🌐 1) Introduction to Network Layer

- The **Network Layer is Layer 3 of the OSI model.**
- It is responsible for **delivering data (packets) from the source device to the destination device across multiple networks.**
- It handles **logical addressing (IP addresses), routing, and packet forwarding.**
- Works with the **Transport Layer above** and the **Data Link Layer below.**
- Example protocols: **IP, ICMP, ARP, RARP, OSPF, RIP, BGP**

🗺️ 2) Network Service Model

- Defines the **type of services the network layer provides to the transport layer.**
- Services decide how the network delivers packets (quality, reliability etc.)

Types:

- **Connectionless service:**
  - Each packet is treated independently (like sending letters).
  - Packets may arrive out of order or get lost.
  - Example: IP (Internet Protocol).
- **Connection-oriented service:**
  - A path is created before data transfer.
  - Packets follow the same path in order.
  - Example: Virtual circuits (like a phone call).

📨 3) Datagram vs Virtual Circuit

Datagram	Virtual Circuit
Connectionless	Connection-oriented
Each packet routed separately	All packets follow same path
No setup before sending	Setup required before sending
Can arrive out of order	Always arrive in order
Example: IP	Example: ATM, Frame Relay

💻 4) IPv4 (Internet Protocol Version 4)

- IPv4 is the most widely used **network layer protocol**.
- Uses **32-bit addresses** (written in dotted decimal like 192.168.1.1)
- Provides **logical addressing + best-effort delivery.**
- **Header fields:**
    - Version, Header Length
    - Source IP, Destination IP
    - Total Length
    - TTL (Time to Live)
    - Protocol (TCP=6, UDP=17)
    - Header Checksum

Limitations:

- Only 4.3 billion addresses
- No built-in security or encryption
- Broadcast-based → wastes bandwidth

🌎 5) IPv6 (Internet Protocol Version 6)

- Next generation of IP.
- Uses **128-bit addresses** (written in hexadecimal like 2001:0db8::1)
- Provides **huge address space** for all modern devices.
- **Improvements over IPv4:**
    - No fragmentation (fixed header size)
    - Better routing
    - Built-in security (IPSec)
    - No checksum (faster)
- Slowly replacing IPv4.

🧠 6) IP Addressing

- IP address is a **unique logical address of a device on a network.**
- **IPv4 = 32-bit**, divided into **4 octets** (0–255).
- Has **Network part + Host part.**
- **Classes:**

- Class A: 1–126 (large networks)
- Class B: 128–191 (medium)
- Class C: 192–223 (small)
- Class D: 224–239 (multicast)
- Class E: 240–255 (research)

- **Special addresses:**
  - 127.0.0.1 = loopback
  - 0.0.0.0 = unknown
  - Broadcast = all 1s

🔬 **7) Subnetting**

- Dividing a big network into smaller networks (subnets).
- Helps in **efficient IP address use and better network management.**
- **Subnet mask** identifies network and host bits.
- Example:
  - IP: 192.168.1.10
  - Subnet mask: 255.255.255.0
  - Network = 192.168.1.0
  - Host = 10

📦 **8) Forwarding and Routing**

- **Forwarding:** Moving packet from router's input to correct output port (inside a router).
- **Routing:** Selecting the **best path from source to destination** (between routers).
- Forwarding is **local**, routing is **global.**
- Routers use **routing tables** to make decisions.

🧭 **9) Routing Algorithms**

- Used to build routing tables and choose best paths.

Two main types:

- **Link State (LS):**
  - Each router knows full network map.

    - Uses Dijkstra algorithm to find shortest path.
    - Faster convergence, more complex.
    - Example: OSPF
- **Distance Vector (DV):**
    - Routers exchange distance info with neighbors.
    - Uses Bellman-Ford algorithm.
    - Simpler but slower to converge.
    - Example: RIP

🚦 **10) Routing Protocols**

- **RIP (Routing Information Protocol):** DV based, uses hop count, max 15 hops.
- **OSPF (Open Shortest Path First):** LS based, uses cost (bandwidth).
- **BGP (Border Gateway Protocol):** Used between different organizations (on the internet).
- **IGRP/EIGRP:** Cisco proprietary protocols.

💉 **11) ICMP (Internet Control Message Protocol)**

- Used by network devices to **send error messages and operational info.**
- Works with IP.
- Example uses:
    - Destination unreachable
    - Time exceeded (TTL expired)
    - Echo request/reply (used by **ping** command)

🧩 **12) ARP (Address Resolution Protocol)**

- Finds **MAC address from a known IP address.**
- Used when sending a packet inside a LAN.
- Steps:
    - Sender broadcasts “Who has 192.168.1.5?”
    - Owner replies with its MAC address.
- ARP cache stores results temporarily.

♻️ **13) RARP (Reverse ARP)**

- Finds **IP address from a known MAC address.**
- Used by **diskless computers** when they start (they don’t know their IP).
- RARP server replies with correct IP.