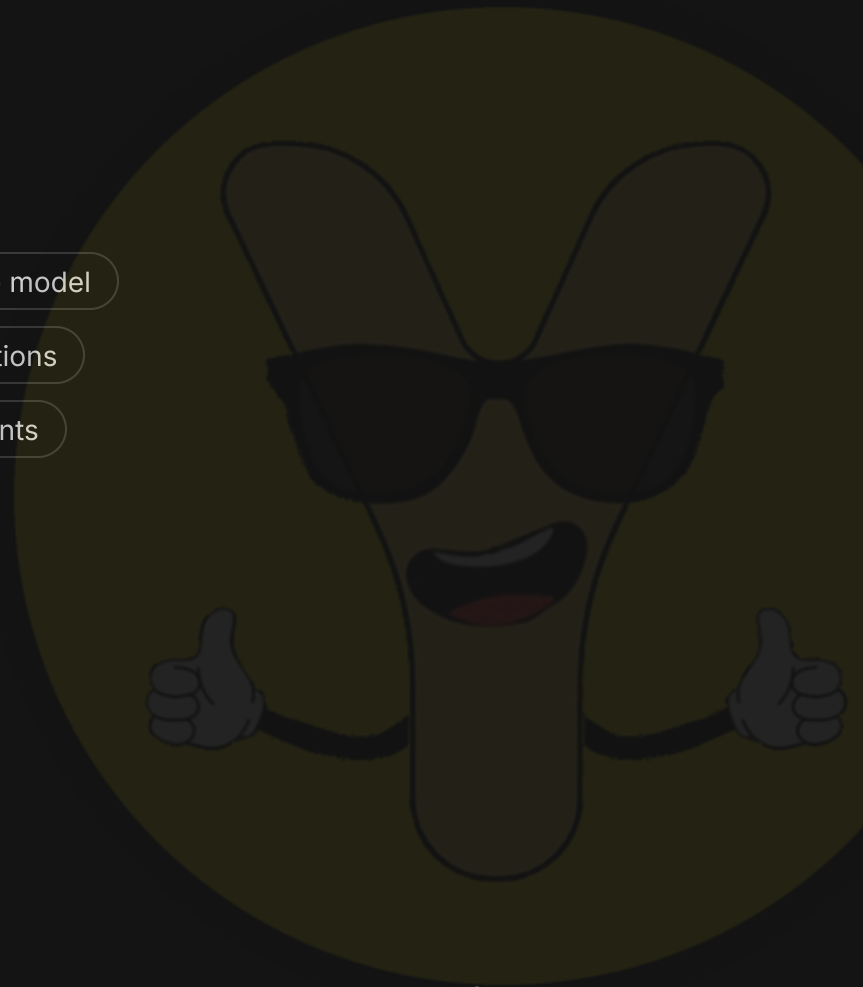
AKTU · 3RD YEAR · SEMESTER 6 · BCS603

Computer Networks

Unit 1 — Introductory Concepts and Physical Layer

- Goals and applications of networks
- Categories of networks
- Organization of the Internet
- ISP
- Network structure and architecture (layering principles, services, protocols and standards)
- The OSI reference model
- TCP/IP protocol suite
- Network devices and components
- Network topology design
- Types of connections
- Transmission media
- Signal transmission and encoding
- Network performance and transmission impairments



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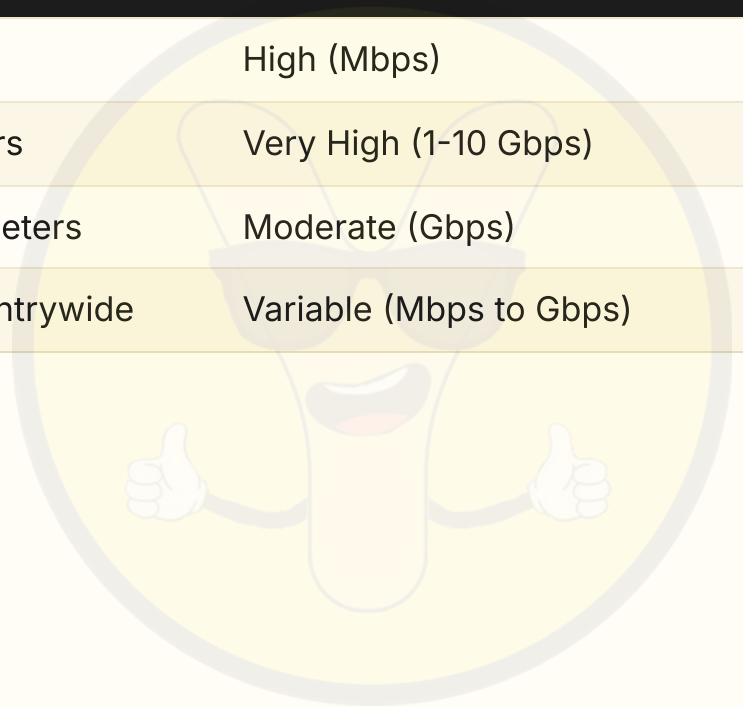
Goals and Applications of Computer Networks

Computer networks enable reliable, high-speed data exchange and resource sharing across interconnected systems.

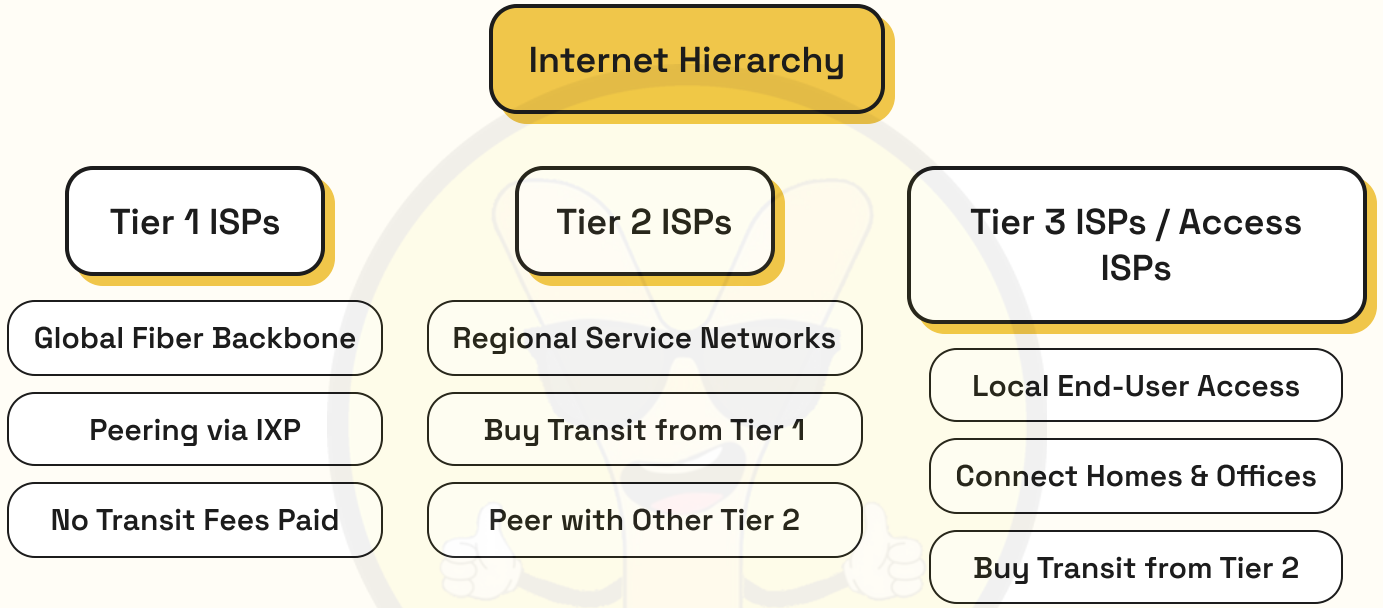
- Resource Sharing: Enables sharing of hardware devices, software licenses, and centralized storage among users.
- High Reliability: Data replication across multiple machines prevents single-point failure and ensures system availability.
- Cost Efficiency: Interconnected workstations offer better price-performance ratio than mainframe-based centralized systems.
- Scalability: Network capacity and connected nodes can be expanded incrementally as organizational requirements grow.
- Communication Medium: Provides real-time messaging, video conferencing, electronic mail, and collaborative platforms.
- Applications: Powers e-commerce, cloud computing platforms, remote telemetry, IoT devices, and distributed databases.

Categories of Computer Networks

Category	Geographic Reach	Data Rate	Error Rate	Typical Example
PAN (Personal Area)	< 10 meters	High (Mbps)	Very Low	Bluetooth, Zigbee
LAN (Local Area)	< 2 kilometers	Very High (1-10 Gbps)	Lowest	College Campus, Office
MAN (Metropolitan Area)	10 - 50 kilometers	Moderate (Gbps)	Moderate	Cable TV, City Broadband
WAN (Wide Area)	Global / Countrywide	Variable (Mbps to Gbps)	Higher	The Internet, Telecom Net



Organization of the Internet and ISP Hierarchy



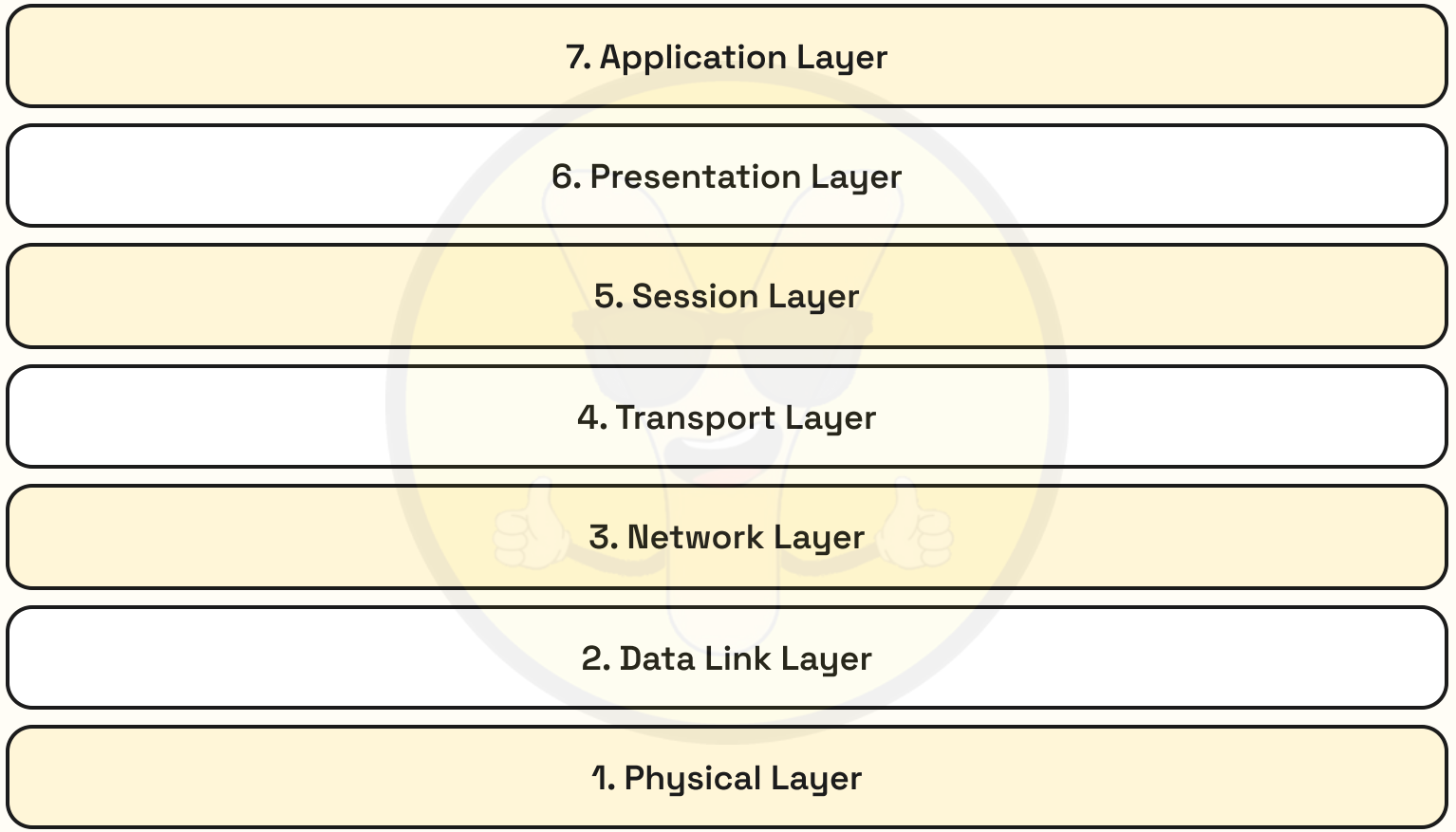
Hierarchical structure of Internet Service Providers (ISPs) interconnected through Internet Exchange Points (IXPs).

Network Architecture and Layering Principles

Layered architecture divides complex networking functionality into modular, manageable logical layers.

- Layering Principle: Each layer performs a dedicated set of functions and relies on lower layers for services.
- Protocol: A set of formal rules and conventions governing communication between peer entities at a specific layer.
- Service Access Point (SAP): The interface boundary where a lower layer provides services to the layer above it.
- Protocol Data Unit (PDU): Combined packet structure of control header and user payload passed down layers.
- Encapsulation: Headers and trailers are prepended at each descending layer during data transmission.
- Standards Organizations: ISO, IEEE, IETF, and ITU-T establish interoperable protocol standards.

The OSI Reference Model (ISO/IEC 7498-1)



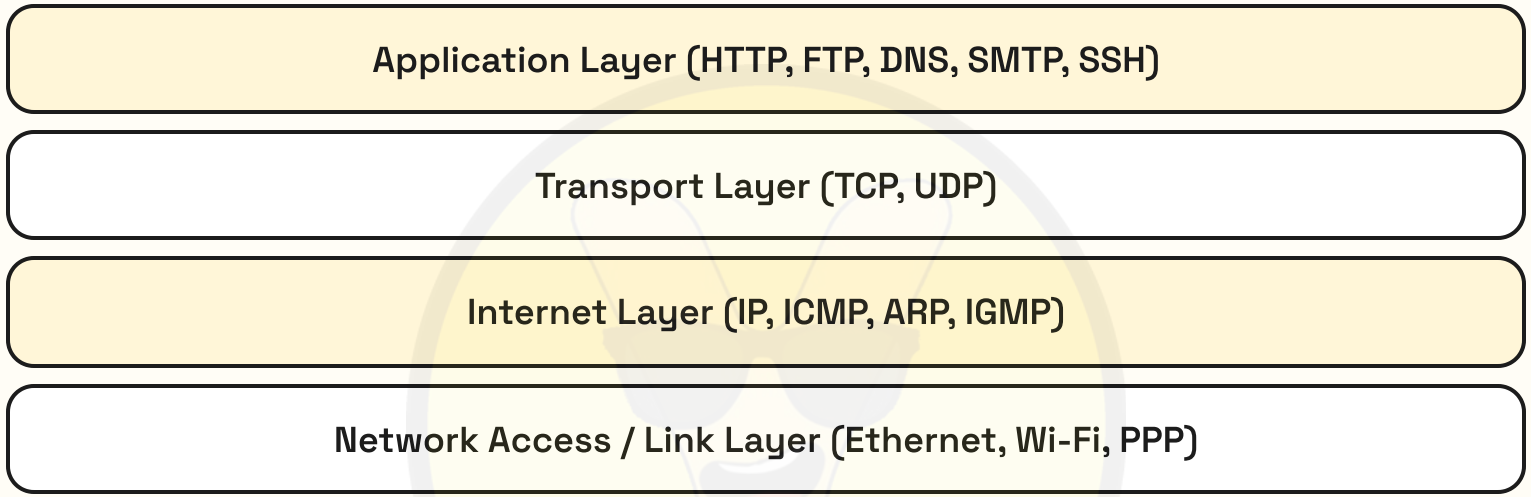
The 7-layer Open Systems Interconnection (OSI) standard architectural model.

OSI Model: Detailed Layer Responsibilities

Each layer of the OSI model addresses specific data communication sub-tasks.

- Physical Layer: Transmits raw bitstreams over physical media; defines electrical, mechanical, and timing specifications.
- Data Link Layer: Provides node-to-node framing, physical MAC addressing, flow control, and error detection.
- Network Layer: Performs logical IP addressing, packet routing across disparate networks, and congestion control.
- Transport Layer: Manages end-to-end message delivery, segmentation, reassembly, port addressing, and flow control.
- Session Layer: Establishes, maintains, synchronizes, and terminates interactive communication sessions.
- Presentation & Application Layers: Handles data formatting, encryption, compression, and provides user application interfaces.

TCP/IP Protocol Suite Architecture



4-Layer practical architecture of the TCP/IP protocol suite.

Comparison: OSI Reference Model vs TCP/IP Model

Parameter	OSI Model	TCP/IP Model
Layer Count	7 Distinct Layers	4 Functional Layers
Approach	Theoretical Reference Model	Practical Implementation Standard
Session & Presentation	Explicitly defined separately	Combined into Application Layer
Protocol Independence	Defined before protocols built	Protocols developed before model
Transport Layer	Supports connectionless & oriented	TCP (oriented), UDP (connectionless)
Network Layer	Supports connectionless & oriented	Connectionless (IP protocol only)

Network Interconnection Devices

Specialized hardware devices operate at specific OSI layers to enable network interconnectivity.

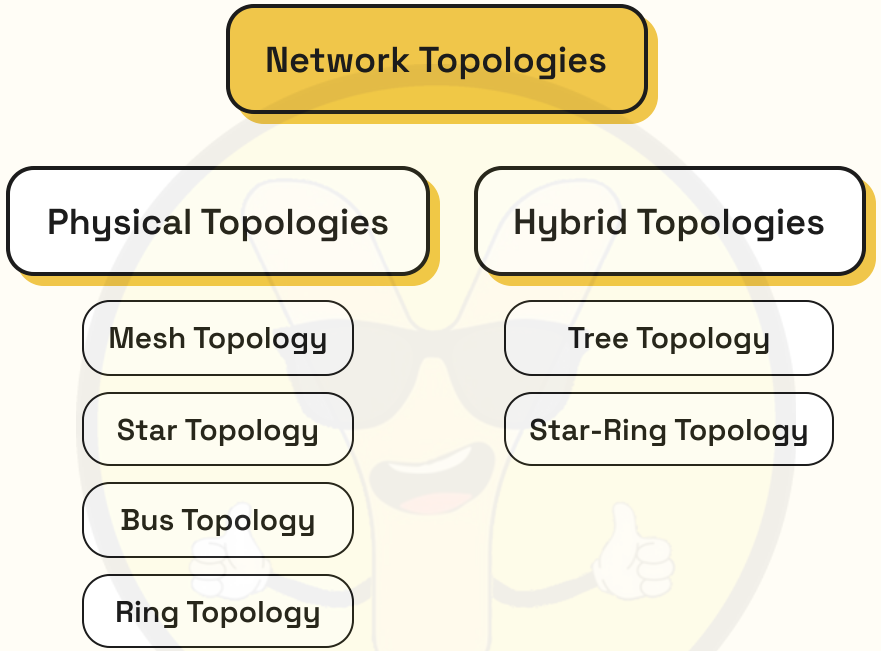
- Repeater (Layer 1): Regenerates degraded electrical or optical signals to extend physical media reach.
- Hub (Layer 1): Multi-port physical layer repeater that broadcasts incoming signals to all connected ports.
- Bridge (Layer 2): Connects LAN segments and filters traffic using hardware MAC address tables.
- Switch (Layer 2/3): Intelligent device that routes frames directly to destination ports using MAC tables.
- Router (Layer 3): Routes data packets across different subnets based on IP addresses and routing algorithms.
- Gateway (Layer 4-7): Connects heterogeneous networks by translating protocol stacks and packet formats.

Connection Types and Data Transmission Modes

Networks configure physical links and directional data flows based on operational requirements.

- Point-to-Point Connection: Dedicated physical link between exactly two network devices (e.g., direct line).
- Multipoint Connection: Shared physical medium where multiple devices share overall link capacity.
- Simplex Mode: One-way directional communication; data flows strictly from transmitter to receiver (e.g., Keyboard).
- Half-Duplex Mode: Two-way communication, but only one device transmits at a time (e.g., Walkie-Talkie).
- Full-Duplex Mode: Simultaneous two-way communication in both directions (e.g., Telephone network).

Classification of Network Topologies



Hierarchical taxonomy of physical network layout topologies.

Comparison of Physical Network Topologies

Topology	Cable Links Required	Fault Isolation	Cost	Reliability
Mesh	$\frac{n(n-1)}{2}$	Very Easy	Very High	Highest (Redundant)
Star	n links	Easy	Moderate	High (Single Hub Point)
Bus	1 Backbone Cable	Difficult	Lowest	Low (Backbone Failure)
Ring	n links	Easy	Low	Low (Single Cable Break)
Tree	Hierarchical links	Easy	Moderate	Moderate

Transmission Media: Guided vs. Unguided

Data transmission occurs across physical conduits or wireless electromagnetic spectra.

- Twisted Pair Cable: Insulated copper wires twisted to cancel EMI; categorised into UTP and STP (e.g., Cat6).
- Coaxial Cable: Central conductor with braid shielding; higher bandwidth, used in Cable TV and broadband.
- Fiber Optic Cable: Transmits light pulses using total internal reflection; immune to EMI with ultra-high bandwidth.
- Radio Waves: Unguided omnidirectional signals used for broad coverage (e.g., FM Radio, Cellular networks).
- Microwaves: Line-of-sight unguided signals requiring focused parabolic antennas (e.g., Satellite, Wi-Fi).
- Infrared: Short-range line-of-sight optical transmission unable to penetrate solid walls (e.g., Remote controls).

Signal Transmission and Digital Encoding

Digital encoding converts binary data into discrete voltage levels suitable for physical medium transmission.

- NRZ-L (Non-Return to Zero-Level): Voltage level represents binary value (High = 0, Low = 1).
- NRZ-I (Non-Return to Zero Inverted): Voltage transition at start of bit interval signifies binary 1.
- RZ (Return to Zero): Signal drops to zero volts mid-bit to ensure clock synchronization.
- Manchester Encoding: Mid-bit transition provides clocking; High-to-Low = 0, Low-to-High = 1 (Ethernet).
- Differential Manchester: Mid-bit transition always occurs; transition at start = 0, no transition = 1.
- Clock Recovery: Self-clocking codes (Manchester) embed timing information directly inside the signal stream.

Transmission Impairments and Performance

Physical transmission media cause signal degradation, limiting overall channel capacity.

- Attenuation: Decaying of signal strength over distance; corrected using signal repeaters or amplifiers.
- Distortion: Change in signal waveform shape caused by different frequency components traveling at different speeds.
- Noise: External unwanted energy added to signal (Thermal, Crosstalk, Impulse, Intermodulation).
- Signal-to-Noise Ratio: $\mathrm{SNR}_{\mathrm{dB}} = 10 \log_{10} \left(\frac{\text{Signal Power}}{\text{Noise Power}} \right)$.
- Nyquist Data Rate: Max bit rate for noiseless channel: $C = 2 \cdot B \cdot \log_2(L)$.
- Shannon Channel Capacity: Max capacity for noisy channel: $C = B \cdot \log_2(1 + \mathrm{SNR})$.

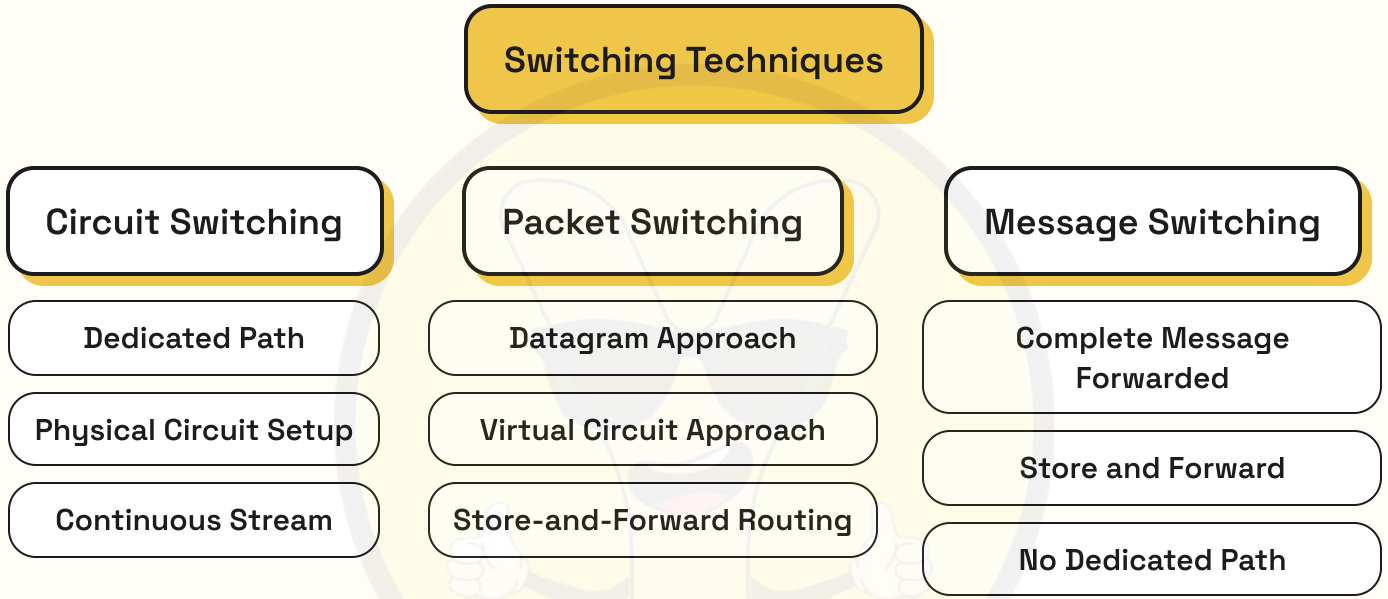
Performance Calculation: Transmission & Propagation Delay

Calculate the total delay to transmit a 5 MB file over a 10 Mbps link of distance 2000 km. Signal propagation speed is 2×10^8 m/s.

1. 1. Convert file size to bits: $L = 5 \times 8 \times 10^6 \text{ bits} = 40 \times 10^6 \text{ bits}$.
2. 2. Convert bandwidth to bps: $R = 10 \times 10^6 \text{ bps}$.
3. 3. Calculate Transmission Delay: $T_t = \frac{L}{R} = \frac{40 \times 10^6}{10 \times 10^6} = 4.0 \text{ seconds}$.
4. 4. Calculate Propagation Delay: $T_p = \frac{\text{Distance}}{\text{Speed}} = \frac{2000 \times 10^3 \text{ m}}{2 \times 10^8 \text{ m/s}} = 0.01 \text{ seconds} = 10 \text{ ms}$.
5. 5. Compute Total Delay: $T_{\text{total}} = T_t + T_p = 4.0 + 0.01 = 4.01 \text{ seconds}$.

Total Latency = 4.01 seconds.

Classification of Switching Techniques



Taxonomy of switching methodologies used across telecommunication networks.

Circuit Switching vs Packet Switching

Parameter	Circuit Switching	Packet Switching
Dedicated Path	Required before transmission	No physical dedicated path
Bandwidth Allocation	Fixed and pre-allocated	Dynamic allocation (Demand)
Store-and-Forward	Not applied	Applied at every router node
Packet Loss	No packet loss during session	Packets dropped under congestion
Suitability	Real-time voice communications	Data traffic and web browsing
Cost / Efficiency	Low resource utilization	High bandwidth efficiency

Multiplexing Techniques (FDM, TDM, WDM)

Multiplexing allows multiple signal streams to share a single high-capacity transmission channel.

- Frequency-Division Multiplexing (FDM): Analog technique; link frequency bandwidth divided into distinct channels separated by guard bands.
- Time-Division Multiplexing (TDM): Digital technique; total bandwidth assigned to users in sequential rotating time slots.
- Synchronous TDM: Pre-allocates fixed time slots to each input line regardless of data availability (idle slots possible).
- Statistical TDM: Dynamically assigns time slots only to active data sources, eliminating empty slot overhead.
- Wavelength-Division Multiplexing (WDM): Optical multiplexing technique combining multiple light signals of different wavelengths onto a single fiber.

AKTU Exam Corner: Unit 1 Important Questions

Q1 Explain the 7 layers of the OSI Reference Model with a neat block diagram and state key functions of each layer.

Q2 Differentiate between the OSI Model and TCP/IP Reference Model in tabular format.

Q3 A channel has a bandwidth of 4 kHz and SNR of 30 dB. Calculate the maximum theoretical channel capacity using Shannon theorem.

Q4 Define Network Topology. Compare Mesh, Star, Bus, and Ring topologies based on cost, reliability, and cable requirements.

Q5 Explain Manchester and Differential Manchester encoding schemes. Draw encoding waveforms for the bit sequence 1011001.

Q6 Compare Circuit Switching and Packet Switching. Differentiate between Datagram and Virtual Circuit packet switching approaches.

Q7 State the differences between Guided and Unguided media. Explain why Fiber Optic Cable is superior to Coaxial Cable.

Q8 Define the terms: Transmission Delay, Propagation Delay, Bandwidth-Delay Product, Attenuation, and Signal-to-Noise Ratio.

Unit 1 done. You are exam-ready.

Revise the Exam corner once more, then open Unit 2 on theycotes.com. Every AKTU subject, unit by unit, free. Notes by Chirag Jain, Ycotes.

