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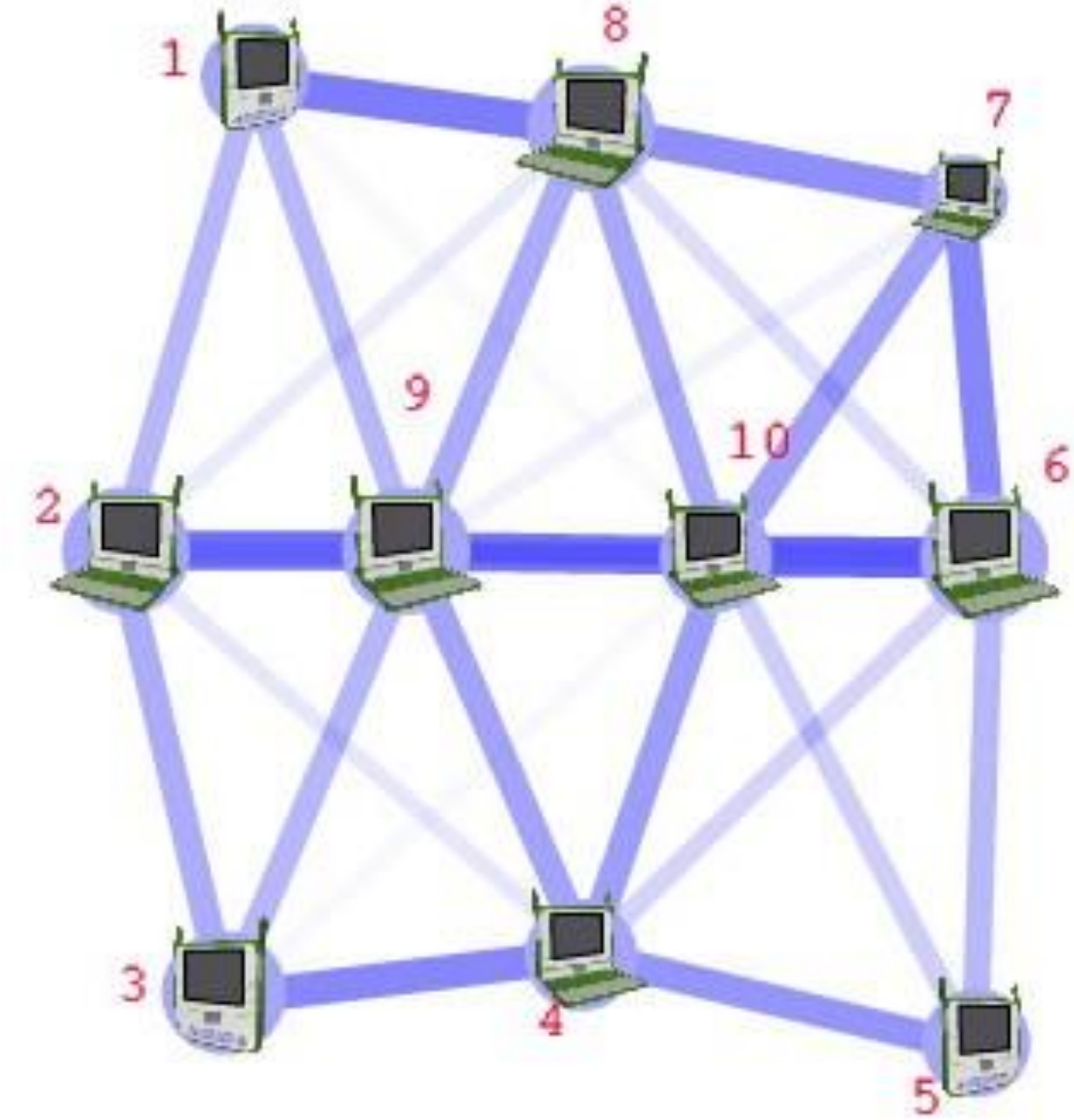
Networks & Infrastructure

What is a computer network?



Computer Network: 2 or more connected computers that share resources

Advantages & Disadvantages

Advantages	Disadvantages
Resource Sharing Data, hardware & processes can be shared amongst machines	**Security Issues** Risks of hacking and unwanted access
Communication Fast and reliable communications	**Setup & Maintenance Cost** Bigger network = Higher costs
Central Data Management Data is stored in one place – easy to access and avoids duplication	**Complexity** Large networks need advanced skills - issues may be difficult to fix
Scalability Add devices to meet demand	**Performance Problems** Too many users causes slow down
Collaboration Many people on a single project	**Dependency** Network breaks, everything breaks

Network Characteristics

Characteristic	Description
Size	Networks can (intentionally) vary in size and scope – LANs, WANs and more!
Scalability	The ability to add new devices to a network while maintaining integrity and performance
Reliability	How strong is the network? Is it likely to fail?
Latency	The delay between a request being made and the data being transferred
Bandwidth	The data transfer rate. How much data can be transferred per unit of time - bits per second (bps). You may have seen mbps from your ISP

Types of Network

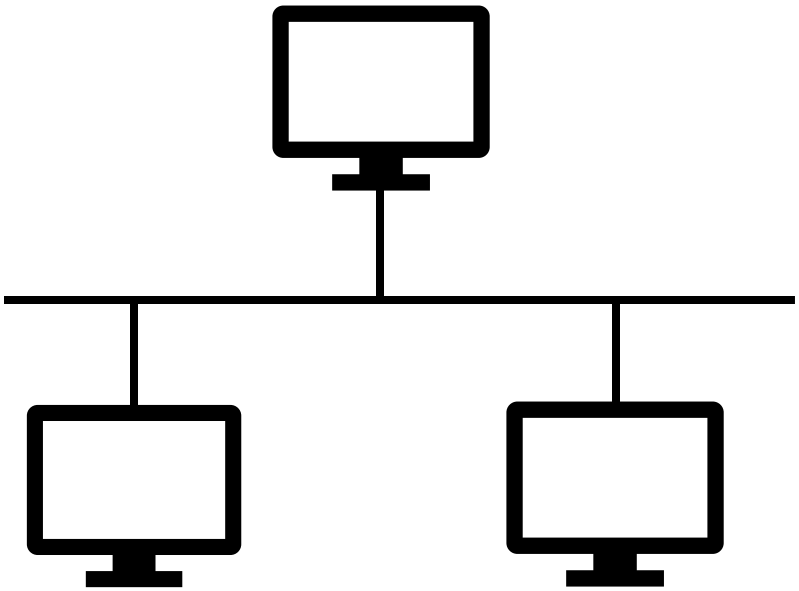
LAN – Local Area Network

Connects devices within a small area – usually a single building

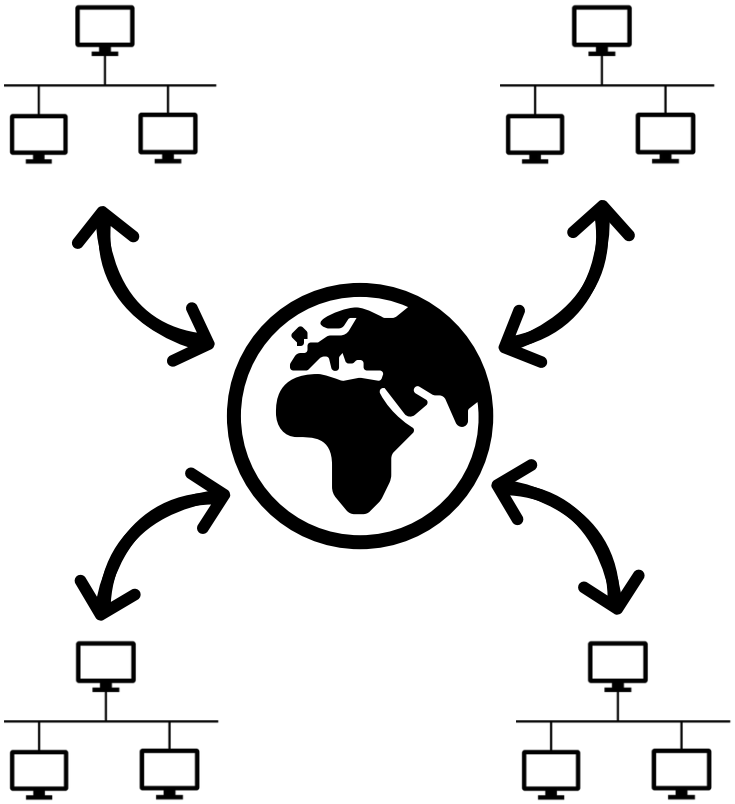
A home with all devices connected to the same router is a typical LAN

Another example, an office or school network with shared peripherals, such as printers

Relatively easy and cheap to set up, but complex LANs may require technicians to manage



WAN – Wide Area Network



Connects over a large geographical area

Connects multiple LANs together

The internet is a worldwide WAN

A WAN is very complicated and expensive to run – the service is provided to us by telecom companies

PAN – Personal Area Network

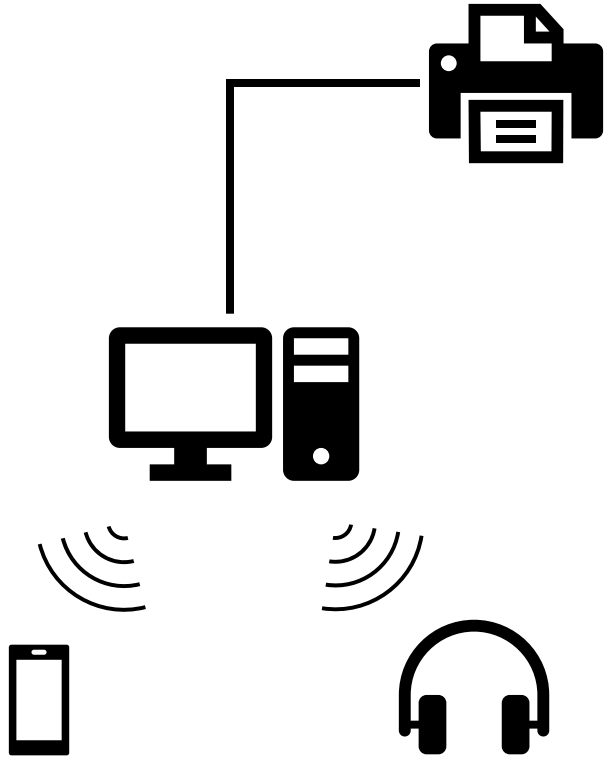
Very small localised network – smaller than LAN

Limited range

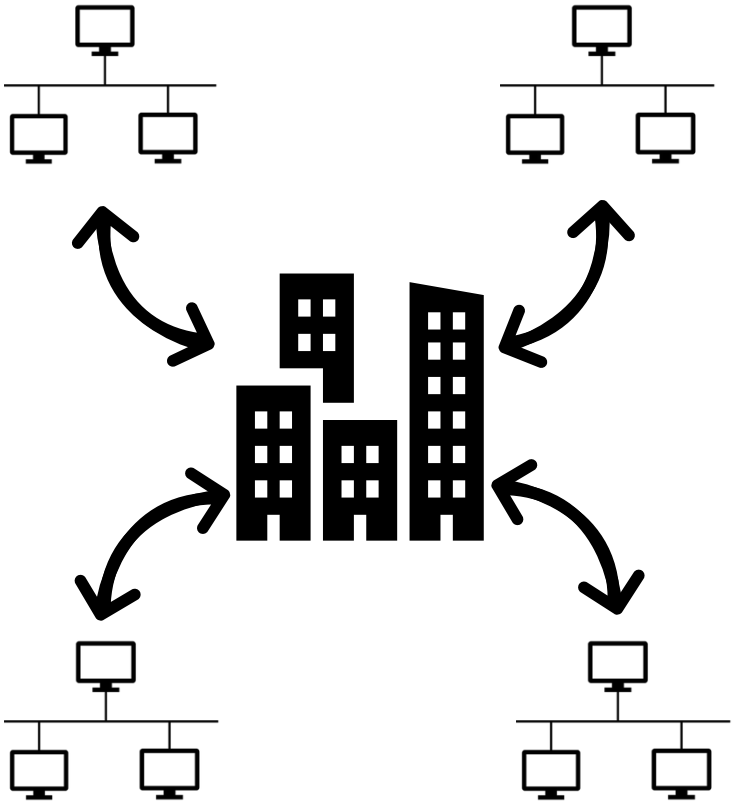
Made up of personal devices

Relatively easy to set up

Connections may be Wi-Fi, Bluetooth and wired



MAN – Metropolitan Area Network



Larger than a LAN, but smaller than a WAN

Connects multiple LANs in a region covering a metropolitan area such as a city or campus

May streamline the connection of LANs to a WAN

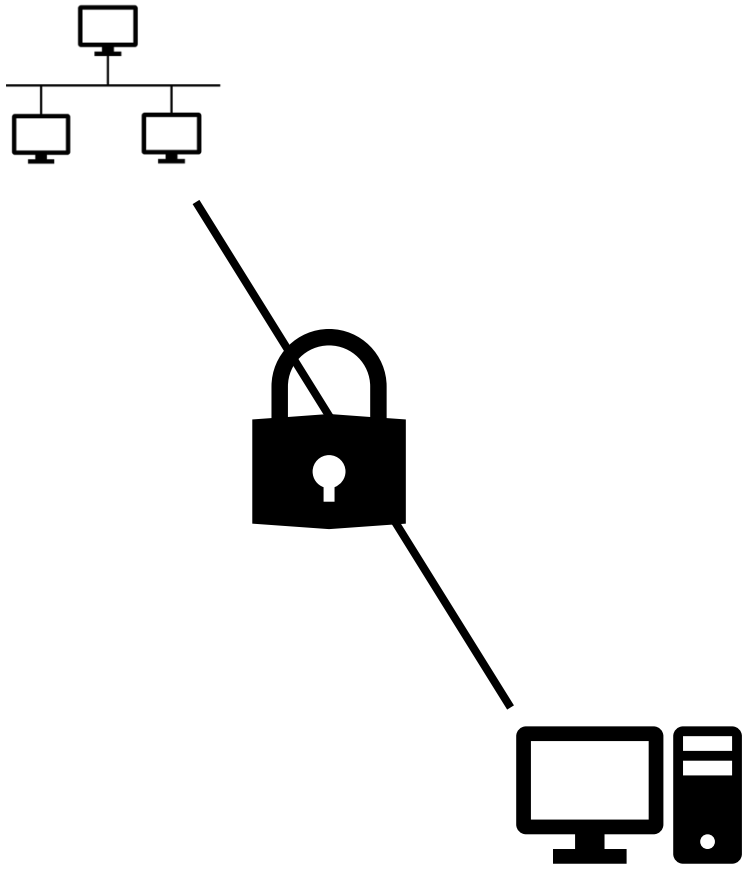
More expensive than to set up and maintain than a LAN but covers a wider range

VPN – Virtual Private Network

Allows for a secure, remote connection to a private network via the internet

They use encrypted tunnels from the device to the private network to protect traffic

Uses the internet so has an extensive range, but the encryption process can slow down traffic



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Networking History

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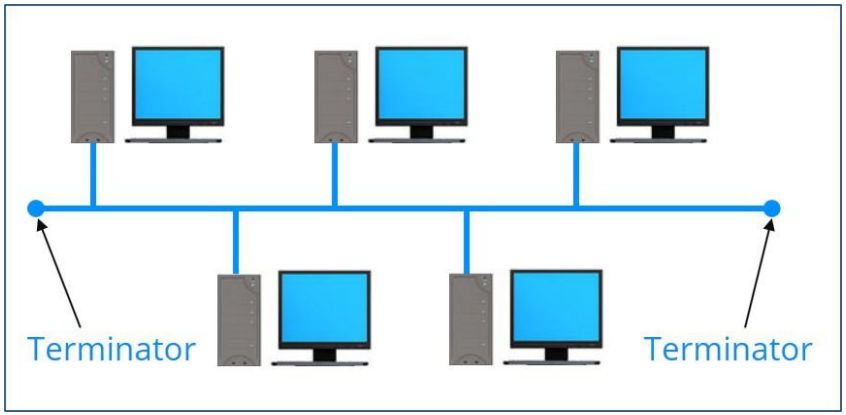
Network Topology

(Arrangement)

Bus Topology



All devices are connected to a single central cable, which has terminators at each end to ensure proper operation

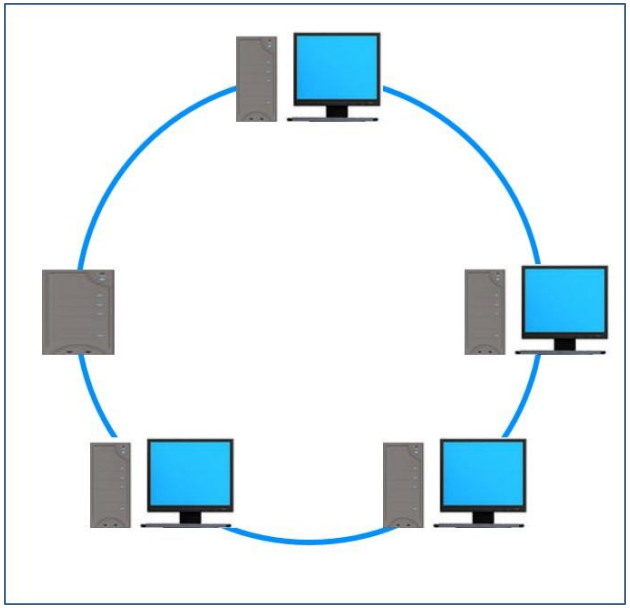
Advantages:

- Easy and inexpensive to install for small networks
- Uses less cable compared to other topologies

Disadvantages:

- If the main cable fails, the whole network goes down
- Difficult to troubleshoot
- Performance degrades as more devices are added due to data collisions

Ring Topology



Devices are connected in a loop, with each device connected to the next, forming a ring

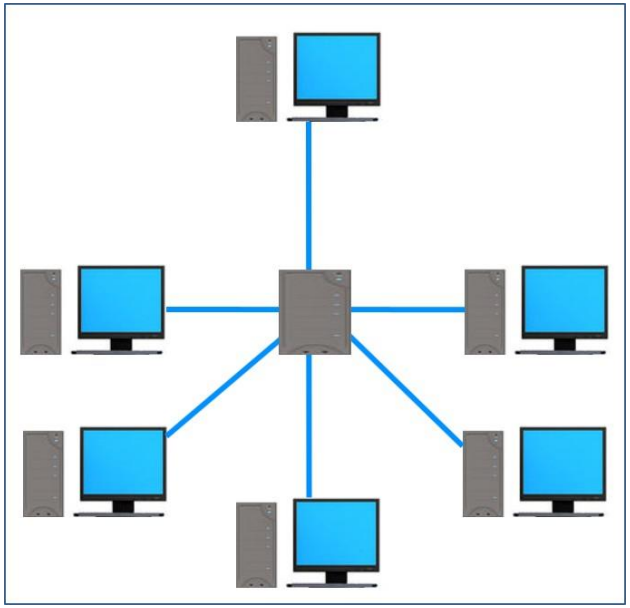
Advantages:

- Data travels in one direction, reducing the chances of collisions
- Better performance than bus topology when handling many devices

Disadvantages:

- A failure in any cable or device breaks the entire network
- Adding or removing devices can disrupt the network

Star Topology



All devices are connected to a central hub or switch, creating a starshaped network

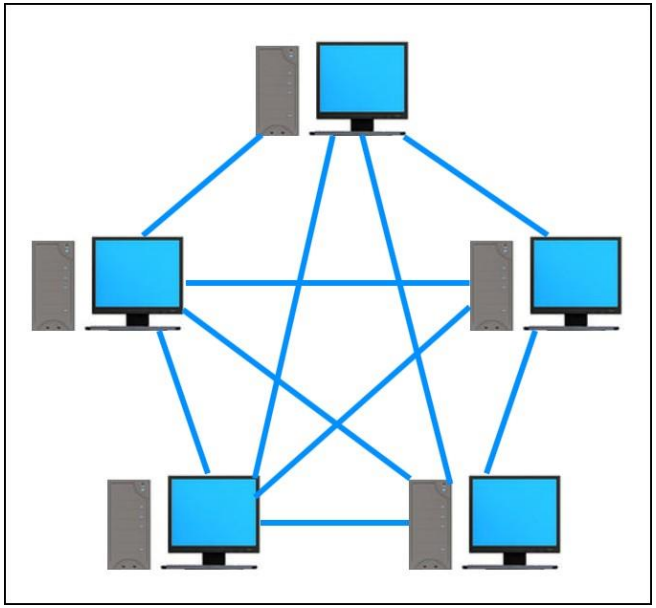
Advantages:

- Easy to install and manage
- Failure of one device doesn't affect the others
- Easy to add new devices without disrupting the network

Disadvantages:

- If the central hub or switch fails, the whole network goes down
- Requires more cable than bus topology, increasing installation costs

Star Topology



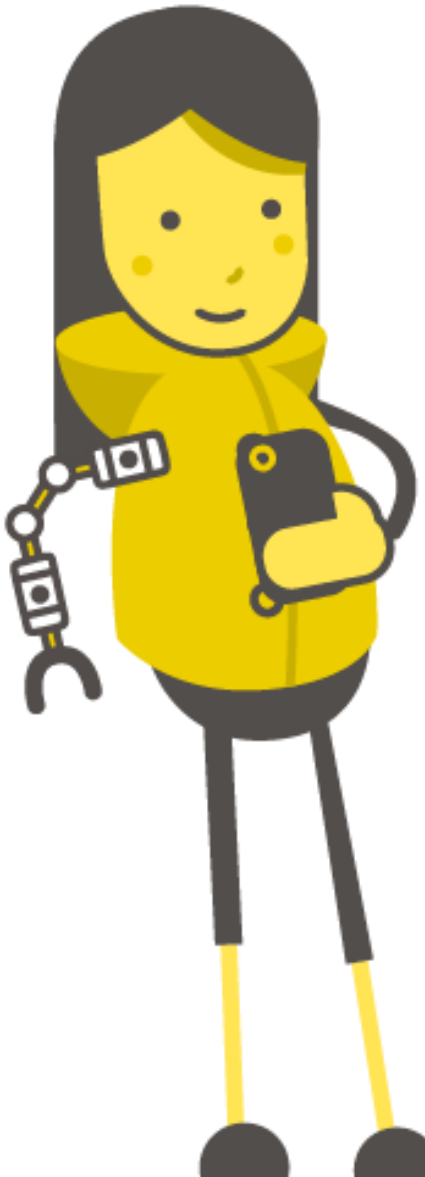
Every device is connected to every other device, providing multiple pathways for data.

Advantages:

- It is highly reliable, as there are many paths for data to travel
- If one path fails, data can take another route
- Can expand and modify the topology without disrupting other nodes

Disadvantages:

- It is expensive and more complicated to install due to the high number of connections required
- Usually needs specific staff employed for maintenance and management



What was our first worldwide communications network?

Stockholm Telephone Exchange – 19th Century

Traditional Telecommunication Systems

Telegraph and Telephone

The beginning of our modern communications network. Enabled point-to-point communications through electrical signals along wires

PSTN – Public Switched Telephone Network

Used for landline phones. Creates a dedicated connection for each call. Communications carried via analogue signals

Dial-up Internet

Early internet access through existing telephone infrastructure – 56 kbps limit. A shared line prevented simultaneous telephone calls

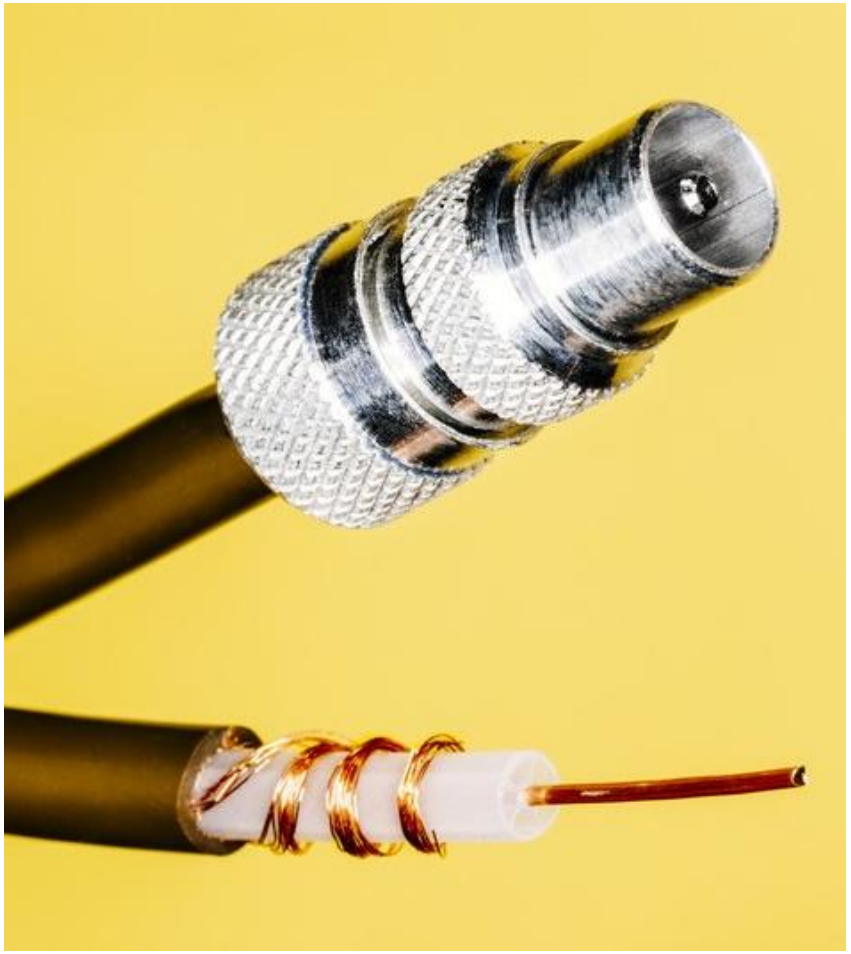
Broadband Technology

ADSL – Asymmetric Digital Subscriber Line

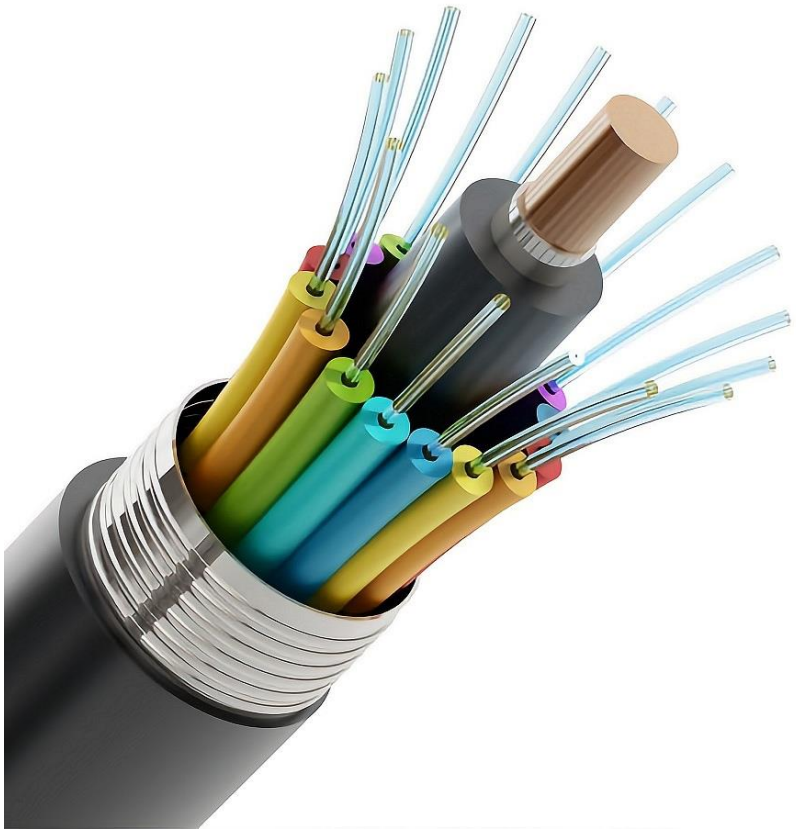
Faster than dial-up without interrupting phone calls. Still uses existing phone lines but splits voice and computer data into separate frequency channels

Cable Broadband

Delivers internet through coaxial cables designed for cable TV. Allows greater speed and bandwidth than ADSL



Fibre Optics & High Speed Networks



Fibre Optic Networks

The foundation of modern broadband. Transmit data as light, providing vastly faster speeds and bandwidth than copper lines

4G/5G Mobile Networks

Advanced wireless networks, enabling high speed internet on mobile devices. 5G offers ultra-low latency and higher speeds, supporting lots of connected devices at once

Wi-Fi

Wireless local area networks (WLAN) started with Wi-Fi 801.11 standards which had limited range and speed

The newest standard, slowly being adopted is Wi-Fi 6

Provides faster speeds, reduces network congestion and enhances connectivity in crowded areas

Emerging Technology

Low Earth Orbit Satellites

Initiatives like Starlink and OneWeb aim to deliver data via satellites orbiting close to the earth for higher speeds and lower latency

6G

Research into 6G networks is progressing, promising even faster speeds, lower latency, and the potential to support cutting-edge technologies.

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Hardware Requirements

What do I need for a modern network connection?

Routers

Connects different networks and sends data between them

Stores addresses of computers on a network using a routing table and transfers data between networks and devices

Helps devices access the internet, directs traffic and manages IP addresses

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Hubs

A basic device for linking devices in a LAN

Sends data to every device in the LAN – cannot isolate just one

Inexpensive but inefficient – slows down the network as data is sent to all devices

Switches

Essentially, a more advanced hub

Analyses each packet of data and sends it to the specific computer it was intended for

Improves network performance through better management of traffic

Bridges

Connects parts of separate networks so that they work together as if they were a single network

Reduces data collisions

Allows for the filtering of data

More on data packets later!

Gateways

Connects different networks that may use different protocols – can translate data from one network type to another (e.g. WAN to LAN)

Helps networks with different protocols to communicate, such as a home network to the internet

More on protocols later!

Wireless Access Points (WAPs)

Allows wireless devices to connect to wire networks using Wi-Fi

Can extend the reach of networks by enabling wireless connectivity

Common in homes and offices for mobile access to the internet

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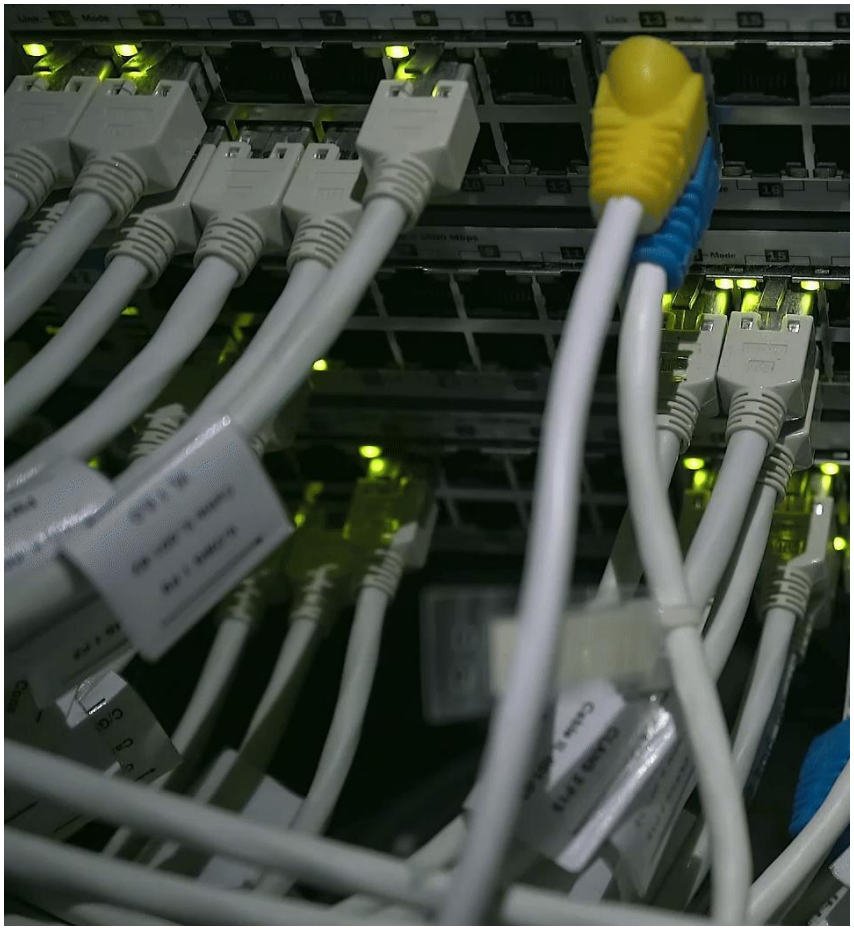
Network Protocols

Network Protocols



Network protocols are established sets of rules that help determine how data is transmitted across a network

They are essential for consistent communication with all devices on a network regardless of their differences

There are several protocols that support network communication…

Network Protocols – Essentials

Transmission Control Protocol (TCP)

The first protocol of the Internet Protocol suite. It ensures a reliable transmission of data across a network. There are four main characteristics of the TCP; reliable transmission, error checking, order delivery and congestion management.

Internet Protocol (IP)

Responsible for getting packets from one location to another through routing. It uses IP addresses to locate the destination.

Network Protocols - HTTP

Hypertext Transfer Protocol (HTTP)

Allows webpages to be shared across different computers and browsers. It explains how messages are set up and sent between web browsers and servers.

Hypertext Transfer Protocol Secure (HTTPS)

A more secure version of HTTP. It helps keep information safe when you use the internet. It uses encryption methods such as SSL/TLS. This coding makes your information unreadable to anyone trying to steal it. Authentication is also used to verify the website's identity.

Network Protocols – Email

Simple Mail Transfer Protocol (SMTP)

The standard protocol for sending emails across the internet.

Post Office Protocol (POP3)

POP is used to receive emails from a remote server. They are downloaded to a local email client and are viewed offline.

Internet Message Access Protocol (IMAP)

IMAP enables emails to be downloaded from the server to multiple client devices. However, unlike POP, the email can be set to remain on the server after being downloaded.

Network Protocols - QoL

File Transfer Protocol (FTP)

Normally used for transferring files between client and server.

Border Gateway Protocol (BGP)

BGP stands for Border Gateway Protocol. It is a system used to share information about the best routes for data to travel on the Internet.

Domain Name System (DNS)

DNS changes website domain names into IP addresses that computers use to find each other. This is important for using the internet because it makes it easier to find websites.

Data Packets

Data Packets

A packet is a unit of data that is transmitted over a network

When data is sent, it is segmented into smaller packets. These packets travel through the network independently to the destination computer, where they are reassembled in the correct order

Segmenting the data into packets enhances efficiency and reliability

In the event of a network issue, routers dynamically find alternative routes for the packets to travel. If a packet is lost, the receiving computer will request the lost packet be re-transmitted

Packet Content

Source IP Address	Destination IP Address
Information for reassembling data into original form	
Tracking information	
Data	Checksum to prove data has not been corrupted

Content of a standard TCP/IP data packet

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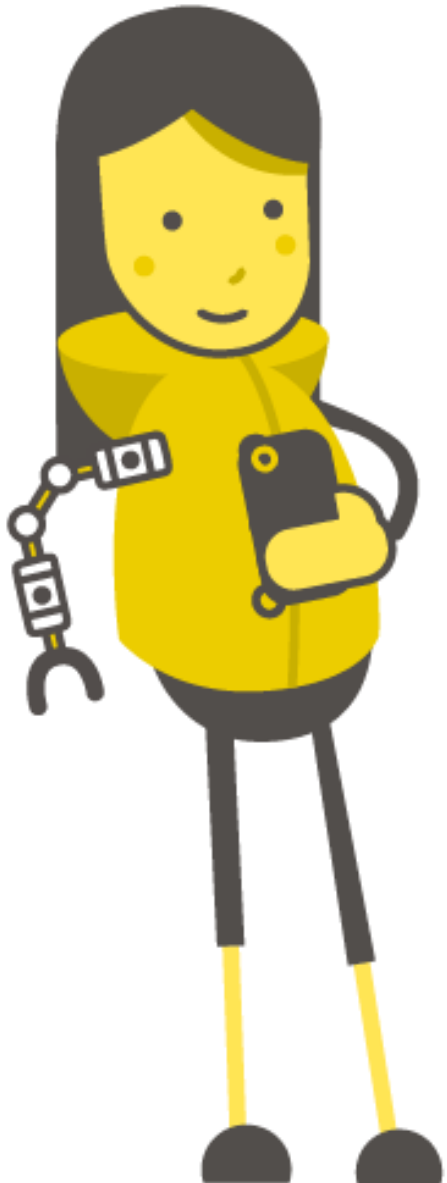
Routing Data



Routing Data

Consider how many connections there are in your home network alone…

Expand that to your school…

Expand that to the internet…

How do we determine the best path to send data packets through a network to their destination?

We calculate the **Routing Cost**

Routing Cost

Network hardware devices store measurements of network routing costs. There are various costs to be considered:

Bandwidth Cost – The data transfer capacity of a link. Routing protocol may prefer higher bandwidths

Delay Cost – The time it takes for a packet to travel from the source to the destination. Lower delay is generally preferred

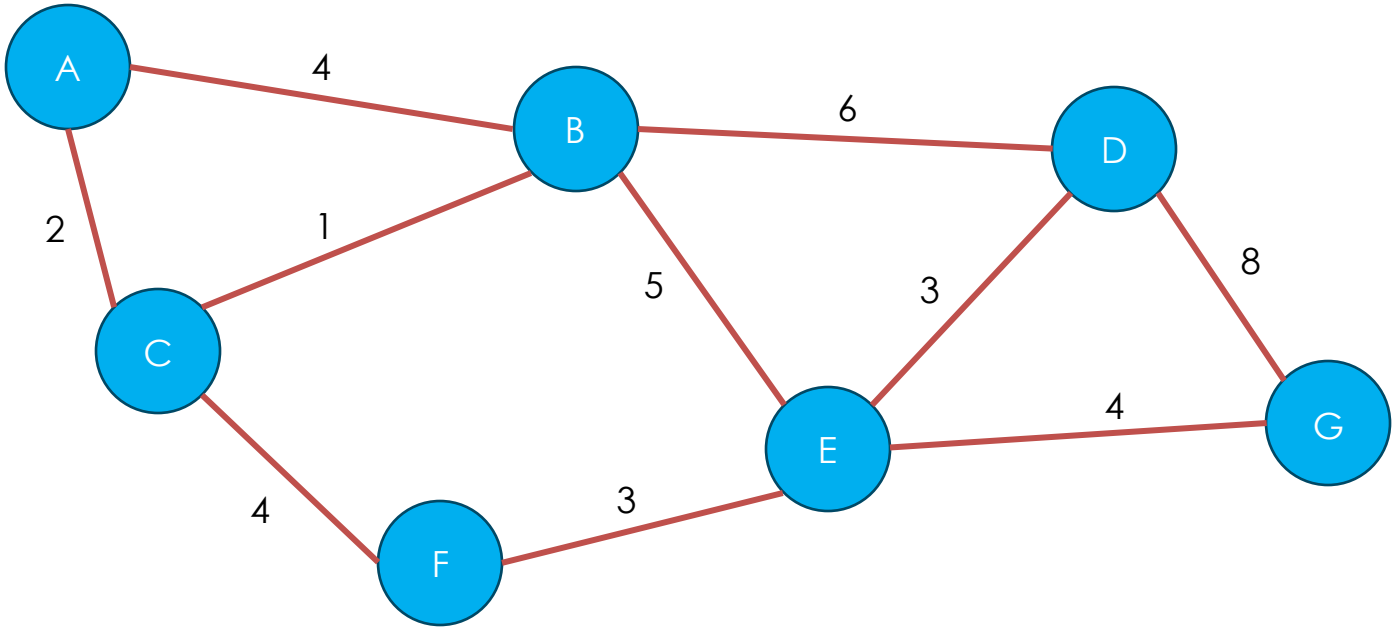
Hop Count – The number of networks or nodes a packet must pass through to reach the destination

Load Cost – The amount of traffic over a network link. Routing decisions may consider the load to avoid congestion

Reliability Cost – The error rate of a link. More stable links are preferred in routing decisions

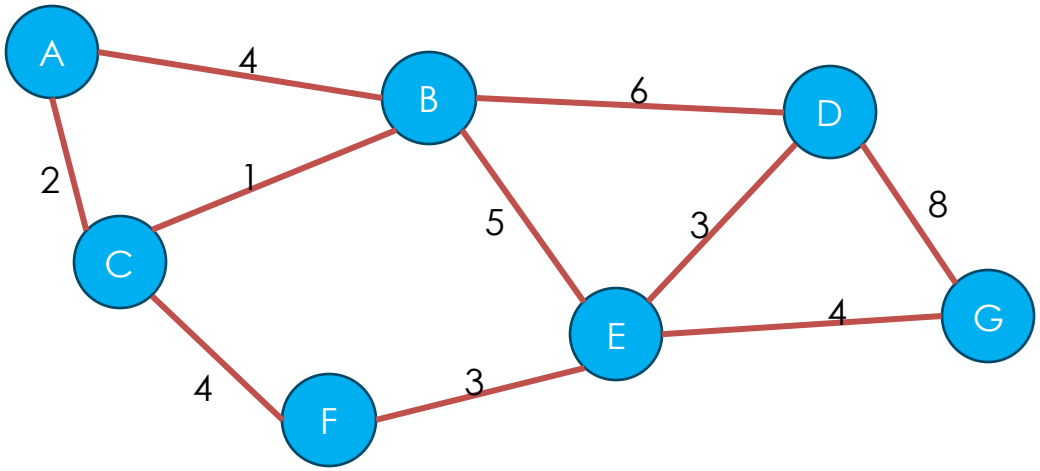
Routing Cost

Device A wants to send a data packet to device G



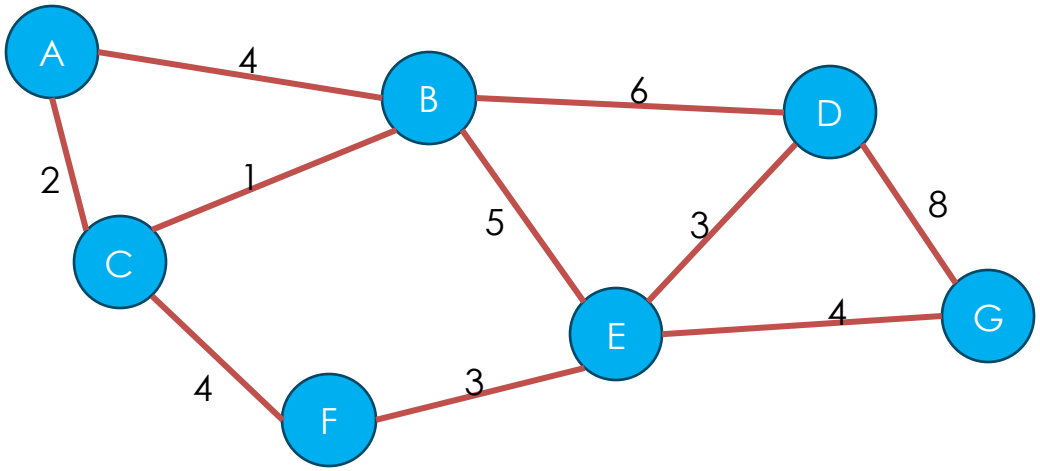
All possible routes are considered with the total costs added up

Routing Cost



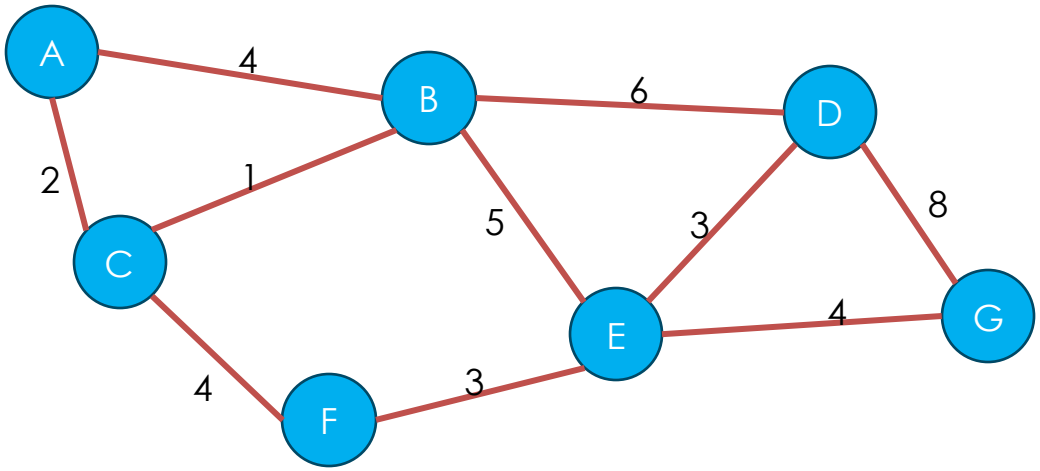
Route	Cost Calculations	Total Cost
A > B > D > G		

Routing Cost



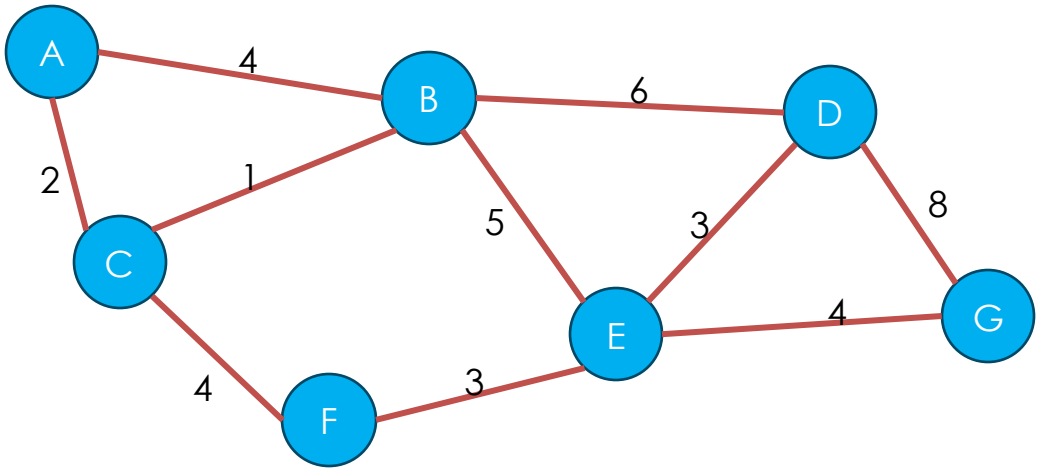
Route	Cost Calculations	Total Cost
A > B > D > G	4 + 6 + 8	

Routing Cost



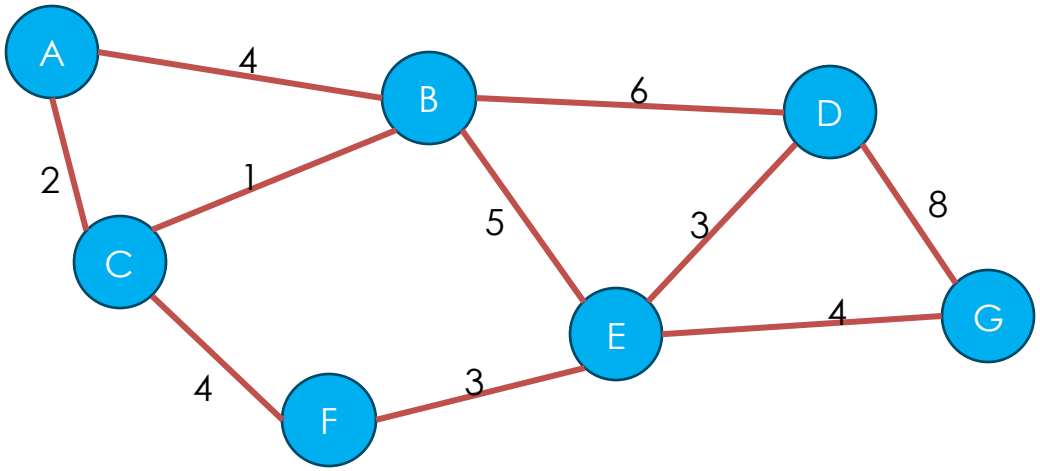
Route	Cost Calculations	Total Cost
A > B > D > G	4 + 6 + 8	18

Routing Cost



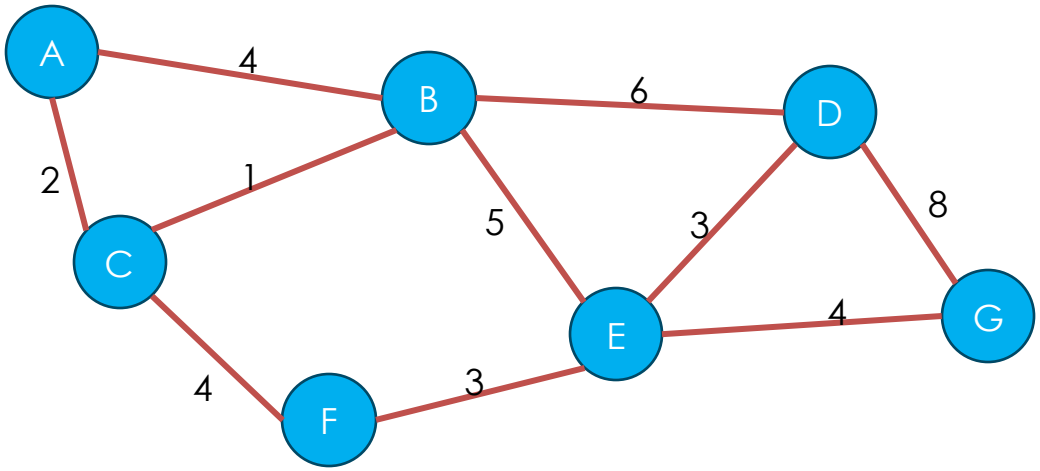
Route	Cost Calculations	Total Cost
A > B > D > G	4 + 6 + 8	18
A > B > E > G		
A > C > F > E > G		
A > C > B > E > G		
A > C > B > D > G		

Routing Cost



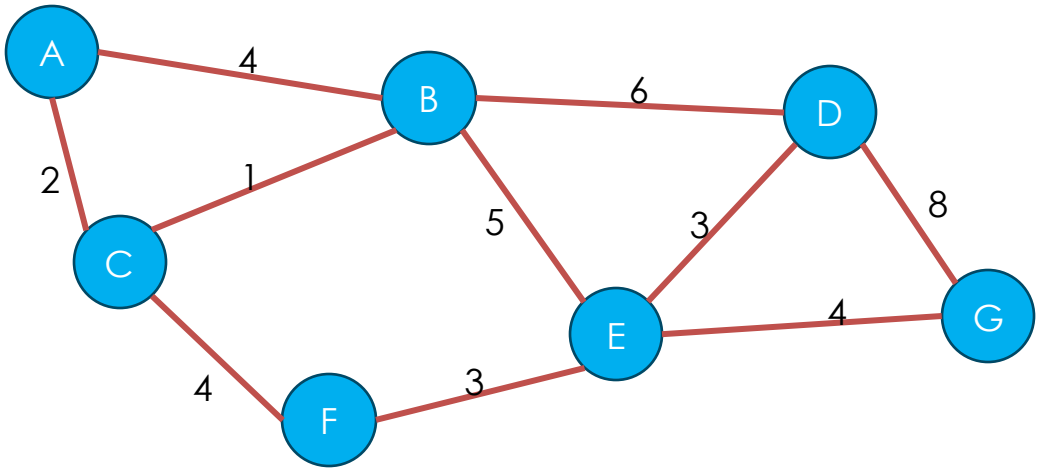
Route	Cost Calculations	Total Cost
A > B > D > G	4 + 6 + 8	18
A > B > E > G	4 + 5 + 4	
A > C > F > E > G	2 + 4 + 3 + 4	
A > C > B > E > G	2 + 1 + 5 + 4	
A > C > B > D > G	2 + 1 + 6 + 8	

Routing Cost



Route	Cost Calculations	Total Cost
A > B > D > G	4 + 6 + 8	18
A > B > E > G	4 + 5 + 4	13
A > C > F > E > G	2 + 4 + 3 + 4	14
A > C > B > E > G	2 + 1 + 5 + 4	12
A > C > B > D > G	2 + 1 + 6 + 8	17

Routing Cost



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A > C > B > D > G	2 + 1 + 6 + 8	17