Networks

Introdução Engenharia Informática

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Why Networking Matters 🌐 i

Networking is the invisible fabric of the modern world. It’s no longer just about computers; it’s about *everything*.

- **Communication:** From email and social media to video calls.
- **Services:** Cloud computing, streaming (Netflix, Spotify), and online gaming.
- **Economy:** E-commerce, banking, and global financial systems.
- **IoT (Internet of Things):** Smart homes, wearable tech, and connected cars.

Why Networking Matters 🌐 ii

Understanding networking is no longer optional; it’s a fundamental skill for any technologist.

Key Network Equipment i

First, let’s meet the hardware that builds a network.

- **Hub:** A “dumb” repeater. Any packet it receives is broadcast to *every* other port. It’s slow, inefficient, and creates “collisions.” (Rarely used today).
- **Switch:** A “smart” device for a LAN. It learns which device is on which port (using MAC addresses) and sends packets *only* to the intended recipient.
- **Router:** A “gateway” that connects *different* networks. Your home router connects your private LAN to your provider’s WAN (the Internet).

Key Network Equipment ii

- **Access Point (AP):** A “translator” that connects wireless devices (using Wi-Fi) to the wired network (the switch).
- **ONT (Optical Network Terminal):** Your “modem” for a fiber-optic connection. It translates light signals from the fiber cable into electrical signals for your router (Ethernet).

Key Network Equipment iii

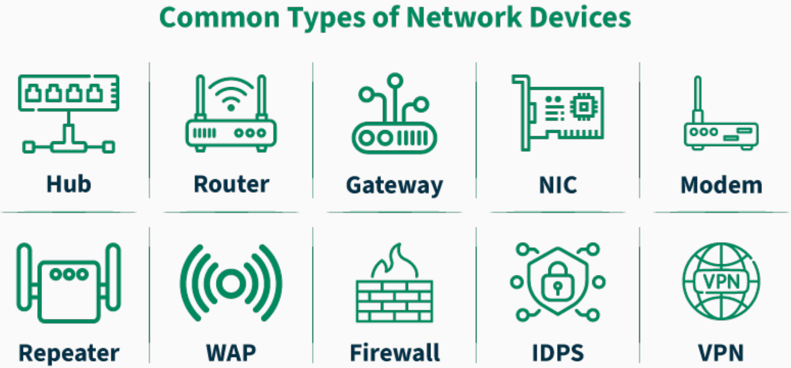


Figure 1: Common Network Devices

Key Network Equipment Connected

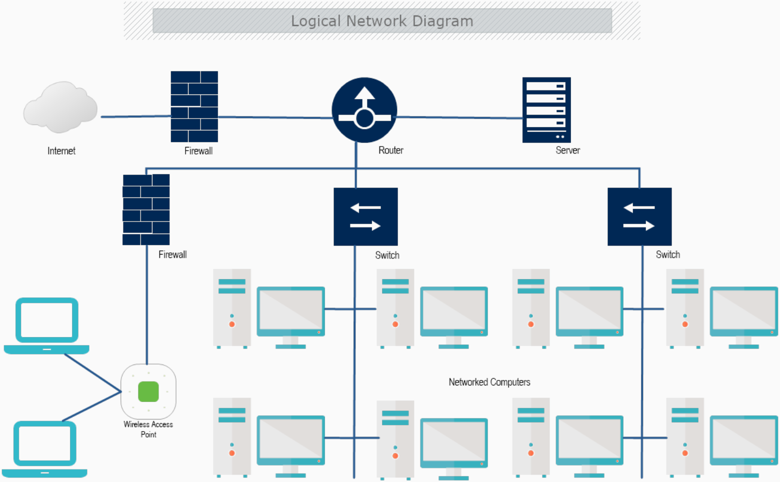


Figure 2: Network Devices Connected

The Two-Address System: MAC & IP i

Every device on a network has **two** addresses. Both are crucial.

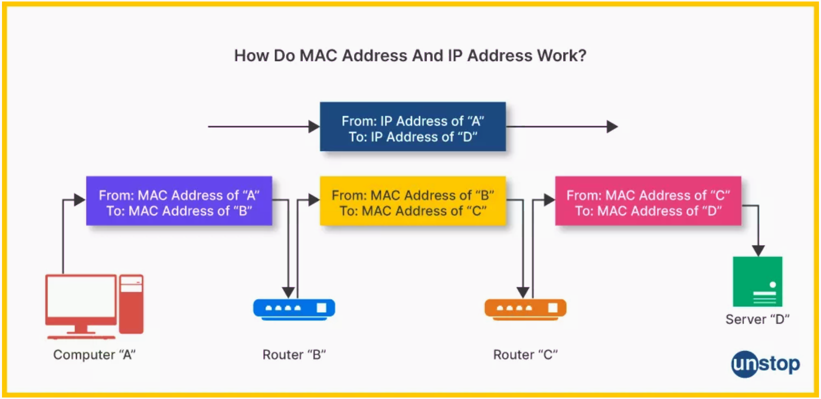
- **MAC Address (Physical Address):**
  - Example: `00:1A:2B:3C:4D:5E`
  - A unique, 48-bit serial number burned into the network card by the manufacturer. It is permanent.
  - **Used for:** Communication *within* the same Local Area Network (LAN).
- **IP Address (Logical Address):**
  - Example: `192.168.1.10`

The Two-Address System: MAC & IP ii

- A logical, 32-bit (or 128-bit for IPv6) address assigned to the device by the network (e.g., by your router). It is temporary.
- **Used for:** Communication *between* different networks (on the WAN/Internet).

Analogy: A MAC address is like your **passport number** (permanent, identifies you). An IP address is like your **home address** (logical, changes if you move).

The Two-Address System: MAC & IP iii



How Do MAC Address And IP Address Work?

From: IP Address of "A"
To: IP Address of "D"

From: MAC Address of "A"
To: MAC Address of "B"

From: MAC Address of "B"
To: MAC Address of "C"

From: MAC Address of "C"
To: MAC Address of "D"

Figure 3: From MAC to IP

How LANs *Really* Work: ARP i

Your computer (192.168.1.10) wants to send a packet to your printer (192.168.1.15) on the same LAN.

- The **Router** only understands IP addresses.
- The **Switch** (which connects them) only understands MAC addresses.

How does the computer find the printer's MAC address?

1. It shouts to the whole LAN: "WHO HAS 192.168.1.15?" This broadcast is the **Address Resolution Protocol (ARP)**.
2. The printer (192.168.1.15) replies: "I DO! My MAC is `00:AB:CD:EF:12:34`."

How LANs *Really* Work: ARP ii

3. Your computer stores this `IP` → `MAC` pair in its **ARP table** and sends the packet.

The Language: IPv4 & The Subnet Mask i

An IPv4 address alone isn’t enough. It’s always paired with a **Subnet Mask**.

- **IP Address:** `192.168.1.10`
- **Subnet Mask:** `255.255.255.0`

The subnet mask’s job is to split the IP into two parts:

1. **Network Part:** `192.168.1.x` (“What street am I on?”)
2. **Host Part:** `x.x.x.10` (“What is my house number?”)

This is how your computer knows if another IP is **local** (on the same network) or **remote** (on a different network).

Special IPv4 Address Ranges i

Not all IPs are equal. They are reserved for specific uses.

- **Loopback Address (localhost):**
  - `127.0.0.1`
  - This address always means **“this computer.”** It’s a virtual interface used for testing applications on your own machine.
- **Private / LAN Addresses:**
  - `10.0.0.0` – `10.255.255.255`
  - `172.16.0.0` – `172.31.255.255`
  - `192.168.0.0` – `192.168.255.255`
  - These are for use *inside* a private network (LAN). They are not routable on the public internet.

Special IPv4 Address Ranges ii

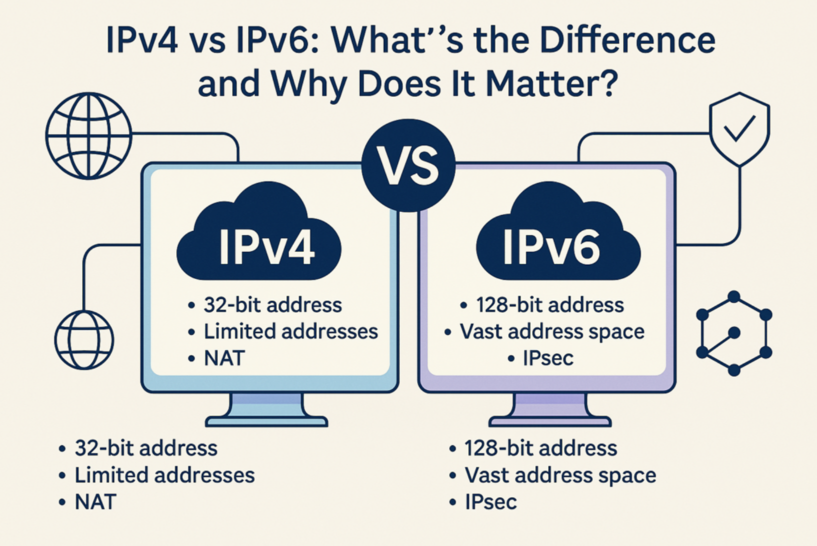
- **Public / WAN Addresses:**
  - Any other address (e.g., `8.8.8.8` or `142.250.184.142`).
  - These are globally unique and routable on the Internet.

Understanding IPv6 Addresses i

IPv4 ran out of addresses. IPv6 is the successor and has its own special types.

- **IPv6 (Internet Protocol v6):**
  - A **128-bit** address (e.g., `2001:0db8:85a3::8a2e:0370:7334`).
  - Provides a virtually limitless supply of addresses.
- **Special IPv6 Addresses:**
  - **Loopback:** `::1` (The equivalent of `127.0.0.1`).
  - **Link-Local:** `fe80::...` (Automatically assigned for *local* LAN communication. Like ARP for IPv6).
  - **Unique Local:** `fd00::...` (The equivalent of private IPv4 ranges).

IPv4 vs. IPv6



IPv4 vs IPv6: What’’s the Difference and Why Does It Matter?

IPv4

- 32-bit address
- Limited addresses
- NAT

IPv6

- 128-bit address
- Vast address space
- IPsec

- 32-bit address
- Limited addresses
- NAT

- 128-bit address
- Vast address space
- IPsec

Addresses Aren’t Enough: Ports i

An IP address gets a data packet to the right *computer*. A **Port** gets it to the right *application* on that computer.

- **Analogy:** If an IP is the building’s street address, the port is the apartment or office number.
- **Common Ports:**
  - `80`: **HTTP** (Web)
  - `443`: **HTTPS** (Secure Web)
  - `22`: **SSH** (Secure Shell)

A connection is made to an **IP + Port** (e.g., `172.217.14.228:443`).

Leaving the LAN: The Default Gateway i

1. Your computer (192.168.1.10) wants to send a packet to Google (8.8.8.8).
2. It looks at its subnet mask (`255.255.255.0`).
3. It realizes that 8.8.8.8 is **not** on its local network.
4. It can't send the packet directly. So, it sends it to the **Default Gateway**.

The **Default Gateway** is the IP address of the **Router** on the LAN (e.g., `192.168.1.1`). It's the "door" out of your local network, responsible for forwarding all non-local traffic.

Connecting Networks: Routing i

Once the packet reaches your router, what’s next?

- The **WAN (Wide Area Network)** is a network of networks (the Internet!).
- **Routing** is the process of finding the best path for data packets to travel from their source to their destination, hopping between thousands of different routers across the globe.

The “Receptionist”: NAT i

NAT (Network Address Translation) is the clever workaround for the IPv4 address shortage.

- It allows an entire private network (e.g., all 50 devices in your home with `192.168.1.x` addresses) to “hide” behind **one single public IP address**.
- Your router acts as a “receptionist,” keeping track of all outgoing requests and ensuring the responses get back to the correct private device.

Try using the IPinfo to identify your public IP.

The “Phonebook”: DNS i

We remember names (`google.com`), but computers only understand numbers (`142.250.184.142`).

DNS (Domain Name System) is the “phonebook of the Internet.” It is a global, distributed system that translates human-readable domain names into machine-readable IP addresses.

More DNS Magic: mDNS & DDNS i

- **mDNS (Multicast DNS):**
  - This is “local” DNS. It lets devices on your LAN find each other by name *without* a central DNS server.
  - This is how `my-laptop.local` or your printer automatically “appears.”
- **DDNS (Dynamic DNS):**
  - Your home’s public IP address can change (it’s “dynamic”).
  - DDNS is a service that automatically updates a domain name to point to your new IP address whenever it changes.
  - This is useful for hosting a server (e.g., Nextcloud) at home.

Keeping the Network Running: NTP & SNMP i

- **NTP (Network Time Protocol):**
  - Keeps the clocks on all computers and network devices in sync.
  - This is **critical** for security (encryption certificates), financial transactions, and accurate log files.
- **SNMP (Simple Network Management Protocol):**
  - Used by network administrators to monitor the health, performance, and configuration of routers, switches, and servers.

What We *Do* on the Network i

Protocols are the “rules of conversation” for specific tasks.

- **HTTP (HyperText Transfer Protocol):** The fundamental protocol for the World Wide Web. It’s how your browser *requests* web pages.
- **HTTPS (HTTP Secure):** This is just HTTP layered on top of **SSL/TLS** encryption. It ensures your communication is private and secure. **Always look for the 🔒!**

Email Protocols i

- **SMTP (Simple Mail Transfer Protocol):**
    - Used for *sending* email.
- **POP3 (Post Office Protocol):**
    - Used for *retrieving* email.
    - It *downloads* mail to your device and (usually) deletes it from the server. This is an older model.
- **IMAP (Internet Message Access Protocol):**
    - Used for *retrieving* email.
    - It *syncs* your mail with the server. This is the modern model. What you do on your phone appears on your laptop.

System & File Protocols i

- **SSH (Secure Shell):**
  - The single most important tool for system administrators.
  - Provides an encrypted command-line connection to a remote server.
- **FTP (File Transfer Protocol):**
  - An old, *insecure* (plain text) protocol for transferring files. **Avoid it.**
  - Use **SFTP** (which runs over SSH) instead.
- **WebDAV / CalDAV / CardDAV:**
  - Extensions of HTTP that let you manage files (WebDAV), calendars (CalDAV), and contacts (CardDAV) on a web server. Used by services like Nextcloud.

IoT Protocols: MQTT i

- **MQTT (Message Queuing Telemetry Transport):**
    - A very lightweight and efficient protocol designed for “publish” and “subscribe” messages (a pub/sub model).
    - Perfect for **IoT (Internet of Things)**: sensors, smart bulbs, and small devices that need to send tiny messages reliably with low power.

Network Configuration i

How does your device get an IP address?

- **Windows:**
  - Managed via the **Control Panel** or the Settings app.
- **Linux (Desktop):**
  - Almost always managed by **NetworkManager**, a user-friendly service with a graphical front-end (your network icon).
- **Linux (Server):**
  - Often managed by `systemd-networkd`.
  - Configuration is done via simple text files in `/etc/systemd/network/`.

Automatic Configuration: DHCP 🤖 i

In the last slide, we asked: “How does your device get an IP address?” For 99% of devices, the answer is **DHCP (Dynamic Host Configuration Protocol)**.

Manually setting an IP on every phone, laptop, and smart TV (a **static IP**) would be a nightmare. DHCP automates this.

1. Your device joins a network and shouts a **DHCP Discover** message: “Is there a DHCP server out there? I need an IP!”
2. A **DHCP Server** (usually your router) replies with a **DHCP Offer**: “Here, you can *use* `192.168.1.50`.”

Automatic Configuration: DHCP 🤖 ii

3. Your device accepts with a **DHCP Request**, and the server confirms with a **DHCP ACK** (Acknowledgement).

DHCP Leases & IP Ranges i

DHCP doesn’t give you an IP forever. It gives you a **lease**.

- **Lease Time:** The IP is “rented” to your device for a specific time (e.g., 24 hours). Before it expires, your device must renew the lease. This ensures that IPs from devices that leave the network are eventually returned to the pool.
- **IP Range (Pool):** The DHCP server is configured to manage a *range* of addresses (e.g., `192.168.1.100` to `192.168.1.200`).

DHCP Leases & IP Ranges ii

- **Static Attribution:** By only using a range, the server leaves other IPs free (e.g., `192.168.1.1` to `192.168.1.99`) for **static assignment**. These are manually configured on important devices like servers, printers, and the router itself, so their addresses never change.

Diagnostic Tool 1: `ping` i

- **The Question:** “Are you there?”
- **The Action:** Sends a small packet (ICMP Echo Request) and waits for a reply.
- **The Answer:** Tells you if a host is reachable and how long the round-trip took (this is **latency**).
- **Example:** `ping google.com`

Diagnostic Tool 2: `traceroute` i

- **The Question:** “What path do my packets take to get to you?”
- **The Action:** Sends packets with increasing “Time-To-Live” (TTL) values.
- **The Answer:** Shows you every single router (or “hop”) your packet passes through on its way to the destination. Great for finding *where* a connection is failing.
- **Example:** `traceroute google.com`

Diagnostic Tool 3: `ip`, `dig`, `nmap` i

- `ip addr show`
  - The modern Linux tool to view your *own* IP configuration and network interfaces. (Replaces the old `ifconfig`).
- `dig google.com`
  - **The Question:** “What is the IP address for this name?”
  - **The Action:** Performs a DNS lookup.
- `nmap localhost`
  - **The Question:** “What doors are open on this machine?”
  - **The Action:** A powerful port scanner.
  - **The Answer:** Reports which ports are open and what services are (likely) running on them.

Network Monitoring: Wireshark i

- **The Tool:** Wireshark is a “network sniffer” or protocol analyzer.
- **The Action:** It captures *every single packet* traveling on your network interface and lets you inspect its contents.
- **Analogy:** It’s like a video camera for your network traffic.
- **Use:** The single most powerful tool for debugging complex network problems.

Network Security: Firewalls i

A **firewall** is the “security guard” for your network or computer.

- It inspects all incoming and outgoing network traffic.
- It decides whether to **allow** or **block** each packet based on a set of rules (e.g., “Allow traffic on port 443, block everything else”).
- This is your first line of defense.

Firewall Examples i

- **iptables:** The classic, powerful, command-line firewall built into the Linux kernel for decades.
- **nftables:** The modern successor to `iptables` in Linux. It has a simpler syntax and better performance.
- **pfSense:** A free, open-source **firewall operating system**. You install it on a dedicated computer to turn it into an extremely powerful, enterprise-grade router and firewall for your entire network.

The Power of SSH: VS Code Remote i

SSH is more than just a remote shell. The “Remote - SSH” extension in VS Code is a game-changer.

- **How it works:** Your editor UI runs locally, but all file editing, terminal commands, and language processing run on the remote server.
- You get the power of a server with the comfort of your local editor.

The Power of SSH: Tunnels & X11 i

- **SSH Tunnels (Port Forwarding):**
  - Lets you securely “wrap” network traffic inside an SSH connection.
  - **Example:** Access a database running on `localhost:5432` on a remote server as if it were running on *your own* machine’s `localhost:5432`.
- **X11 Forwarding:**
  - Lets you run a *graphical* application (like `firefox` or a text editor) on a remote Linux server, but see and interact with the window on your local desktop.

Syncing Files: `rsync` over SSH i

The best way to transfer and sync files. `rsync` is fast, efficient, and versatile.

- **Why it's fast:** It only copies the **differences** (deltas) between files, not the whole file.
- It works perfectly over an SSH connection.
- **Command:**

```
# Sync a local folder UP to a remote server
$ rsync -avzP ./my-project/ user@host:~/projects/
```

The Modern Web: Reverse Proxy i

A **Reverse Proxy** (like NGINX or Caddy) is a server that sits *in front* of your actual application servers.

- It receives all incoming traffic from the Internet.
- It then “proxies” (forwards) the request to the correct internal application (e.g., your Python app, your Node.js app).
- **Uses:**
  - **Load Balancing:** Distribute traffic across multiple app servers.
  - **Security:** Hides your application servers from the Internet.
  - **Hosting:** Host multiple websites on a single IP address.

The Modern Web: HTTPS & Let’s Encrypt i

- **HTTPS** is essential. It provides the encryption (SSL/TLS) that keeps user data private and proves your site’s identity.
- **The Problem:** Certificates used to be expensive and difficult to install.
- **The Solution: Let’s Encrypt**
    - A free, automated, and open **Certificate Authority (CA)**.
    - It provides free SSL/TLS certificates and tools (like `certbot`) to automatically install and renew them.
    - It has made the entire web more secure.

Further Reading & Resources 📚 i

- **Wireshark:** https://www.wireshark.org/
- **Nmap:** https://nmap.org/
- **Let’s Encrypt:** https://letsencrypt.org/
- `ip` **command guide:** https://www.geeksforgeeks.org/ip-command-in-linux-with-examples/
- `rsync` **guide:** https://www.digitalocean.com/community/tutorials/how-to-use-rsync-to-sync-local-and-remote-directories
- **Mozilla’s Guide to HTTP:** https://developer.mozilla.org/en-US/docs/Web/HTTP/Overview