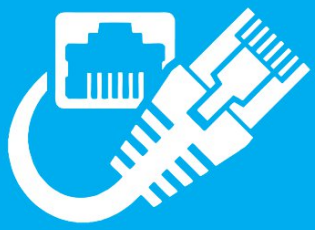
Unit 3 Networks

Short Introduction

In this unit, the fundamentals of computer networks and data communication are discussed. We can understand the basic components of a computer network along with geographical arrangements of devices in a network. Communication model over the Internet is also discussed.



Students' Learning Outcomes

1. **Networks**
   - Defining Computer Network
   - Describing physical structure of a network
   - Understanding need of establishing a computer network
   - Defining Client and Server
2. **Basics of Communication**
   - Explaining the following components of a communication system
     - Sender
     - Receiver
     - Message
     - Protocol
     - Transmission Medium
3. **Understanding Network Models**
   - Defining TCP/IP
   - Describing functions of TCP/IP layers
4. **Basics of Data Communications**
   - Explaining why messages need to contain addressing information (sender/recipient identification)
   - Understanding the importance of addressing in telephone addressing and postal service.
   - Understanding request/response mechanism of the Internet.
   - Understand IP addressing.
5. **Protocols in TCP/IP Suit**
   - Understanding FTP, HTTP and SMTP protocols
6. **Understanding the need for addressing**
   - Understanding importance of addressing in data communication
   - Describing addressing in telephone and postal services.
7. **Understanding HTTP requests and their responses**
   - Differentiating IPv4 and IPv6
8. **Routing**
   - Understating functions of a router
   - Describing the routing process

3.1 Computer Network

In our daily life, we use computers to browse the Internet, send/receive emails, play online games, watch online videos, download music, take online courses, read daily newspapers, etc. All such activities require a computer connected with some other computer to make a computer network. They can be linked through a wire or wirelessly. A communication medium connecting multiple computers is also called a communication channel.

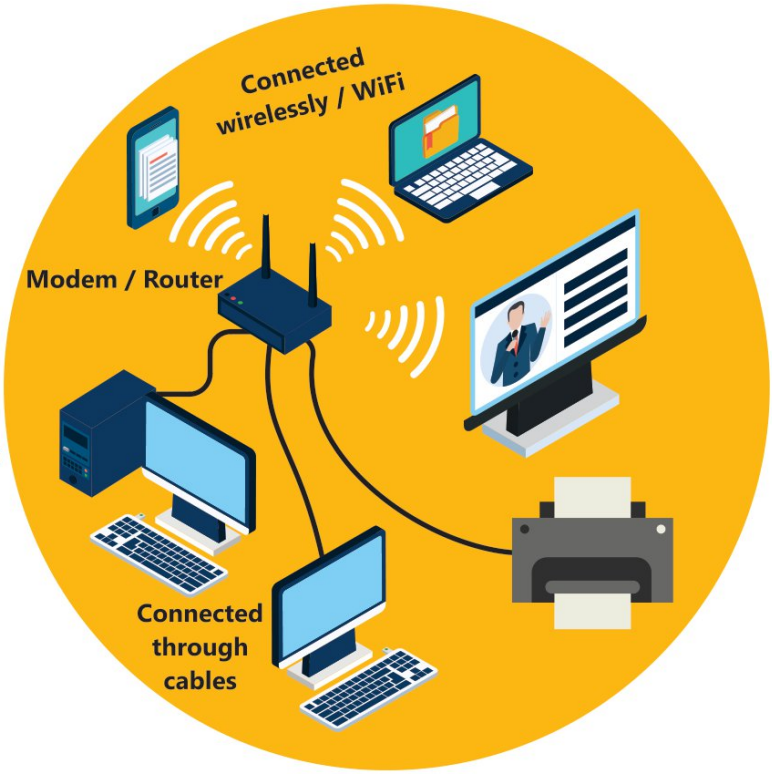


Figure 3-1
Overview of a Computer Network

Definition

A computer network is a group of computer systems and other computing hardware devices linked together through communication channels. A network facilitates communication and resource-sharing among the connected devices as shown in Figure 3-1. Networks are connected together to make a larger network which is called network of networks. The Internet is coinsiderd as the most well known exampe of network of networks.

3.1.1 Need of a Computer Network

A computer network is established for the purpose of sharing resources. Examples of resource sharing are given below.

- **File sharing**:

  Networking of computers helps a network user to share files. For example, if you need date sheet of your board examination, you can get the file through the Internet, without visiting BISE (Board of Intermediate and Secondary Education) office. Similarly, BISE requires your picture and your bio data for admission form. They can get all these files over a network. So, the file sharing is helpful to complete a task systematically as shown in Figure 3-2.

Figure 3-2 File sharing

  Example: If all your school teachers want to prepare a combined result using computers, they can share files over a school network or the Internet.

  Moreover, sharing files with others who are living in a different city or even country is also much helpful and is done in the same way.

- **Hardware sharing**:

  Users can share devices such as printers, scanners, CD-ROM drives, hard disk drives etc. For example, in an office, usually there are less number of printers and scanners than the available number of computers as shown in Figure 3-3. Using a network, these resources are shared to get a cost-efficient solution.

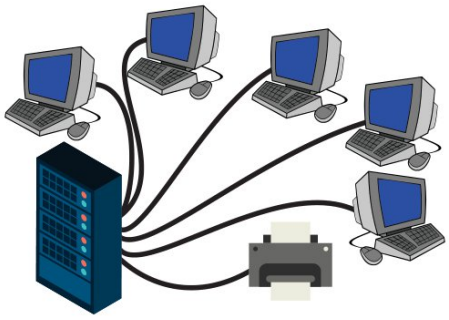


Figure 3-3 Resource Sharing Example

- **Application sharing**

  Applications can be shared over the network. It means that more than one users may use the same application. For example, in a bank; cashier, manager, ATM (automated teller machine) (Figure 3-4) users use same application over the network. Bank balance updated at one point is updated for all branches immediately.

Figure 3-4 ATM

- **Sharing a single Internet connection**

  Using a network at home or office, we can share one Internet connection with more than one user as shown in Figure 3-1.

- **User communication**

  Networks allow users to communicate using e-mail, newsgroups, and video conferencing etc. So, communication with many people sitting on different locations is possible due to a network.

  Example: A video conference comprises the technologies for the reception and transmission of audio-video signals by users at different locations as shown in Figure 3-5.

Figure 3-5 Video Conference

- **Increasing storage capacity**

  Storage capacity means the limit to store data in a computer. If we connect our computer to another computer having more storage, then we can also use the disk space of that computer. In this way we can store and access files stored remotely. In this setup, a computer providing the storage is called file server and the computer accessing that space is called a workstation.

Do you know?

We can use services like DropBox and Google Drive to store our files remotely.

3.1.2 Client Server

A server provides a service and a client gets that service. A client application requests some services from another application which acts as a server. When we access a website, we get contents on our screen served by a server. Our emails are also there on some server, and when we provide username and password, the server verifies credentials and serves our email records. An email user in this example is a client as shown in Figure 3-6.

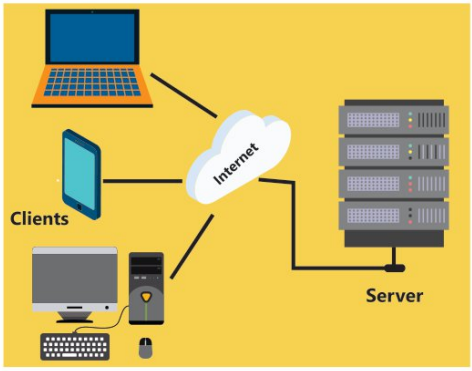


Figure 3-6
Client-Server Communication

A **client** is a process that accesses a service provided by a server. For example, to check email we use web browser as a client. The client provides a user interface to carry out actions, like giving username and password. It forwards requests to the server, which in return provides the required service. It is important to know whether a client is hardware or software. In general, a client is a hardware as shown in Figure 3-6 where a cell phone, laptop and desktop computers are shown as clients, but in particular the software running on that hardware is the process which makes it a client.

A **server** is a physical computer dedicated to run services to serve the needs of its clients. Depending on the service that is running, it could be a file server, database server, print server, or a web server.

3.2 Physical Structure of Networks

Physical structure of networks can be classified in terms of type of connection and topology. In the following sections, we discuss these concepts in detail.

3.2.1 Types of connection

Two devices can communicate with each other when they are connected in some way to the same link at the same time. Point to point and multipoint are two possible types of connections.

Point-to-point connection: A point-to-point connection is a direct link only between two devices, i.e., a sender and a receiver. For example, there is a point to point connection between a remote control and a TV.

Multipoint connection: In multipoint connection, there is a link between a sender and multiple receivers. So, more devices can share a single link. For example, in a Wi-Fi based network a single link is shared among multiple devices.

3.2.2 Network topologies

Topology of a network is a geometric representation of the relationship among the interconnected devices. The four basic network topologies are bus, star, ring and mesh.

- **Bus Topology**

  A bus topology connects all devices of the network through a single common cable having exactly two end points as shown in Figure 3-7. This cable is called backbone of the topology. Bus topology offers a simple way to connect devices. All of the devices of the network are connected to a common transmission medium which has exactly two endpoints. In this simple form of networking, failure of any single device does not affect other devices connected with the cable. However, if there is some problem in the shared communication cable, then all other devices can stop functioning.

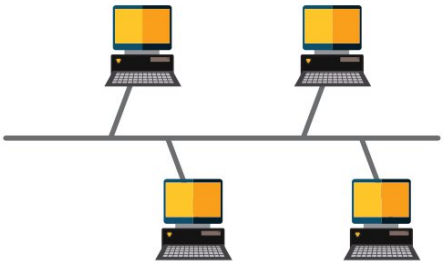


Figure 3-7 Bus Topology

- **Star Topology**

  A star topology connects all devices using point to point connections via cables to a central point as shown in Figure 3-8. The central point is known as a Hub or Switch. The central device controls all the traffic. Therefore, devices can transfer data to each other only through the central point. It is

easy to install and reconfigure. Star topology consumes more cable than the bus topology, however, if there is some problem in a cable, then only the respective computer gets disconnected from the network. On the other hand, if there is some problem in the Hub or Switch, then whole network becomes dead.

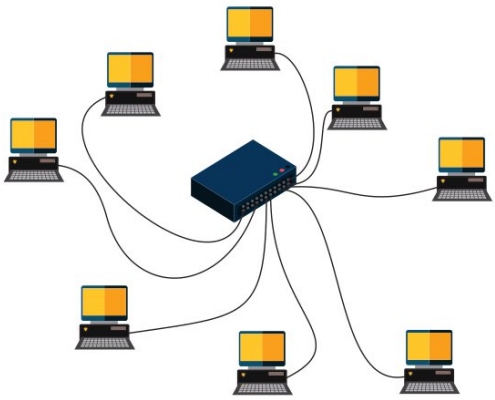


Figure 3-8 Star Topology

- **Ring Topology**

A ring topology connects a computer with exactly two other computers forming a ring of computers as shown in Figure 3-9. A computer can send data to its immediate neighbour. A ring can be unidirectional or bidirectional. In a unidirectional ring topology, data is sent either clockwise or anticlockwise. In a bidirectional ring topology, data can travel in any direction. Upon receiving data, a computer may pass data to its next neighbour. In this way, data reaches the desired destination. A failure of connection between two computers may down the whole network. Unlike star topology, it does not require a central device to manage the connectivity between the devices.

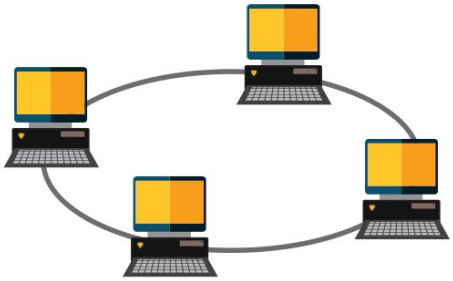


Figure 3-9 Ring Topology

- **Mesh topology**

Mesh topology connects all devices with each other through a direct link as shown in Figure 3-10. As compared to ring topology, data may reach its destination quickly. The mesh

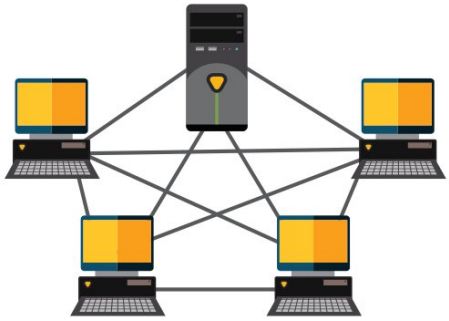


Figure 3-10 Mesh Topology

topology is an expensive topology in terms of cable cost as it uses a lengthy cable to connect computers as compared to the cable used in other topologies. However, the mesh topology is more reliable as it offers point-to-point connection. It is also considered more secure as data travels only between a sender and a receiver.

3.3 Basics of Data Communication

Data communication refers to exchange of messages between sending and receiving devices through some communication medium. These messages are actually the information which can be presented in many forms like text, numbers, images, audio and video.

Figure 3-11 Sending/Receiving

In the following section, we discuss the components involved in sending/ receiving messages over a network.

3.3.1 Components of a Communication System

A communication system is used to transfer data from one point to other. The process of data transmission has well defined steps and they are executed in a particular sequence. For example, if you want to send your picture from your computer or cell phone to someone else, you need a communication system. The main components of a communication system are discussed below.

- **Sender**

  Sender is a device that initiates the communication process. It sends messages consisting of text, numbers, pictures etc. It is also called source or transmitter. Normally, computer is used as a sender in a communication system.

- **Receiver**

  Receiver is a device that receives a message. It is also called sink. The receiver can be a computer, printer or another device. The receiver must

be capable of accepting a message.

- **Message**

  Message is the data or information to be communicated. It may consist of text, numbers, pictures, sound, video or any combination of these.

  In a data communication system, a message is sent in the form of packets. Each message has two parts, i.e., payload and control information. Payload is the actual contents of a message whereas the control information contains information about the sender and the receiver. Control information is also called header of a message. It is just like writing a letter where we write a letter along with the information about its sender and receiver. In this example, your letter is the payload. It requires the control information in order to dispatch and get a reply.

  Example:

  Suppose you want to distribute your books of 8th class to different people and it is possible that the recipient of a book may write you a letter of thanks. You put a label on each book containing the destination address without any further instructions, as shown in Figure 3-7. In this example the label is a header (also called control information) and book itself is a payload (also called message).

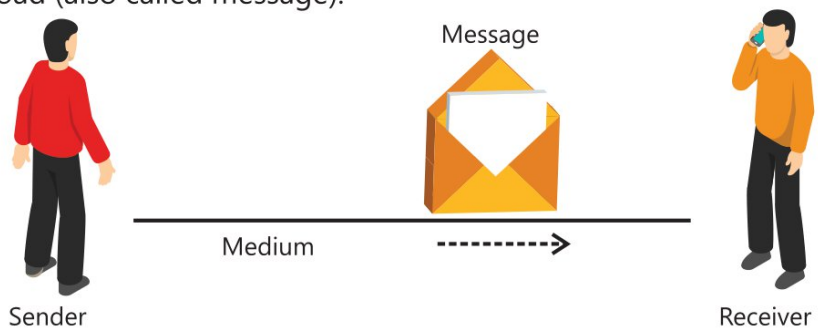


Figure 3-12 Sending a Message Over Some Medium

- **Protocol**

  A protocol is a formal agreement between two parties. A network protocol is a formal arrangement between two computers to send and receive

information. Very specifically, a network protocol defines a set of rules and procedures for communication between a sender and a receiver. Some protocols will be discussed in Section 3.4.1.

- **Transmission Medium**

  Medium is the physical path that connects a sender and a receiver. It is used to transmit data. The medium can be a copper wire, a fibre optic cable, microwaves etc. It is also called a communication channel. Figure 3-13 shows that a message is transmitted from a sender to a receiver through some transmission medium.

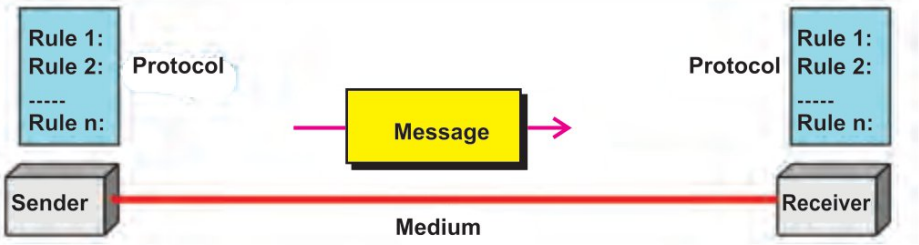


Figure 3-13 Components of a Communication System.

A device may use multiple channels at the same time. For example, if a cell phone is connected with the Internet, it uses a data channel (3G/4G/LTE) for using the Internet services, and a voice channel for calling purpose.

3.4 Computer Network Models

The whole communication process is carried out in different layers, where each layer performs one or more specific tasks. The Internet also uses a layered communication model, called the Transmission Control Protocol/Internet Protocol (TCP/IP) model. The TCP/IP is a suit of protocols that provides end-to-end connectivity between devices. It consists of five layers as shown in Table 3-1.

Application Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

Table 3-1

The concept of layering can be explained with post office example. Suppose you are in Lahore and want to write a letter to your friend in Islamabad. After

writing the letter, you insert it in an envelope, write address of your friend on it and drop it in a mailbox. As there may be many people living at the same address, so you write the name of your friend on the envelope. Your nearest post office takes the letter to general post office in Lahore which sends the same to general postal office in Islamabad. Ultimately, the letter reaches at the address and then to your friend. Then, he/she can read the message and write a reply. Here we relate this example with the layered network model of TCP/IP. Assume that two persons are chatting using a computer network.

Postal System	Layered Network
In writing a letter, you consider only writing proper message without concerning about the names of the post office staff who will handle the envelope. Moreover, you do not need to know the details of the mail delivery system. You simply put it in an envelope and write the street address.	While chatting you are concerned only about the messages without bothering about the kind of network, i.e., wireless or wired. This is called **application layer** where you type a message and send on the network. The address of the receiving device is provided in the form of header before message content.
You write sender and receiver information over the envelope and put it in the letterbox. If the address is incomplete, you may get your letter back. If everything is fine, you simply trust on the postal system. The name of the specific person is mentioned who can open and read the letter.	**Transport layer** establishes connection between a client and a server. It tries to send message but if there is some error like your computer is disconnected from the network then it informs the application program. If the network is fine, then the application trusts the **transport layer** that the message will reach at its destination. At this stage, port number is added with message header for indication of specific application at destination. A port number is used to identify the application which can accept a message.

A letter is moved to other city (Islamabad in this example) by road or air.	A program running on the **network layer** moves the data to the other network. So, a chat message is transferred to other Wi-Fi router of your friend from where it is delivered to your friend and he/she can see it on screen.
Handling of letters is same either if they are letters with photographs, Eid card, or containing text, etc.	A network handles all messages in the same way either if they are emails, pictures, or voice messages etc.
Bikes or vans may carry your letter from letterbox to general post office.	**Data link layer** sends a message to the server connected with sender. If you are chatting at home with a Wi-Fi connection, then the data link layer sends message from your computer to the Wi-Fi router.
For your letter delivery, there is usage of roads, train tracks and may be airlines.	**Physical layer** is about the physical medium used in communication, like cabling etc.

Each layer adds some control information called header with the data received from the layer above it. The actual content of message called payload, is hidden inside the header at each layer, like a letter is hidden inside an envelope. This is called encapsulation.

3.4.1 Protocols in TCP/IP Suit

Each layer of TCP/IP model has its own protocol(s). Every protocol is designed to perform some specific task. Some of the most widely used application layer protocols are discussed below.

- **FTP**

  File Transfer Protocol is the standard TCP/IP protocol which is used for the purpose of transferring files from one computer to another. For example, if we want to transfer a document file

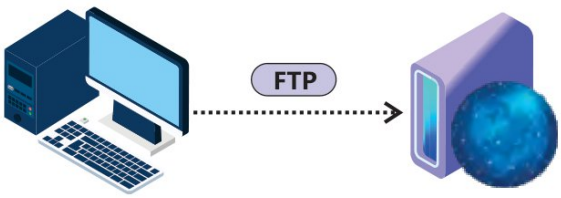


Figure 3-14 Transferring Files Over Network

to a remote computer, then we can use this protocol as shown in Figure 3-14.

- **HTTP**
  Hypertext Transfer Protocol is a protocol used by Word Wide Web (WWW) to transfer webpages between a client and a web server. A web server is also called an HTTP server. We use this protocol while browsing Internet. For secure data transfer, we use HTTPS.

- **SMTP**
  Simple Mail Transfer Protocol is a standard protocol to transmit emails.

3.5 The Need for Addressing

A packet is the unit of data sent from one device to another. It requires its destination address just like we write address on an envelope while sending a letter. An application running on the recipient side accepts packets and assembles them to show a meaningful information. If there are more than one applications ready to accept a packet, then a number called port number distinguishes the targeted application from the other applications. So, proper addressing is required for reliable data transfer.

3.5.1 Importance of Addressing in Data Communication

Before sending a message, source must know the destination address. Devices on a network need addresses in order to communicate with each other. So, giving an address to a message is the first step and the second step is to transmit the packet to its intended recipients.

3.5.2 Mapping between Telephone Addressing and Network Addressing

Suppose you want to make a phone call to your friend. Before calling, you need to know exact telephone address that is the telephone number of your friend. On the Internet, the telephone number corresponds to an IP address (Internet Protocol). Like a telephone number, all IP addresses are unique. Each

device gets its own unique IP address when it gets connected to the Internet. If an IP address of a device is fixed in a network, it is called static IP address. Otherwise if each time a new connection is made a new IP address is assigned, it is called dynamic IP address.

3.6 Sending HTTP Requests and Receiving HTTP Responses over the Internet

The World Wide Web (WWW) is a system of Internet servers. Servers serve a request sent by a client. This request is called HTTP request. So, the communication between a server and a client is based on requests and their respective responses. Using a web browser when you type a URL (Uniform Resource Locator) like http://www.pakistan.gov.pk, you are sending a request. In its response you get the contents of website that may contain text, images, sounds, etc. These contents are embedded in an HTML (Hypertext Markup Language, discussed in Unit#5). In this case, your computer works as HTTP client, whereas the computer serving you a webpage is called HTTP server or web server as shown in Figure 3-15.

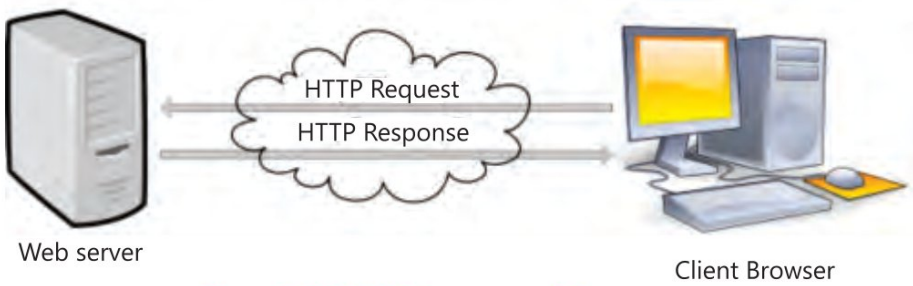


Figure 3-15 HTPP Request and Response

Web browsers are used to access the World Wide Web in an easy manner. Web browsers and web servers function together as a client-server system. Client-server is a standard method for designing applications where data is kept in central locations (server computers) and efficiently shared with any number of other computers (the clients) on request.

3.6.1 Understand IP Addressing

IP address stands for Internet Protocol address, it is a unique identifier that is associated with a device when it is connected to a network. An IP address is assigned by a Dynamic Host Configuration Protocol (DHCP) server. There are two standards of IP addressing, i.e., IPv4 and IPv6.

Example:

- IPv4 address is like: 172.16.54.1
- IPv6 address is like: 2001:db8:0:1234:0:567:8:1.

When the Internet Protocol was originally designed, the standard was known as Internet Protocol Version 4 (IPv4). As shown in the above example, the IPv4 is divided in four groups separated by '.' where each group can contain a decimal value from 0 to 255. We have already learnt in Unit#2 the conversion from decimal to binary and according to that $(255)_{10} = (11111111)_2$. It shows that maximum 8 bits are required for every group of IPv4. So, in total 32 bits are required to store the whole IP address in IPv4 standard.

Due to more and more devices connecting to the Internet, IPv4 addresses are running out. To accommodate the increase in devices, another standard of IP addressing is introduced which is called Internet Protocol Version 6 (IPv6). It consists of 128 bits. In IPv6, there are 8 groups separated by ':', as shown in the above example. Each group can contain 4 hexadecimal digits. To store one hexadecimal digit, we need 4 bits. So, for a group in IPv6 we need 16 bits and for 8 groups total 128 bits are required.

- 1 hexadecimal digit requires 4 bits
- 4 hexadecimal digits require 16 bits
- 1 group has 4 hexadecimal digits, so each group requires $4 \times 4 = 16$ bits
- 8 groups require $8 \times 16 = 128$ bits.

Do you know?

Ipv6 was developed by the Internet Engineering Task Force (IETF). IPv6 became a Draft Standard in December 1998, and became an Internet Standard on 14 July 2017.

Although IPv4 is still in use today and provides approximately 4.3 billion addresses, however this number is less than the population of the whole world We also know that nowadays many persons have more than one devices connected with the Internet at a time. IPv6 can allow up to 2^{128} addresses which is 7.9×10^{28} times more than the number of addresses in IPv4.

3.7 Routing

3.7.1 Understand a Router

A router is a networking device that forwards data packets from one network to another. As the Internet is called network of networks, so a router also directs the traffic on the Internet.

Figure 3-16 Router

A router analyses the destination IP address of an incoming data packet, determines the best route to forward the packet, and then sends it accordingly. A router is usually placed at the meeting point of two or more networks.

3.7.2 Routing in the Internet

We get the Internet service from some Internet Service Provider (ISP). When we send a request from a device it reaches an ISP where router is installed.

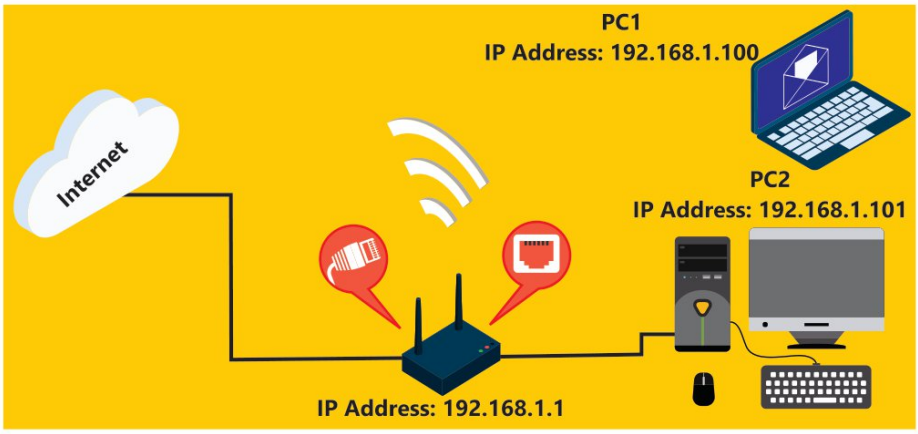


Figure 3-17 Usage of router

The router forwards our request according to header of our message. For communication over the Internet, there may be hundreds of networks between the source and the destination. Hundreds of routers might forward a single packet as it moves from one network to the next on the way to its final destination. Figure 3-17 shows the usage of a router in the Internet.

3.7.3 Routing Process

Routing is a process of taking data from one device and sending it to another device on a different network. Every data packet has two addresses; destination address and source address. Destination address is used to deliver the data packet at destination. Source address is used to identify the sender device.

Consider the following example of IP routing (Figure 3-18)

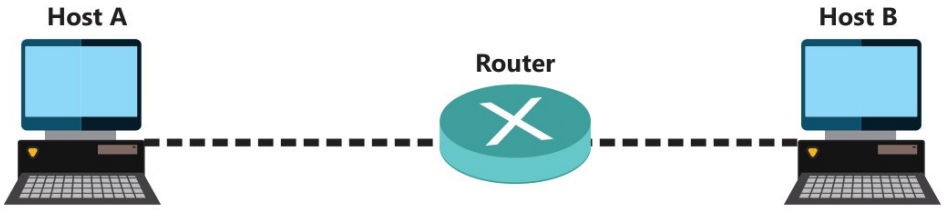


Figure 3-18 Message Routing between Source and Destination

Host A wants to communicate with host B, but host B is on another network. Host A is configured to send all packets destined for remote networks to the router. The router receives the packets, checks the routing table to see if it has an entry for the destination address. A routing table is used by routers to determine the path to the destination network. If the entry exists for the destination address, the router forwards the packet out of the appropriate interface port. If the router doesn't find the entry, it discards the packet.

SUMMARY

- A computer network, is a digital telecommunication network which allows nodes to share resources.
- A client computer is an individual computer that accesses the information and programs stored on a server as part of a network environment.
- A server is a computer program or a device that provides functionality for other programs or devices, called "clients".
- Sender is a device that initiates the communication process. It sends message consisting of text, numbers, pictures, etc.
- Receiver is a device that receives message. It is also known as sink.
- The message is the data or information to be communicated. Message is of various data types such as text, number, pictures, sound and video.
- Rules are defined for the communication between sender and receiver called protocol.
- Medium is the physical path that connects sender and receiver.
- IP stands for Internet Protocol and is an address used for identifying number that is associated with a specific computer when it connects to the Internet, it may be static or dynamic.
- A router is a networking device that forwards data packets from one network to another.
- Routing is a process of taking data from one device and sending it to another device on a different network.
- Network topology is the physical arrangements of devices and connecting lines.
- A network port is used to identify an application going to receive a message.
- TCP/IP is a stack of protocols and it has 5 layers.
- FTP is File Transfer Protocols which is used to transfer file over a network.
- A router directs messages on the Internet.
- For home user, the Internet service is provided by an ISP (Internet Service Provider).

EXERCISE

3-1 Choose the correct option.

1. The IPv4 address is made up of _____ binary bits.

(i) 31 (ii) 29

(iii) 32 (iv) 30

2. Routing is process of taking data from one device and sending it to another device in different_____.

(i) Channel (ii) Network

(iii) Path (iv) Area

3. DHCP stands for _____

(i) Data Hosting Computer Protocol

(ii) Dynamic Host Computer Protocol

(iii) Dynamic Host Configuration Protocol

(iv) None of the above

4. Communications protocols cover _____.

(i) Authentication (ii) Error detection

(iii) Correction (iv) Above all

5. The receiver must be capable of accepting the_____.

(i) Protocol (ii) Message

(iii) Address (iv) Information

3-2 Fill in the blanks.

1. A _____ is a computer device that accesses a service made available by a server.
2. _____allow users to communicate using e-mail, newsgroups, etc.
3. Web browsers and web servers function together as a _____system.
4. A protocol defines _____ and _____ for communication between a sender and a receiver.
5. Routers connect multiple _____ together.
6. Every data packet has an _____ addresses.
7. IP addressing must be understood as part of the _____for conversations over the Internet.

8. Email stands for _____.
9. In a computer network, devices are connected through communication _____.
10. A _____ accesses a service made available by a server.

3-3 Write short answers.

1. How client and server communicate with each other?
2. What are the main components of communication?
3. How telephone addressing relate with network addressing?
4. What is the difference between static and dynamic IP?
5. Define communication channel.
6. Describe the working of web browser.
7. What is the difference between point-to-point and multipoint connection?
8. What is application sharing? Answer with the help of an example.
9. What are the advantages and disadvantages of star topology over bus topology?
10. In a client server model, is client software or hardware? Give reasons to support your answer.

3.4 Answer the following questions.

1. What is network topology? Describe bus, star, ring and mesh topologies with a diagram of each.
2. What is TCP/IP? Describe its five layers with their functions.
3. What are the advantages and disadvantage of star topology over bus topology?
4. What are the sizes of IPv4 and IPv6? Explain the method to calculate the size of these both standards.

Activity

Suppose your school receives 4 printers and 2 scanners. School administration is planning to install them over the network so that all school teachers and students can access them. You can make a diagrams similar to Figures 3-3 and 3-6 to propose the network where the printers and scanners can be used easily.