susceptible to rain, atmospheric variations and objects along the transmission path

Wireless Media

- Indoor : 10 – 50m : Bluetooth, WLAN
- Short range Outdoor : 50 – 200m: WLAN
- Mid Range Outdoor : 200m – 5 Km : GSM, CDMA, WLAN Point-to-Point, Wi-Max
- Long Range Outdoor : 5 Km – 100 Km : Microwave Point-to-Point
- Long Distance Communication : Across Continents : Satellite Communication

Radio Transmission

- Radio frequency easier to generate because of its large wavelength
  - Wavelength = lambda($\boldsymbol{\lambda}$) = Speed of light (C)/Frequency (f)
  - C= 299 792 458 m / s (3x10^8m/s)
- Can penetrate through walls and structures alike
- Can have a wavelength from 1mm to 100,000km
- Frequency ranging from 3KHz (extremely low frequency) to 300GHz (Extremely high frequency).

Radio Transmission

- Lower frequencies can travel through walls
- Higher frequencies can travel in straight line and bounce back
- Power of low frequency waves decreases sharply as they cover long distances
  - High frequency radio waves have more power

Radio Transmission

- Lower frequencies such as VLF, LF, MF can travel on the ground up to 1000 km over the earths surface
- Radio waves of higher frequencies are prone to be absorbed by rain and other obstacles
- High frequency waves use earth ionosphere to refract back to earth

Radio Frequency Bands

Band	Range	Propagation	Application
VLF	3–30 KHz	Ground	Long-range radio navigation
LF	30–300 KHz	Ground	Radio beacons and navigational locators
MF	300 KHz–3 MHz	Sky	AM radio
HF	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication

VLF (Very Low Frequency), LF (Low Frequency), MF (Medium Frequency), HF (High Frequency)

Radio Frequency Bands

Band	Range	Propagation	Application
VHF	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF	3–30 GHz	Line-of-sight	Satellite communication
EHF	30–300 GHz	Line-of-sight	Long-range radio navigation

*Find out the full abbreviations for VHF, UHF, SHF & EHF Frequency bands

Microwave Transmission

- Electromagnetic waves above 100MHz tend to travel in a straight line and signals over them can be sent by beaming those waves towards one particular station
- Both sender and receiver must strictly be in line of sight
- Microwaves can have wavelength ranging from 1mm to 1m and frequency ranging from 300MHz to 300GHz.

Microwave Transmission

- Microwave antennas concentrate the waves making a beam of it.
- Microwaves have higher frequencies and do not penetrate wall like obstacles
- Depends highly upon weather conditions and the frequency using it.

Infrared Transmission

- Infrared lies between visible light spectrum and microwaves
- Has wavelength of 700nm to 1mm and frequency from 300GHz to 430THz
- Used for very short range communication purposes e.g. TV and its remote
- Travels in a straight line hence its directional by nature
- Cannot cross wall-like obstacles because of high frequency

WLAN Channels

- Wireless LAN channels frequently accessed using IEEE 802.11 protocols
- Mostly trademark WiFi used
- Same channels may be accessed by other equipment such as Bluetooth
- 802.11 standard has several distinct radio frequency ranges for WiFi use
  - 900MHz, 2.4GHz, 3.6GHz, 5GHz, and 60GHz bands
  - Each range has several channels
- Specific regulations such as power levels, allowed users are regulated

Common WLAN Channels

- 2.4GHz WiFi (802.11b/g/n/ax)
  - Prominent WiFi Range used in Zambia
  - 14 channels designated spaced 5Hz apart (Except 12MHz space before channel 14)
  - Channel 1 – 2412MHz frequency
  - Channel 13 – 2472MHz frequency
  - Channel 14 – 2484Hz frequency (Not used!)

- 5GHz WiFi (802.11a/h/j/n/ac/ax)
  - Also used for WiFi (unlicensed in Zambia)