Networking Fundamentals – Detailed Notes

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1. A Network's Purpose in Life

What is a Network?

A network is a collection of interconnected devices (computers, servers, switches, routers, etc.) that communicate and share resources.

Key Purposes:

- Communication (emails, messaging, VoIP)
- Resource sharing (printers, storage, applications)
- Data transfer (file sharing, streaming, transactions)
- Centralized management & security

Basic Components:

- **End Devices:** Laptops, PCs, smartphones, servers
- **Networking Devices:** Switches, routers, firewalls, WAPs
- **Transmission Media:** Copper, fiber, wireless
- **Protocols:** Rules governing communication (TCP/IP, HTTP, DNS, etc.)

Benefits of a Network

- Collaboration: Easier sharing of documents, data, and communication tools
- Resource Optimization: Shared printers, storage, and internet connections
- Scalability: Networks can grow from a small LAN to enterprise WANs
- Centralized Control: Security policies, user management, backups
- Cost Savings: Less hardware needed when resources are shared

Networking in Daily Life

- Email, Messaging, Social Media rely on network connectivity
- Online Banking & Shopping use secure transactions over networks
- Streaming Services (Netflix, YouTube) use content delivery networks (CDNs)
- Workplace: Remote access (VPNs), video conferencing, cloud apps

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2. Network Addresses

MAC Addresses

- **Definition:** Media Access Control address; unique 48-bit identifier for a network interface card (NIC)

- **Format:** `00:1A:2B:3C:4D:5E`
- **Assigned by:** Manufacturer, hard-coded into hardware
- **Usage:**
  - Data link layer (Layer 2) addressing
  - Identifies devices within a local network
  - Used by switches for forwarding frames

IPv4 Addresses

- **Definition:** 32-bit logical address used to identify devices across networks
- **Format:** Dotted decimal (e.g., `192.168.1.1`)
- **Classes:**
  - Class A: `1.0.0.0 - 126.255.255.255`
  - Class B: `128.0.0.0 - 191.255.255.255`
  - Class C: `192.0.0.0 - 223.255.255.255`
- **Special Ranges:**
  - Private: `10.0.0.0/8`, `172.16.0.0/12`, `192.168.0.0/16`
  - Loopback: `127.0.0.1`
- **Subnetting:** Breaks large networks into smaller segments using subnet mask (e.g., `255.255.255.0`)

IPv6 Addresses

- **Definition:** 128-bit logical address to overcome IPv4 exhaustion
- **Format:** Hexadecimal (e.g., `2001:0db8:85a3:0000:0000:8a2e:0370:7334`)
- **Types:** Unicast (one-to-one), Multicast (one-to-many), Anycast (one-to-nearest)
- **Advantages:**
  - Larger address space
  - No need for NAT
  - Built-in security (IPSec)
  - Auto-configuration with SLAAC

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3. Pieces and Parts of a Network

Network Interface Cards (NICs)

- Hardware allowing a device to connect to a network
- Has unique MAC address
- Can be wired (Ethernet) or wireless (Wi-Fi adapter)

Switches

- Operate at Layer 2 (Data Link) of OSI model
- Use MAC addresses to forward frames
- Types:

  - Unmanaged (plug-and-play)
  - Managed (VLANs, monitoring, security features)
- Build a MAC address table to determine where to forward traffic

Routers

- Operate at Layer 3 (Network)
- Forward packets between different networks
- Use IP addresses for routing
- Can implement NAT, firewalls, VPNs
- Maintain routing tables (static or dynamic using protocols like OSPF, BGP)

Wireless Access Points (WAPs)

- Provide wireless connectivity (Wi-Fi)
- Connect wireless devices to a wired network
- Operate on 2.4 GHz, 5 GHz, and 6 GHz bands
- Can support multiple SSIDs and encryption (WPA3)

Copper Cabling

- **Types:**
  - UTP (Unshielded Twisted Pair): Common Ethernet cabling
  - STP (Shielded Twisted Pair): Protected against EMI
  - Coaxial: Used in older networks and TV connections
- **Limitations:** Prone to interference, shorter range

Fiber-Optic Cabling

- Uses light signals instead of electricity
- **Types:**
  - Single-mode: Long-distance, high speed
  - Multi-mode: Shorter distance, cheaper
- **Advantages:** Faster speeds, longer distances, resistant to EMI

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4. The OSI Model

Seven Layers

1. **Physical:** Cables, signals, NICs
2. **Data Link:** MAC addresses, switches
3. **Network:** IP addressing, routing
4. **Transport:** TCP/UDP, reliable data delivery
5. **Session:** Manages connections, dialogs
6. **Presentation:** Data formatting, encryption, compression

7. **Application:** End-user applications (HTTP, DNS, FTP)

TCP/IP Model Comparison

- **Layers:**
  - Application
  - Transport
  - Internet
  - Network Access
- More practical, used in real-world networking

Common Protocols

- **HTTP/HTTPS:** Web communication
- **FTP/SFTP:** File transfer
- **SMTP/IMAP/POP3:** Email
- **DNS:** Domain resolution
- **DHCP:** Automatic IP assignment

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5. Network Services

DHCP (Dynamic Host Configuration Protocol)

- Automatically assigns IP addresses to clients
- Reduces manual configuration
- Provides IP, subnet mask, gateway, DNS

DNS (Domain Name System)

- Resolves domain names (like google.com) to IP addresses
- Hierarchical structure with root, TLD, and authoritative servers
- Uses UDP port 53

NAT (Network Address Translation)

- Converts private IPs to public IPs
- **Types:**
  - Static NAT: One-to-one mapping
  - Dynamic NAT: Uses a pool of public IPs
  - PAT (Port Address Translation): Many-to-one mapping
- Conserves IPv4 addresses

NTP (Network Time Protocol)

- Synchronizes system clocks across devices
- Uses UDP port 123

- Critical for logging, authentication, and scheduling

QoS (Quality of Service)

- Manages network traffic priority
- Ensures important services (VoIP, video) get priority over normal traffic
- Prevents congestion and ensures consistent performance

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6. Wireless Networks

Types of Wireless LANs

- **Infrastructure Mode:** Devices connect through WAPs
- **Ad Hoc Mode:** Direct device-to-device connection
- **Mesh Networks:** Multiple APs create a large interconnected network

2.4 GHz vs 5 GHz

- **2.4 GHz:**
  - Longer range, better wall penetration
  - More interference (microwaves, Bluetooth)
  - Lower speeds
- **5 GHz:**
  - Higher speeds
  - Shorter range, less penetration
  - Less interference, more channels

6 GHz Frequency Band

- Introduced with Wi-Fi 6E
- Offers more spectrum, reduced congestion
- Supports ultra-fast speeds, useful for IoT and high-demand apps

Wireless Antenna Types

- **Omni-directional:** Broadcasts in all directions (Wi-Fi routers)
- **Directional (Yagi, Parabolic):** Focused signals for long distances
- **Sector Antennas:** Covers specific angles, often used in cellular networks

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7. Emerging Trends in Networking

Software-Defined Networking (SDN)

- Separates control plane (decision-making) from data plane (traffic forwarding)

- Centralized control via controllers (e.g., OpenFlow)
- **Advantages:**
  - Programmability
  - Scalability
  - Network automation

Virtualization

- Network Function Virtualization (NFV) replaces hardware appliances (firewalls, routers) with software
- Increases flexibility and reduces costs
- Common in cloud data centers

Cloud Technologies

- Networking integrated with IaaS, PaaS, SaaS
- Virtual Private Cloud (VPC) for secure networking
- Hybrid Cloud Networking connects on-prem and cloud
- **Benefits:** Scalability, cost efficiency, global reach

5G and Wi-Fi 6

- **5G:**
  - Faster speeds, low latency (<1 ms)
  - Supports IoT, smart cities, autonomous vehicles
- **Wi-Fi 6:**
  - Improved efficiency (OFDMA, MU-MIMO)
  - Better performance in dense environments
  - Higher throughput per user
