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These complete notes have been made for class 12th board computer science exam.

11.Data Communication

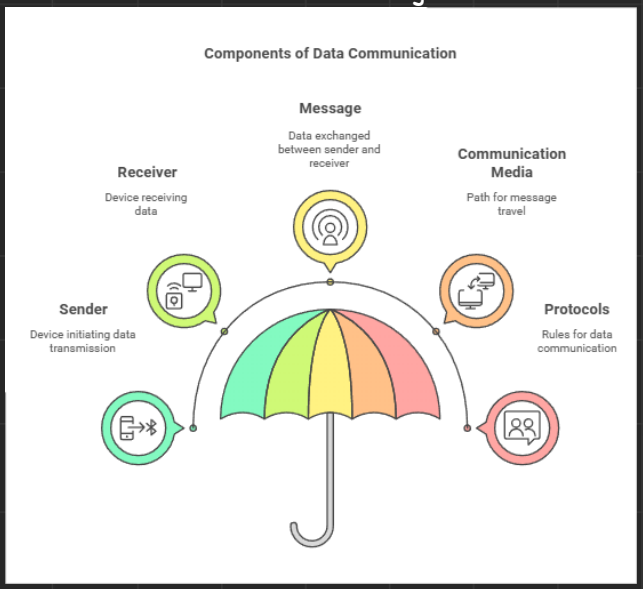
Concept of Communication

The term "Data Communication" comprises two words: Data and Communication. Data can be any text, image, audio, video, and multimedia files. Communication is an act of sending or receiving data. Thus, data communication refers to the exchange of data between two or more networked or connected devices. These devices must be capable of sending and receiving data over a communication medium. Examples of such devices include personal computers, mobile phones, laptops, etc.

Components of Data Communication

Five key components of data communication:

1. **Sender** - A sender is a computer or any such device which is capable of sending data over a network. It can be a computer, mobile phone, smartwatch, walkietalkie, video recording device, etc. (e.g., computer, mobile phone, smartwatch).
2. **Receiver** - A receiver is a computer or any such device which is capable of receiving data from the network. It can be any computer, printer, laptop, mobile phone, television, etc. In computer communication, the sender and receiver are known as nodes in a network. (e.g., printer, laptop, TV).
3. **Message** - It is the data or information that needs to be exchanged between the sender and the receiver. Messages can be in the form of text, number, image, audio, video, multimedia, etc. (text, numbers, images, video, etc.).
4. **Communication Media** - It is the path through which the message travels between source and destination. It is also called medium or link which is either wired or wireless. For example, a television cable, telephone cable, ethernet cable, satellite link, microwaves, etc. (wired or wireless).
5. **Protocols** - It is a set of rules that need to be followed by the communicating parties in order to have successful and reliable data communication. You have already come across protocols such as Ethernet and HTTP. (e.g., Ethernet, HTTP).



Measuring Capacity of Communication Media

- **Bandwidth** – Bandwidth of a channel is the range of frequencies available for transmission of data through that channel. Higher the bandwidth, higher the data transfer rate. Normally, bandwidth is the difference of maximum and minimum frequency contained in the composite signals. Bandwidth is measured in Hertz (Hz).

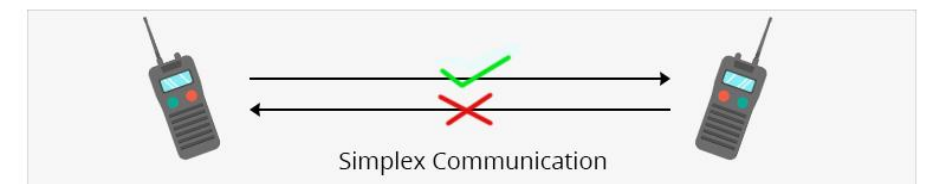
  1 KHz =1000 Hz
  1 MHz =1000 KHz = 1000000 Hz

- **Data Transfer Rate** – The number of bits transmitted per second (bps). Units:
  Data travels in the form of signals over a channel. One signal carries one or more bits over the channel. Data transfer rate is the number of bits transmitted between source and destination in one second. It is also known as bit rate. It is measured in terms of bits per second (bps). The higher units for data transfer rates are:
  - 1 Kbps = 1024 bps
  - 1 Mbps = 1024 Kbps
  - 1 Gbps = 1024 Mbps
  - 1 Tbps = 1024 Gbps

Types of Data Communication

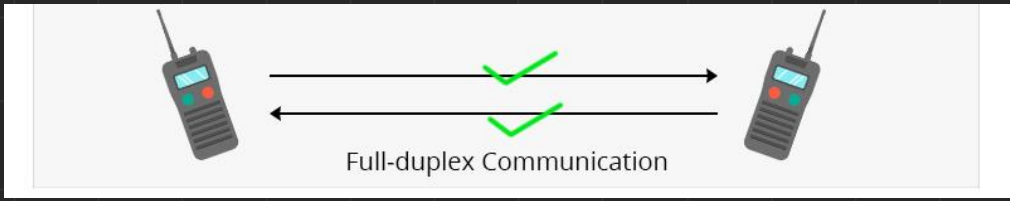
Data communication refers to the transfer of data between devices through a communication channel. It can be classified into three main types: **Simplex, Half-Duplex, and Full-Duplex** communication. Let's explore them with real-life examples to make it interesting

1. **Simplex Communication** – This is a one-way communication system where data flows in a single direction only, meaning there is no possibility of a response from the receiver. It is similar to a one-way street where vehicles can only move in one direction. Examples include a keyboard sending input to a computer or a radio station broadcasting signals to listeners. The sender does not expect any feedback from the receiver in this mode.



2. **Half-Duplex Communication** – In this type, data transmission occurs in both directions, but not simultaneously. It works like a walkie-talkie, where only one person can talk at a time while the other listens. The communication medium is shared, so devices take turns to send or receive data. This is often used in systems where a reply is necessary, but both parties cannot communicate at the same time, such as police radios or two-way intercoms.

3. **Full-Duplex Communication** – This is the most advanced form, allowing data to be sent and received simultaneously in both directions. It works just like a telephone conversation, where both people can talk and listen at the same time without waiting for their turn. Full-duplex systems improve efficiency and speed as they enable continuous communication without interruptions. Examples include mobile phone networks and fiber optic internet connections.



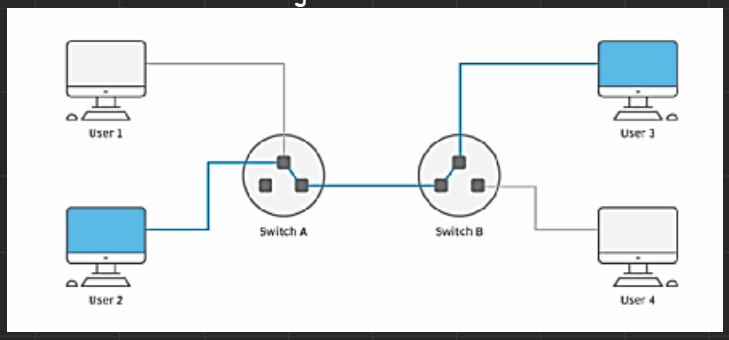
Switching Techniques

Switching allows efficient data transfer in networks. Two common types:

≈ Circuit Switching

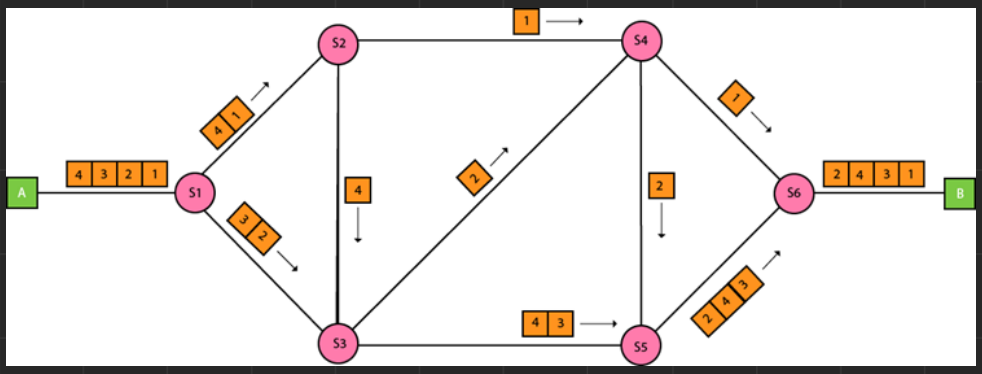
Circuit switching is like making a **phone call**—a dedicated communication path is established between the sender and receiver before data transfer begins. This means that all data follows the same route, ensuring a reliable and continuous connection.

Traditional **telephone networks** use circuit switching, where a call reserves a fixed bandwidth for the entire duration, even if no one is speaking. While this guarantees quality, it is inefficient because the reserved path remains blocked, even when no data is being transmitted.



≈ Packet Switching

Packet switching is the backbone of the **Internet** and modern data communication. Unlike circuit switching, data is divided into smaller packets, and each packet travels **independently** through the network. These packets take different routes and are reassembled at the destination. This makes the system highly **efficient, flexible, and fault-tolerant**. If a network path fails, packets can be rerouted dynamically. However, since multiple users share the same network resources, occasional delays or packet loss can occur, which is why technologies like **TCP/IP** help ensure reliable transmission.



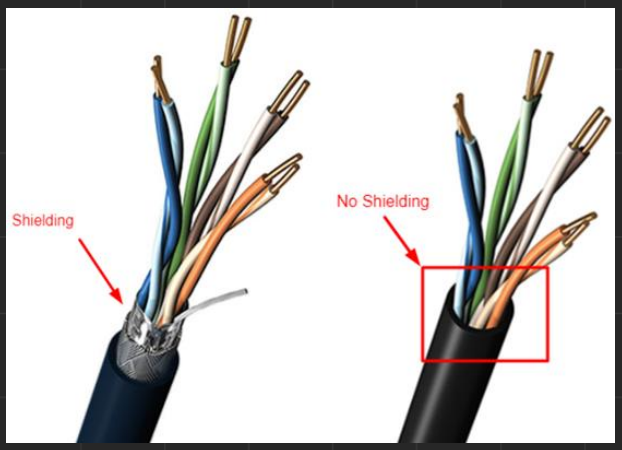
Transmission Media

A transmission medium can be anything that can carry signals or data between the source (transmitter) and destination (receiver). For example, as we switch on a ceiling fan or a light bulb, the electric wire is the medium that carries electric current from switch to the fan or bulb. In data communication, transmission media are the links that carry messages between two or more communicating devices. Transmission can be classified as **guided** or **unguided.**

Guided (Wired) Transmission Media:

In guided transmission, there is a physical link made of wire/cable through which data in terms of signals are propagated between the nodes. These are usually metallic cable, fiber-optic cable, etc. They are also known as wired media.
Three commonly used guided/wired media for data transmission are, twisted pair, coaxial cable, and fiber optic cable. Twisted-pair and coaxial cable carry the electric signals whereas the optical fiber cable carries the light signals.

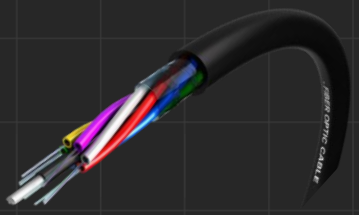
1. **Twisted Pair Cable –** A twisted-pair consists of two copper wires twisted like a DNA helical structure. Both the copper wires are insulated with plastic covers. Usually, a number of such pairs are combined together and covered with a protective outer wrapping. Each of the twisted pairs act as a single communication link. The use of twisted configuration minimises the effect of electrical interference from similar pairs close by. Twisted pairs are less expensive and most commonly used in telephone lines and LANs. These cables are of two types: Unshielded twisted-pair (UTP) and Shielded twisted-pair (STP).



   Types of Twisted Pair Cable:
   - **Unshielded Twisted Pair (UTP)** – Common in LANs.
   - **Shielded Twisted Pair (STP)** – Shielded to prevent interference.

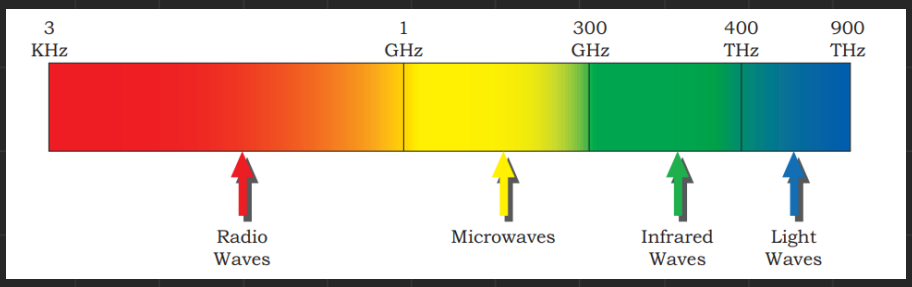
2. **Coaxial Cable –** Coaxial cable is another type of data transmission medium. It is better shielded and has more bandwidth than a twisted pair. it has a copper wire at the core of the cable which is surrounded with insulating material. The insulator is further surrounded with an outer conductor (usually a copper mesh). This outer conductor is wrapped in a plastic cover. The key to success of coaxial cable is its shielded design that allows the cable's copper core to transmit data quickly, without interference of environmental factors. These types of cables are used to carry signals of higher frequencies to a longer distance.

3. **Optical Fiber Cable** – The optical fiber cable carries data as light, which travels inside a thin fiber of glass. Optic fiber uses refraction to direct the light through the media. A thin transparent strand of glass at the center is covered with a layer of less dense glass called cladding. This whole arrangement is covered with an outer jacket made of PVC or Teflon. Such types of cables are usually used in backbone networks. These cables are of light weight and have higher bandwidth which means higher data transfer rate. Signals can travel longer distances and electromagnetic noise cannot affect the cable. However, optic fibers are expensive and unidirectional. Two cables are required for full duplex communication.



Unguided (Wireless) Transmission Media:

In wireless communication technology, information In wireless communication technology, information travels in the form of electromagnetic signals through air. Electromagnetic spectrum of frequency ranging from 3 KHz to 900 THz is available for wireless communication (Figure 11.12). Wireless technologies allow communication between two or more devices in short to long distance without requiring any physical media. There are many types of wireless communication technologies such as Bluetooth, WiFi, WiMax etc. The electromagnetic spectrum range (3KHz to 900THz) can be divided into 4 categories (Figure 11.12) – Radio waves, Microwaves, Infrared waves and Visible or Light waves, according to their frequency ranges. Some of the properties of each wave are listed in Table of these, three are useful for wireless communication.



1. **Radio Waves** – Omni-directional, used in AM/FM radio, TV, and cordless phones.
2. **Microwaves** – High-frequency waves used in satellite communication and mobile networks.
3. **Infrared Waves** – Used for short-range communication (e.g., TV remotes, Bluetooth).

Transmission Waves	Properties
Radio Waves	1. Waves of frequency range 3 KHz – 1 GHz 2. Omni-directional, these waves can move in all directions 3. Radio waves of frequency 300KHz-30MHz can travel long distance 4. Susceptible to interference 5. Radio waves of frequency 3-300KHz can penetrate walls 6. These waves are used in AM and FM radio, television, cordless phones.
Microwaves	1. Electromagnetic waves of frequency range 1GHz – 300GHz. 2. Unidirectional, can move in only one direction. 3. Cannot penetrate solid objects such as walls, hills or mountains. 4. Needs line-of-sight propagation i.e. both communicating antenna must be in the direction of each other. 5. Used in point-to-point communication or unicast communication such as radar and satellite. 6. Provide very large information-carrying capacity.
Infrared waves	1. Electromagnetic waves of frequency range 300GHz – 400THz. 2. Very high frequency waves. 3. Cannot penetrate solid objects such as walls. 4. Used for short-distance point-to-point communication such as mobileto-mobile, mobile-to-printer, remote-control-to-TV, and Bluetoothenabled devices to other devices like mouse, keyboards etc.

Wireless Technologies

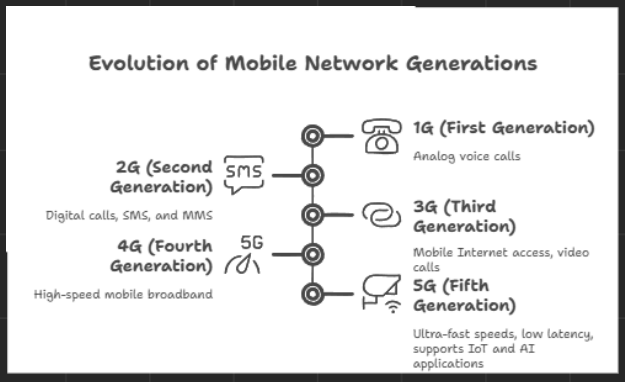
- Bluetooth – Short-range communication (up to 10 meters). Forms small networks called piconets.
  Bluetooth is a short-range wireless technology that can be used to connect mobile-phones, mouse, headphones, keyboards, computers, etc. wirelessly over a short distance. One can print documents with Bluetooth – enabled printers without a physical connection. All these bluetooth-enabled devices have a low cost transceiver chip. This chip uses the unlicensed frequency band of 2.4 GHz to transmit and receive data. These devices can send data within a range of 10 meters with a speed of 1 – 2 Mbps. In Bluetooth technology,
  the communicating devices within a range of 10 meters build a personal area network called piconet. The devices in a piconet work in a master-slave configuration. A master device can communicate with up to 7 active slave devices at the same time. Bluetooth technology allows up to 255 devices to build a network. Out of them, 8 devices can communicate at the same time and remaining devices can be inactive, waiting for a response command from the master device

- **Wi-Fi (Wireless LAN) -** Wireless networking for Internet access using Access Points (APs).
  This is another way of wireless communication. Wireless LAN is a local area network (LAN), and it is a popular way to connect to the Internet. The international organization IEEE assigns numbers to each different standards of LAN. The wireless LAN is number as 802.11, and it is popularly known as Wi-Fi. These networks consist of communicating devices such as laptops and mobile phones, as well as the network device called **APs (access points)** which is installed in buildings or floors.
  An access point is a device that is used to create a wireless local area network, by connecting to a wired router, switch, or hub. The APs are connected to a wired network, and all the devices communicate or access the Internet through an access point
  Wi-Fi gives users the flexibility to move around within the network area while being connected to the network.
  Following are some of the benefits of WLAN:
    - ≈ Wireless connections can be used to extend or replace an existing wired infrastructure.
    - ≈ Resulted in increased access for mobile devices.
    - ≈ Provides easy access to the Internet in public places

- **WiMax -** Similar to Wi-Fi but covers larger areas (used in MANs).

Mobile Telecommunication Technologies

The architecture of the mobile network has rapidly evolved over the last few decades. The different landmark achievements in mobile communication technologies are classified as different generations. They are identified as 1G, 2G, 3G, 4G, and 5G. Let us briefly discuss the mobile telecommunication generations.



≈ The first generation (1G) mobile network system came around 1982. It was used to transmit only voice calls. The analog signals were used to carry voices between the caller and receiver.

≈ The second generation (2G) mobile network system came around 1991. Instead of analog signals, voice calls were transmitted in digital form thus providing improved call quality. This increased capacity allowed more people to talk simultaneously, and led to improved security as the signals could be encrypted. It also enabled an additional service to send SMS and MMS (Multimedia messages).

≈ The third generation (3G) mobile network technology was developed during late 90s, but it was introduced commercially around 2001. It offered both digital voice and data services. 3G provided Internet access via the same radio towers that

provide voice service to the mobile phone. It facilitated greater voice and data capacity. Therefore, more simultaneous calls could happen in the same frequency range and also a significantly faster data transfer speed.

≈ Demand for faster data is always increasing and thus 4G mobile networks were developed and now 5G networks have also come into being. 4G is much faster than 3G and this has revolutionised the field of telecommunication by bringing the wireless experience to a new level altogether. 4G systems support interactive multimedia, voice, video, wireless internet and other broadband services. Technologically, 4G is very different compared to 3G.

≈ The fifth generation or 5G is currently under development. It is expected to be a milestone development for the success of IoT and Machine to Machine (M2M) communications. Machine to machine (M2M) is direct communication between devices – wired and wireless. 5G is expected to allow data transfer in Gbps, which is much faster than 4G. It is expected to be able to support all the devices of the future such as connected vehicles and the Internet of Things.

Protocols in Data Communication

In communication, Protocol is a set of standard rules that the communicating parties – the sender, the receiver, and all other intermediate devices need to follow.

Protocols also define:

- how computers identify one another on a network.
- the form to which the data should be converted for transit.
- how to decide whether the data received is for that node or to be forwarded to another node.
- ensuring that all the data have reached the destination without any loss.
- how to rearrange the packets and process them at the destination.

1. **HyperText Transfer Protocol (HTTP) –**

   HTTP stands for HyperText Transfer Protocol. It is the primary protocol used to access the World Wide Web. Tim Berners-Lee led the development of HTTP at CERN in 1989 in collaboration with Internet Engineering Task Force (IETF) and the World Wide Web Consortium (W3C).

   HTTP is a request-response (also called clientserver) protocol that runs over TCP. The common use of HTTP is between a web browser (client) and a web server (server). HTTP facilitates access of hypertext from the World Wide Web by defining how information are formatted and transmitted, and how the Web servers and browsers should respond to various commands.

   A web page is written using a markup language like HTML and is stored on a web server for access via its URL. Once a user opens a web browser and types in the URL of the intended web page, a logical communication link between the user machine (client) and the web server is created using HTTP.

For example, whenever we enter the URL http// www.ncert.nic.in in a browser, it sends HTTP request to the web-server where ncert.nic.in is hosted. The HTTP response from the web-server fetches and sends the requested Web-page, which is displayed on your browser.

2. **File Transfer Protocol (FTP) –** Used for transferring files over the Internet.
   File Transfer Protocol (FTP) is the protocol used for transferring files from one machine to another. Like HTTP, FTP also works on a client-server model.
   When a user requests for a file transfer with another system, FTP sets up a connection between the two nodes for accessing the file. Optionally, the user can authenticate using user ID and password. The user then specifies the file name and location of the desired file. After that, another connection sets up and the file transfer happens directly between the two machines. However, some servers provide FTP logins without authentication for accessing files.
   File transfer between two systems seems simple and straightforward because FTP takes care of issues between two communicating devices, such as: •
   - use of different conventions while naming files.
   - representation of text and data in different formats.
   - having different directory structure

3. **Point-to-Point Protocol (PPP) –** Used for direct communication between two devices.
   PPP is a communication protocol which establishes a dedicated and direct connection between two communicating devices. This protocol defines how two devices will authenticate each other and establish a direct link between them to exchange data. For example, two routers with direct connection communicate using PPP. The Internet users who connect their home computers to the server of an Internet Service Provider (ISP) through a modem also use PPP. The communicating devices should have duplex modes for using this protocol. This protocol maintains data integrity ensuring that the packets arrive in order. It intimates the sender about damage or lost packets and asks to resend it.

4. **Simple Mail Transfer Protocol (SMTP) –** Protocol for sending emails.
   SMTP is a protocol used for email services. It uses information written on the message header (like an envelope on a letter sent by post), and is not concerned with the content of the email message. Each email header contains email addresses of recipients. The email containing header and body are entered into a queue of outgoing mails. The SMTP sender program takes mails from the outgoing queue and transmits them to the destination(s). When the SMTP sender successfully delivers a particular mail to one or more destinations, it removes the corresponding receiver's email address from the mail's destination list. When that mail is delivered to all the recipients, it is removed from the outgoing queue. The SMTP receiver program accepts each mail that has arrived and places it in the appropriate user mailbox

5. **Transmission Control Protocol/Internet Protocol (TCP/IP)** – Standard protocol for Internet communication.
   TCP/IP stands for Transmission Control Protocol/ Internet Protocol. It is a set of standardised rules that uses a client-server model of communication in which a user or machine (a client) requests a service by a server in the network.
   The IP protocol ensures that each computer or node connected to the Internet is assigned an IP address, which is used to identify each node independently. It can be considered to be the adhesive that holds the whole Internet together. TCP ensures that the message or data is broken into smaller chunks, called IP packets. Each of these packets are routed (transmitted) through the Internet, along a path from one router to the next, until it reaches the specified destination. TCP guarantees the delivery of packets on the designated IP address. It is also responsible for ordering the packets so that they are delivered in sequence.
   There are many redundant connection paths in the Internet, with backbones and ISPs connecting to each other in multiple locations. So, there are many possible paths between two hosts. Hence, two packets of the same message can take two different routes depending on congestion and other factors in different possible routes. When all the packets finally reach the destination machine, they are reassembled into the original message at the receiver's end.

Summary

- Data communication involves exchanging data between networked devices.
- Communication can be **simplex, half-duplex, or full-duplex**.
- Transmission media can be **wired (twisted pair, coaxial, optical fiber) or wireless (radio, microwave, infrared)**.
- **Switching techniques** include **circuit switching and packet switching**.
- **Mobile networks** have evolved from **1G to 5G**.
- **Common protocols** include **HTTP, FTP, PPP, SMTP, and TCP/IP**.

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