Communication

A-Level Computer Science

Networks: purpose and benefits

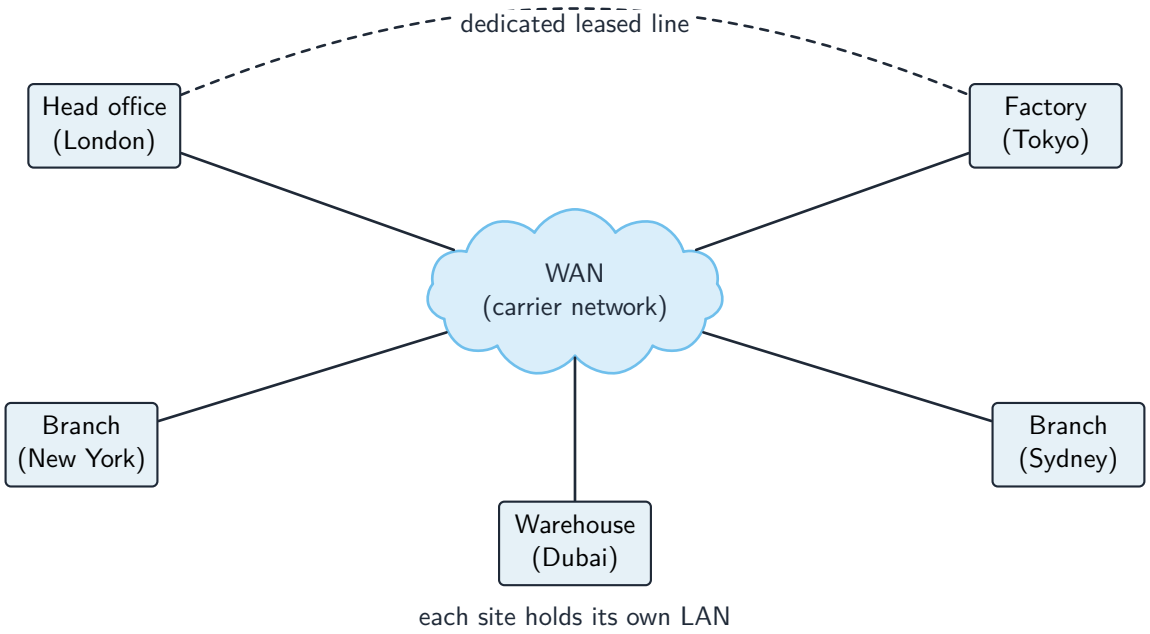
A **network** 网络 is a set of computing devices connected so they can communicate and share resources. Benefits:

- **sharing resources** (printers, file servers, internet) —cheaper than equipping each computer.
- **sharing data** —many users access the same files.
- **central management** —install software, manage users and back up once on a server.
- **communication** —email, video calls, messaging.
- **remote access** —work from anywhere.

LAN vs WAN

A **local area network** 局域网 (LAN) covers a **small area** —a home, office or school, usually owned by the organisation, with high data rates and low **latency** 延迟.

A **wide area network** 广域网 (WAN) covers a **large area** —a city, country, or the world (the internet is the largest WAN). It uses telecom-company infrastructure —often the **Public Switched Telephone Network** 公共交换电话网 (PSTN), leased lines or fibre —with lower data rates and higher latency. A WAN connects LANs together.

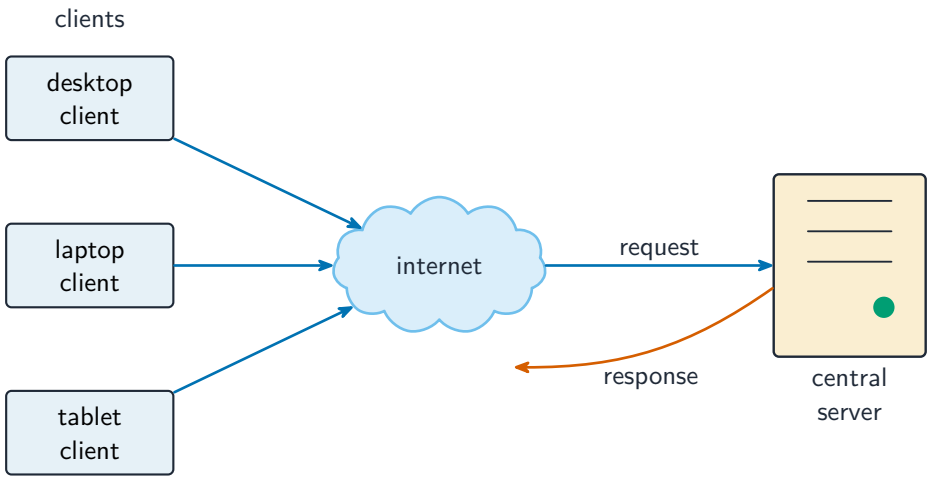


A wide-area network links many systems across a large area

Client-server and peer-to-peer

Client-server

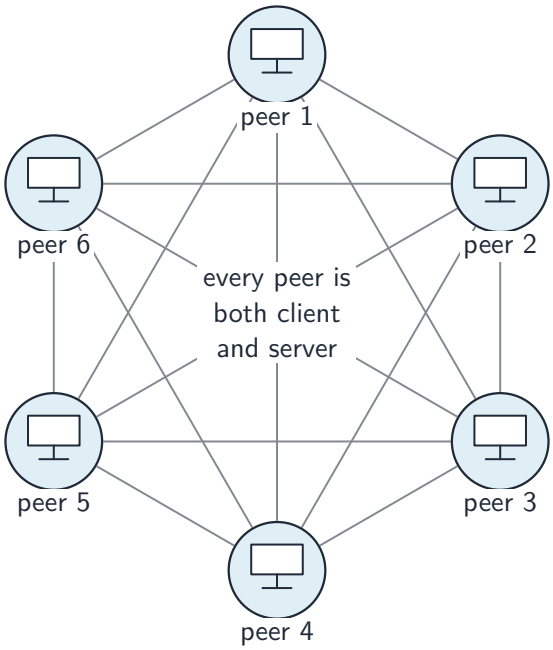
- powerful machines act as **servers** 服务器, providing services (files, web pages, email).
- other machines are **clients** 客户端 that request services.
- central and easy to manage, but the server is a single point of failure unless backed up.



In a client-server network, clients request services from a central server

Peer-to-peer (P2P)

- all machines are equal **peers**; each can be both client and server (**peer-to-peer** 对等网络).
- resources are spread across the peers —no central server. Robust to one failure, but harder to keep secure and consistent.



In a peer-to-peer network, every node is both client and server

Thin and thick clients

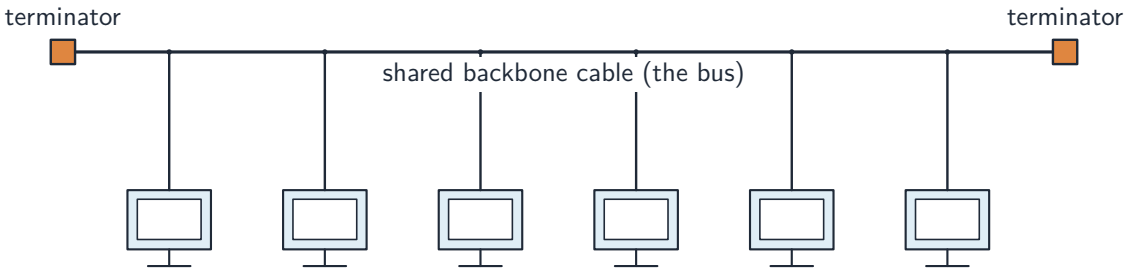
A **thin client** 瘦客户端 does **little processing locally** and relies on a powerful server (web terminals, remote desktops). A **thick client** 胖客户端 has **strong local processing and storage** and runs full applications itself (a normal desktop PC).

Feature	Thin client	Thick client
Local processing	minimal	substantial
Local storage	minimal	substantial
Reliance on network	high	lower
Server load	high	lower

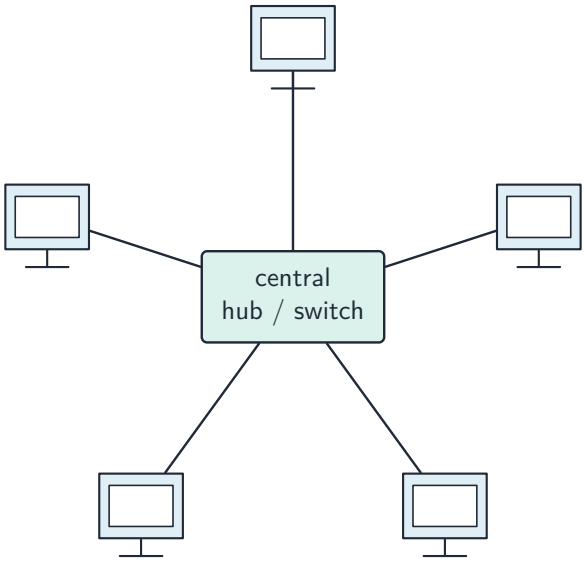
Network topologies

The **topology** 拓扑 is how the nodes and links are arranged.

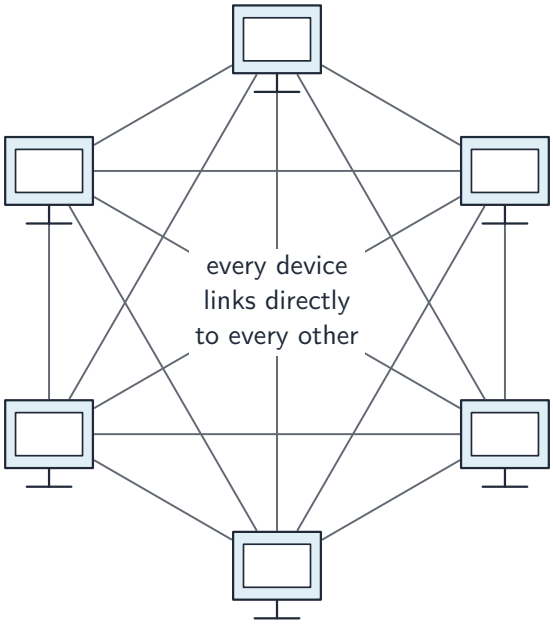
- **bus** 总线—all devices on one shared cable. Cheap; the whole LAN fails if the bus fails; performance drops as more devices share the **bandwidth** 带宽.
- **star** 星形—every device connects to a central switch. One device failing does not affect others; the switch failing brings all down. Most common today.
- **mesh** 网状—every device links directly to others, with many paths. Very **fault-tolerant** 容错 (traffic reroutes) but needs lots of cabling.
- **hybrid** —a mix (a star in each office, mesh links between offices).



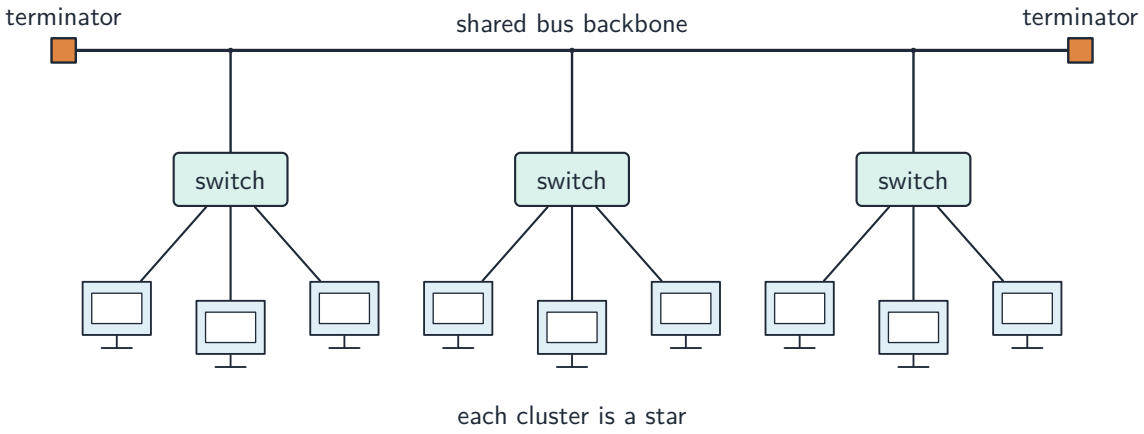
Bus topology: all devices share one cable with a terminator at each end



Star topology: every device connects to a central hub or switch



Mesh topology: every device links directly to the others



Hybrid topology: star clusters joined by a central bus

Cloud computing

Cloud computing 云计算 delivers computing services (servers, storage, software) **over the internet**, hosted by a third party. Benefits: **scalability** 可扩展性 (pay for what you need), lower cost, access from anywhere, and reliable redundant data centres. Drawbacks: needs internet, your data is held by a third party, and possible vendor lock-in.

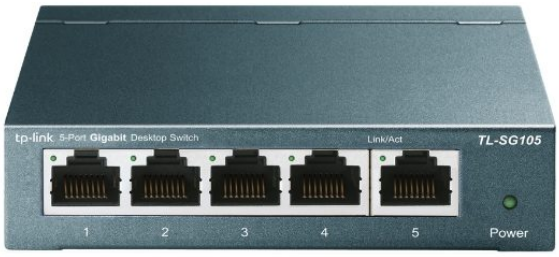
Wired vs wireless

- **wired** (**Ethernet** 以太网 over **twisted-pair** 双绞线 or **fibre-optic** 光纤): higher speed, lower latency, fewer errors, more secure.
- **wireless** (Wi-Fi, Bluetooth, cellular): no cables, devices can move, but slower, prone to interference and eavesdropping.

For the same generation, wired wins on speed and reliability; wireless wins on convenience.

LAN hardware

- **network interface card** 网络接口卡 (NIC) —lets a device send and receive on the network; has a unique **MAC address** MAC 地址 (a 48-bit hardware address). A wireless device uses a **wireless network interface card** 无线网络接口卡 (WNIC).
- **switch** 交换机—forwards Ethernet frames only to the port for the destination MAC address.
- **hub** 集线器—a simpler device that copies traffic to all ports (now obsolete).
- **wireless access point** 无线接入点 (WAP) —lets wireless clients join a wired LAN.
- cabling —twisted-pair for short runs; fibre-optic for longer, faster runs.

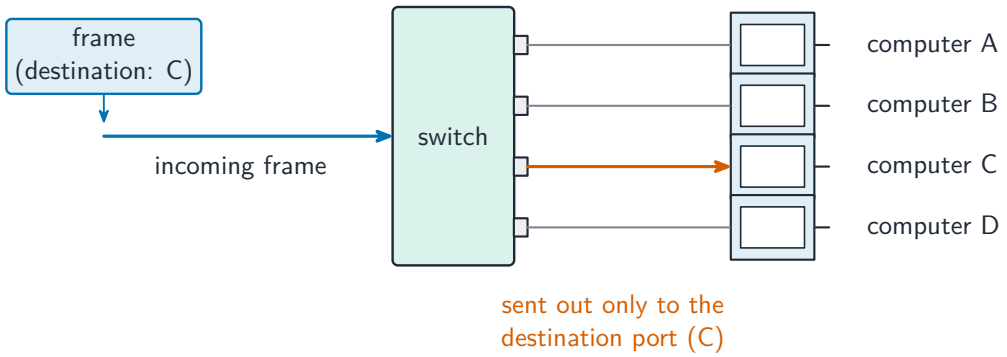


A network switch: each device's cable plugs into one of its ports

Image: TP-Link, Product image (www.tp-link.com)

An RJ-45 plug on a twisted-pair Ethernet cable

Image: Cable Matters, Product image (www.cablematters.com)

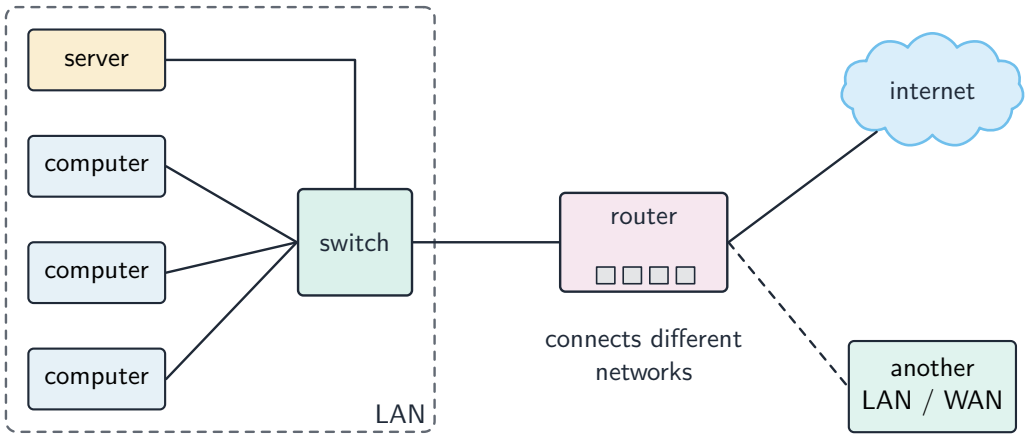


A switch sends each frame only to the port for its destination

Routers

A **router** 路由器 connects **different networks** and forwards data between them — usually at the boundary of a LAN and the internet. It does:

- **forwarding** —reads each **packet** 数据包's destination **IP address** IP 地址 and sends it out the right port, using a **routing table** 路由表.
- **network address translation** 网络地址转换 (NAT) —lets many private LAN addresses share one public IP.
- **DHCP** 动态主机配置协议—hands out private IP addresses to LAN devices.
- **firewall** 防火墙—blocks unwanted incoming traffic.



A router connects a LAN to the internet or another network

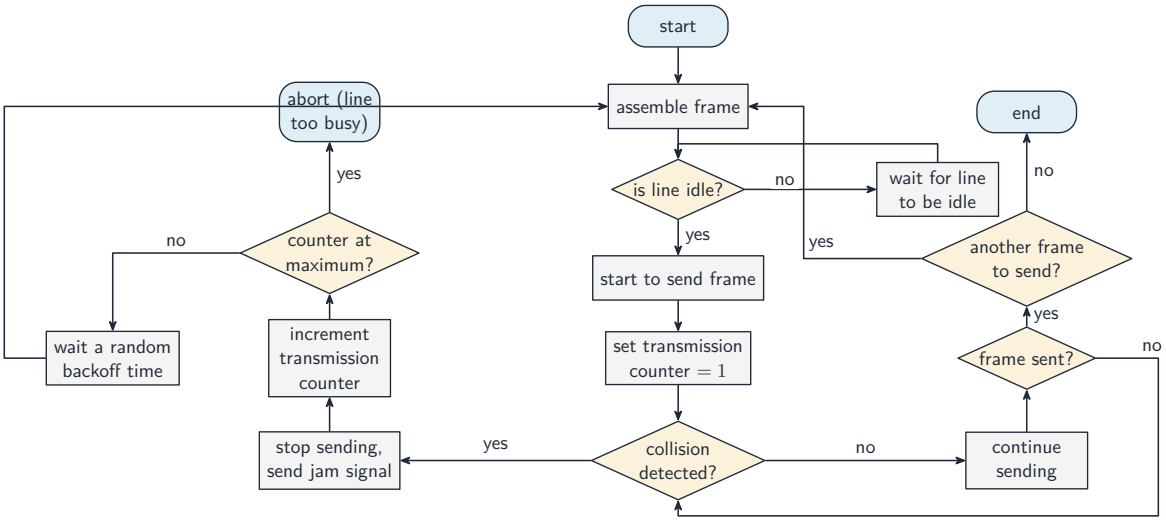
Ethernet and CSMA/CD

Ethernet is the main wired LAN technology. On shared media a **collision** 冲突 can happen when two devices send at once. The protocol is **CSMA/CD** 载波侦听多路访问 (Carrier Sense Multiple Access with Collision Detection):

1. **carrier sense** —listen before sending; wait if the cable is busy.

2. **multiple access** —many devices share the medium.
3. **collision detection** —keep listening while sending; a clash is a collision.
4. on a collision, both stop, send a brief ”jam” signal, then wait a **random backoff** time before retrying.

Modern switched Ethernet uses **full-duplex** 全双工 point-to-point links, so collisions no longer happen.



The CSMA/CD process for handling collisions on shared media

Bit streaming

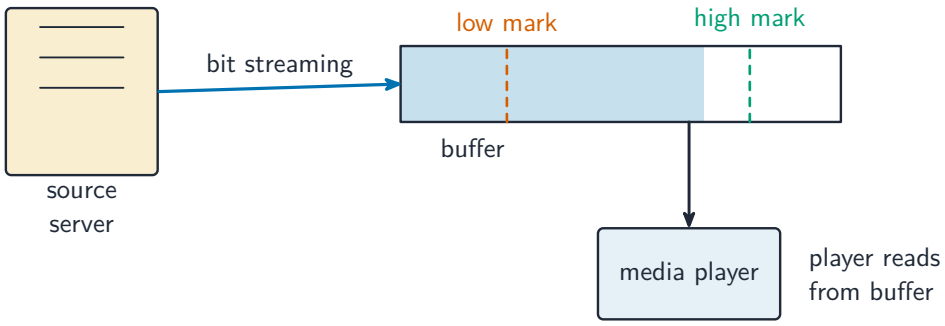
Bit streaming 流式传输 sends multimedia as a continuous stream that the receiver plays as it arrives, instead of downloading the whole file first.

- **real-time** (live): captured and streamed as it happens (live sport, video calls). You cannot rewind; low latency is vital.
- **on-demand**: pre-recorded on a server (YouTube, Netflix). You can pause and rewind; the server can **buffer** 缓冲 ahead.

Real-time streaming works as a short pipeline:

1. **capture and sample** the source (a camera or microphone).
2. **encode** it, using **compression** 压缩 to shrink the data.
3. **send** it across the network as packets.
4. the receiver buffers a little, then plays it live —**dropping any packet that arrives late**, because a live stream cannot wait for it.

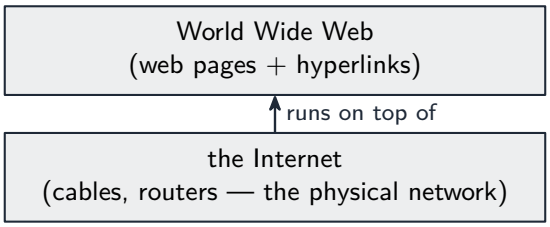
Lossy 有损 compression is used here: moving pictures hide small losses, and the stream must be small enough to fit the bandwidth.



Data streams from the server into a buffer before the media player reads it

The internet and the World Wide Web

The **internet** 互联网 is a global **network of networks** using a common **protocol** 协议 suite (TCP/IP). The **World Wide Web** 万维网 (WWW) is a **service** that runs over it: hyperlinked documents identified by URLs, viewed in browsers via HTTP/HTTPS. Email and file transfer are other internet services that are not part of the WWW.



The Web is one service running on top of the Internet

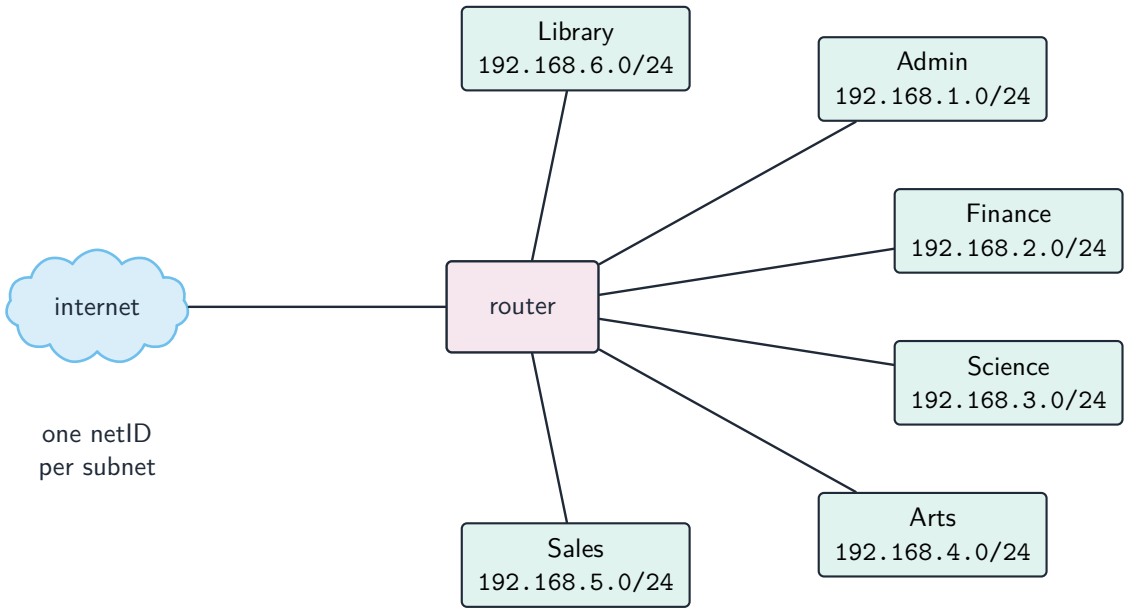
IP addresses

An IP address uniquely identifies a device.

- **IPv4** —32-bit, four denary numbers 0–255 (`192.168.1.10`); about 4.3×10^9 addresses (now exhausted).
- **IPv6** —128-bit, eight groups of four hex digits; about 3.4×10^{38} addresses.

Subnetting

A network can be split into **subnets** 子网. The IP address splits into a network part and a host part, given by a **subnet mask** 子网掩码 (e.g. `255.255.255.0` = first 24 bits are network). Subnetting improves management, cuts broadcast traffic, and improves security.



Splitting a network into subnets, one netID per department

Public vs private addresses

- **private** addresses are used within a LAN and are not routable on the internet (e.g. `192.168.0.0/16`).
- a **public IP address** is globally unique and routable, assigned by an **ISP** 互联网服务提供商.

Devices behind NAT with private addresses are not directly reachable from the internet, giving some protection.

Static vs dynamic

- a **static IP address** is fixed; used for servers that must be found at a known address.
- a **dynamic IP address** is assigned by DHCP and may change; easier for client devices and uses a limited address pool efficiently.

Worked example. A host has IP address `192.168.10.130` with subnet mask `255.255.255.192`. Which network is it on, and is `192.168.10.200` on the same one? The mask's last octet, `192`, is `11000000` in binary, so the first **26** bits are the network part and the last 6 bits address the host. That makes the subnets step in blocks of $256 - 192 = 64$: `.0`, `.64`, `.128`, `.192`. The address `130` falls in the block starting at `.128`, so the host is on network **`192.168.10.128/26`**, whose usable hosts run `.129` to `.190` (`.191` is the broadcast address). `200` falls in the **next** block (`.192`), so it is on a **different** subnet and traffic between the two must pass through a **router**. Get the block size from the mask first (256 minus the mask octet) - guessing from the first three octets is what makes these go wrong.

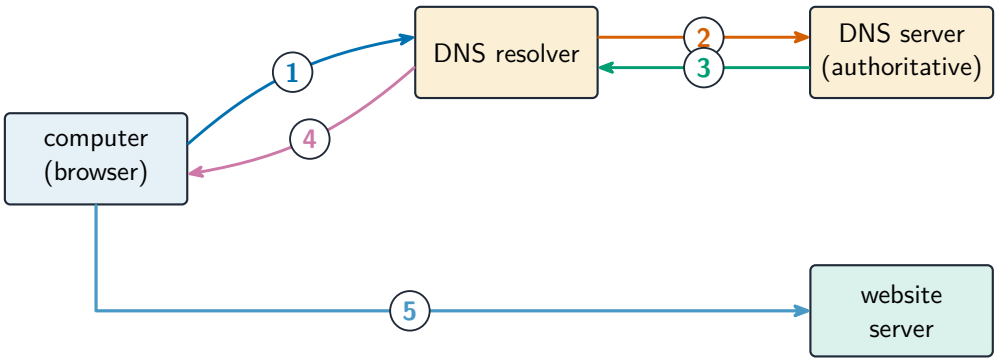
URL and DNS

A **URL** 统一资源定位符 (Uniform Resource Locator) locates a resource on the WWW:

```
https://www.example.com/about/contact.html
protocol     domain name        path
```

- **protocol**: `http`, `https`, etc.
- **domain name** 域名: a readable server address.
- **path**: the resource on that server.

The **Domain Name System** 域名系统 (DNS, also called the Domain Name Service) is a distributed set of servers that turns **domain names into IP addresses**. When you type a URL, the browser asks a DNS resolver for the IP, which queries DNS servers (root → top-level → authoritative) until it finds it; the browser then connects to that IP and requests the path. DNS saves humans from memorising IP addresses and lets a site change server without changing its name.



How DNS finds a website's IP address before the browser connects

Exam tips

- Distinguish **LAN vs WAN** and **client-server vs peer-to-peer** by who stores and controls the resources.
- Match each **topology** (bus, star, mesh) to its advantages and drawbacks (cost, reliability, collisions).
- Know the job of each device: a **switch** directs within a LAN by MAC address, a **router** routes between networks by IP.
- Explain **bit streaming** and why buffering is needed (data arrives at a different rate from playback).
- Distinguish **IPv4 vs IPv6** and public vs private addresses; DNS turns a URL into an IP address.