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CCTN Chapter 6: Introduction to Physical-Layer Services & Systems

Transmission Media

Shubhangi Kheeche

6.1. Introduction to physical media, coax, fiber, twisted pair, DSL, HFC, WiMax, Cellular, Satellite, and Telephone n/w's, bit Transmission, frequency division multiplexing, time division multiplexing. 08 Hrs

ACCESS NETWORKS AND PHYSICAL MEDIA [Kurose Ross]

Access Networks: The physical link(s) that connect an end system to ~~any~~ its edge router, which is the first router on a path from the end system to any other distant end system.

Access n/w thus provides the infrastructure to connect the so called customer premises into the n/w infrastructure.

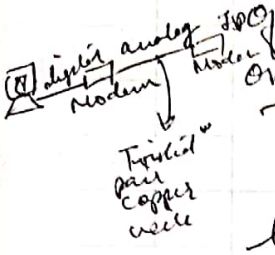
Access n/w's technology is closed tied to physical media Technology.

Classification of Access Networks

- Residential Access → Connecting home end systems into the n/w.
- Company Access → Connecting end systems in a business or educational institution into the n/w.
- Wireless Access → Connecting end systems (that are often mobile) into the n/w.

Residential Access

- Connects a home end system to an edge router.
- e.g. is dial-up modem over an ordinary analog telephone line into a residential ISP.
- The home modem converts the digital output of the PC into analog format for transmission over analog phone line.
- This analog phone line is made of twisted pair copper wire and is the same telephone line used to make ordinary phone calls.
- At the other end of the analog phone line, a modem in the ISP converts the analog signal back into digital form for input to the ISP router.



* Thus the access n/w is simply a pair of modems along with a point to point dial up phone line.

Today's modem speeds allow dial-up access at rates upto 56 Kbps. However due to the poor quality of the twisted pair line bet'n many homes and ISPs, many users get an effective rate significantly less than 56 Kbps.

Many residential users find a dial up modem's 56 Kbps access to be excruciatingly slow. for e.g. it takes appx 8 minutes to download a single three minute MP3 song over a 56 Kbps dial up modem.

Moreover, dial up modem access ties up a user's ordinary phone line - while a residential user uses a dial up modem to surf the web, the user cannot receive and make ordinary phone calls over the phone line.

Fortunately, new broadband access technologies are providing residential users higher bit rates, and they are also providing means for users to access the Internet and talk on the phone at the same time. There are two common types of broadband residential access: digital subscriber line (DSL) and Hybrid fiber-coaxial cable (HFC).

Types of Broadband residential Access

- Digital Subscriber Line (DSL) [DSL 2004] → Europe & Asia
- Hybrid fibre-Coaxial Cable (HFC). [Cable Labs 2004] → United States

- DSL and HFC are being rapidly deployed throughout the World with HFC being generally more prevalent in the United states and DSL being generally more prevalent in Europe & Asia.

Digital Subscriber Line (DSL)

- provided by telecomm company or by an Independent ISP
- Similar to dial up modems:
  - Runs over existing twisted pair telephone lines
  - DSL can transmit & Receive data at much higher rates (BS the distance bet^n user & ISP modem is restricted)
- Asymmetric data rates: Higher: (> 16 MBPS) from ISP router to home (DL)
  Lower: Home to ISP router (UL) (> 1 MBPS)

List Six access technologies. Classify each one as residential access, company access or mobile access.

① DSL ② HFC ③ Shared Ethernet ④ Switched Ethernet

- DSL uses frequency division multiplexing.
- DSL common link bet^n the house & ISP is divided into three nonoverlapping frequency bands:

① High speed downstream channel (50 KHz to 1MHz Band)

② Medium speed upstream channel (4KHz to 50KHz band)

③ An ordinary two-way telephone channel (0 to 4KHz band).

- DSL and dial up modems use ordinary phone lines.
  (HFC access n/w use current cable n/w)
- Both DSL and HFC requires special modems, called cable modems.
- Typically, cable modem is an external device and connects to the home PC through a 10-Base T Ethernet port.
- Cable modems divide the HFC n/w into two channels, a downstream (middle x^n late) and an upstream channel (bottom x^n late)

Hybrid fiber-coaxial cable (HFC)

- HFC is a shared broadcast medium.
- uses Cable Modems.
- Divides cable modems into upstream & downstream channels.

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- HFC N/w provides a reasonably higher transmission rates than D.S.L.

- One of the attractive features for DSL and HFC is that the services are always ON; that is, the user can leave his or her computer ON and remain permanently connected to an ISP while simultaneously making & receiving ordinary telephone calls.

Company Access

- On corporate and university campuses, a local area N/w (LAN) is typically used to connect an end system to the edge router.
- Ethernet (LAN) technology is currently by far the most prevalent access technology in company N/w's.
- Ethernet operates at 10 MbPS or 100 MbPS (and now even at 1 GbPS and 10 GbPS).
- It uses ~~other~~ either twisted pair copper wire or coaxial cable to connect a number of end systems with each other and with an edge router.
- The edge router is responsible for routing packet that have destination outside of that LAN.
- Like HFC, Ethernet uses a shared medium; so that end users share the transmission rate of the LAN.
- More recently, shared Ethernet technology has been migrating toward switched Ethernet technology.
- Switched Ethernet uses multiple twisted pair Ethernet ~~to be delivered to different users~~ segments connected to a "switch" to allow the full X'n rate to be delivered to different users on the same LAN simultaneously.

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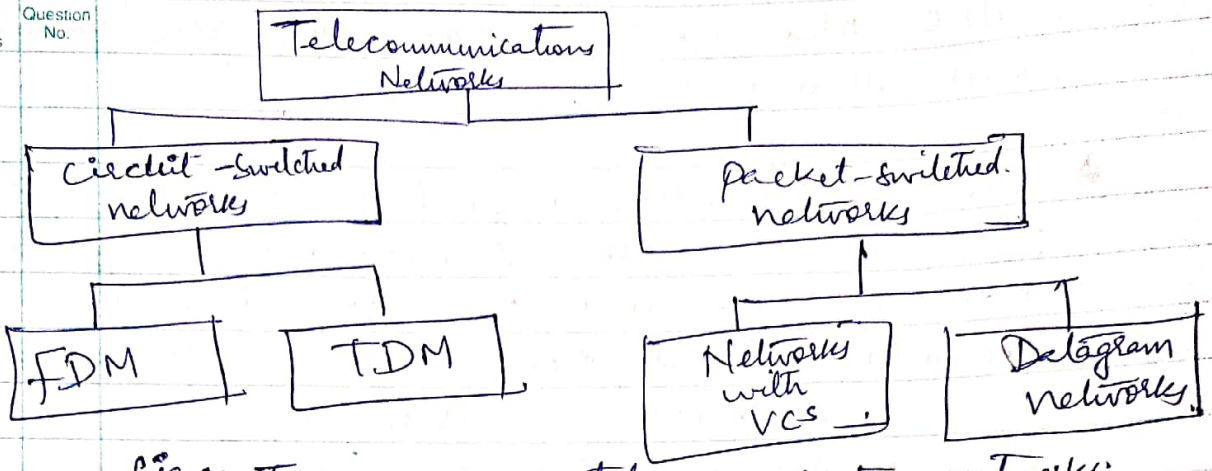

fig: Taxonomy of telecommunication networks.

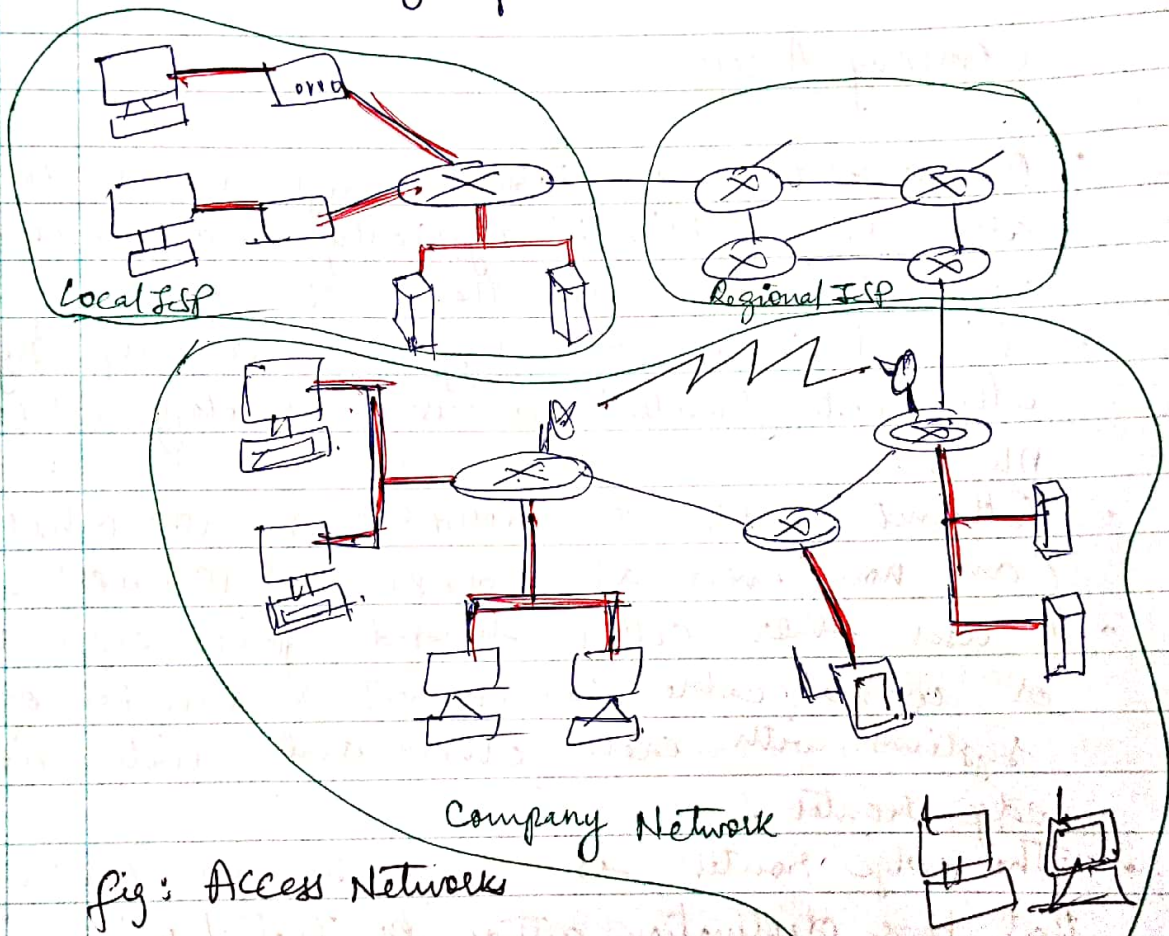

fig: Access Networks

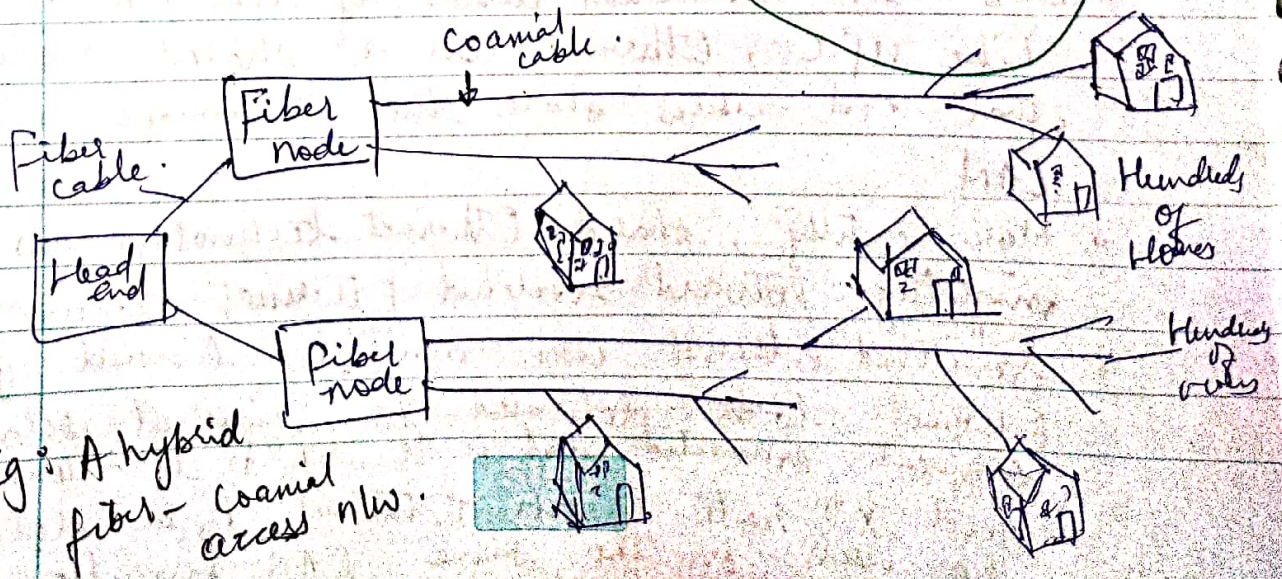

fig: A hybrid fiber-coaxial access n/w.

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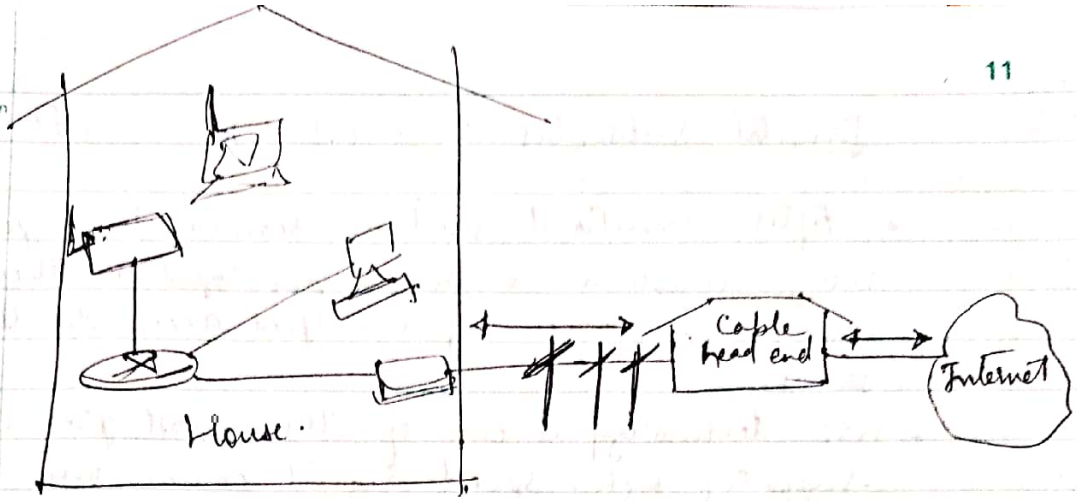

fig : A schematic of a typical home network.

Wireless Access

- Introduction :
- Wireless LAN → wireless users transmit / receive packets to/from a base station (also known as a wireless access point) within a radius of a few tens of meters.
  - The base station is typically connected to the wired Internet and thus serves to connect W/L users to the wired n/w.
- Wide-area wireless access n/w's :→ In WAWAN the base station is managed by a telecommunication provider and serves users within a radius of tens of kilometers.

WLANs → IEEE 802.11 → Wireless Ethernet
↳ Wi-fi

- WAP
- WAP phones.
- WAP Markup Language (WML)

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Digital Subscriber Line (DSL) [Forouzan]

- After traditional modems reached their peak data rate, telephone companies developed another technology DSL, to provide higher-speed access to the Internet.
- DSL technology is one of the most promising for supporting high-speed digital comm over the existing telephone line.
- DSL technology is a set of technologies, each differing in the first letter (ADSL, VDSL, HDSL and SDSL).
- The set is often referred to as xDSL, where x can be replaced by A, V, H or S.

ADSL

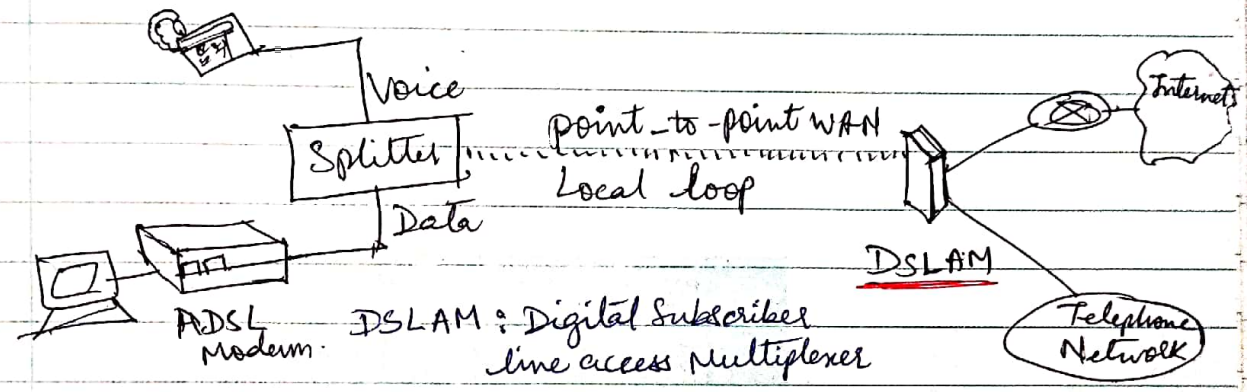
- ADSL like a 56 K modem, provides higher speed (bit rate) in the downstream direction (from the Internet to the resident) than in the upstream direction (from the resident to the Internet). That is the reason it is called asymmetric.
- The ADSL service is not suitable for business customers who need a large BW in both directions.

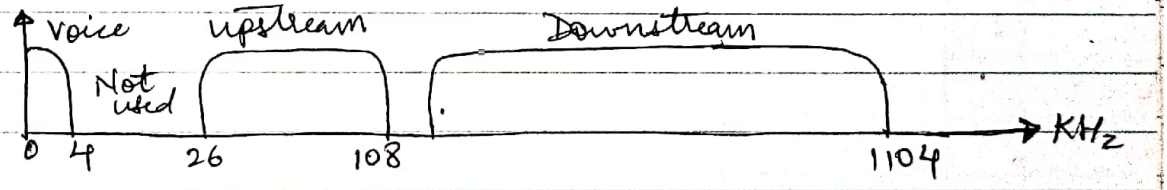
- **Using Existing Local Loops:**

One interesting point is that ADSL uses the existing telephone lines (local loop).

But how does ADSL reach a data rate that was never achieved with traditional modem?

The answer is that the twisted-pair cable used in telephone lines is actually capable of handling BW's upto 1.1 MHz, but the filter installed at the end office of the telephone company where each local loop terminates limits the bandwidth to 4 KHz (sufficient for voice communication). If the filter is removed, however, the entire 1.1 MHz is available for data & voice comm's. Typically, an available BW of 1.104 MHz is divided into a voice channel, an upstream channel, and a downstream channel, as in fig below.





- fig: ADSL point-to-point network

- ADSL allows the subscriber to use the voice channel and data channel at the same time.
- The rate for the upstream can reach 1.44-Mbps.
  However, the data rate is normally below 500Kbps because of the high level noise in this channel.
- The downstream data rate can reach 13.4 Mbps.
  However, the data rate is normally below 8 Mbps because of noise in this channel.
- A very interesting point is that the telephone company in this case serves as the ISP, so services such as email or Internet access are provided by the telephone company itself.

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Q.1 What is DSL technology? What are the services provided by the telephone companies using DSL? Distinguish between a DSL modem and a DSLAM.

Q.2. What type of topology is used when customers in an area use DSL modems for data transfer purposes? Explain.

Q3. Calculate the minimum time required to download one million bytes of information using ADSL implementations (consider the minimum rates).

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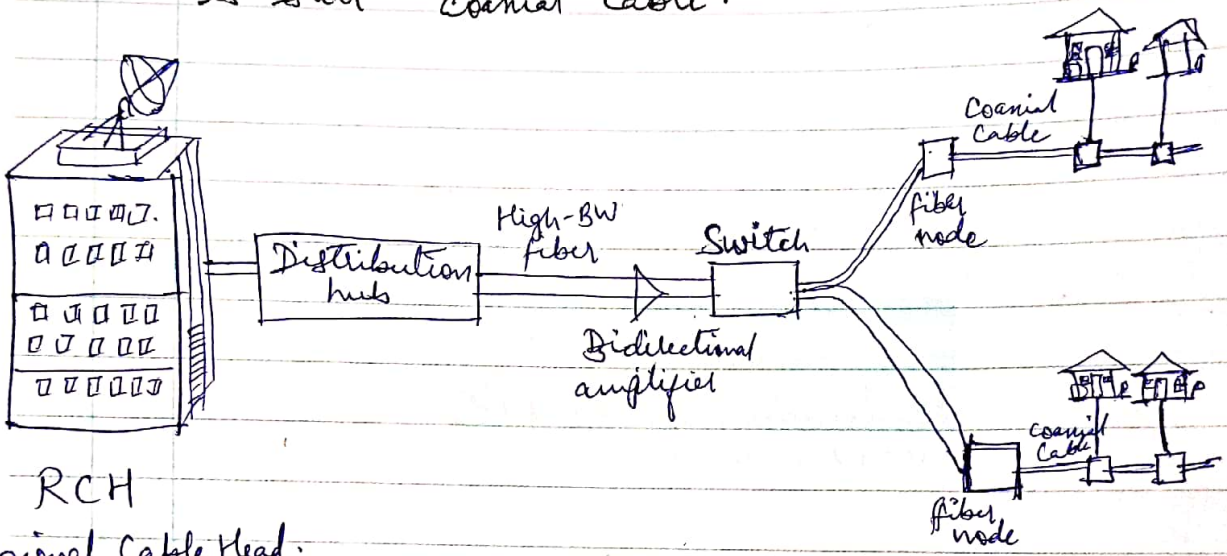
Hybrid Fiber-Coaxial (HFC) Network

- The 2nd Generation of cable Nw is called a hybrid fiber-coaxial (HFC) network.
- The nlw uses a combination of fiber optic & coaxial cable.
- The transmission medium for the cable TV office to a box, called the fiber node, is optical fiber, from the fiber node into the neighborhood and into the house is still coaxial cable.



RCH
Regional Cable Head.

- fig: Hybrid fiber-coaxial (HFC) network

- The regional cable head (RCH) normally serves up to 400,000 subscribers.
- The RCHs feed the distribution hubs, each of which serves upto 40,000 subscribers.
- The distribution hub plays an important role in the new infrastructure.

  Modulation and distribution of signals are done here; the signals are then fed to the fiber nodes through fiber-optic cables.
- The fiber node splits the analog signals so that the same signal is sent to each coaxial cable.

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- Each coaxial cable serves upto 1000 subscribers.
- The use of fiber-optic cable reduces the need for amplifiers down to eight or less.

One reason for moving from traditional to hybrid infrastructure is to make the cable n/w bidirectional (two-way).

TRANSMISSION MEDIA

- Transmission media are actually located below the physical layer and are directly controlled by the physical layer.
- Thus Tx^n media belongs to layer zero.
- A guided medium provides a physical conduit from one device to another.
- Twisted pair cable consists of two insulated copper wires twisted together.
- Twisted pair cable is used for voice & data communications.
- Coaxial cable consists of a central conductor and a shield.
- Coaxial cable is used in cable TV n/w's & traditional Ethernet LAN's.
- Fiber-optic cables are composed of a glass or plastic inner core surrounded by cladding, all encased in an outside jacket.
- Fiber-optic x^n is becoming increasingly popular due to its noise resistance, low attenuation, and high BW capabilities.
- Fiber-optic cable is used in backbone n/w's, cable TV n/w's and fast Ethernet n/w's.

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- Unguided media (free space) transport electromagnetic waves without the use of a physical conductor.
- Wireless data are transmitted thro' ground propagation, sky propagation, and line-of-sight propagation.
- Wireless waves can be classified as radio waves, microwaves, or infrared waves.
- Radio waves are omnidirectional; microwaves are unidirectional.
- Microwaves are used for cellular phone, satellite and wireless LAN communications.
- Infrared waves are used for short-range communications such as those bet^n a PC & a peripheral device. They can also be used for indoor LANs.

Introduction:

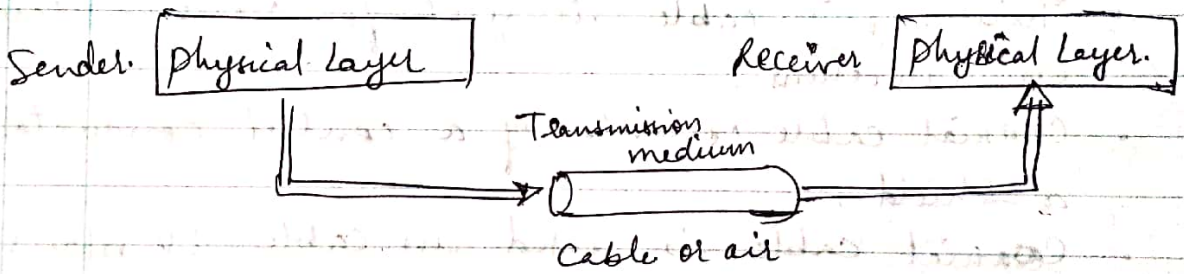


fig: Transmission medium & physical layer.

- Transmission medium belongs to layer zero.
- It carries information from source to destination.

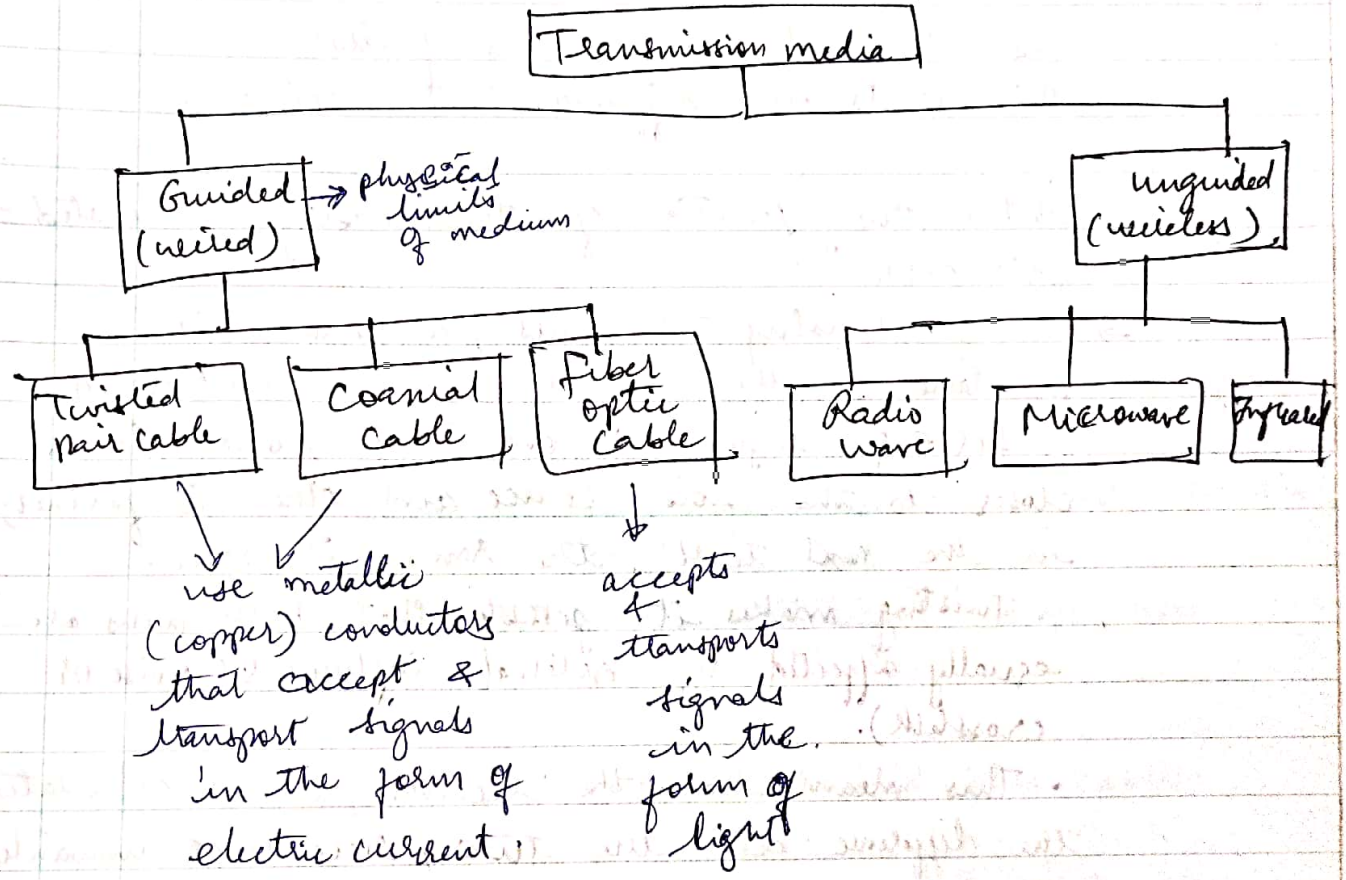
Transmission medium examples:
air ⇒ dinner conversation
written message ⇒ mail carrier, truck or an airplane

- In data communications:
  x^n medium is usually free space, metallic cable, or fiber optic cable.

In Telecommunications, transmission media can be divided into two broad categories: guided and unguided.

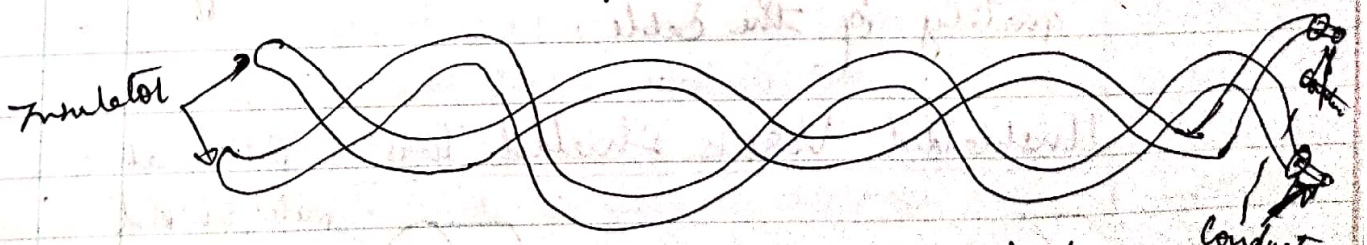
* Unguided medium is free space.

Classes of transmission media:



TWISTED PAIR CABLE

- It consists of two conductors (normally copper), each with its own plastic insulation, twisted together



- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.
- The receiver uses the difference between the two.

- In addition to the signal sent by the sender on one of the wires, interference (noise) & crosstalk may affect both wires and create unwanted signals.
- If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources (e.g., one is closer and the other is farther).
- This results in a difference at the receiver.

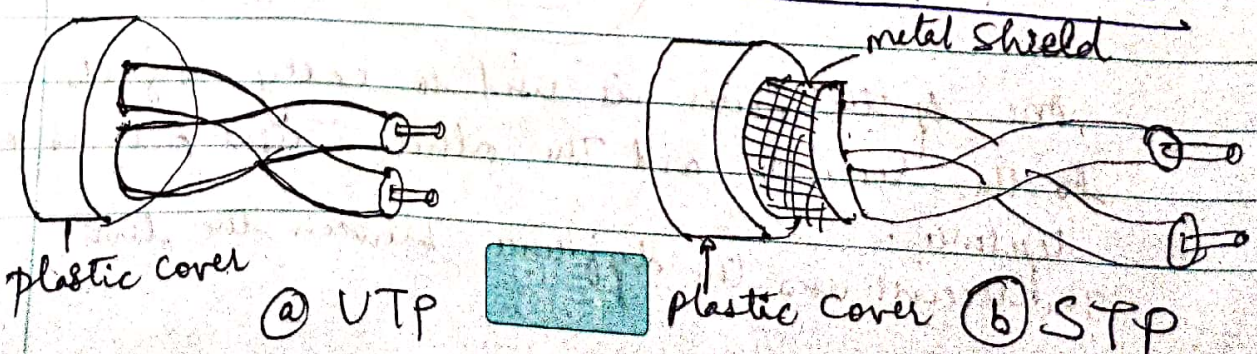
Q. What is the function of the twisting in twisted-pair cable?

→ By twisting the pairs, a balance is maintained in the received signal at the receiver.

For e.g., suppose in one twist, one wire is closer to the noise source and other is farther; in the next twist, the reverse is true.

- Twisting makes it possible that both wires are equally affected by external influences (noise or crosstalk).
- This means that the receiver, which calculates the difference bet^n the two, receives no unwanted signals.
- The unwanted signals are mostly canceled out.
- From above, it is clear that the number of twists per unit of length (e.g., inch) has some effect on the quality of the cable.

Unshielded Versus Shielded Twisted-Pair Cable



(a) UTP (b) STP

- The most common twisted-pair cable used in communications is referred to as unshielded twisted-pair (UTP).
- IBM has also produced a version of twisted pair cable for its use, called shielded twisted pair (STP).
- STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors.
- Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive.

(STP is seldom used outside of IBM)

Categories

- The Electronic Industries Association (EIA) has developed standards to classify unshielded twisted pair cable into seven categories.
- Categories are determined by cable quality, with 1 as the lowest and 7 as the highest.

Each EIA category is suitable for specific uses. Table below shows these categories.

Table 1: Categories of unshielded twisted-pair cables.

Category	Specification	Data Rate (MBPS)	Use
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring n/w's	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs

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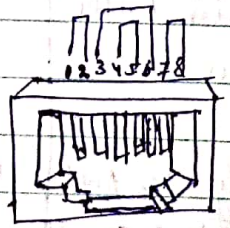
Categories of unshielded twisted-pair cables (continued)

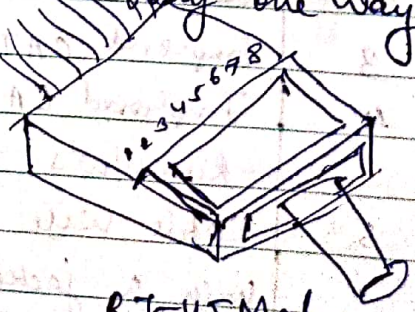
Category	Specification	Data Rate (MBPS)	Use
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200 MBPS data rate.	200	LANs
7.	Sometimes called SSTP (Shielded Screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs.

Connectors

- The most common UTP connector is RJ45 (RJ stands for registered jack), as shown in fig below.
- The RJ45 is a keyed connector, meaning the connector can be inserted in only one way.



RJ-45 female



RJ-45 Male

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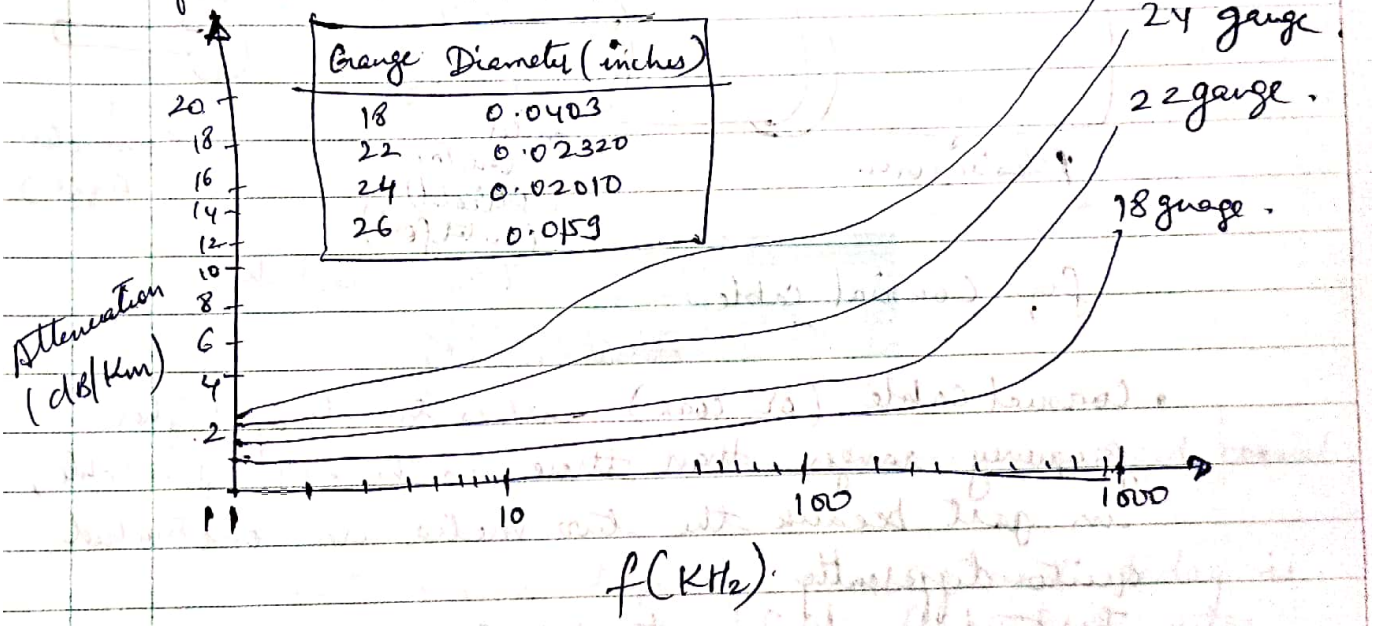
Performance:

- One way to measure the performance of twisted pair cable is to compare attenuation versus frequency and distance.
- A twisted-pair cable can pass a wide range of frequencies.
- However, fig below, shows that with increasing frequency, the attenuation, measured in decibels per kilometer (dB/Km), sharply increases with frequencies above 100 KHz.
Note that Guage is a measure of the thickness of the wire.

Guage	Diameter (inches)
18	0.0403
22	0.02320
24	0.02010
26	0.0159



Applications of Twisted pair Cables:

1) Telephone Lines (to provide Voice & data channels)
2) Local loop
3) DSL lines (telephone companies).
4) Local area n/w's. (10 Base-T, 100 Base-T).

- Twisted pair cables are used in telephone lines to provide voice & data channels.
- The local loop - the line that connects subscribers to the central telephone office - commonly consists of unshielded twisted pair cables.

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- The DSL lines that are used by the telephone telephone companies to provide high-data-rate connections also use the high BW capability of unshielded twisted pair cables.
- Local-area networks, such as 10 Base-T and 100 Base-T, also use twisted pair cables.

Coaxial Cable

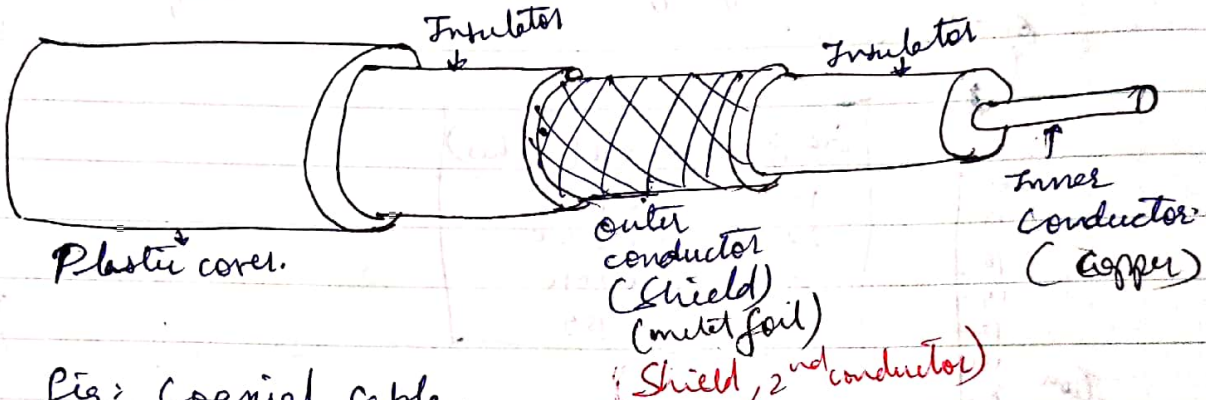

fig: Coaxial cable.

- Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted-pair cable, in part because the two media are constructed quite differently.
- Instead of having two wires, coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which, in turn, encased in an outer conductor of metal foil, braid, or a combination of the two.
- The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the ckt.
- The outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

Coaxial Cable Standards

- Coaxial cables are categorized by their Radio Government (RG) ratings.
- Each RG number denotes a unique set of ~~physical~~ physical specifications, including the wire guage of the inner conductor, the thickness and type of the inner insulator, the construction of shield and the size and type of the outer casing.

Table2: Categories of Coaxial cables

Category	Impedance	Use
RG-59	75Ω	Cable TV
RG-58	50Ω	Thin Ethernet
RG-11	50Ω	Thick Ethernet

Coaxial Cable Connectors:

- To connect coaxial cable to devices, we need coaxial connectors.
- The most common type of connector used today is the Bayonet Neill-Concelman (BNC) connector.
- 3- popular types of these connectors: the BNC Connector, the BNC T connector, and the BNC terminator
- The BNC connector is used to connect the end of the cable to a device, such as a TV set. The BNC T connector is used in Ethernet networks to branch out to a connection to a computer or other devices. The BNC terminator is used at the end of the cable to prevent the reflection of the signal.

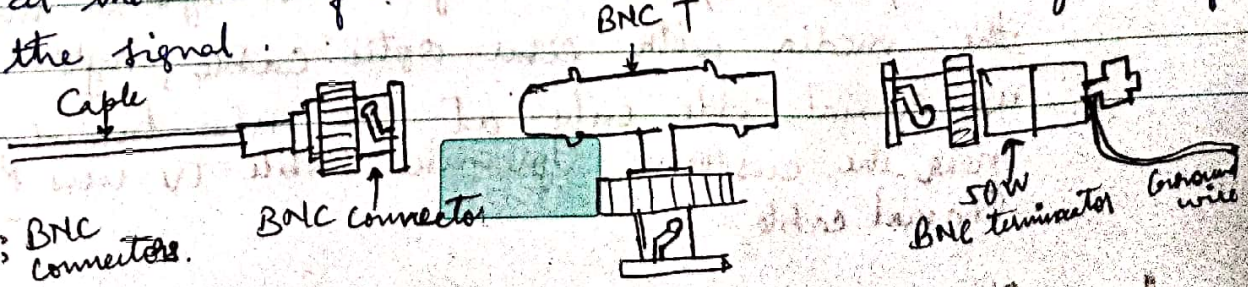

fig: BNC connectors.

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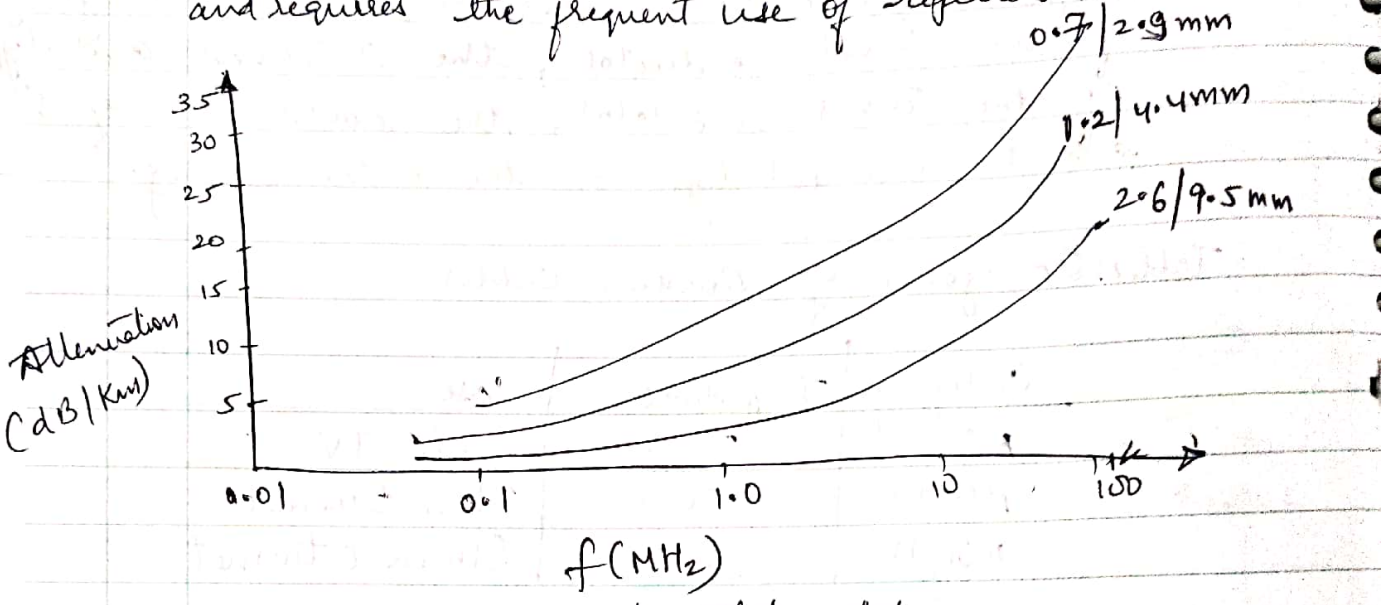
Performance

Fig below shows that the attenuation is much higher in coaxial cable than in twisted pair cable. In other words, although coaxial cable has a much higher Bandwidth, the signal weakens rapidly and requires the frequent use of repeaters.



Applications:

1. Analog Telephone nlw's
2. Digital Telephone nlw's
3. Cable TV nlw's
4. Traditional Ethernet LANs.

- Coaxial cable was widely used in analog telephone nlw's where a single coaxial nlw could carry 10,000 voice signals.
- Later it was used in digital telephone nlw's where a single coaxial cable could carry digital data upto 600 MBPS.
- However, coaxial cable in telephone nlw's has largely been replaced today with fiber optic cable.
- Cable TV nlw's also use coaxial cables.
- In the traditional cable TV nlw, the entire nlw used coaxial cable.
- Later, however, cable TV providers replaced most of the media with fiber-optic cable; hybrid nlw's use coaxial cable only at the nlw boundaries, near the customer premises. Cable TV uses RG-59 coaxial cable.

Another common application of coaxial cable is in traditional Ethernet LANs.

- Because of its high BW, and consequently high data rate, coaxial cable was chosen for digital xn in early Ethernet LANs.
- The 10Base-2 or Thin Ethernet, uses RG-58 coaxial cable with BNC connectors to transmit data at 10MBPS with a range of 185 m
- The 10 Base-5 or Thick Ethernet, uses RG-11 (thick coaxial cable) to transmit 10 MbPS with a range of 5000 m.
- Thick Ethernet has specialized connectors.

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Unguided Media (wireless medium) (air, space, water)

- Transmit information in the form of waves
- No physical path between two devices for transmission of data

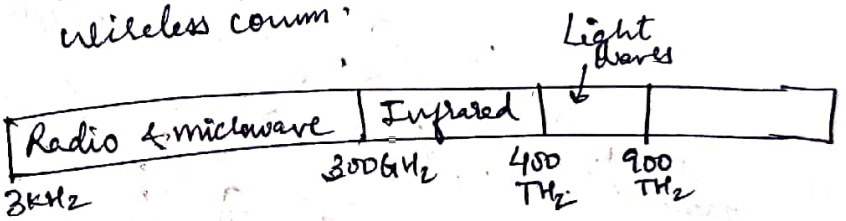
unguided medium

- Microwave
- Satellite Comm.
- Mobile Comm.

Microwave

- Data transmission through air
- High frequency waves which can only travel in a straight line
- LOS has to be maintained bet^n the Tx & Rx towers
- Mwaves cannot bend or pass through obstacles (like trees, mountains) (Drawback)
- Scope of Mwaves is city
- repeaters are required over a distance of 20 to 30 miles to maintain LOS.
- Mwaves cannot be used for long distance comm (repeaters, power amplifiers are required, higher height antennas & towers are reqd)
- Same Height antennas are reqd.

Electromagnetic Spectrum for wireless comm.



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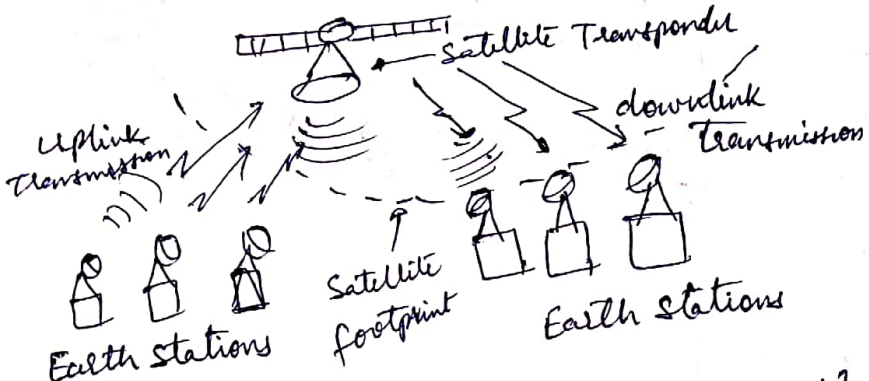
Drawbacks of microwave communication:

- Curvature of earth, mountains and other structures (building, trees) often block the line of sight.

Satellite Communication:

- Instead of antenna, satellite can also be used to transmit microwave messages from one location to another.



Uplink frequency = 6 GHz
Downlink freq = 4 GHz
} In C-Band

- Moon is a natural satellite
- Satellite delay is of 2 seconds for signal from earth to Moon & back from moon to earth
- This satellite delay is in ms (milliseconds) in case of artificial satellites.
- Satellite rotates approx 23300 miles above the earth in precise location.
- A large volume of data can be transmitted at a very high speed.
- Transmission and reception costs are independent of the distance between two points.

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Classification of Satellites

(1) Based on the Principle of operation

Passive Satellites

- Cannot generate power
- Has metal cover on it, which reflects signal from one to the other
- Larger distances are not covered by passive satellites.

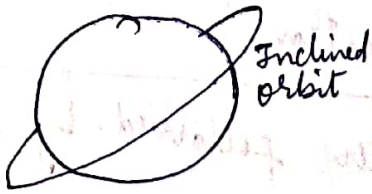
Active Satellites

- Generate power
- Has transponder which receives signal, amplifies it, downconverts & transmits it back to the earth.
- Larger distances are covered by active satellites

(2) Based on orbits (Types of orbits)

- Equatorial orbit Satellites

- Inclined orbit Satellites



- Polar orbit satellites

(3) Based on Altitude of Satellite

- Low Earth orbit (LEO)
- Medium Earth orbit (MEO)
- Geosynchronous Earth orbit (GEO)

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- Different communication satellites are used to carry different kinds of communication.
- Some satellites for → TV transmission
- Some satellites for → Telephone signals transmission (voice transmission)
- Some satellites for → Internet data transmission

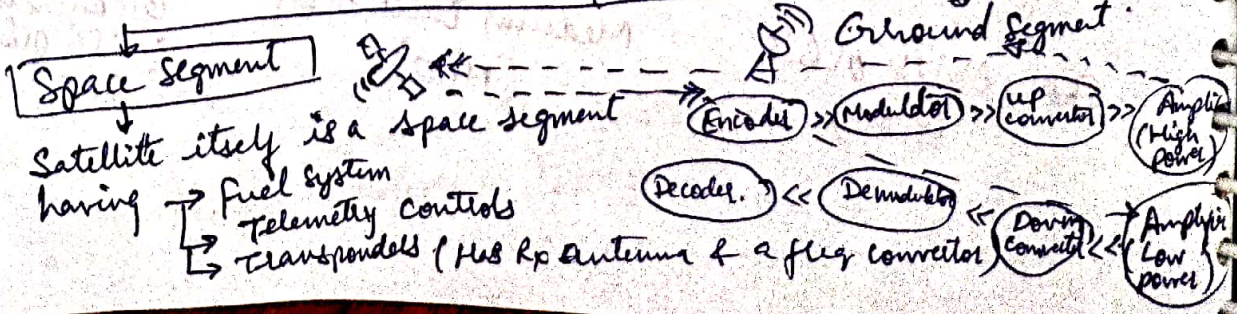
Satellites also used for military communication, weather and radio stations..

Disadvantages of Satellite communication

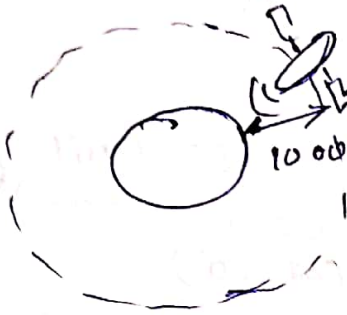
- The bad weather can severely affect the quality of transmission..
- Satellite transmission causes security problems because it is easy to intercept the transmission through air.
- cost of transmission is very high (If it is used for short distance comm.)
- Satellite delay is still present in all our Satellite communication.

- The path followed by the satellite is called as orbit.
- communication satellite receives signals from the transmitting ground station.

Communication Satellite System



smaller distances are covered, so large no of LEO satellites are required (arround 66)



- 3 GEO satellites are required to cover entire earth.

LEO	MEO	GEO
1) 500-1000Km above earth	1) 10000 to 20000Km above earth	1) 36000 Km above earths surface.
2) 95 to 120 min orbiting time	2) 6 Hours (orbiting time)	2) 23 Hrs 59 min 4Sec orbiting time
3) covers very small area	3) covers larger area than LEO	3) covers largest area (40% of earths surface)
4) 66 LEO's are required to cover entire earth.	4) 10-12 MEO satellites are required to cover entire Globle.	4) One GEO satellite covers around 40% of earths surface. So Min. 3 GEO satellites are required to cover entire Globle (at 20°)

~~Shubangi~~
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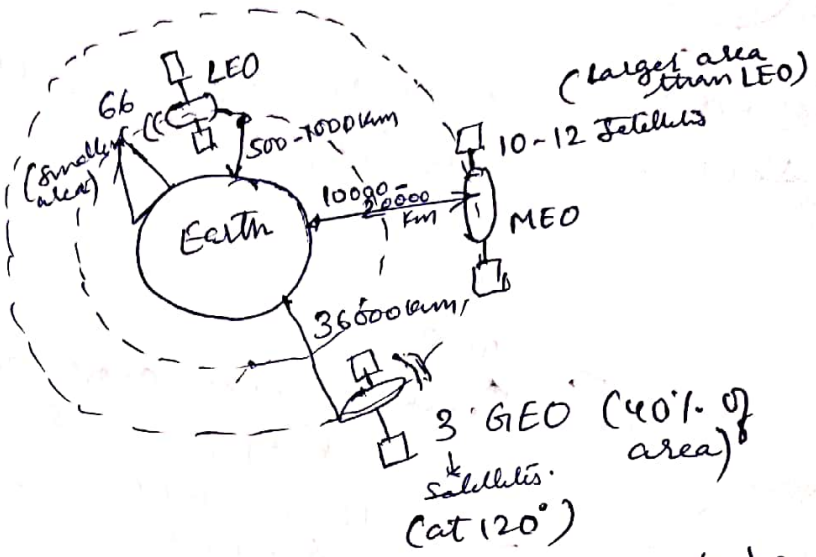

Geostationary Orbit (Satellite appears to be stationary above the earths surface)

- 36000km above the earths surface
- Eastward rotation same as earth rotational speed
- inclination w.r.t. Earth should be zero degree

Geostationary orbit	Geosynchronous orbit
 • circular orbit	 non circular orbit
 • Lies in equatorial plane	 • inclined w.r.t equatorial plane
• only one Geostationary orbit is possible (at 36000km) towards equatorial plane.	• Many Geosynchronous orbits are possible (36000km from earths surface to many planes).

★ All Geostationary are Geosynchronous But All Geosynchronous are not Geostationary.

④ Based on Applications

- Communication Satellite e.g. Intelsat
- Remote Sensing Satellite e.g. IRS
- Navigation Satellite e.g. GPS, GLONASS.

⑤ Based on Coverage Distance:

- National coverage e.g. INSAT
- Regional coverage e.g. ARAB
- International Coverage e.g. INTELSAT

⑥ Based on Orbit of Rotation

- Circular Orbit Satellite
- Elliptical Orbit Satellite.

Q. Why uplink frequency is greater than downlink frequency in satellite communication?

→ uplink and downlink frequencies are different to avoid confusion in communication.

→ uplink signal (Tx Earth station to satellite) should be high energy signal so as to pass through the atmosphere.

→ High energy ∧ frequency signal has high energy

→ So uplink frequency is greater

(Also transponder at satellite cannot maintain power amplifies to amplifies if the received signals are very weak.

(• Transponders are powered with solar cells (solar energy) for its operation :)

→ In downlink, comparatively lower frequency is acceptable than that in the uplink.

→ In C-Band uplink freq = 6GHz & Downlink freq = 4GHz.

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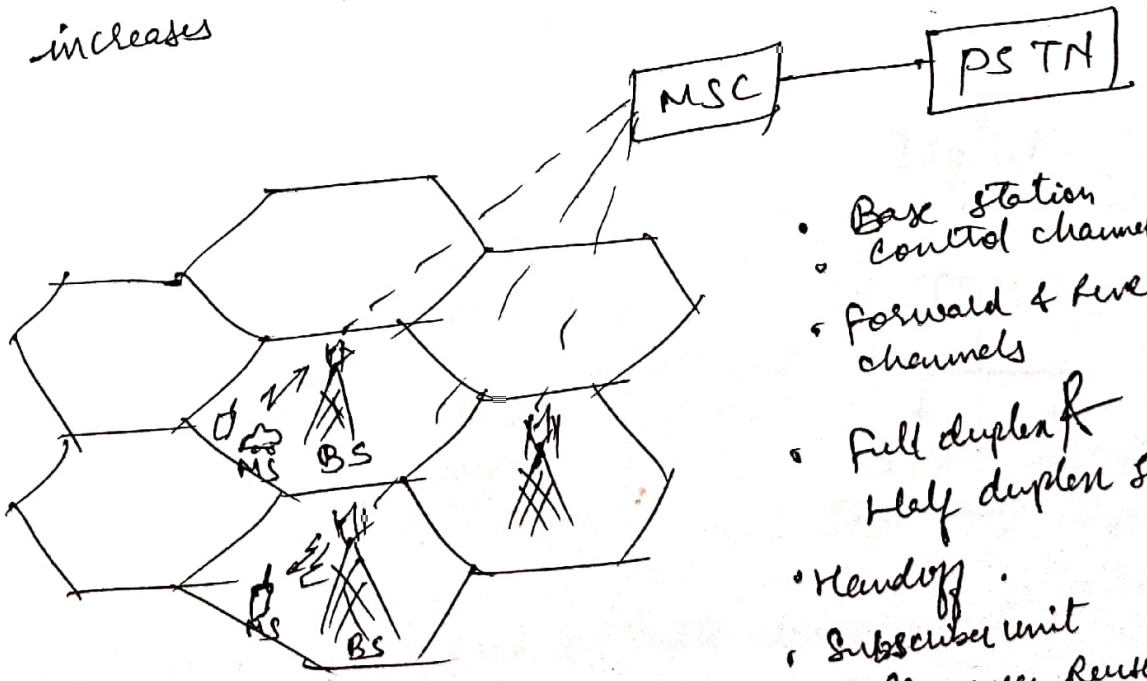
Mobile communication / Cellular Communication

- Above 800 MHz
- 1987 → Guglielmo Marconi

- Mobile Comm. Generations

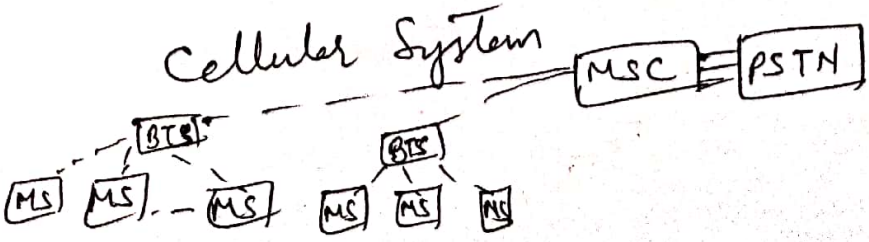
	standards	Data rates	Modulation	Multiple access
1G	AMPS	only voice, No Data	FM	FDMA
2G	GSM	9.6 KbPS	GMSK	TDMA
2.5G	GPRS	115 KbPS	GMSK	TDMA
2.75G	EDGE	384 KbPS	GMSK / octal PSK	TDMA
3G	3GPP	2 MbPS	~~CDMA~~ 8PSK, BPSK	CDMA
4G	4G LTE	100 GbPS	OFDM	OFDMA
5G		More than 600 GbPS	OFDM	OFDMA.

with Increase in mobile comm Generations the BW and Data rates and Spectral efficiency increases



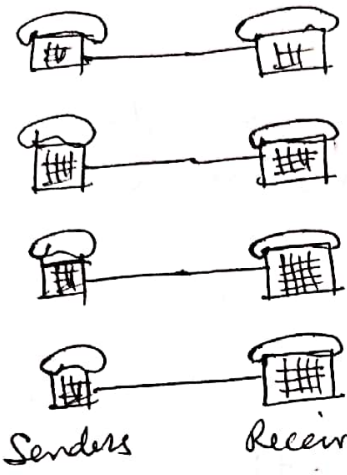
- Base station control channel
- forward & Reverse channels
- Full duplex & Half duplex Systems.
- Handoff
- Subscriber unit
- frequency Reuse
- channel allocation
  - fixed
  - dynamic
- Adjacent & co channel cells
- Cell shapes.

Cellular System

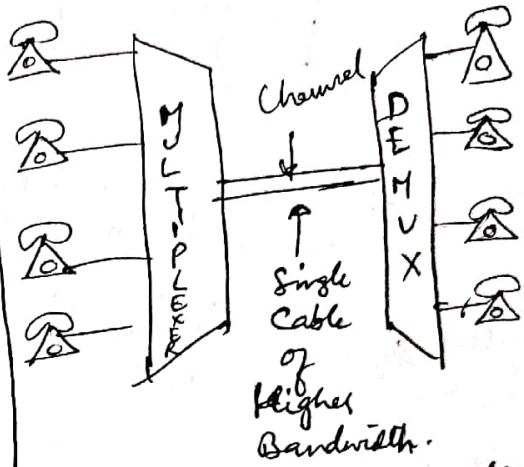


Multiplexing Techniques

Why Multiplexing is Needed?
What is Multiplexing?

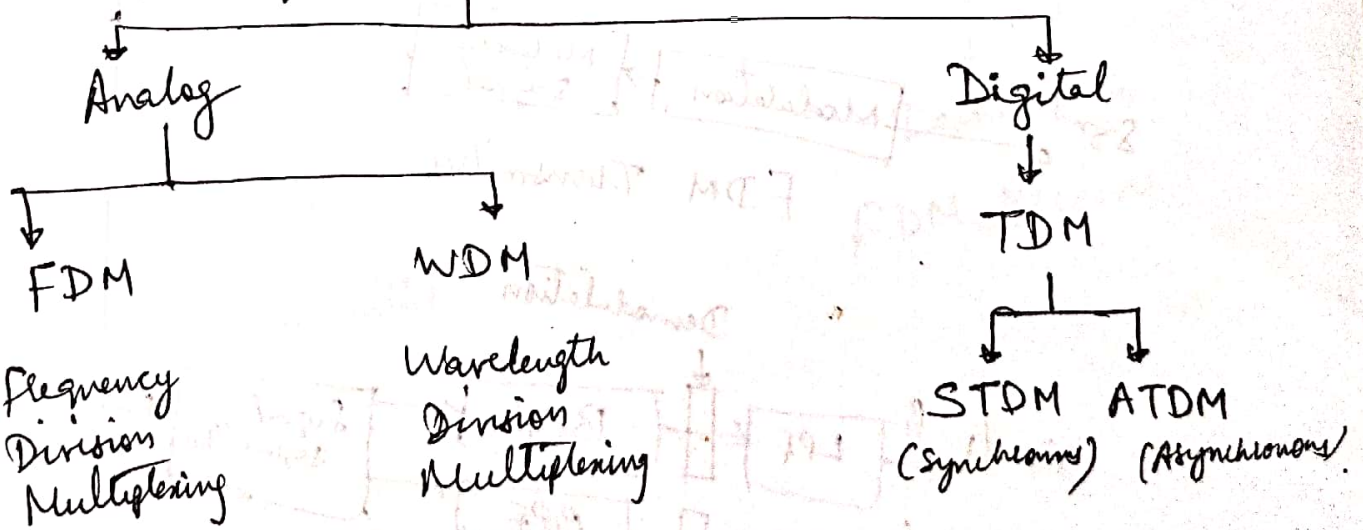


- Point to point links (Twisted pairs) cannot be carried over longer distances so there is need of Multiplexing



- Multiplexing & Demultiplexing
- Here users are sharing the common channel BW.

- Types of Multiplexing



- Multiplexing is required in both telephone & computer networks

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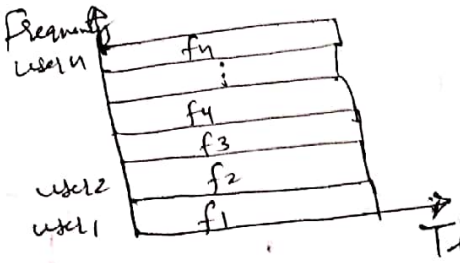
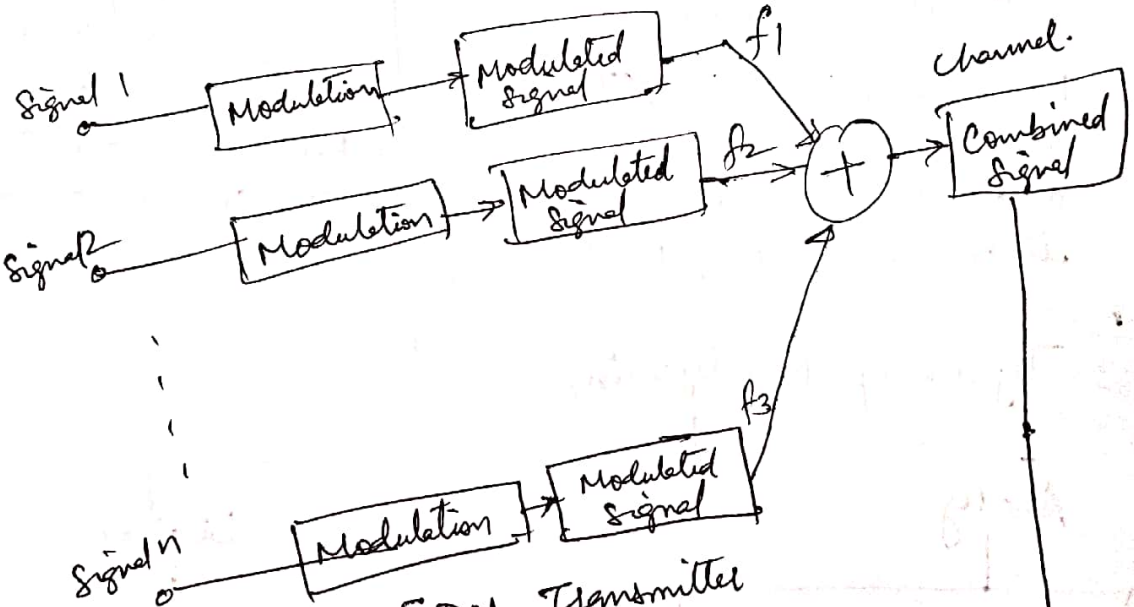
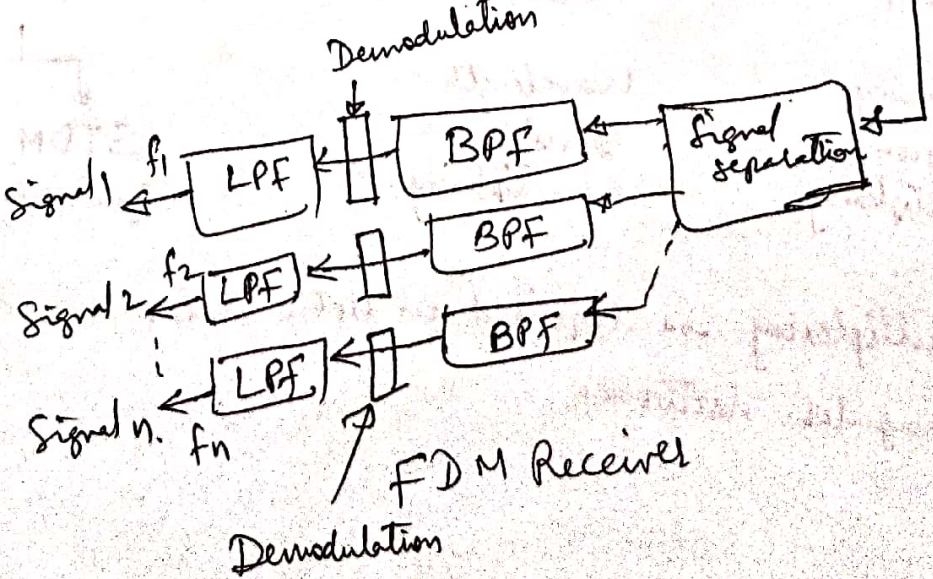
Frequency Division Multiplexing (FDM)



- Here users are separated in frequency. Sharing of channel BW is done based on frequency.



FDM Transmitter



FDM Receiver

Demodulation

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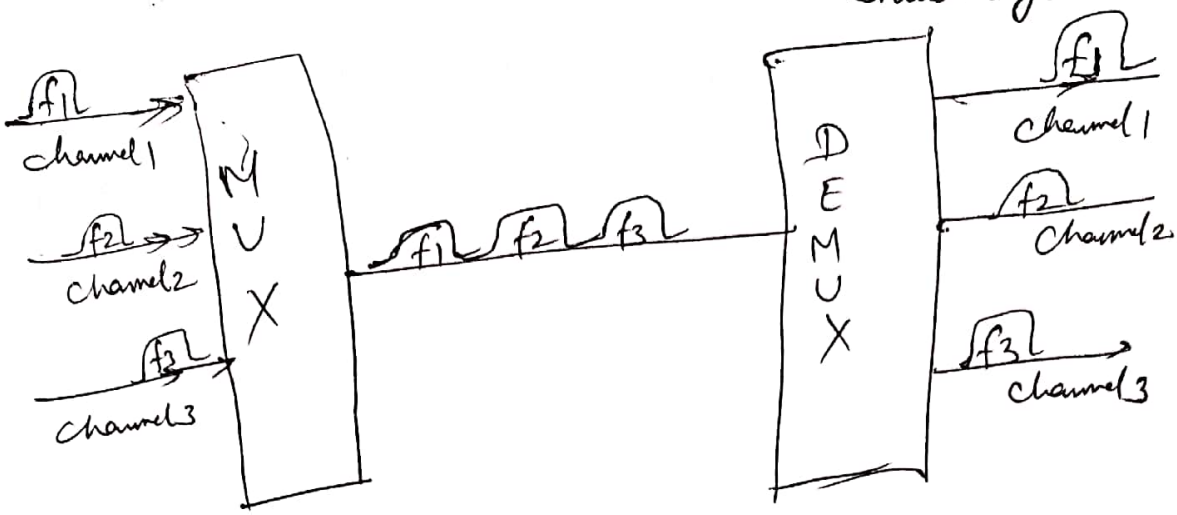
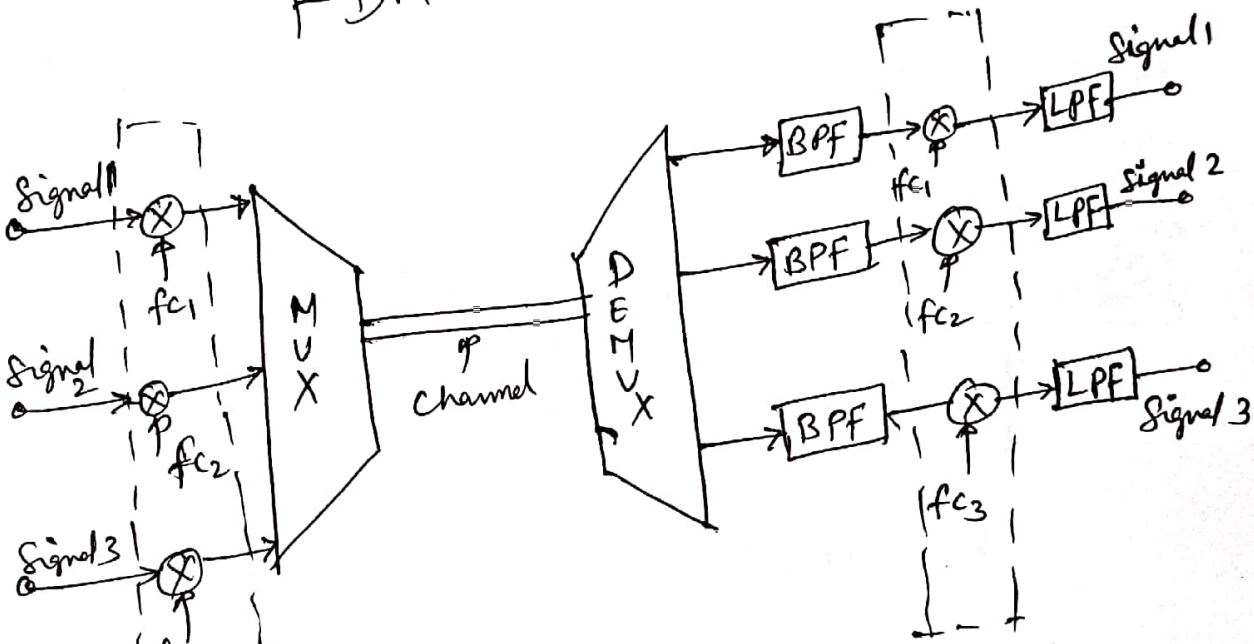


FDM



FDM Transmitter

FDM Receiver

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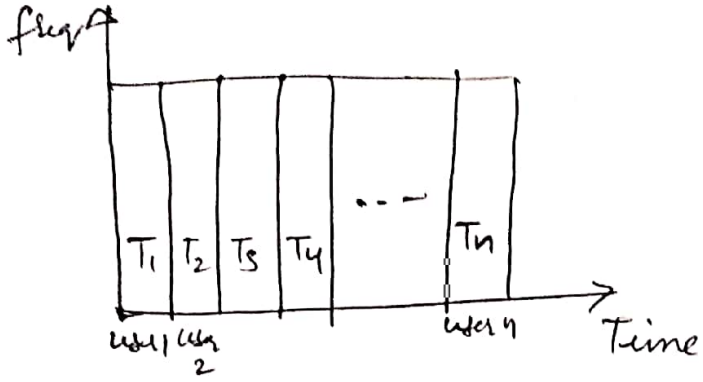
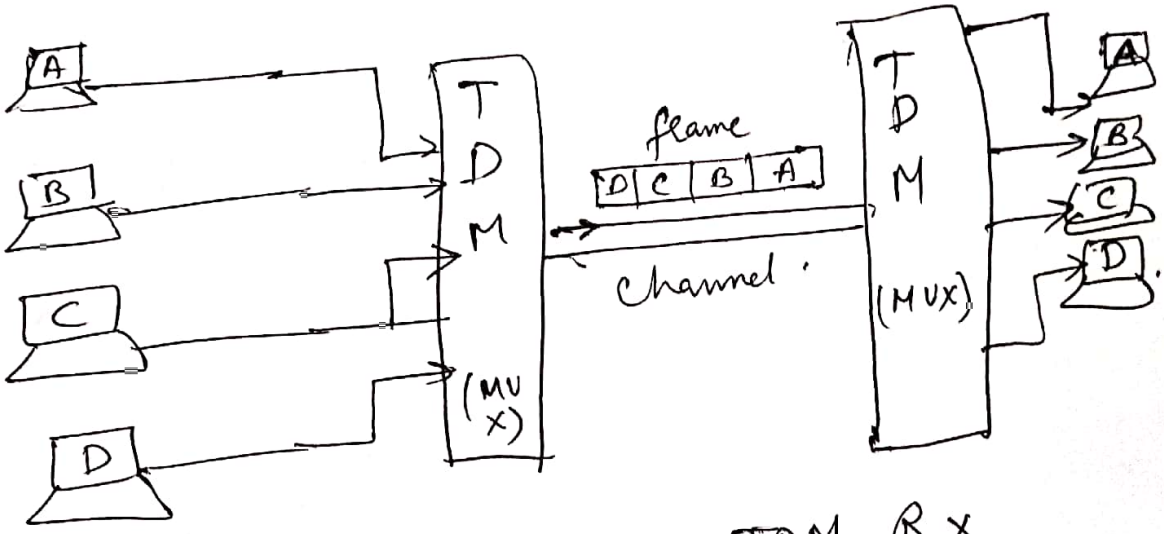
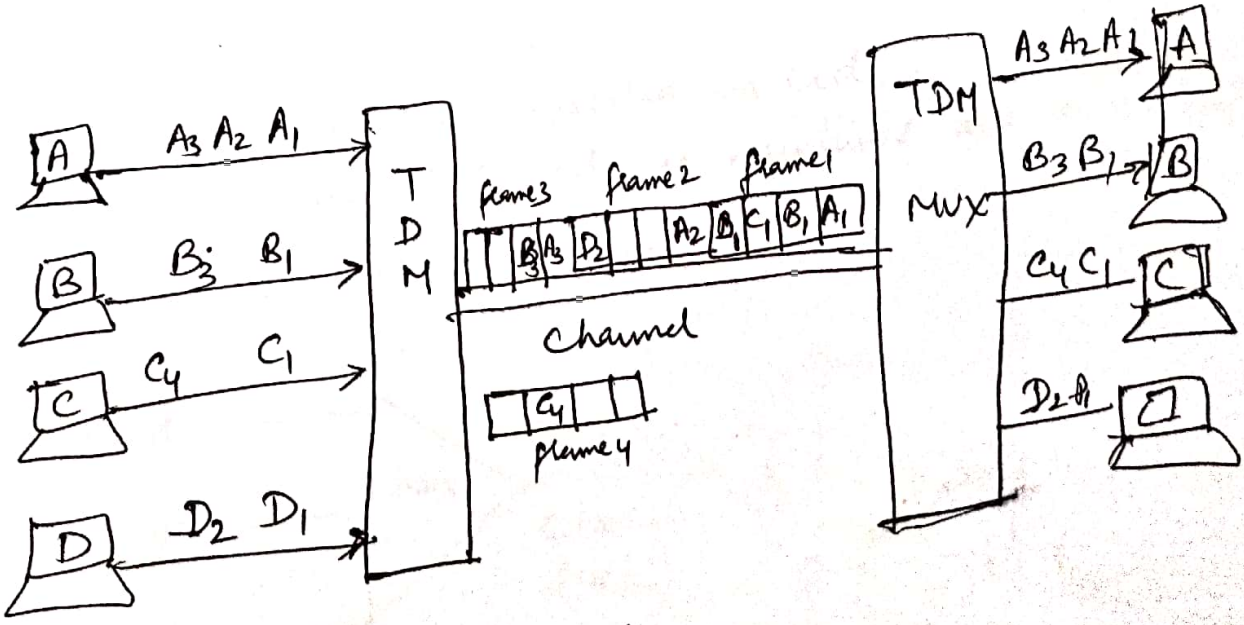
Time Division Multiplexing (TDM)



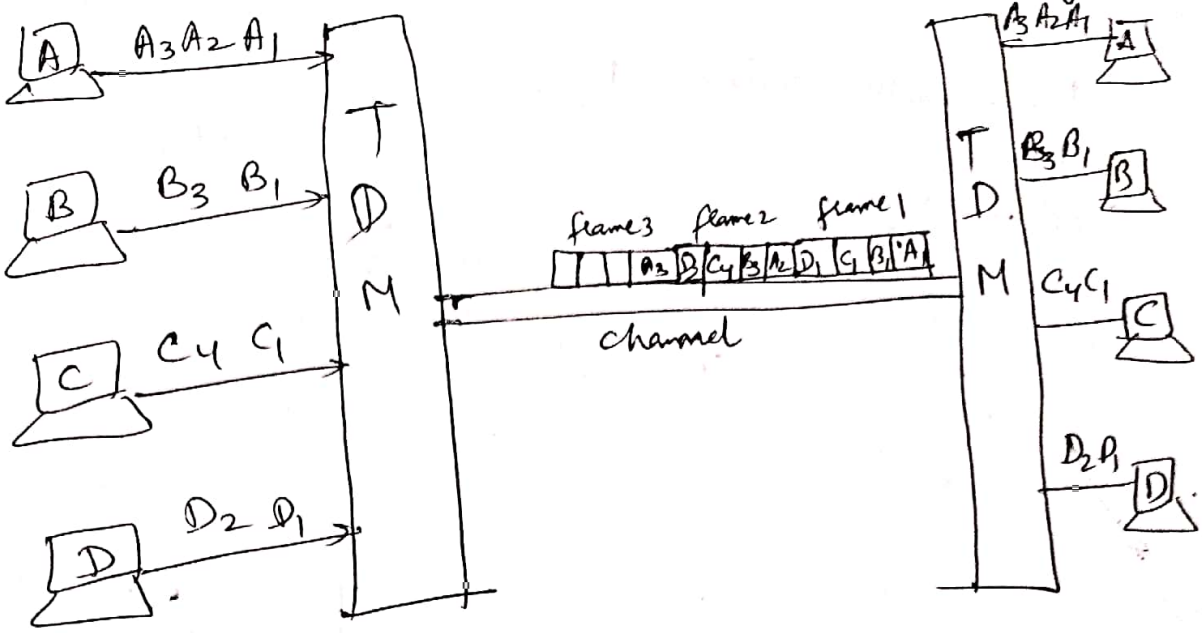


TDM Tx

TDM Rx

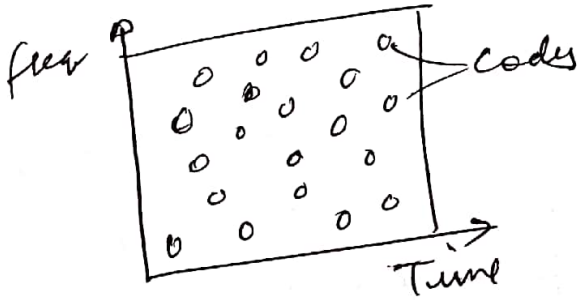


Synchronous TDM

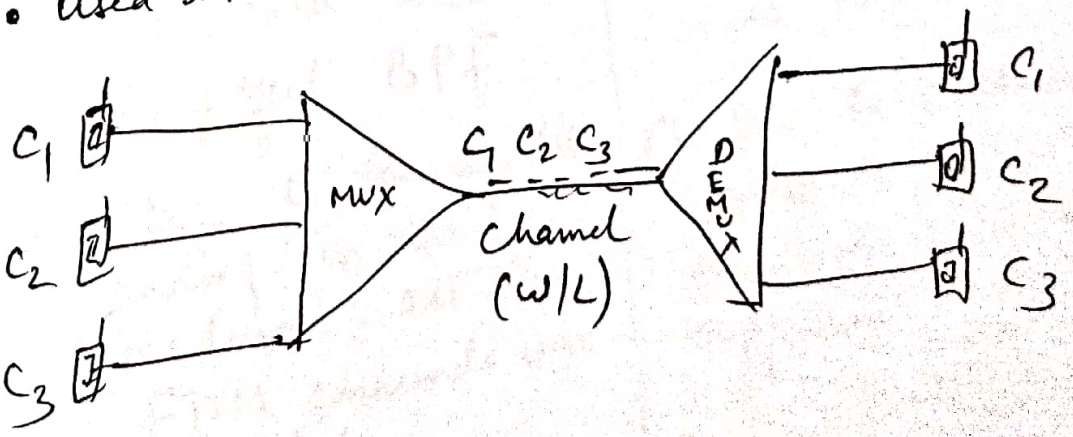


Asynchronous (statistical) TDM.

Code Division Multiplexing (CDM)



- Here users are separated in code.
- More secure (Security is maintained due to unique codes)
- Used in Wireless comm.



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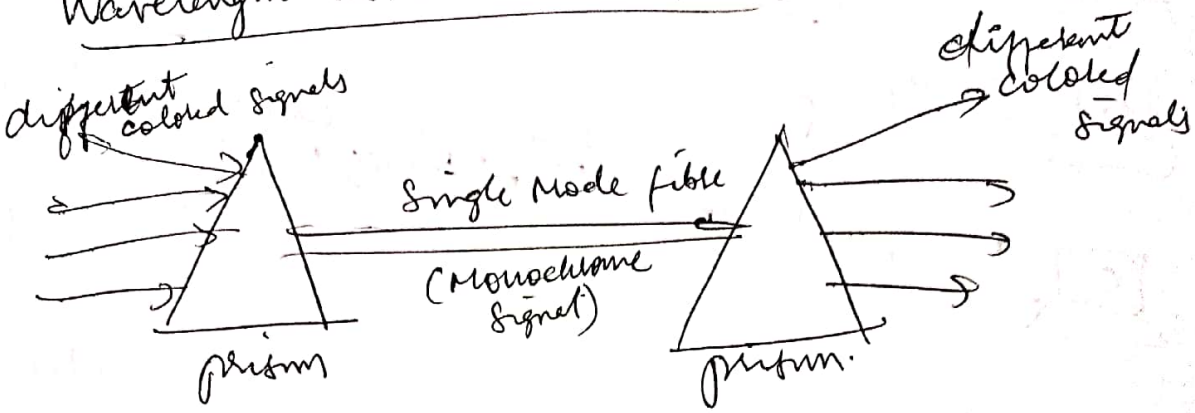
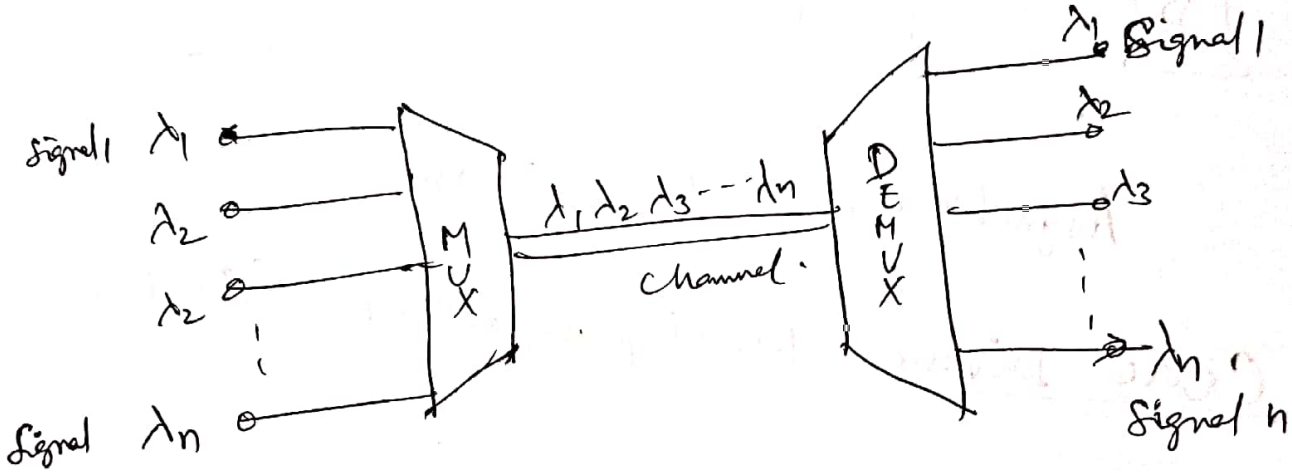
Wavelength division Multiplexing





WDM

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FDM	TDM
1) Signals are transmitted at different frequencies but at the same time. (Multiplexing in frequency domain)	1) Signals are transmitted at different times but at the same frequency (Multiplexing in Time domain)
2) FDM is usually preferred for analog signals	2) TDM is preferred for the digital signals
3) Synchronization is not required	3) Synchronization is required
4) FDM requires a complex circuitry at Tx & Rx	4) TDM requires simple circuitry
5) FDM suffers from the problem of crosstalk due to imperfect BPF	5) In TDM the problem of crosstalk is not severe
6) Due to Bandwidth fading in the Tx medium, all the FDM channels are affected	6) Due to fading only a few TDM channels will be affected.

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Advantages & Disadvantages of Multiplexing Techniques

Multiplexing Technique	Advantages	Disadvantages
Frequency Division Multiplexing	• Simple • Popular with radio, TV, Cable TV • All receivers such as cellular telephones, do not need to be at the same location	• Noise problems due to analog signals • Wastes Bandwidth • Limited by frequency ranges.
Synchronous Time Division Multiplexing	• Digital signals • Relatively simple • commonly used with T-1, ISDN	Wastes Bandwidth
Asynchronous (Statistical) Time Division Multiplexing	• Make efficient use of BW. • Frame can contain control & error information • packets can be of varying size	More complex than Synchronous time division Multiplexing

* T-1 lines used in North America
E-1 lines are used in Europe.

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Multiplexing Technique	Advantages	Disadvantages
Wavelength Division Multiplexing	• Very high capacities over fibre • signals can have varying speeds • scalable	cost complexity
Code Division Multiplexing	• Large capacities Scalable	• Complexity • primarily a wireless technology

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Types of Internet connections:

Methods to get connected to the Internet:

- Dial-up
- Cable Modem
- Digital Subscriber Line (DSL)

Symmetric DSL (SDSL)

- Same Transmission Rate (Upstream & Downstream)
- Data rate upto 1.5 MbPS

Asymmetric DSL (ADSL)

- Upstream 3.5 MbPS
- Downstream 24 MbPS

Very High Speed DSL (VDSL)

- For Short Distance
- Transmission rate up to 100 MbPS
- uses ~~of~~ optical fiber Cables.

- Asymmetric Digital Subscriber line (ADSL) is a type of Digital Subscriber line (DSL) Technology, A data communications Technology that enables faster data Transmission over copper Telephone lines than a conventional voiceband MODEM can provide.
- ADSL differes from the less common symmetric digital subscriber line (SDSL)

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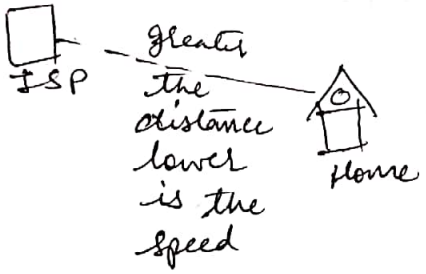
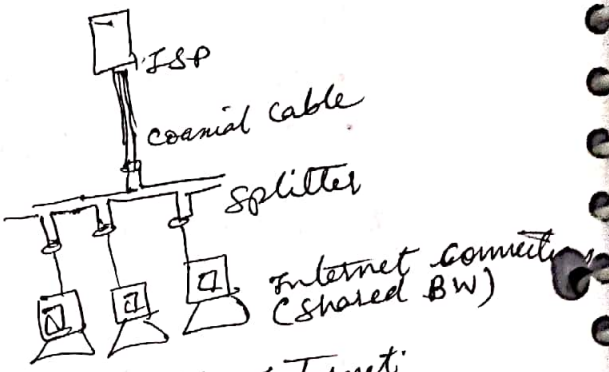
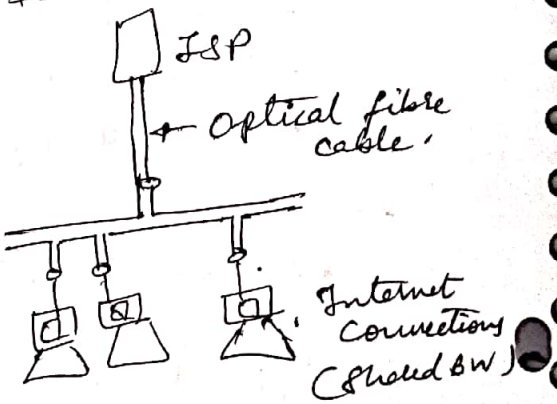
Difference between DSL & VDSL

Digital Subscriber Line (DSL)	Very High Bit rate Digital Subscriber Line (VDSL)
• If distance between ISP & our home increases, then Internet speed becomes slow	• Works similar to cable Internet.
	 fig: Cable Internet
• This is because, in DSL the Internet connection is via the telephone lines which are made of copper (twisted pair) & these copper wires are much more susceptible to Electromagnetic interference So as distance increases Signal becomes weak & speed becomes slow.	• VDSL Internet  fig: VDSL Internet • The connection between ISP & home computers is optical fibre cables. • So even if distance increases, no losses (& no EMI in OFC), the speed is maintained • Download speed 50-52 Mbps • Upload Speed 15-16 Mbps • freq: 12 MHz.

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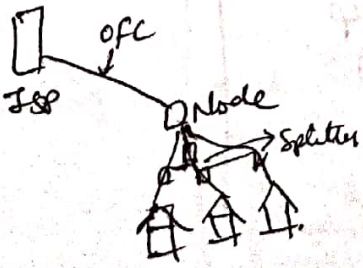
VDSL 2:

- It is the advanced version of VDSL
- freq used is 30MHz
- Higher speed than VDSL

4 Types of VDSL 2 connections

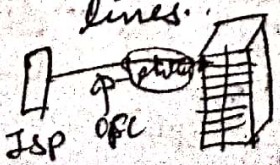
FTTN
(Fibre To The Node)

- Optical fiber cable connecting to the ISP is terminated at a node in our nearby area from where we get Internet connections (in diff houses) using a splitter)

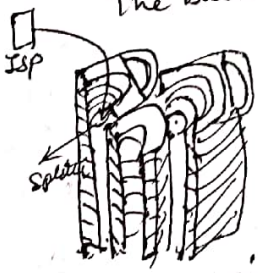


FTTC
(Fibre To The curb)

- Optical fibre cable connecting to the ISP is terminated at a splitter (usually installed either at the top or ground floor of our building) from the splitter the Internet connection is made via the normal Telephone lines.



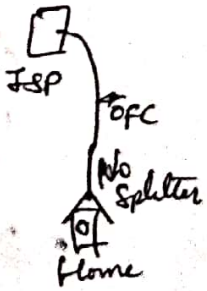
FTTB
(Fibre To The Building)



- 3-4 wings of a Building have a single Splitter from where the Internet connections are made to the users via Telephone lines.

FTTH
(Fibre to the Home)

- The optical fibre cable is directly terminated at each user end (Home)



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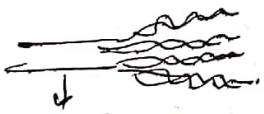
Dial-up Internet connection

- Internet connection via Normal Telephone lines.
- ~~Whenever~~ Voice call & Data (Internet) connection over a single (same) telephone line.
- So whenever there was a voice call coming in during the Internet connection then that connection would be terminated
- Dial up is now replaced by DSL

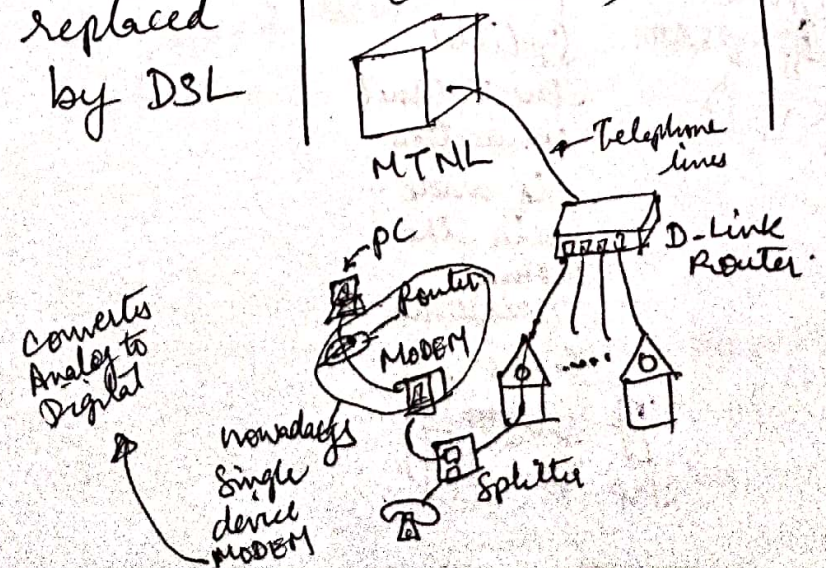
DSL Internet connection

- Internet connection is via normal Telephone lines (twisted pairs) But 30% of the lines are used for voice connection & 70% of the lines are used for data (Internet) connection.



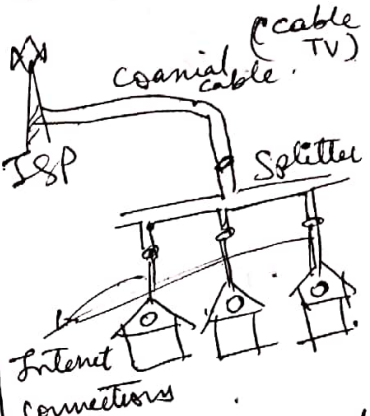
VTP

- Therefore voice calls & Internet connections can be simultaneously done. (which was not possible with Dialup connection)



Cable Internet connection

- Internet connection via ~~cable~~ Television cables (coaxial cables)



- Shared Bandwidth
- Slower than DSL

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Comparison Between Dial up & DSL

Parameter	Dial up	DSL
• Speed	Dial-up access offers speeds upto a maximum of 56KbPS	DSL offers guaranteed speeds (symmetrical up to 1Mbits/s or 35 times faster than 28.8 kbits/s analog modem) and assymetrical upto 7Mbits/s
• flexibility	Dial-up access is capable of providing internet access to only one PC (end-user), thereby charging extra for each additional (PC or enduser) access.	DSL provides Internet access to multiple PC's (end users) on a single connection, thereby not charging extra for all additional PC (end user). DSL is fully scalable service possessing a wide range of potential speeds.
	Dial up access is not a scable service due to its Bandwidth limitations	
• Reliability	Has tedious process of dialing in for the Internet access	No time consuming dialing in for Internet access. Connection is dedicated so no disruptions.

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DSL Vs Cable Modem

Parameters	DSL	Cable Modem
Speed	• DSL offers a wide range of guaranteed speeds as high as 1 MbPS (Symmetrical)	• Cable Modem exists on a shared n/w thereby making speed performance unpredictable; it is entirely contingent on network traffic volume.
Security	• DSL is on a closed dedicated circuit making it less susceptible to outside hackers	• Cable Modem is on a shared n/w making it more vulnerable to hackers.
Reliability	• DSL is on a closed dedicated circuit thereby offering guaranteed speeds	• Cable Modem exists on a shared n/w thereby making speed performance unpredictable.
Accessibility	• DSL utilizes ubiquitous, 100-year old telephone infra-structure (RJ-11 jacks, copper phone wire, data backbones etc), which makes up nearly 100% Market accessibility	• Sporadic & inconsistent service availability. • Cable Modem has a slower rate of market infiltration ~~because of~~

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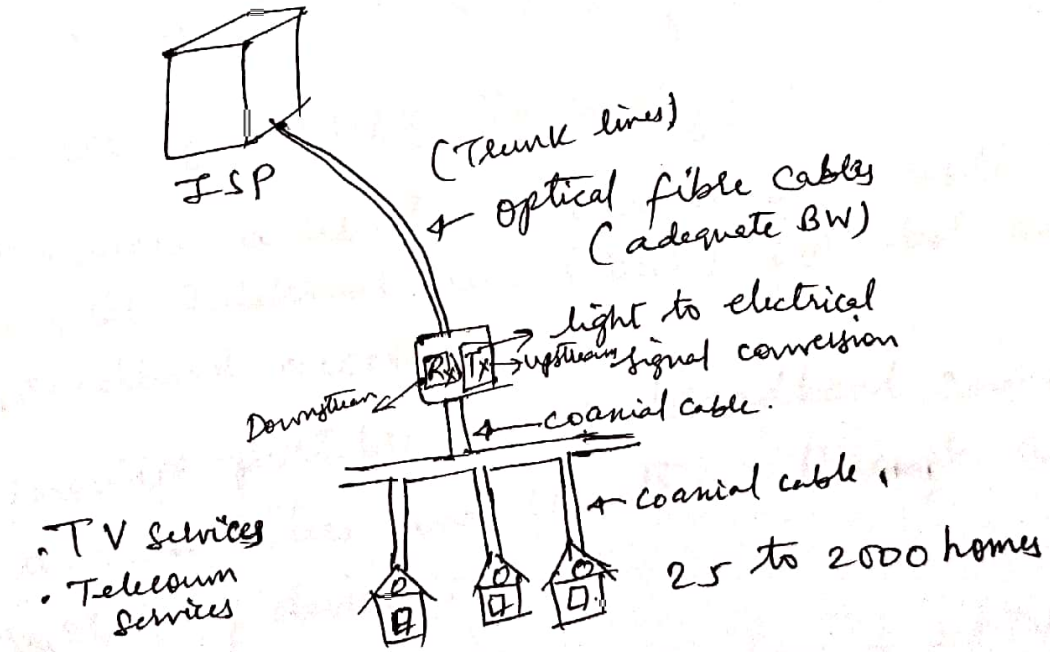
Hybrid Fibre - Coaxial (HFC)

- HFC is telecommunications industry term for Broadband network that combines coaxial & optical fibre cables
- It is globally accepted by network operators since early 1990's.
- In HFC system, the TV channels are sent from cable TV distribution facility, the head end to local community thro optical fible cables.



- Downstream signal is RF modulated (50MHz - 550MHz) (1490 nm) → wavelength
- Upstream signal is RF modulated (5 - 42 MHz) Or ~~5 - 60 MHz~~ (5 ~~to~~ 60 MHz) (1310 nm → wavelength)
- wavelength division multiplexing is used for combining various optical signals.

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WiMAX

- WiMAX – Worldwide Interoperability for Microwave Access
- Wireless communications technology
- WiMAX is the part of 4G
- WiMAX belongs to IEEE 802.16 standard
- Surpasses 30-metre Wireless range of a conventional Wi-Fi Local Area Network (LAN)
- Offers Metropolitan Area Network (MAN) with a Signal radius of 50 Kms

Uses of WiMAX Technology:

- provides a wireless alternative to cable and digital Subscriber line (DSL) for last mile broadband access
- Provides portable mobile broadband connectivity across cities and countries through a variety of devices.
- provides data, telecommunications & IPTV services
- provides a source of internet connectivity as part of a business continuity plan.

Shubhangi V.

	WiMAX	Wi Fi
Coverage	Wide, Broader Area (upto 40 miles)	Small (approx 100 feet)
Spectrum	Licensed	Unlicensed
Mobility	Anywhere, Anytime	Limited to Hotspot locations
Speed	Higher Speed (70MBPS or more)	Limited Speed (54 MBPS)
Quality of Service	Support Multimedia Applications (Guaranteed QoS)	Does not support Multimedia applications, Unreliable. (QoS is not guaranteed)
Standard	Based on IEEE 802.16 Standard	Based on IEEE 802.11 Standard
Waves	Uses microwaves	uses radio waves
Launched in year	2004	1997
Network	MAN	LAN
Channel Bandwidth	~~20MHz~~ Variable, 1.25 - 20 MHz	20 MHz
Subscribers	Unlimited	1-10 approx
Radio Technology	OFDM	Direct access / Spread Spectrum
Access protocol	CSMA/CA	Grant or Request.

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WiMAX (Contd.)

- IEEE 802.16 group was formed in 1998
  - To develop an air interface standard for wireless Broadband
- Initially focused at development of an LOS-based point to multipoint WBS.
  - Slated for operation in the 10GHz-66GHz millimeter wave band.
- The IEEE 802.16 group subsequently produced 802.16a, an ammendment to the 802.16 standard.
  - Employed an orthogonal Frequency Division Multiplexing (OFDM) based physical layer.
  - In 2004, IEEE 802.16 → targetted for fixed applications (referred as fixed WiMAX)
- In December 2005, IEEE 802.16e was approved. (referred as Mobile WiMAX)
- Physical Layer is responsible for transmission and reception of radio signals.
- The WiMAX physical layer is based on OFDM.
  - This offers simplified reception in multipath and allows WiMAX to operate in NLOS conditions.

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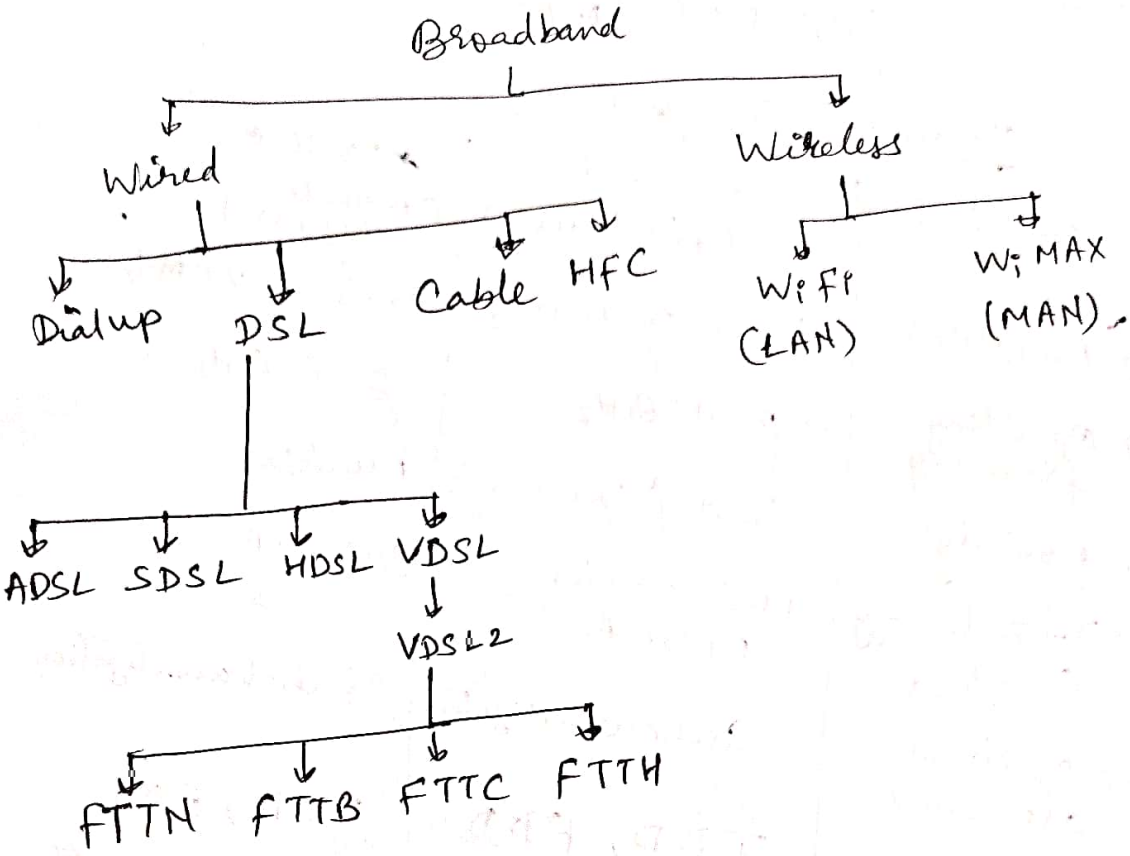
WiMAX Features

- WiMAX supports several Advanced features
  - Scalable Data rate and number of subcarriers (128 - 2048)
  - Adaptive Modding and coding (Number of bits per symbol & Error control)
  - High peak data rates → 75 to 100 MBPS
  - Advanced Antenna Techniques.
- use of TDD (Time division Duplexing) & FDD (Freq division Duplexing)
- Allows sharing of resources.
- WiMAX supports both point to point and point to Multipoint connections.

ADVANTAGES OF WiMAX

1) A Single WiMAX main station can serve hundreds of users. Endpoints are installed within days instead of the weeks required for wired connections
2) Data rates are as high as 80 MBPS & distances of 30 miles are possible. users can operate Mobile within 3-5 miles of a base station at data rates upto 75 MBPS.
3) No radio Licensing is required. Less Expensive than DSL or Coaxial cable broadband technologies.



Disadvantages of WiMAX

1) Line-of-Sight (LOS) is required for long distance (5-30 mile) connections.
2) Heavy rains can disrupt the service
3) Other wireless electronics in the vicinity can interfere with the WiMAX connection and cause a reduction in data throughput or even a total disconnect.

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Wi-MAX (MAN)

Technical Specifications

Specifications	802.16 d (fixed access)	802.16 e (mobile access)
1) BW (MHz)	1.75 to 20 MHz	1.25 to 20 MHz
2) Operating frequency	2-11 GHz	2-6 GHz
3) Mobility	Fixed / (Roaming)	Mobile
4) Tx Technology (access method)	Multicarrier OFDMA Subchannelization	OFDMA Subchannelization
5) Spectrum assignment	TDD, FDD	TDD, FDD
6) Mode	75 MbPS	5, 30 MbPS
7) Peak rate	BPSK, 16 QAM	64 QAM
8) Modulation	Intelligent Antenna Systems	MIMO, HARQ
9) Enhanced Techniques	MIMO, HARQ.	
10) Energy Saving		Idle & sleep mode.

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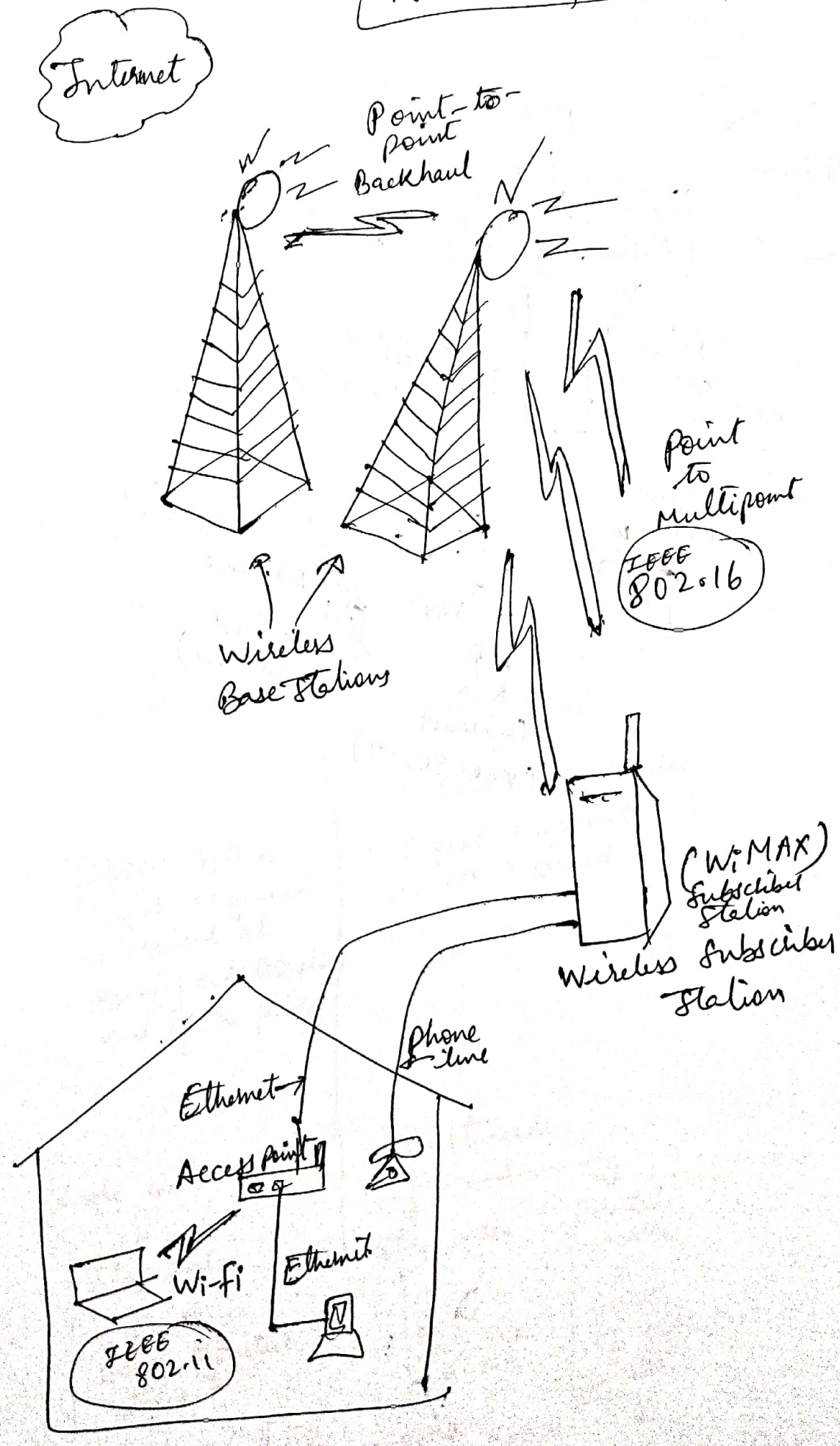
Wi-MAX



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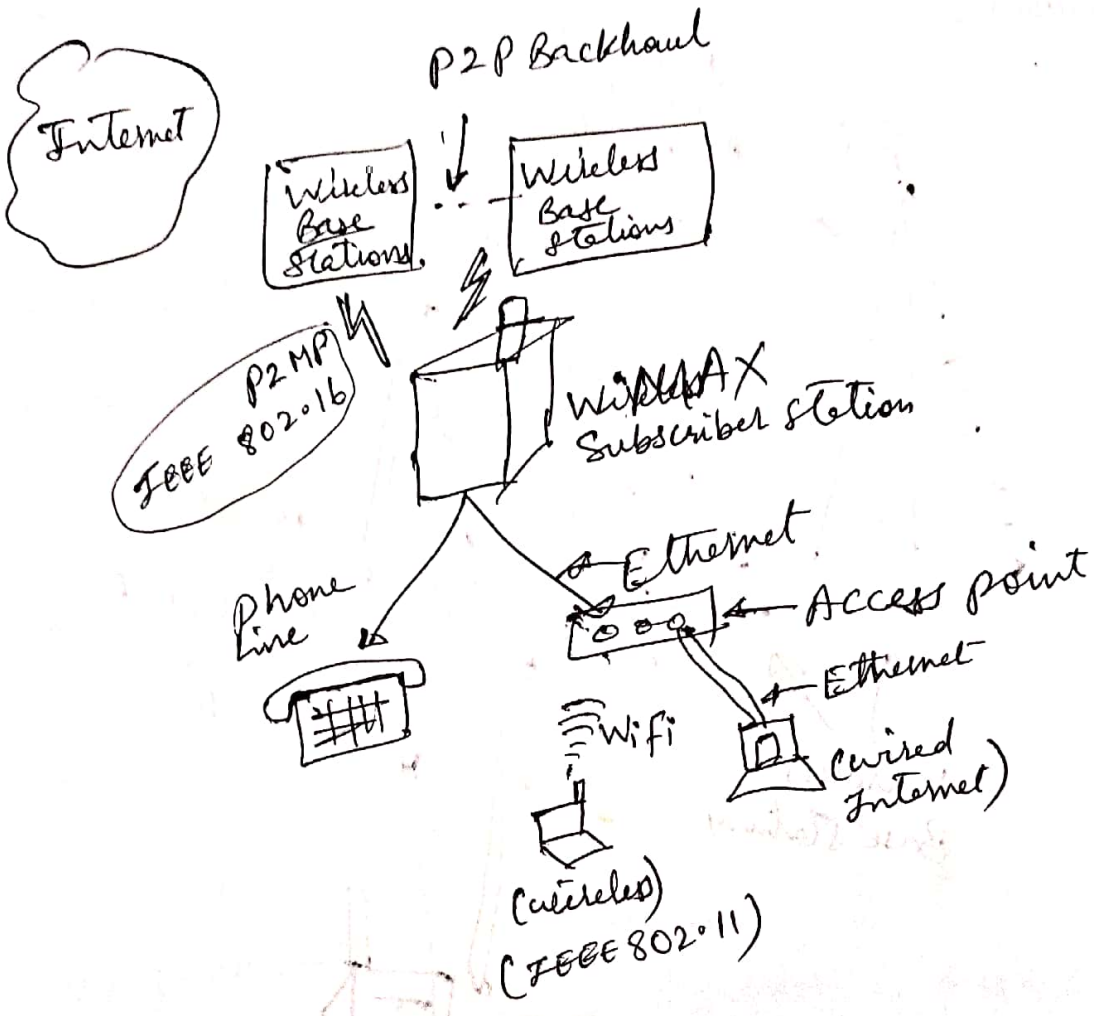
Simple WiMAX Diagram



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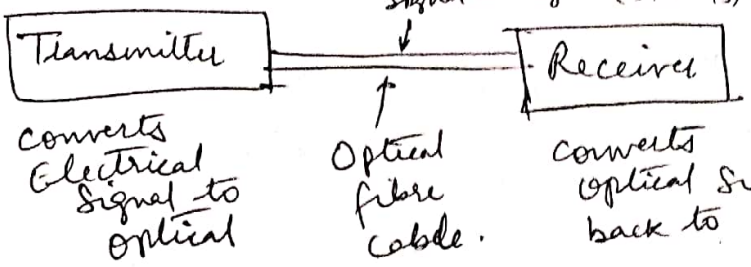
Optical fibre Communication:

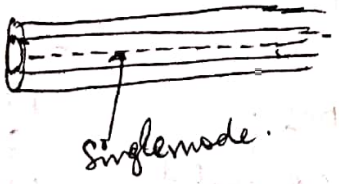
Refer emailed PPTs for guided media with diagrams



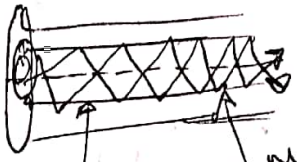
Optical fibre cable

- Single Mode
- Multimode.

- Core → refractive index n_1
- Cladding → refractive index n_2
- Jacket → depending on application more mechanical protection is provided



Single mode for Signal



Signal is dispersed in multimode.
(i.e. follows various paths)

- Signal alignment is not required.

- Proper optical signal alignment is required at opening end (coupling end of the fibre

Single mode

- Step index
- Single refractive index
- covers longest distance

Multimode

- Step index
  - Single refractive index
  - covers moderate distance
- Graded index
  - Variety of refractive indices
  - covers shorter distance

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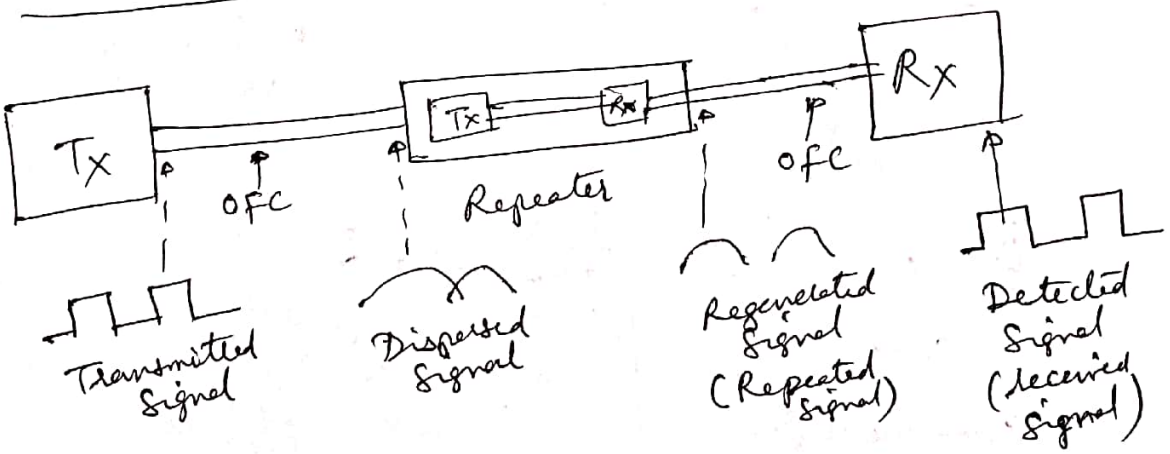
Optical fibre cables deployment:

- The OFC's may be hanging in air
- They may be underground.
- They may be underwater (undersea)

Dispersion phenomenon in OFC



Applications of OFC:

- Internet (Large OFC n/w spans over wider areas (undersea) covering interconnecting various countries)

A Large OFC n/w connects Asia ~~-Europe~~ Africa - Europe to provide Internet connection all over the Globe.

- Reliance Jio, Airtel, Idea (Tata comm.) have installed bigger OFC n/w under sea. (Installion cost is very high; but its one time)
  - Life of OFC is nearly 25 years.
  - Considering wear & tear of OFC cables redundant cabling is provided.

Reliance Jio, Airtel, Idea → Tier I companies (Have installed Submarine OFC spanning various countries)
Tata comm

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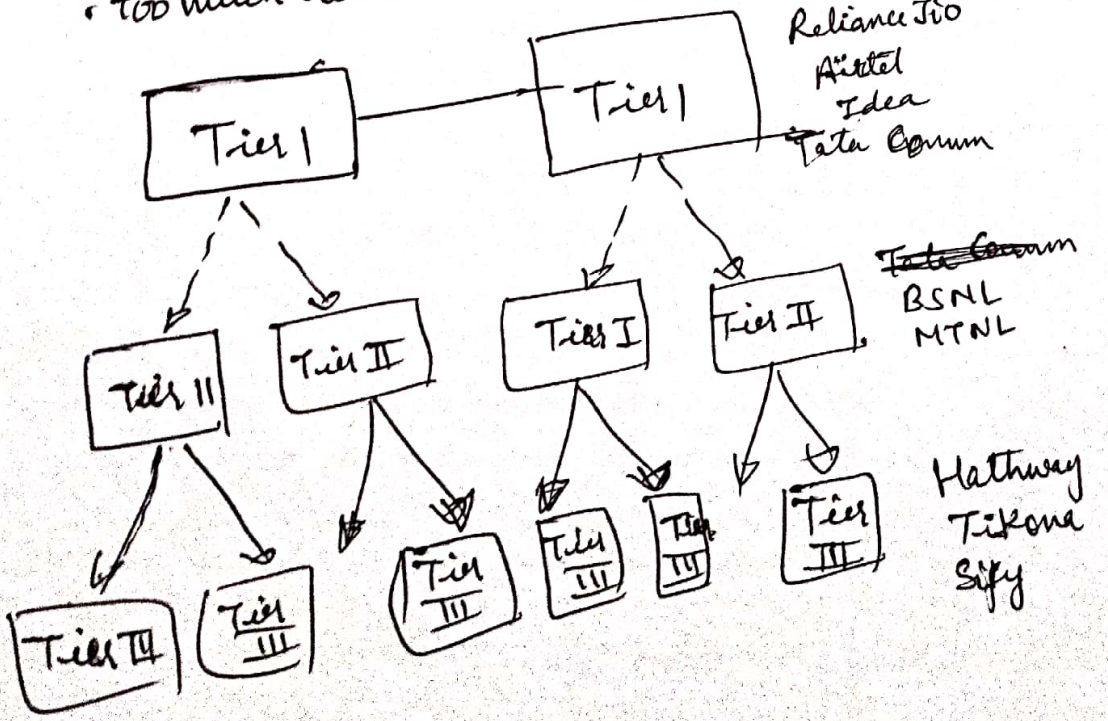
- Optical fibres (cables have thin hair like structure.
- Groups of optical fibres are bundled together to form a cable. (so BW is large)
- Optical fibres are very costly (made of glass or plastic).

Advantages of OFC

- High Bandwidth in GbPS (Hundreds or even thousands of GbPS)
- Longer distance communication
- Low EMI
- No crosstalk
- Lower attenuation
- Security (No hacking possible)

Drawbacks of OFC

- High Installation cost
- Too much delicate



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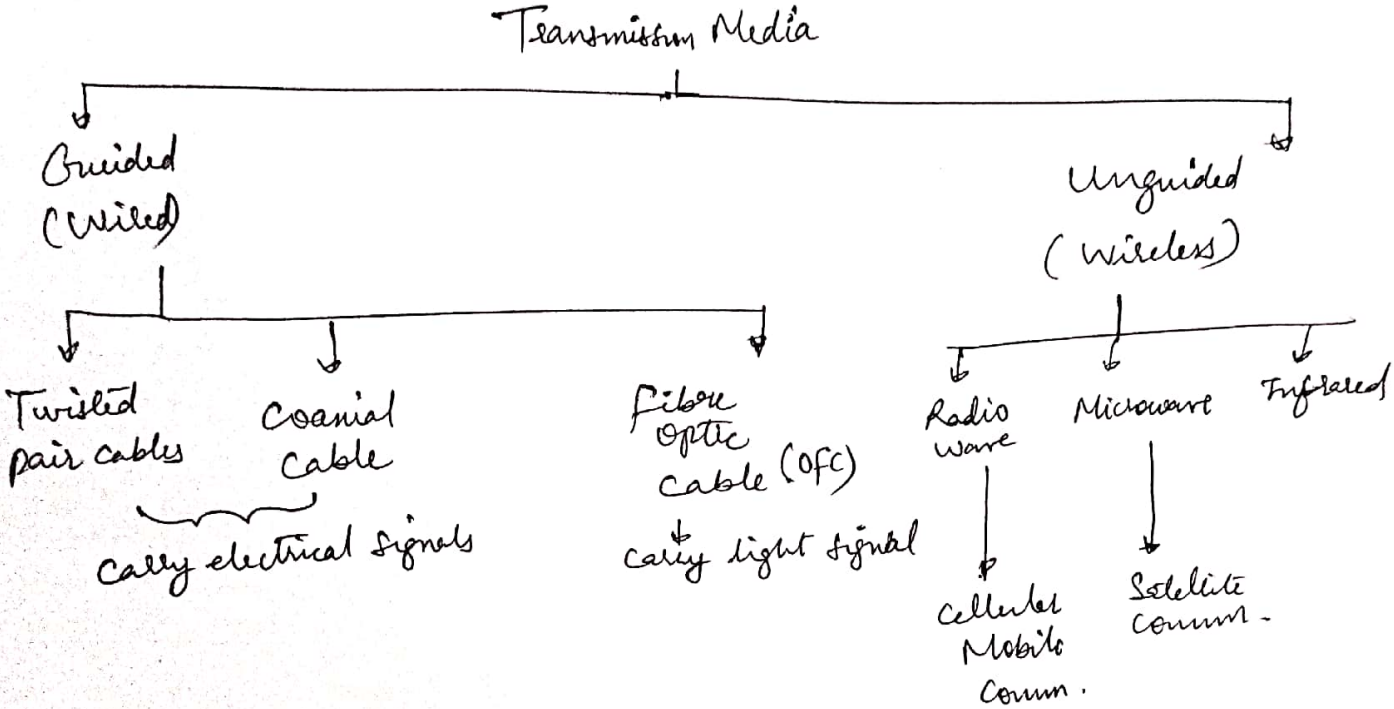
- Each thin cable (hair-like) can handles 20 - 25 thousand voice calls.
- OFC works on internal reflection phenomenon.
- OFC nw is the backbone for Internet

and System

2.1 Introduction to physical media, coax, RJ45, fiber, twisted pair, DSL, HFC, Wimax, Cellular, Satellite, and Telephone networks, bit Transmission, frequency division multiplexing, time division multiplexing



Points to be discussed for:

Twisted pair cables
- construction & operation
- Importance of Twisting
- cost
- Applications

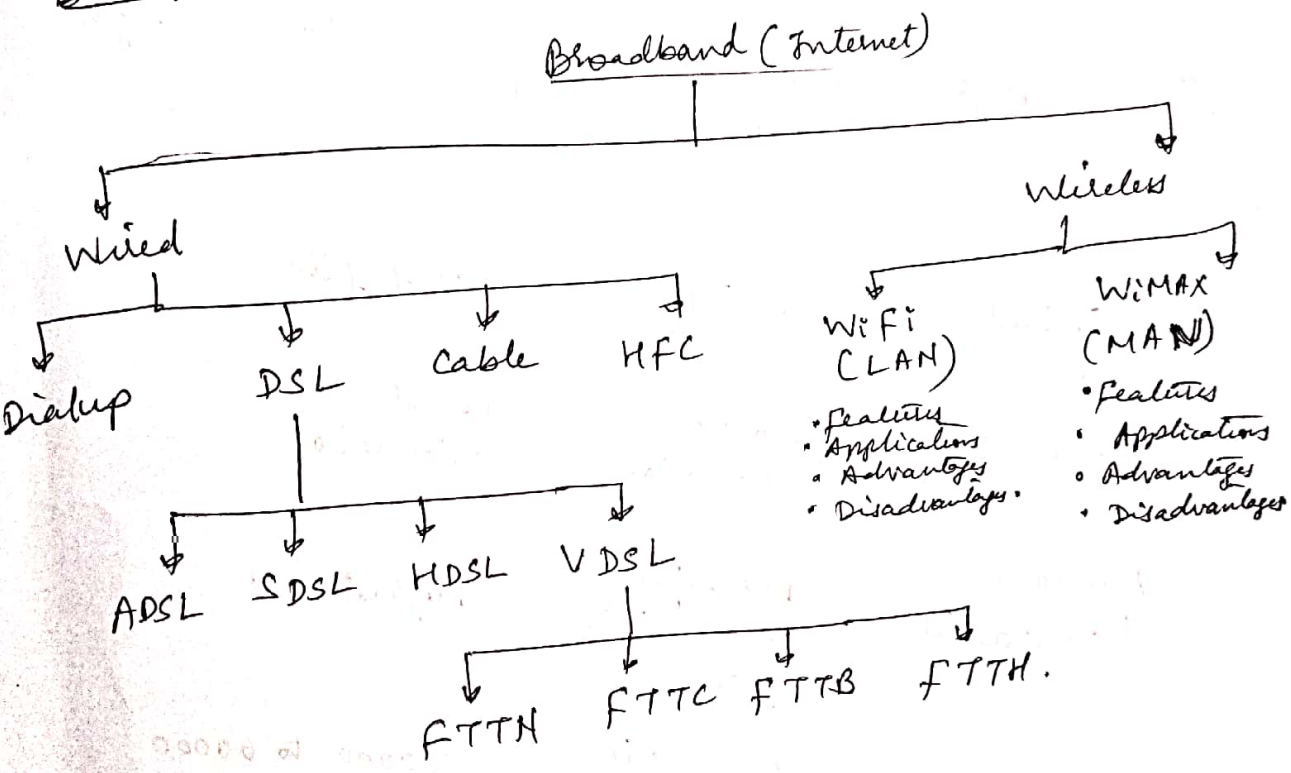
Unshielded twisted pair cables
- construction & operation
- categories (CAT1 → CAT7)
- connectors
- performance
- Applications.

Points to be discussed for Coaxial cable.
- construction & working
- categories (RG-59, RG-58, RG-11)
- performance
- Applications.

points to be discussed for OFC

- operation
- construction
- Types of OFC (modes)
- OFC deployment
- Applications of OFC
- Advantages of OFC.
- Drawbacks of OFC.

Broadband connections (or Types of wired & wireless Internet connections)



Comparison of Guided Media

Media	cost	Bandwidth, data rate	Attenuation/ Repeater spacing	EMI	Security
UTP	Low	3 MHz, 4 MbPS	High, 2-10Km	High	Low (can be tapped easily)
Coaxial	Moderate	350 MHz, 500 MbPS	Moderate, 1-10Km	Moderate	Low
Optical fibre	High	2 GHz, 2 GbPS	low, 10-100Km	Low	high

Twisted pair	Coaxial	Optical fibre
Highest attenuation	Moderate attenuation	Lowest attenuation
BW lower than coaxial	BW higher than twisted pair	Highest BW
	10000 voice channels per cable	20000 to 60000 voice channels per cable.