PART A (2-marks)

Topic	Appeared In	Times
What is Data Communication? (incl. characteristics/components)	Dec21, Dec22, Dec24, May21, May22, May23, May24	**7**
What is TCP/IP?	Dec21, Dec22, Dec23, May22, May23, May24	**6**
Modem (define/what is)	Dec21, Dec22, May22, May23, May24	**5**
ATM (Layer/cell/what is ATM)	Dec21, Dec22, Dec24, May22, May24	**5**
ISDN	Dec21, Dec22, Dec23, Dec24, May23	**5**
Ethernet	Dec22, Dec24, May21, May22, May24	**5**
Error control / detection / correction	Dec21, Dec23, May21, May23, May24	**5**
Digital Network	Dec24, May21, May23, May24	**4**
Broad Band	Dec24, May21, May23, May24	**4**
Packet switching	Dec21, Dec24, May21	3
Multiplexing	Dec22, May21, May22	3
Bridge / Bridges	Dec21, Dec23, May23	3
Topology	Dec21, Dec22	2
Gateway	Dec21, Dec22	2
Router	Dec22, May21	2
WWW	Dec24, May21	2
Full duplex	Dec24, May21	2
Unguided Media	Dec24, May21	2
Switching (general)	May21, May24	2
Application Layer	May22, May24	2
Connectionless services	May22, May24	2
Message switching	May22, May23	2

PART B (5 marks)

Topic	Appeared In	Times
Analog & Digital signals / transmission (explain or compare)	Dec21, Dec22, Dec24, May21, May22, May24	**6**
Error Control	Dec22, Dec24, May21, May22, May24	**5**
ATM Topology / ATM protocol	Dec21, Dec22, Dec24, May21, May24	**5**

Topic	Appeared In	Times
Transmission modes (parallel & serial)	Dec21, Dec23, Dec24, May21	4
Circuit switching	Dec21, Dec24, May21	3
Routing / Routing Algorithm	Dec22, Dec23, May22	3
TCP/IP reference model / TCP/IP Network	Dec22, Dec24, May21	3
Types of Multiplexing	Dec23, May22, May24	3
FDDI	Dec24, May21, May23	3
Bridges and Gateway (discuss both)	Dec21, May22, May24	3
ISDN Layers	May22, May24	2
Wireless Transmission	May22, May24	2

PART C (10 marks)

Topic	Appeared In	Times
OSI Model with neat diagram	Dec24, May21, May22, May24	**4**
Multiplexing — types / frequency division / application	Dec21, Dec22, Dec24, May21, May22	**5**
Connection-oriented & connectionless services	Dec24, May21, May22, May24	**4**
Guided & unguided media (transmission/examples)	Dec21, Dec22, May23	3
ATM (cells / architecture / topology)	Dec22, May22, May24	3
Data communication process	Dec24, May21	2
Routing algorithm with examples	Dec24, May21	2
Parallel and serial transmission (with examples)	Dec22, May24	2
Circuit switching + SMDS	May22, May24	2
WWW & Repeaters (combined short notes)	Dec21, Dec22	2

2 Mark Answers

1. What is Data Communication?

Data communication refers to the exchange of data between two devices via some form of transmission medium such as a wire cable. It is a process of transferring digital or analog data from one device to another in the form of bits or signals.

Components of Data Communication:

1. **Message** – The information (data) to be communicated. It can be text, numbers, images, audio, or video.

2. **Sender** – The device that sends the data message. It can be a computer, workstation, telephone, etc.
3. **Receiver** – The device that receives the message. It can be a computer, workstation, telephone, etc.
4. **Medium** – The physical path through which the message travels from sender to receiver, e.g., twisted pair wire, coaxial cable, fiber optic cable, or radio waves.
5. **Protocol** – A set of rules that governs data communication. It represents an agreement between the communicating devices; without a protocol, two devices may be connected but not communicating.

Characteristics of effective data communication:

- **Delivery** – Data must be delivered to the correct destination.
- **Accuracy** – Data must be delivered accurately, without alteration.
- **Timeliness** – Data must be delivered in a timely manner (real-time or near real-time).
- **Jitter** – Uneven delay in packet delivery should be minimized, especially for audio/video data.

---

2. What is TCP/IP?

TCP/IP (Transmission Control Protocol/Internet Protocol) is a suite of communication protocols used to interconnect network devices on the internet. It is the fundamental communication language of the internet.

Structure: TCP/IP is generally described as a 4-layer model (as opposed to OSI's 7 layers):

1. **Network Interface/Link Layer** – Handles the physical transmission of data over the network hardware.
2. **Internet Layer** – Handles logical addressing and routing (main protocol: IP).
3. **Transport Layer** – Provides end-to-end communication (protocols: TCP for reliable, connection-oriented delivery; UDP for fast, connectionless delivery).
4. **Application Layer** – Provides network services directly to user applications (protocols: HTTP, FTP, SMTP, DNS).

Function:

- **IP** is responsible for addressing and routing packets between devices, ensuring each packet reaches the correct destination.
- **TCP** breaks data into packets, ensures reliable, ordered, and error-checked delivery, and reassembles packets at the destination.

TCP/IP is widely used because it is scalable, vendor-independent, and forms the backbone of internet communication.

---

3. What is a Modem?

A **Modem** (Modulator-Demodulator) is a hardware device that converts digital data from a computer into analog signals for transmission over telephone lines, and converts incoming analog signals back into digital data.

Working:

- **Modulation** – At the sender's end, the modem converts the digital signal generated by the computer into an analog signal suitable for transmission over analog media (like telephone lines).
- **Demodulation** – At the receiver's end, the modem converts the received analog signal back into digital form so the computer can understand it.

Types of Modems:

1. **Dial-up Modem** – Uses standard telephone lines; slow speed.
2. **DSL Modem** – Uses digital subscriber lines for high-speed internet.
3. **Cable Modem** – Uses cable TV lines for broadband internet.
4. **Wireless Modem** – Connects to wireless networks (3G/4G/5G).

Importance: Modems enable computers to communicate over telephone or cable networks by bridging the gap between digital computer systems and analog transmission media, forming the basis of dial-up and broadband internet access.

---

4. What is ATM? (Asynchronous Transfer Mode)

ATM is a high-speed, connection-oriented switching and multiplexing technology designed to carry a combination of voice, video, and data traffic over a single network using fixed-size packets called **cells**.

ATM Cell:

- Each ATM cell is exactly **53 bytes** in size:
- **5 bytes** – Header (contains routing/control information such as Virtual Path Identifier and Virtual Channel Identifier).
- **48 bytes** – Payload (actual user data).
- Fixed cell size allows for predictable, hardware-based switching, resulting in very high speed.

ATM Layers:

1. **Physical Layer** – Defines the transmission medium and bit transmission.
2. **ATM Layer** – Handles cell transfer, including flow control, cell header generation, and virtual circuit/path management.
3. **ATM Adaptation Layer (AAL)** – Converts data from upper layers into the 48-byte payload format and vice-versa.

Features:

- Connection-oriented (uses virtual circuits).
- Supports Quality of Service (QoS) for different traffic types.
- Suitable for integrating voice, video, and data on the same network (B-ISDN backbone technology).

---

5. What is ISDN? (Integrated Services Digital Network)

ISDN stands for **Integrated Services Digital Network**. It is a set of communication standards that allows the simultaneous digital transmission of voice, video, data, and other network services over traditional telephone lines.

Purpose: ISDN was developed to replace the analog telephone system with a fully digital network, enabling faster, higher-quality transmission of multiple types of data over a single line.

Types of ISDN:

1. **Narrowband ISDN (N-ISDN)**

- **BRI (Basic Rate Interface)** – 2 B-channels (64 kbps each for voice/data) + 1 D-channel (16 kbps for signaling). Used for homes/small offices.
- **PRI (Primary Rate Interface)** – 23 B-channels + 1 D-channel (64 kbps) in the US, or 30 B + 1 D in Europe. Used for larger organizations.

2. **Broadband ISDN (B-ISDN)**

- Supports very high data rates (up to hundreds of Mbps).
- Uses ATM as its underlying switching technology.
- Suitable for video conferencing, high-speed data transfer, and multimedia applications.

Advantages: Faster call setup, higher transmission speed than analog lines, ability to carry multiple channels of voice/data simultaneously.

---

6. What is Ethernet?

Ethernet is the most widely used **LAN (Local Area Network)** technology that defines wiring and signaling standards for the physical layer, and frame formats and protocols for the MAC (Media Access Control) sublayer of the data link layer, as specified by the **IEEE 802.3** standard.

Working Principle:

- Ethernet traditionally uses the **CSMA/CD (Carrier Sense Multiple Access with Collision Detection)** protocol.
- Before transmitting, a device "senses" the channel to check if it is free.
- If two devices transmit simultaneously, a collision occurs; both devices detect it, stop transmitting, wait a random time (backoff), and retransmit.

Ethernet Frame Format: Consists of Preamble, Destination Address, Source Address, Length/Type field, Data (payload), and CRC (error-checking field).

Types/Standards:

- **10Base-T** – 10 Mbps over twisted pair.
- **100Base-TX (Fast Ethernet)** – 100 Mbps.
- **1000Base-T (Gigabit Ethernet)** – 1000 Mbps.
- **10 Gigabit Ethernet** – used in backbone networks.

Advantages: Simple, cost-effective, reliable, easily scalable, and forms the backbone of most modern wired LANs.

---

7. Error Control / Detection / Correction

Error Control refers to mechanisms used to detect and correct errors that occur during data transmission due to noise, attenuation, or interference in the communication channel.

Types of Errors:

1. **Single-bit error** – Only one bit in the data unit is changed.
2. **Burst error** – Two or more bits in the data unit are changed (common in serial transmission).

Error Detection Methods:

1. **Parity Check** – A single parity bit is added to make the total number of 1s even (even parity) or odd (odd parity). Simple but cannot detect even numbers of bit errors.
2. **Checksum** – Data is divided into segments, summed, and the checksum is sent along with data; receiver recomputes and compares.
3. **Cyclic Redundancy Check (CRC)** – A polynomial-based method where a remainder (CRC value) is appended to data; the receiver divides the received data and checks if the remainder is zero.

Error Correction Methods:

1. **Forward Error Correction (FEC)** – Redundant bits (e.g., Hamming Code) are sent along with data so the receiver can detect and correct errors without retransmission.
2. **Retransmission (ARQ – Automatic Repeat Request)** – If an error is detected, the receiver requests retransmission of the corrupted data.

Effective error control ensures data integrity and reliability of communication over noisy channels.

---

8. What is a Digital Network?

A Digital Network is a communication network that transmits data in the form of **discrete digital signals (0s and 1s)** rather than continuous analog waveforms.

Characteristics:

- Data (text, voice, video) is converted into binary digital form before transmission.
- Uses digital switching and digital transmission equipment throughout the network.
- Includes technologies like ISDN, DSL, and modern fiber-optic/Ethernet-based networks.

Advantages over Analog Networks:

1. **Better noise immunity** – Digital signals can be regenerated exactly, reducing the effect of noise and distortion.
2. **Higher data rates** – Supports higher bandwidth and faster transmission.
3. **Data security** – Digital data can be easily encrypted.
4. **Integration** – A single digital network can carry voice, video, and data simultaneously (as in ISDN).
5. **Error detection/correction** – Easier to implement using digital coding techniques.

Example: The modern telephone backbone, internet infrastructure, and mobile networks (3G/4G/5G) are all built on digital network principles, replacing older analog systems.

---

9. What is Broadband?

Broadband refers to a **high-capacity, high-speed transmission technique** that uses a wide range of frequencies to transmit large amounts of data (voice, video, and data) simultaneously over a single medium.

Key Features:

1. **High bandwidth** – Supports much higher data transmission rates than traditional narrowband connections (e.g., dial-up).
2. **Multiple channels** – The frequency spectrum is divided into multiple channels using multiplexing (typically FDM), allowing several signals to travel simultaneously without interference.
3. **Always-on connectivity** – Unlike dial-up, broadband connections are typically continuous.
4. **Analog transmission** – Traditionally, broadband transmission is analog in nature, using techniques like FDM to carry multiple signals over one physical medium.

Types/Examples:

- **DSL (Digital Subscriber Line)**
- **Cable Broadband**
- **Fiber-optic Broadband (FTTH)**
- **Broadband Wireless / Satellite Broadband**

Applications: Used for high-speed internet access, video conferencing, streaming media, cable television distribution, and Broadband ISDN (B-ISDN) services.

---

10. What is Packet Switching?

Packet switching is a method of data transmission in which the message to be sent is divided into smaller units called **packets**, each of which is transmitted independently through the network and reassembled at the destination.

Working:

1. The message is broken into fixed or variable-sized packets.
2. Each packet contains a header with source, destination, and sequence information.
3. Packets may travel through different routes/paths across the network based on availability, and may arrive out of order.
4. At the destination, packets are reassembled in the correct sequence to reconstruct the original message.

Types:

1. **Datagram Packet Switching** – Each packet is treated independently and may follow a different route (connectionless).
2. **Virtual Circuit Packet Switching** – A logical path is established before data transfer, and all packets follow the same path (connection-oriented).

Advantages:

- Efficient use of bandwidth (multiple users can share the same links).
- Reduces the impact of a single link/node failure since packets can be rerouted.
- No dedicated path required, unlike circuit switching.

Example: The Internet uses packet switching (IP-based) for data transmission.

---

11. What is Multiplexing?

Multiplexing is a technique that allows multiple signals or data streams to be combined and transmitted simultaneously over a single shared communication channel or medium, thereby making efficient use of available bandwidth.

Need for Multiplexing: Installing a separate physical link for every pair of communicating devices is expensive and impractical; multiplexing allows several signals to share one link.

Types of Multiplexing:

1. **Frequency Division Multiplexing (FDM)** – The available bandwidth of the channel is divided into multiple non-overlapping frequency bands, and each signal is assigned a separate frequency band. Used for analog signals (e.g., radio, cable TV).
2. **Time Division Multiplexing (TDM)** – The channel's time is divided into slots, and each signal is assigned a time slot to transmit its data in turn. Used for digital signals.

- **Synchronous TDM** – Fixed time slots allocated regardless of whether a source has data to send.
- **Statistical (Asynchronous) TDM** – Time slots allocated dynamically based on need.

3. **Wavelength Division Multiplexing (WDM)** – Used in fiber optics; different signals are carried on different light wavelengths.

Demultiplexing is the reverse process at the receiver's end, separating the combined signal back into individual signals.

---

12. What is a Bridge?

A Bridge is a networking device that operates at the **Data Link Layer (Layer 2)** of the OSI model and is used to connect two or more LAN segments, forwarding data frames between them based on MAC addresses.

Functions:

1. **Segmentation** – Divides a large network into smaller segments to reduce collision domains and network congestion.
2. **Filtering** – Examines the destination MAC address of each frame and forwards it only to the segment where the destination device is located, rather than broadcasting to all segments.
3. **Learning** – Bridges build and maintain a table (MAC address table) by learning the source addresses of incoming frames, which improves forwarding efficiency over time.

Types of Bridges:

- **Transparent Bridge** – Automatically builds its address table without manual configuration.
- **Source Routing Bridge** – The source device determines the path the frame will take.
- **Translational Bridge** – Connects networks using different protocols (e.g., Ethernet to Token Ring).

Advantages: Reduces network traffic and collisions, extends the physical length of a network, and improves overall network performance compared to a single large LAN segment.

---

13. What is Topology?

Network Topology refers to the **arrangement or layout** of the various elements (nodes, links, devices) of a computer network, describing how devices are physically or logically connected to one another.

Types of Topology:

1. **Bus Topology** – All devices are connected to a single central cable (the "bus" or backbone). Simple and cheap, but a single cable failure disrupts the entire network.
2. **Star Topology** – All devices are connected to a central device (hub/switch). Easy to manage and troubleshoot, but failure of the central device brings down the network.
3. **Ring Topology** – Each device is connected to exactly two other devices, forming a circular data path. Data travels in one (or both) directions around the ring.
4. **Mesh Topology** – Every device is connected to every other device, providing high redundancy and reliability, but expensive and complex to install.
5. **Tree Topology** – A hybrid topology combining characteristics of star and bus topologies, arranged hierarchically.
6. **Hybrid Topology** – A combination of two or more different topologies.

Importance: The choice of topology affects the network's cost, reliability, scalability, and ease of maintenance.

---

14. What is a Gateway?

A Gateway is a networking device that acts as a "gate" between two networks that use **different protocols**, enabling communication between them by translating data from one protocol format to another.

Function:

- Operates typically at the higher layers of the OSI model (up to the Application Layer), unlike routers/bridges which operate at lower layers.
- Converts data formats, protocols, and communication standards so that dissimilar networks (e.g., a TCP/IP network and an SNA network) can exchange data.
- Often serves as the entry/exit point for traffic leaving or entering a local network to reach an external network like the internet.

Types of Gateways:

1. **Protocol Gateway** – Converts between different network protocols.
2. **Email Gateway** – Converts email messages between different formats.
3. **Cloud Gateway** – Manages traffic between on-premises infrastructure and cloud services.
4. **VoIP Gateway** – Converts voice signals between traditional telephone networks and IP networks.

Example: A home router often functions as a default gateway, connecting the internal LAN to the external internet (WAN).

---

15. What is a Router?

A Router is a networking device that operates at the **Network Layer (Layer 3)** of the OSI model and is responsible for forwarding data packets between different networks based on their IP addresses.

Functions:

1. **Routing** – Determines the best path for data packets to travel from source to destination across interconnected networks, using routing tables and routing algorithms/protocols (e.g., RIP, OSPF, BGP).
2. **Packet Forwarding** – Forwards packets to the appropriate next-hop network based on the destination IP address.
3. **Network Connection** – Connects multiple different networks (e.g., connecting a LAN to the Internet/WAN).
4. **Traffic Management** – Can perform functions like NAT (Network Address Translation) and basic firewall filtering.

How it Works:

- Maintains a **routing table** containing information about network destinations and the paths to reach them.
- When a packet arrives, the router examines its destination IP address, consults the routing table, and forwards the packet along the optimal path toward its destination.

Importance: Routers are essential for interconnecting different networks and form the backbone of the internet, enabling data to travel across multiple networks to reach its final destination.

---

16. What is WWW? (World Wide Web)

The World Wide Web (WWW) is a system of interlinked hypertext documents and multimedia content accessed via the Internet, using web browsers to view pages that may contain text, images, videos, and links to other pages.

Key Components:

1. **URL (Uniform Resource Locator)** – A unique address used to locate resources on the web.
2. **HTTP/HTTPS (HyperText Transfer Protocol)** – The protocol used to transfer web page data between clients (browsers) and servers.
3. **HTML (HyperText Markup Language)** – The standard language used to create and structure web pages.
4. **Web Browser** – Client software (e.g., Chrome, Firefox) used to access and display web pages.
5. **Web Server** – A server that stores and delivers web pages to clients upon request.

Architecture: The WWW follows a **client-server model**, where a client (browser) sends an HTTP request to a web server, and the server responds with the requested web page/resource, which is then rendered by the browser.

Significance: The WWW, invented by Tim Berners-Lee, revolutionized information sharing by making the internet accessible and usable for the general public through hyperlinked documents.

---

17. What is Full Duplex?

Full Duplex is a mode of data transmission in which data can be transmitted and received **simultaneously in both directions** between two communicating devices.

Characteristics:

- Both devices can send and receive data at the same time, using either two separate transmission paths or splitting the bandwidth of a single path between the two directions.
- Provides maximum utilization of the communication channel since both parties can transmit concurrently.

Comparison with Other Modes:

1. **Simplex** – Data flows in only one direction (e.g., television broadcast, keyboard-to-computer).
2. **Half-Duplex** – Data flows in both directions, but only one direction at a time (e.g., walkie-talkies).
3. **Full-Duplex** – Data flows in both directions simultaneously (e.g., telephone conversations).

Example: A telephone network is a classic example of full-duplex communication, where both parties can speak and listen to each other at the same time.

Advantage: Full-duplex significantly increases the effective throughput of a communication link since there is no need to wait for the other party to finish before responding.

---

18. What is Unguided Media?

Unguided (Wireless) Media refers to transmission media that does not use a physical conductor (like a wire or cable) to transmit signals; instead, signals travel through free space (air/vacuum) as electromagnetic waves.

Types of Unguided Media:

1. **Radio Waves** – Omnidirectional waves that can travel in all directions; used for AM/FM radio, cordless phones. Easily generated and can penetrate through walls.
2. **Microwaves** – Unidirectional waves requiring line-of-sight transmission (transmitter and receiver antennas must be aligned); used for long-distance telephone communication and satellite communication.
3. **Infrared Waves** – Short-range communication that cannot penetrate walls; used for remote controls and short-range device communication (e.g., TV remotes).

Characteristics:

- No physical medium required, making it suitable for mobile and hard-to-wire locations.
- Susceptible to interference, weather conditions, and eavesdropping compared to guided media.
- Signal strength decreases with distance (attenuation).

Applications: Mobile communication, satellite communication, Wi-Fi/wireless LANs, Bluetooth, and broadcast radio/television.

---

19. What is Switching (General)?

Switching is the technique used in a network to establish a path or connection between the sender and receiver, allowing data to be transferred efficiently through intermediate nodes (switches) rather than requiring a dedicated link between every pair of devices.

Need for Switching: In a large network, connecting every device directly to every other device (mesh) is impractical; switching allows shared use of network resources by dynamically establishing paths.

Types of Switching:

1. **Circuit Switching** – A dedicated physical communication path (circuit) is established between sender and receiver for the entire duration of the communication before data transfer begins (e.g., traditional telephone networks).
2. **Packet Switching** – Data is divided into packets, and each packet is routed independently through the network, without requiring a dedicated path (e.g., the Internet).
3. **Message Switching** – The entire message is sent as a single unit from source to destination, being stored and forwarded at each intermediate node ("store-and-forward").

Comparison:

- Circuit switching provides a fixed, dedicated path with guaranteed bandwidth but is inefficient if the channel is idle.
- Packet/message switching allows more efficient sharing of network resources but may introduce variable delay.

Switching is fundamental to how data moves efficiently across large, shared networks.

---

20. What is the Application Layer?

The Application Layer is the **topmost layer** of both the OSI model (Layer 7) and the TCP/IP model, responsible for providing network services directly to end-user applications.

Functions:

1. **User Interface** – Provides the interface through which users and application software access network services.
2. **Network Virtual Terminal** – Allows a user to log onto a remote host.
3. **File Transfer, Access, and Management (FTAM)** – Allows a user to access files on a remote host, retrieve files, and manage/control files.
4. **Mail Services** – Provides the basis for email forwarding and storage.
5. **Directory Services** – Provides distributed database sources for global information about various objects and services.

Common Application Layer Protocols:

- **HTTP/HTTPS** – Web browsing.
- **FTP** – File transfer.
- **SMTP** – Email sending.
- **DNS** – Domain name resolution.
- **Telnet** – Remote login.

Importance: This layer is the point of interaction between the network and the software applications used by end users, translating user actions into network requests and vice versa.

---

21. What is Connectionless Service?

Connectionless Service is a type of network communication in which data (packets) are sent from source to destination **without establishing a prior dedicated connection or session** between the communicating devices.

Characteristics:

1. Each packet (often called a datagram) is treated independently and contains full addressing information.
2. Packets may take different routes to reach the destination and may arrive out of order, or even be lost, since there's no guaranteed delivery mechanism.
3. No handshake or setup phase is required before data transmission begins, resulting in lower overhead and faster initial transmission.
4. The receiving end is responsible for reordering packets (if needed) and handling any missing data.

Example Protocol: UDP (User Datagram Protocol) is a classic example of a connectionless transport-layer protocol, commonly used for applications like video streaming, online gaming, and DNS queries where speed is prioritized over guaranteed delivery.

Comparison with Connection-Oriented Service:

- Connection-oriented (e.g., TCP) establishes a dedicated session before data transfer, ensures reliable, ordered delivery, but has higher overhead.
- Connectionless service is faster and simpler but less reliable, making it suitable for applications that can tolerate some data loss in exchange for speed.

22. What is Message Switching?

Message Switching is a network switching technique in which the entire message (not divided into packets) is sent as a complete unit from the source to the destination, using a **"store-and-forward"** mechanism at each intermediate node.

Working:

1. The sender transmits the complete message, along with the destination address, to the nearest intermediate switching node.
2. The intermediate node stores the entire message temporarily (usually on disk/storage) until the next link/node in the path is available.
3. Once the outgoing link is free, the node forwards the message to the next node, and this process repeats until the message reaches its final destination.
4. No direct/dedicated physical connection is required between the sender and receiver at any point in time.

Characteristics:

- No real-time interaction is required between sender and receiver (asynchronous communication).
- Since the entire message is stored at each node, it requires nodes with large storage capacity.
- Introduces higher delay due to store-and-forward processing at each hop, making it unsuitable for real-time applications.

Example: Early telegraph and email systems used message switching principles.

Comparison: Unlike packet switching (which breaks messages into smaller packets for more efficient and parallel transmission), message switching handles the entire message as a single indivisible unit, which is simpler but less efficient for large messages or real-time use.

Part B – 5 Marks

1. Analog & Digital Signals / Transmission

Analog vs. Digital Signals

Signals are representations of data transmitted from one point to another. They can be categorized into two primary types:

- **Analog Signal:**
  - Continuous waveform that changes smoothly over time.
  - Infinite number of values within a given range (e.g., human voice, temperature, light).
  - Highly susceptible to noise and signal degradation during long-distance transmission.
- **Digital Signal:**
  - Discrete time signals represented by binary values (0 and 1, or high and low voltage states).
  - Finite set of values.

- More resilient to noise; can be easily regenerated, filtered, and corrected using error-detection codes.

Analog vs. Digital Transmission

- **Analog Transmission:** Transports analog signals without regard to their content. The signal can be analog data or digital data converted into an analog carrier wave (using modulation techniques like AM, FM, PM). It degrades over distance, requiring amplifiers to boost the signal (which also amplifies background noise).
- **Digital Transmission:** Transports a stream of digital bits. Data can be native digital or analog data digitized via Pulse Code Modulation (PCM). It uses repeaters rather than amplifiers; repeaters regenerate a clean, exact duplicate of the digital pulse, eliminating accumulated noise.

2. Error Control

Error control refers to the techniques used to detect and correct errors that occur when data frames are transmitted over unreliable communication channels.

Key Mechanisms

1. **Error Detection:** Identifies whether errors have occurred during transmission. Common techniques include:
   - **Parity Checking:** Adds a single parity bit (even or odd) to a data block.
   - **Checksum:** An arithmetic sum of data items sent along with the packet; verified at the receiver.
   - **Cyclic Redundancy Check (CRC):** Uses binary division based on generator polynomials to create a robust checksum attached to the frame.
2. **Error Correction:** Recovers the original error-free data. This is done in two ways:
   - **Forward Error Correction (FEC):** The sender adds redundant error-correcting code (like Hamming codes or Reed-Solomon) so the receiver can detect and correct errors without retransmission.
   - **Automatic Repeat reQuest (ARQ):** The receiver detects an error and requests the sender to retransmit the corrupted frame.

Common ARQ Protocols

- **Stop-and-Wait ARQ:** Sender transmits one frame and waits for an acknowledgment (ACK) before sending the next.
- **Go-Back-N ARQ:** Sender can transmit multiple frames up to a window size without waiting for an ACK. If a frame fails, all subsequent frames in the window are retransmitted.
- **Selective Repeat ARQ:** Only the specific corrupted or lost frame is retransmitted, making bandwidth utilization much more efficient.

3. ATM (Asynchronous Transfer Mode) Topology & Protocol Architecture

Asynchronous Transfer Mode (ATM) is a cell-based switching technique designed to handle voice, video, and data simultaneously over high-speed networks.

ATM Topology

- ATM operates in a **star or mesh topology** using high-speed ATM switches.
- It is connection-oriented, meaning a dedicated virtual path must be established between the sender and receiver before data transfer begins using **Virtual Path Identifiers (VPI)** and **Virtual Channel Identifiers (VCI)**.

ATM Protocol Architecture (Reference Model)

The ATM architecture is modeled in three dimensions (planes):

1. **User Plane:** Manages data transfer, flow control, and error recovery.
2. **Control Plane:** Manages connection establishment, maintenance, and termination (signaling).
3. **Management Plane:** Divided into *Layer Management* (manages protocol layers) and *Plane Management* (manages overall system coordination).

Vertical Layers of ATM

- **Physical Layer:** Manages medium-dependent transmission, bit timing, and framing (uses SONET/SDH or physical medium dependent sublayers).
- **ATM Layer:** Responsible for cell creation, routing, VPI/VCI translation, and multiplexing/demultiplexing of fixed-size **53-byte cells** (48 bytes payload + 5 bytes header).
- **ATM Adaptation Layer (AAL):** Translates higher-layer services (like IP, voice, or video) into standard 48-byte ATM payloads. It has several sub-types: AAL1 (Constant Bit Rate), AAL2 (Variable Bit Rate), and AAL5 (Simple and efficient data traffic).

4. Transmission Modes (Parallel & Serial)

Transmission modes define how data is transferred between two devices over a communication channel.

Parallel Transmission

- Multiple bits (usually grouped into a byte or word) are transmitted simultaneously across **multiple physical wires or channels** (e.g., 8 wires for an 8-bit word).
- **Advantages:** Extremely fast data transfer rate over short distances.
- **Disadvantages:** High cabling cost, bulkiness, and **skewing** (bits arrive at slightly different times due to minor physical differences in wires, causing signal degradation over long distances).
- **Applications:** Internal computer buses, printer cables (historically).

Serial Transmission

- Bits are transmitted **sequentially, one single bit at a time**, over a single communication channel or wire.
- **Advantages:** Cost-effective, requires only a single communication line, eliminates skewing, and is suitable for long-distance communication.
- **Disadvantages:** Slower than parallel transmission for a single channel (though modern high-speed serial links use multiplexing and multi-gigabit signaling to overcome this).
- **Sub-categories:**
  - *Asynchronous Serial:* Uses start and stop bits to synchronize sender and receiver.

- *Synchronous Serial:* Transmits data in blocks or frames with precise clock synchronization.
- **Applications:** USB, Ethernet, HDMI, SATA, and long-distance WAN links.

5. Circuit Switching

Circuit switching is a switching technique that establishes a **dedicated, physical or logical communication path** between a sender and a receiver for the entire duration of a communication session.

Phases of Circuit Switching

1. **Circuit Establishment:** A dedicated path is set up across intermediate nodes from source to destination. If any link is busy, the connection request is blocked.
2. **Data Transfer:** Data flows continuously along the dedicated circuit with fixed bandwidth and minimal delay.
3. **Circuit Disconnection:** Once communication is complete, the connection is torn down, and the dedicated resources (switches, bandwidth) are released for other users.

Characteristics & Evaluation

- **Advantages:**
- Guaranteed bandwidth and constant transmission rate.
- No routing delays once the circuit is established; ideal for real-time, continuous data like voice telephony.
- **Disadvantages:**
- Inefficient bandwidth utilization (if the channel is idle during a call, the capacity is wasted).
- Longer initial setup time.
- **Example:** Traditional Public Switched Telephone Network (PSTN).

6. Routing & Routing Algorithms

Routing is the process of selecting the best path across one or more networks from a source to a destination.

Role of Routing Algorithms

Routing algorithms determine the optimal path based on metrics such as hop count, bandwidth, delay, cost, and load. They are implemented by routers in the Network Layer (Layer 3 of OSI).

Major Categories of Routing Algorithms

1. **Distance Vector Routing (e.g., RIP):**
- Routers share their entire routing table with their immediate neighbors periodically (Bellman-Ford algorithm).
- Each entry contains the destination, next hop, and total cost (hop count).
- **Issue:** Prone to the *count-to-infinity* problem and slow convergence.
2. **Link State Routing (e.g., OSPF):**
- Every router floods its local link information (state of directly connected links) to all other routers in the network (Dijkstra's algorithm).

- Every router builds a complete topological map of the entire network and independently computes the shortest path tree.
- **Advantages:** Faster convergence, avoids routing loops, and scales better for large networks.

3. **Path Vector Routing (e.g., BGP):**

- Used for inter-domain routing across Autonomous Systems (AS) on the internet. Instead of metrics, it tracks the exact sequence of AS identifiers to prevent loops and enforce routing policies.

7. TCP/IP Reference Model & Network Architecture

The Transmission Control Protocol/Internet Protocol (TCP/IP) suite is the foundational communication architecture of the Internet. Developed by DARPA, it predates the OSI model and consists of **4 distinct layer**

```
+----------------------------------+
|      Application Layer           |  (HTTP, FTP, SMTP, DNS)
+----------------------------------+
|      Transport Layer             |  (TCP, UDP)
+----------------------------------+
|      Internet Layer              |  (IP, ICMP, ARP)
+----------------------------------+
|      Network Access (Link) Layer |  (Ethernet, Wi-Fi, Framing)
+----------------------------------+
```

Layer Descriptions

1. **Network Access (Link) Layer:** Handles hardware addressing, framing, and physical transmission across the local medium. Corresponds to OSI Physical and Data Link layers.
2. **Internet Layer:** Responsible for logical addressing (IP addresses), packet routing, and forwarding across disparate networks. Core protocol: **IP (Internet Protocol)**.
3. **Transport Layer:** Provides end-to-end communication, reliability, flow control, and error recovery.

- **TCP:** Connection-oriented, reliable, stream-oriented.
- **UDP:** Connectionless, unreliable, datagram-oriented for fast, real-time apps.

4. **Application Layer:** Provides high-level protocols and user-facing services (e.g., HTTP for web, SMTP for email, DNS for name resolution).

8. Types of Multiplexing

Multiplexing is a technique used to combine multiple analog or digital signals into a single, high-capacity transmission channel to maximize bandwidth utilization.

Main Types of Multiplexing

1. **Frequency Division Multiplexing (FDM):**

- Used for **analog signals**.

- The available bandwidth of a single channel is divided into non-overlapping frequency bands, assigned to different users simultaneously. Guard bands prevent interference.
- *Application:* Traditional radio broadcasting, cable television.

2. **Wavelength Division Multiplexing (WDM):**

- An optical version of FDM used in fiber-optic communications.
- Different carrier wavelengths (colors) of light are combined into a single fiber strand and separated at the receiving end using prisms or diffraction gratings.

3. **Time Division Multiplexing (TDM):**

- Used for **digital signals**.
- The total time available on a channel is divided into fixed time slots. Users take turns transmitting data in a round-robin fashion.
- *Synchronous TDM:* Slots are pre-assigned regardless of whether a user has data.
- *Statistical (Asynchronous) TDM:* Slots are dynamically allocated only to active users, improving efficiency.

4. **Code Division Multiplexing (CDM / CDMA):**

- All users share the entire frequency spectrum and time slots simultaneously.
- Each user is assigned a unique orthogonal mathematical code. Signals are encoded and can be filtered out at the receiver by multiplying with the matching code.
- *Application:* 3G mobile networks, GPS.

9. Fiber Distributed Data Interface (FDDI)

FDDI is a standard for data transmission in a local area network (LAN) that uses **fiber-optic cables** as its underlying medium, capable of high-speed data rates up to **100 Mbps**.

Architecture & Topology

- **Dual-Ring Topology:** FDDI uses two independent counter-rotating rings (Primary and Secondary rings) for redundancy and reliability.
  - *Primary Ring:* Used for normal data transmission.
  - *Secondary Ring:* Operates in the opposite direction; acts as a backup in case the primary ring breaks (the rings automatically wrap around to form a single continuous ring past the point of failure).
- **Token Passing Access Mechanism:** Nodes pass a digital token around the ring. Only the node holding the token is permitted to transmit data frames.

Features & Applications

- **High Fault Tolerance:** Self-healing capabilities due to the dual-ring structure.
- **Long Reach:** Supports spans up to 100 km total ring circumference and distances up to 2 km between nodes.
- **Applications:** Historically used as a high-speed backbone network for university campuses, financial institutions, and enterprise networks before Gigabit Ethernet became dominant.

10. Bridges and Gateways

Both bridges and gateways are network internetworking devices used to connect networks, but they operate at different layers and serve distinct purposes.

Bridges

- **Layer:** Operates at the **Data Link Layer (Layer 2)** of the OSI model.
- **Function:** Connects two or more separate LAN segments (e.g., connecting two Ethernet segments) to form a larger logical LAN. It filters and forwards traffic based on **MAC addresses**.
- **Mechanism:** Maintains a bridge table (learning bridge). It listens to network traffic, learns which MAC addresses reside on which segment, and forwards frames only to the intended segment, reducing unnecessary network congestion (collision domains).
- **Types:** Transparent bridges, source routing bridges.

Gateways

- **Layer:** Operates across **all layers** of the OSI model, primarily focusing on **Transport and Application Layers (Layers 4 to 7)**.
- **Function:** Acts as a protocol translator between completely **dissimilar networks or architectures** (e.g., translating a TCP/IP network packet to an SNA network packet, or connecting an enterprise local network to the public Internet).
- **Mechanism:** Disassembles packets from one protocol suite, translates data formats, headers, and addressing schemes, and reassembles them into the format required by the destination network.

11. ISDN Layers

Integrated Services Digital Network (ISDN) is a circuit-switched telephone network system designed to transmit voice, video, and digital data simultaneously over standard copper telephone lines.

ISDN Protocol Architecture (OSI Alignment)

ISDN layers map directly to the lower layers of the OSI model, primarily handled through the **Digital Subscriber Signalling No. 1 (DSS1)** protocol suite.

1. **Physical Layer (Layer 1):**
   - Governs physical electrical/optical characteristics, line coding (e.g., AMI or 2B1Q), and framing over the local loop.
   - Defines standard physical interfaces such as **Basic Rate Interface (BRI)** ($2B+D$, providing two 64 kbps bearer channels and one 16 kbps delta channel) and **Primary Rate Interface (PRI)** ($23B+D$ or $30B+D$).
2. **Data Link Layer (Layer 2):**
   - Utilizes the **LAPD (Link Access Procedure on the D-channel)** protocol.
   - Ensures reliable, error-free transmission of signaling frames across the D-channel using framing, flow control, and sequence numbering (similar to HDLC).
3. **Network Layer (Layer 3):**
   - Handles call control, connection establishment, maintenance, and teardown across the D-channel.
   - Manages routing and signaling instructions between customer premises equipment (CPE) and the ISDN switch at the telephone exchange.

12. Wireless Transmission

Wireless transmission involves sending data electromagnetic waves (radio, microwave, infrared) through free space (air or vacuum) rather than through physical cables.

Electromagnetic Spectrum for Wireless

- **Radio Waves (3 kHz to 1 GHz):** Omnidirectional, capable of penetrating solid walls easily. Used for AM/FM radio, television, and paging.
- **Microwaves (1 GHz to 300 GHz):** Highly directional, requiring line-of-sight propagation. Used for satellite communication, cellular networks, and point-to-point terrestrial links.
- **Infrared (300 GHz to 400 THz):** High frequency, short-range communication. Cannot penetrate solid walls, making it secure from external eavesdropping. Used in TV remotes and legacy local indoor IR links.

Propagation Methods

1. **Ground Wave Propagation ($< 2\text{ MHz}$):** Follows the curvature of the earth; used for low-frequency AM radio.
2. **Sky Wave Propagation (2 MHz to 30 MHz):** Bounces off the Earth's ionosphere back to the surface; used for amateur and international shortwave radio.
3. **Line-of-Sight (LOS) Propagation ($> 30\text{ MHz}$):** Requires direct, unobstructed sightlines between transmitter and receiver antennas; used for Wi-Fi, cellular, and satellite transmission.

Part C – 10 Marks

1. OSI Model

The Open Systems Interconnection (OSI) model is a conceptual framework developed by the International Organization for Standardization (ISO) in 1984. It standardizes the functions of a communication system into **7 abstraction layers**, ensuring interoperability between diverse networking products and software.

Layer Architecture

```
+-------------------------------------------------------+
| 7. Application Layer   (HTTP, FTP, SMTP, DNS)         |
+-------------------------------------------------------+
| 6. Presentation Layer  (Encryption, Compression, SSL) |
+-------------------------------------------------------+
| 5. Session Layer       (Dialog Control, Synchronization)|
+-------------------------------------------------------+
| 4. Transport Layer     (TCP, UDP, End-to-End Delivery)|
+-------------------------------------------------------+
| 3. Network Layer       (IP, Routers, Logical Addressing)|
+-------------------------------------------------------+
| 2. Data Link Layer     (MAC, Switches, Framing)       |
+-------------------------------------------------------+
| 1. Physical Layer      (Cables, Hubs, Bits, Voltages) |
+-------------------------------------------------------+
```

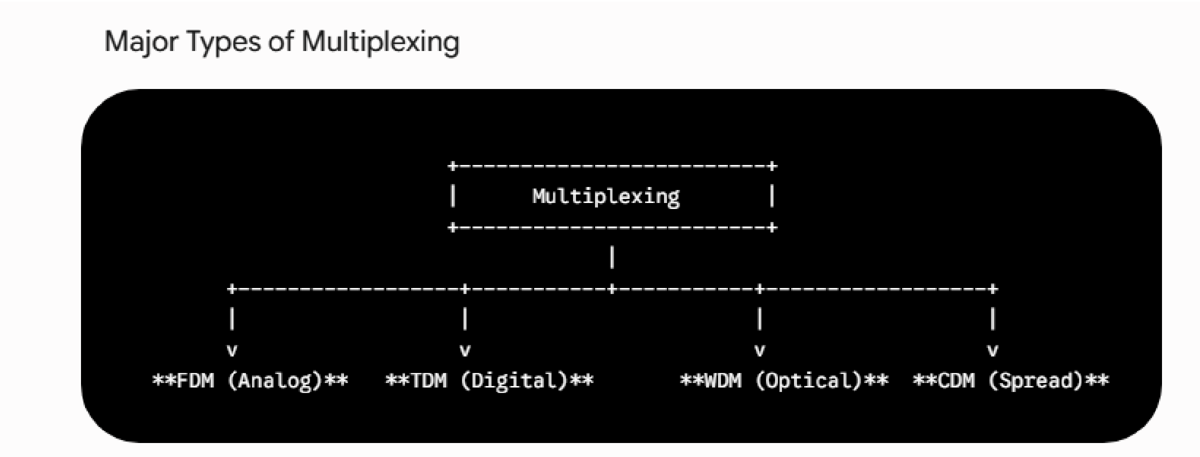
Detailed Layer Breakdown

- **Layer 1: Physical Layer**
  - **Function:** Handles the physical transmission of raw bit streams over a communication medium (cables, wireless). Defines voltages, pin layouts, cabling, and radio frequencies.
  - **Devices:** Hubs, repeaters, network interface cards (NICs), cables.
- **Layer 2: Data Link Layer**
  - **Function:** Responsible for node-to-node data transfer and error-free delivery of data across a local network. It divides data into frames and handles MAC addressing and flow control.
  - **Sub-layers:** Logical Link Control (LLC) and Media Access Control (MAC).
  - **Devices:** Switches, bridges.
- **Layer 3: Network Layer**
  - **Function:** Manages packet forwarding, routing through intermediate routers, and logical addressing (IP addresses). It determines the best path for data from source to destination.
  - **Devices:** Routers, Layer 3 switches.
- **Layer 4: Transport Layer**
  - **Function:** Ensures reliable, transparent, end-to-end data transfer between host systems. Handles error recovery, flow control, and segmentation/reassembly.
  - **Protocols:** Transmission Control Protocol (TCP), User Datagram Protocol (UDP).
- **Layer 5: Session Layer**
  - **Function:** Establishes, manages, and terminates communication sessions between applications across a network. Handles dialog control (simplex, half-duplex, full-duplex) and token management.
- **Layer 6: Presentation Layer**
  - **Function:** Translates data between the application layer and the network format. Handles syntax, data encryption, decryption, and data compression.
  - **Examples:** SSL/TLS, JPEG, ASCII, MPEG.
- **Layer 7: Application Layer**
  - **Function:** Closest to the end-user. Provides network services directly to user applications, enabling communication, file transfers, and email services.

- **Protocols:** HTTP, HTTPS, FTP, SMTP, DNS, DHCP.

2. Multiplexing

Multiplexing is a technique where multiple analog or digital signals are combined into one composite signal over a shared physical communication channel. This maximizes bandwidth utilization and reduces deployment costs.



1. **Frequency Division Multiplexing (FDM)**
   - **Mechanism:** Analog technique where total available bandwidth is divided into non-overlapping frequency bands. Each signal is assigned a distinct frequency channel, separated by guard bands to prevent interference.
   - **Application:** Traditional radio broadcasting, FM/AM radio, television broadcasting, and cable television (CATV).
2. **Time Division Multiplexing (TDM)**
   - **Mechanism:** Digital technique where total time available in a channel is distributed among multiple users in rotating time slots.
   - **Variants:**
     - *Synchronous TDM:* Slots are pre-assigned regardless of data availability.
     - *Statistical (Asynchronous) TDM:* Slots are dynamically allocated based on active demand.
   - **Application:** ISDN networks, traditional telephony (T1/E1 lines), cellular networks (GSM).
3. **Wavelength Division Multiplexing (WDM)**
   - **Mechanism:** Optical multiplexing technique where multiple optical carrier signals are combined onto a single fiber-optic strand using different wavelengths (colors) of laser light.
   - **Variants:** Coarse WDM (CWDM) and Dense WDM (DWDM).
   - **Application:** Long-distance fiber optic communication and high-speed backbone internet networks.
4. **Code Division Multiplexing (CDM) / CDMA**
   - **Mechanism:** Spread-spectrum technique where all users share the same frequency and time slot simultaneously, but each user is assigned a unique orthogonal code sequence to encode their data.
   - **Application:** 3G mobile telecommunications, GPS, and satellite communication.

3. Connection-Oriented & Connectionless Services

Network services operate under two primary communication paradigms based on whether a dedicated path or state is established prior to data transfer.

Comparison Table

Feature	Connection-Oriented Service	Connectionless Service
Path Establishment	Requires a formal setup phase (handshake) before data transmission.	No pre-established path or handshake; packets are sent immediately.
Reliability	Highly reliable; guarantees ordered delivery with built-in error checking and retransmission.	Best-effort delivery; does not guarantee delivery, order, or error correction.
Overhead	High overhead due to connection state maintenance and control packets.	Low overhead; minimal header info needed per packet.
Packet Routing	All packets follow the exact same pre-determined path (virtual circuit).	Packets can take independent, dynamic routes to reach the destination.
Protocols	TCP (Transmission Control Protocol), ATM, MPLS.	UDP (User Datagram Protocol), IP (Internet Protocol), ICMP.
Analogy	**Telephone Call:** Must dial, wait for pickup, converse, and hang up.	**Postal Mail / Letter:** Drop a letter in a box; it travels independently without notifying the receiver beforehand.

4. Guided & Unguided Media

Transmission media forms the physical pathway that carries data signals between transmitters and receivers.

1. Guided (Wired / Bound) Media

Signals are confined within a physical, solid conductor path from source to destination.

- **Twisted-Pair Cable:**
  - *Structure:* Pairs of insulated copper wires twisted together to minimize electromagnetic interference (EMI) and crosstalk.
  - *Types:* Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP).

- *Example/Application:* Ethernet local area networks (Cat5e/Cat6 cables), traditional telephone lines.
- **Coaxial Cable:**
  - *Structure:* Inner copper conductor surrounded by an insulating spacer, a braided metal shield, and an outer plastic jacket. Provides high bandwidth and shielding.
  - *Example/Application:* Cable television distribution (CATV), broadband internet (DOCSIS).
- **Fiber-Optic Cable:**
  - *Structure:* Glass or plastic core surrounded by cladding with a lower refractive index, transmitting data as pulses of light via total internal reflection. Immune to electromagnetic interference.
  - *Types:* Single-Mode Fiber (SMF) and Multi-Mode Fiber (MMF).
  - *Example/Application:* High-speed internet backbones, submarine transoceanic cables, enterprise campus networks.

2. Unguided (Wireless / Unbound) Media

Signals are broadcasted through free space (air, vacuum, or water) using electromagnetic radio waves without physical conductors.

- **Radio Waves:**
  - *Characteristics:* Omnidirectional propagation, easily penetrate walls, long-range capability.
  - *Example/Application:* AM/FM radio, television broadcasting, garage door openers, Wi-Fi.
- **Microwaves:**
  - *Characteristics:* High-frequency directional beams, require line-of-sight (LOS) propagation between antennas.
  - *Example/Application:* Satellite communication, cellular phone networks, long-distance terrestrial point-to-point links.
- **Infrared:**
  - *Characteristics:* High-frequency waves restricted by physical barriers (cannot pass through walls), secure within a single room.
  - *Example/Application:* TV remote controls, short-range device pairing, wireless computer peripherals.

5. Asynchronous Transfer Mode (ATM)

ATM is a high-performance, cell-based switching and multiplexing technology designed to unify voice, video, and data traffic over a single digital network infrastructure.

Key Architectural Concepts

- **Fixed-Size Cells:**
  - Unlike variable-length packet networks (like IP), ATM splits all data into uniform blocks called **cells**.
  - **Cell Size:** Exactly **53 bytes** total (5-byte header + 48-byte payload).
  - *Advantage:* Fixed-size cells eliminate queuing delays for high-priority voice/video traffic, making ATM ideal for real-time Quality of Service (QoS).
- **ATM Architecture:**
  - **Physical Layer:** Manages physical transmission media and framing.
  - **ATM Layer:** Responsible for cell multiplexing, switching, generic flow control, and routing using Virtual Path Identifiers (VPI) and Virtual Channel Identifiers (VCI).

- **ATM Adaptation Layer (AAL):** Converts higher-layer protocols (like IP, Ethernet, or voice streams) into standard 53-byte ATM cells and vice versa.

- **ATM Network Topology:**
    - Typically deployed in a **Star or Mesh topology** utilizing ATM switches.
    - It operates primarily in a connection-oriented mode, establishing Virtual Circuits (VCs) and Virtual Paths (VPs) before data transmission begins.

6. Data Communication Process

The data communication process involves the systematic transfer of data between a source (sender) and a destination (receiver) through a transmission medium.

Fundamental Components of Data Communication

1. **Message:** The actual information or data to be communicated (text, audio, video).
2. **Sender:** The device that generates and transmits the data message (computer, phone, server).
3. **Receiver:** The device destined to accept and process the incoming message.
4. **Transmission Medium:** The physical path or wireless channel through which the message travels.
5. **Protocol:** A set of standardized rules and conventions that govern how data is formatted, transmitted, and received.

Step-by-Step Communication Lifecycle

```
[ Sender Application ]
         |
         v (Encapsulation: Add Headers - App -> Trans -> Net -> Link -> Phys)
[ Physical Transmission across Medium ]
         |
         v (De-encapsulation: Strip Headers - Phys -> Link -> Net -> Trans -> App)
[ Receiver Application ]
```

1. **Data Generation:** The sender application creates the data message.
2. **Encapsulation:** As the data moves down the OSI/TCP-IP layers, control headers and trailers (containing source/destination addresses, sequence numbers, and error-check codes) are appended to the data chunk at each layer.
3. **Conversion & Modulation:** Digital bits are converted into physical signals (electrical voltages, light pulses, or radio waves) suited for the transmission medium.
4. **Transmission:** Signals travel across the guided or unguided medium to the destination.
5. **Reception & Demodulation:** The receiver captures the physical signals and converts them back into binary bit streams.
6. **De-encapsulation:** The data travels up the receiver's protocol layers; each layer strips its corresponding header, processes the control info, and passes the payload upward.
7. **Delivery:** The final reconstructed message is delivered to the target application.

7. Routing Algorithms

Routing algorithms are protocols and logic used by network routers to determine the most optimal, cost-effective path for forwarding packets from a source network to a destination network.

Major Classes of Routing Algorithms

1. Distance Vector Routing Algorithm

- **Mechanism:** Routers periodically share their entire routing table (or updates) with their immediate neighbors. Uses the **Bellman-Ford equation** to calculate the minimum cost path based on "hop count" or arbitrary cost metrics.
- **Issues:** Prone to the *Count-to-Infinity* problem and slow convergence.
- **Examples: RIP (Routing Information Protocol)**, **IGRP**.

2. Link State Routing Algorithm

- **Mechanism:** Each router maps the entire network topology by broadcasting its local link states to all routers in the network (Link State Advertisements). Every router then runs **Dijkstra's Shortest Path First (SPF)** algorithm independently to compute the optimal route.
- **Advantages:** Fast convergence, prevents routing loops, highly scalable.
- **Examples: OSPF (Open Shortest Path First)**, **IS-IS (Intermediate System to Intermediate System)**.

Example: Dijkstra's Shortest Path Algorithm

Consider a simple graph with routers A, B, and C:

- Link A to B = Cost 2
- Link B to C = Cost 3
- Link A to C = Cost 6

Calculation from Router A to C:

- Path 1 ($A \to C$): Cost = 6
- Path 2 ($A \to B \to C$): Cost = $2 + 3 = 5$
- **Selected Route:** $A \to B \to C$ is chosen because it offers the lowest total metric cost ($5 < 6$).

8. Parallel and Serial Transmission

Data transmission modes dictate how individual binary bits of a data stream are transferred across a communication channel.

Detailed Comparison

Feature	**Parallel Transmission**	**Serial Transmission**
Mechanism	Multiple bits (usually a full byte or word, e.g., 8 bits) are transmitted	Bits are sent sequentially, **one single bit after another**, over a

Feature	Parallel Transmission	Serial Transmission
	simultaneously over **separate, parallel wires** or channels.	single communication line or channel.
Speed	Extremely fast over short distances due to simultaneous multi-bit transfer.	Slower per clock cycle, but modern serial links compensate via high clock frequencies.
Hardware Cost	Expensive; requires multi-wire cables and complex interface circuitry.	Inexpensive; requires simple single-wire lines and lower pin-count controllers.
Distance Limitation	**Short distance only** (typically < 2 meters) because long-distance wire skew causes bits to arrive out of sync.	**Long distance** capable; signal degradation and timing skew are easily managed.
Examples / Usage	Internal computer data buses, CPU-to-RAM communication, older parallel printer cables (IEEE 1284).	USB (Universal Serial Bus), Ethernet (Cat6), SATA hard drives, HDMI, PCI Express (PCIe).

9. Circuit Switching + SMDS

This topic covers traditional circuit-switching networking principles alongside Switched Multi-megabit Data Service technology.

Part A: Circuit Switching

Circuit switching is a switching methodology in which a **dedicated, physical communication path** is established between a sender and receiver for the entire duration of a communication session.

- **Three Phases of Circuit Switching:**

1. *Circuit Establishment:* A dedicated path is reserved from source to destination through intermediate switching nodes.
2. *Data Transfer:* Continuous communication takes place over the dedicated circuit.
3. *Circuit Termination:* The connection is torn down, and resources/bandwidth are released.

- **Characteristics:** Guaranteed bandwidth, constant transmission delay, but poor resource utilization if the channel sits idle during a call (e.g., traditional analog telephone networks/PSTN).

Part B: Switched Multi-megabit Data Service (SMDS)

SMDS is a high-speed, connectionless, public packet-switched data communication service developed in the 1990s to connect Local Area Networks (LANs) across wide geographic areas (MANs/WANs).

- **Key Features of SMDS:**
  - **Connectionless Service:** Operates like a datagram network (similar to IP), where each data packet (referred to as an SMDS Data Unit or L3_PDU) contains full source and destination addresses and routes independently.
  - **High Performance:** Offered high bandwidths ranging from 1.5 Mbps (T1) up to 45 Mbps (T3/DS3).
  - **Public Switched Architecture:** Provided enterprise customers with a public, packet-switched infrastructure managed by telecommunication carriers, acting as a precursor to modern frame relay and ATM services.

10. World Wide Web (WWW) & Repeaters

A combined technical overview of the World Wide Web software architecture and physical layer networking hardware.

Part 1: The World Wide Web (WWW)

The World Wide Web is an information space consisting of interconnected hypertext documents and resources, accessed via the Internet using standard protocols.

- **Key Components:**
  - **Uniform Resource Locator (URL):** Standardized address syntax used to locate resources on the web (e.g., `[https://www.example.com](https://www.example.com)`).
  - **HyperText Transfer Protocol (HTTP / HTTPS):** The foundational request-response protocol used by clients (web browsers) and web servers to transfer web pages and data.
  - **HyperText Markup Language (HTML):** Standard formatting markup language used to structure web pages, text, links, and media.
  - **Web Servers & Browsers:** Servers (Apache, Nginx) host and serve web files; browsers (Chrome, Firefox) render the retrieved HTML/CSS into interactive visual pages.

Part 2: Repeaters

A repeater is an electronic networking device operating at **Layer 1 (Physical Layer)** of the OSI model.

- **Function:** Signals degrade, attenuate, and distort over long cable runs due to resistance and noise. A repeater captures incoming weakened signals, **regenerates, amplifies, and retimes** them, and retransmits them with full power over the remaining cable segment.
- **Applications:** Extended maximum cable run lengths in Ethernet local area networks (e.g., overcoming the 100-meter limit of twisted-pair copper cables) and boosting long-distance fiber optic and wireless transmission lines.