TCP/IP Protocols and Networking Basics

TCP/IP Protocol Suite

The TCP/IP protocol suite is the foundation of the internet and modern networking. It consists of a set of protocols organized into layers. Each layer is responsible for specific tasks and interacts with the layers directly above and below it.

Layers of the TCP/IP Model:

1. **Application Layer:** Interfaces directly with user applications. Protocols include HTTP, FTP, SMTP, and DNS.
2. **Transport Layer:** Provides end-to-end communication services. Key protocols are TCP and UDP.
3. **Internet Layer:** Manages logical addressing and routing. The primary protocol is IP (Internet Protocol).
4. **Network Interface Layer:** Concerned with physical addressing and access to the transmission medium. Includes Ethernet, Wi-Fi, and ARP.

Key Protocols:

- **HTTP (Hypertext Transfer Protocol):** Used for transmitting web pages.
- **FTP (File Transfer Protocol):** Used for file transfers.
- **SMTP (Simple Mail Transfer Protocol):** Used for sending emails.
- **DNS (Domain Name System):** Resolves domain names to IP addresses.
- **TCP (Transmission Control Protocol):** Ensures reliable, ordered, and error-checked delivery of data.
- **UDP (User Datagram Protocol):** Provides a connectionless, unreliable service for low-latency transmissions.
- **IP (Internet Protocol):** Handles logical addressing and routing. IPv4 and IPv6 are the two versions.
- **ARP (Address Resolution Protocol):** Resolves IP addresses to MAC addresses in a local network.

OSI Model

The OSI (Open Systems Interconnection) model is a conceptual framework used to understand and implement network protocols in seven layers. It helps in designing and troubleshooting networks.

Seven Layers of the OSI Model:

1. **Physical Layer (Layer 1):**
    - **Function:** Transmits raw bit streams over a physical medium.
    - **Examples:** Cables (Ethernet, fiber optic), Hubs, Repeaters.
    - **Protocols/Technologies:** Ethernet (physical aspect), USB.
2. **Data Link Layer (Layer 2):**
    - **Function:** Provides node-to-node data transfer and error detection/correction.
    - **Examples:** Switches, Bridges.
    - **Protocols/Technologies:** Ethernet (MAC), Wi-Fi (MAC), ARP.

3. **Network Layer (Layer 3):**
    - **Function:** Handles logical addressing, routing, and packet forwarding.
    - **Examples:** Routers.
    - **Protocols/Technologies:** IP (IPv4, IPv6), ICMP.
4. **Transport Layer (Layer 4):**
    - **Function:** Provides end-to-end communication, error recovery, and flow control.
    - **Examples:** Gateways.
    - **Protocols/Technologies:** TCP, UDP.
5. **Session Layer (Layer 5):**
    - **Function:** Manages sessions between applications.
    - **Examples:** N/A (mostly implemented in software).
    - **Protocols/Technologies:** NetBIOS, RPC.
6. **Presentation Layer (Layer 6):**
    - **Function:** Translates data formats, encrypts/decrypts data.
    - **Examples:** N/A (mostly implemented in software).
    - **Protocols/Technologies:** SSL/TLS, JPEG, ASCII.
7. **Application Layer (Layer 7):**
    - **Function:** Provides network services directly to applications.
    - **Examples:** Web browsers, Email clients.
    - **Protocols/Technologies:** HTTP, FTP, SMTP, DNS.

IPv4 and IPv6 Addresses

IPv4 Addresses

IPv4 addresses are 32-bit numbers, typically represented in dot-decimal notation (e.g., 192.168.1.1).

Structure:

- **Network Portion:** Identifies the network segment.
- **Host Portion:** Identifies the specific device on the network.

Classes of IPv4:

- **Class A:** Supports 16 million hosts on each of 128 networks.
    - Format: `0.0.0.0` to `127.255.255.255`
- **Class B:** Supports 65,000 hosts on each of 16,000 networks.
    - Format: `128.0.0.0` to `191.255.255.255`
- **Class C:** Supports 254 hosts on each of 2 million networks.
    - Format: `192.0.0.0` to `223.255.255.255`
- **Class D:** Reserved for multicast groups.
    - Format: `224.0.0.0` to `239.255.255.255`
- **Class E:** Reserved for experimental use.
    - Format: `240.0.0.0` to `255.255.255.255`

Special IPv4 Addresses:

- **Private IP Addresses:**

    - Class A: `10.0.0.0` to `10.255.255.255`
    - Class B: `172.16.0.0` to `172.31.255.255`
    - Class C: `192.168.0.0` to `192.168.255.255`
- **Loopback Address:** `127.0.0.1`
- **Broadcast Address:** `255.255.255.255`

Subnetting: Dividing a network into smaller sub-networks. Subnets are identified by a subnet mask (e.g., 255.255.255.0).

IPv6 Addresses

IPv6 addresses are 128-bit numbers, typically represented in hexadecimal notation (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334).

Structure:

- **Global Unicast:** Similar to IPv4 public addresses, routable on the internet.
- **Link-Local:** Used for communication within a local network segment.
- **Unique Local:** Used within a site or organization, not routable on the global internet.
- **Multicast:** Used for one-to-many communication.

Features of IPv6:

- **Larger Address Space:** 128-bit addresses provide a vastly larger number of unique addresses.
- **Simplified Header:** Improves routing efficiency.
- **Auto-configuration:** Supports stateless address auto-configuration (SLAAC).
- **No Broadcasts:** Uses multicast and anycast instead of broadcast.
- **Enhanced Security:** IPSec is mandatory for IPv6.

Network Devices

Router

A router is a network device that forwards data packets between computer networks. It performs traffic directing functions on the Internet.

Functions:

- **Routing:** Determines the best path for data packets based on IP addresses.
- **Inter-network Communication:** Connects different network segments.
- **Packet Filtering:** Uses ACLs (Access Control Lists) to filter incoming and outgoing traffic.
- **NAT (Network Address Translation):** Translates private IP addresses to a public IP address for internet access.

Types:

- **Home Routers:** Typically combine routing, switching, and wireless access.
- **Enterprise Routers:** High-performance devices used in large networks.

- **Core Routers:** Operate within the backbone of the network and route data across the network.

Switch

A switch is a network device that connects devices within a local area network (LAN) and uses MAC addresses to forward data to the correct destination.

Functions:

- **MAC Address Learning:** Stores MAC addresses in a table and uses it to forward traffic.
- **Frame Forwarding:** Directs data packets only to the intended recipient device.
- **Loop Prevention:** Uses protocols like STP (Spanning Tree Protocol) to prevent network loops.

Types:

- **Unmanaged Switch:** Simple, plug-and-play devices with no configuration options.
- **Managed Switch:** Provides more control over data traffic and network configuration, typically used in enterprise networks.
- **Layer 3 Switch:** Combines switching and routing capabilities, often used in large networks.

Hub

A hub is a basic networking device that connects multiple Ethernet devices, making them act as a single network segment.

Functions:

- **Broadcasts Data:** Sends incoming data packets to all ports, regardless of the destination.
- **No Intelligence:** Does not filter or manage traffic, leading to potential collisions and inefficiencies.

Types:

- **Active Hub:** Amplifies the signal before broadcasting.
- **Passive Hub:** Simply connects devices without signal amplification.

Comparison of Devices:

- **Hub vs. Switch:**
    - Hubs broadcast data to all devices, while switches send data only to the intended recipient.
    - Hubs operate at the OSI Physical Layer, while switches operate at the Data Link Layer.
- **Switch vs. Router:**

- Switches connect devices within the same network and operate based on MAC addresses.
- Routers connect different networks and operate based on IP addresses.