4 Network Architecture

4.1. Introduction

Network architectures deal with the physical connection, *i.e.* topologies, access methods and connection protocols. Some examples of network architectures are :

(a) Ethernet

(b) Token ring

(c) Appletalk

(d) ARCNET

(e) ATM etc.

Out of these network architectures you will learn ARCNET in detail.

4.2. What is ARCNET?

Digital communication networks have become a core technology in advanced building automation systems. Communication networks such as MS/TP, ARCNET and ethernet can be categorized as discrete-event dynamic systems (DEDS).

The Attached Resource Computer Network (ARCNet) standard was created in 1970 at the Data Point Corporation by a scientist-John Murphy. ARCNet uses the token-passing protocol over a star and bus topology. The star and bus topology combines the flexibility of a star with the simplicity and throughput of a bus. Thus, ARCNet standard has a unique protocol/topology combination : Token passing protocol and Distributed star/bus topology.

Like Ethernet and Controller Area Network (CAN), ARCNET is a data-link layer technology with no defined application layer. ARCnet is an extremely easy-to-install LAN since it offers a flexible topology with few limitations. It can be configured as a simple Star of Bus topology network, or a Combined Star and Bus topology network. The ARCnet card is equipped with a standard BNC female connector for connection to RG-62 A/U coaxial cable.

ArcNet technology is described by the ANSI standard 878.1 and predates the IEEE Project 802 standards. Arcnet should not be confused with the IEEE Token Bus standard, IEEE 802.4. However, ArcNet does loosely comply to this token passing specification. ArcNet techonogy is described by the ANSI standard 878.1 and predates the IEEE Project 802 standards. ArcNet should not be confused with the IEEE Token Bus standard, IEEE 802.4. However, ArcNet doss loosely comply to this token passing specification.

The token moves from one computer to another based on node addresses instead of the physical location of computers. This means that ArcNet passes the token to the next address regardless of whether the address is on a workstation in the same room or in a separate building.

Each computer in an ArcNet network is connected by a cable to a hub, which can be an active, a passive or a smart hub.

The standard cabling used for ArcNet is 93 ohm RG-62 A/U coaxial cable. ArcNet also supports twisted pair and fiber optic cables.

The use of star topology and cable filtering make ArcNet networks reliable. In a distributed star design, ArcNet uses passive and active hubs to control and route data tokens froms one workstation to the next. Since token passing is done at a fixed rate and collisions do not occur, ArcNet is very stable.

4.3. ARCNET- Embedded Network

ARCNET's use as an office automation network has diminished; however, ARCNET continues to find success in the industrial automation industry because its performance characteristics are well suited for control. ARCNET has proven itself to be very robust. ARCNET also is fast, provides deterministic performance and can span long distances making it a suitable fieldbus technology.

The term fieldbus is used in the industrial automation industry to signify a network consisting of computers, controllers and devices mounted in the "field". ARCNET is an ideal fieldbus. Unlike office automation networks, a fieldbus must deliver messages in a time predictable fashion. ARCNET's token-passing protocol provides this timeliness. Fieldbus messages are generally short. ARCNET packet lengths are variable from 0 to 507 bytes with little overhead and, coupled with ARCNET's high data rate, typically 2.5 Mbps, yields quick responsiveness to short messages. Fieldbuses must be rugged. ARCNET has built-in CRC-16 (cyclic redundancy check) error checking and supports several physical cabling schemes including fiber optics. Finally there must be low software overhead. ARCNET's data link protocol is self-contained in the ARCNET controller chip. Network functions such as error checking, flow control and network configuration are done automatically without software intervention.

APPLICATION

PRESENTATION

SESSION

TRANSPORT

NETWORK

DATA LINK

PHYSICAL

In terms of the International Organization of Standards OSI (Open Systems Interconnect) Reference Model. ARCNET provides the Physical and Data Link layers of this model. In other words. ARCNET provides for the successful transmission and reception of a data packet between two network nodes. A node refers to an ARCNET controller chip and cable transceiver connected to the network. Nodes are assigned addresses called MAC (medium access control) IDs and one ARCNET network can have up to 255 uniquely assigned nodes.

4.3.1. Deterministic Performance

The key to ARCNET's performance and its attractiveness as a control network is its token-passing protocol. In a token-passing network, a node can only send a message when it receives the "token." When a node receives the token it becomes the momentary master of the network; however, its mastery is short lived. The length of the message that can be sent is limited and, therefore, no one node can dominate the network since it must relinquish control of the token. Once the message is sent, the token is passed to another node allowing it to become the momentary master. By using token passing as the mechanism for mediating access of the network by any one node, the time performance of the network becomes predicatable or deterministic. In fact, the worst case time that a node takes to deliver a message to another node can be calculated. Industrial networks require predictable performance to ensure that controlled events occur when they must. ARCNET provides this predictability.

4.3.2. Logical Ring

A token (ITT—Invitation to Transmit) is a unique signaling sequence that is passed in an orderly fashion among all the active nodes in the network. When a particular node receives the token, it has the sole right to initiate a transmission sequence or it must pass the token to its logical neighbor. This neighbor, which can be physically located anywhere on the network. has the next highest address to the node with the token. Once the token is passed, the recipient (likewise) has the right to initiate a transmission. This token-passing sequence continues in a logical ring fashion serving all nodes equally. Node addresses muts be unique and can range from 0 to 255 with 0 reserved for broadcast messages.

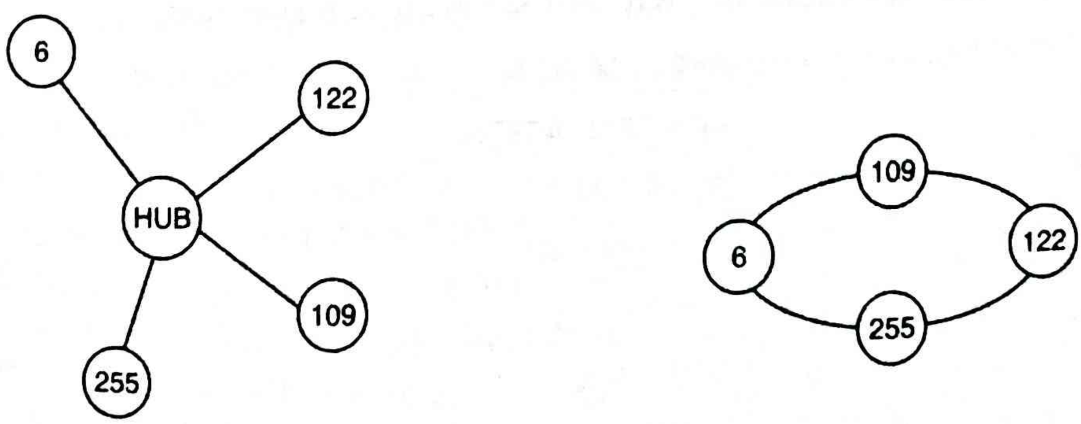

Fig. 4.1

For example, assume a network consisting of four nodes addressed 6, 109, 122 and 255. Node assignments are independent of the physical location of the nodes on the network. Once the network is configured, the token is passed from one node to the node with the next highest node address even though another node may by physically closer. All nodes have a logical neighbor and will continue to pass the token to their neighbor in a logical ring fashion regardless of the physical topology of the network.

4.3.3. Directed Messages

In a transmission sequence, the node with the token becomes the source node and any other node selected by the source node for communication becomes the destination node. First the source node inquires if the destination node is in a position to accept a transmission by sending out a Free Buffer Enquiry (FBE). The destination node responds by returning an Acknowledgement (ACK) meaning that a buffer is available or by returning a Negative Acknowledgement (NAK) meaning that no buffer is available. Upon an ACK, the source node sends out a data transmission (PAC) with either 0 to 507 bytes of data (PAC). If the data was properly received by the destination node as evidenced by a successful CRC test. the destination node sends another ACK. If the transmission was unsuccessful, the destination node does nothing, causing the source node to timeout. The source node will, therefore, infer that the transmission failed and will retry after it receives the token on the next token pass. The transmission sequence terminates and the token is passed to the next node. If the desired message exceeds 507 bytes, the message is sent as a series of packets—one packet every token pass. This is called a fragmented message. The packets are recombined at the destination end to form the entire message.

4.3.4. Broadcast Messages

ARCNET supports a broadcast message, which is an unacknowledged message to all nodes. Instead of sending the same message to individual nodes one message at a time, this message can be sent to all nodes with one transmission. Nodes that have been enabled to receive broadcast messages will receive a message that specifies node 0 as the destination address. Node 0 does not exist on the network and is reserved for this broadcast function. No ACKs or NAKs are sent during a broadcast message making broadcast messaging fast.

4.3.5. Automatic Reconfigurations

Another feature of ARCNET is its ability to reconfigure the network automatically if a node is either added or deleted from the network. If a node joins the network, It does not automatically participate in the token-passing sequence. Once a node notices that it is never granted the token, it will jam the network with a reconfiguration burst that destroys the token-passing sequence. Once the token is lost, all nodes will cease transmitting and begin a timeout sequence based upon their own node address. The node with the highest address will timeout first and begin a token pass sequence to the node with the next highest address. If that node does not respond, it is assumed not to exist. The destination node address is incremented and the token resent. This sequence is repeated until a node responds. At that time, the token is released to the responding node and the address of the responding node is noted as the logical neighbor of the originating node. The sequence is repeated by all nodes until each node learns its logical neighbor. At that time the token passes from neighbor to neighbor without wasting time on absent addresses.

If a node leaves the network the reconfiguration sequence is slightly different. When a node releases the token to its logical neighbor, it continues to monitor network activity to ensure that the logical neighbor responded with either a token pass or a start of a transmission sequence. If no activity was sensed, the node that passed the token infers that its logical neighbor has left the network and immediately begins a search for a new logical neighbor by incrementing the node address of its logical neighbor and initiating a token pass. Network activity is again monitored and the incrementing process and resending of the token continues until a new logical neighbor is found. Once found, the network returns to the normal logical ring routine of passing tokens to logical neighbors.

With ARCNET, reconfiguration of the network is automatic and quick without any software intervention.

4.3.6. Unmatched Cabling Options

ARCNET is the most flexibly cabled network. It supports bus, star and distributed star topologies. In a bus topology, all nodes are connected to the same cable. The star topology requires a device called a hub (passive or active) which is used to concentrate the cables from each of the nodes. The distribute star (all nodes connect to an active hub with all hubs cascaded together) offers the greatest flexibility and allows the network to extend to greater than four miles (6.7 km) without the use of extended timeouts. Media support includes coaxial, twisted-pair and glass fiber optics.

4.3.7. Network Interface Modules

Each ARCNET node requires an ARCNET controller chip and a cable transceiver that usually reside on a network interface module (NIM). NIMs also contain bus interface logic compatible with the bus structure they support. These network adapters are removable and are, therefore termed "modules". ARCNET NIMs are available for all the popullar commercial bus structures. NIMs differ in terms of the ARCNET controller they incorporate and the cable transceiver supported.

4.3.8. ARCNET Controllers

The heart of any NIM is an ARCNET Controller chip that forms the basis of an ARCNET node. Datapoint Corporation Developed the original ARCNET node as a discrete electronics implementation. referring to it as a resource interface module or RIM. Standard Microsystems Corporation (SMSC) provided the first large-scale integration (LSI) implementation of the technology. Since then. other chip manufactures were granted licenses to produce RIM chips. Today. SMSC and its subsidiary Toyo Microsystems Corporation (TMC) provide the leadership in new ARCNET chip designs.

ARCNET Controllers

Model	Description
90C26	First generation controller
90C65	XT bus interface
90C98A	XT bus interface
90C126	XT bus interface
90C165	XT bus interface
90C66	AT bus interface
90C198	AT bus interface
20010	Microcontroller interface
20019	Microcontroller interface
20020	Microcontroller interface
20022	Microcontroller interface
20051	Integral microcontroller
20051+	Integral microcontroller

4.3.9. Use of Hubs

Hubs facilitate cabling by interconnecting multiple NIMs and, in most cases, they exercise no control over the network. The primary function of a hub is to provide a convenient method of expanding a network. There are two types of hubs that can perform this task—a passive hub or an active hub.

Passive Hubs : Passive hubs are inexpensive, require no power and their sole purpose is to match line impedances, which they do with resistors. These hubs usually have four ports to connect four coaxial star transceivers. One of the disadvantages of these hubs is that they limit the network to 200 feet and each segment of the network to 100 feet. Also, unused ports must be terminated with a 93 ohm resistor for proper operation. Passive hubs are used on small (four nodes or less) coaxial star networks.

Active Hubs : Active hubs are essentially electronic repeaters. Although they require power, active hubs support all cabling options, support longer distances than passive hubs, provide isolation and guard against cabling faults and reflections. These are the hubs which are used to cable distributed star networks.

Unused ports on an active hub need not be terminated. Unlike passive hubs, active hubs do not attenuate signals and can be cascade. A cable failure will affect only one port on an active hub. Active hubs are available as either internal or external devices. Internal hubs reside inside a computer that also has a NIM, while external hubs are stand-alone devices.

Active hubs can be configured as two port devices as well. A link is a two port device with differing cable options on each port allowing for the transitin of one medium type to another such as coaxial to fiber conversion. A repeater is a two-part device of the same cable option.

4.3.10. Advantages of ARCNET

Here are some of the ARCNET's advantages :

1. It is extremely reliable.
2. ARCNET is easy to install and troubleshoot.
3. It has an excellent track record of interoperability for those using ARCNET components from various manufactures.
4. ARCNET supports a variety of cable types including coaxial, UTP and Fiber Optics.
5. It is inexpensive and built to stay that way.

4.3.11. Disadvantages of ARCNET

Here are some disadvantages of ARCNET :

1. Standard ARCNet is very slow (2.5 Mb/s). It is almost seven times slower than Token Ring.
2. ARCNET was not designed with interconnectivity in mind. For many installations, it's difficult to go beyond the confines of single LAN.

4.3.12. ARCNET Applications

ARCNET is being used in a wide variety of embedded networking applications. Some examples of these applications are :

1. Industrial monitoring and control systems for a variety of industries including nuclear power plant systems.
2. Networking of switching systems used in pay telephone products.
3. Unconventional energy sources, such as these windmills, which need to provide uninterrupted service-even during thunderstorms.
4. Video graphics and character generator equipment used by television broadcasters, cable providers and post-production facilities.
5. Race track pari-mutuel wagering systems which print bet tickets, calculate odds, and process redemption of winning tickets.
6. Shipboard communications in US Navy vessels.
7. Factory automation systems, such as those used in welding controls.
8. Space travel simulation equipment used by NASA to train its astronauts.

9. Medical image networking, such as communications in X-ray equipment.
10. Communications in medical electronic equipment.
11. For people on the go, ARCNET is used in paging and messaging control systems.

4.4. Ethernet

Ethernet is a family of computer networking technologies for local area (LAN) and larger networks. It was commercially introduced in 1980 while it was first standardized in 1983 as IEEE 802.3, and has since been refined to support higher bit rates and longer link distances. Over time, Ethernet has largely replaced competing wired LAN technologies such as token ring, FDDI, and ARCNET. The primary alternative for contemporary LANs is not a wired standard, but instead a wireless LAN standardize as IEEE 802.11 and also known as Wi-Fi.

The Ethernet standards comprise several wiring and signaling variants of the OSI physical layer in use with ethernet. The original 10BASE5 Ethernet used coaxial cable as a shared medium. Later the coaxial cables were replaced with twisted pair and fiber optic links in conjunction with hubs or switches. Data rates have been incrementally increased from the original 3 megabits per second experimetal version to a 100 gigabits per second standard over its history.

Systems communicating over Ethernet divide a stream of data into shorter pieces called frames. Each frame contains source and destination addresses and error-checking data so that damaged data can be detected and re-transmitted. As per the OSI model, Ethernet provides services up to and including the data link layer.

Since its commercial release, Ethernet has retained a good degree of backward compatibility. Features such as the 48-bit MAC address and Ethernet frame format have influenced other networking protocols.

4.4.1. Standardization

In February 1980, the Institute of Electrical and Electronics Engineers (IEEE) Started Project 802 to standardize local area networks (LAN). The "DIX-group" with Gary Robinson (DEC), Phil Arst (Intel), and Bob Printis (Xerox) submitted the so-called "Blue Book" CSMA/CD specification as a candidate for the LAN specification. In addition to CSMA/CD, Token Ring (supported by IBM) and Token Bus (selected and henceforward supported by General Motors) were also considered as candidates for a LAN standard. Competing proposals and broad interest in the initiative led to strong disagrement over which technology to standardize. In December 1980, the group was split into three subgroups, and standardization proceeded separately for each proposal.

Delays is the standards process put at risk the market introduction of the Xerox Star workstation and 3 Com's Ethernet LAN products. With such business implications in mind, David Liddle (General Manager, Xerox Office Systems) and Metcalfe (3 Com) strongly supported a proposal of Fritz Roscheisen (Siemens Private Networks) for an alliance in the emerging office communication market, including Siemens' support for the international standardization of Ethernet (April 10, 1981), Ingrid Fromm, Siemens' representative to IEEE 802, quickly achieved broader support for Ethernet beyound IEEE by the establishment of a competing Task Group "Local Networks" within the European standards body ECMA TC24. As early as March 1982 ECMA TC24 with its corportae members reached agreement on a standard for CSMA/CD based on the IEEE 802 draft. Because the DIX proposal was most technically complete and because of the speedy action taken by ECMA which decisively contributed to the conciliation of opinions within IEEE, the IEEE 802.3 CSMA/CD standard was approved in December 1982. IEEE published the 802.3 standard as a draft in 1983 and as a standard in 1985.

Approval of Ethernet on the international level was achieved by a similar, cross-partisan action with Formm as liaison officer working to integrate International Electrotechnical Commission, TC83 and International Organization for Standardization (ISO) TC97SC6, and the ISO/IEEE 802/3 standard was approved in 1984.

4.4.2. Ethernet Technologies

In the OSI model, Ethernet technology operates at the physical and data link layers-Layers One and Two respectively. Ethernet supports all popular network and higher-level protocols, principally IP. **Traditional Ethernet** supports data transfers at the rate of 10 Megabits per second (Mbps). Over time, as the performance needs of LANs have increased the industry created additional Ethernet specifications for **Fast Ethernet** and **Gigabit Ethernet.** Fast Ethernet extends traditional Ethernet performance up to 100 Mbps and Gigabit Ethernet up to 1000 Mbps speeds.

Although products aren't yet abvailable to the average consumer, 10 Gigabit Ethernet (10000 Mbps) also remains an active area of research.

Ethernet cables likewise are manufactured to any of several standard specifications. The most popular Ethernet cable in current use, Category 5 or CAT5, supports both traditional and fast Ethernet. The Category 5e (CAT5e) cable supports Gigabit Ethernet.

To connect Ethernet cables to a computer, a person normally uses a network adapter, also known as a network interface card (NIC). Ethernet adapters interfaces directly with a computer's system bus. The cables, in turn, utilize connectors that in many cases look like the RJ-45 connector used with modern telephones.

4.4.3. Types of Ethernet

Often referred to as **Thicknet, 10 Base5** was the first incarnation of Ethernet technology. The industry used Thicknet in the 1980s until **10Base2 Thinnet** appeared. Compared to Thicknet, Thinnet offered the advantage of thinner (5 millimetres vs 10 millimetres) and more flexible cabling, making it easier to wire office buildings for Ethernet.

The most common form of traditional Ethernet, however, is **10Base-T**. 10Base-T offers better electrical properties than Thicknet or Thinnet, bacause 10Base-T cables utilize unshilded twisted pair (UTP) wiring rather than coaxial. 10Base-T also proved more cost effective than alternatives like fiber optic cabling.

The table below details these traditional Ethernet technologies. Besides the type of cable involved, another important aspect of Ethernet networking is the **segment length**. A segment is a network connection made by a single unbroken network cable. Ethernet cables and segments can only span a limited physical distance, after which transmissions will likely fail due to line noise, reduced signal strength and other degradation. Per the Ethernet specifications, manufacturers of Ethernet equipment must meet the below minimum specifications for segment length.

Name	Segment Length (Max.)	Cable
10Base5	500m/1640ft.	RG-8 or RG-11 coaxial
10Base2	185m/606ft.	RG 58 A/U or RG 58 C/U coaxial
10Base-T	100m/328ft.	Category 3 or better unshielded twisted pair

Numerous other lasser-known Ethernet standards exist, including 10Base-FL, 10Base-FB, and 10Base-FP for fiber optic networks and 10Broad36 for Broadband (cable television) cabling.

4.5. Fast Ethernet

In the mid-1990s, Fast Ethernet technology matured and met its design goals of (a) increasing the performance of traditional Ethernet while (b) avoiding the need to completely re-cable existing Ethernet networks. Fast Ethernet comes in two major varieties :

100Base-T (using unshielded twisted pair cable)

100Base-FX (using fiber optic cable)

By far the most popular of these is 100Base-T, a standard that includes 100Base-TX (Category 5 UTP), 100Base-T2 (Category 3 or better UTP), and 100Base-T4 (100Base-T2 cabling modified to include two additional wire pairs).

Gigabit Ethernet : Wheareas Fast Ethernet improved traditional Ethernet from 10 Megabit to 100 Megabit speed, Gigabit Ethernet boasts the same order-of-magnitude improvement over Fast Ethernet by offering speeds of 1000 Megabits (1 Gigabit). Gigabit Ethernet was first made to travel over optical and copper cabling, but the 1000Base-T standard successfully supports it as well. 1000Base-T uses Category 5 cabling similar to 100 Mbps Ethernet, although achieving gigabit speed requires the use of additional wire pairs.

Ethernet Topology, Protocol and Devices

Ethernet Topologies and Protocols : Traditional Ethernet employs a **bus** topology, meaning that all devices or **hosts** on the network use the same shared commnication line. Each device possesses an Ethernet address, also known as MAC address. Sending devices use Ethernet addresses to specify the intended recipient of messages.

Data sent over the Ethernet exists in the forms of **frames**. An Ethernet frame contains a header, a data section, and a footer having a combined length of no more than 1518 bytes. The Ethernet header contains the addresses of both the intended recipient and the sender.

Data sent over the Ethernet is automatically **broadcast** to all devices on the network. By comparing their Ethernet address against the address in the frame header, each Ethernet device tests each frame to determine if it was intended for them and reads or discards the frame as appropriate. Network adapters incorporate this function into their hardware.

Devices wanting to transmit on the Ethernet first perform a preliminary check to determine whether the medium is available or whether a transmission is currently in progress. If the Ethernet is available, the sending device transmits onto the wire. It's possible, however, that two devices will perform this test at approximately the same time and both transmit simultaneously.

By design, as a performance tradeoff, the Ethernet standard does not prevent multiple simultaneous transmission. These so-called **collisions**, when they occur, cause both transmissions to fail and require both sending devices to re-transmit. Ethernet uses an algorithm based on random delay times to determine the proper waiting period between re-transmissions. The network adapter also implements this algorithm.

In traditional Ethernet, this proctocol for broadcasting, listening and detecting collisions is known as **CSMA/CD** (Carrier Sense Multiple Access/Collision Detection). Some newer forms of Ethernet do not use CSMA/CD. Instead, they use the so-called **full duplex** Ethernet protocol, which supports point-to-point simultaneous sends and receives with no listening required.

Ethernet Devices

As mentioned earlier, Ethernet cables are limited in their reach, and these distances (as short as 100 metres) are insufficient to cover medium-sized and large network installations. A **repeater** in Ethernet networking is a device that allows multiple cables to be joined and greater distances to be spanned. A **bridge** device can join an Ethernet to another network of a different type, such as a wireless network.

One popular type of repeater device is an Ethernet hub. Other devices sometimes confused with hubs are switches and routers.

Ethernet network adapters also exist in multiple forms. Newer personal computers often include a built-in Ethernet adapter. Otherwise, one can purchase and install an add-in card. PCI cards are most popular for desktop computers and PCMCIA ("credit card") adapters are most popular for notebooks. USB Ethernet adapters also exist for both desktops and laptops. Wireless Ethernet adapters can also be configured to work with newer computers.

4.6. Introduction to Media Connectivity

By transmission media or communication channels of network, it is meant that the 'connecting cables' or 'connecting media' are being talked about. The cables that connect two or more workstations are the communication channels.

Transmission media refers to the mode of physical connection needed for data transmission. In LANs *(Local Area Networks)* many different types of media are in use. Copper conductors in the form of twisted pair or coaxial are by far the most common. More recently, very serious consideration has been given to the use of optical fiber technology in LANs. Other media *e.g.*, microwave transmission, infrared, telephone line etc. are also used. We can group the communication media in two categories : guided media and unguided media. The guided media include cables and unguided media include waves through air, water or vacuum.

There are several types of communication media. Some of the most common media are as follows :

4.6.1. Twisted Pair Cable

A twisted cable is the oldest and most common medium of transmission. It is generally used in telephone systems. A twisted pair consists of two insulated copper wires, typically 1 mm thick, twisted together just like a DNA molecule. The wire is twisted so as to reduce the electrical interference from and to the adjacent copper pairs. (The two conducting wires, which run parallel to each other, may cause electrical interference).

When many twisted pairs run in parallel over a long distance, they are bundled together and enclosed in a protective sheath, so as not to interfere with each other. Twisted pair is also used in a LAN (Local Area Network).

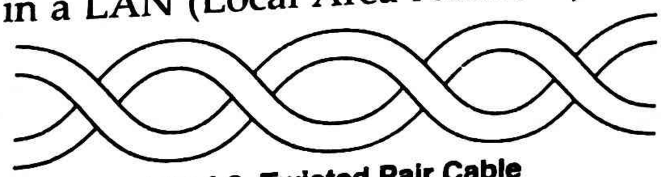

Fig 4.2. Twisted Pair Cable

Twisted pair wires are cheaper as a medium for data transmission, because they are easy to install and use. However, their use is limited because they easily pick up noisy signals which results in high error rates when the distance extends beyond 100 metres. They are of the following types :

(i) Type–1 : Two twisted pairs, each 22 gauge, shielded.

(ii) Type–2 : Four pairs of telephone type twisted pair wires with metallic shield plastic cover.

(iii) Type–3 : Telephone type cable with 24 gauge wire.

Advantages

- It can be used for analog as well as digital transmission.
- It is one of the cheapest media of transmission and has adequate performance.

Disadvantages

- It is more prone to pick up noise signals.
- A twisted pair can transmit data only upto a certain distance.

4.6.2. Coaxial Cable

Coaxial Cables are a group of specially wrapped and insulated wires capable of transmitting data at very high rate. They consist of a central copper wire (inner conductor) surrounded by a PVC (polyvinyl chloride) insulation over which a sleeve of copper mesh (second conductor) is covered as shown in the figure ahead :

The metal sleeve is again shielded by an outer shield of thick PVC material. The signal is transmitted by the inner copper wire and is electrically shielded by the outer metal sleeve. Coaxial cables are extensively used in long-distance telephone lines and in closed-circuit T.V.

Coaxial cables are capable of transmitting digital signals at very high rates or 10 mega Bits per second. In many cases, coaxial cables are packaged into a single large cable that can handle over 15000 approx. telephone calls simultaneously. They have a much higher noise immunity and can offer clear data transmission with less distortion or loss of signal power. But they are more expensive.

There are two types of coaxial cables : base band and broad band. A base band cable can transmit voice, data or video on a single channel at very high speed. With the help of time-division multiplexing, many users can share the channel. However, the distance over which the signals can be transmitted on a base band cable is rather limited to few hundred metres.

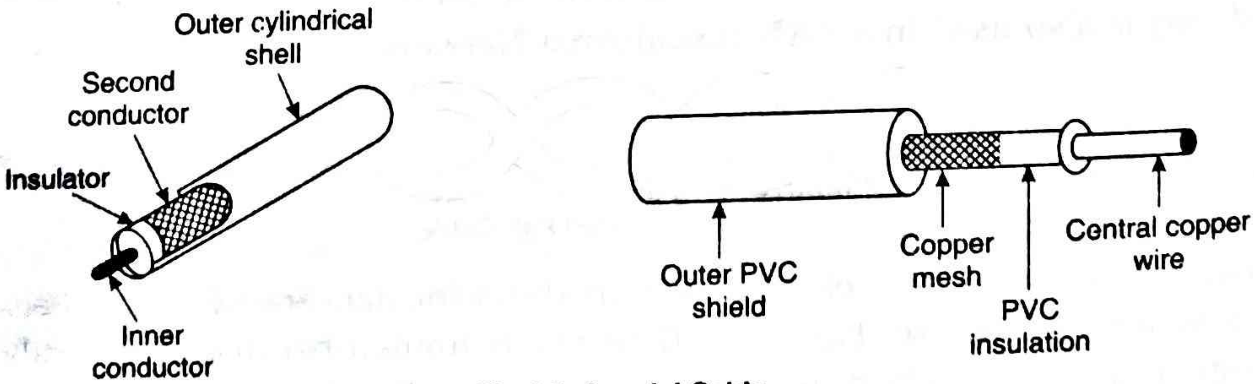

Fig 4.3. Coaxial Cable

On the other hand, broad band cable can carry multiple signals at a time. For instance in a TV network, as many as 50 to 100 channels are available in cities. Thus, it is complex in construction as compared to base band cable.

Advantages

- They are capable of transmitting digital signals at a very high rate of approximately 10 mega bits per second.
- They have higher noise immunity.

Disadvantages

- These are comparatively costly.
- Such cables can be easily tapped, posing security problems.

4.6.3. Optical Fibre

An optical fibre is a piece of hair-thin glass material of a different refractive index. Such a fibre is capable of transmitting data at the speed of light with no significant loss of intensity over long distances.

Fibre-optic links are based on the principle of 'total internal reflection'. When an electromagnetic wave, travailing in a medium with high refractive index, falls on the boundary of the surrounding medium of lower refractive index, a special phenomenon takes place. Up to a certain angle of incidence, light passes through the boundary and enters the medium that has a lower refractive index. But if the angle of incidence is more than the 'critical angle' the light is reflected from the boundary and comes back to the first medium. This is called '*total internal reflection*'.

An optical transmission system based on fibre-optics has three components, the transmission medium, the light source and the detector. The transmission medium is the ultra-thin glass fibre. The light source is either an LED (light emitting diode) or a laser diode which emits light pulses when electric current is applied. The detector is a photo diode which generates electric pulses when light falls on it.

By attaching the LED or the laser diode to one end of an optical fibre and a photo diode at the other end, we can have uni-directional data transmission system that accepts an electrical signal, converts and transmits it by light pulses and then reconverts the output to an electrical signal at the receiving end.

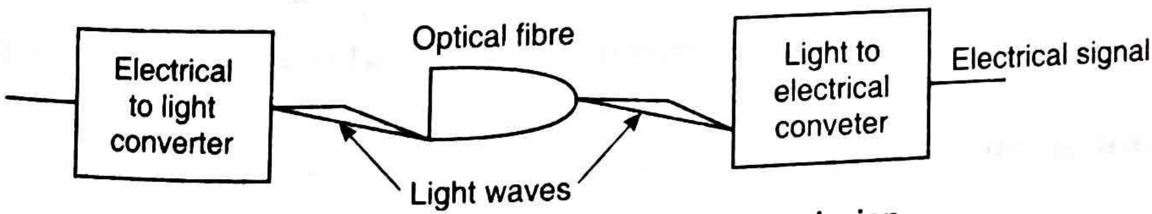

Fig 4.4. Principle of optical fibre transmission

Optical fiber has the capacity to carry voice, video and data at extremely high speed in the range of several million bits per second. It offers low bit error rates, zero electrical interference and complete electrical isolation. The isolation from electrical currents is the major advantage of optical fiber systems. The disadvantage of optical fiber is that a limited number of direct connections can be made to a given length of the cable.

In case of optical fiber, it is not possible to have branch lines by taping off a fiber which is an added advantages as far as data security is concerned.

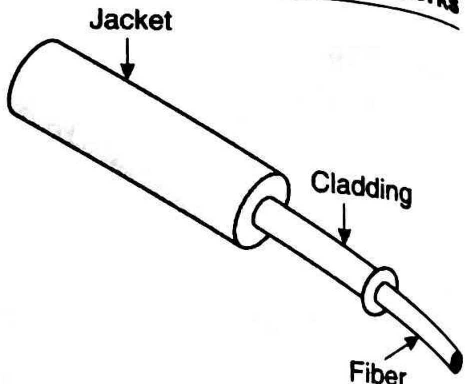

Fig 4.5. Optical Fiber Cable

Advantages

- It has very high rate of transmission of data.
- It has better noise immunity.
- It can transmit data over long distances.
- Data is transmitted with high security.
- The fibres are small in size.

Disadvantages

- Limited physical arc of cable. Bend it too much and it will break!
- Difficult to splice.

The cost of optical fibre is a trade-off between capacity and cost. At higher transmission capacity, it is cheaper than copper. At lower transmission capacity, it is more expensive.

4.6.4. Microwave Communication

Microwave radiation is also a popular medium of transmission. It does not require the laying of expensive cables. Microwave links use very high frequency radio waves to transmit data through space. Microwave links use repeaters at intervals of about 25 to 30 km in between the transmitting and receiving stations.

Parabolic antennas are mounted on towers to send a beam to another antenna, which could be tens of kilometres away, but should be in line of sight. The higher the tower the greater is the range. Microwave radio transmission is widely used for long-distance communication. It overcomes the problem of weak signals.

Microwave transmission is a line-of-sight method of communication. It has become widely used for broadband communications and telephone service. Even private microwave service is especially useful for organizations that need to link a number of locations within a limited area.

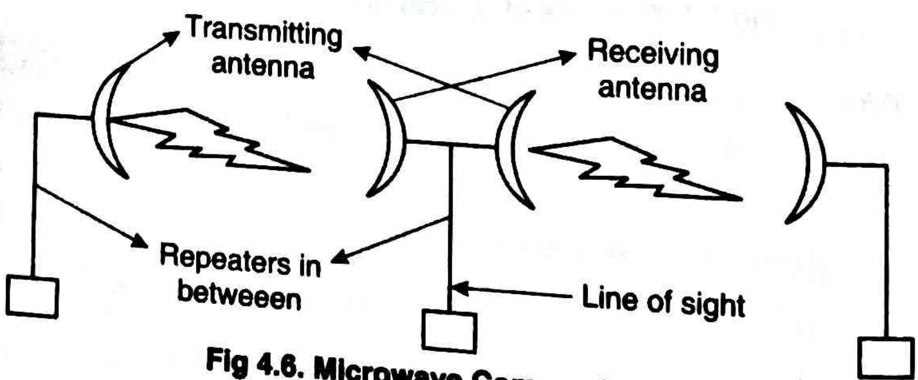

Fig 4.6. Microwave Communication

Although private microwave service can provide dedicated communication at moderate cost, there are limitations to its use. For example, microwave channels are generally assigned by the Federal Governments, and in some cities few channels remain open. Unlike telephone wires and commercial radio signals, microwave transmission is line-of-sight. The transmission range is limited to about 25 to 30 kilometres, after which the microwaves must be relayed.

Microwave communication is used when it is not possible to communicate through ground methods due to the following two main reasons :

(i) Due to fading of signal : that can not be amplified without noise.

(ii) Rugged terrain such as desert, sea, hills etc.

Advantages

- Building two towers is cheaper than digging a 100-km trench and laying cables in it.
- It can permit transmission rates of about 16 giga bits (1 giga bit $=10^9$ bits) per second.

Disadvantages

- Repeaters, if used along the way, are to be maintained regularly.
- Physical vibration will show up as signal noise!

4.6.5. Radio Transmission or Radio Frequency (RF) Transmission

This method of cableless communication uses some specific radio frequencies for direct data or voice communication. In some countries such as USA, the Federal Communications Commission has allocated certain radio frequencies for use by private businesses for direct voice communications.

Private citizens and business users may be licensed to operate either a class A or D radio station, with a mobile or fixed location. Users of class A stations, such as delivery vehicles or taxicabs operate only on a single, assigned frequency. Whereas class D station users operate on any of the 40 designated frequencies on a shared basis. Sometimes it is called Citizens Band (CB) radio. Radio transmission is extremely useful for customer services like courier, home deliveries, on site repair and maintenance etc.

Data transmission through air (and not through any channel) is called unguided transmission. Data is carried over electro-magnetic radiation in the form of radio waves. Such propagation is classified by the type of wave used for propagation. There are three types of RF (radio frequency) propagation :

1. Ground wave
2. Ionospheric
3. Line of Sight (LOS)

1. Ground Wave Propagation

Ground wave propagation follows the curvature of the Earth. Ground waves have carrier frequencies up to 2 MHz. The AM radio is an example of ground wave propagation.

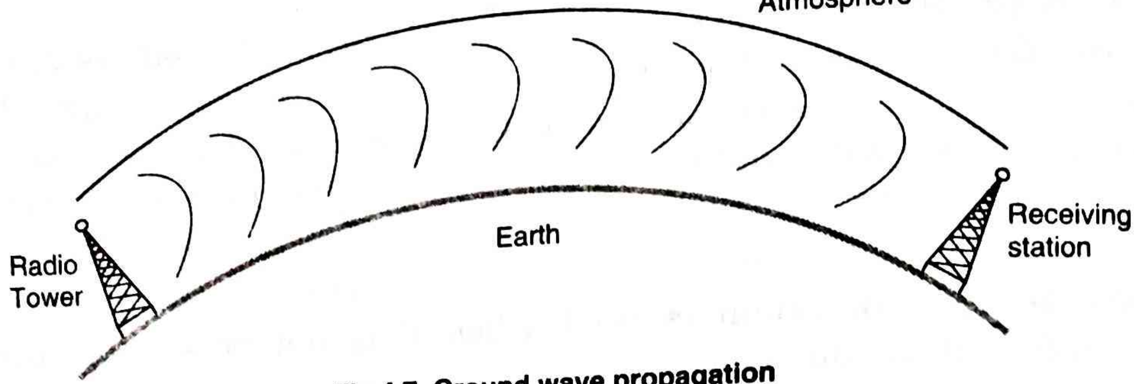

Fig 4.7. Ground wave propagation

2. Ionospheric Propagation

Ionospheric propagation bounces off of the Earth's ionospheric layer in the upper atmosphere. It is sometimes called double hop propagation. It operates in the frequency range of 30-85 MHz. Because it depends on the Earth's ionosphere, it changes with the weather and the time of day. The signal sent from a radio tower bounces off the ionosphere and comes back to earth to a receiving station, as shown in the figure.

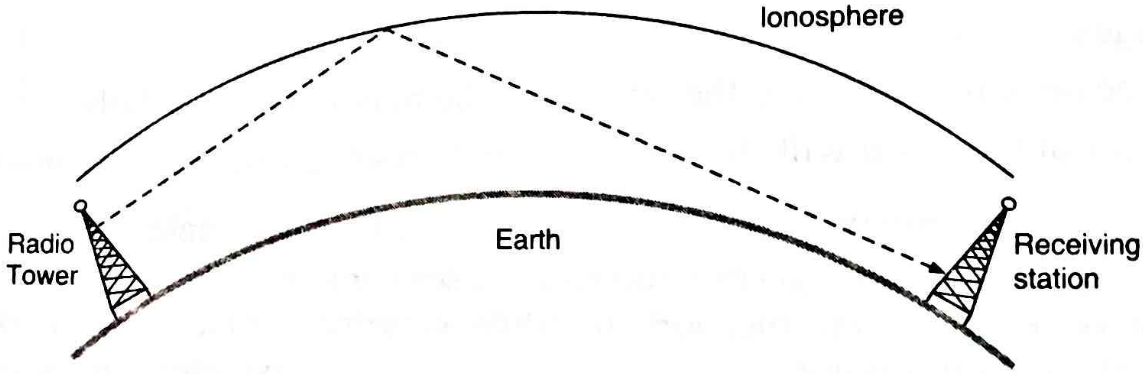

Fig 4.8. Ionospheric propagation

3. Line of Sight Propagation

Line of sight propagation transmits exactly in the line of sight. The receiving station must be in the view of the transmit station. It sometimes called *space wave* or *tropospheric propagation*. It is limited by the curvature of the Earth for ground-based stations (100 km, from horizon to horizon). Reflected waves can cause problems. Examples of line of sight propagation are FM radio, and satellite microwave.

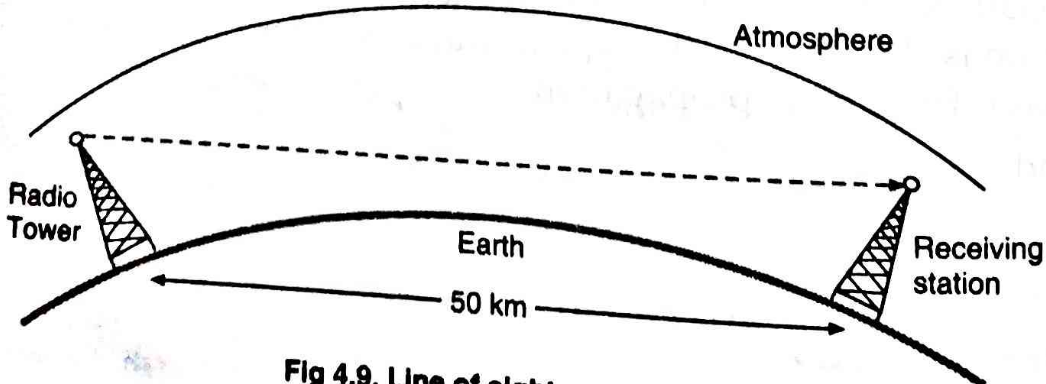

Fig 4.9. Line of sight propagation

Radio Frequencies

The three types of radio frequency propagation employ different radio frequencies. These frequencies are detailed in the following table.

The frequency spectrum operates from 0 Hz to 1019 Hz. Radio frequencies are in the range of 300 kHz to 10 GHz.

Name	Frequency (Hertz)	Examples
Gamma Rays	10^{19}	Used in medicine, industry, consumer goods and science.
X-Rays	10^{17}	Used in both medicine and industry for microscopy or micro radiography.
Ultra-Violet Light	7.5×10^{15}	For medical treatment of skin and sterilization.
Visible Light	4.3×10^{14}	Development of the source of coherent light, the laser.
Infra-red Light	3×10^{11}	Infra-red astronomy, thermo-graphy and other medical applications.
EHF–Extremely High	30 GHz (Giga $= 10^9$ Hz)	Radar Frequencies
SHF–Super High	3 GHz	Satellite and Microwaves Frequencies
UHF–Ultra High Frequencies	300 MHz (Mega $= 10^6$ Hz)	UHF TV
VHF–Very High Frequencies	30 MHz	FM and TV
HF–High Frequencies	3 MHz	Short Wave Radio
MF–Medium Frequencies	300 kHz (kilo $= 10^3$)	AM Radio
LF–Low Frequencies	30 kHz	Navigation
VLF–Very Low Frequencies	3 kHz	Submarine Communications
VF–Voice Frequencies	300 Hz	Audio
ELF–Extremely Low Frequencies	30 Hz	Power Transmission

The disadvantage of radio transmission is lack of security. Therefore, it is not suitable for transfer of large files or data bases because it has very low transmission speed.

Now-a-days one can see an emerging technology called wireless LANs. Radio frequencies can be used to connect workstations together in a wireless LAN. Some wireless LANs use infrared technology.

4.6.6. Infrared Transmission

Like microwave transmission, infrared transmission also discards wiring altogether. There are point-to-point infrared links that are used to replace cables between adjacent buildings.

In this mode of transmission a highly intensity modulated infrared beam is bounced off the ceiling of an organization which scatters around the room. It can be only received by a data communicating device using a simple solid-state detector. This device can also bounce its own data against the ceiling through a solid state infrared emitter and broadcast it to all other devices in the organization.

Infrared transmission is optical in nature, carried by beams of light invisible to the naked eye. It provides a compact and inexpensive means of line-of-sight, narrowband transmission among and between building within the same general area, for it is limited to distances of a few hundred feet. Though unaffected by most artificial light and weather conditions, very heavy snow or fog degrades its quality. The main advantage of this transmission is that the data communicating devices do not require exact positioning. However, the infrared signals are highly susceptible to high intensity light and the data can be overheard by the neighbours also. It is moderately secure.

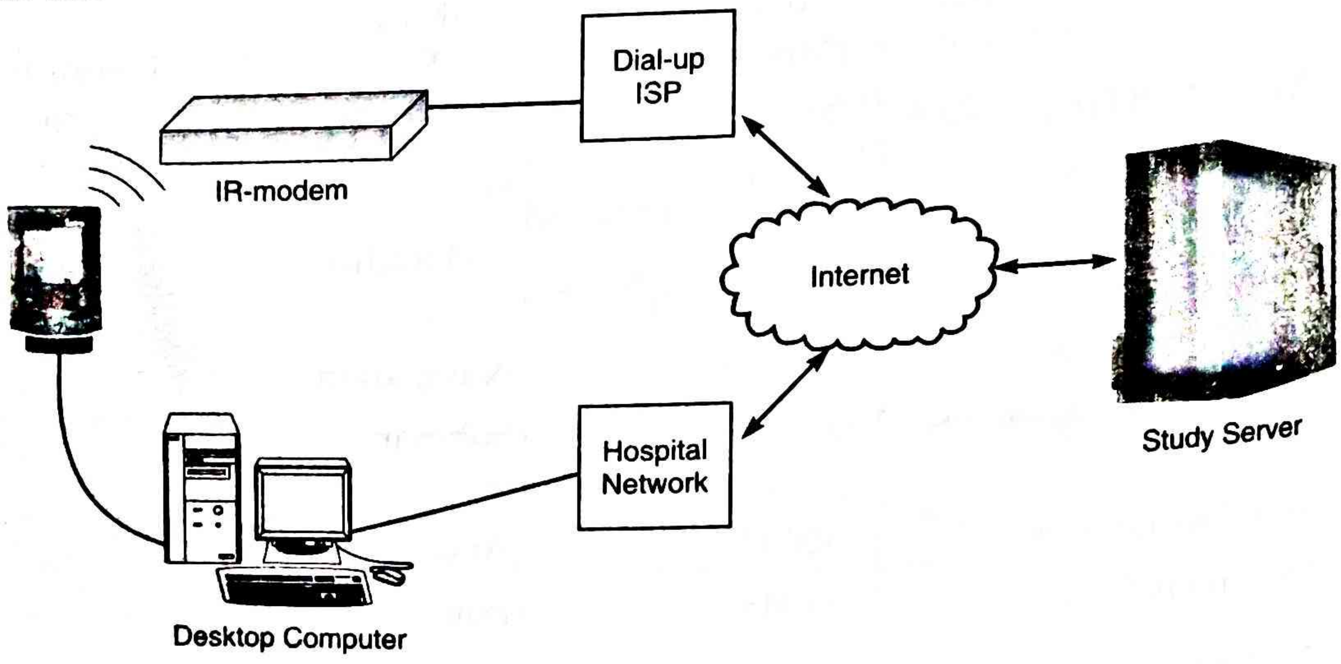

Fig 4.10. Infrared Transmission

4.6.7. Satellite

The problem with microwave communications is of line of sight. Because of the curvature of earth, mountains and the other high structures often block the line of sight. So you require several repeater stations for long-distance transmission, which increases the cost of data transmission. This problem is overcome by using satellites.

A communication satellite is an electrical device positioned in an orbit around the earth. It can be thought of a big microwave repeater in the sky. It contains one or more 'transponders,' each of which listens to some portion of the frequency spectrum, amplifies the incoming signal and then rebroadcasts it at another frequency. Different frequencies are used for 'uplinking' and 'downlinking' to avoid any interference of signals. Uplink refers to data flow from the earth to the satellite. Here the earth station works as a transmitter and the satellite transponder as a receiver. Downlink refers to data flow from the satellite to the earth. Here the satellite works as a transmitter and the earth station as a receiver.

A number of communication satellites, owned by both governments and private organizations, have been placed in stationary orbits about 22,300 miles above the earth's surface. These satellites act as relay stations for communication signals. The satellites accept data/signals transmitted from an earth station, amplifies them, and retransmits them to another earth station.

Some communications satellites have multiple, independent reception and transmission devices known as transponders. But in a commercial communication satellite, a single transponder is capable of handling complete task alongwith several different types of data/signals. Do you know, firms that market Satellite communications service own a satellite and others lease a portion of a satellite and provide transmission facilities in smaller units to their users.

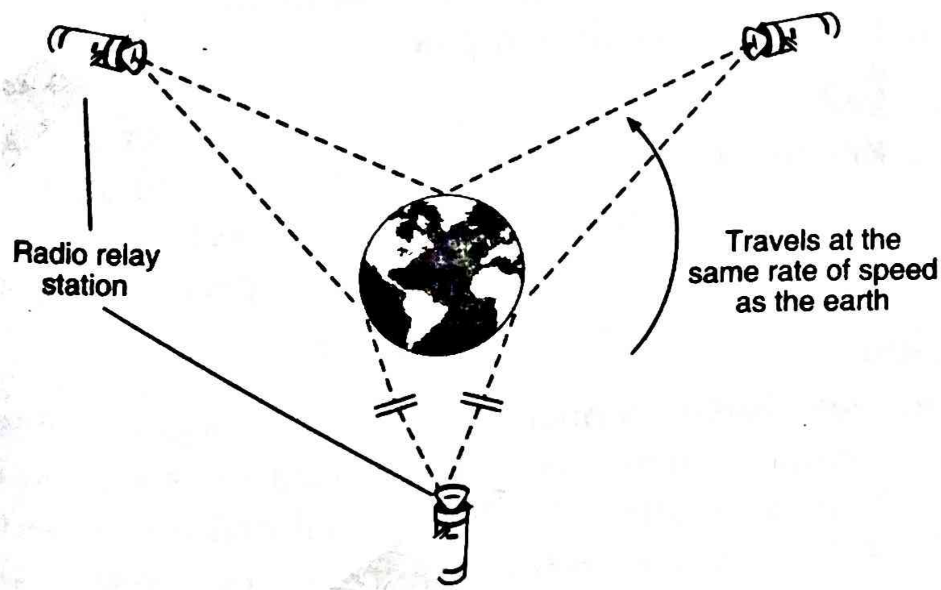

Fig 4.11. Satellite Communication

Now-a-days earth station with very small diameters around 40 cm are becoming popular. These earth station are called as very small aperture terminals (VSATs). These terminals are so inexpensive that even small organisation can afford them. Even in India, IITs, Technical Universities and engineering colleges are having VSAT installations under All India Council of Technical Education (AICTE) programme.

Several factors limit the use of satellite communications. Some communication satellites are placed in geosynchronous orbit above the equator, which means that their orbital speed is synchronized to keep them over the same point on the earth at all times. A satellite, then, is also a line-of-sight means of transmission. There may be signal delay caused by the extreme length of the transmission path between sender and receiver. This can cause an echo that is annoying to some individuals using voice communications.

Security is usually provided by the user through coding and decoding equipments.

The transmission speed of various discussed transmission modes is given below:

	Transmission Mode	Transmission Speed
1.	Twisted pair	100 mbps
2.	Coaxial cable	140 mbps
3.	Fiber optics	2 Gbps
4.	Microwave	275 mbps
5.	Radio	2 mbps
6.	Infrared	275 mbps
7.	Satellite	275 mbps.

Advantages

- There is no line of sight restriction, so, transmission and reception is possible between any two randomly chosen places.

Disadvantages

- Launching a satellite into an orbit costs a lot.

A signal sent to a satellite is broadcasted to all receivers within the satellite's range. So, measures are required to prevent unauthorized tampering of information.

4.7. Leased Line

A permanent telephone connection between two points set up by a telecommunications common carrier. Typically, leased lines are used by businesses to connect geographically distant offices. Unlike normal dial-up connections, a leased line is always active. The fee for the connection is a fixed monthly rate. The primary factors affecting the monthly fee are distance between end points and the speed of the circuit.

Because the connection doesn't carry anybody else's communications, the carrier can assure a given level of quality.

A leased line is a service contract between a provider and a customer, whereby the provider agrees to deliver a symmetric telecommunications line connecting two or more locations in exchange for a monthly rent (hence the term lease). It is sometimes known as a "private circuit" or "data line". Unlike traditional PSTN lines it does not have a telephone number, each side of the line being permanently connected to the other. Leased lines can be used for telephone, data or Internet services. Some are ringdown services, and some connect to PBXes. Typically, leased lines are used by businesses to connect geographically distant offices. Unlike dial up connections, a leased line is always active. The fee for the connection is a fixed monthly rate. The primary factors affecting the monthly fee are distance between end points and the speed of the circuit. Because the connection does not carry anybody else 's communications, the carrier can assure a given level of quality.

An Internet leased line is a premium internet connectivity product, delivered over fiber normally, which is dedicated and provides uncontended, symmetrical speeds, full-duplex. It is also known as an ethernet leased line, DIA line, data circuit or private circuit.

For example, a T-1 channel can be leased, and provides a maximum transmission speed of 1.544 Mbit/s. The user can divide the connection into different lines for multiplexing data and voice communication, or use the channel for one data circuit. Leased lines, as opposed to DSL, are being used by companies and individuals for internet acces because they afford faster data transfer rates and are cost-effective for heavy users of the Internet.

4.7.1. Application of Leased Line

Leased lines are used to build up private networks, private telephone networks (by interconnecting PBXs) or access the internet or a partner network (extranet).

Here is a review of the leased line application in Network designs over time :

Site to Site Data Connectivity

Terminating a leased line with two routers can extend network capabilities across sites. Leased lines were fires used in the 1970s by enterprise with proprietary protocols such as IBM System Network Architecture and Digital Equipment DECnet, and with TCP/IP in University and Research networks before the Internet became widely available. Note that other Layer 3 protocols were used such as Novell IPX on enterprise networks until TCP/IP became ubiquitous in the 2000s. Today, point to point data circuits are typically provisioned as either TDM, Ethernet, or Layer 3 MPLS.

Site to Site PBX Connectivity

Terminating a leased line with two PBX allowed customers to by-pass PSTN for inter-site telephony. This allowed the customers to manage their own dial plan (and to use short extensions for internal telephone number) as well as to make significant savings if enough voice traffic was carried across the line (specially when the savings on the telephone bill exceded the fixed cost of the leased line).

Site to Network Connectivity

As demand grew on data network telcos started to build more advanced network using packet switching on top of their infrastructure. Thus number of telecommunication companies added ATM, Frame-relay or ISDN offerings to their services portfolio. Leased lines were used to connect the customer site to the telco network access point.

International Private Leased Circuit

An international prived leased circuit (IPLC) functions as a point-to-point private line. IPLCs are usually time-division multiplexing (TDM) circuits that utilize the same circuit amongst many customers. The nature or TDM requires the use of a CSU/DSU and a router. Usually the router will include the CSU/DSU.

Then came the Internet (in the mid-1990s) and since the most common application for leased line is to connect a customer to its ISP point of presence . With the changes that Internet brought in the networking world other technologies were developed to propose alternative to frame-relay or ATM networks such as VPNs (hardware and software) and MPLS networks (that are in effect an upgrade to TCP/IP of existing ATM/frame-relay infrastructures).

Leased Line Alternatives

Leased lines are more expensive than alternative connectivity services including (ADSL, SDSL, etc.) because they are reserved exclusively to the leaseholder. Some internet service providers have therefore developed alternative products that aim to deliver leased-line type services (Carrier Ethernet-based, zero contention, guaranteed availability), with more moderate bandwidth, over the standard UK national broadband network. While a leased line is full-duplex, most leased line alternatives provide only half-duplex or in many cases asymmetrical service.

4.8. ISDN

ISDN (Integrated Services Digital Network) is a set of CCITT/ITU standards for digital transmission over ordinary telephone copper wire as well as over other media. Home and business users who install an ISDN adapter (in place of a telephone modem) receive web pages at up to 128 Kbps compared with the maximum 56 Kbps rate of a modem connection. ISDN requires adapters at both ends of the transmission so your access provider also needs an IDSDN adapter. ISDN is generally available from your phone company in most urban areas in the United States and Europe. In many areas where DSL and cable modem service are now offered, IDSN is no longer as popular an option as it was formerly.

There are two levels of service; the Basic Rate Interface (BRI), intended for the home and small enterprise, and the Primary Rate Interface (PRI), for larger users. Both rates include a number of B-channels and a D-channels. Each B-channel carries data, voice, and other services. Each D-channel carries control and signaling information.

The Basic Rate Interface consists of two 64 Kbps B-channels and one 16 Kbps D-channel. Thus, a Basic Rate user can have up to 128 Kbps service. The Primary Rate consists of 23 B-channels and one 64 Kpbs D-channel in the United States or 30 B-channels and 1 D-channel in Europe.

ISDN is concept is the integration of both analog or voice data together with digital data over the same network. Although the ISDN you can install is integrating these on a medium designed for analog transmission, broadband ISDN (BISDN) is intended to extend the integration of both services throughout the rest of the end-to-end path using fiber optic and radio media. Broadband ISDN encompasses frame relay service for high-speed data that can be sent in large bursts, the Fiber Distributed-Data Interface (FDDI), and the Synchronous Optical Network (SONET). BISDN is intended to support transmission from 2 Mbps up to much higher, but as yet unspecified, rates.

4.8.1. ISDN Elements

Integrated services refers to ISDN's ability to deliver at minimum two simultaneous connections, in any combination of data, voice, video, and fax, over a single line. Multiple devices can be attached to the line, and used as needed. That means an ISDN line can take care of most people's complete communications needs (apart from broadband Internet access and entertainment television) at a much higher transmission rate, without forcing the purchase of multiple analog phone lines. It also refers to integrated switching and transmission in that telephone swithing and carrier wave transmission are integrated rather than separate as in earlier technology.

Basic Rate Interface

The entry level interface to ISDN in the Basic (s) Rate Interface (BRI), a 128 kbit/s service delivered over a pair of standard telephone copper wires. The 144 kbit/s payload rate is broken down into two 64 kbit/s bearer channels ('B' channels) and one 16 kbit/s signaling channel ('D' channel or data channel). This is sometimes referred to as 2B+D.

The interface specifies the following network interfaces :

- The U Interface is a two-wire interface between the exchange and a network terminating unit, which is usually the demarcation point in non-North American networks.
- The T Interface is a serial interface between a computing device and a **terminal adapter**, which is the digital equivalent of a modem.
- The S interface is a four-wire bus that ISDN consumer devices plug into ; the S & T reference points are commonly implemented as a single interface labeled 'S/T' on an **Network termination 1** (NT1).

- The **R interface** defines the point between a non-ISDN device and a terminal adapter (TA) which provides translation to and from such a device.

BRI-ISDN is very popular in Europe but is much less common in North America. It is also common in Japan-Where it is known as INS64.

Primary Rate Interface

The other ISDN access available is the Primary Rate Interface (PRI), which is carried over an **E1** (2048 kbit/s) in most parts of the world. An E1 is 30 'B' channels of 64 kbit/s, one 'D' channel of 64 kbit/s and a timing and alarm channel of 64 kbit/s.

In North America PRI service is delivered on one or more **T1 carriers** (often referred to as 23B+D) of 1544 kbit/s (24 channels). A PRI has 23 'B' channels and 1 'D' channel for signalling (Japan uses a circuit called a J1, which is similar to a T1). Inter-changeably but incorrectly, a PRI is referred to as T1 because it uses the T1 carrier format. A true T1 (commonly called "Analog T1' to avoid confusion) uses 24 channels of 64 kbit/s of **in-band signaling.** Each channel uses 56 kb for data and voice and 8 kb for signaling and messaging. PRI uses out of band signaling which provides the 23 B channels with clear 64 kb for voice and data and one 64 kb 'D' channel for signaling and messaging. In North America, **Non-Facility Associated Signalling** allows two or more PRIs to be controlled by a single **D channel,** and is sometimes called "23B+D + n*24B". D-channel backup allows for a second D channel in case the primary fails. NFAS is commonly used on a **T3.**

PRI-ISDN is popular throughout the world, especially for connecting **PBXs** to **PSTN.**

While the North American PSTN can use PRI or Analog T1 format from PBX to PBX, the POTS of BRI can be delivered to a business or residence. North American PSTN can connect from PBX to PBX via Analog T1, T3, PRI, OC3, etc ...

Even though many network professionals use the term "ISDN" to refer to the lower-bandwidth BRI circuit, in North America BRI is relatively uncommon whilst PRI circuits serving PBXs are common place.

4.9. PSTN

PSTN (public switched telephone network) is the world's collection of interconnected voice-oriented public telephone networks, both commercial and government-owned. It's also referred to as the Plain Old Telephone Service (POTS). It's the aggregation of circuit-swithcing telephone networks that has evolved from the days of Alexander Graham Bell ("Doctor Watson, come here!"). Today, it is almost entirely digital in technology except for the final link from the central (local) telephone office to the user.

In relation to the Internet, the PSTN actually furnishes much of the Internet's long-distance infrastructure. Because Internet service providers ISPs pay the long-distance providers for access to their infrastructure and share the circuits among many users through packet-switching, Internet users avoid having to pay usage tolls to anyone other than their ISPs.

4.10. DSL Technology

Telephones are connected to the telephone exchange via a local loop, which is a physical pair of wires. Prior to the digital age, the use of the local loop for anything other than the transmission of speech, encompassing an audio frequency range of 300 to 3400 Hertz (voiceband or commercial bandwidth) was not considered. However, as long distance trunks were gradually converted from analog to digital operation, the idea of being able to pass data through the local loop (by utilizing frequencies above the voice band) took hold, ultimately leading to DSL.

For a long time it was thought that it was not possible to operate a conventional phoneline beyond low-speed limits (typically under 9600 bit/s). In the 1950s, ordinary twisted-pair telephone-cable often carried four megahertz (MHz) television signals between studios, suggesting that such lines would allow transmitting many megabits per second. One such circuit in the UK ran some ten miles (16 km) between the BBC studios in Newcastle-upon-Tyne and the Pontop Pike transmitting station. It was able to give the studios a low quality cue feed but not one suitable for transmission. However, these cables had other impairments besides Gaussian noise, preventing such rates from becoming practical in the field. The 1980s saw the development of techniques for broadband communications that allowed the limit to be greatly extended.

The local loop connecting the telephone exchange to most subscribers has the capability of carrying frequencies well beyond the 3·4 kHz upper limit of POTS. Depending on the length and quality of the loop, the upper limit can be tens of megahertz. DSL takes advantage of this unused bandwidth of the local loop by creating 4312·5 Hz wide channels starting between 10 and 100 kHz, depending on how the system is configured. Allocation of channels continues at higher and higher frequencies (up to 1·1 MHz for ADSL) until new channels are deemed unusable. Each channel is evaluated for usability in much the same way an analog modem would on a POTS connection. More usable channels equates to more available bandwidth, which is why distance and line quality are a factor (the higher frequencies used by DSL travel only short distances). The pool of usable channels is then split into two different frequency bands for upstream and downstream traffic, based on a preconfigured ratio. This segregation reduces interference. Once the channel groups have been established, the individual channels are bonded into a pair of virtual circuits, one in each direction. Like analog modems, DSL transceivers constantly monitor the quality of each channel and will add or remove them from service depending on whether they are usable.

Joseph W. Lechleider's contribution to DSL was his insight that an asymmetric arrangement offered more than double the bandwidth capacity of symmetric DSL. This allowed Internet Service Providers to offer efficient service to consumers, who benefited greatly from the ability to download large amounts of data but rarely needed to upload comparable amounts. ADSL supports two modes of transport; fast channel and interleaved channel. Fast channel is preferred for streaming multimedia, where an occasional dropped bit is acceptable, but lags are less so. Interleaved channel works better for file transfers, where the delivered data must be error free but latency (time delay) incurred by the retransmission of error containing packets is acceptable.

Because DSL operates above the 3·4 kHz voice limit, it cannot pass through a load coil. Load coils are, in essence, filters that block out any non-voice frequency. They are commonly set at regular intervals in lines placed only for POTS service. A DSL signal cannot pass through a properly installed and working load coil, while voice service cannot be maintained past a certain distance without such coils. Therefore, some areas that are within range for DSL service are disqualified from eligibility because of load coil placement. Because of this, phone companies endeavor to remove load coils on copper loops that can operate without them and by conditioning other lines to avoid them through the use of fiber to the neighbourhood or node (FTTN).

The commercial success of DSL and similar technologies largely reflects the advances made in electronics over the decades that have increased performance and reduced costs even while digging trenches in the ground for new cables (copper or fiber optic) remains expensive. Several factors contributed to the popularity of DSL technology :

- Until the late 1990s, the cost of digital signal processors for DSL was prohibitive. All types of DSL employ highly complex digital signal processing algorithms to overcome the inherent limitations of the existing twisted pair wires. Due to the advancements of Very-large-scale integration (VLSI) technology, the cost of the equipment associated with a DSL deployment lowered significantly. The two main pieces of equipment are a Digital subscriber line access multiplexer (DSLAM) at one end and a DSL modem at the other end.
- A DSL connections can be deployed over existing cable. Such deployment, even including equipment, is much cheaper than installing a new, high-bandwidth fiber-optic cable over the same route and distance. This is true both for ADSL and SDSL variations.
- In the case of ADSL, competition in Internet access caused subscription fees to drop significantly over the years, thus making ADSL more economical than dial up access. Telephone companies were pressured into moving to ADSL largely due to competition from cable companies, which use DOCSIS cable modem

technology to achieve similar speeds. Demand for high bandwidth applications, such as video and file sharing, also contributed to popularize ADSL technology.

Most residential and small-office DSL implementations reserve low frequencies for POTS service, so that (with suitable filters and/or splitters) the existing voice service continues to operate independent of the DSL service. Thus POTS-based communications, including fax machines and analog modems, can share the wires with DSL. Only one DSL modem can use the subscriber line at a time. The standard way to let multiple computers share a DSL connection uses a router that establishes a connection between the DSL modem and a local Ethernet, Powerline or Wi-Fi network on the customer's premises.

Once upstream and downstream channels are established, a subscriber can connect to a service such as an Internet service provider.

4.10.1. Protocols and Configurations

Many DSL technologies implement an Asynchronous Transfer Mode (ATM) layer over the low-level bitstream layer to enable the adaptation of a number of different technologies over the same link.

DSL implementations may create bridged or routed networks. In a bridged configuration, the group of subscriber computers effectively connect into a single subnet. The earlieast implementations used DHCP to provide network details such as the IP address to the subscriber equipment, with authentication via MAC address or an assigned host name. Later implementations often use Point-to-Point Protocol (PPP) or Asynchronous Transfer Mode (ATM) (Point-to-Point Protocol over Ethernet (PPPoE) or Point-to-Point Protocol over ATM (PPPoA)), while authenticating with a userid and password and using Point-to-Point Protocol (PPP) mechanisms to provide network details.

4.10.2. Other Important xDSL Technologies

The line-length limitations from telephone exchange to subscriber impose more restrictions on higher data-transmission rates. Technologies such as VDSL provide very high-speed, short-range links as a method of delivering "triple play" services (typically implemented in fiber to the curb network architectures). Technologies like GDSL can further increase the data rate of DSL. Fiber optic technologies exist today that allow the conversion of copper based IDSDN, ADSL and DSL over fiber optics.

DSL Technologies (sometimes summarized as xDSL) Include :

Symmetric digital subscriber line (SDSL), umbrella term for xDSL where the bitrate is equal in both directions.

- ISDN digital subscriber line (IDSL), ISDN based technology that provides a bitrate equivalent to two ISDN bearer and one data channel, 144 kbit/s symmetric over one pair.

- High bit rate digital subscriber line (HDSL), ITU-T G.991.1, the first DSL technology that used a higher frequency spectrum than ISDN 1,544 kbit/s and 2,048 kbit/s symmetric services, either on 2 or 3 pairs at 784 kbit/s each, 2 pairs at 1,168 kbit/s each, or one pair at 2320 kbit/s.
- High bit rate digital subscriber line 2/4 (HDSL2, HDSL4), ANSI, 1,544 kbit/s symmetric over one pair (HDSL2) or two pairs (HDSL4).
- Symmetric digital subscriber line (SDSL), specific proprietary technology, up to 1,544 kbit/s symmetric over one pair.
- Single-pair high-speed digital subscriber line (G.SHDSL), ITU-T G.991.2, standardized successor of HDSL and proprietary SDSL, up to 5,696 kbit/s per pair, up to four pairs.

Asymmetric digital subscriber line (ADSL), umbrella term for xDSL where the bitrate is greater in one direction than the other.

- ANSI T1·413 Issue 2, up to 8 Mbit/s and 1 Mbit/s.
- G.dmt, ITU-T G.992.1, up to 10 Mbit/s and 1 Mbit/s
- G.lite, ITU-T G. 992.2, more noise and attenuation resistant than G.dmt, up to 1,536 kbit/s and 512 kbit/s.
- Asymmetric digital subscriber line 2 (ADSL2), ITU-T G.992.3, up to 12 Mbit/s and 3.5 Mbit/s.
- Asymmetric digital subscriber line 2 plus (ADSL2+), ITU-T G.992.5, up to 24 Mbit/s and 3.5 Mbit/s.
- Very-high-bit-rate digital subscriber line (VDSL), ITU-T G.993.1, up to 52 Mbit/s and 16 Mbit/s.
- Very-high-bit-rate digital subscriber line 2 (VDSL2), ITU-T G.993.2, an improved version of VDSL, compatible with ADSL2+, sum of both directions up to 200 Mbit/s.G.vector crosstalk cancelling feature (ITU-T G.993.5) can be used to increase range at a given bitrate, *e.g.* 100 Mbit/s at up to 500 metres.
- G.fast, ITU-T G.9700 and G.9701, up to approximately 1 Gbit/s aggregate uplink and downlink at 100m. Expected to be finalized in April 2014.
- Bonded DSL Rings (DSL Rings), A shared ring topology at 400 Mbit/s
- Etherloop Ethernet local loop
- High Speed Voice and Data Link

Internet Protocol subscriber line (IPSL), developed by Rim Semiconductor in 2007, allowed for 40 Mbit/s using 26 AWG copper telephone wire at a 5,500 ft (1,700 m) radius, 26 Mbit/s at a 6,000 ft (1,800 m) radius. The company operated until 2008.

Rate-adaptive digital subscriber line (RADSL), designed to increase range and noise tolerance by sacrificing up stream speed

Uni-DSL (Uni digital subscriber line or UDSL), technology developed by Texas Instruments, backwards compatible with all DMT standards

4.11. Cable Modem Networks

Cable modem network access and **DSL** are two alternative ways to connect to a network service provider (NSP) without the use of more expensive dedicated service, such as Frac-T1/T3. Both cable modem and DSL networks achieve the same result of providing dedicated access to a network service, often the Internet, but each do so using differing technologies. DSL technology has been discussed in previous section. Let us discuss cable access technology in detail.

4.11.1. Cable Access Technologies

Cable television (CATV) is a unidirectional medium carrying broadcast analog video channels to the most customers possible at the lowest possible cost to the CATV service provider. Since the introduction of CATV more than 50 years ago, little has changed beyond increasing the number of channels supported.

Fearing loss of market share when DSL was introduced (in the 1990s) and recognizing the need to offer advanced services to remain economically viable, key multiple system operators (MSOs) formed the Multimedia Cable Network System Partners, Ltd. (MCNS). The goal of the MCNS was to define a standard product and system capable of providing data and future services over the CATV infrastructure. MCNS partners included Comcast Cable Communications, Cox Communications, Tele-Communications Inc., Time Warner Cable, MediaOne, Rogers CableSystems, and Cable Television Laboratories (CableLabs). The MCNS defined the Data Over Cable Service Interface Specification (DOCSIS) 1.0 standard, which was in turn accepted as the North American standard. These key MSOs defined upgrade and construction programs to provide two-way functionality to the end-user over the CATV infrastructure.

4.11.2. Cable Access Architecture

To deliver data services over a cable network, one television channel (50 to 750 MHz range) is allocated for downstream traffic to homes and another channel (5 to 42 MHz band) is used to carry upstream signals.

The following list details the cable access network architecture :

- Residential and business end-users are connected to fiber nodes by coaxial cables. Users attach to this cable through an Ethernet network interface card (NIC) installed in the PC, in turn connected to a cable modem.
- The fiber nodes house the cable modem termination system (CMTS) at the head-end, communicating with the cable modems at the end-user premise. This communication creates a LAN connection between the end-user and the cable modem service provider.
- Most cable modems are external hardware devices connecting to a PC through a standard 10Base-T Ethernet card or Universal Serial Bus (USB) connection.
- These fiber nodes are connected by fiber rings (such as SONET) to the distribution hubs, which are in turn connected by fiber rings to a regional cable head-end.

- The cable head-end then forwards the traffic to the appropriate network—the PSTN for VoIP applications and the public Internet for all other IP traffic.

A single downstream 6 MHz television channel can carry up to 27 Mbps of downstream data throughput from the cable head-end; upstream channels can deliver 500 Kbps to 10 Mbps from home and business end-users. This upstream and downstream bandwidth is shared by other data subscribers connected to the same cable network segment, which is often 500 to 2000 homes on a modern network.

An individual cable modem subscriber can reach speeds from 500 Kbps to 1.5 Mbps or more, depending on the network architecture (for example oversubscription ratio) and traffic load.

Note that, other users on the network segment affect cable modem speed, the CATV-signal does not affect this speed because each signal (CATV and cable modem) uses a different frequency on the line. This means that your cable modem connection will not be slower if you are watching TV.

When you are surfing the World Wide Web, your system's performance can be affected by Internet backbone congestion. The local access provider has no direct management control over this backbone congestion; it's the Internet.

4.11.3. DSL and Cable Modem Networks

DSL and cable modem network access are two alternate ways to connect to an NSP without the use of more expensive dedicated service. DSL technology is a modem technology using existing twisted-pair telephone lines capable of carrying high-bandwidth applications.

There are several forms of xDSL, each designed around specific goals and needs of the marketplace. Each of these is summarized in the following table :

Table : Summary of DSL Services

DSL Type	Description	Data Rate Downstream; Upstream	Distance Limit	Application
ADSL	Asymmetric digital subscriber line	1.544 to 6.1 Mbps downstream; 16 to 640 Kbps upstream	1.544 Mbps at 18,000 feet; 2.048 Mbps at 16,000 feet; 6.312 Mbps at 12,000 feet; 8.448 Mbps at 9,000 feet	Used for Internet and web access, motion video, video on demand, remote LAN access.
HDSL	High-data-rate digital subscriber line	1.544 Mbps duplex on two twisted-pair lines; 2.048 Mbps duplex on three twisted-pair lines	12,000 feet on 24-guage wire	T1/E1 service between server and phone company or within a company; WAN, LAN, server access.

SDSL	Single-line digital subscriber line	1.544 Mbps duplex (U.S. and Canada); 2.048 Mbps (Europe) on a single duplex line downstream and upstream	12,000 feet on 24-gauge wire	Same as for HDSL but requiring only one line of twisted-pair.
VDSL	Very-high digital subscriber line	12.9 to 52.8 Mbps downstream; 1.5 to 2.3 Mbps upstream; 1.6 Mbps to 2.3 Mbps downstream	4500 feet at 12.96 Mbps; 3000 feet at 25.82 Mbps; 1000 feet at 51.84 Mbps	ATM networks; Fiber to the Neighbourhood.

Cable systems originally were designed to deliver broadcast television signals efficiently to subscriber's homes. Downstream video programming signals begin around 50 MHz, the equivalent of channel 2 for over-the-air television signals. The 5 MHz to 42 MHz portion of the spectrum is usually reserved for upstream communications from subscribers homes.

Each standard television channel occupies 6 MHz of the Radio Frequency (RF) spectrum. Traditional cable systems have 400 MHz of downstream bandwidth, capable of carrying the equivalent of 60 analog TV channels. Modern hybrid fiber/coax (HFC) systems have 700 MHz of downstream bandwidth, with the capacity for approximately 110 channels.

4.12. VSAT

Short for very small aperture terminal, an earthbound station used in satellite communications of data, voice and video signals, excluding broadcast television. A VSAT consists of two parts, a transceiver that is placed outdoors in direct line of sight to the satellite and a device that is placed indoors to interface the transceiver with the end user's communications device, such as aPC. The transceiver receives or sends a signal to a satellite transponder in the sky. The satellite. sends and receives signals from a ground station computer that acts as a hub for the system. Each end user is interconnected with the hub station via the satellite, forming a star topology. The hub controls the entire operation of the network. For one end user to communicate with another, each transmission has to first go to the hub station that then retransmits it via the satellite to the other end user's VSAT. VSAT can handle up to 56 Kbps.

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 ouside antenna with a transceiver. The transceiver 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. Each end user is interconnected with the hub station via the satellite in a star topology. 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 handles data, voice and video signals.

VSAT is used both by home users who sign up with a large service such as DirecPC and by private companies that operate or lease their own VSAT systems. VSAT offers a number of advantages over terrestrial alternatives. For private applications, companies can have total control of their own communication system without dependence on other companies. Business and home users also get higher speed reception than if using ordinary telephone service or ISDN.

4.13. International Private Leased Circuit (IPLC) Services

Secure end-to-end connectivity for all your communication needs. International Private Leased Circuit (IPLC) is an essential business tool to increase your operational efficiency and connectivity between multiple global offices. Leveraging on being the only International data service provider to have access on all cables landing in Sri Lanka, Dialog is well positioned to ensure that the customer receives the most reliable, secure and customized solutions to any destination.

Features

- **End-to-end Solution with Single Point of Accountability** : Dialog provides convenience to its customers by providing a customized solution that can access multiple applications including data, video, voice and multimedia. In addition to a simplified ordering and billing process, Dialog is the single point of contact for service management and fault resolution.
- **Optimum Redundancy** : Dialog owns and leases capacity on all major submarine fiber optic cables landing in Sri Lanka. As the only International data service provider to have access to all cables in Sri Lanka, it enables us to provide diversity and service levels, allowing automatic routing to a different path in case of a service disruption.
- **Points of Presence** : A robust network built on our own PoPs in key global locatios in Singapore, UK and Hong Kong. It enables seamless connectivity to our partners extending our reach to more than 90 countries eliminating all interoperability concerns.
- **Last Mile Solutions** : Our superior service is offered via diversified last mile solutions to any location in Sri Lanka. With our rapidly expanding Colombo Metro project fiber optical infrastructure is extended to customer premises. Our wireless solution extends coverage to all parts of Sri Lanka to ensure best-in-class service end-to-end.
- **Global Partnerships** : Dialog has partnered with more than 50 Tier-1 and Tier-2 international global service providers to provide uniterrupted connectivity to our customers in more than 90 countries. Global providers now use Dialog to extend coverage to their customers establishing a presence in Colombo.

Benefits

- **Diversity :** Diversified cable routing paths creates seamless connectivity and ensures optimal performance. In the event of an interruption, service will be switched to an alternate path to enable maximum performance levels.
- **Service Management :** Dialog's real-time network monitoring optimizes your network performance by offering 24/7 dedicated coverage from our Technical Support Team. A single point of contact is created for failure detection, isolation and resolution.
- **Commercial Flexibility :** Comprehensive global access via a simplified ordering and billing process with flexible service terms of one, two and three year leases. Customer will have one supplier and point of contact for ordering, installation, management and billing of the circuit. Services are provisioned promptly in order to meet the demanding requirements of the customer.
- **Service Level Guarantee :** Dialog assures as uncompromising service quality, backed by our SLA on service performance.

EXERCISE

1. Name any four network architectures.
2. What is ARCNET?
3. Define hub and its types.
4. What are the advantages and disadvantages of using ARCNET?
5. Write short note on ethernet.
6. Explain in brief types of ethernet.
7. Define transmission media and its types.
8. Compare between coaxial and fibre optical media.
9. Explain some unguided media with examples.
10. Write short note on ISDN.