A-Level
Computer Science

Introduction to computer networks

Lesson Objectives

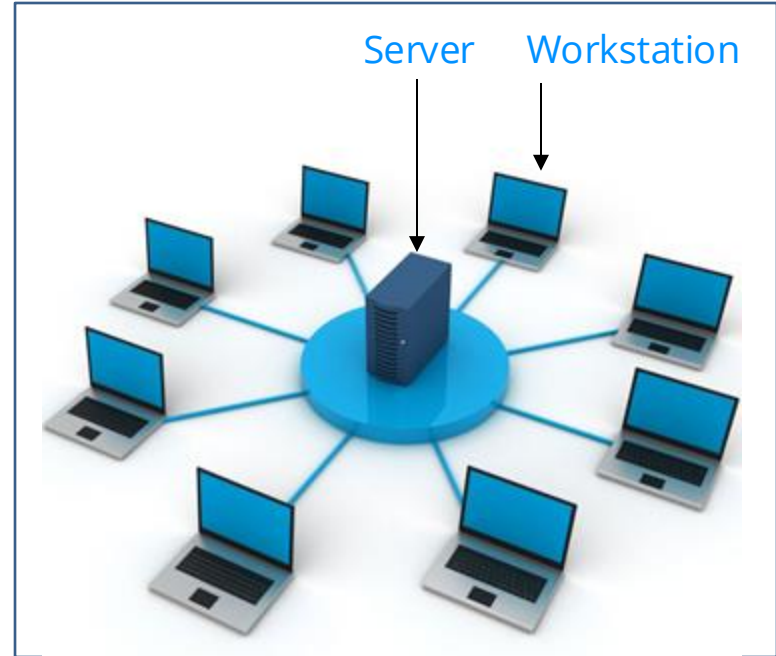Students will learn about:

- A network and its types

- Wired and wireless networks

- Hardware components required for networking

- Different types of routing

- Technologies to implement LAN

- Wi-Fi

1.

Content

Introduction

- Two or more devices are connected together using networks.

- Files are sent from one device to another in the form of data packets.

Server   Workstation

Data packets

- A file sent over a network is broken into small chunks of data known as data packets.

- These data packets are transmitted by the sender.

- At the receiver end, the file is rebuilt by arranging the data packets in order.

- Protocols define the set of rules that control the way the data is sent over the network.

Data packet

A data packet consists of:
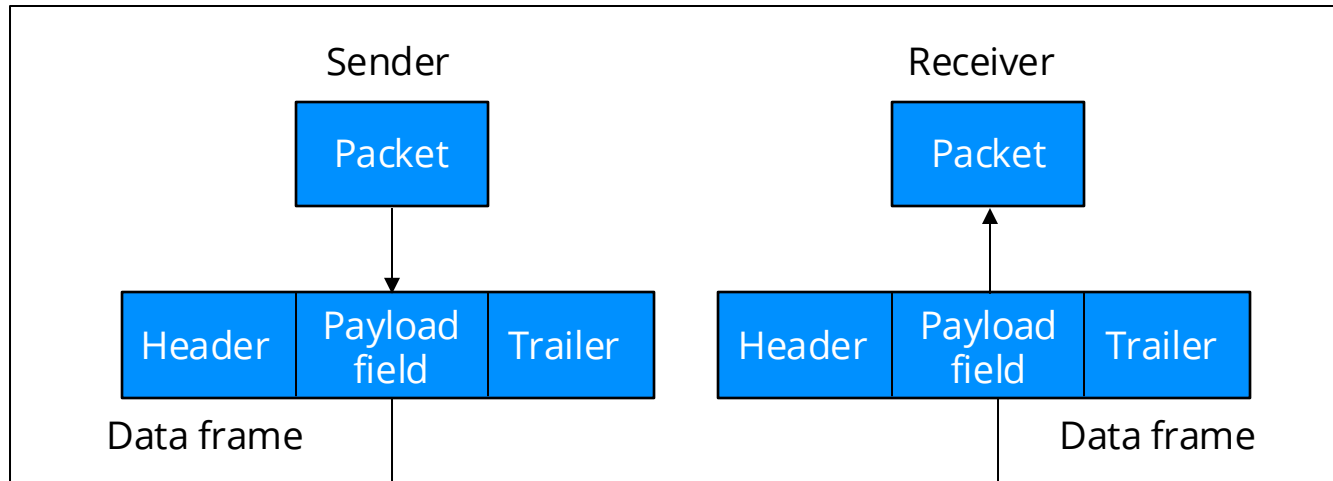
- Header
- Payload
- Trailer

Data packet:
Header

Part of packet	Contents	Function
Header	Sender's IP address	Sender's identity
	Receiver's IP address	Receiver's identity
	Protocol	Determines what type of data is sent. For example: e-mail, file, web page, etc.
	Packet number	The packets are segmented at the sender's end. At the receiver's end, the packets are rearranged in the correct order using a packet number.
	Length of packet	The length of data

Data packet:
Payload & trailer

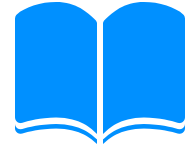| Part of packet	Contents	Function
Payload	Data	Data sent is sometimes padded with dummy information to ensure that the correct number of bytes are sent.
Trailer	End of packet marker	Indication that the end of packet has been reached.
	Error correction data	Error-checking data (CRC)

Data frames

	Sender			Receiver	
	Packet			Packet	
Header	Payload field	Trailer	Header	Payload field	Trailer
Data frame				Data frame	

Advantages and disadvantages of using networks

| Advantages of using networks	Disadvantages of using networks
• Communication • Monitoring user activity • Controlling and updating workstations • Roaming • Sharing information • Resource sharing • Software streaming	• Dependence • Security issues • Setting up hardware • Malware

Types of Networks

- *A network can be anything from a connection of two computers to millions of computers that are connected together worldwide using the Internet.*

- *Networks are classified based on the nature of the connection as LAN, WAN, PAN, MAN, SAN, WPAN, VPN.*
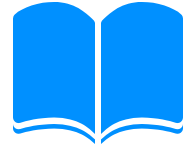
Local Area Network (LAN)

- Local Area Network (LAN) is a network of computers within the same building.

- These computers need not be connected to the Internet.

- **For example**: connection of computers in an office or school.

- A group of technicians install and maintain the network based on the network engineer's advice.
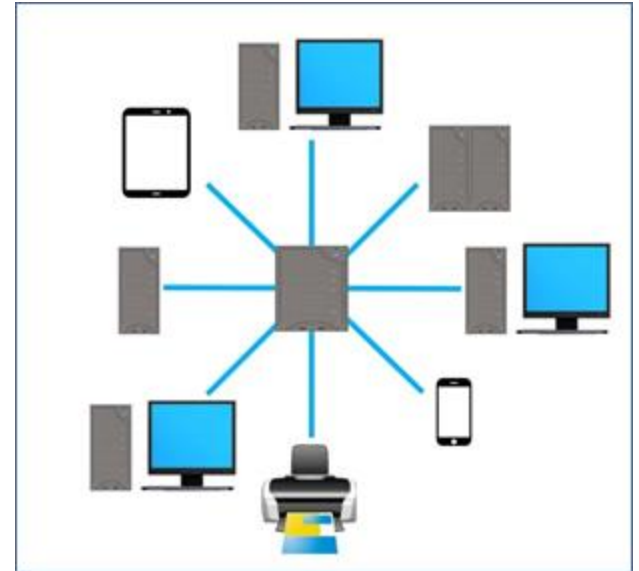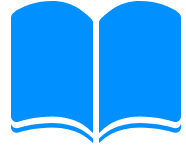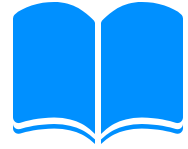
Wide Area Network (WAN)

- Wide Area Network (WAN) is a network of LANs in different geographical places, that is, connecting different cities in the world.

- For example: the Internet.

- This type of service is provided by telecom companies.

Other types of networks

- PAN: Personal Area Network (PAN) is a wired network used to connect personal devices in a home.

- MAN: Metropolitan Area Network (MAN) is used to connect devices in a city.

- SAN: A storage area network (SAN) provides servers that enable users to store files on a large scale.

Wireless Personal Area Network (WPAN)

- Wireless Personal Area Network (WPAN) is a short-distance wireless network to connect mobile computing devices such as smartphones to desktop machines.

- For example: A Bluetooth connection within devices in a car.

Virtual Private Network (VPN)

- A Virtual Private Network is a type of network that creates a safe and secure connection for an organisation over the Internet.

- Safety and security is provided by encryption algorithms.
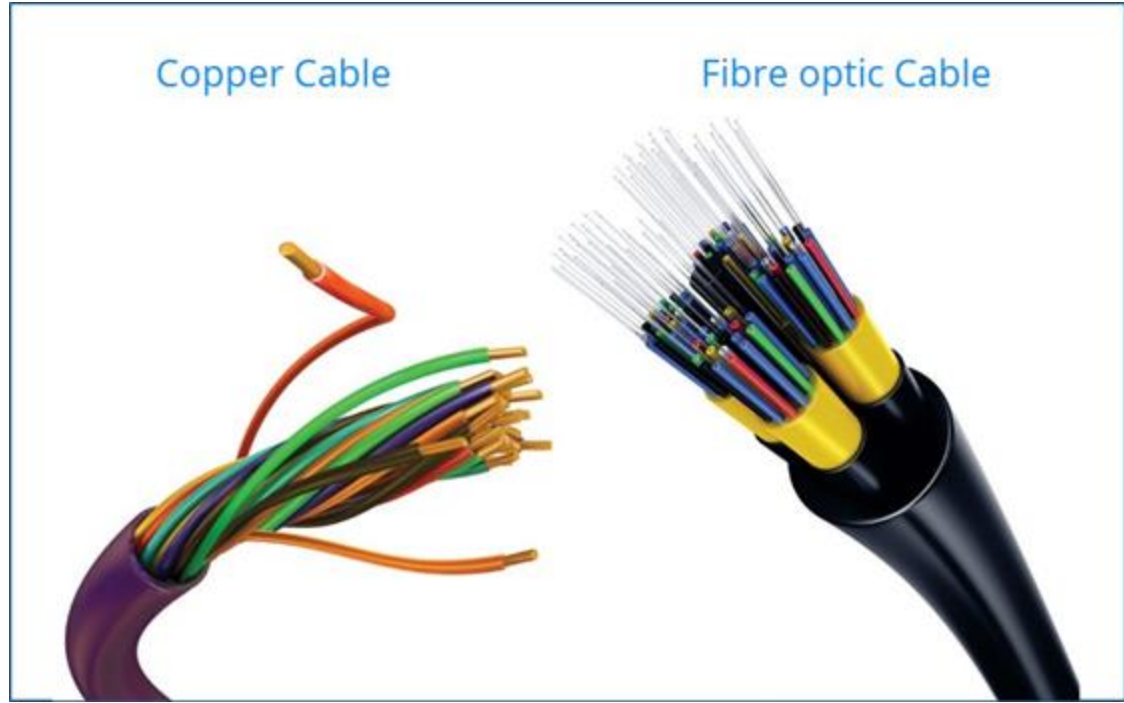
Types of network connections

Wired connection:

A wired network uses copper cables or fibre-optic cables to connect the components of a computer.

Wireless connection:

A wireless network uses radio signals to connect computers within its range.

18

Wired connection

Copper Cable   Fibre optic Cable

Copper cable

Digital data is sent in the form of electrical signals through copper cables.

Coaxial:

Cables need to be replaced from time to time, as the insulation may degrade.

Unshielded twisted pair: Copper cables are twisted around each other. The data transmission is fast and crosstalk is reduced. UTP is easy to install because of its thin and flexible nature.

Shielded twisted pair: Metal shielding is provided to twisted pair cables to reduce electromagnetic interference.

Copper cable

Advantages	Disadvantages
Telephones can be powered directly from this cable. Inexpensive to install.	Short lifetime.

Fibre-optic cables

- Fibre-optic cables are made of glass.

- The digital data is transmitted in the form of light signals using the principle of total internal reflection.

- At the receiver end, the light signals are decoded back to digital form.

Advantages

Long lifetime. Less electromagnetic interference when compared to that of copper cables.

Disadvantages

Expensive to install.

Wireless connection

- A wireless network uses radio signals to connect computers within its range.

- Computers need to have a wireless network interface card (NIC).

- A wireless router connects the computer with the physical network.

- A wireless adapter translates digital data into radio signals, and a wireless receiver translates radio signals into binary so that the computer can understand it.

| Advantages |
| --- |
| Cheap and easy to install. Multiple devices can be connected without any additional hardware. |

Disadvantages
Slower compared to a wired network. Quality is disrupted due to obstructions. Security issues such as hacking.

Device Address

- Data packets contain the information of sender and receiver such as the device address.

- Computers need a Network Interface Card (NIC) to connect to the Internet. NIC is a small circuit board that is a part of the motherboard. It is responsible for providing an electrical signal to send data over the network and for receiving incoming data. It also implements the required protocol for communication.

- Gaming consoles also contain NIC to connect to the Internet. Smartphones contain GSM chips to connect to telephone networks.

Device Address

- All devices in networks have a specific MAC address, which is assigned by its manufacturer.

- It consists of 48 bits and is written using 12 hexadecimal characters. A user cannot change the MAC address.
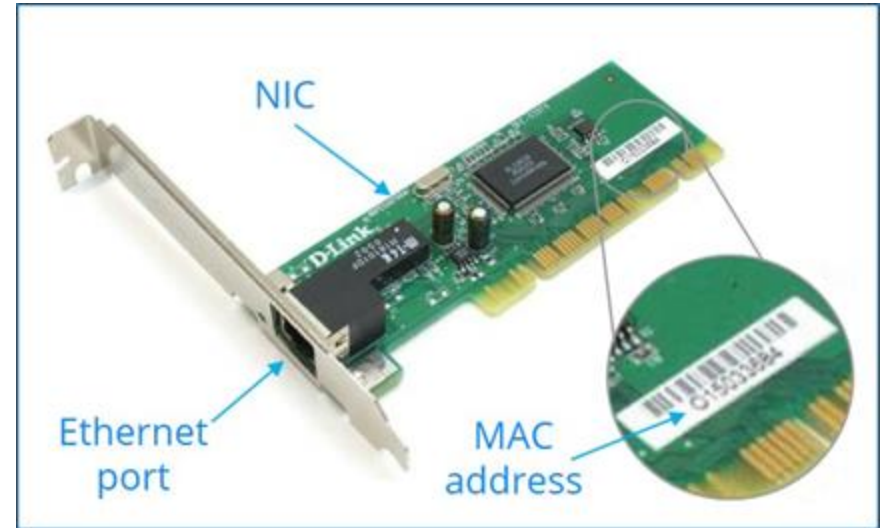
Network hardware

Hardware for networking

The various hardware used for networking are:

a) Routers

b) Gateway

c) Modem

d) Hubs

e) Switches

f) Bridges

g) Wireless Access Points (WAP)

Routers

- A router forwards data packets between computer networks until it reaches its destination.

- A router decides about the path in which the data packet has to be sent.

- Routers know the complete connection of the network and apply certain algorithms to find out the shortest path and fastest path (less congestion) to send the data packet.

- The act of traversing between a router to another across a network is called a hop.

- Devices within a building are connected using routers to form a LAN.

- Sometimes, a router has the capabilities of modem, hubs, switches and bridges in its hardware.

Gateway

- When a data packet transverses across a network that uses different protocols, hardware is required to translate the information.

- A gateway is used in such cases rather than a router.

- When a gateway receives a data packet, it removes the header to get the original data.

- According to the parameters of the new protocol of the other network, the original data is encapsulated.

Modem

- A modem turns digital data into an electrical signal.

- At the receiver side, another modem uses the electrical signal to recover the digital data.

- Multiple devices are connected to a router using hubs, switches and bridges.

- A modem-cum router is shown.

Hubs

- Hubs broadcast data from a device to all devices on its network irrespective of the requirement of the devices.

- This results in unnecessary data transfers.

- Hubs do not have a routing table and are unable to find the destination of the data packet.

- Hubs are used in small networks such as PAN as it is easy to set up and inexpensive compared to switches and routers.
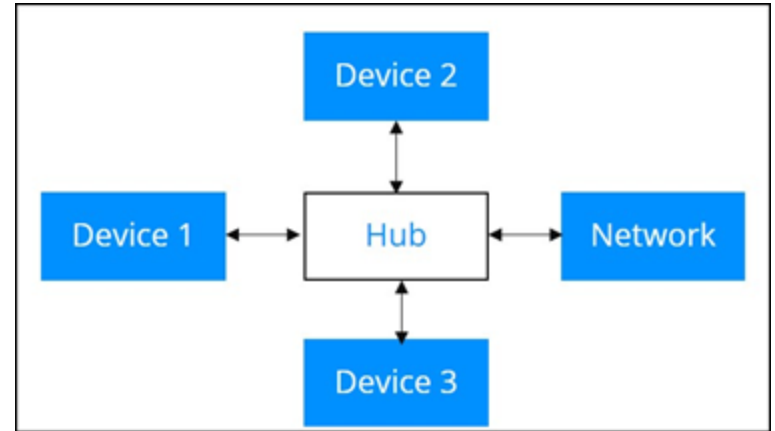
Switches

- Switches store the MAC address of devices on a network.
- It filters the data packets according to the MAC address and forwards it to a specific device.
- Switches are efficient and reduce unnecessary traffic.
- Switches are used in medium and large-scale networks.
- Switches are widely used for Ethernet installation where the required speed of transmission is 14480 packets per second.
- It can also be used in fast Ethernet connections where the required speed is 148800 packets per second.

Bridges

- A bridge connects two separate LAN networks.

- A computer with an operating system also acts as a bridge.

- Unnecessary data transfers are avoided as bridges check whether the receiver is present and whether it has already received this data before sending a data packet.

Wireless Access Points (WAP)

- WAP is network hardware that allows a wireless-capable device to connect to a wired network through a wireless standard such as Wi-Fi.

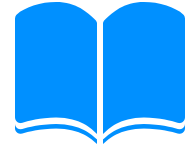- WAP connects to the router but, in most cases, it is in-built in the router.

Ethernet

- Ethernet is one of the technologies used to implement LANs since the 1980s.

- LAN is used to interconnect devices using a wired medium such as UTP copper cables or fibre-optic cables, hubs and switches.

- This technology provides a transmission rate of up to 100 Gb/s.
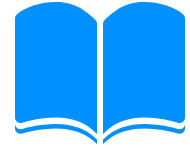
Ethernet network

- An Ethernet network is divided into various segments.

- Each segment has a UTP cable or fibre-optic cable that is shared among few devices.

- For example: in an organisation, the devices in the human resource department form a segment, devices in the engineering department form another segment, etc.

- Devices in a segment are expected to communicate with each other more often. As a result, the overall data collision of the network decreases and the performance of the network is enhanced.

Ethernet network

- Network interface card and routers segment data into frames.
- An error-checking mechanism is applied to the frames.
- Source and destination MAC addresses are also added to each of the frames.
- The receiver checks for errors in the frames, and in case of error, the sender is requested to resend the data packet.
- A frame is broadcast to all devices present on the Ethernet network.
- If the destination address matches with the receiver's address, the frame is accepted. Otherwise, the frame is discarded.

CSMA/CD

- In an Ethernet, if two data frames are transmitted at the same time, both the frames may collide with each other resulting in errors.

- CSMA/CD (Carrier-sense multiple access with collision detection) is a technology incorporated in LAN networks to overcome this issue.

- In CSMA/CD, the sender senses the channel before sending data frames. The data frames are only sent if the channel is sensed to be quiet.

- In case any transmission is in progress, the sender waits until the channel is available.
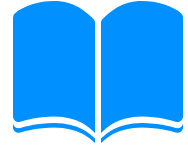
CSMA/CD

- In case two senders transmit at the same time, collision occurs and the data corrupts.

- In CSMA, the problem with the scenario is solved as the senders receive a corrupted form of data frame sent by them.

- Then, the senders wait for a random amount of time and resend the data.

- As the waiting time is different for both senders, data collision is avoided.

Disadvantages of Ethernet

- Length of cabling is limited.

- Limited size of segments results in more data packets and hence, more data collisions.

- CSMA/CD is not optimal when a large number of devices are present in a network. Therefore, a network is segmented and more switches are used.

Repeaters in Ethernet network

- Repeaters are devices that listen to signals in a particular segment of a network and resend them to other segments.

- This device is used when the length of a cable is not enough for a network.

Wi-Fi

- Wi-Fi is a technology that enables wireless connectivity to all sorts of devices such as laptops, tablets, smartphones, etc.
- The data is transmitted and received using radio signals.

> *With these developments we have every reason to anticipate that in a time not very distant most telegraphic messages across the oceans will be transmitted without cables. For short distances we need a "wireless" telephone, which requires no expert operators. The greater the spaces to be bridged, the more rational becomes communication without wires.*

–Nikola Tesla,

From "The Problem of Increasing Human Energy with Special References to the Harnessing of the Sun's Energy" in Century Illustrated Magazine (June 1900)

Let's review some concepts

LAN

Local Area Network (LAN) is a network of computers within the same building.

WAN

Wide Area Network (WAN) is a network of LANs in different geographical places, that is, connecting different cities in the world.

Wired connection

A wired network uses copper cables or fibre-optic cables to connect the components of a computer.

Wireless connection

A wireless network uses radio signals to connect computers within its range.

Hardware for networking
Routers
Gateways
Modem
Hubs
Switches
Bridges
Wireless Access Points (WAP)

Cyclic redundancy check (CRC)

CRC is a mechanism to detect errors in a data packet. Extra information is generated from the data using an algorithm.

Let's review some concepts

Wi-Fi

Wi-Fi is a technology that enables wireless connectivity to all sorts of devices such as laptops, tablets, smartphones, etc. using radio signals.

Channel

A waveband can be separated into several channels. A channel is a communication link to send and receive data.

Encryption

Encryption is the process of changing the data into another form or code so that only people with access to a secret key or password can read it.

CSMA/CA

Carrier Sense Multiple Access with Collision Avoidance is a protocol used to transmit packets in WiFi.

RTS/ CTS signals

Hidden nodes problem is avoided using the Request to Send and Clear to Send signals.

Security

WPA2: Each network is identified by a 32-character code Service Set Identifier (SSID).

MAC whitelists maintained by the network administrators.

2.

Activities

Activity-1

Duration: 10 minutes

1. In the table, different types of networks are given. Complete the table by stating where each network is used.

Types of network	Where is it used?
LAN	
WAN	
MAN	
PAN	
SAN	
WPAN	
VPN	

Activity-2

Duration: 15 minutes

1. In the table, different types of network hardware is given. Complete the table by stating the function of each network hardware.

Network hardware	Function
Routers	
Hub	
Switches	
Modem	
Bridges	
Wireless Access point	

Activity-3
Duration: 20 minutes

1. Complete the 'to', 'from' and 'message' fields in the data packet below. You may send a message to any student in your class. In the message field, fill in a letter per box. Do not choose the receiver to be someone sitting next to you.

To:					
From:					
Message					
Hop limit:					

Activity-3
Duration: 20 minutes

2. Hop limit is set to any value between 0 and 255 by the Internet Protocol according to the geographical locations of the sender and receiver. Every time it passes through a router, the hop limit is decremented by 1.

When a router receives it, it checks the value of this hop count. If the hop count is greater than 0, it passes it to the next router. If the value is 0, the message is discarded.

Choose any number between 1 and 9. Add 2 to this number and fill in the data packet. This is the hop limit.

Activity-3
Duration: 20 minutes

3. Now, it's time to send the message to the receiver of this message. Pass it to any student near you, who may pass this message to the receiver. Do not stand from your place.

4. At this step, you would have received someone else's message. You act as a router. Decrease the hop limit by 1, strike the old hop limit and write down the new hop limit in the data packet. Do not erase the old hop limit. Pass this message to another student. Do not stand from your place.

Activity-3
Duration: 20 minutes

5. Continue passing messages that you receive if you are not its intended receiver. If you receive any message with a hop limit of 0, give it to the teacher.