Computer Networks

What is a computer network?

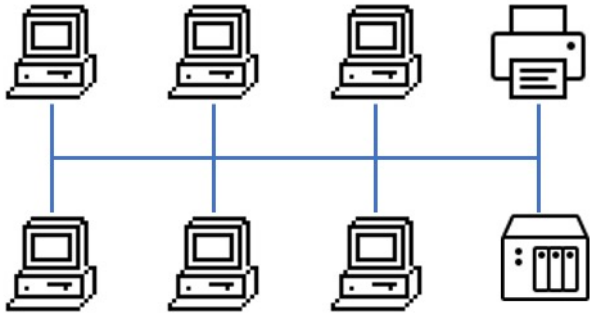
Two or more devices connected so that they can convey information

How the presentation is organized: will go through a few examples of computer network types from old-school local ones up to the internet
As we encounter different network links i.e. the physical way information is transported (blue) or network concepts i.e. the way data is packaged/etc (purple) will go into more details of those

The first network: the ‘Sneakernet’

- People physically moving information between computers
- Data can be stored as punch cards / magnetic tape / floppy disks / USB sticks
- Still used for high security situations / getting data off old lab computers
- **Pros**: secure
- **Cons**: slow and inconvenient

The first Local Area Networks (LANs)



- Developed in the 1970s, used widely from the 1980s
- Allowed groups of computers to communicate and share resources like storage and printers
- Technologies included ARCNET, Token Ring and (most commonly) ethernet
- **Pros**: fast and convenient
- **Cons**: Without switches can get a build up of traffic and message collisions

Ethernet technology basically took over the other wired LAN technologies

Network Links: Copper wires

- Used by telephone cables and ethernet cables
- Data is converted into electrical signals which are passed along copper wires

Telephone cables:

- Great as they were already there
- Slow – not designed to carry high frequency signals which are needed to transmit lots of data

Ethernet cables:

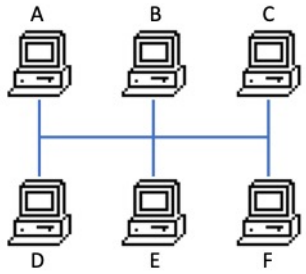
- Invented by a team in Xerox in California in 1973
- Has evolved over the years, come in many varieties
- Speeds can be up to 10 Gb/s

- Phone lines - Initially used modems to translate analogue signals in phone lines to digital signals in computers. Would connect to internet via 'dial up' – v slow
- Question – my WiFi router still plugs into a telephone socket, so why isn't it slow?

- Ethernet cables – initially were co-axial which means copper shielding around the copper wire to protect it from interference. Nowadays twisted pair copper wires which reduces interference.

Ethernet communication protocol: CSMA/CD

- Carrier Sense Multiple Access with Collision Detect (CSMA/CD)
  - Uses Media Access Control (MAC) address to make sure message is only processed by the intended recipient
  - Exponential back off to avoid collisions

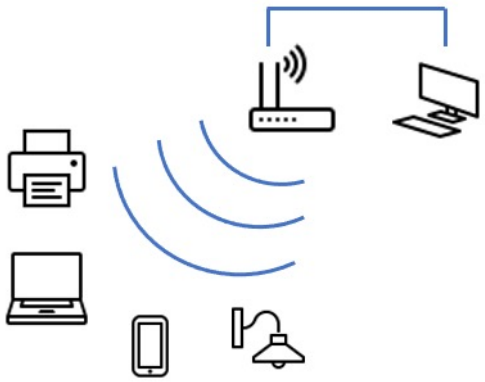


Ethernet basically took out other LAN technologies like Token Rings not just because of the hardware but also the protocols it used to send information

CSMA = carrier sense multiple access.
The sender sends a signal across the ethernet cable and all connected devices can see this signal, but only those with the correct MAC (Media Access Control) address will process the information. Detects collisions and waits to resend messages. Instead of all waiting 1 second it waits 1 second + random period of time so they don't all resend a second later. Can also detect if there is lots of traffic and wait even more time until the traffic becomes lighter. This protocol is still used in ethernet and wifi systems today.

As networks got bigger also added switches to reduce unnecessary traffic

Modern day LANs

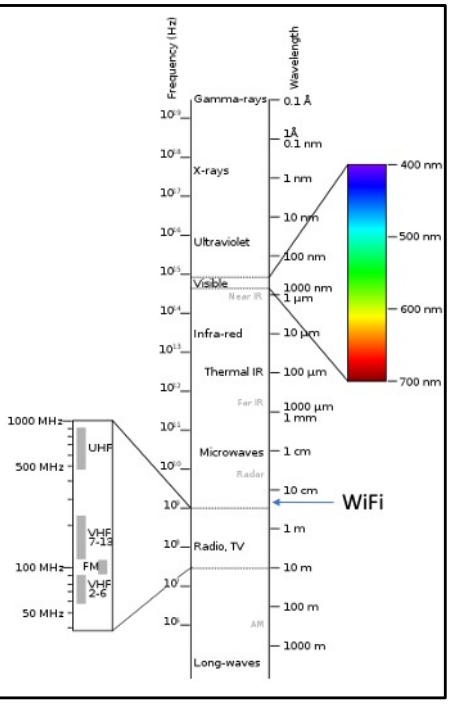


- Many households have their own LAN
- WiFi modem act as network switches which convert electrical signals to radio waves
- Many devices now connected by WiFi including household appliances ('Internet of Things')
- **Pros**: WiFi makes devices portable, switches reduce traffic on the system

What can you plug into your ethernet port? A Wifi router

Network Links: WiFi

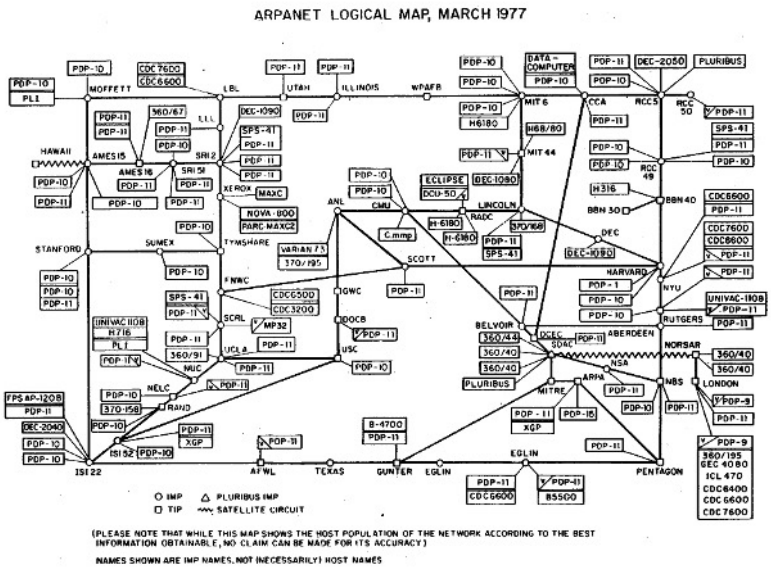
- Electromagnetic waves in the air (wavelength ~ 12cm)
- WiFi modems can emit domes around 20-30m wide of WiFi signals which can travel through walls and ceilings
- Two frequencies are used: 2.4 GHz or 5.0GHz
- Devices receive and translate WiFi signals into electrical messages using a wireless card
- Information is coded into the radio waves by modulating the carrier waves



- hindered by obstacles, if walls are thick
- WiFi signals can be blocked by some different material – you can actually buy a WiFi blocking paint in it which has some metal particles in

- my WiFi router now has both 2.4 or 5 GHz that I can connect to (called a dual band WiFi routers), single band routers only emit 2.4GHz
- Two bands can be useful because microwaves and cordless phones also use 2.4 GHz and can interfere with signal. 5GHz used by fewer devices.

The precursor to the internet: the ARPANET



- Linked computers at Pentagon-funded research institutes over phone lines
- Initially 1969 between some west coast universities, then grew (over 100 computers 1977) to cover US, England and Norway
- Made during the Cold War (1969) – no central hub so robust to attack

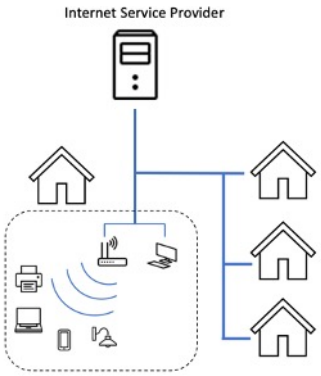
ARPA = advanced research projects agency in Department of Defense, made by Eisenhower in response to the Sputnik launch in 1957
First universities: UCLA, UC Santa Barbara, Stanford and Utah University

Helped develop concepts that are used in today's internet like packet switching and TCIP/IP

From ARPANET to the Internet

- The ARPANET connected together with other networks in the 1970s to make the **internet**
- 1987 internet connected 20,000 computers, but it was restricted to specific universities and corporations
- Late 1980s ARPANET project ended and the internet was passed over to **NSFNET**
- Commercial traffic was made legal on the internet in 1992

- 1995 NSFNET shut down and handed over to **Internet Service Providers** (ISPs)
- End users pay ISPs to provide access to the internet (still how it is today)



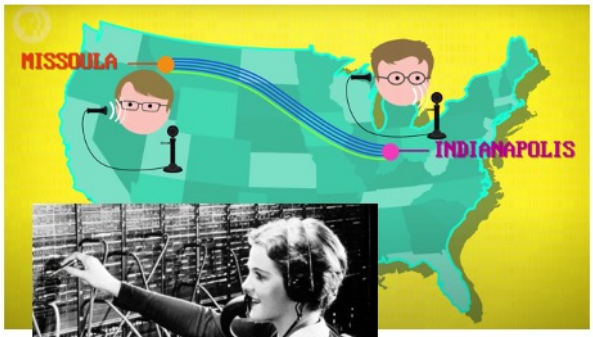
Internet is short for 'internetworking' because it was literally just networks connected together
Initially just used for research, there was some commercialization of access to islands of networks at off-peak times

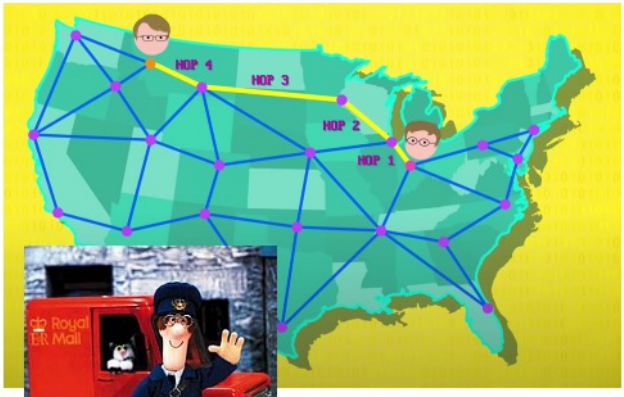
National Science Foundation (NSF) totally took over as backbone in 1990
Nowadays connect to the internet by connecting your household LAN to a local WAN (wide area network) which are connected together and so on

Many concepts of the early internet are still used today

- Packet switching
- Communication protocols
- Domain Name System

Circuit Switching vs Message Switching



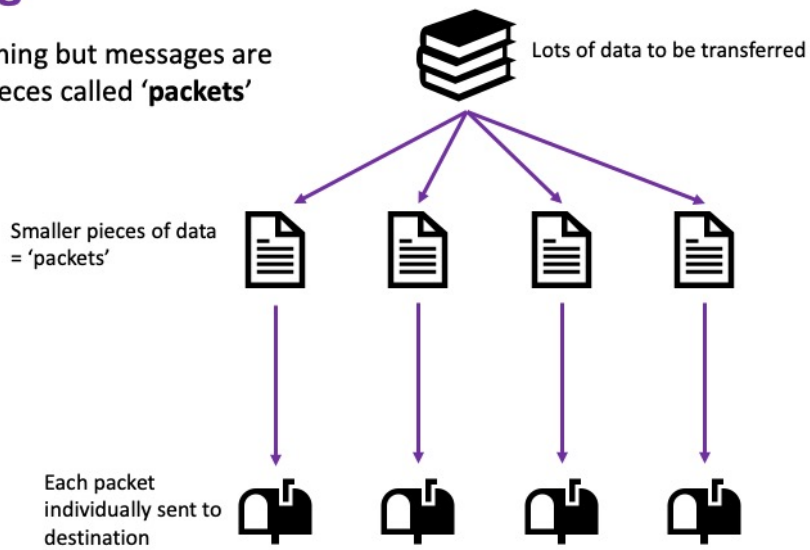


Circuit switching is what was original used for phone calls – you spoke to a phone operator who physically connected you
Literally switch whole circuits, secure so still used by military etc, but also expensive and inefficient

Message switching more like the postal system, take several hops along the way and there are multiple routes that can be taken between the source and destination
Much more flexible and robust, if a link is broken can take another route
Hop count is collected and attached to each message, can see it using route trace

Packet Switching

- Similar to Message Switching but messages are broken up into smaller pieces called '**packets**'

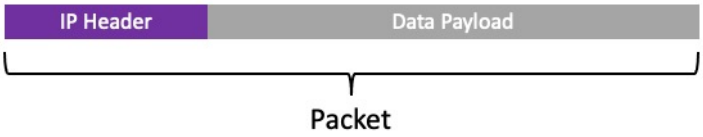


Big messages can clog up a link so better to break it into smaller pieces
Can think of it as if we want to send a book, we would need to divide it into smaller documents and post each one individually

Communication Protocols

Way of formatting packets to make sure it gets to its destination

Internet Protocol (IP)



Packet

- IP address e.g. 8.8. 8.8. 8.8. 4.4.
  - Of destination
  - and of the source
- Hop limit

Can continue with analogy – in order to post our document we need to put it in an envelope with the correct address written on it
Similarly IPs make sure packets of data get to their destination correctly

IP header includes: IP address – example is of a google page

Hop limit – if it gets stuck in a link it will just die at some point otherwise it would go on forever

Communication Protocols

Way of formatting packets to make sure it gets to its destination

Transmission Control Protocol / Internet Protocol (TCP/IP)

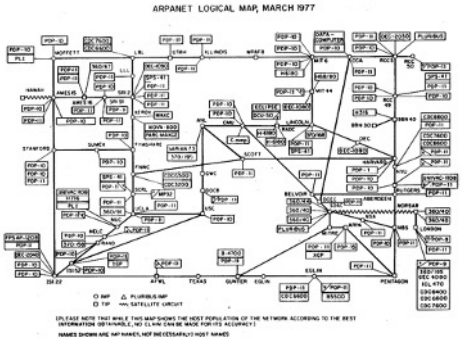
- Port number
- Checksum for each packet header
- Ordering of packets
- Confirmation that packet has been received

TCP header includes extra features to make sure messages get to destination
- Port number: so the receiving computer knows what to do with the data e.g. which application to send it to – question, how does this relate to interactive ports I can open with HPC?-

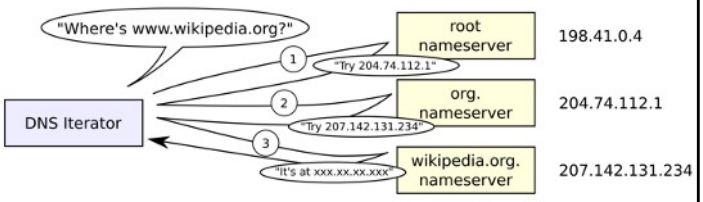
- Check sum: to make sure packets have not been corrupted, if corrupted throw it away
- Ordering – the packets might not arrive in the correct order if they have taken different routes so puts them back together correctly (pages in book)
- Can also send a message back to the sender to say the packet has been received, so if the sender doesn't get this message it can send the package again

Domain Name System (DNS)

- From 1973 ARPANET kept an 'address book' of all IP addresses at Stanford University
- But as the internet got bigger it was harder to keep this updated



- DNS – tree structure much better than a list
- Set up a network whose job to keep track of addresses and connections.
- When you type in www.wikipedia.org it goes to DNS server to find the IP address



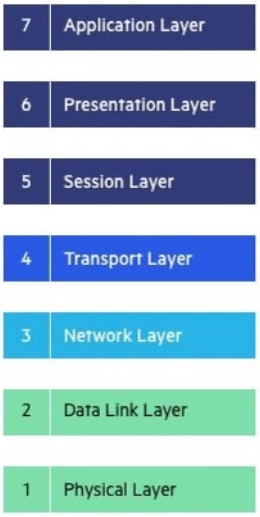
LHS before DNS:

- To go to a webpage would need to know the IP address
- When you sent an email some applications needed to know every address that the email would pass through on its journey, which meant you needed a printed copy of this map on your desk so every time you wrote an email you had to manually type in every stop along the way
- And emailing was very common! It was invented in 1971 but already by 1973 up to 3/4 of ARPANET's packets were emails

So needed a better system… RHS is about DNS

- Easier way to find addresses by structured tree with different levels
- Also no longer done manually but by a network itself which is continually updated
- DNS converts a hostname eg google.com into its IP address

Protocol Layers: OSI model



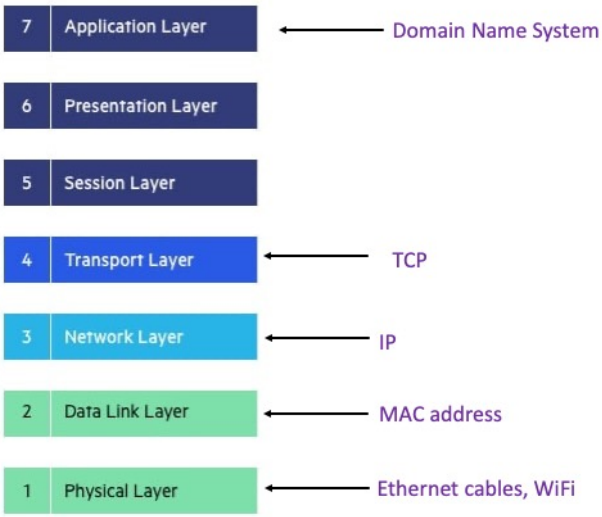
Layering allows us to:

- Develop standards and adapt them for new software and hardware
- Easily think and talk about networking concepts
- Change each layer independently

Open Systems Interconnection Model

1, packets converted into electrical/radio/optical pulses and transmitted as bits
2, Protocol within a network. most common – ethernet.
3, protocol between networks, most common is is IP
4, way to transmit data and QC, most common protocols TCP and UDP
5, controls connections between computers
6, data translated into a form the application can accept
7, data usable by software, protocol HTTP

Protocol Layers: OSI model



Computer Networks Summary

Network Links:

- Telephone cables
- Ethernet cables
- WiFi
- (Optical fibers)

Networking concepts:

- CSMA/CD
- Packet Switching
- Communication Protocols
- Domain Name System
- Protocol layers
- (Routers and switches)
- (World Wide Web)

Network Links: Electromagnetic spectrum in comms

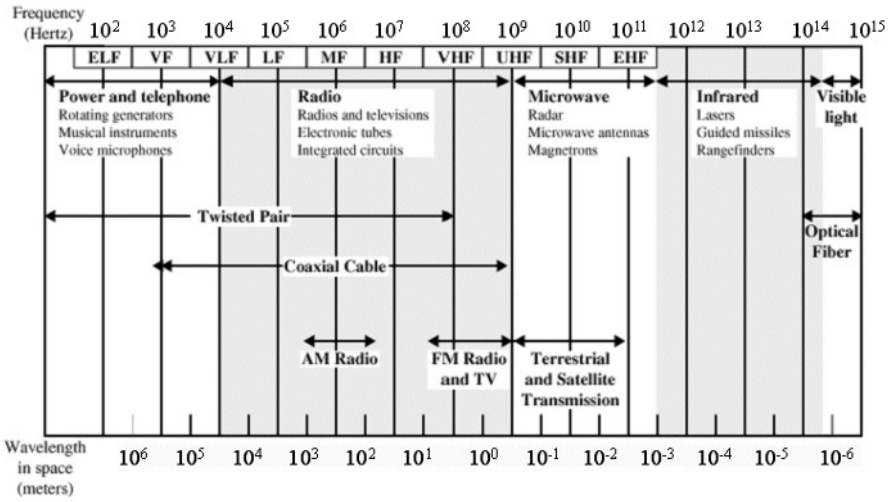
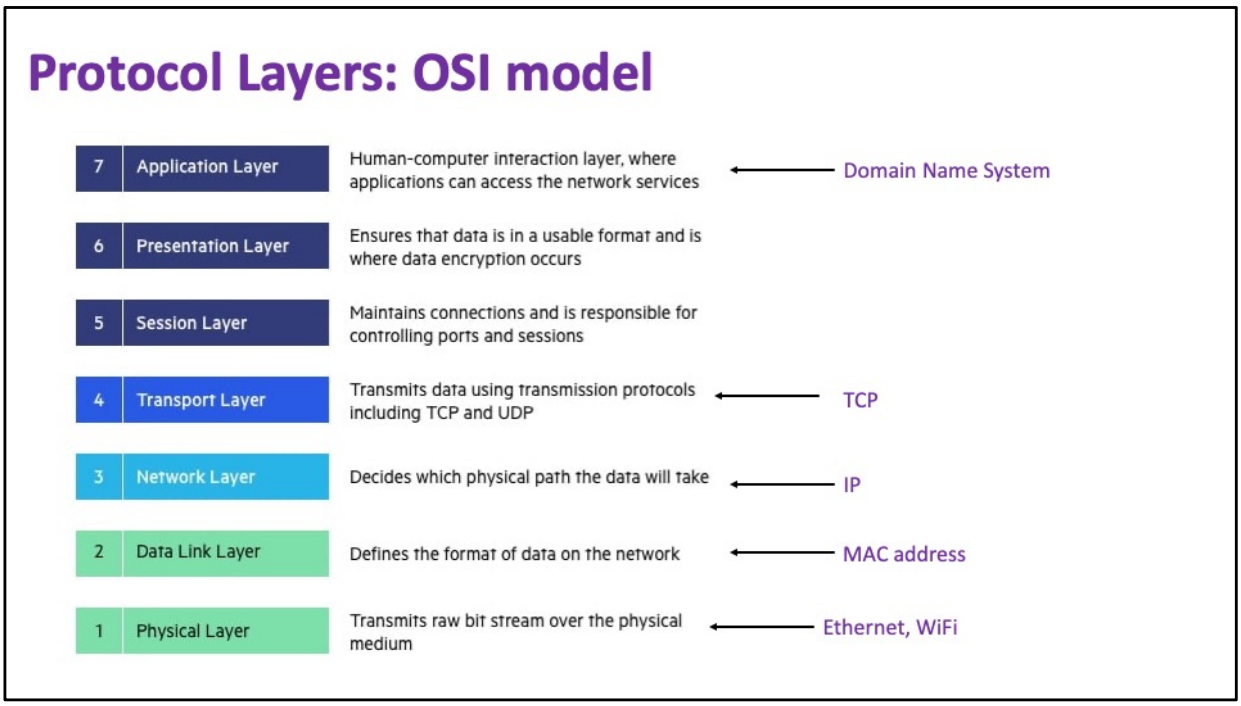


Figure 3.1 Electromagnetic Spectrum for Telecommunications



These protocols