Reference Books

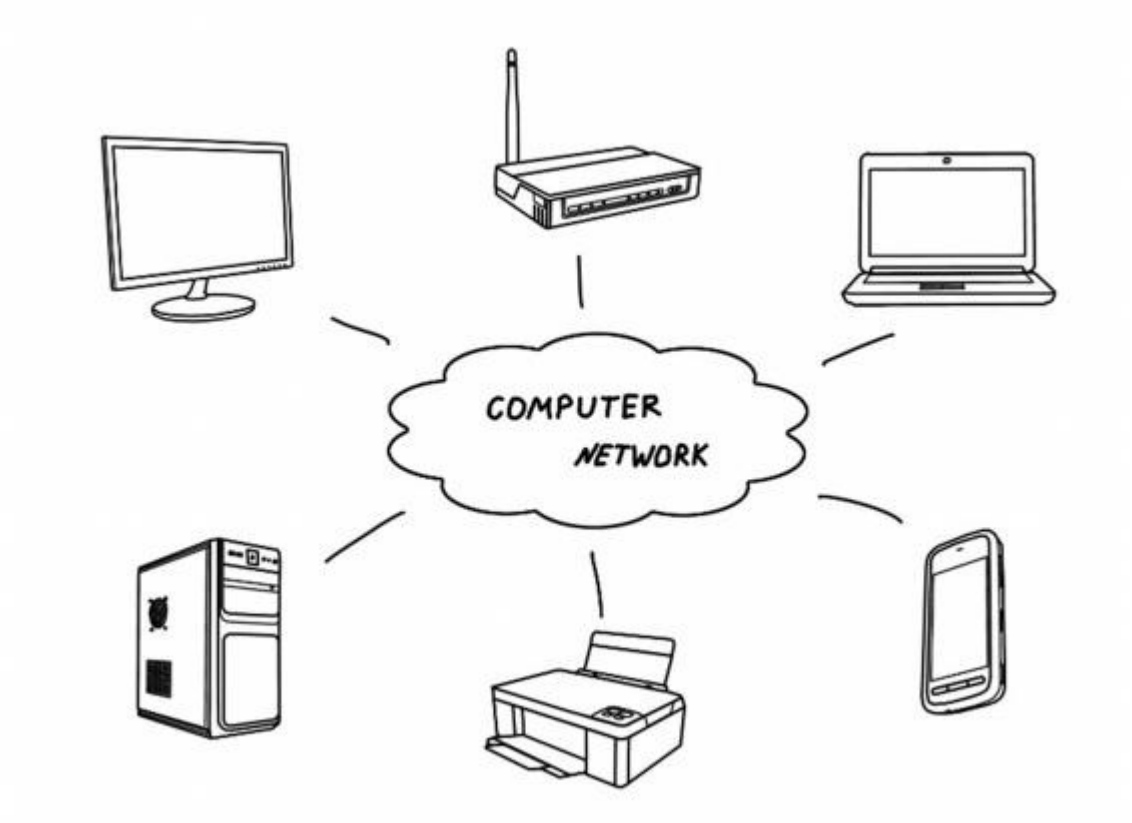
1. Computer Networking- A Top-Down approach (6th edition), Kurose and Ross, Pearson
2. Computer Networks- A Top-Down approach, Behrouz Forouzan, McGraw Hill
3. Computer Networks (5th edition), Andrew Tanenbaum, Prentice Hall
4. Computer Networking and the Internet (5th edition),Fred Halsall, Addison Wesley
5. Data Communications and Networking (5th edition), Behrouz Forouzan, McGraw Hill 6. TCP/IP Protocol Suite (4th edition), Behrouz Forouzan, McGraw Hill

What is a network?

Set of devices communicating with each other.

- Could be a CPU, monitor and other peripheral devices connected (and exchanging data) to each other.
- Could be a group of people …. A network of friends.
- Or, could be a set of computers communicating with each other.

Computer network



Computer Network is a system in which multiple computers are connected to each other to share information and resources.

Advantages of Computer Networks

- **File sharing**
- **Resource sharing**
- **Better connectivity and communications**
- **Internet access**
- **Entertainment**
- **Inexpensive system**
- **Flexible access**
- **Instant and multiple access**

Disadvantages of Computer Networks

- **Lack of data security and privacy**
- **Presence of computer viruses and malwares**
- **Lack of Independence**
- **Lack of Robustness**
- **Need an efficient handler**

Use (Applications) of Computer Networks

- **Financial services**
- **Business**
- **Email Services**
- **TeleConferencing**
- **Directory Services**
- **Mobile Application**

Types of Computer Network

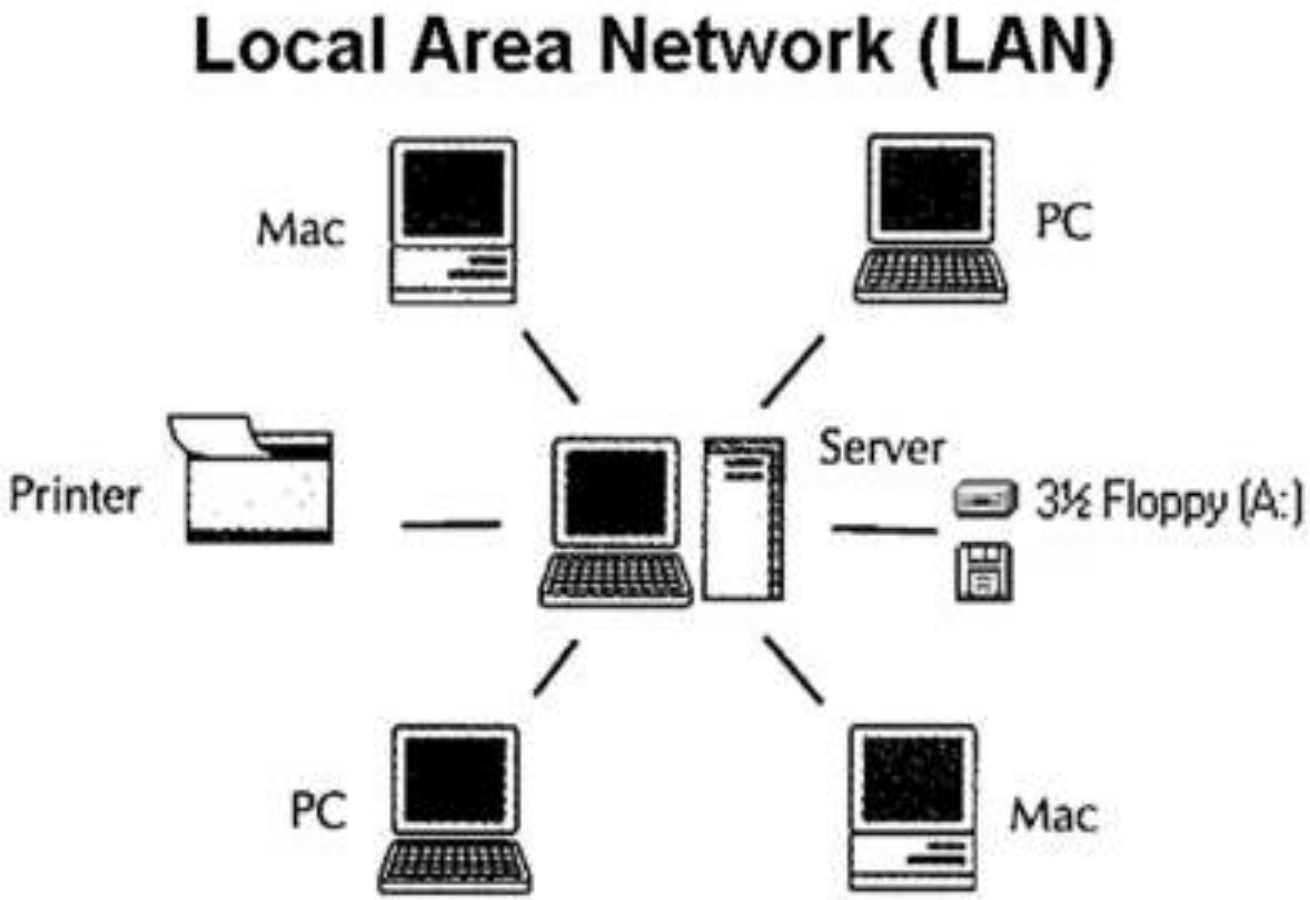
Local Area Networks

- It is privately-owned networks within a single building or campus
- They are widely used to connect personal computers and workstations
- easy to design
- connected to a single cable
- limited geographical area

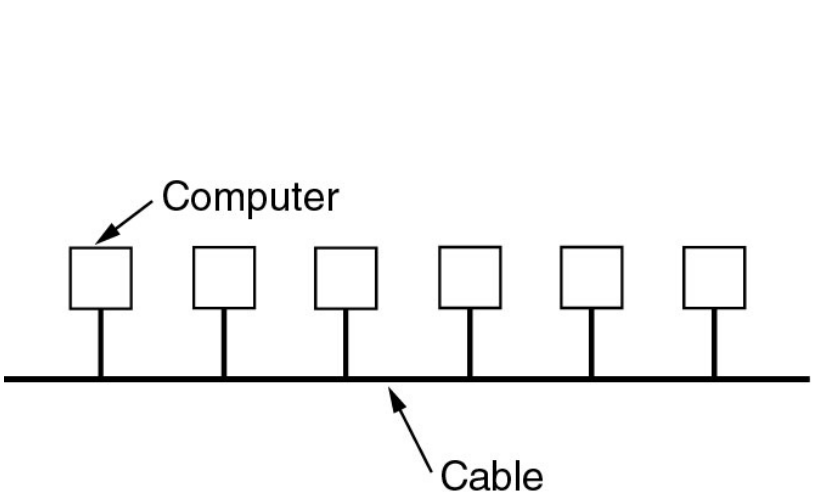
Advantages:

- LAN transfers data at high speed.
- LAN technology is generally less expensive.

Local Area Network(LAN)



Local Area Networks(LAN)



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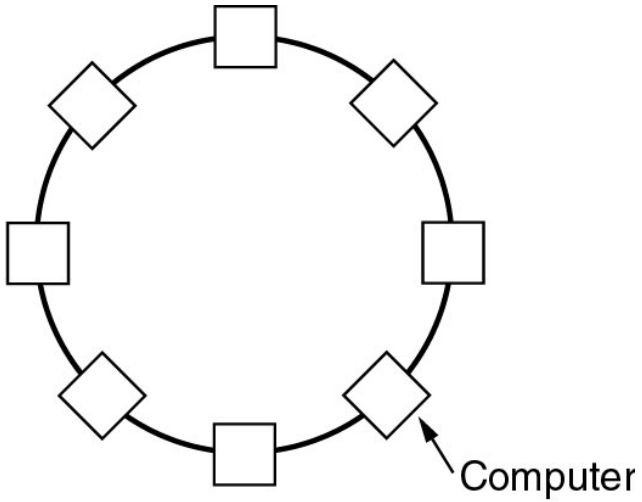


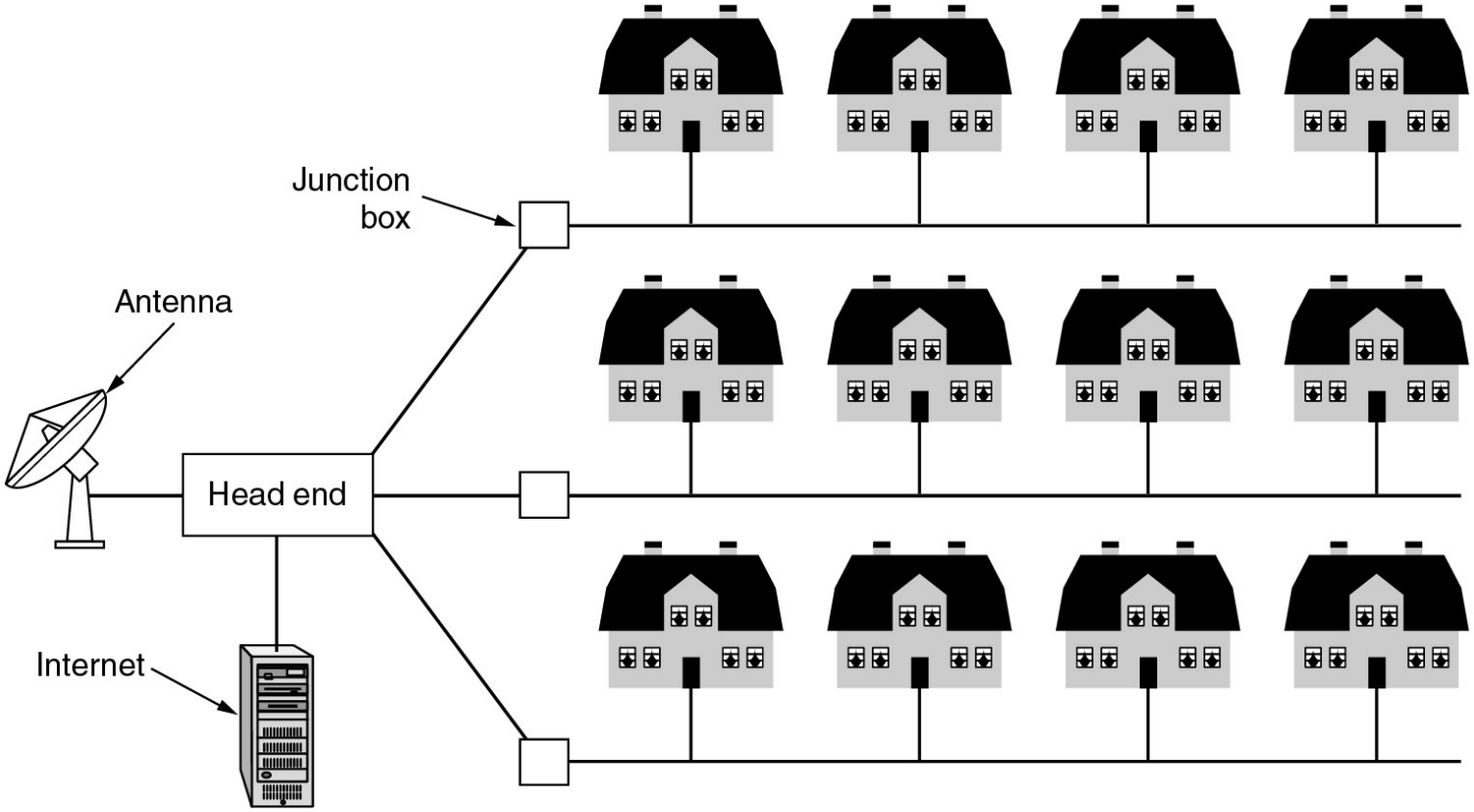
(b)

Two broadcast networks
(a) Bus
(b) Ring

Metropolitan Area Networks(MAN)

- Covers an area that is larger than the covered by LAN
- Example of a MAN is the cable television network available in many cities.
- Connects two or more LANs

Metropolitan Area Networks

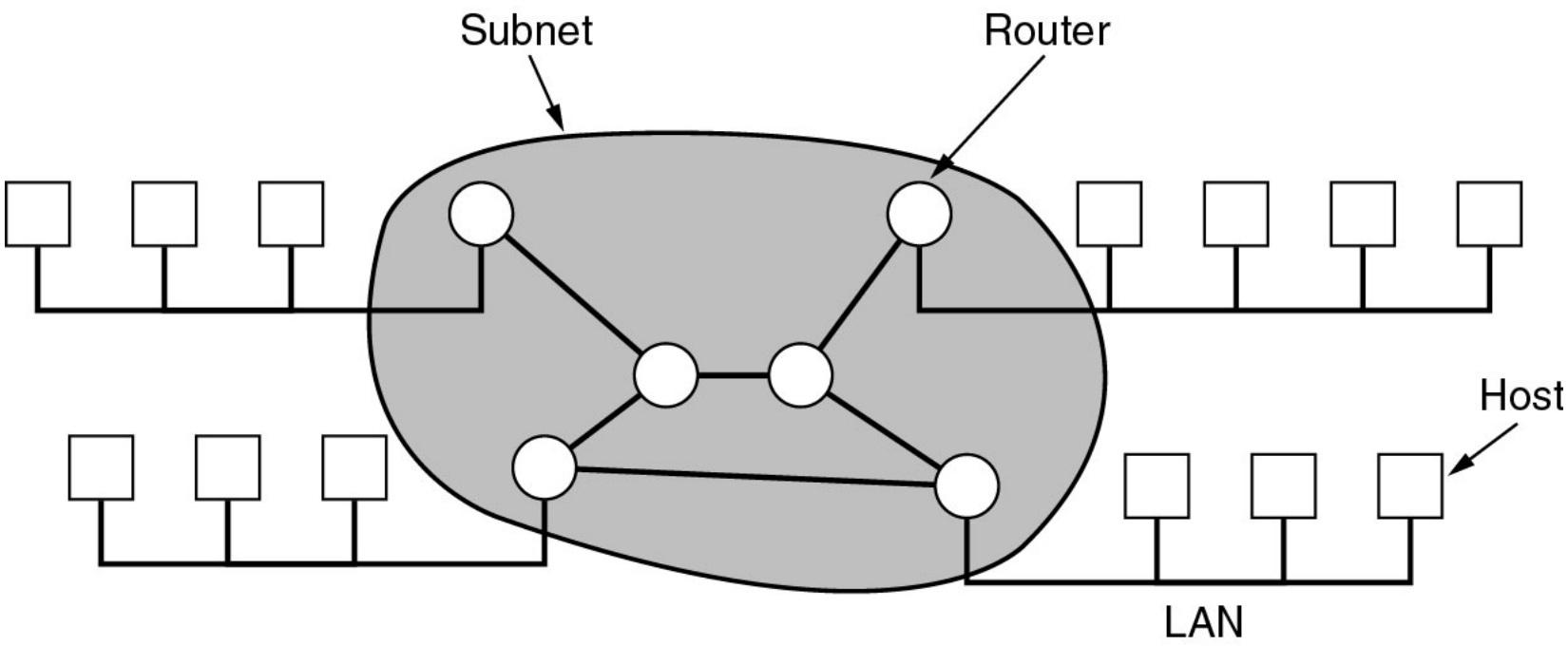


A metropolitan area network based on cable TV.

Wide Area Networks(WAN)

- large geographical area, often a country or region
- located entirely with in a state or a country
- It contains a collection of machines intended for running user (i.e., application) programs
- The communication between different users of WAN is established using leased telephone lines or satellite links and similar channels.

Wide Area Networks



Relation between hosts on LANs and the subnet.

In most wide area networks, the subnet consists of two distinct components: **transmission lines and switching elements**.

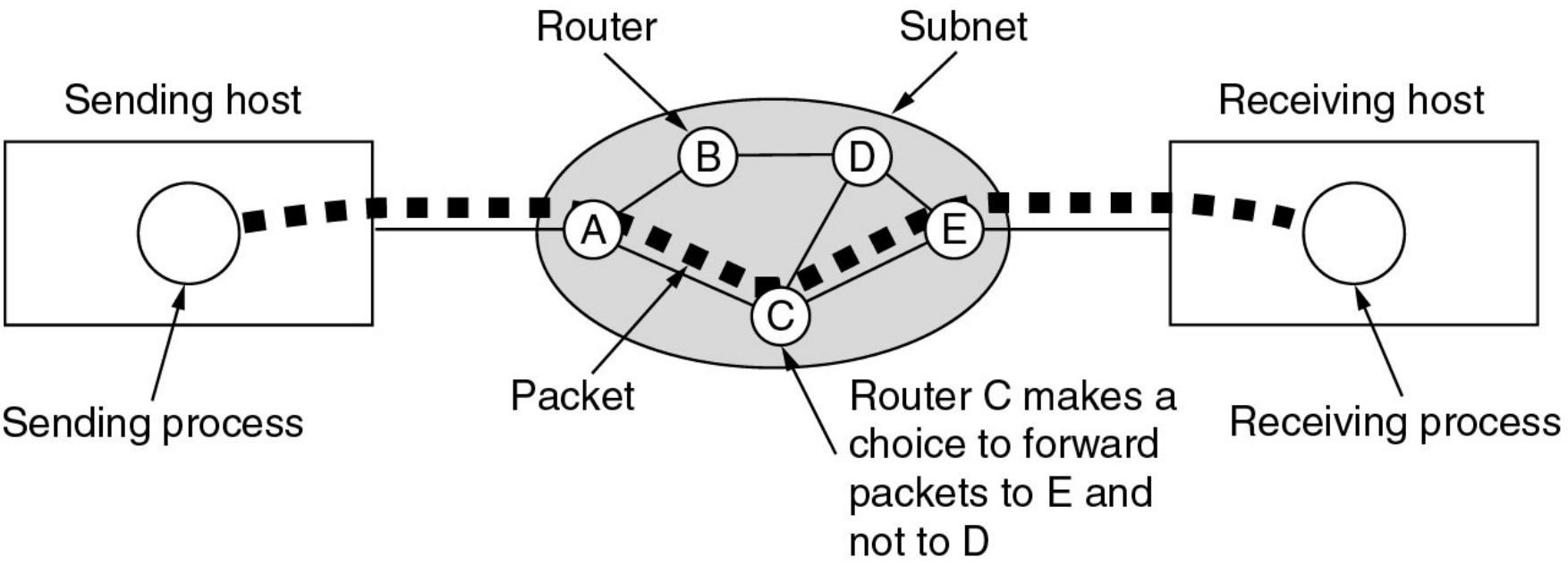
Transmission lines move bits between machines. They can be made of copper wire, optical fiber, or even radio links.

Switching elements are specialized computers that connect three or more transmission lines. When data arrive on an incoming line, the switching element must choose an outgoing line on which to forward them.

A short comment about the term "subnet" is in order here.

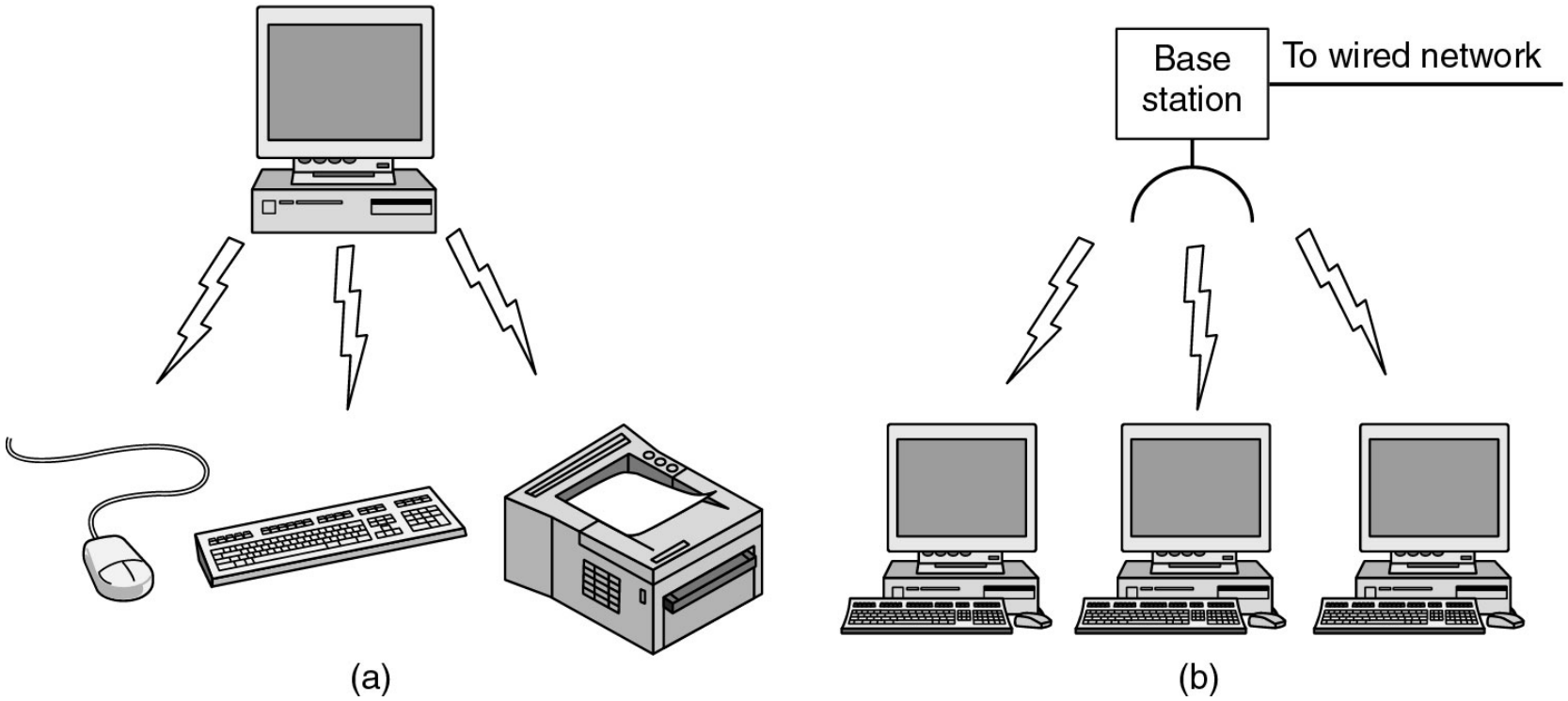
Originally, its only meaning was the collection of routers and communication lines that moved packets from the source host to the destination host.

Wide Area Networks (2)



A stream of packets from sender to receiver.

Wireless Networks (2)



(a) Bluetooth configuration

(b) Wireless LAN

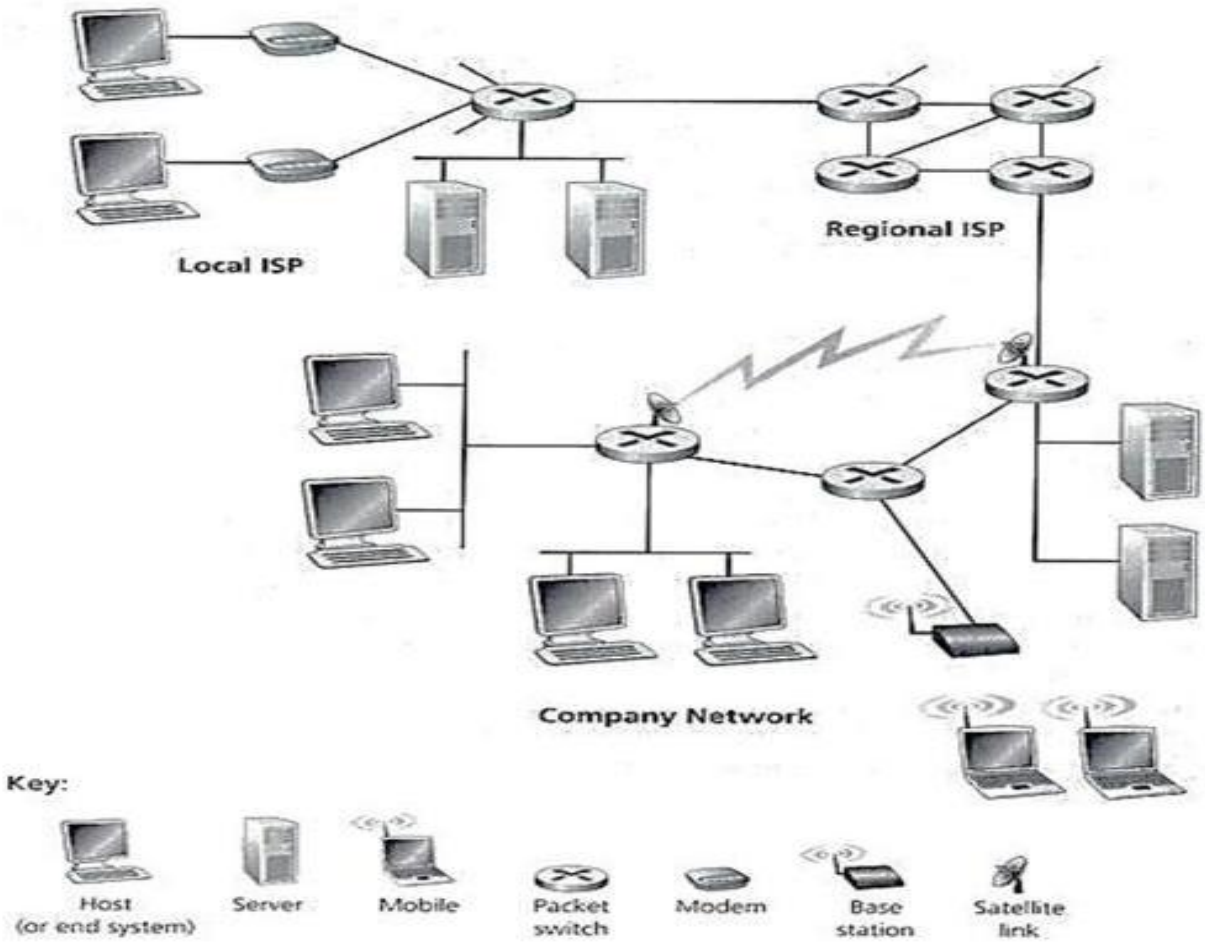
Difference between LAN, MAN and WAN

Parameter	LAN	MAN	WAN
Area covered	Covers small area.	Covers larger than LAN	Covers large area
	i.e. within building	& smaller than WAN	
Error rates	Lowest	Moderate	Highest
Transmission speed	High speed	Moderate speed	Low speed
Equipment cost	Inexpensive	Moderate expensive	Most expensive
Design & maintenance	Easy	Moderate	Difficult

Internet

- world-wide computer network
- collection of infinite numbers of connected computers that are spread across the world
- established as the largest network and sometimes called network of network that consists of numerous academic, business and government networks, which together carry various information
- Internet is a global computer network providing a variety of information and communication facilities
- When two computers are connected over the Internet, they can send and receive all kinds of information

Internet


Local ISP
Regional ISP
Company Network
Key:
Host
(or end system)
Server
Mobile
Packet
switch
Modem
Base
station
Satellite
link

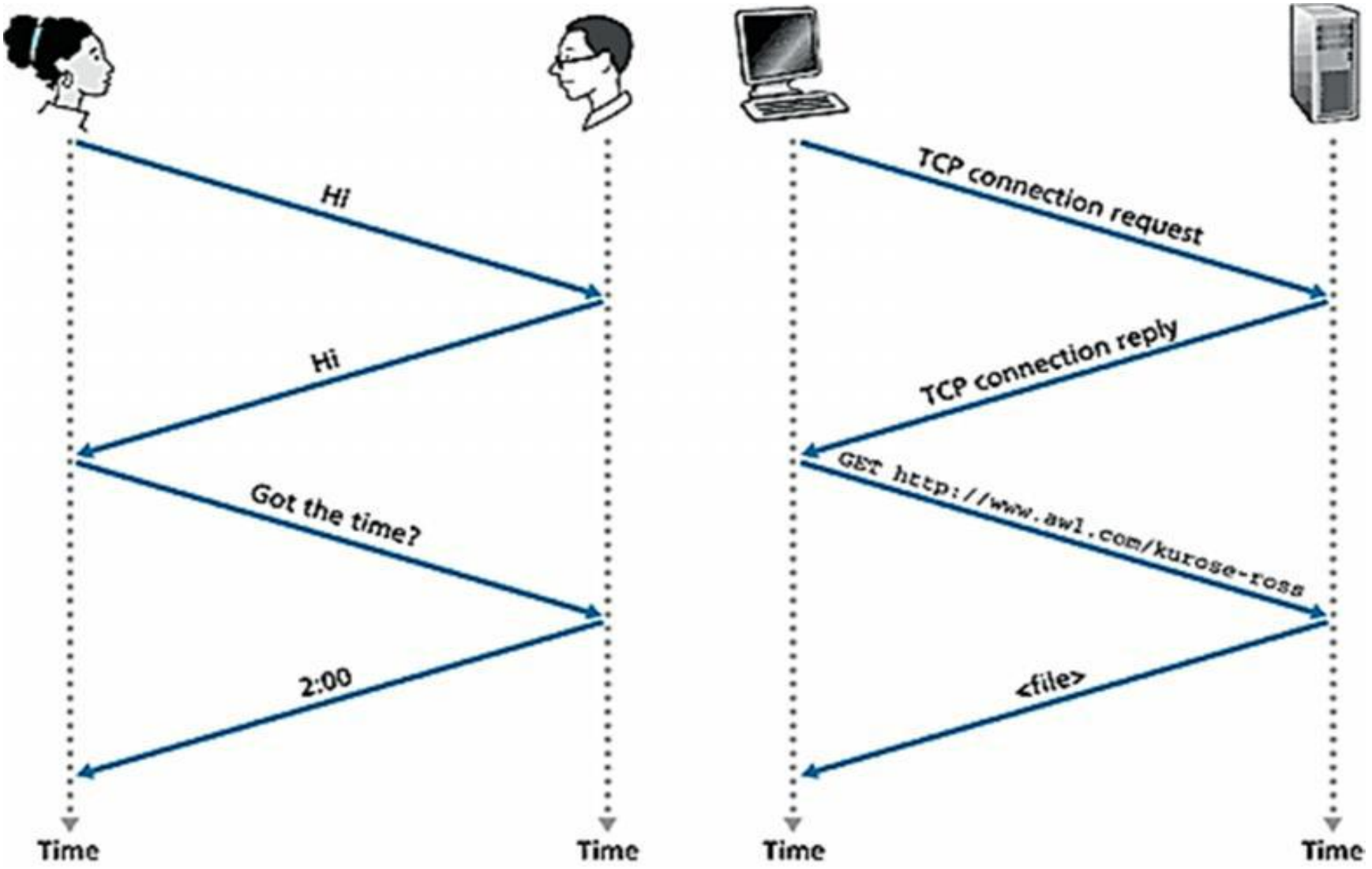
Protocol

- set of rules that governs (manages) data communications
- Protocols defines methods of communication, how to communicate, when to communicate etc.
- Important elements of protocols are:

1. Syntax
2. Semantics
3. Timing

- **Syntax**:- format of data or the structure how it is presented
- **Semantics:-** each section of bits e.g. the address bit means the route of transmission or final destination of message.
- **Timing**:- At what time data can be sent and how fast data can be sent.
- Example: HTTP, IP, FTP etc…

Human protocol and a computer network protocol



The Network Edge

- It defines those computers of the network used at the edge (end) of the network. These computers are known as hosts or end system
- Host can be classified in two types:
- **Clients:** Refer to the computer systems that request servers for the completion of a task
- **Servers:** Refer to the computer systems that receive requests from the clients and process them
- The various networks design models are as follows:

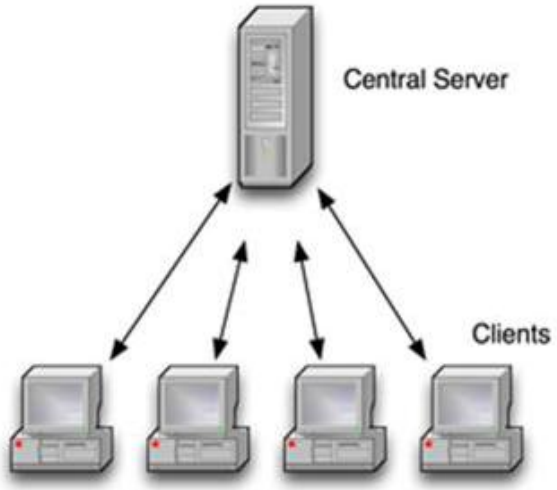
1. Peer to Peer network
2. Client Server network

Peer to Peer network

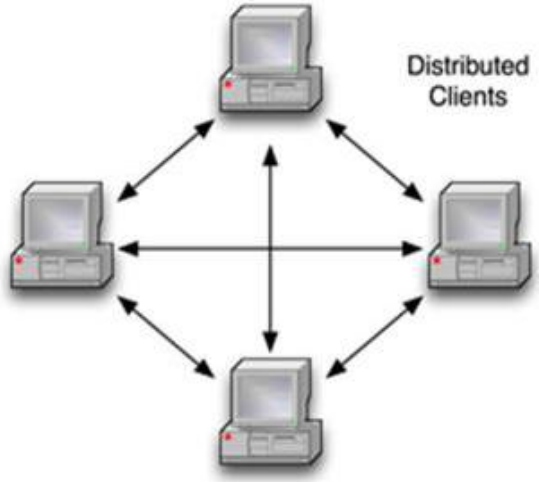
- group of computers is connected together so that users can share resources and information
- no central location (server) for authenticating users
- users must remember which computers in the workgroup have the shared resource or information that they want to access
- **Advantage**:
  - easy to setup.
  - no need of any committed server as each peer acts as both server and client
  - The network implementation is quite cheap
  - The resources of a peer can be shared with other peers very easily in the network

Peer to Peer network

- **Disadvantage:**
  - The speed of the network decreases due to heavy usage
  - It is not easy to keep track of information on each computer
  - There is no central backup of files and folders
  - Network and data security are weak



Client / Server



Peer to Peer

Client/Server network

- a system where one or more computers called clients connect to a central computer named as server to share or use resources.
- The client requests a service from server
- In which the files and resources are centralized
- **Advantage**:

  - The server system holds the shared files
  - The server system can be scheduled to take the file backups automatically
  - Network access is provided only to authorize users through user security at the server
  - The software applications shared by the server are accessible to the clients.

Client/Server network

- **Disadvantage:**
  - The implementation of the network is quite expensive.
  - An NOS (Network Operating System) is essential.
  - If server fails, the entire network crashes.
  - There may be congestion if more than one client requests for a service at the same time.

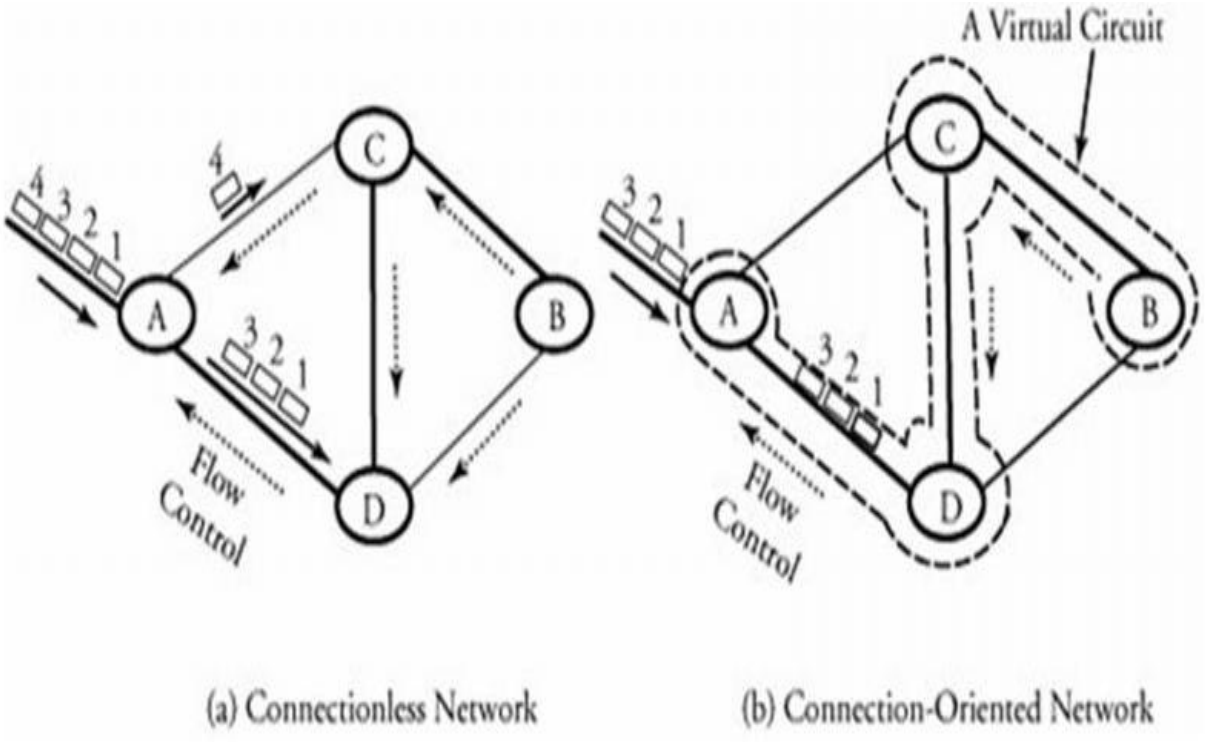
Techniques used in data communications to transfer data

1. Connection-oriented method

- Connection-oriented communication includes the steps of setting up a call from one computer to another, transmitting/receiving data, and then releasing the call, just like a voice phone call
- Connection-oriented communication is done in one of two ways over a packet switched network:
  - Without virtual circuits
  - With virtual circuits
- The only two machines in the Internet are aware about connection
- One benefit of establishing the connection is that the flow of packets from the source to the destination

2. Connectionless method

- Connectionless communication is just packet switching where no call establishment and release occur
- A message is broken into packets, and each packet is transferred separately
- provided by the UDP (User Datagram Protocol)



Transmission Media

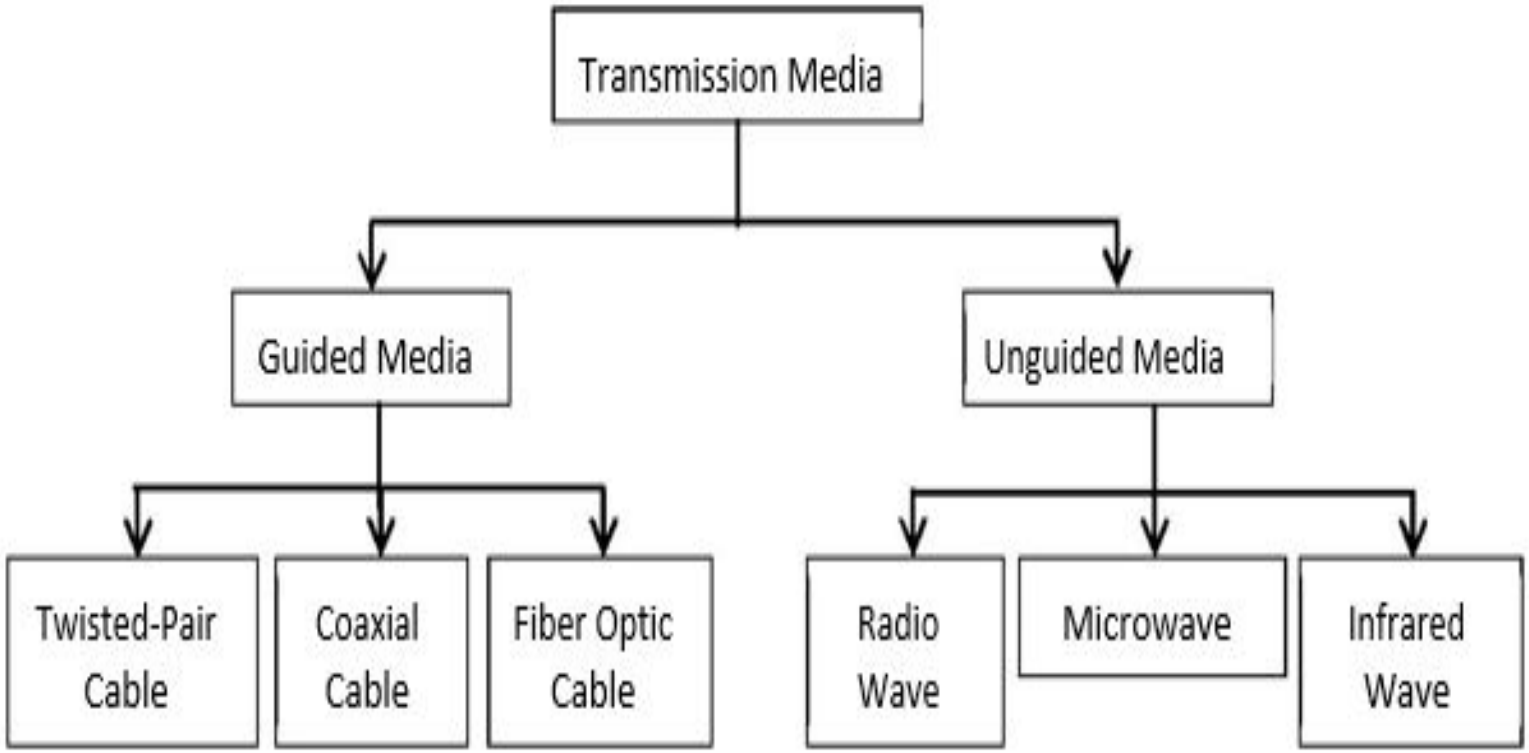


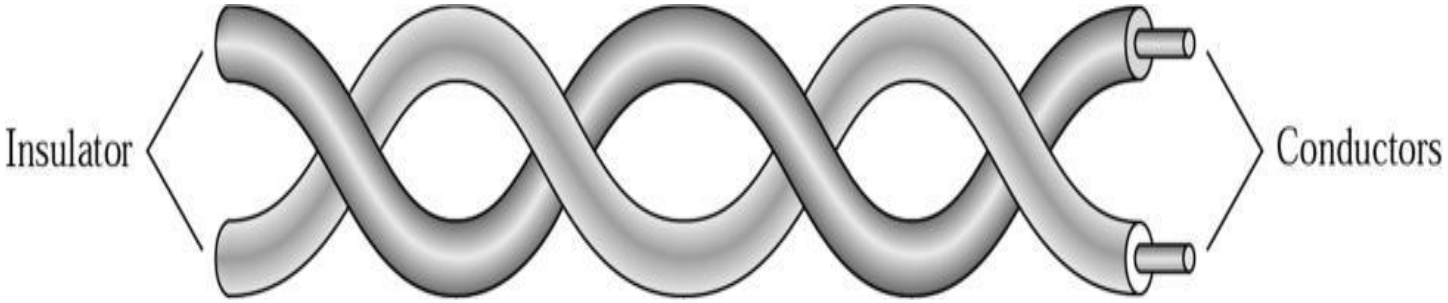
Figure 8: Classification Transmission Media

Guided Transmission Media

- Guided media are those that provide a channel from one device to another.

1. **Twisted Pair**

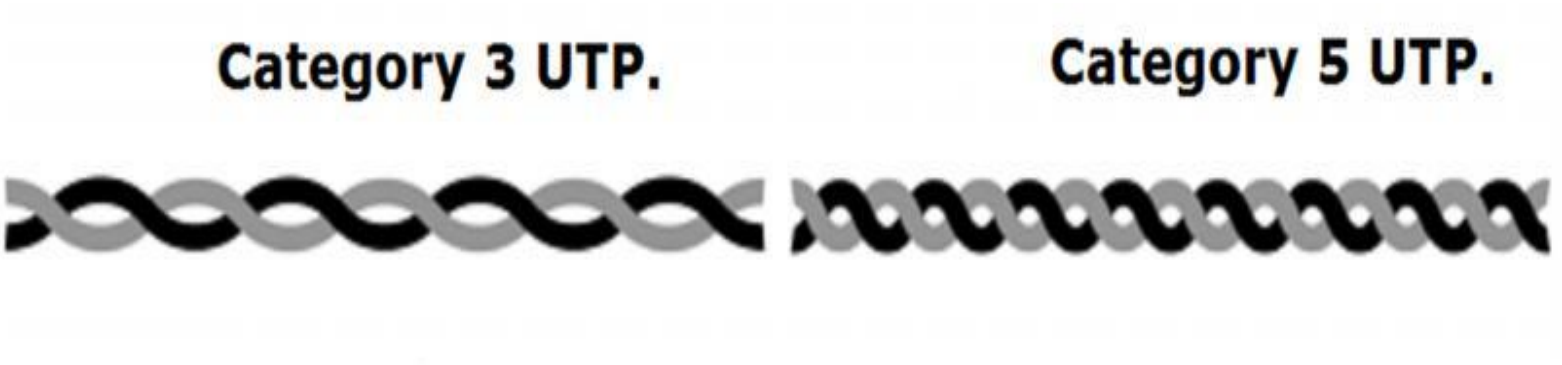
- consists of two insulated copper wires, typically about 1 mm thick
- wires are twisted together in a helical form, just like a DNA molecule
- When the wires are twisted, the waves from different twists cancel out, so the wire radiates less effectively.



Types of Twisted-Pair Cable

1) Unshielded twisted-pair (UTP)

- **Category 3** twisted pairs consist of two insulated wires gently twisted together
- Most office buildings had one category 3 cable running from a central wiring
- **Category 5** is the more advanced twisted pair
- They are similar to category 3 pairs, but with more twists per centimetre
- Up-and-coming categories are 6 and 7



Types of Twisted-Pair Cable

2) Shielded twisted-pair (STP).

- STP cable has a metal foil that encases each pair of insulated conductors
- Metal casing improves the quality of cable
- more expensive

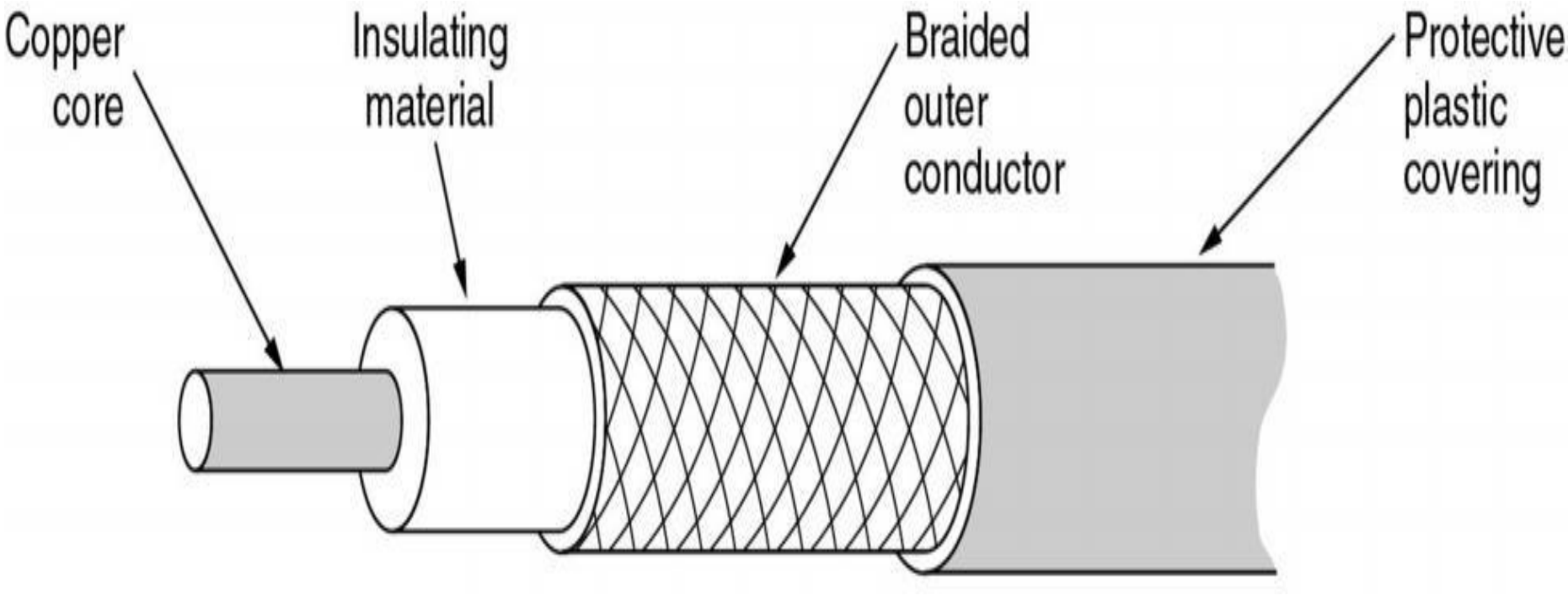
Applications:

- Used in telephone lines to provide voice and data channels
- Telephone companies use the high-bandwidth capability of UTP cables.
- LANs, such as 10Base-T, 100Base-T also uses twisted-pair cables

Coaxial Cable

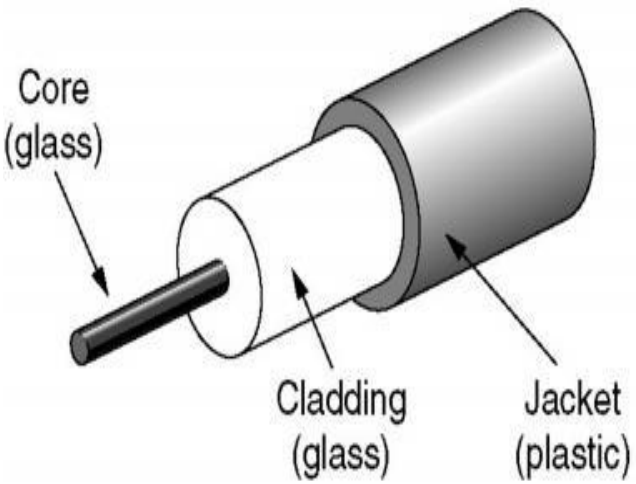
- better shielding than twisted pairs
- Two kinds of coaxial cable : **50-ohm** cable which is commonly used for **digital transmission** from the start
- **75-ohm** cable which is used for **analog transmission**
- coaxial cable consists of a copper wire as the core surrounded by an insulating material
- insulator is encased by a cylindrical conductor
- The bandwidth possible depends on the cable quality, length and signal-to-noise ratio of the data signal
- It have a bandwidth of close to 1 GHz
- It is widely used within the telephone system for long-distance lines

Coaxial Cable



Fiber Optics

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



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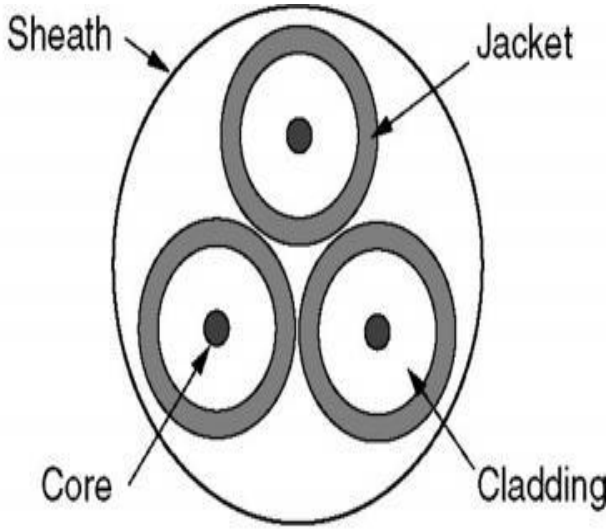


(b)

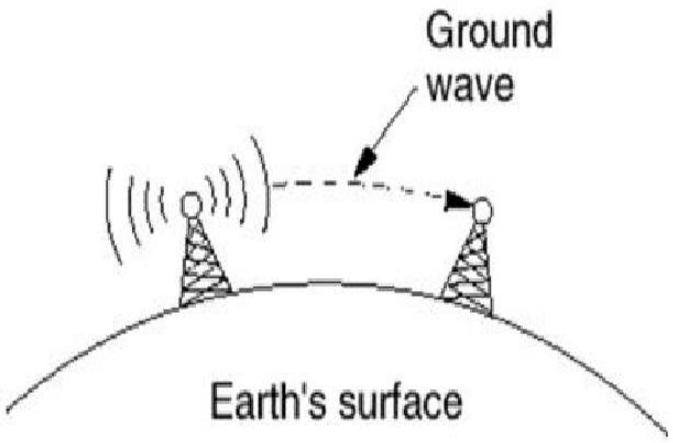
Unguided transmission media

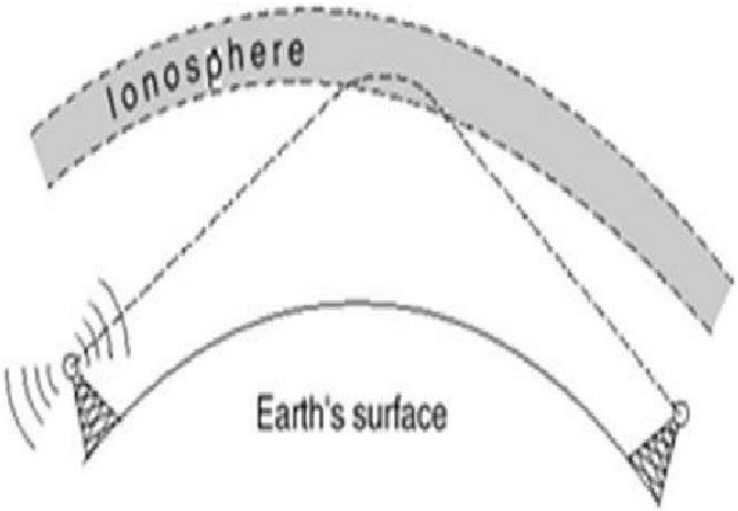
- Unguided media transport electromagnetic waves without using a physical conductor
- referred to as wireless communication

- ✔ Radio Transmission
- ✔ Microwave Transmission
- ✔ Infrared
- ✔ Light wave Transmission

Radio Transmission

- easy to generate, can travel long distances, and can penetrate buildings easily, so they are widely used for communication, both indoors and outdoors
- they travel in all directions from the source
- The properties of radio waves are frequency dependent
- At high frequencies, radio waves tend to travel in straight lines and bounce off obstacles





Microwave Transmission

- microwaves travel in a straight line
- microwaves do not pass through buildings well
- Above 100 MHz, the waves **travel in straight lines**
- **parabolic antenna** gives a much higher signal to noise ratio

Advantages:

- No right way is needed (compared to wired media).
- Relatively inexpensive.
- Simple to install.

Disadvantages:

- Multipath fading problem
- Absorption by rain above 8 GHz.
- Severe shortage of spectrum.

Infrared Transmission

- widely used for **short-range** communication
- The remote controls used on televisions, VCRs, and stereos all use infrared communication
- relatively directional, cheap, and easy to build
- major drawback is do not pass through solid objects
- infrared system in one room of a building
- security of infrared systems is better than radio systems
- no government license is needed to operate an infrared system

Topologies (Network Topologies)

- schematic description of a network arrangement
- connecting various nodes (sender and receiver) through lines of connection
- Types of network topologies :

✔ Bus
✔ Ring
✔ Tree
✔ Mesh
✔ Star
✔ Hybrid

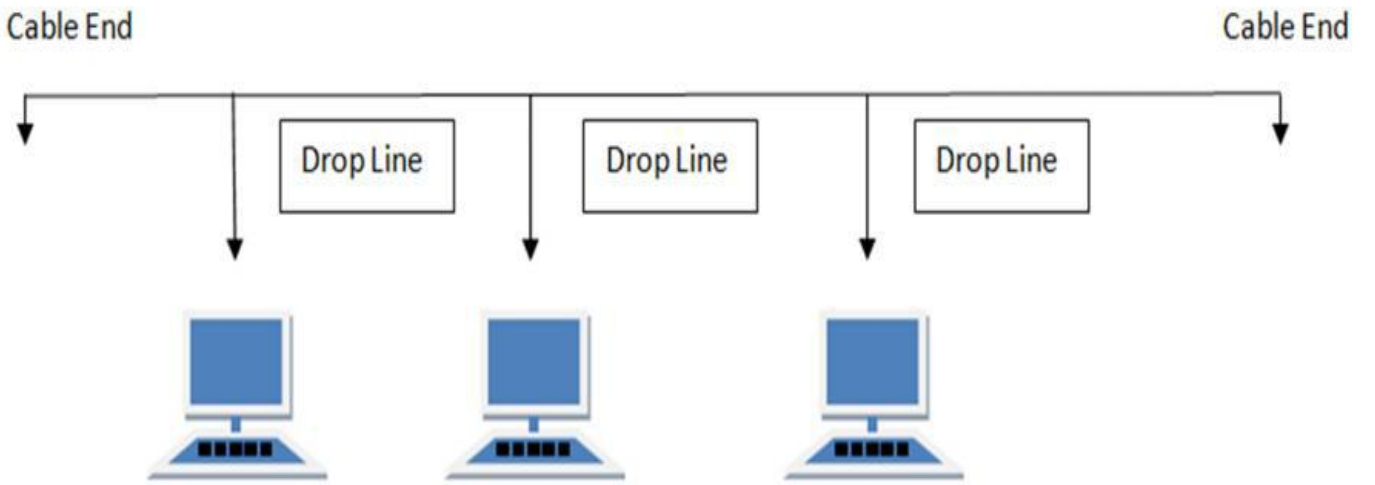
Topologies (Network Topologies)

1. Bus Topology

- Bus topology is a network type in which every computer and network device is connected to single cable

Features:

- It transmits data only in one direction.
- Every device is connected to a single cable.



Topologies (Network Topologies)

Advantages:

- It is cost effective (cheaper)
- Cable required is least compared to other network topology
- Used in small networks
- It is easy to understand
- Easy to expand joining two cables together

Disadvantages:

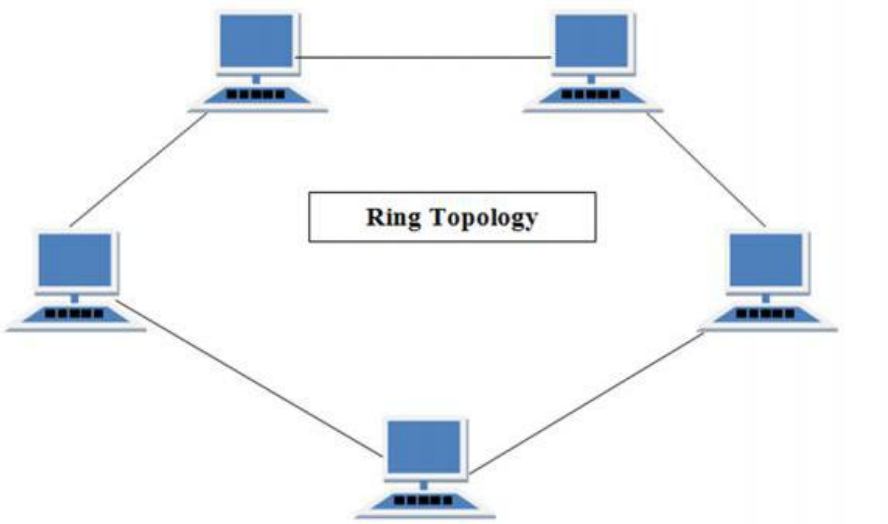
- Cables fails then whole network fails
- If network traffic is heavy or nodes are more the performance of the network decreases.
- Cable has a limited length.

Ring Topology

- It forms a ring as each computer is connected to another computer, with the last one connected to the first

Features:

- A number of repeaters are used and the transmission is unidirectional.
- Date is transferred in a sequential manner that is bit by bit.



Ring Topology

Advantages:

- Transmitting network is not affected by high traffic or by adding more nodes, as only the nodes having tokens can transmit data
- Cheap to install and expand

Disadvantages:

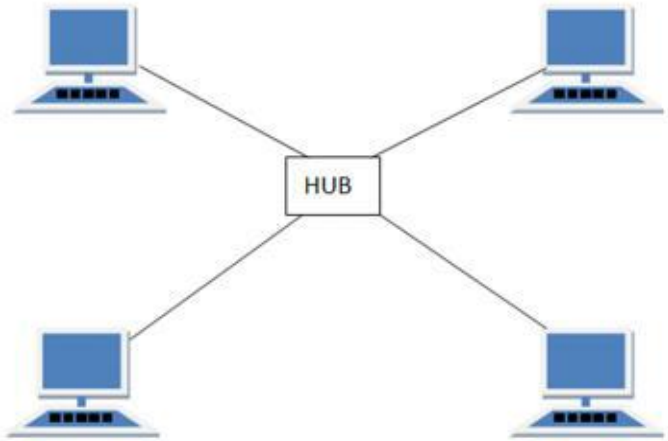
- Troubleshooting is difficult in ring topology.
- Adding or deleting the computers disturbs the network activity.
- Failure of one computer disturbs the whole network.

Star Topology

- In this type of topology all the computers are connected to a single hub through a cable
- hub is the central node and all others nodes are connected to the central node

Features:

- Every node has its own dedicated connection to the hub.
- Acts as a repeater for data flow.
- Can be used with twisted pair, Optical Fibre or coaxial cable



Star Topology

Advantages:

- Fast performance with few nodes and low network traffic.
- Hub can be upgraded easily.
- Easy to setup and modify.
- Only that node is affected which has failed rest of the nodes can work smoothly

Disadvantages:

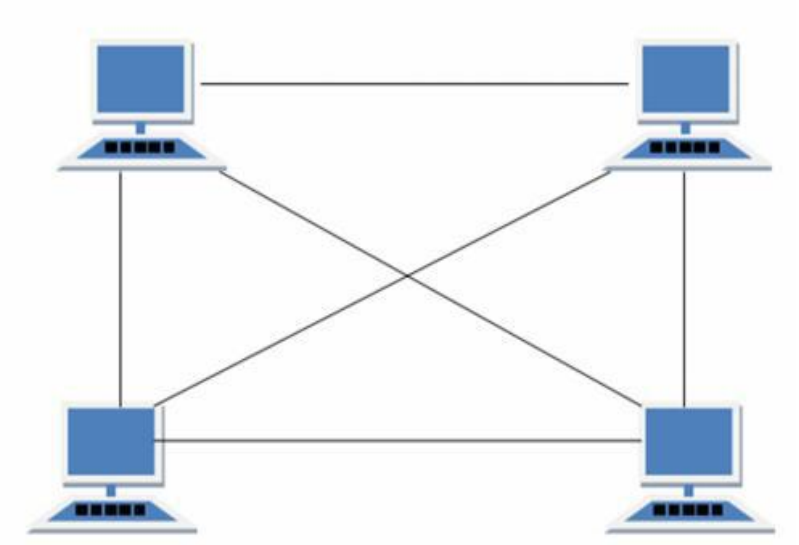
- Cost of installation is high.
- Expensive to use.
- If the hub is affected then the whole network is stopped

Mesh Topology

- It is a point-to-point connection to other nodes or devices.
- Traffic is carried only between two devices or nodes to which it is connected

Features:

- Fully connected.
- Robust.
- Not flexible.



Mesh Topology

Advantages:

- Each connection can carry its own data load.
- It is robust
- Fault is diagnosed easily.
- Provides security and privacy.

Disadvantages:

- Installation and configuration is difficult.
- Cabling cost is more
- Bulk wiring is required.

Tree Topology

- It has a root node and all other nodes are connected to it forming a hierarchy
- It is also called hierarchical topology
- It should at least have three levels to the hierarchy

Features:

- Ideal if workstations are located in groups.
- Used in Wide Area Network.

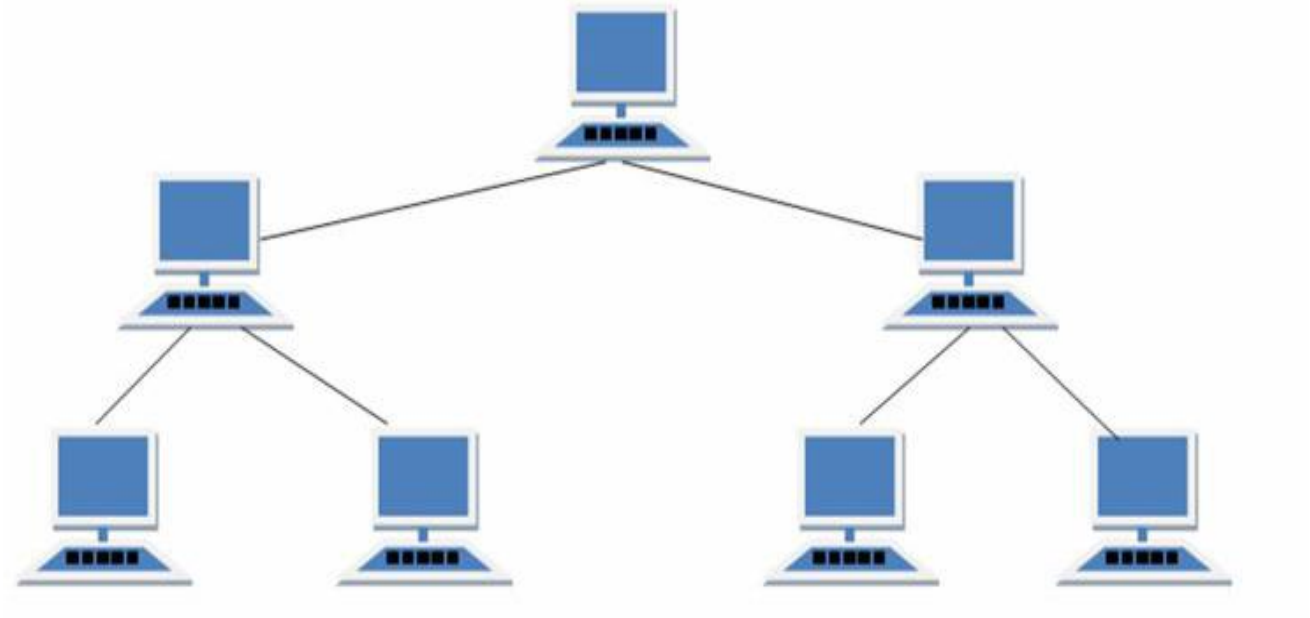
Advantages:

- Extension of bus and star topologies.
- Expansion of nodes is possible and easy.
- Easily managed and maintained.
- Error detection is easily done.

Tree Topology

Disadvantages:

- Heavily cabled.
- Costly.
- If more nodes are added maintenance is difficult.
- Central hub fails then network fails.



Hybrid Topology

- A network structure whose design contains more than one topology is said to be hybrid topology.

Features:

- It is a combination of two or more topologies
- Inherits the advantages and disadvantages of the topologies included

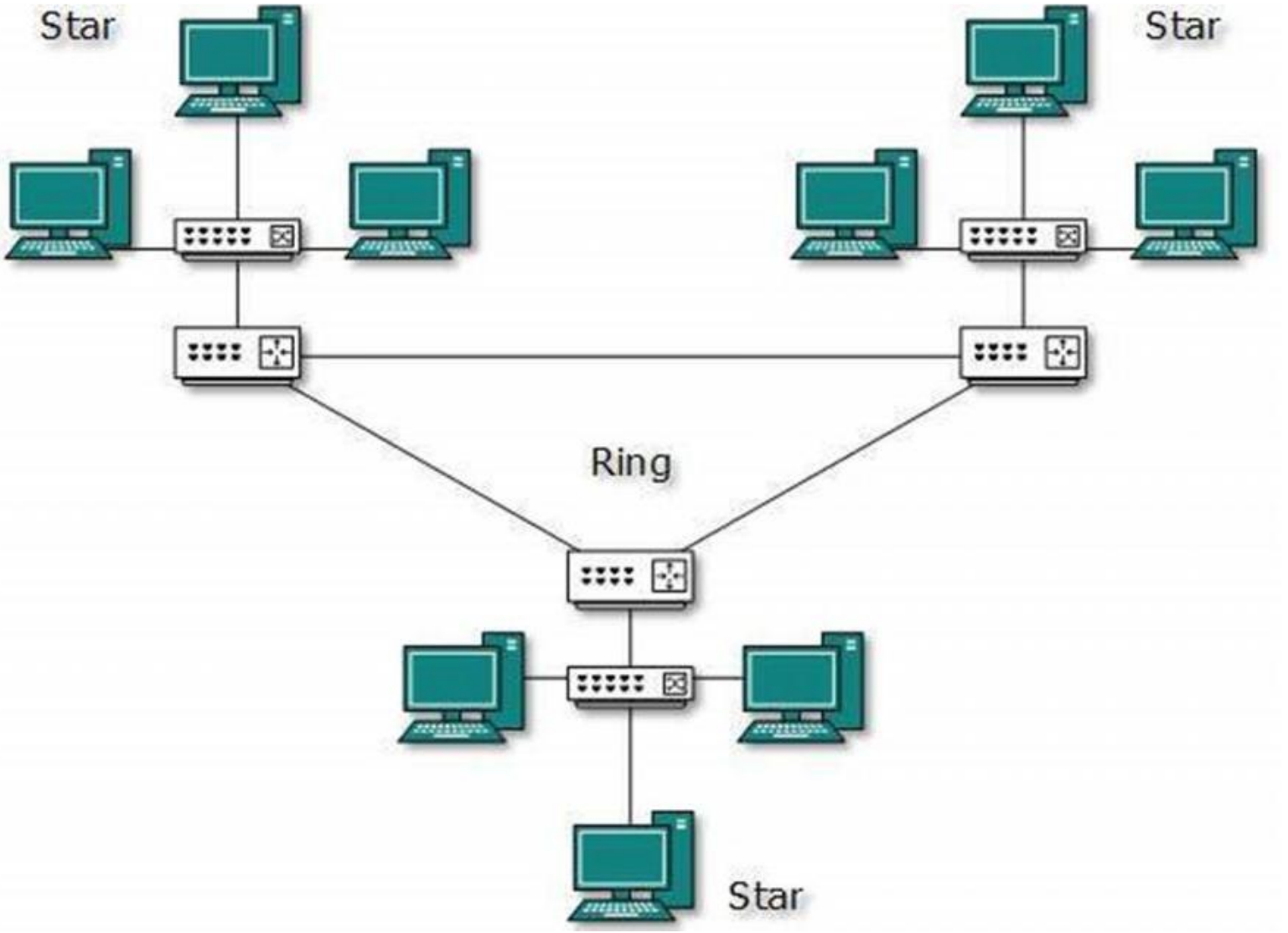
Advantages:

- Reliable as error detecting and trouble shooting is easy.
- Scalable as size can be increased easily.
- Flexible.

Disadvantages:

- Complex in design.
- Costly.

Hybrid Topology



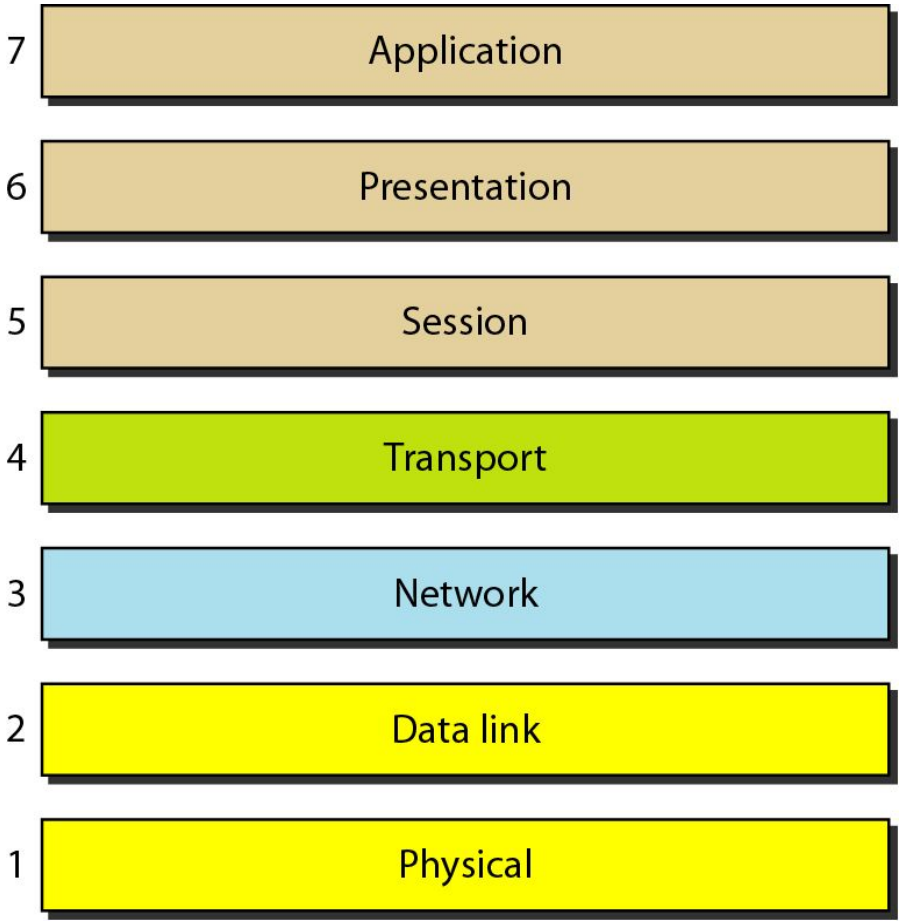
OSI Reference Models

- OSI model is based on a proposal developed by the International Standards Organization (ISO) as a first step toward international standardization of the protocols used in the various layers
- The model is called the OSI (Open Systems Interconnection) Reference Model because it deals with connecting open systems—systems that are open for communication with other systems
- The OSI model has seven layers.
  - Physical Layer
  - Data Link Layer
  - Network Layer
  - Transport Layer
  - Session Layer
  - Presentation Layer
  - Application Layer

Note

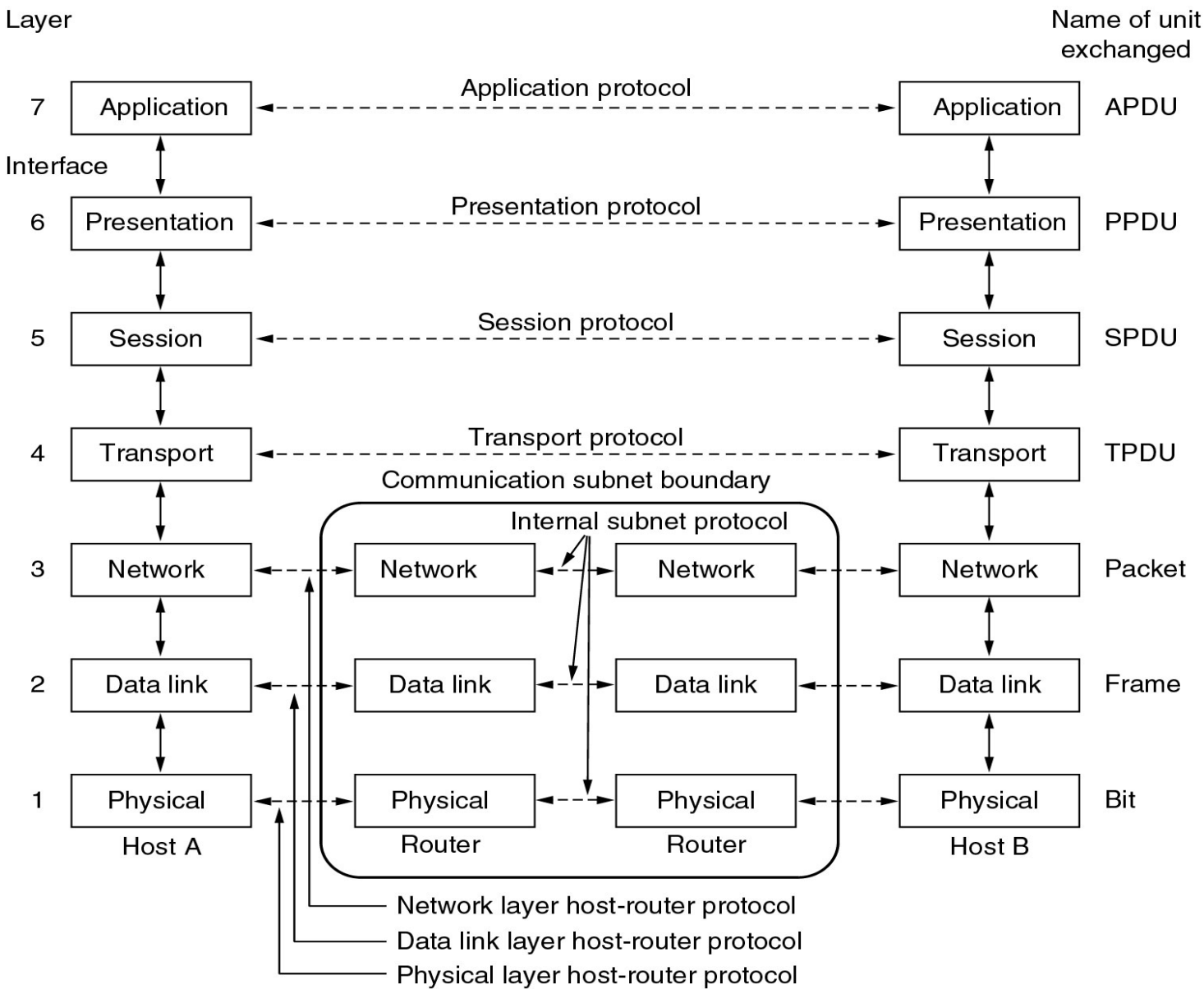
ISO is the organization.
OSI is the model.

Figure Seven layers of the OSI model



OSI Reference Model

The OSI reference model.



The physical layer is also concerned with the following:

- Physical characteristics of interfaces and medium.
- Representation of bits.
- Data rate.
- Synchronization of bits
- Line configuration
- Physical topology
- Transmission mode

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

Figure Physical layer

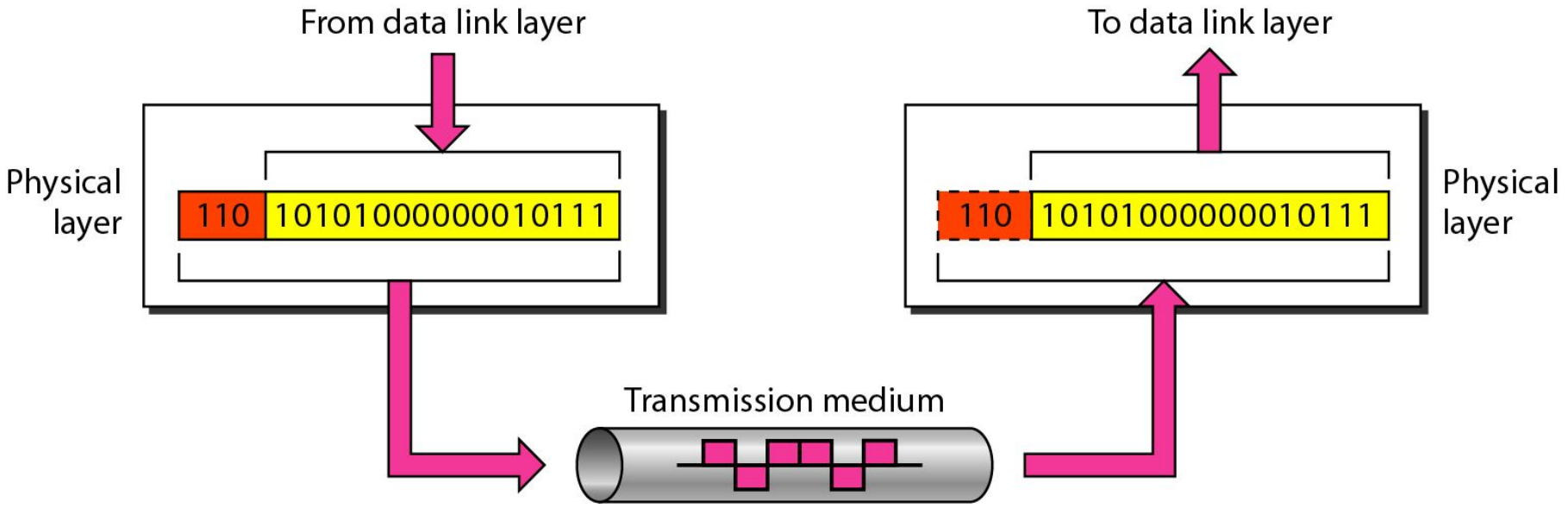
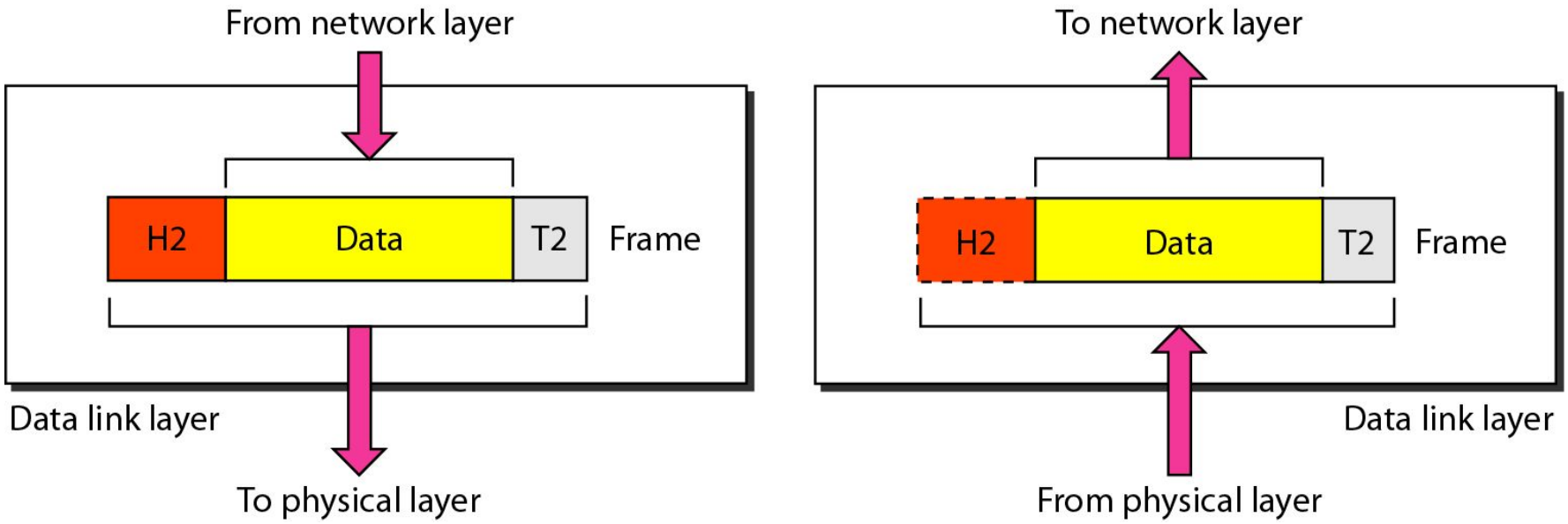


Figure Data link layer



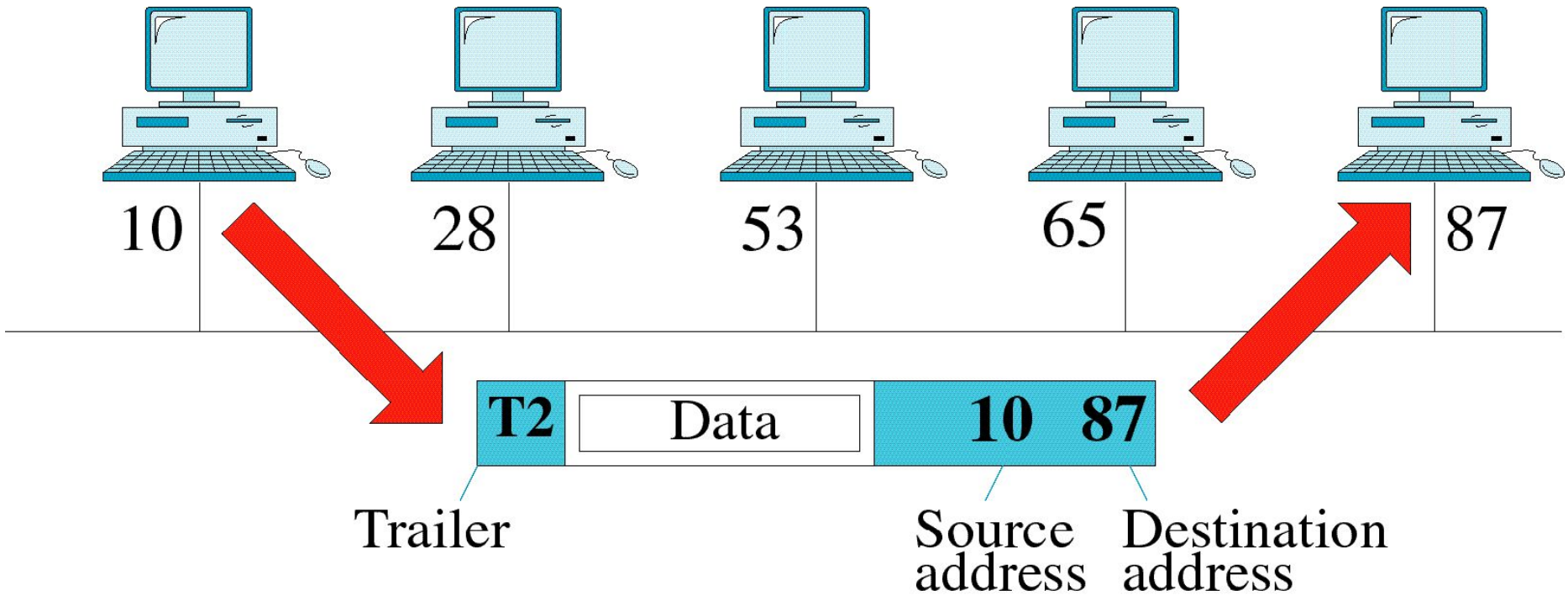
Note

The data link layer is responsible for moving frames from one hop (node) to the next.

Responsibilities of the data link layer

- Framing
- Physical addressing
- Flow control
- Error control
- Access control

Data Link Layer Example



Functionality of Network Layer

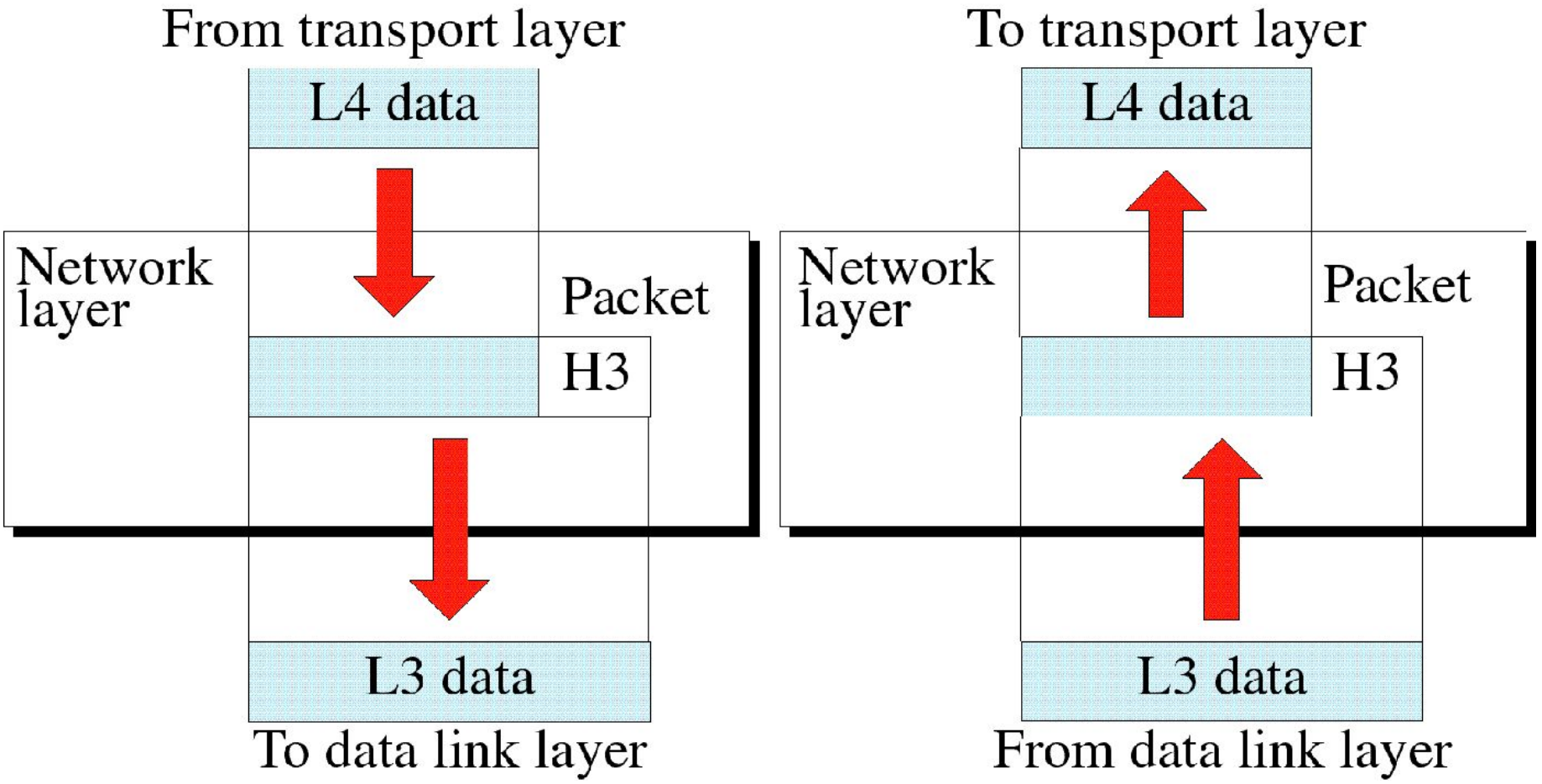
Logical Addressing

Routing

Note

The network layer is responsible for the delivery of individual packets from the source host to the destination host.

Network Layer



Functionality of Transport Layer

Service-point addressing

Segmentation and reassembly

Connection control

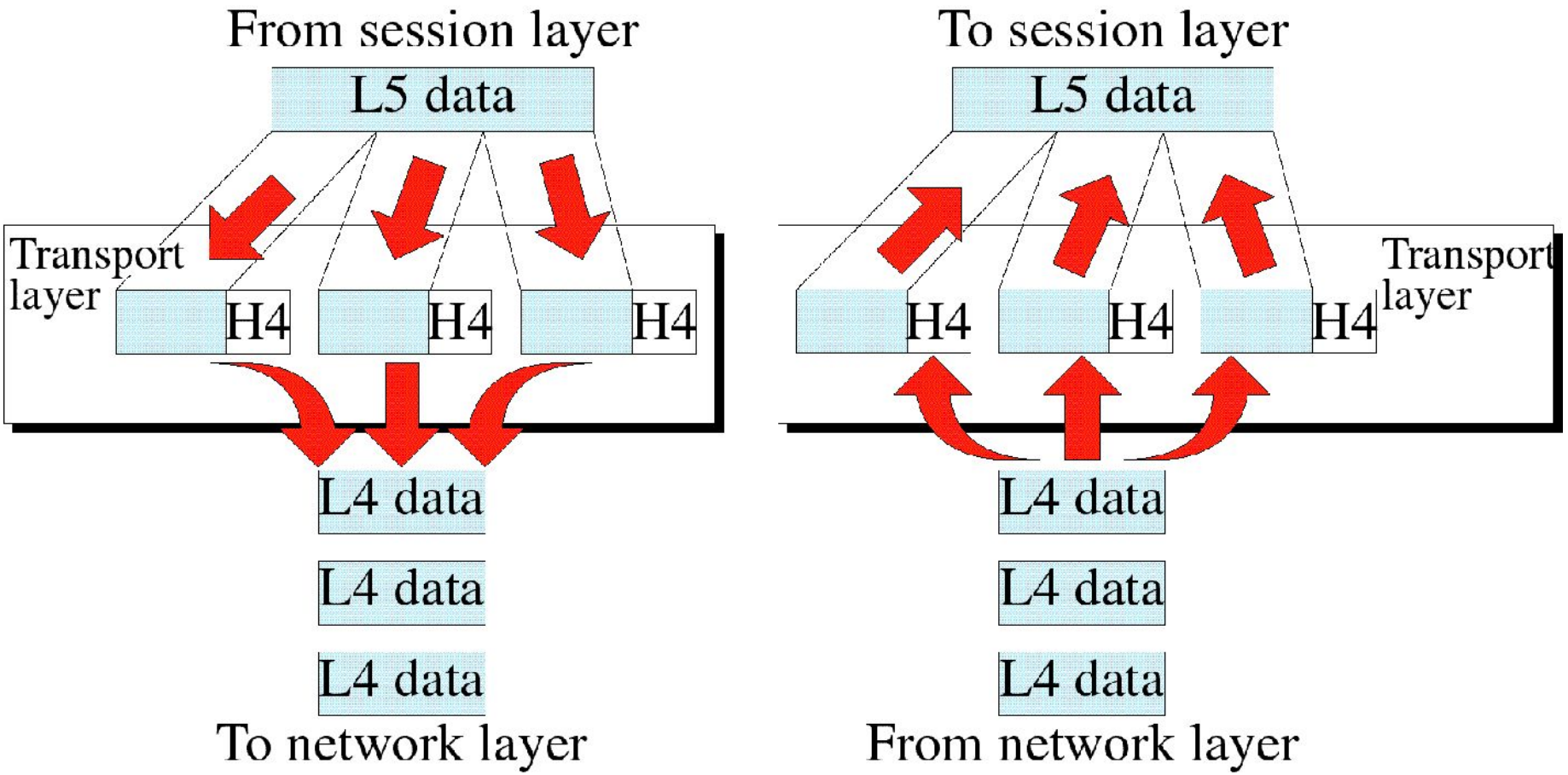
Flow control

Error control

Note

The transport layer is responsible for the delivery of a message from one process to another.

Transport Layer



It establishes, maintains, and synchronizes the interaction among communicating systems.

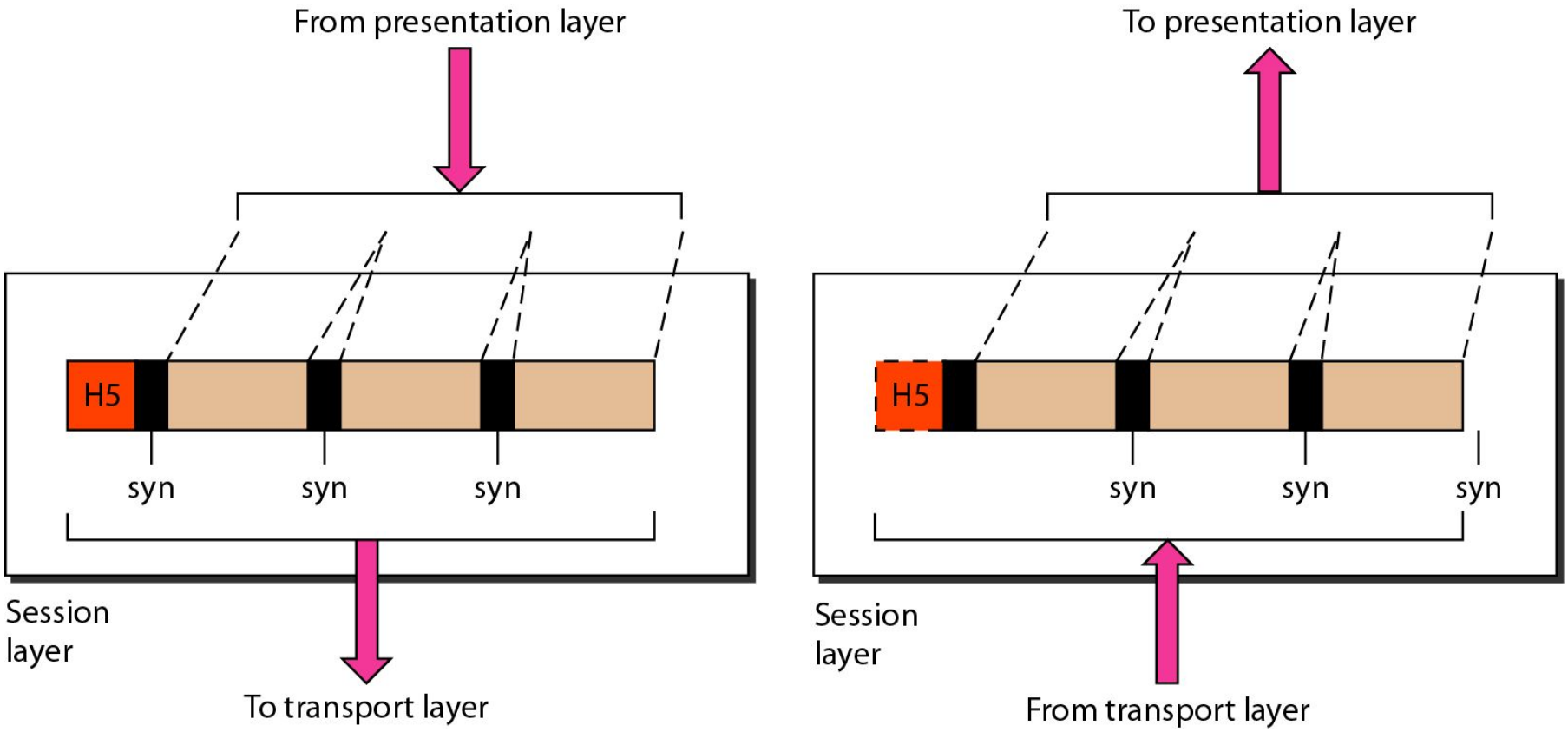
Specific responsibilities of the session layer

- Dialog control
- Synchronization

Note

The session layer is responsible for dialog control and synchronization.

Figure Session layer



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

Specific responsibilities of the Presentation layer

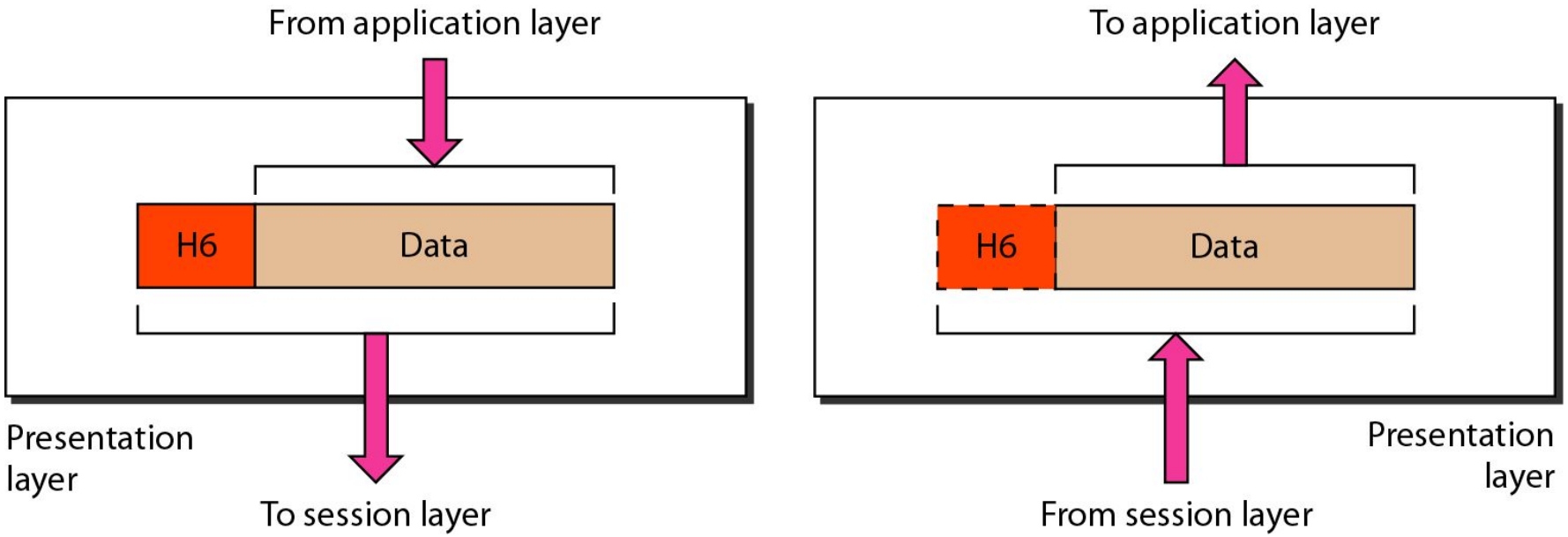
Translation

Encryption

Compression

The presentation layer is responsible for translation, compression, and encryption.

Figure Presentation layer



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.

Specific services provided by the application layer

- **Network virtual terminal.**
- **File transfer, access, and management(FTAM)**
- **Mail services (X.400)**
- **Directory services (X.500)**

Note

The application layer is responsible for providing services to the user.

Figure Application layer

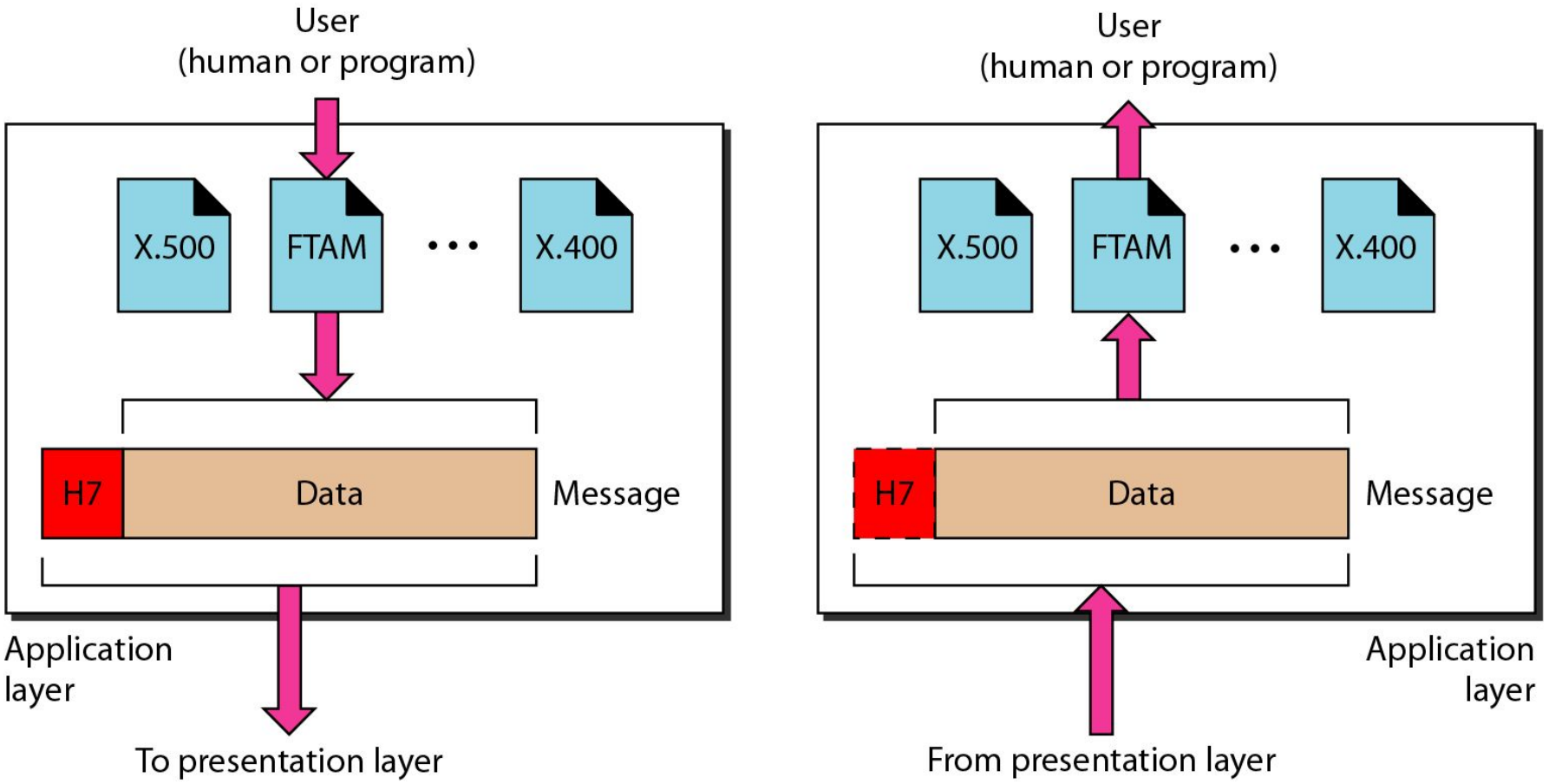
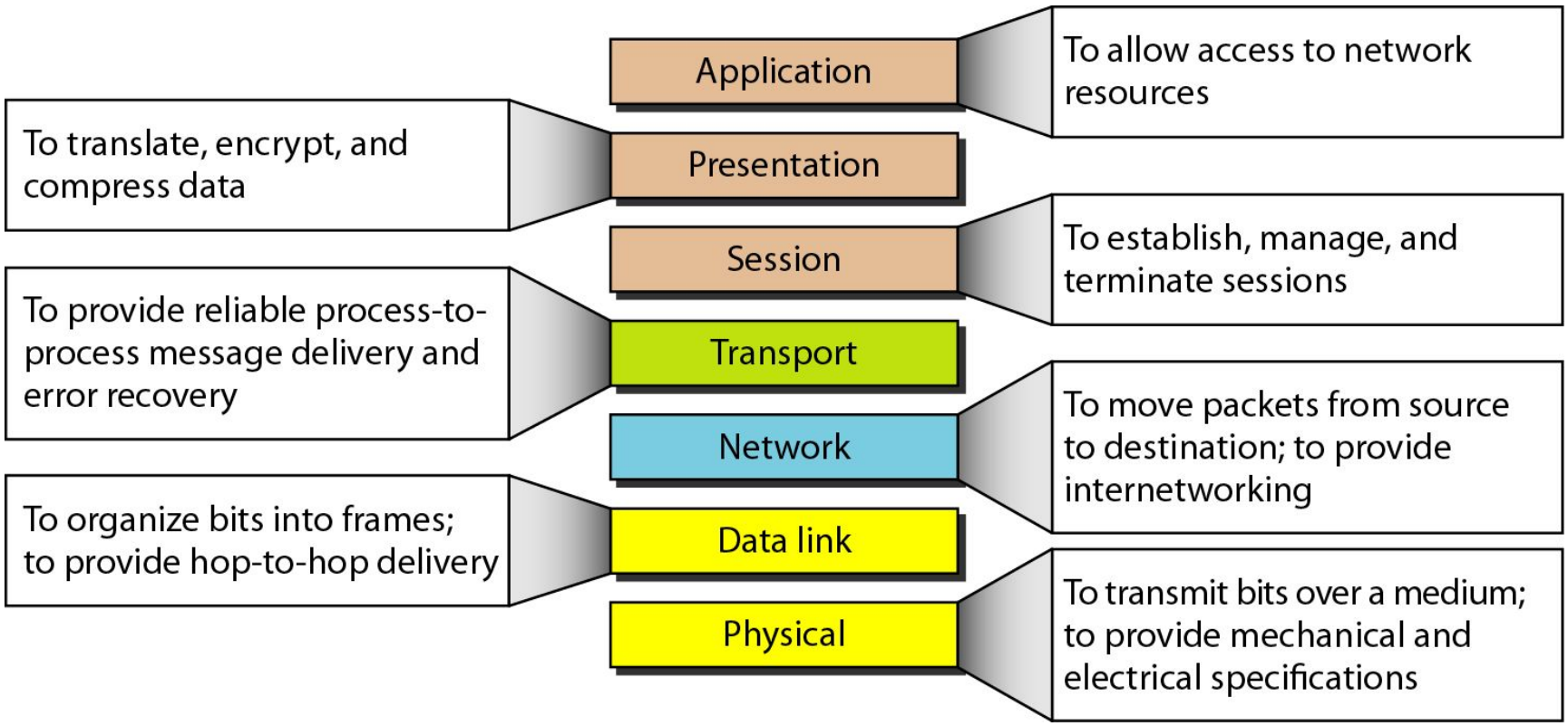


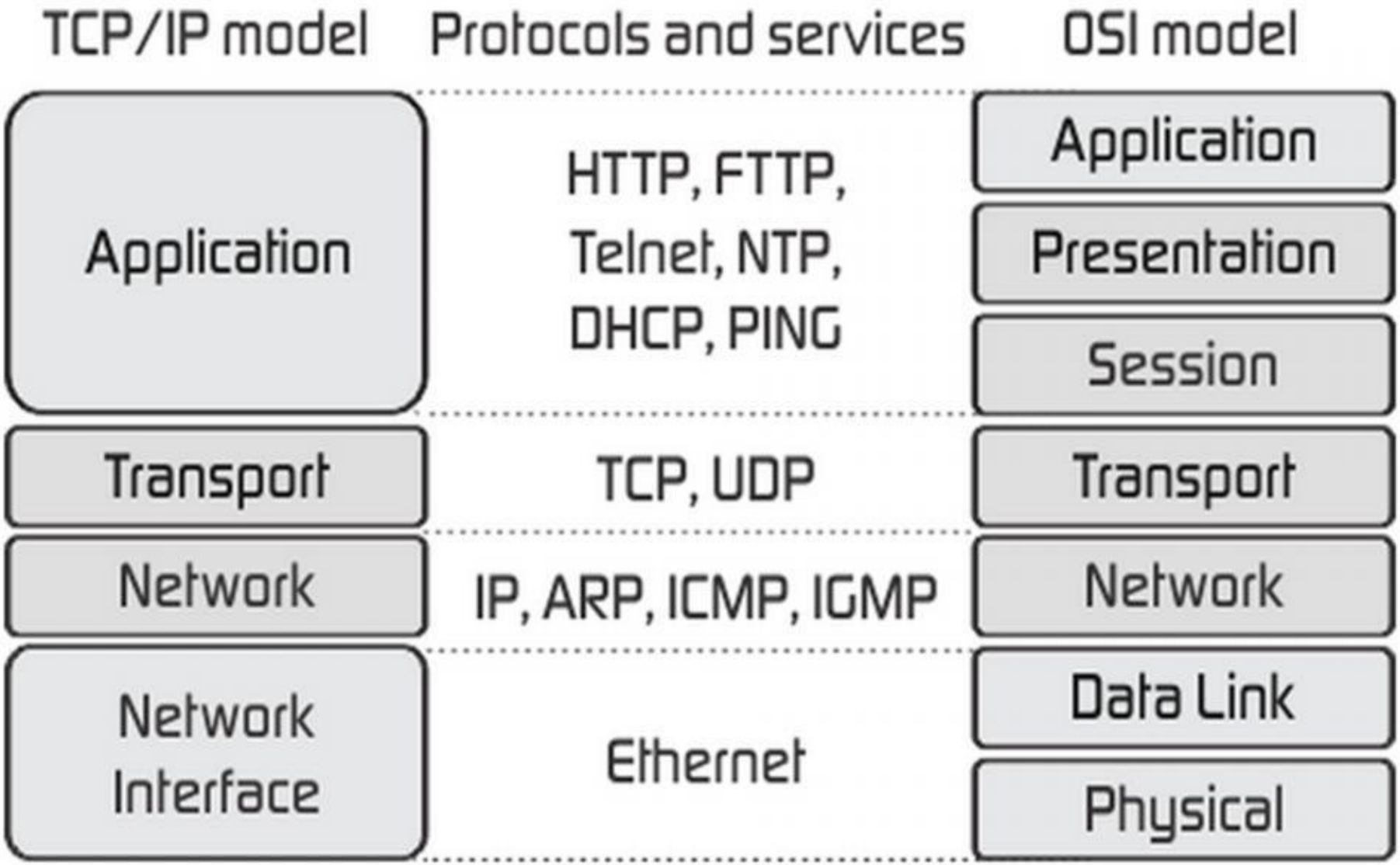
Figure Summary of layers



TCP/IP Reference Model

- *Also known as Internet Protocol Stack layers*
- Transmission Control Protocol/Internet Protocol (TCP/IP) protocol suite is the engine for the Internet and networks worldwide
- TCP/IP either combines several OSI layers into a single layer
- TCP/IP is a set of protocols developed to allow cooperating computers to share resources across the network
- The TCP/IP model has five layers.
  - Application Layer
  - Transport Layer
  - Internet Layer
  - Data Link Layer
  - Physical Network

TCP/IP Reference Model



Application layer

- TCP/IP model combines the functions of Data link Layer and Physical Layer
- Application layer defines TCP/IP application protocols and how host programs interface with Transport layer services to use the network
- It includes all the higher-level protocols like DNS (Domain Naming System), HTTP (Hypertext Transfer Protocol), Telnet, SSH, FTP (File Transfer Protocol), TFTP (Trivial File Transfer Protocol), SNMP (Simple Network Management Protocol), SMTP (Simple Mail Transfer Protocol), DHCP (Dynamic Host Configuration Protocol), X Windows, RDP (Remote Desktop Protocol)

Transport Layer

- Transport layer is to permit devices on the source and destination hosts to carry on a conversation.
- Transport layer defines the level of service and status of the connection used when transporting data.
- end-to-end data transfer by delivering data

- **Funtionality:**

✔ Reliable delivery data

✔ Congestion control

✔ Duplicate data suppression

✔ Flow control

Network Layer

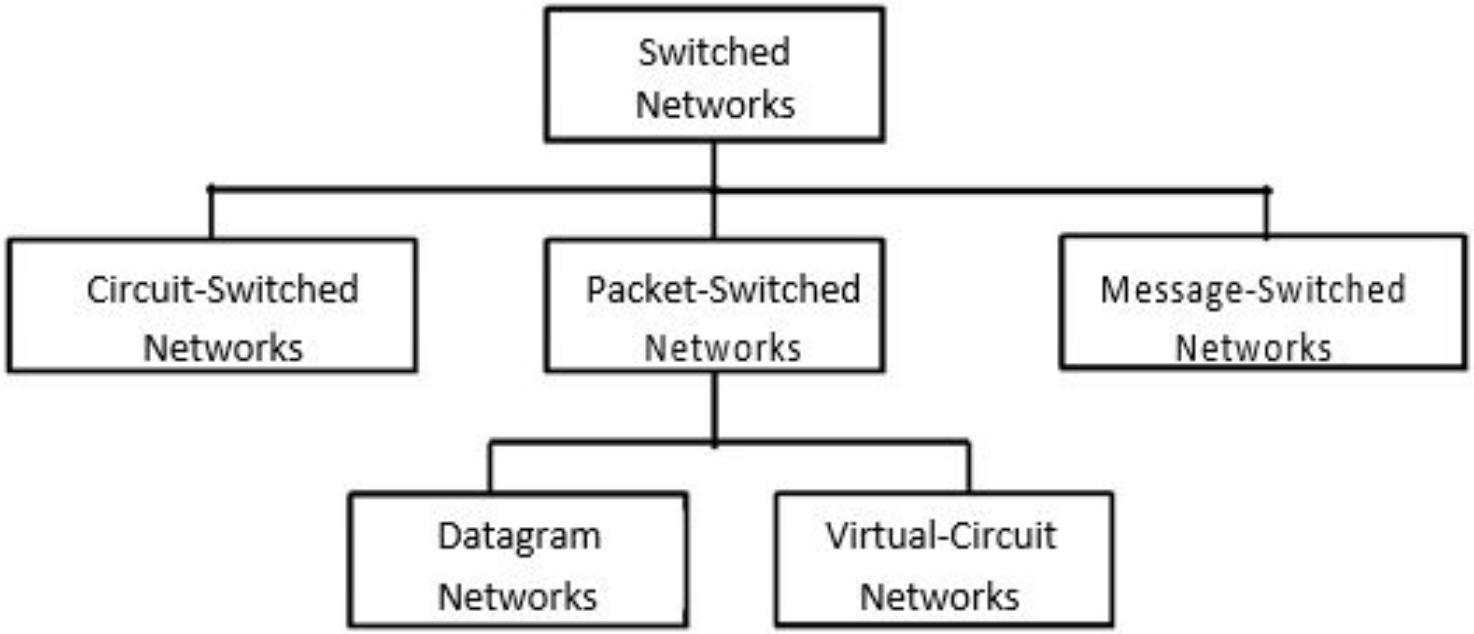
- It pack data into data packets known as IP datagrams, which contain source and destination address
- responsible for routing of IP datagrams
- Internet Protocol (IP) is the most important protocol
- connectionless protocol
- IP provides a routing function that attempts to deliver transmitted messages to their destination
- These message units in an IP network are called an IP datagram
- Example: IP, ICMP, IGMP, ARP, and RARP

Network Interface Layer

- Network Access Layer defines details of how data is physically sent through the network
- It defines how bits are electrically or optically signalled by hardware devices that interface directly with a network medium
- The protocols included in Network Access Layer are Ethernet, Token Ring, FDDI, X.25, Frame Relay etc.

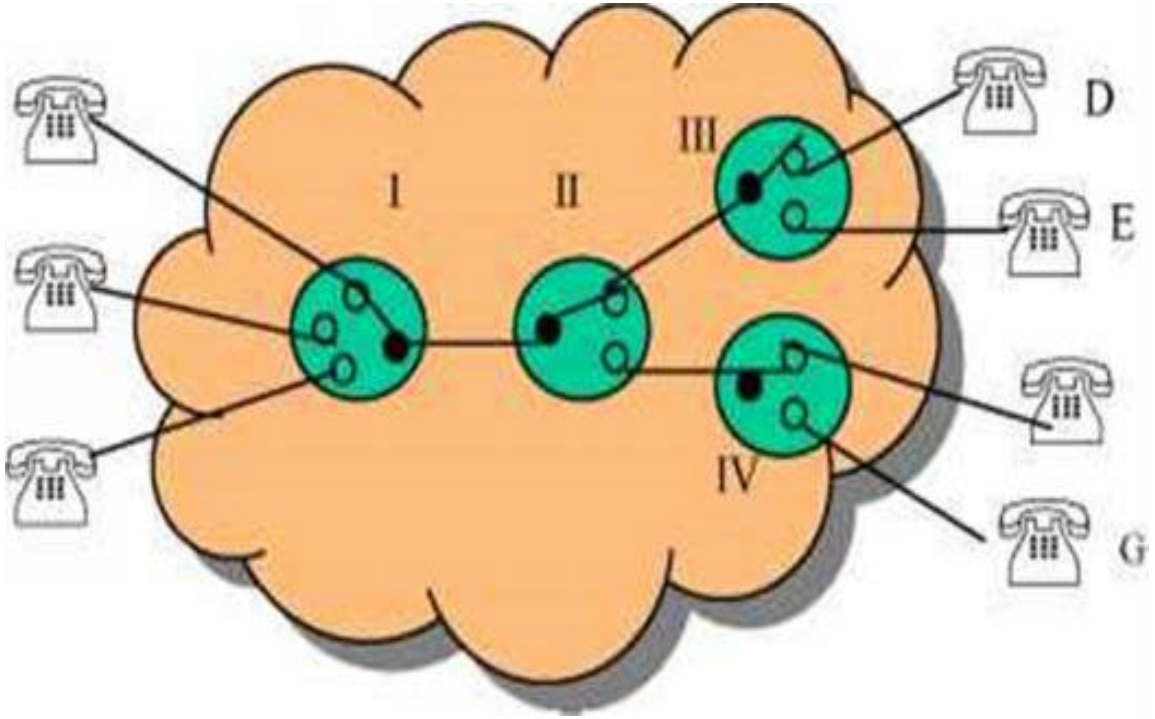
The Network Core

- Network core defines the connection of different network segments together
- It transmit the data packets across the network
- implemented through the use of switching techniques



Circuit Switching

- used in public telephone networks
- Developed for analog environment
- basis for private networks built on leased-lines.
- It was developed to handle voice traffic but also digital data
- The connection is transparent



- Communication via circuit switching involves three phases:
  - Circuit Establishment
  - Data Transfer
  - Circuit Disconnect
- Connection path must be established before data transmission begins
- Circuit switching is inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
  - Data is transmitted at a fixed data rate with no delay

Packet Switching

- It was designed to provide a more efficient facility than circuit-switching for bursty data traffic
- a station transmits data in small blocks, called packets
- Store and forward mechanism
- the internal operation is datagram or virtual circuit (VC)
- Packets handled in two ways:

Datagram:

- Each packet treated independently
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets

Packet Switching

Virtual Circuit:

- Preplanned route established before any packets sent.
- Call request and call accept packets establish connection (handshake)
- Each packet contains a Virtual Circuit Identifier (VCI) instead of destination address
- No routing decisions required for each packet
- Not a dedicated path

Message Switching

- middle of circuit switching and packet switching
- the whole message is treated as a data unit and is transferred in its entirety
- first receives the whole message and buffers it until there are resources available to transfer it to the next hop
- If the next hop is not having enough resource, it will stored and wait

Delay, Loss and Throughput

Throughput:

- Network Throughput is the rate of successful message delivery over a communication channel

Packet Loss:

- Packet loss is the failure of one or more transmitted packets to arrive at their destination
- The loss of data packets increases with the increases in the traffic intensity

Delay:

- The time required to examine the packet's header and determine where to direct the packet is part of the processing delay