UNIT 3
OPTICAL COMMUNICATION AND SWITCHING TECHNIQUES

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Outcomes

- Describe the principles of coaxial cables and its usage
- Describe fiber optical communication and its applications
- Illustrate possible topologies of fiber and coaxial communication
- Differentiate circuit switch and packet switched networks
- Apply different mode of transmissions in modern networks

Coaxial Cable

Coaxial cable

Coaxial cable has better shielding than twisted pairs, so it can span a longer distance at high data rate. Modern cables have a bandwidth of up to 1GHz.

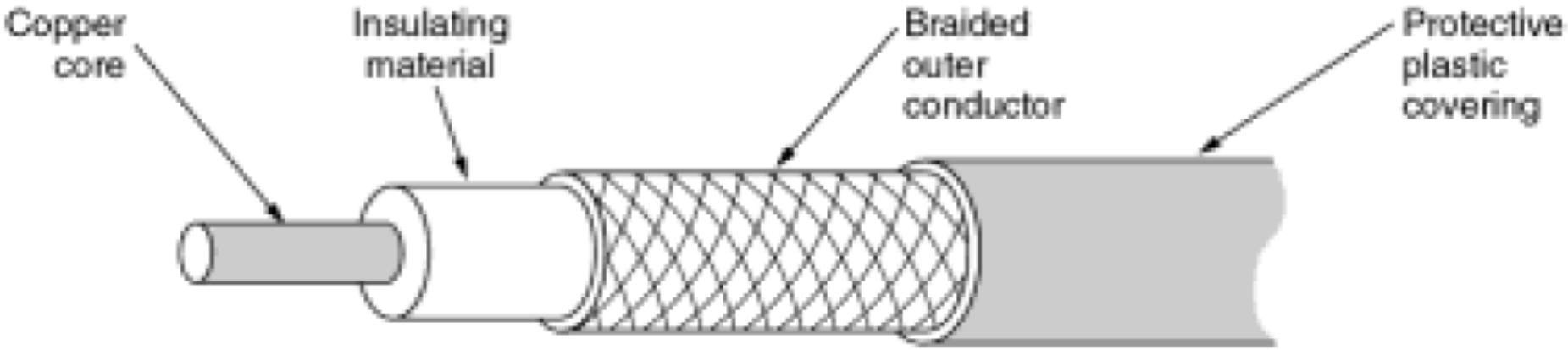


Figure 1.12. A coaxial cable [1].

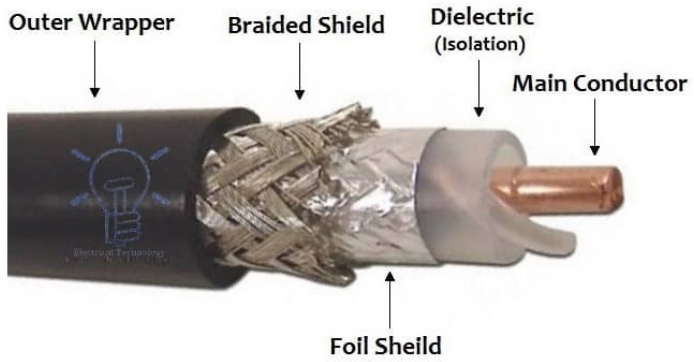
Two kinds of coaxial cables are widely used:

- 50 Ohm for data connection (first LANs)
- 75 Ohm for cable TV and now with Internet via TV cable also 75 Ohm for data

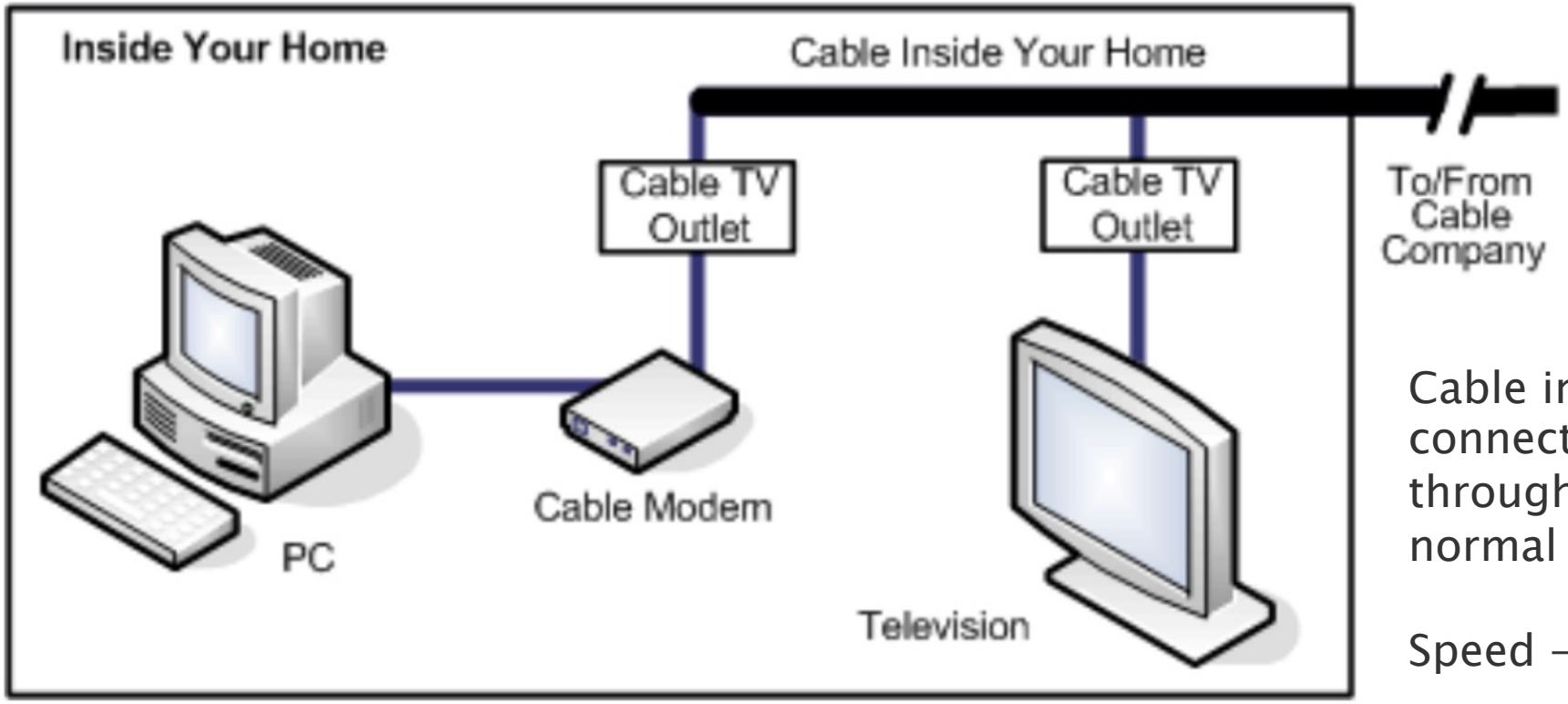
Advantages and Disadvantages of Coaxial Cables

- Advantages
  - High Bandwidth (400 MHz – 600 MHz, up to 10,800 Voice conversations)
  - Can be tapped easily (pros & cons)
  - Much less suspectable to interference (than twisted pair)
  - High Durability
  - Best performance for short distance transmission

- Disadvantages
  - High Attenuation rate makes it expensive over long distance
  - Bulky – coaxial cabling is difficult to install
  - Less Security
  - Susceptible to damages from lightening



Cable Internet Connection at the end premises

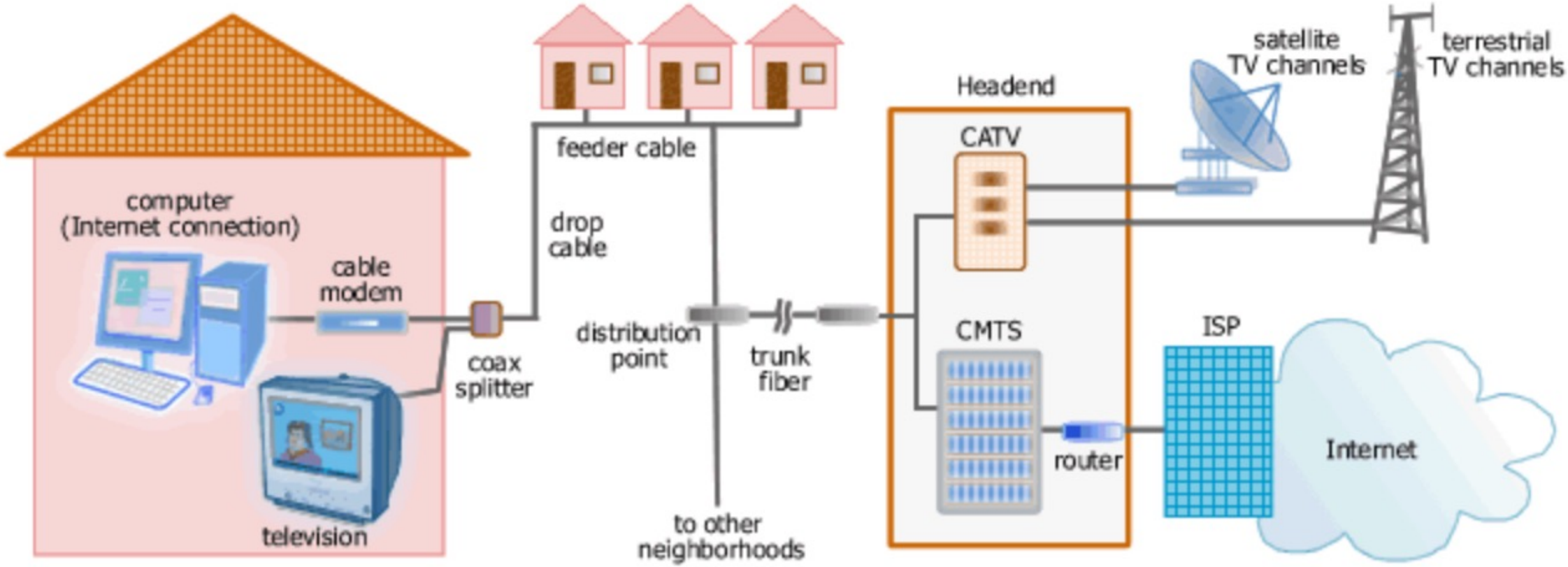


Cable internet is a high-speed connection that connects through coaxial cable to a normal television jack.

Speed – 5Mbps to 500Mbps

Issues is, at the peak (rush hours) data rate is shared by many users and effective data reduced (However, faster than DSL)

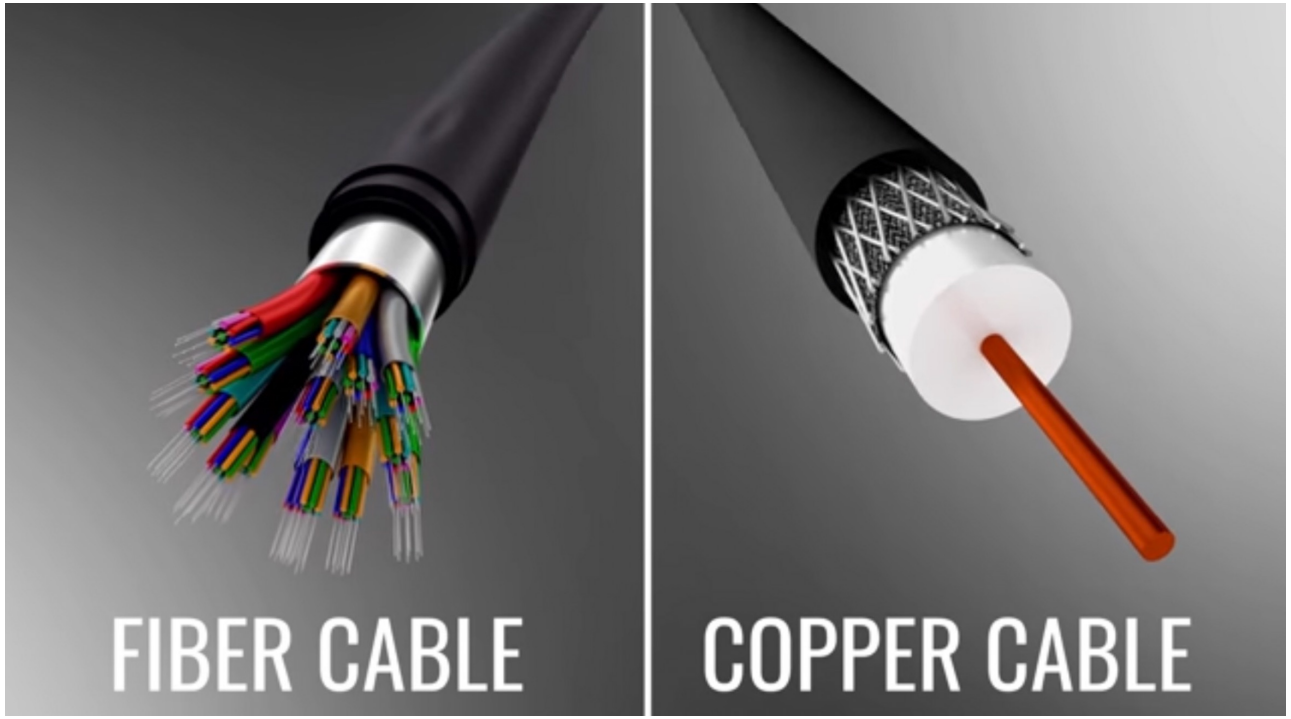
Internet Access Over Cable TV connection



CMTS - Cable Modem Termination System

CATV - Community Antenna Television

Optical Fiber Transmission Media

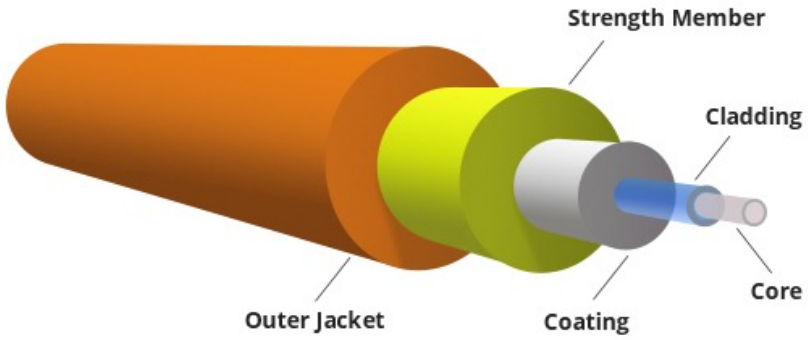


Why Fiber?

- Requires less maintenance
- Transmits information over long distance
- Signal has a higher speed
- Large information carrying capacity

Optical Fiber

- Fibre optics uses a technique of transferring data from one point to another while sending light pulses.
- An optical fibre is a long, narrow strand of plain substance.
- Cladding functions as a barrier protection shell in this case.



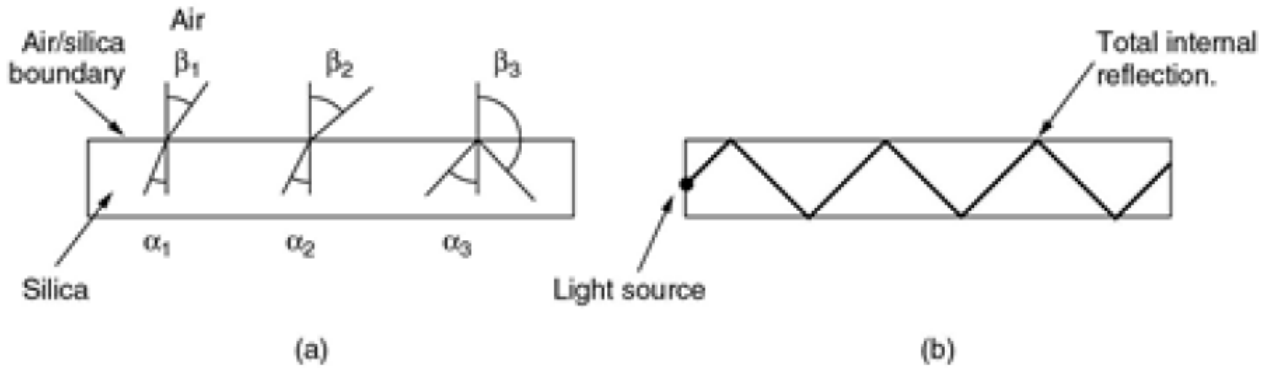
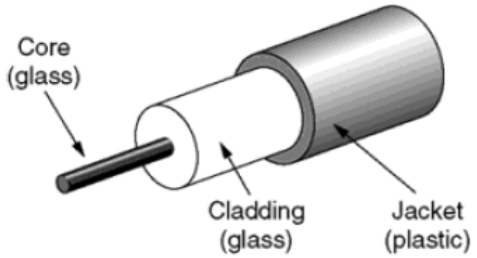
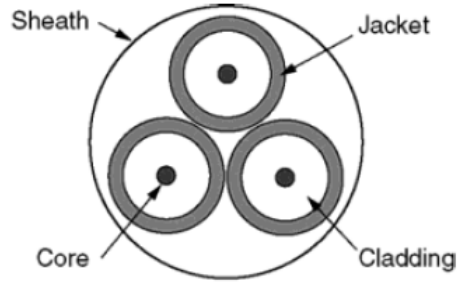


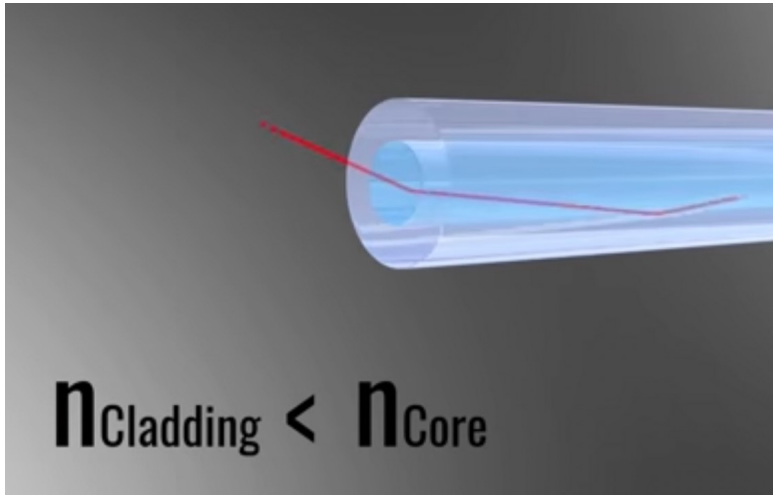
Figure 1.13. a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angle; b) Light trapped by total internal reflection [1]

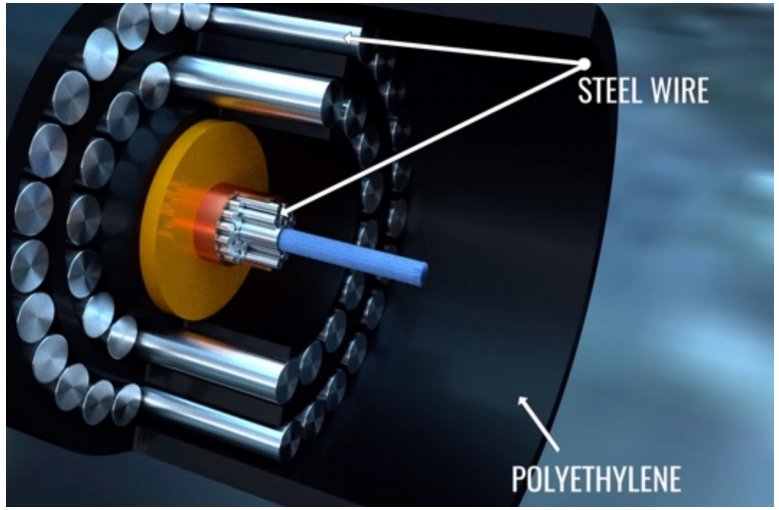
When the incoming angle of a light ray higher than the critical angle, it will be reflected internally and propagates along the fiber for a long distance. In this case, light ray can be used to transmit data signal.

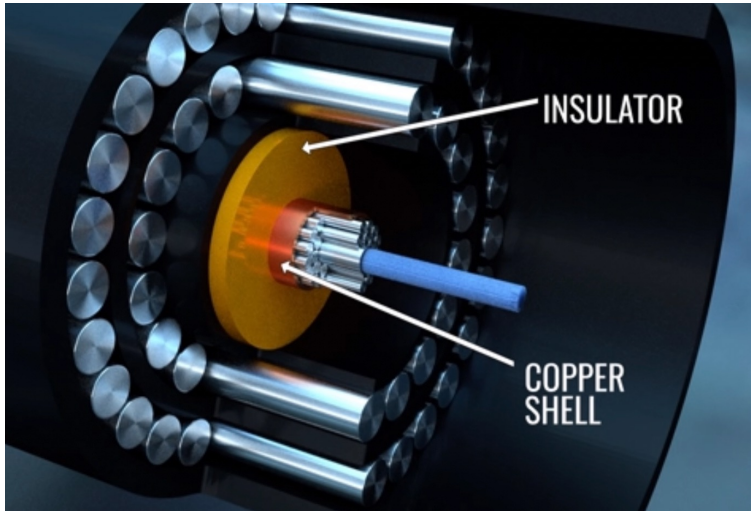
An optical fiber is a transparent fiber made of very pure glass to transmit light between two ends of the fiber. It offers a transmission over a very long distance at high data rate.



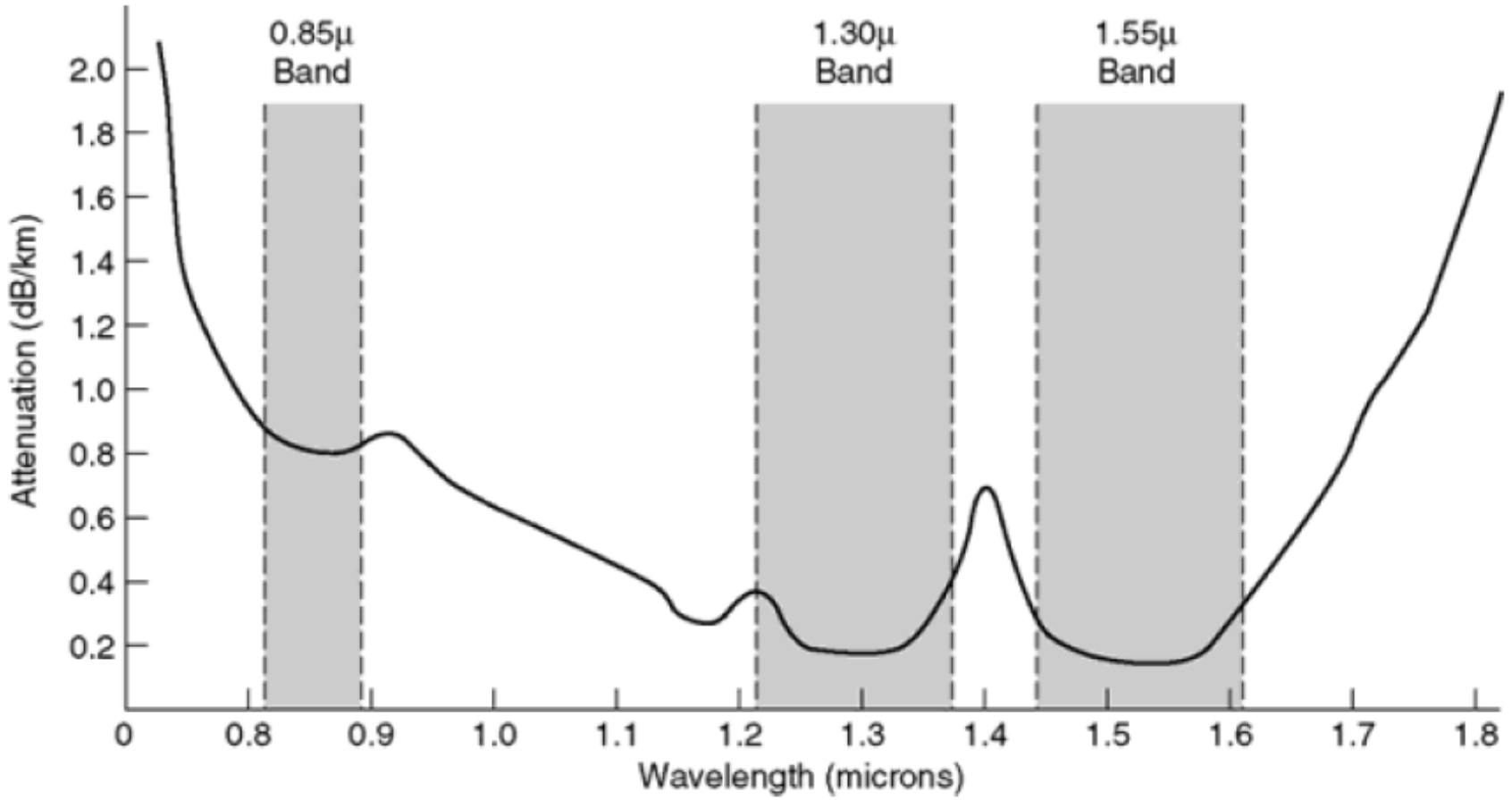



nCladding < nCore


STEEL WIRE
POLYETHYLENE


INSULATOR
COPPER
SHELL

Attenuation of Light through Fiber



Three wavelength bands are most used at present for optical communication.

They are centered at 0.85, 1.30, and 1.55 microns, respectively. All three bands are 25,000 to 30,000 GHz wide.

The 0.85-micron band was used first. It has higher attenuation and so is used for shorter distances

The last two bands have good attenuation properties (less than 5% loss per kilometer).

The 1.55-micron band is now widely used.

Advantages and Disadvantages of Optical Fiber

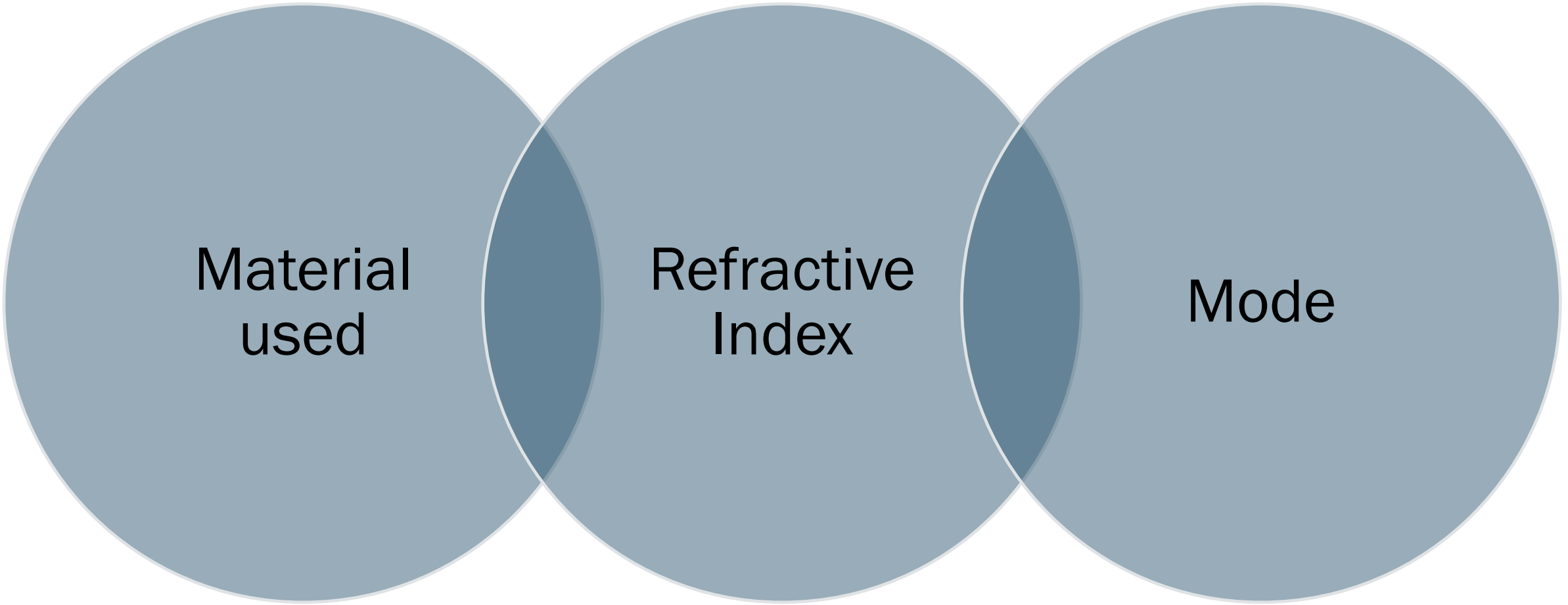
Advantages

- Higher Capacity and Long-distance transmission (>>Gbps)
- Less Attenuation and lower power loss
- Smaller size and light weight
- High Reliability with Longevity
- Resistance to electromagnetic interference
- Highly secure due to tap difficulty and lack of signal radiation
- Greater repeater space – 10s of km at least

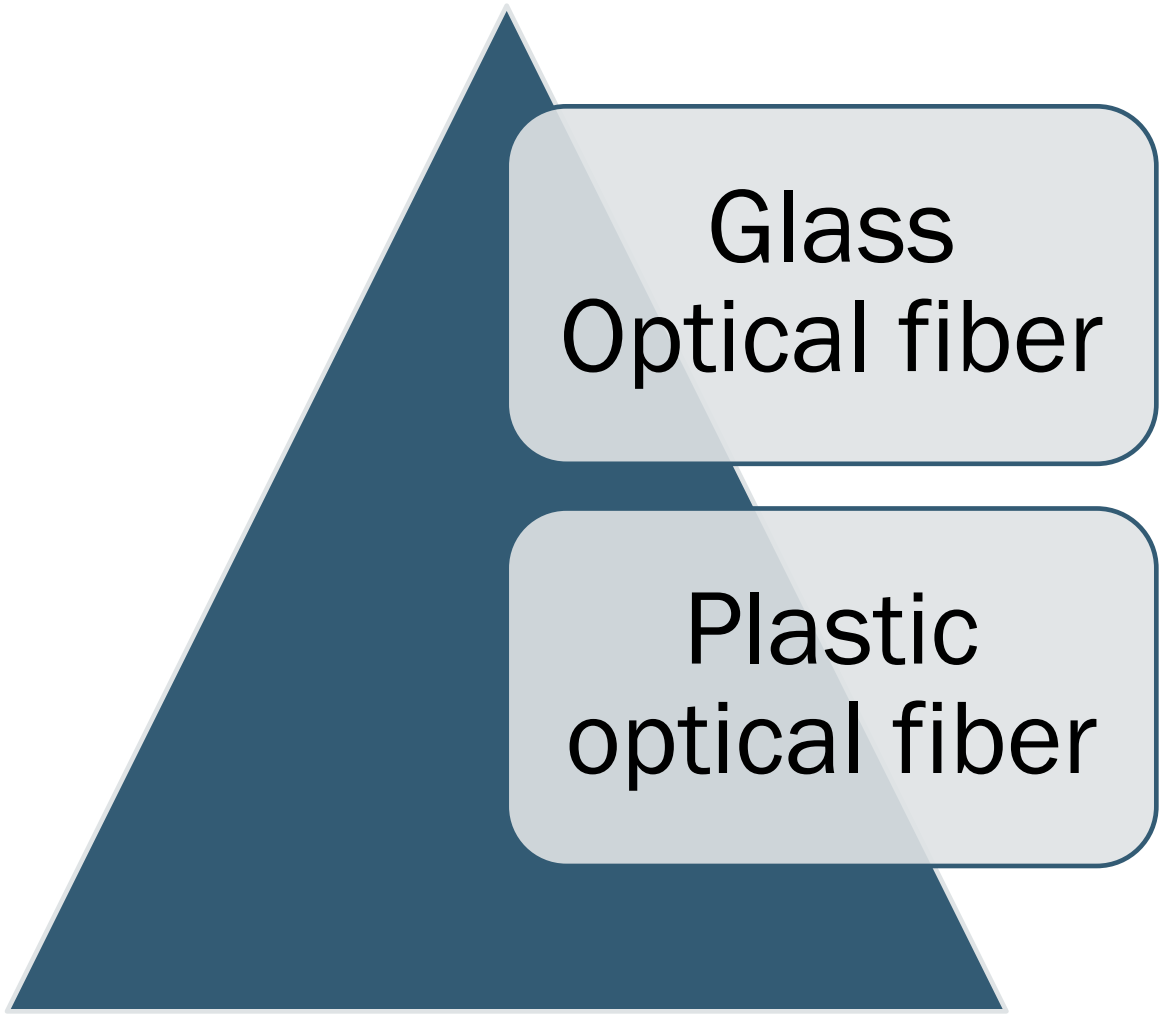
Disadvantages

- Expensive over Short Distance
- It has limited physical arc of cables.
- The optical fiber is lightweight and more compact.
- More complex transmitter and reception equipment are essential.
- Requires skill installers
- It is an expensive investment or installation and maintenance
- not as robust as the wires.

Main Category Definitions



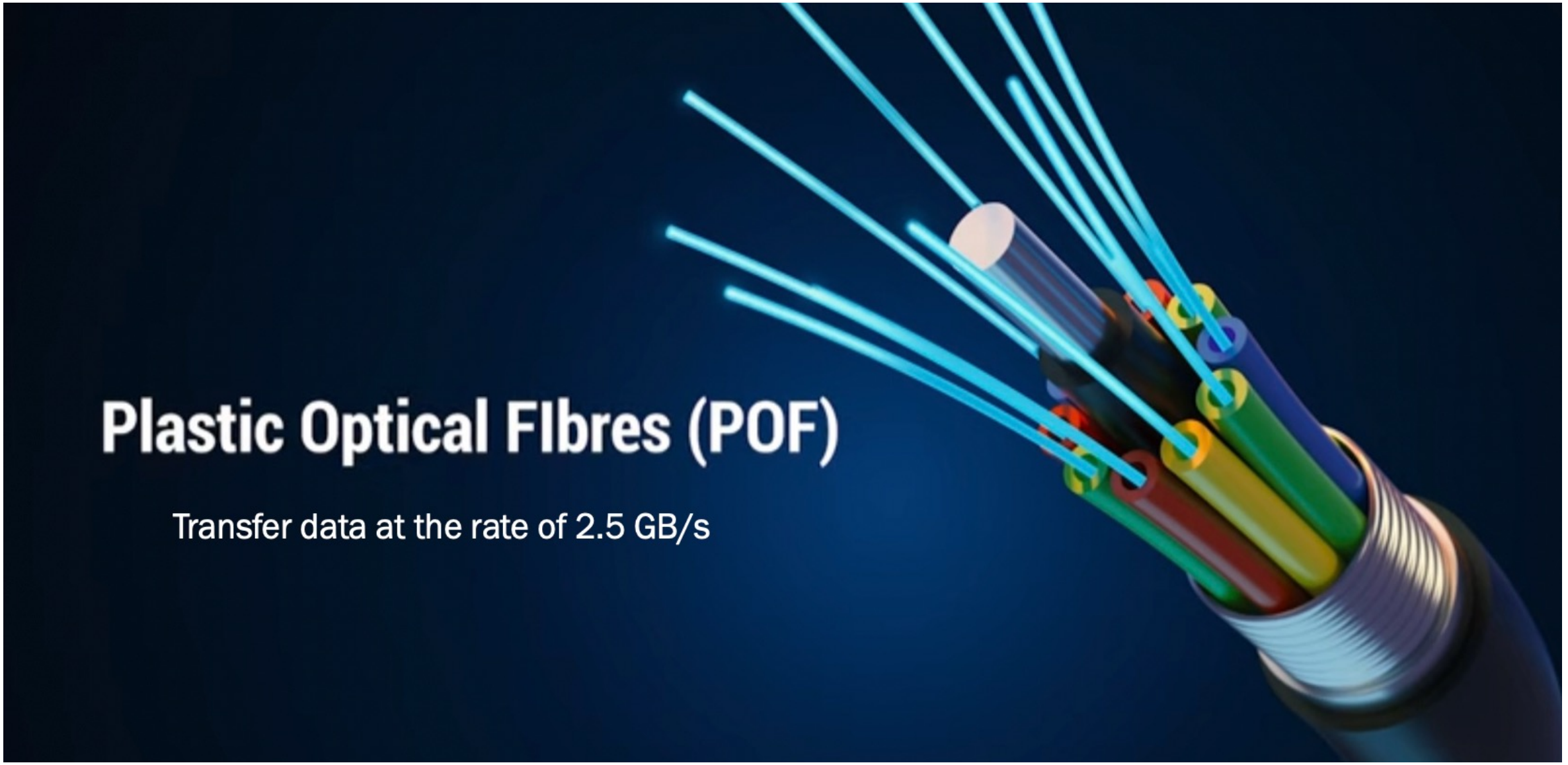
Fiber category – Material used



The plastic optical fiber (POF) is a polymer optical fiber. It transmits light signals through its core but is more robust than glass fiber because it is quite resistant to stretching and bending.

Glass Optical Fiber

- Made of silica
- Transfer data at a rate of 100Mb/s
- High Transmission speed
- Delicate in nature
- Withstand extreme temperatures
- Low signal loss
- Need trained


Plastic Optical FIbres (POF)
Transfer data at the rate of 2.5 GB/s

MODE

NUMBER OF RAYS THAT CAN PASS THROUGH THE OPTICAL FIBRE AT A TIME

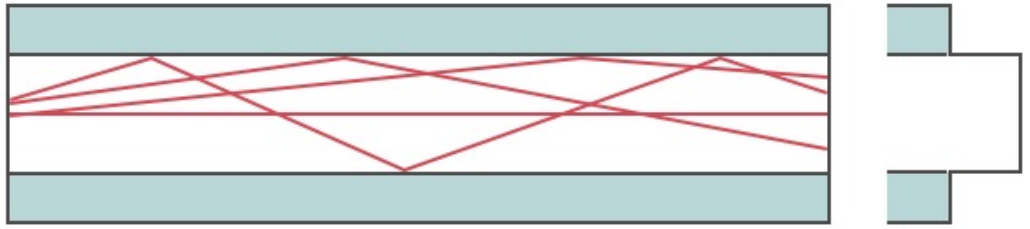
Common Fiber Optic Cable Types

- Single Mode Fiber Optic Cable
- Multimode Fiber Optic Cable

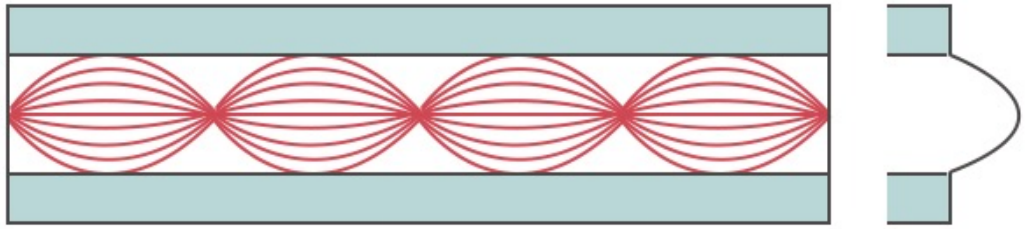
Single mode fiber

Singlemode Index Profile

Multi mode fiber



Multimode, Step-index



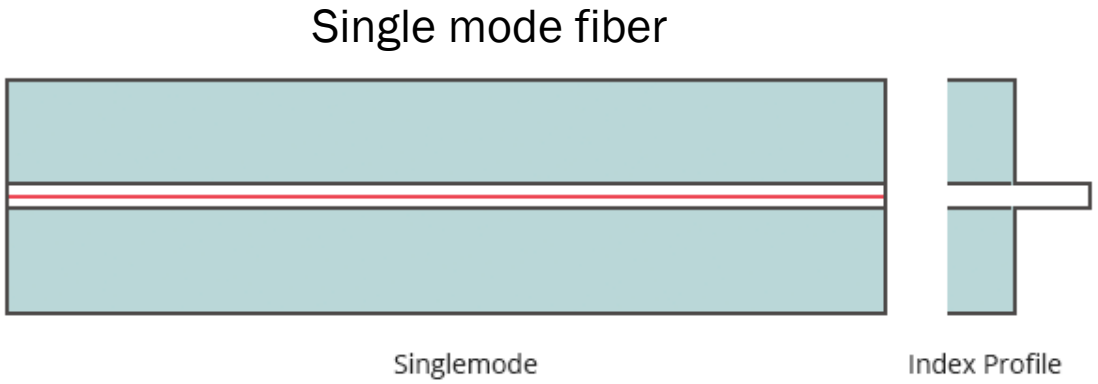
Multimode, Graded Index Index Profile

Except for fibers used in specialty applications, single mode fiber can be considered as one size and type. If you deal with long haul telecom or submarine cables, you may have to work with specialty single mode fibers.

Comparison of core/cladding sizes

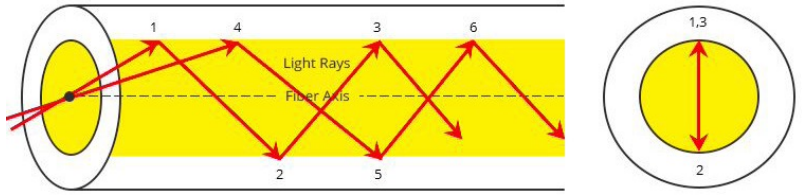
Single Mode Fiber

- Single mode fiber has a smaller core diameter of 9 microns (8.3 microns to be exact) and
- only allows a single wavelength and pathway for light to travel, which greatly decreases light reflections and lowers attenuation.
- Slightly more expensive than its multimode counterparts,
- single mode fiber optic cable is often used in network connections over long lengths.

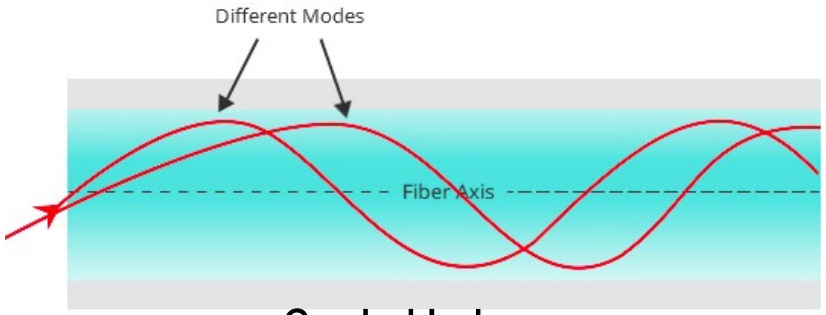


Multimode Fiber Optic Cable

- Multimode optical fiber has a larger core diameter than that of single mode fiber optic cable
- It allows multiple pathways and several wavelengths of light to be transmitted.
- Multimode optical fiber is available in two sizes, 50 microns and 62.5 microns.
- It is commonly used for short distances, including patch cable applications such as fiber to the desktop or patch panel to equipment, data and audio/video applications In LANs.
- According to the fiber refractive index distribution, multimode fiber can be divided into two types:
  - **Step-Index Multimode Fiber**
  - **Graded-Index Multimode Fiber.**



Step-Index

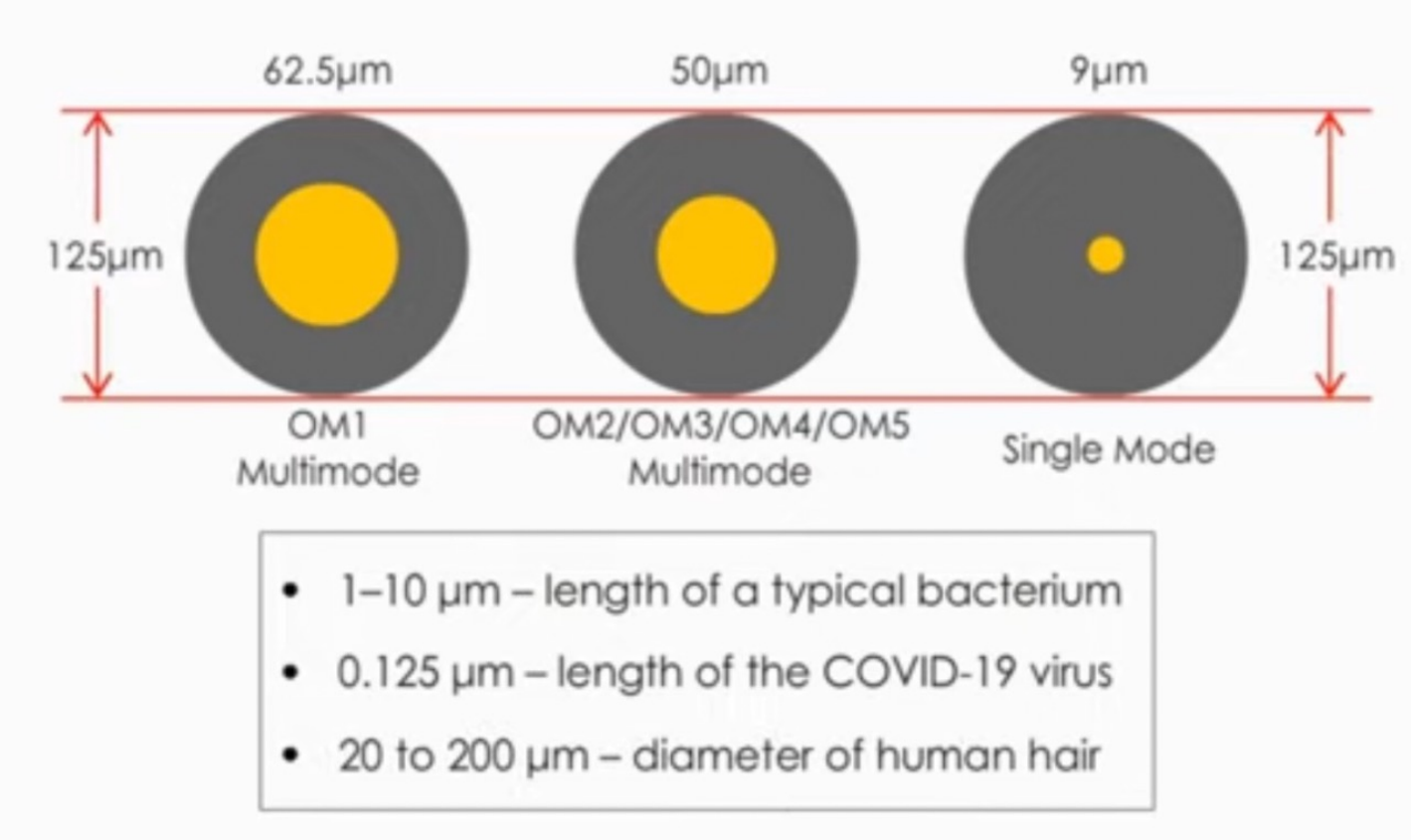


Graded-Index

Graded index multimode fiber offers hundreds of times more bandwidth than step index fiber - up to about 2GHz.

Two types are in use, 50/125 and 62.5/125, where the numbers represent the core/cladding diameter in microns.

OPTICAL FIBER CORE DIAMETER: SINGLE MODE VS MULTIMODE



REFRACTIVE INDEX

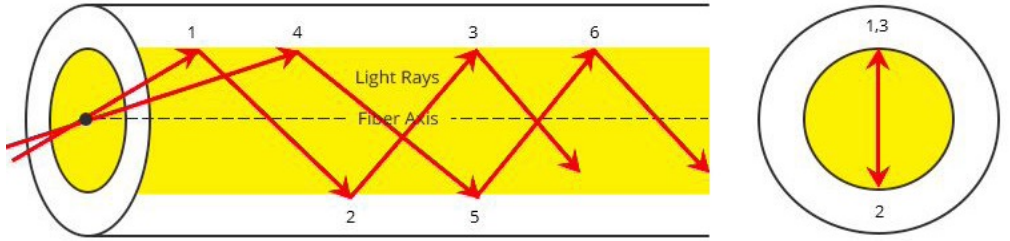
REFRACTIVE INDEX DETERMINES HOW FAST LIGHT CAN TRAVEL THROUGH A MEDIUM

Step-Index Fiber

Graded-Index Fiber

Step-Index Multimode Fiber

- A step-index fiber is a fiber where a uniform refractive index exists within the core and
- A sharply decreased refractive index exists in the core-cladding interface because of the lower refractive index in cladding.
- The light propagates in the shape of a zigzag along the fiber/core axis according to the principle of total reflection.
- Dispersion is high and used for Short distance communication (within few kilometres) and low speed (8 Mb/s or less) with relatively low cost



Step index multimode fiber was the first fiber design.

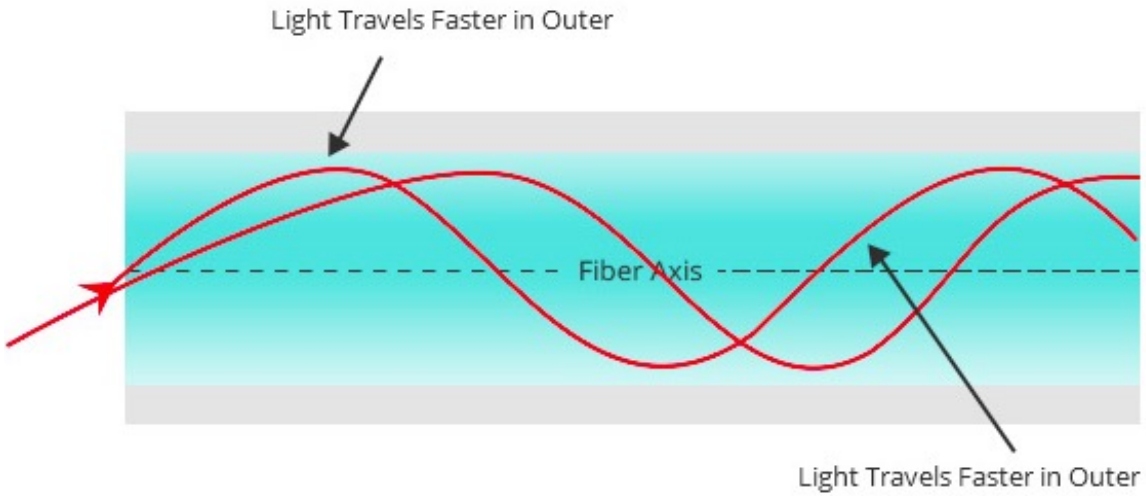
It has a core of one type of It has higher attenuation and is too slow for many uses, due to the dispersion caused by the different path lengths of the various modes travelling in the core.

Step index fiber is not widely used - generally only POF (Plastic Optical Fiber) and PCS/HCS (plastic or hard clad silica, plastic cladding on a glass core) use a step index design today.

Graded-Index Multimode Fiber

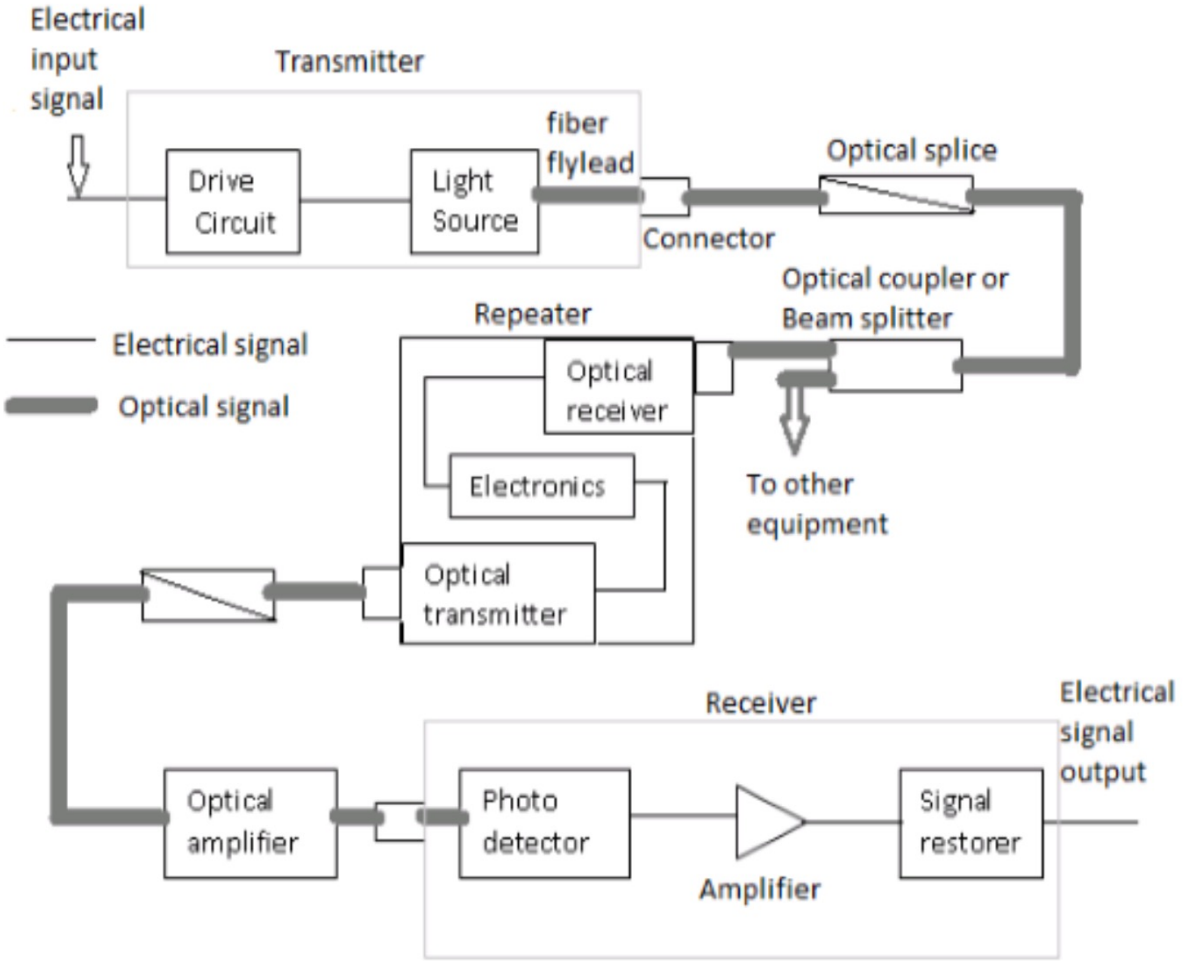
- The refractive index is higher at the axis of the core and then it decreases gradually towards the core-cladding interface.
- The refractive index of a graded-index fiber gradually decreases from its center, and eventually decreases to the same value as the cladding at the core edge.
- The change in refractive index causes refraction rather than total internal reflection.
- When light passes through a layer with a lower refractive index, the light will fold back to the fiber axis.
- For graded-index multimode fiber, the light travels forward in the form of sinusoidal oscillation.

- The speed of light propagation in graded-index multimode fiber is different because the speed of guided light varies with the refractive index of the fiber core
- Dispersion reduced, hence higher BW, High speed (34-140 Mb/s) and Distance (10 -20 km) than step Index fiber
- Dispersion refers to the widening or spreading of pulses of light as they travel down an optical fiber.



Step-Index Vs Graded-Index (Advantages & Disadvantages)

Feature	Step-Index Multimode Fiber	Graded-Index Multimode Fiber
Bandwidth Size	Lower bandwidth	Higher bandwidth
Diameter of the Core	50-200 μm	About 50 μm
Application Scenarios	Normally used in short-distance (within a few kilometers) and low-speed (8 Mb/s or less) communication systems	Usually used in medium-distance (10~20 km) and relatively higher-speed (34~140 Mb/s) communication systems
Data Transmission Form	Light propagates in the shape of a zigzag along the fiber/core axis	Light travels forward in the form of sinusoidal oscillation/curves
Modal Dispersion	Affects the transmission capacity of the fiber and limits the relay distance	Greatly decreased dispersion than step-index multimode fiber, making a higher bandwidth
Performance	Relatively worse	Relatively better
Cost	Lower	Higher



OPTICAL TRANSMISSION SYSTEM BLOCK DIAGRAM

Optical Transmitter and Receiver

Transmitter:

An electric signal is applied to the optical transmitter. The optical transmitter consists of driver circuit, light source and fiber flylead.

- Driver circuit drives the light source.
- Light source converts electrical signal to optical signal.
- Fiber flylead is used to connect optical signal to optical fiber.

Receiver:

Optical signal is applied to the optical receiver. It consists of photo detector, amplifier and signal restorer.

- Photo detector converts the optical signal to electrical signal.
- Signal restorers and amplifiers are used to improve signal to noise ratio of the signal as there are chances of noise to be introduced in the signal due to the use of photo detectors.

Transmission channel

It consists of a cable that provides mechanical and environmental protection to the optical fibers contained inside. Each optical fiber acts as an individual channel.

- Optical splice is used to permanently join two individual optical fibers.
- Optical connector is for temporary non-fixed joints between two individual optical fibers.
- Optical coupler or splitter provides signal to other devices.
- Repeater converts the optical signal into electrical signal using optical receiver and passes it to electronic circuit where it is reshaped and amplified as it gets attenuated and distorted with increasing distance because of scattering, absorption and dispersion in waveguides, and this signal is then again converted into optical signal by the optical transmitter.

Short and Long-Distance Communication Requirements

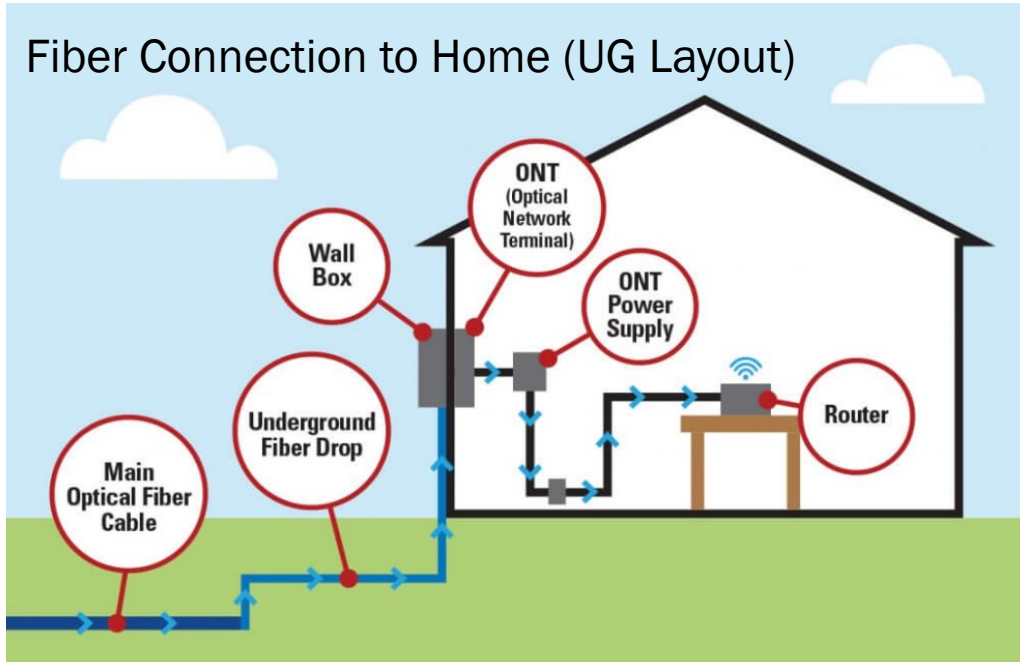
For short distance communication only, main elements are required.

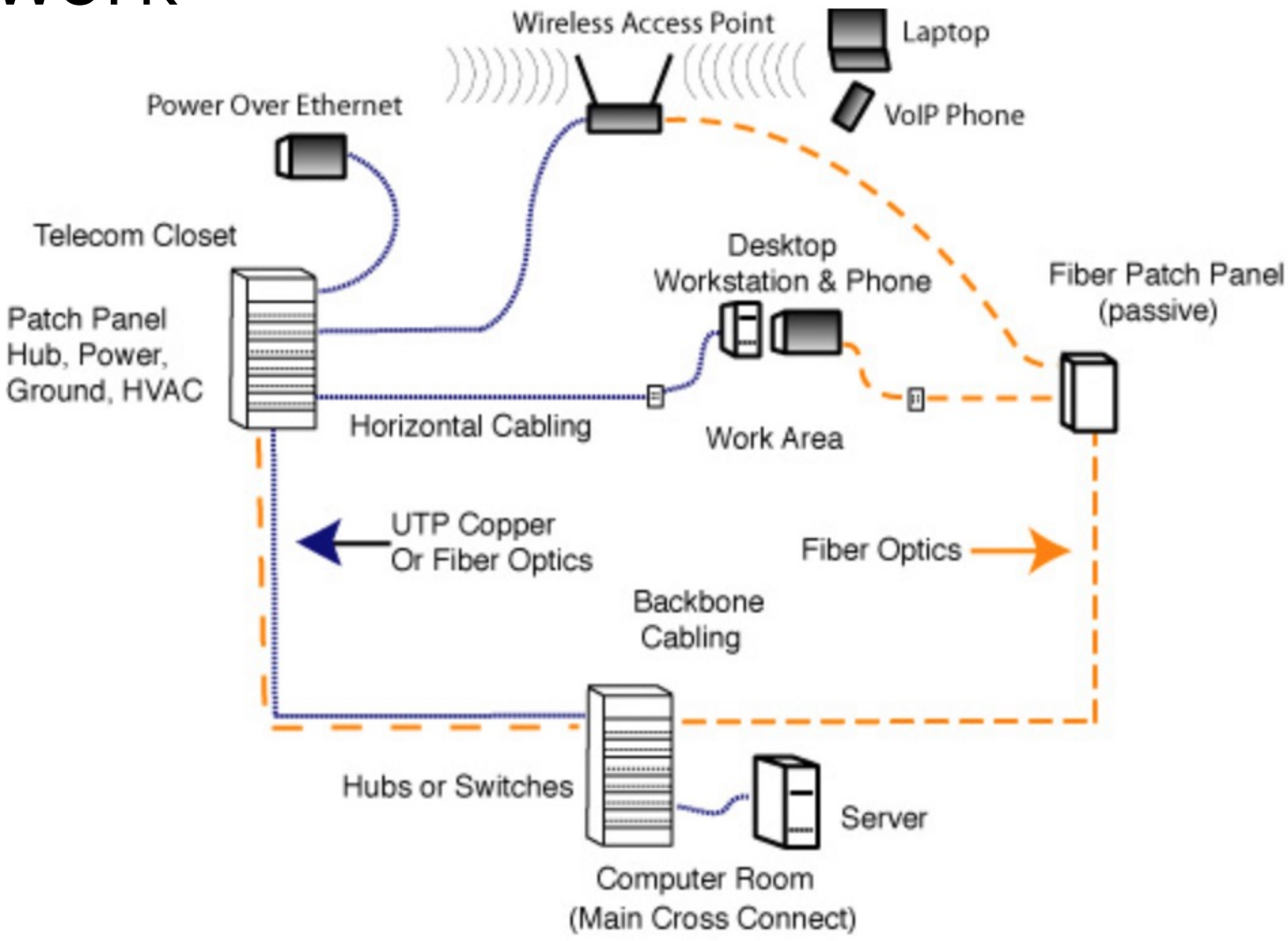
- Source - LED
- Fiber - Multimode step index fiber
- Detector - PIN detector

For long distance communication along with the main elements there is need for couplers, beam splitters, repeaters, optical amplifiers.

- Source - LASER diode
- Fiber - single mode fiber
- Detector- Avalanche photo diode (APD)

Fiber LAN distribution network

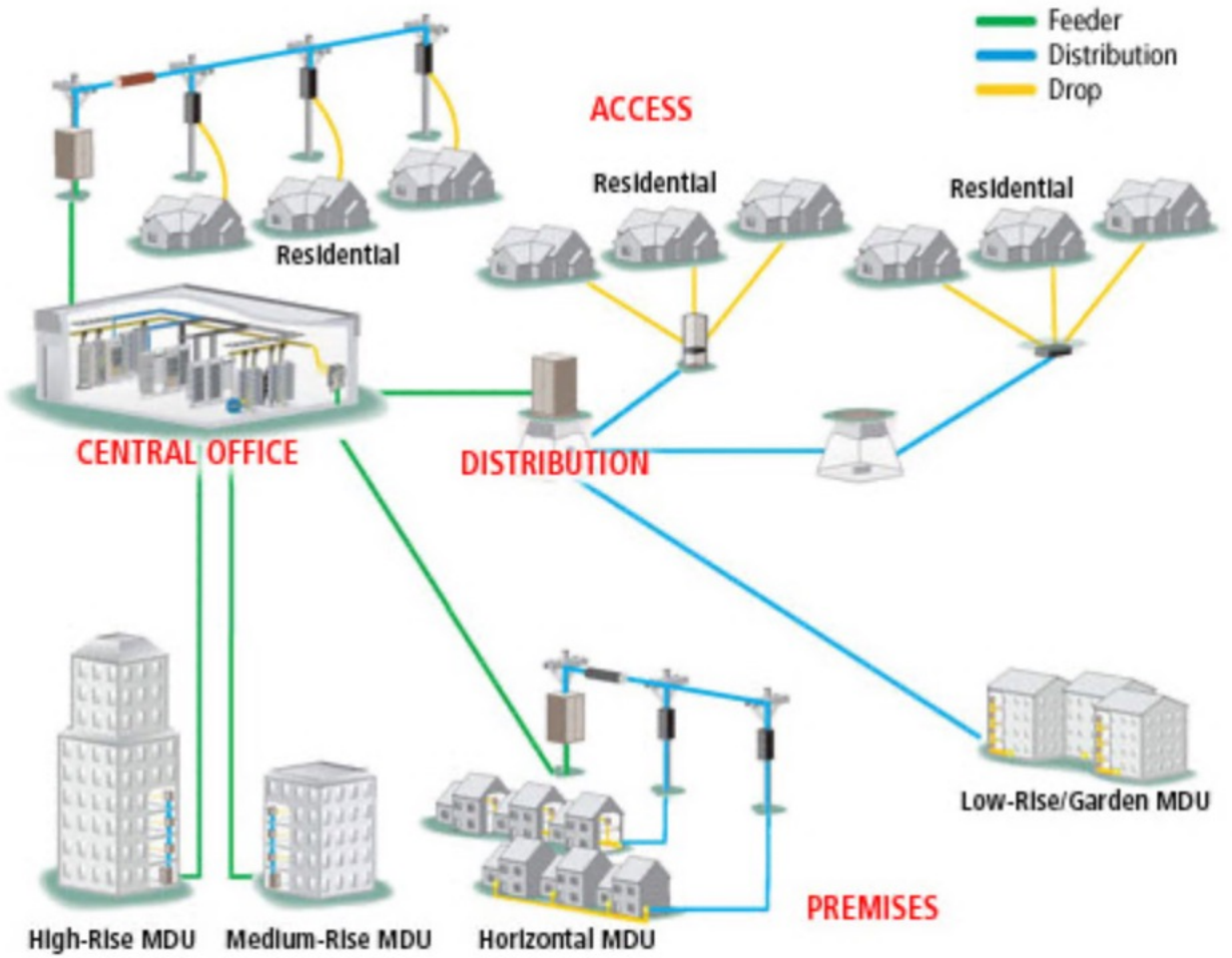




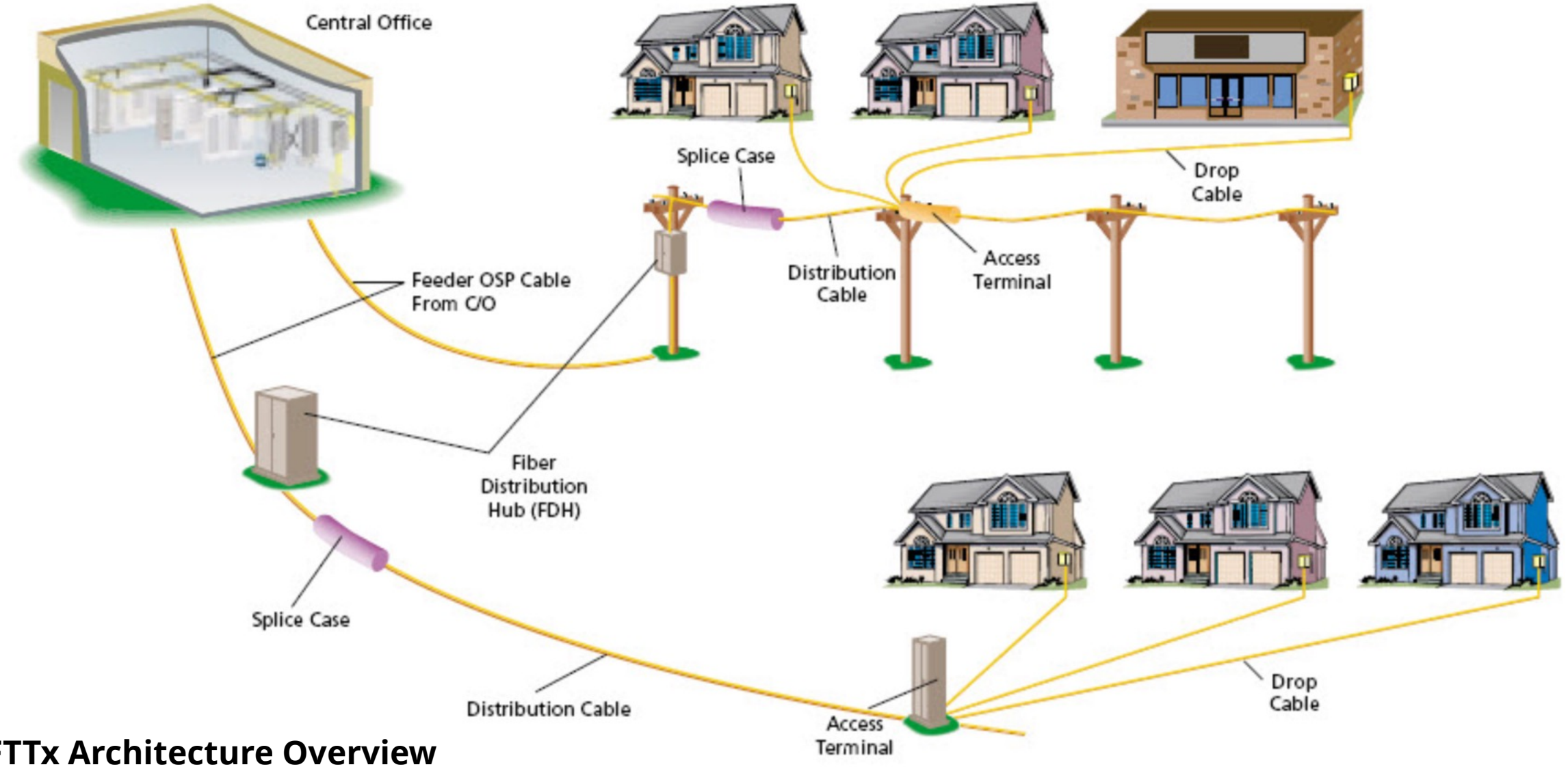
Fiber LAN distribution network

Fiber to the Home / Fiber to the Premise (FTTH / FTTP)

- FTTH / FTTP (Fiber to the Home / Fiber to the Premise) is a fiber-optic broadband triple play service (Voice/Data/Video) currently in deployment.
- The architecture of this deployment is called a PON (Passive Optical Network).
- This is a completely passive (the signal is transported by laser with no electronics) network consisting of fiber optic cabling, passive splitters, attenuators, and couplers.
- These listed components are also referred as the ODN (Optical Distribution Network) elements that distribute an optical signal through a branched topology to an ONT (Optical Network Terminal).

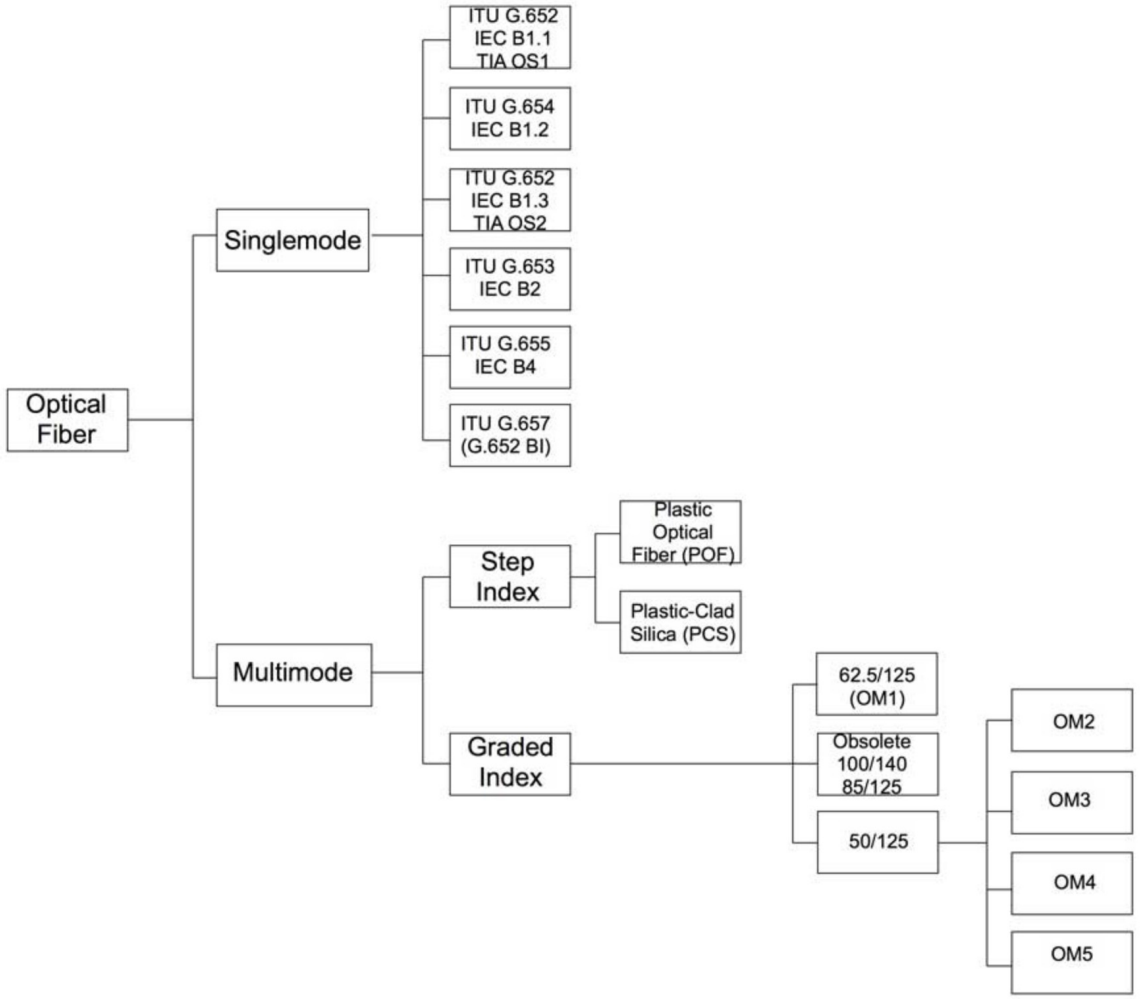


FTTP Architecture



FTTx Architecture Overview

Optical Fiber Family Tree



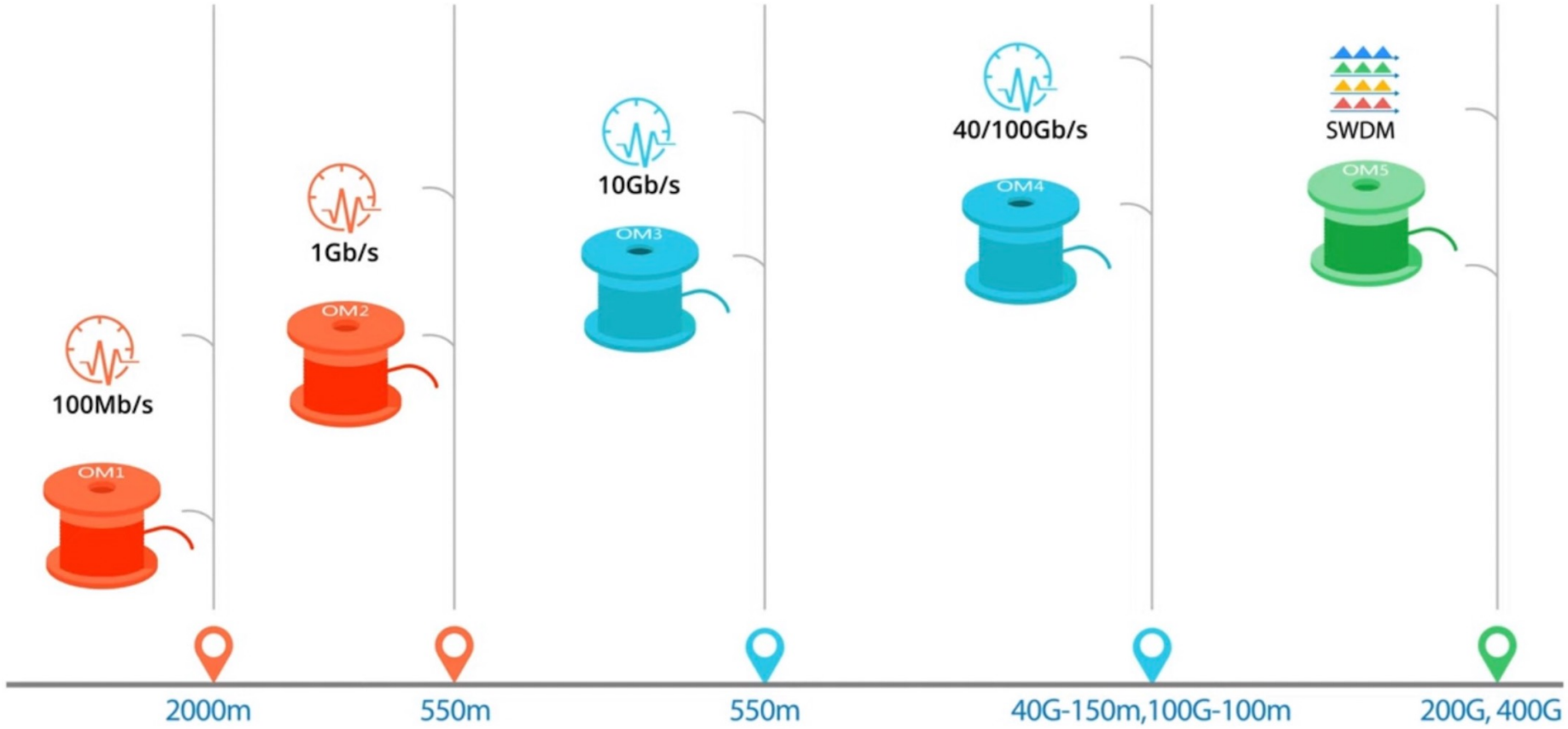
Multimode fibers originally came in several sizes, optimized for various networks and sources, but the data industry standardized on 62.5 core fiber in the mid-80s (62.5/125 fiber has a 62.5-micron core and a 125-micron cladding. It's now called OM1 standard fiber.)
Recently, as gigabit and 10 gigabit networks have become widely used, an old fiber design has been revived.

50/125 fiber was used from the late 70s with lasers for telecom applications before single-mode fiber became available. 50/125 fiber (OM2 standard) offers higher bandwidth with the laser sources used in the gigabit LANs and can allow gigabit links to go longer distances.

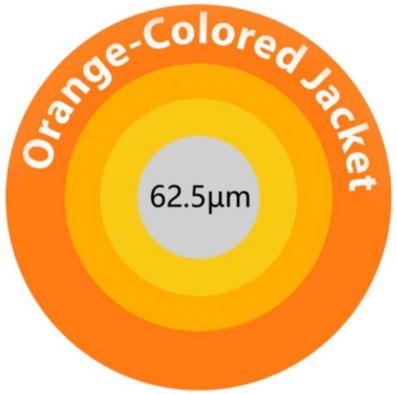
Newer OM3 or laser-optimized 50/125 fiber today is considered by most to be the best choice for multimode applications.

OM4 fiber is a higher bandwidth fiber for 10G+ networks. OM5 is wideband multimode fiber optimized for wavelength division multiplexing with VCSELs in the 850-950nm range.

Multimode – OM categories



Multimode – OM colour codes



OM1

OM2

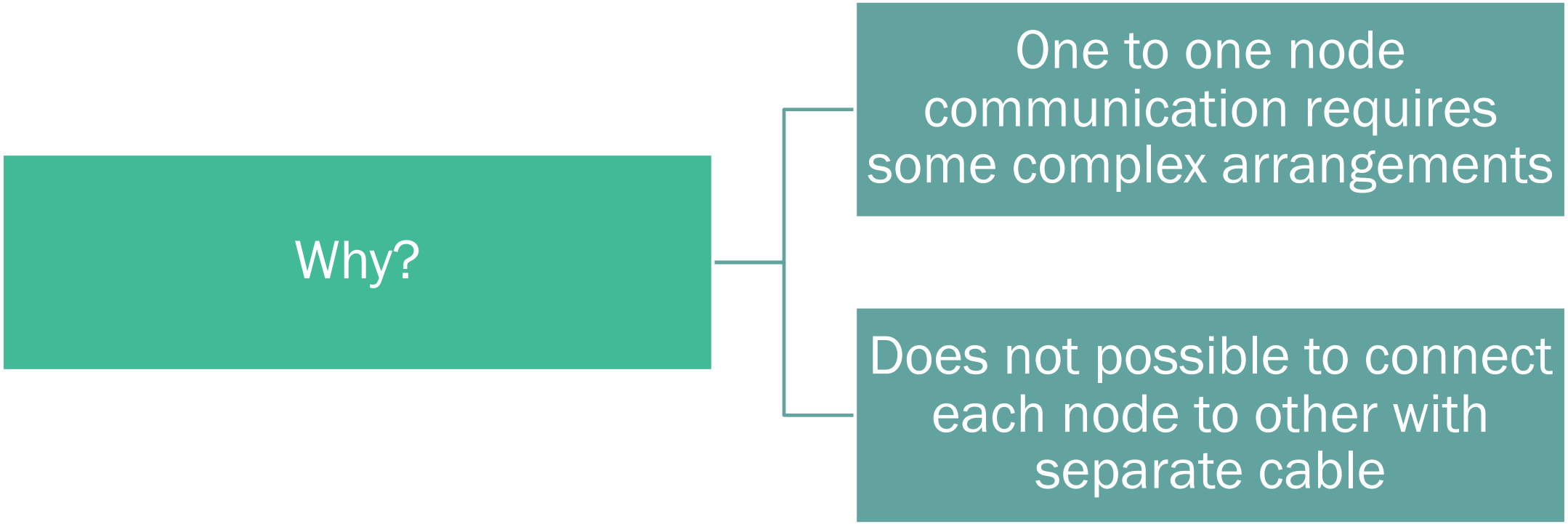
OM3 & OM4

OM5

Fiber Types and Typical Specifications (OM/OS refers to TIA types, B refers to IEC types, G refers to ITU types)			
Core/Cladding	Attenuation	Bandwidth	Applications/Notes
Multimode Graded-Index			
	@850/1300 nm	@850/1300 nm	
50/125 microns (OM2, G.651.1)	3/1 dB/km	500/500 MHz-km	Laser-rated for GbE LANs
50/125 microns (OM3, G.651.1)	2.5/0.8 dB/km	1500/500 MHz-km	Optimized for 850 nm VCSELs
50/125 microns (OM4, G.651.1)	2.5/0.8 dB/km	3500/500 MHz-km	Optimized for 850 nm VCSELs, higher speed
50/125 microns (OM5)	2.5/0.8 dB/km	3500/500 MHz-km	Wideband MMF, optimized for WDM 850-950 nm VCSELs, higher speed
100/140 microns	3/1 dB/km	150/300 MHz-km	Obsolete
Singlemode			
	@1310/1550 nm		
9/125 microns (OS1 B1.1 or G.652)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Singlemode fiber, most common for Telco/CATV/long high speed LANs
9/125 microns (OS2, B1.2 or G.652)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Low water peak fiber
9/125 microns (B2 or G.653)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Dispersion shifted fiber
9/125 microns (B1.2 or G.654)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Cutoff shifted fiber
9/125 microns (B4 or G.655)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Non-zero dispersion shifted fiber
Multimode Step-Index			
	@850 nm	@850 nm	
200/240 microns	4-6 dB/km	50 MHz-km	Slow LANs & links
POF (plastic optical fiber)			
	@ 650 nm	@ 650 nm	
1 mm	~ 1 dB/m	~5 MHz-km	Short Links & Cars

Switching Techniques

Switching techniques



Solution Switching

Switch is a connecting device that links network devices

Capable of building provisional connections between two or more nodes

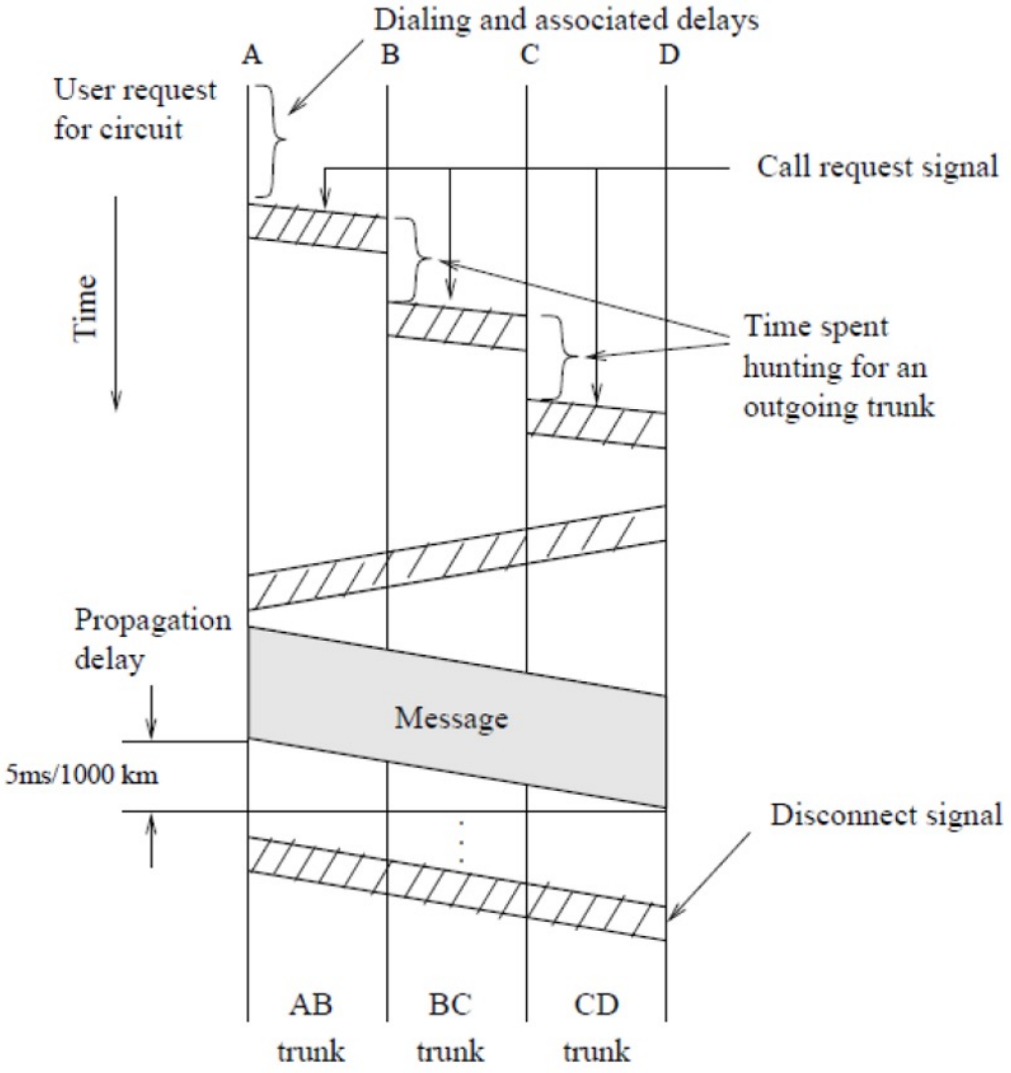
Two important methods of switching:

Circuit Switching	Packet switching

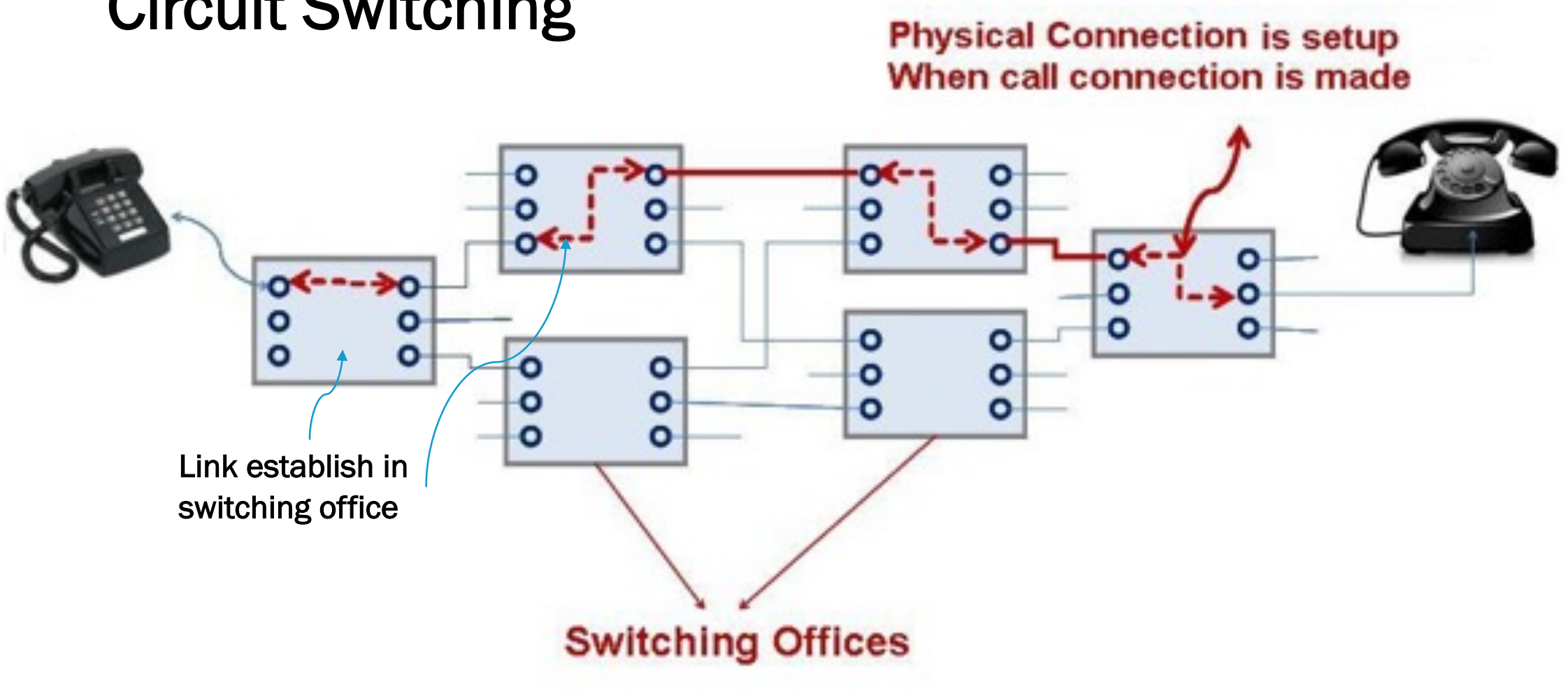
Circuit Switching

The properties of circuit switching are

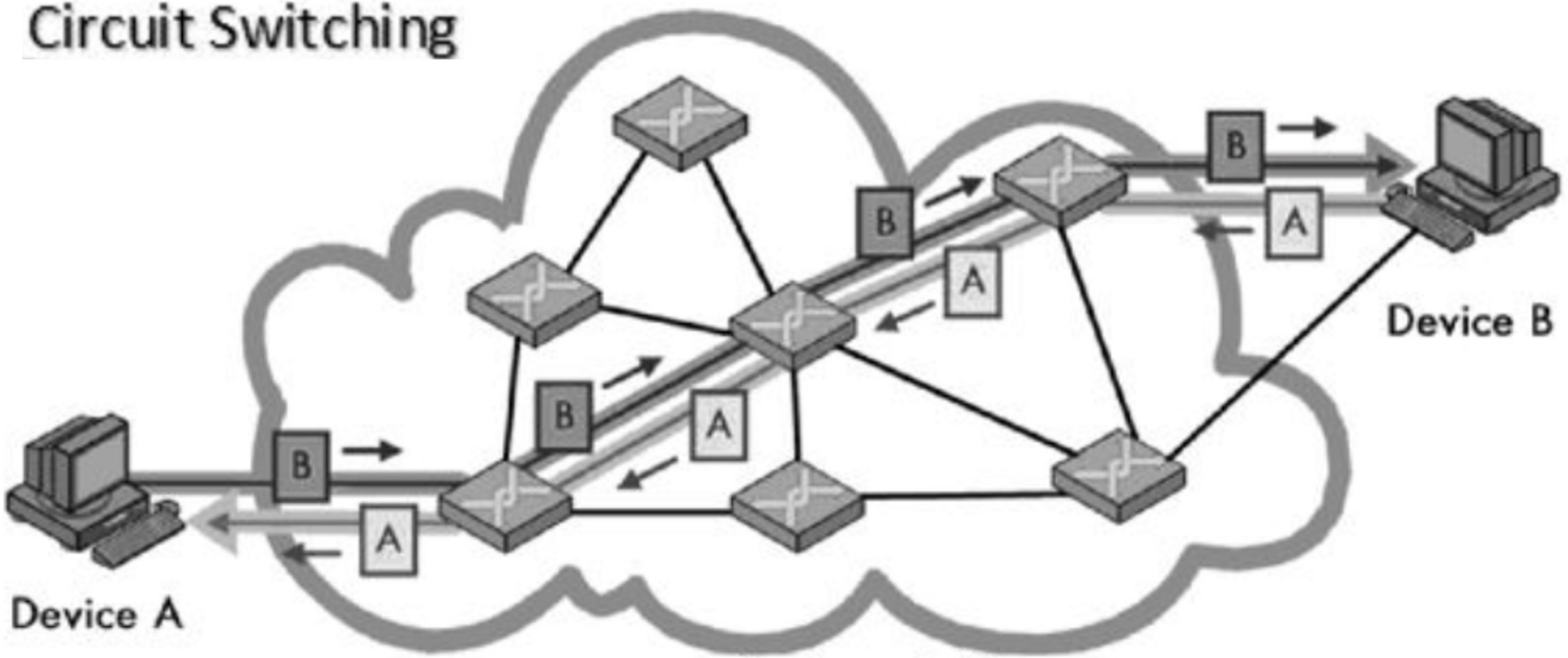
- Dedicated access to a channel
- Data rate is guaranteed and not load dependent
- Senders and receivers operate at the same data rate
- Transfer path is booked during transfer of data and other system cannot use until data transfer complete
- All data follows the same path
- Common example is telephone network like PSTN



Circuit Switching



Circuit Switching



Circuit Switching

Advantages of Circuit Switching

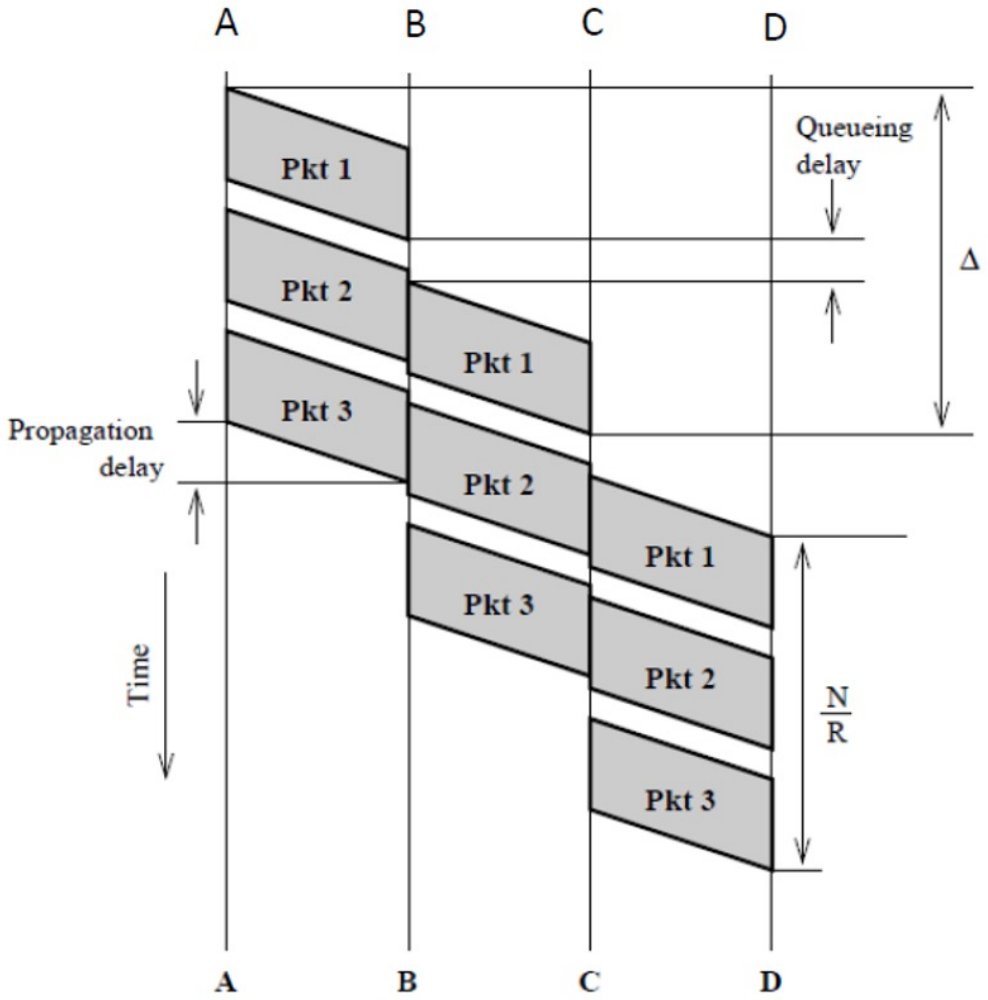
- The circuit switching communication is efficient.
- There are fewer chances of errors.
- It is also highly reliable

Disadvantages of Circuit Switching

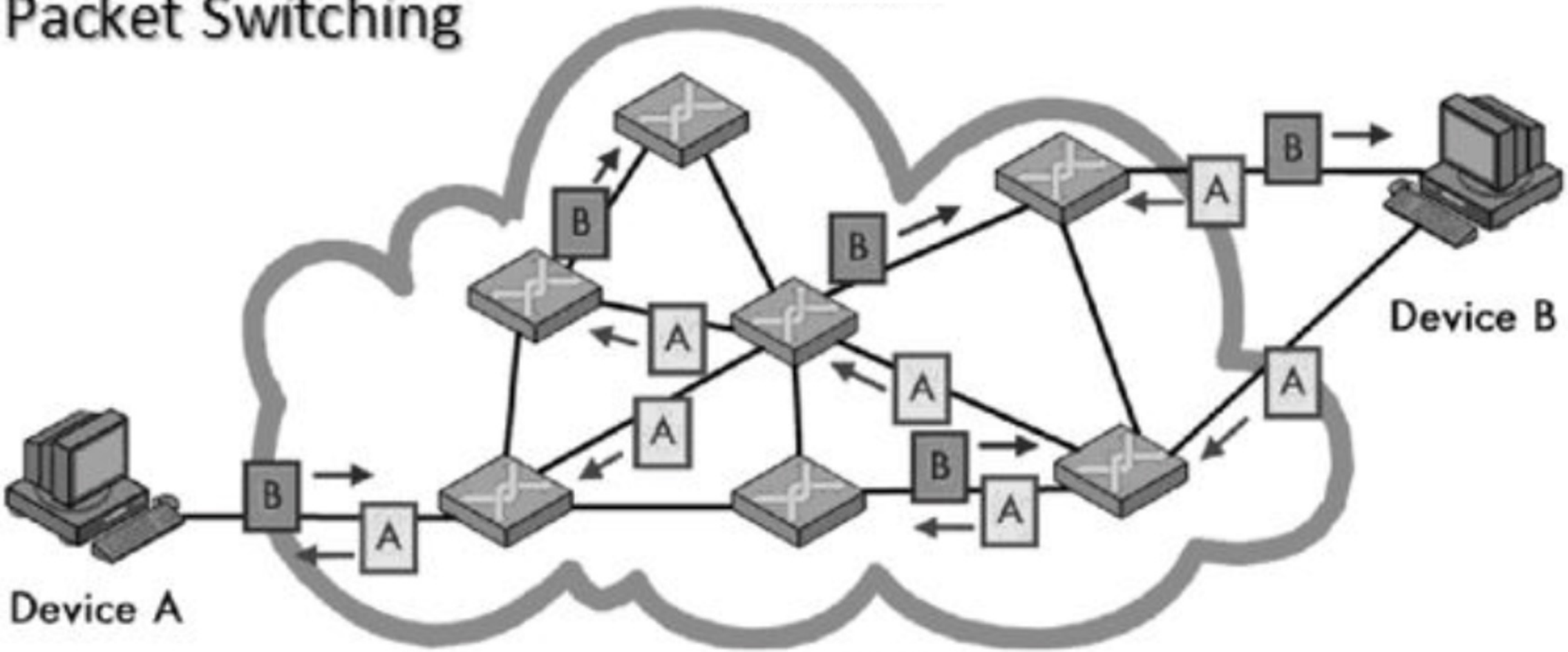
- Circuit switching requires a lot of formalities, during formation of the connection.
- The bandwidth may be wasted, especially; when a user is only listening, and not talking.
- The setting up of the channel may take longer time.

Packet Switching

- In the packet switching, the block of data (packets) are stored and forwarded from one node to another
- Each packet contains "header" which consist of routing information form source to destination.
- The packet switching suffers from queuing delays since packets are always stored in the memory of a node before being forwarded to the next node
- Packets are independent of each other and use connectionless mode transmission
- Example is internet where most of applications transfer data via connectionless model of communication



Packet Switching



Packet switching

Advantages of Packet Switching

- It makes efficient use of network resources.
- It can manage variable data rates.
- It can easily handle increase number of transactions

Disadvantages of Packet Switching

- It is not good scheme for small data packages,
- The ordering of packets may alter during the transmission and re-ordering takes more time.

Circuit Switching Vs Packet Switching

- Reserve entire channel before data transmissions
- Physical path between source and destination)
- Idle reserved resources can't be used by any other ongoing connection
- No waiting at the switches
- Not efficient (bandwidth wastage)
- Suitable for real-time services
- Connection-oriented
- Support less users simultaneously
- Allocate dedicated transmission resources
- All packets use same path

- Channels NOT reserved before data transmission
- No fixed physical connection
- The idle resources can be used by any other ongoing user
- Waiting at switches if data rate is more than the link capacity
- Efficient (No Bandwidth wastage)
- Suitable for best effort services
- Connectionless
- Support more users simultaneously
- Allocate variable transmission rate based on demand
- Packet travels independently

Switching and Routing

- Switch act as connector only, receives packets and sent them directly
- Switching examines the MAC address and determines where packet should be sent within the data link header of packet
- Switching maintains information about MAC address and related ports in database and uses it to find next location

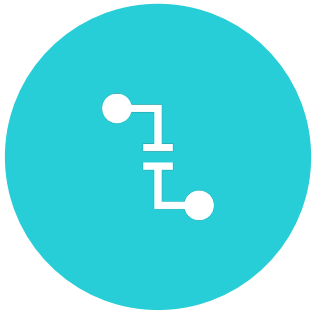
- Routing method makes use of routes
- Router acts as connector and a scheduler and manages traffic of network
- Determines optimal path in network and rout packet accordingly
- Router makes use of this routing to determine the route to destination host.

Routing - Packet switching Technique

- Process of transferring information from one location to other
- Referred to as procedure of selecting a path to send the packets over a network
- Important feature of internet
- Each node receives information and passes it to other until it reaches to its destination
- Router receives packets and forwards it to next destination node
- Network connection point which connects two different networks with each other

Source Routing

Path is set by source node



Technique used to specify the route of packet through the network

Source needs to pass information along a specified way

Can be used to troubleshoot a network and increase network performance

Hop-by-Hop Routing

SOURCE NODE NOT HAVE ALL INFORMATION ABOUT THE DESTINATION

EACH NODE ALONG THE PATH PASSES THE INFORMATION PACKET ONLY TO THE NEXT NODE

PACKET FORWARDING PROCESS KEEPS ON WORKING UNTIL THE FINAL DESTINATION IS REACHED

ROUTING DECISIONS ARE BASED ON CHANNEL AVAILABILITY AND READINESS OF ADJACENT NODES

ANY QUESTION??

THANK YOU!!