Foundations of Computer Science (KU2DSCCSE102)

FYIMP S2 24 - 25

KU2DSCCSE102 Foundations of Computer Science

References:

- V Rajaraman, Neeharika Adabala, Fundamentals of computers, 6th edition, PHI.
- Pradeep K Sinha and Priti Sinha, Computer Fundamentals.
- Computer Networks, Andrew S. Tanenbaum and David J. Wetherall.
- Computer Networking: A Top-Down Approach, James F. Kurose and Keith W. Ross.

Unit III: Computer Networks: Definition - Advantages - Components - Categories. Transmission Modes: Simplex, Half duplex, Full duplex. Topology: Definition, Characteristics, Advantages and Disadvantages of Mesh, Star, Bus, Ring. Transmission Media - Wired (Definition, Characteristics, Advantages and Disadvantages of Shielded and Unshielded Twisted Pair, Coaxial, Optical) - Wireless (Definition, Characteristics, Advantages and Disadvantages of Microwave, Radio Wave and Infrared). Overview of OSI and TCP/IP Models. Networking Devices: Hub, Switch, Repeater, Bridge, Router. IP Address: V4 and V6. Case Study of networking command: host, hostname, ping, ifconfig, ip, traceroute, tracepath, netstat, ss, dig.

What is a Network?

- A (computer) network is a set of multiple devices that communicate with one another
- Number of devices in the set can be as low as 2 or as large as billions of devices

What is a Network?

- Connection can be either wired or wireless

Examples of Network?

- The Wi-Fi network in your home
- The various devices in your home are wirelessly connected to the router
- Router as a central node (server) for the household
- The router is hooked to a much larger network: the Internet

Advantages Network?

- Shared use of data
- Shared use of resources
- Central control of programs and data
- Central storage and backup of data
- Shared processing power and storage capacity
- Easy management of authorizations and responsibilities

Data Communication & Networks*

- Ability to communicate and network has revolutionized the way we do our day to day affairs in private and public life
- When we are armed with the power of communication over a network, it resulted in swift decision making in all walks of life!

Data Communication & Networks

- We know that traditional way of communication gave way to telecommunication!
- **Tele** means far
- The term telecommunication, which includes telephony, telegraphy, and television, means the communication at a distance
- The term data refers to the information presented in whatever form is mutually agreed upon by the parties creating and using the data

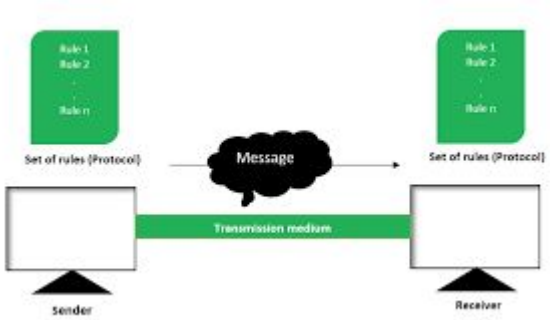
Data Communication & Networks

- Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable
- To communicate each other, there has to be a combination of hardware (physical equipment) and software (programs)

Data Communication & Networks

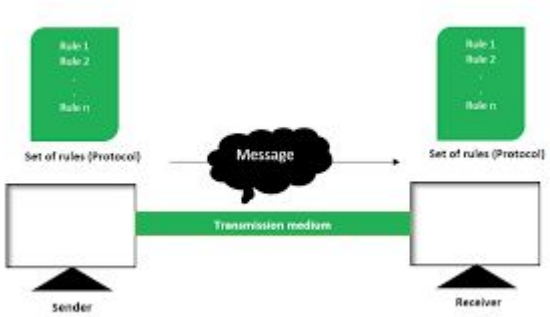
- The effectiveness of a data communications system depends on four fundamental characteristics:
  - Delivery - Data should be delivered to the intended recipient
  - Accuracy - The system must deliver the data accurately without any loss or changes
  - Timeliness - delivery of data should be in a timely manner
  - Jitter - Refers to the variability in the delay of received packets. Imagine you are in a video call with someone over the internet. If the network introduces jitter, the packets carrying audio and video data may not arrive at a constant rate.

Data Communication - Components



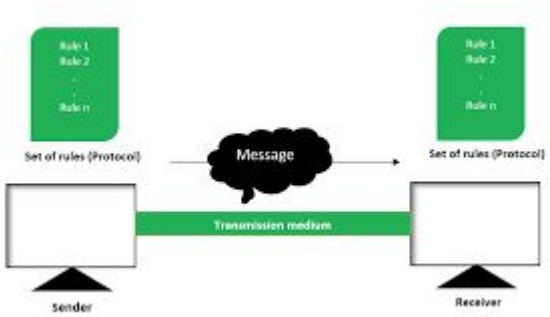
1. Message
2. Sender
3. Receiver
4. Transmission Medium
5. Set of rules (Protocol)

Data Communication - Components



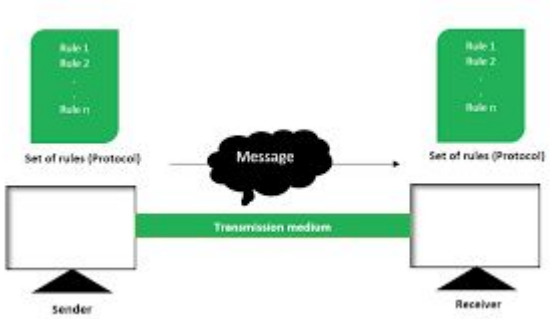
1. Message
   a. Information (data) to be communicated
   b. It could be text, numbers, pictures, audio, or video

Data Communication - Components



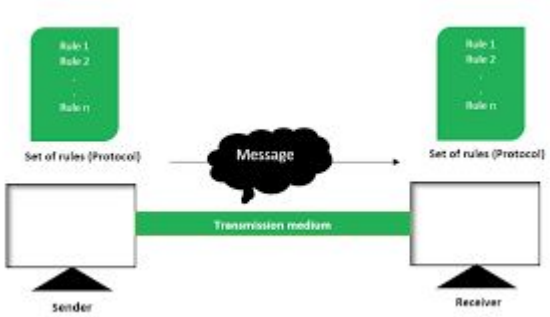
2. Sender
   a. The device that sends the message
   b. It can be a computer, workstation, telephone handset, video camera, and so on

Data Communication - Components



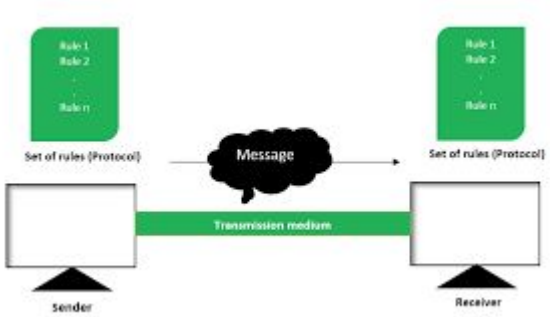
3. Receiver
   a. The device that receives the message
   b. It can be a device such as computer, workstation, telephone handset or video camera

Data Communication - Components



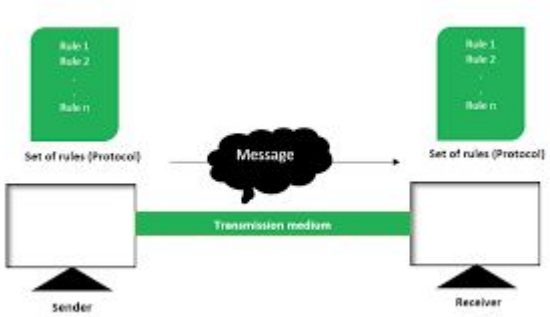
4. Transmission Medium
   a. The physical path by which a message travels from sender to receiver
   b. Examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves

Data Communication - Components



5. Protocol
   a. A set of rules that govern data communications
   b. It represents an agreement between the communicating devices
   c. Without a protocol, the devices connected each other can not communicate!
   d. Similar to the case where a malayali speaks to a gujarati and either parties do not know the language of the other!

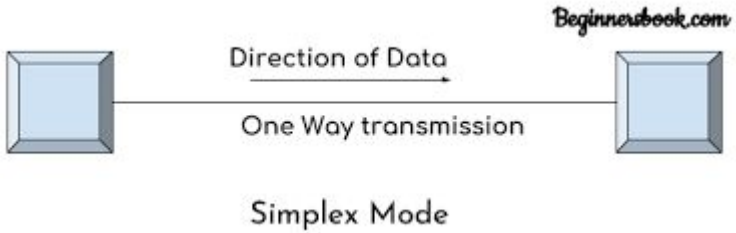
Data Communication - Data Representation



1. Text
2. Numbers
3. Image
4. Audio
5. Video

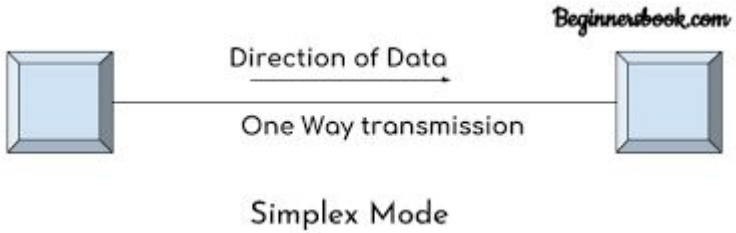
Data Communication - Data Flow

1. Simplex
2. Half-duplex
3. Full-duplex



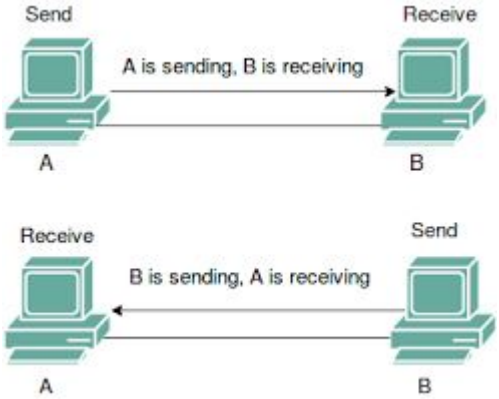
Data Communication - Data Flow

1. Simplex
   - The communication is unidirectional
   - Only one of the two devices on a link can transmit; the other can only receive
   - Examples of simplex devices?!



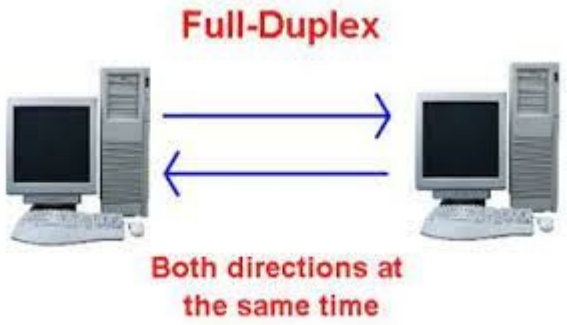
Data Communication - Data Flow

1. Simplex
   - The communication is unidirectional
   - Only one of the two devices on a link can transmit; the other can only receive
   - Examples of simplex devices
     i. Keyboard - it can only give us what is keyed in
     ii. Monitor - it can only display what is given to it for display



Data Communication - Data Flow

2. Half Duplex
   - Each device can send and receive data
   - But a device can only send or receive data at a time
   - The entire capacity of a channel is used entirely by the device that sends the data
   - Examples of half duplex devices
     i. Walkie-talkies and CB (citizens band) radios



Data Communication - Data Flow

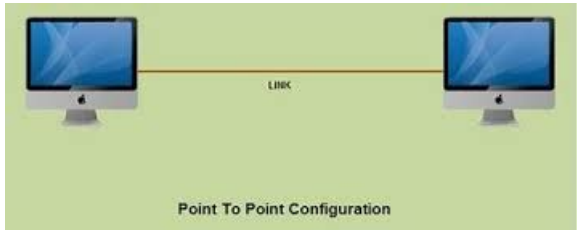
3. Full Duplex (Also called as Duplex)
   - Each device can transmit and receive simultaneously
   - The capacity of the channel is divided between signals traveling in both directions
   - Example: telephone network
     i. When two people are communicating by a telephone line, both can talk and listen at the same time

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

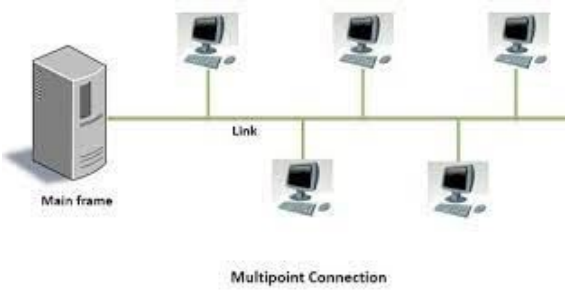
Networks - Types of Connection (Line Configuration)*

- A communication link is to be laid between the device that engage in communication
- There are two types of connections
  - Point-to-point
  - Multipoint



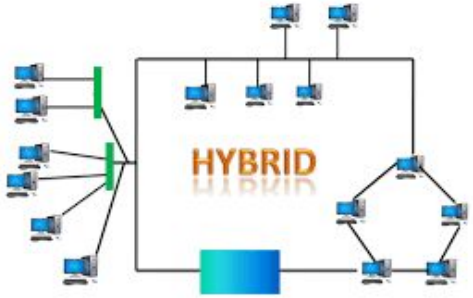
Networks - Types of Connection (Line Configuration) - Point to Point

- 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
- In most cases, an actual length of wire or cable are used to connect the two ends; But other options, such as microwave or satellite links, are also possible
- Example:-
  - When we change television channels by infrared remote control, we are establishing a point-to-point connection between the remote control and the television's control system



Networks - Types of Connection (Line Configuration) - Multipoint or Multidrop

- A connection is one in which more than two specific devices share a single link
- The capacity of the channel is shared, either spatially or temporally among the devices
  - If several devices can use the link simultaneously, it is a spatially shared connection
  - If users must take turns, it is a timeshared connection*



Networks - Topology

- The arrangement with which computer systems or network devices are connected to each other

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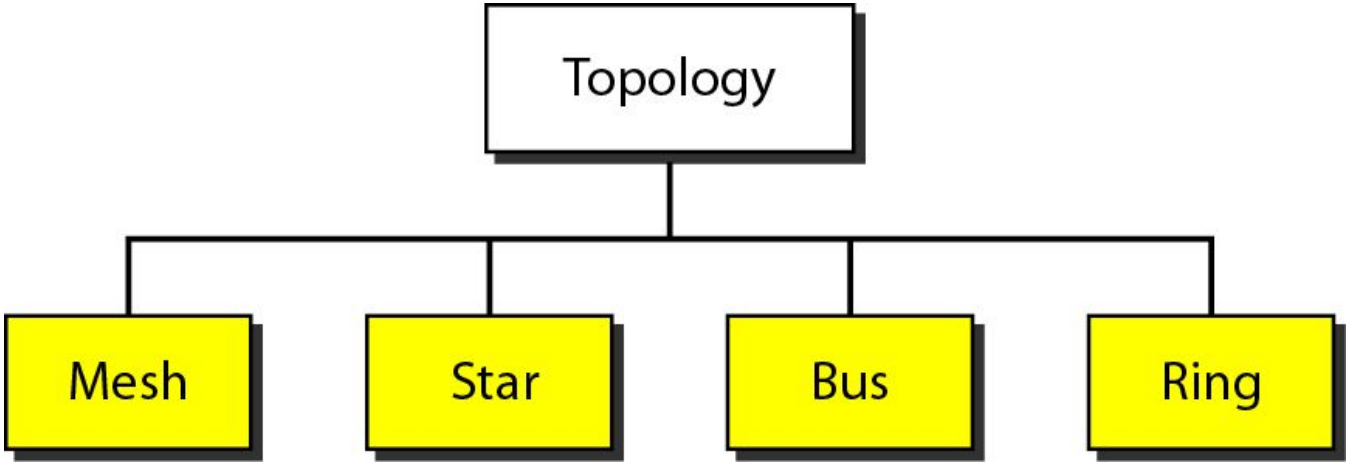
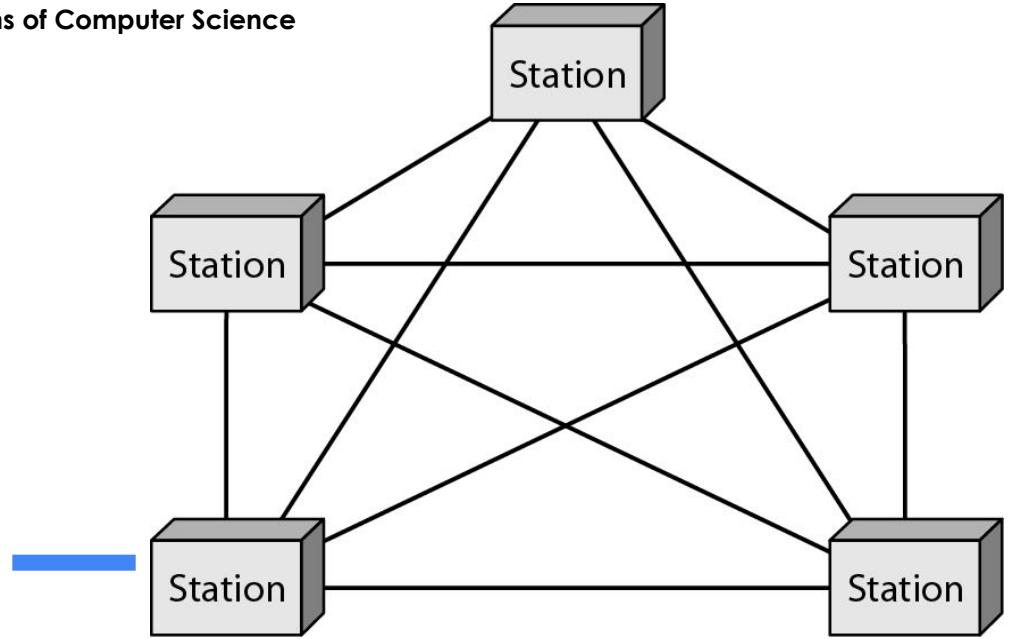


Networks - Topology - Mesh

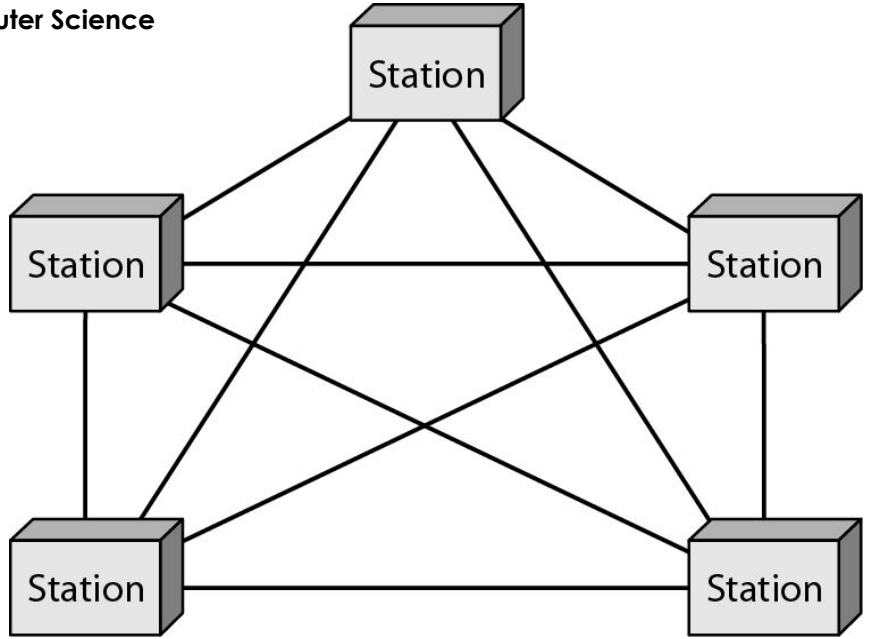


- Each node in the network is connected with each of the nodes in point to point connection method

Networks - Topology - Mesh

Advantages

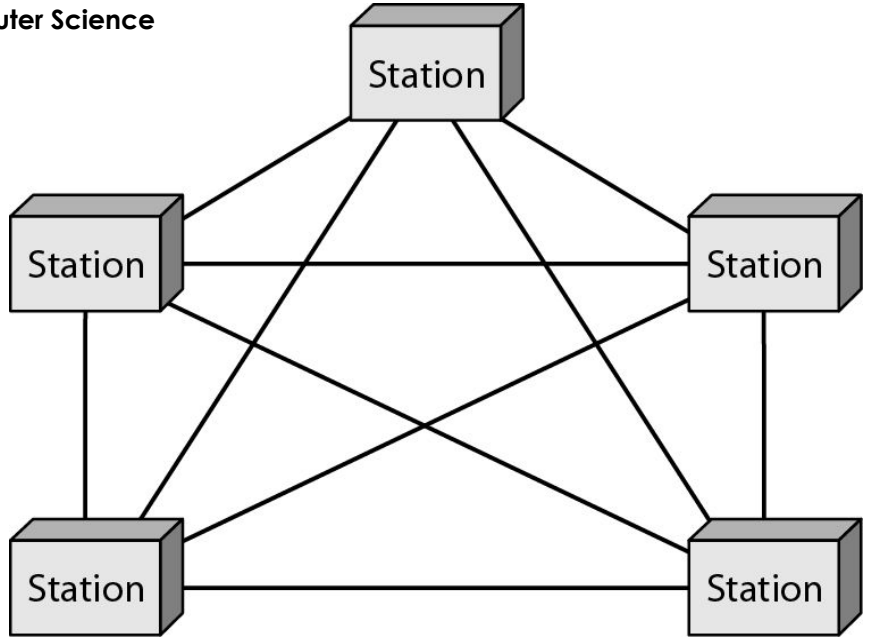
- Since each link is connected to other using a dedicated link, issue in data traffic found In shared link can be eliminated
- Its robust - If one link becomes unusable, it does not affect the entire system
- Since traffic between any two nodes is connected with a dedicated link, privacy and security of the message is ensured
- Point-to-point links make fault identification and fault isolation easy



Networks - Topology - Mesh

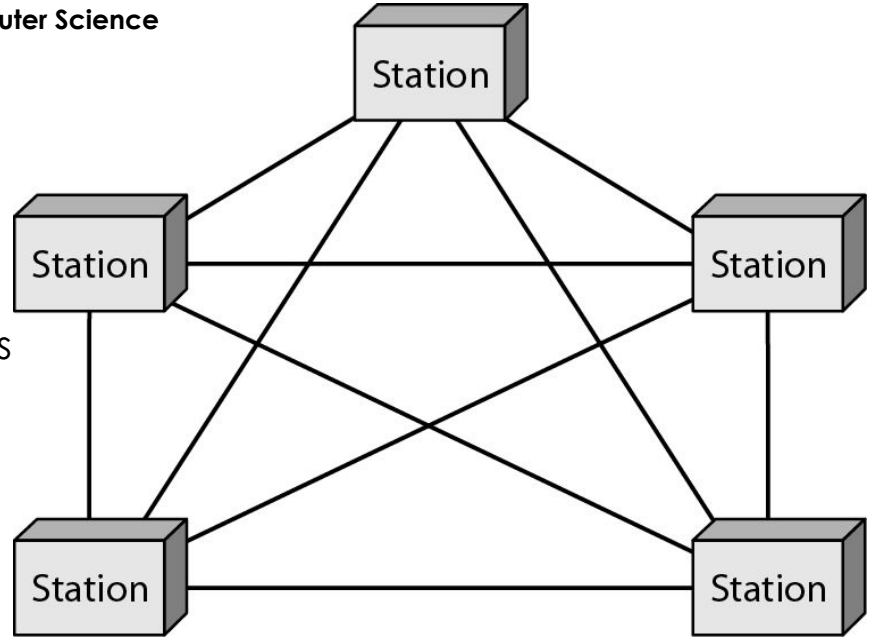
Disadvantages

- Due to point to point connectivity among nodes, installation and reconnection are difficult
- Cables needed will exceed the available space can accommodate
- The hardware required to connect each link (I/O ports and cable) can be highly expensive

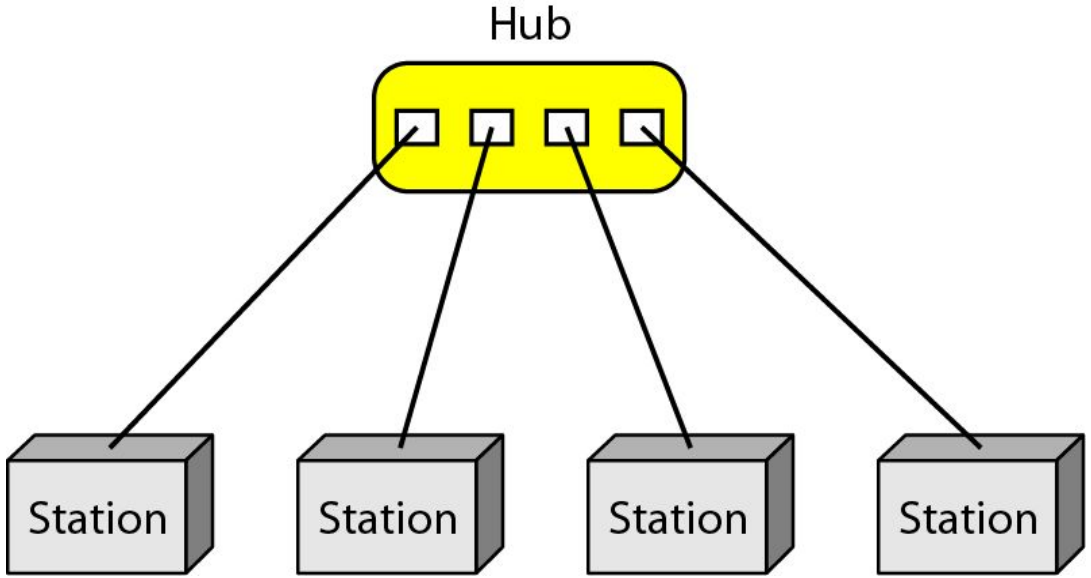


Networks - Topology - Mesh

- One practical example of a mesh topology is the connection of telephone regional offices in which each regional office needs to be connected to every other regional office

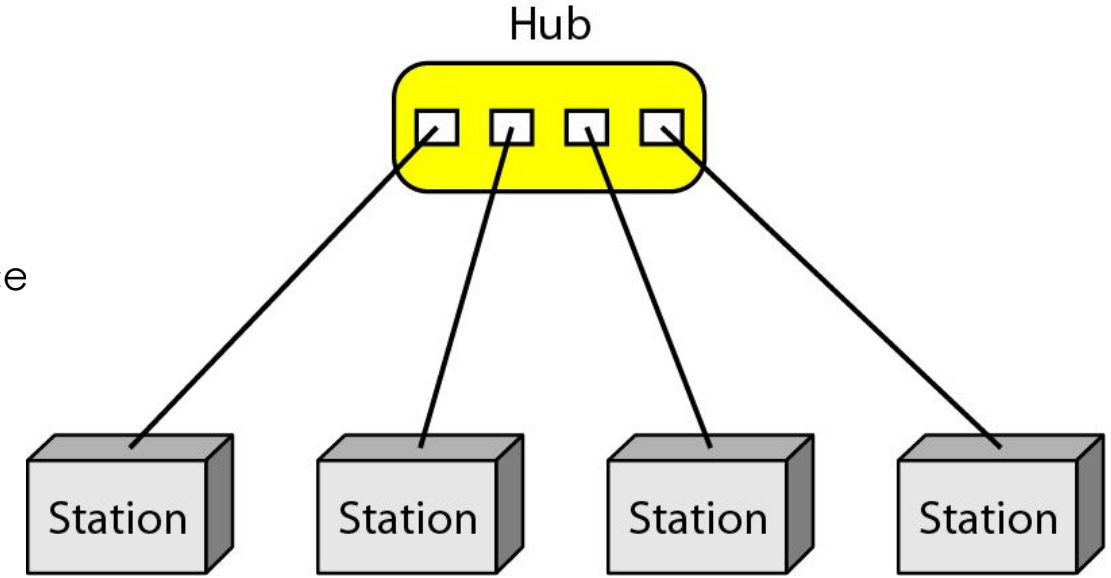


Networks - Topology - Star



- Each node 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 Hub 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

Networks - Topology - Star



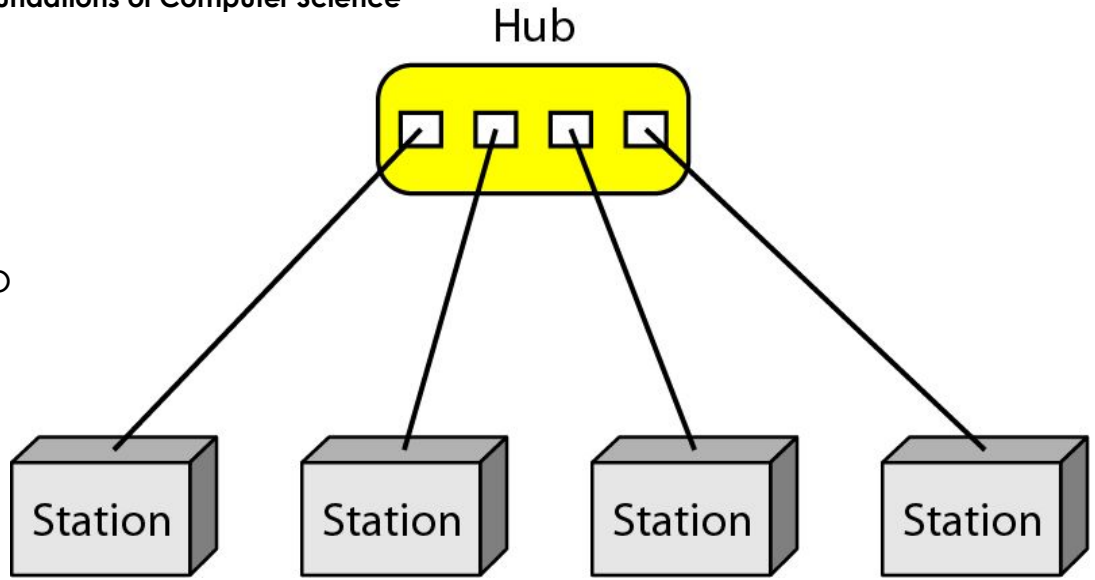
Advantages

- Less expensive - each each device needs only one link and one I/O port to connect it to any number of others
- Easy to network and configure
- Less cable need
- Additions, moves, and deletions in involve only one connection: between that device and the hub
- Robustness - If one link fails, only that link is affected. All other links remain active
- Easy fault identification and fault isolation

Networks - Topology - Star

Disadvantages

- Entire network depends on the hub
- If the hub goes down, the whole system is dead

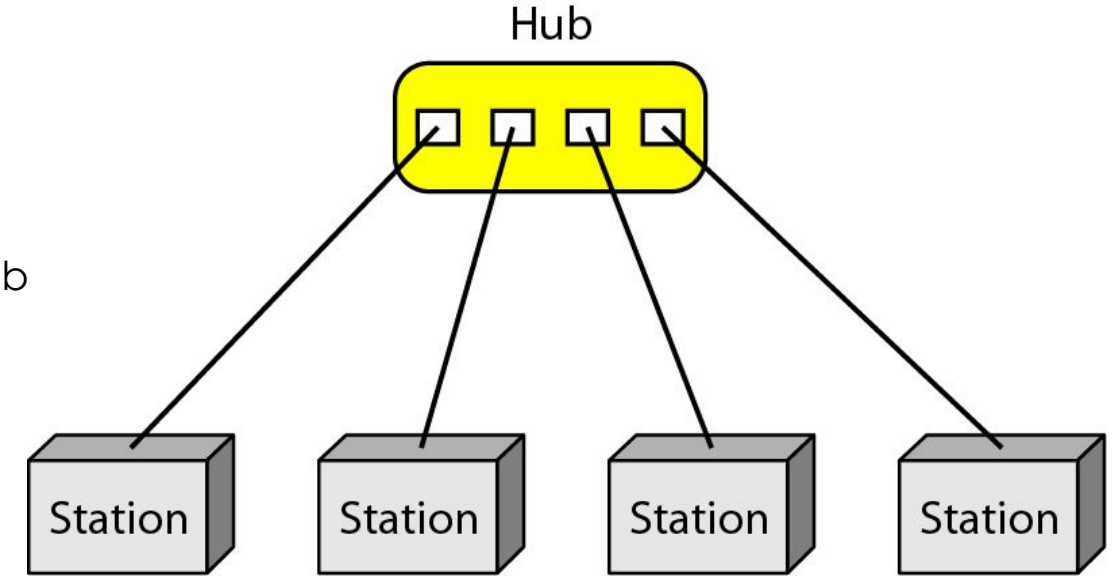


- Each node must be linked to a central hub. For this reason, often more cabling is required in a star than in some other topologies (such as ring or bus)

Networks - Topology - Star

Disadvantages

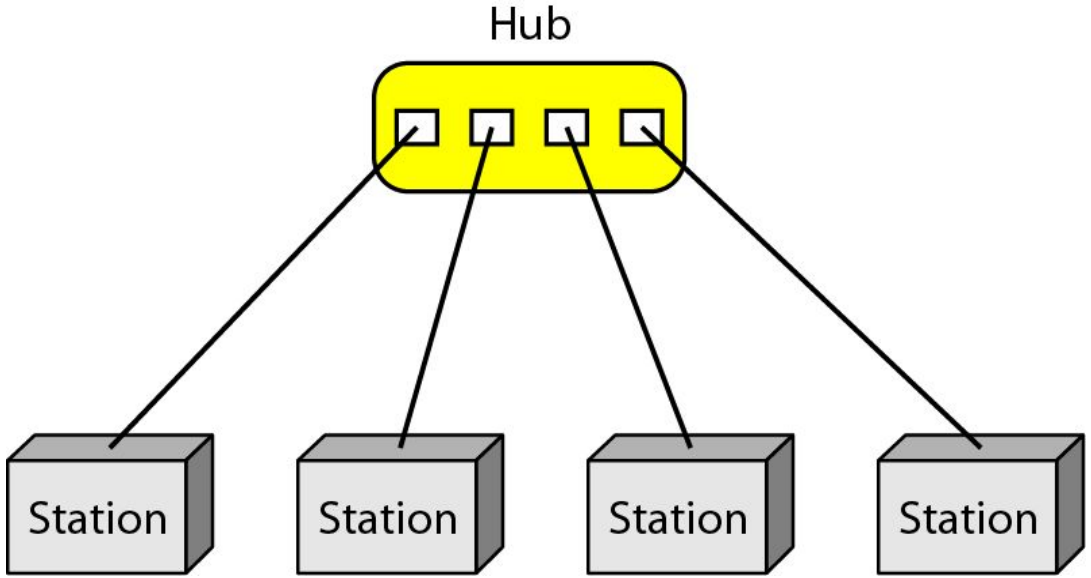
- Entire network depends on the hub
- If the hub goes down, the whole system is dead

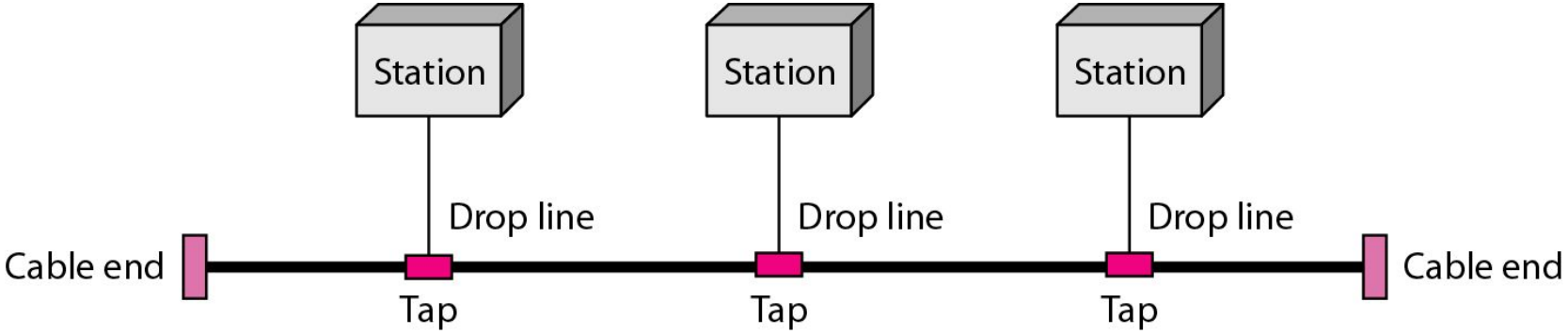


- Each node must be linked to a central hub. For this reason, often more cabling is required in a star than in some other topologies (such as ring or bus)

Networks - Topology - Star

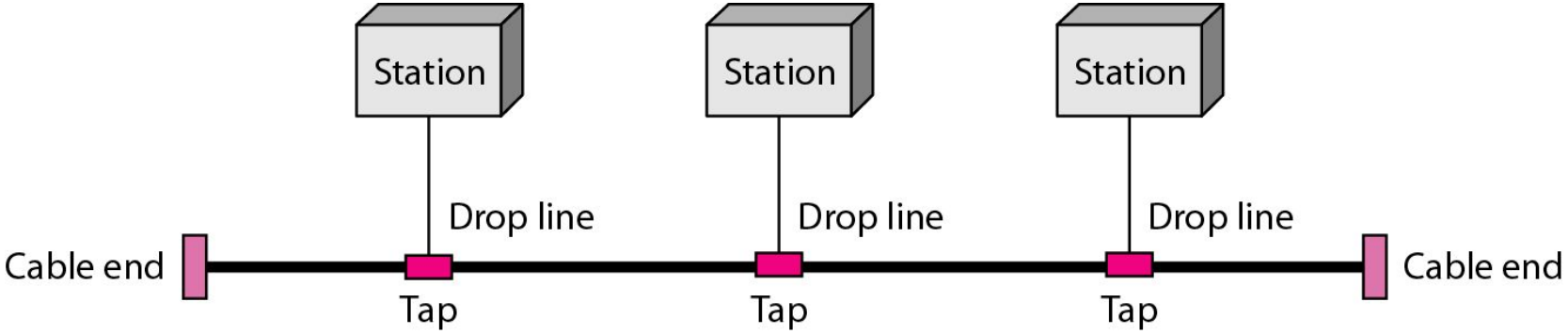
- Star topology is used in LANs





Networks - Topology - Bus

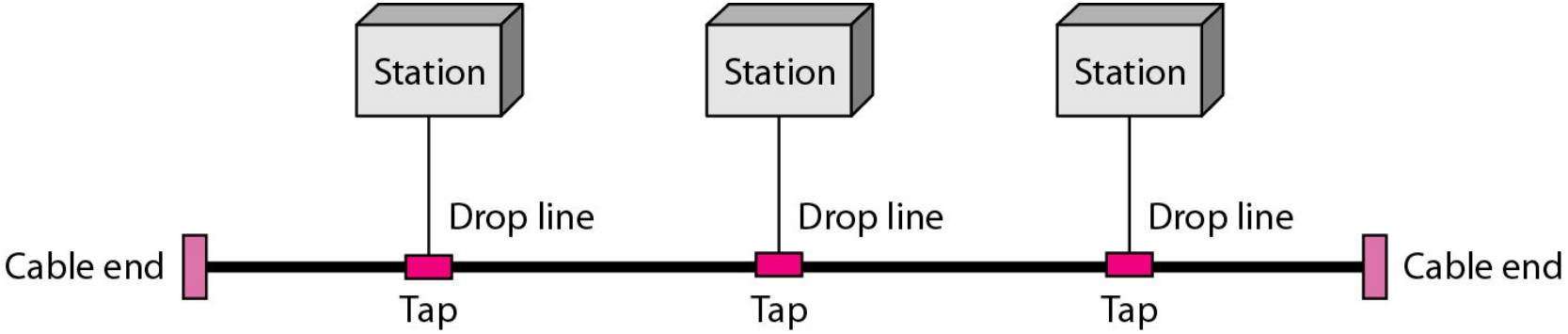
- A multipoint topology
- One long cable acts as a backbone to link all the devices in a network
- Nodes are connected to the bus cable by drop lines and taps
- A drop line is a connection running between the device and the main cable
- A tap is a connector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core



Networks - Topology - Bus

Advantages

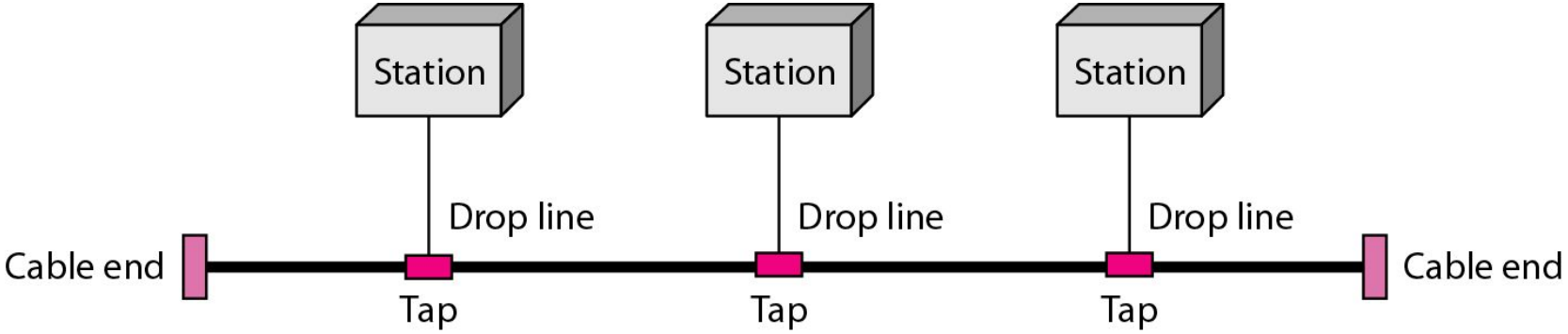
- Ease of installation - less cabling than mesh or star topologies



Networks - Topology - Bus

Disadvantages

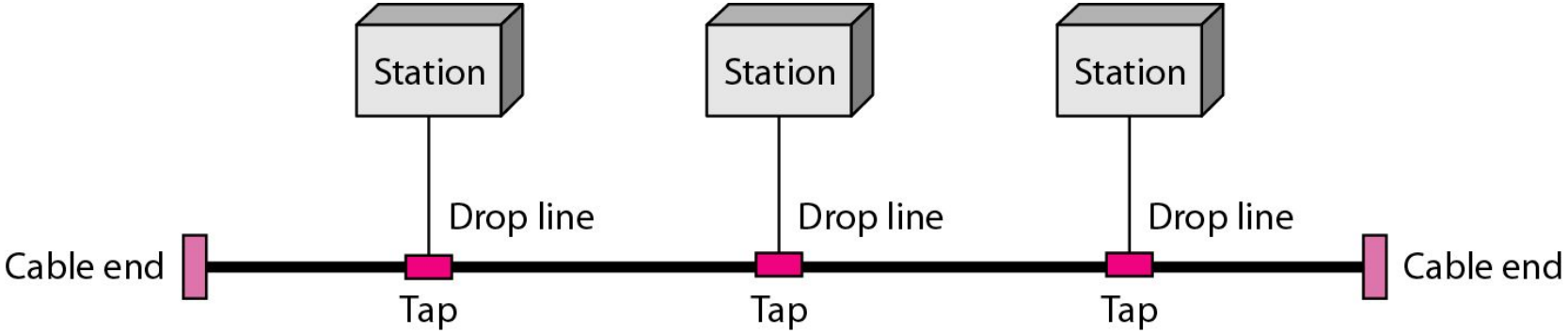
- As a signal travels along the backbone, some of its energy is transformed into heat. Therefore, it becomes weaker and weaker as it travels farther and farther. Due to this reason there is a limit on the number of taps a bus can support and on the distance between those taps



Networks - Topology - Bus

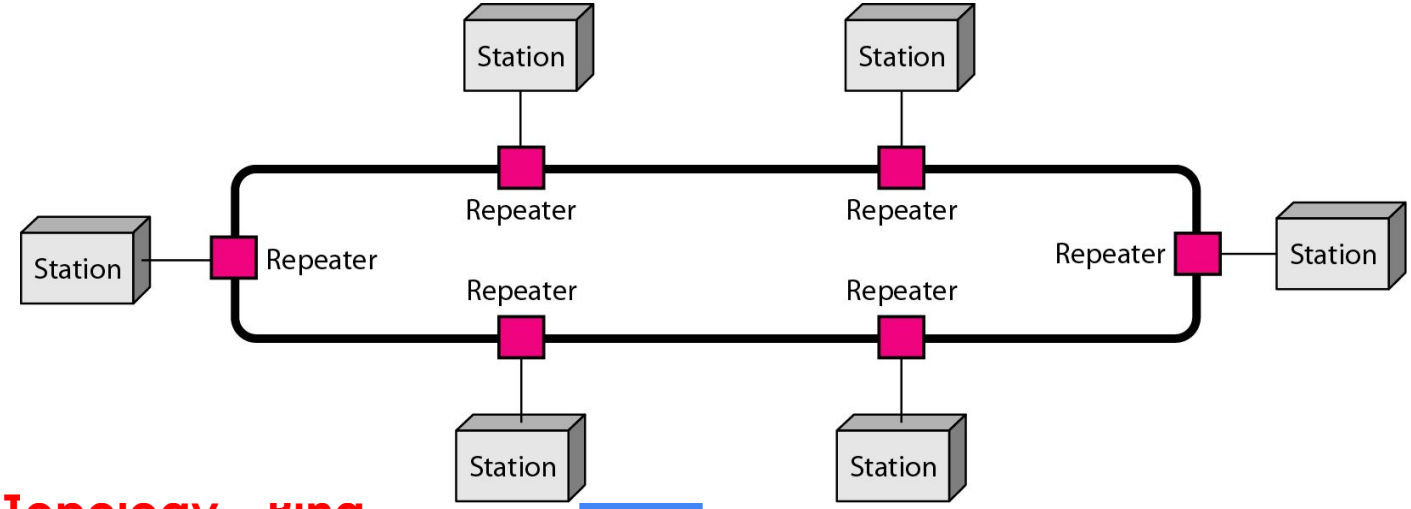
Disadvantages

- Difficult reconnection and fault isolation
- Signal reflection at the taps can cause degradation in quality
- Adding new devices may therefore require modification or replacement of the backbone
- A fault or break in the bus cable stops all transmission



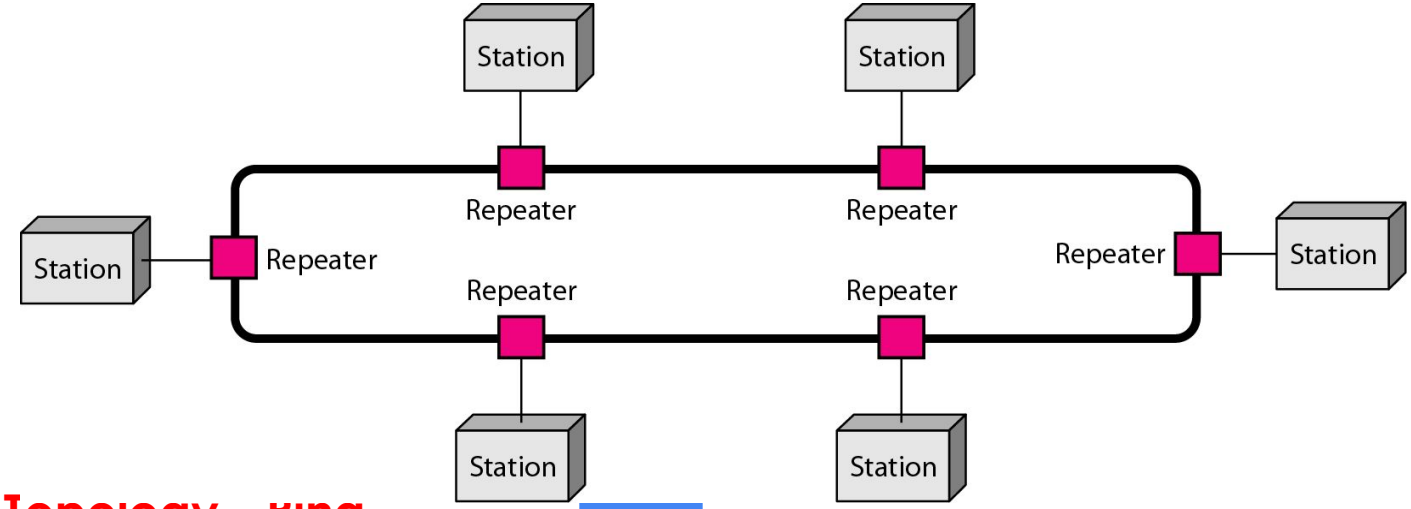
Networks - Topology - Bus

- A Bus topology was the one of the first topologies used in the design of early local area networks
- Ethernet LANs can use a bus topology



Networks - Topology - Ring

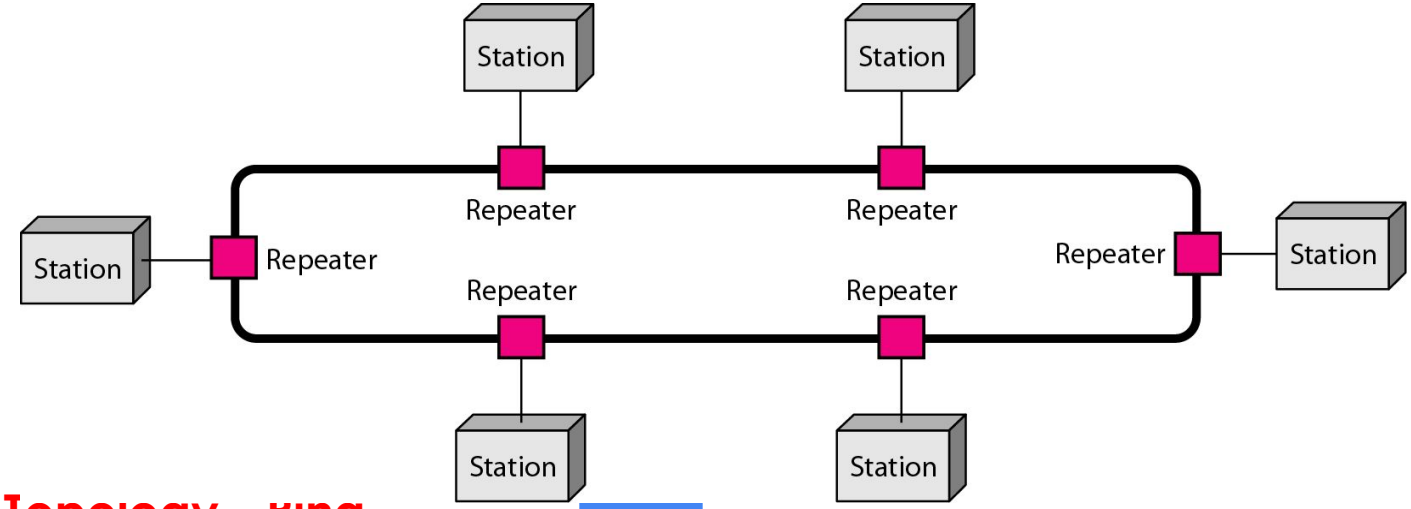
- Each device has a dedicated point-to-point connection with only the two devices on either side of it
- A signal is passed along the ring in one direction, from device to device, until it reaches its destination
- Each device in the ring incorporates a repeater. When a device receives a signal intended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



Networks - Topology - Ring

Advantages

- Relatively easy to install and reconfigure
- To add or delete a device requires changing only two connections
- Simple fault isolation - in a ring, a signal is circulating at all times. If one device does not receive a signal within a specified period, it can issue an alarm. The alarm alerts the network operator to the problem and its location



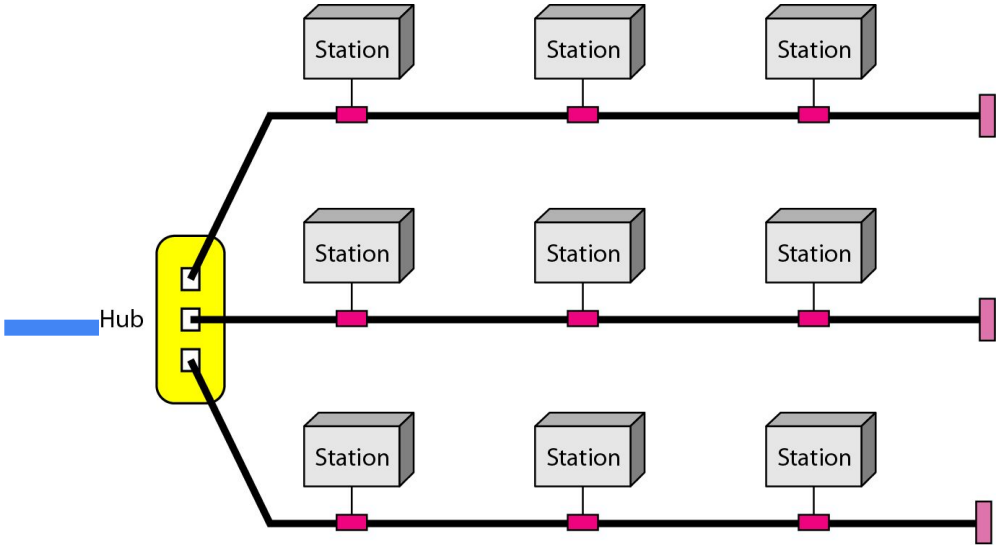
Networks - Topology - Ring

Disadvantages

- Unidirectional traffic can be a disadvantage
- In a simple ring, a break in the ring (such as a disabled station) can disable the entire network. This weakness can be solved by using a dual ring or a switch capable of closing off the break

Networks - Topology - Hybrid

- 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

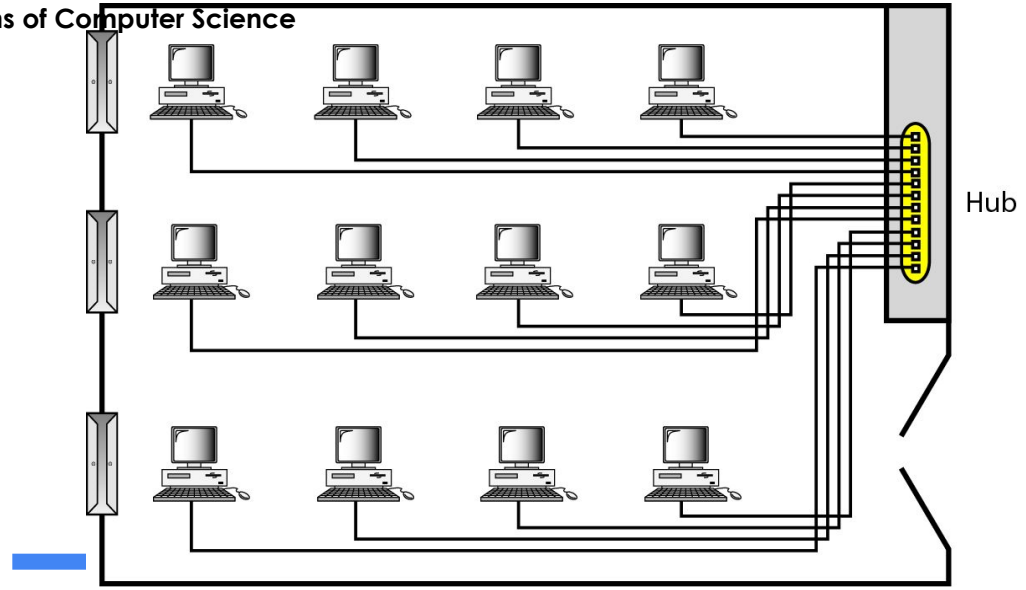


Networks - Categories

- Local Area Networks (LANs)
    - Short distances
    - Designed to provide local interconnectivity
- Wide Area Networks (WANs)
    - Long distances
    - Provide connectivity over large areas
- Metropolitan Area Networks (MANs)
    - Provide connectivity over areas such as a city, a campus

Networks - Categories

- Local Area Networks (LANs)
- Wide Area Networks (WANs)
- Metropolitan Area Networks (MANs)

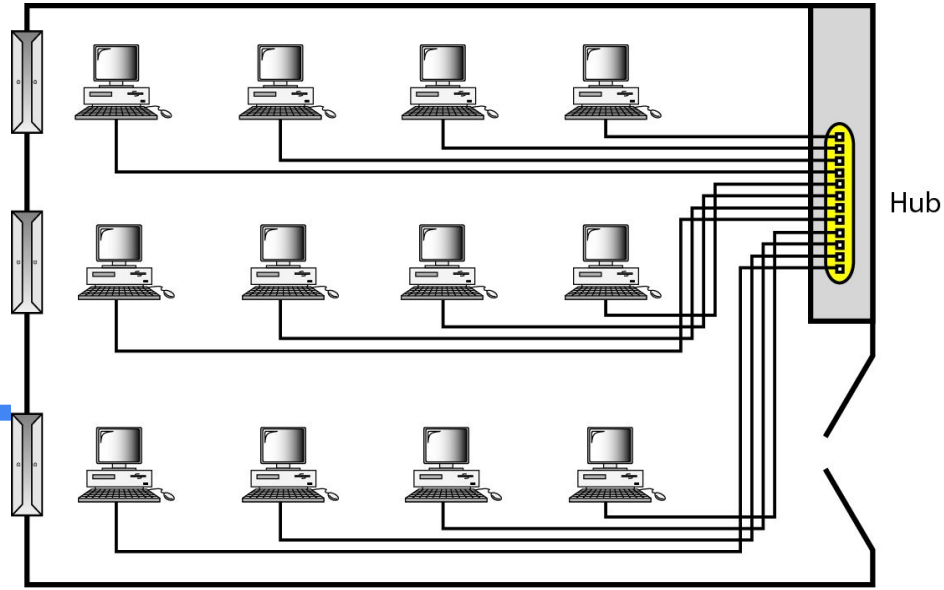


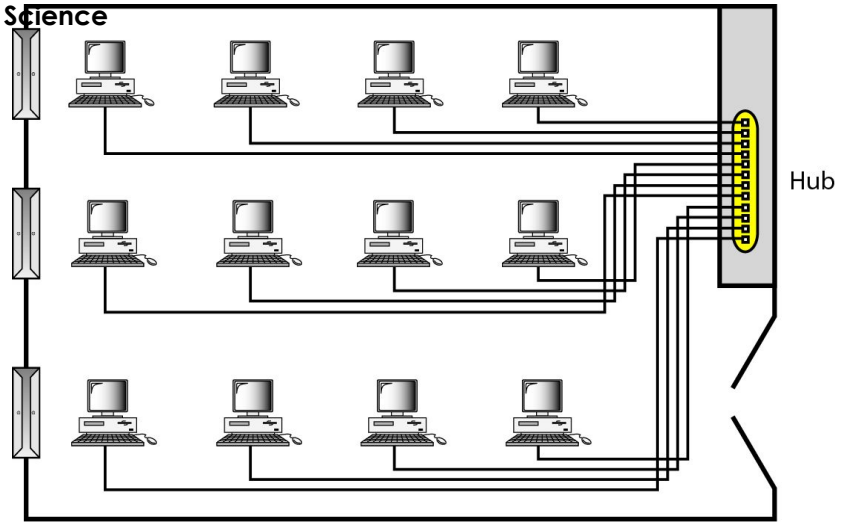
Networks - Categories

- Local Area Networks (LANs)
  - Short distances
  - Designed to provide local interconnectivity
  - 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

Networks - Categories

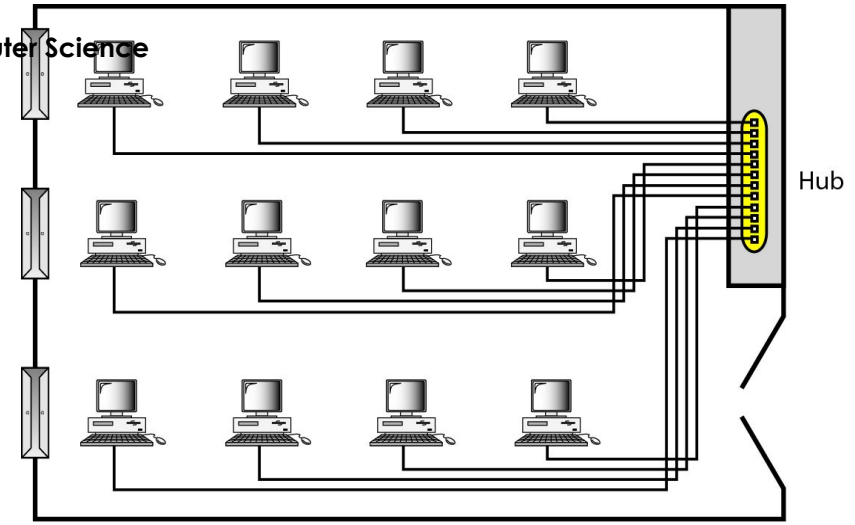
- Local Area Networks (LANs)
  - Designed to allow resources to be shared between personal computers or workstations
  - The resources to be shared can include hardware (e.g., a printer), software (e.g., an application program), or data





Networks - Categories

- Local Area Networks (LANs)
  - 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
  - Speeds are normally 100 or 1000 Mbps(Mbps stands for megabits per second)
  - Wireless LANs are the newest evolution in LAN technology



Networks - Categories

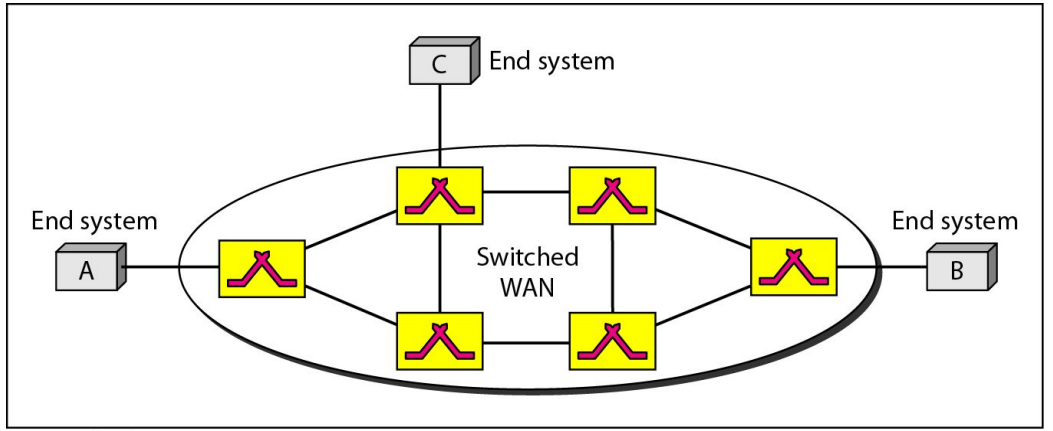
- Local Area Networks (LANs)
  - LANs are distinguished from other types of networks by their transmission media and topology
  - In general, a given LAN will use only one type of transmission medium
  - The most common LAN topologies are bus, ring, and star
  - Speeds are normally 100 or 1000 Mbps(Mbps stands for megabits per second)
  - Wireless LANs are the newest evolution in LAN technology

Networks - Categories - Wide Area Networks (WANs)

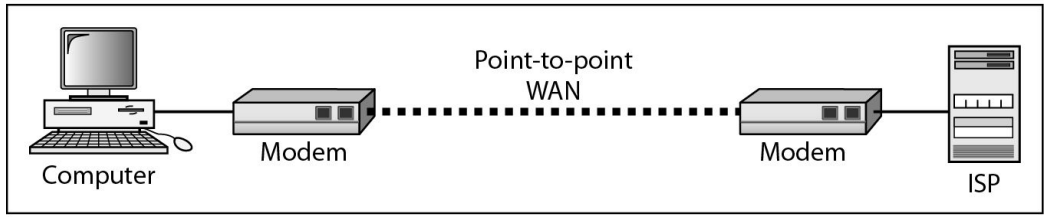
- Wide Area Networks (WANs)
    - Long distances
    - Provide connectivity over large areas that may comprise a country, a continent, or even the whole world

Networks - Categories - Wide Area Networks (WANs)

- A WAN can be as simple as a dial-up line that connects a home computer to the Internet
- It is called a Point to Point WAN (Fig a)
- 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 (ISP)



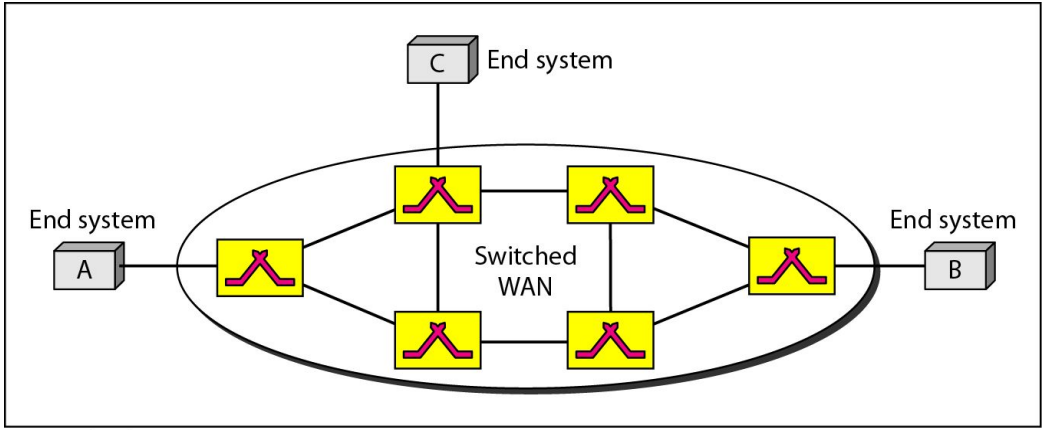
a. Switched WAN



b. Point-to-point WAN

Networks - Categories - Wide Area Networks (WANs)

- A WAN can be as complex as the backbones that connect the Internet
- It is called a Switched WAN (Fig a)
- A switched WAN is a type of network that connects different locations by routing data through various switches across a wide geographic area
- It is similar to a mail system, where each piece of data (like a letter) is sent from one location to another, passing through different post offices (switches) until it reaches its destination
- The switched WAN connects the end systems, which usually comprise a router (internetworking connecting device) that connects to another LAN or WAN



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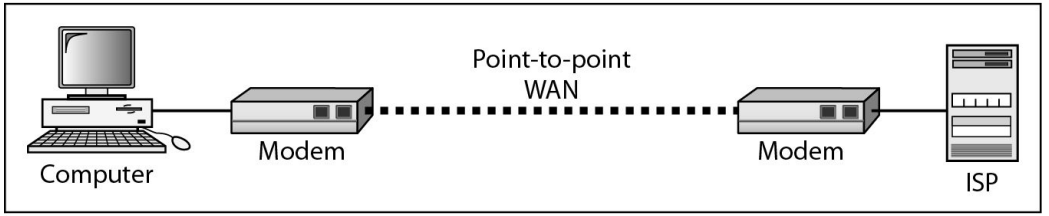
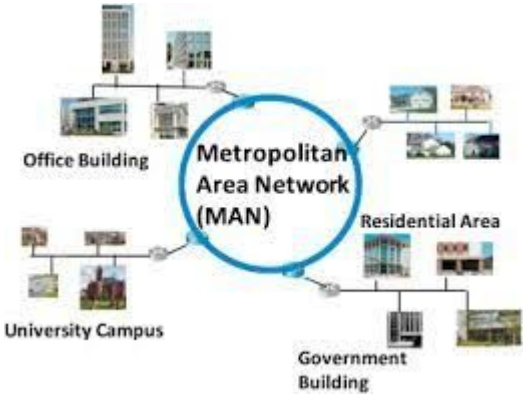


b. Point-to-point WAN

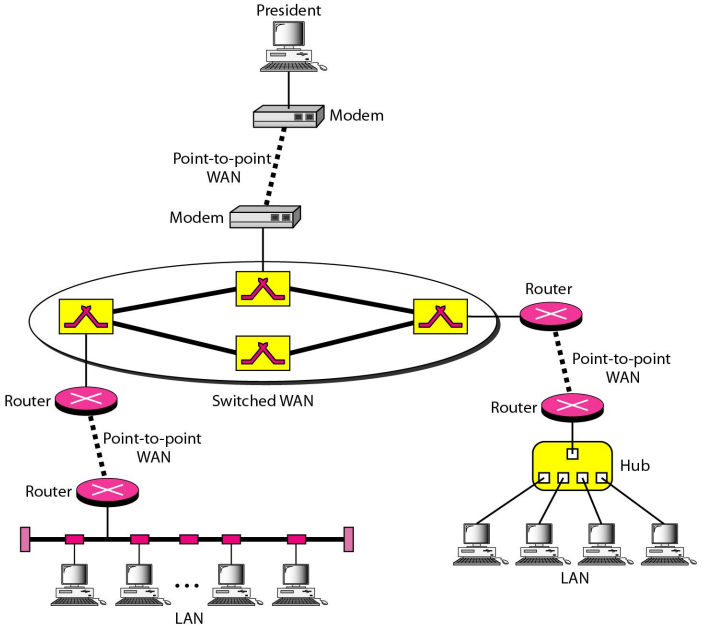


Networks - Categories - Metropolitan Area Networks (MANs)

- Provide connectivity over areas such as a city or a campus
- A network with a size between a LAN and a WAN
- 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

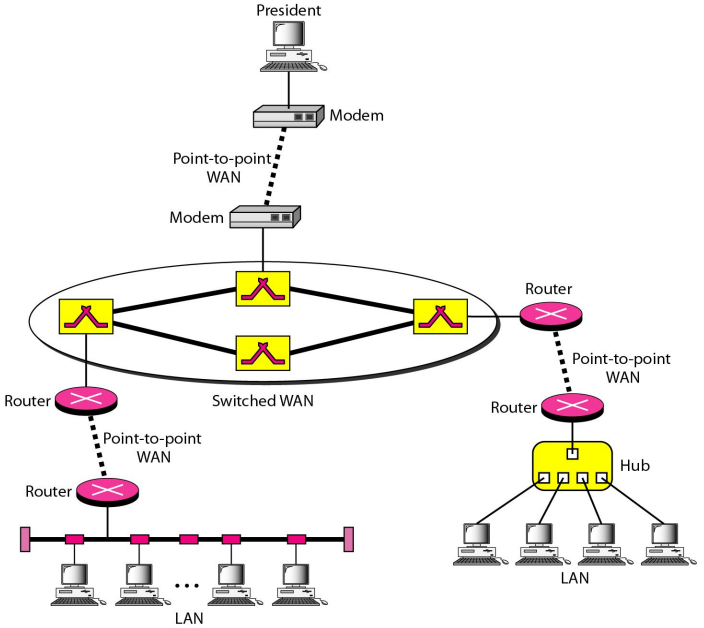
Networks - Interconnection of Networks: Internetwork

- When two or more networks are connected, they become an internetwork, or internet
- Consider an organization that has two offices, one on the east coast and the other on the west coast
- The existing office on the west coast has a bus topology LAN
- The newly opened office on the east coast has a star topology LAN



Networks - Interconnection of Networks: Internetwork

- The CEO lives somewhere in the middle and needs to have control over the company from his home
- To create a backbone WAN for connecting these three entities (two LANs and the president's computer), a switched WAN (operated by a service provider such as a telecom company) has been leased
- To connect the LANs to this switched WAN, however, three point-to-point WANs are required



Networks - Interconnection of Networks: Internet

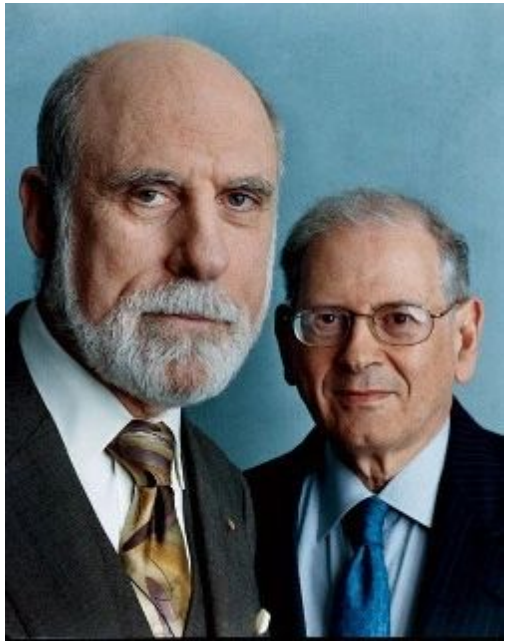
- An **internet** (note the lowercase letter i) is two or more networks that can communicate with each other
- The most notable internet is called **the Internet** (uppercase letter I), a collaboration of more than hundreds of thousands of interconnected networks
- Private individuals as well as various organizations such as government agencies, schools, research facilities, corporations, and libraries all over the world use the Internet
- Millions of people are users. Yet this extraordinary communication system only came into being in 1969!

Networks - Interconnection of Networks: Internet

- In the mid-1960s, mainframe computers in research organizations were standalone devices - they were not communicating each other
- The Advanced Research Projects Agency (ARPA) in the Department of Defense (DoD) was keen to have a networked system so that the researchers funded by them can better collaborate by sharing their resources
- In 1967, at an Association for Computing Machinery (ACM) meeting, ARPA presented its ideas for ARPANET, a small network of connected computers
- By 1969, ARPANET was a reality. Four nodes, at the University of California at Los Angeles (UCLA), the University of California at Santa Barbara (UCSB), Stanford Research Institute (SRI), and the University of Utah, were connected
- Software called the Network Control Protocol (NCP) provided communication between the hosts

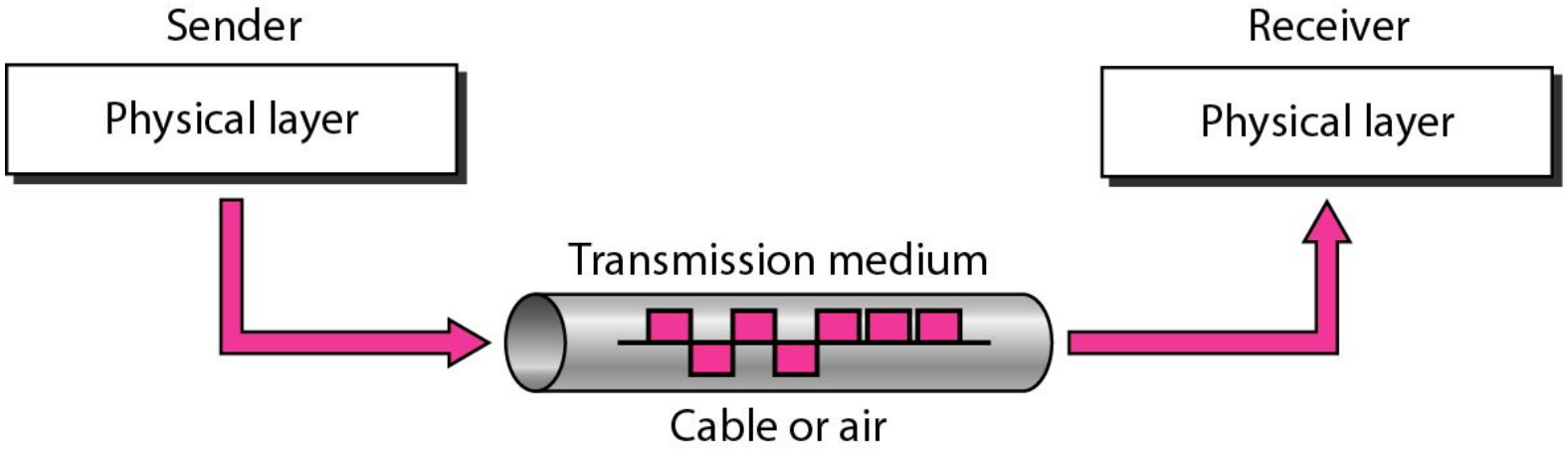
Networks - Interconnection of Networks: Internet

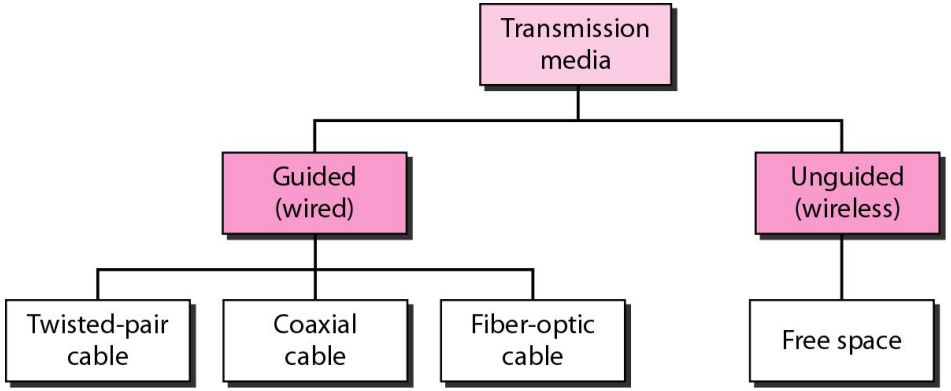
- In 1972, Vint Cerf and Bob Kahn (both of them were part of the core ARPANET group), collaborated on the Internetting Project
- They are still alive and called as Fathers of Internet



Transmission media

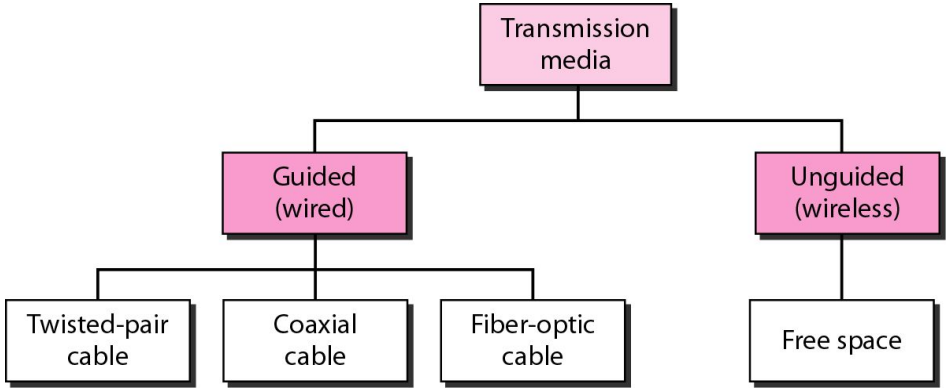
- A transmission medium can be broadly defined as anything that can carry information from a source to a destination
- For example, the transmission medium for engaging an offline class session is the air
- In data communications the definition of the information and the transmission medium is more specific
- The transmission medium is usually free space, metallic cable, or fiber-optic cable
- The information is usually a signal that is the result of a conversion of data from another form





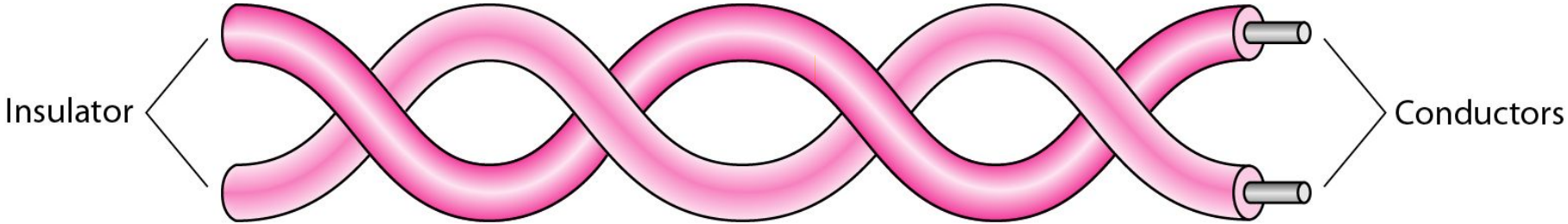
Transmission media - Un Guided Media

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



Transmission media - Guided Media

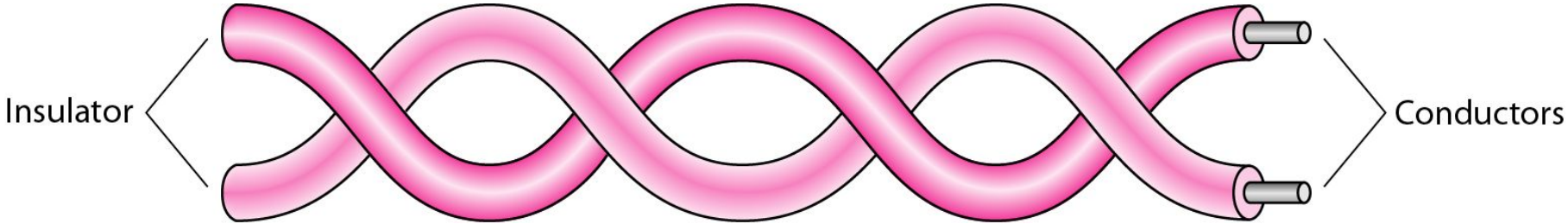
- The physical medium through which
- the signals are transmitted
- Also called as Bounded media



Transmission media - Guided Media - Twisted-Pair Cable

- 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. The receiver uses the difference between the two

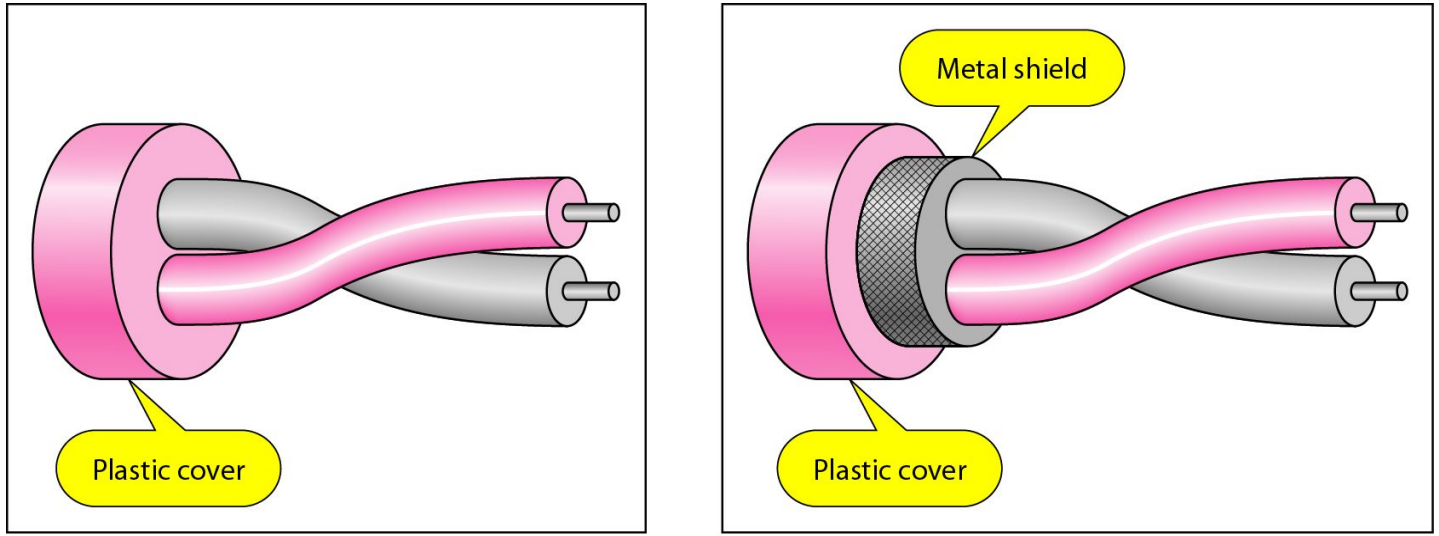
- Why the cable is twisted?!



Transmission media - Guided Media - Twisted-Pair Cable

Why the cable is twisted?!

- By twisting the pairs, a balance is maintained
    - For example, if in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse happens
    - Twisting makes it probable that both wires are equally affected by external influences noise or crosstalk)
    - This means that the receiver, which calculates the difference betwee the two, receives no unwanted signals
- Hence it it is clear that the number of twists per unit of length has an effect on the quality of the cable



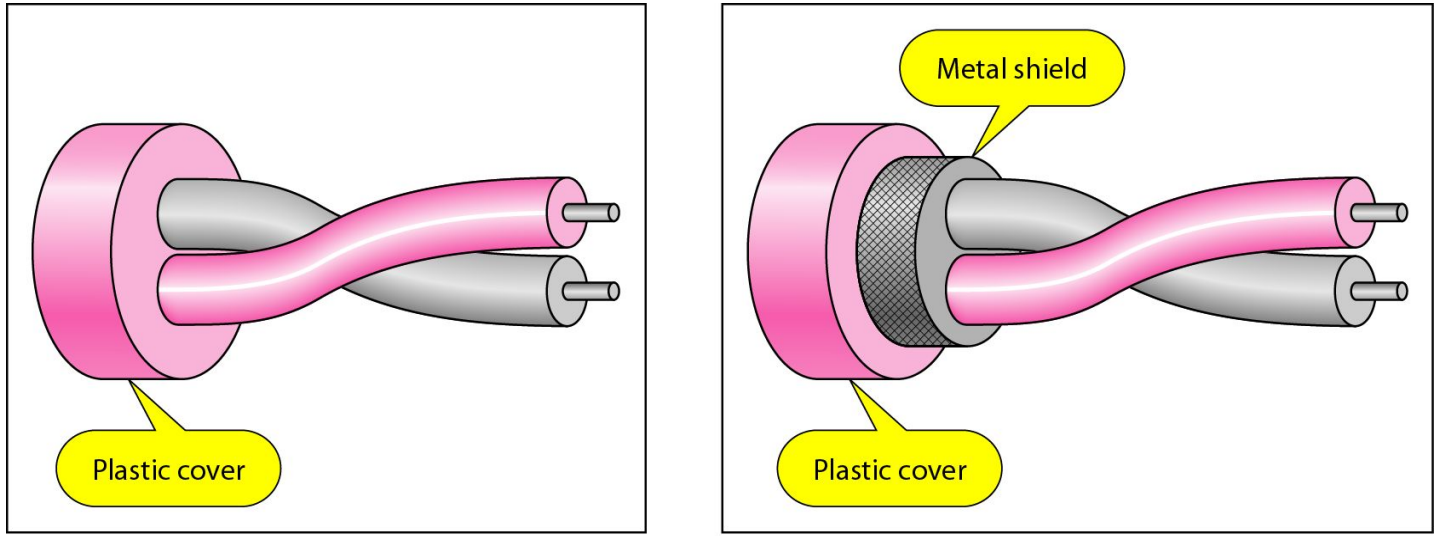
a. UTP b. STP

Transmission media - Guided Media - Twisted-Pair Cable

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 braidedmesh covering that encases each pair of insulated conductors

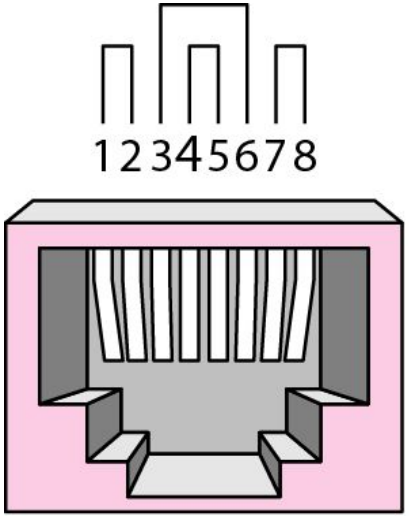


a. UTP b. STP

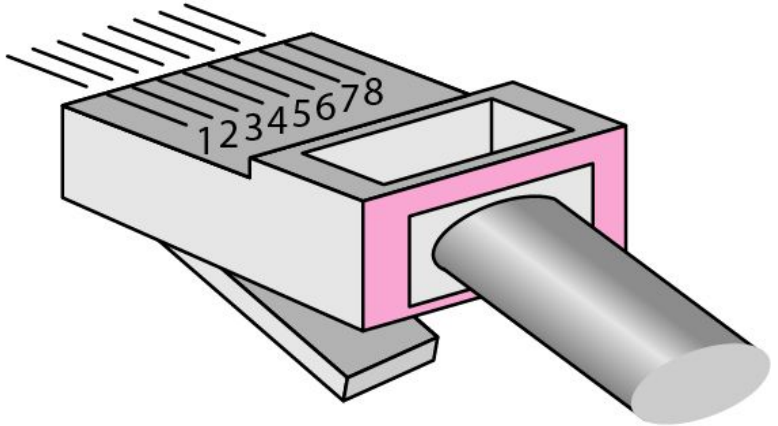
Transmission media - Guided Media - Twisted-Pair Cable

Unshielded Versus Shielded Twisted-Pair Cable

- Shield prevents the penetration of noise or crosstalk; but is expensive and bulkier



RJ-45 Female

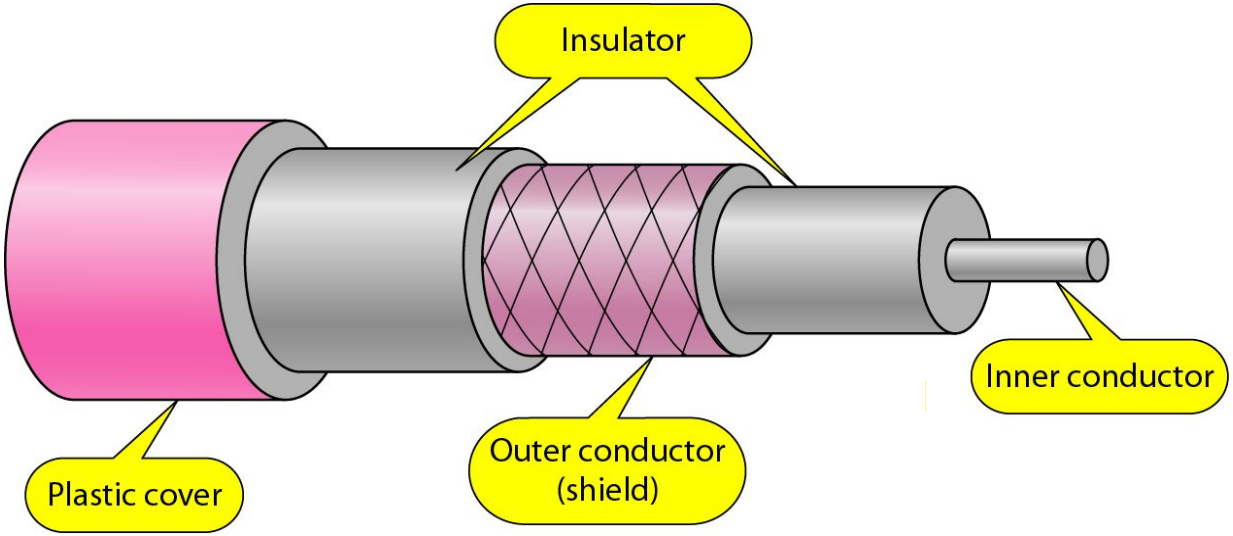


RJ-45 Male

Transmission media - Guided Media - Twisted-Pair Cable

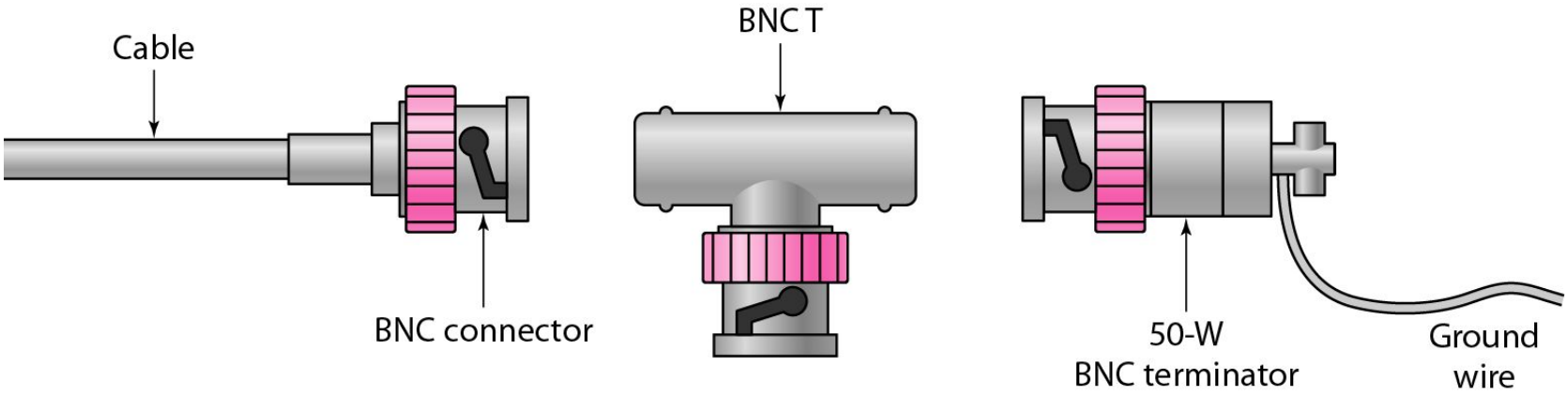
Unshielded Versus Shielded Twisted-Pair Cable

- The most common UTP connector is RJ45 (RJ stands for registered jack)
- The RJ45 is a keyed connector, meaning the connector can be inserted in only one way



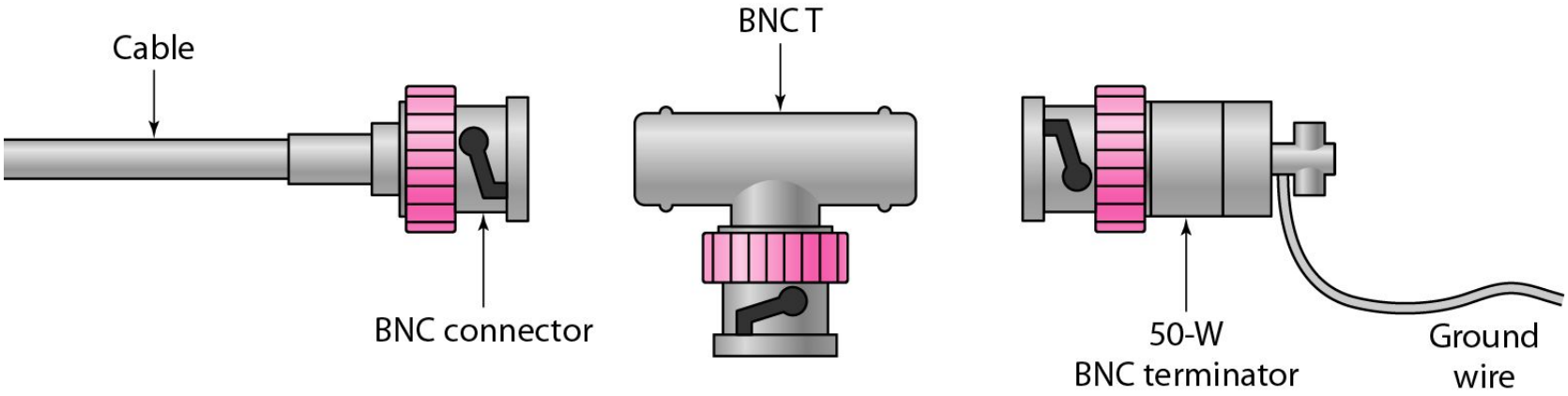
Transmission media - Guided Media - Coaxial Cable

- The core copper conductor is used for the transmission of signals
- The insulator is used to provide insulation to the copper conductor
- The insulator is surrounded by a braided metal conductor which helps to prevent the interference of electrical signals and prevent cross talk
- This entire setup is again covered with a protective plastic layer to provide extra safety to the cable



Transmission media - Guided Media - Coaxial Cable

- The most common type of coaxial connectors is the Bayone-Neill-Concelman (BNe), connector.
- Three popular types of BNC connectors are : the BNC connector, the BNC T connector, and the BNC terminator

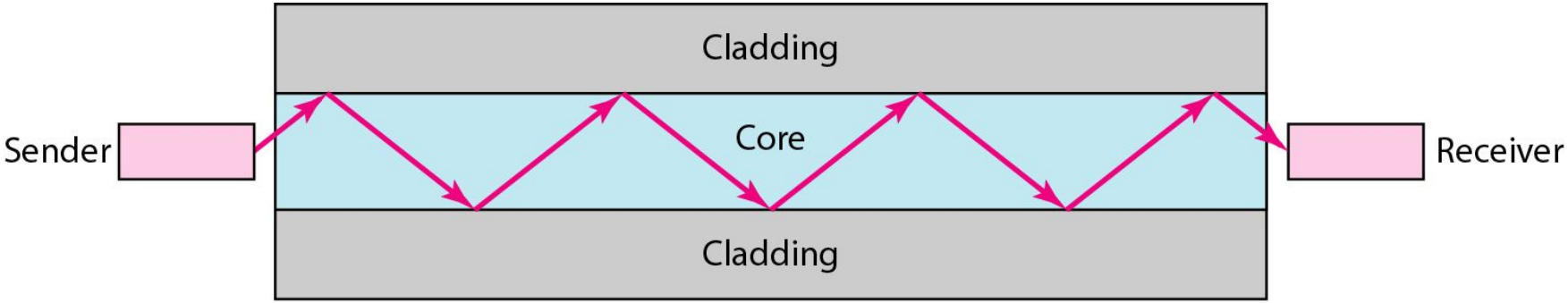


Transmission media - Guided Media - Coaxial Cable

- The BNC connector is used to connect the end of the cable to a device, such as a TV set
- The BNC T connector is used in Ethernet networks to branch out to a connection to a computer or other device
- The BNC terminator is used at the end of the cable to prevent the reflection of the signal**

Transmission media - Guided Media - Fiber-Optic Cable

- A network cable that is made of glass fibers inside an insulated casing
- Transmits signal in the form of light
- Designed for long-distance, high-performance data networking, and telecommunications
- Invented by Narinder Singh Kapany (Indian-born American physicist) in 1952

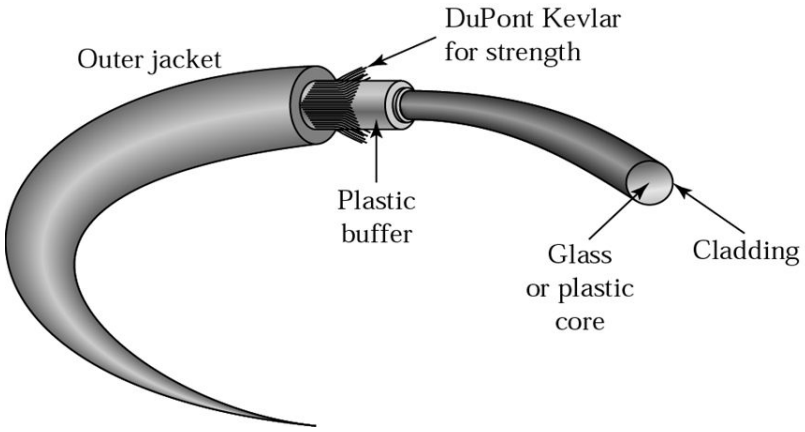


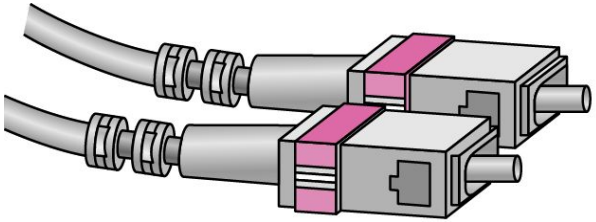
Transmission media - Guided Media - Fiber-Optic Cable

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

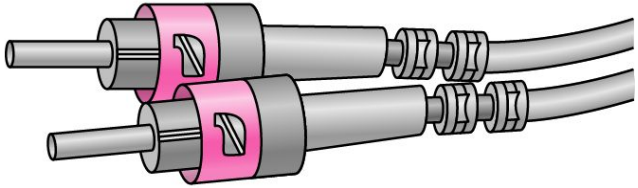
Transmission media - Guided Media - Fiber-Optic Cable

- Has a cylindrical shape and consists of three concentric sections
    - the core, the cladding and the jacket
- The core is made up of dense plastic or glass and it is here that the light travels
- The cladding is made up of less dense material which reflects the light signals back to the core instead of absorbing it
- The jacket surrounds one or more cladded cores to protect against environmental dangers

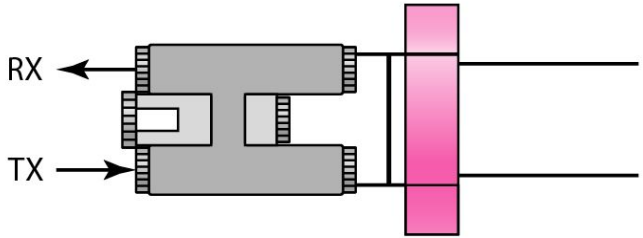




SC connector



ST connector



MT-RJ connector

- The subscriber channel (SC) connector is used for cable TV. It uses a push/pull locking system
- The straight-tip (ST) connector is used for connecting cable to networking devices. It uses a bayonet locking system and is more reliable than SC
- MT-RJ is a connector that is the same size as RJ45

Transmission media - Guided Media - Fiber-Optic Cable - Advantages

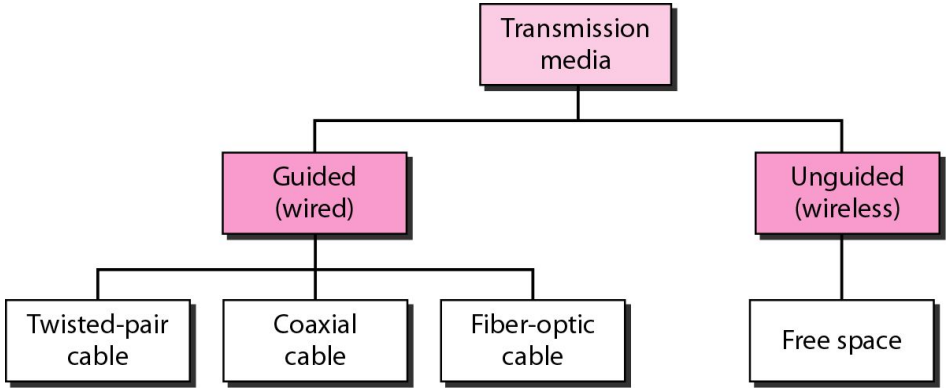
- **The Higher bandwidth**
  - Fiber-optic cable can support higher bandwidths (and hence data rates) than either twisted-pair or coaxial cable. Currently, data rates and bandwidth utilization over fiber-optic cable are limited not by the medium but by the signal generation and reception technology available
- **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 For coaxial or twisted-pair cable, we need repeaters every 5 km

Transmission media - Guided Media - Fiber-Optic Cable - Advantages

- **Immunity to electromagnetic interference**
  - Electromagnetic noise cannot affect fiber-optic cables
- **Resistance to corrosive materials**
  - Glass is more resistant to corrosive materials than copper
- **Light weight**
  - Fiber-optic cables are much lighter than copper cables
- **Greater immunity to tapping**
  - Fiber-optic cables are more immune to tapping than copper cables

Transmission media - Guided Media - Fiber-Optic Cable - Disadvantages

- **Installation and maintenance**
  - Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise. However this issue is getting marginalized now a days
- **Unidirectional light propagation**
  - Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed
- **Cost**
  - **The cable and the interfaces are relatively more expensive than those of other guided media**



Transmission media - Un Guided Media

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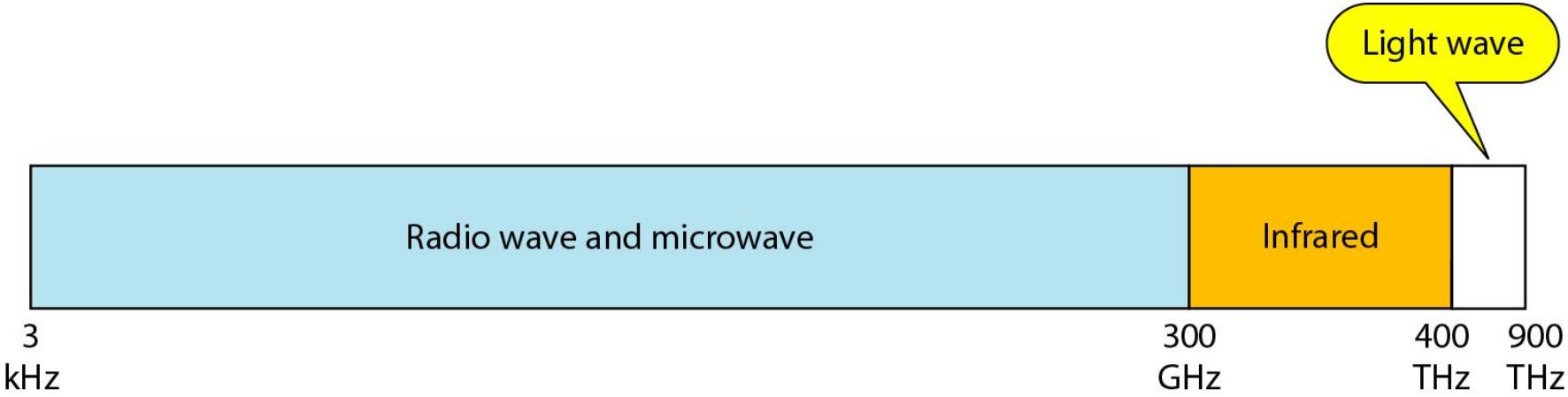
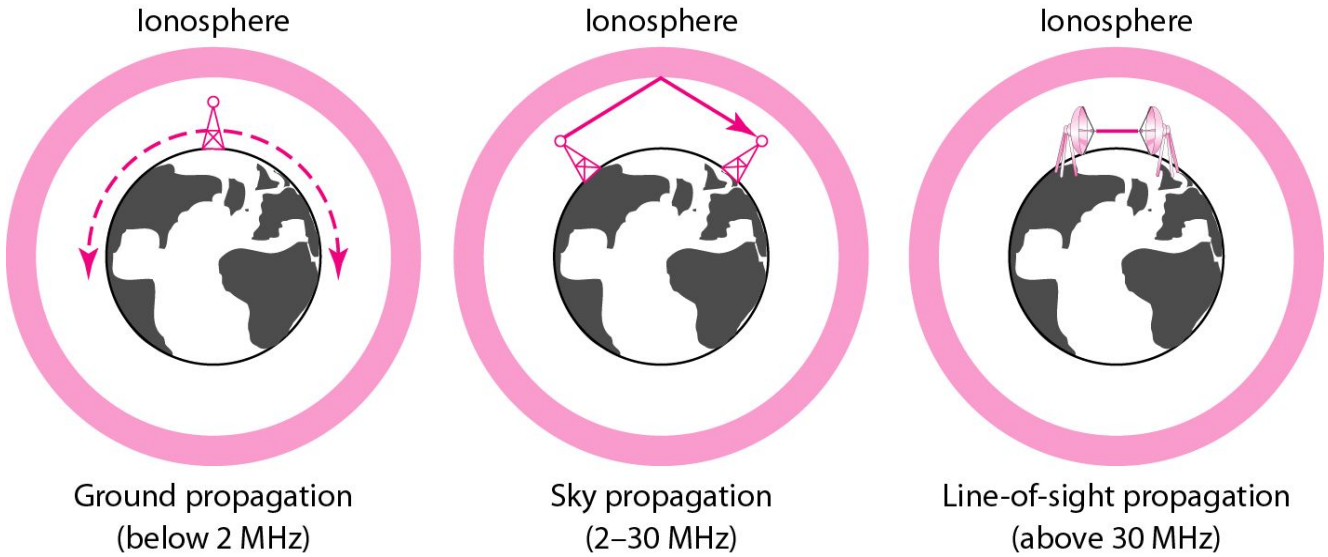


Transmission media - Un Guided Media

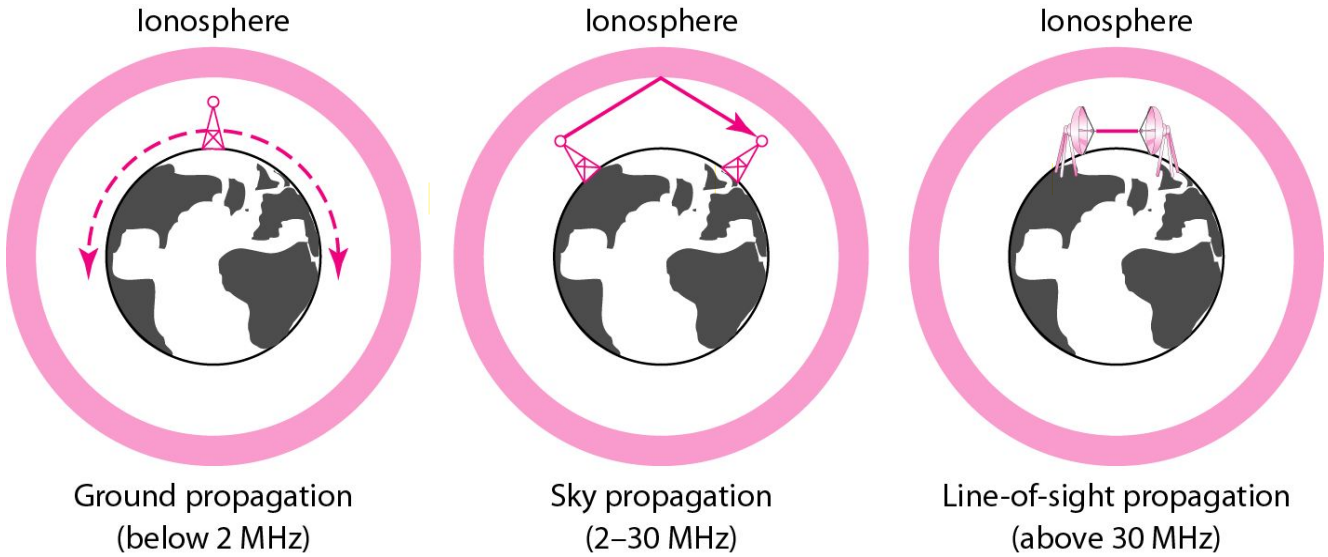
- The part of the electromagnetic spectrum, ranging from 3 kHz to 900 THz, used for wireless communication



Transmission media - Unguided Media - Modes of Propagation

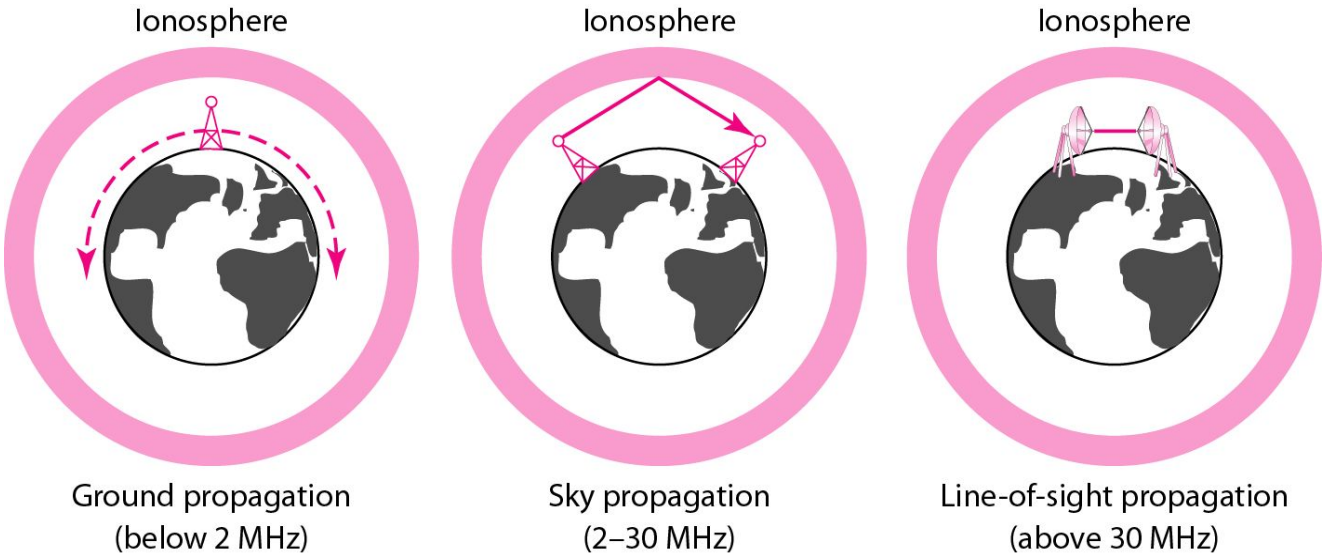
- In **ground propagation**, radio waves travel through the lowest portion of the atmosphere, closer to the earth
- These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet

Distance depends on the amount of power in the signal: The greater the power, the greater the distance



Transmission media - Unguided Media - Modes of Propagation

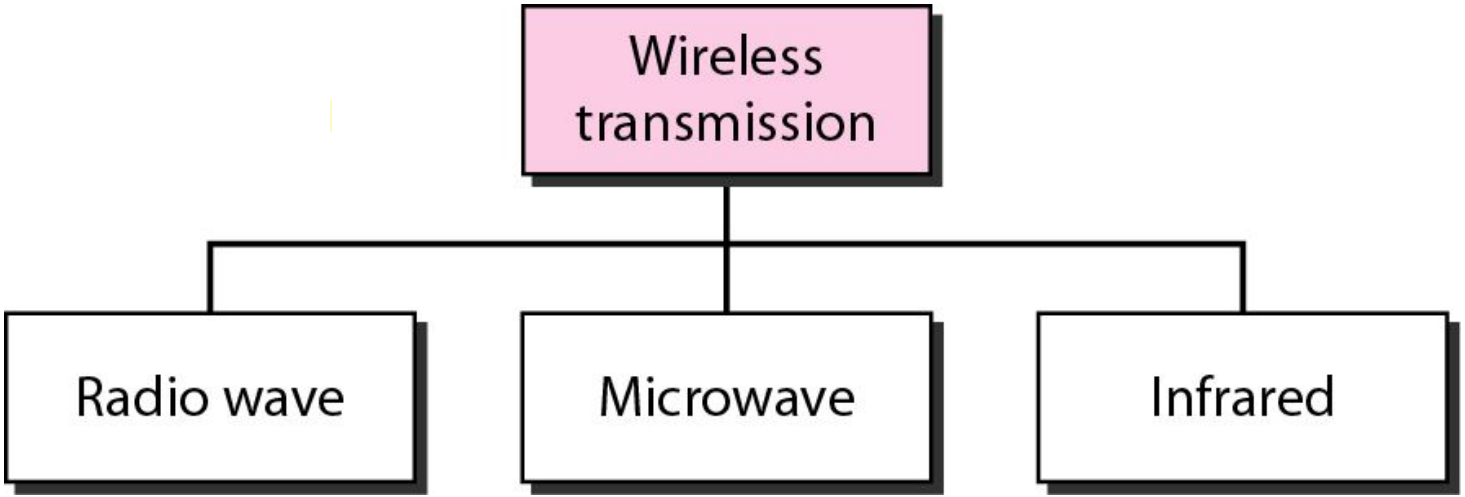
- In **sky propagation**, higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth
- This type of transmission allows for greater distances with lower output power



Transmission media - Unguided Media - Modes of Propagation

- In **line-or-sight propagation**, very high-frequency signals are transmitted in straight lines directly from antenna to antenna
- Antennas must be directional, facing each other and either tall enough or close enough together not to be affected by the curvature of the earth

Line-of-sight propagation is tricky because radio transmissions cannot be completely focused



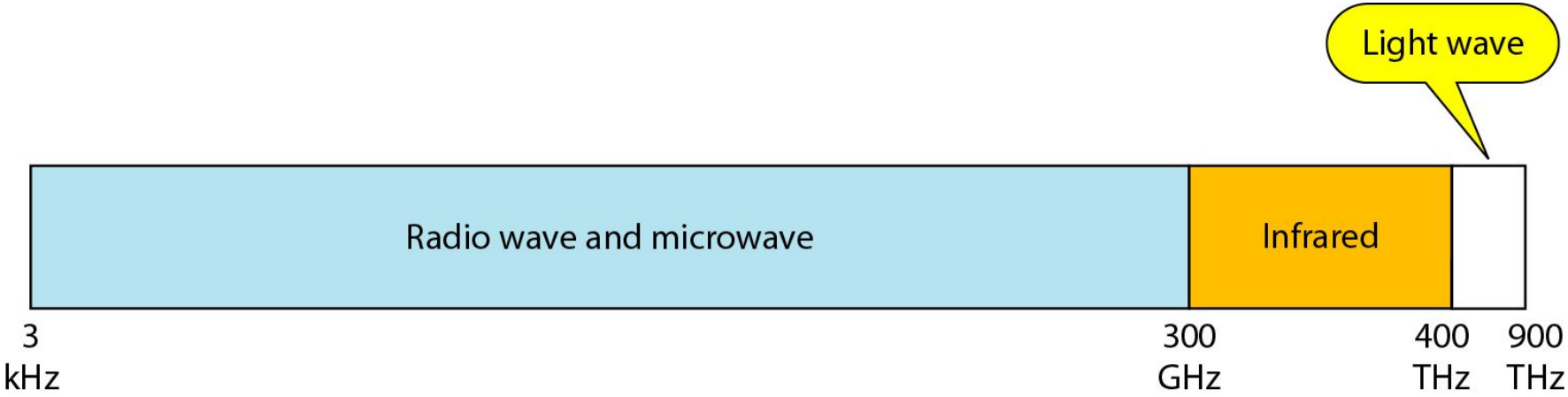
Transmission media - Unguided Media - Wireless Transmission - Classification

- **Reading Assignment!**

Network Models - Layered Architecture

- How communication occurs through a network?
- How data is routed from the sender the receiver?

.....



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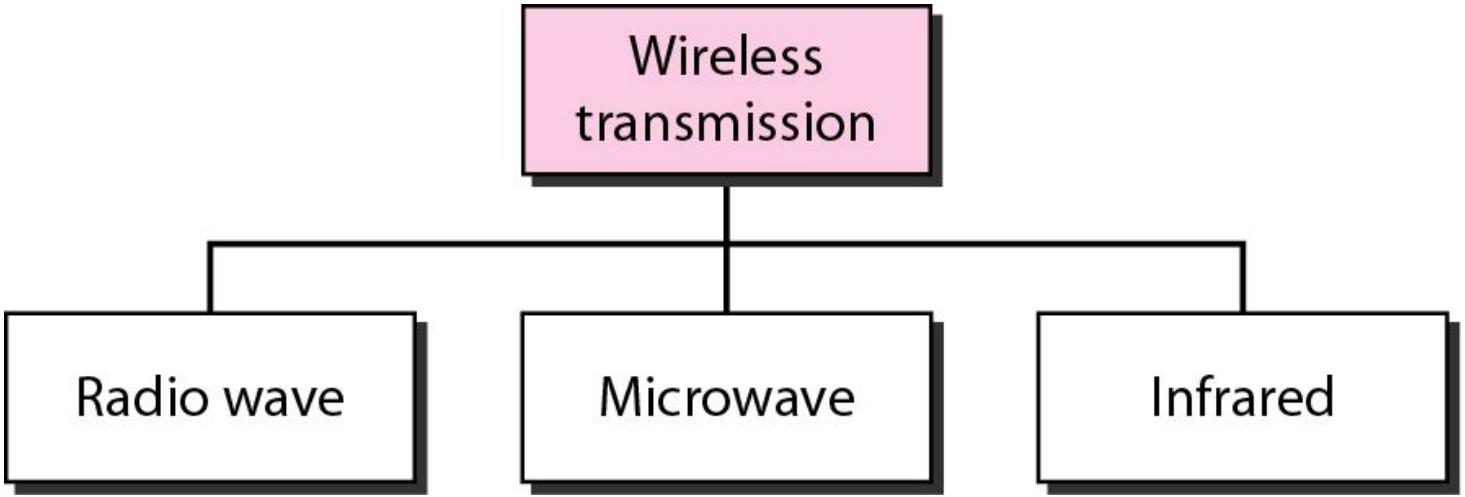

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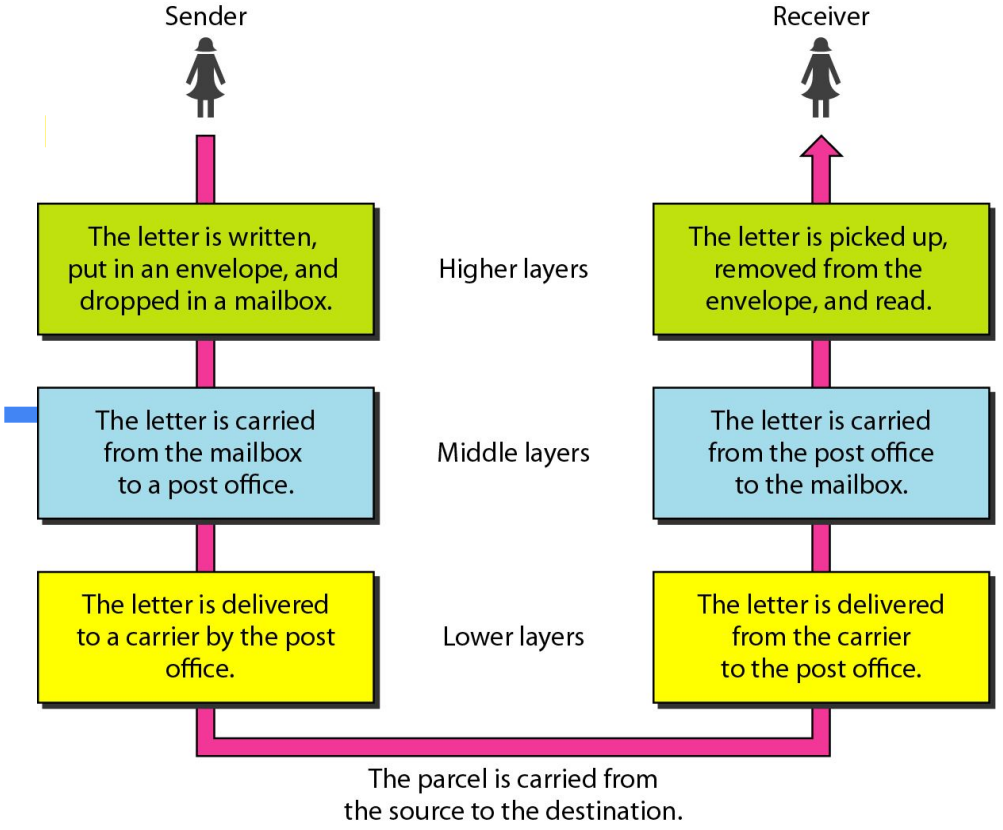
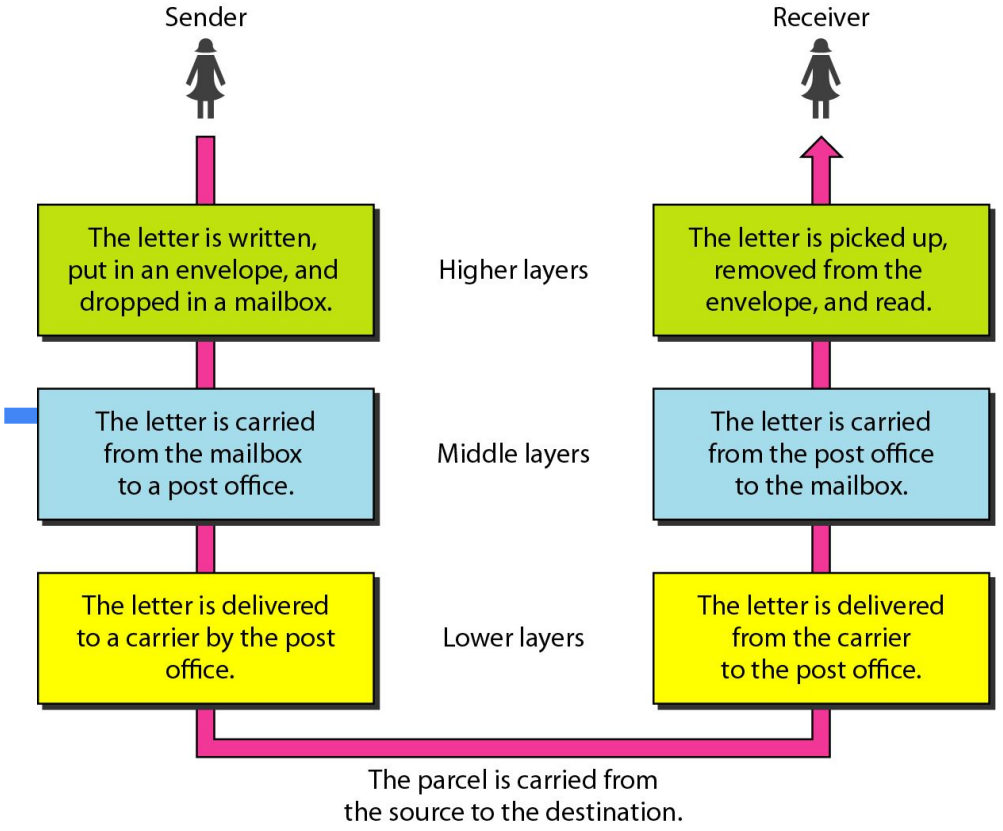
Network Models - Layered Architecture



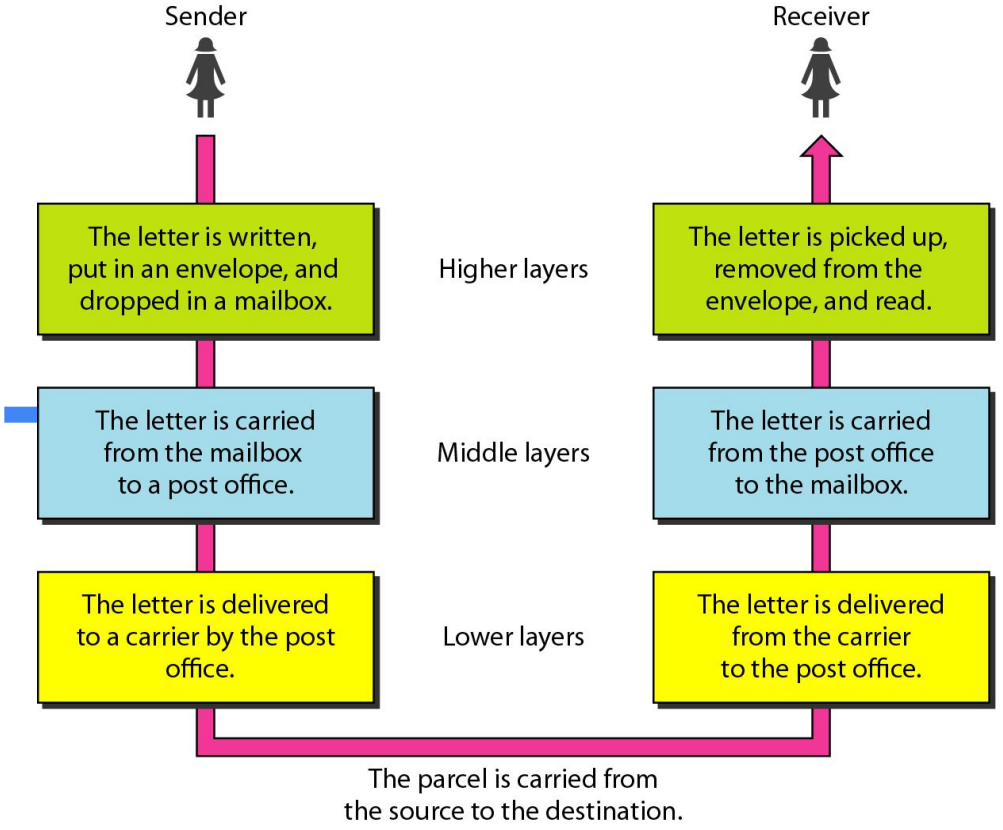
Network Models - Layered Architecture

- First let us look how postal communication is done
- We have a sender, a receiver, and a carrier that transports the letter
- Each of them has a hierarchy of tasks to be performed - to achieve the goal



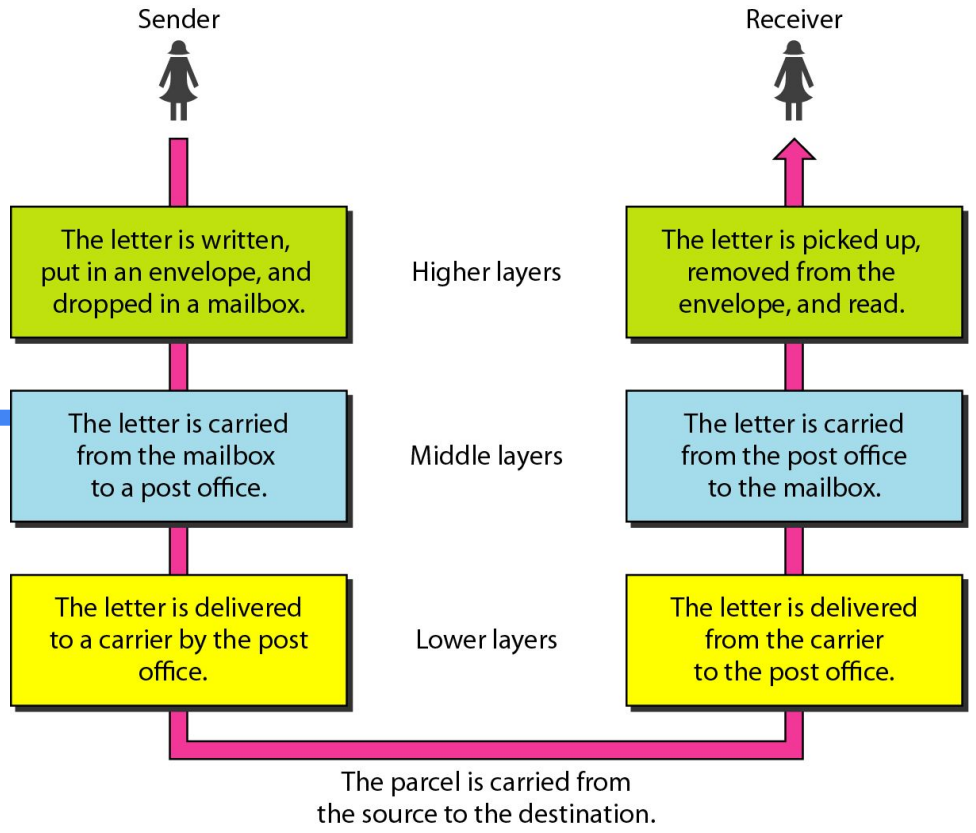
Network Models - Layered Architecture

- A layered approach is adopted here to do the task
- Sender, Receiver and Carrier has different kinds of activities
- Each layer at the sending site uses the services of the layer immediately below it
  - The sender at the higher layer uses the services of the middle layer. The middle layer uses the services of the lower layer. The lower layer uses the services of the carrier!



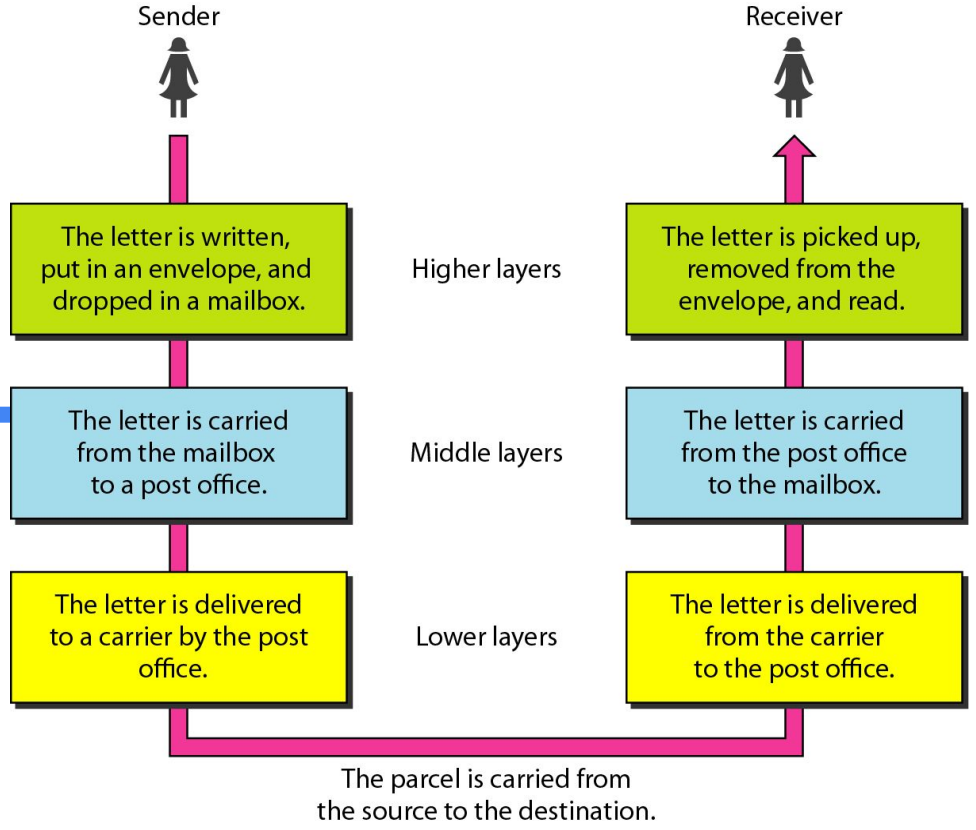
Network Models - Layered Architecture

- Initially the sender will have his letter in a sealed cover labelled with an address
- When the letter reaches at postal station, they attach a date stamp on it
- They even add additional information such as PIN code
- That means each layer may add few additional information to the actual data - but the actual letter contents will be still maintained intact



Network Models - Layered Architecture

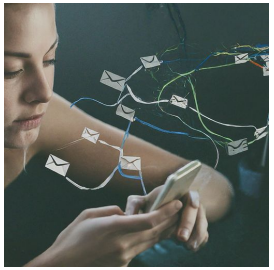
- Upon reception from a preceding layer, the current layer, will only refer to the data needed for its processing
- Hence there is an unwrapping of the data - the carrier may take everything in the mailbox to the post office. Sorter in the office will add additional information required to carry the letter to the destination. Carrier will look only the destination post office code for delivering the letter. Later from the post office, the letter is routed to the mailbox concerned



Packet switching

- Daily we make use of Internet for various types of communication
- Data being passed from sender to receiver is not transmitted as such!
- Instead it is split into segments at the sender's side and reassembled at the receiver's side
- Let us take an example
  - Imagine you have five toys, and you want to send them to your friend who lives far away
  - Instead of sending all five toys in one big box, you decide to send each toy separately
  - Also assume that each package can take different paths to reach your friend, depending on which roads are less crowded
  - Eventually, your friend gets all five toys, and he can put them together again to see the full set!

Packet switching



- Internet make use of packet switching for data transfer
- Packet Switching is like sending many small packages instead of one big one
- The Internet is like a giant map with many roads and highways
- Each packet takes the best or fastest route at the time. Sometimes, a packet may take a longer route if other roads are too busy, but they all reach the same destination
- When your packets reach your friend's house (or in the Internet's case, the receiving computer), they are put back together in the correct order to show the complete message or file
- Your data packets move through different computers and networks, like how your toy packages pass through post offices on the way to your friend
- These post offices on the Internet are called routers. They help send your packets in the right direction until they reach the final destination

Network Models - Layered Architecture

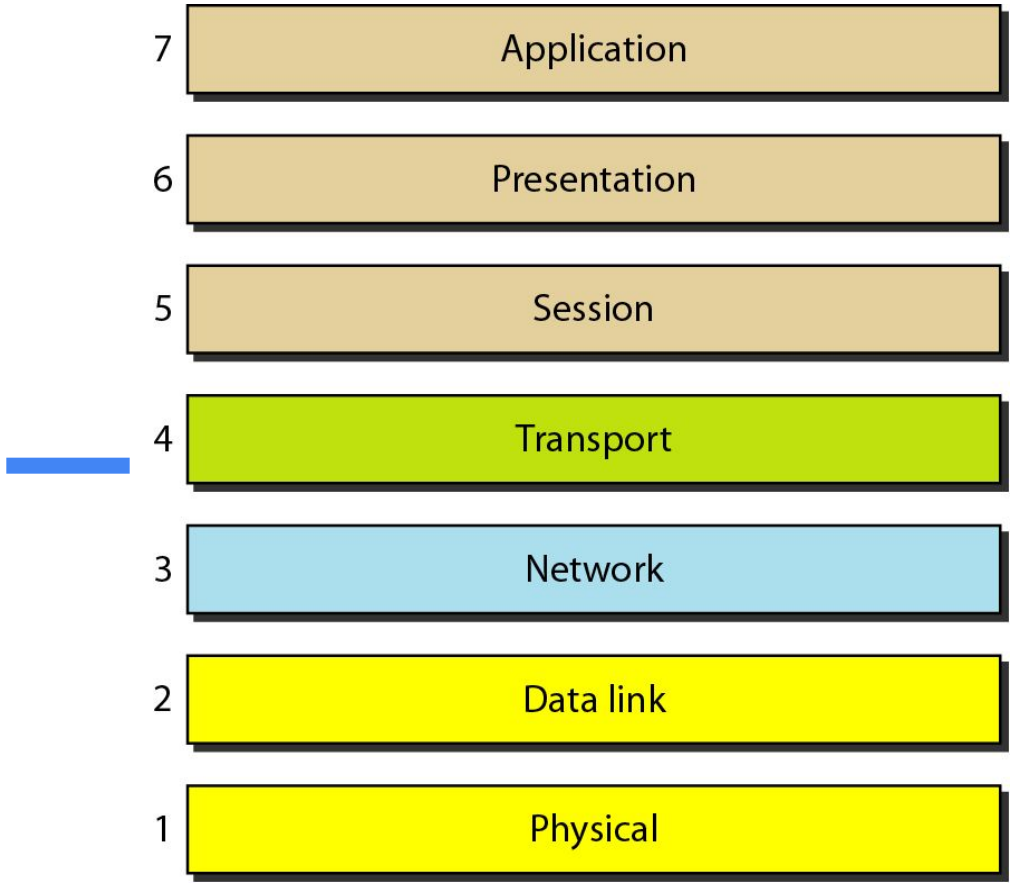
- Even in networking, a layered model is adopted
- Established in 1947, the International Standards Organization (ISO) is a multinational body dedicated to worldwide agreement on international standards
- An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model. It was first introduced in the late 1970s

Network Models - Layered Architecture

- The purpose of the OSI model is to show how to facilitate communication between different systems without requiring changes to the logic of the underlying hardware and software
- The OSI model is not a protocol; it is a model for understanding and designing a network architecture that is flexible, robust, and interoperable

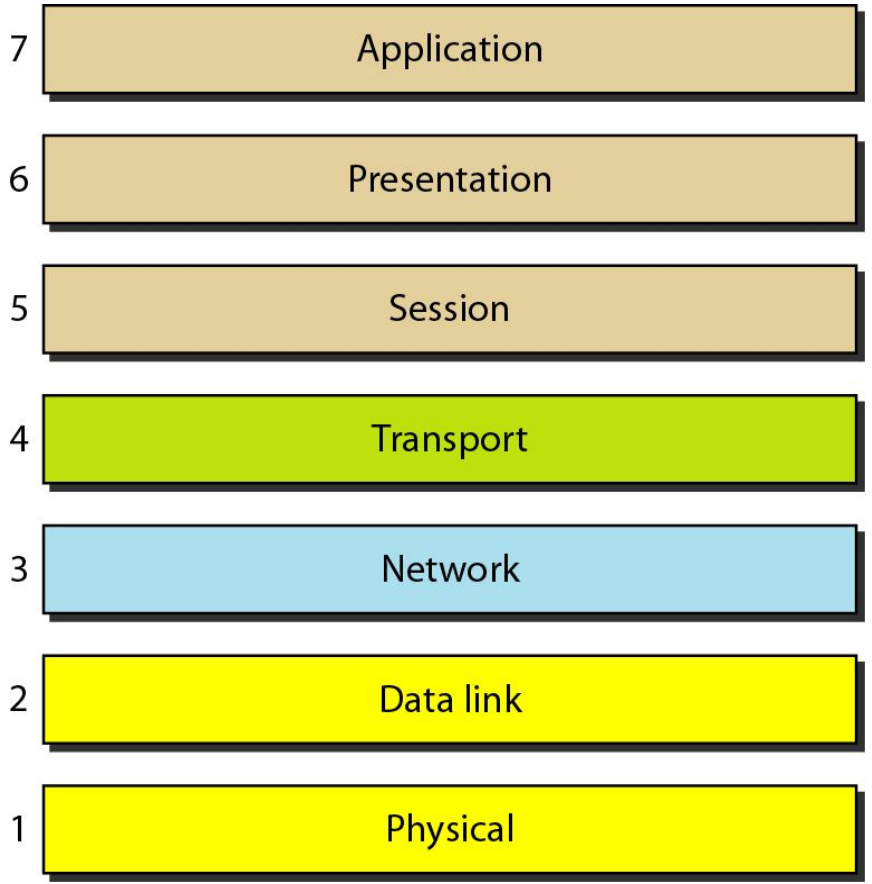
Network Models - OSI Model

- Consists of 7 ordered layers
  - Physical (layer 1)
  - Data link (layer 2),
  - Network (layer 3)
  - Transport (layer 4)
  - Session (layer 5)
  - Presentation (layer 6)
  - Application (layer 7)



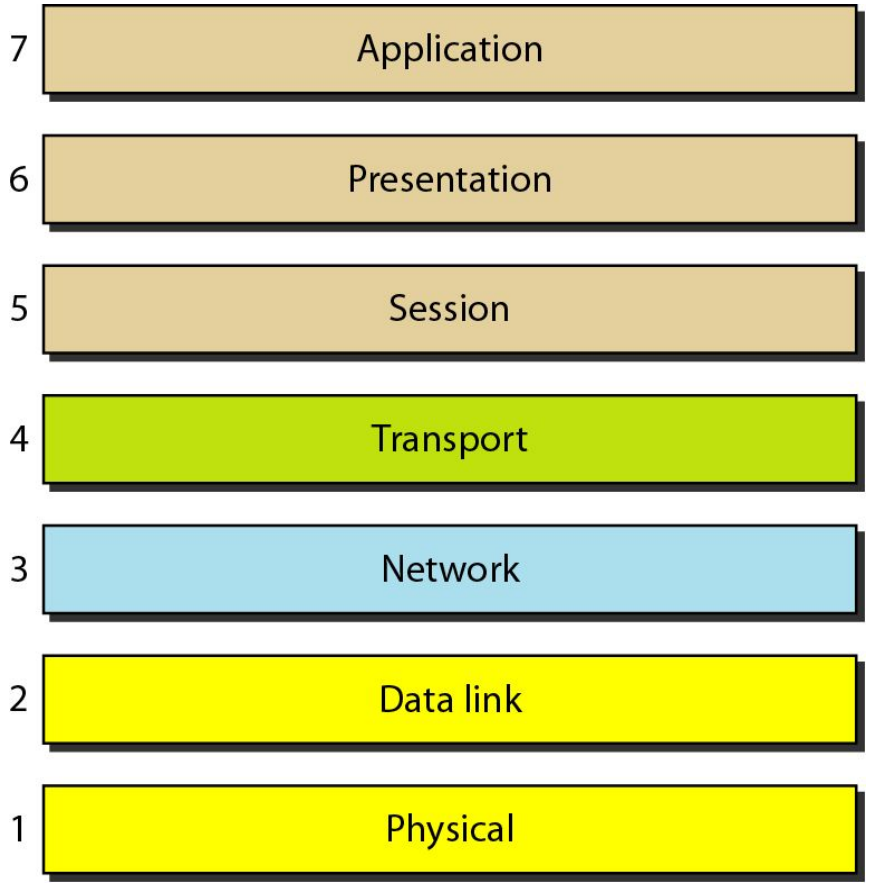
Network Models - OSI Model

- How these layers are modelled?
  - Developers identified which networking functions had related uses and collected those functions into discrete groups
  - Each of these groups became a layer
  - Each layer defines a family of functions distinct from those of the other layers



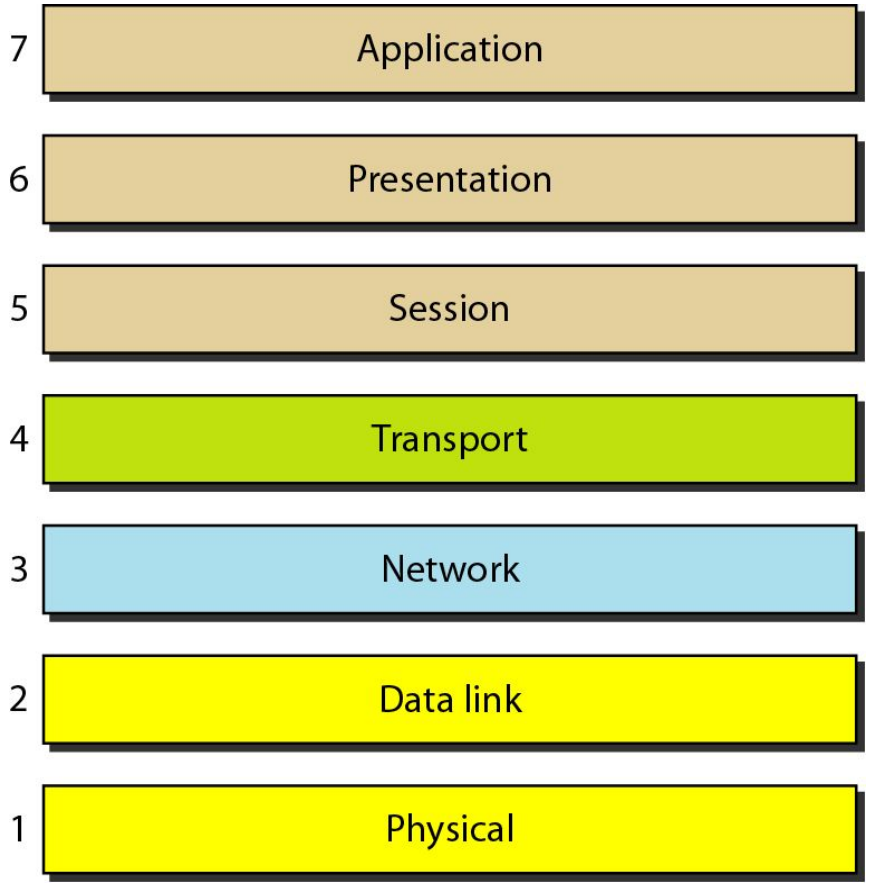
Network Models - OSI Model

- OSI model allows complete interoperability between otherwise incompatible systems
- Within a single machine, each layer calls upon the services of the layer just below it
- Layer 3, for example, uses the services provided by layer 2 and provides services for layer 4
- Between machines, layer x on one machine communicates with layer x on another machine



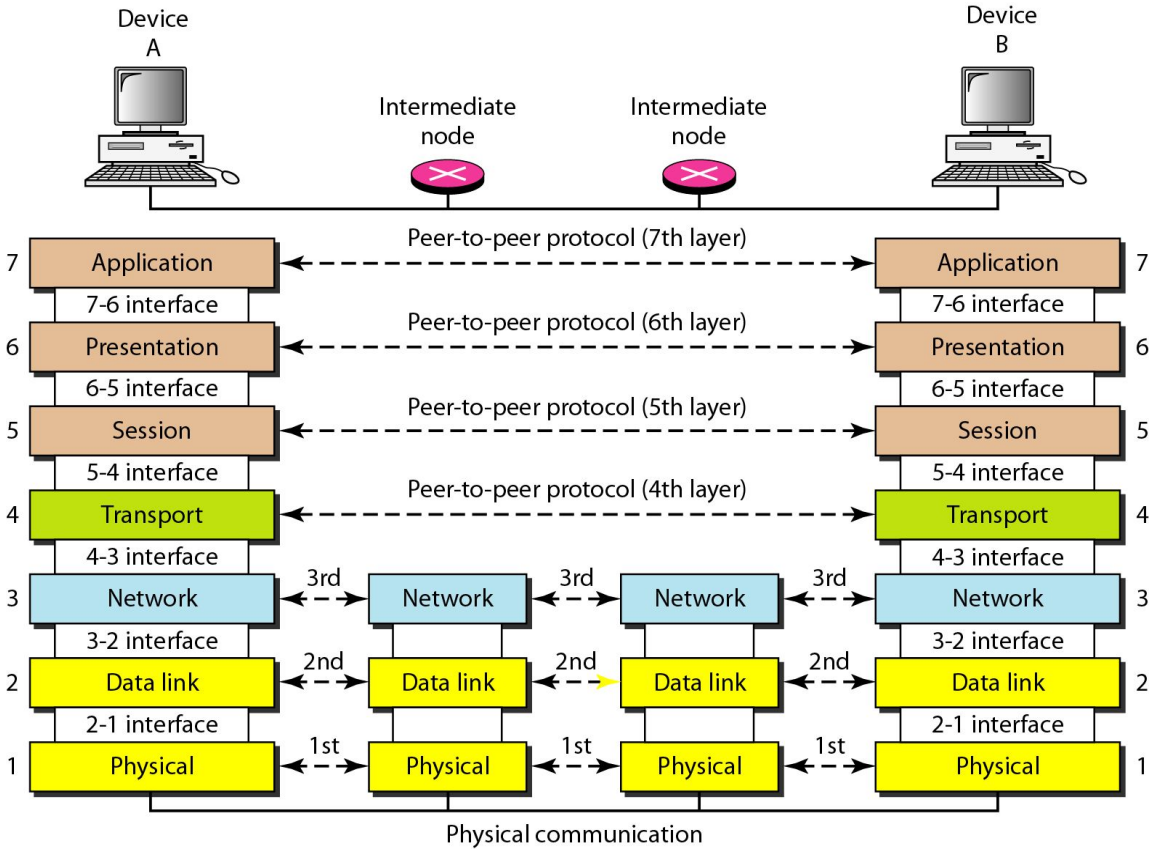
Network Models - OSI Model

- This communication is governed by an agreed-upon series of rules and conventions called protocols
- The processes on each machine that communicate at a given layer are called peer-to-peer processes
- Communication between machines is therefore a peer-to-peer process using the protocols appropriate to a given layer



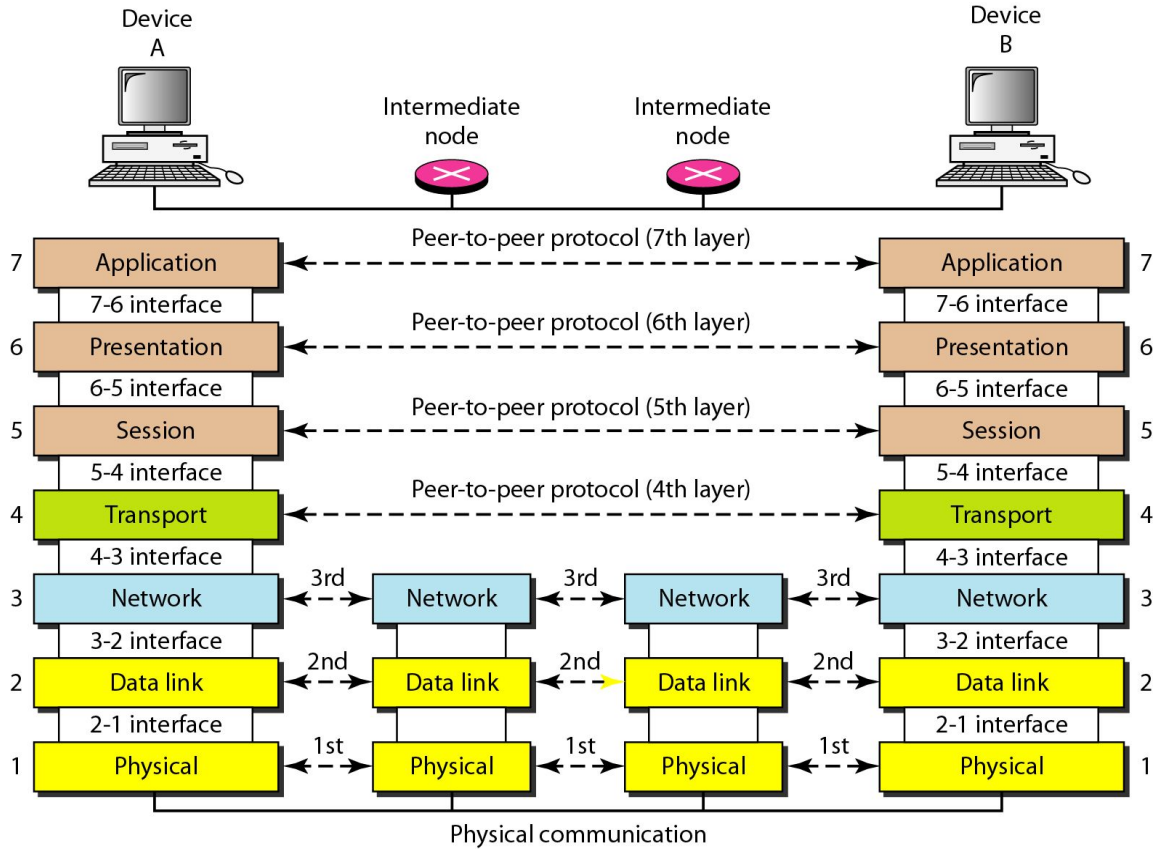
Network Models - OSI Model

- At the physical layer, communication is direct
- Device A sends a stream of bits to device B (through intermediate nodes)



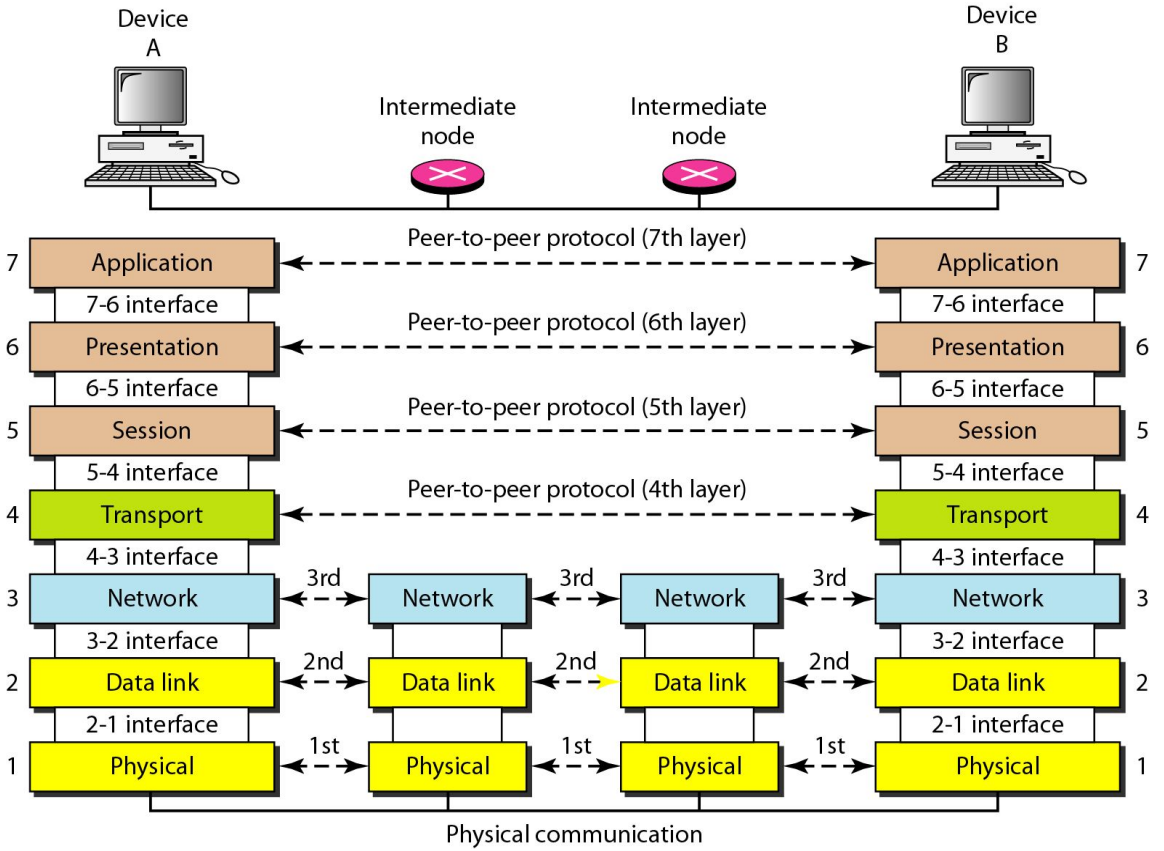
Network Models - OSI Model

- At the higher layers, however, communication must move down through the layers on device A, over to device B
- Upon reaching device B, it should go in the upward direction - remember the postal communication!



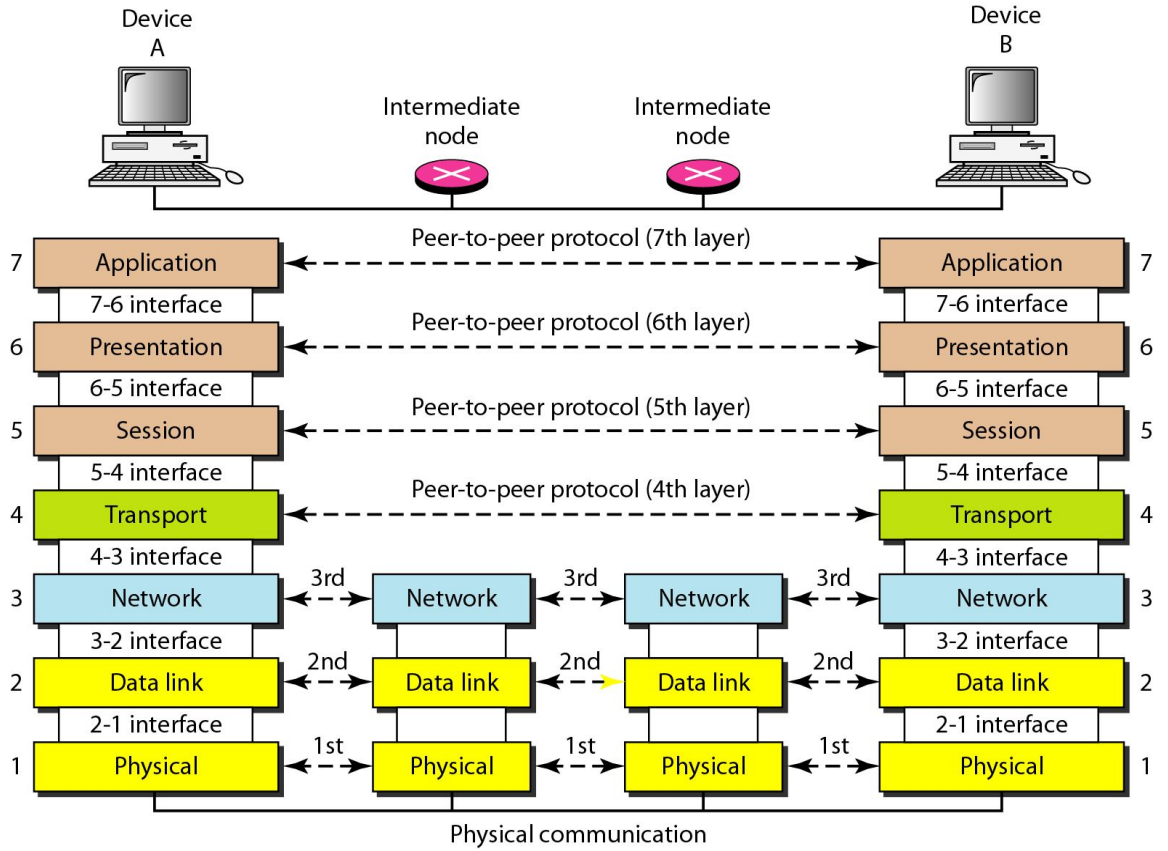
Network Models - OSI Model

- Each layer in the sending device adds its own information to the message it receives from the layer just above it and passes the whole package to the layer just below it



Network Models - OSI Model

- At last at Layer 1 in the sending side, the entire data is transferred to Layer 1 in the receiving side
- Each layer unwraps the data it received from its previous layer, takes the data meant for it and transfers the remaining data to the next layer



Network Models - OSI Model

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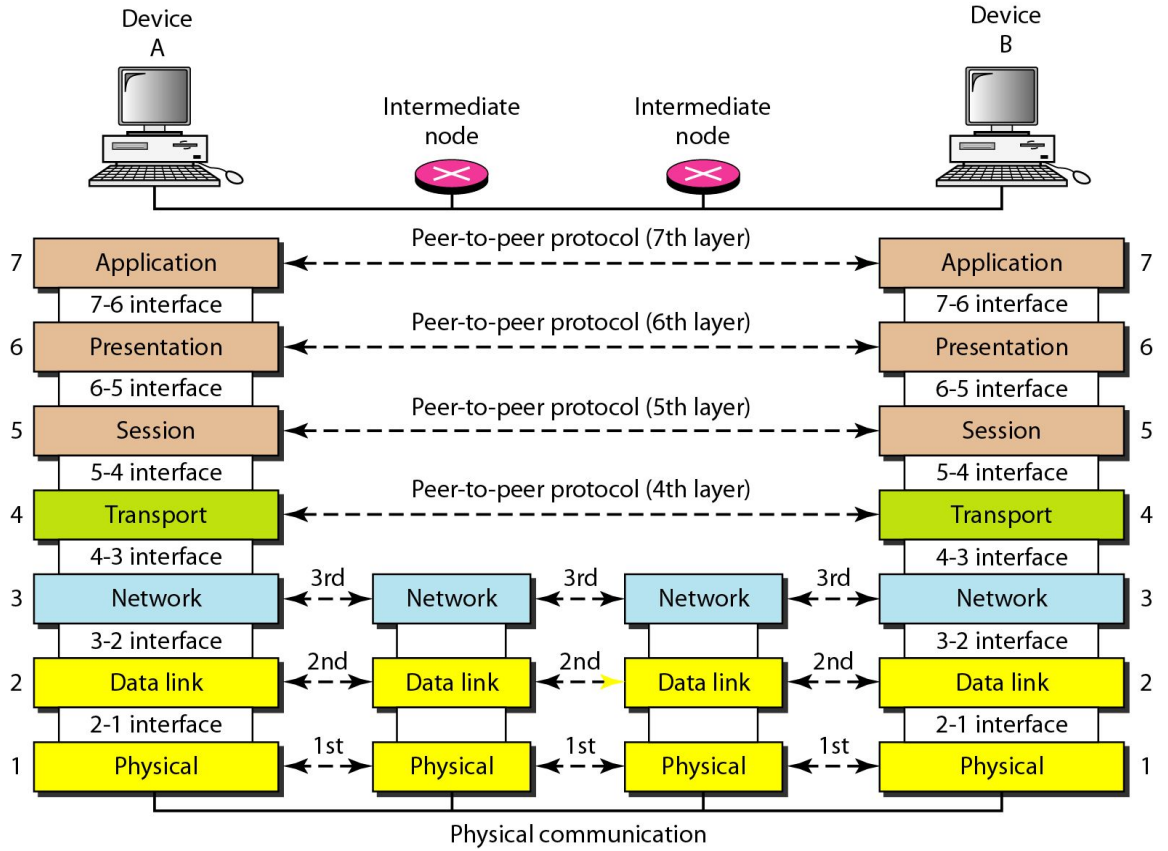
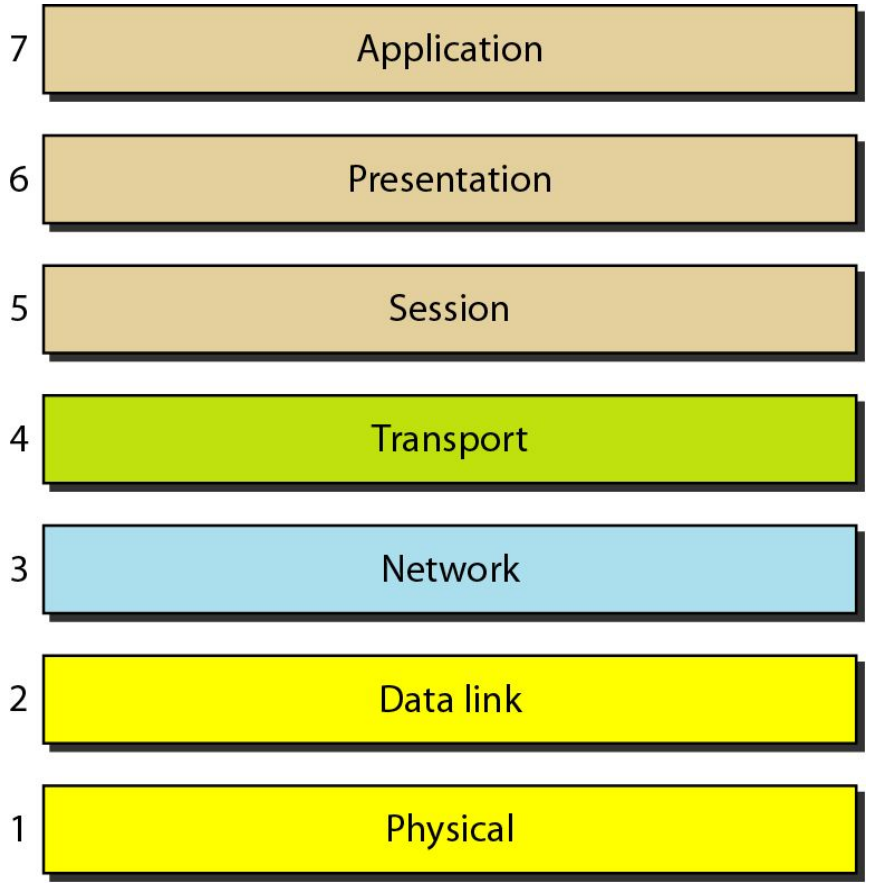


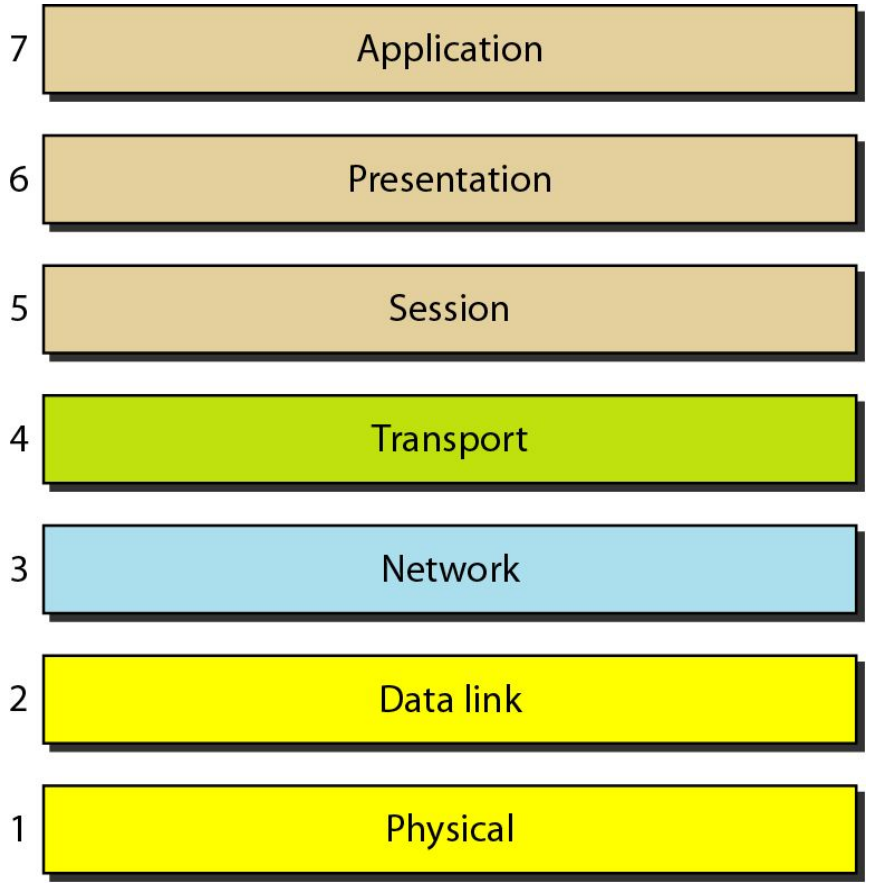
Network Models - OSI Model - Organization of Layers

- Seven layers can be grouped as
- Network support layers (Layers 1, 2, 3)
  - Deals the physical aspects of moving data from one device to another (such as electrical specifications, physical connections, physical addressing, and transport timing and reliability)



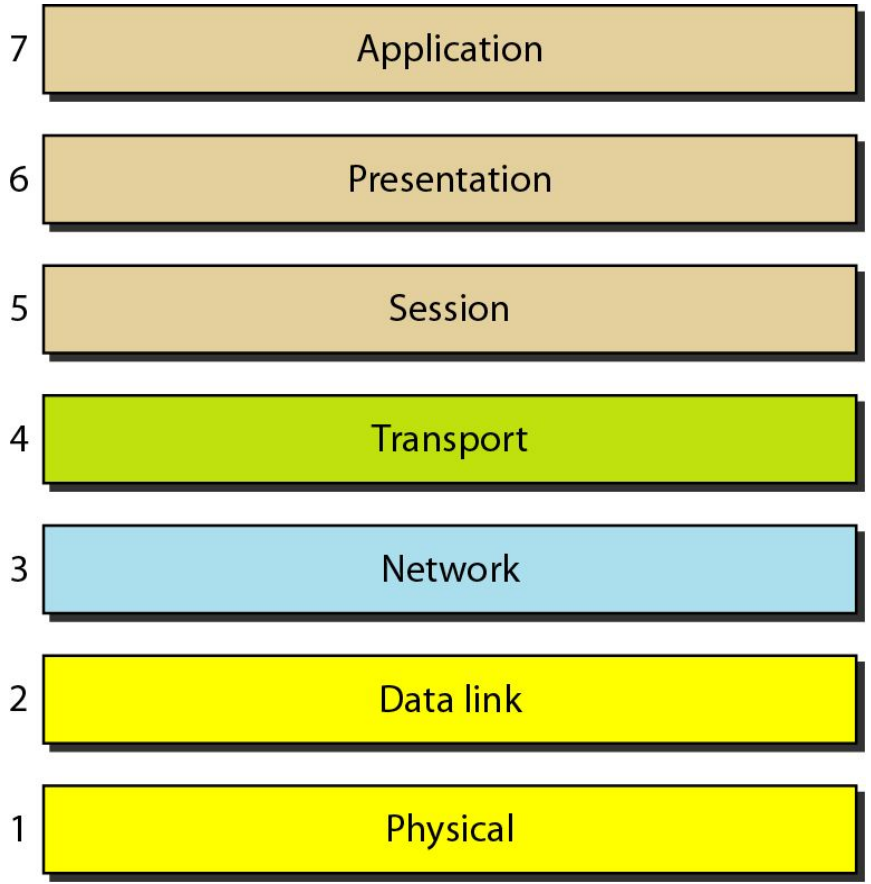
Network Models - OSI Model - Organization of Layers

- Seven layers can be grouped as
- User Support Layers (Layers 5, 6, and 7)
  - They allow interoperability among unrelated software systems



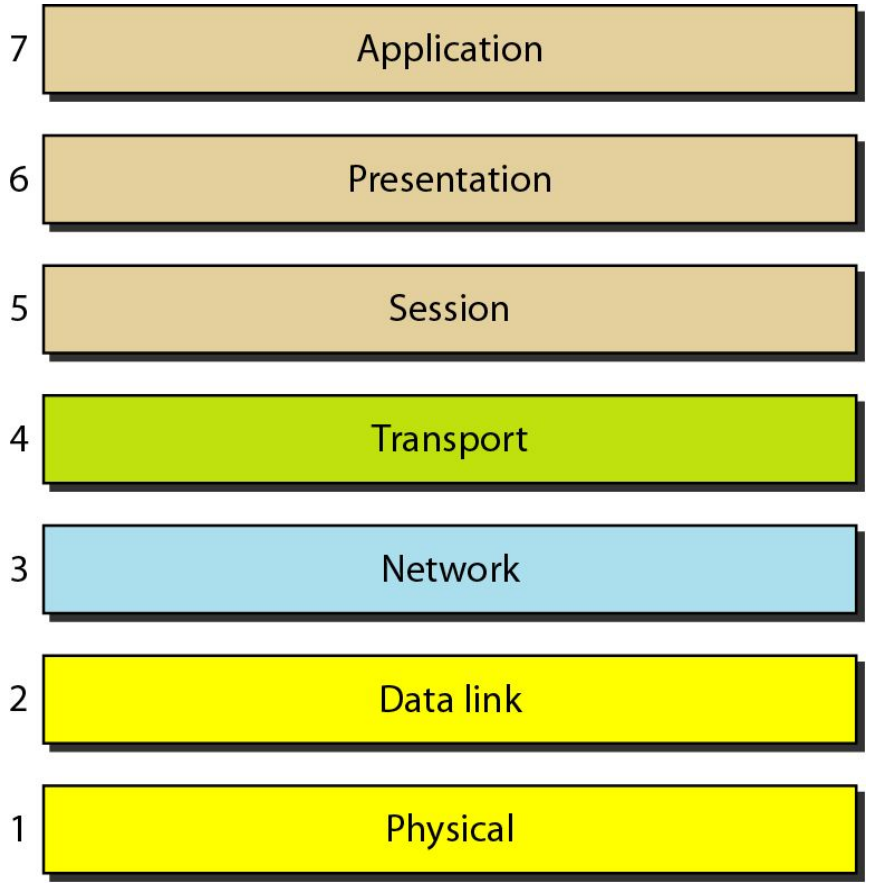
Network Models - OSI Model - Organization of Layers

- Seven layers can be grouped as
- The Transport Layer (Layer 4)
  - Links the two subgroups and ensures that what the lower layers have transmitted is in a form that the upper layers can use



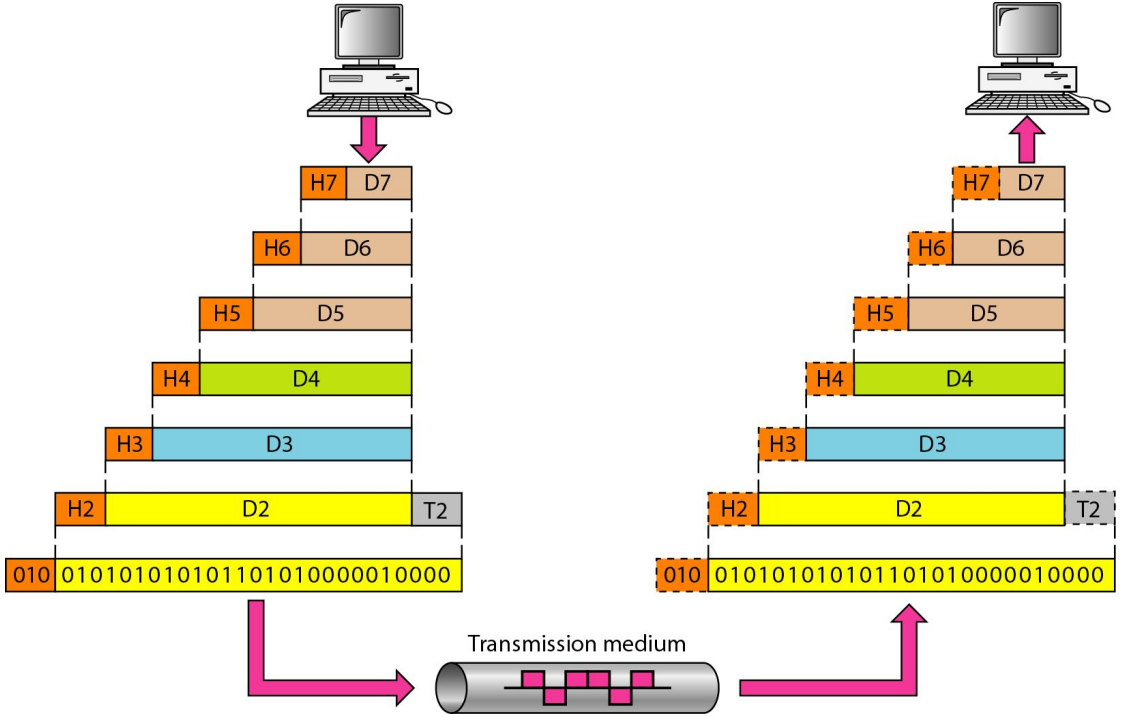
Network Models - OSI Model - Organization of Layers

- The upper OSI layers are almost always implemented in software
- The lower layers are a combination of hardware and software,
- The physical layer, is mostly implemented as hardware



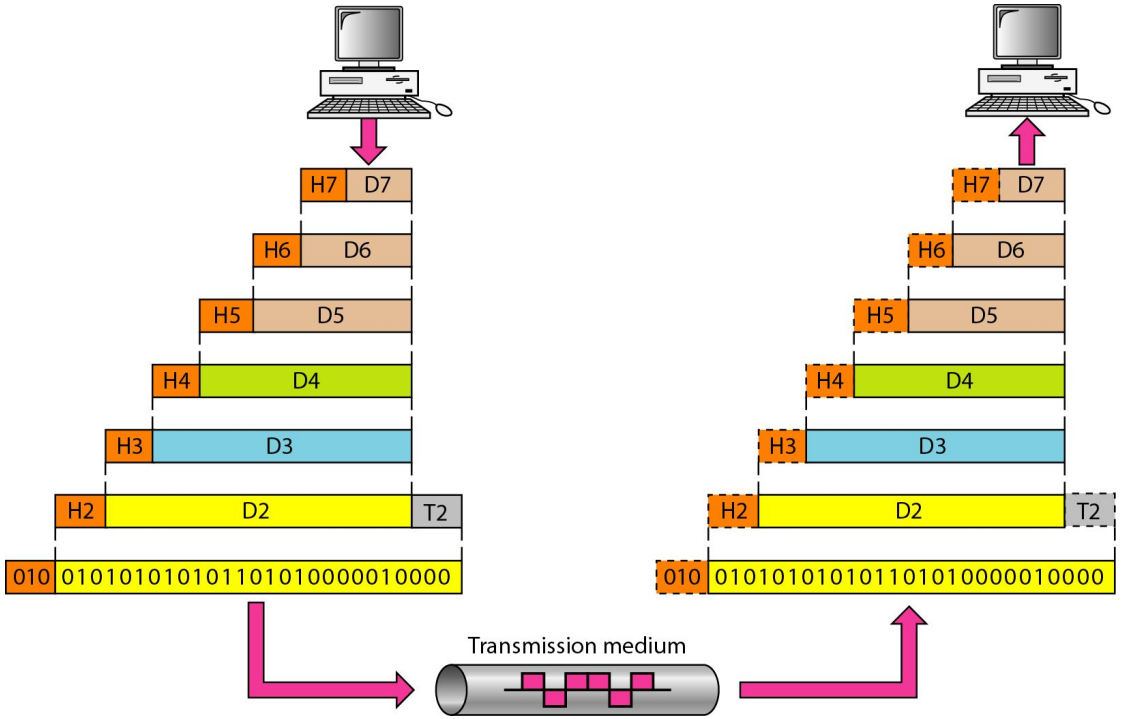
Network Models - OSI Model - Organization of Layers

- D7 is the data unit at layer 7, D6 is the data unit at layer 6 and so on
- The process starts at layer 7 (the application layer), proceeding through all all layers downward, in descending, sequential order



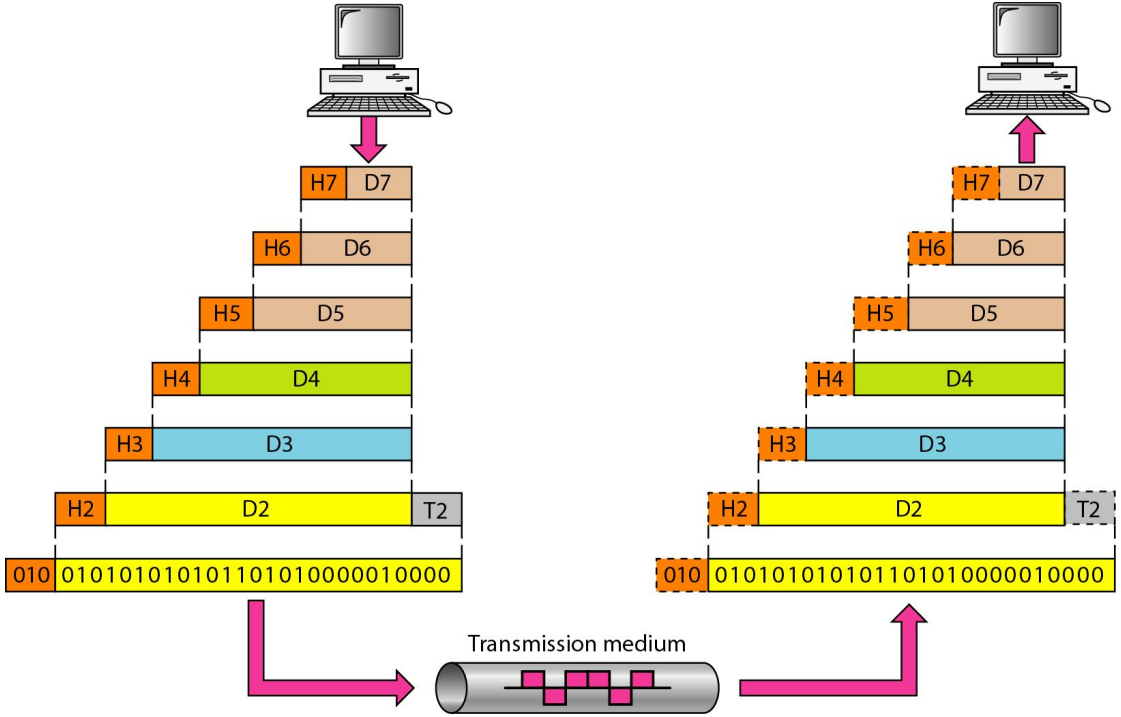
Network Models - OSI Model - Organization of Layers

- At each layer, a header/trailer can be added to the data unit
- When the formatted data unit passes through the physical layer (layer 1), it is changed into an electromagnetic signal and transported along a physical link



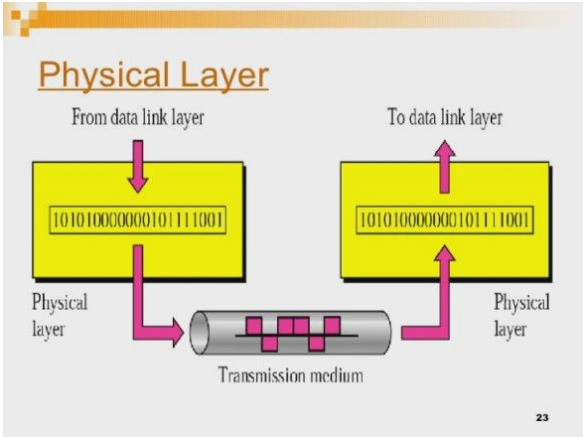
Network Models - OSI Model - Organization of Layers

- At the receiver's side, the same process is repeated - data unit is attached with a header/trailer and in each layer in the upward direction



Network Models - OSI Model - Physical Layer

- Remember the postal delivery system - Roads are the physical layer here!
- Just as the roads carry trucks, the physical layer carries the electrical signals (wired media - copper cables), light pulses (wired media - fibre optic cables), or radio waves (wireless media) that transmit data.



Network Models - OSI Model - Physical Layer

- Functions of physical layer are
  - **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
  -
    - T

Network Models - OSI Model - Physical Layer

- Functions of physical layer are
  - **Representation of bits**
    - The physical layer data consists of a stream of bits (sequence of 0s or 1s) with no interpretation
    - To be transmitted, bits must be encoded into signals--electrical or optical
    - The physical layer defines the type of encoding (how Os and Is are changed to signals
- **Data Rate**
  - The transmission rate - the number of bits sent each second
  - The physical layer defines the duration of a bit, which is how long it lasts

Network Models - OSI Model - Physical Layer

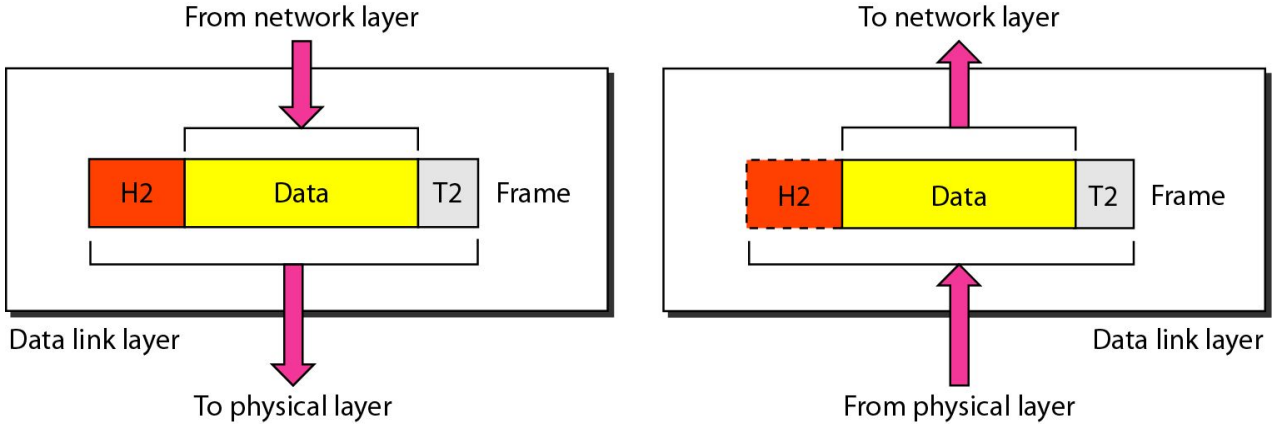
- Functions of physical layer are
  - **Synchronization of bits**
    - The sender and receiver must use the same bit rate for data transmission
    - Data transmission must be synchronized at the bit level
  - **Line configuration**
    - The physical layer is concerned with the connection of devices 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**
    - Which topology is used for configuring the network

Network Models - OSI Model - Physical Layer

- Functions of physical layer are
  - **Transmission mode**
    - Simplex / Half-duplex / Full-duplex

Network Models - OSI Model - Data Link Layer

- Remember the postal delivery system - Mail Trucks corresponds to the Data Link Layer!
- It's responsible for ensuring that the letters (data) are packaged correctly and sent from one post office (network node) to another
- The data link layer handles the packaging and error checking.

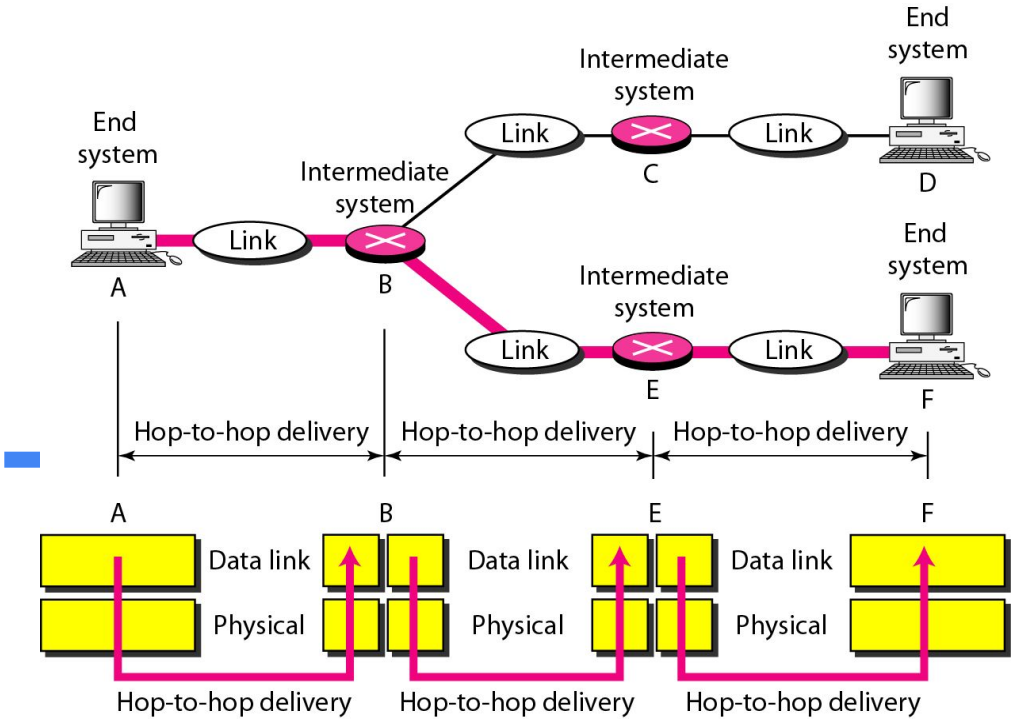


Network Models - OSI Model - Data Link Layer

- 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)
- It is responsible for moving frames from one hop (node) to the next

Network Models - OSI Model - Data Link Layer

- Communication at the data link layer occurs between two adjacent nodes
- To send data from A to F, three partial deliveries are made
- First, the data link layer at A sends a frame to the data link layer at B (a router)
- When the packet arrives at router B, the router makes a decision based on the final destination (F) of the packet
- Router B uses its routing table to find that the next hop is router E
- The network layer at B, therefore, sends the packet to the network layer at E.



Network Models - OSI Model - Data Link Layer

- The network layer at E, in tum, sends the packet to the network layer at F
- Note that values of headers in each of these packets will be different

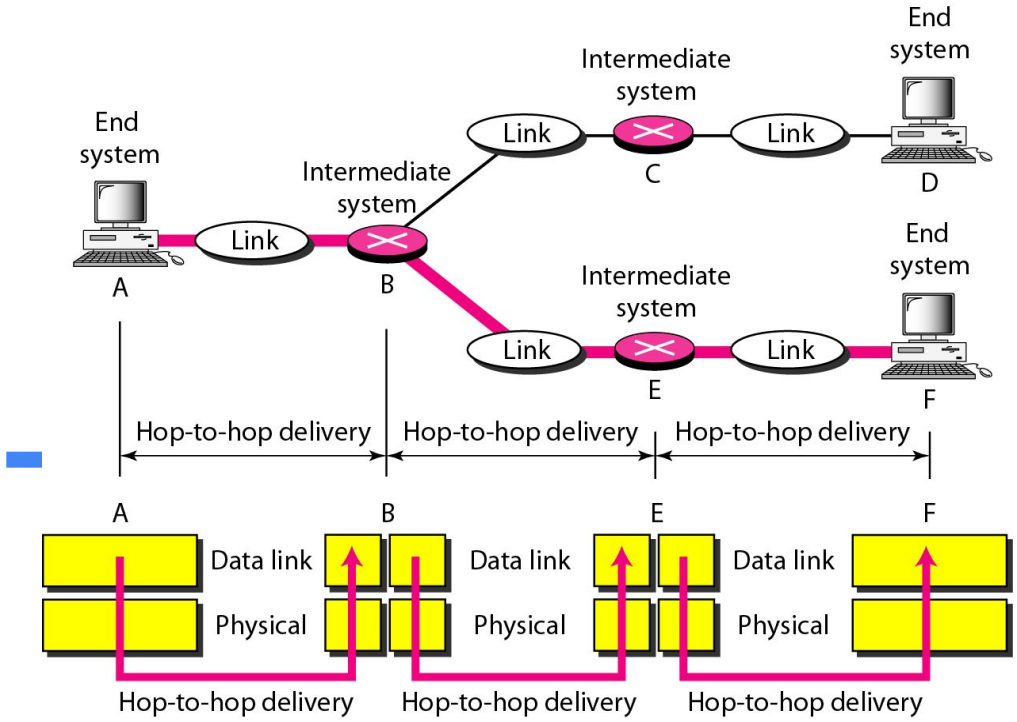
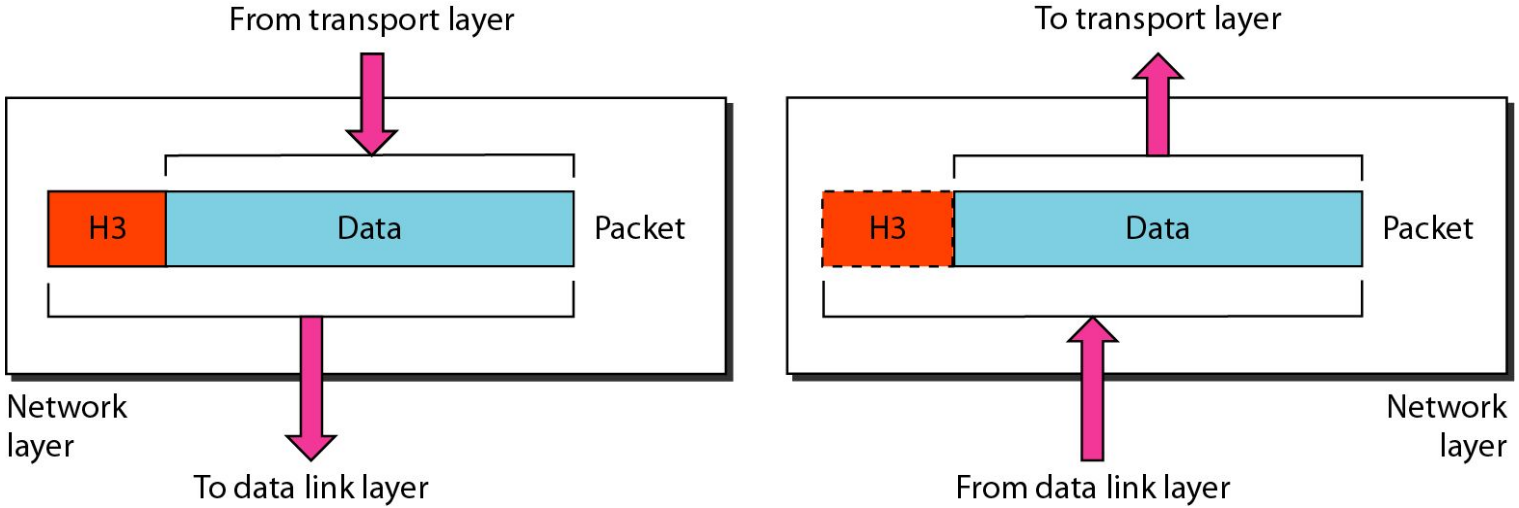


Image Source:-
https://computernetworkingsimplified.wordpress.com/2013/06/16/compare-and-contrast-computer-networks-with-postal-networks/

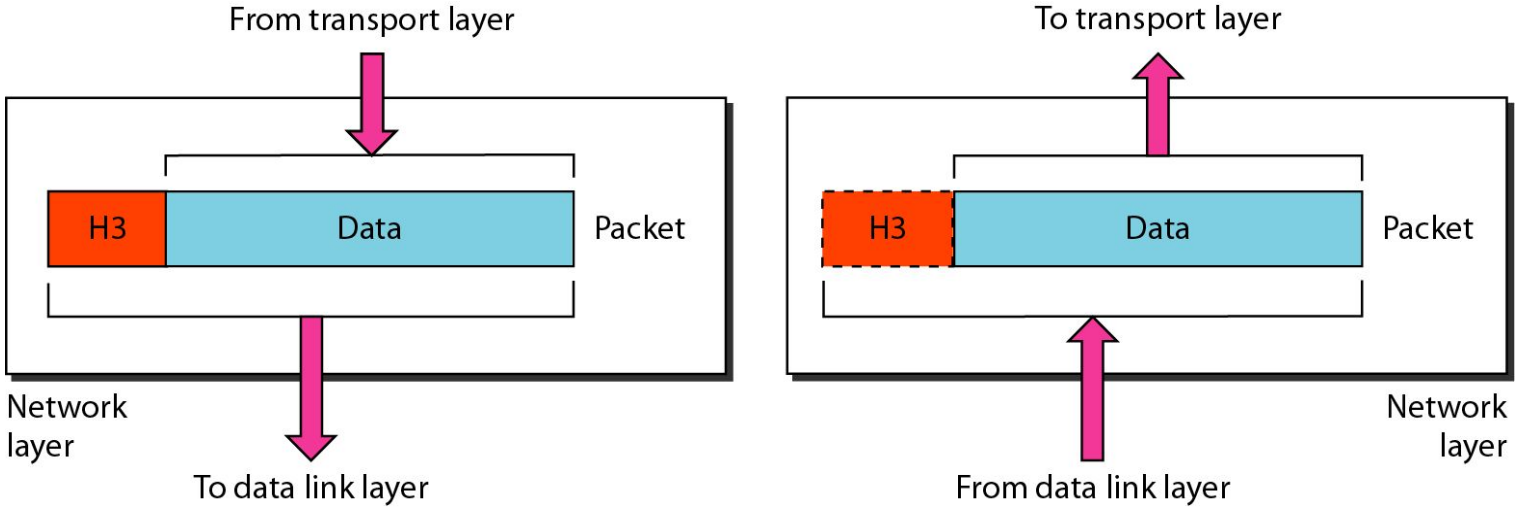
Network Models - OSI Model - Network Layer

- The address system in postal delivery network corresponds to the network layer!
- Just as the post office uses addresses to deliver letters to the correct destination, the network layer uses IP addresses to route data to the correct location across the network



Network Models - OSI Model - Network Layer

- The network layer is responsible for the source-to-destination delivery of a packet, possibly across multiple networks (links)
- The data link layer takes cares 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 - the source host to the destination host

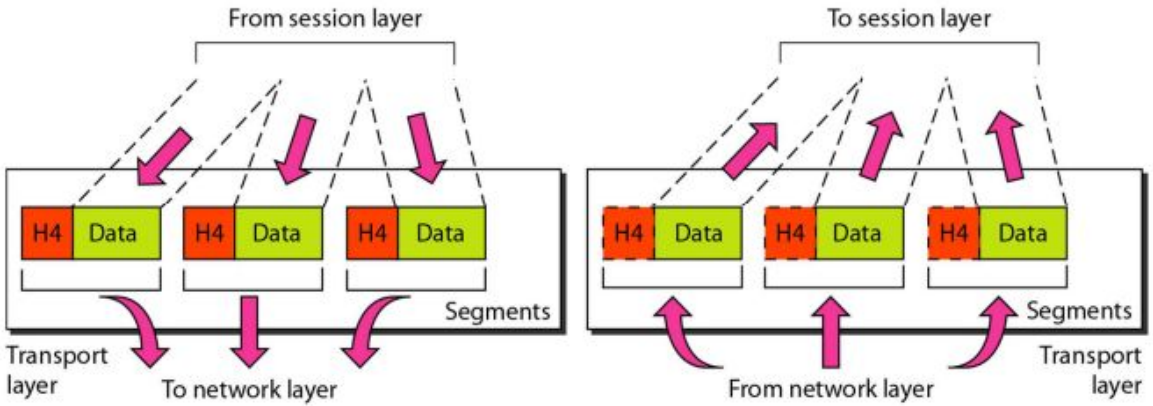


Network Models - OSI Model - Network Layer

- Switches and routers are used in this layer
- The network layer is implemented on networking devices
- It uses the destination host and the source host's logical address (IP address) to send the data
- An IP address is a combination of the network address and host machine address

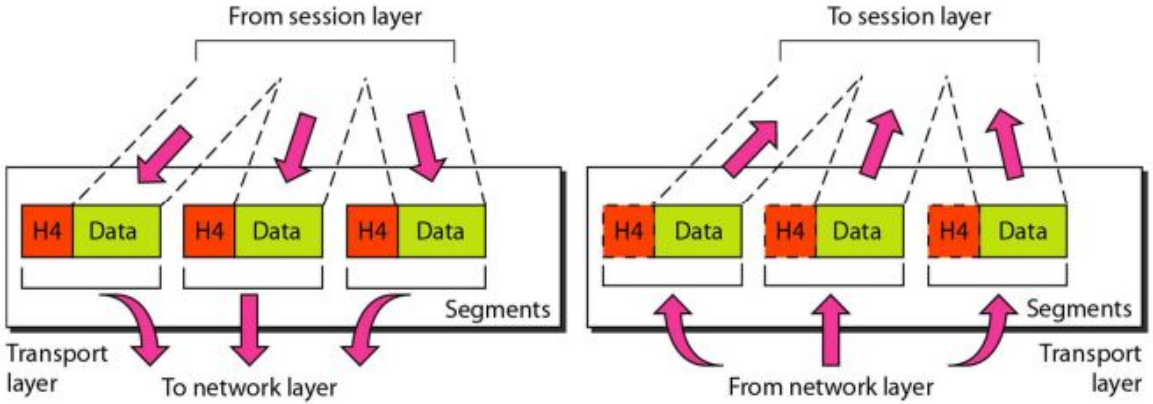
Network Models - OSI Model - Transport Layer

- The Post Office Sorting Room!
- Think of this layer as the sorting room in a post office where letters are sorted and sent to the correct mail truck
- The transport layer ensures data is sent and received in the correct order and without errors, just like making sure all parts of a letter arrive together



Network Models - OSI Model - 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
- The network layer ensures the source-to-destination delivery of individual packets, it does not recognize any relationship between those packet
- The transport layer ensures that the whole message arrives intact and in order, overseeing both error control and flow control at the source-to-destination level

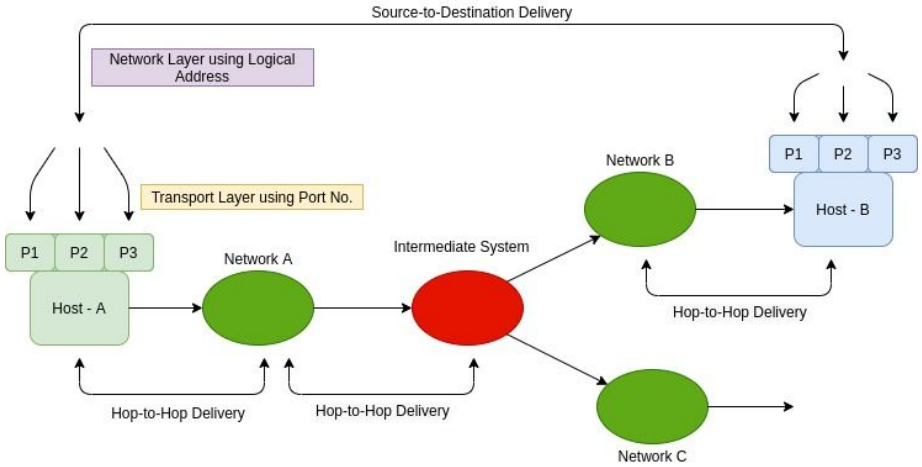


Network Models - OSI Model - Transport Layer

- The Transport layer ensures that messages are transmitted in the order in which they are sent and there is no duplication of data
- The basic function of the Transport layer is to accept data from the layer above, split it up into smaller units, pass these data units to the Network layer, and ensure that all the pieces arrive correctly at the other end
- The responsibility of the network layer is to transmit the data from one computer to another computer and the responsibility of the transport layer is to transmit the message to the correct process - process to process delivery

Network Models - OSI Model - Transport Layer

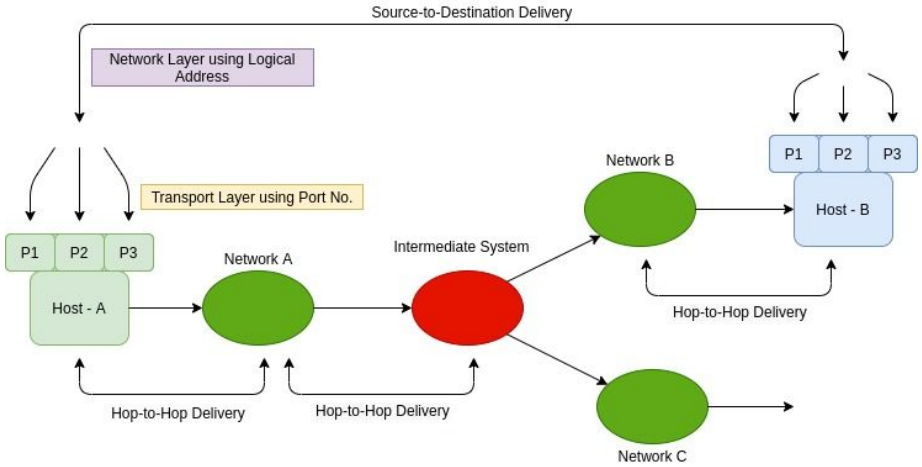
- What is the need for a network layer in addition to a transport layer in OSI Model?



- Host-A, and Host-B are running in Network-A and Network-B, respectively
- There are three processes running on each of these end devices - p1, p2, p3
- Each process of Host-A wants to send the data to some processes of Host-B
- Sending data from one process to another process is accomplished by the transport layer
- To do this, first we need to send the data to the destination host - network layer is used for this purpose, as both of the processes are in different networks

Network Models - OSI Model - Transport Layer

- What is the need for a network layer in addition to a transport layer in OSI Model?



- The transport layer adds its header, assigns each process a unique port number, and passes it to the network layer
- Furthermore, the network layer uses the logical addresses of the source host and destination host. It routes the data to its destination host
- This is the reason the network layer is known as the source-to-destination delivery layer. It'll make a routing table for the shortest possible path from source to destination. Also, it switches the packets from different networking devices
- When the packets reach their destination host, the transport layer will route the packets to their respective processes using their port number

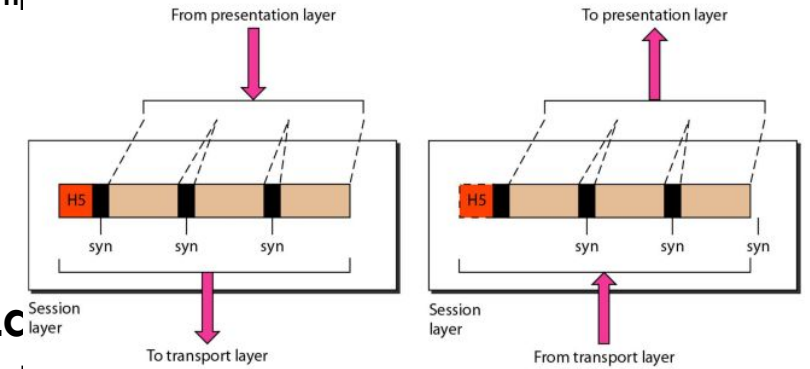
Network Models - OSI Model - Transport Layer Vs Network Layer

Transport Layer	Network Layer
Responsible to send entire message from a host to a destination	Responsible to send packets from a host to a destination
It's process-to-process communication or port-to-port communication	It's host-to-host communication
Used inside of same network and different networks as well	Used when the hosts are in different networks
Uses the port address to ensure the communication	Uses logical address ensure for the communication
Implemented on host machine	Implemented on networking devices such as routers and switches
Provide better flow control and error control	Flow control and error control is not as good as the transport layer

Image taken from
https://www.baeldung.com/cs/osi-transport-vs-networking-layer#:~:text=Sending%20data%20from%20one%20process,processes%20are%20in%20different%20networks.

*Network Models - OSI Model - Session Layer

- The delivery Instructions ina postal delivery system!
- This layer is like the special instructions on a package, such as fragile or do not bend
- It manages and controls the delivery process, ensuring the sender and receiver are synchronized and the communication session stays open as long as needed

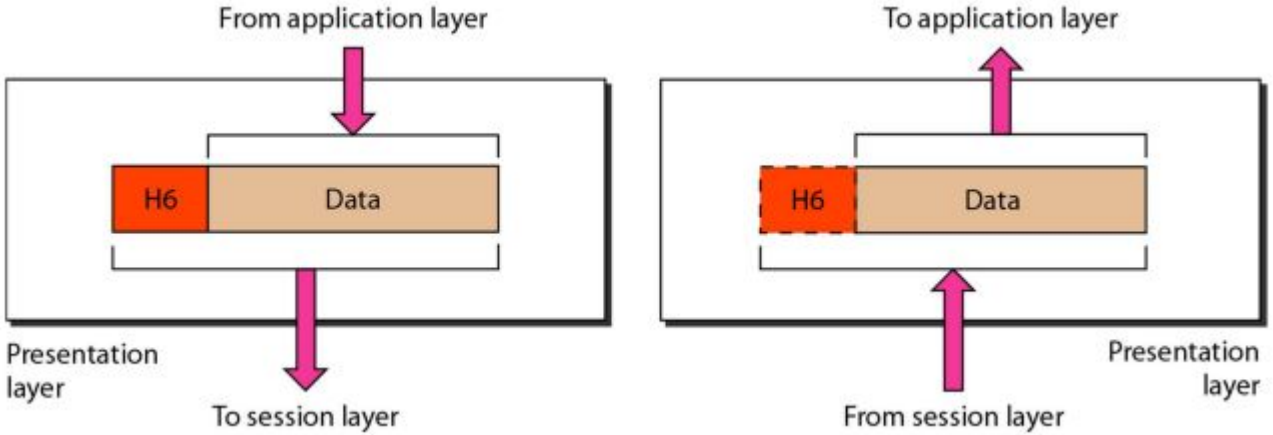


*Network Models - OSI Model - Session Lc

- Session layer establishes, maintains, and synchronizes the interaction among communicating systems
- It creates communication channels, called sessions, between devices
- It is responsible for opening sessions, ensuring they remain open and functional while data is being transferred, and closing them when communication ends

Network Models - OSI Model - Presentation Layer

- The Letter Inside the Envelope!
- Just as the letter inside the envelope needs to be understandable by the recipient (e.g., in the correct language or format), the presentation layer formats data so it can be understood by the application layer above

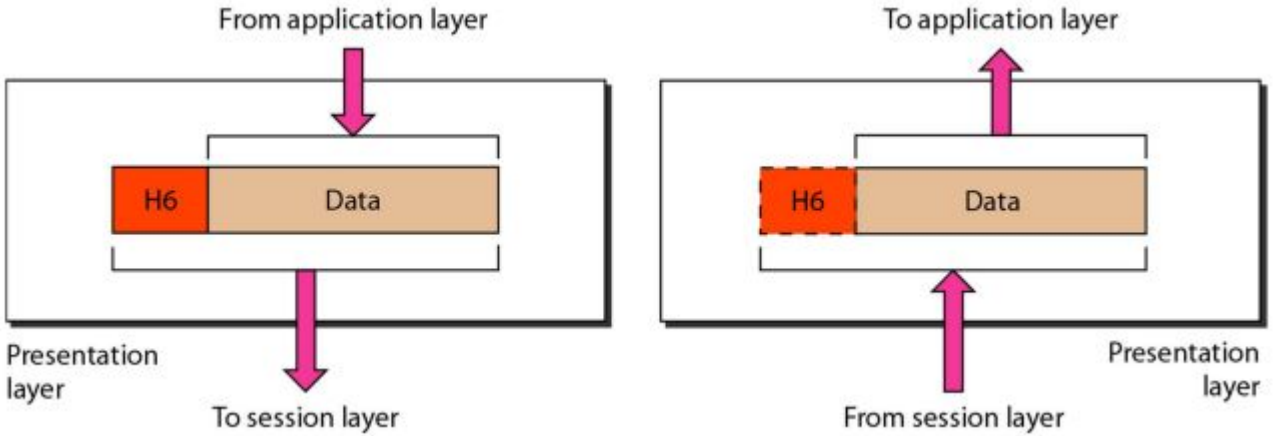


Network Models - OSI Model - Presentation Layer

- The presentation layer is concerned with the syntax and semantics of the information exchanged between two system

Functions:

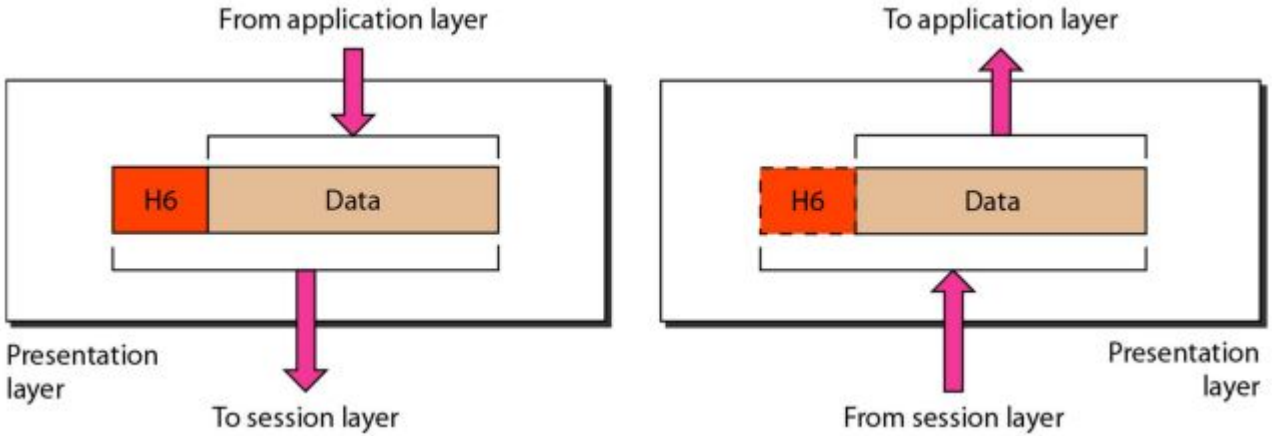
- **Translation:-**
- The processes (running programs) in two systems usually exchange information in the form of character strings, numbers, and so on. The information must be changed to bit streams before being transmitted



Network Models - OSI Model - Presentation Layer

Functions:

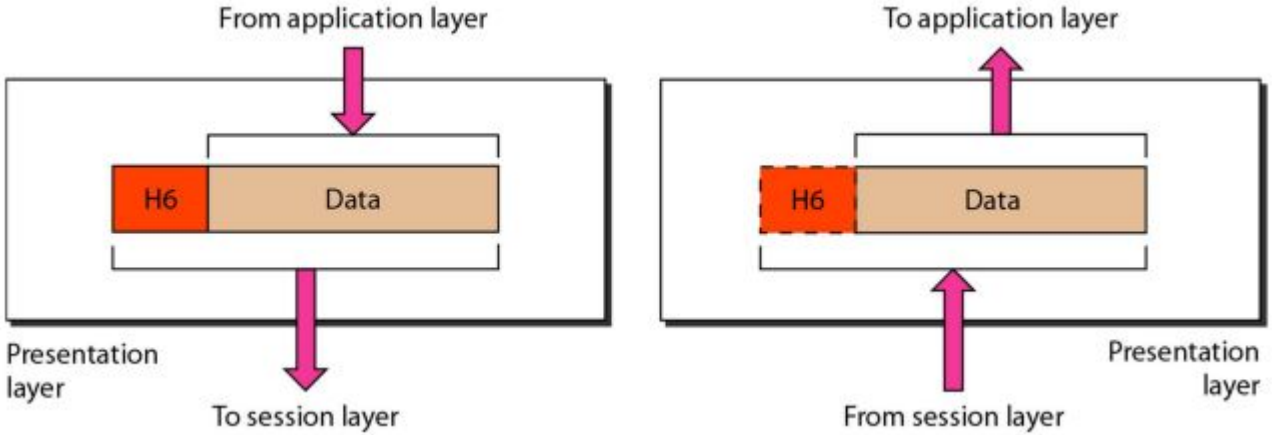
- **Translation:-**
- Because different computers use different encoding systems, the presentation layer is responsible for interoperability between these different encoding methods.
- The **presentation layer at the sender** changes the information from its sender-dependent format into a common format. **The presentation layer at the receiving machine** changes the common format into its receiver-dependent format



Network Models - OSI Model - Presentation Layer

Functions:

- **Encryption:-**
- To ensure privacy in communication encryption is used
- 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



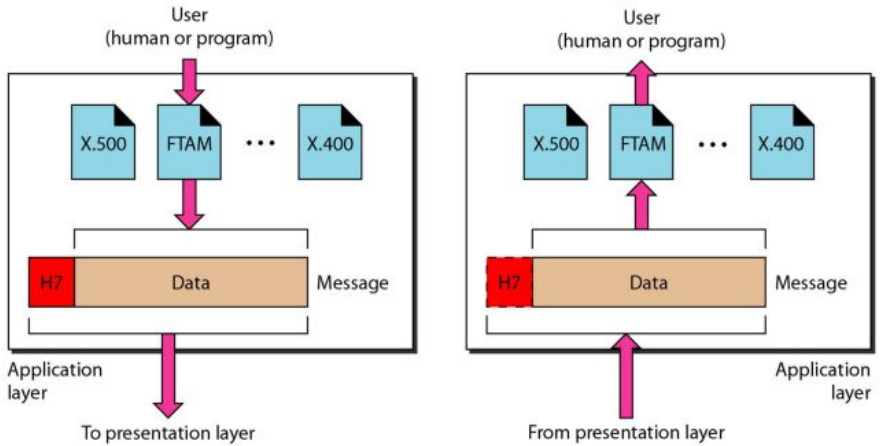
Network Models - OSI Model - Presentation Layer

Functions:

- **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

Network Models - OSI Model - Application Layer

- Finally, this layer is the person receiving and reading the letter
- The application layer is where the data is interpreted and used by applications, such as email clients, web browsers, or file transfer tools.



Network Models - OSI Model - 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 application layer is responsible for providing services to the user

- How the data from node to another node in the same network is transmitted?
- How the data from node to another node in the two different networks are transmitted?
- How the OSI layers are involved in these scenarios?!

How the data from node to another node in the same network is transmitted?

- Sending a Postcard from One House to Another in the Same Town (Network)

- Physical Layer - The Path
  - The physical layer represents the physical medium used to transport the postcard, such as roads, sidewalks, or the postal worker's bike
  - In a network, this corresponds to cables, fiber optics, or wireless signals that physically transmit the data as electrical pulses, light signals, or radio waves

- Data Link Layer - The Postcard and House Address (MAC Address)
  - The data link layer is the layer that takes care of delivering the postcard to the correct house on the right street within the same town
  - It ensures the postcard reaches the correct recipient's house (MAC address). This layer handles the framing of data and manages local delivery, including error detection and correction

How the data from node to another node in the same network is transmitted?

- Sending a Postcard from One House to Another in the Same Town (Network)

- Network Layer - Sorting Mail by Neighborhood (IP Address)
  - The network layer is responsible for determining the best route for the postcard if it had to travel across different neighborhoods
  - Since the postcard is staying within the same town (network), it quickly identifies that no complex routing is necessary
  - It would only route the data if it were going to a different network. Here, it uses IP addresses to determine the destination.

- Transport Layer - Ensuring the Message is Delivered Intact
  - The transport layer ensures that the postcard's message is not only delivered but that it's complete and correct
  - It's like verifying that the postcard isn't damaged or missing parts of the message when it arrives. In networking, this layer manages data transfer reliability, flow control, and error recovery, ensuring the complete message is received as intended

How the data from node to another node in the same network is transmitted?

- Sending a Postcard from One House to Another in the Same Town (Network)

- Session Layer - Managing Conversations
  - The session layer keeps track of the conversation between the sender and recipient
  - If multiple postcards (messages) are being exchanged, this layer manages each session separately. It's like knowing which postcard is a reply to a previous one
  - In networking, it establishes, manages, and terminates connections between applications
- Presentation Layer - Formatting the Message
  - The presentation layer is like ensuring the postcard's message is written in a language or format that the recipient understands
  - If the message needed encryption, translation, or formatting, this layer would handle it
  - In networking, it translates data between the application layer and the lower layers, ensuring that it's in a usable format

How the data from node to another node in the same network is transmitted?

- Sending a Postcard from One House to Another in the Same Town (Network)

- Application Layer - Reading and Using the Message
  - Finally, the application layer is where the postcard's recipient opens and reads the message
  - This is the layer where the data is actually used
  - In networking, this is the layer that interacts with the end-user applications, such as web browsers, email clients, or file transfer tools

How the data from node one network to another node in a different network is transmitted?

- Scenario: Sending a Postcard from One House in One Town to Another House in a Different Town

- Physical Layer - The Path
  - The physical layer represents the physical medium used to transport the postcard, such as roads, sidewalks, or the postal worker's bike
  - In a network, this corresponds to cables, fiber optics, or wireless signals that physically transmit the data as electrical pulses, light signals, or radio waves

- Data Link Layer - The Postcard and Local Address (MAC Address)
  - Data link layer handles the delivery of the postcard within each town (local network)
  - It ensures that when the postcard reaches a town, it can be delivered to the correct house
  - This involves using the MAC address within each local network segment. For example, in Town A, the postcard is delivered to the local post office (network switch) that handles it based on local addresses

How the data from node one network to another node in a different network is transmitted?

- Scenario: Sending a Postcard from One House in One Town to Another House in a Different Town

- Network Layer - Routing Between Towns (IP Address)
  - The network layer is where the real journey between towns (networks) happens
  - This layer is like the postal system deciding how to route the postcard from one town to another across different regions (networks)
  - It uses IP addresses to determine the best route to take, whether it's via highways, trains, or planes (routers and gateways)
  - This layer ensures that the postcard is sent from Town A to Town B, crossing over any intermediate towns if necessary
- Transport Layer - Ensuring the Message Reaches the Correct House Intact
  - The transport layer ensures that the postcard's message is intact and delivered to the correct house in Town B
  - It's like checking that each part of the message has arrived and that nothing was lost or damaged along the way
  - This layer manages end-to-end communication, ensuring reliability, correct ordering of data packets, and error handling

How the data from node one network to another node in a different network is transmitted?

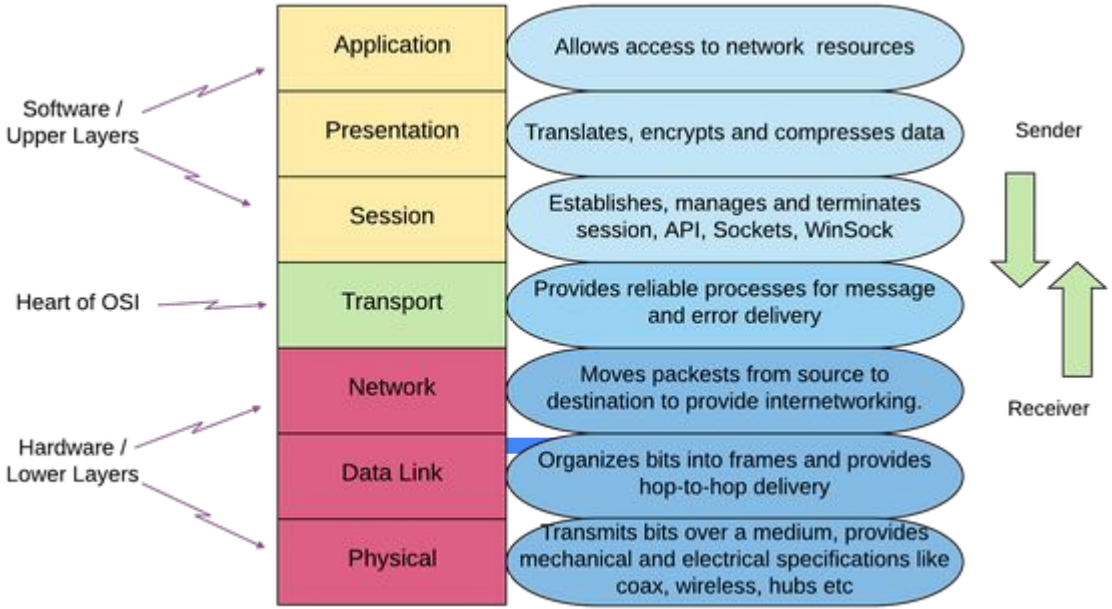
- Scenario: Sending a Postcard from One House in One Town to Another House in a Different Town

- Session Layer (Layer 5) - Managing Cross-Town Conversations
  - The session layer keeps track of the ongoing communication between the sender in Town A and the recipient in Town B
  - If multiple postcards (messages) are being exchanged across towns, it ensures that the communication sessions are correctly maintained and synchronized
  - It's like making sure that each reply corresponds to the correct initial message, even if multiple exchanges are happening simultaneously

- Presentation Layer (Layer 6) - Preparing the Message for a Different Town:
  - The presentation layer ensures that the message on the postcard is in a format that can be understood by someone in the other town
  - If the two towns speak different languages or use different formats (data encoding), this layer translates or re-encodes the message so it's understood correctly by the recipient
  - In networking, this involves data translation, encryption, and compression.

How the data from node one network to another node in a different network is transmitted?

- Scenario: Sending a Postcard from One House in One Town to Another House in a Different Town
- Application Layer (Layer 7) - Reading and Using the Message in the Other Town
    - Finally, the application layer is where the recipient in Town B receives, reads, and understands the postcard. This is where the data is actually used by the application, such as email clients, web browsers, or file-sharing programs



Network Models - OSI Model - Summarised Functions of all Layers

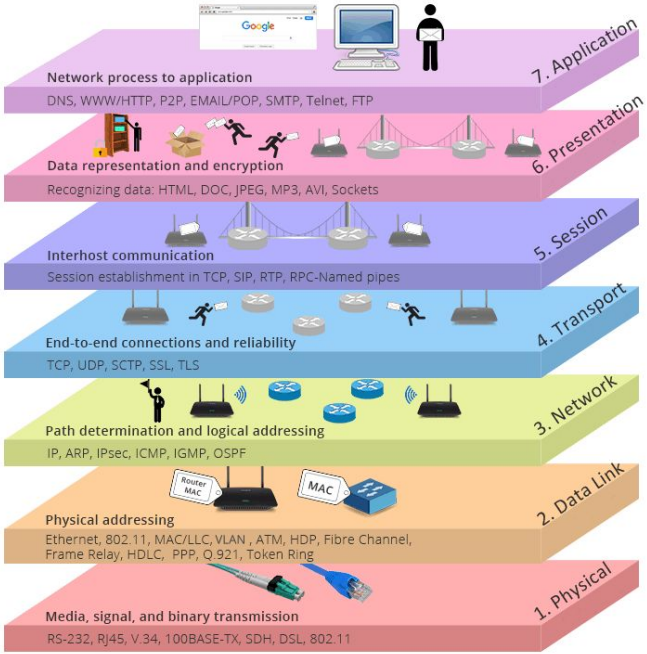


Image Source:
https://community.fs.com/blog/tcpip-vs-osi-whats-the-difference-between-the-two-models.html

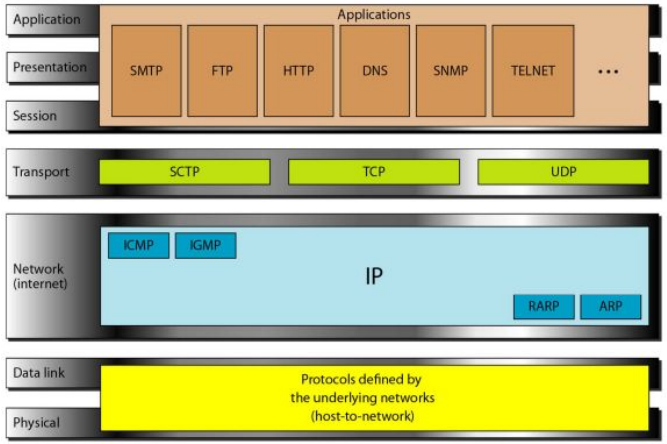
Network Models - OSI Model

OSI model is not directly implemented as a practical networking model. Instead, the OSI model serves as a conceptual framework and reference model for understanding networking principles and designing network protocols.

Network Models - OSI Model - Summarised Functions of all Layers

Network Models - TCP/IP Model

- The TCP/IP protocol suite was developed prior to the OSI model
- The protocol suite is made of five layers: physical, data link, network, transport, and application



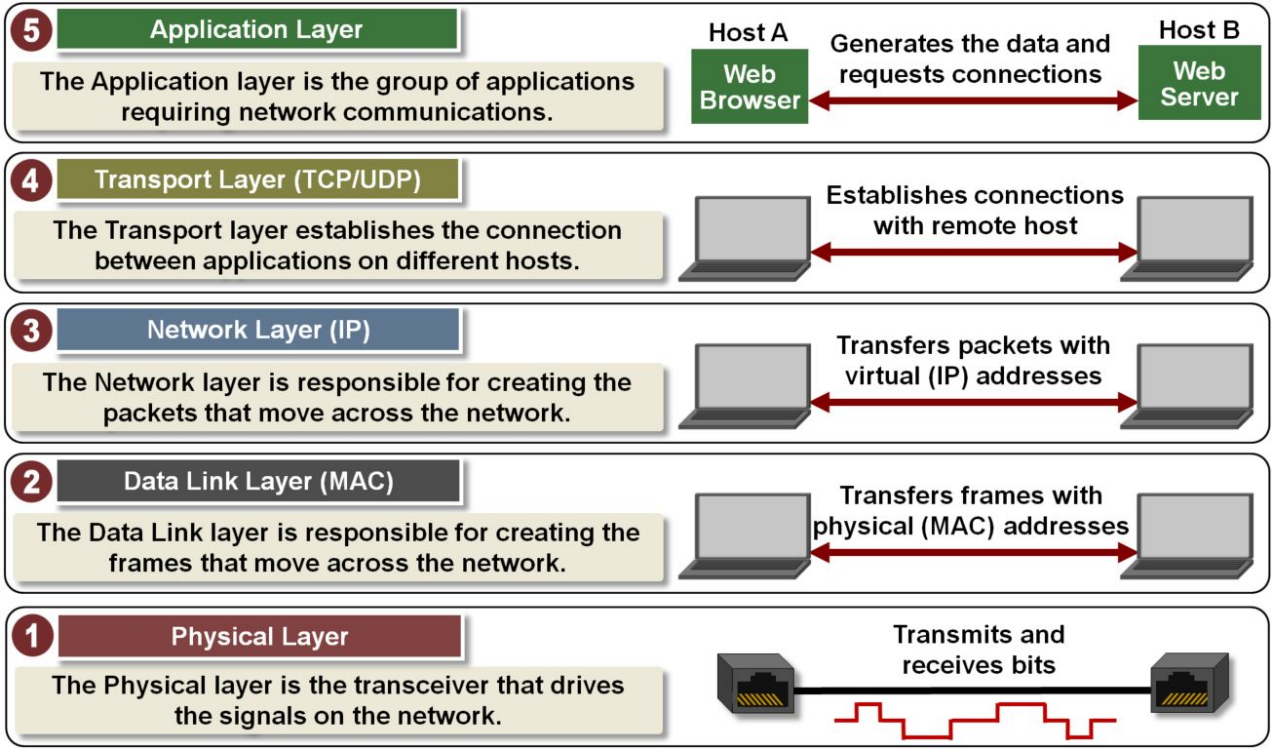
Network Models - TCP/IP Model

- Application, Presentation and Session layers of OSI Model are combined in TCP/IP model as Application Layer in TCP/IP Model
- Transport Layer in OSI Model is retained as such in TCP/IP Model
- Network Layer in OSI Model is also called as Internet Layer in TCP/IP Model
- Data Link Layer and Physical Layer are available in TCP/IP Model too

Network Models - TCP/IP Model

- TCP/IP transfers data from one device to another
- Data being sent should be free all kinds of errors and noise when it reaches the destination - reliability and accuracy of data should be ensured
- To ensure this, the TCP/IP model divides its data into packets and combines them at the other end, which helps in maintaining the accuracy of the data while transferring from one end to another end
- TCP and IP are different protocols of Computer Networks
- The basic difference between TCP (Transmission Control Protocol) and IP (Internet Protocol) is in the transmission of data
- In simple words, IP finds the destination of the mail and TCP has the work to send and receive the mail

Network Models - TCP/IP Model - Summary

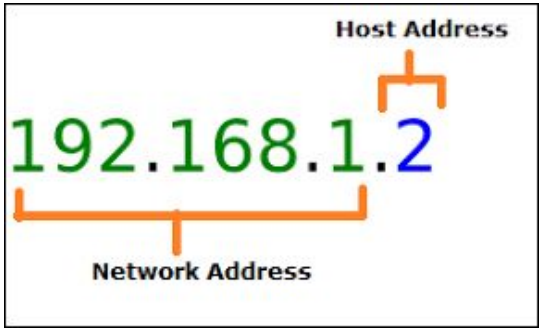


IP Address

- Imagine a big building with many flats. Each such building represents a network (like a home, office, or a school network)
- Each building has a unique address such as Building 1, Building 2
- Each building represents a network that consists of many flats connected in it!
- Each flat has a unique address, such as Flat 1, Flat 2
- The complete address to locate a flat might be Building 1, Flat 101
- When we want to send something to a specific apartment, we need both the building number and the flat number!

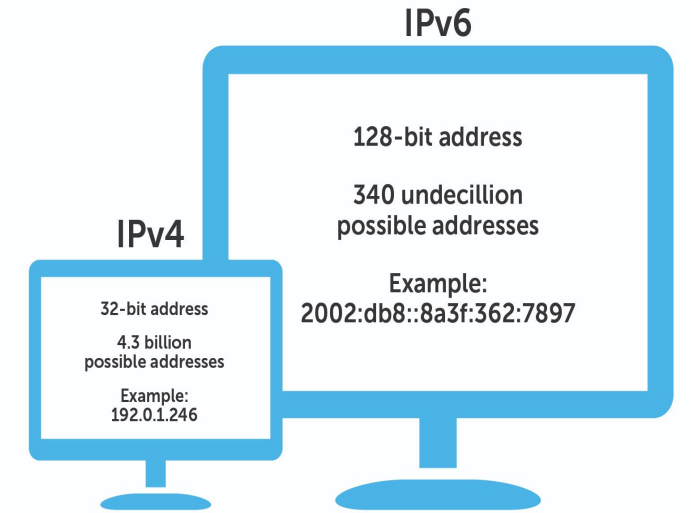
IP Address

- Every device hooked to Internet should have an address
- An IP Address is similar to the Building No and Flat No Address System
- The first part of the IP address tells us which building (network) the data needs to go to
- The second part of the IP address tells us which flat (device) inside that network needs to receive the data
- An IP address looks like 192.168.1.5
  - 192.168.1 represents the building (network)
  - 5 represents the flat (device)

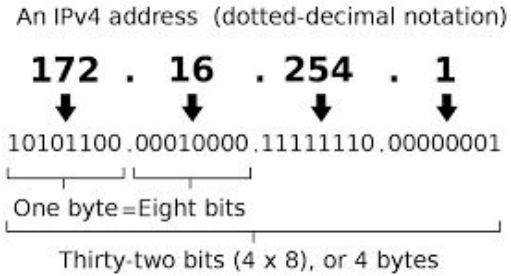


IP Address

- IP Address has two versions
  - Version 4 (32 Bits)
  - Version 6 (64 bits)



IP Address

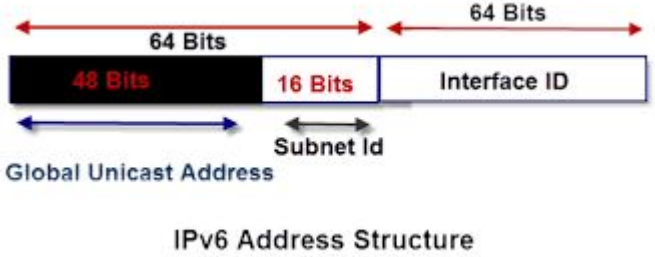


- IP Address has two versions
  - **Version 4 (32 Bits)**
    - 32 bits long
    - There are approximately 4.3 billion unique addresses (2^{32})
    - Example of an IPv4 address: 172.16.254.1
    - Written in dotted decimal notation, divided into four octets (8 bit blocks) separated by periods
    - Each octet can have a value between 0 and 255
    - Example: 172, 16, 254, and 1 are octets (groups of 8 bits)
  -

IP Address

- Due to the ease of use and affordability, the number o devices that are hooked to the Internet increases day b day
- The address space of 4.3 billion unique addresses is nearly exhausted!
- This and other performance related issues paved way for the new IP Address version called IP Version 6

IP Address

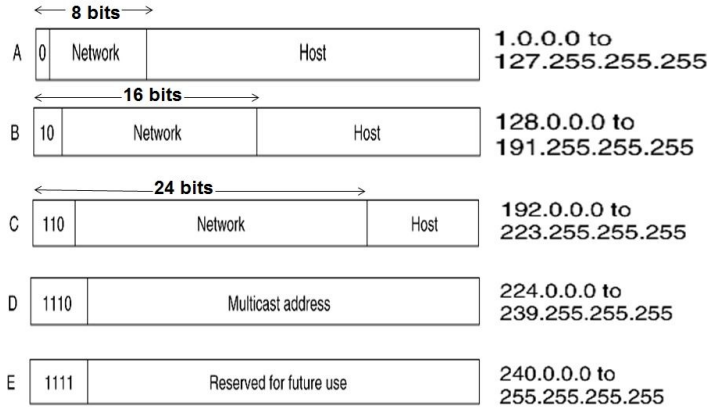


IPv6 Address Structure

- IP Address has two versions
  - **Version 6 (128 Bits)**
    - 128 bits long
    - There are approximately 340 undecillion unique addresses (3.4×10^{38}) unique addresses
    - This vast address space solves the issue of IPv4 address exhaustion.
    - Example of an IPv6 address: 2001:0db8:85a3:0000:0000:8a2e:0370:7334
    - Leading zeros in each group can be omitted, and consecutive zeros can be compressed with a double colon (::), like 2001:db8::8a2e:370:7334
  -

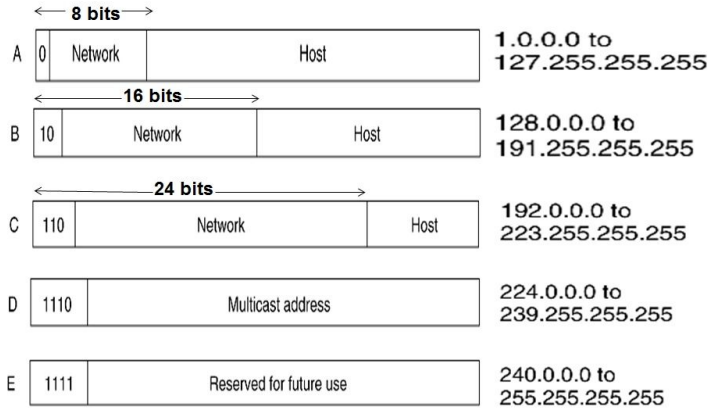
IP Address - Classes

- Buildings that house the flats can be categorized such as Large and Small depending on the number of flats they house
- Similarly IP Version 4 addresses can also be categorized into various classes
- Class A (Large Networks)
  - Similar to a huge building complex with many flats
  - Class A networks have a large number of hosts
  - Class A can be typically used by a large multinational company with thousands of computers, servers, and devices across multiple offices globally



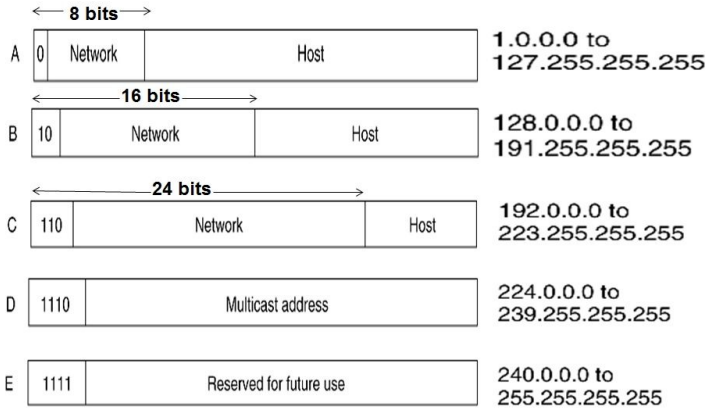
IP Address - Classes

- Class B (Medium-sized Networks)
  - A medium-sized building complex with fewer flats compared to Class A
  - Class B networks are designed for mid-sized organizations like universities or regional businesses
  - The building isn't as huge as a Class A building but still has a decent number of flats (hosts)
  - Address range: 128.0.0.0 to 191.255.255.255.
  - Example: A university with a few thousand devices, such as computers in labs, offices, and dormitories



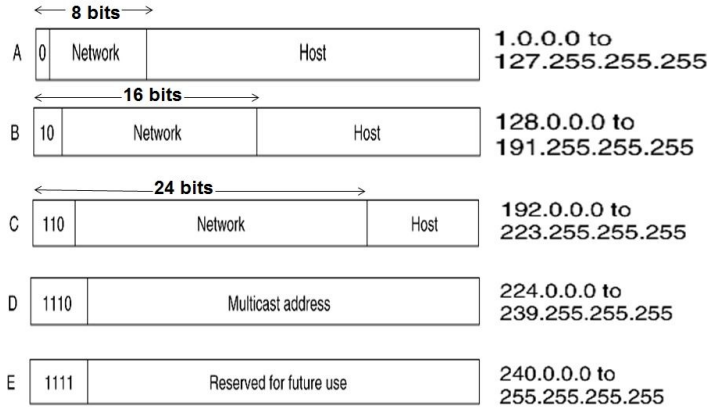
IP Address - Classes

- Class C (Small Networks)
  - A small apartment building with just a few flats
  - Class C networks are for small businesses or homes, where there's only a limited number of devices (up to 254 hosts per network)
  - It's like a small building where each flat has just a few people or devices connected



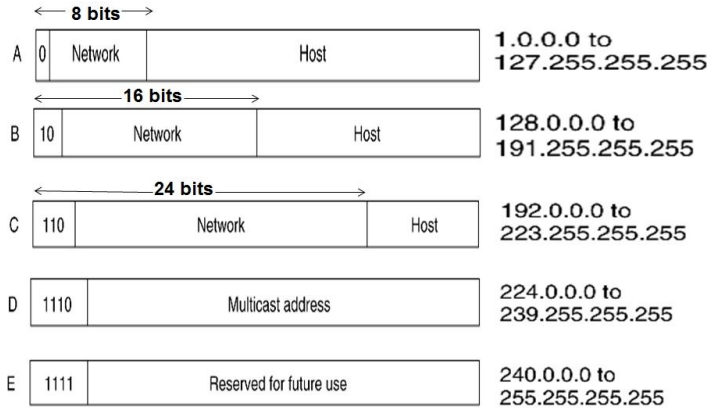
IP Address - Classes

- Class D (Multicasts)
  - A conference room in the building complex
  - Class D isn't about one apartment or a specific building but is more like a room where certain people gather for special meetings.
  - It's used for multicasting, where a group of devices need to receive the same information simultaneously, like streaming a video to many viewers at once
  - Address range: 224.0.0.0 to 239.255.255.255.
  - Example: A live stream or a video conference where several participants in different locations are receiving the same data at the same time



IP Address - Classes

- Class E (Experimental)
  - Analogy: Reserved empty land next to the building
  - Explanation: Class E addresses are reserved for experimental purposes, like an empty plot of land where no buildings (networks) are built yet. It's reserved for future use or special projects.
  - Address range: 240.0.0.0 to 255.255.255.255.
  - Example: Reserved for research or future technologies, not used for regular networks



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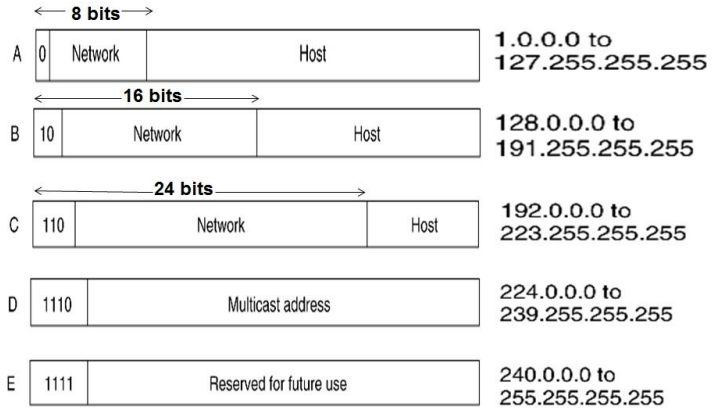


Network Devices - Functions

- Facilitate data transmission and communication between devices
- Enable efficient and secure network connectivity
- Enhance network performance and optimize traffic flow
- Provide network security
- Simplify network management
- Extend network coverage and overcome signal limitations

Network Devices - Hub

- Hub can be compared to a central hallway or shared space that connects various flats in a building complex
- Hub works on physical layer
- It is used to connect PCs in a LAN - in a single network
- It has many ports - exact number of ports varies as per the make of the product. A device is connected to the a port on the hub
- When a data frame arrives at a port, hub broadcasts it to all other ports, without considering whether it is destined for a particular destination or not
- Hubs can also act as a repeater or amplifier for information that has to travel over long distances

Network Devices - Hub - Advantages*

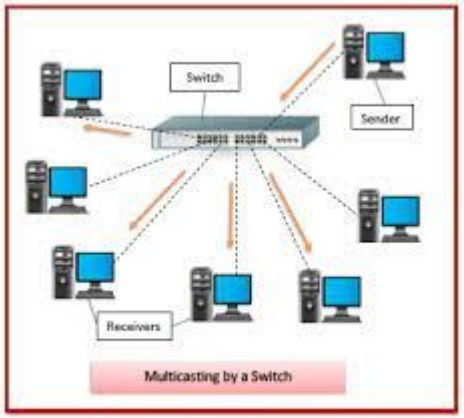
- **Message broadcast**: A host in a hub sends messages to every other device in the connecting network
- **Cheaper devices**: Hub is the cheapest networking device
- **Easy installation**: It can be easily installed - addition nodes to the network is also simpler
- **Easy removal of damaged device**: Removal of nodes can be easily done. Even if a node is removed or not functioning, the hub remains perfectly functional

Network Devices - Hub - Disadvantages

- **Not intelligent**: Hub does not have any software unit along with it for management. It can just forward the incoming frames to the nodes in the network
- **SPOC**: Hub is the Single Point of Contact in the network. Hence the entire network fails if the hub is not working
- **No filtering**: Hubs forward the incoming frames as such to all nodes in the networks without locating the destination MAC address of the target device
- **No security**: Since the hub broadcasts messages to every port, it is not possible to send any private frame. This allows other connected ports to access the private data

Network Devices - Hub - Disadvantages

- **Network Traffic is high**: Due to the broadcasting of all incoming frames by a hub, the traffic is high
- **Does not use full duplex transmission mode**: Hubs use the half-duplex method for transmission. Hence It is not possible to send and receive frames simultaneously
- **Cannot connect to different network architectures**: Hubs cannot connect networks with different network architectures

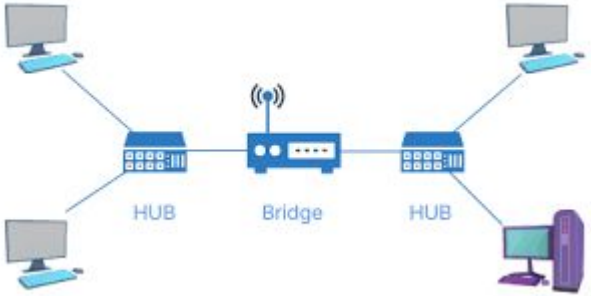


Network Devices - Switch

- A switch is a data link layer networking device
- It is used to connect devices in a network
- It has many ports - exact number of ports varies as per the make of the product. A device is connected to the a port on the switch
- When a data frame arrives at a port, switch examines the destination address and sends the frame to the corresponding device(s)
- While switches and hubs perform similar functions, switches are often preferred because they improve network efficiency and network security

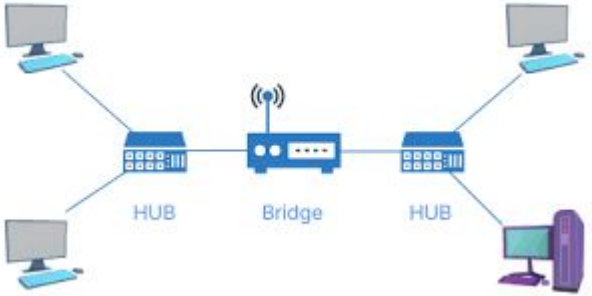
Network Devices - Hub Vs Switch

Hub	Switch
Operates on the OSI physical layer	Operates on the OSI data link layer
Works in half-duplex mode	Works in full-duplex mode
A passive device	An active device
Shares the bandwidth between the ports	Provides dedicated bandwidth to the ports
Number of ports are fewer	Number of ports are larger
Sends messages to all ports	Sends messages to the intended devices



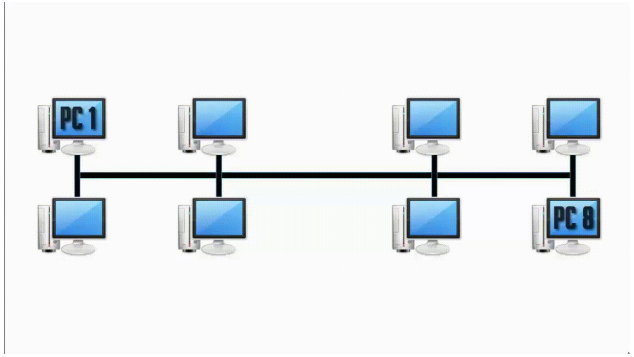
Network Devices - Bridge

- A bridge is a device that connects two or more LANs or network segments, enabling them to communicate with each other
- It operates at the data link layer of the OSI model
- It reads the source address of the incoming data packets, forwarding them only to their target destination instead of broadcasting them to all connected segment



Network Devices - Bridge

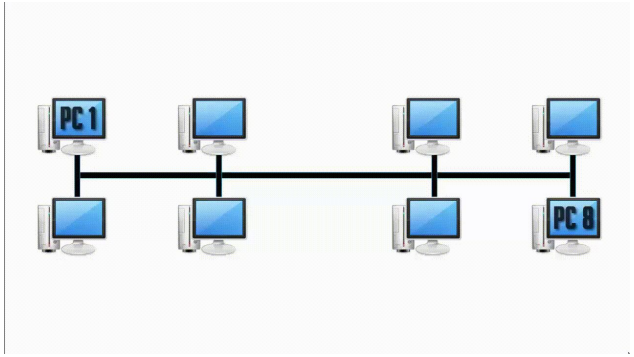
- What is the exact use of a bridge?



Network Devices - Bridge

- What is the exact use of a bridge?
- Figure illustrates a bus topology
- Let PC1 wants to send data to PC2 - it will broadcasts the data to the entire network and ultimately it reaches the destination

- Let us see how a bridge can help us in this regard



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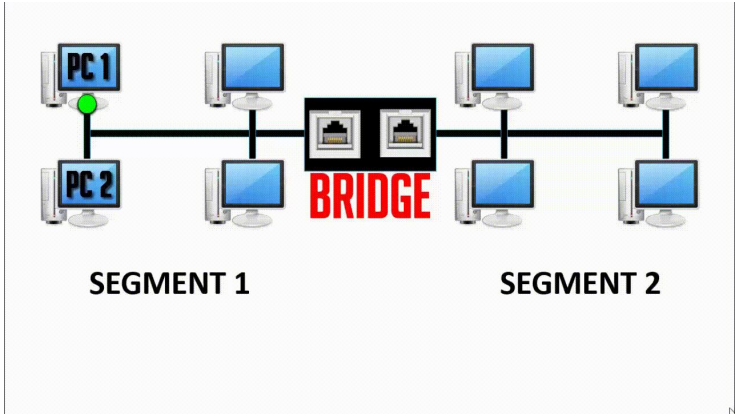
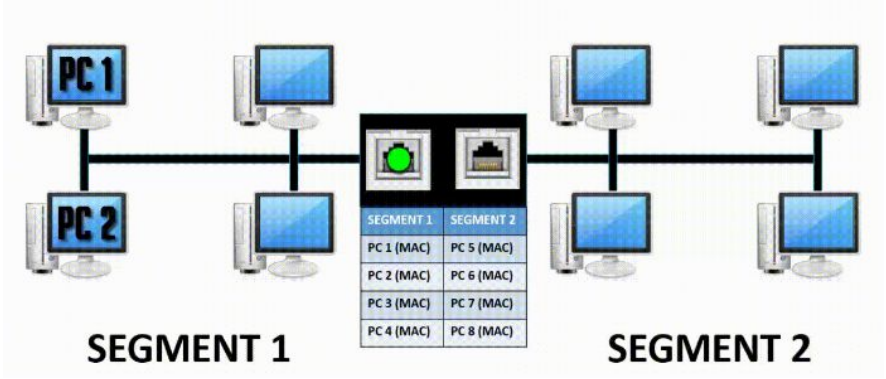


Network Devices - Bridge

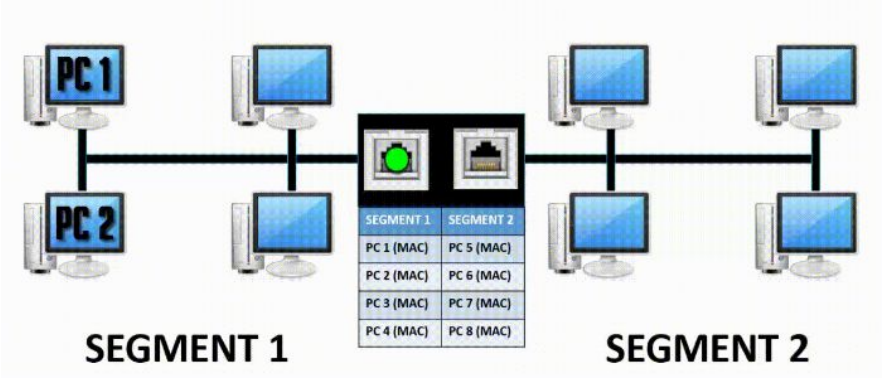
- What is the exact use of a bridge?
- Bridge is used to create two segments of the LAN



Network Devices - Bridge

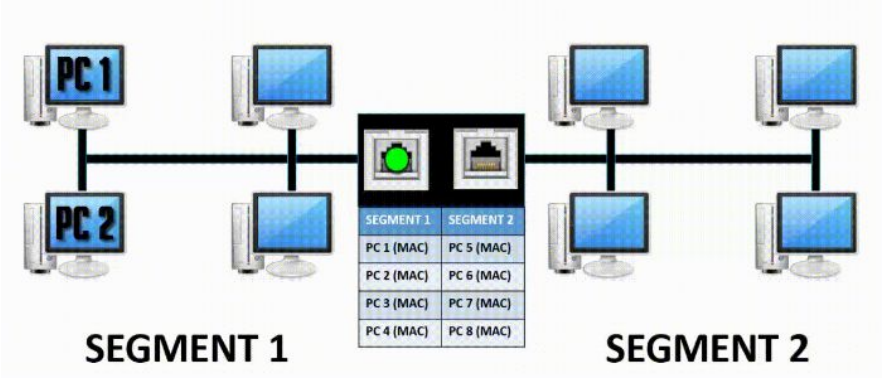
Source: https://www.learnabhi.com/bridge-in-computer-network/

- What is the exact use of a bridge?
- Bridge is used to create two segments of the LAN
- It stores the MAC addresses of all the devices in the network
- Now when PC1 sends data to PC2, data is received by the bridge first
- Bridge will read MAC address from the header of the data frame
- Now the bridge can decide whether to send the data to segment 1 or segment 2
- Hence data will be broadcasted to segment 1 alone
- Bridge reduces the traffic on a computer network!



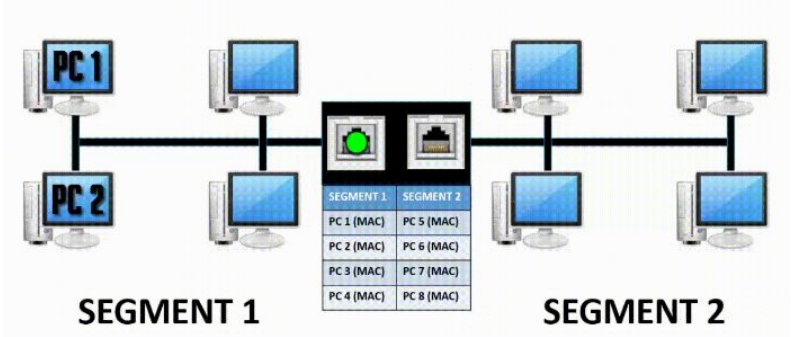
Network Devices - Bridge- Advantages

- **Enhances Network Performance**: Bridges can segment the network into smaller parts, reducing congestion and improving network performance
- **Easy Isolation of Faulty Nodes**: A bridge can isolate network problems and prevent them from affecting the entire network
- **Filtering of Data Frames**: A bridge can filter traffic of frames based on MAC addresses.This reduces unnecessary traffic and improves network efficiency
- **Scalability**: Bridges can be easily added to a network to connect additional LANs, making them scalable



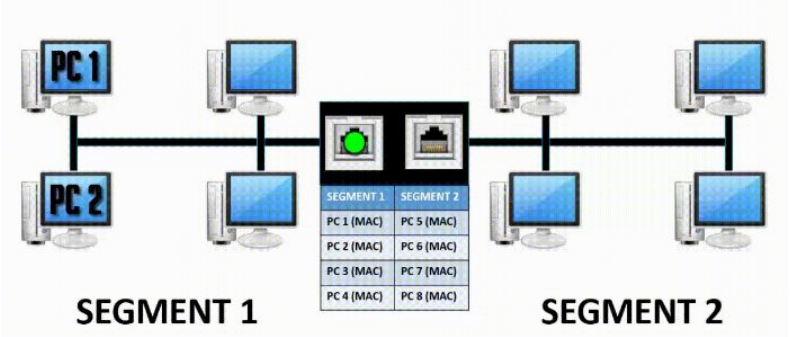
Network Devices - Bridge- Advantages

- **Cost-Effective**: Bridge is less expensive than routers or switches, making it a cost-effective option for smaller networks



Network Devices - Bridge- Disadvantages

- **Broadcast Storms**: If a bridge receives data with an unknown destination MAC address, it will forward the data to all connected LANs, which can cause a broadcast storm and degrade network performance
- **Security Risks**: Bridge does not offer the same level of security features as routers or switches, which may make it more vulnerable to security threats
- **Limited Traffic Control:** Bridge does not offer the same level of traffic control as routers or switches, which may limit its usefulness in some network configurations



Network Devices - Bridge- Uses

- Connecting LANs: Bridge is used to connect two or more LANs and enable communication between them. This allows devices on different LANs to communicate with each other
- **Segmenting Networks**: Bridges can segment a network into smaller parts, which improves network performance by reducing congestion and increasing the overall speed of the network
- **Extending Wireless Networks**: Bridges can be used to extend wireless networks and improve coverage by connecting two or more access points

Network Devices - Switch Vs Bridge

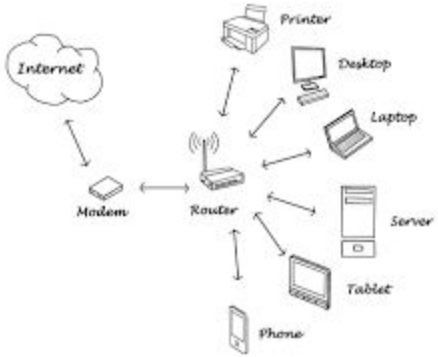
Switch	Bridge
A data link layer networking device	A datalink layer device
Used to connect devices in a network and interconnect different networks	Used to segment a LAN or connect LANs with different architectures
Has more number of ports	Has fewer number of ports
Has buffers for each link connected to it	Do not have any buffers
A hardware based device	A software based device
Do error checking	Do not perform error checking

Network Devices - Router

- Take the case of an air traffic controller and aircrafts heading to different airports
- Each aircraft has its own unique destination and it follows a unique route to its destination
- Air traffic controller makes sure that the aircrafts reach their destinations without any disruptions

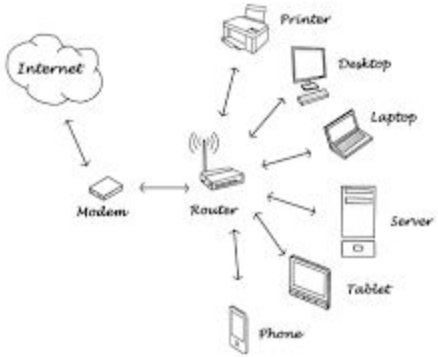
Network Devices - Router

- Consider the the router as an air traffic controller and data packets as aircraft headed to different airports (or networks)
- Just as each aircraft has a unique destination and follows a unique route, each packet needs to be guided to its destination as efficiently as possible
- Similar to an air traffic controller performs its functions, a router helps direct data packets to their destination IP address



Network Devices - Router

- A network layer device
- Acts a switch that routes data packets based on their IP addresses
- A device that connects two or more packet-switched networks or subnetworks
- It serves two primary functions:
  - managing traffic between these networks by forwarding data packets to their intended IP addresses, and
  - allowing multiple devices to use the same Internet connection

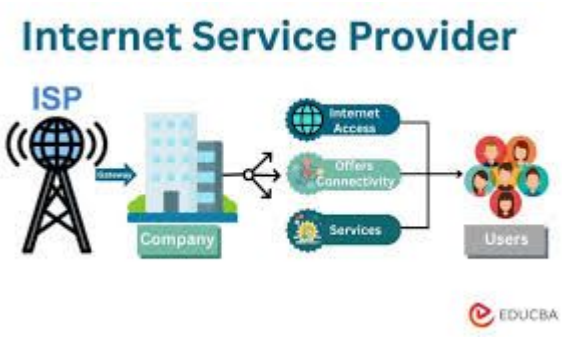


Network Devices - Router - Applications

- It connects multiple networks and forwards packets destined either for directly attached networks or more remote networks
- It provides support for a fast rate of data transmission
- Internet service providers use routers to send the data from source to destination in the form of e-mail, a web page, image, voice, or a video file. Furthermore, it can send data all over the world with the help of an IP address of the destination
- To provide access restrictions to users

Network Devices - Router Vs Switch

Switch	Router
A data link layer networking device	A network layer device
Used to connect devices in a network and interconnect different networks	Used to connect different networks
Used only in LAN	Used in LAN and WAN
Data is sent as frames	Data is sent as packets
Maximum speed for wireless and wired connections is 1-10 Mbps and 100 Mbps, respectively	Maximum speed is 10Mbps to 100Mbps



Internet Service and Internet Service Providers

- Just like water flows through pipes to reach our home, data flows through cables (like fiber optics or phone lines) to reach our device
- ISPs use cables, wireless signals, or satellites to deliver the Internet to our homes and businesses
- In our house, the water tap controls how much water we receive. We can turn it on to use more water (download data) or turn it off
- Our Internet connection (through a modem or router) is like the water tap. When it's on, we can access online services like browsing, streaming, or downloading files

Rank	ISP	Logo	Narrowband Su Sort ascending	Broadband Subscribers	Total Subscribers
1	Jio		—	428,200,000	428,200,000
2	Airtel		19,969,265	268,028,831	287,998,096
3	Vi		11,043,432	124,896,076	135,939,508
4	BSNL		2,882,539	24,588,532	27,471,071
5	Atria Convergence Technologies		—	2,159,293	2,159,293

Internet Service Providers in India

- The number of internet users in India as on 2023 is 895.832 million. The table shows the top 5 ISPs in India by total subscriber base as of 30 June 2023 (Source: https://en.wikipedia.org/wiki/List_of_internet_service_providers_in_India)

Wireless Communication

- Wireless communication is the transfer of data or information between devices without using physical cables or wires. Instead, it uses radio waves, infrared, or other wireless signals to transmit data through the air
- Common Types of Wireless Communication:
  - Wi-Fi: For internet access in homes and offices
  - Bluetooth: For short-range communication between devices (like headphones and phones)
  - Cellular Networks (4G/5G): For mobile communication and data
  - Satellite Communication: For long-distance communication

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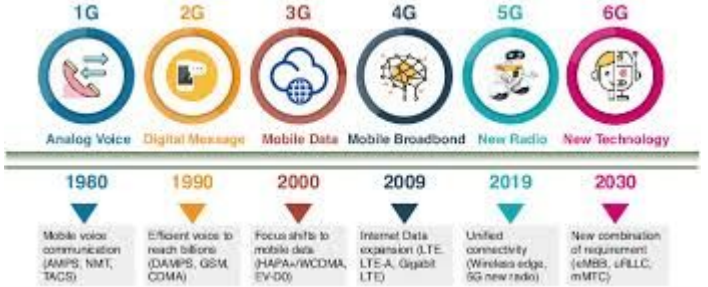
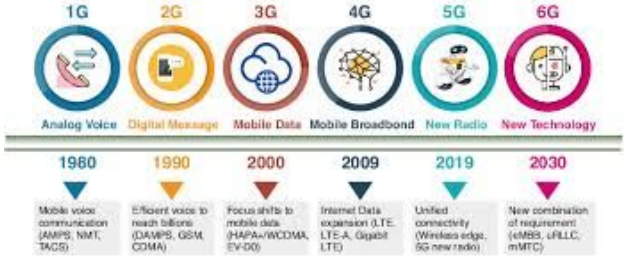


Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 1G (First Generation) – Analog Voice (1980s)
  - 1G, or the first-generation mobile network, refers to the initial analog telecommunications standards introduced in the 1980s
  - 1G utilized analog signals to transmit voice data
  - The development of 1G began in the late 1970s, with significant contributions from telecom giants like NTT in Japan and AT&T in the USA



Wireless Communication - Generations

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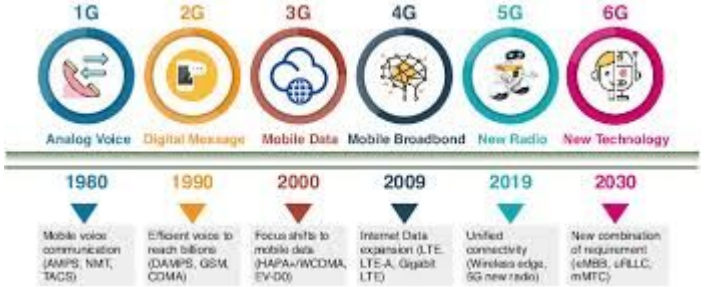
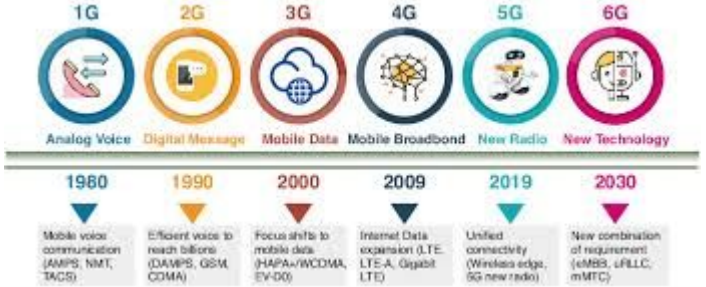
- 1G (First Generation) – Analog Voice (1980s)
  - The development of 1G began in the late 1970s, with significant contributions from telecom giants like NTT in Japan and AT&T in the USA
  - It used analog signals to transmit voice calls, marking the first time people could communicate wirelessly via mobile phones
  - It only supporting basic voice communication, with poor sound quality and frequent call drops
  - The data transfer speed was around 2.4 kbps, and it offered no data services like text messaging or internet access
  - Security was a major issue, as calls could easily be intercepted due to the lack of encryption



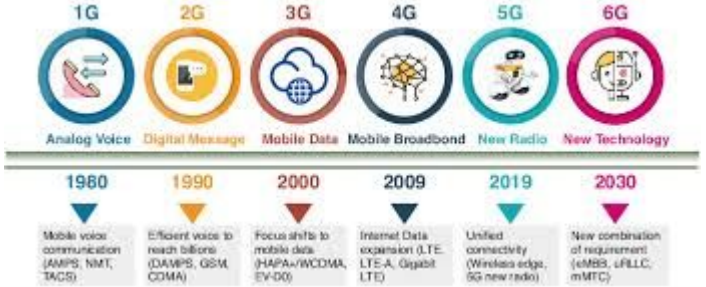
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 1G (Second Generation) – Limitations
  - Poor Voice Quality: Voice quality was often poor, with significant interference.
  - Signal Interference: Analog signals were prone to interference from various sources, affecting call quality
  - Lack of Security: Calls were not encrypted, making them vulnerable to eavesdropping and unauthorized listening
  - Limited Coverage: Network coverage was limited to urban areas, leaving rural regions with little service
  - High Cost: The initial cost of mobile phones and network usage was high, making it accessible only to a few



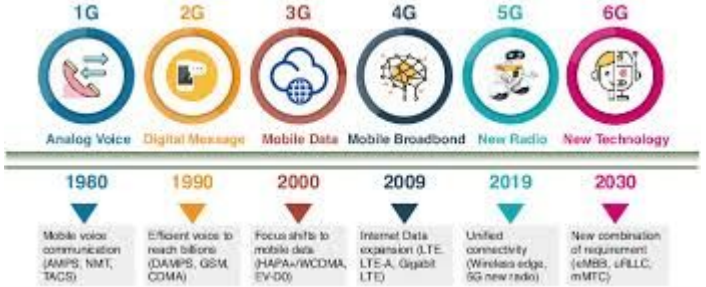
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 2G (Second Generation) – Digital Voice and Text (1990s)
  - Marked the shift from analog to digital signals
  - This improvement enhanced voice quality, provided better security through encryption, and allowed for new services like SMS (text messaging) and MMS (multimedia messaging)
  - With speeds of up to 64 kbps, 2G was the first to offer limited data services, enabling basic mobile internet and email access
  - It supported GSM (Global System for Mobile Communications), which became a global standard for mobile networks



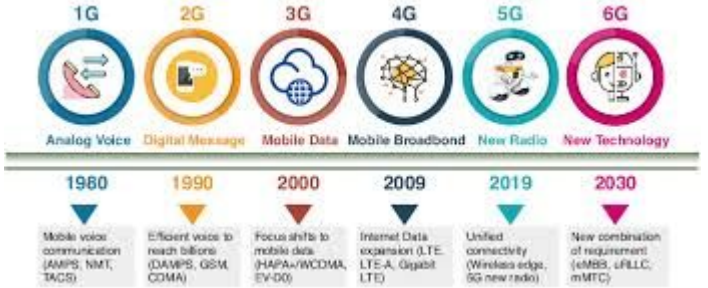
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 2G (Second Generation) – Digital Voice and Text (1990s)
  - Technology: Digital signals (GSM, CDMA)
  - Speed: Up to 64 kbps
  - Features: Introduction of text messaging (SMS) and picture messaging (MMS), improved call quality
  - Key Feature: Enhanced security with encryption and support for limited data services like SMS and MMS



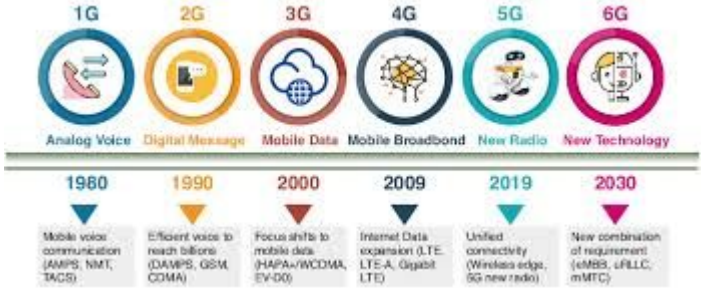
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 2G (Second Generation) – Limitations
  - Low Data Speeds: Limited to around 64 kbps, insufficient for modern internet usage
  - No Support for Multimedia: Can't handle video streaming or high-quality audio services
  - Poor Internet Browsing: Web access is slow and limited to basic websites
  - Limited Capacity: Can handle fewer simultaneous connections compared to later generations
  - Outdated Security: Vulnerable to eavesdropping and limited encryption compared to newer networks



Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 3G (Second Generation) – Mobile Data (2000s)
  - Significantly improved mobile data speeds, allowing for mobile internet access, video calls, and multimedia messaging
  - With data transfer rates ranging from 144 kbps to 2 Mbps, 3G enabled the rise of smartphones and the use of apps, web browsing, and email on mobile devices
  - 3G introduced technologies like UMTS and CDMA2000, enhancing network efficiency and providing global coverage
  - It also supported services like GPS navigation and mobile TV



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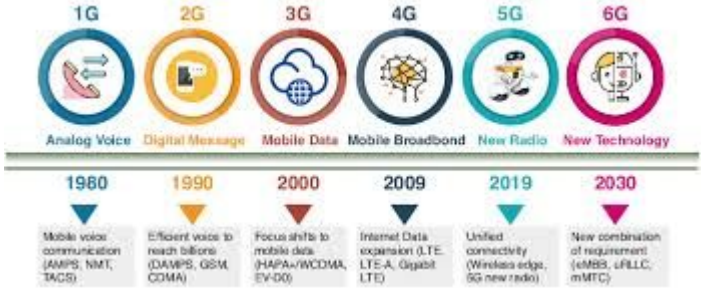
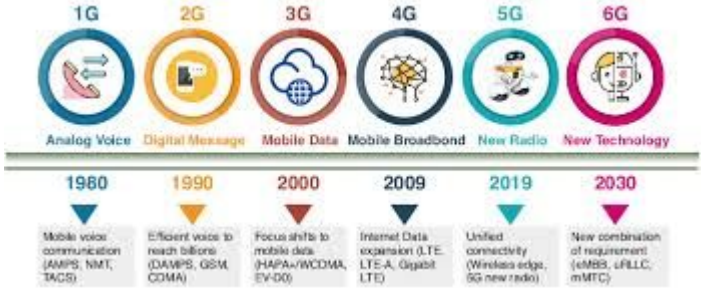
- 3G (Second Generation) – Mobile Data (2000s)
  - Technology: UMTS, CDMA2000
  - Speed: 144 kbps to 2 Mbps
  - Features: Mobile internet access, video calls, and multimedia messaging
  - Key Feature: Enabled smartphones with apps and web browsing, expanding mobile data use



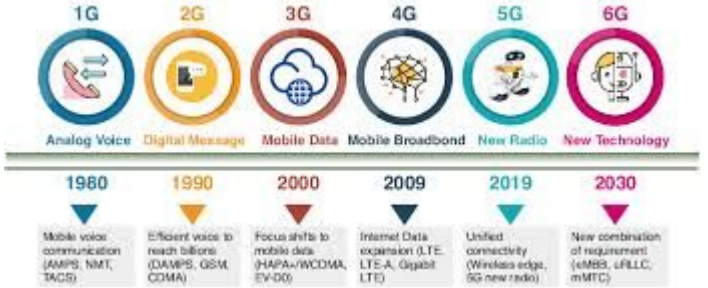
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 3G (Third Generation) – Key Limitations
  - Slower Data Speeds: Limited to around 2 Mbps, inadequate for HD video streaming and large downloads
  - High Latency: Delays in data transmission, affecting real-time applications like gaming and video calls
  - Battery Drain: 3G devices tend to consume more power, reducing battery life
  - Limited Capacity: Struggles to support a large number of connected devices simultaneously.
  - Insufficient for Modern Applications: Can't efficiently handle newer services like cloud computing or IoT devices



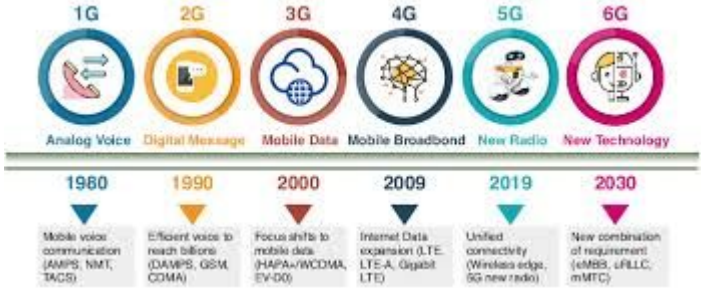
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 4G (Fourth Generation) – High-Speed Data (2010s)
  - Revolutionized mobile networks by providing high-speed data, low latency, and better connectivity
  - It offers data transfer speeds ranging from 100 Mbps to 1 Gbps, making it suitable for HD video streaming, online gaming, and video conferencing
  - Operates on an all-IP network, meaning it uses Internet Protocol (IP) for all data transmission, enhancing efficiency
  - Supports a wide range of services, including VoIP (Voice over IP), mobile TV, and real-time multimedia
  - It became the foundation for mobile broadband, offering seamless connectivity for users worldwide, and set the stage for the IoT (Internet of Things) and smart devices



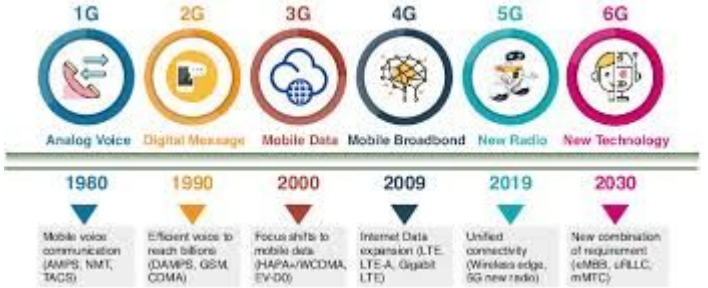
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 4G (Fourth Generation) – High-Speed Data (2010s)
  - Technology: LTE (Long-Term Evolution)
  - Speed: 100 Mbps to 1 Gbps
  - Features: HD video streaming, high-quality video calls, online gaming, and mobile broadband.
  - Key Feature: Fully digital networks supporting data-intensive applications like streaming and cloud storage



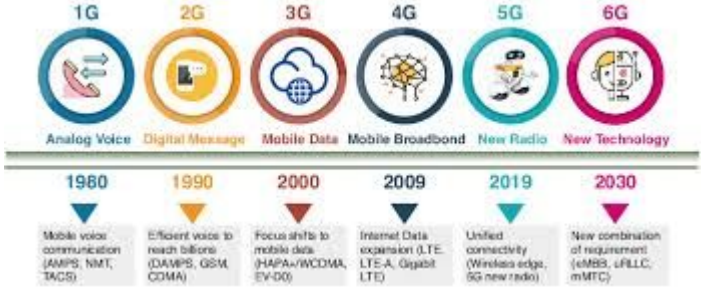
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 4G (Fourth Generation) – Applications
  - Mobile Internet and Browsing: 4G enables faster and more reliable mobile internet and browsing, enhancing the user experience.
  - Streaming Services: The high-speed capabilities of 4G support seamless streaming of music and videos and online gaming.
  - IoT Connectivity: 4G provides robust connectivity for IoT devices, enabling smart applications and innovations in various sectors.



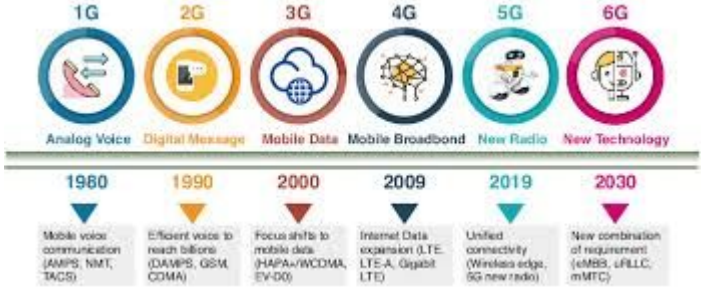
Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 5G (Fifth Generation)
  - The latest advancement in wireless technology, introduced in the 2020s
  - It offers ultra-fast data speeds ranging from 1 Gbps to 10 Gbps, enabling seamless streaming of 4K/8K video, virtual reality (VR), and online gaming with minimal lag
  - With extremely low latency (less than 1 millisecond), 5G supports real-time applications like autonomous vehicles, remote surgeries, and smart cities
  - Uses technologies like mmWave and Massive MIMO, providing increased capacity for a large number of connected devices, making it ideal for the Internet of Things (IoT) and industrial automation
  - It also improves network efficiency and supports a wide range of devices and applications



Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 5G (Fifth Generation)
  - Technology: mmWave, Sub-6 GHz, Massive MIMO
  - Speed: 1 Gbps to 10 Gbps
  - Features: Ultra-fast speeds, extremely low latency (almost real-time communication), support for massive IoT, smart cities, autonomous vehicles, and virtual/augmented reality (VR/AR)
  - Key Feature: Beyond faster speeds, 5G supports real-time communication for advanced technologies like remote surgeries and self-driving cars



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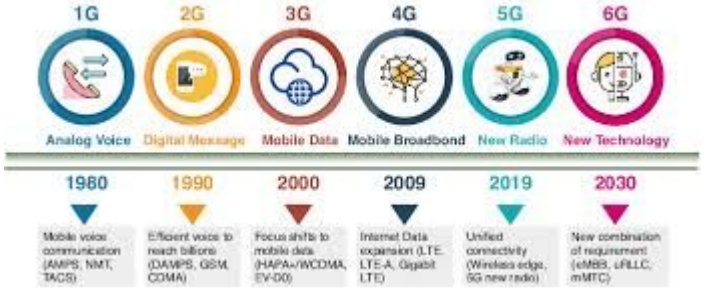
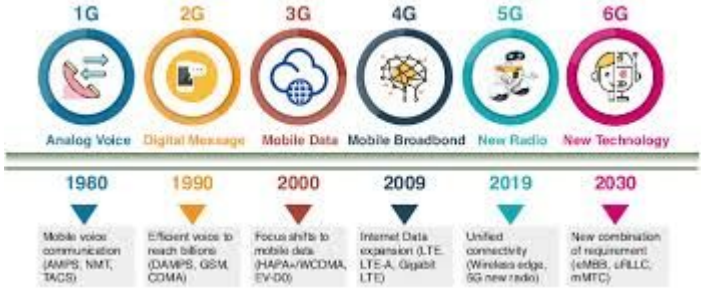


Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 5G (Fifth Generation) - Limitations
  - Limited Coverage: 5G networks, especially those using mmWave, have a shorter range, requiring more cell towers and base stations for widespread coverage
  - Penetration Issues: 5G signals, particularly high-frequency ones, struggle to penetrate buildings, walls, and dense urban environments, leading to connectivity challenges indoors
  - High Infrastructure Costs: Building and maintaining the infrastructure for 5G, including the dense network of antennas, is expensive for providers
  - Device Compatibility: Users need 5G-compatible devices (smartphones, routers, etc.) to access 5G networks, requiring upgrades from 4G equipment
  - Battery Consumption: 5G technology can be more power-intensive, leading to faster battery drain on mobile devices compared to 4G



Wireless Communication - Generations

- Wireless communication has evolved significantly with each generation (G), offering faster speeds, lower latency, and more advanced services
- 6G (Sixth Generation) -
  - Expected around 2030
  - Aims to surpass the capabilities of 5G by offering unprecedented data speeds (up to 1 Tbps) and ultra-low latency (<1 millisecond)
  - Will integrate cutting-edge technologies like terahertz (THz) waves and artificial intelligence (AI) to provide intelligent, adaptive networks
  - Will enable advanced applications such as holographic communication, immersive extended reality (XR), and digital twins, where physical and digital worlds are seamlessly interconnected
  - It will support the massive growth of the Internet of Things (IoT), smart cities, and autonomous systems (drones, robots, etc.)

Network commands - host

- It is used to get the IP Address of a domain name such as www.google.com
- Syntax: host <domain_name>

Network commands - hostname

- It is used to display or change the hostname of device
- hostname command displays the host name assigned to the device
- hostname <hostname> command sets the hostname for the device. his change will only persist until the next reboot

Network commands - ping

- Ping is the short for “Packet Internet Groper”
- It is used to test connectivity between two devices
- It determines if a specific host or IP address is reachable from our system
- It measures the round-trip time (latency) of packets between our device and the target, providing insights into network performance
- Syntax: ping <destination>
- Example:-
  - Ping a website: ping google.com
  - Ping an IP address: ping 8.8.8.8

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