NETWORKS

A network is a set of devices (often referred to as nodes) connected by communication links. A node can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network.

“Computer network’’ to mean a collection of autonomous computers interconnected by a single technology. Two computers are said to be interconnected if they are able to exchange information.

The connection need not be via a copper wire; fiber optics, microwaves, infrared, and communication satellites can also be used.

USES OF COMPUTER NETWORKS

1. Business Applications

 to distribute information throughout the company (resource sharing). sharing physical resources such as printers, and tape backup systems, is sharing information

 client-server model. It is widely used and forms the basis of much network usage.

 communication medium among employees.email (electronic mail), which employees generally use for a great deal of daily communication.

 Telephone calls between employees may be carried by the computer network instead of by the phone company. This technology is called IP telephony or Voice over IP (VoIP) when Internet technology is used.

- Desktop sharing lets remote workers see and interact with a graphical computer screen
- doing business electronically, especially with customers and suppliers. This new model is called e-commerce (electronic commerce) and it has grown rapidly in recent years.

2 Home Applications

- peer-to-peer communication
- person-to-person communication
- electronic commerce
- entertainment.(game playing,)

3 Mobile Users

- Text messaging or texting
- Smart phones,
- GPS (Global Positioning System)
- m-commerce
- NFC (Near Field Communication)

Physical Structures

Before discussing networks, we need to define some network attributes.

Type of Connection

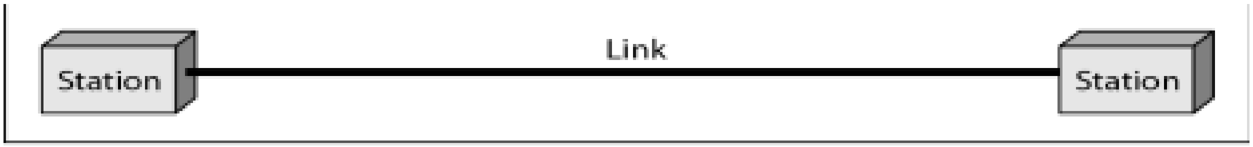
A network is two or more devices connected through links. A link is a communications pathway that transfers data from one device to another. There are two possible types of connections: point-to-point and multipoint.

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

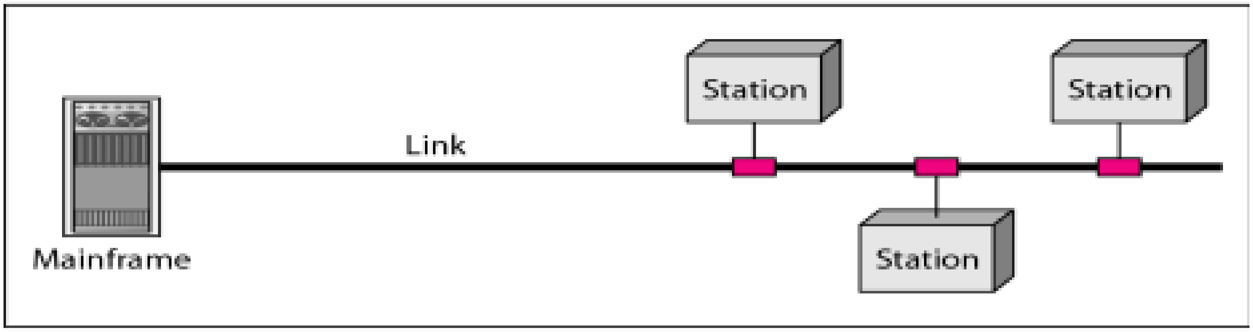
When you change television channels by infrared remote control, you are establishing a point-to-point connection between the remote control and the television's control system.

Multipoint A multipoint (also called multi-drop) 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. If several devices can use the link simultaneously, it is a *spatially shared* connection. If users must take turns, it is a *timeshared* connection.



a. Point-to-point

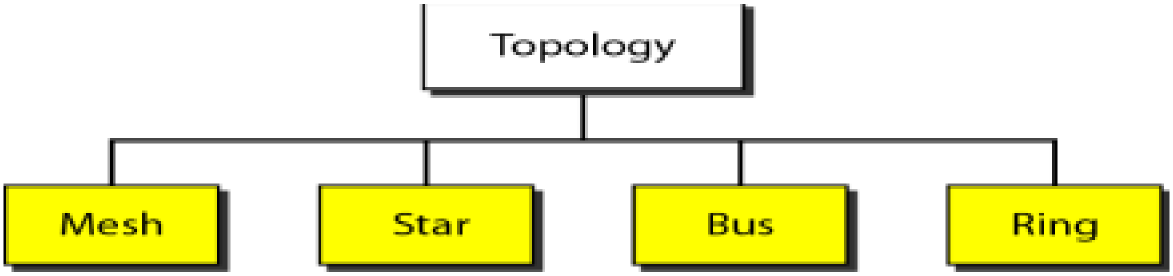


b. Multipoint

Physical Topology

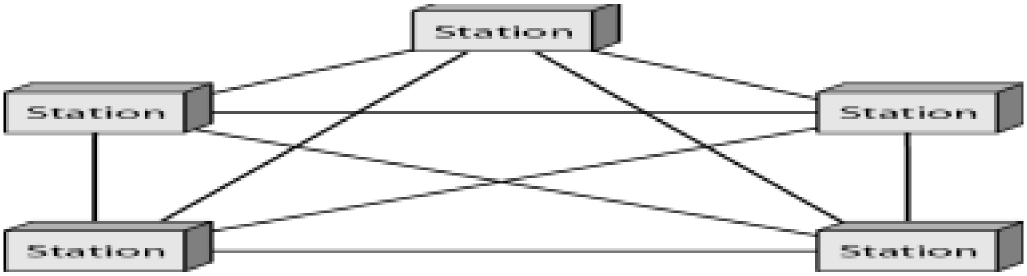
The term *physical topology* refers to the way in which a network is laid out physically.

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**



MESH:

A mesh topology is the one where every node is connected to every other node in the network.



A mesh topology can be a **full mesh topology** or a **partially connected mesh topology**.

In a *full mesh topology*, every computer in the network has a connection to each of the other computers in that network. The number of connections in thisnetwork can be calculated using the following formula (***n*** is the number of computers in the network): **n(n-1)/2**

In a *partially connected mesh topology*, at least two of the computers in the network have connections to multiple other computers in that network. It is an inexpensive way to implement redundancy in a network. In the event that one of the primary computers or connections in the network fails, the rest of the network continues to operate normally.

Advantages of a mesh topology

· Can handle high amounts of traffic, because multiple devices can transmit data simultaneously.

· A failure of one device does not cause a break in the network or transmission of data.

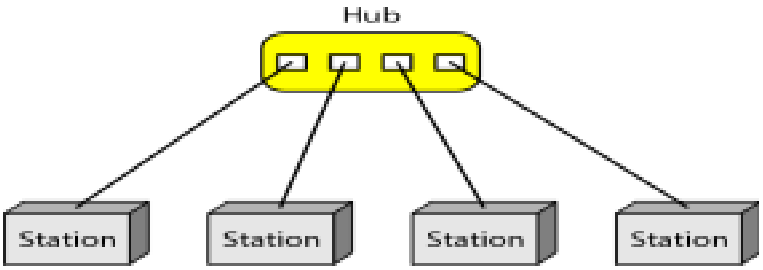
· Adding additional devices does not disrupt data transmission between other devices.

Disadvantages of a mesh topology

· The cost to implement is higher than other network topologies, making it a less desirable option.

·Building and maintaining the topology is difficult and time consuming. · The chance of redundant connections is high, which adds to the high costs and potential for reduced efficiency.

STAR:



A star network, star topology is one of the most common network setups. In this configuration, every node connects to a central network device, like a hub, switch, or computer. The central network device acts as a server and the peripheral devices act as clients.

Advantages of star topology

· Centralized management of the network, through the use of the hub, or switch.

· Easy to add another computer to the network.

· If one computer on the network fails, the rest of the network continues to function normally.

· The star topology is used in local-area networks (LANs), High-speed LANs often use a star topology with a central hub.

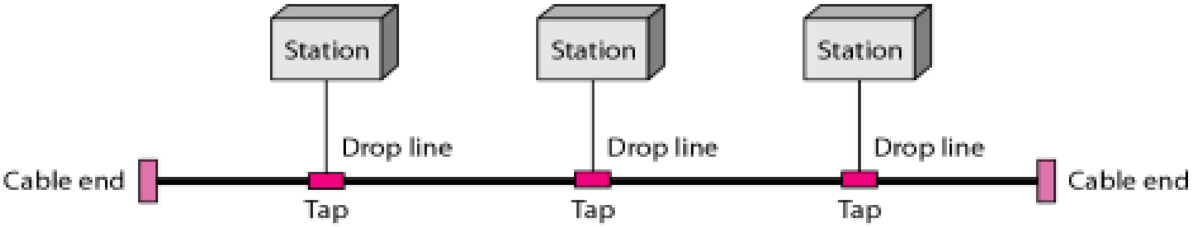
Disadvantages of star topology

· Can have a higher cost to implement, especially when using a switch or router as the central network device.

· The central network device determines the performance and number of nodes the network can handle.

· If the central computer, hub, or switch fails, the entire network goes down and all computers are disconnected from the network

BUS:



a **bus topology** is a network setup in which each computer and network device are connected to a single cable or backbone. Advantages of bus topology

· It works well for small network.

· It's the easiest network topology for connecting computers or peripherals in a linear fashion.

· It requires less cable length than a star topology.

Disadvantages of bus topology

· It can be difficult to identify the problems if the whole network goes down.

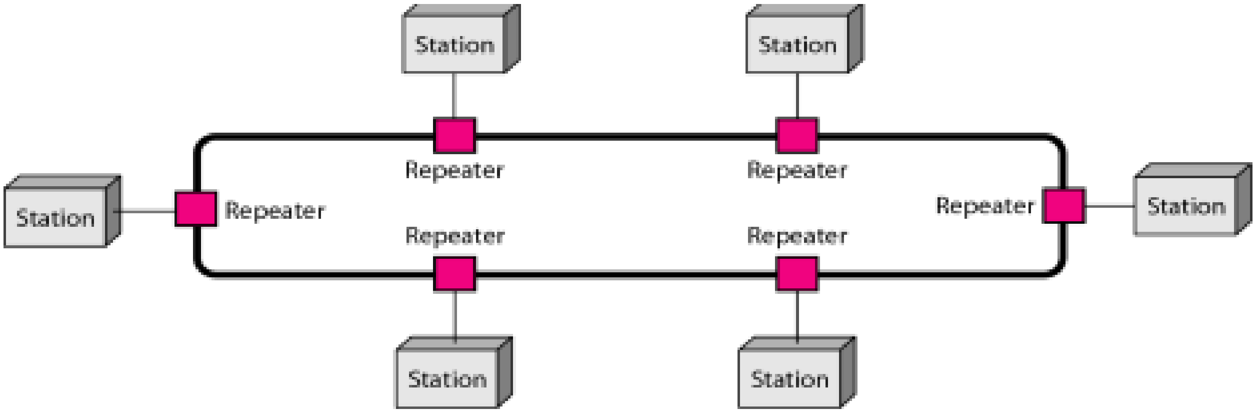
· Bus topology is not good for large networks.

· Terminators are required for both ends of the main cable.

· Additional devices slow the network down.

· If a main cable is damaged, the network fails or splits into two.

RING:



A **ring topology** is a network configuration in which device connections create a circular data path. In a ring network, packets of data travel from one device to the next until they reach their destination. Most ring topologies allow packets to travel only in one direction, called a **unidirectional** ring network. Others permit data to move in either direction, called **bidirectional**.

The major disadvantage of a ring topology is that if any individual connection in the ring is broken, the entire network is affected.

Ring topologies may be used in either local area networks (LANs) or wide area networks (WANs).

Advantages of ring topology

· All data flows in one direction, reducing the chance of packet collisions. ·

A network server is not needed to control network connectivity between each workstation.

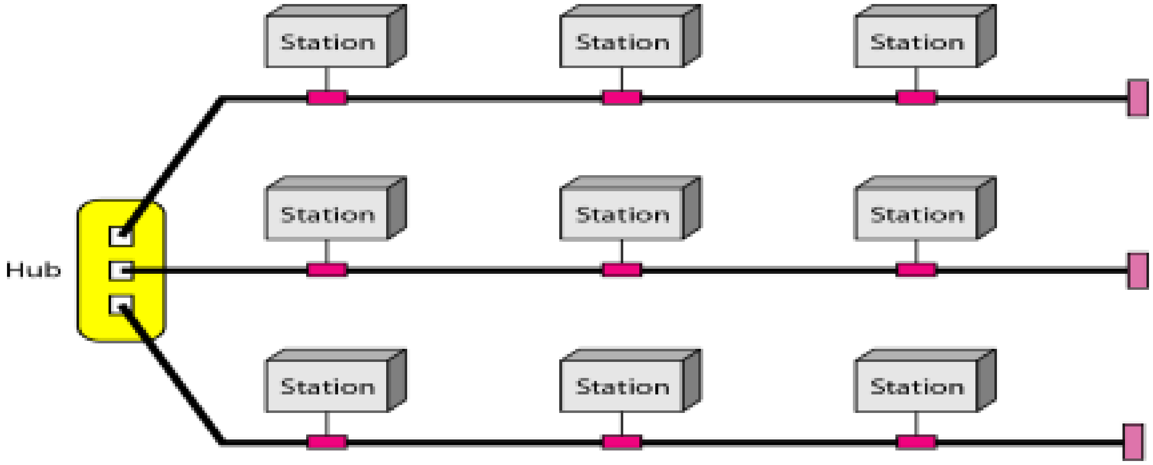
· Data can transfer between workstations at high speeds. · Additional workstations can be added without impacting performance of the network.

Disadvantages of ring topology

·All data being transferred over the network must pass through each workstation on the network, which can make it slower than a star topology.

The entire network will be impacted if one workstation shuts down. · The hardware needed to connect each workstation to the network is more expensive than Ethernet cards and hubs/switches.

Hybrid Topology A network can be hybrid. For example, we can have a main star topology with each branch connecting several stations in a bus topology as shown in Figure



Types of Network based on size

The types of network are classified based upon the size, the area it covers and its physical architecture. The three primary network categories are LAN, WAN and MAN. Each network differs in their characteristics such as distance, transmission speed, cables and cost.

Basic types

LAN (Local Area Network)

Group of interconnected computers within a small area. (room, building, campus) .

LAN helps to share files, folders, printers, applications and other devices.

Coaxial or CAT 5 cables are normally used for connections.

Due to short distances, errors and noise are minimum.

Data transfer rate is 10 to 100 mbps.

Example: A computer lab in a school.

MAN (Metropolitan Area Network)

Design to extend over a large area.

Connecting number of LAN's to form larger network, so that resources can be shared.

Networks can be up to 5 to 50 km.

Owned by organization or individual.

Data transfer rate is low compare to LAN.

Example: Organization with different branches located in the city, cable tv networks

WAN (Wide Area Network)

Span over a country, a continent etc..

Contains multiple LAN's and MAN's.

Distinguished in terms of geographical range.

Uses satellites and microwave relays.

Data transfer rate depends upon the ISP provider and varies over the location. Best example is the internet.

Other types

WLAN (Wireless LAN)

A LAN that uses high frequency radio waves for communication. Provides short range connectivity with high speed data transmission.

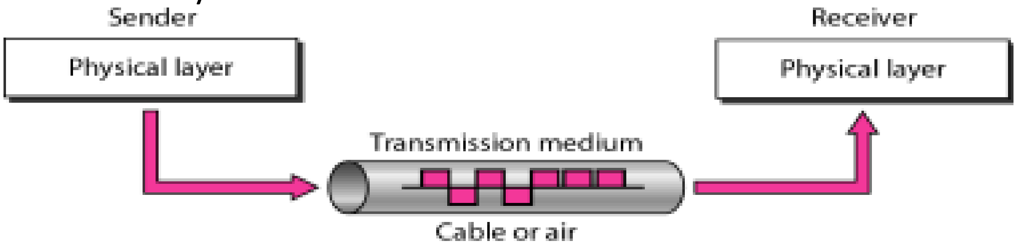
PAN (Personal Area Network)

Network organized by the individual user for its personal use. **SAN (Storage Area Network)**

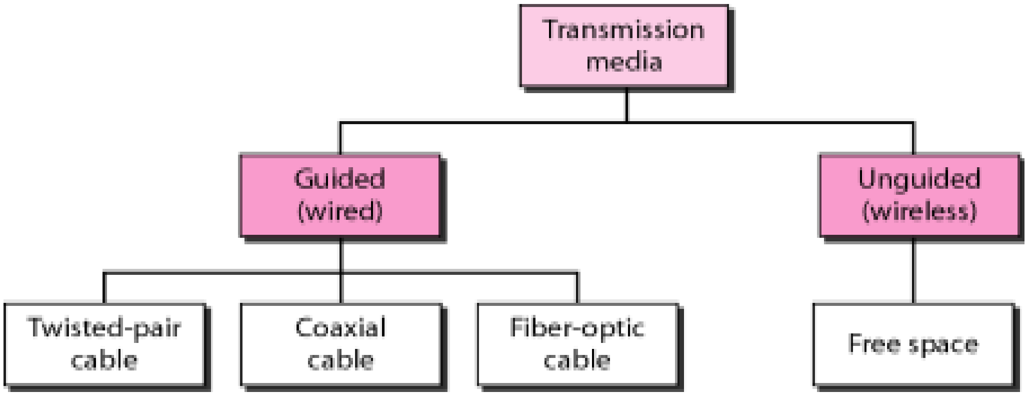
Connects servers to data storage devices via fiber-optic cables. E.g.: Used for daily backup of organization or a mirror copy

MEDIUM

A **transmission medium** can be broadly defined as anything that can carry information from a source to a destination.

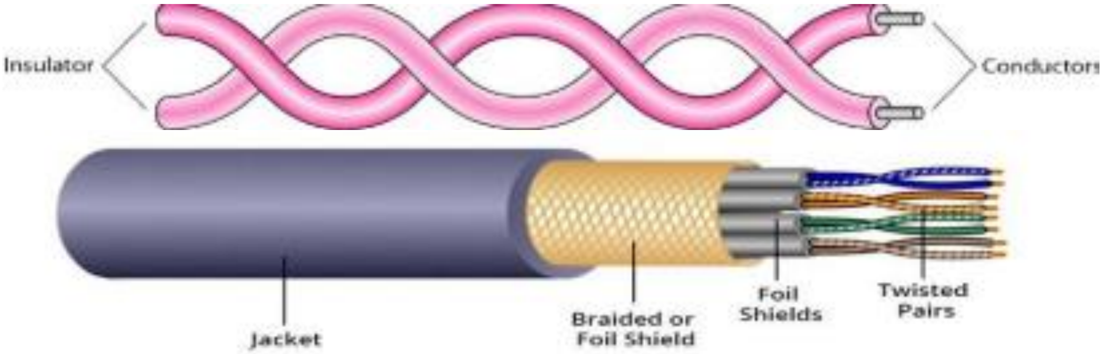


Classes of transmission media



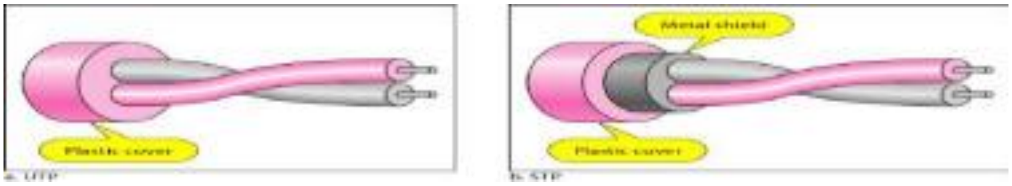
Guided Media: Guided media, which are those that provide a medium from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.

Twisted-Pair Cable: A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together. One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.



Unshielded Versus Shielded Twisted-Pair Cable

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



The most common UTP connector is RJ45 (RJ stands for registered jack)

Applications

Twisted-pair cables are used in telephone lines to provide voice and data channels.

Local-area networks, such as l0Base-T and l00Base-T, also use twisted-pair cables.

Coaxial Cable

Coaxial cable (or *coax)* carries signals of higher frequency ranges than those in twisted pair cable. coax has a central core conductor (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid. The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

The most common type of connector used today is the Bayone-Neill-Concelman (BNe), connector.

Applications

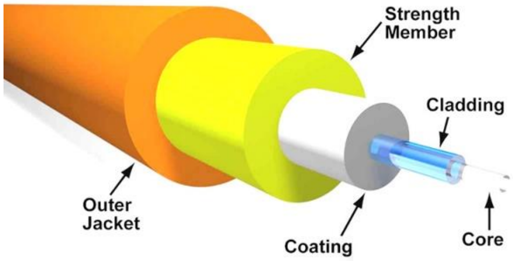
Coaxial cable was widely used in analog telephone networks,digital telephone networks

Cable TV networks also use coaxial cables.

Another common application of coaxial cable is in traditional Ethernet LANs

Fiber-Optic Cable

A fiber-optic cable is made of glass or plastic and transmits signals in the form of light. fibers use reflection to guide light through a channel. A glass or plastic core is surrounded by a cladding of less dense glass or plastic.



The **subscriber channel** (SC) **connector,** The **straight-tip** (ST) **connector, MT-RJ(mechanical transfer registered jack)** is a connector

Applications

Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective..

Some cable TV companies use a combination of optical fiber and coaxial cable,thus creating a hybrid network.

Local-area networks such as 100Base-FX network (Fast Ethernet) and 1000Base-X also use fiber-optic cable

Advantages and Disadvantages of Optical Fiber

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

1 Higher bandwidth.

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

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

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

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

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

Disadvantages There are some disadvantages in the use of optical fiber.

1Installation and maintenance

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

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

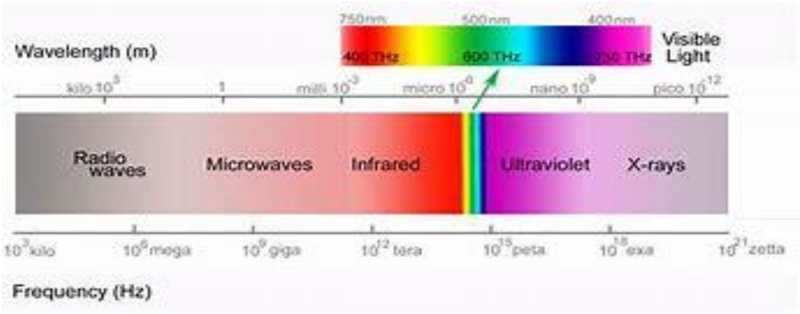
UNGUIDED MEDIA: WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.

Radio Waves

Microwaves

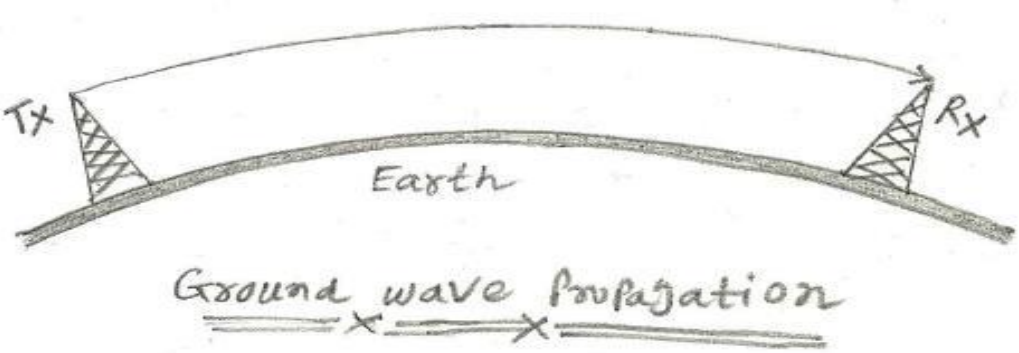
Infrared



Propagation modes

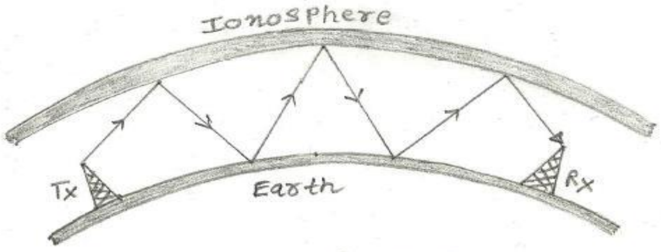
Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation.

Ground wave



Ground wave Propagation

Ground Ground Wave propagation is a method of radio wave propagation that uses the area between the surface of the earth and the ionosphere for transmission, it. Ground wave propagation is also called surface wave propagation. The ground wave follows the contour of the earth and hence it can propagate considerable distances.



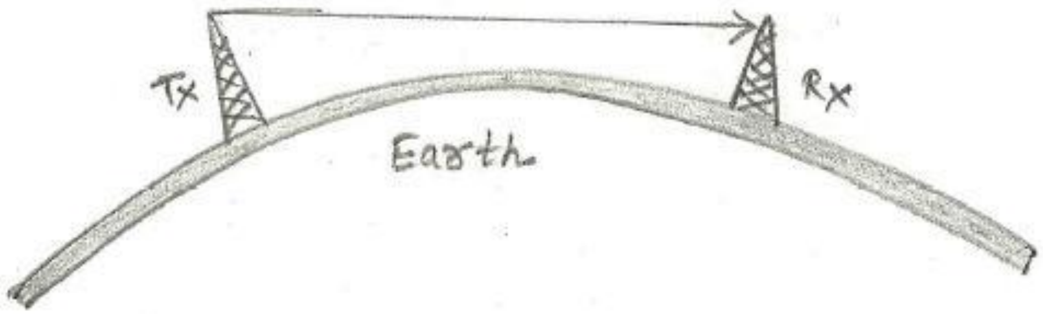
sky wave Propagation

Sky wave

Sky wave A radio wave directed towards the sky and reflected by the ionosphere towards the desired location of the earth is called a sky wave.
The radio waves of frequency range 3MHz to 30MHz are suitable for sky wave propagation.

This range of frequencies are reflected by the ionosphere towards the earth. The electromagnetic wave of frequencies higher than 30MHz penetrates the ionosphere and are not reflected back.

LOS wave



Line-of-Sight Propagation

Line-of-Sight (LoS) propagation is a characteristic of electromagnetic radiation in which two stations can only transmit and receive data signals when they're in direct view of each other with no obstacles in between. Satellite and microwave transmission are two common examples of LoS communication. All radio waves with a frequency greater than 2 MHz have an LoS characteristic.

Radio Waves

Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves. Radio waves are omni directional. When an antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned. A sending antenna sends waves that can be received by any receiving antenna. The omni directional property has a disadvantage, too. The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.

Omni directional Antenna

Radio waves use omnidirectional antennas that send out signals in all directions. Based on the wavelength, strength, and the purpose of transmission, we can have several types of antennas

Applications

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

Microwaves

Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. The sending and receiving antennas need to be aligned. The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas

Unidirectional Antenna

Microwaves need unidirectional antennas that send out signals in one direction. Two types of antennas are used for microwave communications: the parabolic dish and the horn

Applications:

Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs

Infrared

Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls. This advantageous characteristic prevents interference between one system and another.

When we use our infrared remote control, we do not interfere with the use of the remote by our neighbors. Infrared signals useless for long-range communication. In addition, we cannot use infrared waves outside a building because the sun's rays contain infrared waves that can interfere with the communication.

Applications:

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

ISO OSI MODEL

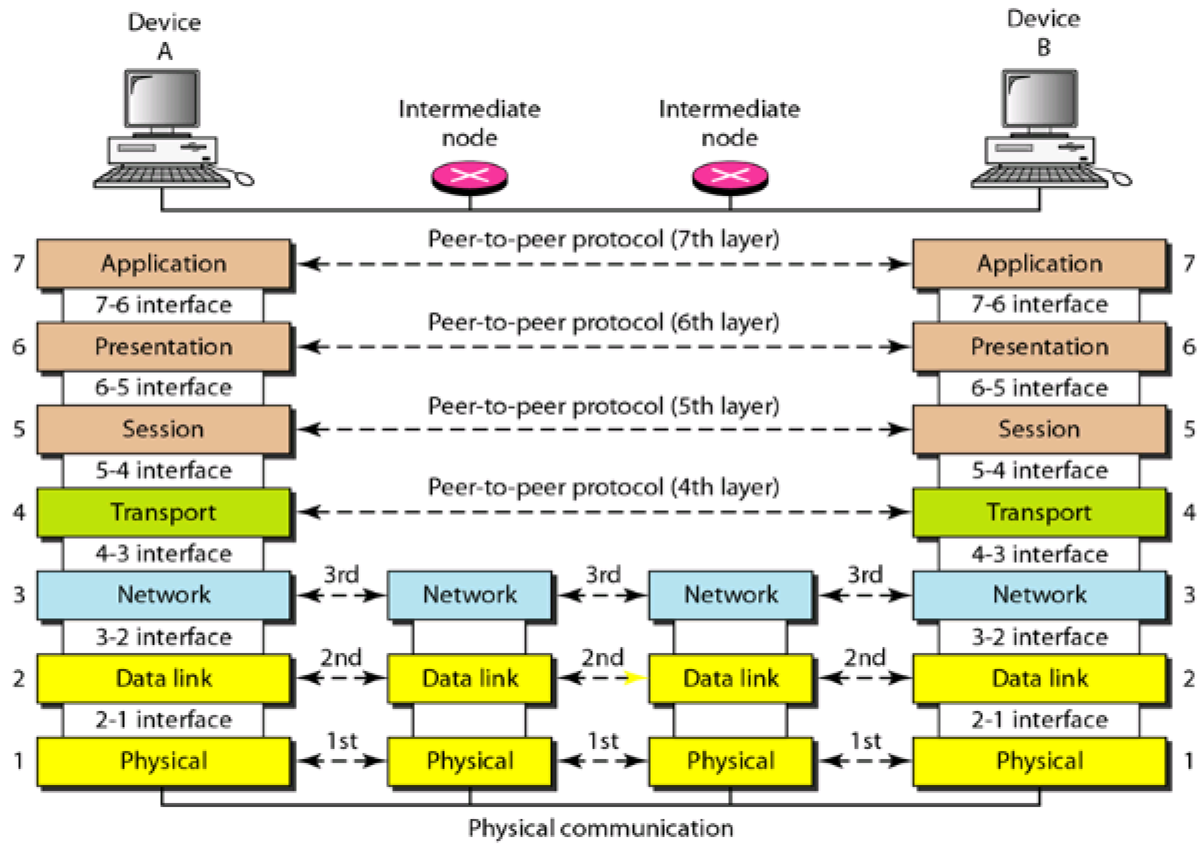
Layers of OSI Model

OSI stands for **Open Systems Interconnection**. It has been developed by ISO – '**International Organization for Standardization**', in the year 1984. It is a 7 layer architecture with each layer having specific functionality to perform. All these 7 layers work collaboratively to transmit the data from one person to another across the globe. Layers 1,2 and 3 are called lower layers of osi model and layers 5,6,and 7 are called upper layers of osi model.Lowerlayers are implemented in hardware and upper layers are implemented as softwares.

Lower layers will provide services to upper layer.

What is a protocol stack and why is it layered?

Protocol stacks are **a layered collection of protocols that work together to provide communication services**. Each protocol in the stack is responsible for a specific task, and by layering them, we can create a more robust and reliable system



Physical Layer (Layer 1) :

The lowest layer of the OSI reference model is the physical layer.

The physical layer contains information in the form of **bits.**

It is responsible for transmitting individual bits from one node to the next. When receiving data, this layer will get the signal received and convert it into 0s and 1s and send them to the Data Link layer.

The functions of the physical layer are as follows:

1. **Bit synchronization:** The physical layer provides the synchronization of the bits by providing a clock. This clock controls both sender and receiver thus providing synchronization at bit level.
2. **Bit rate control:** The Physical layer also defines the transmission rate i.e. the number of bits sent per second.
3. **Physical topologies:** Physical layer specifies the way in which the different, devices/nodes are arranged in a network i.e. bus, star, or mesh topology.
4. **Transmission mode:** Physical layer also defines the way in which the data flows between the two connected devices. The various transmission modes possible are Simplex, half-duplex and full-duplex.

* Hub, Repeater, Modem, Cables are Physical Layer devices.

2. Data Link Layer (DLL) (Layer 2) :
The data link layer is responsible for the node-to-node delivery of the message. The main function of this layer is to make sure data transfer is error-free from one node to another, over the physical layer. When a packet arrives in a network, it is the responsibility of DLL to transmit it to the Host using its MAC address.
Data Link Layer is divided into two sublayers:

1. Logical Link Control (LLC)
2. Media Access Control (MAC)

The functions of the Data Link layer are :

1. **Framing:** . It provides a way for a sender to transmit a set of bits that are meaningful to the receiver. This can be accomplished by attaching special bit patterns to the beginning and end of the frame.
2. **Physical addressing:** After creating frames, the Data link layer adds physical addresses (MAC address) of the sender and/or receiver in the header of each frame.
3. **Error control:** Data link layer provides the mechanism of error control in which it detects and retransmits damaged or lost frames.
4. **Flow Control:** The data rate must be constant on both sides else the data may get corrupted thus**, flow control coordinates the amount of data that can be sent before receiving acknowledgement.**
5. **Access control:** When a single communication channel is shared by multiple devices, the MAC sub-layer of the data link layer helps to determine which device has control over the channel at a given time.

** Packet in Data Link layer is referred to as **Frame.***
** Data Link layer is handled by the NIC (Network Interface Card) and device drivers of host machines.
*** Switch & Bridge are Data Link Layer devices.

3. Network Layer (Layer 3) :
The network layer works for the transmission of data from one host to the other located in different networks. It also takes care of packet routing i.e. selection of the shortest path to transmit the packet, from the number of routes available. The sender & receiver’s IP addresses are placed in the header by the network layer.

The functions of the Network layer are :

1. **Routing:** The network layer protocols determine which route is suitable from source to destination. This function of the network layer is known as routing.
2. **Logical Addressing:** In order to identify each device on internetwork uniquely, the network layer defines an addressing scheme. The sender & receiver's IP addresses are placed in the header by the network layer. Such an address distinguishes each device uniquely and universally.

** Segment* in Network layer is referred to as **Packet**.

** Network layer is implemented by networking devices such as routers.

4. Transport Layer (Layer 4) :

The transport layer provides services to the application layer and takes services from the network layer. The data in the transport layer is referred to as *Segments*. It is responsible for **the End to End Delivery of the complete message**. The transport layer also provides the acknowledgement of the successful data transmission and re-transmits the data if an error is found.

At sender's side: Transport layer receives the formatted data from the upper layers, performs **Segmentation**, and also implements **Flow & Error control** to ensure proper data transmission. It also adds Source and Destination port numbers in its header and forwards the segmented data to the Network Layer.

Note: *The sender needs to know the port number associated with the receiver's application.*

Generally, this destination port number is configured, either by default or manually. For example, when a web application makes a request to a web server, it typically uses port number 80, because this is the default port assigned to web applications. Many applications have default ports assigned.

At receiver's side: Transport Layer reads the port number from its header and forwards the Data which it has received to the respective application. It also performs sequencing and reassembling of the segmented data.

The functions of the transport layer are as follows:

1. **Segmentation and Reassembly:** This layer accepts the message from the (session) layer, and breaks the message into smaller units. Each of the segments produced has a header associated with it. The transport layer at the destination station reassembles the message.
2. **Service Point Addressing:** In order to deliver the message to the correct process, the transport layer header includes a type of address called service point address or port address. Thus by specifying this address, the transport layer makes sure that the message is delivered to the correct process.

The services provided by the transport layer :

A. Connection-Oriented Service: It is a three-phase process that includes
– Connection Establishment
– Data Transfer
– Termination / disconnection

In this type of transmission, the receiving device sends an acknowledgement, back to the source after a packet or group of packets is received. This type of transmission is reliable and secure.

B. Connectionless service: It is a one-phase process and includes Data Transfer. In this type of transmission, the receiver does not acknowledge receipt of a packet. This approach allows for much faster communication between devices. Connection-oriented service is more reliable than connectionless Service.
** Data in the Transport Layer is called as **Segments**.*
*** Transport layer is operated by the Operating System. It is a part of the OS and communicates with the Application Layer by making system calls.*
*Transport Layer is called as **Heart of OSI** model.*
5. Session Layer (Layer 5) :
This layer is responsible for the establishment of connection, maintenance of sessions, authentication, and also ensures security.
The functions of the session layer are :

1. **Session establishment, maintenance, and termination:** The layer allows the two processes to establish, use and terminate a connection.
2. **Synchronization:** This layer allows a process to add checkpoints which are considered synchronization points into the data. These synchronization points help to identify the error so that the data is re-synchronized properly, and ends of the messages are not cut prematurely and data loss is avoided.
3. **Dialog Controller:** The session layer allows two systems to start communication with each other in half-duplex or full-duplex.

***All the below 3 layers(including Session Layer) are integrated as a single layer in the TCP/IP model as “Application Layer”.*
***Implementation of these 3 layers is done by the network application itself. These are also known as **Upper Layers** or **Software Layers**.*

Scenario:

Let us consider a scenario where a user wants to send a message through some Messenger application running in his browser. The “Messenger” here acts as the application layer which provides the user with an interface to create the data. This message or so-called Data is compressed, encrypted (if any secure data), and converted into bits (0’s and 1’s) so that it can be transmitted.

6. Presentation Layer (Layer 6):

The presentation layer is also called the **Translation layer**. The data from the application layer is extracted here and manipulated as per the required format to transmit over the network.

The functions of the presentation layer are :

- **Translation:** For example, ASCII to EBCDIC.
- **Encryption/ Decryption:** Data encryption translates the data into another form or code. The encrypted data is known as the ciphertext and the decrypted data is known as plain text. A key value is used for encrypting as well as decrypting data.
- **Compression:** Reduces the number of bits that need to be transmitted on the network.

7. Application Layer (Layer 7) :

At the very top of the OSI Reference Model stack of layers, we find the Application layer which is implemented by the network applications. These applications produce the data, which has to be transferred over the network. This layer also serves as a window for the application services to access the network and for displaying the received information to the user.

Example: Application – Browsers, Skype Messenger, etc.

***Application Layer is also called Desktop Layer.*

The functions of the Application layer are :

1. Network Virtual Terminal
2. FTAM-File transfer access and management
3. Mail Services
4. Directory Services

OSI model acts as a reference model and is not implemented on the Internet because of its late invention. The current model being used is the TCP/IP model.

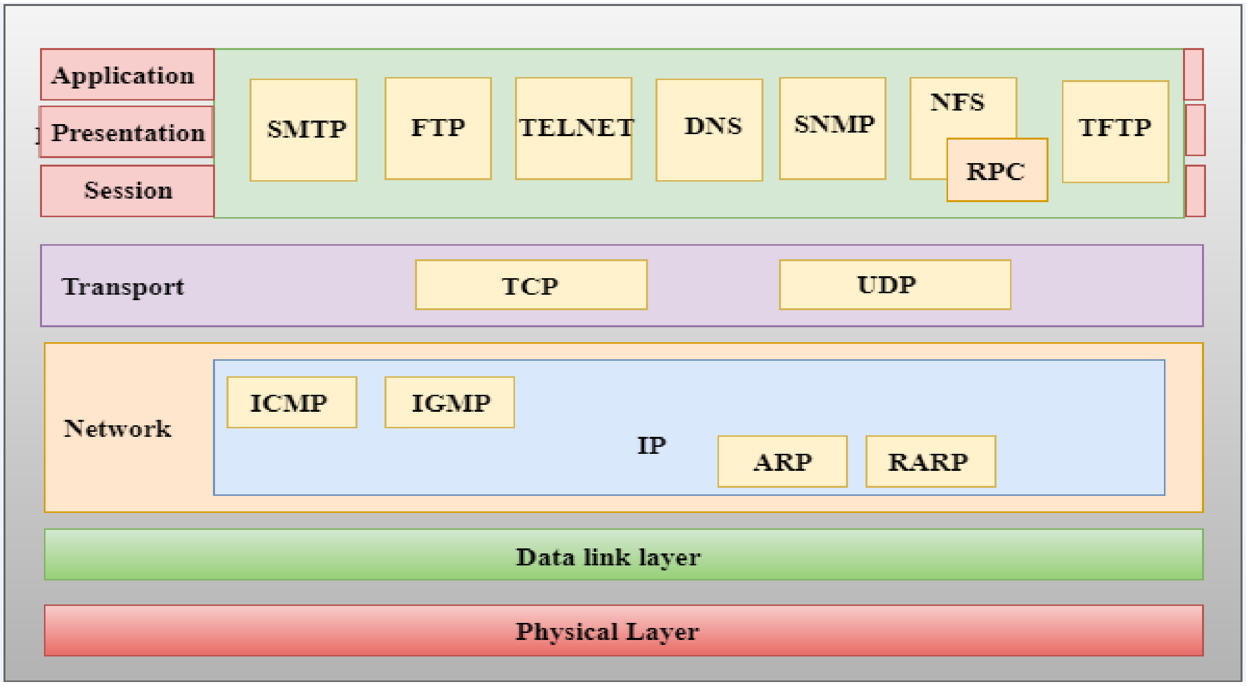
The TCP/IP model

- It stands for Transmission Control Protocol/Internet Protocol. The **TCP/IP model** is a concise version of the OSI model. It contains four layers, unlike seven layers in the OSI model. TCP/IP is a hierarchical protocol made up of interactive modules, and each of them provides specific functionality.

Here, hierarchical means that each upper-layer protocol is supported by two or more lower-level protocols.

The layers are:

1. Process/Application Layer
2. Host-to-Host/Transport Layer
3. Internet Layer
4. Network Access/Link Layer



Network Access Layer

- A network layer is the lowest layer of the TCP/IP model.
- A network layer is the combination of the Physical layer and Data Link layer defined in the OSI reference model.
- It defines how the data should be sent physically through the network.

- This layer is mainly responsible for the transmission of the data between two devices on the same network.
- The functions carried out by this layer are encapsulating the IP datagram into frames transmitted by the network and mapping of IP addresses into physical addresses.
- The protocols used by this layer are ethernet, token ring, FDDI, X.25, frame relay.

Internet Layer

- An internet layer is the second layer of the TCP/IP model.
- An internet layer is also known as the network layer.
- The main responsibility of the internet layer is to send the packets from any network, and they arrive at the destination irrespective of the route they take.

Following are the protocols used in this layer are:

IP Protocol: IP protocol is used in this layer, and it is the most significant part of the entire TCP/IP suite.

Following are the responsibilities of this protocol:

- **IP Addressing:** This protocol implements logical host addresses known as IP addresses. The IP addresses are used by the internet and higher layers to identify the device and to provide internetwork routing.
- **Host-to-host communication:** It determines the path through which the data is to be transmitted.
- **Data Encapsulation and Formatting:** An IP protocol accepts the data from the transport layer protocol. An IP protocol ensures that the data is sent and received securely, it encapsulates the data into message known as IP datagram.
- **Fragmentation and Reassembly:** The limit imposed on the size of the IP datagram by data link layer protocol is known as Maximum Transmission unit (MTU). If the size of IP datagram is greater than the MTU unit, then the IP protocol splits the datagram into smaller units so that they can travel over the local network. Fragmentation can be done by the sender or

intermediate router. At the receiver side, all the fragments are reassembled to form an original message.

- **Routing:** When IP datagram is sent over the same local network such as LAN, MAN, WAN, it is known as direct delivery. When source and destination are on the distant network, then the IP datagram is sent indirectly. This can be accomplished by routing the IP datagram through various devices such as routers.

ARP Protocol

- ARP stands for **Address Resolution Protocol**.
- ARP is a network layer protocol which is used to find the physical address from the IP address.
- **The two terms are mainly associated with the ARP Protocol:**
    - **ARP request:** When a sender wants to know the physical address of the device, it broadcasts the ARP request to the network.
    - **ARP reply:** Every device attached to the network will accept the ARP request and process the request, but only recipient recognize the IP address and sends back its physical address in the form of ARP reply. The recipient adds the physical address both to its cache memory and to the datagram header

ICMP Protocol

- **ICMP** stands for Internet Control Message Protocol.
- It is a mechanism used by the hosts or routers to send notifications regarding datagram problems back to the sender.
- A datagram travels from router-to-router until it reaches its destination. If a router is unable to route the data because of some unusual conditions such as disabled links, a device is on fire or network congestion, then the ICMP protocol is used to inform the sender that the datagram is undeliverable.
- An ICMP protocol mainly uses two terms:
    - **ICMP Test:** ICMP Test is used to test whether the destination is reachable or not.
    - **ICMP Reply:** ICMP Reply is used to check whether the destination device is responding or not.

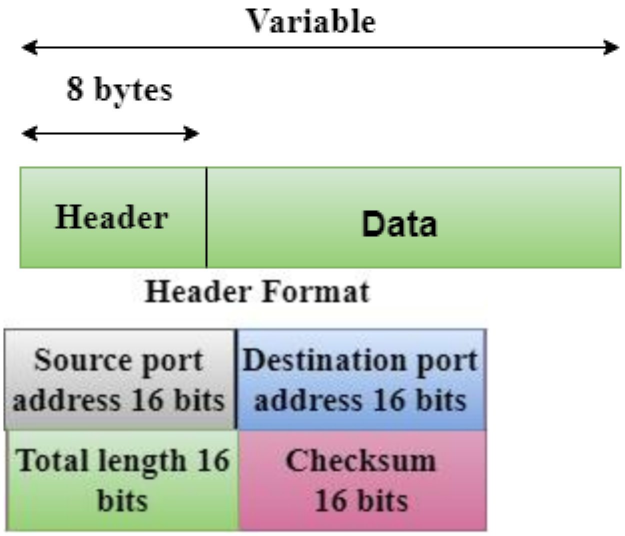
- The core responsibility of the ICMP protocol is to report the problems, not correct them. The responsibility of the correction lies with the sender.
- ICMP can send the messages only to the source, but not to the intermediate routers because the IP datagram carries the addresses of the source and destination but not of the router that it is passed to.

Transport Layer

The transport layer is responsible for the reliability, flow control, and correction of data which is being sent over the network.

The two protocols used in the transport layer are **User Datagram protocol and Transmission control protocol**.

- **User Datagram Protocol (UDP)**
    - It provides connectionless service and end-to-end delivery of transmission.
    - It is an unreliable protocol as it discovers the errors but not specify the error.
    - User Datagram Protocol discovers the error, and ICMP protocol reports the error to the sender that user datagram has been damaged.
    - **UDP consists of the following fields:**
      Source port address: The source port address is the address of the application program that has created the message.
      Destination port address: The destination port address is the address of the application program that receives the message.
      Total length: It defines the total number of bytes of the user datagram in bytes.
      Checksum: The checksum is a 16-bit field used in error detection.
    - UDP does not specify which packet is lost. UDP contains only checksum; it does not contain any ID of a data segment.



Header Format

Source port address 16 bits	Destination port address 16 bits
Total length 16 bits	Checksum 16 bits

- **Transmission Control Protocol (TCP)**
  - It provides a full transport layer services to applications.
  - It creates a virtual circuit between the sender and receiver, and it is active for the duration of the transmission.
  - TCP is a reliable protocol as it detects the error and retransmits the damaged frames. Therefore, it ensures all the segments must be received and acknowledged before the transmission is considered to be completed and a virtual circuit is discarded.
  - At the sending end, TCP divides the whole message into smaller units known as segment, and each segment contains a sequence number which is required for reordering the frames to form an original message.
  - At the receiving end, TCP collects all the segments and reorders them based on sequence numbers.

Application Layer

- An application layer is the topmost layer in the TCP/IP model.
- It is responsible for handling high-level protocols, issues of representation.
- This layer allows the user to interact with the application.
- When one application layer protocol wants to communicate with another application layer, it forwards its data to the transport layer.
- There is an ambiguity occurs in the application layer. Every application cannot be placed inside the application layer except those who interact

with the communication system. For example: text editor cannot be considered in application layer while web browser using **HTTP** protocol to interact with the network where **HTTP** protocol is an application layer protocol.

Following are the main protocols used in the application layer:

- **HTTP:** HTTP stands for Hypertext transfer protocol. This protocol allows us to access the data over the world wide web. It transfers the data in the form of plain text, audio, video. It is known as a Hypertext transfer protocol as it has the efficiency to use in a hypertext environment where there are rapid jumps from one document to another.
- **SNMP:** SNMP stands for Simple Network Management Protocol. It is a framework used for managing the devices on the internet by using the TCP/IP protocol suite.
- **SMTP:** SMTP stands for Simple mail transfer protocol. The TCP/IP protocol that supports the e-mail is known as a Simple mail transfer protocol. This protocol is used to send the data to another e-mail address.
- **DNS:** DNS stands for Domain Name System. An IP address is used to identify the connection of a host to the internet uniquely. But, people prefer to use the names instead of addresses. Therefore, the system that maps the name to the address is known as Domain Name System.
- **TELNET:** It is an abbreviation for Terminal Network. It establishes the connection between the local computer and remote computer in such a way that the local terminal appears to be a terminal at the remote system.
- **FTP:** FTP stands for File Transfer Protocol. FTP is a standard internet protocol used for transmitting the files from one computer to another computer.

DATA LINK LAYER

Design Issues

1. Providing services to the network layer:

1 Unacknowledged connectionless service.

Appropriate for low error rate and real-time traffic. Ex:
Ethernet

2. Acknowledged connectionless service.
Useful in unreliable channels, WiFi. Ack/Timer/Resend

3. Acknowledged connection-oriented service.

Guarantee frames are received exactly once and in the right order. Appropriate over long, unreliable links such as a satellite channel or a long distance telephone circuit

2. **Framing:** Frames are the streams of bits received from the network layer into manageable data units. This division of stream of bits is done by Data Link Layer.
3. **Flow Control**. The source machine must not send data frames at a rate faster than the destination machine can accept them. **:** Without flow control, the receiver's buffer can overflow, and frames can get lost
4. **Error Control:** Error control includes both error detedction and correction.Duplicateframes,damaged and lost frames managed using this mechanism by retransmission of frames,

FRAMING:

The framing is the primary function of the data link layer and it provides a way to transmit data between the connected devices.

Framing uses frames to send or receive data. The data link layer receives packets from the network layer and converts them into frames.

If the frame size is too large, then the packet can be divided into smaller frames. Small frames are more efficient for flow control and error control.

The data link layer needs to pack bits into frames so that each frame is distinguishable from another.

Parts of a Frame

The frame is consist of four parts as follows.

Each frame in data link layers comprises four parts header, payload field, trailers and flag.

Header–The source and destination address is placed into the header part of the frame.

Payload field–It contains the actual message or information that the sender wants to transmit to the destination machine.

Trailer–The trailer comprises error detection and error correction bits.

Flag–It shows the beginning and end of a particular frame.

Framing methods

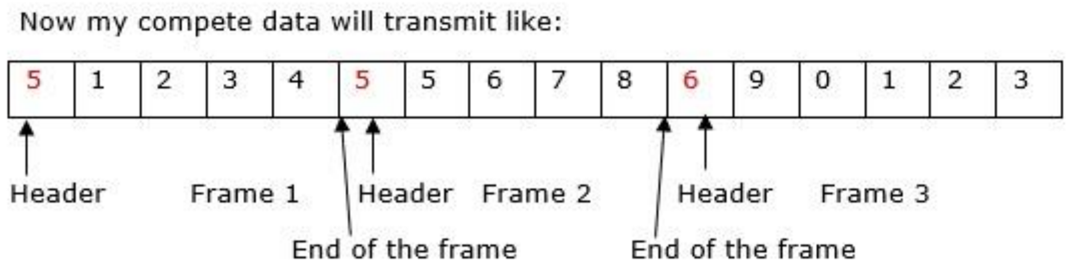
1. Character count.
2. Flag bytes with byte stuffing.
3. Starting and ending flags, with bit stuffing.
4. Physical layer coding violations.

Character Count

First framing method uses a field in the header to specify the number of characters in the frame. When the data link layer at the destination sees the character count, it knows how many characters follow and hence where the end of the frame is.

For Example,

Consider a data − 1 2 3 4 5 6 7 8 9 0 1 2 3



Now my compete data will transmit like:

5	1	2	3	4	5	5	6	7	8	6	9	0	1	2	3

Types of Framing in Computer Networks

There are two types of framing that are used by the data link layer in computer networks., the following are the types of framing in computer networks,

- Fixed Size Framing
- Variable Size Framing

Fixed Size Framing

The frame has a fixed size. In fixed-size framing, there is no need for defining the boundaries of the frames to mark the beginning and end of a frame.

For example- This type of framing is used in ATMs, Wide area networks. They use frames of fixed size called cells.

Variable Size Framing

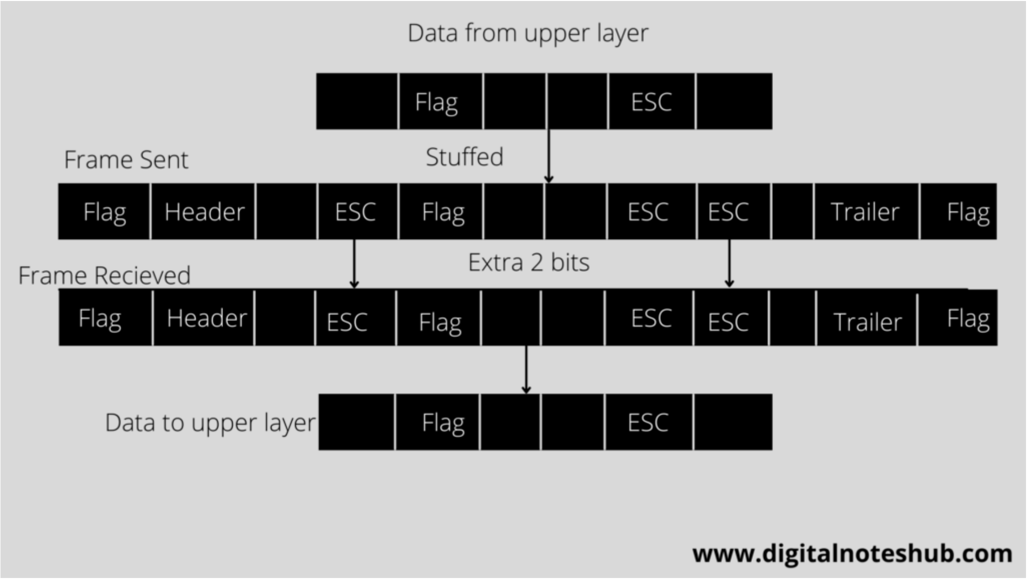
The size of the frame is variable in this type of framing. In variable size framing, we need a way to define the end of the frame and the beginning of the next frame. This is used in local area networks.

End Delimeter–To identify the size of the frame, a pattern is used as a delimiter. Two methods are used to avoid this situation if the pattern occurs in the message.

- Character Oriented Approach (Byte Stuffing)
- Bit Oriented Approach (Bit Stuffing)

Flag bytes with byte stuffing In recent years most protocols have used byte, called a flag byte, as both the starting and ending delimiter as FLAG. In this way, if the receiver ever loses synchronization, it can just search for the flag byte to find the end of the current frame

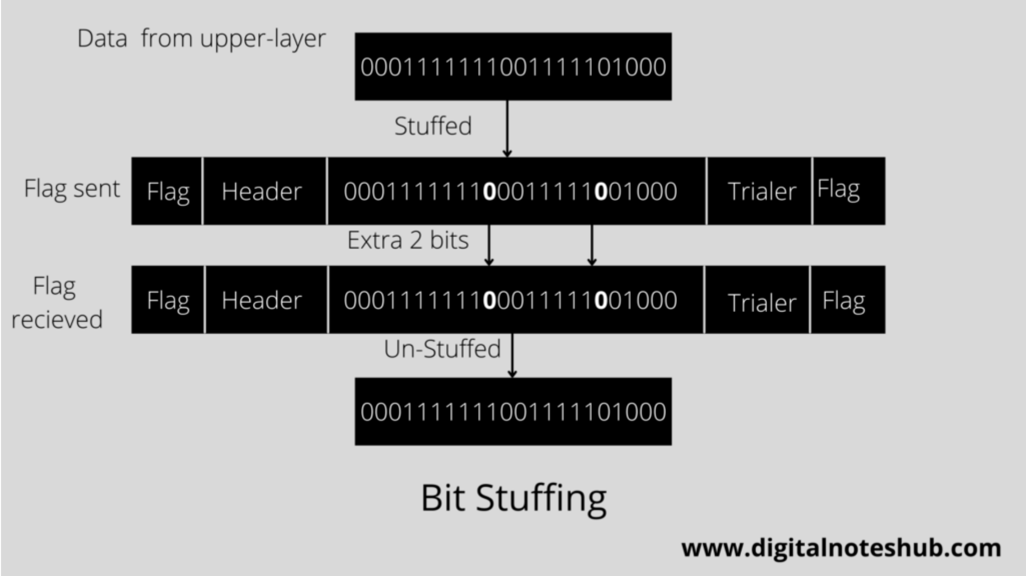
It may easily happen that the flag byte's bit pattern occurs in the data. This situation will usually interfere with the framing. One way to solve this problem is to have the sender's data link layer insert a special escape byte (ESC) just before each ''accidental'' flag byte in the data. The data link layer on the receiving end removes the escape byte before the data are given to the network layer. This technique is called byte stuffing or character stuffing.



Byte stuffing is the process of adding an extra byte when there is a flag or escape character in the text.

Starting and ending flags, with bit stuffing Each frame begins and ends with a special bit pattern, 01111110 (in fact, a flag byte). Whenever the sender's data link layer encounters five consecutive 1s in the data, it automatically stuffs a 0 bit into the outgoing bit stream. This bit stuffing is analogous to byte stuffing, in which an escape byte is stuffed into the outgoing character stream before a flag byte in the data.
When the receiver sees five consecutive incoming 1 bits, followed by a 0 bit, it automatically de- stuffs (i.e., deletes) the 0 bit. If the user data contain the

flag pattern, 01111110, this flag is transmitted as 011111010 but stored in the receiver's memory as 01111110.
data as they are stored in the receiver's memory after destuffing.



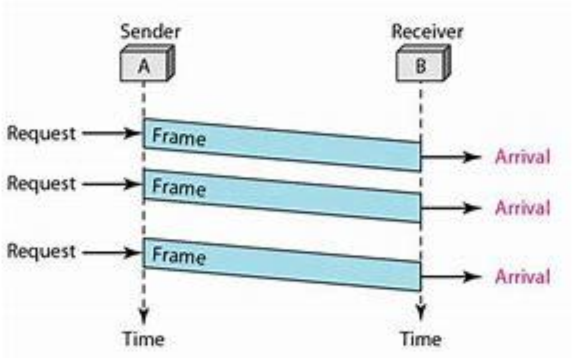
Physical layer coding violations method of framing is only applicable to networks in which the encoding on the physical medium contains some redundancy. For example, some LANs encode 1 bit of data by using 2 physical bits. Normally, a 1 bit is a high-low pair and a 0 bit is a low-high pair. The scheme means that every data bit has a transition in the middle, making it easy for the receiver to locate the bit boundaries. The combinations high-high and low-low are not used for data but are used for delimiting frames in some protocols.

As a final note on framing, many data link protocols use combination of a character count with one of the other methods for extra safety. When a frame arrives, the count field is used to locate the end of the frame. Only if the appropriate delimiter is present at that position and the checksum is correct is the frame accepted as valid. Otherwise, the input stream is scanned for the next delimiter

ELEMENTARY DATA LINK PROTOCOLS

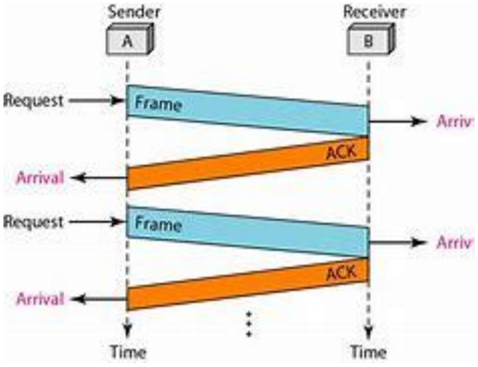
Simplest Protocol

It is very simple. The sender sends a sequence of frames without even thinking about the receiver. Data are transmitted in one direction only. Both sender & receiver always ready. Processing time can be ignored. Infinite buffer space is available. And best of all, the communication channel between the data link layers never damages or loses frames. **it does not handle either flow control or error correction**



Stop-and-wait Protocol

It is still very simple. The sender sends one frame and waits for feedback from the receiver. When the ACK arrives, the sender sends the next frame It is Stop-and-Wait Protocol because the sender sends one frame, stops until it receives confirmation from the receiver , and then sends the next frame.unidirectional communication for data frames, but ACK frames (acknowledgment) travel from the other direction. Here flow control is added.



NOISY CHANNELS

Sliding Window Protocols:

1 Stop-and-Wait Automatic Repeat
Request

Stop & Wait ARQ

Stop & Wait ARQ is a **sliding window protocol** for flow control and it overcomes the limitations of Stop & Wait, we can say that it is the improved or modified version of Stop & Wait protocol.

Stop & Wait ARQ assumes that the communication channel is noisy .Stop & Wait ARQ also assumes that errors may occur in the data while transmission.

Working of Stop & Wait ARQ

Working of Stop & Wait ARQ is almost like Stop & Wait protocol, the only difference is that it includes some additional components, which are:

1. Time out timer
2. Sequence numbers for data packets
3. Sequence numbers for feedbacks

Stop & Wait ARQ is a 1-bit sliding window protocol where the size of the sender window as well as the receiver window is 1. Thus, in Stop & Wait ARQ technique, the minimum number of sequence numbers required is equal to the sum of sender window size & receiver window size

[minimum number of sequence numbers required = sender window size + receiver window size]

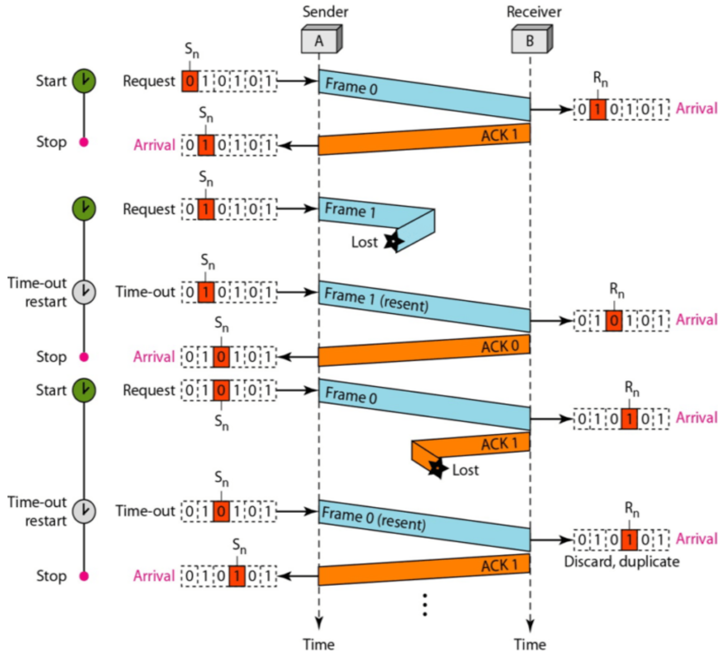
Thus, the minimum number of sequence numbers required in Stop & Wait ARQ is 2, which are 0 and 1.

Stop & Wait ARQ overcoming the problem of a lost data packet

After transmitting the data packet to the receiver, the sender starts the time out timer. Now if the acknowledgement is received by the sender before the timer expires, then the sender stops the timer and transmits the next data packet.

And if the time out timer expires and the feedback is not received by the sender then, the sender retransmits the data packet. This prevents the occurrence of deadlock in the network.

An illustration of the process is shown in the image below.



The problem of a damaged data packet

Whenever a data packet is damaged/corrupted, the receiver then sends negative feedback to the sender and then it resends the same data packet.

Limitations

The Stop & Wait ARQ is very less efficient because the **sender window size is 1**, which allows the sender to keep only one frame without feedback. So, the sender sends a data packet and waits for the feedback, and it gets the feedback it sends another data packet.

2. Go-Back-N Automatic Repeat Request

To improve the efficiency of transmission (filling the pipe), multiple frames must be in transition while waiting for acknowledgment. In other words, we need to let more than one frame be outstanding to keep the channel busy while the sender is waiting for acknowledgment.This is called pipelining.

In Go-Back-N Automatic Repeat protocol we can send several frames before receiving acknowledgments; we keep a copy of these frames until the acknowledgments arrive.

In the Go-Back-N Protocol, the sequence numbers are modulo 2^m, where m is the size of the sequence number field in bits. The sequence numbers range from 0 to *2 power m*- 1. For example, if *m* is 4, the only sequence numbers are 0 through 15 inclusive.

The **sender window** at any time divides the possible sequence numbers into four regions.

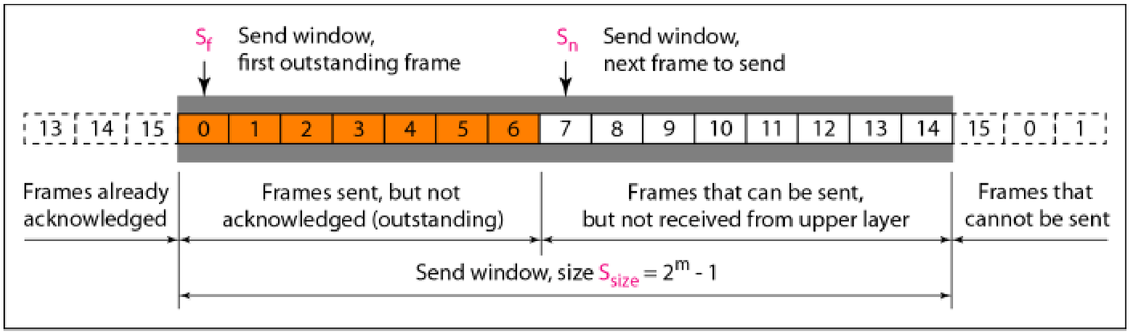
The first region, from the far left to the left wall of the window, defines the sequence numbers belonging to frames that are already acknowledged. The sender does not worry about these frames and keeps no copies of them.

The second region, colored in Figure (a), defines the range of sequence numbers belonging to the frames that are sent and have an unknown status. The sender needs to wait to find out if these frames have been received or were lost. We call these outstanding frames.

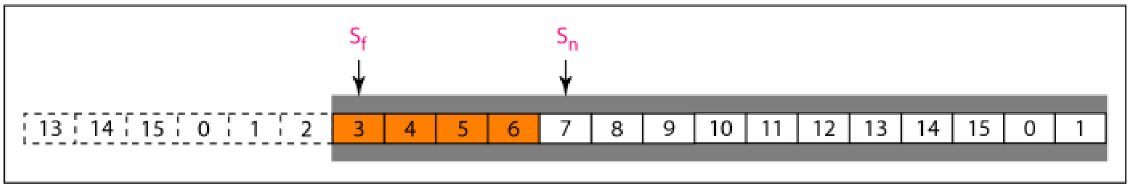
The third range, white in the figure, defines the range of sequence numbers for frames that can be sent; however, the corresponding data packets have not yet been received from the network layer.

Finally, the fourth region defines sequence numbers that cannot be used until the window slides

The send window is an abstract concept defining an imaginary box of size 2^m − 1 with three variables: S_f, S_n, and S_{size}. The variable *Sf* defines the sequence number of the first (oldest) outstanding frame. The variable *Sn* holds the sequence number that will be assigned to the next frame to be sent. Finally, the variable Ssize defines the size of the window.


S_f Send window, first outstanding frame
S_n Send window, next frame to send
13 14 15 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 0 1
Frames already acknowledged
Frames sent, but not acknowledged (outstanding)
Frames that can be sent, but not received from upper layer
Frames that cannot be sent
Send window, size $S_{size} = 2^m - 1$

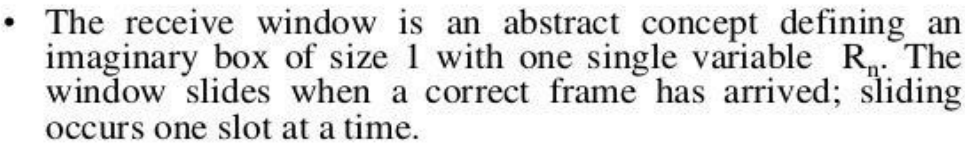
a. Send window before sliding



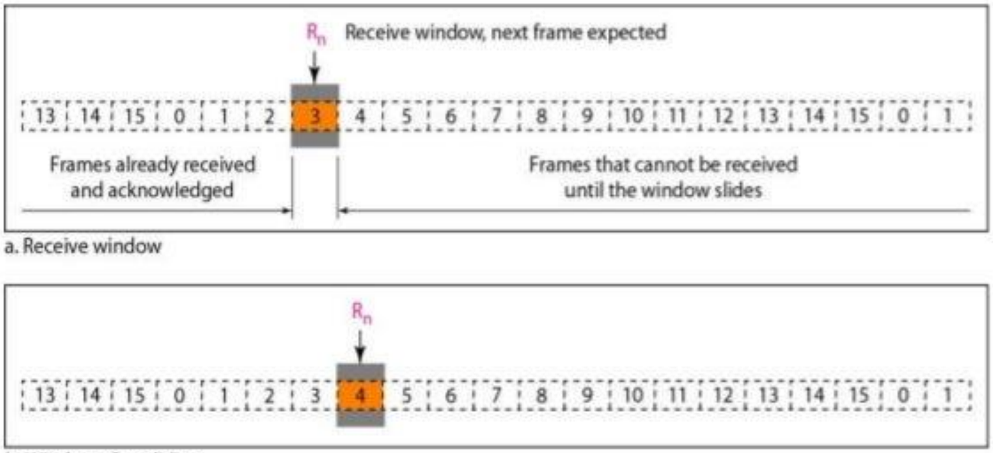
b. Send window after sliding

Figure (b) shows how a send window can slide one or more slots to the right when an acknowledgment arrives from the other end. The acknowledgments in this protocol are cumulative, meaning that more than one frame can be acknowledged by an ACK frame. In Figure, frames 0, I, and 2 are acknowledged, so the window has slide to the right three slots. Note that the value of *Sf* is 3 because frame 3 is now the first outstanding frame. **The send window can slide one or more slots when a valid acknowledgment arrives.**

<u>Receiver window:</u> variable *Rn* (receive window, next frame expected) . The sequence numbers to the left of the window belong to the frames already received and acknowledged; the sequence numbers to the right of this window define the frames that cannot be received. Any received frame with a sequence number in these two regions is discarded. Only a frame with a sequence number matching the value of *Rn* is accepted and acknowledged. The receive window also slides, but only one slot at a time. When a correct frame is received (and a frame is received only one at a time), the window slides.(see below figure for receiving window)



- The receive window is an abstract concept defining an imaginary box of size 1 with one single variable R_n. The window slides when a correct frame has arrived; sliding occurs one slot at a time.


R_n
Receive window, next frame expected
13 14 15 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 0 1
Frames already received and acknowledged
Frames that cannot be received until the window slides
R_n
13 14 15 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 0 1

a. Receive window

b. Window after sliding

Timers

Although there can be a timer for each frame that is sent, in our protocol we use only one. The reason is that the timer for the first outstanding frame always expires first; we send all outstanding frames when this timer expires.

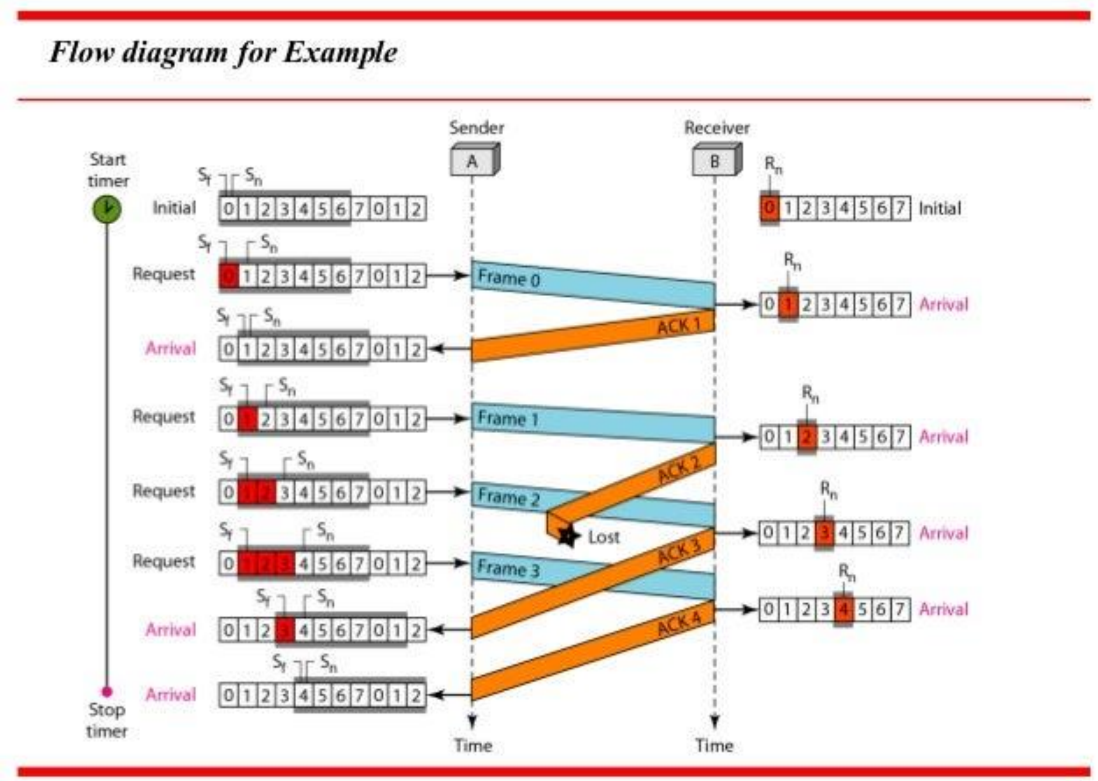
Acknowledgment

The receiver sends a positive acknowledgment if a frame has arrived safe and sound and in order. If a frame is damaged or is received out of order, the receiver is silent and will discard all subsequent frames. The silence of the receiver causes the time out of timer.The sender to go back and resend all frames, beginning with the one with the expired timer. The receiver does not have to acknowledge each frame received. It can send one cumulative acknowledgment for several frames.

Resending a Frame

When the timer expires, the sender resends all outstanding frames. For example, suppose the sender has already sent frame 6, but the timer for frame 3 expires. This means that frame 3 has not been acknowledged; the sender goes back and sends frames 3,4,5, and 6 again. That is why the protocol is called *Go-Back-N* ARQ.

Below figure is an example(if ack lost) of a case where the forward channel is reliable, but the reverse is not. No data frames are lost, but some ACKs are delayed and one is lost. The example also shows how cumulative acknowledgments can help if acknowledgments are delayed or lost



Flow diagram for Example

11.51

Below figure is an example(if frame lost)

Stop-and-Wait ARQ is a special case of Go-Back-N ARQ in which the size of the send window is 1.

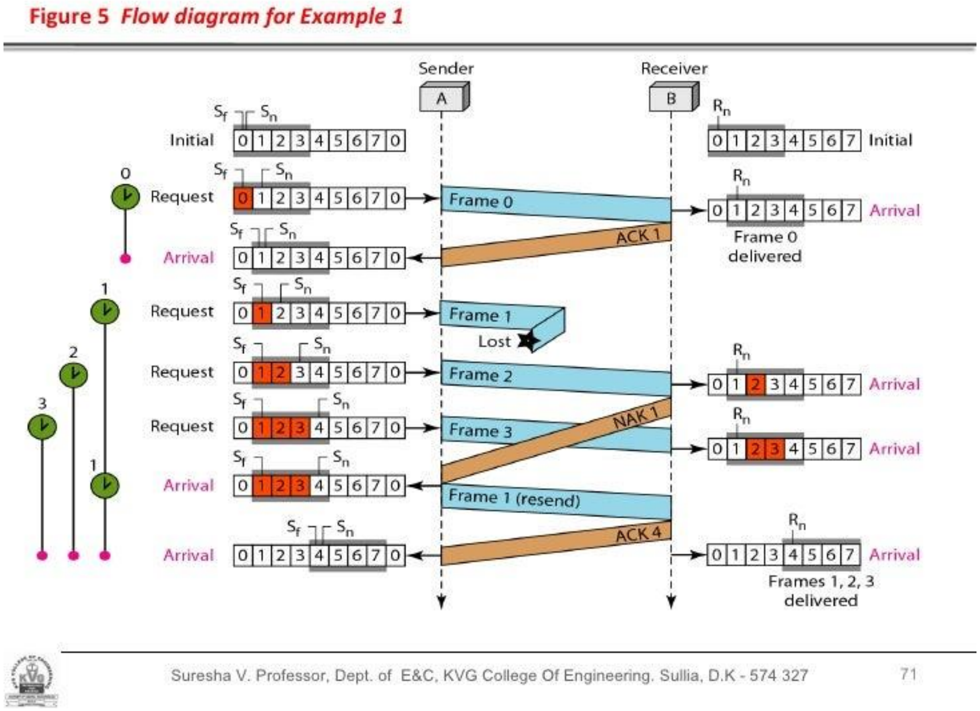


Figure 5 *Flow diagram for Example 1*

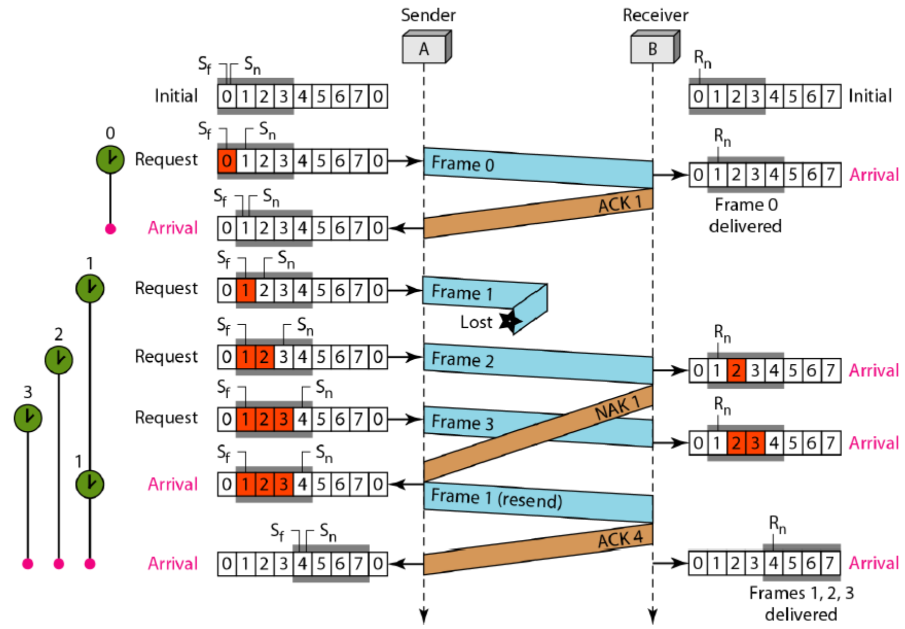
Suresha V. Professor, Dept. of E&C, KVG College Of Engineering. Sullia, D.K - 574 327 71

3 Selective Repeat Automatic Repeat Request

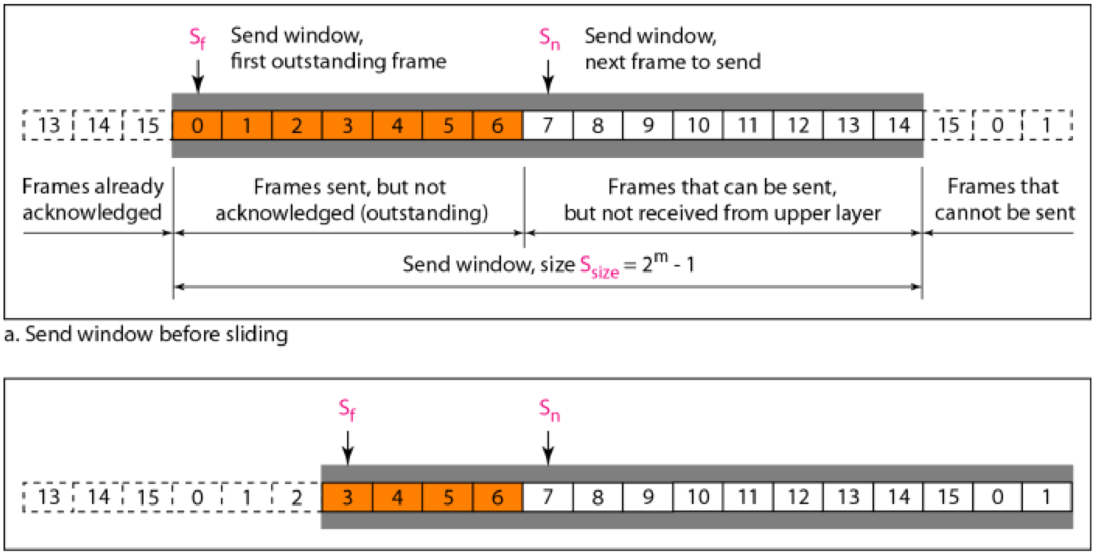
In Go-Back-N ARQ, The receiver keeps track of only one variable, and there is no need to buffer out-of- order frames; they are simply discarded. However, this protocol is very i*nefficient for a noisy link.*

In a noisy link a frame has a higher probability of damage, which means the resending of multiple frames. This resending uses up the bandwidth and slows down the transmission.

Selective Repeat ARQ , the sender seds n frames at a time.but the receiver does not resend *N* frames when just one frame is damaged; only the damaged frame is resent. It is more efficient for noisy links, but the processing at the receiver is more complex.



Sender Window



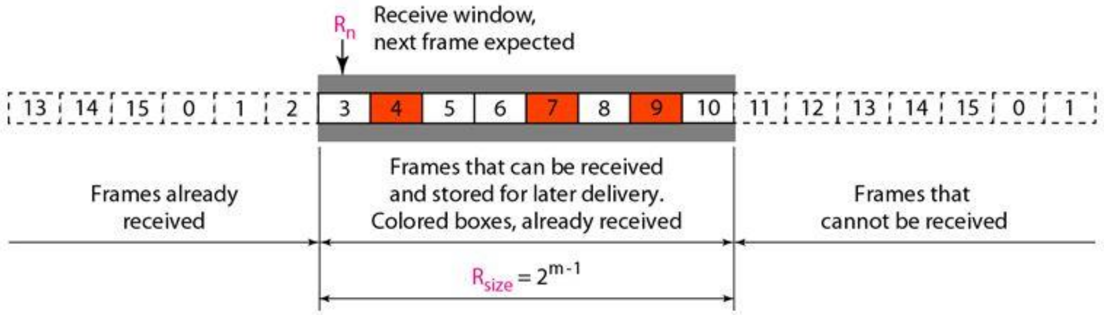
a. Send window before sliding

b. Send window after sliding

The only difference in sender window between Go-back N and Selective Repeat is Window size)

Receiver window

The receiver window in Selective Repeat is totally different from the one in Go Back-N. First, the size of the receive window is the same as the size of the send window *(2^{m-1}).*


R_n
Receive window, next frame expected
13
14
15
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
1
Frames already received
Frames that can be received and stored for later delivery. Colored boxes, already received
Frames that cannot be received
$R_{size} = 2^{m-1}$

The Selective Repeat Protocol allows out of order frames at the receiver. Above Figure shows the receive window. Those slots inside the window that are colored define frames that have arrived out of order and are waiting for their neighbors to arrive before delivery to the network layer.

In Selective Repeat ARQ, the size of the sender and receiver window must be at most one-half of 2^m

Piggybacking

A technique called **piggybacking** is used to improve the efficiency of the bidirectional protocols. When a frame is carrying data from A to B, it can also carry control information about arrived (or lost) frames from B; when a frame is carrying data from B to A, it can also carry control information about the arrived (or lost) frames from A.