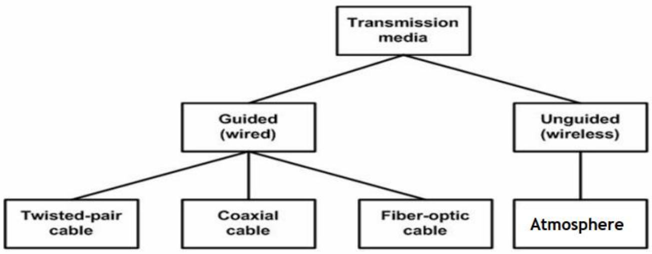
Unit II

Syllabus
Physical Layer: Transmission modes, DTE-DCE Interface, Modems, Guided media, Unguided media, Performance, Multiplexing, Switching, DSL, FTTC.

Transmission Modes

Transmission media can be defined as physical path between transmitter and receiver in a data transmission system.



Classes of transmission media

- **Guided**: Transmission capacity depends critically on the medium, the length, and whether the medium is point-to-point or multipoint (e.g. LAN). Examples are coaxial cable, twisted pair, and optical fiber.
- **Unguided:** provides a means for transmitting electro-magnetic signals but do not guide them. Example wireless transmission.

  Characteristics and quality of data transmission are determined by medium and signal characteristics. For guided media, the medium is more important in determining the limitations of transmission. While in case of unguided media, the bandwidth of the signal produced by the transmitting antenna and the size of the antenna is more important than the medium. Signals at lower frequencies are omni-directional (propagate in all directions).
  For higher frequencies, focusing the signals into a directional beam is possible. These properties determine what kind of media one should use in a particular application.

Guided Transmission Media

Commonly used guided transmission media include twisted-pair of cable, coaxial cable and optical fiber.

- Twisted Pair

In twisted pair technology, two copper wires are strung between two points:

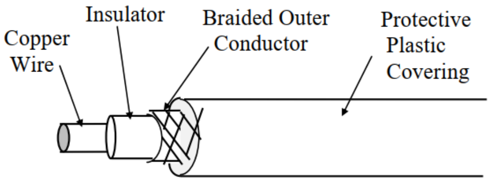
  - The two wires are typically ``twisted" together in a helix to reduce interference between the two conductors as shown in Fig. above. Twisting decreases the crosstalk interference between adjacent pairs in a cable. Typically, a number of pairs are bundled together into a cable by wrapping them in a tough protective sheath.
  - Can carry both analog and digital signals. Actually, they carry only analog signals. However, the ``analog" signals can very closely correspond to the square waves representing bits, so we often think of them as carrying digital data.
    - Data rates of several Mbps common.
    - Spans distances of several kilometers.
    - Data rate determined by wire thickness and length. In addition, shielding to eliminate interference from other wires impacts signal-to-noise ratio, and ultimately, the data rate.
    - Good, low-cost communication. Indeed, many sites already have twisted pair installed in offices -- existing phone lines!

Typical characteristics: Twisted-pair can be used for both analog and digital communication. The data rate that can be supported over a twisted-pair is inversely proportional to the square of the line length. Maximum transmission distance of 1 Km can be achieved for data rates up to 1 Mb/s. For analog voice signals, amplifiers are required about every 6 Km and for digital signals, repeaters are needed for about 2 Km. To reduce interference, the twisted pair can be shielded with metallic braid. This type of wire is known as *Shielded Twisted-Pair* (STP) and the other form is known as *Unshielded Twisted-Pair* (UTP).

Use: The oldest and the most popular use of twisted pair are in telephony. In LAN it is commonly used for point-to-point short distance communication (say, 100m) within a building or a room.

Base Band Coaxial

With ``coax", the medium consists of a copper core surrounded by insulating material and a braided outer conductor as shown in Fig. The term *base band* indicates digital transmission (as opposed to *broadband* analog).



Physical connection consists of metal pin touching the copper core. There are two common ways to connect to a coaxial cable:

1. With *vampire taps*, a metal pin is inserted into the copper core. A special tool drills a hole into the cable, removing a small section of the insulation, and a special connector is screwed into the hole. The tap makes contact with the copper core.
2. With a *T*-junction, the cable is cut in half, and both halves connect to the T-junction. A T-connector is analogous to the signal splitters used to hook up multiple TVs to the same cable wire.

Characteristics: Co-axial cable has superior frequency characteristics compared to twisted-pair and can be used for both analog and digital signaling. In baseband LAN, the data rates lie in the range of 1 KHz to 20 MHz over a distance in the range of 1 Km. Coaxial cables typically have a diameter of 3/8". Coaxial cables are used both for *baseband* and *broadband* communication. For broadband CATV application coaxial cable of 1/2" diameter and 75 Ω impedance is used. This cable offers bandwidths of 300 to 400 MHz facilitating high-speed data communication with low bit-error rate. In broadband signaling, signal propagates only in one direction, in contrast to propagation in both directions in baseband signaling. Broadband cabling uses either dual-cable scheme or single-cable scheme with a headend to facilitate flow of signal in one direction. Because of the shielded, concentric construction, co-axial cable is less susceptible to interference and cross talk than the twisted-pair. For long distance communication, repeaters are needed for every kilometer or so. Data rate depends on physical properties of cable, but 10 Mbps is typical.

Use: One of the most popular use of co-axial cable is in cable TV (CATV) for the distribution of TV signals. Another importance use of co-axial cable is in LAN.

Broadband Coaxial

The term *broadband* refers to analog transmission over coaxial cable. (Note, however, that the telephone folks use broadband to refer to any channel wider than 4 kHz). The technology:

- Typically, bandwidth of 300 MHz, total data rate of about 150 Mbps.
- Operates at distances up to 100 km (metropolitan area!).
- Uses analog signaling.
- Technology used in cable television. Thus, it is already available at sites such as universities that may have TV classes.

- Total available spectrum typically divided into smaller channels of 6 MHz each. That is, to get more than 6MHz of bandwidth, you have to use two smaller channels and somehow combine the signals.
- Requires amplifiers to boost signal strength; because amplifiers are one way, data flows in only one direction.

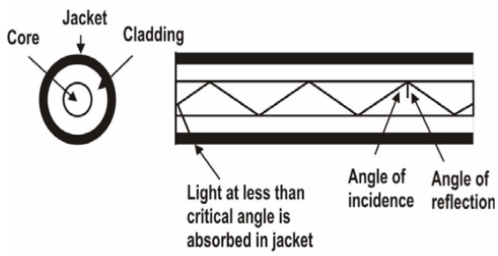
Two types of systems have emerged:

1. Dual cable systems use two cables, one for transmission in each direction:
   a. One cable is used for receiving data.
   b. Second cable used to communicate with *headend*. When a node wishes to transmit data, it sends the data to a special node called the *headend*. The headend then resends the data on the first cable. Thus, the headend acts as a root of the tree, and all data must be sent to the root for redistribution to the other nodes.
2. *Midsplit* systems divide the raw channel into two smaller channels, with each sub channel having the same purpose as above.

Which is better, broadband or base band? There is rarely a simple answer to such questions. Base band is simple to install, interfaces are inexpensive, but doesn't have the same range. Broadband is more complicated, more expensive, and requires regular adjustment by a trained technician, but offers more services (e.g., it carries audio and video too).

Fiber Optics

In fiber optic technology, the medium consists of a hair-width strand of silicon or glass, and the signal consists of pulses of light. For instance, a pulse of light means ``1", lack of pulse means ``0". It has a cylindrical shape and consists of three concentric sections: the ***core***, the ***cladding***, and the ***jacket*** as shown in Fig.



The core, innermost section consists of a single solid dielectric cylinder of diameter d_1 and of refractive index n_1. The core is surrounded by a solid dielectric cladding of refractive index n_2 that is less than n_1. As a consequence, the light is propagated through multiple total internal reflection. The core material is usually made of ultra-pure fused silica or glass and the cladding is either made of glass or plastic. The cladding is surrounded by a jacket made of plastic. The jacket is used to protect against moisture, abrasion, crushing and other environmental hazards.

Three components are required:

1. Fiber medium: Current technology carries light pulses for tremendous distances (e.g., 100s of kilometers) with virtually no signal loss.
2. Light source: typically, a Light Emitting Diode (LED) or laser diode. Running current through the material generates a pulse of light.
3. A photo diode light detector, which converts light pulses into electrical signals.

Advantages:

1. Very high data rate, low error rate. 1000 Mbps (1 Gbps) over distances of kilometers common. Error rates are so low they are almost negligible.
2. Difficult to tap, which makes it hard for unauthorized taps as well. This is responsible for higher reliability of this medium. How difficult is it to prevent coax taps? Very difficult indeed, unless one can keep the entire cable in a locked room!
3. Much thinner (per logical phone line) than existing copper circuits. Because of its thinness, phone companies can replace thick copper wiring with fibers having much more capacity for same volume. This is important because it means that aggregate phone capacity can be upgraded without the need for finding more physical space to hire the new cables.
4. Not susceptible to electrical interference (lightning) or corrosion (rust).
5. Greater repeater distance than coax.

Disadvantages:

1. Difficult to tap. It really is point-to-point technology. In contrast, tapping into coax is trivial. No special training or expensive tools or parts are required.
2. One-way channel. Two fibers needed to get full duplex (both ways) communication.

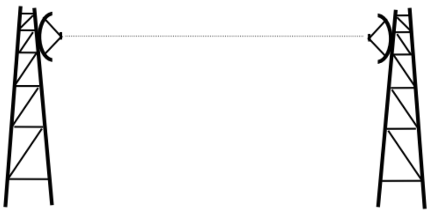
Fiber Uses:

Because of greater bandwidth (2Gbps), smaller diameter, lighter weight, low attenuation, immunity to electromagnetic interference and longer repeater spacing, optical fiber cables are finding widespread use in long-distance telecommunications. Especially, the single mode fiber is suitable for this purpose. Fiber optic cables are also used in high-speed LAN applications. Multi-mode fiber is commonly used in LAN.

- Long-haul trunks-increasingly common in telephone network (Sprint ads)
- Metropolitan trunks-without repeaters (average 8 miles in length)
- Rural exchange trunks-link towns and villages
- Local loops-direct from central exchange to a subscriber (business or home)
- Local area networks-100Mbps ring networks.

Unguided Transmission

Unguided transmission is used when running a physical cable (either fiber or copper) between two end points is not possible. For example, running wires between buildings is probably not legal if the building is separated by a public street. Infrared signals typically used for short distances (across the street or within same room), Microwave signals commonly used for longer distances (10's of km). Sender and receiver use some sort of dish antenna as shown in Fig.

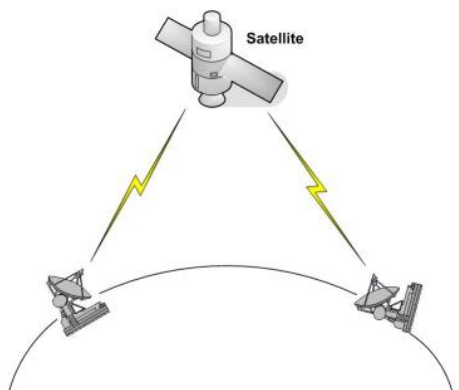


Difficulties:

1. Weather interferes with signals. For instance, clouds, rain, lightning, etc. may adversely affect communication.
2. Radio transmissions easy to tap. A big concern for companies worried about competitors stealing plans.
3. Signals bouncing off of structures may lead to out-of-phase signals that the receiver must filter out.

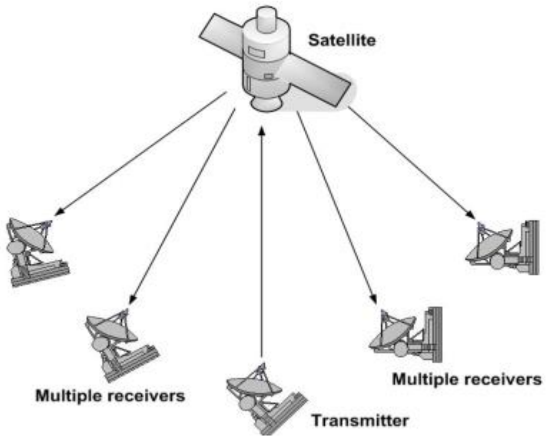
Satellite Communication

Satellite communication is based on ideas similar to those used for line-of-sight. A communication satellite is essentially a big microwave repeater or relay station in the sky. Microwave signals from a ground station is picked up by a transponder, amplifies the signal and rebroadcasts it in another frequency, which can be received by ground stations at long distances as shown in Fig. below



(a) Point-to-point link via satellite microwave

To keep the satellite stationary with respect to the ground-based stations, the satellite is placed in a geostationary orbit above the equator at an altitude of about 36,000 km. As the spacing between two satellites on the equatorial plane should not be closer than 4^0, there can be 360/4 = 90 communication satellites in the sky at a time. A satellite can be used for point-to-point communication between two ground-based stations or it can be used to broadcast a signal received from one station to many ground-based stations as shown in Fig. below. Number of geo-synchronous satellites limited (about 90 total, to minimize interference). International agreements regulate how satellites are used, and how frequencies are allocated. Weather affects certain frequencies. Satellite transmission differs from terrestrial communication in another important way: One-way *propagation delay* is roughly 270 ms. In interactive terms, propagation delay alone inserts a 1 second delay between typing a character and receiving its echo.



Characteristics:

Optimum frequency range for satellite communication is 1 to 10 GHz. The most popular frequency band is referred to as 4/6 band, which uses 3.7 to 4.2 GHz for down link and 5.925 to 6.425 for uplink transmissions. The 500 MHz bandwidth is usually split over a dozen transponders, each with 36 MHz bandwidth. Each 36 MHz bandwidth is shared by time division multiplexing. As this preferred band is already saturated, the next highest band available is referred to as 12/14 GHz. It uses 14 to 14.5GHz for upward transmission and 11.7 to 12.2 GHz for downward transmissions. Communication satellites have several unique properties. The most important is the long communication delay for the round trip (about 270 ms) because of the long distance (about 72,000 km) the signal has to travel between two earth stations. This poses a number of problems, which are to be tackled for successful and reliable communication. Another interesting property of satellite communication is its broadcast capability. All stations under the downward beam can receive the transmission. It may be necessary to send encrypted data to protect against piracy.

Use: Now-a-days communication satellites are not only used to handle telephone, telex and television traffic over long distances, but are used to support various internet based services such as e-mail, FTP, World Wide Web (WWW), etc. New types of services, based on communication satellites, are emerging.

Comparison/contrast with other technologies:

1. Propagation delay very high. On LANs, for example, propagation time is in nanoseconds -- essentially negligible.
2. One of few alternatives to phone companies for long distances.
3. Uses broadcast technology over a wide area - everyone on earth could receive a message at the same time!
4. Easy to place unauthorized taps into signal.

Satellites have recently fallen out of favor relative to fiber.

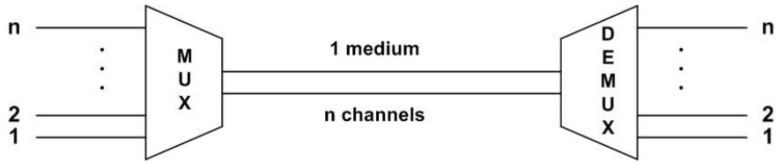
However, fiber has one big disadvantage: no one has it coming into their house or building, whereas anyone can place an antenna on a roof and lease a satellite channel.

Multiplexing

It has been observed that most of the individual data-communicating devices typically require modest data rate. But communication media usually have much higher bandwidth. As a consequence, two communicating stations do not utilize the full capacity of a data link. Moreover, when many nodes compete to access the network, some efficient techniques for utilizing the data link are very essential. When the bandwidth of a medium is greater than individual signals to be transmitted through the channel, a medium can be shared by more than one channel of signals. The process of making the most effective use of the available channel capacity is called **Multiplexing**.

For efficiency, the channel capacity can be shared among a number of communicating stations just like a large water pipe can carry water to several separate houses at once. Most common use of multiplexing is in long-haul communication using coaxial cable, microwave and optical fibre.

Figure below depicts the functioning of multiplexing functions in general. The **multiplexer** is connected to the **demultiplexer** by a single data link. The multiplexer combines (multiplexes) data from these 'n' input lines and transmits them through the high capacity data link, which is being demultiplexed at the other end and is delivered to the appropriate output lines. Thus, **Multiplexing** can also be defined as a technique that allows simultaneous transmission of multiple signals across a single data link.



Multiplexing techniques can be categorized into the following three types:

- ***Frequency-division multiplexing (FDM)*****:** It is most popular and is used extensively in radio and TV transmission. Here the frequency spectrum is divided into several logical channels, giving each user exclusive possession of a particular frequency band.
- ***Time-division Multiplexing (TDM):*** It is also called synchronous TDM, which is commonly used for multiplexing digitized voice stream. The users take turns using the entire channel for short burst of time.
- ***Statistical TDM:*** This is also called asynchronous TDM, which simply improves on the efficiency of synchronous TDM.

Switching

When there are many devices, it is necessary to develop suitable mechanism for communication between any two devices. One alternative is to establish point-to-point communication between each pair of devices using **mesh topology.** However, mesh topology is impractical for large number of devices, because the number of links increases exponentially (n(n-1)/2, where n is the number of devices) with the number of devices. A better alternative is to use switching techniques leading to switched communication network. In the **switched network** methodology, the network consists of a set of interconnected nodes, among which information is transmitted from source to destination via different routes, which is controlled by the switching mechanism. A basic model of a switched communication is shown in Fig. 4.1.1. The end devices that wish to communicate with each other are called *stations*. The switching devices are called *nodes*. Some nodes connect to other nodes and some are to connected to some stations. Key features of a switched communication network are given below:

- Network Topology is not regular.
- Uses FDM or TDM for node-to-node communication.
- There exist multiple paths between a source-destination pair for better network reliability.
- The switching nodes are not concerned with the contents of data.
- Their purpose is to provide a switching facility that will move data from node to node until they reach the destination.

The switching performed by different nodes can be categorized into the following three types:

- Circuit Switching.
- Packet Switching.
- Message Switching.

Circuit Switched Networks − Circuit switched networks are connection-oriented networks. Here, a dedicated route is established between the source and the destination and the entire message is transferred through it.

Packet Switched Networks − Packet switched networks are connectionless networks. Here, the message is divided and grouped into a number of units called packets that are individually routed from the source to the destination.

Message Switched Networks - With message switching, there is no limit at all on block size, which means that routers (in a modern system) must have disks to buffer long blocks. It also means that a single block can tie up a router-router line for minutes, rendering message switching useless for interactive traffic.

DTE and DCE

DTE (Data terminating equipment) is a terminal residing at physical layer or can be anything that could be able to generate to consume digital data like computers. In other words, it is an assembly that operates either as a source of or as a destination for **binary digital data.** There is no direct mechanism for DTE to communicate, so communication occurs place through some intermediary devices.

Customer devices that connect to the telephone company's (telco's) equipment are known as **CTE (Customer telephony Equipment)**. **Demarcation point (demarc)** is the meeting spot of customer equipment (DTE) and telephone equipment (DCE).

DCE (Data circuit terminating equipment) involves operative units that transfer or receives data in the form of digital or analog signal within a network. In the physical layer, the DCE obtain the data produced by the DTE and convert it to suitable signals. Then it introduces the signal onto the telecommunication link. Generally, the DCE's we use at this layer involves **modems** (modulator/demodulator).

In a network, a DTE produces digital data and move them to a DCE. Then DCE translates the data in a specific form that can be accepted by the transmission medium and sends the translated signal to another DCE on the network. The second DCE extracts the signal out of the line, and transforms it into such a form that its DTE can use and deliver.