Computers use a binary number system consisting of only 0s and 1s. Everything on a computer must be represented in binary.

Units of Data Storage		
1 Bit	b	A single 0 or 1
1 Byte	B	8 bits
1 Kilobyte	KB	1000 Bytes
1 Megabyte	MB	1000 Kilobytes
1 Gigabyte	GB	1000 Megabytes
1 Terabyte	TB	1000 Gigabytes

Base number systems
Binary is a base 2 number system.
Denary is a base 10 number system.
Hexadecimal is a base 16 number system.

Data storage equivalents (These are approximate values)	
One character of text.	1 Byte
A full page of text.	30KB
One small digital colour photograph.	3MB
Music CD capacity.	650MB
DVD capacity.	4.5 GB
Hard disk capacity.	1TB

Most significant bit (MSB)

The bit that is furthest to the left.

Least significant bit (LSB)

The bit that is furthest to the right.

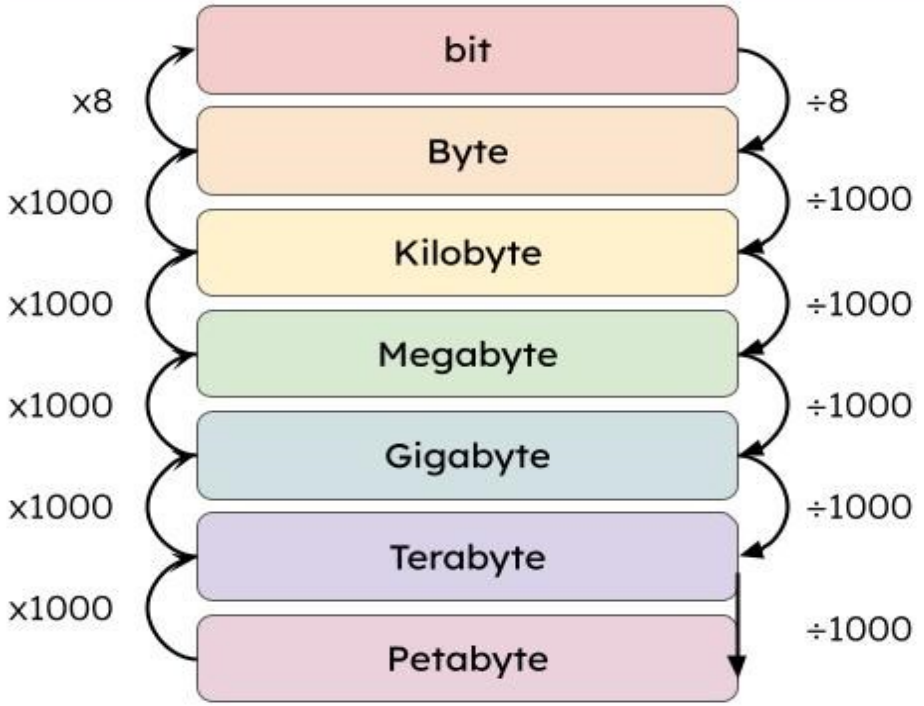
x128	x64	x32	x16	x8	x4	x2	x1
1	0	0	1	1	1	0	1

Working out the largest number of possibilities with a set number of bits.

$2^{\text{number of bits}}$

Largest possible combinations with **8 bits**	$2^8 = 256$
Largest possible combinations with **32 bits**	$2^{32} = 4{,}294{,}967{,}296$

Converting Between Units of Data Storage



Example 1

You are downloading a small game that is 4GB in size. Calculate the file size in megabytes.

Solution:
4GB Game x 1000MB= **4000 Megabytes**

Example 2

A photographer creates a video using their images. Each image has an average size of 1MB. The maximum amount of storage is 3GB. Calculate how many images they can store.

Solution:
1000MB = 1GB
1000 x 3 = **3000 Images**

Example 3

A musician records an album consisting of 8 songs. Each song on average is 6MB in size. Calculate the total size of the album in Bytes.

Solution:
6MB x 8 songs = 48MB
48MB x 1000KB = 48000KB
48000KB x 1000 Bytes = **48000000 Bytes**

Example 4

A USB stick with a capacity of 1GB is purchased to store 50 videos, each approximately 45MB in size. This is **not** possible, prove by calculating the required amount of storage needed.

Solution:
45MB x 50 Videos = **2250MB**

Converting from Binary to Denary

Question: Convert the binary number 11001010 to a denary number

Step 1: From left to right, write the number into the base 2 table.

x128	x64	x32	x16	x8	x4	x2	x1
1	1	0	0	1	0	1	0

Step 2: Add all of the numbers together with a one.

```
  12
 128
  64
   8
   2
+  1
 203
```

Additional information

Even binary numbers will always have a 0 at the end

Odd binary numbers will always have a 1 at the end.

Binary numbers are numbers recognised by a computer.

Denary numbers are human readable numbers.

Converting from Denary to Binary

Question: Convert the denary number 56 to an 8 bit binary number.

Step 1: Create the base 2 table.

x128	x64	x32	x16	x8	x4	x2	x1

Step 2: Start with the most significant bit (128) and ask yourself, *"does this number fit into 56?"*.

Step 3a: If the number does fit, You add a one in the table and then subtract that number from 56.

Step 3b: If the number does not fit, you move on to next most significant bit.

Step 4: With the new number or previous number. Repeat step 2 and 3 until the process until you reach 0.

Solution:

128 **does not** fit in to 56. 0 Is added to x128.
64 **does not** fit in to 56. 0 Is added to x64.
32 **does** fit into 56. 1 is added to x32 and 56-32 = 24
16 **does** fit into 24. 1 is added to x16 and 24-16 = 8
8 **does** fit into 8. 1 is added to x8 and 8-8 = 0
As we have 0, 0 is placed in the rest of the numbers.
56 in binary is **00111000**

Hexadecimal

- Hexadecimal (or hex) is a number system which uses base 16. As there are only 10 digits in the denary number system, it uses 0-9 and and letters A to F.
- Hexadecimal is useful because large numbers can be represented using fewer digits, making hexadecimal is easier to remember than binary. It is also easier to
- People are also likely to make errors with fewer digits.

Denary Number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hex	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**A**	**B**	**C**	**D**	**E**	**F**

Binary to Hexadecimal

Question: Convert the binary number 11100101 to a hexadecimal number.

Step 1: Divide the binary number into two nibbles of 4 bits.

1110 0101

Step 2: Convert each nibble into its hex value and rejoin.
1110 = 14 = E in Hex 0101 = 5 in Hex

Answer: 11100101 = E5 in hexadecimal.

Hexadecimal to Binary

Question: Convert the hexadecimal number 3B into an 8 bit binary number.

Step 1: Split the two hex characters and convert them to their binary equivalent.

3 = 0011 in binary **B** = 1011 in binary

Step 2: Join the binary numbers together.

Answer: 3B = 0011 1011 in binary.

Hexadecimal to Denary

Question: Convert the hexadecimal number 2A into a denary number.

Step 1: Place the number 2A into a base 16 table.

x16	x1
2	A

Step 2: Multiply the left hand digit by 16 and then add the units.

A = 10
2 x 16 = 32 + 10 = 42

Answer: 2A in hexadecimal is 42 in denary.

Denary to Hexadecimal

Question: Convert the denary number 18 in to a hexadecimal number.

Step 1: Divide 18 by 16.

```
    1
16 ⟌18
   -16
    2
```

The answer is 1 with a remainder of 2.

This will give you how many 16's in the given number. The remainder give you the units.

Answer: the denary number 18 is 12 in hexadecimal. **<u>This is spoken "one two, not twelve"</u>**

Overflow Error

When the result of an addition is too large for the number of bits there will be an overflow error.

```
  1 1 1 1
    1 1 1 1 0 0 0 0
    1 0 0 1 1 1 1 1
+ 1 1 0 0 0 1 1 1 1
  9th Bit
```

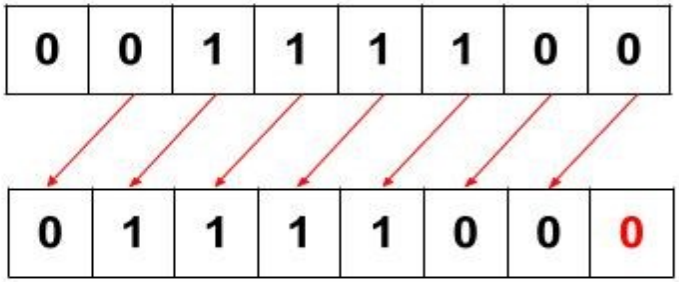
Binary Addition Rules

0 + 0 = 0
0 + 1 = 1
1 + 1 = 0 Carry 1
1 + 1 + 1 = 1 Carry 1

```
    1 1
    1 1 1 0   14
+   1 1 0 0   12
= 1 1 0 1 0   26
  Carry Bit
    Rule 5
      Rule 4
        Rule 2 or 3
          Rule 1
```

Left Binary Shifts

A left binary shift of one bit moves all the bits one place to the left.



Left shifts multiply the number.
A left shift of 1 will multiply the number by 2
A left shift of 3 will multiply the number by 8

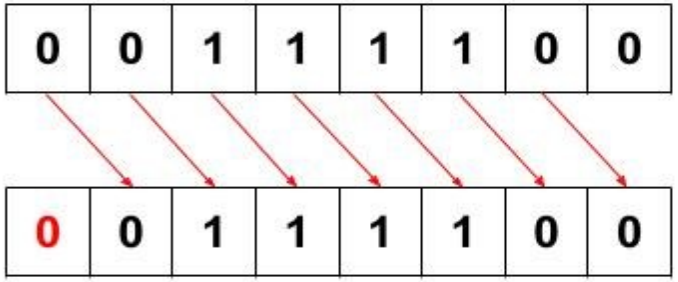
Each left shift will double the number each time.

Example 1:
Starting number, 1000 = 8
Left shift once, 10000 = 16
Left shift again, 100000= 32

Example 2:
Starting number, 1001 = 9
Left shift once, 10010 = 18
Left shift again, 100100 = 36

Right Binary Shifts

A right binary shift of one bit moves all the bits one place to the right.



Right shifts divide the number.
A right shift of 1 will divide the number by 2
A right shift of 3 will divide the number by 8

Each right shift will half the number each time.

Example 1:
Starting number, 1000 = 8
Right shift once, 100 = 4
Right shift again, 10 = 2

Example 2:
Starting number, 1001 = 9
Right shift once, 100 = 4
Right shift again, 10 = 2

A right shift may also lose bits which can cause a precision error.

22/4 is not exactly 5.

Character Sets

A character set is a set of letters, symbols and digits that can be represented by a computer.
Every character on the keyboard is represented by a binary value.

ASCII

ASCII (American Standard Code for Information Interchange) has become the standard code, used worldwide.

Each character in ASCII uses 7 bits to represent each character. This means ASCII can have a maximum of 128 characters.

$$2^7 = 128$$

For example, the letter A will be represented as **01000001**

ASCII Extended

ASCII only has enough bits to store lowercase and uppercase letter, 10 numbers, and some symbols. ASCII extended is used to store more characters.

ASCII extended uses 8 bits to store each character, totalling 256 possible characters.

UNICODE

Each character in UNICODE uses 16 bits (2Bytes) to represent each character. This means UNICODE can have maximum of 65,536 characters.

$$2^{16} = 65,536$$

As ASCII can only support 128 character or its extended version 256, UNICODE was developed to support more than one language.

Working the File Size of a Text File

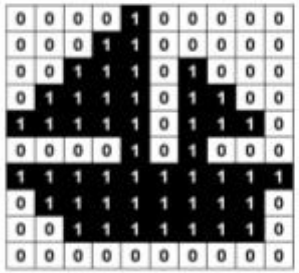
Text file size (bits) = *bits per character x number of characters*

Example: A letter with a total of 4000 characters using the extended ASCII characters set.

8 x 4000 = 32,000 bits

Colour Depth

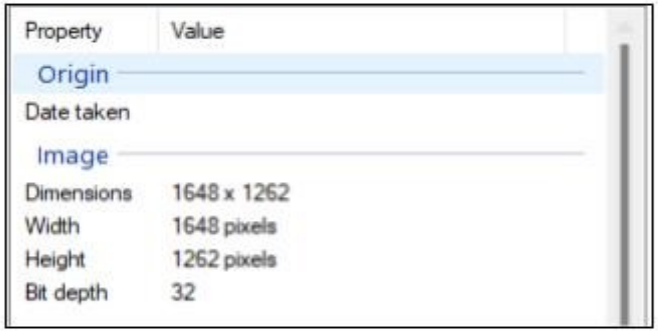
- With images, each pixel is given a number of bits.
- The number of combinations (2^n) dictates the colour depth, leading to the number of colours each pixel can be represented.
- High colour-depth gives a greater range of colour and a better quality, but will lead to larger file sizes.
- 8 bits per pixel = 2^8 = 256 colours
- 16 bits per pixel = 2^{16} = 65,536 colours
- 24 bits per pixel = 2^{24} = 16,777,216 colours



Metadata

Metadata is data about data and with images, will contain information about the image including:

- Colour depth in bits per pixel
- Resolution
- Date Created
- Author



Calculating File Size (Images)

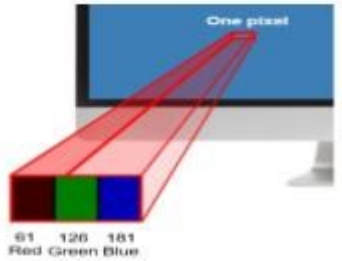
Image file size (bits) = *colour depth x image height (px) x image depth (px)*

Example : An image with a resolution of 250 x 100 and a colour depth of 2.

250 x 100 x 2 = 50,000 bits

Colour Values

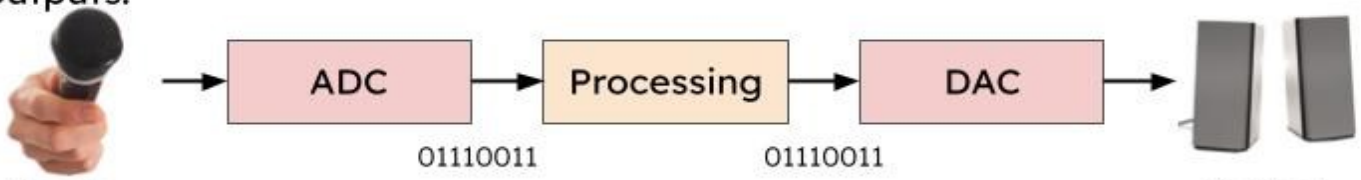
Colour values of individual pixels are expressed in software as denary RGB values and in hexadecimal. RGB (Red, Green and Blue) values range between 0-255.



Audio Waves

Sounds must be converted into a digital form in order to be stored and process b a computer.

An Analogue to Digital Convertor (ADC) is used to convert input to digital signals.A Digital to Audio Convertor (DAC) is used to convert digital signals to outputs.



Calculating File Sizes (Sound)

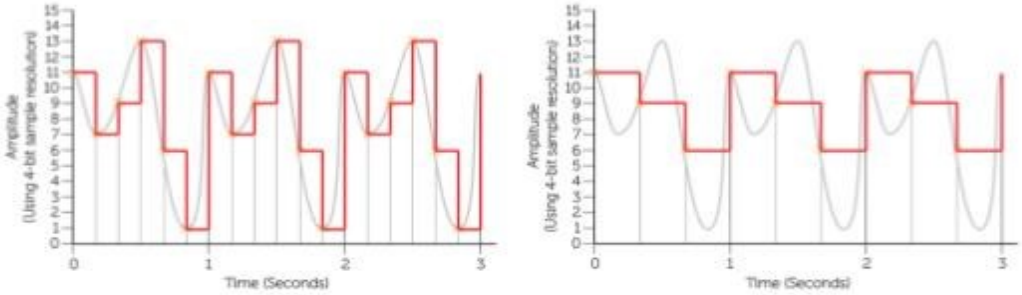
File size (bits) = *sample rate x bit depth x duration.*

Example: A 5 second audio file with a sample rate of 6000Hz, a bit depth of 4.

6000 x 4 x 5 = 120,000 bits

Sample Rate

The sample rate is the number of samples taken per second. This is measured in hertz (Hz)



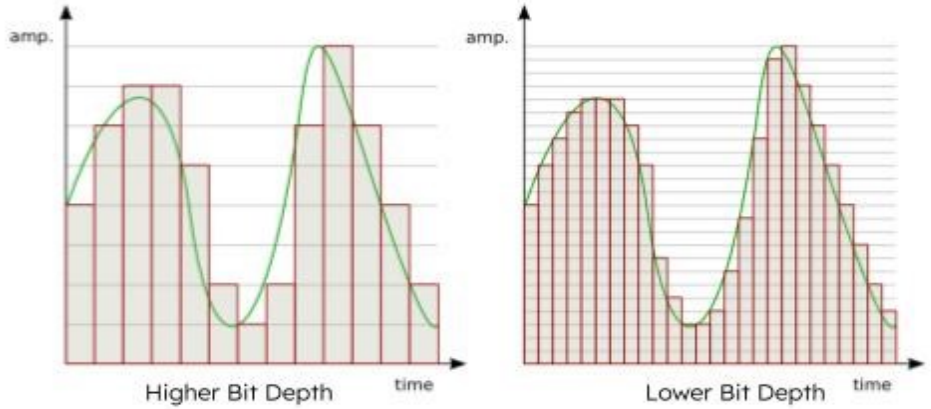
Higher Sample Rate

Lower Sample Rate

Increasing the sample rate will affect the level of detail in the digital representation. Leading to increased file size.

Bit Depth

Increasing the bit depth will determine how closely the waved is sampled on the Y axis. In this case, it will increase the levels of amplitude a recording will have.



Higher Bit Depth

Lower Bit Depth

Compression

File compression is the method of reducing a file size from its original size. Often we need to transfer files over a network, store multiple files on a system that may have low storage or allow files to be sent over email.

Lossy Compression

Lossy compressions will reduce file size by permanently removing data.

This type of compression is often used to compress images, audio files and video files.

This is because audio, video and images are still recognisable after losing quality. Often lossy will reduce image quality, colour depth and bit depth.

Therefore making data loss acceptable

Advantages	Disadvantages
Can produce smaller data files.	Data loss occurs leading to lower quality of the file.

Lossless Compression

Lossless compression will use algorithms to ensure no data is lost.

Lossless compression is best used for text files, records and executable code.

This is because any data from these files removed will lose sensitive data and/or a program will not run as expected.

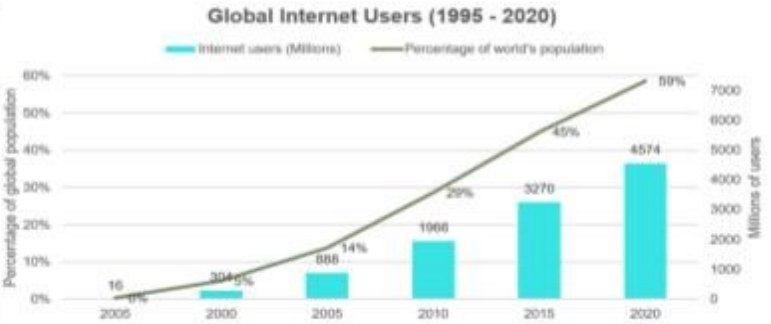
Therefore making data loss not acceptable.

Advantages	Disadvantages
Reduced file size without any data loss.	Lower file size reduction than lossy.

Networks

Networks are a series of connected devices, allowing them to communication to each other.

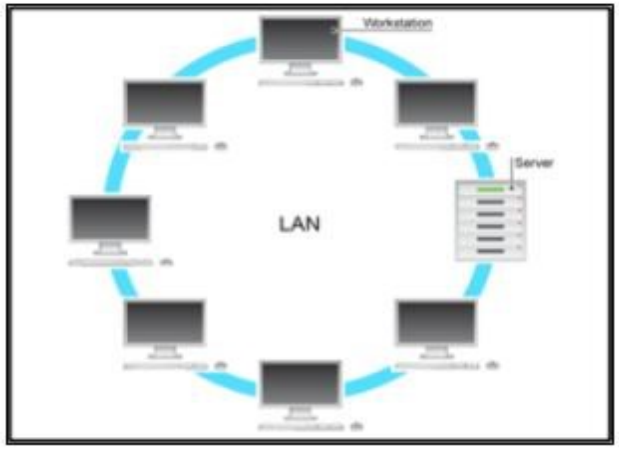
Each device on a network is called a **node.**

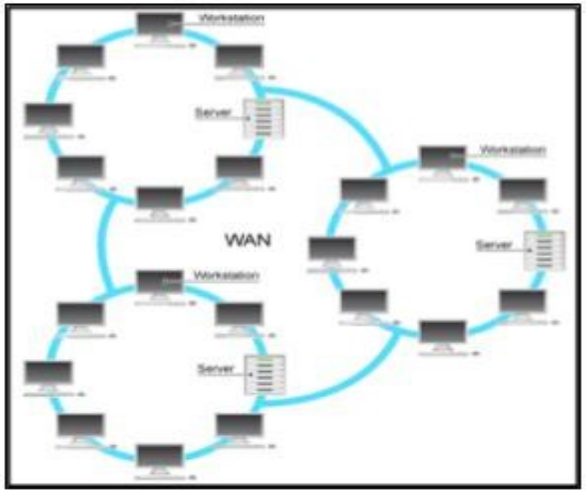


Local Area Network (LAN)

A number of nodes connected to each other in a small geographical area.

For example, a school is a single site and will have different buildings but are still within a small geographical area, each having their own set of computers, printers, telephones and access points. These networks are created, organised and operated by a single person or group of people in an organisation.





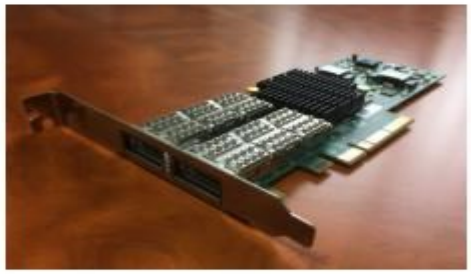
Wide Area Network (WAN)

Multiple LAN's together to form one network. The greatest example of a WAN is the internet. However there are large and medium sized organisations that used WAN's.

For example, a business office may have a headquarters in a one city and many different branches in various cities. In order for these branches to connect together, they will need to rely on a third party provider to provide the network. It uses cables, satellites, telephone lines and radio waves to connect to each LAN to each other.

NIC (Network Interface Card)

These are required for any device that is network enabled to be connected to a network. These are physical components that can provide either a wired or wireless connection to a network. Every device with a NIC will have an attached MAC address.



WAP (Wireless Access Point)

The WAP allows for devices to connect to a network wirelessly. This is particularly useful for devices that are unable to connect via wired connection.

They use a radio transceiver to allow wireless connections.

Router

Routers are designed to route data packets across a wide area network (WAN). Without a router, you will not be able to connect to a WAN. Uses an IP address to route traffic and finds the most efficient route to take when sending a packet.

Network Switch

The switch allows you to connect multiple devices to a local area network (LAN). They are used to forward network traffic to the correct location. This is achieved by learning which devices are connected and forward them to the correct location.

Bandwidth

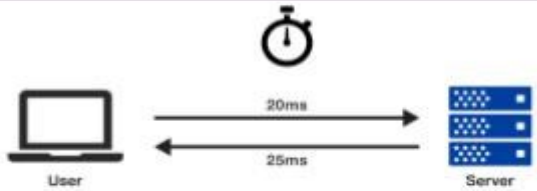
Bandwidth is the amount of data that can be carried through a connection at a time.

Bandwidth is measured in bits per second (bps) also called the bit rate.

Latency

Latency is the technical word for 'delay'. The larger the network, then the longer it takes for a bit to travel from one point to another.

Latency is measured in milliseconds (ms).



Factors Affecting Network Performance

- Type of cable connection (Ethernet or fibre optic).
- Bandwidth available.
- Number of users.
- Latency.
- The number of connections available.
- Range from WAP.
- Radio interference.
- Physical layout; solid walls and floors block signals.

Transmission Media Comparison

	Advantages	Disadvantages
Wired	• Reliable • Very fast transmission • Excellent security	• Harder to physically move devices • More expensive due to cables
Wireless	• No cables • Devices can be used anywhere • Easier to add devices to a network	• Limited range • More prone to network threats • Affected by radio interference

Star Network Topology

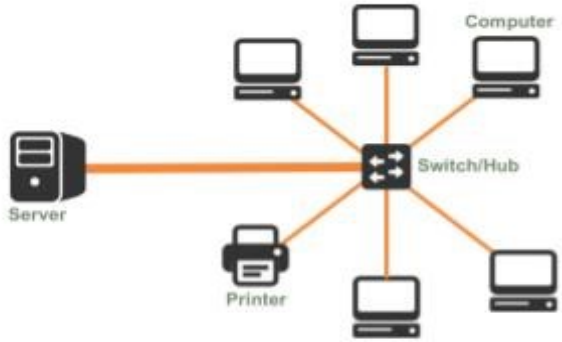
Star networks have their own cable connecting them to a central device. The central device could be a switch or server. Very popular in offices or small companies. Low cost and easy setup.

Advantages

- Fast data transfer to central device due to each wire not being shared with other computers.
- If one cable fails, the other computers are not affected.
- Easier to add nodes due having its own cable to the server.

Disadvantages

- Requires additional hardware such as the central device and network cables.
- If the central device fails, the whole network goes down.
- Usually requires network specialists to set up.



Mesh Network Topology

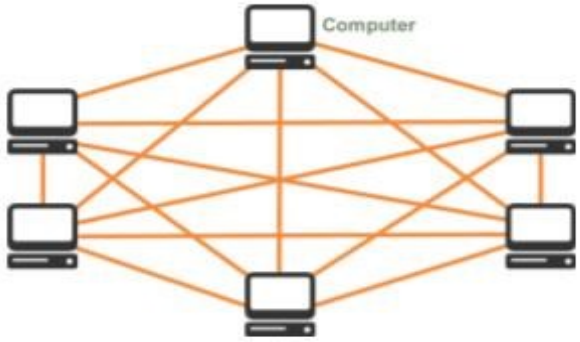
Mesh networks have no central device. Instead, all devices are connected to each other. Due to each node connecting to each other, wireless connections are used to limit the cost of cables.

Advantages

- No single point of failure - it is resilient
- Expansion and modification can be done without disrupting the network.
- Data can be transmitted from different devices simultaneously.

Disadvantages

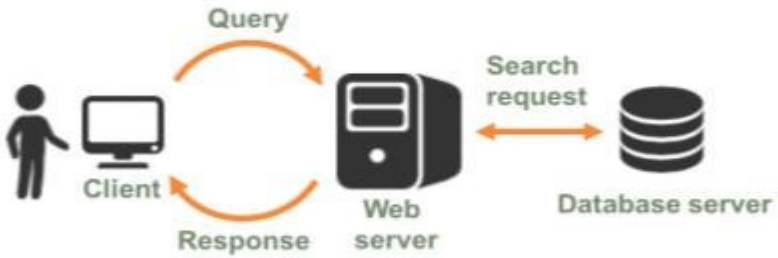
- Number of connections increase as more nodes added.
- Expensive to install cabling if using wired connections.
- Network maintenance and administration is difficult.



Client Server Network

Client based networks have a server that controls all aspects of the network. Each computer on the network is referred to as a client. It can request to the server for data connection. The server controls:

- All security
- All access to internet
- Printing jobs
- Provides backups of data
- Provides a shared file store to save files



Advantages

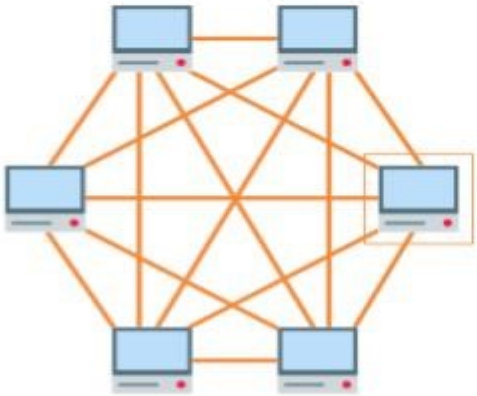
- Easier to manage security.
- Easier to install updates.
- Easier to back up data.

Disadvantages

- Expensive to set up and maintain.
- Requires specialist staff to maintain.
- File access is lost if the server fails.

Peer-to-peer Network

Peer to peer networks do not use a server and instead each computer on the network are all equal and connected to each other. Each computer is referred to a peer. Each has to manage their own: security, backup of data and have their own printers. They can also share files between each peer.



Advantages

- Easy to maintain.
- Cheaper to set up.
- Easier to back up data.

Disadvantages

- Less secure.
- Users need to manage their own backup.
- More difficult to manage.

DNS (Domain Name System)

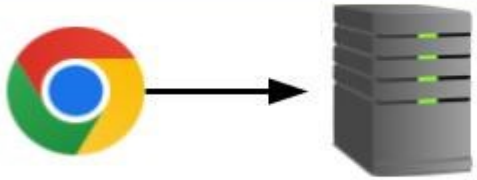
The Domain Name System (DNS) was created to help users remember web addresses. The task of the DNS is to translate a web address into the correct IP address.

Advantages of DNS

- You do not need to remember any IP addresses.
- If you are connected to a DNS server you can access any website for which there is a stored IP address.

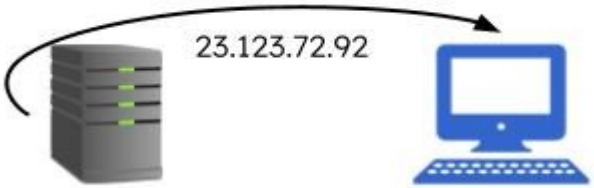
Stages of the Domain Name System

1. Type in website/webpage to a web browser.

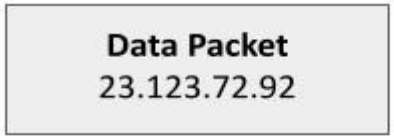


2. Browser makes contact with a DNS server.

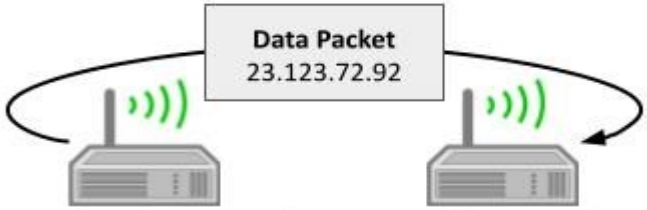
3. The DNS server matches the domain name to its registered IP address.



4. If the IP address is found, the DNS sends this back your computer.



5. The computer then attaches the IP address to the data packet to be sent.



6. The data packet travels over the internet to its destination.

7. The server where the website is stored sends back the data which you requested.

Cloud Computing

The 'Cloud' is a term used to refer to services that are delivered over the Internet. It enables users connected to any Internet-enabled computer to access these services.

Usually these services are used on a subscription basis and can be access online, meaning the software does not need to be installed on a local machine. They can also be access from any Internet-connect computer including smartphones.

Advantages

- You can access your data and applications from anywhere at any time
- You don't need a powerful computer with a huge hard drive – everything is stored and run on a remote computer
- Backing up data is no longer crucial – it is done by the service provider.

Disadvantages

- Personal data will be stored on another company's servers
- If the Internet connection is lost, often the service becomes unusable
- Slow Internet connections may result in a poor quality of service

Web Hosting

Web hosting is a service offered by companies that will host web pages and files for websites.

Web hosts will often provide data servers. Companies that provide more general hosting, such as backup server, are known as hosting providers.

Advantages:

- They have far more bandwidth. (Serve more users)
- Can monitor their equipment 24 hours a day.
- Web hosts will backup websites remotely.

Internet Protocols

Protocols are an agreed set of rules of how to communicate over a network.

Website Protocols

HTTP (Hypertext Transfer Protocol) Used for accessing and receiving web pages via the Internet.

HTTPS (secure HTTP)
Encrypts the information so that it cannot be understood by an eavesdropper. Banks, online shops and social networks often use HTTPS.

File Transfer Protocol

FTP (File Transfer Protocol)
A standard network protocol used to transfer (i.e. upload and download) files between a client and server on a computer network.

Email Protocols

POP (Post-Office-Protocol)
Downloads emails to your local and will remove the email from the server.This is similar to the protocol of sending a letter through a post office

IMAP (Internet Message Access Protocol)
Stores emails on a server and can be accessed by multiple devices and only remove when the user deletes them.

SMTP (Simple Message Transport Protocol)
Email software, such as Outlook, sends the email to the SMTP server used by the company or individual. The mail server then relays the message through various other servers known as mail relays. Finally, the email arrives at the destination mail server.

TCP/IP Protocol

TCP (Transmission Control Protocol)
Breaks up messages sent over the internet into small chunks called packets. Then reassembles the packets at the other end, detects errors and resend lost messages.

IP (Internet Protocol)
Routes the individual packets from one IP address to another.

The 4 Layer TCP/IP Stack

The protocol stack defines four layers that enable communication on the Internet. This is a modular design with each layer being responsible for a small part of the communication process.

Benefits of Using Layers

Layers are self-contained
The functionality of one layer can be changed without affecting the functionality of other layers.

Different hardware or software operates on a particular layer
For example, manufacturer's routers operating on the Internet layer, will operate with another manufacturer's Network Interface Cards (NICs) operating on the Link layer.

Application layers uses email clients and web browsers to create data to send and receive in this layer.

Transport layers creates the connection between two computers. Data is divided into packets, then reassembled. If there is a missing packet, a request is sent back to the sender to retrieve the missing packet.

Internet layers are responsible for routing packets. The sender and destination IP addresses are written on the packets ready for transmission.

Link layers are responsible for transmitting and receiving data packets through either a cable such as an ethernet cable or wireless such as WIFI.