UNIT III

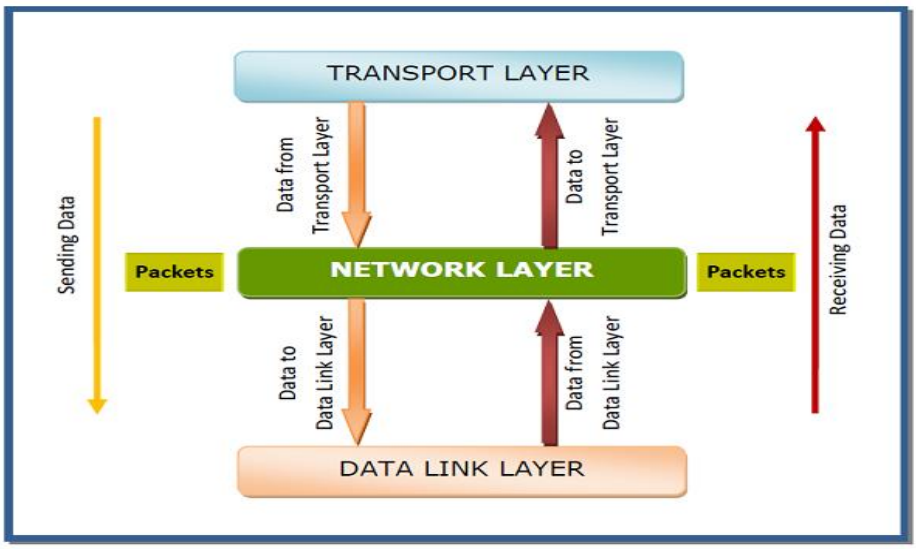
THE NETWORK LAYER

Functions of the Network Layer:

The functions of the network layer are to **route data packets** across different networks, assign **logical addresses** like IP addresses, **forward** packets to their destination, and handle **fragmentation and reassembly**. It's also responsible for **error detection and recovery**, and can manage quality of service to prioritize traffic.

Key functions of the network layer

- **Logical Addressing:** Assigns unique, logical addresses (like IP addresses) to devices on a network to distinguish them from one another.
- **Routing:** Determines the best path for data packets to travel from source to destination across multiple networks.
- **Forwarding:** Moves the data packets from one network to another along the determined route.
- **Packetization and Reassembly:** Breaks down large data into smaller packets for transmission and reassembles them at the destination.
- **Error Handling:** Detects and reports errors that occur during transmission. The Internet Control Message Protocol (ICMP) is a key protocol used for this purpose, as seen with the `ping` and `traceroute` tools.
- **Quality of Service (QoS):** Manages network traffic to provide different levels of service for different types of data, helping to avoid issues like congestion and delay.



The network layer (Layer 3 of the OSI model) is responsible for end-to-end communication across different networks, a task accomplished through three primary, interconnected functions: **logical addressing, routing, and forwarding**.

Logical Addressing

Logical addressing provides a system for uniquely identifying devices across the global internet. Unlike physical (MAC) addresses, which are hard-coded into network interfaces and only used within a local network segment (Layer 2), logical addresses are software-based and can be dynamically assigned.

- **Purpose:** To assign a hierarchical, non-permanent address (e.g., an IP address in IPv4 or IPv6) that identifies both the specific network a device is on and the host within that network.
- **Mechanism:** The network layer encapsulates data from the transport layer into a packet (or datagram) and adds a header containing the source and destination logical addresses.
- **Protocols:** The most common protocol is the **Internet Protocol (IP)**, with IPv4 and IPv6 being the prevalent versions.

Routing

Routing is the global process of determining the optimal path for a data packet to travel from the source network to the destination network across potentially many intermediate networks.

- **Process:** Routers use routing algorithms (such as OSPF, BGP, or RIP) to exchange information about network topology and build comprehensive **routing tables**. These algorithms consider metrics like hop count, bandwidth, and delay to select the most efficient path.

- **Scope:** This is a network-wide, control-plane function, involving decision-making that happens "between" routers to establish the end-to-end route.

Forwarding

Forwarding is the local, per-router action of actually moving a packet from an incoming interface to the appropriate outgoing interface, based on the decisions made during the routing process.

- **Process:** When a router receives a packet, it inspects the destination IP address in the header and uses its local **forwarding table** (derived from the routing table) to determine the next "hop" or the correct output port.
- **Scope:** This is a data-plane function that occurs continuously and quickly for every single packet as it traverses each router along the chosen path.

In essence, **routing creates the map** of the network, and **forwarding moves the traffic** according to that map, using **logical addresses** as the guide.

IP addressing: IPv4 and IPv6:

IPv4 and IPv6 are the primary **Internet Protocols (IP) used at the network layer** (Layer 3 of the OSI model) to provide unique identification and logical addressing for devices across networks. IPv6 was developed to address the critical shortage of IPv4 addresses and offers several technical improvements.

IPv4 (Internet Protocol Version 4)

IPv4 was the first widely deployed version and is still in common use today.

- **Address Length:** Uses a **32-bit** addressing scheme, which provides approximately 4.3 billion unique addresses.
- **Format:** Addresses are represented in **dotted-decimal notation** (e.g., `192.168.1.1`).
- **Addressing Types:** Supports unicast, multicast, and broadcast addressing.
- **Configuration:** Typically requires manual configuration or the use of **DHCP** (Dynamic Host Configuration Protocol) servers to assign addresses.
- **Header Size:** Has a variable header size, ranging from 20 to 60 bytes.
- **Limitations:** The main limitation is the exhausted address space, necessitating workarounds like Network Address Translation (NAT) to extend its usability.

IPv6 (Internet Protocol Version 6)

IPv6 is the successor to IPv4, designed to accommodate the exponential growth of internet-connected devices (IoT, mobile, etc.).

- **Address Length:** Uses a **128-bit** addressing scheme, capable of generating approximately 340 undecillion (3.4×10383.4 cross 10 to the 38th power 3.4×1038) unique addresses.
- **Format:** Addresses are represented in **hexadecimal format**, separated by colons (e.g., `2001:0db8::1`).
- **Addressing Types:** Supports unicast, multicast, and anycast addressing, but does not use broadcast.
- **Configuration:** Supports **stateless address auto-configuration (SLAAC)**, allowing devices to configure their own addresses without a DHCP server, though DHCPv6 is also supported.
- **Header Size:** Has a fixed, simplified header size of 40 bytes, which allows for more efficient routing and processing by routers.
- **Improvements:** Includes built-in security features (IPsec is mandatory), better Quality of Service (QoS) support, and eliminates the need for NAT.

Key Differences

Feature	**IPv4**	**IPv6**
Address Length	32-bit	128-bit
Address Space	~4.3 billion addresses	Virtually unlimited
Notation	Dotted-decimal(e.g., `192.0.2.1`)	Hexadecimal (e.g., `2001:0db8::1`)
Header Size	Variable (20-60 bytes)	Fixed (40 bytes)
Addressing Modes	Unicast, broadcast, multicast	Unicast, multicast, anycast
Security (IPsec)	Optional	Built-in/mandatory capability
Configuration	Manual/DHCP	Auto-configuration (SLAAC)/DHCPv6