MODULE-1

Introduction

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Data Communications

- The **term telecommunication** means communication at a distance.
- The word **data** refers to information presented in whatever form is agreed upon by the parties creating and using the data.
- **Data communications** are the exchange of data between two devices via some form of transmission medium such as a wire cable.

Characteristics of data communication system

- **Delivery** : The system must deliver data to the correct destination .
- **Accuracy** :The system must deliver the data accurately.
- **Timeliness**: The system must deliver data in a timely manner. Data delivered late are useless.
- **Jitter**: Jitter refers to variation in the packet arrival time. For example, Video packets are sent every 30 ms . If some of the packets arrive with 30-ms delay and others with 40-ms delay, an uneven quality in the video is the result.

Components of a data communication system

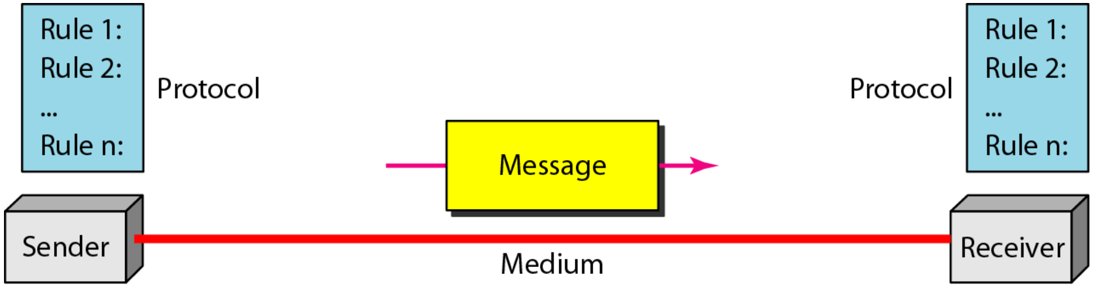


Fig: Five components of data communication

- **Message :** The message is the information (data) to be communicated .
- **Sender:** The sender is the device that sends the data message.
- **Receiver :**The receiver is the device that receives the message.
- **Transmission medium :**The transmission medium is the physical path by which a message travels from sender to receiver.
- **Protocol :** A protocol is a set of rules that govern data communications

Data Representation

- Text
  - Represented as bit pattern (sequence of bits 0s or 1s)
  - Different set of bit pattern used to represent symbols or characters.
  - Each set is called code
  - Process of representing symbols is called encoding
  - Ex: ASCII,UNICODE
- Numbers
  - Represented as bit pattern
  - Directly converted to binary form
- Audio
  - Recording or broadcasting of sound or music.
  - Continuous not discrete

- Video
  - Recording or broadcasting of picture or a movie
  - Produced as :
  - Continuous entity [TV camera]
  - Combination of images-discrete entity
- Images
  - Represented as bit pattern
  - Image is divided into matrix of pixels(smallest element of an image)
  - Each pixel is assigned a bit pattern (size and value of pattern depend on image)
  - Ex: black and white dots (chessboard) -1 bit pattern is enough to represent a pixel, gray scale- 2 bit pattern.
  - Several methods to represent colour images : RGB,YCM

Data Flow

- Communication between two devices can be

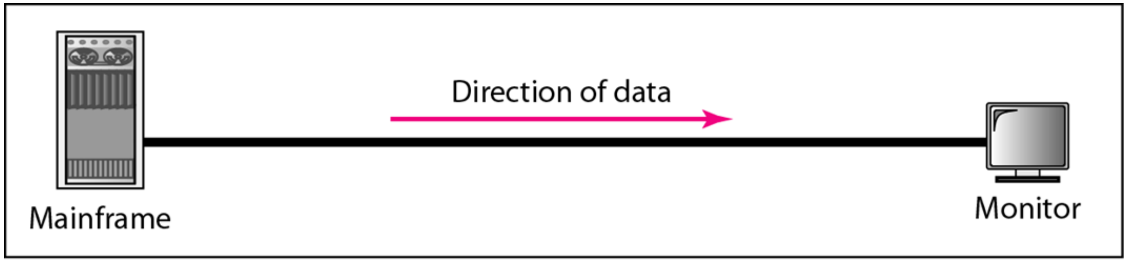
  1.Simplex

  2.Half-duplex

  3.Full-duplex

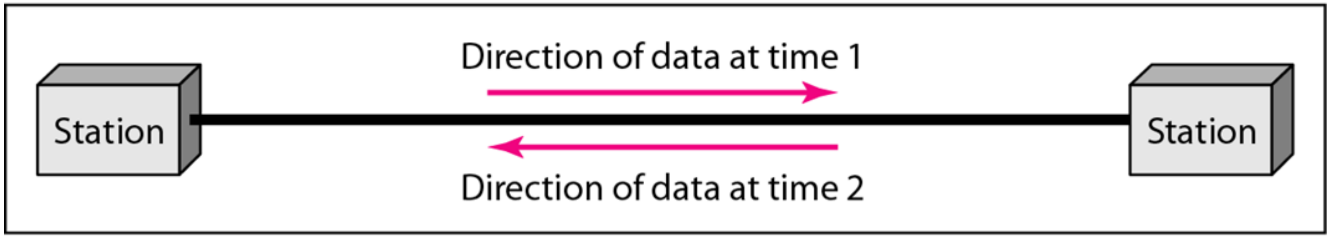
1. Simplex

- Communication is unidirectional
- Only one of the two devices on a link can transmit; the other can only receive.
- E.g. : One way street, Keyboard , Monitor.



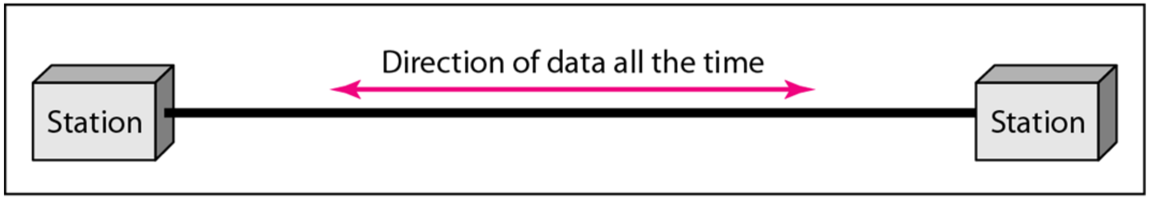
2. Half duplex

- Each station can both transmit and receive, but not at the same time.
- When one device is sending, the other can only receive, and vice versa.
- E.g.: Walkie Talkie.



3. Full duplex

- Both stations can transmit and receive simultaneously.
- It is like a two way street with the traffic flowing in both the directions at the same time.
- E.g .: Telephone network



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.
- A link can be a cable, air, optical fiber, or any medium which can transport a signal carrying information.

Network Criteria

1. Performance

- Measured using:
  - Transit time: time taken to travel a message from one device to another.
  - Response time: time elapsed between enquiry and response.
- Depends on following factors:
  - Number of users
  - Type of transmission medium
  - Efficiency of software
- Evaluated by 2 networking metrics:
  - Throughput (high)
  - Delay (small)

2. Reliability

- Measured by
  - Frequency of failure.
  - Time taken to recover from a network failure.
  - Network robustness in a disaster.

3. **Security**

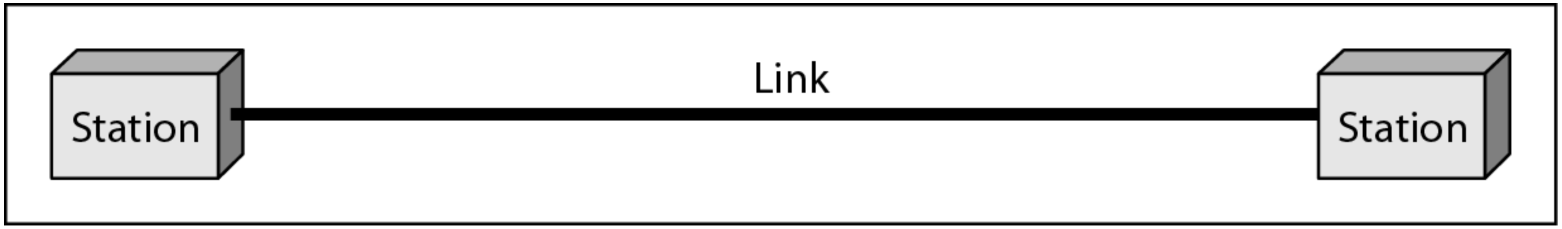
- Protecting data from unauthorized access, damage and development.
- Implementing policies and procedures for recovery from breaches and data losses.

Physical Structures

Type of Connection

1. Point to Point :

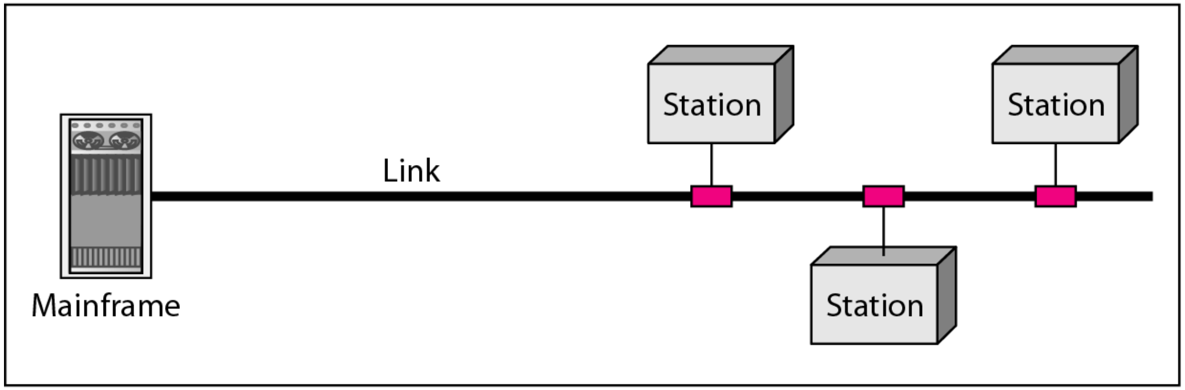
- It provides a dedicated link between two devices .
- The entire capacity of the link is reserved for transmission between those two devices.
- It uses an actual length of wire or cable to connect the two ends.



- When we change TV channels by infrared remote control, we are establishing a point-to-point connection between remote control and TV's control system

2. Multipoint

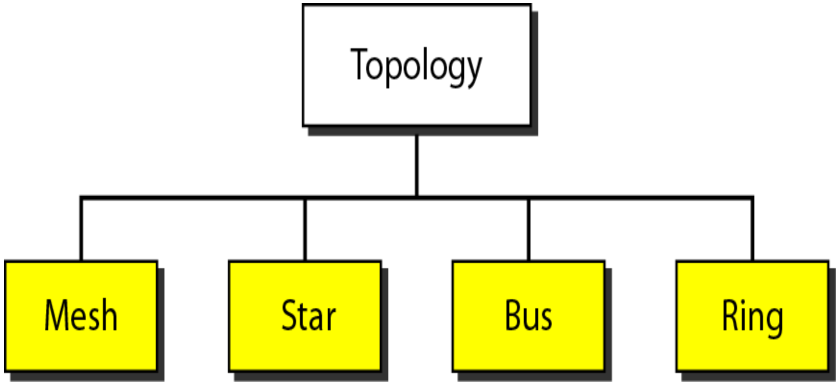
- It is the one in which more than two specific devices share a single link.



- Capacity of the channel is either spatially or temporally shared.
  - Spatially shared : Several devices can use the link simultaneously.
  - Temporally shared : Users take turns.

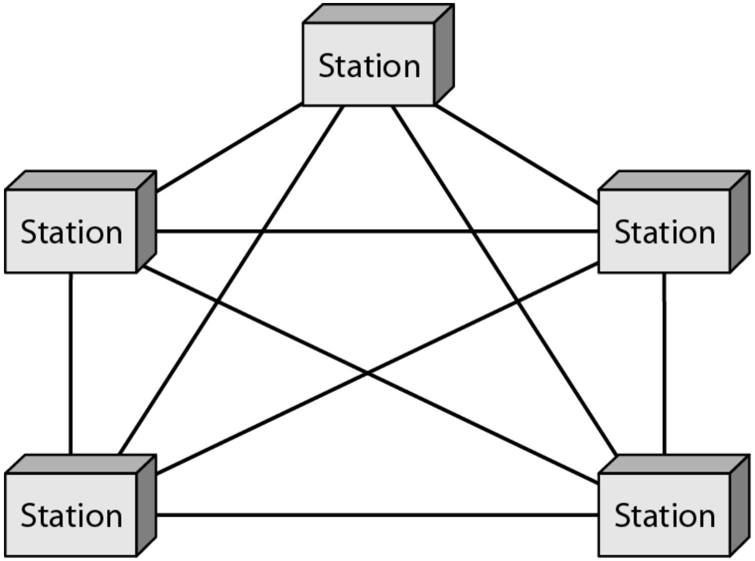
Physical Topology

- Topology of network is the geometric representation of all links and linking devices to one another
- Basic topologies:
  1. Mesh
  2. Star
  3. Bus and
  4. Ring



1. Mesh Topology

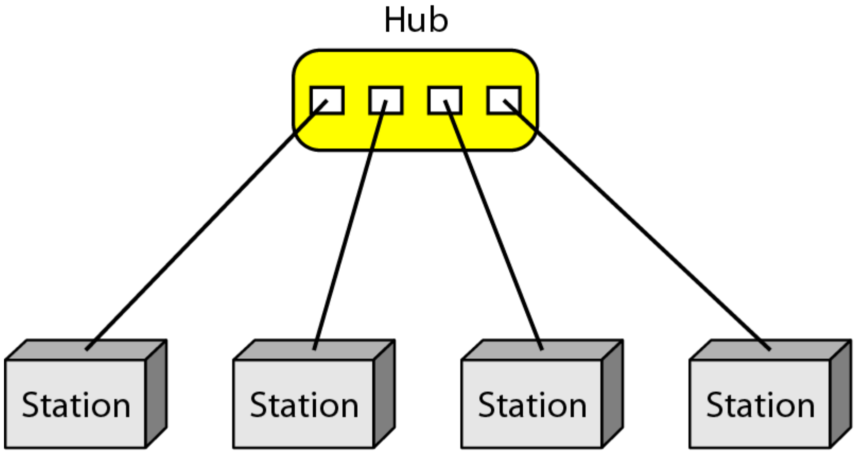
- Point to Point connection
- Every device has a dedicated point-to point link to every device.
- The term dedicated means that the link carries traffic only between the two devices it connects.
- For **n** nodes
  - n(n-1) physical links
  - n(n-1)/2 duplex mode links
- Every device have (n-1) I/O ports to be connected to other (n-1) devices.



- **Advantages:**
  - A mesh topology is robust. If one link becomes unusable, it does not incapacitate the entire system.
  - Point-to-point links make fault identificationand fault isolation easy.
  - Privacy or security : When every message travels along a dedicated line, only the intended recipient sees it.
- **Disadvantages:**
  - Difficult installation and reconfiguration.
  - Bulk of wiring occupies more space than available space.
  - Hardware required to connect each link is expensive.
- **Practical example:** connection of telephone regional offices in which each regional office needs to be connected to every other regional office.

2. Star Topology

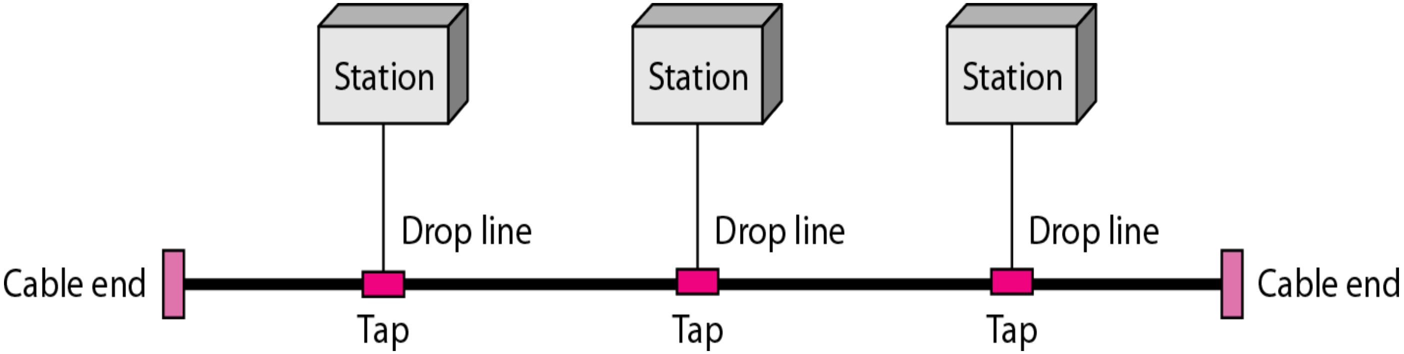
- Point to Point connection
- All the devices are connected to a central controller called a hub
- Dedicated point-to-point link between a device & a hub.
- The devices are not directly linked to one another. Thus, there is no direct traffic between devices.
- The hub acts as a junction:
    - If device-1 wants to send data to device-2,
    - the device-1 sends the data to the hub, then the hub relays the data to the device-2.



- **Advantages:**
  - A star topology is less expensive than a mesh topology. Each device needs only one link and one I/O port to connect it to any number of others.
  - Easy to install and reconfigure.
  - Requires less cabling, less expensive than mesh topology.
  - Robustness: If one link fails, only that link is affected. All other links remain active. As a result fault identification and fault isolation becomes easy.
- **Disadvantages :**
  - Dependency of whole topology on one single point, the hub.
- **Example** : Local area network

3. Bus Topology

- Multipoint connection
- All the devices are connected to the single cable called bus (backbone)
- Devices are connected to the bus by drop-lines and taps.
- A drop-line is a connection running between the device and the bus (main cable).
- A tap is a connector that links to the bus.

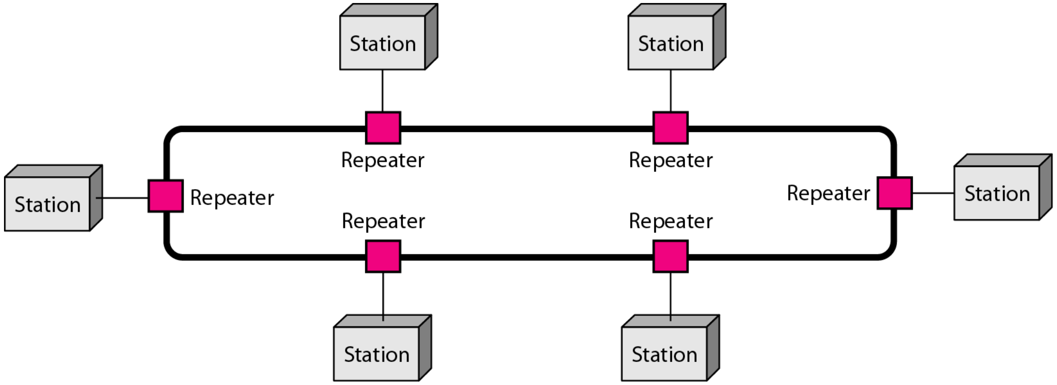


- As a signal travels along the backbone, some of its energy is transformed into heat.
- As a result there is a limit on the number of taps a bus can support and on the distance between those taps.
- **Advantages:**
  - Ease of installation : Backbone cable can be laid along the most path, then connected to the nodes and drop lines.
  - Cable required is the least compared to mesh/star topologies.
  - Redundancy is eliminated : Only the backbone cable stretches through the entire facility.

- **Disadvantages:**
  - Signal reflection at the taps can cause degradation in quality
  - A fault/break in the cable stops all transmission.
  - There is a limit on
    - Cable length
    - Number of nodes that can be connected.
  - Security is very low because all the devices receive the data sent from the source.
- **Example**
  - It is used to implement the basic Ethernet network.

4. Ring Topology

- Each device has a dedicated point-to-point connection with only he 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

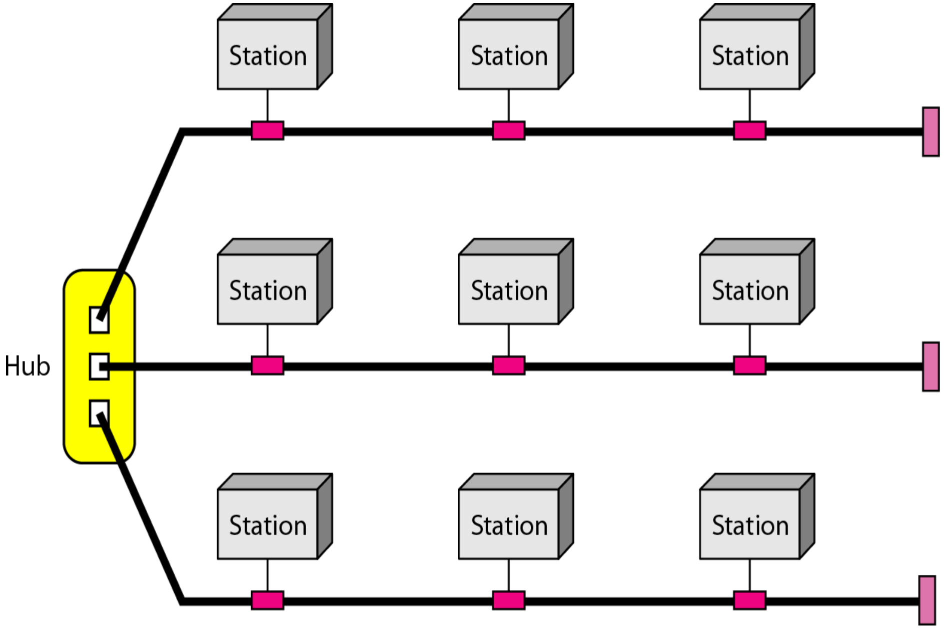


- **Advantages**
  - Easy installation and reconfiguration. To add/delete a device, requires changing only 2 connections
  - Fault isolation is simplified. If one device does not receive a signal within a specified period, it can issue an alarm. The alarm alerts the network-operator to the problem and its location
  - Congestion reduced: Because all the traffic flows in only one direction.
- **Disadvantages**
  - Unidirectional traffic
  - A fault in the ring/device stops all transmission.

    - The above 2 drawbacks can be overcome by using dual ring.
  - There is a limit on
    - Cable length
    - Number of nodes that can be connected.
  - Slower: Each data must pass through all the devices between source and destination.
- **Example:** Used in industrial control systems, metropolitan area networks, and office networks

Hybrid Topology

- Example: having a main star topology with each branch connecting several stations in a bus topology



Categories of Networks

- Network Category depends on its size

1. Local Area Networks (LANs)
2. Wide Area Networks (WANs)
3. Metropolitan Area Networks (MANs)

1. Local Area Networks (LANs)

- It is privately owned and links the devices in a single office, building, or campus.
- LAN can be as simple as two PCs and a printer in someone's home office. Its size is limited to a few kilometers.
- LANs are 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).

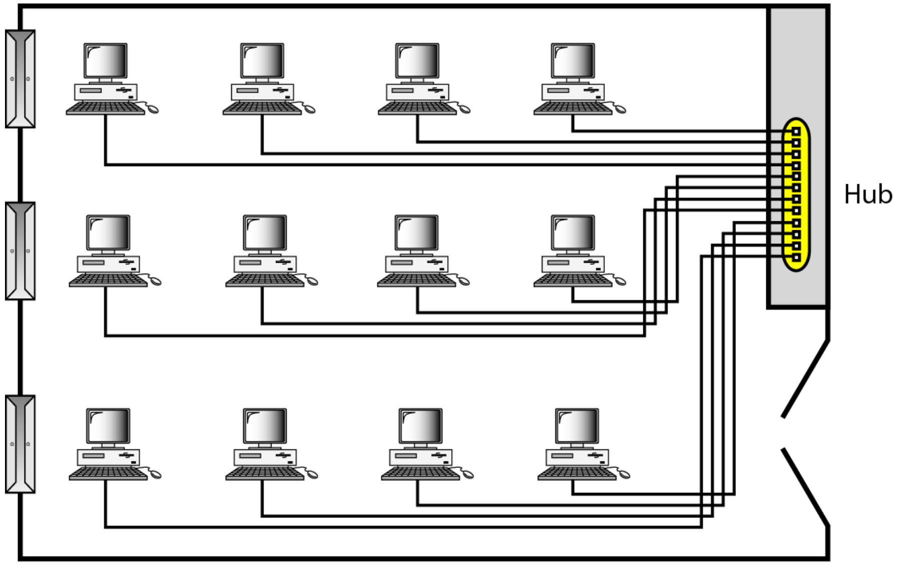


Fig: An isolated LAN connecting 12 computers to a hub in a closet

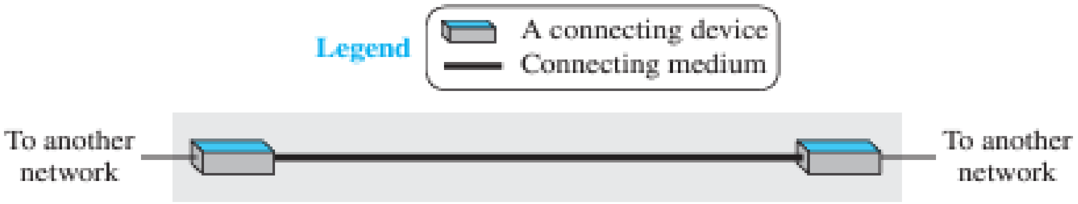
- **Advantages**:

- Resource Sharing: Computer resources like printers and hard disks can be shared by all devices on the network.
- Expansion: Nowadays, LANs are connected to WANs to create communication at a wider level.

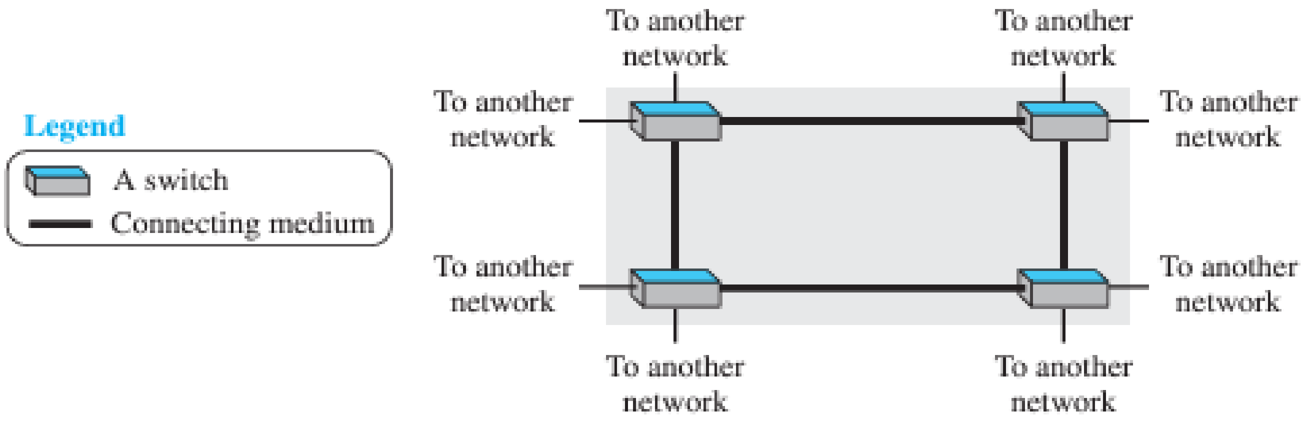
- **Disadvantages**
  - Limited distance: Local area networks are used only in buildings or apartment complexes it cannot be occupied in bigger areas.
  - Installing LAN is expensive: It is expensive to establish a LAN. Here specialized software is essential to install a server. Communication hardware such as hubs, switches, routers, and cables are expensive to buy.
  - Limited scalability: LANs are limited in terms of the number of devices that can be connected to them. As the number of devices increases, the network can become slow and congested.
  - Single point of failure: LANs typically have a single point of failure, such as a central server. If this server fails, the entire network can go down.
  - Maintenance and management: LANs require regular maintenance and management to ensure optimal performance. This can be time-consuming and costly.

2. Wide Area Networks (WAN)

- It provides long-distance transmission of data, image, audio, and video information over large geographic areas that comprise a country, a continent or even the whole world.
- Two types of WAN:
  - Point to Point WAN : A point-to-point WAN is a network that connects two communicating devices through a transmission media (cable or air).

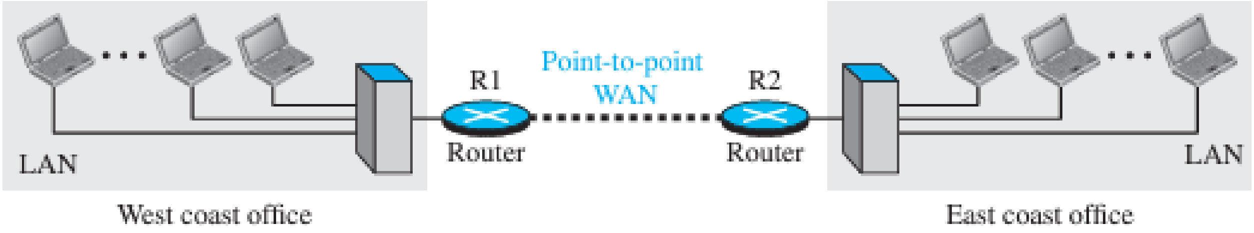


- The switched WAN : A switched WAN is a network with more than two ends. switched WAN is a combination of several point-to-point WANs that are connected by switches.



Internetwork

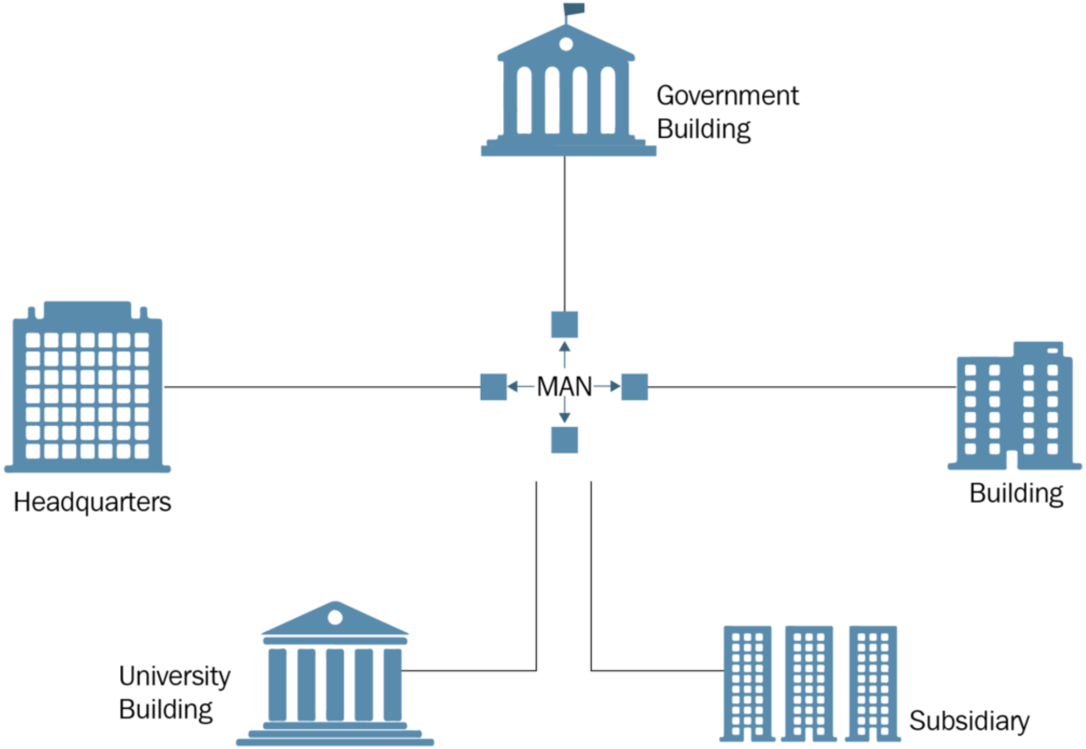
- A network of networks is called an **internet**. (inter-network)
- As an example, assume that an organization has two offices, one on the east coast and the other on the west coast.
- Each office has a LAN that allows all employees in the office to communicate with each other.
- To make the communication between employees at different offices possible, the management leases a point-to-point dedicated WAN from a service provider, such as a telephone company, and connects the two LANs.
- Now the company has an internetwork, or a private internet. Communication between offices is now possible.



- When a host in the west coast office sends a message to another host in the same office, the router blocks the message, but the switch directs the message to the destination.
- On the other hand, when a host on the west coast sends a message to a host on the east coast, router R1 routes the packet to router R2, and the packet reaches the destination.

3. Metropolitan Area Networks (MAN)

- A metropolitan area network (MAN) is a computer network that connects computers within a metropolitan area, which could be a single large city, multiple cities and towns, or any given large area with multiple buildings.
- A MAN is larger than a local area network (LAN) but smaller than a wide area network (WAN). It is commonly used on large companies or school campuses with multiple buildings.
- It serves as a high-speed network to permit the sharing of regional resources.
- The most common examples of MAN are cable TV networks and telephone company networks.


Government Building
Headquarters
MAN
Building
University Building
Subsidiary

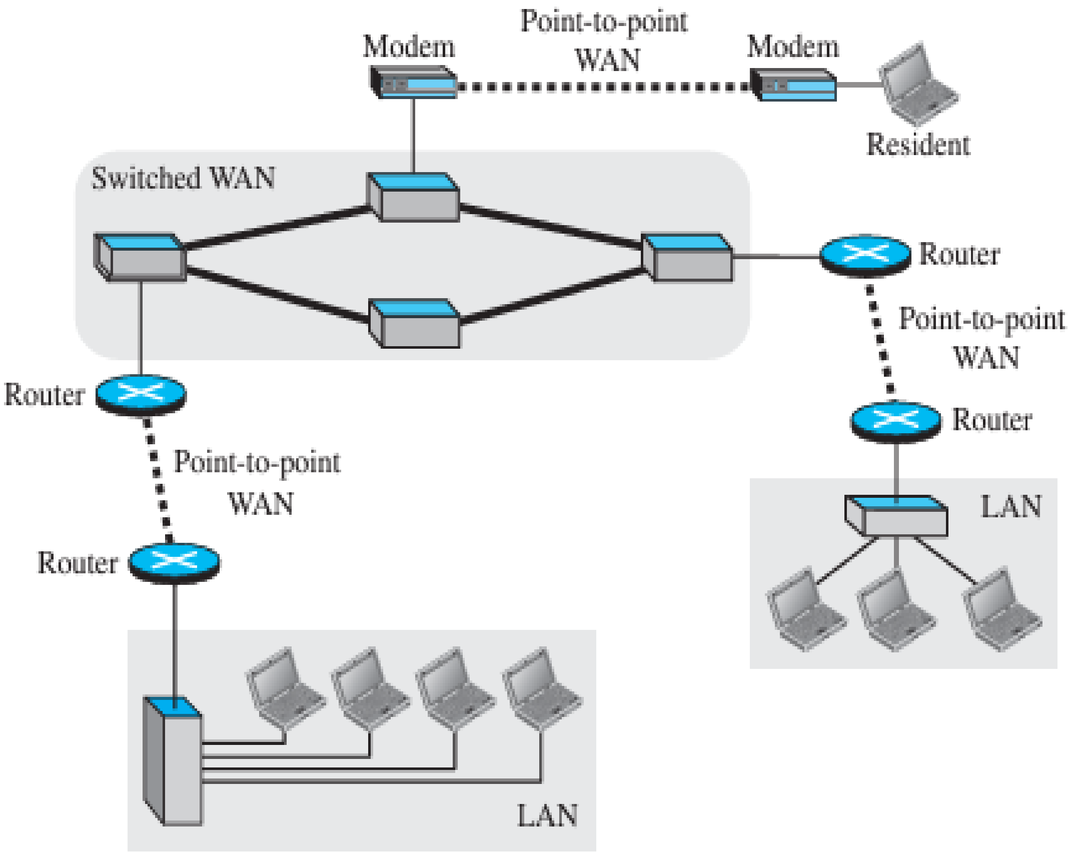


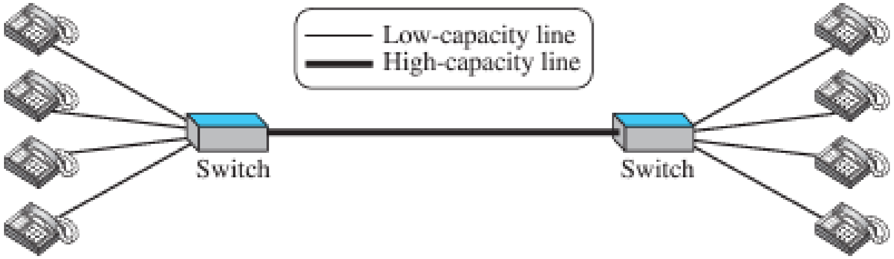
Fig: A heterogeneous network made of four WANs and three LANs

Switching

- An internet is a switched network in which a switch connects at least two links together.
- A switch needs to forward data from a network to another network when required.
- The two most common types of switched networks are
    1. circuit-switched
    2. packet-switched networks.

1. Circuit-Switched Network

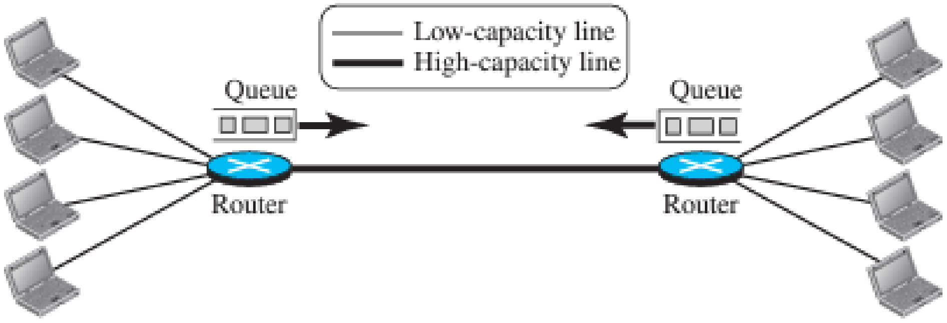
- In a circuit-switched network, a dedicated connection, called a circuit, is always available between the two end systems; the switch can only make it active or inactive.



- In Figure, the four telephones at each side are connected to a switch. The switch connects a telephone set at one side to a telephone set at the other side.
- The thick line connecting two switches is a high-capacity communication line that can handle four voice communications at the same time; the capacity can be shared between all pairs of telephone sets.

2. Packet-Switched Network

- In a computer network, the communication between the two ends is done in blocks of data called packets.



- A router in a packet-switched network has a queue that can store and forward the packet.
- Now assume that the capacity of the thick line is only twice the capacity of the data line connecting the computers to the routers.
- If only two computers (one at each site) need to communicate with each other, there is no waiting for the packets.
- However, if packets arrive at one router when the thick line is already working at its full capacity, the packets should be stored and forwarded in the order they arrived.

The Internet

- Internet is composed of thousands of interconnected networks.

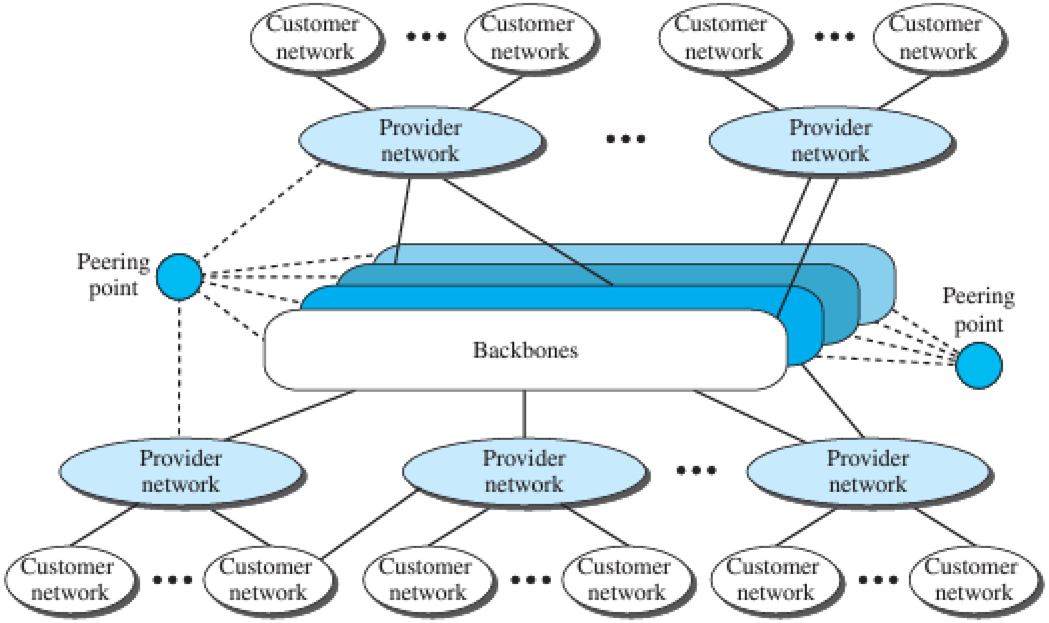


Fig: The Internet today

- At the top level, the backbones are large networks owned by some communication companies such as Sprint, Verizon (MCI), AT&T, and NTT. The backbone networks are connected through some complex switching systems, called peering points.
- At the second level, there are smaller networks, called provider networks, that use the services of the backbones for a fee.
- The provider networks are connected to backbones and sometimes to other provider networks. The customer networks are networks at the edge of the Internet that actually use the services provided by the Internet.
- They pay fees to provider networks for receiving services. Backbones and provider networks are also called Internet Service Providers (ISPs).
- The backbones are often referred to as international ISPs; the provider networks are often referred to as national or regional ISPs.

Accessing the Internet

1. Using Telephone Networks

- Dial up Service : To the telephone line add a modem that converts data to voice. But it is very slow when line used for internet connection.
- DSL Service : Telephone companies have upgraded their telephone lines to provide higher speed internet services .

2. Using Cable Networks

- The cable companies have been upgrading their cable networks to provide internet connection. But speed varies depending on the number of neighbors that use the same cable.

3. Using Wireless Networks

- A household or small business can be connected to the internet through a wireless LAN.

4. Direct Connection to the internet

- A large organization can become a local ISP and be connected to internet.

Network Models

Protocol Layering

- A protocol defines the rules that both the sender and receiver and all intermediate devices need to follow to be able to communicate effectively.
- When communication is
  - Simple -only one simple protocol.
  - complex, we need to divide the task b/w different layers. We need a protocol at each layer, or protocol layering.
- Elements of a Protocol
- Syntax
  - Structure or format of the data
  - Indicates how to read the bits - field delineation
- Semantics
  - Interprets the meaning of the bits
  - Knows which fields define what action
- Timing
  - When data should be sent and what
  - Speed at which data should be sent or speed at which it is being received.

Scenarios

First Scenario

- Communication is so simple that it can occur in only one layer.
- Assume Maria and Ann are neighbors with a lot of common ideas.
- Communication between Maria and Ann takes place in one layer, face to face, in the same language

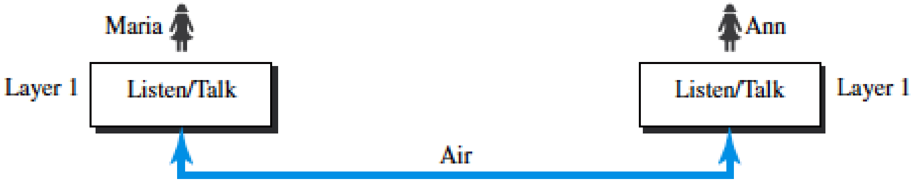


Fig: single layer protocol

- Even in this simple scenario, we can see that a set of rules needs to be followed.

1. Maria and Ann know that they should greet each other when they meet.
2. They know that they should confine their vocabulary to the level of their friendship.
3. Each party knows that she should refrain from speaking when the other party is speaking.

Second Scenario

- Assume that Ann is offered a higher-level position in her company, but needs to move to another branch located in a city very far from Maria.
- The two friends still want to continue their communication and exchange ideas because they have come up with an innovative project to start a new business when they both retire.
- They decide to continue their conversation using regular mail through the post office.
- They do not want their ideas to be revealed by other people if the letters are intercepted. They agree on an encryption/decryption technique
- Now we can say that the communication between Maria and Ann takes place in three layers

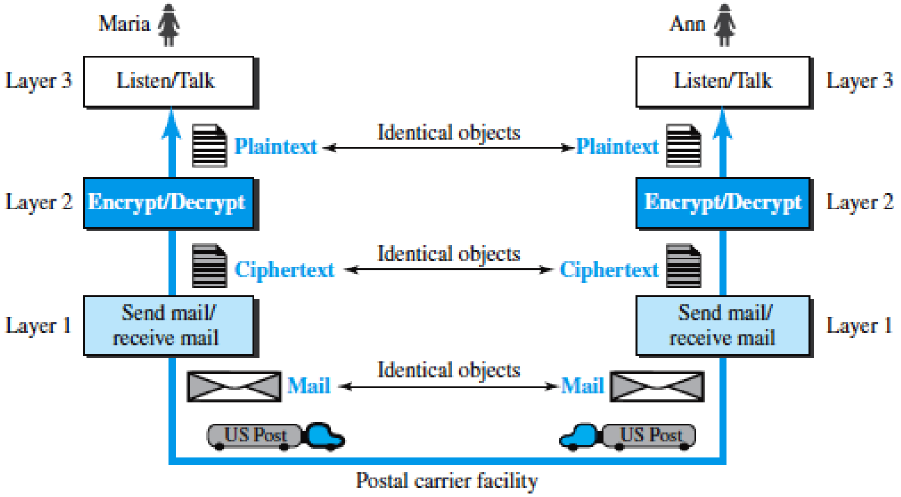


Fig: A three-layer protocol

- Let us assume that Maria sends the first letter to Ann.

At Maria side:

- Maria talks to the machine at the third layer as though the machine is Ann and is listening to her.
- The third layer machine listens to what Maria says and creates the plaintext which is passedto the second layer machine.

- The second layer machine takes the plaintext, encrypts it, and creates the ciphertext, which is passed to the first layer machine.

- The first layer machine, presumably a robot, takes the ciphertext , puts it in an envelope, adds the sender and receiver addresses, and mails it.

At Ann's side

- The first layer machine picks up the letter from Ann's mail box, recognizing the letter from Maria by the sender address.
- The machine takes out the ciphertext from the envelope and delivers it to the second layer machine.
- The second layer machine decrypts the message, creates the plaintext and passes the plaintext to the third-layer machine.
- The third layer machine takes the plaintext and reads it as though Maria is speaking.

- Protocol layering enables us to divide a complex task into several smaller and simpler tasks.
- For example, in Figure 2.2, we could have used only one machine to do the job of all three machines. However, if Maria and Ann decide that the encryption/ decryption done by the machine is not enough to protect their secrecy, they would have to change the whole machine.
- In the present situation, they need to change only the second layer machine; the other two can remain the same. This is referred to as ***modularity***.
- Modularity in this case means independent layers.
- A layer (module) can be defined as a black box with inputs and outputs, without concern about how inputs are changed to outputs

Advantages of protocol layering

- Allows to separate the services from the implementation.
  - A layer needs to be able to receive a set of services from the lower layer and to give the services to the upper layer; we don't care about how the layer is implemented.
  - For example, Maria may decide not to buy the machine (robot) for the first layer; she can do the job herself. As long as Maria can do the tasks provided by the first layer, in both directions, the communication system works.
- Reduces the complexity at the intermediate system
- Communication does not always use only two end systems; there are intermediate systems that need only some layers, but not all layers.
- If we did not use protocol layering, we would have to make each intermediate system as complex as the end systems, which makes the expensive.

Principles of Protocol Layering

First Principle

- The first principle dictates that if we want bidirectional communication, we need to make each layer so that it is able to perform two opposite tasks, one in each direction.
- For example, the third layer task is to listen (in one direction) and talk (in the other direction). The second layer needs to be able to encrypt and decrypt. The first layer needs to send and receive mail.

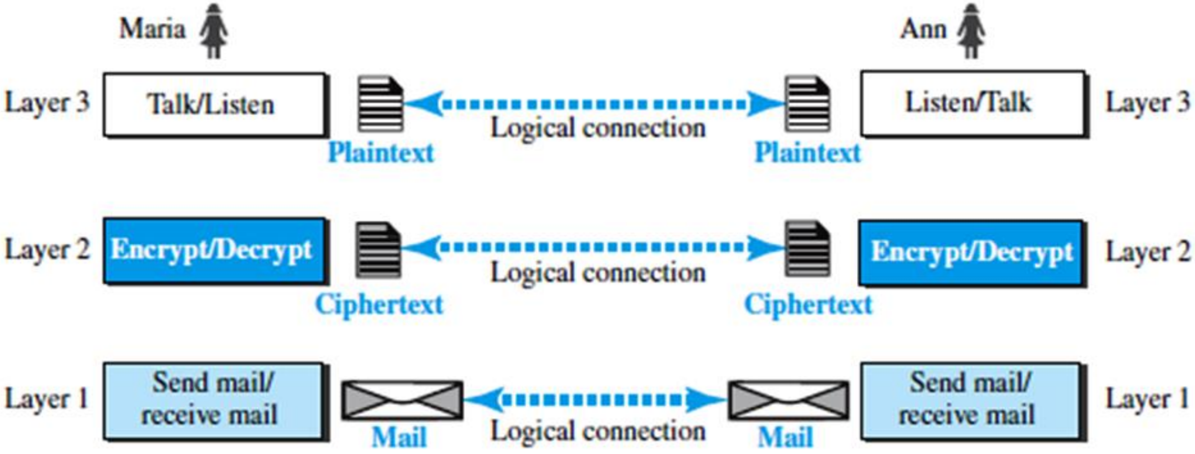
Second Principle

- The second principle that we need to follow in protocol layering is that the two objects under each layer at both sites should be identical.

- For example, the object under layer 3 at both sites should be a plaintext letter. The object under layer 2 at both sites should be a ciphertext letter. The object under layer 1 at both sites should be a piece of mail.

Logical Connections

- Two protocols at the same layer can have a logical Connection
- This means that we have layer-to-layer communication.



- Maria and Ann can think that there is a logical (imaginary) connection at each layer through which they can send the object created from that layer.

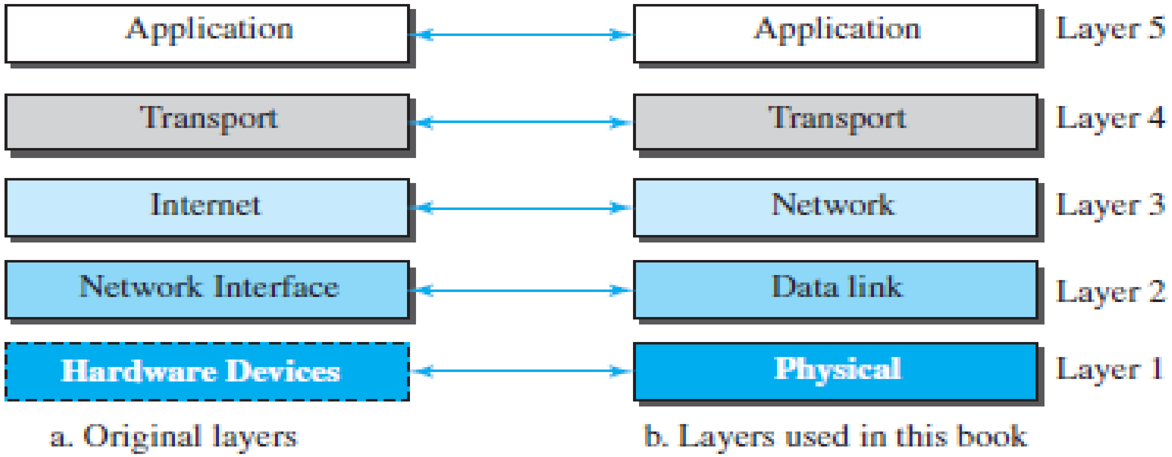
TCP/IP PROTOCOL SUITE

- TCP/IP is a protocol-suite used in the Internet today.
- Protocol-suite refers a set of protocols organized in different layers.
- It is a hierarchical protocol made up of interactive modules, each of which provides a specific functionality.
- The term hierarchical means that each upper level protocol is supported by the services provided by one or more lower level protocols.
- TCP/IP is thought of as a five-layer model.

Layered Architecture

- To show how the layers in the TCP/IP protocol suite are involved in communication between two hosts, we assume that we want to use the suite in a small internet made up of three LANs (links), each with a link- layer switch.
- We also assume that the links are connected by one router

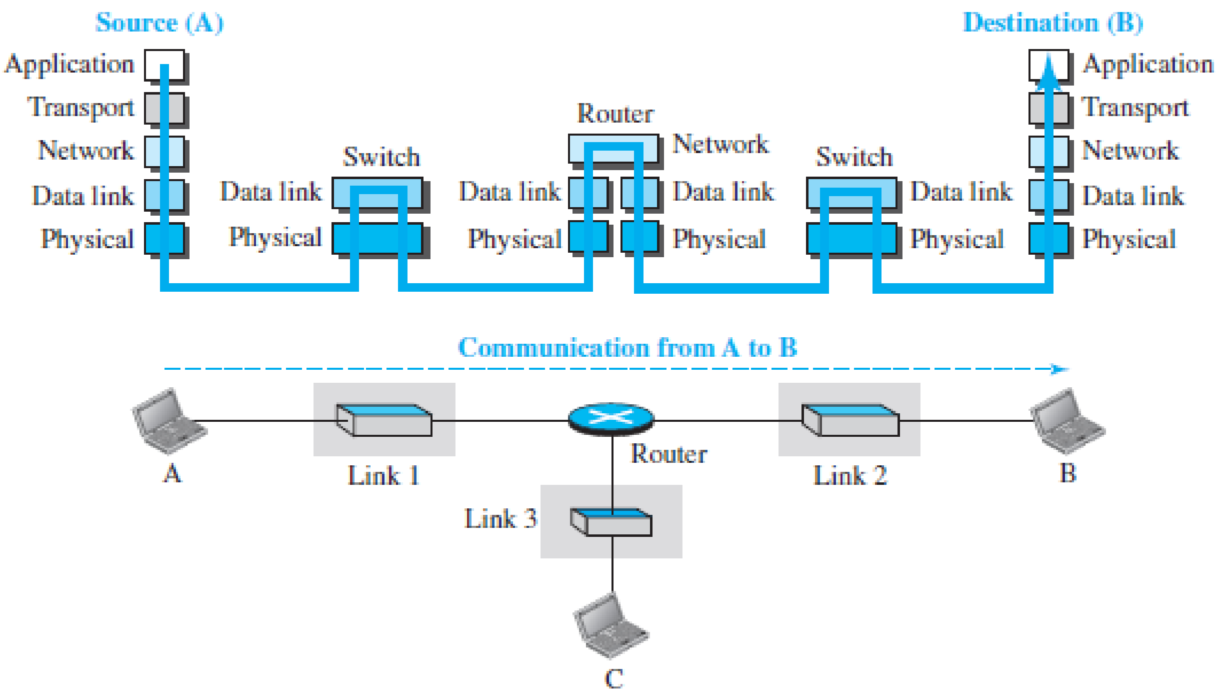
Figure 2.4 *Layers in the TCP/IP protocol suite*



a. Original layers

b. Layers used in this book

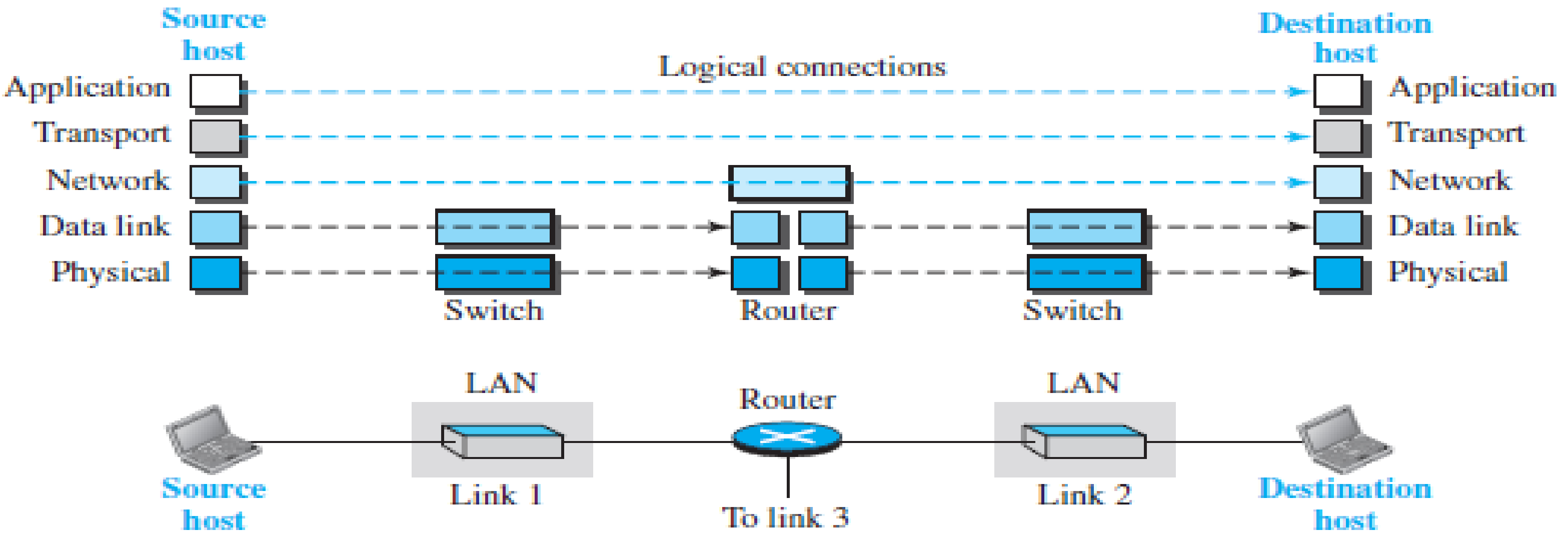
Figure 2.5 *Communication through an internet*



Layers in the TCP/IP Protocol Suite

- To better understand the duties of each layer, we need to think about the logical connections between layers.

Figure 2.6 *Logical connections between layers of the TCP/IP protocol suite*



- The duty of the application, transport, and network layers is end-to- end.
- The duty of the data-link and physical layers is hop-to-hop, in which a hop is a host or router.
- The domain of duty of the top three layers is the internet, and the domain of duty of the two lower layers is the link.
- Another way of thinking of the logical connections is to think about the data unit created from each layer.
- In the top three layers, the data unit (packets) should not be changed by any router or link-layer switch.
- In the bottom two layers, the packet created by the host is changed only by the routers, not by the link-layer switches.