



**MINISTRY OF EDUCATION
GHANA ASSOCIATION OF
SCIENCE TEACHERS**



Computing

for Senior High Schools

Year 3



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Ghana Education
Service (GES)





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FOREWORD

Ghana's new Senior High School Curriculum aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, knowledge, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, progress to further studies and enter the world of work. This is the first time that Ghana has developed a Senior High School Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

The Ministry of Education is proud to have overseen the production of these Learner Materials which can be used in class and for self-study and revision. These materials have been developed through a partnership between the Ghana Education Service, teacher unions (Ghana National Association of Teachers- GNAT, National Association of Graduate Teacher -NAGRAT and the Pre-Tertiary Teachers Association of Ghana- PRETAG) and National Subject Associations. These materials are informative and of high quality because they have been written by teachers for teachers with the expert backing of each subject association.

I believe that, if used appropriately, these materials will go a long way to transforming our Senior High Schools and developing Ghana so that we become a proud, prosperous and values-driven nation where our people are our greatest national asset.

Haruna Iddrisu MP
Minister for Education

SECTION

1

BOOLEAN ALGEBRA

00 011

1 1

11 0101
1 1 01 0 1 00 011

COMPUTER ARCHITECTURE & ORGANISATION

DATA STORAGE AND MANIPULATION

INTRODUCTION

This section builds on previous computer and network basics from year 1 to 2. We will explore some complex way of how computers think, calculate and connect with each other.

By the end of the section you shall master the Boolean logic, discover how CPUs perform lightning-fast math using binary codes and clever shortcuts. Hand-on activities with real-life challenges are used to section interactive and understanding.

Remember, every master was once a beginner. Your curiosity, determination and the solid foundation you already built will help carry you through this exciting exploration. Stay curious, ask questions and celebrate every breakthrough moment.

Key Ideas

1. Circular Shift (Rotation) moves bits where those that “fall off” one end wrap around to the other end, useful in cryptography and error detection.
2. Critical Points are vital inputs, outputs or internal paths where a single fault can lead to total system failure or undesirable behaviour in digital systems.
3. Fail-Safe Design ensures systems default to a known ‘safe’ state when power fails or invalid signals are detected, preventing dangerous or unpredictable states.
4. Floating-Point Precision issues occur because computers use binary representation which cannot perfectly represent all decimal fractions, requiring rounding functions for accurate calculations.
5. Logical shift operations move bits left or right with empty spaces filled with zeros, primarily used for unsigned numbers and fast multiplication/division by powers of 2.
6. Shift-and-Add Multiplication is more efficient than repeated addition because it requires fewer operations based on binary representation rather than multiple additions.
7. Two’s Complement Subtraction allows computers to perform subtraction using addition by finding the two’s complement of the subtrahend and adding it to the minuend.

UNDERSTANDING CRITICAL POINTS

Think of critical points like the main switch in your house. If that one switch fails (gets burnt), your entire house loses power. Everything stops working. Similarly, in computer systems, critical points are those special parts where one small problem can cause the whole system to fail.

Think of having automatic lights at home. The ones that turn on by themselves when it gets dark. This system works using several connected parts: a light sensor that detects darkness, some wiring, switching circuit and the light bulb itself. All of these parts work together like a team. Now, in a system like this, there are certain parts that are very important. We call these critical points. If just one of them fails, the whole system can stop working properly. Let us look at a few examples of what can go wrong. The sensor might send the wrong signal for example, saying it is daylight (0') when it is actually dark ('1'), a signal might disappear completely, meaning no message is sent through the circuit or maybe a wire breaks and the connection is lost. Even if just one of these happens, the lights might not turn on when they should and that is a big problem. In Computing and Artificial Intelligence, the systems used are made of many connected components such as sensors, processors and software. A failure in any critical point could affect how the entire system performs.

Critical points are the most important inputs, outputs or connections in a digital system. When these fail, the entire system either stops working completely, does something dangerous or wrong and behaves in ways we do not want.

REAL-LIFE EXAMPLES

1. Mobile Money Transfer Systems

When you send money through mobile money transfer systems, the critical point is the network connection between your phone and the telecom company. When the connection fails, your transaction might fail.

2. Traffic Lights System

Traffic lights rely on sensors and input signals to know when to stop or let cars go. Let us say the signal that tells cars to stop at a red light fails due to heavy rain or damage. The light might stay red forever or not work at all. This could cause massive traffic jams, accidents or confusion. The sensor or signal input is a critical point in the system.

3. Smart Thermostat (Heating System Sensor)

Think about a smart thermostat — it's a device that automatically controls room temperature. It uses a sensor to check how warm or cold the room is. If the sensor fails and wrongly says the room is too cold, the heater will keep running. This wastes electricity and makes the room too hot. If it wrongly reports the room is too hot, the heater will not turn on. Then the room will stay cold, even when it is needed. The sensor is a critical point. A small error here affects the whole system.

4. Digital Clocks or Calculators

Digital devices like clocks and calculators use signals to light up number displays. Each number is shown using different lines or segments. If a part of the circuit that controls one of the segments breaks, the number will not display properly. For instance, if the top line (segment) needed to show a “7” does not work, the number might look like “/” instead of “7”. That single signal path is a critical point. When it is damaged, the device gives wrong information.

Let us imagine there is a smart system on a farm in Ziavi, Ho, where water must be used wisely. This system is supposed to water the crops automatically but only when needed.

Let us see how it works step by step:

Step 1: Moisture Sensor (INPUT)

This sensor is placed in the soil to check how dry the soil is. If the soil is too dry, the sensor sends a digital signal ‘1’ meaning TRUE or YES, indicating the soil needs water. However, if the soil is not dry, it sends ‘0’ meaning FALSE indicating no need to water the soil. This is a critical point because if it sends the wrong signal (e.g., says the soil is wet when it is actually dry), the plants will not get water.

Step 2: Timer (INPUT)

The system only waters during certain times of day. For instance, early morning or late evening, to avoid too much evaporation. The timer checks the current time. If it is within the set time, it sends ‘1’ (TRUE – it is a good time to water, otherwise, it sends ‘0’ (FALSE – not time to water yet). This is also a critical point. If the timer fails, water might flow at the wrong time or not at all.

Step 3: Pump (OUTPUT)

The pump is the device that turns on to water the crops, but it only turns on if both the Moisture Sensor and the Timer send ‘1’. This is an AND Logic Gate. It means “If soil is dry (1) AND it is the right time (1), THEN water the plants.”

Table 1.1: Smart Farm Irrigation System

Moisture Sensor	Timer	Pump
0	0	0
0	1	0
1	0	0
1	1	1

From table 1.1, if only when both inputs are 1, the pump turns ON. The AND logic is a critical decision point. If the logic is set wrongly, the pump might turn on even when it is not needed, wasting water. This farm system, therefore, uses logical thinking (Boolean logic) to make smart decisions:

Activity 1.1 Identifying Critical Point

1. What will happen to the power supply of your house if device in **Figure 1.1** gets burnt?

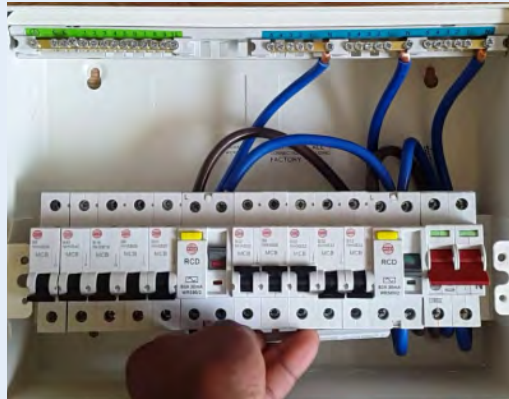


Figure 1.1 Main Switch

2. Yes, the power supply goes off.

Activity 1.2 Identifying Critical Point 2

A farmer has installed a basic automatic watering system. The system has a moisture sensor and a timer to conserve water in a tank. Follow the steps to design a logic circuit for the system.

Steps

1. Create a truth table with inputs M, T and B.
2. Write the Boolean expression.
3. Draw your logic circuit diagram.
4. Show your design to your teacher for approval or compare it with a peer's design.

Hint

- Reflect and write three things you found interesting about the activity
- Keep your completed design in a safe place for the next activity

UNDERSTANDING FAIL-SAFES AND REDUNDANCY

When we study logic systems like those used in computers, traffic lights or automatic machines, we look for parts of the system where something could go wrong. These parts are called critical points. If one of these critical points fails, the whole system might stop working or behave in the wrong way. So, when we analyse critical points, we are really checking for weaknesses in the system. To prevent serious problems, engineers use “fail-safe” designs and “redundancy” as strategies to make systems more resilient to faults.

FAIL-SAFE FLIP-FLOPS

A flip-flop is a small circuit used in digital systems to store one bit of data, either a 0 or a 1. It remembers a value until something tells it to change. What happens if the power goes off or if something goes wrong in the system? That is where fail-safe flip-flops come in. They are systems that automatically go to a “safe” position when something goes wrong. Like an electronic car, when the fuel pump sensor detects something is wrong, it automatically prevents the car from starting. Also, when there is a fault with an electrical item, they typically have a fuse that blows to protect people and any other electronics connected to the power.

Fail-safe flip-flops are special types of flip-flops that are designed to handle errors safely. What they do are to:

1. Safe when power fails or signals are wrong. If the power suddenly cuts off, or if the flip-flop receives an invalid or unexpected signal, it does not freeze or crash. Instead, it goes to a known safe value. For instance, in a railway system, if something goes wrong, the signals may all turn red to stop the trains. That is a safe action. Similarly, a fail-safe flip-flop chooses a value (like 0 or 1) that keeps the system safe.
2. Can sometimes detect problems inside themselves. For instance, if the clock signal (which controls timing) is faulty or if the output gets stuck at 0 or 1 and does not change when it should, the flip-flop can notice the fault and respond by entering a safe condition or sending an error signal.
3. The main goal is to prevent danger. When a system fault happens, the flip-flop helps the system shut down safely or keeps it in a stable condition until help arrives. This helps avoid unpredictable behaviour which could cause damage or risk to people.

REDUNDANCY

Redundancy is having backup plans or extra components, so the system keeps working even when parts fail. Think about how your family prepares for ECG power cut off, you may have candles or a lamp ready or when your phone battery dies, you might have a power bank ready to recharge. This is exactly what fail-safes and redundancy mean in computer systems.

Fail-safe design helps a system stay safe if something goes wrong. It is used in places where a failure could hurt people, waste money or stop important services. Examples include planes, hospital machines and bank systems. The system is built to switch to a safe setting instead of causing danger. This makes the system more dependable and keeps people, information and machines safe.

Types of Redundancy

1. **Hardware Redundancy** means having two or more of the same physical things so if one breaks, the other can take over immediately. An example is having multiple chargers for the same device. If one charger fails, the other can still charge.
2. **Logic Redundancy** means creating multiple different paths or methods to achieve the same result. If one method fails, another method can still work. An example is written codes to catch runtime error. Also, in a security system, instead of using just one AND gate, you could add OR gates and other backup paths. This way, if one part of the circuit stops working, another part can still detect danger and sound the alarm. This helps the system to keep working even when a small fault happens.
3. **Time Redundancy** means doing the same thing several times and comparing results to make sure you get the right answer. Additionally, if a system reads a sensor, it might check the value three times. If one reading is wrong because of noise or a small error, the system can still trust the other two. It is like asking three people for directions to be sure you are going the right way.

Activity 1.3 Add Redundancy

1. Review the logic that you undertook in **Activity 1.2** and add a redundant gate to improve your work.
2. In your words, describe how a redundant gate improved the logic automatic water system
3. Show the results to your teacher for approval

Activity 1.4 Application of Critical Points

The Alberta family's current security system is designed to trigger an alarm only when both motion sensors detect movement simultaneously. Here's how it currently works:

Sensor A (front door area) AND Sensor B (living room area) → Alarm.

Sensor A	Sensor B	Alarm	What This Means
0 (no motion)	0 (no motion)	0 (OFF)	No intruder detected
0 (no motion)	1 (motion)	0 (OFF)	Motion only in the living room
1 (motion)	0 (no motion)	0 (OFF)	Motion only at the front door
1 (motion)	1 (motion)	1 (ON)	Motion in both areas

1. What is the major security flaw in this system?
2. Give 3 real-world scenarios where this system would FAIL to protect the family:
 - a. Scenario 1: Intruder enters through...
 - b. Scenario 2: What if Sensor A breaks...
 - c. Scenario 3: What if the intruder moves slowly...
3. Why is using AND logic dangerous for security systems?
4. Design a truth table and draw the gates for a better logic approach (Think about OR logic)?
5. Explain how this activity improved your understanding of design logical circuit
6. Share answers and new knowledge with the class or peers.

OPTIMISATION AND PROBLEM-SOLVING THROUGH LOGIC SYNTHESIS

Logic optimisation is the process of making digital circuits faster, cheaper and more efficient without changing what they do.

Have you seen a Ghanaian parent cooking jollof before? They do not use 10 different pots when 1 will do the job perfectly. Gas, time or ingredients are not wasted. This is exactly what logic optimisation means, making computer circuits work better by using fewer parts, less time and less power while getting the same results.

When we optimise a circuit, we are trying to do the following;

1. Use fewer logic gates. This helps to save space and reduce cost, especially when building the circuit into a chip.
2. Make signals move faster. If signals take less time to pass through the circuit (less propagation delay), the system will respond more quickly.

Save energy. Using fewer gates or more efficient ones can help the circuit use less power, which is important in devices like phones or laptops.

OPTIMISATION TECHNIQUES

Activity 1.5 Benefits of Optimisation

Analyse the table below and comment on the benefits of optimising the process

Technique	Description	Technical Example	Optimised Example	Real-Life Example	Comment
Gate Reduction	Using fewer gates to achieve the exact same logical output. This often involves applying Boolean algebra rules.	Before: AND gate → NOT gate = 2 gates	After: Single NAND gate = 1 gate	Before: School security needs 2 guards - one to check students, another to check bags After: 1 guard checks both students AND bags together	
Gate Type Simplification	Use universal gates like NAND/NOR only instead of mixing different gate types	Before: Circuit uses AND, OR, NOT gates (3 different types)	After: Same circuit using only NAND gates	Before: Kitchen with different utensils - rice spoon, soup spoon, stirring spoon After: One multi-purpose spoon does all jobs	
Timing Optimisation	Minimise delay by reducing gate levels to make circuits respond faster	Before: Input → Gate1 → Gate2 → Gate3 → Output (3 delays)	After: Input → Combined Gate → Output (1 delay)	Before: Getting to Sunyani from Accra via Dambai then Kwame Danso (long route) After: Direct Accra to Sunyani route	

Example

Expression: $Y = A*B + A*\bar{B}$

Simplify: $Y = A$

This eliminates the need for an AND, NOT and OR gate, hence saving time and space.

SHIFT/ROTATION OPERATIONS & BOOLEAN ALGEBRA CONNECTION

How much cedis are 10 pieces of 50 pesewas?

You may have guessed that right. Just like converting pesewas to cedis, the process is shorter with you just moving the decimal point one place to the right:

- a. 50 pesewas $\rightarrow$ 5.0 cedis (moved decimal right).
- b. 100 pesewas $\rightarrow$ 10.0 cedis (moved decimal right).

Computers do not understand regular numbers like 13 or 100 the way we do. They think in binary, which is just patterns of 0s and 1s. Examples include the decimal number 13 becomes 00001101 in 8-bit binary.

Shift Operation means moving all the 0s and 1s in a binary number to the left or right, just like moving the decimal point in regular numbers. The emphasis is on binary numbers. This action does not change the number randomly. They follow clear rules, and they are very useful in computing.

Example

Imagine you are selling oranges at Kejetia Market, and a customer wants 8 oranges at 2 cedis each. You are likely to perform the calculation like this: $2 + 2 + 2 + 2 + 2 + 2 + 2 + 2 = 16$ cedis. The time taken for this calculation process is 8 additions.

With the computer's calculator or an analogue calculator, it will compute it as $8 \times 2 = 16$ shifted 3 positions left. Answering 16 cedis. The time taken for this process is just 1 addition. This fast process of calculation is known as the shift operation. These operations are important because of the reasons discussed below:

1. Super-Fast Multiplication & Division

In binary, **shifting bits** left or right is a **quick way** for the computer to do multiplication or division, especially with **powers of 2**. For instance, if you have the binary number **00000101** (which is 5 in decimal) and you shift it one place to the left, it becomes **00001010** (which is 10). That is the same as multiplying by 2. It works like adding a zero at the end of a number in base 10 to multiply by 10. That is **$23 \times 10 = 230$** . In binary, shifting makes maths **much faster** for the computer because it uses **simple movement of bits** instead of full calculations.

2. Data Compression

Bit shifting can help with data compression. It means saving space when storing information. It allows a computer to pack two or more small pieces of data into one binary number. For example, imagine you have two 4-bit numbers. Normally, each one takes up its own space, but with bit shifting, you can move one to the left and then combine it with the other. This way, both numbers fit into the space of one 8-bit value. It is like folding two small papers to fit into one envelope instead of using two

envelopes. In doing this, we save memory or send data more efficiently in a computer system.

3. Cryptography & Low-Level Programming

Bit shifting is very important in cryptography and low-level programming. In cryptography, it helps to hide information by mixing up the bits in a special way. This is used to keep data secret like when sending a message over the internet. In low-level programming such as working with the hardware of the computer, you sometimes need to control individual bits directly. Shifting and rotating bits allows programmers to do this quickly and exactly are useful tools that help the computer work with data in a more secure and efficient way.

Types of Shift Operations

1. Logical Shift

This is like moving students in a line. Imagine your days in basic school, standing in a line with your friends for a group photo. Like this Real-Life Analogy (Logical Shift):



Kofi

Ama

Aku

Kwame

Afi

Adowa

Kojo

Yaa

Abenau

- When a left shift is applied; every learner moves one position to the left. Which will make “**Kofi**” drop off from the picture. Then “**Abena’s**” position becomes empty.
- For another learner to join, the learner must join from the right by taking “**Abena’s**” empty position.

***Note** that this logical shift can be applied from left to right or right to left. Any empty spaces are filled with 0s. Bits that fall off the end are lost. Logical shifts are mainly used for numbers that are always positive (unsigned numbers) because they do not protect the ‘sign bit’ (the bit that tells if a number is positive or negative).*

Example of Logical Shift with Number

The binary number for 13 is 1101.

Logical Left Shift by 1 position: Let us left shift the binary

$$\leftarrow 1\ 1\ 0\ 1 = 101 = 1010$$

Remember that any number that drops is lost, so the first one is lost, and the empty space is filled with a zero.

The result of our new binary (1010) is 10.

Logical Right Shift by 1 position: If we right shift 1010,

$$1\ 01\ 0 = 101 = 0101$$

This new result of 1010 is the decimal number 5.

Note that in computing, we add 4 or 8 leading zeros to the binary to ensure a consistent length of values like

- i. 0101 (5 decimal) = 00000101
- ii. 1010 (10 decimal) = 00001010
- iii. 1101 (13 decimal) = 00001101

Activity 1.6 Shifting of Binary Operation

1. Convert 2 and 26 to binary numbers and perform one left shift each.
2. Pad the results with leading zeros to get 8 bits.
3. Perform logical left shift by 2 positions on 1101 and 001101
4. Perform logical right shift by 2 positions on 1001110

Activity 1.7 Bits Packing

We can combine bits to make a single bit. *For example*, RGB colour codes combines two or three bits into a single bit.

Let us combine (13) and (6) to make one 8-bit byte using shifts.

Steps

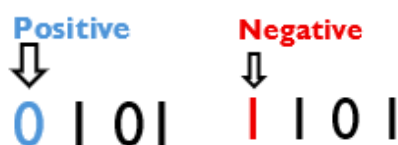
1. Convert 13 and 6 into binary
2. Add 4 leading zeros to the right of 13
3. Add 4 leading zeros to the left of 6
4. Use the bitwise OR to combine the results (the bitwise OR is simply the use of OR logic where $1 \text{ OR } 0 = 1$ and $0 \text{ OR } 0 = 0$).
5. Show your final answer to your teacher for confirmation.

Activity 1.8 Application of Logical Shift in Real-Life

In your groups, solve this problem. A weather sensor records two 4-bit temperatures, 1011 (11°C) and 0100 (4°C). Pack them into one 8-bit byte.

ARITHMETIC SHIFT

Unlike logical shift, arithmetic shift keeps track of positive/negative signs. While the shifting process occurs. It is used when working with signed numbers. That is, numbers that can be positive or negative. It works almost like a logical shift, but with one important difference. It keeps the sign bit (the first bit on the left) the same. This is very important because if the number is positive, the sign bit is 0 and if the number is negative, the sign bit is 1. In keeping the sign bit the same, the arithmetic shift makes sure that a positive number stays positive while a negative number stays negative. The illustration of the arithmetic shift is shown here. The key things to keep in mind are the values of the left-most number.



During the shifting process, when you shift everything left, the old sign bit also moves over. The bit that was next to the sign bit now becomes the new sign bit. This causes an overflow. Meaning that the number 1011 (-5 decimal) shifts to become 0110 (+6 decimal). This problem occurs because the original sign bit ('1') was pushed out and a '0' took its place. This completely changed the meaning of the number from negative to positive, which is an **overflow**. However, computers have special ways to notice when this “overflow” happens (like setting an “overflow flag”) so they know the calculation went wrong.

1. Arithmetic Right Shift

An arithmetic right shift moves all the bits one place to the right, but it keeps the sign of the number the same. If the number is positive (starts with a 0), then 0s are added on the left. If the number is negative (starts with a 1), then 1s are added on the left. This helps the number stay in its correct positive or negative form when using two complement representations.

2. Arithmetic Left Shift

An arithmetic left shift moves all the bits one place to the left, and 0s are added on the right just like in a logical shift but there is a risk. If the shift pushes a bit into the sign position (the first bit), it can change the sign of the number by mistake. This is called an overflow, and it can turn a positive number into a negative one or vice versa. Most CPUs have overflow flags to detect when this happens.

Let us look at an example using the binary number 1011 (4 bits): In two's complement, the first bit is the sign bit. Since it starts with 1, it means the number is negative. $1011 = -5$ in decimal.

Original: 1 0 1 1 (Sign bit is '1', so it is negative.)

Let us use the 4-bit binary number 1 0 1 1. The first bit (on the left) is the sign bit because it is 1, the number is negative. In two's complement, $1011 = -5$ in decimal.

a. **Arithmetic Right Shift (by 1 position)**

Move all the bits from one place to the right. The rightmost bit falls off. The sign bit (1) is copied into the empty space on the left. Hence, $1011 \rightarrow 1101$. The new binary number is 1101. In decimal, $1101 = -3$. The number is still negative, and the sign is kept correctly. This is a typical example of safe shifts.

b. **Arithmetic Left Shift (by 1 position)**

Move all the bits from one place to the left. A 0 is added on the right but now, the sign bit might be overwritten. Hence, $1011 \rightarrow 0110$. The new binary number is 0110. In decimal, $0110 = +6$ but we started with -5 , and now it has become $+6$. This is a mistake caused by overflow. The shift changed the sign, which means the result is not correct. This indicates a typical example of an unsafe shift due to overflow.

Real-Life Application

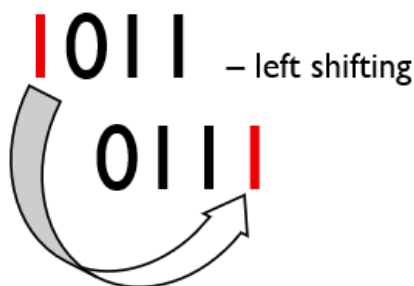
Imagine a line of learners sitting in chairs. The learner on the far left is the leader of the group. This leader represents the sign bit. If the group is asked to shift one seat to the right, each learner moves one seat to the right. A new learner must join the far left to fill the empty seat. Notably, the leader controls who joins the line. If the leader is negative, a negative student (another 1) join. In the same way, if the leader is positive, a positive student (a 0) join. This keeps the overall attitude (sign) of the group the same even after the shift.

3. Circular Shift (Rotation)

Is type of shift does not lose the numbers that drop off. It is like people dancing in a circle.

An example is using a 4-bit binary number 1011).

- a. Circular Left Shift by 1 position (Rotate Left): The leftmost bit (1) drops off but reappears at the right-hand end. Result: $1011 \rightarrow 0111$.



Every number moves one position left and nothing gets lost. Every number is still in the circle as demonstrated.

- b. Circular Right Shift (Rotate Right by 1). The rightmost bit (1) drops off but reappears at the left-hand end. Result: $1011 \rightarrow 1101$

Use Case: Circular shifts are often used in Cryptography to reorder binary data in a way that can later be reversed and error detection and correction to rotate bit patterns while preserving the original algorithms.

Real-Life Application: Imagine a picture a group of learners seated in a circle. If everyone moves one seat to the left, no one leaves the group. Also, the learner at the “end” simply moves to the first seat. In the same way, a circular shift keeps all the bits but rearranges their positions.

Real-Life Application

1. Caesar Cipher (Encryption)

A Caesar cipher shifts letters forward by a set number of positions (e.g., A becomes D with a shift of +3).

A binary version in simple embedded systems uses scrambled binary data. For instance, rotating 1011 to the left results in 0111. This basic scrambling method is a simple form of encryption.

2. Fast Math in CPUs

Computers use bit shifts to do quick multiplication or division by powers of 2.

- a. Left Shift ($\ll$) = Multiply by 2. Shifting bits to the left doubles the number for each shift.
- i. Example 1: 0010 (which is 2) shifted left by 1 becomes 0100 (4).
 - ii. Example 2: 00011010 (which is 26) shifted left by 1 becomes 00110100 (52).
- b. Right Shift ($\gg$) = Divide by 2

Shifting bits to the right halves the number for each shift. The result depends on whether the number is signed (can be negative) or unsigned (always positive).

- i. Example 1 (Signed): 1100 (which is -4 in signed 4-bit) shifted right by 1 becomes 1110 (-2, using arithmetic shift).
- ii. Example 2 (Unsigned): 00011010 (which is 26) shifted right by 1 becomes 00001101 (13, using logical shift).

Activity 1.9 Computation of Circular Shifts

1. Perform a left circular shift on 1101 for two positions
2. Compare your answers with your peers

COMPARING REPEATED ADDITION VS. SHIFT-AND-ADD MULTIPLICATION

Being a human, we solve 5×3 as $5 + 5 + 5 = 15$.

However, this process has a disadvantage for calculating larger numbers such as 2000×1000 , this process will involve adding 2000 by itself 1000 times.

Computational calculators are able to solve this task faster because of the use of shift and add process known as bitwise optimisation. Let us practice how computers do this.

Activity 1.10 Shift-and-Add Multiplication

Work with your group to do the following task

1. Watch this video by clicking this [link](https://www.youtube.com/watch?v=jr1bwXPbPY) or scanning the QR code to guide you through the activity.



(<https://www.youtube.com/watch?v=jr1bwXPbPY>)

Note: Alternatively, seek assistance from your teacher on how to do the calculation if you cannot access an internet-connected device.

2. What is the value of $19 \times 3 =$ _____
3. Convert these decimal numbers to binary
 - a. 9 in decimal = _____ in binary (4 bits)
 - b. 3 in decimal = _____ in binary (4 bits)
4. Identify the bit multiplier position and use it to fill the table

Bit Position	Multiplier Bit	Action Needed
	1	10011×1 , no shift
	1	
	0	
	0	

5. Apply the left shift, add the results
6. Show your final answer to your teacher for confirmation

BINARY SUBTRACTION USING TWO'S COMPLEMENT (4-BIT BINARY)

Computers use a very clever trick for performing subtraction. They convert subtraction into addition using a method called Two's Complement.

The process of doing this subtraction is demonstrated in the example below.

Example

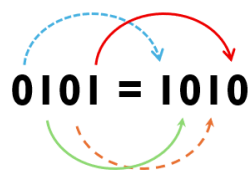
Traditional, $7 - 5 = 2$

Computers convert these numbers to binary

- decimal 7 = 0111
- decimal 5 = 0101

To get (-5), the two's complement is applied. The complement involves two steps

1. Change the bits as illustrated in the image. We are inverting all the bits of 5 (thus, changing all 0s to 1s and 1s to 0s).



2. Adding 1 to the result

$1010 + 1 = 1011$ à this result becomes (-5).

Let's now add the bits of 7 and (-5).

$$\begin{array}{r} 0111 \\ + 1011 \\ \hline 10010 \end{array}$$

Handle the overflow. The final bit carries a "1" while the bits in operation are 4 bits. So, there is an overflow from the leftmost bit; we discard the overflow. The result is 0010, which is the same as decimal 2.

Activity 1.11 Application of Shift and Two's Complement

1. Try this task to deepen your understanding of the Shift and Add operation
 - a. A trader sells 6 oranges at 4 cedis each. Calculate 6×4 using binary multiplication.
 - b. A school needs 7 boxes of chalk at 2 cedis each. Calculate 7×2 .
2. Ama has 9 cedis and withdraws 4 cedis. Calculate $9 - 4$ using two's complement.

PYTHON APPLICATION OF ARITHMETIC OPERATIONS TO REAL-WORLD PROBLEMS

We have been doing computational calculations for quite a while now. Let's use the scenario below to explore how we can use arithmetic operations in Python.

Scenario

You work for the Ghana Meteorological Agency and need to create a temperature conversion app for international weather reporting. Ghana reports temperatures in Celsius, but many international partners need Fahrenheit readings.

To address this task, we first need to understand the conversion formula of Fahrenheit (F) to Celsius (C).

$$F = C \times 9/5 + 32$$

Activity 1.12 Manual Calculation of Temperature

Work with your partner to understand this formula by solving these Ghanaian weather examples

1. Accra Hot Season: 35°C (typical March temperature)
calculation: $35 \times 9/5 + 32 = \underline{\hspace{2cm}}^{\circ}\text{F}$
2. Kumasi Cool Morning: 18°C (typical December morning)
calculation: $18 \times 9/5 + 32 = \underline{\hspace{2cm}}^{\circ}\text{F}$
3. Cape Coast Sea Breeze: 28°C (typical coastal temperature)
calculation: $28 \times 9/5 + 32 = \underline{\hspace{2cm}}^{\circ}\text{F}$
4. Special Cases to Test:
 - a. Water freezing point: $0^{\circ}\text{C} = \underline{\hspace{2cm}}^{\circ}\text{F}$
 - b. Water boiling point: $100^{\circ}\text{C} = \underline{\hspace{2cm}}^{\circ}\text{F}$
 - c. Mysterious temperature: $-40^{\circ}\text{C} = \underline{\hspace{2cm}}^{\circ}\text{F}$ (calculate and see what happens!)

Activity 1.13 Developing the Ghana Weather App

1. Let's create the function, use a Python offline or online compiler for this activity
2. Scan the first QR code or click on this [link](#) to access the online compiler
3. Scan the second QR code or click on this [link](#) to access the second source code. Follow the instructions in the document and continue with the activity.

Compiler	Source Code
	
https://www.programiz.com/python-programming/online-compiler/	https://docs.google.com/document/d/1aKwr5RJGzYjrit2IOAMopRSrWhkaD6kvqU16ZKqvMRM/edit?tab=t.0

Seek assistance from your teacher when needed.

Activity 1.14 Application of Boolean Algebra

ECG needs to implement “dumsor” (load shedding) intelligently to prevent total grid collapse. Instead of random blackouts, they want a smart system that prioritises essential services.

System Inputs

1. H = Hospital/Emergency Services (1 = needs power, 0 = can use backup)
2. I = Industrial Areas (1 = factories running, 0 = factories closed)
3. R = Residential Areas (1 = peak usage time, 0 = low usage time)

Priority Logic (Fail-Safe for Grid Stability)

1. Power should be cut (Load Shedding = 1) when:
 - a. Hospitals do not need grid power ($H = 0$) AND its industrial time ($I = 1$),
OR
 - b. It is not peak residential time ($R = 0$) AND hospitals have backup power ($H=0$)
2. Fail-Safe Rule: Hospitals NEVER lose power unless they confirm backup generators are running.

Tasks

1. Create a truth table for the load shedding logic
2. Write the Boolean expression for when to cut power
3. Design the logic circuit
4. Create a priority schedule for different areas of Accra
5. Explain how this prevents total grid collapse
6. Write Python code for the schedule of different areas
7. Show your design to your teacher for approval

EXTENDED READING

- Al Sweigart. (2020). Automate the boring stuff with Python: Practical programming for total beginners (2nd ed.). No Starch Press. Access it [here](#) or on <https://automatetheboringstuff.com/>
- Harris, D. M., & Harris, S. L. (2012). Digital design and computer architecture (2nd ed.). Morgan Kaufmann. Access it from [Link](#) or https://www.r-5.org/files/books/computers/hw-layers/hardware/digital-desigh/David_Harris_Sarah_Harris-Digital_Design_and_Computer_Architecture-EN.pdf.
- Mano, M. M., & Ciletti, M. D. (2017). Digital design: With an introduction to the Verilog HDL, VHDL, and System Verilog (6th ed.). Pearson. Get it from the link [here](#) or <https://mrce.in/ebooks/Digital%20Design%20With%20an%20Introduction%20to%20the%20Verilog%20HDL,%20VHDL%20and%20Systemverilog%206th%20Ed.pdf>.

REVIEW QUESTIONS

1. What is the result of a right shift by one position on the binary number 1100?
2. Using binary, calculate 6×5 by both the repeated addition and shift-and-add method. Comment on efficiency.
3. Compare how left shift and rotation left operations affect binary numbers, using an 8-bit register.
4. Write a Python program that accepts daily expenses, stores them in a list and calculates total, average and highest expense. Explain how these models real-world budgeting.



SECTION

2

SYSTEM SOFTWARE COMPONENTS

COMPUTER ARCHITECTURE & ORGANISATION

COMPUTER HARDWARE AND SOFTWARE INTRODUCTION

In previous years, you learnt about how barcodes and QR codes are used to store and retrieve information. Barcodes, with their black and white lines, provide basic data storage while QR codes offer a more advanced way to store larger amounts of information. You also explored the fundamental concept of software as the set of instructions that enable a computer to function, acting as its “brain.”

This section builds upon that knowledge by delving deeper into the features of computer hardware and software by introducing you to the various categories of system software. You will begin by understanding the fundamental role of operating systems which are the core programs that manage all the hardware and software on your computer. You will also learn about their essential functions such as managing memory, controlling hardware devices and running applications.

Furthermore, you will compare various operating systems by examining their unique characteristics and common applications in different environments.

Finally, you will gain practical knowledge by learning how to perform basic system administration tasks such as setting up user accounts, installing and updating software, monitoring processes, configuring networks and backing up data to ensure computers stay secure, organised and reliable.

KEY IDEAS

- **Basic system administration** involves tasks such as user and group management, software installation and updates, process monitoring and service control, etc.
- **Operating system (OS)** is system software that acts as an intermediary between hardware and applications.
- **OS comparison criteria** are about how different operating systems can be compared based on user interface (GUI vs CLI), resource requirements, etc. to determine the best fit for a given environment.
- **System software** encompasses programs that support the core functions of computer like operating systems, device drivers and utilities that enable hardware operation.

Activity 2.1 Revision on Types of Software

Pair with your friend and do the following.

1. Write down in your jotter
 - a. Two types of software you know.
 - b. The differences between the two types of software.
 - c. Examples of the types of software used in Ghana.
2. Share your responses with the class.
3. Write the opinions the class shared with you during the presentation in your notes.

SYSTEM SOFTWARE (OPERATING SYSTEMS AND UTILITY SOFTWARE)

SYSTEM SOFTWARE

System Software encompasses programs that support the core functions of computers. This includes operating systems, device drivers and utilities that enable hardware operation and performs maintenance tasks and facilitate application execution.

Categories of System Software

1. Operating Systems (e.g., Windows, MacOS, Linux).
2. Utilities (disk defragmenters, antivirus tools).
3. Device Drivers (enabled hardware-software communication).
4. Firmware
 - Embedded code in hardware (BIOS/UEFI on motherboards).
 - Manages low-level device operations.



Figure 2.1 Icons of 3 operating system

Operating Systems

It is the core system software that acts as an interface between the users and the system. It makes the computer easier to use. It provides an interface that is more user-friendly than the underlying hardware.

Functions of the operating system

1. **Process Management:** Manages the execution of all processes (programs) and ensures their smooth operation including starting, stopping and scheduling them.

For example, when you open a web browser, the OS creates a process for it. If you then open a word processor, the OS manages both these processes and ensures they run efficiently without interfering with each other.

2. **Memory Management:** Allocates and deallocates memory space to running programs and data,. This helps to optimise memory usage and prevent conflicts. When you run multiple applications, the OS decides which parts of the RAM each application can use.

For instance, if you are editing a large image in Photoshop, the OS allocates sufficient memory for it and when you close Photoshop, the OS reclaims that memory for other applications to use.

3. **Resource Management:** Controls and allocates system resources such as the CPU, storage and peripheral devices among different applications and users.

Imagine you are printing a document while also downloading a large file and streaming music. The OS manages the CPU time given to each task and ensures the printer gets the data it needs and allocates bandwidth for both the download and streaming.

4. **I/O Operations:** Handles input and output requests, by enabling communication between the computer and external devices like keyboards, printers and storage drives. When you type on your keyboard, the OS processes those keystrokes and displays them on the screen. When you save a file, the OS writes that data to your hard drive. When you click a mouse, the OS interprets that click and sends it to the active application.

5. **Data Management:** Organises and manages data on storage devices including file creation, deletion, access control and ensuring data integrity. This includes creating folders, moving files, renaming documents and ensuring that files are not corrupted.

For example, when you save a document, the OS finds a place on your hard drive, names the file and keeps track of where it is stored. It also sets permissions so only authorised users can access or modify certain files.

6. **Providing Security:** Implements security features to protect user data and system resources from unauthorised access and malicious activities. This involves user authentication (like requiring a password to log in), setting file permissions to restrict access and often includes firewalls to prevent unauthorised network access.

For example, if multiple users share a computer, the OS ensures that each file of users and settings are kept private from other users.

Types of Operating Systems

Operating systems come in various forms with each designed for specific purposes and environments. Understanding these different types will help you appreciate their diverse applications.

1. Personal Computer (PC) Operating Systems

These are the most common operating systems used on desktop and laptop computers. They provide a graphical user interface (GUI) and manage all the hardware and software on a single machine.

2. Windows (Microsoft)

This is the most widely used PC operating system globally. It is known for its user-friendly interface, extensive software compatibility and broad hardware support.

Examples include Windows 10 and Windows 11.

3. MacOS (Apple)

It is developed by Apple for its Macintosh computers. It is known for its elegant design, strong security features and integration with the ecosystem of Apple devices and services.

4. Linux

An open-source operating system that is highly customisable and free to use. It comes in various distributions (e.g., Ubuntu, Fedora), and it is popular among developers, system administrators and users who prefer greater control over their system.

5. Mobile Operating Systems

This is designed specifically for smartphones and tablets. These operating systems are optimised for touch interfaces and low power consumption.

6. Android (Google)

The dominant mobile operating system worldwide. It is open-source and highly customisable, found on a vast array of devices from different manufacturers.

7. iOS (Apple)

Developed by Apple for its iPhone and iPad devices. Known for its simplicity, security and seamless integration with hardware and services of Apple.

8. Server Operating Systems

These operating systems are designed to manage network resources, host websites and provide services to multiple clients on a network. They prioritise stability, security and robust performance.

9. Windows Server (Microsoft)

This is a version of Windows optimised for server environments. They offer features like active directory, file sharing and web hosting.

10. Linux (various distributions like Ubuntu Server, Red Hat Enterprise Linux)

They are widely used in server environments due to its stability, security and cost-effectiveness.

11. Unix

It is an older and powerful operating system that forms the basis for many modern operating systems including Linux and macOS. It is known for its multi-user and multitasking capabilities.

12. Embedded Operating Systems

These are specialised operating systems designed for specific and non-computer devices. They are typically lightweight and optimised for a particular function.

Examples: Operating systems found in smart TVs, GPS devices, washing machines, smart home devices and industrial control systems. They are often stripped-down versions of larger OSes or custom-built for specific needs of devices.

13. Real-Time Operating Systems (RTOS)

RTOS are designed to handle data with precise timing constraints. They are used in applications where operations must be performed within strict deadlines. They are often in mission-critical systems.

Examples: Used in industrial control systems, medical imaging equipment, aircraft control systems and robotics where timely responses are crucial.

Compare Different Types of Operating Systems and Their Applications

OS Category	Examples	Key Characteristics	Typical Applications
Desktop OS	Windows, MacOS, Linux	User-friendly GUIs; rich app ecosystem	Office work, software development, gaming
Mobile OS	Android, iOS	Touch interfaces; power-efficient; app stores	Phone calls, mobile apps, location services
Server OS	Windows Server, Ubuntu Server, CentOS	High reliability; remote management; virtualisation support	Web hosting, databases, cloud platforms
Embedded/RTOS	FreeRTOS, VxWorks	Real-time guarantees; minimal footprint	IoT devices, automotive systems, industrial controllers

Activity 2.2 Types of Operating System

Organise yourself into a group of 3 to 4 members

1. Observe the following operating systems available in the computer lab or through screenshots:
 - a. Windows
 - b. Linux (if available)
 - c. Android/iOS (if mobile devices are available)
2. Write about the user interface, features and functions of their assigned OS in your notebook.
3. Write on the similarities and differences of the operating systems you have observed.
4. Share your findings with the class.
5. Tell the class the new things you have observed.

UTILITY SOFTWARE

Think of utility software as a toolbox for your computer. Just like you use a spanners and pliers to fix your bike or a broom to clean your room, utility software helps check, fix, speed up and maintain your computer. It does not do the main jobs like your web browser or your games, but it works in the background to make sure everything runs smoothly.

Types of Utility Software

Utilities come in different types, each with a special job.

1. **Disk Management:** These tools help keep your computer storage (your hard drive or SSD) clean and organised.
 - a. Disk Cleanup: Finds and removes junk files you do not need like old downloads or temporary internet files. It is like throwing out the trash to free up space in your room.
 - b. Disk Defragmenter: Imagine your notes for a project are scattered across ten different pages in your notebook. A defragmenter gathers all the related bits of information and puts them together. This helps your computer find and open files much faster.
 - c. Disk Checker: This does a health check on your storage to find and fix any errors before they become big problems.
 - d. Partition Manager: Lets you divide your hard drive into separate sections (called partitions). You could have one section for your schoolwork, one for your games, and another for the OS.

2. **File Management:** These utilities help you handle your files more efficiently.
 - a. **File Compression:** Tools like WinZip or 7-Zip can squish big files into a smaller package. This is super helpful for saving space or sending large files through email. It is like vacuum-packing a big puffy jacket into a small bag!
 - b. **File Recovery:** Accidentally deleted an important photo or assignment. Recovery software like Recuva can often dive into your digital trash and get it back for you.
 - c. **File Sync:** Keeps your files updated across all your devices. If you change a document on your laptop, it automatically updates on your phone too.
3. **Security Utilities:** These are personal security guards of your computer. It protects you from online threats. These utilities include:
 - a. **Antivirus:** This software is like a doctor for your computer. It scans for, detects and removes viruses and malware that can steal your information or crash your system.
 - b. **Firewall:** It monitors all the data coming into and going out of your computer from the internet and blocks anything that looks suspicious.
 - c. **Anti-spyware:** Protects you from **spyware**. Spyware is malicious software that tries to watch what you do online and steal personal information like your passwords.
4. **System Optimisation:** These tools tune up your computer to make it run faster and more efficiently.
 - a. **Registry Cleaners:** The **registry** of your computer is like a giant address book for all its settings. Over time, it can get cluttered with old and useless entries. A registry cleaner tidies this up, which can sometimes help speed things up.
 - b. **Startup Managers:** When you turn on your computer, lots of programs try to launch all at once, which can make it take forever to start. A startup manager lets you choose which programs run automatically so that your computer can boot up faster.
5. **Backup Utilities** This is one of the most important tools you can have.
 - a. It makes a copy (a backup) of all your important files like photos, videos, game saves, school projects, etc.
 - b. You can schedule it to happen automatically. If your computer ever gets stolen, breaks or loses data due to a virus, you can restore all your files from your backup and not lose a thing. It is like having a magic copy of everything in a safe place.

How Utilities and OS work Together

Your Operating System (OS) and utility software are a team. They need each other to give you the best experience. Think of the OS as the boss of the computer. It manages everything the hardware, the software, and you! The utility software is the boss of your team of expert helpers.

1. **Teamwork Makes the Dream Work:** The OS provides the basic functions and utilities add special features to enhance them. Together, they make your computer a powerful and safe tool.

2. **Built-in Helpers:** Your OS already comes with some basic utilities built right in (like Windows Defender and Disk Cleanup). However, you can often download third-party utilities that have even more features.
3. **Working Together:** Utilities need the OS to run, and the OS can use utilities to stay in top shape. It is a perfect partnership to keep your computer healthy and happy!

Practical Software Application in Ghana

1. **In Schools and Universities**
 - a. In many schools, computer labs use Windows computers with antivirus software to keep them safe from viruses.
 - b. At universities, IT staff use disk management tools to keep lab computers running smoothly.
 - c. Schools also use backup tools to save important files like student results and lesson notes, so they do not get lost.
2. **In Businesses**
 - a. Small businesses in Ghana use file compression tools (like ZIP) to send big documents faster and easier.
 - b. Banks use security software to protect customer money and private information.
 - c. Some local companies use system clean-up tools to help old computers work better and last longer.
3. **At Home and On Phones**
 - a. Many people use storage tools on their phones to clear space and delete unused files.
 - b. Families with home computers use antivirus apps to stop harmful software (malware) that is common in Ghana.
 - c. Students sometimes use file recovery tools to get back assignments they accidentally deleted.

Activity 2.3 Operating System

Organise yourself into a group of 3 to 4 members.

1. Observe and make note as the teacher explains and demonstrates:
 - a. The core functions of operating systems with visual aids and examples.
 - b. How an operating system acts as an intermediary between hardware and applications.
 - c. How these functions are relevant in Ghanaian computing.
2. Share what you understand with the class.
3. Write down the feedback and additional information the class gives you in your jotter.

OPERATING SYSTEM INSTALLATION, CONFIGURATION AND MANAGEMENT

Operating System Installation

Imagine you bought a new mobile phone, but it had no Android or iOS. It would just be a blank screen! Similarly, computers need operating systems to:

1. Run your favourite applications (like games, browsers, or school software).
2. Connect to the internet and Wi-Fi.
3. Save and organise your files (photos, documents, music).
4. Keep your computer secure from viruses.

It is important we understand this steps before installing an OS.

Step 1: Preparation Phase

1. **Backing Up Your Important Files:** Before installing a new OS, you must save your important files like school assignments and projects, family photos and videos, etc on an external hard drive, USB flash drives, cloud storage (Google Drive, Dropbox) or another computer.
2. **Checking if the computer is Strong Enough:** It is important to check if your computer meets the minimum requirements for the new operating system. Check out for the memory (RAM), storage space and processor speed.
3. **Making Installation Media:** You need to create a special USB drive or DVD that contains the operating system by followings these points
 - a. Get a USB flash drive (at least 8GB - bigger than most music files!)
 - b. Download the operating system from the official website
 - c. Use special software to make the USB drive “bootable” (able to start the installation)
 - d. Test that the USB drive works properly

Step 2: Installing the Operating System

1. Starting the Installation
 - a. Boot from Installation Media: Insert your prepared USB drive and restart your computer
 - b. Choose Your Language: Select English or your preferred language
 - c. Select Your Location: Choose Ghana or your specific region so the computer knows your time zone and local settings.
2. Set up your computer's storage by disk partition. It is like dividing your house into different rooms:
 - a. One “room” for the operating system
 - b. Another “room” for your personal files

- c. Maybe a “room” for games and entertainment
- 3. Choosing Installation Type
 - a. Clean Installation: Like moving into a completely empty house and starting fresh
 - b. Upgrade: Like renovating your current house while keeping some of your existing things
- 4. Creating Your User Account: This is like getting your house keys and setting up security:
 - a. Choose a username (like your house number)
 - b. Create a strong password (like a secure lock)
 - c. Set up other family members’ accounts if needed
- 5. Connecting to the Internet: Connect to your network so your computer can:
 - a. Download important updates
 - b. Access online services
 - c. Stay secure with the latest protection

Step 3: After Installation Tasks

- 1. Installing Drivers: Drivers are like instruction manuals that teach your operating system how to use different parts of your computer (camera, speakers, Wi-Fi, etc.). It is like teaching a new house manager how to use all the appliances!
- 2. Getting Updates: Just like you might need to fix small problems in a new house, your operating system needs updates to:
 - a. Fix security problems
 - b. Make it work better
 - c. Add new features
- 3. Setting Up Security: This is like installing locks, alarms and security cameras in your new house:
 - a. Firewall: Like a security guard that checks who can enter your computer
 - b. Antivirus: Like a security system that watches for dangerous visitors
 - c. User permissions: Like deciding which family members can access which rooms
- 4. Installing Your Programs: At this point you can install the software you need:
 - a. School programs: Microsoft Office, educational software
 - b. Entertainment: Games, music players, video apps
 - c. Communication: WhatsApp Desktop, Zoom, browsers
- 5. Restoring Your Files: remember those files backed up during the pre-installation can now be moved back to the computer. Like unpacking your belongings in your new house!
- 6. Testing Everything: Make sure everything works properly:

- a. Can you connect to the network – via ethernet or Wi-Fi?
- b. Do your speakers work?
- c. Can you print documents?
- d. Are all your programs running smoothly?

Activity 2.4 Installation and Post installation Processes of OS

Organise yourself into a group of 5 members

1. Observe and make note as the teacher presents an overview of current operating systems with examples of their use in Ghana.
2. Based on the overview, choose your preferred OS and share your view about it with the class.
3. Observe and make note as the teacher takes you through, demonstrates or explains:
 - a. Pre-installation planning process of OS.
 - b. Different installation scenarios of OS.
 - c. How to:
 - Download OS installation files from official sources.
 - Verify file integrity.
 - Create bootable USB installation media.
 - Configure BIOS/UEFI settings for booting from external media.
 - d. Common issues encountered during media preparation and their solutions.
 - e. Complete the OS installation process.
 - f. Essential post-installation tasks.
4. Based on what you have observed or learnt, install OS on your assigned PC in the Lab.
5. Share your experience with your colleagues.
6. Write down the feedback and additional information the teacher gives you in your jotter.

Alternative to Activity 2.4

1. Go online, watch a video on how to install your preferred OS.
2. Write down pre-installation, installation and post-installation processes carefully.
3. Follow the written processes carefully and install the OS on your assigned PC.
4. Write down what was successful or challenging during the processes.

5. Write down how you overcome these challenges.
6. Share your experience with your friends.

MANAGING OPERATING SYSTEMS

Management of an OS is like taking care of your house - you need regular maintenance to keep everything running smoothly. Here are key areas you need to regularly maintain.

1. **User Account Management:** This is like managing who lives in your house:
 - a. Create accounts for different family members
 - b. Give different people different levels of access (parents might have more privileges than children)
 - c. Set up strong passwords for security
 - d. Organise users into groups (family, friends, guests)
2. **System Maintenance:** This is like regular house cleaning and maintenance:
 - a. Regular Updates: Like getting regular maintenance for your house – fixing small problems before they become big ones
 - b. Disk Cleanup: Like cleaning out your wardrobe – removing old, unnecessary files to make space for new ones
 - c. Managing Startup Programs: Like deciding which appliances should turn on automatically when you wake up – too many can slow things down!
 - d. Performance Monitoring: Like checking that all your house systems (electricity, water, internet) are working well
 - e. Backup Scheduling: Like regularly taking photos of your important belongings in case something happens to them
3. **Software Management:** This is like managing all the things in your house:
 - a. Installing new programs: Like buying new appliances - make sure they're compatible and useful
 - b. Removing old programs: Like getting rid of broken or unused items
 - c. Updating software: Like upgrading your appliances to newer, better versions
 - d. Managing licences: Like keeping receipts and warranties for your purchases
4. **System Monitoring and Troubleshooting:** This is like being a detective when things go wrong in your house:
 - a. Task Manager: Like a control panel that shows you what's using electricity, water, or internet in your house
 - b. Event Logs: Like a diary that records everything that happens in your computer – helpful when trying to solve problems

- c. Resource Monitoring: Like checking your electricity, water, and internet usage to make sure nothing is being wasted
- d. Problem Solving/Troubleshooting: Like being a handyman who can fix common household problems

System Restore: Like having a time machine that can take your computer back to when it was working perfectly.

Activity 2.5 Operating System Discussion

Pair with a colleague and answer the following questions in your workbook.

1. Which operating system would be best for a student in Ghana? Why?
2. What challenges might Ghanaian students face when managing operating systems?
3. How can we help our families and friends maintain their computers?
4. Share your answers with other group members and the teacher.

Activity 2.6 Managing an OS

This activity requires the use of computers; it can be done individually or as a group. If there are no computers, do the alternate activity.

1. Creating a backup of important files on the computer.
2. Explore the system settings on your computer.
3. Create a maintenance checklist for your computer.
4. Share with your class what you found challenging or easy in this activity. Indicate how you overcome the challenges.

Alternate Activity

1. Draw a diagram showing the installation process.
2. Create a step-by-step guide for backing up files on a mobile phone.
3. Discuss how the concepts apply to smartphones.

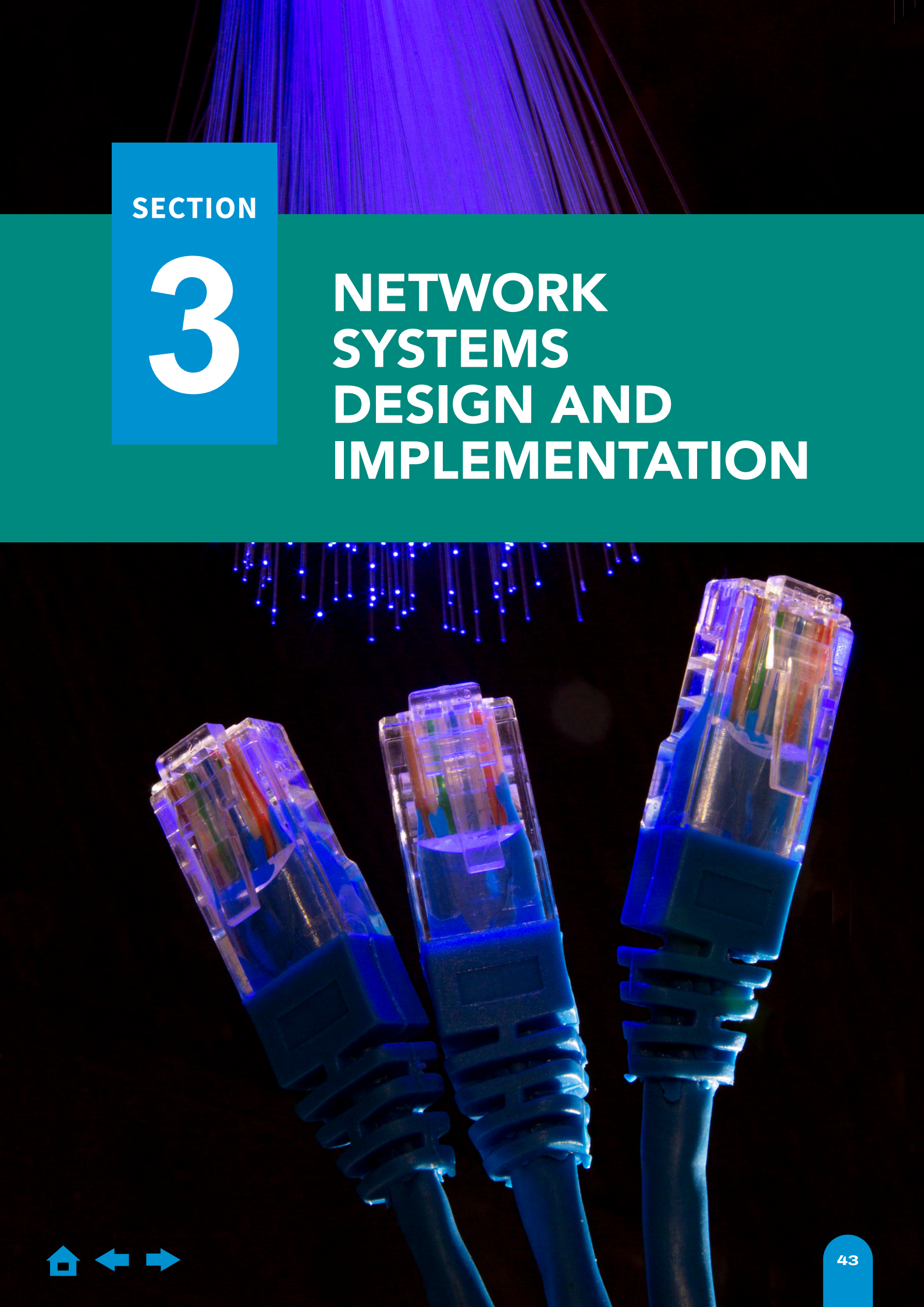
Share with your friends what you found challenging or easy in this activity. Indicate how you overcame the challenge.

EXTENDED READING

- <https://mu.ac.in/wp-content/uploads/2021/05/Operating-System-Final.pdf>
- <https://kahedu.edu.in/naac/C-3/Additional%20documents/E-content/2850.pdf>
- <https://cfd.annauniv.edu/coursematerial/ss1.ppt>
- https://fmcet.in/CSE/CS2304_uw.pdf

REVIEW QUESTIONS

1. What are three types of storage devices that can be used to back up important files before installing an operating system?
2. List the three main steps involved in the operating system installation process.
3. Name four examples of information that should be backed up before installing a new operating system.
4. Explain the difference between a “clean installation” and an “upgrade” when installing an operating system. Give one advantage of each method.
5. Compare disk partitioning to organising a house. Explain why partitioning might be useful for a Ghanaian student.

The background of the entire page is a close-up photograph of fiber optic cables. At the top, a dense bundle of fibers is illuminated with a bright blue light, creating a starburst effect. Below this, three individual RJ45 network cables are shown in the foreground, angled upwards. They have clear plastic RJ45 connectors and blue braided shields. The background is dark, making the blue light from the fibers stand out.

SECTION

3

NETWORK SYSTEMS DESIGN AND IMPLEMENTATION

COMPUTER ARCHITECTURE & ORGANISATION

DATA COMMUNICATION AND NETWORK SYSTEMS

INTRODUCTION & RECAP

In years one and two, you explored the various types of networks, their topologies and architecture. Further, you designed several LANs and configured and set up network processes for connection. You will build upon the previous learning in this section by exploring how a network system is designed and implemented. Additionally, this section provides you with practical knowledge to configure networks based on specific needs. You will also examine various network topologies, transmission media, bandwidth requirements, and security measures to design efficient and reliable network solutions for different environments.

KEY IDEAS

- **Biometric Authentication:** Biometric authentication is a way of verifying the identity of a person using their fingerprints, face, voice or eye (iris) patterns.
- **Data traffic:** The amount of data moving through a network at any time.
- **Domain Name System (DNS):** It translates website names into IP addresses.
- **IP Addressing:** An IP (Internet Protocol) address is a unique set of numbers assigned to each device on a network to identify it.
- **Network address:** It is a unique number or name given to a computer or device on a network.
- **Two-Factor Authentication (2FA):** it is an extra security step where you confirm your identity with two things.

NETWORK SYSTEM DESIGN AND IMPLEMENTATION

We are about learning the design of network systems and their implementation. Before we do that, let us recap on our previous learnings on network concepts and topologies from years 1 and 2 by performing **Activity 3.1** and the extended activity.

Activity 3.1 Revision on Network Purpose

1. What can you remember about the purpose of a network?
2. What can you remember about network design?
3. Indicate their common applications in Ghana.
4. Write your thoughts in your jotter.
5. Share your thoughts with peers and the teacher in the class.

Extended Revision Activity on Network Purpose and Design

1. Search for a video on how to design a network or click on the link [here](https://www.youtube.com/watch?v=cACIKWmzNeM) or <https://www.youtube.com/watch?v=cACIKWmzNeM>, to watch a video on how to design a network.
2. Summarise the process of network design in your notebook.
3. Complete the following activities
 - a. Choose either scenario A or B below.
 - i. Scenario A: Design a network for a small primary school in rural Ghana
 - ii. Scenario B: Design a network for a medium-sized business in Accra
 - b. Ask the teacher for questions on the scenario (if any).
 - c. Plan your chosen network design by considering:
 - i. Network topology
 - ii. Required components
 - iii. Basic security measures
 - iv. Detailed security measures
 - v. Bandwidth allocation plans
 - vi. Scalability considerations
 - d. Create simple network diagrams to illustrate their designs either manually or with the use of software (e.g., student Packet Tracer or draw.io).
4. Present your network design to the class within the allotted time given to you.

You have successfully revised previous learnings on networks. Now, let us look at the designs of network systems and their implementation.

Network system design is the process of carefully planning and setting up a computer network that meets the specific needs of an organisation, like a school, bank or hospital. It includes selecting the right network topology. What are the ways computers and devices are arranged and connected? Such as a star, bus, or ring. It also considers scalability, meaning

the network should be able to grow in the future without major changes. To protect data and systems, security measures like firewalls, strong passwords and antivirus software are added. The design also involves choosing the best transmission media, like fibre optic cables or wireless connections, depending on what suits the environment. Lastly, it involves managing bandwidth properly so that the network runs smoothly, even when many users are online at the same time.

As a learner, imagine your school's ICT lab network design helps decide how computers are linked, whether using cables or Wi-Fi. It also makes sure more devices can be added in the future without starting over. Just like your school has security gates and a security man/woman, the network needs protection like passwords and firewalls to stop hackers and viruses. It also helps control how much internet each user gets, so the network does not slow down when everyone is online.

NETWORK TOPOLOGIES

In Years 1 and 2, we studied different types of network topologies, which describe how computers and devices are arranged and connected in a network. Let us now learn further about it.

Star Topology

Star topology is a type of network topology where all devices, such as computers and printers, are connected to a central device such as such as a hub, switch or router. The central device acts like a controller that manages communication between all the connected devices. It is used in our schools and offices. It has the following features:

1. All devices, such as computers and printers, are connected to a central device.
2. Each device needs its own separate cable to connect to the central device in this topology.
3. It is the most widely used topology in modern Local Area Networks (LANs).
4. In our schools, such as ICT labs and offices, star topology is popular because it is easy to manage and troubleshoot.

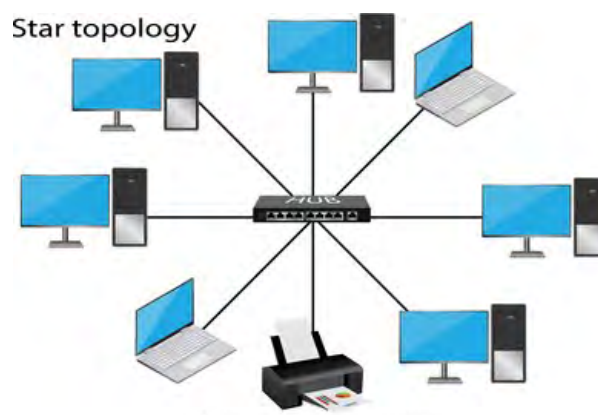


Figure 3. 1 Star Topology

Advantages of Star Topology

The advantages of star topologies include the following:

1. If one device or its cable stops working, the rest of the network is not affected.
2. It is easy to add, remove, or change devices without disturbing the whole network.
3. The central device makes it easier to manage and monitor the entire network.
4. It provides better performance compared to the bus topology because data does not have to travel through every device.
5. It is commonly used in many Ghanaian schools, offices and ICT labs due to its reliability.

Disadvantages of Star Topology

Star topology has disadvantages. Some of these are:

1. It needs more cables than the bus topology. This is due to each device connects separately to the central point.
2. The whole network depends on the central device. If it fails, the entire network goes down.
3. It is more expensive to set up because of the extra cabling and the cost of the central device.

Activity 3.2 Act Like a Star Topology

NB: One of you will act as the central switch, and the rest of you are computers.

Perform the following activities as a class by following the following steps.

1. Hold a string and connect only to the central person.
2. Try to send a “message” (a paper with a word on it) from one computer to another through the switch.
3. Observe, think and answer the following questions individually:
 - a. What happens if the switch sits down (fails)?
 - b. Is it easy to send messages? Justify your response.
 - c. What happens if one computer stops working?
4. Create a poster explaining how star topology works.
5. Draw the star topology based on the activity you did as a poster.
6. Write 2 pros and cons under the topology you just drew.

Bus Topology

Bus topology is a type of network topology where all computers and devices are connected to a single central cable, known as the backbone. The main cable carries data to and from all devices in the network. It has the following characteristics.

1. All devices are connected to one central cable, known as the backbone. This cable carries the data and connects every device in the network.
2. It is simple and cheap to set up, which made it popular in the past. However, it is not commonly used in modern networks because it can be slow and difficult to troubleshoot when something goes wrong.
3. You may still find bus topology in older buildings or computer installations in Ghana, especially in places where the network has not been upgraded yet.

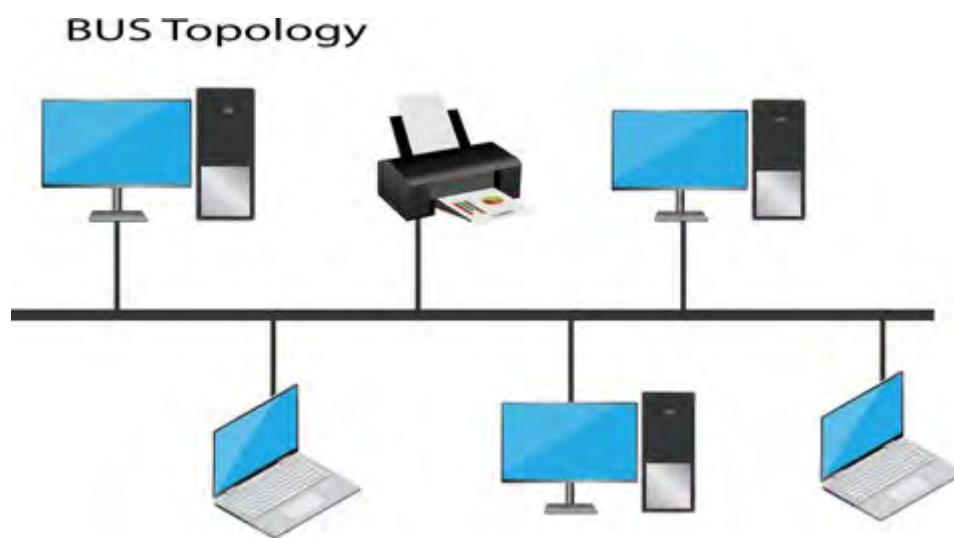


Figure 3. 2 Bus Topology

Advantages of Bus Topology

- i. Easy to set up and extend: Bus topology is simple to install, and if more devices need to be added, they can be connected along the same central cable without much difficulty.
- ii. Requires less cabling than other topologies: Since all devices share one main cable (the backbone), fewer cables are needed compared to star topology, where each device needs a separate cable to a central device.
- iii. Well-suited for small networks: This topology works best in small networks where there are not too many devices, and data traffic is low.
- iv. Cost-effective for linear arrangements: Bus topology is a budget-friendly option, especially in classrooms in Ghanaian schools where computers are often arranged in a straight line, making it easier and cheaper to connect them using one main cable.

Disadvantages of Bus Topology

- i. If the main cable fails, the whole network stops working: Since all devices depend on one central cable (the backbone), any damage to that cable can cause the entire network to go down.
- ii. Performance becomes poor when more devices are added: As more computers or devices are connected, the network becomes slower because they all share the same cable to send and receive data.
- iii. The cable length is limited: Bus topology can only support a certain number of devices over a short distance. This makes it hard to use in large buildings or across school blocks.
- iv. Troubleshooting is difficult: When there is a problem in the network, it can be hard to find out exactly where the fault is, especially if the cable is hidden or runs through walls or ceilings.

Ring Topology

Ring topology is a type of network topology where each device is connected to exactly two other devices, forming a circular path or “ring” for data to travel. In this topology, data moves in one direction, passing through each device until it reaches its destination. Ring this topology has the following as its characteristics:

1. Devices are connected in a circular arrangement: All computers and devices are connected one after the other, forming a closed loop or ring.
2. Each device connects to exactly two other devices: Every device in the ring has two connections. One to the device before it and one to the device after it.
3. Data travels in one direction around the ring: Information moves from one device to the next in a single direction (either clockwise or anticlockwise), passing through each device until it reaches its destination.

Ring topology

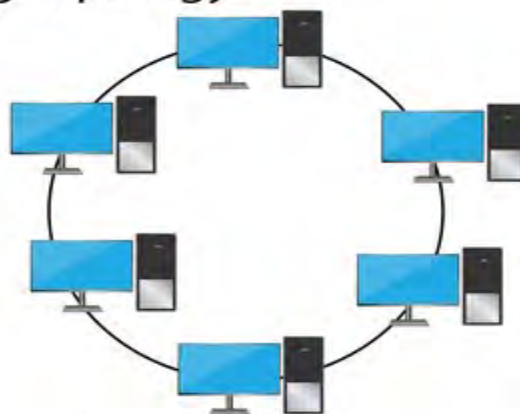


Figure 3. 3 Ring Topology

Advantages of Ring Topology

- i. Equal access for all devices: Every device has the same opportunity to send data, which helps prevent one device from using too much of the network’s resources.

- ii. It performs well under heavy network load: Because data travels in an organised path, ring topology can handle more data traffic without slowing down too much.
- iii. There are no data collisions: This is because data moves in one direction around the ring, hence, there is less chance of two devices sending data at the same time and causing a collision.
- iv. It is suitable for fibre optic networks: Ring topology works well with fibre optic cables, which are often used for fast and reliable data transmission, especially in advanced networks.

Disadvantages of Ring Topology

- i. Failure of one device can affect the entire network: If one computer or connection breaks, it can stop the whole network from working, since the loop is broken.
- ii. Adding or removing devices disrupts the network: You cannot easily plug in or remove a device without temporarily shutting down the network.
- iii. It is more difficult to implement than bus or star topologies: Setting up a ring topology can be more complicated and may require more careful planning and configuration.

Activity 3.3 Act Like a Ring Topology

Perform the following activities as a class by following the steps below.

1. Form a circle.
2. Pass a note in one direction only, from one to another in the circle.
3. Think about whether someone leaves the circle or refuses to pass the note, can it reach the end? Justify your answer.
4. Pass the same note in the opposite direction. Indicate what changed.
5. Use a circular topology diagram on a poster to support understanding of the one-directional data flow.
6. Draw your own ring topology on poster paper showing each device and arrows for data direction.
7. Present your poster and justifications to peers.

Mesh Topology

Mesh topology is a type of network topology where every device is connected directly to several other devices in the network. This creates multiple paths for data to travel, making the network very reliable and secure. It has the following characteristics:

1. Each device connects directly to multiple every other device in the network: This means there are several possible routes for data to take. Devices can still communicate even if one connection fails.

2. It provides redundancy and fault tolerance: If one path or cable is damaged, the data can still reach its destination through another path. This makes the network more reliable and less likely to fail.
3. It is used in critical networks like banking systems in Ghana: Mesh topology is typically used in places where network failure is not an option, such as in banks, government agencies or military networks, where secure and constant communication is very important.

Mesh topology

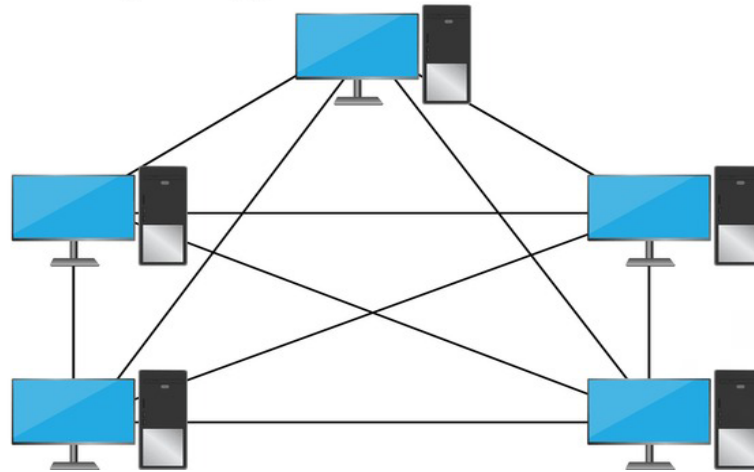


Figure 3. 4 Mesh Topology

Advantages of Mesh Topology

1. High redundancy and fault tolerance: If one cable or device fails, the data can still find another route, so the network keeps working without interruption.
2. No single point of failure: Unlike star or bus topologies, the failure of one device does not bring down the whole network.
3. Highly secure and private: Because data can travel on many different paths. It is harder for hackers to intercept, making mesh networks more secure.
4. Good for critical applications: Mesh topology is ideal for important systems like banking networks in Ghana, where constant, secure communication is essential.

Disadvantages of Mesh Topology

1. Very expensive to implement: Connecting every device to many others requires lots of cables and network equipment, which increases the cost.
2. Complex to set up and manage: Building and maintaining a mesh network is difficult and usually requires advanced technical skills.
3. Requires significant cabling: Since each device needs to connect to several others, the amount of cabling can be overwhelming, especially in large networks.
4. Difficult to scale: As you add more devices, the number of connections grows quickly, making it hard to expand without running into problems.

Activity 3.4 Build a Mesh Network

Imagine you are designing a network for your school. Security is everything. You are tasked to build a network that still works even if a cable fails.

Demonstrate this network setup by going through the following steps:

1. Connect to at least two other peers with string or rope.
2. Send a message to your peer, but if one person drops out, you must find another person to connect to.
3. Indicate if you can still send the message?
4. Indicate what makes this network strong based on your observation?
5. Show a pre-made mesh topology poster showing redundancy and multiple paths.
6. Create posters mapping critical networks in Ghana (banks, hospitals) that could use mesh and explain why.
7. Present your findings to your peers.

SCALABILITY CONSIDERATIONS

Scalability means designing your network in a way that it can grow or expand without breaking or becoming slow. Think of it like building a house. You might build a small house today, but if you plan well, you can add more rooms later without pulling the whole building down. In the same way, a computer network in a school or an organisation should be designed to handle more users, more devices and more internet traffic in the future, even if it starts small now.

1. Hardware Scalability

This part is about making sure the physical equipment of the network like cables, switches, routers, and Wi-Fi devices can be expanded later when needed.

a. Modular Equipment

Some network devices are modular, which means they are built like a puzzle. You can add new parts (like more ports or functionalities) as the network grows. A modular switch can allow you to add 8 more ports next year without replacing the whole device.

b. Planning for Future Capacity

When setting up a network of an organisation or institution today, do not just plan for the 60 users using Wi-Fi now. Think ahead! If your school might have 5000 learners in the next 2 years, install a wireless access point that can handle that future number even if it seems too much for now.

c. Hierarchical Design

This is a clever way of structuring a network, so it is easy to grow and manage. The network is divided into three layers:

- i. **Access Layer:** This is where the actual devices such as computers, phones, and tablets connect to the network. An instance is where the computers in the ICT lab of your school are connected to the network.
- ii. **Distribution Layer:** This connects different access layers and applies rules, such as who gets access to what. An instance is connecting the ICT lab and the administration office together.
- iii. **Core Layer:** This is the fast, central part of the network that links everything together. This is also a strong network connection that joins all school departments. With this design, if one part of the school (like the library) wants to upgrade (expand) its network, it can do so without affecting the entire network of the school.

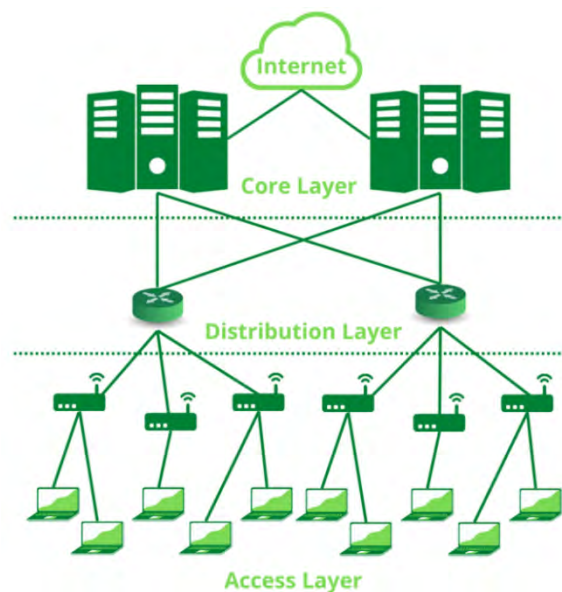


Figure 3. 5 Hierarchical Design

2. Address Planning

Every device on a network needs a unique IP address to communicate, just like every house in your community has a unique house number.

a. IP Addressing Schemes

When setting up a school network, it is important to plan how you assign IP addresses. If you give them out randomly, you might quickly run out of addresses as more devices are added. Think of it like this: if desks in your classroom were numbered randomly, it would be hard to find who sits where. However, a good numbering system will help you stay organised.

b. Subnetting

This means dividing a large network into smaller parts called subnets to make it easier to manage. Imagine this: Your school has many departments. Instead of using one general address for everyone, you assign separate address groups for the ICT lab, the library, and the administration office. This keeps things neat and prevents confusion.

c. **Planning for IPv6 Transition**

Right now, most devices use IPv4 addresses, but these are becoming limited. IPv6 is the newer system that can give addresses to billions more devices. In simple terms: IPv6 is like moving from a small exercise book to a large notebook – you now have more space to write! Even if you are still using IPv4, it is smart to buy devices (routers and switches) that can also support IPv6.

3. Performance Scalability

As your school or organisation grows, more people and devices will use the network. Without good planning, it can become slow and frustrating. Performance scalability ensures your network stays fast, even when busy.

a. **Handling Increased Traffic**

As more people use the internet or send files, the network handles more traffic (data). You need switches and routers that can process this data quickly. Think of it like a busy road. You need a strong traffic system (switches/routers) to keep things moving.

b. **Bandwidth Upgrades**

Bandwidth is the amount of data that can move through the network at a time. Imagine bandwidth as a road: A wider road (more bandwidth) lets more cars (data) move freely. As your school grows, you will need to contact your internet provider (like MTN or Telecel or AT) to upgrade your bandwidth for faster access.

c. **Quality of Service (QoS)**

Sometimes, certain activities are more important than others. QoS helps the network decide what to prioritise. For instance, during an online class, video calls should be given more importance than a student downloading a large movie file. QoS makes sure important activities work smoothly, even when the network is busy.

Activity 3.5 A Poster of Scalable School Network

1. Use paper or digital tools to sketch:
 - a. Core, distribution and access layers.
 - b. Devices (e.g., router, switch, access points).
 - c. Label with future expansion options.
2. Share your poster with peers.

SECURITY MEASURES

Network security is very important to protect your computer, school network and personal information from people who want to steal, destroy or misuse it. Just like how you lock your phone or home to stop strangers from getting in, you must also lock your digital systems. One of the easiest and most effective ways to do this is by using strong passwords.

Password Security

Passwords are like the keys to your computer or online accounts. Without strong passwords, it is easy for someone (a hacker) to break into your email, school network, or social media accounts.

1. **Strong Password Policies:** A good password protects your online accounts just like a strong lock protects your door. It should be long and contain letters (capital and small), numbers, and symbols. For a password to be strong enough, it should be at least 12 characters long, include mixture of uppercase letters (e.g., A, B, C), lowercase letters (e.g., a, b, c), numbers (e.g., 0, 7, 9) and symbols such as #, \$, %, @. It is advisable not to use your name (e.g., Daniel123) or date of birth (e.g. 15July2025) that are easy to guess. Rather use something complex and personal like Ms@2025D!mTech.
2. **Regular Password Changes.** It is also smart to change your password every few months just like how you sometimes change the padlock to your dormitory or bicycle for safety. If someone has guessed or stolen your password, changing it blocks their access. Changing of passwords helps you stay in control of your accounts. Always remember to set a reminder to update your passwords at the beginning of each new school term or semester.
3. **Multi-Factor Authentication (MFA):** MFA adds an extra layer of protection to your accounts. It means that even if someone knows your password, they still cannot log in without a second piece of information. With MFA, anytime you enter your password, a code is sent to your phone through SMS or email. You then have to enter the code to complete the login section. This is good because hackers do not have access to your phone. Apps and services that support MFA are Gmail, Facebook, Instagram, school portals or learning management systems.

Internet Safety

The internet is a powerful tool for learning, communication and shopping, but it also comes with risks. Internet safety means using the internet wisely to avoid being tricked, hacked, or scammed. You need to be careful when you are online just like you stay alert in a busy marketplace.

1. Safe Browsing Practices

When using the internet, be careful about the websites you visit. Not all sites are safe. Usually, look out for websites that begin with “https://” instead of just “http://”. The “s” means secure. It shows that the website encrypts your data.

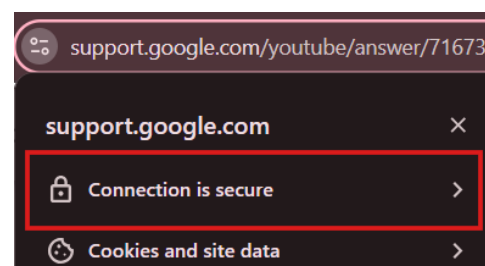


Figure 3. 6 Site Protection Indicator

Also, a padlock symbol as shown in the address bar means your connection to the site is protected. As shown in figure 3.6

Run away from websites that are too promising with freebies and websites you do not know or that look suspicious (e.g., strange colours, too many flashing ads, spelling errors).

2. Recognising Phishing Attempts

Phishing is when cybercriminals try to trick you into giving your personal information, such as passwords, bank details or exam logins. In instance, they send you emails or messages that look like they come from real companies such as MTN, AT, Telecel, your bank, school or WAEC. The message may sound urgent. For example, “Your account will be blocked! Click here to fix it.” We are setting up your MTN mobile money account, type your MTN MoMo pin to let help you out or follow our instruction keenly. Be smart and run away from them.

3. Secure Online Transactions

Use websites that are secure, use your own internet connection (like mobile data) when entering your bank or mobile money details or buying airtime, paying school fees, or buying something on an online shop like Jumia. Make sure you are using a trusted website and ask someone if you are not sure. Using public Wi-Fi in places like cafés, lorry parks or school labs when making mobile money transfers or online payments or entering personal or payment details on unknown websites should be avoided.

Malware Protection

Malware stands for malicious software. It is software created by cybercriminals to damage, steal, or take control of your computer or phone without your permission. Think of malware like a virus that spreads in a school, it makes people sick. But in this case, malware makes your computer sick. These malwares include viruses, worms, ransomware and spyware. These malwares can attach themselves to files and spread to other computers, spread automatically through a network, locks your files and asks you to pay money to unlock them and secretly watches what you do and sends it to hackers respectively. To curb malware attacks,

1. Use Antivirus and Anti-malware Software

Antivirus software acts like a security guard for your computer. This scans your computer for malware, removes any harmful files or programs and protects your device in real time against threats. What you to do is to regularly keep it updated.

2. Regularly Update Your System

Malware often takes advantage of weaknesses (called “vulnerabilities”) in the operating system or apps of your computer. Updating your computer system regularly fixes the bugs and seal loopholes and makes your device harder to attack. Skipping the updates makes it easier for viruses to take over your device.

3. Practise User Education

The best way to protect your computer is by being smart and careful online. You are to download software only from trusted sources, ask a teachers or ICT coordinator if you are not sure about a link or file and be careful when inserting pen drives in your computer. You are not to open email attachments from unknown sources, click on strange links or WhatsApp messages, and download cracked games or software from random websites. These are information you should have in your mind as you connect to the computer network.

Data Backup Strategies

It means making a copy of your important files such as assignments, notes, photos, and projects so that even if the original is lost or damaged, you can still get it back. Think of writing a long essay on your computer and then the laptop crashes or gets stolen and everything is gone! How will you take it? I guess will not be happy. That is why it is important to back up your data.

To keep your files safe, practice these backup strategies:

1. Regular Backup Schedules

Backing up your files regularly means saving copies often just like you revise your notes daily, weekly or periodically to avoid last-minute cramming depending on how often it changes. You can set up your device such as phones, laptop or digital device to automatic backups so that you do not forget.

2. On-site and Off-site Backup Solutions

It is a good idea to save your backups in more than one place, just like how banks do not keep all their money in one safe. You can use on-site backup or offsite backup. On-site back means storing the backup in the same place as your main computer such as your USB drive, external hard drive or another computer in your home or school while off-site backup means storing the backup in a different physical location usually online (cloud storage). You can use Google Drive, OneDrive or Dropbox to store your files as off-site backup locations.

3. Testing Backup Restoration

You should not just back up. You must also make sure the backup works. Sometimes backups become corrupted or incomplete, and you will not know until it is too late. That is why you need to test your backup by restoring a few files once in a while. You should try opening a backed-up assignment, download a photo from your cloud storage and check if it works well.

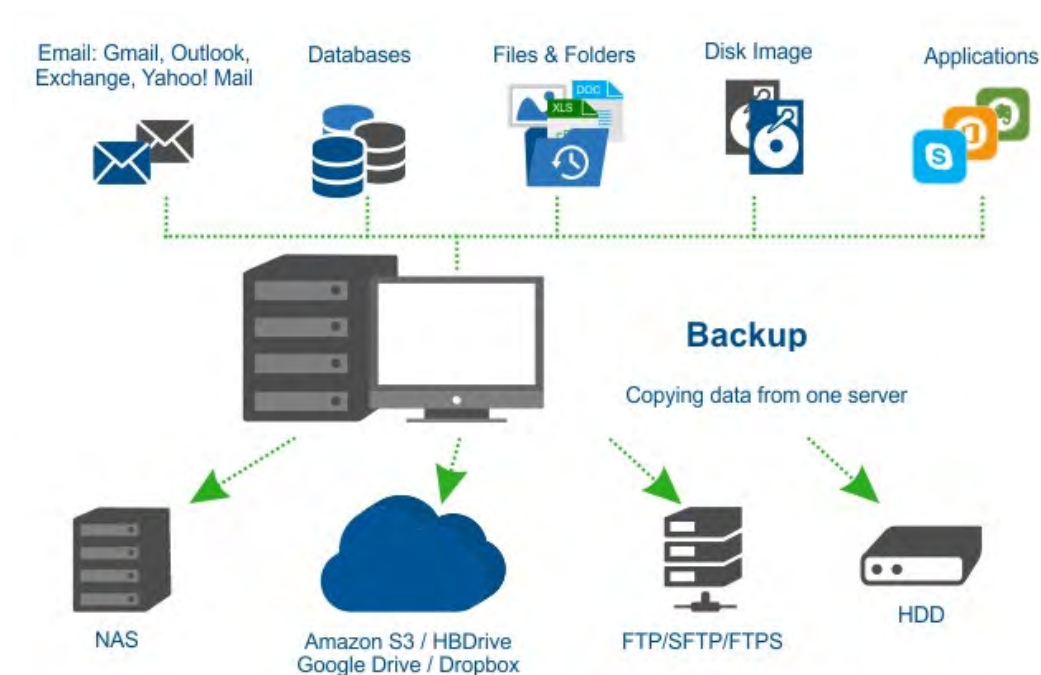


Figure 3. 7 Backup Solutions

Activity 3.6 Backup a File to Cloud Service

Perform the following:

1. Log into Google Drive or OneDrive.
2. Upload a file (e.g., project work or notes).
3. Share the file with your teacher or peers.

DEVICE SECURITY

Your device like a smartphone, tablet or laptop is like your personal locker. It contains your school projects, pictures, messages, apps and important files. If someone steals it or hacks into it, they could misuse your information. That is why device security is very important. This protects your physical device and the digital data inside it.

1. Physical Security Measures

Physical security means keeping your device safe from theft, loss, or damage. To stay safe, always lock your laptop or desktop in a safe place, especially in school ICT labs, do not leave phones or tablets unattended in classrooms or public places like internet cafés or trotro stations, use a laptop lock or cable lock in public places (e.g., computer labs, libraries) and mark your devices with your name or school ID to identify them if lost.

2. Device Encryption

Encryption is like putting your data in a secret code that only you can read. Even if someone steals your phone or computer, they cannot access the files without your password. The modern phones such as Android and iPhones already come with encryption turned on. Laptops can also be encrypted using tools like: BitLocker (for Windows) and FileVault (for macOS).

3. Mobile Device Management (MDM)

In schools or businesses where many people use phones, tablets or laptops connected to the same network, MDM software helps to manage and protect all those devices. If Wa Senior High gives tablets to all students, the school can install MDM to lock the devices to school use only, stop learners from installing games, and find the device if it goes missing. They MDM are used to set rules for all school-owned devices (e.g., block harmful websites), track devices if they get lost or stolen, wipe data remotely to protect sensitive information and install or update apps on all devices from one central place.

4. Transmission Media

Whenever you send a message, browse the internet or watch a video online, data is travelling from one point (sender) to another (receiver). The path that this data takes is called transmission media. Transmission media is like a road that connects two towns. The town here represents networked devices. Transmission media can be either wired (using cables) or wireless (using air signals). Let us begin with wired media.

5. Wired Media

This involves real, physical cables that connect devices to one another. You may have seen some of these cables in the computer lab of your school or on your home TV setup.

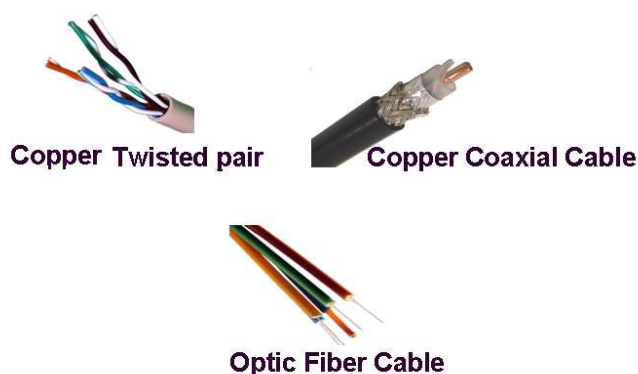


Figure 3. 8 Wired Transmission Media

6. Twisted Pair Cables (UTP and STP)

These are the most common types of cables used in Local Area Networks (LANs) like the one in your school. Inside the cable, wires are twisted in pairs to reduce noise and improve signal quality. There are two types of these cables:

- a. UTP (Unshielded Twisted Pair): These cables are **cheap** and easy to install, commonly used in homes, offices, and schools in Ghana, usually found in telephone lines and LAN cables and needs no special protection from electrical interference.
- b. STP (Shielded Twisted Pair): These cables have metal shield around the wires to protect them from interference and used in factories or places with heavy electrical equipment that might affect signal quality.

7. Coaxial Cables

This type of cable has a single copper wire in the centre, with layers of insulation and metal around it. It was used for older computer networks and still used for TV services like MultiTV, DStv or GOTv in our homes. They are also strong and durable. Note that if you have helped connect a satellite dish or seen a TV technician working during satellite installation, you have likely seen a coaxial cable.

8. Fibre Optic Cables

This is the fastest and most advanced type of wired media. It transmits data as pulses of light through very thin glass or plastic fibres. It offers very high speed and bandwidth (can carry lots of data quickly). It is not affected by electrical interference. They are usually used to connect cities, countries, and even continents. Sample of the fibre optic cable is the undersea cables that carry the internet to Ghana. MTN Ghana uses fibre optic cables as transmission media.

9. Wireless Media

Wireless media allows data to travel through the air using electromagnetic waves, instead of wires. This means devices can connect to the internet or to each other without physical cables.

Think about sending your assignment to the teacher from your phone using Wi-Fi or Bluetooth. There is no cable between your phone and the router or the teacher's phone, yet the message still goes through. That depicts wireless communication in action.

Let us look at the three main types of wireless media you will likely encounter in Ghana:

a. Wi-Fi

Wi-Fi is the technology that allows phones, laptops, and tablets to connect to the internet wirelessly (without cables or wires). It uses radio waves to send and receive data. The term 802.11 refers to the international standards that define how Wi-Fi works. There are different versions such as 802.11n – good range and speed (used in many homes), 802.11ac – faster and better for streaming and 802.11ax (Wi-Fi 6) – even faster and more efficient with many devices connected (used in modern schools and offices).

b. Bluetooth

Bluetooth is used to connect devices over short distances, usually up to 10 metres. It is useful for pairing phones with wireless speakers or headphones, sending files between devices (e.g., phone-to-phone file sharing) or connecting a wireless mouse or keyboard to your computer. If you share a song with a classmate using

Bluetooth or connect your phone to a portable speaker to play music, you have used wireless media.

c. **Cellular Networks (3G, 4G, 5G)**

Cellular technology connects mobile phones to the internet using mobile towers. It is what your MTN, Telecel or AT sim card uses to give you internet access even when you are moving. Let us break down the ‘G’ generations:

- i. 3G (Third Generation): First allowed mobile internet (slow browsing and downloads).
- ii. 4G (LTE) (Fourth Generation): Much faster, good for YouTube streaming, Zoom classes and WhatsApp calls and widely used across Ghana.
- iii. 5G (Fifth Generation): Newest, fastest and growing network in Ghana. It is lower delay (latency), supports more devices and useful for smart cities and real-time applications.



Figure 3. 9 Wireless Transmission Media

Activity 3.7 Internet Connection Methods in Ghana

1. Listen and make note as the teacher explains the following:
 - a. Mobile broadband (MTN, Telecel, AT).
 - b. Fixed broadband (fibre optic from providers like Surflin, Busy Internet)
 - c. DSL connections.
2. Share the advantages and limitations of each method with your teacher and peers.

INTERNET CONNECTIVITY AND NETWORK CONFIGURATION

Activity 3.8 Identification of Network Devices

1. Observe as your teacher displays real devices or pictures/videos of hub, switch, router and modem.
2. Complete this table on your worksheet or in notebook as you observe.

Device	Appearance (Sketch or Description)	Function	Example of use in Ghana
Hub			
Switch			
Router			
Modem			

3. Share your response with the teacher and peers.

It is good to know that internet connectivity simply means your devices (such as phone, computer or tablet) can connect to the internet to access resources like websites, emails, videos and online services. Just like you did in some activities and questions that were given to you throughout year one and now, year three.

In Ghana and around the world, internet access has become essential for education (e.g., online research, virtual classes), business (e.g., sending emails, marketing on social media), healthcare (e.g., online consultations) and daily communication (e.g., WhatsApp, Zoom, Telegram). Having a stable and fast connection means information move quickly between your device and the internet.

Activity 3.9 IP addressing

1. Listen and make notes as the teacher explains how to:
 - a. Check an IP address of a device.
 - b. Configure static and dynamic IP address.
 - c. Set up DNS servers.

- d. Observe and take note on how the teacher:
 - i. Check an IP address of a device.
 - ii. Configure static and dynamic IP address.
 - iii. Set up DNS servers
 - e. Follow along with the teacher and practice the demonstration on available devices.
2. Share your findings with peers and teacher.

NETWORK ADDRESSING

For you to send a letter from Dorma to Aflao, all in Ghana but different regions, you need to write the recipient's address so that Ghana Post can deliver it to the correct house. Without that address, the letter gets lost. The computer network works the same way. Each device on a network needs a unique address, called an IP Address. This made it possible for data to be delivered to the right device.

1. IP Addressing

An IP (Internet Protocol) address is a unique number that identifies each device on a network. Your phone, your laptop, a school printer, or even your smart TV need their own IP address to find each other, send and receive data and access the internet.

a. IPv4 vs. IPv6

- i. IPv4 (Internet Protocol version 4) is the older and still most common type of IP address. It looks like four numbers separated by dots, like 192.168.1.1. Additionally, there are about 4 billion possible IPv4 addresses. Some years ago, that sounded like more than enough. But today, with billions of phones, laptops, TVs, printers and smart gadgets all connecting to the internet. We are running out of IPv4 addresses. This is where IPv6 comes in.

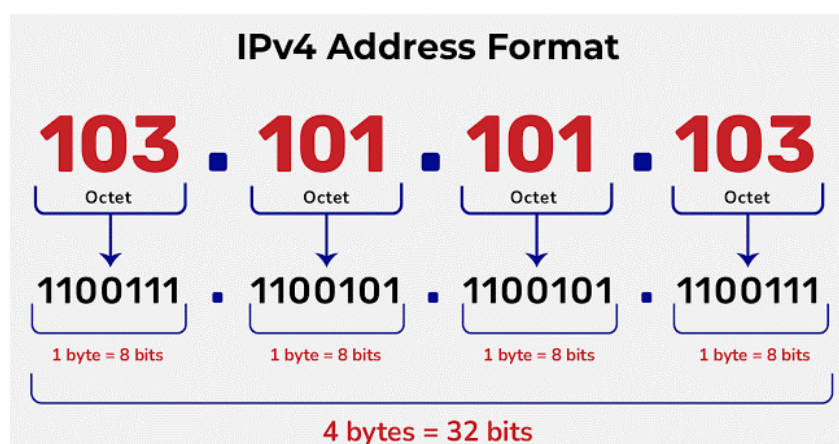


Figure 3.10 IPv4 Address Format

- ii. IPv6 (Internet Protocol version 6) was introduced to primarily to solve the problem of running out of addresses. IPv6 addresses are much longer and more complex, like 2001:0db8:85a3:0000:0000:8a2e:0370:7334. It allows for trillions upon trillions of unique addresses. This is enough for every device in the world and beyond.

IPv6 address

2001 : 0DC8 : E004 : 0001 : 0000 : 0000 : 0000 : F00A

16 bits : 16 bits : 16 bits : 16 bits : 16 bits : 16 bits : 16 bits : 16 bits

128 Bits

Figure 3.11 IPv6 Address

Think of IPv4 like the old Ghana Post address system in towns and IPv6 like giving every single tree in Ghana its own postal code. That is how much more space IPv6 gives.

IPv4 is already built into many systems, hence it is still widely used. However, the world is slowly moving to IPv6 because of its benefits.

2. Assigning IP Addresses

How Does a Device Get an IP Address? Primarily, there are two ways to assign IP addresses. They can be done:

- a. **Statically:** The IP address is manually set by a network administrator. It does not change. It is like having your own reserved desk with your name on it. It is used for important devices such servers, printers, CCTV systems. This makes them to be found easily on the internet.
- b. **Dynamically:** IP address is automatically assigned by a DHCP server (Dynamic Host Configuration Protocol) to connected devices on the network. It is like a car park attendant who directs your car to an available spot. This is fast and flexible and changes depending on who joins the network. Widely, it is used for everyday devices such as your phone when it connects to school Wi-Fi, learner's laptops or tablets, guests' devices.

Activity 3.10 Access Configuration Page of a Router

1. Form a group of 3 to 5 members. In your group:
 - a. Observe and take note on how the teacher:

- i. accesses the configuration page of a router using a web browser with given IP address: 192.168.2.1.
 - ii. sets a router password.
 - iii. rename a router.
 - iv. configure Wi-Fi settings (SSID, password, security type).
 - v. set up DHCP for automatic IP assignment.
 - b. Follow along with the teacher and practice accessing router settings on available devices.
2. Share your configuration with peers and the teacher in the class.

DNS (DOMAIN NAME SYSTEM)

Imagine trying to call your friends, but instead of using their names, you had to remember their phone numbers. Is that easy? That is how the internet would feel without DNS. Humans remember names better than numbers, but computers understand numbers better than names. That is where DNS (Domain Name System) comes in.

DNS works like a digital phonebook for the internet. When you type a web address like <https://curriculumresources.edu.gh/>, into your browser, your computer does not know where that is. It then needs to ask a DNS server. The DNS server will respond with 192.168.105.6 as an IP address after checking its records. With this reply, your computer can now connect and open the website.

In Ghana, most people use DNS servers provided by their Internet Service Providers (ISPs) such as MTN, Telecel and AT. However, there are also global DNS providers you can use. They are Google DNS – 8.8.8.8, Cloudflare DNS – 1.1.1.1, etc. These global servers are sometimes faster, more secure, or more reliable.

1. Network Security Measures

Network security means protecting your network and the data on it from people who are not allowed to access it. Think of it like protecting your school, locking the gates (like passwords), having a security guard (like a firewall), using codes and rules to control who enters and who should not. Just like a school needs security to stay safe, a computer network needs protection to stop hackers, viruses, and unwanted visitors from causing harm to it.

2. Firewall

A firewall is like a security guard that stands at the entrance to your network monitoring all the data traffic coming in and going out. It checks all the data that tries to come in or go out and decides whether it is safe. It protects network of your school, businesses, and homes with internet access. Firewalls can be either:

- a. **Hardware Firewall:** These are physical devices placed between your network and the internet. They are commonly found in networks of computer labs or banks in Ghana.
- b. **Software Firewall:** This is a program installed on your computer or phone to filter incoming or outgoing messages to or from your network. Windows Defender Firewall on your PCs is a typical example of software firewall.

These firewalls are used to block hackers and malware, allow safe websites and app, protect your personal and school data based on set rules and access levels of users.



Figure 3. 10 Windows Firewall

3. Encryption

Encryption is like writing a message in a secret code that only someone with the right key can understand. If you write a letter in code and give the key to your best friends, only they can read it, even if someone else intercepts it. In computing, encryption protects your data as it moves across a network or is stored on your device. We use encryption every day in:

- a. **WPA2/WPA3 for Wi-Fi:** When you connect your phone or laptop to a Wi-Fi network and enter a password, you are using encryption. WPA2 and WPA3 are security methods that encrypt the data moving between your device and the Wi-Fi router. This means that even if someone nearby tries to spy on your internet connection, they cannot read what you are doing. In your school, Wi-Fi networks that require a password are protected by WPA2 or WPA3 hence, your online learning activities remain private.
- b. **SSL/TLS for Websites (HTTPS):** Have you seen the padlock icon in your web browser or noticed websites that begin with: `https://`? The “S” in HTTPS stands for Secure. SSL (Secure Sockets Layer) and TLS (Transport Layer Security) are types of encryptions used by websites to protect your information. This is especially important when shopping online, doing online banking, entering passwords or personal details. When you open `www.mtn.com.gh` and see “`https://`” in the address bar, your connection is encrypted and safe from hackers.

- c. **VPN (Virtual Private Network):** A VPN creates a secure tunnel for your internet traffic. It is useful when you are connecting to a school or company network from far away, you are using public Wi-Fi (e.g., in a café, airport, or market), you want to hide your location and browsing activity. A VPN can be used to encrypt your data, so no one else can read it, or hides your IP address for privacy's sake. A teacher working from Tamale can use a VPN to safely access school files stored on a Kumasi-based server.

4. Authentication

Authentication is the process of proving your identity before a system lets you in. Think of it like entering a school exam room, you show your student ID card or course registration slip to prove you are the right student. Without it, you cannot write the exam. In computing, authentication is how devices, apps and websites confirm that you are the real user before giving you access (login). Common ways to authenticate are:

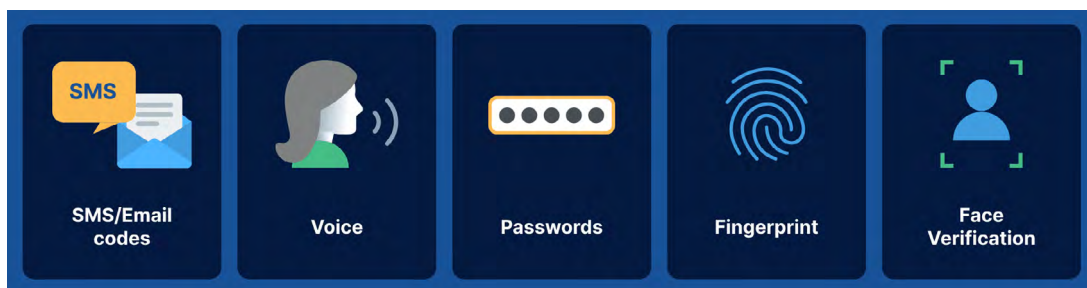


Figure 3.11 Common ways to authenticate

- a. **Username/Password Systems:** This is the most common method. Whenever you want to log into secure systems, you are made to enter your username for your identity and your password as your secret key. Once these match with existing details in the database, you are given the access. A typical example is when you are logging into WAEC Transcript Portal, you type your username and password to have access once your details match with the details in the transcript system. Note that when someone steals your correct username and password, they can access your account unless you add extra protection. This is where two-factor authentication comes to play.

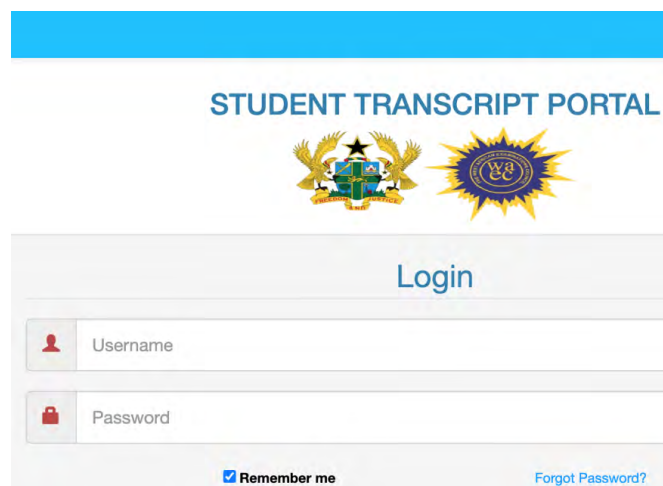


Figure 3.12 WAEC Student Transcript Portal Authentical page

- b. **Two-Factor Authentication (2FA):** 2FA adds an extra layer of security. After typing your password, you must also enter a code sent to your phone by SMS or use a code from an authenticator app (like Google Authenticator). For instance, if you log in to your Gmail account, or social media sites, you enter your password. Then a code is sent to your phone or app. It is only after going through both steps successfully without error, you will gain access. Note that even if someone steals your password, they still cannot log in without your phone or authenticator app. It is therefore advisable to use the app method instead of SMS. It is more secure and less likely to be hijacked.
- c. **Biometric Authentication:** This method uses your body features that are unique to you. An examples is using fingerprint scan to unlock your smartphone, face recognition (like Face ID on iPhones or some Infinix/TECNO phones) or iris scanner (used in some government security systems). Some banks in Ghana also use fingerprint authentication when you are verifying your identity for mobile banking or withdrawing money from ATM.

With biometrics, you cannot forget them like passwords, they are very hard for hackers to copy and make logging in faster and more secure.

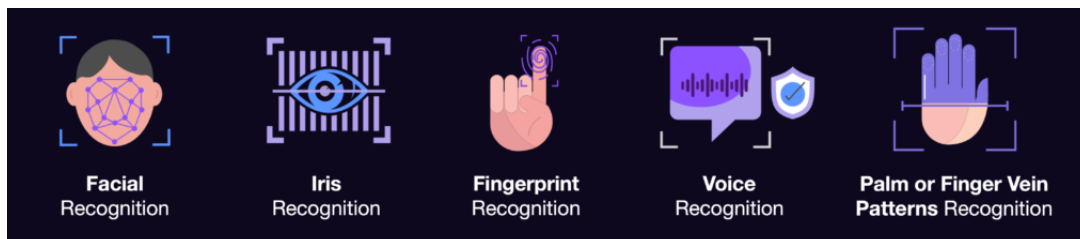


Figure 3. 13 Biometric Authentications

Activity 3.11 Password Strength Test

Individually,

1. Create 2 sample passwords: one weak (e.g., “Daniel123”), one strong (e.g., “D@n13L!2025”).
2. Test the strength of the two passwords [here](#) or <https://www.security.org/how-secure-is-my-password/>.
3. Write guidelines for creating strong passwords.
4. Share your response with peers in class.

Activity 3.12 Design and Pitch a Smart School Network

Your school is upgrading its facilities into a “Smart School” where learners, teachers, administrators and smart devices need constant, secure and fast network access. The head of the ICT department has asked your class to form network consultancy teams and submit a proposal to design, implement and maintain a computer network for the new smart school.

NB. The best proposal will be awarded contract for smart school implementation.

Form a group of 3 to 5 members and perform the following:

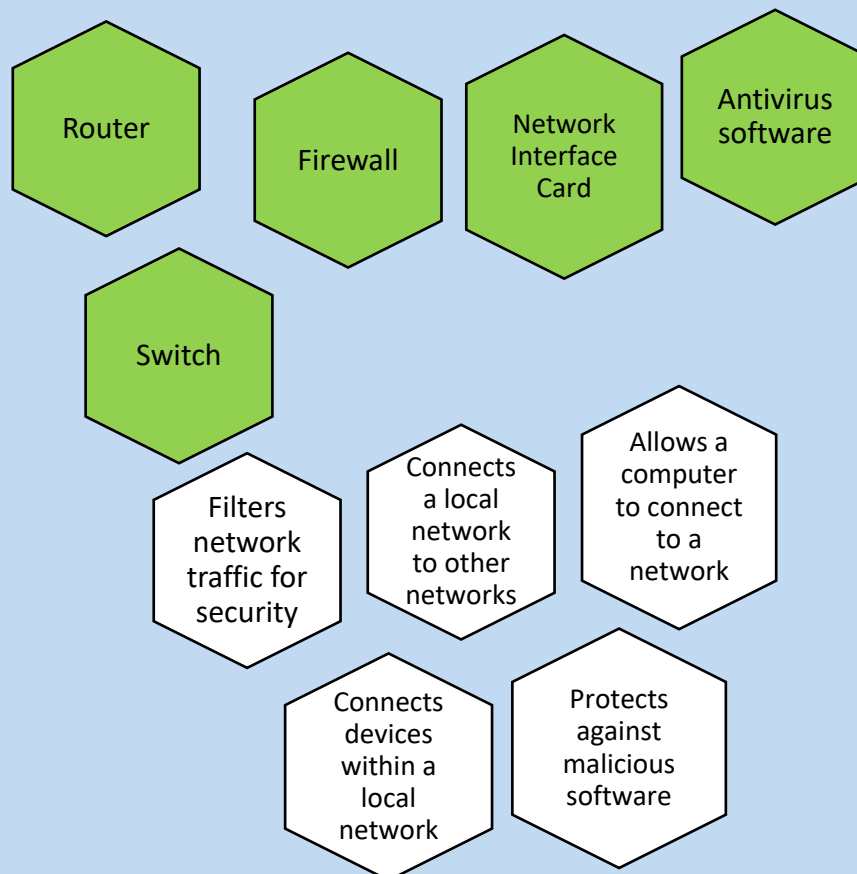
1. Conduct network needs analysis.
2. Indicate the users of the network and the required devices, connections and bandwidth.
3. Choose a suitable network types and topology.
4. Justify your choices of LAN for specific areas such as labs and CAN for whole school.
5. Justify your choice of the topology used for specific areas such admin, critical systems.
6. Design a network diagram manually or with the Cisco Packet Tracer or draw.io.
7. In your design, show wired and wireless segments.
8. Include network devices in your proposed design.
9. Indicate and justify which part of the school need wireless or wired.
10. Suggest cloud for storage or backups. Discuss its benefits over local servers.
11. Briefly explain how OSI layers apply to data transfer in your network.
12. Suggest a primary ISP and backup for the network
13. Compare wireless (e.g. 4G) and wired (e.g. fibre optic) for the school.
14. Outline steps to configure switches, assign IPs, set up Wi-Fi SSID, passwords.
15. Present your design to the class as a pitch.
16. Submit a short proposal document (4 pages max) with diagrams and justifications.

EXTENDED READING

- Click [here](#) or <https://www.chingfordfoundation.org/National-Online-Safety-Information-Posters/> national online safety information posters for educators, parents and children.
- Click [here](#) or <https://www.cisco.com/en/US/docs/routers/access/800/850/software/configuration/guide/routconf.pdf> to download a book on basic configuration of a router.
- For more information on IP addresses, click [here](#) or <https://www.cisco.com/c/en/us/tech/ip/ip-addressing-services/index.html>.
- Read more on network topology by clicking here or <https://www.geeksforgeeks.org/computer-networks/network-topology/>

REVIEW QUESTIONS

1. Match each network component (in green colours) with its correct function.



2. How does a switch differ from a hub in a network?
3. Identify two places in Ghana where you are likely to find a router being used and explain its function.
4. In your own words, describe a real-life situation where a router is more useful than a switch.
5. Why is dynamic IP addressing preferred for student Wi-Fi in a school?
6. Explain what happens when you type a website name into your browser.
7. Islamic SHS in Wa has internet access, but the network is slow, and students complain about delays. Which network device should the school upgrade and why?
8. A student receives an email asking for their Wi-Fi password. What type of attack is this, and how should they respond?
9. St. Paul's SHS in Hatsukope is planning to install internet in all classrooms. Which transmission medium should they choose and why?
10. Compare and contrast mobile broadband (e.g., MTN 4G) and fixed broadband (e.g., Telecel fibre) in terms of reliability, speed, cost, and availability in different parts of Ghana. Which would you recommend for a rural SHS and why?

A close-up, high-magnification photograph of a hard drive's internal components. The image shows a polished, reflective metal platter with several circular read/write heads mounted on a central spindle. The lighting is dramatic, with strong highlights and deep shadows, emphasizing the metallic textures and the precision engineering of the device. The background is dark, making the metallic parts stand out.

SECTION

4

MASS STORAGE MEDIA AND ARTIFICIAL INTELLIGENCE

COMPUTATIONAL THINKING (PROGRAMMING LOGIC)

ALGORITHM AND DATA STRUCTURE

INTRODUCTION

In years one and two, you explored the various types of storage devices and their features and were introduced to Machine Learning concepts and ethical considerations so far as machine learning is concerned. In this learning, you will explore how computational thinking, data storage and artificial intelligence (AI) are connected. You will also further examine different types of mass storage technologies such as hard drives, SSDs and cloud storage, looking at their features, uses and how well they perform. You will also compare traditional systems with intelligent systems to help you build a basic understanding of how AI works and where it is used. Through practical activities, real-life case studies and group problem-solving tasks, you will learn how to choose the most suitable storage option for different situations. Additionally, this learning also introduces how AI is changing the way we manage and process data both in Ghana and across the world. Finally, understanding how these concepts will empower you to develop and deploy innovative solutions that drive efficiency, performance and innovation across various industries in the future.

KEY IDEAS

- **Artificial Intelligence (AI):** Machines that can mimic human intelligence, such as learning, reasoning and decision-making.
- **Conventional systems:** A system that follows fixed rules and cannot learn.
- **Hybrid systems:** Systems that combine traditional computing with AI to improve reliability and adaptability.
- **Intelligent systems** are systems that learn through experience.
- **Mass storage:** Devices that can store large amounts of data for long-term use.

MASS STORAGE MEDIA

Let us recap on what we have learnt about storage devices in our previous learning by performing the activity below.

Activity 4.1 Revision on Storage devices

1. Pair with a colleague and answer the following questions. Note your answers in your jotters.
 - a. What are some of the storage devices you have used before?
 - b. How did you save data on any of the storage devices you have used?
 - c. What went well or wrong? Justify why that happens.
2. Share your responses with peers or a teacher.

Mass storage media are devices used to store large amounts of data permanently even when the power is switched off. Unlike main memory (RAM), which is temporary and loses data when the computer is shut down, mass storage provides long-term, non-volatile storage for things like the operating system, software applications and user files such as documents, videos and pictures.

Classification of Mass Storage Media

Mass storage media can be grouped into three main categories based on how they store and access data. These include:

1. Magnetic Storage Media

These use magnetised materials to store data. Data is saved by changing the direction of tiny magnetic particles. It is widely used in older or large-capacity systems.

Some examples are:

- a. **Hard Disk Drive (HDD):** It is commonly in some traditional desktop computers and laptops. It has metallic platters that spin quickly while a tiny magnetic head reads and writes data. It has large storage capacity, low cost per GB and slower than newer technologies. Also, it can be damaged by shock or movement.
- b. **Magnetic Tape:** It looks like cassette tape used in our homes and is used for long-term storage and backups especially in organisations. It stores data in sequence which means it takes longer to find specific files. It is very good for archiving data and affordable for huge amounts of data. However, it has slow access speed and not suitable for daily use.

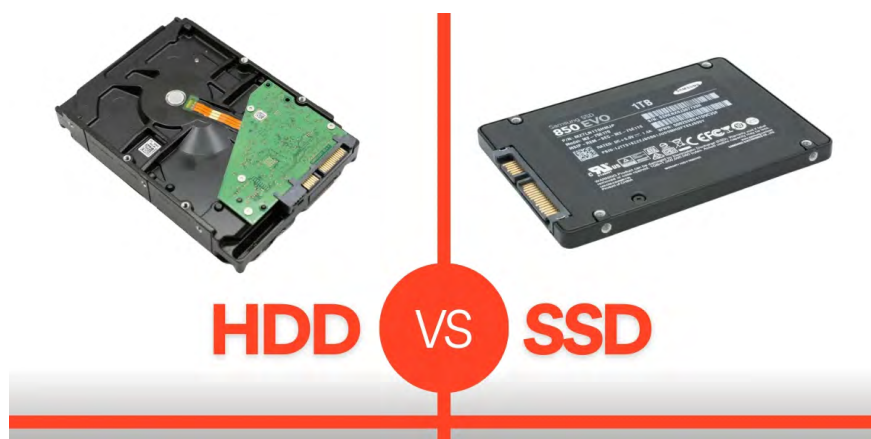


Figure 4.1 HDD vs SSD

Some of the characteristics of magnetic storage media include

- i. **High Storage Capacity:** Magnetic storage devices like Hard Disk Drives (HDDs) can store hundreds of gigabytes (GB) or even several terabytes (TB) of data. This makes them suitable for storing large files such as videos, software and databases.
- ii. **Low Cost Per Gigabyte:** Compared to other types of storage (like SSDs), magnetic storage is cheaper for the amount of data it can hold. This affordability makes it ideal for general use in homes, schools, and offices.
- iii. **Mechanical Components:** Magnetic storage devices have moving parts such as spinning platters and read/write heads that move across the disk. These parts can wear out over time due to friction and usage. Also, HDD can get damaged or fail if dropped or shaken while in use.
- iv. **Slower than Solid-State Devices:** Because of the moving parts, accessing data on magnetic storage is slower than on solid-state drives (SSDs) which have no mechanical components. Also, would realise that opening large applications or transferring files takes longer on an HDD than on an SSD.

2. Optical Storage Media

Optical storage media are types of devices that use laser light technology to read and write data. These media have a shiny, reflective surface and data is stored in the form of tiny pits and lands that a laser can scan. They include:

- a. **Compact Discs (CDs):** They store up to 700 MB of data. They are usually used to store music files, small documents and light software installations. Common formats are CD-ROM (Read Only), CD-R (Recordable), CD-RW (Rewritable).
- b. **Digital Versatile Discs (DVDs):** They store 4.7 GB (single layer) to 8.5 GB (dual layer). They are best for storing larger files like full length movies, software applications or backup data. Common formats are DVD-ROM, DVD-R/DVD+R, DVD-RW/DVD+RW.
- c. **Blu-ray Discs:** They store 25 GB (single layer) to 50 GB (dual layer). Typically, they are made for storing high-definition videos, games and large scale backups. They have faster data transfer rate, better image quality and greater storage capacity than DVDs.



Figure 4.2 Optical Storage Devices

Optical storage media are

- i. **Portable and durable:** Optical discs are lightweight and easy to carry. They can be used to distribute content, such as music, films, and educational software. With proper handling, they can last many years without data loss.
- ii. **Resistant to Magnetic Interference:** Unlike magnetic storage like hard drives, optical media are not affected by magnetic fields. What it means is that storing your files on a CD means they will not get wiped by a strong magnet near your laptop bag. This makes them safer for long-term storage especially in environments with electrical or magnetic equipment.
- iii. **Longer Shelf Life:** Optical discs can remain readable for 10–25 years, sometimes longer if kept in a cool, dry place. It is good for archiving important document such as photos or records.

3. Flash Storage Media

Flash storage media use flash memory chips to store data electronically without any moving parts. This makes them more durable, compact and faster than traditional magnetic storage.

Examples include:

- a. **Solid State Drives (SSDs):** They are modern storage devices used in computers and laptops. Newer computers in schools and homes now use SSDs for faster performance and quick boot-up times. They store the operating system, software and user files just like a hard drive but are much faster.
- b. **USB Flash Drives (Pen Drives):** They are small, portable devices that we connect to computers via a USB port. They are popular in schools, internet cafés and offices for storing assignments, presentations and music files. They are easy to carry, plug and play and can be reused many times. They are used to transfer, save and back up data.
- c. **Memory Cards (SD cards and microSD cards):** They are small storage cards used mostly in portable electronic devices. They are SD cards (Secure Digital cards), used in digital cameras and our tablets and microSD cards, a smaller version of SD cards used in mobile phones and portable music players to store photos, videos, music and app data.



Figure 4.3 Flash Storage Media

Some of its characteristics are

- i. **No Moving Parts (More Durable):** Flash storage devices such as SSDs, USB drives and memory cards do not use spinning disks or moving parts like hard drives do. This makes them less likely to break if dropped or bumped.
- ii. **Fast Read/Write Speeds:** Flash storage can access and save data very quickly. This speed helps programmes and files open faster. It also means copying data takes less time. For instance, installing software on a laptop with an SSD will take much less time than on a traditional HDD.
- iii. **Low Power Consumption:** Flash media uses less electricity than magnetic or optical media. Devices with flash memory save battery life and produce less heat. For instance, smartphones and tablets using flash memory last longer on a single charge and good for areas with limited electricity access.

How SSDs Work

SSD uses electronic memory chips specifically NAND flash memory to store data.

- a. **NAND Flash Memory Chips:** SSDs store all files, applications and system data inside tiny cells of flash memory. These data are stored in blocks, and the blocks are made up of many cells. Each cell can hold electrical charges which are interpreted as binary data (0s and 1s).
- b. **The SSD Controller:** It is like the “brain” of the SSD. It manages how and where data is stored. It keeps the SSD running efficiently by distributing data evenly and preventing too much wear on any one part of the memory. It also retrieves data very fast when you open a file or launch an application.

For instance, if you are using a school tablet or laptop with an SSD, it will boot up in seconds, files open almost instantly, you can carry it to school without worrying much about damage from bumps but if the laptop uses an HDD, it might take longer to start, opening large files or programmes will be slower and a fall from your schoolbag could damage the internal disk.

Comparison of Mass Storage Media

Mass storage devices come in different types, and each type has its own strengths and weaknesses depending on what it is used for. The table below compares the three main types: Magnetic Storage, Optical Storage and Flash Storage.

Criteria	Magnetic Storage	Optical Storage	Flash Storage
Cost per GB	Low - Affordable for large storage	Medium – Cheaper than SSDs, costlier than HDDs	High – Most expensive per GB
Access Speed	Medium – Faster than CDs, slower than SSDs	Slow – Takes time to load data	Fast to Very Fast – Quick file access and booting

Durability	Medium – Moving parts can wear out	High – No moving parts, scratch-resistant (if handled well)	High – No moving parts, very shock-resistant
Portability	Low (HDDs) – Heavy and fragile, High (Tapes) – Easier to carry	High – Lightweight and easy to move around	Very High – USBs and SD cards are pocket-sized
Capacity	Very High – Can store multiple terabytes	Low to Medium – Max around 50 GB (Blu-ray)	Medium to High – From a few GBs to multiple TBs
Power Consumption	High – Needs more energy (spinning parts)	Low – Efficient power usage	Low – Very energy-efficient
Lifespan	3–5 years (HDDs) – May fail with heavy use	10+ years – If well cared for	5–10 years – Can degrade with many writes

Activity 4.2 Examples of Mass Storage Media

You will be provided with storage media components for this activity.

1. Examine the physical difference between them and group them into the three main types of storage media.
2. Write down your observations in your notebook.
3. Complete the table below by researching on their characteristics as highlighted in the column names.

Storage Type	Examples	How Data is Stored	Typical Capacity	Advantages	Disadvantages	Average Cost	Sample of storage Image
Magnetic							
Optical							
Flash							

Compare your completed table with a colleague.

Real-World Applications

Understanding where and how each type of storage media is used helps you connect classroom learning to real-world technologies.

1. Magnetic Storage

- a. Enterprise Data Centres: Companies use HDDs in large numbers to store customer information, website data and transaction records because they offer huge storage space at a lower cost.
- b. Long-Term Archiving: Magnetic tapes are used to store old or less frequently accessed data for many years such as government records or scientific research archives.
- c. Desktop Computers: Some desktop computers still use HDDs as a storage drive for storing documents, games and software.

2. Optical Storage

- a. Distribution of Software and Media: Companies use DVDs and Blu-rays to distribute movies, video games and software especially where internet access is limited.
- b. Long-Term Archiving: CDs and DVDs can be used to store important documents such as school projects and photos for long periods as they are less likely to lose data over time.
- c. Backup of Personal Data: Individuals can burn personal files like music, videos or photos onto DVDs as a backup option.

3. Flash Storage

- a. Modern Computers: Most new computers use SSDs for fast booting, file loading and improved performance.
- b. Mobile Devices: Phones, tablets, and cameras use memory cards (e.g., microSD) to store pictures, videos and apps.
- c. Data Transfer Between Devices: USB drives make it easy to carry and move files between school, home and computers of friends.
- d. High-Performance Computing: SSDs are used in advanced systems where speed and quick access to data are critical such as in gaming PCs, scientific research, graphic designing or video editing.

Future Trends in Storage Technologies

As technology continues to advance, the way we store, and access data is also evolving. Some key trends shaping the future of storage systems are:

1. Higher Storage Densities: Storage devices are now able to hold more data in smaller physical spaces. For example, a memory card the size of your fingernail can now store hundreds of gigabytes. This is made possible through technological improvements in miniaturisation and efficiency.

2. **Flash Storage Becoming More Popular:** Flash-based storage like SSDs and USB drives is becoming faster, more reliable and cheaper over time. It is now replacing magnetic hard drives in many devices due to its speed and durability. As prices fall, even low budget computers and mobile phones are beginning to use flash storage.
3. **Cloud Storage as a Companion to Local Storage:** Many people and businesses are now storing data online in the cloud. This allows access to files from anywhere with an internet connection. Cloud storage is often used alongside local storage to provide backups, easy sharing and collaboration.
4. **Emerging Technologies: DNA and Holographic Storage**
 - a. **DNA Storage:** Scientists are developing ways to store digital data inside strands of DNA. This could allow massive amounts of data to be stored in a very tiny space.
 - b. **Holographic Storage:** This uses 3D techniques to store data in patterns of light, offering extremely fast access and large capacity.

These technologies are still being developed but could become revolutionary in the future.

Activity 4.3 Extended Learning on Mass Storage Media

1. Go online and find a tutorial video explaining different mass storage types.
2. Compare the storage media – considering storage, pricing, speed and anything else that may be important.
3. Explain different use cases for the different storage media that you have researched.
4. Share your findings with peers.

Activity 4.4 Other Mass Storage Media

1. What storage devices do you have challenges with?
2. Analyse cost-benefit ratios of different storage solutions.
3. Create infographics comparing different storage devices.
4. Present your findings to your peers.
5. Summarise the key points about each storage type.

ARTIFICIAL INTELLIGENCE (PRINCIPLES, COMPONENTS AND APPLICATIONS)

Activity 4.5 Revision on Smart Devices

1. Tell the class what you know about smart devices.
 - a. Indicate the features they possess that make them smart.
 - b. Identify examples of smart devices around us.
2. Share your responses with your peers.

Activity 4.6 AI in Motion

In this activity, we will observe how AI is used in automobiles.

1. Watch this short video of a self-driving car <https://www.youtube.com/watch?v=P-BzbBje-8I> or [here](#).
2. Write in your notebooks
 - a. The relationship of what you have observed to AI.
 - b. The data you think this AI needs to learn.
 - c. What could go wrong if this AI makes a mistake?
3. Share your observation and thoughts with the class.

ARTIFICIAL INTELLIGENCE (AI)

AI is a field of computer science that is focused on creating smart machines and systems that can perform tasks which would normally require human intelligence. Think about a machine that can learn from its experiences like you do in school, understand what people are saying, recognise faces and objects, solve problems and make decisions. That is the kind of ability AI tries to give computers, thus making machines intelligent, doing similar things like us as humans.



Figure 4.4 AI

Characteristics of AI

1. Simulating Human Intelligence

Primarily, AI is about making machines think and learn like humans. Instead of just following fixed instructions like most traditional computer programs, AI systems analyse information, recognise patterns and make decisions based on what they find.

2. Learning and Adapting from Data

One of the most powerful parts of AI is its ability to learn from experience. This is called machine learning. Just like you get better at Mathematics, Computing or English by practising past questions, AI systems improve their performance by studying data, learn from mistakes and get better over time. For instance, Apps like Google Maps can suggest to you quicker routes to take to avoid too much traffic by looking at real-time traffic data from thousands of users.

3. Performing Complex Tasks

AI is not just about doing simple jobs but also to solve difficult problems that humans usually handle such as translating languages (Goggle Translate), diagnosing illnesses in hospitals, driving cars without a human driver (self-driven cars) and chatting like a human (chatbots or virtual assistants).

Types of Artificial Intelligence

AI can be grouped into three main types based on what it is capable of doing.

Narrow AI (Weak AI)

This is the most common and only type of AI that exists today. Narrow AI is built to do just one specific task, and it does that task very well. However, it cannot work outside of what it has been programmed or trained to do. For examples, Siri on an iPhone which can answer your questions or set an alarm, but it cannot hold a deep conversation or understand your emotions. Recommendation system of YouTube suggests videos you may like based on your viewing history, but it cannot cook or clean. Other more advanced narrow AIs are ChatGPT, Gemini or Grok which can answer questions, write essays or code but cannot think or reason like a human across different topics. Although Narrow AI seems intelligent, it is still limited to its area of training and does not have general understanding like a human.



Figure 4.5 Siri icon

General AI (Strong AI)

This is the next stage in the development of Artificial Intelligence which does not yet exist. General AI would be a machine with intelligence equal to that of a human being. It would not just perform a single task but would be able to understand, reason, learn and solve problems across a wide range of areas just like you do. A General AI could learn any subject or skill on its own, solve problems it has never encountered before, adapt to new situations without needing to be reprogrammed and hold deep conversations and even show emotional understanding just like human beings. The idea of General AI is often shown in science fiction films for example, robots that think and feel like humans or computer

systems that run entire cities. However, in real life, this level of AI is still under research and development.

Superintelligent AI

This type of Artificial Intelligence is still purely theoretical. It describes a future possibility where a machine becomes far more intelligent than the smartest human beings in nearly every area from solving scientific problems to showing creativity, wisdom and understanding human emotions. A Superintelligent AI is anticipated to make discoveries faster than any human scientist, understand and respond to emotions of humans better than we can, make decisions with greater logic and fairness and possibly create better versions of itself without human help. At the moment, Superintelligent AI does not exist. It is mostly a concept used in science fiction books and movies and by researchers imagining what the future might hold. Many scientists are discussing how we might prepare for it in case it ever becomes a reality.



Figure 4.6 Narrow, General and Super AI

Activity 4.7 How AI works in real life

1. Identify at least three AI commonly used in Ghana.
2. Indicate how helpful each AI mentioned above is to Ghanaians.
3. Write on how AI powered fraud detection is important for the security of mobile money services in Ghana.
4. Share your response with your peers and teacher.

BRIEF HISTORY OF AI

The idea of building machines that can think like humans has been around for many years. However, the modern study of Artificial Intelligence (AI) began to take shape in the mid-20th century.

The Beginning

The term “Artificial Intelligence” was first introduced in 1956 at a meeting held at Dartmouth College in the United States. This event is considered the official birth of AI as a field of study. At that time, researchers were filled with excitement and hope. Early AI projects focused on building systems that could follow rules, solve logic problems and play games such as chess. These early systems were basic, but they laid the foundation for what we have today.

AI Winters

The journey of Artificial Intelligence has not always been smooth. There were times when progress in AI slowed down a lot. These periods are known as “AI winters”. During AI winters, many people lost interest in AI and funding for research was cut. This happened because early scientists made big promises about what AI could do but the technology at the time was not advanced enough to meet those goals. As a result, expectations were not met and support for AI research declined for a while.

The Recent Boom in AI

In the last 20 years, AI has become very popular and powerful again. This big improvement is called a “boom” in AI. Three main reasons caused this boom, and they are:

1. **Increased Computing Power:** Modern computers are much faster and more powerful than those in the past. This improvement means that computers can now run very complex AI programmes quickly and efficiently. As a result, tasks like speech recognition, image analysis and machine learning have become much easier to perform.
2. **Big Data:** Today, there is a huge amount of data available from the internet, mobile apps and digital devices. AI systems use this data to learn patterns, improve performance and make better decisions. The more data AI has, the smarter and more accurate it can become.
3. **Better Algorithms:** Scientists have developed smarter and more efficient methods, known as algorithms, that allow AI systems to learn faster and make more accurate decisions. These modern algorithms are key to the success of how powerful AI is today.

Components of Artificial Intelligence

AI is not a single technology but rather a combination of several key components that work together to make machines intelligent. These components include the following:

Machine Learning (ML)

Machine Learning is a branch of Artificial Intelligence that enables computers to learn from data without being explicitly programmed. Instead of writing detailed instructions for every possible situation, developers design algorithms that allow machines to improve automatically through experience. As the system processes more data, it becomes better at identifying patterns and making predictions.

1. *Supervised Learning*: This is like studying with an answer key. The AI system is trained using a labelled dataset where each piece of data already has the correct answer provided. For example, imagine teaching a computer to recognise spam emails. You would give it thousands of emails each already labelled as either “spam” or “not spam.” The AI looks at these examples and learns the features (patterns) that are common in spam emails such as certain words, links or senders. Once trained, the AI can then use this learning to predict whether a new or unseen email is spam or not.
2. *Unsupervised Learning*: This is like sorting a big pile of jumbled information without anyone telling you what it means. The AI is given data without labels, so it does not know the correct answers in advance. Instead, it has to find patterns, similarities or groupings on its own. For instance, in online course learning, a course portal might want to understand different types of learners based on the subjects or courses they select. The AI can analyse the data and automatically group learners who take similar courses or learn at similar times without being told which group is which. This helps schools send targeted adverts to each group.
3. *Reinforcement Learning*: It is like learning from experience, the same way you might learn to play a game or ride a bicycle. The AI learns by trying different actions and getting feedback. This feedback can be a reward if it does something right and a penalty if it makes a mistake. Think about a computer learning to score a goal; if it scores, it gets a reward. However, if it loses, it gets a penalty. Over time, by repeating the game again and again, the AI figures out the best way to play to earn the highest score and avoid penalty. This is how reinforcement learning works, thus trial and error with feedback.

Neural Networks

Neural Networks are computer systems designed to work like the human brain. Just as our brain has neurons that have billions of interconnected cells that communicate to process data, Artificial Neural Networks (ANNs) have artificial “neurons” arranged in layers that help in passing signals to each other.

1. *How They Work*: The network typically has input layer that takes in the data, pass it to hidden layers to process and transform the data. The processed data is then passed to the output layer which then produces the result. In a nutshell, each neuron receives input, processes it, and passes the result to the next layer.
2. *Deep Learning*: This is a special type of Machine Learning that uses neural networks with many layers, sometimes dozens or even hundreds. It is called “deep” because of the depth (number of layers) in the network. Each layer in a deep neural network learns to detect more detailed features of the data.

For instance, the first layer might detect edges in an image, the next layer sees shapes while the later layers recognise objects like a face or a car. It can automatically learn features from data hence there is no need to tell it what to look for. It also works well on large and complex datasets and powers the most advanced AI today. In our world today, deep learning is used in self-driving cars to detect people, cars, traffic lights, voice assistants like Alexa and Siri to understanding spoken words, face recognition on phones and laptops and translation apps like Google Translate.

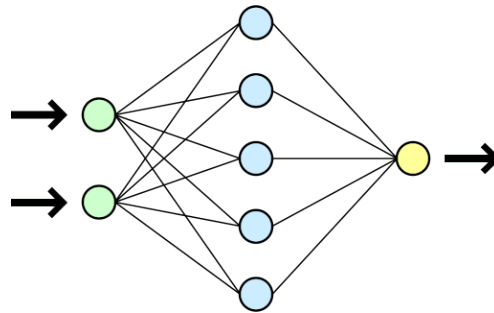


Figure 4.7: Illustration of Neural Networks

Natural Language Processing (NLP)

It is a branch of Artificial Intelligence (AI) that allows computers to understand, interpret and generate text or speech of human language just like the way we write or speak. NLP enables machines to read, listen to and respond to human language in a meaningful way. It combines linguistics (language rules) with machine learning to make sense of natural (everyday) language. It understands what you type or say, provides responses with sensible answers, translates between languages, summarises long texts into shorter ones and identifies emotions or intentions in speech or text. Every time you speak to your phone or use a language translation app, you are making use of NLP.

Applications

NLP is used in many technologies you interact with daily. Below are some of the common applications:

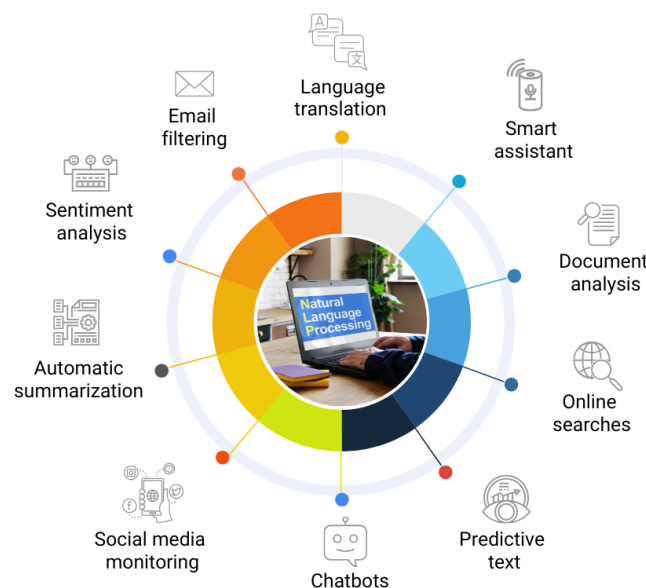


Figure 4.8 Applications of NLP

1. **Language Translation:** Services like Google Translate can convert spoken or written text from one language into another. This helps people communicate across different languages with ease.
2. **Chatbots and Virtual Assistants:** When you chat with a support both on a website or use a virtual assistant like Siri, Alexa or Google Assistant, NLP is what allows the system to understand what you are saying and reply in a natural just like human.
3. **Speech Recognition:** This technology turns spoken words into text. For example, when you use the microphone on your phone to dictate a message, speech recognition converts your voice into written words.
4. **Sentiment Analysis:** NLP is used to analyse text such as product reviews, tweets or comments to determine the emotion or tone behind it. It determines whether it is positive, negative or neutral. This is useful for businesses to understand how customers feel about their products or services.

Computer Vision

Computer Vision is a field of AI that enables computers to “see” and interpret the visual world, just as humans do. Computers can identify, classify and make sense of what they observe through processing of digital images or video streams from cameras and sensors.

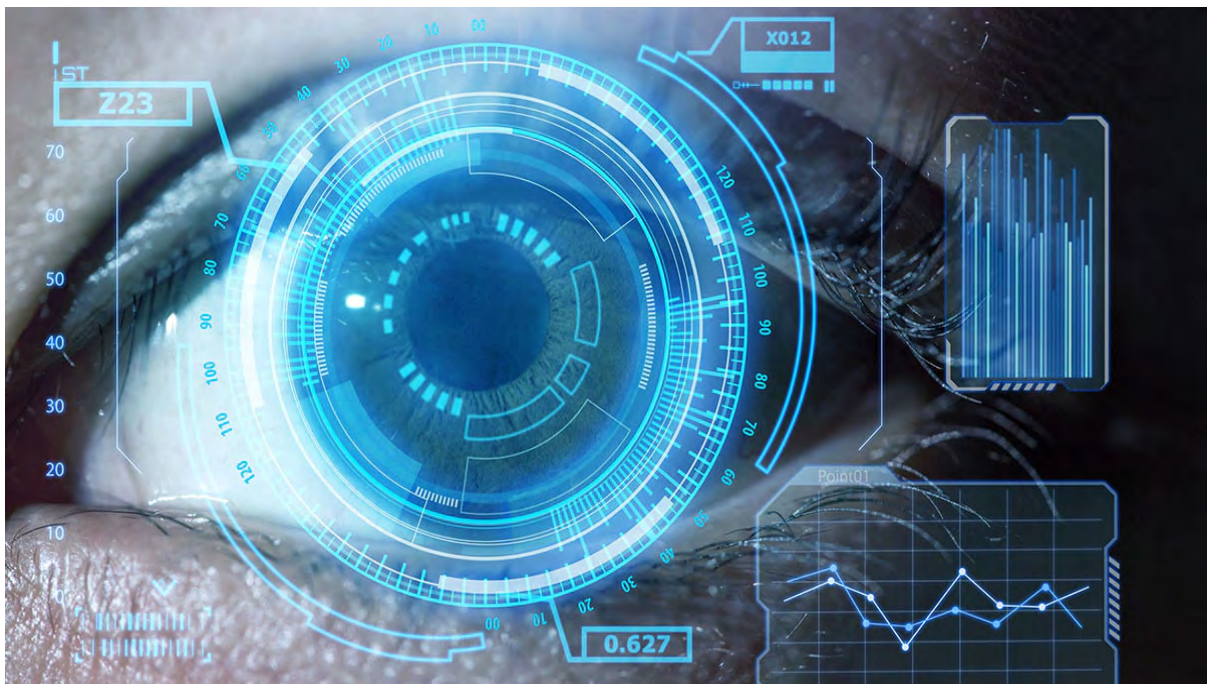


Figure 4.9 Computer Vision

Activity 4.8 Vision Simulation

In this activity, you will explore how to train your own AI using Teachable Machine.

1. Use <https://teachablemachine.withgoogle.com/train/image> or click [here](#) and explore how computers detect objects using online demos.
2. What data do you think this AI needs to learn?
3. Use the samples of the identified data to train the machine to recognise gestures or sounds.
4. What could go wrong if this AI makes a mistake?
5. Present your results to the class.

Applications of Computer Vision

1. **Image Recognition:** Social media platforms such as Facebook use computer vision to recognise faces in photos. This allows them to suggest tagging your friends automatically.
2. **Object Detection:** Self-driving cars rely on computer vision to detect and identify pedestrians, other vehicles, road signs, traffic lights and lane markings. This helps the car make safe decisions while navigating.
3. **Facial Recognition:** Many smartphones use facial recognition technology to unlock the device securely. It is also increasingly used in security systems and access control.
4. **Medical Image Analysis:** Doctors and radiologists use computer vision to examine medical images such as X-rays, CT scans and MRIs. This helps in the early and accurate detection of conditions like cancer, fractures or brain abnormalities.

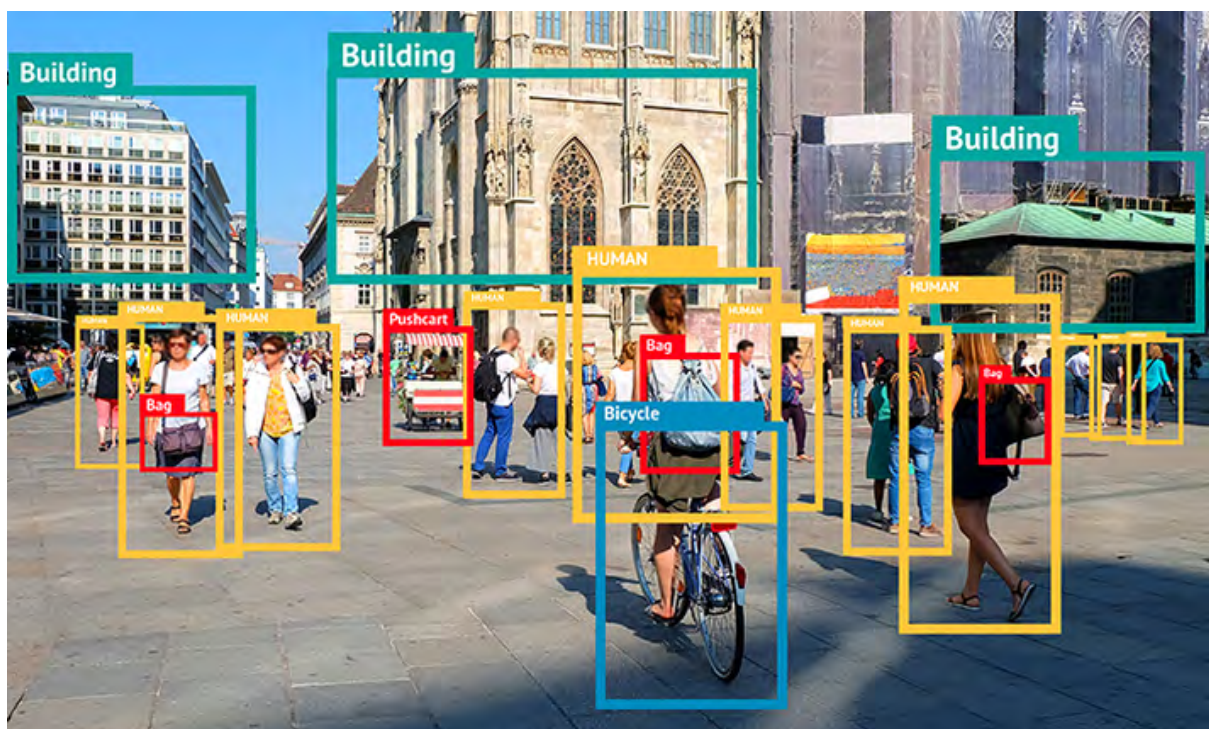


Figure 4.10 Application of AI

Activity 4.9 Real-World Application of AI

Working with your peers, you will explore how AI helps in real life.

1. You will be assigned one real-world application of AI to explore using provided resources or internet access in groups:
 - a. Group A: Image Recognition (e.g., Facebook photo tagging, phone Face ID).
 - b. Group B: Language Translation (e.g., Google Translate).
 - c. Group C: Virtual Assistants (e.g., Siri, Google Assistant).
 - d. Group D: AI in Finance (e.g., mobile money fraud detection).
2. Documents how the AI works in simple terms, list its benefits and find one challenge or limitation.
3. Share your findings with the class.

REAL-WORLD APPLICATIONS OF AI

1. **Image Recognition:** AI enables computers to “see” and recognise images. For example, your phone can unlock using Face ID by recognising your face. Social media platforms like Facebook can suggest tagging friends in photos because they identify who is in the picture.
2. **Language Translation:** AI helps translation apps such as Google Translate or Apple Translate to enable people to understand and communicate in different languages. Some apps even allow you to point your camera at a sign or book and the AI will translate the text instantly.
3. **Virtual Assistants:** Digital assistants like Siri, Google Assistant or Alexa use AI to respond to your voice. You can ask them to set an alarm, search for homework answers or play your favourite music or videos and will be done for you.
4. **Healthcare Applications:** AI is used in hospitals and clinics to help doctors detect diseases early. It can analyse medical scans such as X-rays or MRIs and spot signs of illness sometimes even before a doctor would notice it. This helps to improve the speed and accuracy of diagnosis.
5. **Financial Services:** AI helps protect your money. For instance, mobile banking and mobile money platforms use AI to monitor for unusual behaviour. If someone tries to access your account or make a suspicious transaction, the system can block it to prevent fraud.
6. **Transportation:** Apps like Google Maps use AI to suggest the fastest route by analysing real-time data such as road conditions, accidents and traffic levels. This is particularly useful in busy cities like Accra and Kumasi by helping you avoid traffic jams and get to your destination faster.

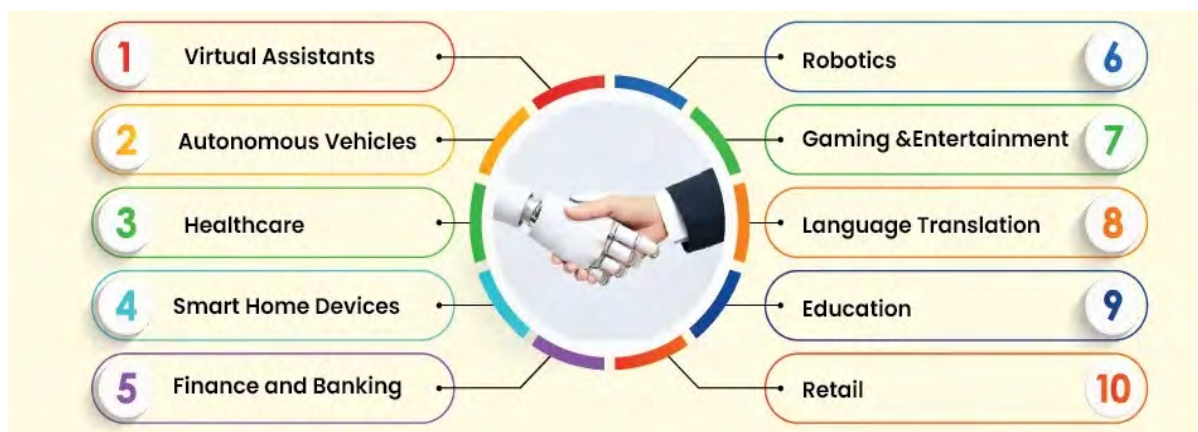


Figure 4.11 Examples of real-life applications of AI

Activity 4.10 How AI works in real life

1. Using Google Assistant or Siri app, ask it the following questions:
 - a. What is the weather in Kumasi?
 - b. Set a timer for 2 minutes.
 - c. Translate 'good morning' into Twi and Ewe.
 - d. Create a personal timetable for my studies.
 - e. Convert 100 dollars to Ghana cedis.
 - f. Ask for directions from Accra to Aflao.
2. Based on the feedback from the app, answer the following questions:
 - a. What kind of questions worked best?
 - b. Why did some commands fail?
 - c. What languages does the assistant understand?
 - d. Could a voice assistant understand Twi or Ewe?
 - e. What challenges arise?
3. Share your thoughts with peers.

CONVENTIONAL SYSTEMS AND INTELLIGENT SYSTEMS

Conventional Computing Systems

Conventional computing systems are traditional computers that can only perform tasks based on the exact instructions given to them by humans. You can think of them like very obedient robots. They will only do what they are told and nothing more. They have the following features:

1. **Follow Step-by-Step Instructions**

These systems run based on specific, detailed instructions known as algorithms. If you don't tell them exactly what to do, they won't know how to proceed.

2. **No Independent Thinking**

They cannot make decisions or solve problems on their own. Everything must be predefined by the programmer.

3. **Same Input = Same Output**

If you give them the same input, they will always give you the same output. There is no variation or creativity in their responses.

4. **No Learning Ability**

They cannot learn from experience. If they make a mistake, they will keep making it until a human corrects the instructions. They do not improve over time.

Examples of Conventional Computing Systems

1. **ATM Machines at Banks:** They follow programmed instructions. They let you withdraw money, check your balance or transfer funds, but only within the exact limits and rules they were coded to follow.
2. **School Grading Systems:** The computer systems your school uses to store and manage the grades of students are conventional. They simply record the marks entered by teachers and calculate results based on fixed rules without any ability to learn or make decisions.
3. **Government Databases:** Systems that track information like births, deaths, ID numbers, or tax records are conventional. They store and retrieve data based on queries but cannot analyse or predict patterns.
4. **Basic Apps on Your Phone:** Many apps that show you fixed information, like calculators, calendars, or contact lists, are examples. They do what they're programmed to do but do not improve with use.
5. **Regular Websites:** Websites that display static information such as a school timetable or news articles follow the same rule. They provide set content based on what is built into them and do not respond in intelligent or personalised ways.

Intelligent Systems

Intelligent systems are the “smart” version of traditional computers. Unlike conventional systems that follow strict instructions, intelligent systems can understand their environment, learn from experience and make decisions even when faced with new situations.

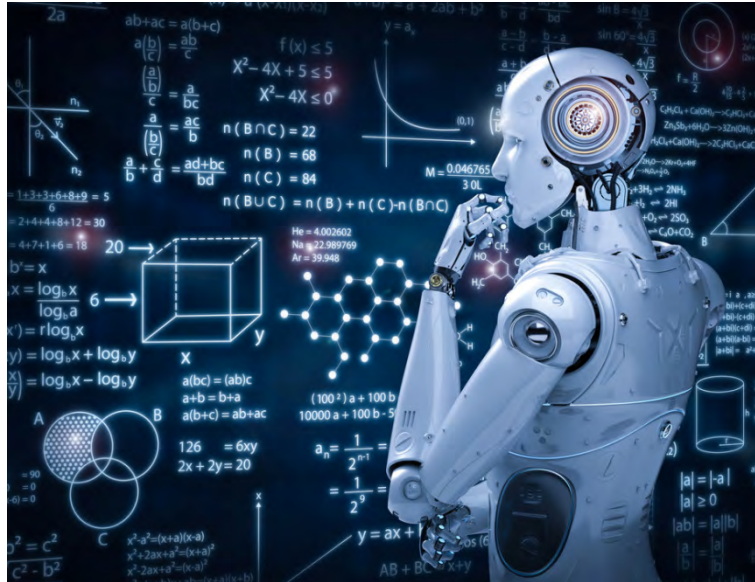


Figure 4.12 Intelligent System

Characteristics of Intelligent Systems

1. They can figure things out even with incomplete information
Intelligent systems do not need to be told exactly what to do every time. They can make sense of what is going on even when some details are missing.
2. They get better at tasks over time as they gain experience
Just like humans, intelligent systems can learn from past mistakes and improve their performance. This is possible through techniques like machine learning.
3. They can think in ways that are similar to humans. They can analyse, reason and even understand language or recognise patterns and behave in ways that are close to human thinking.
4. They can make educated guesses when they are not 100% sure. Instead of freezing or giving an error, intelligent systems use probability and patterns to make sensible decisions, even if they are uncertain.

Examples are:

- a. Systems that help farmers detect plant diseases before they spread. These systems can identify signs of disease early using images of crops. This helps farmers take quick action and protect their harvests.
- b. Programmes that spot suspicious transactions in mobile money services. AI systems monitor mobile money activity and can detect unusual behaviour. This helps to prevent fraud and keep money safe for users.

- c. Tools that help doctors diagnose medical conditions. AI-powered tools analyse medical scans or symptoms and assist doctors in identifying health problems faster and more accurately.
- d. Apps that translate between English and local languages like Twi, Ewe, Dagbani, Dagaare, etc. These apps use NLP to understand and translate speech or text. This helps to bridge communication gaps.
- e. Systems that help manage traffic flow in some busy cities like Ho, Accra, Takoradi and Kumasi. They analyse traffic data in real time and adjust traffic lights or suggest better routes to reduce congestion and save time.

Comparing Conventional and Intelligent Systems

Understanding the difference between conventional and intelligent systems helps us see how computing has evolved:

Feature	Conventional Systems	Intelligent Systems
How they work	Follow fixed instructions step-by-step	Learn from data and experience
Adaptability	Cannot adapt or improve on their own	Improve performance over time
Problem-solving	Handle well-defined problems with clear rules	Can solve complex or unclear problems
Transparency	Easy to understand; behaviour is predictable	Often work like a “black box”; decisions may be hard to explain
Hardware Requirements	Run on simple, affordable hardware	Require powerful, specialised hardware
Example Analogy	Like a calculator – always gives the same answer	Like a human tutor – adapts to your needs and learns over time

In summary, conventional systems are like dependable workers, good at routine tasks but unable to learn or adjust. Intelligent systems on the other hand are like smart apprentices. They get better with experience, find hidden patterns and can handle more complex challenges even if they are harder to understand.

Hybrid Approaches

Hybrid systems are combination of conventional computing and intelligent systems. They are designed to benefit from both reliability and adaptability. In other words, they combine the strict rules of traditional systems with the learning power of AI. They use fixed rules and step-by-step logic for consistency and control add intelligent features like pattern recognition and learning from data and provide a balance between explainability (easy to understand) and flexibility (able to adapt).

In Ghana, smart farming tools combine traditional knowledge such as planting seasons and local crop diseases with AI that can detect signs of pests or diseases from photos of leaves. This helps farmers act quickly and increase their crop yields. In Healthcare Systems, in some hospitals, standard treatment protocols are followed but AI assistants also support doctors by analysing scans or predicting the likelihood of complications thereby improving diagnosis and patient care. Also, educational platforms like online learning systems use structured lesson plans based on the curriculum while also tracking how each student learns. The AI adjusts the pace, difficulty or even the teaching style to match the needs of the learners.



Figure 4.13: Hybrid Computing System in Hospital

Activity 4.11 Concepts of various computing systems

1. Organise yourself into a group of 2 to 4 members.
 - a. Create a comparison chart between conventional computing systems and intelligent systems.
 - b. Identify at least 3 key differences in terms of:
 - i. Problem-solving capabilities
 - ii. Adaptability
 - iii. Learning capacity
 - iv. Resource requirements
 - v. Transparency and explainability
 - c. Identify and document at least two real-world examples of each system type currently used in Ghana.
 - d. Store your work on the storage device of your teacher.
2. Present your response to your class.

Activity 4.12 Reflection

1. From *activity 4.11*
 - a. Think about the different perspectives shared in class.
 - b. Write a debate on your reflection.
 - c. Connect your debate points to real-world applications in Ghana.
 - d. Address misconceptions about both system types.
2. Present your debate to the class.
3. Provide answers to questions the teacher and peers will ask you.

EXTENDED READING

- https://uomustansiriyah.edu.iq/media/lectures/4/4_2025_04_05%2110_25_44_AM.pdf?utm_source=chatgpt.com to read on magnetic (HDD, tape), optical (CD, DVD, Bluray) and solidstate (SSD, flash) media, their advantages/disadvantages and technical structure.
- Click [here](#) or <https://www.mdpi.com/2227-7390/10/15/2552> to read on Review of Artificial Intelligence and Machine Learning Technologies: Classification, Restrictions, Opportunities and Challenges.
- Use the link <https://www.geeksforgeeks.org/machine-learning/machine-learning/> or [here](#) to read more on machine learning.

Click [here](#) or <https://www.geeksforgeeks.org/artificial-intelligence/evolution-of-ai/> to read more on the evolution of AI.

REVIEW QUESTIONS

1. Name two examples of mass storage media.
2. What is the difference between volatile and non-volatile storage?
3. Compare HDD and SSD in terms of speed and durability.
4. Explain how artificial intelligence improves the performance of cloud storage systems.
5. Why is storage capacity important in AI systems?
6. Evaluate the advantages and disadvantages of using AI to manage data in healthcare systems compared to traditional methods.
7. Justify why SSDs are preferred over HDDs in AI model training.
8. Propose a suitable storage system for a hospital using AI for medical imaging.
9. Design a basic framework for a hybrid system in education that integrates mass storage and AI to personalise learning for students in rural areas.

```
remove_action( 'wp_head', 'rsd_link' );  
remove_action( 'wp_head', 'wlwmanifest_link' );  
remove_action( 'wp_head', 'wp_generator' );  
remove_action( 'wp_head', 'start_post_rel_link' );  
remove_action( 'wp_head', 'index_rel_link' );  
remove_action( 'wp_head', 'adjacent_posts_rel_link' );  
remove_action( 'wp_head', 'wp_shortlink_wp_head' );  
}  
add_action( 'dhs_remove_feeds' );
```

SECTION

5

WEB TECHNOLOGIES AND DATABASES



COMPUTATIONAL THINKING (PROGRAMMING LOGIC)

WEB TECHNOLOGIES AND DATABASES

INTRODUCTION

In years one and two, you were introduced to web design, web development and cybersecurity, where you looked at their various concepts. You created web pages using basic HTML and CSS and grasped how to protect your accounts and be safe online. In this learning, you will design well-structured and visually appealing web pages using web editors, incorporating sections, text, images and user interface elements. You will also design a simple e-commerce page for a chosen business, indicating an understanding of how websites support local businesses in Ghana and abroad. Additionally, you will apply basic cybersecurity practices to protect your personal data.

KEY IDEAS

- **Database:** A structured system for storing, organising and retrieving data.
- **Password Reuse Risks:** Using the same password across multiple accounts increases the risk of multiple accounts being hacked if one is breached.
- **Phishing:** A form of online deception where attackers trick users into revealing personal or financial information.
- **PHP Connectivity:** The process of linking PHP code to a database to send, receive or manage data dynamically.
- **Social Engineering:** The use of manipulation to get individuals to share confidential information, such as impersonating a trusted source.

Activity 5.1 Revision on Database

This activity is to refresh our minds on the key components of databases

1. In your own words, explain what a table, column, row and primary key are in a database.
2. Share your work with your colleagues or teacher.

CREATING A DATABASE

In year 2, we learnt about databases as structured collections of data that can be easily accessed, managed and updated. Imagine a video game. A database stores all the players' information, like their name, score, and inventory. This lets the game quickly find your character's stats so you can play without a delay.

For an e-commerce website, the database keeps track of everything from product names and prices to customer reviews and shipping addresses. When you search for headphones, the site quickly looks up all the headphone information in its database and shows you the results.

Let us create a database for an e-commerce website.

Activity 5.2 Installation and launches

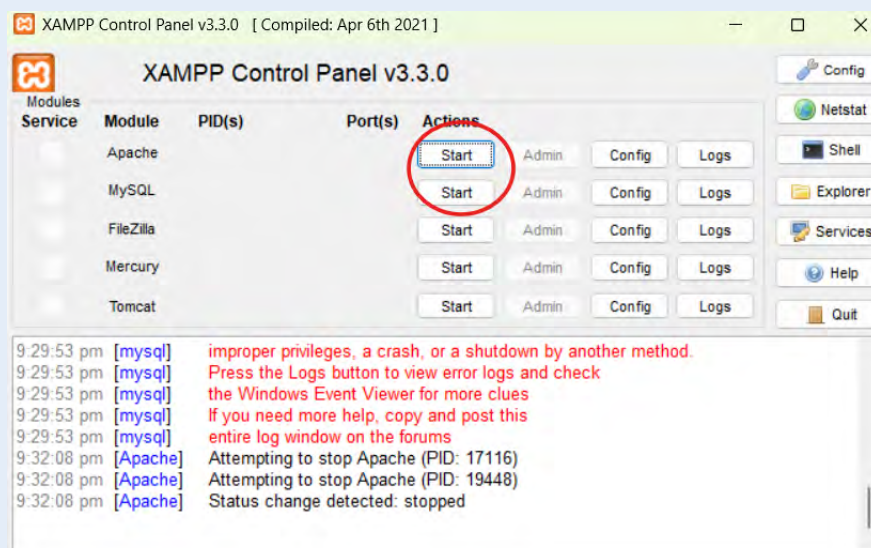
Follow the steps below to enable you to install XAMPP

Step 1: Installation of XAMPP

1. Download XAMPP from <https://www.apachefriends.org/index.html>
2. Click Download XAMPP for Windows (or Mac/Linux depending on your device).
3. Open the downloaded file and follow the installation steps:
4. Click Next until it installs.
5. Choose default settings.
6. Once installed, open the XAMPP Control Panel

Step 2: Start Apache and MySQL

1. In the XAMPP Control Panel:
 - a. Click Start next to Apache
 - b. Click Start next to MySQL



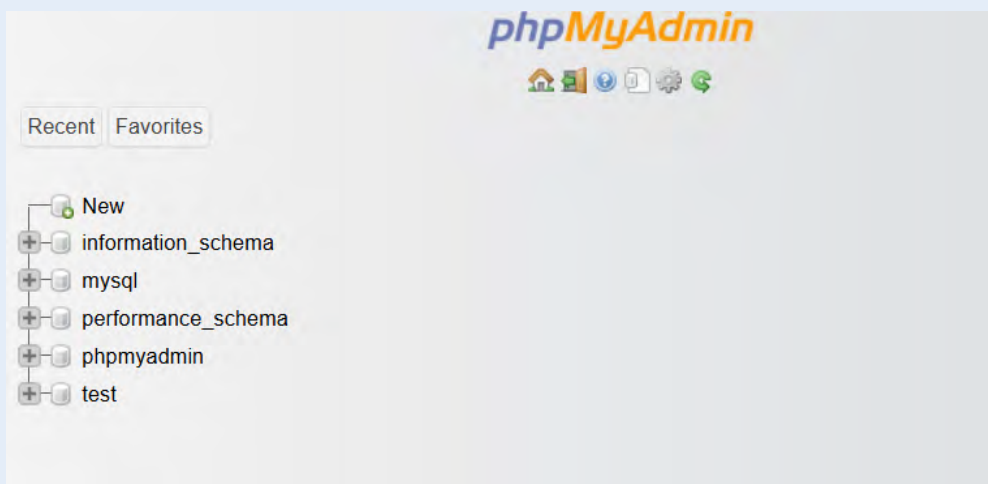
2. Both should turn green that means they are running

Note the following while doing **steps 1 and 2**

- If you have MySQL installed already, you may get error messages like the ones in the screenshot
- What you need to do is copy the error message into an AI and ask it to help you resolve the error.
- The key thing you will be doing in resolving the error is changing the port number in the configuration.

Step 3: Open phpMyAdmin

1. Open your web browser (Chrome, Edge, etc.).
2. Type this in the address bar: **http://localhost/phpmyadmin**
3. You will see the phpMyAdmin dashboard. This is where you will create your database.



Activity 5.3 Creating a Database and Tables

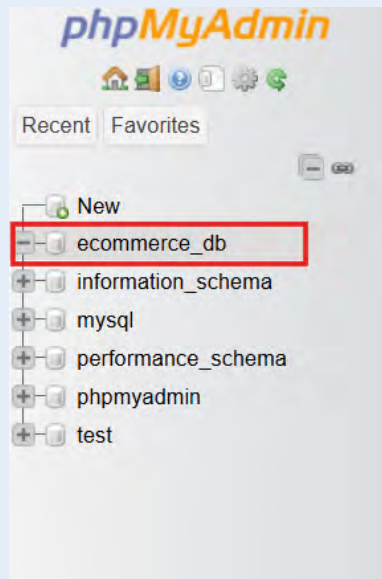
This activity is a build-up on activity 5.2. In this activity, we will use the phpMyAdmin to create a database and a table. Let the following steps guide you.

Step 1: Create a New Database

1. On the left side, click **New** ( **New**).
2. In the “Database name” box, type: **ecommerce_db**
3. Leave the default settings and click **Create**.

Step 2: Create a Table Called products

1. After creating the database, click on ecommerce_db in the left panel.



2. Under “Create table”, type:
 - a. Table name: products
 - b. Number of columns: 4

3. Click create.

Step 3: Creating table fields

1. Fill the columns like this by following the red dots

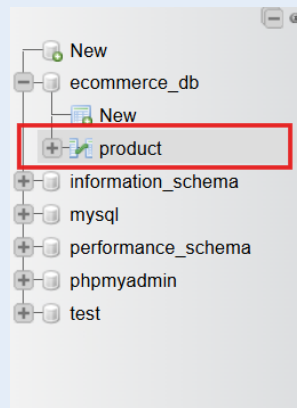
Name	Type	Length/Values	Default	Collation	Attributes	Null	Index	A_	C
id	INT		None			☐	PRIMARY	☒	
productName	VARCHAR	100	None			☐	---	☐	
price	DECIMAL	6,2	None			☐	---	☐	
image_url	VARCHAR	255	None			☐	---	☐	

2. Scroll down and click **Save**.

Activity 5.4 Adding products to the table

Step 1: Production addition

1. Click on the products table in the left panel



2. Go to the Insert tab
3. Add a product like this

Column	Type	Function	Null	Value
id	int(11)			
productName	varchar(100)			Cool Sneakers
price	decimal(6,2)			120
image_url	varchar(255)			images/sneakers.jpg

4. Click on **Go** to save each product
5. To add the 2 and 3 products, let's use the SQL statements as alternative.

Sample code

```
INSERT INTO `product` (`id`, `productName`, `price`, `image_url`) VALUES
(NULL, 'Smart Watch', '450', 'images/smartwatch.jpg');
```

```
INSERT INTO `product` (`id`, `productName`, `price`, `image_url`) VALUES
(NULL, 'Bluetooth Speaker', '90', 'images/bluetoothspeaker.jpg');
```

Step 2: Product View

1. Click the Browse tab in the products table.
2. You will see your product list arranged in rows

Activity 5.5 Database Challenge

Challenge 1: Create two additional tables called

- a. categories with (id, category_name)
- b. product_categories with (product_id, category_id)

Challenge 2: Create a new database with the Student_Details

- a. Design a table that includes these details (studentName, age, program and index number)
- b. Design another table that has the grades for (Computing, Maths, ICT and English)
- c. Show your finished work to a colleague or teacher (Seek assistance where necessary)

CREATING A SIMPLE E-COMMERCE WEBSITE

E-commerce is basically just online shopping. It is how people buy and sell stuff using the internet. Instead of going to a physical store. E-commerce is more than just a website. It's a whole system that lets people buy and sell stuff using the internet. Instead of going to a physical store. A website or an app on a phone is used to view products, add them to a cart and pay for them.

Follow these activities (5.6 -5.8) and let us create a simple one for ourselves.

Activity 5.6 Installing and Setting Up VS Code

Step 1: Install Visual Studio Code



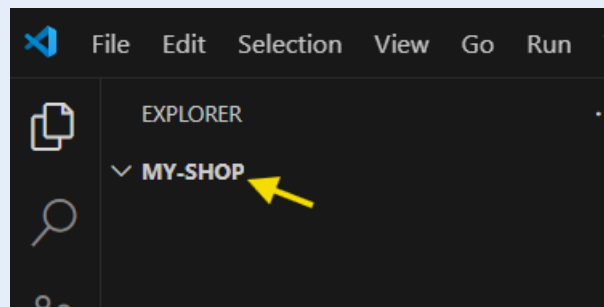
1. Go to <https://code.visualstudio.com>
2. Click Download for Windows (or Mac/Linux, depending on your device).
3. Open the downloaded file and follow the installation steps
4. Once installed, open VS Code.

Step 2: Create a New Project Folder.

1. On your desktop or in your documents, create a folder called **my-shop** ( my-shop).
2. Download this **image** folder into **my-shop** folder ([link](#)) or scan the QR code.



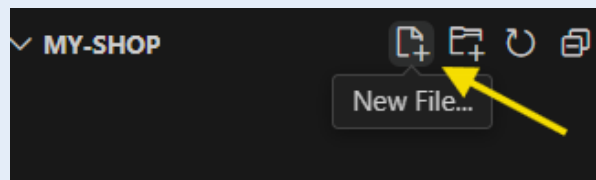
3. Open VS Code
4. Click File > Open Folder and select **my-shop**



You will see the folder name appear like this at the left-side

Step 3: Create an HTML File

1. In VS Code, click File > New File



2. Save it as index.html inside your my-shop folder
3. Add the Sample Code in the resource [link](#) or scan the QR code to get access copy and paste this into your VS code.



Section 5: Resource file

4. Save the file
5. Click on the **index.html** under the **my-shop** folder > Select open with edge > open with browser.

Step 4: Add Sample Products

1. Inside the `<div id= "products" >`, copy and paste the second set of codes like this

```

<body>
  <h1>Welcome to My Online Shop</h1>
  <div id="products">
    <!-- Products will be displayed here -->
    <div class="product">
      <h2>Cool Sneakers</h2>
      
      <p>Price: ghc 120.00</p>
    </div>

    <div class="product">
      <h2>Smart Watch</h2>
      
      <p>Price: ghc 450.00</p>
    </div>

    <div class="product">
      <h2>Bluetooth Speaker</h2>
      
      <p>Price: ghc 450.00</p>
    </div>
  </div>
</body>
</html>

```

2. Save the file again

Activity 5.7 Challenge Tasks

1. Add More Products
 - a. Create 3 new product entries using the same structure.
 - b. Use different images and prices.
2. Create a Separate CSS File
 - a. Make a new file called style.css
 - b. Move all the **<style>** code from your HTML into this file.
 - c. Link it in your HTML.
3. Add a “**Buy Now**” Button to Each Product

Activity 5.8 Reflection

1. How will you address the display of the images if they are in another folder called **home images** inside the **images** folder?
2. If your HTML file is inside a folder called **pages**, how would you link to an image in the **images** folder?
3. How can you make all product images appear in a circle shape using CSS?
4. What other product details could you add to make your shop more realistic?

CONNECTING A WEBSITE TO THE DATABASE

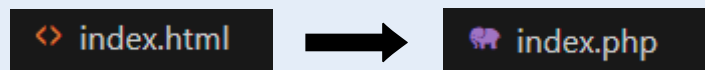
When you build a website like the online shop we did, we have to store and retrieve data. Like product details, customer information, orders, messages or reviews. To do this, our website needs to connect to a database like MySQL which we developed earlier in the section. So, it can send and receive information.

Activity 5.9 Connecting an e-commerce page to a database

In this step-by-step activity, if you encounter an error, seek help from your teacher or a peer. Alternatively, copy and paste the error into an AI and ask for step-by-step guidelines to resolve it.

Step 1

1. Open your XAMPP installation folder usually fold on drive C
2. Locate **htdocs** folder ( **htdocs**) and open it
3. Copy the **my-shop** folder and paste into **htdocs** folder
4. Launch VS code and locate the my-shop folder within htdocs
5. Rename **index.html** to **index.php** in the VS code. By right clicking on the file and select rename.



Note: we are renaming because PHP code only runs in files. Renaming allows you to mix HTML and PHP.

Step 2

1. Open the section 5 resource file again and copy the php code in it.
2. Paste the codes at the very top before `<html>` tag
3. Within the `<div id="products">` copy the PhP id product codes and replace with the static codes we wrote earlier like this.

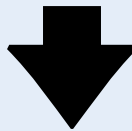
```

<body>
  <h1>Welcome to My Online Shop</h1>
  <div id="products">
    <!-- Products will be displayed here -->
    <div class="product">
      <h2>Cool Sneakers</h2>
      
      <p>Price: ghc 120.00</p>
    </div>

    <div class="product">
      <h2>Smart Watch</h2>
      
      <p>Price: ghc 450.00</p>
    </div>

    <div class="product">
      <h2>Bluetooth Speaker</h2>
      
      <p>Price: ghc 450.00</p>
    </div>
  </div>
</body>
</html>

```



```

<body>
  <h1>Welcome to My Online Shop</h1>
  <div id="products">
    <!-- Products will be displayed here -->
    <?php
      $result = mysqli_query($conn, "SELECT * FROM products");

      while ($row = mysqli_fetch_assoc($result)) {
        echo "<div class='product'>";
        echo "<img src='images/' . $row['image_url'] . ' ' alt=' ' . $row['productName'] . ' '>";
        echo "<h2>" . $row['productName'] . "</h2>";
        echo "<strong>$" . $row['price'] . "</strong>";
        echo "</div>";
      }
    <?>
  </div>
</body>

```

Note

- This will loop through your products in the database and display them.
- Take note of the **red dots**. Ensure they match with your database field names.
- Your final database table should look like this

				id	productName	price	image_url
☐	 Edit	 Copy	 Delete	1	Cool Sneakers	120.00	sneakers.jpg
☐	 Edit	 Copy	 Delete	3	Smart Watch	450.00	smartwatch.jpg
☐	 Edit	 Copy	 Delete	4	Bluetooth Speaker	90.00	bluetoothspeaker.jpg

4. Type **http://localhost/my-shop/index.php** in your URL address.
5. Press enter and see your newly created dynamic website.

Activity 5.10 Reflection on Database Connections and Challenge

1. What is the primary difference between a static website and a dynamic website?
2. What was most challenging, and how did you address it?

Activity 5.11 E-Commerce Challenge

This is an extended activity to challenge yourself on how to develop a good-looking e-commerce website.

Seek help from your teacher when needed

Step 1

1. Watch this video (https://drive.google.com/file/d/18lk7bEHxMhv4IH3SZq3rEmVF1b7r48jh/view?usp=drive_link) to see how the website looks and interact with other pages.
1. Download the files (ecommerce_demo and ecommerce.zip) from https://drive.google.com/drive/folders/1g7KDTK7v5Y-Eqk7E5hb_W61xoYgtIdxH?usp=drive_link
2. Unzip the files and use the required software to open the files.
3. Analyse how the codes are written
4. Connect the DB with the website and run it.

Step 2: Develop a similar website or modify the codes from scratch with product categories.

UNDERSTANDING CYBERSECURITY THREATS

Cybersecurity means keeping computers, mobile phones, networks and the data they hold from people who try to break in, steal information or cause damage. These people are sometimes called hackers or cybercriminals. It also involves using tools, rules and good habits to stop bad things from happening online.

Importance of Cybersecurity In the growing digital economy of Ghana

1. **Keeping mobile money safe:** If someone guesses your PIN or tricks you into sending money, you can lose your savings. Cybersecurity helps by adding strong passwords, alerts and extra checks before money is moved.
2. **Protecting online banking accounts:** Without proper security, criminals can get into your account and steal money. Cybersecurity tools like encryption, one-time passwords (OTPs) and secure apps protect you.
3. **Securing e-commerce (online shopping):** Some fake websites pretend to sell things but only want your money or card details. Cybersecurity helps identify real shops and protect your payment details.
4. **Making government digital services safe to use and many other online systems:** Services like Ghana.gov allow you to pay taxes, renew licences or apply for passports online. These systems store personal information like your name, ID, address, etc. Cybersecurity protects this information from being stolen or changed.

Activity 5.12 Understanding Cybersecurity Threats

1. Share your view on cybersecurity and common threats with the class.
2. Analyse the scenario below and answer the questions that follow.

Scenario: *A student receives a call asking for his/her WhatsApp security code sent to him/her few minutes ago so that he/she can be migrated to the new group they have created for them.*

- a. Identify the type of cyber threat.
 - b. Explain why this scenario is a threat.
 - c. Propose ways to avoid falling victim.
3. Share your responses with peers and your teacher.

COMMON CYBER THREATS IN GHANA

1. Mobile Money Fraud

While it is very useful, it is also targeted by criminals who use tricks to steal from people. These tricks are called cyber threats and some of them are:

- a. **SIM card swapping:** A criminal goes to a mobile network office and pretends to be you. They use fake ID or lie to the staff to get a new SIM card with your number. Once they get the new SIM, they receive all your calls and messages including your Mobile Money details and OTPs (one-time passwords). They can then access your account and withdraw your money.
- b. **Fake USSD codes:** Fraudulent messages asking you to dial codes that steal money like “Congratulations! You have won 10,000 cedis. Dial *170*1*2*PIN# to claim your prize!”* This is fake. The USSD code may send money from your wallet or allow the fraudster to control your account. These fake codes are designed to steal your money or information. Once you dial them, you may unknowingly approve a transaction for the fraudster.
- c. **Social engineering:** Someone calls you and says they work with the telco office in Ghana. They can claim there is a problem with your account and ask for your mobile money PIN to fix it for you or instruct you to dial some codes he/she will be giving you to solve the problem. They are lying. No real staff member will ever ask for your PIN.
- d. **Emergency Fraud:** You get a phone call from someone pretending to be a nurse, teacher or even a police officer. They tell you your child or relative in boarding school is very sick or has had an accident and needs urgent money for treatment. This creates fear so that people act quickly and send money without checking the truth.

2. Online Shopping Scams

Online shopping has become popular in Ghana, especially through websites and social media. But there are also many scams. Let us look at some examples and how to stay safe.

- a. **Fake e-commerce sites:** Some websites pretend to sell phones, TVs, clothes, shoes or home appliances. They look real but once you pay through mobile money or a bank transfer, the sellers vanish, no item is delivered, and the contact numbers stop working. These are scam websites designed to steal your money. For instance, a website claims they are selling a new double door fridge for GH¢900. After payment, you receive no delivery and there is no way to contact the seller.
- b. **Social media scams:** Some sellers on Facebook, Instagram or WhatsApp offer products at low prices. They post pictures of real goods such as phones, sneakers or wigs but once you send money, they block your number or delete their account. For instance, you see someone advertising original sneakers for GH¢ 100. You pay by mobile money to a registered number, but nothing arrives, and the page disappears the next day.
- c. **Too-good-to-be-true deals:** Scammers offer deals that are far cheaper than the real price to attract victims. For example, someone says they are selling an iPhone 14 for GH¢ 500 and claim it is “from Dubai,” “slightly used” or “a gift I do not need.” Also, A WhatsApp status shows: “Brand new iPhone 14, only GH¢ 500. Call fast, limited stock!” You send the money quickly thinking it is a bargain but ends up losing it.

3. Phishing Attacks

Phishing is when scammers trick people into giving out private information like passwords, mobile money PINs or bank details. They usually send fake messages that look real and official. These scams are common in Ghana especially through email, SMS and WhatsApp.

- Fake bank emails or SMS:** You may receive a message that looks like it came from your bank, saying, “Your bank account has been blocked. Click this link to unblock it now.” If you click and enter your account number and PIN, the scammers use it to steal money from your account. For instance, a message says: “Dear customer, your Bank account has been suspended. Visit “bank-securelogin.com to fix it.” This is a fake website made to steal your login details.
- Government impersonation:** Scammers send fake messages pretending to be from the Ghana Revenue Authority (GRA) telling you to pay a fine or tax or risk arrest. These messages may come by SMS or email with GRA logos. For example, an SMS says: “GRA Notice: You owe GH¢1,200 in unpaid tax. Pay within 24 hours to avoid arrest. Call 02XXXXXXX.” Note that this is a scam.
- Academic scams:** Some scammers claim they can help you pass WASSCE or get admission into universities in Ghana. They may ask for money to send you a fake result slip or admission letter. For instance, on Facebook, someone posts: “Need help passing WASSCE 2025? Pay GH¢300 for leaked questions” or “UG Admission 2025 is closing soon!” Pay GH¢500 to secure your slot. Note that these are scams.

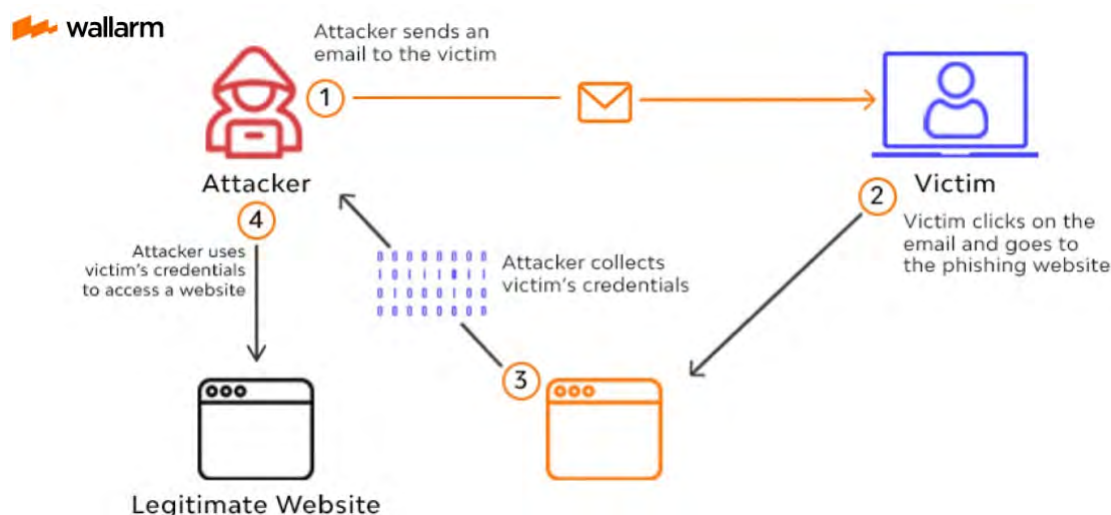


Figure 5.1 Phishing Attacks Process

4. Ransomware and Malware

Malware stands for malicious software are harmful programs or files that damage computers, steal data or block access to important systems. Ransomware on the other hand is a special type of malware that locks your files and demands payment (a ransom) to unlock them.

- a. **School computer infections:** Some schools in Ghana have computer labs that are connected to the internet but have weak security. A student or teacher can unknowingly download a file that locks all the computers of the school and displays a message such as “Your files have been encrypted. Pay GH¢1,000 in Bitcoin to recover them.” The school cannot access lesson notes, exam results or admin records unless the ransom is paid.
- b. **USB-spread malware:** In Ghana, flash drives are commonly used to transfer files between computers. Some students or teachers plug infected USB drives into school or café computers. These USBs can contain hidden malware that automatically copies private files, installs keyloggers to record what you type (including passwords), and slows down or damages the computer.
- c. **Fake apps:** Scammers create mobile apps that pretend to be useful like free loan apps, health apps or even WAEC result checkers but are secretly stealing your data. These fake apps can access your contacts and photos, record your keystrokes or send your data to hackers.

Activity 5.13 Awareness Against Cybersecurity Threats

1. Go online and find out more about cybersecurity threats.
2. Create an awareness campaign material on cybersecurity for different communities using the following types of cyber threats:
 - a. Mobile money fraud targeting market traders
 - b. Social media scams targeting students
 - c. Email phishing targeting office workers
 - d. Online shopping scams targeting urban consumers

The deliverables for the campaign should cover

- a. Real examples of the threat from a Ghanaian context
 - b. How the scam works step-by-step
 - c. Who is most vulnerable and why
 - d. Warning signs people should watch for
 - e. Prevention strategies specific to Ghana
3. Present your deliverables in class.

WHY GHANA IS VULNERABLE

As Ghana becomes more connected through mobile phones, internet banking and online services, cybercriminals are finding more ways to attack. The following reasons explain why the country is at risk:

1. **Rapid digital adoption:** The use of digital platforms such as mobile money, online banking and e-learning has grown quickly in Ghana. However, most users have not been trained on how to stay safe online.
2. **Limited cybersecurity education in schools and communities:** Most schools in Ghana teach basic ICT but do not focus on how to spot online scams, phishing messages or fake apps. Many communities also lack training programs on digital safety. This contributes to their falling for scams.
3. **High smartphone usage with low security knowledge:** Smartphones are common across Ghana, even in rural areas yet many users do not use passwords, download apps from unknown websites, click on links in suspicious WhatsApp broadcasts and do not install antivirus software. They get attacked at the end.
4. **Trust-based culture that scammers exploit:** Ghanaian society values politeness, respect and trust especially toward authority figures or elders. Scammers take advantage of this and pretend to be bank workers, government officials, school administrators or religious leaders and scam people.

PASSWORD SECURITY AND AUTHENTICATION

Common Password Mistakes

In Ghana, it is easy to find or guess personal information such as full names, birthdates, phone numbers, or hometowns. These details often appear on social media profiles, in public places or are collected casually during registrations for SIM cards, mobile banking, church membership, Ghana card or voter ID card. Cybercriminals use this information to break into your accounts. Also, many Ghanaians make it even easier by repeating common password mistakes.

Examples of Common Password Habits in Ghana

1. **Using Common Words or Patterns as passwords:** People often choose passwords that are easy to remember but also easy for hackers to guess. Adding a few numbers to a name, country, town, institution or city name is not enough. For instance, for a password like “Denu2000”, a hacker who knows you were born in Denu, and your age can guess your password quickly.
2. **Using the Same Password for All Accounts:** Many Ghanaians use the same password for all their different accounts - mobile money, email, Facebook or Instagram. If one of these gets hacked, all the others are in danger. For instance, if a scammer steals your Facebook password and you have used the same password for your mobile money wallet, they can have access to your funds.

3. **Sharing Passwords with Family for Convenience:** In Ghana, it is common to share accounts among siblings or even parents and children. While this seems helpful, it increases the chances of passwords being misused, forgotten or written down and left in public places for unauthorised access.
4. **Using Personal Information in Passwords:** Many people in Ghana still use date of birth such “23031997”, phone number: “02XXXXXXXX”, Ghana Card number, favourite football team like “KKKK99”. This makes it easy for scammers who know even a little about you to crack your password.

Strong Password Strategies: How to Create a Safer Password

A strong password helps to protect your digital accounts from cybercriminals. Weak passwords are easy to guess especially when personal details are publicly available. To protect your email, mobile money and social media, follow these key practices when creating a password:

1. Password Creation Method

- a. **Length:** Minimum 12 characters. The longer your password, the harder it is to crack. Avoid short combinations like “Doe123” or “Ghana1957”.
- b. **Complexity:** Mix the password with uppercase, lowercase, numbers and symbols. This makes the password harder to guess through simple trials or automated tools. For instance, Ghana1957 is a weak password while GhAna!19£57&@* is a strong password.
- c. **Uniqueness:** You must use a different password for each account. Never repeat passwords across services. If one gets hacked, the others remain protected.
- d. **Memorability:** Use local or cultural references you can remember. You do not need to write it down if the password means something to you. Use Ghanaian proverbs, food names or songs and combine them with numbers and symbols. Password: “ILOveGhAnaAkpE2o25!”

This combines patriotism (Ghana), a favourite dish (Akple), the current year and a special character (!).

Activity 5.14 Creating Strong Passwords

Create strong passwords for these scenarios

1. Mobile money account for a market trader in Tamale
2. University email for a student at the University of Ghana
3. Online banking for a teacher in Cape Coast
4. Social media account for a young entrepreneur in Kumasi

Note: You can use this link to verify the strength of your password (<https://www.passwordmonster.com/>)

2. Two-Factor Authentication (2FA)

This is an extra layer of security used to confirm your identity. It requires two steps to log in with your usual password and a one-time code sent to your phone by SMS, Email or generated by an authentication app. Even if someone knows your password, they cannot access your account without the second step.

- Bank apps:** In Ghana, mobile banking platforms require users to receive a one-time password (OTP) on their phone before any transaction can be completed.
- Email accounts:** Gmail, Yahoo, and Outlook allow you to turn on 2FA for better protection.
- Social media:** Facebook, Instagram, WhatsApp Business and TikTok support 2FA through SMS or an app like Google Authenticator.

With the rise in mobile money fraud and account takeovers, 2FA offers a simple but effective way to block cybercriminals even if they have your password.

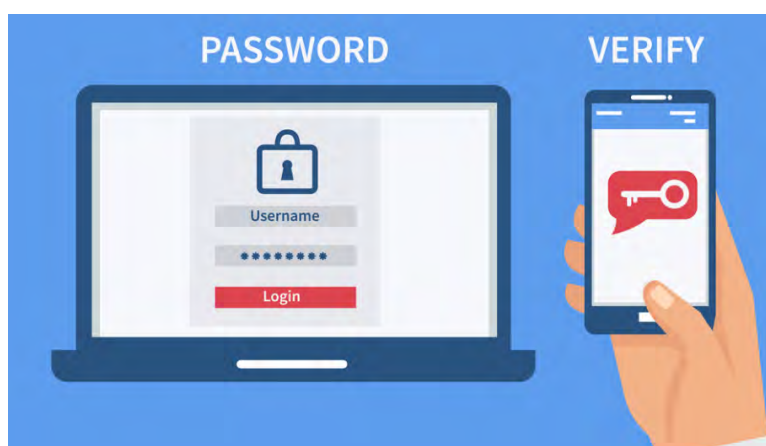


Figure 5.2: 2FA verification

Activity 5.15 Checking Strength of Passwords

Evaluate these common Ghanaian passwords by identifying their strength and the problem with the password, if any. Suggest an improved password where necessary.

Password	Strength			Problem	Improvement
	W	M	S		
ghana123					
MyPhone0244					
ILoveWA&Ho2025					
Sunyani@Airport215					
Takoradi2024!					

SMARTPHONE SECURITY PRACTICES

Mobile phones are widely used in Ghana for banking, communication and daily transactions. This makes them a common target for cybercriminals. To stay safe, users should apply the following security practices:

1. Device Lock Security

- a. Screen locks: Set up a PIN, pattern, fingerprint or face unlock. This stops others from easily opening your phone.
- b. Auto-lock timing: Set your phone to lock automatically after 1 or 2 minutes of inactivity. This reduces risk if you forget to lock it.
- c. Lock screen information: Limit what is visible when locked. Do not allow messages or private information to show on your lock screen. It can reveal personal details to strangers.

2. App Security

- a. Official app stores: Download apps only from official stores such as Microsoft Store, Google Play Store or Apple App Store. Avoid downloading apps from random links or websites.
- b. App permissions: Check what each app is allowed to access. Deny permissions that are not needed to camera, location, contacts, etc.
- c. Regular updates: Keep your apps and operating system of your phone up to date. Updates fix security problems.
- d. App removal: Uninstall apps you no longer use. They can have security weaknesses or collect data in the background.

3. Mobile Money Security

- a. PIN protection: Never share your mobile money PIN to anyone, not even with family members. No telecom agent will ever ask for it.
- b. Transaction verification: Always confirm the name and number before completing a transaction. Double-check to be sure to avoid fraud.
- c. Balance monitoring: Check your wallet balance regularly. Report any strange deduction immediately to your provider.
- d. Secure networks: Free or open Wi-Fi at cafes, stations, or schools is not safe for transactions. Use your mobile data or a secure connection.

Activity 5.16 Checking Security Level Against Cybersecurity Threats

1. Audit your phone or your parents' phones using this checklist
 - Screen lock enabled (PIN/pattern/biometric)
 - Auto-lock set to 2 minutes or less

- Apps only from official stores
 - Mobile money app has additional PIN
 - Bluetooth set to non-discoverable
 - Location services reviewed and limited
 - Regular backups enabled
 - Find My Phone/Device Manager enabled
2. Write a report on your finding after the auditing.
 3. What was good and what needs improvement?
 4. Suggest best ways to protect your phone or parent's phone.
 5. Present your report to your teacher.

PERSONAL DATA PROTECTION

Personal data means any information that can be used to identify you, whether on its own or when combined with other details. It includes both obvious things like your name and more hidden information that still reveals who you are.

Types of Personal Data Commonly Shared

Understanding the types of personal data we often give out can help us protect ourselves better. In Ghana, it is quite normal to share personal information during school registration, job applications, SIM card registration or even online shopping. However, not all situations are safe. Let us look at types of personal data commonly shared:

1. Identity Information

Name, Age, Hometown and School: These are basic details used to identify you in many systems such as schools, banks and hospitals. However, if someone collects this information without your knowledge, they could pretend to be you (identity theft), use your name to create fake social media accounts and target you with scams such as fake scholarship or job offers. We usually give this information out when we are filling out forms for SIM card registration, applying for SHS/University admission or joining WhatsApp groups for school or church.

2. Contact Details

Phone Number, Email and Residential Address: These details allow others to reach you whether for school updates, job offers, deliveries or family communication. In Ghana, phone numbers are especially important. They are tied to mobile money, used for WhatsApp and are often requested during registrations at events, workshops, businesses or even church programmes. However, when these details fall into the wrong hands, they can be used for fraudulent calls and messages, SIM swap fraud, spam and phishing emails.

3. **Financial Information**

Mobile Money PIN, Bank Details (Account Numbers, Card Details). This kind of data gives direct access to your money. In Ghana, mobile money services are widely used not only for personal transfers but also for business transactions, school fees and bill payments. Due to this, financial information is a major target for scammers. If someone gets access to your mobile money PIN, they can withdraw all your money or transfer it to another number, bank login or card number, they can shop online, create fake transactions or empty your account and SMS alerts, they may learn your transaction habits and pretend to be from your bank or mobile money provider.

4. **Biometric Data**

Fingerprints (for phone unlock, bank access), Facial Scans (increasingly for verification): Biometric data refers to your physical traits that are naturally part of you used for identification. Unlike a password or PIN, you cannot change your fingerprint or face if they are stolen or misused. This makes them permanently sensitive information.

In Ghana, when registering for your Ghana Card, you provide your fingerprint and photograph. Also, during SIM re-registration facial capture and fingerprint input were required, some banks now use fingerprint verification for ATM access or account setup and some phones use fingerprints or face ID for unlocking or authorising mobile money or banking transactions. Note that if your biometric data is stored insecurely by an organisation, it could be stolen by hackers and if biometric authentication is combined with poor security, someone who accesses your phone can access everything.

It is there good to only allow biometric registration at authorised centres like NIA, banks and telecom offices, do not use fingerprint or face unlock alone on your phone, rather, combine it with a strong PIN or password and avoid sharing devices with biometric access saved.

5. **Location Data**

Where you go, when you travel (via phone GPS, app usage): Your GPS of your phone tracks your movement even in the background. Some apps request location access even when not in use. When you post photos or statuses, your location may be automatically included. Services like mobile money, ride-hailing and food delivery rely on location. Criminals use your location data to track your daily movement or know when you are not home. Companies sell your movement patterns to advertisers without your knowledge and apps with poor security can leak your real-time location to strangers. Therefore, only allow trusted apps to access your location, check your phone settings to control which apps use GPS, turn off location sharing in apps when it is not needed and be cautious when posting real-time updates.

6. **Social Information**

Friends, Family, Relationships (from social media, contact lists): Many people in Ghana use WhatsApp and Facebook as their main communication tools. Sharing your social network makes it easier for scammers to impersonate someone you know. Social engineering attacks, harassment or blackmail and loss of privacy are risks associated with social information sharing. It is advisable you avoid giving apps full access to

your contact list unless necessary, be mindful of tagging people or revealing family details on public posts, set your social media accounts to private where possible and never trust a request just because it seems to come from someone you know. You have always verified.

Activity 5.17 Data Protection Plan

1. Develop personal data protection strategies by creating a plan or mini booklet that answers:
 - a. What data do I share online?
 - b. Who can see it?
 - c. How can I protect it?
 - d. What should I never share?
2. Explain your plan to the class in 1 – 2 minutes.

Activity 5.18 Cybersecurity Threats and Data Protection

Mobile money scams have become a major cybersecurity threat in Ghana. As a computer science student with knowledge of cyber threats:

1. Create a campaign guide to educate people who are 40+ years old about this threat.
2. Present your guide to the class.

GHANA'S DATA PROTECTION ACT (2012): RIGHTS AND PROTECTIONS

The Data Protection Act (Act 843) is a law passed in 2012 by the Parliament of Ghana. It was created to make sure that your personal information is collected and handled in a safe and lawful way. It applies to anyone or any organisation that collects or processes personal data, whether it is a school, a bank, a hospital or even an online company.

Key Rights of Ghanaians Under the Act

1. Right to Know What Data is Collected

You have the right to be told what kind of personal information an organisation is collecting from you, why they need it and how they plan to use it. This protects you from being kept in the dark about how your information is handled. If an internet café

in Madina asks for your ID before allowing you to browse, they must explain what they are using it for. Whether it is for security, record keeping or reporting.

2. **Right to Correct Wrong Information**

If the personal data an organisation holds about you is inaccurate, outdated or incomplete, you have the right to request that it be corrected or updated. This ensures that decisions made using your data such as school admissions, job applications or financial transactions are based on truthful and current information. If your name is misspelled on a mobile money account or your date of birth is wrongly recorded at your bank, you have the right to demand that they correct the error, so it does not affect your identification or access to services.

3. **Right to Delete Your Data (Right to Erasure)**

You have the right to ask an organisation to delete or remove your personal data in specific situations. This is also known as the right to be forgotten. You can request erasure when the data is no longer needed for the original purpose, you withdraw your consent for it to be used, and the data was collected unlawfully. If you signed up for a marketing SMS service but later decide you no longer want your number stored or used, you can ask the company to delete your number from their records.

4. **Right to Limit How Data is Used (Right to Restriction of Processing)**

You have the right to ask an organisation to limit how they use your personal data especially when certain conditions apply. This does not mean the data is deleted but its use is paused or restricted. You can request restriction if you challenge the accuracy of the data and it is being verified, the processing is unlawful, but you prefer restriction over deletion, the organisation no longer needs the data, but you require it for legal claims or you objected to the processing and a decision is pending. If a bank sends your personal information to third-party marketers and you object to this, you can request that they restrict such processing while your complaint is investigated.

5. **Right to Move Your Data to Another Service (Right to Data Portability)**

You have the right to request your personal data from one organisation and transfer it to another. This must be done in a structured, commonly used and machine-readable format such as CSV or Excel. This right applies when you provided the data yourself during account registration, the processing is based on your consent or a contract, or the processing is carried out by automated means. If you decide to stop using a mobile money service from one provider and switch to another, you can ask the old provider to transfer your transaction history or contact details to the new one, provided the systems support such transfer. This helps maintain continuity in your digital records.

6. **Right to Object to Processing**

You have the legal right to object to the use of your personal data under certain circumstances, particularly when it is being used for direct marketing such as promotional SMS, unsolicited emails, profiling or based on legitimate interests claimed by the organisation. Once you object, the organisation must stop processing your data for that purpose unless they can demonstrate a stronger legal basis to continue. If you begin receiving unsolicited advertising messages after signing up for a service and

you did not agree to be contacted for marketing, you can file a complaint or formally request that the organisation stop using your number or email for such promotions.

Organisations in Ghana that **MUST** Protect Your Data Under the Act

The Data Protection Act, 2012 (Act 843) applies to all organisations (entities) being it public or private that collect, hold, use or disclose personal data. These are known as data controllers and data processors. The law requires them to act responsibly and transparently in handling your information. These organisations include:

1. **Banks and Financial Institutions**

These include commercial banks, savings and loans companies, microfinance institutions and fintech platforms. They process sensitive data such as mobile money PINs, account numbers, transaction histories and biometric verification. Compliance helps prevent financial fraud and identity theft.

2. **Telecommunications Companies**

They collect and store large volumes of personal data from subscribers. This includes call records and SMS logs, internet browsing and data usage history, GPS-based location tracking and SIM registration details. Under the Data Protection Act, these companies are required to ensure that such information is collected lawfully, stored securely and not shared without your consent. Given the sensitivity and scale of the data involved, telecom companies must uphold strong privacy safeguards.

3. **Schools and Universities**

Educational institutions ranging from basic schools to tertiary institutions store personal data about both students and staff. This includes full names, dates of birth and home addresses, academic records and examination results, medical or health-related information, contact details of parents or guardians and disciplinary records and behavioural reports. These institutions have a legal duty to protect such information from misuse or unauthorised access. Proper handling of this data ensures privacy of students and promotes trust between institutions and families.

4. **Government Agencies**

Government bodies across Ghana routinely collect and process personal data for public service delivery. These include the National Identification Authority (NIA), the Ghana Revenue Authority (GRA), Ministries, Departments, and Local Assemblies which gather data for public records, social welfare programmes, business permits and voter registration. These agencies are legally required to safeguard the data they collect. This includes ensuring accuracy, limiting access, securing storage and using the data only for lawful and stated purposes.

5. **Online Businesses**

Any business, being it local or foreign that collects personal data from individuals in Ghana through websites, mobile apps or digital platforms falls under the scope of the Data Protection Act. This includes e-commerce platforms, food delivery apps, ride-hailing services and social media platforms. They are required to protect user data by

securing it against unauthorised access, clearly informing users how their data will be used and allowing them to exercise their rights under the law even if the company is headquartered outside Ghana.

6. Hospitals and Healthcare Providers

Hospitals, clinics, pharmacies, and other healthcare institutions in Ghana collect and store highly sensitive personal data. This includes medical history and diagnosis, laboratory results and prescriptions, National Health Insurance (NHIS) and biometric data and emergency contact and next of kin details. These organisations must ensure confidentiality, accuracy and secure storage of patient information. Given the private nature of health data, any breach can result in serious consequences for individuals, including stigma or discrimination. The law requires that such information be handled with the highest degree of care and only be accessed by authorised personnel.

Activity 5.19 Cybersecurity Policy of Ghana

Discuss the cybersecurity policy of Ghana with your peers.

Activity 5.20 Cybersecurity Threats and Data Protection

1. Design an e-commerce web page for your school.
2. Utilise web page editors and design principles to create visually appealing and user-friendly web pages, incorporating sections, text, images and Graphical User Interface (GUI) elements.
3. Summarise the best practices of cybersecurity you have applied on your designs and campaign.
4. Present your work to the class.

EXTENDED READING

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REVIEW QUESTIONS

1. Give one example of a strong password.
2. Define authentication in computer systems.
3. How do you use XAMPP to start and access the MySQL database server?
4. What steps are involved in creating a new database using phpMyAdmin?
5. How do you define and organise fields (data types, lengths) in a table?
6. How can public Wi-Fi pose a threat to your personal data?
7. Compare a weak password and a strong password. Suggest the best one among them.
8. Design a basic password policy for SHS students.
9. Evaluate the use of biometric authentication on smartphones.
10. How can you use SQL queries to retrieve specific data based on multiple conditions?
11. If your database fails to connect in XAMPP, what troubleshooting steps would you take and why?
12. Create a guide for students to safely use social media. What rules should they follow?

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GLOSSARY

- **Artificial Intelligence (AI):** The ability of machines to think, learn and make decisions like humans.
- **Authentication:** The process of verifying the identity of a user before granting access to a system or data.
- **Backup Software:** Utility that creates data copies to restore information in case of loss or failure.
- **Backup:** A copy of your important data saved in a safe place (like an external drive or cloud storage) so you can recover it if something goes wrong.
- **Backup:** Making a copy of data.
- **BIOS/UEFI:** Basic firmware on a motherboard that initiates hardware during boot-up and prepares the system to load the OS.
- **Bluetooth:** A short-range wireless technology that connects devices like phones, headphones, and speakers.
- **Clock Cycle:** A single tick of the system clock that defines when data is processed or transferred.
- **Cloud Storage:** Saving data online.
- **Command-Line Interface (CLI):** Text-based interface for controlling and managing system tasks using typed commands.
- **Conventional System:** A basic computer system that follows fixed instructions only.
- **Critical Path:** The longest sequence of dependent steps in a digital circuit determines the minimum operating time.
- **Data Breach:** An incident where sensitive, protected, or confidential information is accessed or disclosed without permission.
- **Data Mining:** Using AI to discover patterns and useful information from large data sets.
- **Device Driver:** Software that enables communication between the operating system and hardware devices.
- **DHCP (Dynamic Host Configuration Protocol):** A system that automatically assigns devices IP addresses when they connect to a network.
- **Disk Defragmenter:** A utility that reorganises fragmented data on hard drives for faster access.
- **DNS (Domain Name System):** It translates website names (e.g., www.google.com) into IP addresses.
- **App Permissions:** The access rights that mobile apps request, such as access to contacts, camera or location.
- **Encryption:** A way of scrambling data so only someone with the right key or password can understand it.
- **Encryption:** The process of converting information into a secret code to protect it from unauthorised access.
- **Expert System:** An AI system that mimics a human decision-making expert.

- **Facial Recognition:** AI that can identify people based on their face.
- **Fail-Safe:** A design feature that ensures a system defaults to a safe condition in the event of failure.
- **File Compression:** Process of reducing file size for easier storage or transmission.
- **Firmware:** Embedded software in hardware devices that controls low-level operations, such as BIOS/UEFI.
- **Flash Drive:** A portable device that stores data using flash memory.
- **Graphical User Interface (GUI):** Visual interface that allows users to interact with software using windows, icons and menus.
- **Hard Disk Drive (HDD):** A storage device inside most computers that saves programs and files.
- **Hybrid System:** Combination of both rule-based computing and intelligent features.
- **Intelligent System:** A system that can learn, adapt and make decisions without being reprogrammed.
- **IPv4:** The older version of IP addressing using four numbers (e.g., 192.168.0.1). It's still common today.
- **IPv6:** The newer version of IP addressing, using longer and more complex addresses to support more devices.
- **Learning Algorithm:** A method used by AI to improve from data over time.
- **Logic Synthesis:** Translating high-level behaviour into optimised gate-level hardware representations.
- **Malware:** Harmful software designed to damage, disrupt or gain unauthorised access to a computer.
- **Memory Management:** Function of the OS that allocates and monitors system memory usage.
- **Modem:** A device that connects your network to the internet, usually provided by your internet service provider (ISP).
- **Multi-Factor Authentication (MFA):** A security method that requires two or more ways to prove who you are before you can log in (e.g., password + code sent to your phone).
- **Multitasking:** An OS capability allowing multiple processes to run simultaneously.
- **Network Configuration:** Process of setting up system connectivity through IP addressing, firewall settings and routers.
- **Network Topology:** The physical or logical layout of how computers and devices are connected in a network (e.g., star, bus, ring, mesh).
- **Operating System (OS):** Core software that manages hardware and software resources, providing services for computer programs.
- **Optical Disk:** A disk like a CD or DVD that uses light (laser) to read/write data.
- **Overflow:** A condition where the result of a calculation exceeds the storage capacity of the system.

- **Patch Management:** Applying updates and fixes to software to improve security and functionality.
- **Personal Data:** Any information that can be used to identify an individual such as name, ID number or phone number.
- **Phishing:** A type of cyber-attack where criminals send fake messages to trick people into giving personal data.
- **Phishing:** A type of online scam where someone tries to trick you into giving out personal information, like passwords or bank details.
- **Process Management:** Oversight of running applications and tasks by the operating system.
- **Real-Time Operating System (RTOS):** Specialised OS designed for tasks with strict timing and reliability requirements.
- **Redundancy:** Adding extra components or processes to a system to increase reliability or availability.
- **Registry Cleaner:** Utility that removes obsolete entries from the Windows Registry to improve performance.
- **Router:** A device that connects different networks and helps data find the best path to travel on the internet.
- **Scalability:** The ability of a computer network to grow (add more devices or users) without slowing down or failing.
- **Secondary Storage:** Storage media like hard drives, USBs or CDs that keep data permanently.
- **Shift Operation:** Moving binary digits left or right, often used for fast multiplication or division.
- **Shift-and-Add Multiplication:** A method of multiplying binary numbers using shifts and additions instead of full multipliers.
- **Social Engineering:** Manipulative tactics used by attackers to trick people into sharing confidential information.
- **Solid State Drive (SSD):** Faster and more durable version of a hard drive.
- **Strong Password:** A password that is difficult to guess usually containing a mix of letters, numbers and symbols.
- **Switch:** A network device that connects multiple devices (like computers and printers) in a local area network (LAN) and manages data traffic efficiently.
- **System Administration:** Maintenance tasks performed to ensure system stability, security and efficiency.
- **System Software:** Programs essential for running a computer, including operating systems, device drivers and utilities.
- **Timing Analysis:** The process of checking signal timing in digital circuits to ensure correct operation.
- **Two-Factor Authentication (2FA):** A security measure that requires two separate forms of identification before access is granted.

- **Two's Complement:** A method for representing negative numbers in binary and performing subtraction.
- **Utility Software:** Tools designed to optimise, maintain and protect a computer system (e.g., antivirus, disk cleanup).
- **Virtual Machine:** Software-based emulation of a computer system used to run multiple OS environments on one physical device.
- **Wi-Fi:** A wireless way of connecting devices to a network or the internet using radio waves.

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