CST 303 COMPUTER NETWORKS

MODULE 1

INTRODUCTION AND PHYSICAL LAYER

Module - 1 (Introduction and Physical Layer)

Introduction – Uses of computer networks, Network hardware, Network software. Reference models – The OSI reference model, The TCP/IP reference model, Comparison of OSI and TCP/IP reference models.

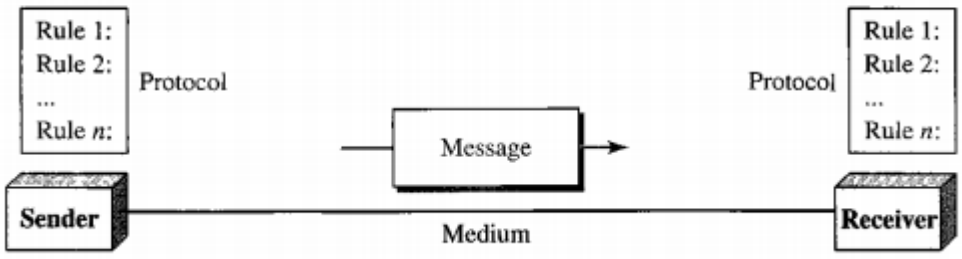
Physical Layer – Modes of communication, Physical topologies, Signal encoding, Repeaters and hub, Transmission media overview. Performance indicators – Bandwidth, Throughput, Latency, Queuing time, Bandwidth–Delay product.

Introduction

Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable. For data communications to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (programs).

Components

A data communications system has five components:



1. Message. The message is the information (data) to be communicated. Popular forms of information include text, numbers, pictures, audio, and video.

2. Sender. The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.

3. Receiver. The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.

4. Transmission medium. The transmission medium is the physical path by which a message travels from sender to receiver. Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves.

5. Protocol. A protocol is a set of rules that govern data communications. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating.b

A **computer network** is a set of connected computers. Computers on a network are called **nodes**. The connection between computers can be done via cabling, most commonly the Ethernet cable, or wirelessly through radio waves. The connection is called as **link**. Connected computers can share resources, like access to the Internet, printers, file servers etc.

Computer network

A computer network is a set of computers connected together for the purpose of sharing resources. The most common resource shared today is connection to the Internet. Other shared resources can include a printer or a file server. The Internet itself can be considered as a computer network.

Uses of computer networks

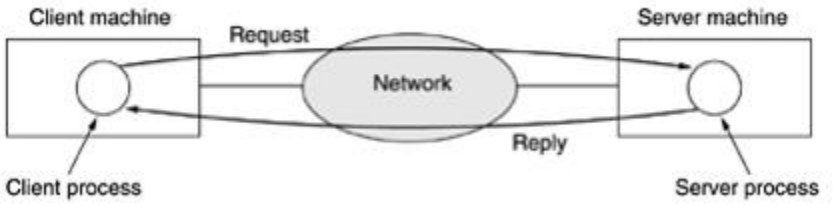
Business Applications

- **Resource sharing**

Large or small company may have a computer for each worker. The goal is to make all programs, equipment, and especially data available to anyone on the network without regard to the physical location of the resource or the user.

- **Client-server application**

In client-server model , two processes are involved, one on the client machine and one on the server machine. Communication takes the form of the client process sending a message over the network to the server process. The client process then waits for a reply message. When the server process gets the request, it performs the requested work or looks up the requested data and sends back a reply. it is widely used and forms the basis of much network usage. It is applicable when the client and server are both in the same building (e.g., belong to the same company), but also when they are far apart



- **Communication among employees**

Another goal of setting up a computer network has to do with people rather than information or even computers. A computer network can provide a powerful communication medium among employees.eg: email, videoconferencing

- **E-commerce**

Another goal is doing business with consumers over the Internet. Airlines, bookstores, and music vendors have discovered that many customers like the convenience of shopping from home. Consequently, many companies provide catalogs of their goods and services online and take orders on-line. This sector is expected to grow quickly in the future. It is called e-commerce (electronic commerce).

Home Applications

Some of the more popular uses of the Internet for home users are as follows:

1. Access to remote information.

2. Person-to-person communication.- Telephone. E-mail

3. Interactive entertainment.

4. Electronic commerce.

Access to remote information comes in many forms. It can be surfing the World Wide Web for information or just for fun. Information available includes the arts, business, cooking, government, health, history, hobbies, recreation, science, sports, travel, and many others. Fun comes in too many ways to mention, plus some ways that are better left unmentioned.

- On-line digital library
- **peer-to-peer communication**- , individuals who form a loose group can communicate with others in the group. Every person can, in principle, communicate with one or more other people; there is no fixed division into clients and servers.

Mobile Users

Mobile computers, such as notebook computers and personal digital assistants (PDAs), are one of the fastest growing segments of the computer industry.

There are two types of transmission technology that are in widespread use. They are as follows:
1. Broadcast links.

2. Point-to-point links.

Broadcast networks have a single communication channel that is shared by all the machines on the network. Point-to-point networks consist of many connections between individual pairs of machines. To go from the source to the destination, a packet on this type of network may have to first visit one or more intermediate machines. Machine are received by all the others..

- Wireless networking

Network Hardware

Categories of Networks

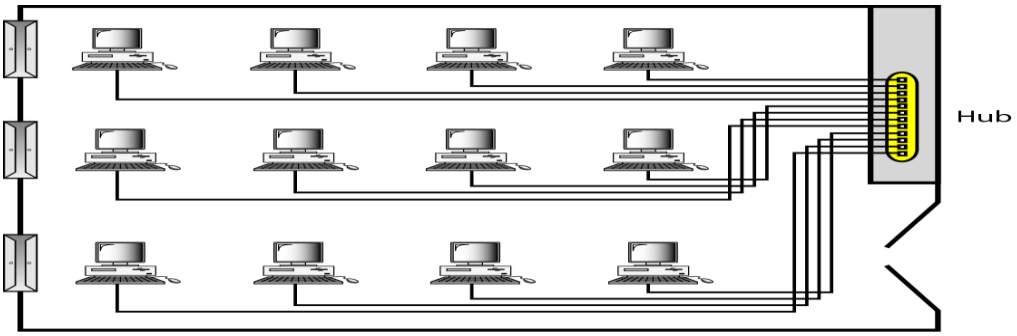
We are generally referring to two primary categories: ***local-area networks and wide-area networks***. The category into which a network falls is determined by its size.

Local Area Network

A local area network (LAN) is usually privately owned and links the devices in a single office, building, or campus (see Figure 1.10). Depending on the needs of an organization and the type of

technology used, a LAN can be as simple as two PCs and a printer in someone's home office; or it can extend throughout a company and include audio and video peripherals. Currently, ***LAN size is limited to a few kilometers.***

In addition to size, LANs are distinguished from other types of networks by their transmission media and topology. In general, a given LAN will use only one type of transmission medium. The most common LAN topologies are bus, ring, and star. Early LANs had data rates in the 4 to 16 megabits per second (Mbps) range. Today, however, speeds are normally 100 or 1000 Mbps.



Wide Area Network

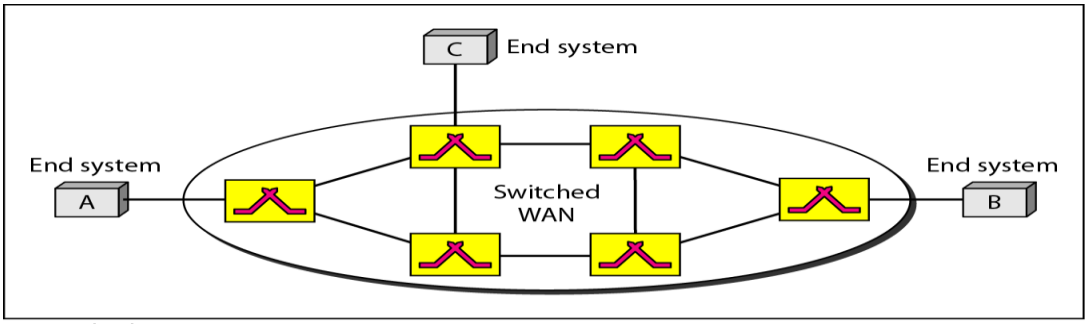
A wide area network (WAN) provides long-distance transmission of data, image, audio, and video information over large geographic areas that may comprise a country, a continent, or even the whole world. A WAN can be as complex as the backbones that connect the Internet or as simple as a dial-up line that connects a home computer to the Internet.

We normally refer to the first as a ***switched WAN*** and to the second as a ***point-to-point WAN.***

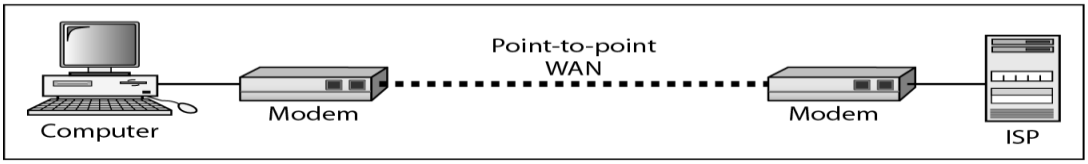
The switched WAN connects the end systems, which usually comprise a router (internetworking connecting device) that connects to another LAN or WAN.

The point-to-point WAN is normally a line leased from a telephone or cable TV provider that connects a home computer or a small LAN to an Internet service provider (lSP). This type of WAN is often used to provide Internet access.

A good example of a switched WAN is the ***asynchronous transfer mode (ATM) network***, which is a network with fixed-size data unit packets called cells.



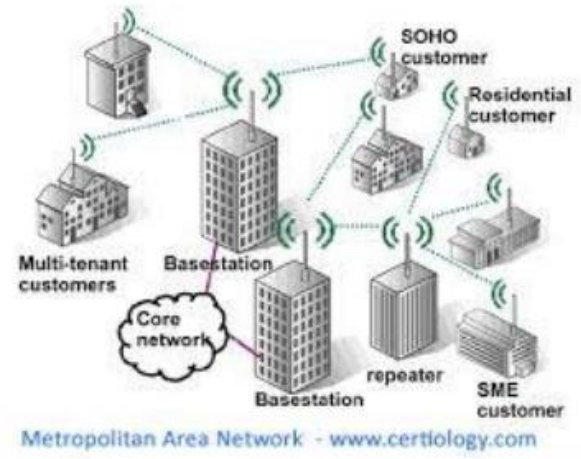
a. Switched WAN



b. Point-to-point WAN

Metropolitan Area Networks

A metropolitan area network (MAN) is a network with a size between a LAN and a WAN. It normally covers the area inside a town or a city. It is designed for customers who need a high-speed connectivity, normally to the Internet, and have endpoints spread over a city or part of city. A good example of a MAN is the part of the ***telephone company network*** that can provide a high-speed DSL line to the customer. Another example is the ***cable TV network*** that originally was designed for cable TV, but today can also be used for high-speed data connection to the Internet.

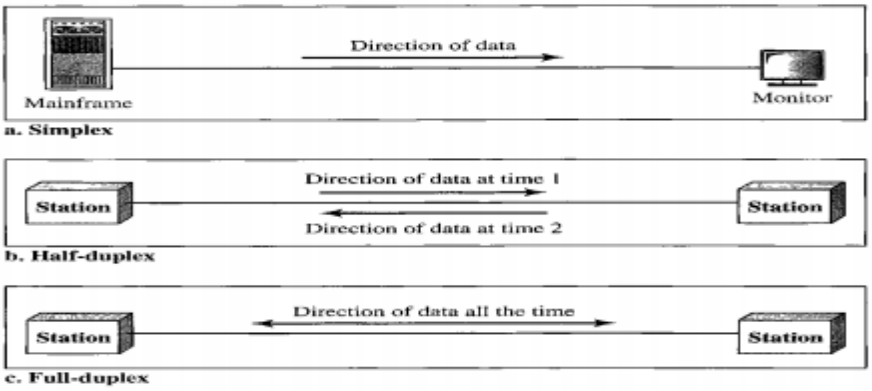


Personal area networks(PAN)

Personal Area Network (PAN) The smallest and most basic type of network, a PAN is made up of a wireless modem, a computer or two, phones, printers, tablets, etc., and revolves around one person in one building. These types of networks are typically found in small offices or residences and are managed by one person or organization from a single device. Eg : wireless computers ,keyboard &Mouse Bluetooth embedded headphones

Data Flow

Communication between two devices can be simplex, half-duplex, or full-duplex as shown in Figure.



Simplex

In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive. Keyboards and traditional monitors are examples of simplex devices. The keyboard can only introduce input; the monitor

can only accept output. The simplex mode can use the entire capacity of the channel to send data in one direction.

Half-Duplex

In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa. In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time. Walkie-talkies and CB (citizens band) radios are both half-duplex systems, The half-duplex mode is used in cases where there is no need for communication in both directions at the same time; the entire capacity of the channel can be utilized for each direction.

Full-Duplex

In full-duplex made (also, called duplex), both stations can transmit and receive simultaneously. In full-duplex mode, signals going in one direction share the capacity of the link with signals going in the other direction. This sharing can occur in two ways: Either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals travelling in both directions. One common example of full-duplex communication is the telephone network. The full-duplex mode is used when communication in both directions is required all the time. The capacity of the channel, however, must be divided between the two directions.

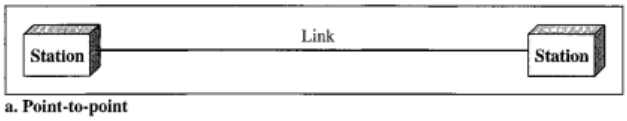
Type of Connection

A network is two or more devices connected through links. A link is a communications pathway that transfers data from one device to another. For communication to occur, two devices must be connected in some way to the same link at the same time. There are two possible types of connections: point-to-point and multipoint.

Point-to-Point

A point-to-point connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices. Most point-to- point

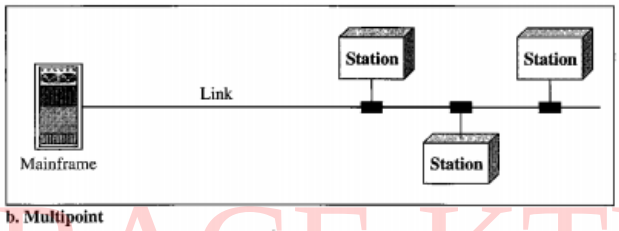
connections use an actual length of wire or cable to connect the two ends, but other options, such as microwave or satellite links, are also possible.



a. Point-to-point

Multipoint

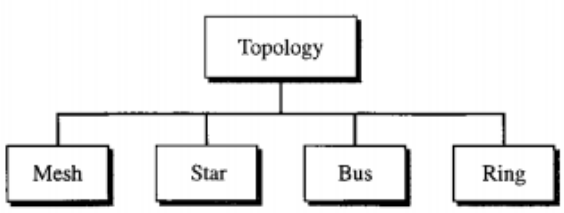
A multipoint (also called multidrop) connection is one in which more than two specific devices share a single link. In a multipoint environment, the capacity of the channel is shared, either spatially or temporally. If several devices can use the link simultaneously, it is a spatially shared connection. If users must take turns, it is a timeshared connection.



b. Multipoint

Physical Topology

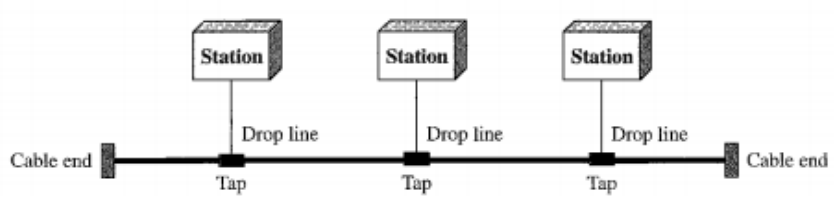
The term physical topology refers to the way in which a network is laid out physically. Two or more devices connect to a link; two or more links form a topology. The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called nodes) to one another. There are four basic topologies possible: mesh, star, bus, and ring.



Bus Topology

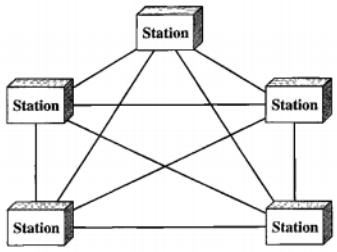
The preceding examples all describe point-to-point connections. A bus topology, on the other hand, is multipoint. One long cable acts as a backbone to link all the devices in a network. Nodes

are connected to the bus cable by drop lines and taps. A drop line is a connection running between the device and the main cable. A tap is a connector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core.



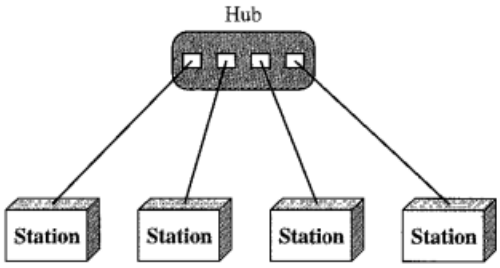
Mesh

In a mesh topology, every device has a dedicated point-to-point link to every other device. The term dedicated means that the link carries traffic only between the two devices it connects. Let n be the number nodes, then n(n-1)/2 duplex links will be there in the network. A mesh topology is robust. If one link becomes unusable, it does not incapacitate the entire system.



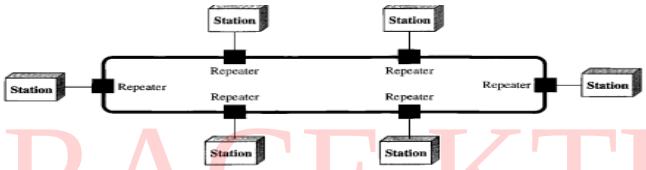
Star Topology

In a star topology, each device has a dedicated point-to-point link only to a central controller, usually called a hub. The devices are not directly linked to one another. Unlike a mesh topology, a star topology does not allow direct traffic between devices. The controller acts as an exchange: If one device wants to send data to another, it sends the data to the controller, which then relays the data to the other connected device.



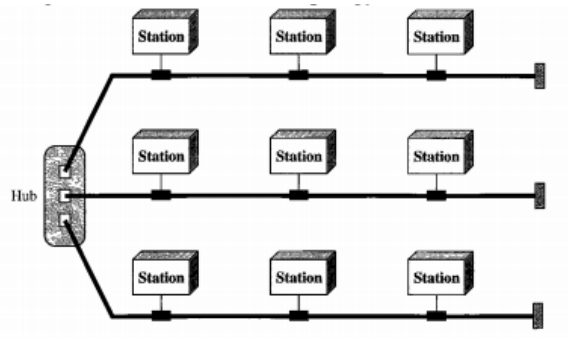
Ring Topology

In a ring topology, each device has a dedicated point-to-point connection with only the two devices on either side of it. A signal is passed along the ring in one direction, from device to device, until it reaches its destination. Each device in the ring incorporates a repeater. When a device receives a signal intended for another device, its repeater regenerates the bits and passes them along.



Hybrid Topology

A network can be hybrid. For example, we can have a main star topology witheach branch connecting several stations in a bus topology as shown:



Network software

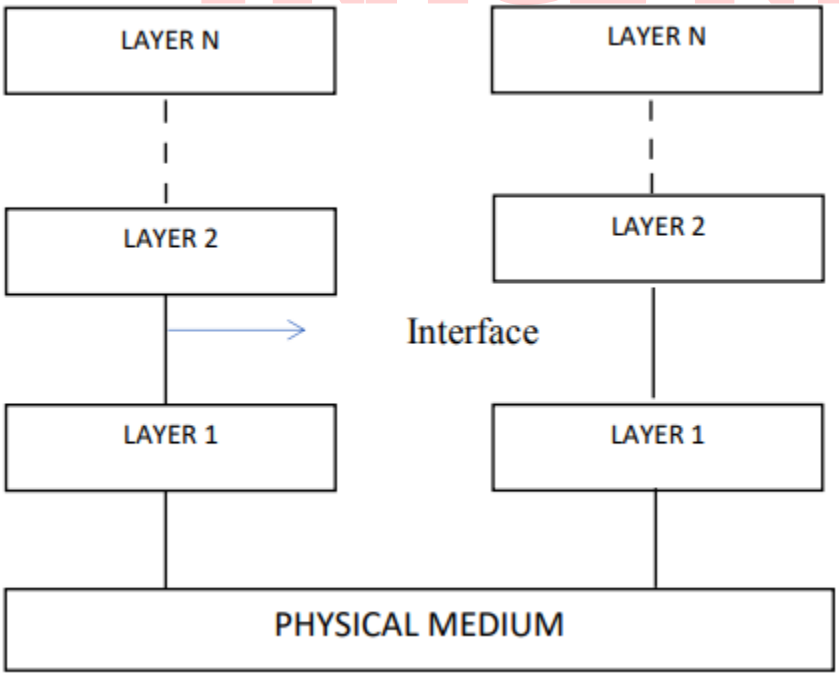
The first computer networks were designed with the hardware as the main concern and the software as an afterthought. This strategy no longer works. Network software is now highly structured.

PROTOCOL

In computer networks, communication occurs between entities in different systems. An entity is anything capable of sending or receiving information. However, two entities cannot simply send bit streams to each other and expect to be understood. For communication to occur, the entities must agree on a protocol. A protocol is a set of rules that govern data communications. A protocol defines what is communicated, how it is communicated, and when it is communicated. The key elements of a protocol are syntax, semantics, and timing.

PROTOCOL HIERARCHIES

To reduce their design complexity, most networks are organized as a stack of layers or levels, each one built upon the one below it. The number of layers, the name of each layer, the contents of each layer, and the function of each layer differ from network to network. The purpose of each layer is to offer certain services to the higher layers, shielding those layers from the details of how the offered services are actually implemented. Layer n on one machine carries on a conversation with layer n on another machine. The rules and conventions used in this conversation are collectively known as the layer n protocol.



In order to understand how the actual communication is achieved between two remote hosts connected to the same network, a general network diagram is shown above divided into a series of layers. As it seen later on the on the course the actual number as well as their function of each layer differs from network to network. Each layer passes data and control information to the layer below It. As soon as the data are collected form the next layer, some functions are performed there and the data are upgraded and passed to the next layer. This continues until the lowest layer is reached. Actual communication occurs when the information passes layer 1 and reaches the Physical medium. This is shown with the solid lines on the diagram. Theoretically layer n on one machine maintains a conversation with the same layer in the other machine. The way this conversation is achieved is by the protocol of each layer.

Protocol is collection of rules and conventions as agreement between the communication parties on how communication is to proceed. The latter is known as virtual communication and is indicated with the dotted lines on the diagram above. Layer n of one machine carries a conversion with the layer n of another machine. The rules and conversion are collectively known as protocol. Entities comprising layers of different machine is called peer process. The data and information is passed by each layer to the lower layer. When the lower layer is reached it is passed to the physical medium which actual communication occurs.

Between the pair of adjacent layer their lies the **interface**. The interface defines which type of services the lower layer offers to the upper layer. Protocols are together called **protocol stack** or set of protocols. As far as the above diagram is concerned another important issue to be discussed is the interface between each layer. It defines the services and operation the lower layer offers to the one above It. When a network is built decisions are made to decide how many layers to be included and what each layer should do. So each layer performs a different function and as a result the amount of information past from layer to layer is minimized.

Design issues for a layer

➢ Every layer has a mechanism of connection establishment. Since a network has many computers, some having multiple process. A machine has to specify with whom it has to establish connection. Because of having consequence of multiple destination, the addressing is needed in order to specify the specific destination.

➢ Another set of design decisions concerns the rules for data transfer. In some data transfer take place in one direction and in some other it travel in both direction but not simultaneously. And there are situations were data transfer takes place simultaneously. Protocol determines how many logical channels are needed per connection.

➢ Error control: The physical communication circuits are not perfect. There are error detecting and error correcting codes. Both ends of the connection should agree which one is being used.

The receiver must someway tell the sender which message is have been correctly received and which is not.

➢ Speed of sender is greater than the receiver. There will be some kind of access from the receiver to the sender directly & indirectly about the receiver current situation.

➢ Inability of process to accept long message.

➢ Very expensive to set up connection for each communication process.

➢ Reliability: It is a design issue of making a network that operates correctly even when it is made up of unreliable components.

➢ Addressing: There are multiple processes running on one machine. Every layer needs a mechanism to identify senders and receivers.

➢ Error Control: It is an important issue because physical communication circuits are not perfect. Many error detecting and error correcting codes are available. Both sending and receiving ends must agree to use any one code.

➢ Flow Control : If there is a fast sender at one end sending data to a slow receiver, then there must be flow control mechanism to control the loss of data by slow receivers. There are several mechanisms used for flow control such as increasing buffer size at receivers, slow down the fast sender, and so on. Some process will not be in position to accept arbitrarily long messages. This property leads to mechanisms for disassembling, transmitting and the reassembling messages.

➢ Multiplexing and De-multiplexing : If the data has to be transmitted on transmission media separately, it is inconvenient or expensive to setup separate connection for each pair of communicating processes. So, multiplexing is needed in the physical layer at sender end and de-multiplexing is need at the receiver end.

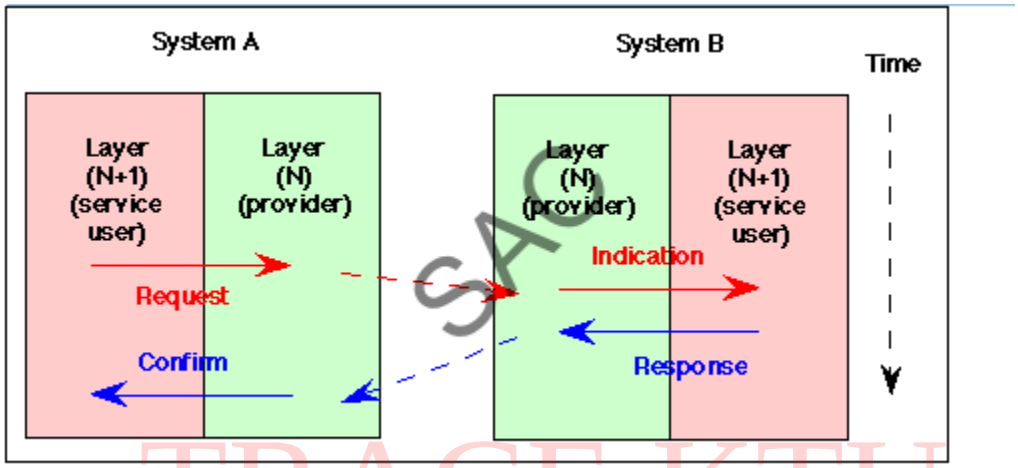
➢ Scalability : When network gets large, new problem arises. Thus scalability is important so that network can continue to work well when it gets large.

➢ Routing : When there are multiple paths between source and destination, only one route must be chosen. This decision is made on the basis of several routing algorithms, which chooses optimized route to the destination.

➢ Confidentiality and Integrity: Network security is the most important factor. Mechanisms that provide confidentiality defend against threats like eavesdropping. Mechanisms for integrity prevent faulty changes to messages.

Service Primitives : Each protocol which communicates in a layered architecture communicates in a peer to peer manner with its remote protocol entity. Communication between adjacent protocol layers (i.e. within the same communications node) are managed by calling functions, called Primitives, between the layers. A service is formally specified by a set of primitives (operations) available to a user process to access the service. These primitives tell the service to perform some action or report on an action taken by a peer .

➢ There are various types of actions that may be performed by primitives. Examples of primitives include: Connect, Data, Flow Control, and Disconnect.



Some of the services are:

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Each primitive specifies the action to be performed or advises the result of a previously requested action. A primitive may also carry the parameters needed to perform its functions. One parameter is the packet to be sent/received to the layer above/below (or, more accurately,

includes a pointer to data structures containing a packet, often called a "buffer"). There are four types of primitive used for communicating data.

The four basic types of primitive are :

- Request : A primitive sent by layer (N + 1) to layer N to request a service. It invokes the service and passes any required parameters.
- Indication : A primitive returned to layer (N + l) from layer N to advise of activation of a requested service or of an action initiated by the layer N service.
- Response : A primitive provided by layer (N + 1) in reply to an indication primitive. It may acknowledge or complete an action previously invoked by an indication primitive.
- Confirm : A primitive returned to the requesting (N + l)st layer by the Nth layer to acknowledge or complete an action previously invoked by a request primitive.

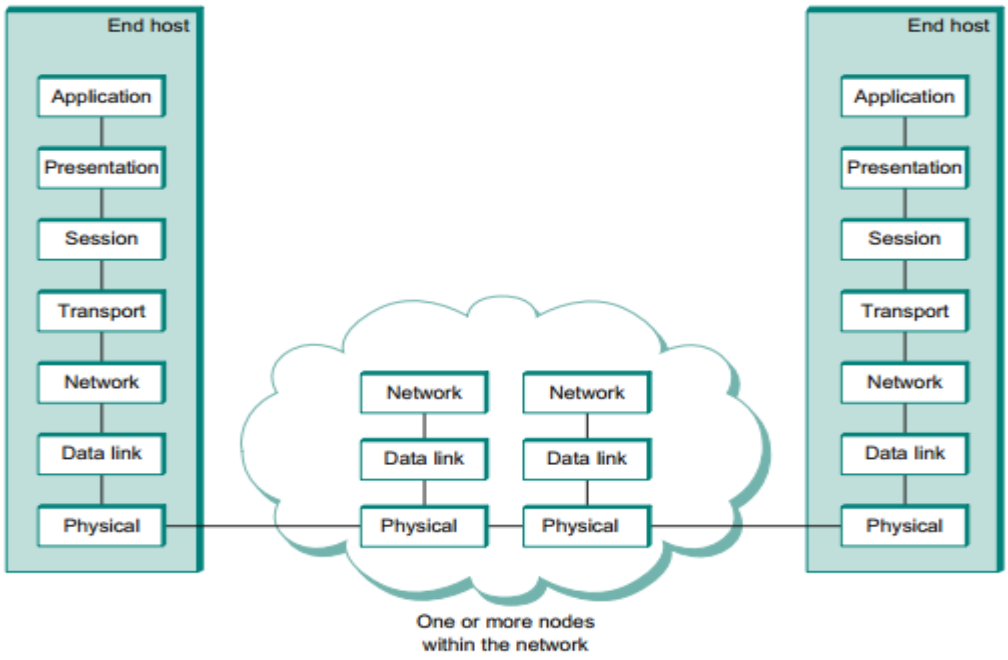
To send Data, the sender invokes a Data. Request specifying the packet to be sent, and the Service Access Point (SAP) of the layer below. At the receiver, a Data. Indication primitive is passed up to the corresponding layer, presenting the received packet to the peer protocol entity.

THE OSI MODEL

The OSI model is a layered framework for the design of network systems that allows communication between all types of computer systems. It consists of seven separate but related layers, each of which defines a part of the process of moving information across a network.

Layered Architecture

The OSI model is composed of seven ordered layers: physical (layer 1), data link (layer 2), network (layer 3), transport (layer 4), and session (layer 5), and presentation (layer 6), and application (layer 7). The following figure shows the layers involved when a message is sent from device A to device B. As the message travels from A to B, it may pass through many intermediate nodes. These intermediate nodes usually involve only the first three layers of the OSI model. Within a single machine, each layer calls upon the services of the layer just below it.



Layers In The Osi Model

Physical Layer

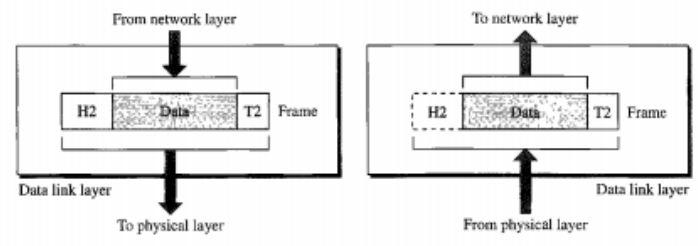
The physical layer coordinates the functions required to carry a bit stream over a physical medium. It deals with the mechanical and electrical specifications of the interface and transmission medium. It also defines the procedures and functions that physical devices and interfaces have to perform for transmission to occur. The physical layer is also concerned with the following:

- Physical characteristics of interfaces and medium. The physical layer defines the characteristics of the interface between the devices and the transmission medium. It also defines the type of transmission medium.
- Representation of bits. The physical layer data consists of a stream of bits (sequence of 0s or ls) with no interpretation. To be transmitted, bits must be encoded into signals - electrical or optical. The physical layer defines the type of encoding (how 0s and 1s are changed to signals).

- Data rate. The transmission rate--the number of bits sent each second--is also defined by the physical layer. In other words, the physical layer defines the duration of a bit, which is how long it lasts.
- Synchronization of bits. The sender and receiver not only must use the same bit rate but also must be synchronized at the bit level. In other words, the sender and the receiver clocks must be synchronized.
- Line configuration. The physical layer is concerned with the connection of devices to the media. In a point-to-point configuration, two devices are connected through a dedicated link. In a multipoint configuration, a link is shared among several devices.
- Physical topology. The physical topology defines how devices are connected to make a network. Devices can be connected by using a mesh topology (every device is connected to every other device), a star topology (devices are connected through a central device), a ring topology (each device is connected to the next, forming a ring), a bus topology (every device is on a common link), or a hybrid topology (this is a combination of two or more topologies).
- Transmission mode. The physical layer also defines the direction of transmission between two devices: simplex, half-duplex, or full-duplex. In simplex mode, only one device can send; the other can only receive. The simplex mode is a one-way communication. In the half-duplex mode, two devices can send and receive, but not at the same time. In a full-duplex (or simply duplex) mode, two devices can send and receive at the same time.

Data Link Layer

The data link layer transforms the physical layer, a raw transmission facility, to a reliable link. It makes the physical layer appear error-free to the upper layer (network layer). The figure shows the relationship of the data link layer to the network and physical layers.



Other responsibilities of the data link layer include the following:

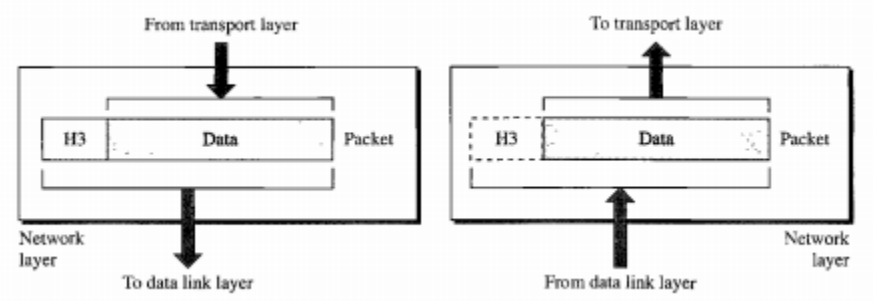
- Framing. The data link layer divides the stream of bits received from the network layer into manageable data units called frames.
- Physical addressing. If frames are to be distributed to different systems on the network, the data link layer adds a header to the frame to define the sender and/or receiver of the frame. If the frame is intended for a system outside the sender's network, the receiver address is the address of the device that connects the network to the next one.
- Flow control. If the rate at which the data are absorbed by the receiver is less than the rate at which data are produced in the sender, the data link layer imposes a flow control mechanism to avoid overwhelming the receiver.
- Error control. The data link layer adds reliability to the physical layer by adding mechanisms to detect and retransmit damaged or lost frames. It also uses a mechanism to recognize duplicate frames. Error control is normally achieved through a trailer added to the end of the frame.
- Access control. When two or more devices are connected to the same link, data link layer protocols are necessary to determine which device has control over the link at any given time.

Network Layer

The network layer is responsible for the source-to-destination delivery of a packet, possibly across multiple networks (links). Whereas the data link layer oversees the delivery of the packet between two systems on the same network (links), the network layer ensures that each packet gets from its point of origin to its final destination. If two systems are connected to the same link, there is usually no need for a network layer. However, if the two systems are attached to different networks (links) with connecting devices between the networks (links), there is often a need for the network layer to accomplish source-todestination delivery. The figure shows the relationship of the network layer to the data link and transport layers.

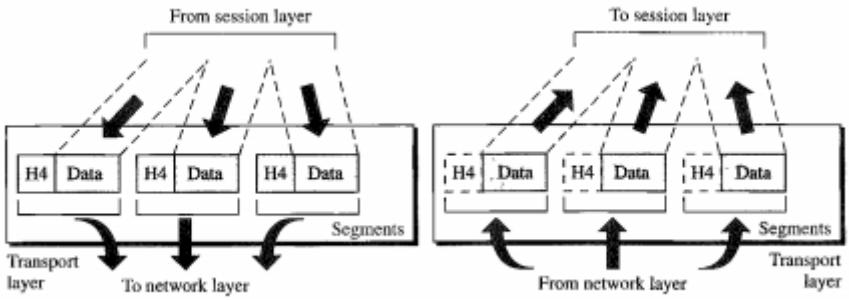
Other responsibilities of the network layer include the following:

- Logical addressing. The physical addressing implemented by the data link layer handles the addressing problem locally. If a packet passes the network boundary, we need another addressing system to help distinguish the source and destination systems. The network layer adds a header to the packet coming from the upper layer that, among other things, includes the logical addresses of the sender and receiver.
- Routing. When independent networks or links are connected to create internetworks (network of networks) or a large network, the connecting devices (called routers or switches) route or switch the packets to theirnetwork layer is to provide this mechanism.



Transport Layer

The transport layer is responsible for process-to-process delivery of the entire message. A process is an application program running on a host. Whereas the network layer oversees source-to-destination delivery of individual packets, it does not recognize any relationship between those packets. It treats each one independently, as though each piece belonged to a separate message, whether or not it does. The transport layer, on the other hand, ensures that the whole message arrives intact and in order, overseeing both error control and flow control at the source-to-destination level. The figure shows the relationship of the transport layer to the network and session layers.



Other responsibilities of the transport layer include the following:

- Service-point addressing. Computers often run several programs at the same time. For this reason, source-to-destination delivery means delivery not only from one computer to the next but also from a specific process (running program) on one computer to a specific process (running program) on the other. The transport layer header must therefore include a type of address called a service-point address (or port address). The network layer gets each packet to the correct computer; the transport layer gets the entire message to the correct process on that computer.
- Segmentation and reassembly. A message is divided into transmittable segments, with each segment containing a sequence number. These numbers enable the transport layer to reassemble the message correctly upon arriving at the destination and to identify and replace packets that were lost in transmission.
- Connection control. The transport layer can be either connectionless or connection-oriented. A connectionless transport layer treats each segment as an independent packet and delivers it to the transport layer at the destination machine. A connection-oriented transport layer makes a connection with the transport layer at the destination machine first before delivering the packets. After all the data are transferred, the connection is terminated.
- Flow control. Like the data link layer, the transport layer is responsible for flow control. However, flow control at this layer is performed end to end rather than across a single link.
- Error control. Like the data link layer, the transport layer is responsible for error control. However, error control at this layer is performed process-to-process rather than across a single link. The sending transport layer makes sure that the entire message arrives at the receiving transport layer without error (damage, loss, or duplication). Error correction is usually achieved through retransmission.

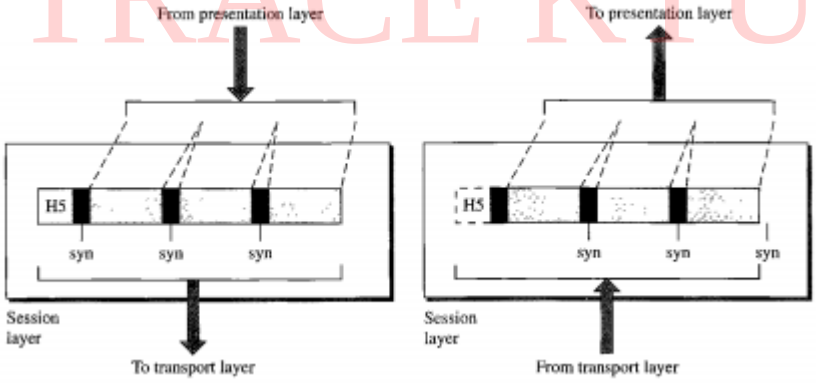
Session Layer

The services provided by the first three layers (physical, data link, and network) are not sufficient for some processes. The session layer is the network dialog controller. It establishes, maintains, and synchronizes the interaction among communicating systems.

Specific responsibilities of the session layer include the following:

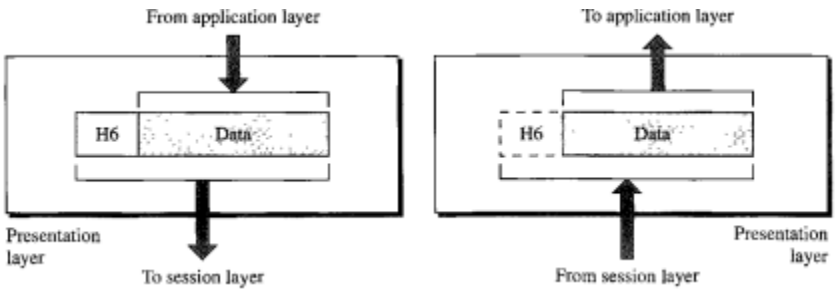
- Dialog control. The session layer allows two systems to enter into a dialog. It allows thecommunication between two processes to take place in either half- duplex (one way at a time) or full-duplex (two ways at a time) mode.
- Synchronization. The session layer allows a process to add checkpoints, or synchronization points, to a stream of data. For example, if a system is sending a file of 2000 pages, it is advisable to insert checkpoints after every 100 pages to ensure that each 100-page unit is received and acknowledged independently. In this case, if a crash happens during the transmission of page 523, the only pages that need to be resent after system recovery are pages 501 to 523. Pages previous to 501 need not be resent.

The figure illustrates the relationship of the session layer to the transport and presentation layers.



Presentation Layer

The presentation layer is concerned with the syntax and semantics of the information exchanged between two systems. The figure shows the relationship between the presentation layer and the application and session layers.

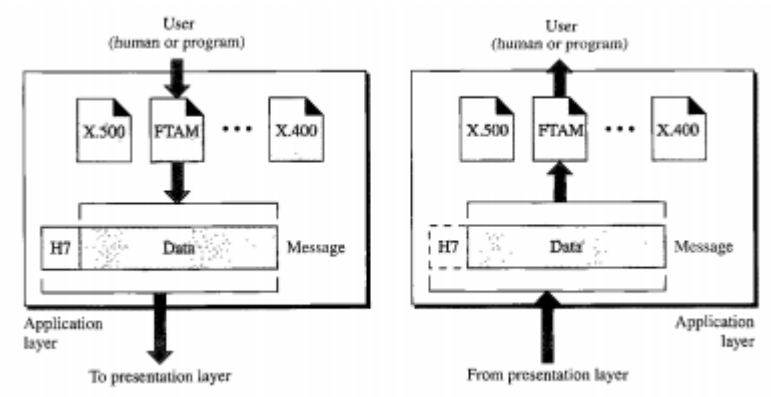


Specific responsibilities of the presentation layer include the following:

- Translation. The processes (running programs) in two systems are usually exchanging information in the form of character strings, numbers, and so on. The information must be changed to bit streams before being transmitted. Because different computers use different encoding systems, the presentation layer is responsible for interoperability between these different encoding methods. The presentation layer at the sender changes the information from its sender-dependent format into a common format. The presentation layer at the receiving machine changes the common format into its receiver-dependent format.
- Encryption. To carry sensitive information, a system must be able to ensure privacy. Encryption means that the sender transforms the original information to another form and sends the resulting message out over the network. Decryption reverses the original process to transform the message back to its original form.
- Compression. Data compression reduces the number of bits contained in the information. Data compression becomes particularly important in the transmission of multimedia such as text, audio, and video.

Application Layer

The application layer enables the user, whether human or software, to access the network. It provides user interfaces and support for services such as electronic mail, remote file access and transfer, shared database management, and other types of distributed information services. The figure shows the relationship of the application layer to the user and the presentation layer.

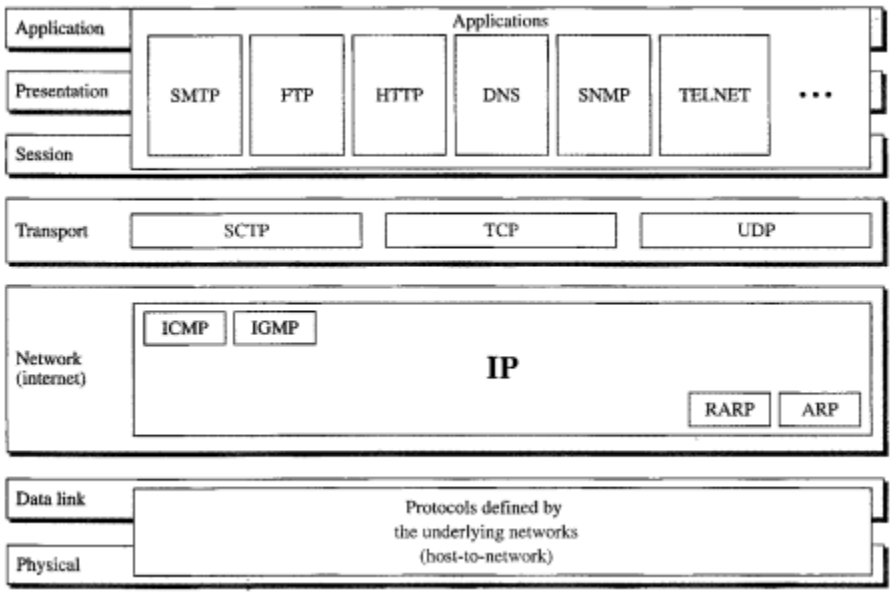


Specific services provided by the application layer include the following:

- Network virtual terminal. A network virtual terminal is a software version of a physical terminal, and it allows a user to log on to a remote host. To do so, the application creates a software emulation of a terminal at the remote host. The user's computer talks to the software terminal which, in turn, talks to the host, and vice versa. The remote host believes it is communicating with one of its own terminals and allows the user to log on.
- File transfer, access, and management. This application allows a user to access files in a remote host (to make changes or read data), to retrieve files from a remote computer for use in the local computer, and to manage or control files in a remote computer locally.
- Mail services. This application provides the basis for e-mail forwarding and storage.
- Directory services. This application provides distributed database sources and access for global information about various objects and services.

TCP/IP PROTOCOL SUITE

The TCP/IP protocol suite is made of five layers: physical, data link, network, transport, and application. The first four layers provide physical standards, network interfaces, internetworking, and transport functions that correspond to the first four layers of the OSI model. The three topmost layers in the OSI model, however, are represented in TCP/IP by a single layer called the application layer.



TCP/IP is a hierarchical protocol made up of interactive modules, each of which provides aspecific functionality; however, the modules are not necessarily interdependent. Whereas the OSI model specifies which functions belong to each of its layers, the layers of the TCP/IP protocol suite contain relatively independent protocols that can be mixed and matched depending on the needs of the system. The term hierarchical means that each upper-level protocol is supported by one or more lower-level protocols. At the transport layer, TCP/IP defines three protocols: Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and Stream Control Transmission Protocol (SCTP). At the network layer, the main protocol defined by TCP/IP is the Internetworking Protocol (IP); there are also some other protocols that support data movement in this layer.

Physical and Data Link Layers

At the physical and data link layers, TCP/IP does not define any specific protocol. It supports all the standard and proprietary protocols. A network in a TCP/IP internetwork can be a local-area network or a wide-area network.

Network Layer

At the network layer (or, more accurately, the internetwork layer), TCP/IP supports the Internetworking Protocol. IP, in turn, uses four supporting protocols: ARP, RARP, ICMP, and IGMP.

Internetworking Protocol (IP)

The Internetworking Protocol (IP) is the transmission mechanism used by the TCP/IP protocols.

It is an unreliable and connectionless protocol--a best-effort delivery service. The term best effort means that IP provides no error checking or tracking. IP assumes the unreliability of the underlying layers and does its best to get a transmission through to its destination, but with no guarantees. IP transports data in packets called datagrams, each of which is transported separately. Datagrams can travel along different routes and can arrive out of sequence or be duplicated. IP does not keep track of the routes and has no facility for reordering datagrams once they arrive at their destination.

Address Resolution Protocol

The Address Resolution Protocol (ARP) is used to associate a logical address with a physical address. On a typical physical network, such as a LAN, each device on a link is identified by a physical or station address, usually imprinted on the network interface card (NIC). ARP is usedto find the physical address of the node when its Internet address is known.

Reverse Address Resolution Protocol

The Reverse Address Resolution Protocol (RARP) allows a host to discover its Internet address when it knows only its physical address. It is used when a computer is connected to a network for the first time or when a diskless computer is booted.

Internet Control Message Protocol

The Internet Control Message Protocol (ICMP) is a mechanism used by hosts and gateways to send notification of datagram problems back to the sender. ICMP sends query and error reporting messages.

Internet Group Message Protocol

The Internet Group Message Protocol (IGMP) is used to facilitate the simultaneous transmission of a message to a group of recipients.

Transport Layer

Traditionally the transport layer was represented in TCP/IP by two protocols: TCP and UDP. IP is a host-to-host protocol, meaning that it can deliver a packet from one physical device to another. UDP and TCP are transport level protocols responsible for delivery of a message from a process (running program) to another process. A new transport layer protocol, SCTP, has been devised to meet the needs of some newer applications.

User Datagram Protocol

The User Datagram Protocol (UDP) is the simpler of the two standard TCP/IP transport protocols. It is a process-to-process protocol that adds only port addresses, checksum error control, and length information to the data from the upper layer.

Transmission Control Protocol

The Transmission Control Protocol (TCP) provides full transport-layer services to applications.

TCP is a reliable stream transport protocol. The term stream, in this context, means connection-oriented: A connection must be established between both ends of a transmission before either can transmit data. At the sending end of each transmission, TCP divides a stream of data into smaller units called segments. Each segment includes a sequence number for reordering after receipt, together with an acknowledgment number for the segments received. Segments are carried across theinternet inside of IP datagrams. At the receiving end, TCP collects each datagram as it comes in and reorders the transmission based on sequence numbers.

Stream Control Transmission Protocol

The Stream Control Transmission Protocol (SCTP) provides support for newer applications such as voice over the Internet. It is a transport layer protocol that combines the best features of UDP and TCP.

Application Layer

The application layer in TCP/IP is equivalent to the combined session, presentation, and application layers in the OSI model. Many protocols are defined at this layer.

Comparison between TCP/IP and OSI model

OSI MODEL	TCP/IP MODEL
Contains 7 Layers	Contains 4 Layers
Uses Strict Layering resulting in vertical layers.	Uses Loose Layering resulting in horizontal layers.
Supports both connectionless & connection-oriented communication in the Network layer, but only connection-oriented communication in Transport Layer	Supports only connectionless communication in the Network layer, but both connectionless & connection-oriented communication in Transport Layer
It distinguishes between Service, Interface and Protocol.	Does not clearly distinguish between Service, Interface and Protocol.
Protocols are better hidden and can be replaced relatively easily as technology changes (No transparency)	Protocols are not hidden and thus cannot be replaced easily. (Transparency) Replacing IP by a substantially different protocol would be virtually impossible
OSI reference model was devised before the corresponding protocols were designed.	The protocols came first and the model was a description of the existing protocols

Signal encoding

Encoding is the process of converting the data or a given sequence of characters, symbols, alphabets etc., into a specified format, for the secured transmission of data. **Decoding** is the reverse process of encoding which is to extract the information from the converted format.

Data Encoding

Encoding is the process of using various patterns of voltage or current levels to represent **1s** and **0s** of the digital signals on the transmission link.

The common types of line encoding are Unipolar, Polar, Bipolar, and Manchester.

Encoding Techniques

The data encoding technique is divided into the following types, depending upon the type of data conversion.

- **Analog data to Analog signals** − The modulation techniques such as Amplitude Modulation, Frequency Modulation and Phase Modulation of analog signals, fall under this category.
- **Analog data to Digital signals** − This process can be termed as digitization, which is done by Pulse Code Modulation (PCM). Hence, it is nothing but digital modulation. As we have already discussed, sampling and quantization are the important factors in this. Delta Modulation gives a better output than PCM.
- **Digital data to Analog signals** − The modulation techniques such as Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), etc., fall under this category. These will be discussed in subsequent chapters.
- **Digital data to Digital signals** − These are in this section. There are several ways to map digital data to digital signals. Some of them are −

- **Nonreturn to Zero-Level (NRZ-L)**
- **Nonreturn to Zero Inverted (NRZI)**
- **Bipolar -AMI**
- **Manchester**
- **Differential Manchester**

Digital signal

- Discrete, discontinuous voltage pulses
- Each pulse is a signal element
- Binary data encoded into signal elements

Unipolar -All signal elements have same sign

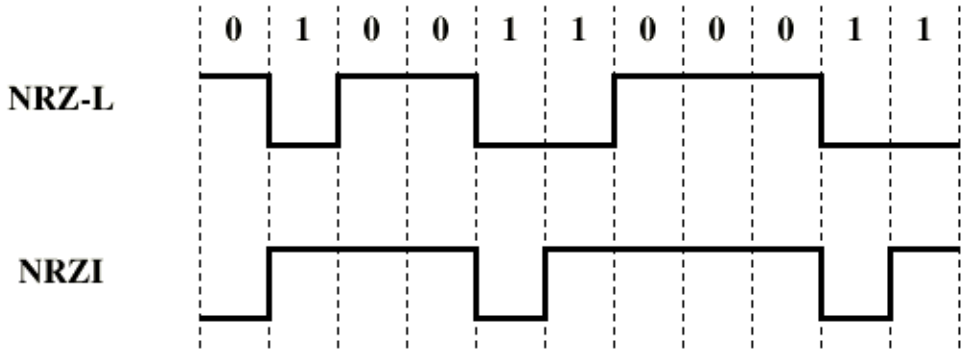
Polar-One logic state represented by positive voltage the other by negative voltage

Data rate-Rate of data transmission in bits per second

Duration or length of a bit-Time taken for transmitter to emit the bit

Modulation rate-Rate at which the signal level changes .Measured in baud = signal elements per second

- **Nonreturn to Zero-Level (NRZ-L)**
  - Two different voltages for 0 and 1 bits
  - Voltage constant during bit interval
  - no transition I.e. no return to zero voltage
  - negative voltage for one value and positive for the other
  - This is NRZ-L
- **Nonreturn to Zero Inverted (NRZI)**
  - Nonreturn to zero inverted on ones
  - Constant voltage pulse for duration of bit
  - Data encoded as presence or absence of signal transition at beginning of bit time
  - Transition (low to high or high to low) denotes a binary 1
  - No transition denotes binary 0
  - An example of differential encoding



Pros of NRZ

- Easy to engineer
- Make good use of bandwidth
- Used for magnetic recording

- Not often used for signal transmission

Cons of NRZ

- dc component
- Lack of synchronization capability
- Use more than two levels

Bipolar-AMI

- zero represented by no line signal
- one represented by positive or negative pulse
- one pulses alternate in polarity
- No loss of sync if a long string of ones (zeros still a problem)
- No net dc component
- Lower bandwidth
- Easy error detection

Biphase encoding

Manchester

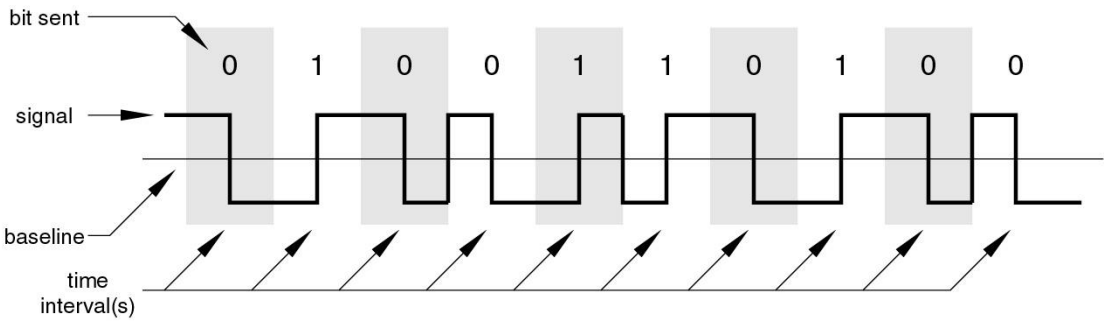
- Transition in middle of each bit period
- Transition serves as clock and data
- Low to high represents one
- High to low represents zero
- Used by IEEE 802.3

Differential Manchester

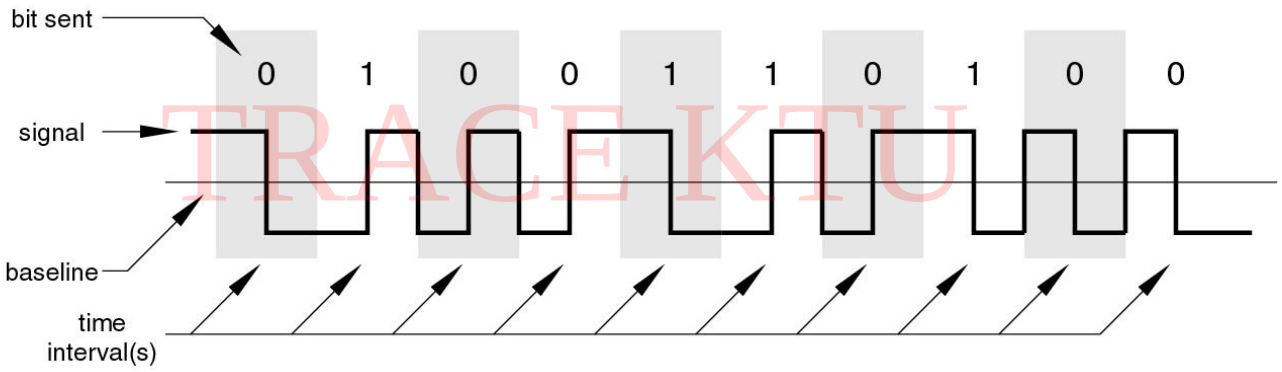
- Middle bit transition is clocking only
- Transition at start of a bit period represents zero
- No transition at start of a bit period represents one
- Note: this is a differential encoding scheme

- Used by IEEE 802.5

Manchester Encoding



Differential Manchester Encoding



Cons of biphase

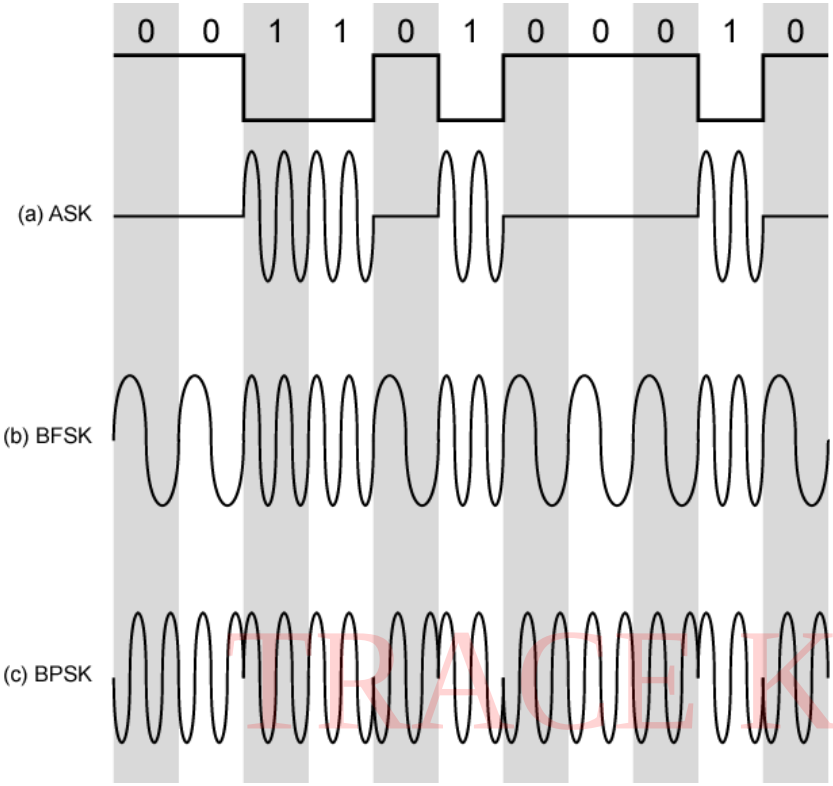
- At least one transition per bit time and possibly two
- Maximum modulation rate is twice NRZ
- Requires more bandwidth

Pros of biphase

- Synchronization on mid bit transition (self clocking)
- No dc component
- Error detection

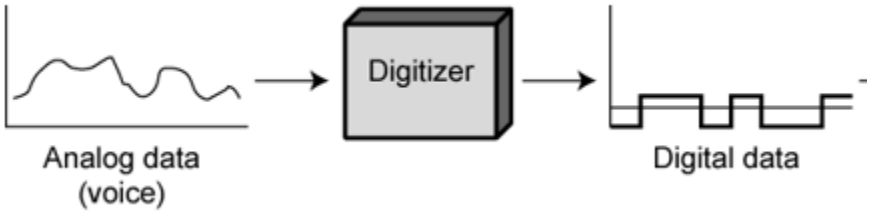
- Absence of expected transition

Digital Data, Analog Signal



Analog Data, Digital Signal

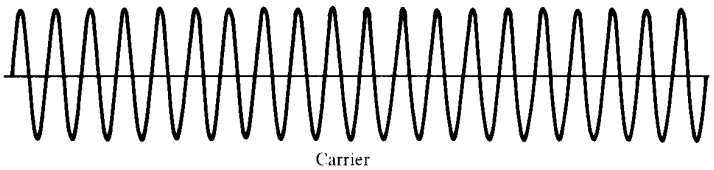
- Digitization
- Conversion of analog data into digital data
- Digital data can then be transmitted using NRZ-L
- Digital data can then be transmitted using code other than NRZ-L
- Digital data can then be converted to analog signal
- Analog to digital conversion done using a codec
- Pulse code modulation
- Delta modulation

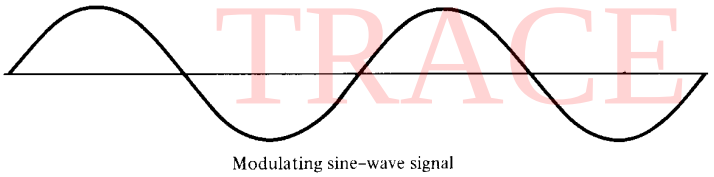


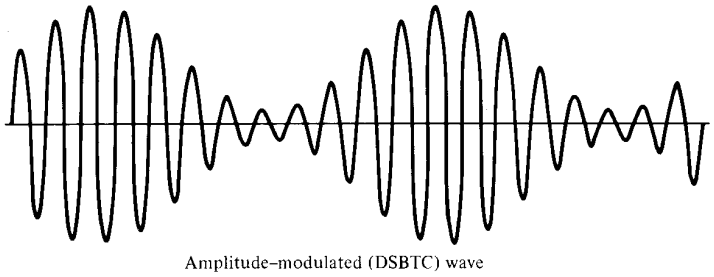
Analog Data, Analog Signals

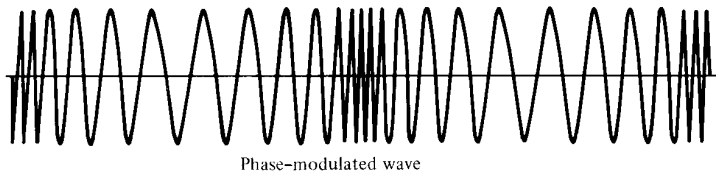
Types of modulation

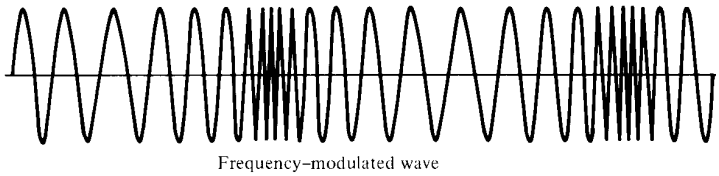
- Amplitude
- Frequency
- Phase









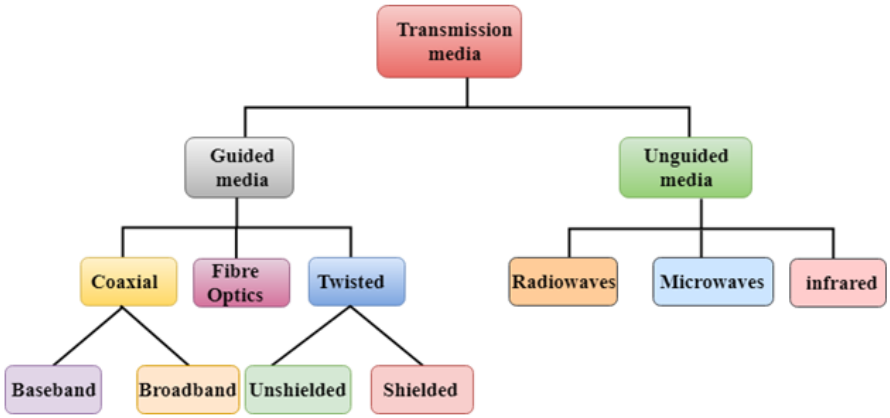


Transmission media

The purpose of the physical layer is to transport a raw bit stream from one machine to another. Various physical media can be used for the actual transmission. Each one has its own niche in terms of bandwidth, delay, cost, and ease of installation and maintenance.

Types

- Guided media
- Unguided media



Guided Media

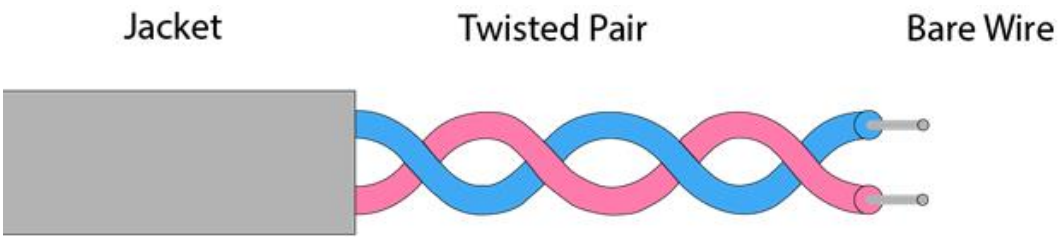
It is defined as the physical medium through which the signals are transmitted. It is also known as Bounded media.

Types Of Guided media:

Twisted pair:

Twisted pair is a physical media made up of a pair of cables twisted with each other. A twisted pair cable is cheap as compared to other transmission media. Installation of the twisted pair cable is easy, and it is a lightweight cable. The frequency range for twisted pair cable is from 0 to 3.5KHz.

A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern.



Types of Twisted pair:

Unshielded Twisted Pair:

An unshielded twisted pair is widely used in telecommunication. Following are the categories of the unshielded twisted pair cable:

- **Category 1:** Category 1 is used for telephone lines that have low-speed data.
- **Category 2:** It can support upto 4Mbps.
- **Category 3:** It can support upto 16Mbps.
- **Category 4:** It can support upto 20Mbps. Therefore, it can be used for long-distance communication.
- **Category 5:** It can support upto 200Mbps.

Advantages Of Unshielded Twisted Pair:

- It is cheap.
- Installation of the unshielded twisted pair is easy.
- It can be used for high-speed LAN.

Disadvantage:

- This cable can only be used for shorter distances because of attenuation.

Shielded Twisted Pair

A shielded twisted pair is a cable that contains the mesh surrounding the wire that allows the higher transmission rate.

Characteristics Of Shielded Twisted Pair:

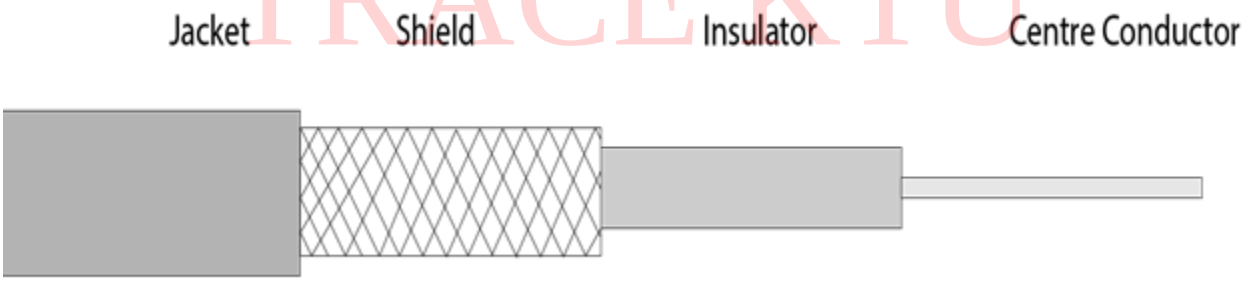
- The cost of the shielded twisted pair cable is not very high and not very low.
- An installation of STP is easy.
- It has higher capacity as compared to unshielded twisted pair cable.
- It has a higher attenuation.
- It is shielded that provides the higher data transmission rate.

Disadvantages

- It is more expensive as compared to UTP and coaxial cable.
- It has a higher attenuation rate.

Coaxial Cable

- Coaxial cable is very commonly used transmission media, for example, TV wire is usually a coaxial cable.
- The name of the cable is coaxial as it contains two conductors parallel to each other.
- It has a higher frequency as compared to Twisted pair cable.
- The inner conductor of the coaxial cable is made up of copper, and the outer conductor is made up of copper mesh. The middle core is made up of non-conductive cover that separates the inner conductor from the outer conductor.
- The middle core is responsible for the data transferring whereas the copper mesh prevents from the **EMI**(Electromagnetic interference).



Coaxial cable is of two types:

1. **Baseband transmission:** It is defined as the process of transmitting a single signal at high speed.
2. **Broadband transmission:** It is defined as the process of transmitting multiple signals simultaneously.

Advantages Of Coaxial cable:

- The data can be transmitted at high speed.

- It has better shielding as compared to twisted pair cable.
- It provides higher bandwidth.

Disadvantages Of Coaxial cable:

- It is more expensive as compared to twisted pair cable.
- If any fault occurs in the cable causes the failure in the entire network.

Fibre Optic

- Fibre optic cable is a cable that uses electrical signals for communication.
- Fibre optic is a cable that holds the optical fibres coated in plastic that are used to send the data by pulses of light.
- The plastic coating protects the optical fibres from heat, cold, electromagnetic interference from other types of wiring.
- Fibre optics provide faster data transmission than copper wires.

Diagrammatic representation of fibre optic cable:

Basic elements of Fibre optic cable:

- **Core:** The optical fibre consists of a narrow strand of glass or plastic known as a core. A core is a light transmission area of the fibre. The more the area of the core, the more light will be transmitted into the fibre.
- **Cladding:** The concentric layer of glass is known as cladding. The main functionality of the cladding is to provide the lower refractive index at the core interface as to cause the reflection within the core so that the light waves are transmitted through the fibre.

- **Jacket:** The protective coating consisting of plastic is known as a jacket. The main purpose of a jacket is to preserve the fibre strength, absorb shock and extra fibre protection.

Following are the advantages of fibre optic cable over copper:

- **Greater Bandwidth:** The fibre optic cable provides more bandwidth as compared copper. Therefore, the fibre optic carries more data as compared to copper cable.
- **Faster speed:** Fibre optic cable carries the data in the form of light. This allows the fibre optic cable to carry the signals at a higher speed.
- **Longer distances:** The fibre optic cable carries the data at a longer distance as compared to copper cable.
- **Better reliability:** The fibre optic cable is more reliable than the copper cable as it is immune to any temperature changes while it can cause obstruct in the connectivity of copper cable.
- **Thinner and Sturdier:** Fibre optic cable is thinner and lighter in weight so it can withstand more pull pressure than copper cable.

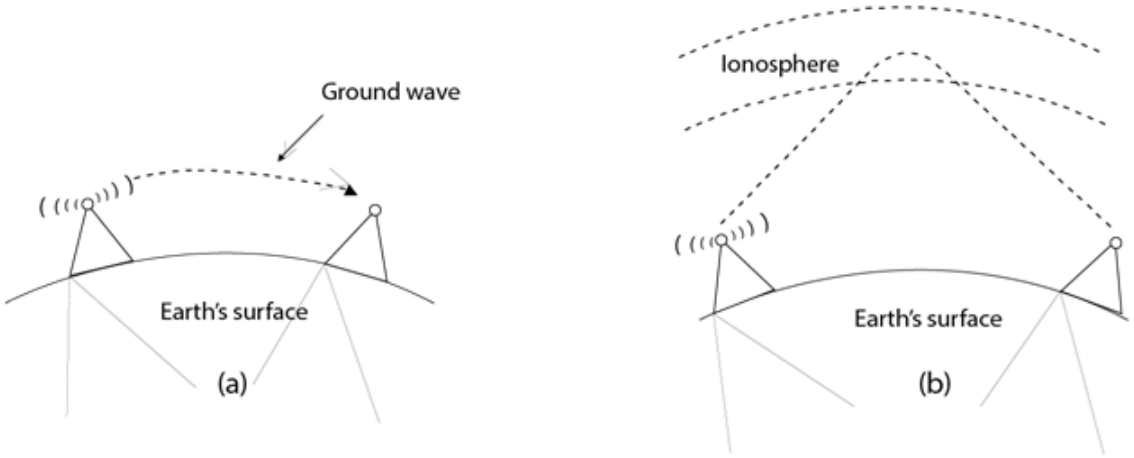
UnGuided Transmission

- An unguided transmission transmits the electromagnetic waves without using any physical medium. Therefore it is also known as **wireless transmission**.
- In unguided media, air is the media through which the electromagnetic energy can flow easily.

Unguided transmission is broadly classified into three categories:

Radio waves

- Radio waves are the electromagnetic waves that are transmitted in all the directions of free space.
- Radio waves are omnidirectional, i.e., the signals are propagated in all the directions.
- The range in frequencies of radio waves is from 3Khz to 1 khz.
- In the case of radio waves, the sending and receiving antenna are not aligned, i.e., the wave sent by the sending antenna can be received by any receiving antenna.
- An example of the radio wave is **FM radio**.



Applications Of Radio waves:

- A Radio wave is useful for multicasting when there is one sender and many receivers.
- An FM radio, television, cordless phones are examples of a radio wave.

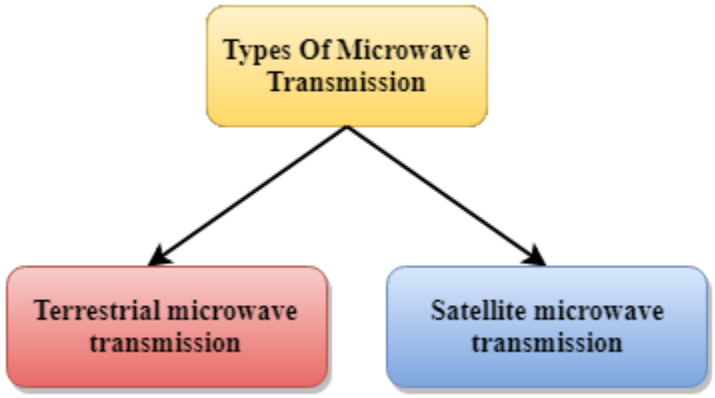
Advantages Of Radio transmission:

- Radio transmission is mainly used for wide area networks and mobile cellular phones.
- Radio waves cover a large area, and they can penetrate the walls.
- Radio transmission provides a higher transmission rate.

Microwaves

Microwaves are of two types:

- Terrestrial microwave
- Satellite microwave communication.



Terrestrial Microwave Transmission

- Terrestrial Microwave transmission is a technology that transmits the focused beam of a radio signal from one ground-based microwave transmission antenna to another.
- Microwaves are the electromagnetic waves having the frequency in the range from 1GHz to 1000 GHz.
- Microwaves are unidirectional as the sending and receiving antenna is to be aligned, i.e., the waves sent by the sending antenna are narrowly focussed.
- In this case, antennas are mounted on the towers to send a beam to another antenna which is km away.
- It works on the line of sight transmission, i.e., the antennas mounted on the towers are the direct sight of each other.

Characteristics of Microwave:

- **Frequency range:** The frequency range of terrestrial microwave is from 4-6 GHz to 21-23 GHz.
- **Bandwidth:** It supports the bandwidth from 1 to 10 Mbps.
- **Short distance:** It is inexpensive for short distance.
- **Long distance:** It is expensive as it requires a higher tower for a longer distance.
- **Attenuation:** Attenuation means loss of signal. It is affected by environmental conditions and antenna size.

Advantages Of Microwave:

- Microwave transmission is cheaper than using cables.

- It is free from land acquisition as it does not require any land for the installation of cables.
- Microwave transmission provides an easy communication in terrains as the installation of cable in terrain is quite a difficult task.
- Communication over oceans can be achieved by using microwave transmission.

Disadvantages of Microwave transmission:

- **Eavesdropping:** An eavesdropping creates insecure communication. Any malicious user can catch the signal in the air by using its own antenna.
- **Out of phase signal:** A signal can be moved out of phase by using microwave transmission.
- **Susceptible to weather condition:** A microwave transmission is susceptible to weather condition. This means that any environmental change such as rain, wind can distort the signal.
- **Bandwidth limited:** Allocation of bandwidth is limited in the case of microwave transmission.

Satellite Microwave Communication

- A satellite is a physical object that revolves around the earth at a known height.
- Satellite communication is more reliable nowadays as it offers more flexibility than cable and fibre optic systems.
- We can communicate with any point on the globe by using satellite communication.

How Does Satellite work?

The satellite accepts the signal that is transmitted from the earth station, and it amplifies the signal. The amplified signal is retransmitted to another earth station.

Advantages Of Satellite Microwave Communication:

- The coverage area of a satellite microwave is more than the terrestrial microwave.
- The transmission cost of the satellite is independent of the distance from the centre of the coverage area.
- Satellite communication is used in mobile and wireless communication applications.

- It is easy to install.
- It is used in a wide variety of applications such as weather forecasting, radio/TV signal broadcasting, mobile communication, etc.

Disadvantages Of Satellite Microwave Communication:

- Satellite designing and development requires more time and higher cost.
- The Satellite needs to be monitored and controlled on regular periods so that it remains in orbit.
- The life of the satellite is about 12-15 years. Due to this reason, another launch of the satellite has to be planned before it becomes non-functional.

Infrared

- An infrared transmission is a wireless technology used for communication over short ranges.
- The frequency of the infrared in the range from 300 GHz to 400 THz.
- It is used for short-range communication such as data transfer between two cell phones, TV remote operation, data transfer between a computer and cell phone resides in the same closed area.

Characteristics Of Infrared:

- It supports high bandwidth, and hence the data rate will be very high.
- Infrared waves cannot penetrate the walls. Therefore, the infrared communication in one room cannot be interrupted by the nearby rooms.
- An infrared communication provides better security with minimum interference.
- Infrared communication is unreliable outside the building because the sun rays will interfere with the infrared waves.

Performance indicators

Performance

The effectiveness of computations distributed over the network often depends directly on the efficiency with which the network delivers the computation's data. Network performance is measured in two fundamental ways: bandwidth
(also called throughput) and latency (also called delay).

Bandwidth

One characteristic that measures network performance is bandwidth. However, the term can be used in two different contexts with two different measuring values: bandwidth in hertz and bandwidth in bits per second.

Bandwidth in Hertz

Bandwidth in hertz is the range of frequencies contained in a composite signal or the range of frequencies a channel can pass. For example, we can say the bandwidth of a subscriber telephone line is 4 kHz.

Bandwidth in Bits per Seconds

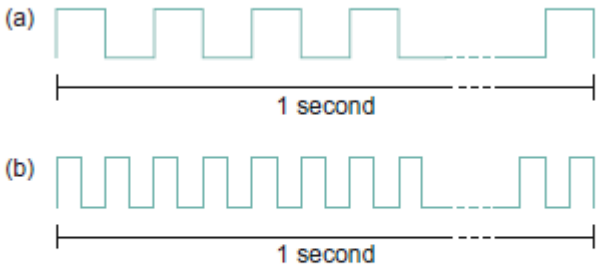
The term bandwidth can also refer to the number of bits per second that a channel, a link, or even a network can transmit. For example, one can say the bandwidth of a Fast Ethernet network (or the links in this network) is a maximum of 100 Mbps. This means that this network can send 100Mbps.

Relationship

There is an explicit relationship between the bandwidth in hertz and bandwidth in bits per seconds. Basically, an increase in bandwidth in hertz means an increase in bandwidth in bits per second. The relationship depends on whether we have baseband transmission or transmission with modulation.

The bandwidth of a network is given by the number of bits that can be transmitted over the network in a certain period of time. For example, a network might have
a bandwidth of 10 million bits/second (Mbps), meaning that it is able to
deliver 10 million bits every second. It is sometimes useful to think of bandwidth in terms of how long it takes to transmit each bit of data. On a10-Mbps network, for example, it takes 0.1

microseconds (μs) to transmit each bit. For example, each bit on a 1-Mbps link is 1 μs wide, while each bit on a 2-Mbps link is 0.5 μs wide, as illustrated in Figure 1.16.



■ **FIGURE 1.16** Bits transmitted at a particular bandwidth can be regarded as having some width: (a) bits transmitted at 1 Mbps (each bit is 1 μs wide); (b) bits transmitted at 2 Mbps (each bit is 0.5 μs wide).

Throughput

The throughput is a measure of how fast we can actually send data through a network. Although, at first glance, bandwidth in bits per second and throughput seem the same, they are different. A link may have a bandwidth of B bps, but we can only send T bps through this link with T always less than B. In other words, the bandwidth is a potential measurement of a link; the throughput is an actual measurement of how fast we can send data. For example, we may have a link with a bandwidth of 1 Mbps, but the devices connected to the end of the link may handle only 200 kbps. This means that we cannot send more than 200 kbps through this link.

Latency (Delay)

The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

The second performance metric, latency, corresponds to how long it takes a message to travel from one end of a network to the other. (As with bandwidth, we could be focused on the latency of a single link or an end-to-end channel.) Latency is measured strictly in terms of time. For

example, a transcontinental network might have a latency of 24 milliseconds (ms); that is, it takes a message 24 ms to travel from one coast of North America to the other.

We can say that latency is made of four components: propagation time, transmission time, queuing time and processing delay.

Latency = propagation time + transmission time + queuing time + processing delay

Propagation Time

Propagation time measures the time required for a bit to travel from the source to the destination. The propagation time is calculated by dividing the distance by the propagation speed. The propagation speed of electromagnetic signals depends on the medium and on the frequency of the signal.

Propagation time = Distance/Speed

Transmission Time

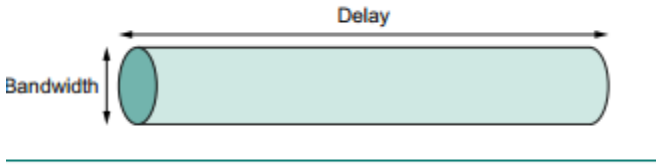
In data communications we don't send just 1 bit, we send a message. The first bit may take a time equal to the propagation time to reach its destination; the last bit also may take the same amount of time. However, there is a time between the first bit leaving the sender and the last bit arriving at the receiver. The first bit leaves earlier and arrives earlier; the last bit leaves later and arrives later. The time required for transmission of a message depends on the size of the message and the bandwidth of the channel.

Transmit time = Size of the message/Bandwidth

Queuing Time

The third component in latency is the queuing time, the time needed for each intermediate or end device to hold the message before it can be processed. The queuing time is not a fixed factor; it changes with the load imposed on the network. When there is heavy traffic on the network, the queuing time increases. An intermediate device, such as a router, queues the arrived messages and processes them one by one. If there are many messages, each message will have to wait.

Delay × Bandwidth Product



18 Network as a pipe.

Let a channel between a pair of processes as a hollow pipe , where the latency corresponds to the length of the pipe and the bandwidth gives the diameter of the pipe, then the delay × bandwidth product gives the volume of the pipe—**the maximum number of bits that could be in transit through the pipe at any given instant**. Said another way, if latency (measured in time) corresponds to the length of the pipe, then given the width of each bit (also measured in time) you can calculate how many bits fit in the pipe. For example, a transcontinental channel with a one-way latency of 50 ms and a bandwidth of 45 Mbps is able to hold

50×10^{-3} s $\times 45 \times 10^{6}$ bits/s= 2.25×10^{6} bits or approximately 280 KB of data.

In other words, this example channel (pipe) holds as many bytes as the memory of a personal computer from the early 1980s could hold.

Q: the distance between the sender and receiver systems is about 200 KM. The speed of the transmission is 2Gb/s. Find out Propagation Time?

Propagation = Distance/Speed

$=200*10^{3}/2*10^{9}$

$=100*10^{-6}$ s

Interconnecting devices

Repeater

- Layer 1 device

A single Ethernet segment can have a maximum length of 500 meters with a maximum of 100 stations (in a cheapernet segment it is 185m). To extend the length of the network, a repeater may be used as shown in Fig. Functionally, a repeater can be considered as two transceivers joined together and connected to two different segments of coaxial cable. The repeater passes the digital signal bit-by-bit in both directions between the two segments. As the signal passes through a repeater, it is amplified and regenerated at the other end.

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 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 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 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.

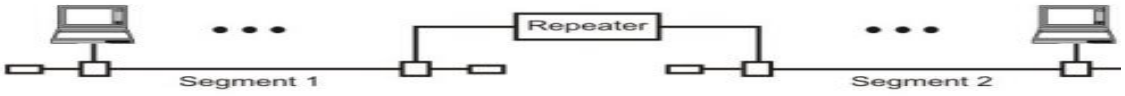


Figure 6.1.1 Repeater connecting two LAN segments

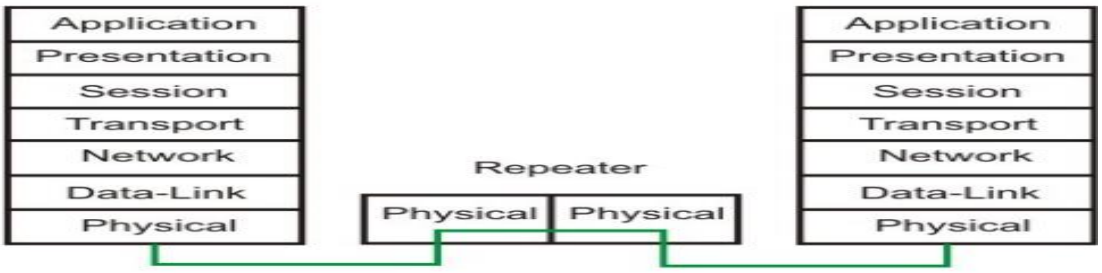


Figure 6.1.2 Operation of a repeater as a level-1 relay

Hub

- Multiport repeater
- Layer 1 device
- It can be used to create multiple levels of hierarchy of stations. The stations connect to the hub with RJ-45 connector having maximum segment length is 100 meters. This type of interconnected set of stations is easy to maintain and diagnose. Whenever a station wants to send a data it will send it to the hub. Hub will broadcast the data to all the stations which are connected to it.
- Hubs cannot filter data, so data packets are sent to all connected devices. In other words, the collision domain of all hosts connected through Hub remains one. Also, they do not have the intelligence to find out the best path for data packets which leads to inefficiencies and wastage.
- Active (regenerate the signal before broadcasting) and passive hubs (provide simply a path)
- Active Hub:- These are the hubs that have their own power supply and can clean, boost, and relay the signal along with the network. It serves both as a repeater as well as a wiring center. These are used to extend the maximum distance between nodes.
- Passive Hub :- These are the hubs that collect wiring from nodes and power supply from the active hub. These hubs relay signals onto the network without cleaning and boosting them and can't be used to extend the distance between nodes.

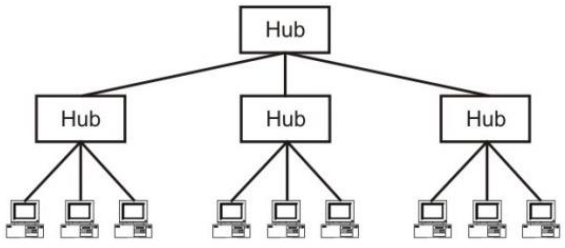


Figure 6.1.3 Hub as a multi-port repeater can be connected in a hierarchical manner to form a single LAN with many nodes

Bridge

- The device that can be used to interconnect two separate LANs is known as a bridge. It is commonly used to connect two similar or dissimilar LANs
- Layer 2 device
- 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.

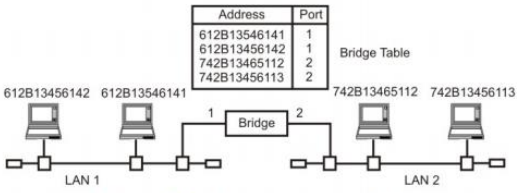


Figure 6.1.4 A bridge connecting two separate LANs

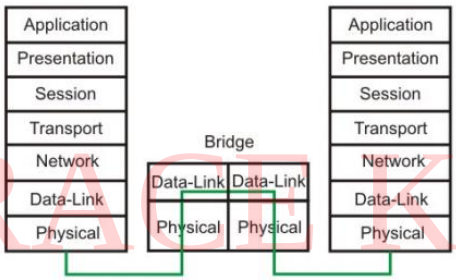


Figure 6.1.5 Information flow through a bridge

Switch

- Layer 2 device
- A switch is essentially a fast bridge having additional sophistication that allows faster processing of frames. Some of important functionalities are:
- Ports are provided with buffer
- Switch maintains a directory: #address - port#
- Each frame is forwarded after examining the #address and forwarded to the proper port#
- . The switch can perform error checking before forwarding data, which makes it very efficient as it does not forward packets that have errors and forward good packets selectively to the correct port only

Router

- A router is considered as a layer-3 relay that operates in the network layer, that is it acts on network layer frames.
- It can be used to link two dissimilar LANs.(different similar networks), similar LAN tohether, similar WAN together or LAN to WAN together
- A router isolates LANs in to subnets to manage and control network traffic. However, unlike bridges it is not transparent to end stations.
- Routers normally connect LANs and WANs together and have a dynamically updating routing table based on which they make decisions on routing the data packets. Router divide broadcast domains of hosts connected through it.

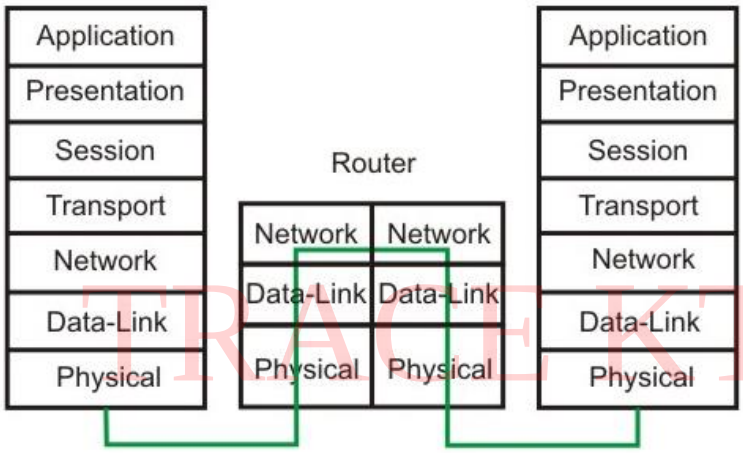


Figure 6.1.16 Communication through a router

Gateway

- Protocol converter
- It connects two or more different dissimilar networks
- Translates one format to another
- 7 layer device
- It is a passage to connect two networks together that may work upon different networking models. They basically work as the messenger agents that take data from one system, interpret it, and transfer it to another system. Gateways are also called protocol converters and can operate at any network layer. Gateways are generally more complex than switches or routers.

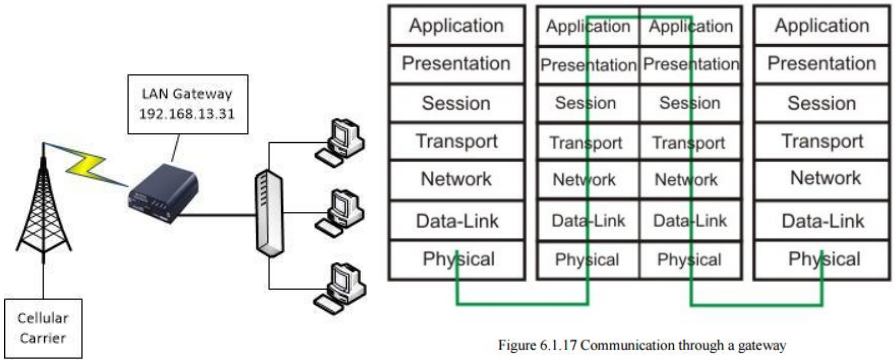


Figure 6.1.17 Communication through a gateway