Senior and Master Air Cadet

Satellite and Data Communications

Module (Learning Outcome) 3:

Know the principles of data communications

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Module 3 Learning Outcomes

- Know the **principles of data communication**, including:
  - The **protocols** used in data communications.
  - The different types of data **networks**.
  - The role of **servers** within a computer network.

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Lessons in Module 3

1. Basic Principles of Data Communications.
2. Data Transfer.
3. Protocols.
4. Types of Networks.
5. Computer Network Servers.

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Lesson 1:

Basic Principles of Data Communications

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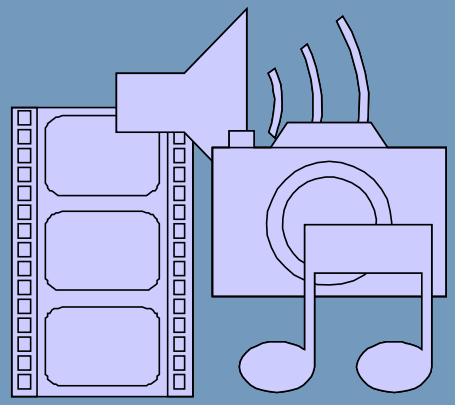
Data Communications Basic Principles

- In this lesson you will learn about the basic principles of data communications, including:
  - Data and information.
  - Bits and encoding.
  - The roles of data communications.
  - Data communications elements.

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Data, Information and *Knowledge*

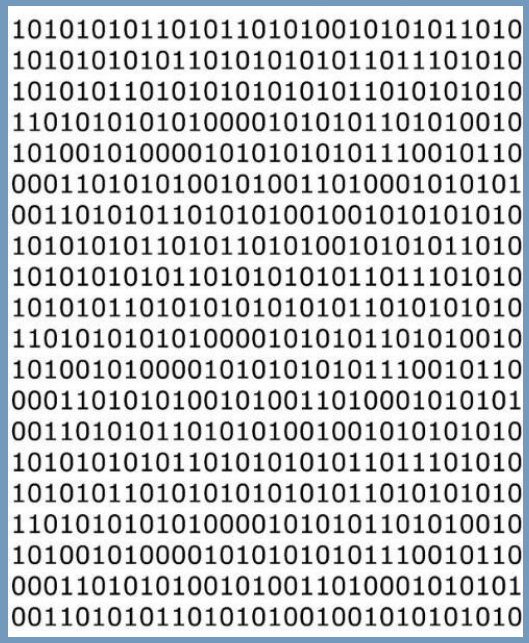
- *Data* is a set of numbers, characters, etc. that can be stored, processed and communicated.
  - E.g. “30”.
  - Data does not by itself having any meaning, as it is without context.
  - Data temporarily takes the place of information, in such a way that the information can be recovered.
- *Information* is the meaning that people give to data in particular contexts.
  - E.g. “30mm of rain fell in Redhill yesterday”.
- Information may exist in many forms, referred to as *multimedia,* such as:
  - Text (words, numbers).
  - Audio (speech, music).
  - Static images (photos, pictures).
  - Dynamic images (video, animations).
- *Knowledge* is drawing inferences from data.
  - E.g. “It’s probably going to rain later – I should take an umbrella”.



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Bits and Encoding

- Data within computers and networks usually takes the form of a collection of *bits.*
- Bit is an abbreviation for ***bi****nary digi****t****.*
- A bit can have just one of two values, either **1** (one) or **0** (zero).
- Any type of information can be represented with bits using en*coding* methods and *file formats*, for example:
  - Numbers in binary bytes.
  - Text in 7-bit ASCII characters.
  - Pictures in JPEG format.
  - Audio in MP3 format.
  - Video in MPEG format.



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Roles of Data Communications

- A data communication system enables the *exchange of information* electronically between:
  - Users, i.e. *Person to Person.*
  - Users and devices, i.e. *Person to Machine.*
  - Devices, i.e. *Machine to Machine (m2m).*
- The objective of a data communications network is to provide services to users connected to the network, allowing them to:
  - Share hardware resources, such as printers and scanners.
  - Share data, across more than one device/location.
  - Communicate with each other (particularly relevant for organisations with people spread across different locations).

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Data Communications Elements

- Data communications is the process of using computing and communication technologies to transfer data from one place to another.
- It enables the movement of electronic digital data between two or more devices, regardless of geographical location, technological medium or the type of data.
- Distributed data communications is built around three elements:
  - Applications.
  - Computers.
  - Networks.

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Applications

- In computing, information is exchanged between applications.
- An *application* is the use to which something is put.
- Application *software* is the program running on a computing device realising application functionality for both organisational, personal or home use, for example;
  - Resource and information sharing – e.g. collaborative working, databases, wikis, World Wide Web.
  - Communications and connectivity – e.g. messaging, email, social networks, IP telephony, desktop sharing.
  - Business and electronic commerce – e.g. on-line banking, financial payments, eCommerce.
  - Entertainment – e.g. media players, game playing.
  - Education – e.g. information publishing and delivery.
  - Monitoring and control – e.g. remote sensing and actuation.
- Computers can typically run several applications simultaneously.

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Users

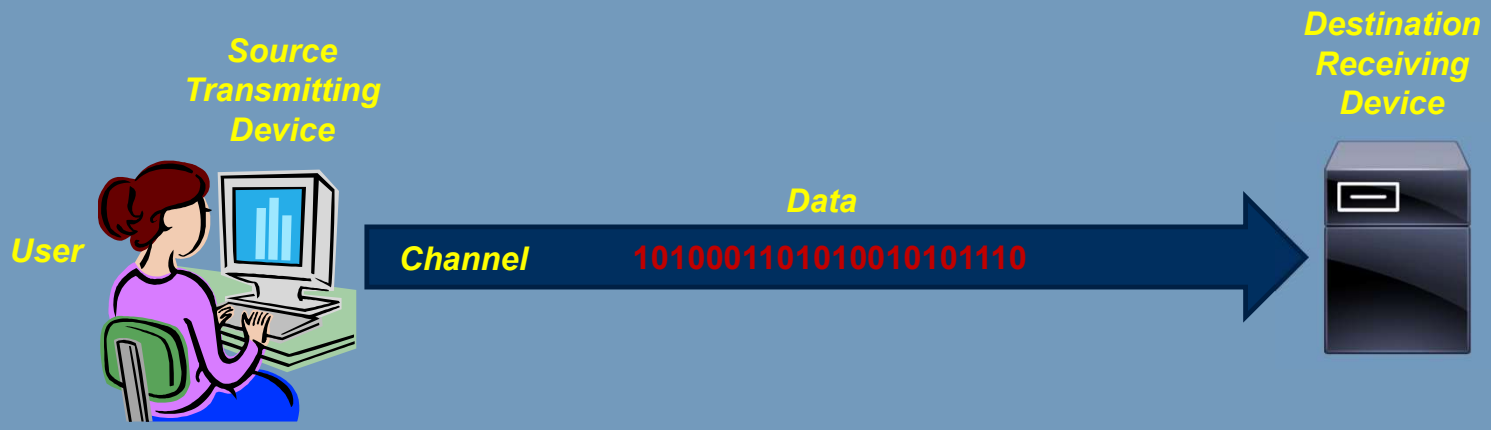
- A user is a person who interacts with and derives benefit from using a computer application.
- The user captures, enters or retrieves and directs its processing.
- The user may be the source of the information, such as the content of an email message.



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Channel

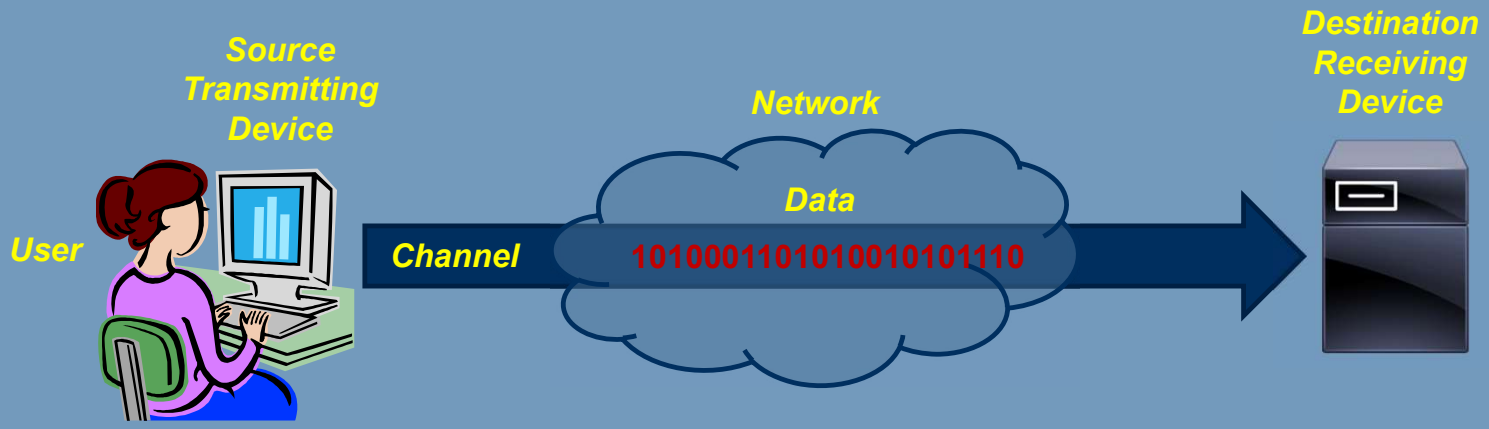
- When exchanging data between devices, the transmitting device receives data from a user application or other external sources.
- The transmitter then processes the data into a format that can be sent to a communication *channel* which conveys data from a source transmitter to a destination receiver.



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Network

- If the two or more devices in different locations some distance apart need to exchange information, then some form of *network* will be required.
- A network is the communications *infrastructure* connecting the computer devices running the applications.
- Networks are often represented in diagrams as a *cloud*.



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Lesson 2:

Data Transfer

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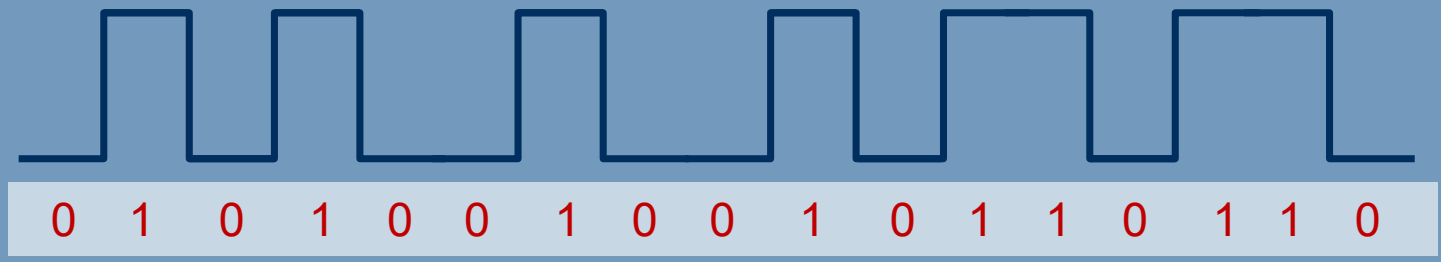
Data Transfer

- In this lesson you will learn about the methods of transferring data in a data communications network, and the concepts of:
  - Bits streams.
  - Channel capacity.
  - Nodes and links.
  - Data packets.
  - Switching and routing.
  - Data preservation.

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Bit Streams

- All forms of information can be represented by electrical signals.
- Binary data can be transmitted by encoding each data bit into one of more electrical pulses – e.g.
  - 1 is typically represented by a pulse being present.
  - 0 is typically represented by a pulse not being present.
- When data is sent from a transmitting device to a receiving device, streams of bits are conveyed across the communication channel as a series of digital pulses.



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Channel Capacity

- Data can be transmitted across a communication channel at various speeds, called the **data rate**. This is expressed as the number of bits transmitted per second (bit/s or bps).

Data Rate (bps)	Exponent	Prefix	Unit	Example
1	10^0	-	bps	Morse code
1,000	10^3	kilo	kbps	Fax, dial-up
1,000,000	10^6	Mega	Mbps	Broadband, mobile
1,000,000,000	10^9	Giga	Gbps	Local Area Network
1,000,000,000,000	10^{12}	Tera	Tbps	Internet Service Provider

- The measure of the ability of a link to transfer data is known as its *bandwidth*, which defines the maximum data transfer rate a link can support.
- A data communication channel must have the capacity to both:
  - Handle the required amount of data messages over a given time period.
  - Transfer individual messages as quickly as they are arriving from the sender.

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Nodes

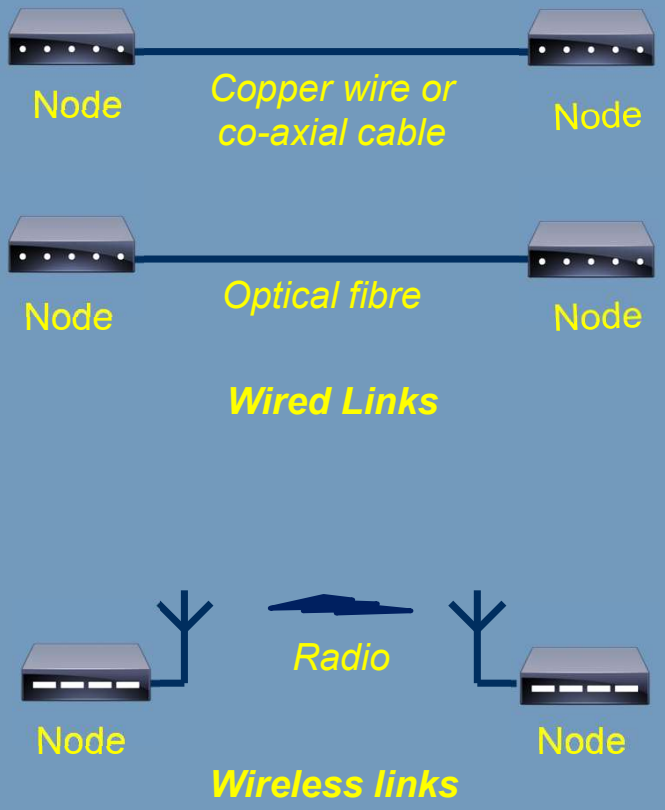
- A networked computing device is often referred to as a *node.*
- A node is any device connected to a network either:
  - Ass an end point where the communication link finishes.
  - Some point which lies in the middle of a communication link.
- Every node contains at least one *Network Interface Card* (NIC), which:
  - Provides the physical interface between the node and the communications link.
  - Controls the flow of data over the network.
- Each node has a unique identity number known as its *Media Access Control (MAC)* address which is assigned to the hardware device when manufactured.
- A standard format for printing addresses is six groups of two hexadecimal digits (0-10, a-e), separated by colons (:). E.g. **01:23:45:67:89:ab**



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Links

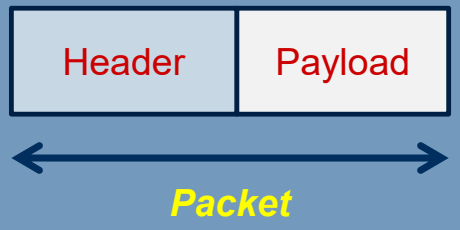
- To send data between nodes there must be some kind of communication *link* or path between them.
- The network conveys data from transmitter to receiver over some form of *transmission media.*
- There are two main classes of links:
  - *Wired* networks use physical cables such as copper wire, co-axial cable or optical fibre to connect nodes.
  - *Wireless* networks use electromagnetic waves such as radio to connect nodes.



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Data Packets

- Data is passed over a network as a sequence of *packets* which are chunks of data that an application wants to deliver to another device.
- A packet is organised in a pre-determined structured format.
- The data has information added, usually to the front of the packet, containing instructions for where the data needs to go and what the destination system should do with it once it arrives.
- The *header* contains all the information sufficient for routing from the originating node to the destination node.
- The *payload* is the data to be transported from source to destination.
- The addition of this routing and usage information is called *encapsulation*.



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Packet Switching

- The network needs to select the most appropriate route for data packets to travel from A to B.
- Most modern networks use *packet switching* which establishes a *virtual circuit* (rather than a dedicated physical circuit for the connection between sender and receiver).
- Each data stream is divided into number-sequenced data packets which are:
  - Sent to the network.
  - Mixed with all of the other packets.
  - Relayed through the network to the correct receiver.
- Packets are directed to their destination:
  - Independently.
  - In any order.
  - Potentially using different routes to their final destination.
- The received packets are arranged into the correct order to reconstruct the original data stream.

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Routing

- A node needs to identify other nodes on the network it wants to communicate with.
- This is achieved by assigning each node an address.
- When a source node wants the network to deliver a message to a certain destination node, it specifies the address of the destination node.
- The addresses are carried in the header of the data packets.
- If the sending and receiving nodes are not directly connected, then the switches of the network use this address to decide how to forward the message toward the destination.
- The process of determining systematically how to forward messages toward the destination node based on its address is called routing.
- Devices called routers, which hold information about the structure of the network, make decisions about how the data should be routed through it.

Router symbol



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Data Preservation

- Data packets can often be corrupted by noise and other flaws when sent through a communications link.
- Some bits may be “damaged” – i.e. 1s become 0s, or 0s become 1s.
- To prevent this from happening additional error control bits are added.
  - The receiver performs a mathematical function called error detection to identify incorrect bits.
  - The receiver can then request the corrupt data packets be retransmitted until received correctly.
- More complex mathematical functions can be used to go one step further and perform error correction.
  - The correct message is recovered directly from the incorrect bits that were originally received.

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Lesson 3:

Protocols

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Protocols

- In this lesson you will learn about data communication protocols and the concepts of:
  - Software Communications Layers.
  - Protocols.
  - Standards.
  - TCP/IP.

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Software Communications Layers

- The transfer of data from source to destination involves:
  - First getting the data to the source computer in which the application resides.
  - Then passing it to the intended application within the destination computer.
- For a message, file or any other data to travel through a network, it must pass through several software communications layers.
- A layer is designed to offer certain services to the layers above, shielding the layers below.
- Each software layer carries out a different function associated with data transfer and has its own set of protocols designed to make sure the data gets through accurately.

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Protocols

- Information exchange in a network involves many interacting functions.
- When software on two devices carry on a conversation, the rules and conventions used are known as a *protocol*.
- A protocol is an agreement between those communicating with each other on how to proceed.
- It can be explained using an analogy with the way people talk to each other.
  - People don't just put words together in a random way.
  - They have a set of rules (grammar) that determines the order of words and how sentences are formed
  - They also need to have a common understanding of the meaning of different words
- Data communications protocols operate in a similar way.
- A list of protocols, one operating at each layer, is called a protocol stack.
- A complete set of layers and protocols is called a network protocol architecture.

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Standards

- Fortunately, several organisations have taken responsibility for ensuring that many communication protocols are clearly stated, recorded and made available to others.
- These organisations agree on and produce the necessary *standards*.
- Standards are a technical specification that sets out rules that everyone will follow, to ensure interoperability.
- A standards document is usually drawn up with the involvement and agreement of all interested parties including representatives of users, manufacturers and government agencies.

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TCP/IP

- Transmission Control Protocol/Internet Protocol (TCP/IP) is the almost universally adopted network protocol architecture standard and is used with the Internet.

Layer	Functions	Example Protocol
Application	• Runs programs that make use of the network	Hyper Text Transfer Protocol (HTTP) *used by web browsers*
Transport	• Ensures reliability of data communication across the network without errors • Controls the sequencing and flow of data	Transmission Control Protocol (TCP)
Internet	• Deals with how to - combine multiple communications links into networks - combine networks together - send packets between remote devices • Finds the path along which to route packets	Internet Protocol (IP)
Network Access	• Provides the software interface between host devices and communications links	Ethernet *used by LANs*

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Cadet Learning Activity

- Using devices Cadets have authorised access to, search through the device settings, identify and note down some examples of the following parameters:
  - E-mail address formats.
  - Port numbers for any applications.
  - Device IP address.
  - Device MAC address.
- Using the settings of the device, identify the following information about your data connection:
  - Device MAC address.
  - Device IP address.
  - Data rate.

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Lesson 4:

Types of Networks

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Types of Networks

- In this lesson you will learn about data communication networks and the concepts of:
  - Networked computing.
  - Types of networks.
    - Personal Area Networks.
    - Local Area Networks.
    - Wide Area Networks.
  - Internetworking.
    - Intranet.
    - Extranet.
    - The Internet.
  - The World Wide Web.
  - Wireless networks.
  - Network security.

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Networked Computing

- Two devices are *networked* if connected in some way and able to exchange information.
- Networks come in different sizes, shapes and forms and are usually interconnected together to make larger networks.
- In forming a network, there are choices to be made depending on:
  - Where the computers are located in relation to one another.
  - How they need to interact with each other.
- Data networks can be classified by the type communications link used to connect devices (wired or wireless) and the geographical range of coverage.

Network Type	Typical Reach	Coverage
Personal Area Network	1 m	Person, Vehicle
	10 m	Room
Local Area Network	100 m	Building
	1 km	Campus
Wide Area Network	10 km	City
	100 km	Country
	1,000 km	Continent
The Internet	10,000km	Planet

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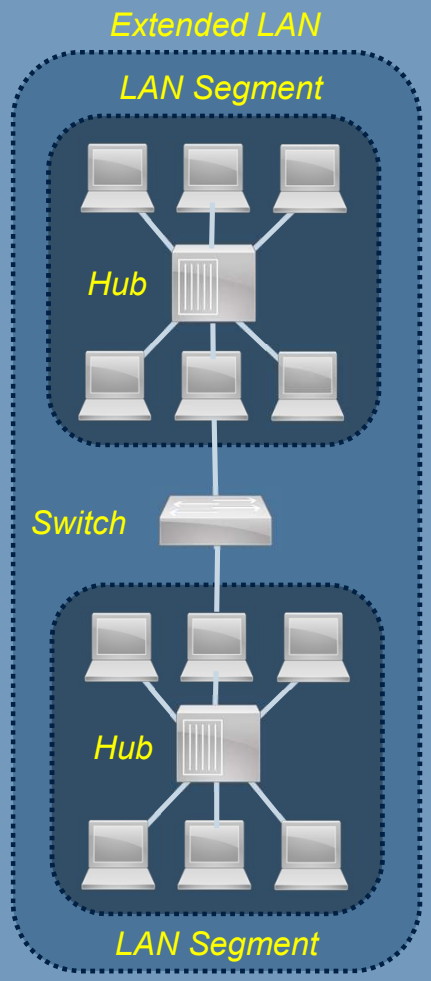
Personal Area Networks

- *PANs* are used for close communication, typically a few metres apart such as:
  - On a person, in a single room or a car.
  - Among personal devices themselves.
  - For connecting to a higher level network and the Internet.
- They are aimed at low power, low cost implementations and are used in applications such as;
  - Industrial control.
  - Public safety.
  - Automotive sensing.
  - Home networking and automation.
- Wireless PANs use wireless technologies such as *Bluetooth.*

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Local Area Networks

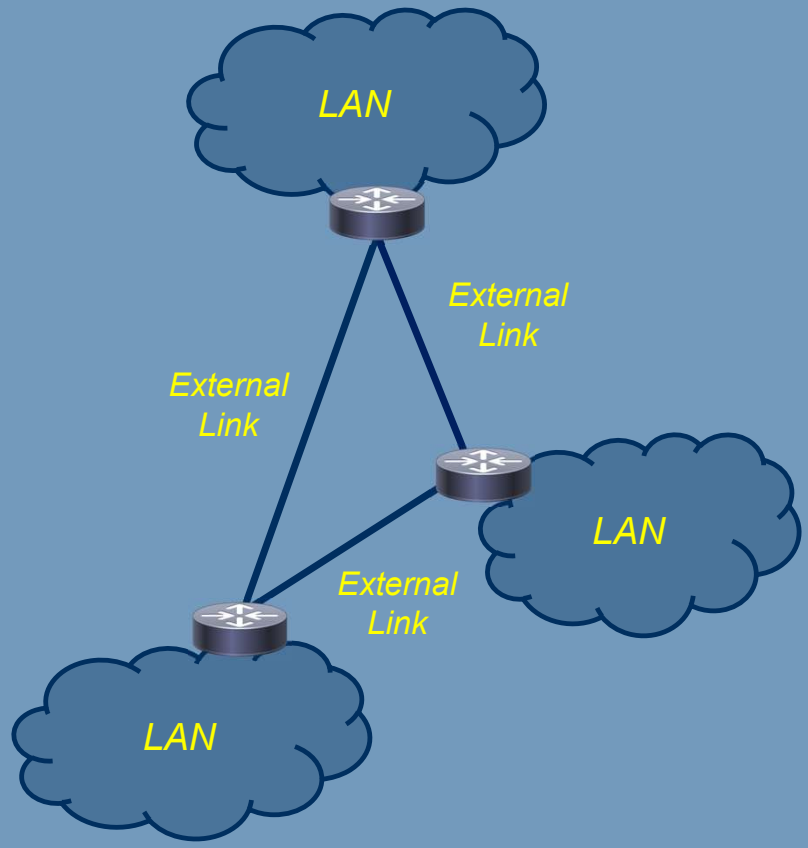
- *LANs* connect together between two and hundreds of nodes in a single building, or group of buildings on a single site, such as a home, office or factory.
- LANs are usually privately owned or belong to a single organisation.
- Ethernet was the first and is the most universal LAN type conforming to the IEEE 802.3 standard.
- Each LAN node connects to a device at the centre of a star configuration, called a hub or switch.
- They act as ‘policemen’ to route and move data to the correct node.
- LAN segments can be extended or joined together using switches to form an extended LAN.
- A single Ethernet unswitched LAN segment can connect 1024 devices.



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Wide Area Networks

- An organisation can interconnect the LANs at different geographic locations into a single *Wide Area Network (WAN).*
- A WAN typically consists of a number of interconnected switching nodes connected to an external telecommunications provider's links.
- A transmission from any one device is routed through these internal nodes to the specified destination device.
- The nodes that interconnect the networks are *routers*.



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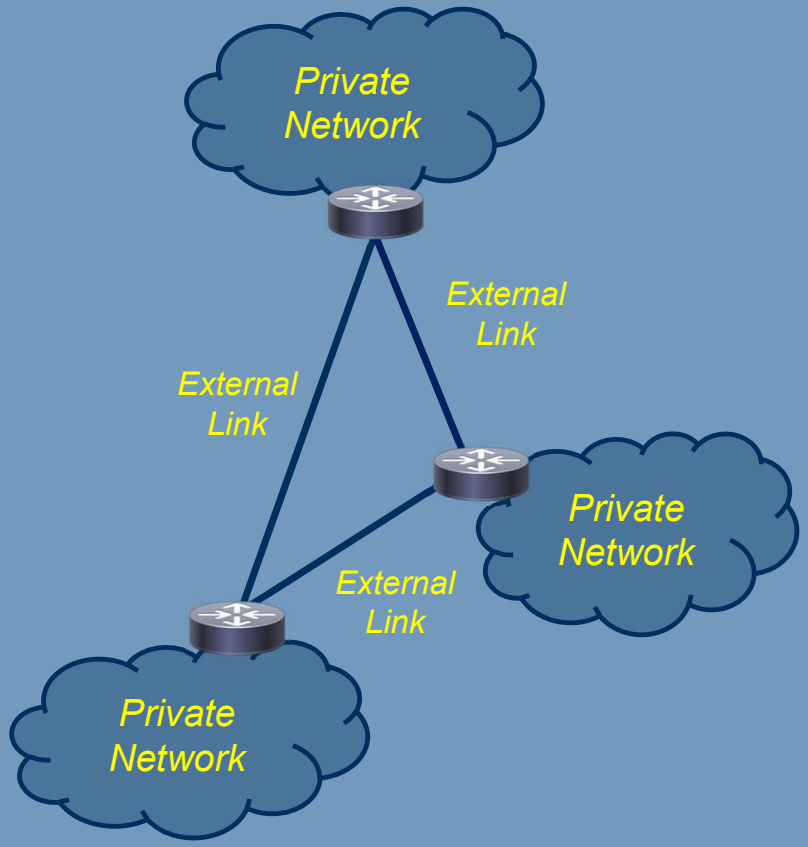
Internetwork

- Networks, often using different technology, can be further interconnected to form a ‘network of networks’ called an *internetwork.*
- An internetwork is set of interconnected networks using the IP protocol.
- It is usually limited in scope to a single organisation and appears to the user to be a single, seamless data communication system.
- Additional hardware and software systems are used to interconnect the individual networks together securely.
- There are three forms of internetwork:
  - Intranet.
  - Extranet.
  - The Internet.

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Intranets

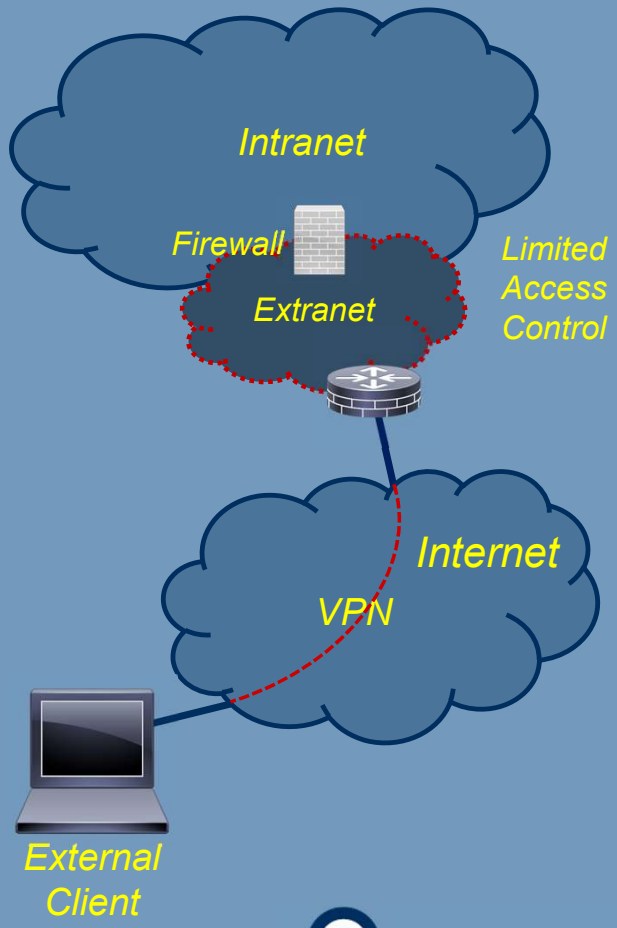
- An *intranet* is an internetwork limited in scope to a single organisation.
- Organisations often interconnect their existing and separate internal networks together securely to form a larger private network called an *Enterprise Network*.
- It is really a large WAN and is concerned with ownership, control and administration rather than technology.
- Intranets facilitate cross-organisation communications and collaboration.
- They are made inaccessible by anybody from outside the organisation by special security features called a *Firewall*.



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Extranets

- An *extranet* is an intranet that is made partially accessible to users outside an organisation.
- It is an effective and secure way for organisations, external customers, partners and suppliers to share information and do business.
- External users connect to the network through the Internet using a secure *Virtual Private Network* (VPN) connection.
- Access can be restricted to a compartmentalised area of an intranet without granting access to the entire network, using firewalls.



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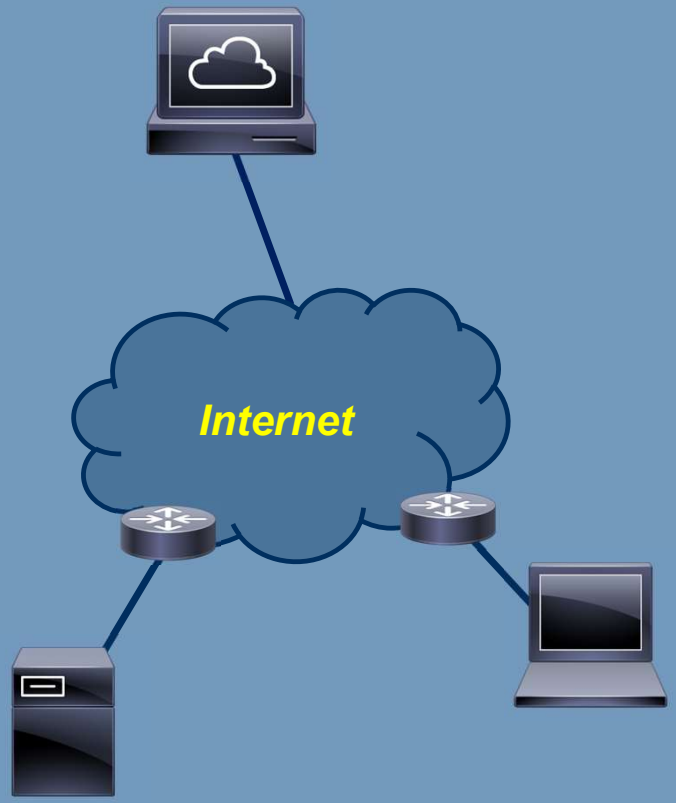
The Internet

- The Internet (capital ‘I’) is a specific and unique internetwork, the largest one on the planet. It is not really a network at all, but a vast collection interconnected networks.
- The Internet evolved from a US government computing infrastructure research project called ARPANET, launched in 1969.
- In the 1980s commercial applications were allowed on the Internet and it was gradually privatised and made accessible to everyone.
- It is unusual in that it is not planned or centrally controlled by anyone.
- Users purchase Internet access or connectivity from an Internet Service Provider (ISP) which allows the computer to exchange data with all the other accessible computers on the Internet.
- A device or network can connect to the Internet by several different means.
  - Wired (e.g. a phone line with a broadband modem, a cable television system with a cable modem).
  - Wireless (e.g. wi-fi, mobile phone networks).

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The World Wide Web

- The *World Wide Web* (WWW) is not strictly a network but the collection of Internet connected devices that happen to host web pages.
- It is a way of accessing linked information content spread across millions of computers over the Internet.
- The WWW consists of a vast, global collection of content in the form of Web Pages generally viewed with an application called a web browser.



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Wireless Networks

- *Wireless* networks are an alternative to fixed wired networks enabling devices to connect to a network and communicate:
  - Without connecting cables.
  - Using radio signals as a communicating medium.
  - Typically covering a range of up to 100m.
- They provide advantages over wired networks in terms of mobility and ease of installation and configuration.
- However, wireless LANs ~~cannot match the speed of wired LANs~~ and are limited by their range.
- WLANs are available for use in many public areas, workspaces and the home.



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Network Security

- *Network security* refers to the proper safeguarding of everything associated with a network including data, media and equipment.
- It involves administration functions, vulnerability assessment and uses special technical tools and facilities.
- Network *administrators* need to be sure that network resources are used appropriately, in accordance with a prescribed policy, and only by people who are authorised to have access.
- A difficulty with network security is determining how much security is really necessary.
- To determine this, an assessment is made of potential *threats* and *attacks*.
- Threats and attacks can be prevented by appropriate *security responses* which can be implemented using specialised network security technology and applications.

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Security Applications

- **Encryption** ensures a message can only be read by the intended recipient by transforming ('scrambling') data using a secret key.
- **Authentication** enables a message recipient to verify the identity of a sender, e.g. by:
  - Sharing a secret; e.g. password or challenge response (question and answer).
  - Possessing a physical device or token; e.g. swipe card.
  - Detecting a physical attribute or biometric; e.g. iris scan, voice recognition.
- **Digital Signatures** binds the sender's identity to a message, to provide assurance that:
  - A message hasn't been tampered with in transit (*authenticity*).
  - The sender can't deny sending the message (*non-repudiation*).
- **Firewalls** prevent unauthorised network access by determining what traffic is allowed in and out of the network. May also monitor network access and raise alerts for suspicious activity.

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Satellite & Data Communications

Lesson 5:

Computer Network Servers

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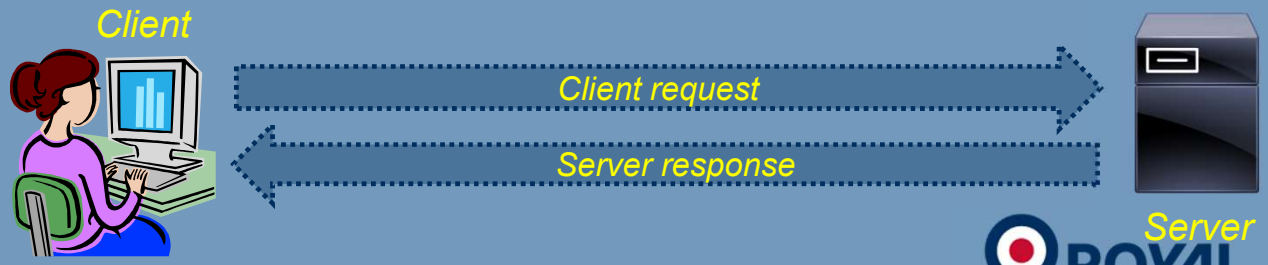
Computer Network Servers

- In this lesson you will learn about computer servers, and the concepts of:
  - Client-server computing.
  - Server types.
  - Server farms.
  - Data centres.

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Client-Server Computing

- Data is often stored on powerful, centralised, networked computers called *servers*.
- The primary role of a server is to respond to data requests, typically from *clients*.
- Clients are simpler computing devices that users use to access data hosted on servers.
- The client:
  - Accepts instructions from the user.
  - Makes requests of the server.
  - Displays responses from the server for the user.
- This arrangement is called a *client-server* computing model.



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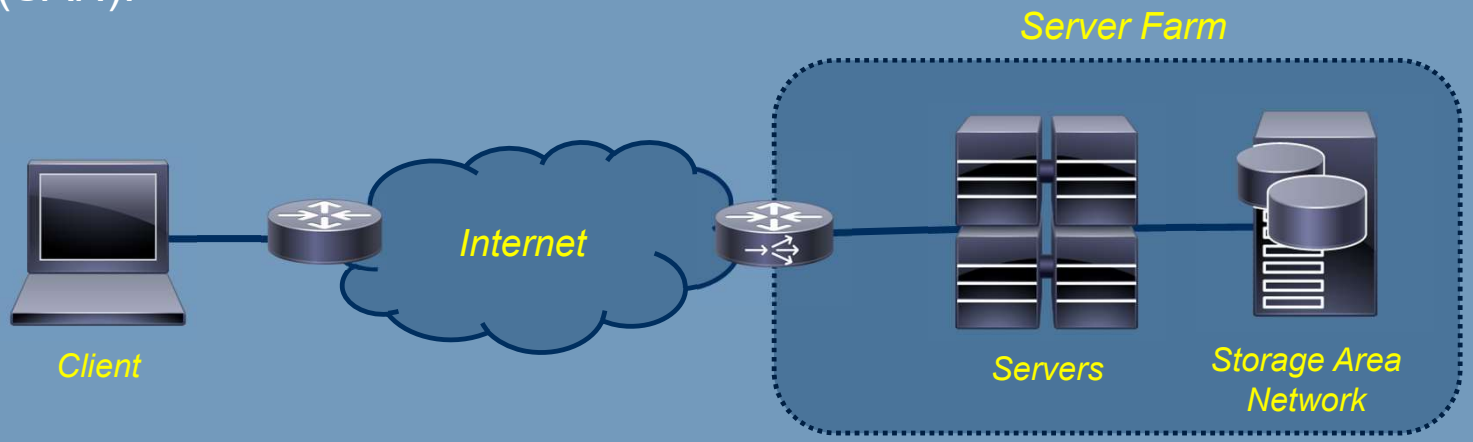
Server Types

- *Servers:*
  - Contain programs and data files that can be accessed by other client computers in a network.
  - Provide services ranging from computation, logic and storage to networked applications
  - Specialise in specific functions such as file storage, printing, databases, communications, mail or web applications.
- Servers can range from normal home PCs through to very powerful computers with many processors, gigabytes of memory, terabytes of storage, and high-speed networking capability.
- Some servers can handle thousands of transactions per second.
- They are often centrally housed, far apart and connected by the Intranet.
- For example, websites are stored on web servers.
  - A web browser is the client application which makes a request to the server, and the server sends the website to the browser piece by piece (e.g. one image at a time).

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Server Farms

- Under most conditions, one server can handle a large number of clients, but it can only serve so many requests before the load is too great.
- Organisations that provide a lot of content use *Server Farms*.
- A server farm provides a set of servers that look like a single server or web site to its clients.
- Each server has access to a copy of the content which is often stored on a *Storage Area Network* (SAN).



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Data Centres

- Server Farms are housed in secure Data Centres that are well connected to the rest of the Internet.
- Clusters of computers are housed in a large room, entire building or group of buildings.
- Today's data centres are likely to have thousands of very small but powerful servers running continuously, 24 hours a day, 7 days a week.
- The computers are stacked in racks that are placed in rows.



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Summary of Module (Learning Outcome) 3

- You should now know the **principles of data communication**, including:
  - The **protocols** used in data communications.
  - The different types of data **networks**.
  - The role of **servers** within a computer network.

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