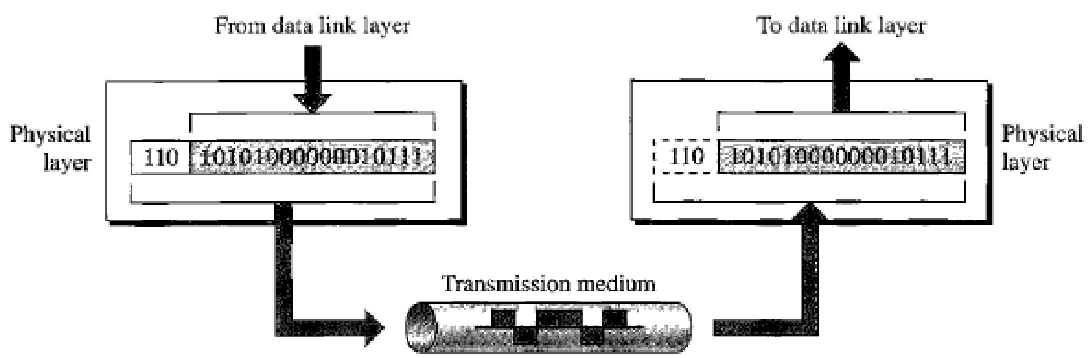
Unit 2: Physical Layer and Network Media

Physical Layer:

The physical layer coordinates the functions required to carry a bit stream over a physical medium. It deals with the mechanical and electrical specifications of the interface and transmission medium. It also defines the procedures and functions that physical devices and interfaces have to perform for transmission to occur. Figure below shows the position of the physical layer with respect to the transmission medium and the data link layer.

Figure 2.5 *Physical layer*

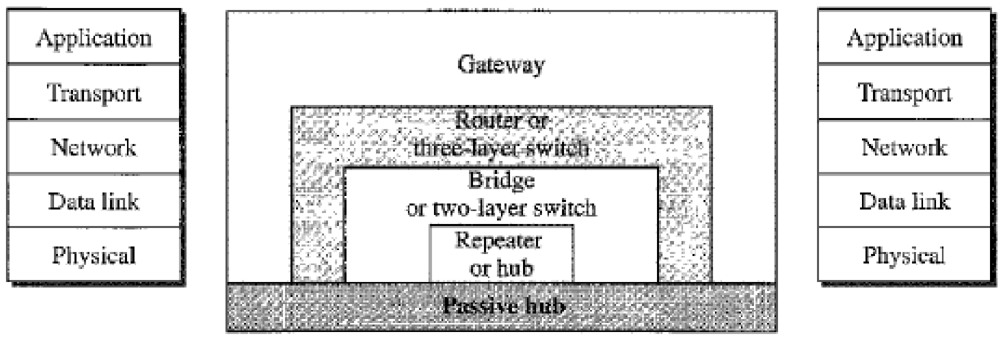


The physical layer is responsible for movements of individual bits from one hop (node) to the next.

Network Devices (Connecting Devices):

We divide connecting devices into five different categories based on the layer in which they operate in a network, as shown in Figure below.

Figure 15.1 *Five categories of connecting devices*



The five categories contain devices which can be defined as:

1. Those which operate below the physical layer such as a passive hub.
2. Those which operate at the physical layer (a repeater or an active hub).
3. Those which operate at the physical and data link layers (a bridge or a two-layer switch).
4. Those which operate at the physical, data link, and network layers (a router or a three-layer switch).
5. Those which can operate at all five layers (a gateway).

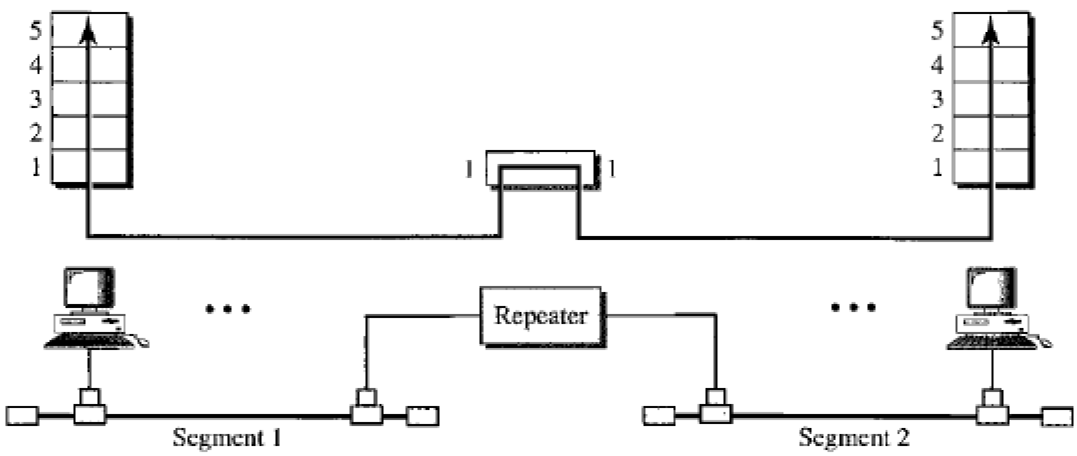
Passive Hubs:

A passive hub is just a connector. It connects the wires coming from different branches. In a star-topology Ethernet LAN, a passive hub is just a point where the signals coming from different stations collide; the hub is the collision point. This type of a hub is part of the media; its location in the Internet model is below the physical layer. It does not regenerate the signals, just provides the multipoint connection to extend the network.

Repeaters:

A repeater operates at the physical layer. Its job is to regenerate the signal over the same network before the signal becomes too weak or corrupted so as to extend the length to which the signal

Figure 15.2 *A repeater connecting two segments of a LAN*

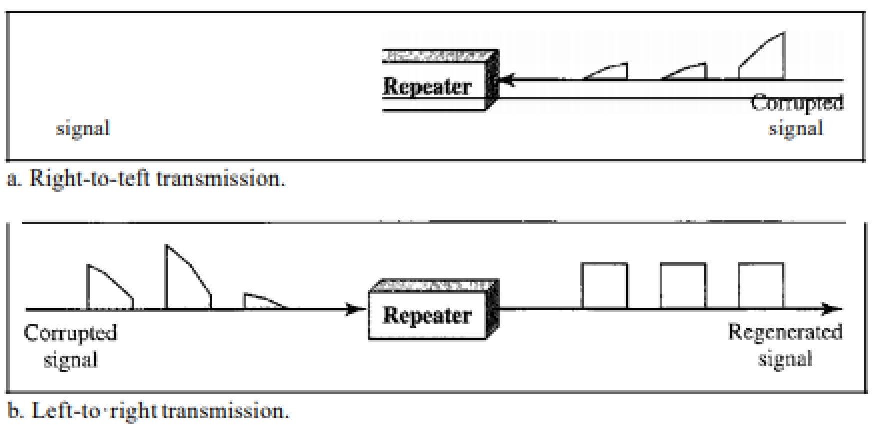


can be transmitted over the same network. An important point to be noted about repeaters is that they do not amplify the signal. When the signal becomes weak, they copy the signal bit by bit and regenerate it at the original strength. It is a 2-port device.

A repeater does not actually connect two LANs; it connects two segments of the same LAN. The segments connected are still part of one single LAN. A repeater is not a device that can connect two LANs of different protocols.

A repeater can overcome the Ethernet length restriction. In this standard, the length of the cable is limited to 500 m. To extend this length, we divide the cable into segments and install repeaters between segments. Note that the whole network is still considered one LAN, but the portions of the network separated by repeaters are called segments. The repeater acts as a two-port node, but operates only in the physical layer. When it receives a frame from any of the ports, it regenerates and forwards it to the other port.

Figure 15.3 *Function ofa repeater*

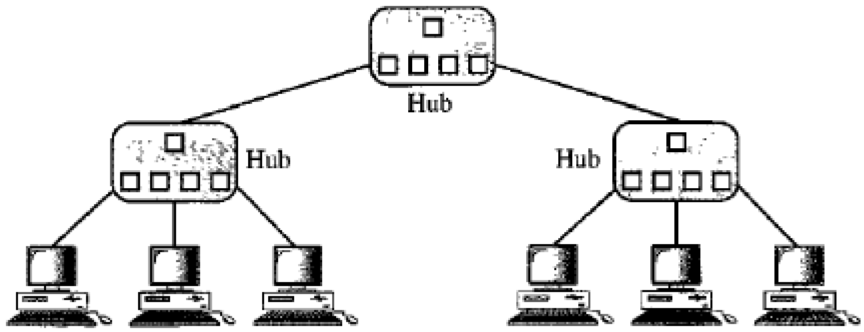


Active Hubs:

An active hub is actually a multiport repeater. It is normally used to create connections between stations in a physical star topology. However, hubs can also be used to create multiple levels of hierarchy, as shown in Figure below. The hierarchical use of hubs removes the length limitation of Ethernet.

The following diagram represents a Tree Topology. There is a central hub which is acting as active hub, the other two secondary hubs connected are acting as passive hubs.

Figure 15.4 *A hierarchy of hubs*



Difference between Active and passive hub:

- Active hub strengthens the signal where passive hub repeat/copy signals.
- Active hub needs Electricity whereas passive hub work without it.
- Active hub is smarter than passive hub.

- Passive hub is just a connector which connects wire coming from other devices.
- Active hub is multi-point repeater with capability of regeneration of signals.
- Active hub can process and monitor information while passive hub cannot do this.

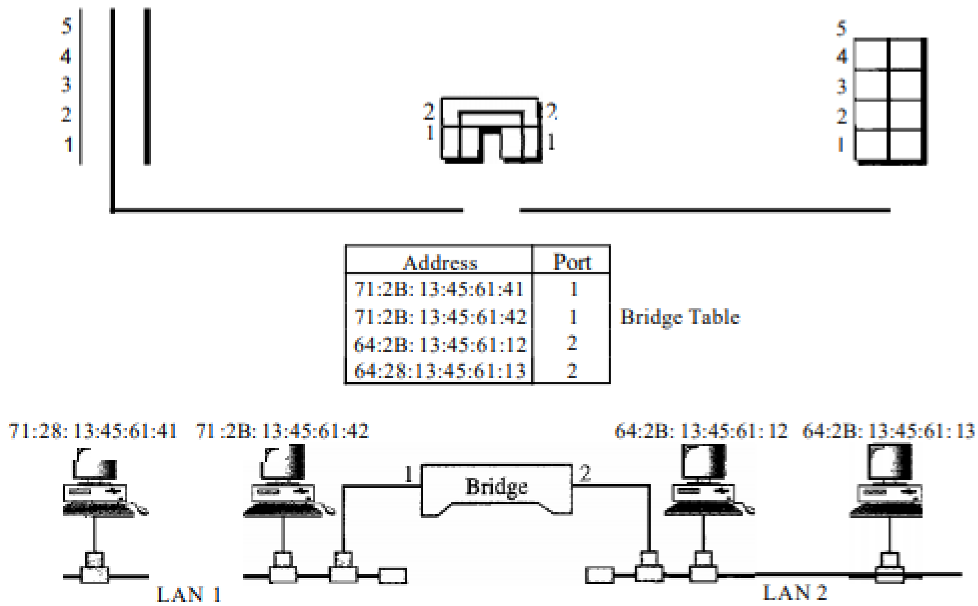
Bridges:

A bridge operates at data link layer. A bridge is a repeater, with add on the functionality of filtering content by reading the MAC addresses of source and destination. It is also used for interconnecting two LANs working on the same protocol. It has a single input and single output port, thus making it a 2-port device.

Types of Bridges

- Transparent Bridges: - These are the bridge in which the stations are completely unaware of the bridge's existence i.e. whether or not a bridge is added or deleted from the network, reconfiguration of the stations is unnecessary. These bridges make use of two processes i.e. bridge forwarding and bridge learning.
- Source Routing Bridges: - In these bridges, routing operation is performed by source station and the frame specifies which route to follow. The route can be discovered by sending a special frame called discovery frame, which spreads through the entire network using all possible paths to destination.

Figure 15.5 *A bridge connecting two LANs*



Switch:

A switch is a multiport bridge with a buffer and a design that can boost its efficiency (a large number of ports imply less traffic) and performance. We can have a two-layer switch or a three-layer switch. A three-layer switch is used at the network layer; it is a kind of router. The two-layer switch performs at the physical and data link layers.

Two Layer Switch:

A two-layer switch is a bridge, a bridge with many ports and a design that allows better (faster) performance. A bridge with a few ports can connect a few LANs together. A bridge with many ports may be able to allocate a unique port to each station, with each station on its own independent entity. This means no competing traffic (no collision, as we saw in Ethernet).

A two-layer switch, as a bridge does, makes a filtering decision based on the MAC address of the frame it received. However, a two-layer switch can be more sophisticated. It can have a buffer to hold the frames for processing. It can have a switching factor that forwards the frames faster. Some new two-layer switches, called cut-through switches, have been designed to forward the frame as soon as they check the MAC addresses in the header of the frame.

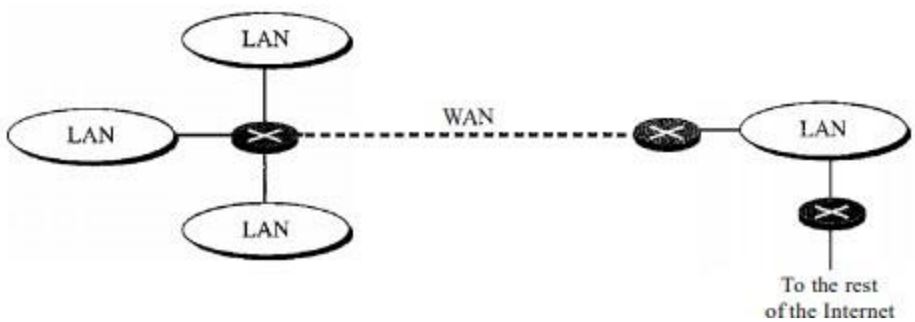
Three Layer Switch:

A three-layer switch is a router, but a faster and more sophisticated. The switching fabric in a three-layer switch allows faster table lookup and forwarding. In this book, we use the terms router and three-layer switch interchangeably.

Routers:

A router is a three-layer device that routes packets based on their logical addresses (host-to-host addressing). A router normally connects LANs and WANs in the Internet and has a routing table that is used for making decisions about the route. The routing tables are normally dynamic and are updated using routing protocols. Figure below shows a part of the Internet that uses routers to connect LANs and WANs.

igure 15.11 *Routers connecting independent LANs and WANs*



Gateway:

Although some sources use the terms gateway and router interchangeably, most of the literature distinguishes between the two. A gateway is normally a computer that operates in all five layers of the Internet or seven layers of OSI model. A gateway takes an application message, reads it, and interprets it. This means that it can be used as a connecting device between two internetworks that use different models. For example, a network designed to use the OSI model can be connected to another network using the Internet model. The gateway connecting the two systems can take a frame as it arrives from the first system, move it up to the OSI application layer, and remove the message. Gateways can provide security by filtering unwanted application-layer messages.

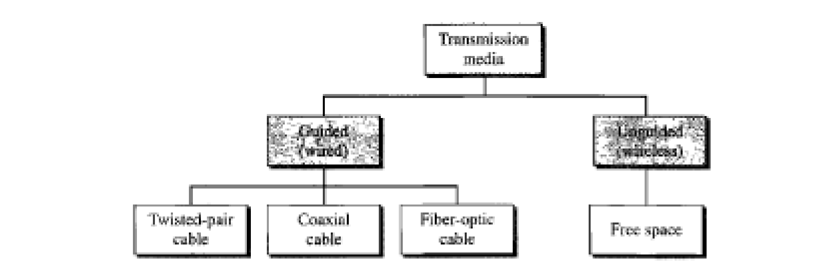
TRANSMISSION MEDIA:

A transmission medium can be broadly defined as anything that can carry information from a source to a destination. For example, the transmission medium for two people having a dinner conversation is the air. For a written message, the transmission medium might be a mail carrier, a truck, or an airplane.

In data communications, the definition of the information and the transmission medium is more specific. The transmission medium is usually free space, metallic cable, or fiber-optic cable. The information is usually a signal that is the result of a conversion of data from another form.

Classification of Transmission Media:

Figure 7.2 *Classes of transmission media*



Guided Media

Guided media, which are those that provide a channel from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable. A signal traveling along any of these media is directed and contained by the physical limits of the medium. Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current. Optical fiber is a cable that accepts and transports signals in the form of light.

1. Twisted-Pair Cable

A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure below.

Figure 7.3 *Twisted-pair cable*

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) and 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.

By twisting the pairs, a balance is maintained. For example, suppose in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse is true. Twisting makes it probable that both wires are equally affected by external influences (noise or crosstalk). This means that the receiver, which calculates the difference between the two, receives no unwanted signals. The unwanted signals are mostly canceled out. From the above discussion, it is clear that the number of twists per unit of length (e.g., inch) has some effect on the quality of the cable.

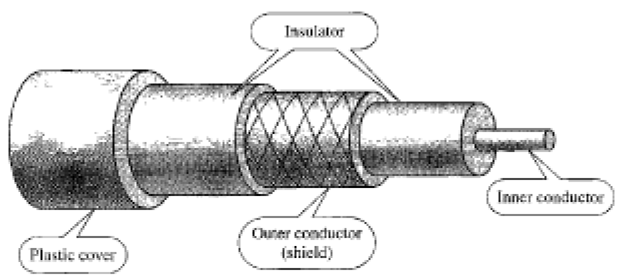
Applications

Twisted-pair cables are used in telephone lines to provide voice and data channels. The local loop-the line that connects subscribers to the central telephone office-commonly consists of unshielded twisted- pair cables. The DSL lines that are used by the telephone companies to provide high-data-rate connections also use the high-bandwidth capability of unshielded twisted-pair cables. Local-area networks also use twisted-pair cables.

2. 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 is, 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 circuit. This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover (see Figure below).

Figure 7.7 *Coaxial cable*



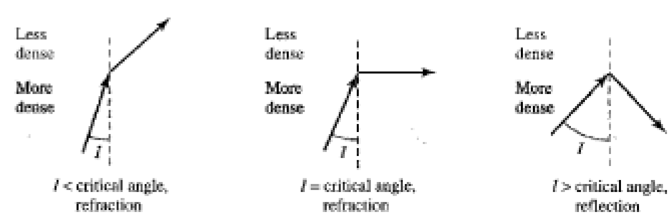
Applications

Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals. Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps. However, coaxial cable in telephone networks has largely been replaced today with fiber-optic cable. Cable TV networks also use coaxial cables. In the traditional cable TV network, the entire network used coaxial cable. Later, however, cable TV providers replaced most of the media with fiber-optic cable; hybrid networks use coaxial cable only at the network boundaries, near the consumer premises. Cable TV uses RG-59 coaxial cable. Another common application of coaxial cable is in traditional Ethernet LANs. Because of its high bandwidth, and consequently high data rate, coaxial cable was chosen for digital transmission in early Ethernet LANs.

3. Fiber Optic Cable:

A fiber-optic cable is made of glass or plastic and transmits signals in the form of light. To understand optical fiber, we first need to explore several aspects of the nature of light. Light travels in a straight line as long as it is moving through a single uniform If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction. Figure below shows how a ray of light changes direction when going from a more dense to a less dense substance.

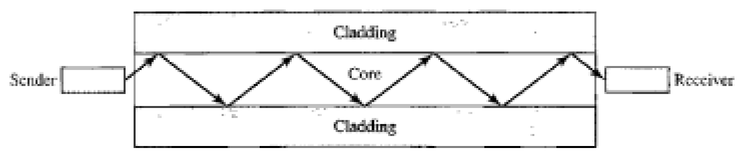
Figure 7.10 *Bending of light ray*



As the figure shows, if the angle of incidence I (the angle the ray makes with the line perpendicular to the interface between the two substances) is less than the critical angle, the ray refracts and moves closer to the surface. If the angle of incidence is equal to the critical angle, the light bends along the interface. If the angle is greater than the critical angle, the ray reflects (makes a turn) and travels again in the denser substance. Note that the critical angle is a property of the substance, and its value differs from one substance to another.

Optical fibers use reflection to guide light through a channel. A glass or plastic core is surrounded by a cladding of less dense glass or plastic. The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it. See Figure below.

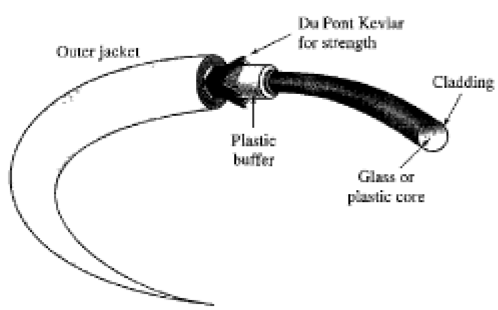
Figure 7.11 *Optical fiber*



Cable Composition

Figure below shows the composition of a typical fiber-optic cable. The outer jacket is made of either PVC or Teflon. Inside the jacket are Kevlar strands to strengthen the cable. Kevlar is a strong material used in the fabrication of bulletproof vests. Below the Kevlar is another plastic coating to cushion the fiber. The fiber is at the center of the cable, and it consists of cladding and core.

Figure 7.14 *Fiber construction*



Applications

Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective. Today, with wavelength-division multiplexing (WDM), we can transfer data at a rate of 1600 Gbps. Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating a hybrid network. Optical fiber provides the backbone structure while coaxial cable provides the connection to the user premises. This is a cost-effective configuration since the narrow bandwidth requirement at the user end does not justify the use of optical fiber. Local-area network such as Fast Ethernet uses fiber-optic cable.

Advantages and Disadvantages of Optical Fiber Advantages

Fiber-optic cable has several advantages over metallic cable (twisted pair or coaxial).

a. Higher bandwidth. Fiber-optic cable can support dramatically higher bandwidths (and hence data rates) than either twisted-pair or coaxial cable. Currently, data rates and bandwidth utilization over fiber-optic cable are limited not by the medium but by the signal generation and reception technology available.

b. Less signal attenuation. Fiber-optic transmission distance is significantly greater than that of other guided media. A signal can run for 50 km without requiring regeneration. We need repeaters every 5 km for coaxial or twisted-pair cable.

c. Immunity to electromagnetic interference. Electromagnetic noise cannot affect fiber-optic cables.

d. Resistance to corrosive materials. Glass is more resistant to corrosive materials than copper.

e. Light weight. Fiber-optic cables are much lighter than copper cables.

f. Greater immunity to tapping. Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antenna effects that can easily be tapped.

Disadvantages

There are some disadvantages in the use of optical fiber.

a. Installation and maintenance. Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere.

b. Unidirectional light propagation. Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.

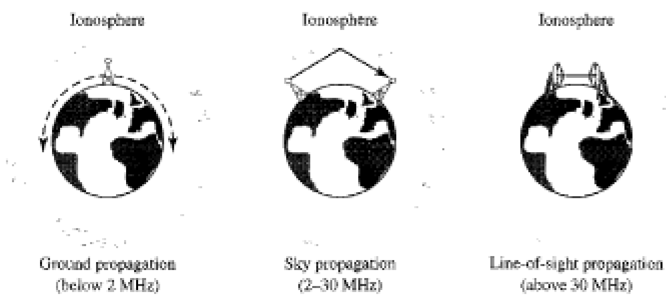
c. Cost. The cable and the interfaces are relatively more expensive than those of other guided media. If the demand for bandwidth is not high, often the use of optical fiber cannot be justified.

UNGUIDED MEDIA: WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication. Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.

Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation, as shown in Figure below.

Figure 7.18 *Propagation methods*

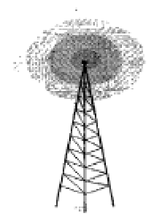


In ground propagation, radio waves travel through the lowest portion of the atmosphere, hugging the earth. These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet. Distance depends on the amount of power in the signal: The greater the power, the greater the distance. In sky propagation, higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to earth. This type of transmission allows for greater distances with lower output power. In line-or-sight propagation, very high-frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other, and either tall enough or close enough together not to be affected by the curvature of the earth. Line-of-sight propagation is tricky because radio transmissions cannot be completely focused.

1. Radio Waves

Waves ranging in frequencies between 3 kHz and 1 GHz are called radio waves. Radio waves, for the most part, are omnidirectional. When an antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned. A sending antenna sends waves that can be received by any receiving antenna. The omnidirectional property has a disadvantage, too. The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band. Radio waves, particularly those waves that propagate in the sky mode, can travel long distances. This makes radio waves a good candidate for long-distance broadcasting such as AM radio. Radio waves, particularly those of low and medium frequencies, can penetrate walls. This characteristic can be both an advantage and a disadvantage. It is an advantage because, for example, an AM radio can receive signals inside a building. It is a disadvantage because we cannot isolate a communication to just inside or outside a building. The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band. When this band is divided into sub bands, the sub bands are also narrow, leading to a low data rate for digital communications.

Figure 7.20 *Omnidirectional antenna*

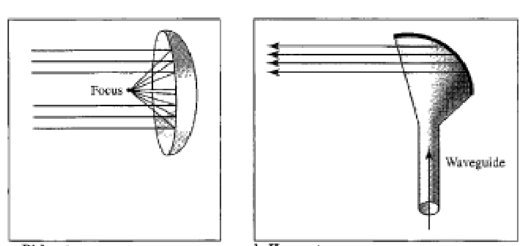


Applications: The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers. AM and FM radio, television, maritime radio, cordless phones are examples of multicasting.

2. Microwaves

Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas.

Figure 7.21 *Unidirectional antennas*



Microwaves need unidirectional antennas that send out signals in one direction. Two types of antennas are used for microwave communications: the parabolic dish and the horn (see Figure). A parabolic dish antenna is based on the geometry of a parabola: Every line parallel to the line of symmetry (line of sight) reflects off the curve at angles such that all the lines intersect in a common point called the focus. Outgoing transmissions are broadcast through a horn aimed at the dish. The microwaves hit the dish and are deflected outward in a reversal of the receipt path.

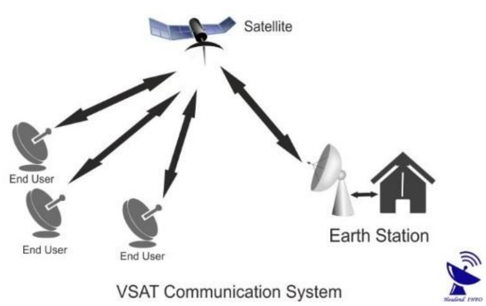
3. Infrared

Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls. This advantageous characteristic prevents interference between one system and another; a short-range communication system in one room cannot be affected by another system in the next room. When we use our infrared remote control, we do not interfere with the use of the remote by our neighbors. However, this same characteristic makes infrared signals useless for long-range communication. In addition, we cannot use infrared waves outside a building because the sun's rays contain infrared waves that can interfere with the communication.

The infrared band, almost 400 THz, has an excellent potential for data transmission. Such a wide bandwidth can be used to transmit digital data with a very high data rate.

VSAT:

A very small aperture terminal (VSAT) is a small telecommunication earth station that receives and transmits real-time data via satellite. VSAT is a satellite communications system that serves home and business users. A VSAT end user needs a box that interfaces between the user's computer and an outside antenna with a transceiver. The tranceiver receives or sends a signal to a satellite transponder in the sky. The satellite sends and receives signals from an earth station computer that acts as a hub for the system. For one end user to communicate with another, each transmission has to first go to the hub station which retransmits it via the satellite to the other end user's VSAT.

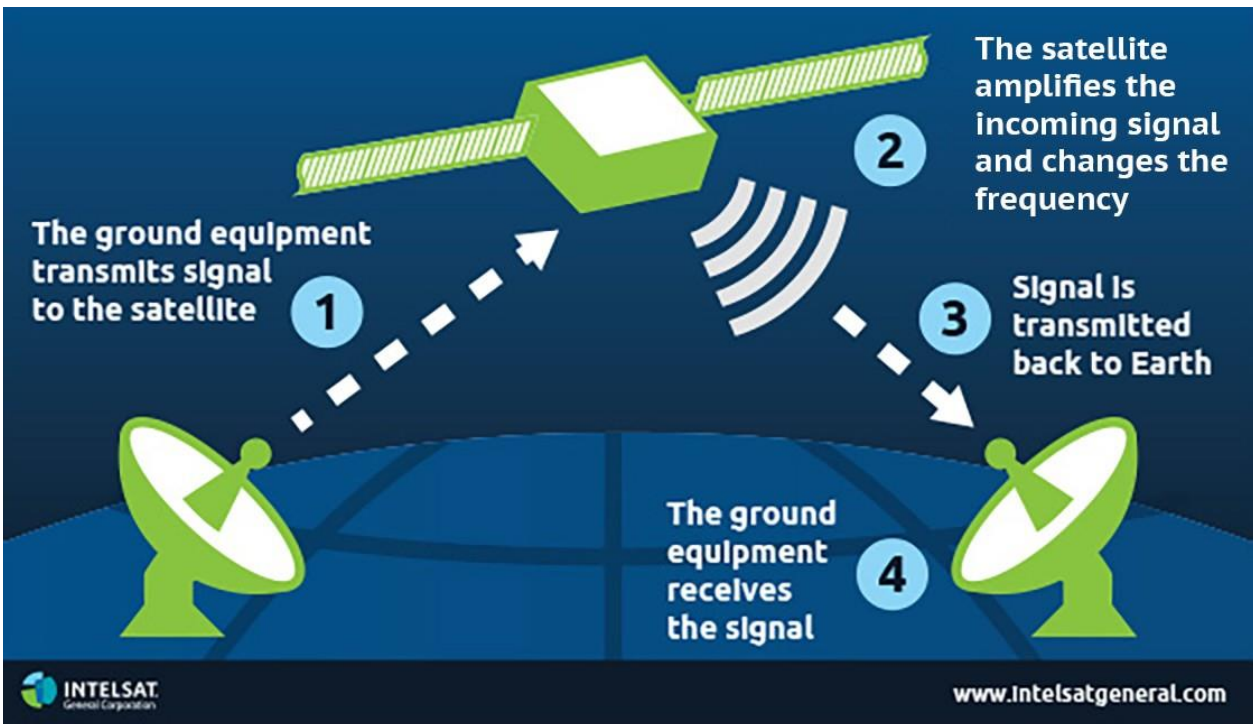


VSAT is designed to serve both businesses and individuals and involves the use of specific technology and devices that are designed to facilitate effective telecommunications and Internet connectivity.
When the system is comprised of multiple users, in order to establish communications with one another the data must be

transmitted to the station-based PC which sends the signal to the sky satellite. The satellite sky transponder then forwards the data transmission to the end user's VSAT antenna and finally to the end user's device. VSAT can be used by both home users who sign up with a primary VSAT service and by private organizations and companies that lease or operate their own VSAT infrastructure. A main advantage of VSAT is it provides companies with complete control over their own communications infrastructure without having to depend upon third party sources.

Satellite:

A communications satellite is an artificial satellite that relays and amplifies radio telecommunications signals via a transponder; it creates a communication channel between a source transmitter and a receiver at different locations on Earth. Communications satellites are used for television, telephone, radio, internet, and military applications. The purpose of communications satellites is to relay the signal around the curve of the Earth allowing communication between widely separated geographical points.



Applications: Television, Internet, Military

Ethernet Cable Standards:

Ethernet, developed by the Electrical and Electronic Engineers Institute, IEEE Standard 802, is the most popular LAN (local area network) technology used today. It defined the number of conductors that are required for a connection, the performance thresholds that can be expected, and provides the framework for data transmission.

The Ethernet cables for connectivity in most office and home environments rely on twisted wire pairs within an overall cable - Cat 5, Cat 6 and Cat 7 all used this format.

The Ethernet cables are available in a variety of lengths as patch cables, or the cable itself is available for incorporating into systems, buildings, etc. The terminations can then be made to the required connector using a crimp tool. These network cables are available in a variety of lengths - long Ethernet cables are available, some of the longest being up to 75 meters.

Earlier network cables were unshielded, but later ones were shielded to improve the performance. For example, an unshielded twisted pair (UTP) cable may be satisfactory for a short run between a computer and router, but a foil shielded cable, FTP, is best longer runs or where the cable passes through areas of high electrical noise.

Flat Ethernet cable and connector

There are different methods that can be used for shielding Ethernet cables. The most common is to place a shield around each twisted pair. This not only provides shielding for the cable externally, but also reduces crosstalk between the internal twisted pairs as well. Manufacturers can further enhance the performance by placing shielding around all the wires in the cable just under the cable sheath. There are different codes used to indicate the different types of shielding:

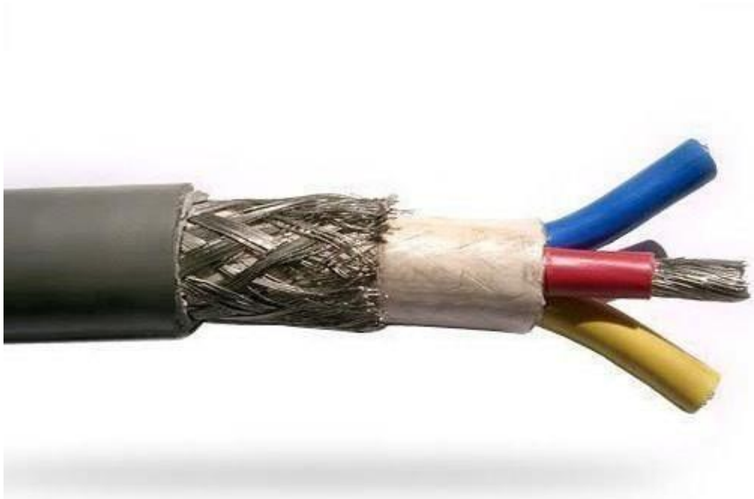
- U/UTP - Unshielded cable, unshielded twisted pairs
- F/UTP - Foil shielded cable, unshielded twisted pairs
- U/FTP - Unshielded cable, foil shielded twisted pairs
- S/FTP - braided shielded cable, foil shielded twisted pairs

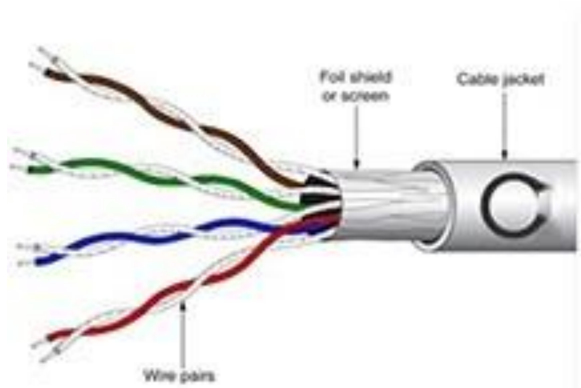
Where: TP = twisted pair, U = unshielded, F = foil shielded, S =

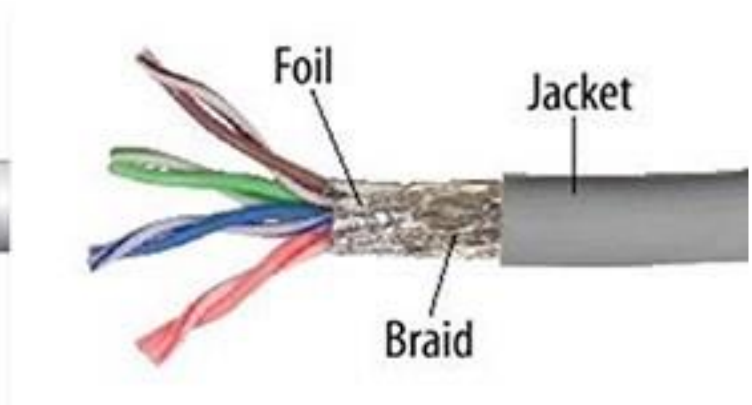
braided shielding.

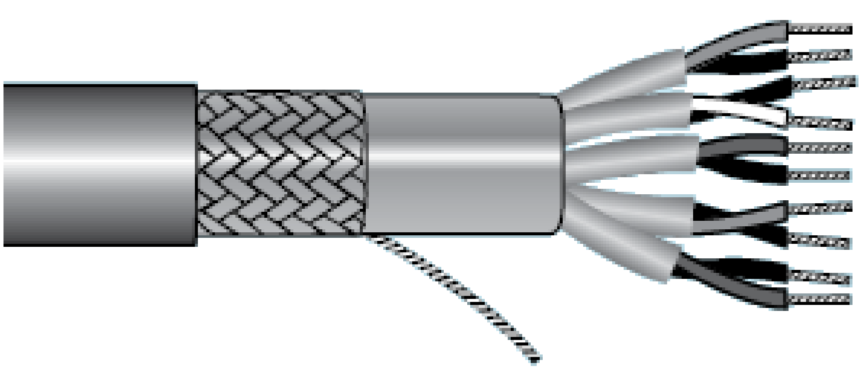
A further difference within the Ethernet cables whether Cat 5, Cat 5e, Cat 6, Cat 6e, or Cat 7 can be whether solid or stranded wires are used within the cable. As the description implies, a solid cable uses a single piece of copper for the electrical conductor within each wire of the cable whilst stranded wire uses a series of copper strands twisted together. Although when buying a patch cable, it may not be necessary to know this, when installing a long cable run it may be important as each type is slightly more suitable for different applications.

- Stranded cable: This type of wire is more flexible and it is more applicable for Ethernet cables where the cable may be moved - often it is idea for patch leads at desks or general connections to PCs, etc where some movement may be needed and expected.
- Solid cable: Solid cable is not as flexible as the stranded type, but it is also more durable. This makes it best for use in permanent installations like cable installations under floors, embedded in walls and the like.



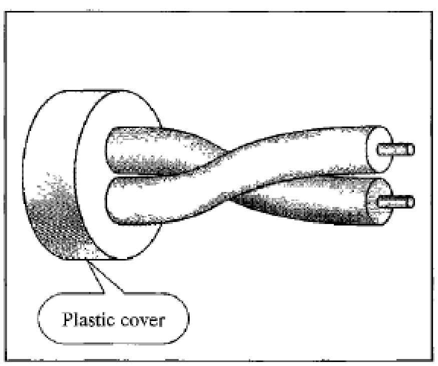

Foil shield
or screen
Cable jacket
Wire pairs


Foil
Jacket
Braid

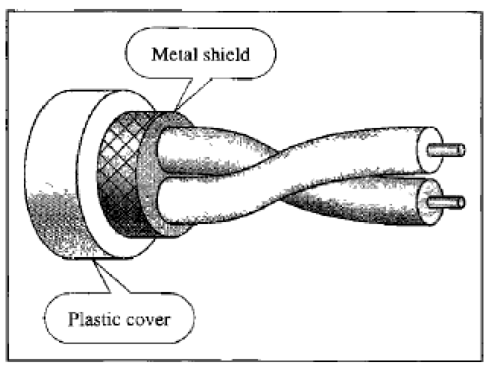


Category	Shielding	Maximum Transmission Speec (at 100m)	Maximum Bandwidth
Cat 3 cable	unshielded	10 Mbps	16 MHz
Cat 5 cable	unshielded>	10/100 Mbps	100 MHz
Cat 5e cable	unshielded	1000 Mbps / 1 Gbps	100 MHz
Cat 6 cable	shielded or unshielded	1000 Mbps / 1 Gbps	250 MHz
Cat 6a cable	shielded	10000 Mbps/ 10 Gbps	500 MHz
Cat 7 cable	shielded	10000 Mbps / 10 Gbps	600 MHz

Figure 7.4 *UTP and STP cables*

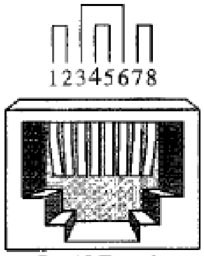


a. UTP

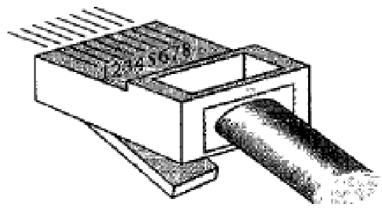


b. STP

UTP connector



RJ-45 Female



RJ-45 Male

Fiber Cable Standards:

Optical Fiber cables can support high bit rates, up to Gbps, immune to EMI, has very low signal attenuation up to 100 km. Standard is optical carrier (OC), ranges from 51.8 Mbps to39.8 Gbps.

There are two primary types of fiber – multimode and single mode. With the great popularity of optical links in the last few years, the main part of them is currently based on modern single-mode fibers. However, both single-mode and multimode fibers are divided into many types/categories that comply with established standards and factory specifications.

The popular markings are based on shorts of the fiber kinds:

- Single Mode (Mono Mode): Single mode transmits a single beam of light from the core, hence with much smaller diameter. Used for longer distance and LASER is used as light source.
- Multi-Mode: Multimode is so named because multiple beams from a light source move through the core in different paths. Used for shorter distance and LED is used as light source. Two popular sizes of multimode fiber exist today for use in commercial applications: 50 micron and 62.5 micron. Each has a common cladding diameter (125 microns), but different core diameters (50 microns and 62.5 microns).

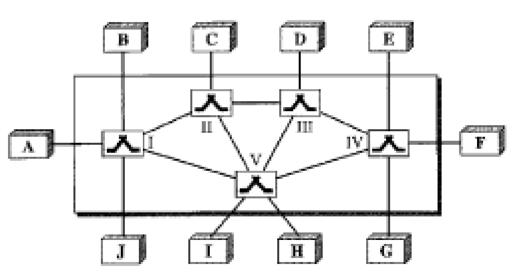
With demand increasing for bandwidth on data networks and LANs, single-mode fiber is becoming steadily more popular in new applications. Many installations include multimode fiber for current systems and single-mode fiber in the event of future expansion.

Switching:

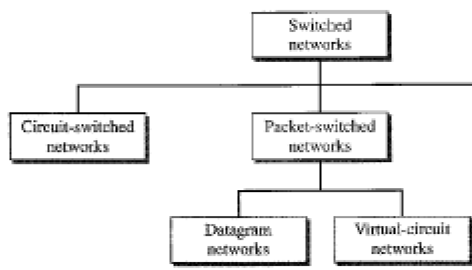
A network is a set of connected devices. Whenever we have multiple devices, we have the problem of how to connect them to make one-to-one communication possible. One solution is to make a point-to- point connection between each pair of devices (Mesh topology) or between a central device and every other device (a star topology). These methods are not applicable for very large networks. Other topologies employing multipoint connections are also not efficient due to the distances between devices and the total number of devices increase beyond the capacities of the media and equipment.

A better solution is **switching**. A switched network consists of a series of interlinked nodes, called switches. Switches are devices capable of creating temporary connections between two or more devices linked to the switch.

Switched network



We can divide today's network into three broad categories: circuit-switched networks, packet-switched networks and message-switched networks.



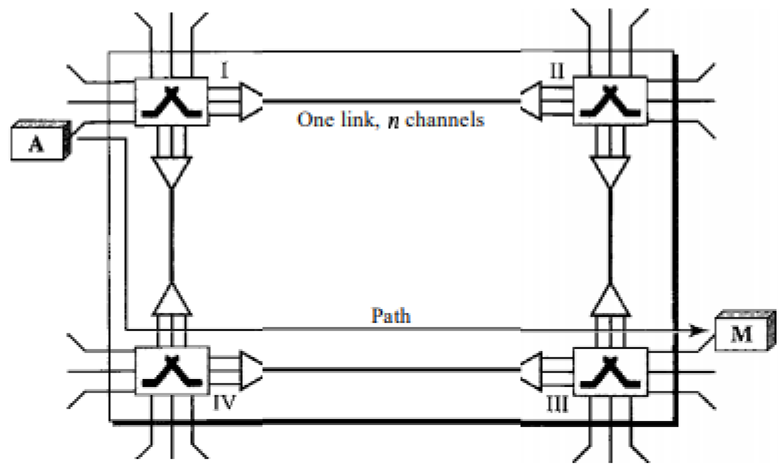
8.2 *Taxonomy of switched networks*

Circuit Switched Networks:

A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links. However, each connection uses only one dedicated channel on each link. Each link is normally divided into n channels by using FDM or TDM.

Figure below shows a trivial circuit-switched network with four switches and four links. Each link is divided into n (n is 3 in the figure) channels by using FDM or TDM.

A trivial circuit-switched network



We have explicitly shown the multiplexing symbols to emphasize the division of the link into channels even though multiplexing can be implicitly included in the switch fabric.

The end systems, such as computers or telephones, are directly connected to a switch. We have shown only two end systems for simplicity. When end system A needs to communicate with end system M, system A needs to request a connection to M that must be accepted by all switches as well as by M itself. This is called the setup phase; a circuit (channel) is reserved on each link, and the combination of circuits or channels defines the dedicated path. After the dedicated path made of connected circuits (channels) is established, data transfer can take place. After all data have been transferred, the circuits are torn down.

We need to emphasize several points here:

- Circuit switching takes place at the physical layer.
- Before starting communication, the stations must make a reservation for the resources to be used during the communication. These resources, such as channels (bandwidth in FDM and time slots in TDM), switch buffers, switch processing time, and switch input/output ports, must remain dedicated during the entire duration of data transfer until the teardown phase.
- Data transferred between the two stations are not packetized (physical layer transfer of the signal). The data are a continuous flow sent by the source station and received by the destination station, although there may be periods of silence.
- There is no addressing involved during data transfer. The switches route the data based on their occupied band (FDM) or time slot (TDM). Of course, there is end-to-end addressing used during the setup phase.

Three Phases:

The actual communication in a circuit-switched network requires three phases: connection setup, data transfer, and connection teardown.

Setup Phase

Before the two parties (or multiple parties in a conference call) can communicate, a dedicated circuit (combination of channels in links) needs to be established. The end systems are normally connected through dedicated lines to the switches, so connection setup means creating dedicated channels between the switches.

Data Transfer Phase

After the establishment of the dedicated circuit (channels), the two parties can transfer data. Teardown Phase

When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.

Packet Switched Networks:

A packet switched network (PSN) is a type of computer communications network that groups and sends data in the form of small packets. It enables the sending of data or network packets between a source and destination node over a network channel that is shared between multiple users and/or applications. A packet switched is also known as a connectionless network, as it does not create a permanent connection between a source and destination node. Packet-switched describes the type of network in which packets are routed through a network based on the destination address contained within each packet. Breaking communication down into packets allows the same data path to be shared among many users in the network.

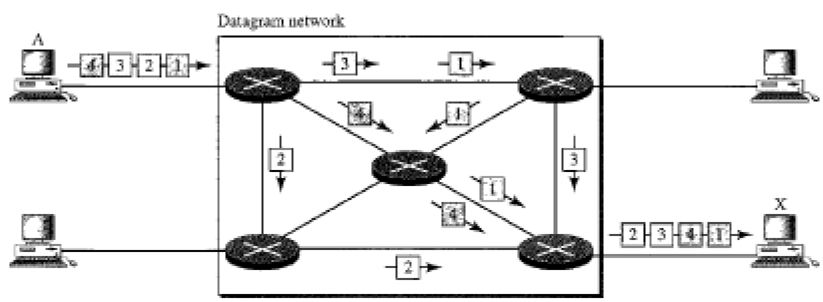
In packet switching, there is no resource allocation for a packet. This means that there is no reserved bandwidth on the links, and there is no scheduled processing time for each packet. Resources are allocated on demand. The allocation is done on a first-come, first serve basis. When a switch receives a packet, no matter what is the source or destination, the packet must wait if there are other packets being processed.

Packet switching may be classified into connectionless packet switching, also known as datagram switching, and connection-oriented packet switching, also known as virtual circuit switching.

Datagram Approach:

In a datagram network, each packet is treated independently of all others. Even if a packet is part of a multipacket transmission, the network treats it as though it existed alone. Packets in this approach are referred to as datagrams. Datagram switching is normally done at the network layer.

Figure 8.7 *A datagram network with four switches (routers)*

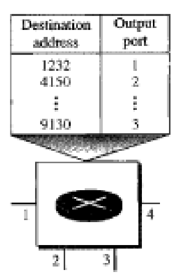


In this example, all four datagrams belong to the same message, but may travel different paths to reach their destination. This is so because the links may be involved in carrying packets from other sources and do not have the necessary bandwidth available to carry all the packets from A to X. This approach can cause the datagrams of a transmission to arrive at their destination out of order with different delays between the packets. Packets may also be lost or dropped because of a lack of resources.

The datagram networks are sometimes referred to as connectionless networks. The term connectionless here means that the switch does not keep information about the connection state. There are no setup and or teardown phases. Each packet is treated the same by a switch regardless of its source or destination.

Since there are no setup or teardown phases, each switch has a routing table which is based on the destination address. The routing tables are dynamic and are updated periodically. The destination address and the corresponding forwarding output ports are recorded in the tables. This is different from circuit-switched network in which each entry is created when the setup phase is completed and deleted when the teardown phase is over.

Routing table in a datagram network

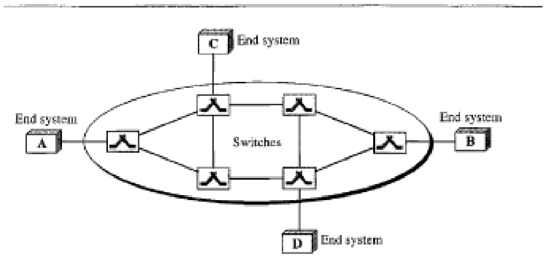


Virtual Circuit Networks:

A virtual circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both.

- As in a circuit-switched network, there are setup and teardown phases in addition to the data transfer phase.
- Resources can be allocated during the setup phase, as in a circuit-switched network, or on demand, as in a datagram network.
- As in a datagram network, data are packetized and each packet carries an address in the header. However, the address is of the next hop to be reached towards the destination.
- As in a circuit-switched network, all packets follow the same path established during the connection.
- A virtual-circuit network is normally implemented in the data link layer, while a circuit-switched network is implemented in the physical layer and a datagram network is implemented in the network layer.

10 Virtual-circuit network

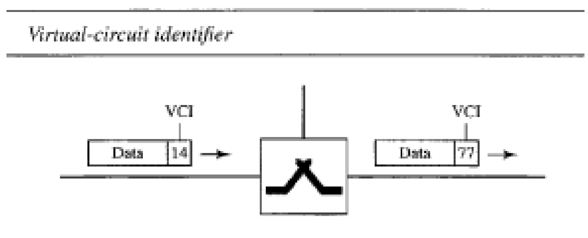


Addressing:

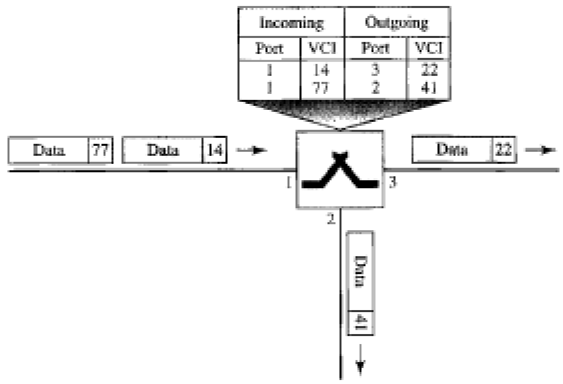
In a virtual-circuit network, two types of addressing are involved: global and local.

Global addressing: A source or a destination needs to have a global address-an address that can be unique in the scope of the network or internationally.

Local Addressing: The address that is actually used for data transfer is called the virtual-circuit identifier (VCI). A VCI, unlike a global address, is a smaller number that has only one switch scope; it is used by a frame between two switches.



Switch and tables in a virtual-circuit network



Three phases:

As in circuit-switched network, a source and destination need to go through three phases in a virtual circuit network: setup, data transfer, and teardown.

In the setup phase, the source and destination use their global addresses to help switches make table entries for the connection.

In the teardown phase, the source and destination inform the switches to delete the corresponding entry.

Data transfer occurs between these two phases.

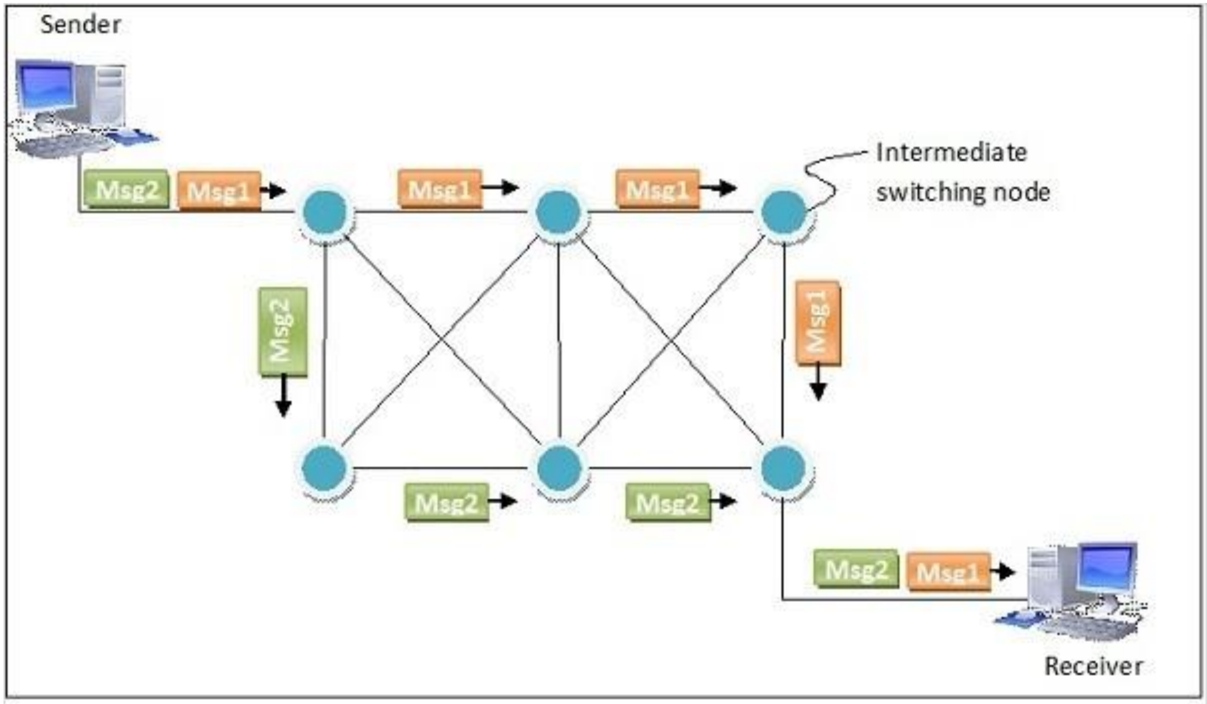
Message Switched Networks:

Message switching is a network switching technique in which data is routed in its entirety from the source node to the destination node, one hop at a time. During message routing, every intermediate switch in the network stores the whole message. If the entire network's resources are engaged or the network becomes blocked, the message-switched network stores and delays the message until ample resources become available for effective transmission of the message.

Before the advancements in packet switching, message switching acted as an efficient substitute for circuit switching.

In message switching, the source and destination nodes are not directly connected. Instead, the intermediary nodes (mainly switches) are responsible for transferring the message from one node to the next. Thus, every intermediary node inside the network needs to store every message prior to retransferring the messages one-by-one as adequate resources become available. If the resources are not available, the messages are stored indefinitely. This characteristic is known as store and forward.

The following diagram represents routing of two separate messages from the same source to same destination via different routes, using message switching.



Public Switched Telephone Network (PSTN):

The public switched telephone network (PSTN) is the aggregate of the world's circuit-switched telephone networks that are operated by national, regional, or local telephone operators, providing infrastructure and services for public telecommunication. The PSTN consists of telephone lines, fiber optic cables, microwave transmission links, cellular networks, communications satellites, and undersea telephone cables, all interconnected by switching centers, thus allowing most telephones to communicate with each other. The public switched telephone network was formerly known simply as the public telephone network. The task of building the networks and selling services to customers fell to the network operators. In some countries, however, the job of providing telephone networks fell to government as the investment required was very large and the provision of telephone service was increasingly becoming an essential public utility.

The original concept was that the telephone exchanges are arranged into hierarchies, so that if a call cannot be handled in a local cluster, it is passed to one higher up for onward routing. This reduced the number of connecting trunks required between operators over long distances and also kept local traffic separate. A PSTN is made up of switches at centralized points on a network that function as nodes to enable communication between two points on the network. A call is placed after being routed through multiple switches. Voice signals can then travel over the connected phone lines.

Integrated Services Digital Network (ISDN):

Integrated Services Digital Network (ISDN) is a set of communication standards for simultaneous digital transmission of voice, video, data, and other network services over the traditional circuits of the public switched telephone network. Prior to ISDN, the telephone system was viewed as a way to transport voice, with some special services available for data. The key feature of ISDN is that it integrates speech and data on the same lines, adding features that were not available in the classic telephone system.

ISDN Interfaces:

Among the types of several interfaces present, some of them contains channels such as the B-Channels or Bearer Channels that are used to transmit voice and data simultaneously; the D-Channels or Delta Channels that are used for signaling purpose to set up communication.

The ISDN has several kinds of access interfaces such as −

- Basic Rate Interface (BRI)
- Primary Rate Interface (PRI)
- Narrowband ISDN
- Broadban

d ISDN Basic Rate Interface (BRI)

The Basic Rate Interface or Basic Rate Access, simply called the ISDN BRI Connection uses the existing telephone infrastructure. The BRI configuration provides two data or bearer channels at 64 Kbits/sec speed and one control or delta channel at 16 Kbits/sec. This is a standard rate. The ISDN BRI interface is commonly used by smaller organizations or home users or within a local group, limiting a smaller area.

Primary Rate Interface (PRI)

The Primary Rate Interface or Primary Rate Access, simply called the ISDN PRI connection is used by enterprises and offices. The PRI configuration is based on T-carrier or T1 in the

US, Canada and Japan countries consisting of 23 data or bearer channels and one control or delta channel, with 64kbps speed for a bandwidth of 1.544 M bits/sec. The PRI configuration is based on E-carrier or E1 in Europe, Australia and few Asian countries consisting of 30 data or bearer channels and two-control or delta channel with 64kbps speed for a bandwidth of 2.048 M bits/sec. The ISDN PRI interface is used by larger organizations or enterprises and for Internet Service Providers.

Narrowband ISDN

The Narrowband Integrated Services Digital Network is called the N-ISDN. This can be understood as a telecommunication that carries voice information in a narrow band of frequencies. This is actually an attempt to digitize the analog voice information. This uses 64kbps circuit switching. The narrowband ISDN is implemented to carry voice data, which uses lesser bandwidth, on a limited number of frequencies.

Broadband ISDN

The Broadband Integrated Services Digital Network is called the B-ISDN. This integrates the digital networking services and provides digital transmission over ordinary telephone wires, as well as over other media. It is defined as, “Qualifying a service or system requiring transmission channels capable of supporting rates greater than primary rates.” The broadband ISDN speed is around 2 MBPS to 1 GBPS and the transmission is related to ATM, i.e., Asynchronous Transfer Mode. The broadband ISDN communication is usually made using the fiber optic cables. As the speed is greater than 1.544 Mbps, the communications based on this are called Broadband Communications. The broadband services provide a continuous flow of information, which is distributed from a central source to an unlimited number of authorized receivers connected to the network.

ISDN Standards:

The ISDN works based on the standards defined by ITU-T. The Telecommunication Standardization Sector (ITU-T) coordinates standards for telecommunications on behalf of the International Telecommunication Union (ITU) and is based in Geneva, Switzerland. The various principles of ISDN as per ITU-T recommendation are:

- To support switched and non-switched applications
- To support voice and non-voice applications
- Reliance on 64-kbps connections
- Intelligence in the network
- Layered protocol architecture
- Variety of configurations

Advantages of ISDN

ISDN is a telephone network-based infrastructure, which enables the transmission of both voice and data simultaneously. There are many advantages of ISDN such as −

- As the services are digital, there is less chance for errors.
- The connection is faster.
- The bandwidth is higher.
- Voice, data and video − all of these can be sent over a single ISDN line.

Disadvantages of ISDN

The disadvantage of ISDN is that it requires specialized digital services and is costlier. However, the advent of ISDN has brought great advancement in communications. Multiple transmissions with greater speed are being achieved with higher levels of accuracy.