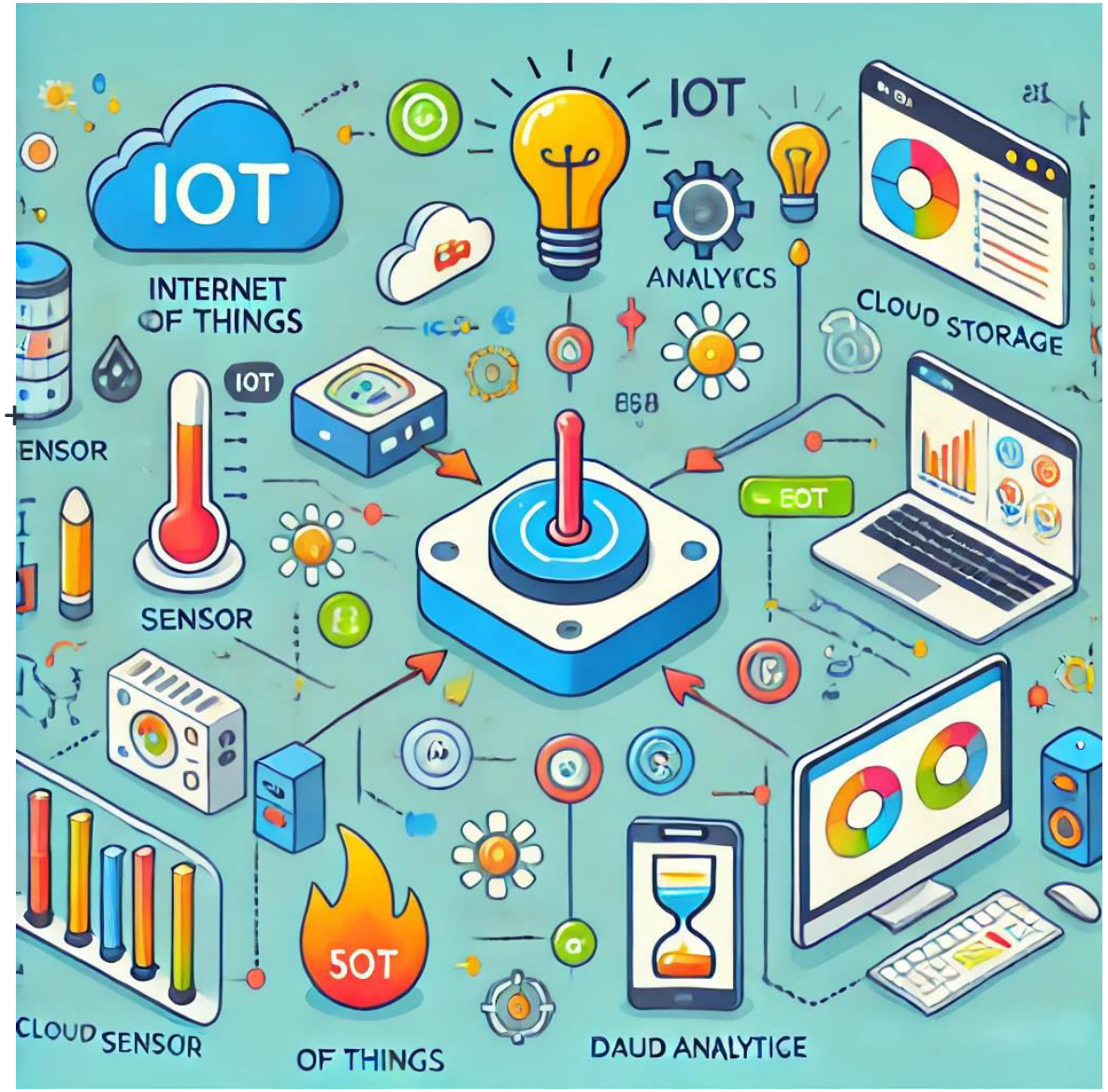
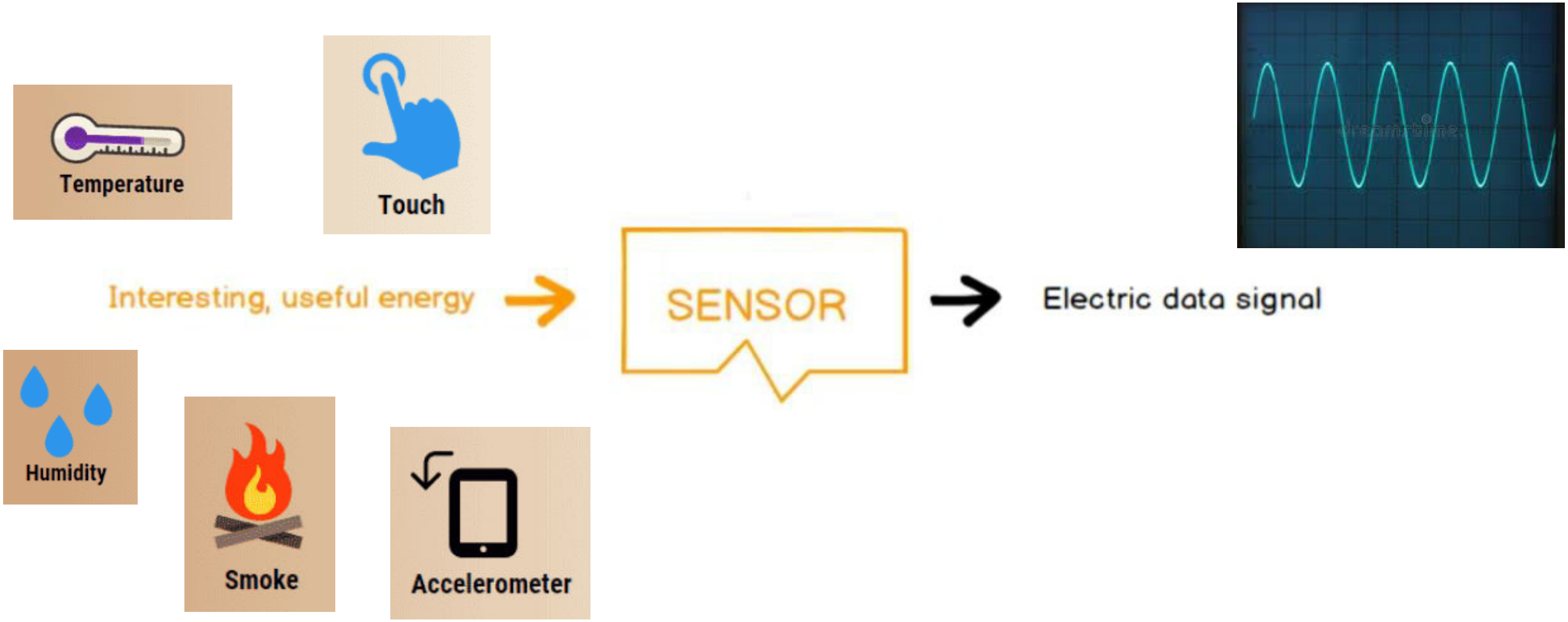
CH - 3 : IOT Sensors and Actuators

IoT = Physical object (“thing”) + Controller (“brain”) + Sensors + Actuators + Networks (Internet)



Sensors


Temperature
Touch
Humidity
Smoke
Accelerometer
Interesting, useful energy
SENSOR
Electric data signal

Sensors :

- A **sensor** is a device that **detects changes** and **events** in a **physical environment**.

- It may convert physical parameters like **humidity, pressure, temperature, heat, motion, etc.**, into **electrical signals**.

- This signal can be converted into a **human-readable display** and sent across a **network** for **additional processing**.

- There are the two primary types of sensors.
  - Active sensors
  - Passive sensors

- **Active sensors** necessitate a **power supply**, whereas **passive sensors** **don't require** a **power supply.**

Key role of Sensors in IoT:

Data Collection:
Sensors are the primary source of data in an IoT system. They collect real-time information from their surroundings, which can be anything from environmental conditions to machine status in an industrial setting.

Communication: Sensors transmit the collected data wirelessly to an IoT gateway or hub. This can happen via various communication protocols such as Wi-Fi, Bluetooth, Zigbee, LoRa, or cellular networks.

Triggering Actions: Based on the data collected, sensors can trigger specific actions automatically. For example, a motion sensor in a smart home could turn on lights when it detects movement.

Monitoring and Control: IoT sensors enable remote monitoring and control. For instance, in a smart city, sensors can monitor air quality, traffic conditions, or utility usage, allowing city managers to respond quickly to issues.

Need of sensors in IoT:

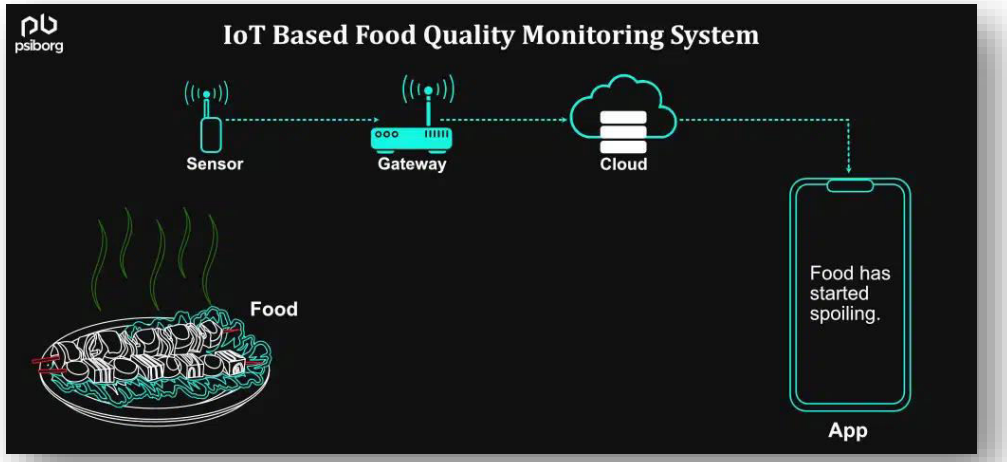
1. To provide Real-time data.

2. To improve Safety

Smoke or fire detector

3. To Automate processes

4. To improve Product quality



5. To reduce costs

Detect abnormal vibrations in machinery

Classification of Sensors in IoT:

1. Active Sensors
2. Passive Sensors

Active sensors :

- Active sensors in IoT are devices that actively emit energy in the form of sound, light, or electromagnetic waves to detect, measure, and interact with their environment.

- They then analyze the changes in the reflected signal to gather information about the surroundings.

- This active emission allows them to detect precise data like distance, speed, and movement, making them highly suitable for applications requiring accurate real-time measurements.

Types of Active Sensors in IoT:

Ultrasonic Sensors:

- Emit ultrasonic sound waves and measure the time taken for the echo to return, determining the distance to an object.Used in obstacle detection, parking sensors, and level measurement.

Lidar Sensors:

- Emit laser light and measure the time it takes for the light to return, creating a 3D map of the surroundings.Used in autonomous vehicles, terrain mapping, and environmental monitoring.

Radar Sensors:

- Emit radio waves and analyze the reflected signals to detect objects, their speed, and direction.Used in automotive applications (adaptive cruise control, collision avoidance), traffic monitoring, and security systems.

Passive sensors :

- Passive sensors in IoT are devices that detect and measure environmental parameters without emitting any energy of their own.
- They rely on external sources of energy, such as light, heat, or electromagnetic fields, to gather data from the environment. Passive sensors are typically used for monitoring and detecting changes in conditions like temperature, humidity, light, pressure, and motion.

Types of Active Sensors in IoT:

1. **Temperature Sensors:** Detect ambient temperature changes without emitting any heat or energy. Examples include thermistors, resistance temperature detectors (RTDs), and thermocouples.
   Applications: Smart thermostats, environmental monitoring, and HVAC systems.

2. **Humidity Sensors:** Measure the amount of moisture in the air using changes in electrical resistance or capacitance.
   Applications: Smart agriculture, weather stations, and indoor air quality monitoring.

3. **Light Sensors (Photocells):** Detect ambient light levels based on changes in electrical resistance when exposed to light.
   Applications: Automatic lighting controls, light-based security systems, and smart devices for energy management.

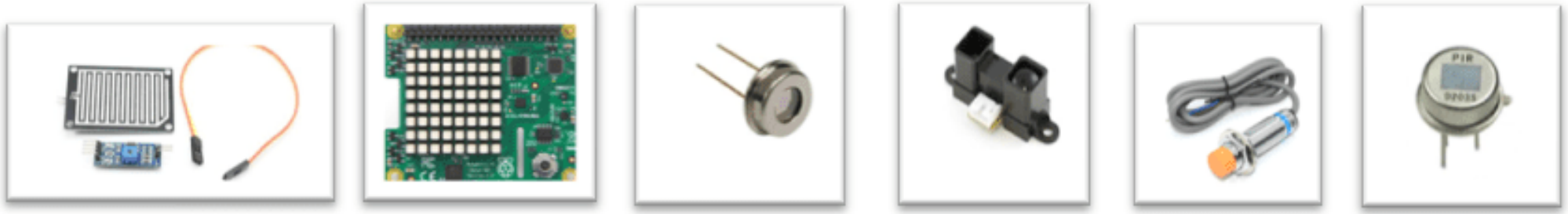
4. **Pressure Sensors:** Measure the force exerted by a fluid (liquid or gas) by converting the pressure into an electrical signal.
   Applications: Tire pressure monitoring, weather forecasting, and industrial process control.

Types of IoT Sensors

Alcohol Sensor | Ultrasonic Sensor | IR optical Sensor | LDR Sensor | Gas Sensor | Gyroscope Sensor

Different types of Sensors

Iot4beginners



Rain Sensor | Sense Hat | Photo Diode | IR proximity Sensor | Proximity Sensor | PIR Sensor

Temperature Sensors

- The temperature sensor senses the heat in the surroundings and can detect any physical change in the temperature.
- The sensor can be embedded with anything, be it humans or objects, where it senses, collects and transfers the temperature data to the control device and, after that, initiates the action according to the defined algorithms.
- In a logistics application, temperature sensors play a vital role in ensuring that shipped product remains within a pre-defined temperature range so that items reach their destination without any damage or quality deterioration.

Use cases of temperature sensors:

https://www.iqsdirectory.com/articles/thermocouple/temperature-sensors.html

- Controlling AC temperature or refrigerator cooling with temperature sensors.
- Monitoring air and water temperature in smart buildings or smart thermostats.
- Checking rise or fall in temperature of food storage areas in the food industry.
- Real-time monitoring of soil temperature and instant alerts are sent to farmers in agriculture.

Proximity Sensors

- Proximity Sensors are sensors that detect movement or presence of an objects without making physical contact with the object and converts that captured information into an electrical signal.
- Such type of sensors are also called as non contactable sensors.
- Proximity sensors are to be used when the object that needs to be detected is too small, lightweight or too soft to operate a mechanical switch.
- When there is a need for rapid response and high switching rates such as the counting objects, proximity sensors are ideal for the task.
- Proximity sensors should also be used when there's a need to sense material through nonmetallic barriers such as glass, bottles, plastic, or paper cartons or when working in hostile environments that demand electrical isolation from the product being monitored.

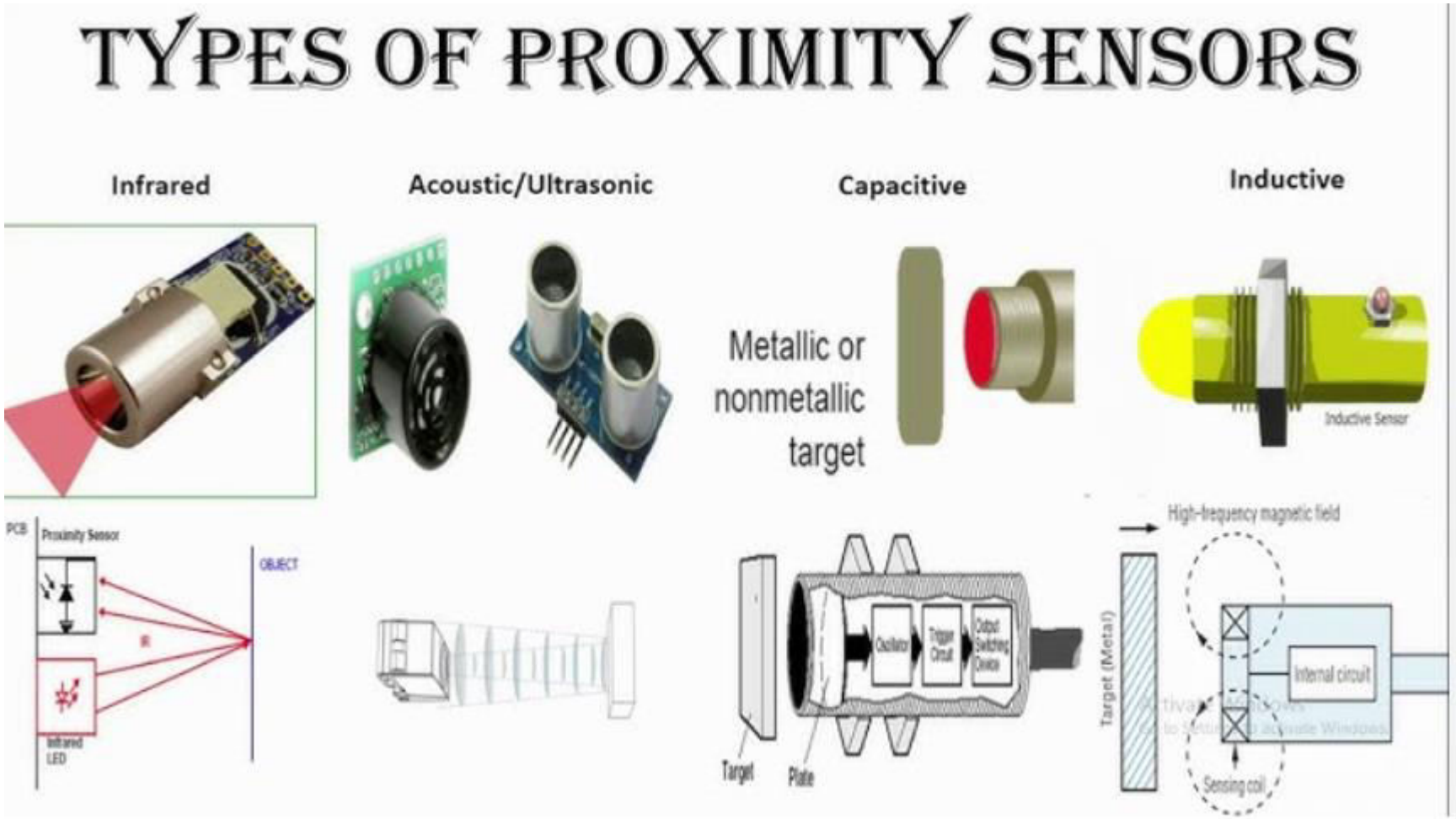
https://electricalacademia.com/motor-control/proximity-sensor-working-principle-inductive-proximity-sensor-capacitive-proximity-sensor/

There Are Many Types Of Proximity Sensors And They Each Sense The Presence Of An Object In Their Own Distinct Ways.

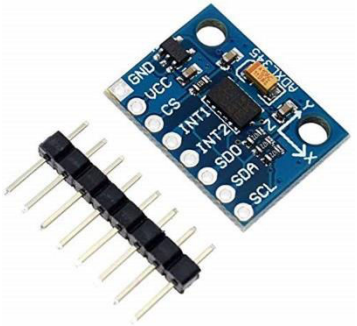
Two Most Commonly Used Proximity Sensors

- Capacitive Proximity Sensor
- Inductive Proximity Sensor

→ **Proximity Sensors**



Accelerometer Sensors



- An accelerometer is a device that measures the vibration, or acceleration of motion, of a structure.
- The force caused by vibration or a change in motion (acceleration) causes the mass to “squeeze” the piezoelectric material which produces an electrical charge that is proportional to the force exerted upon it.
- Since the charge is proportional to the force, and the mass is constant, then the charge is also proportional to the acceleration.
- These sensors are used in a variety of ways – from space stations to handheld devices – and there’s a good chance you already own a device with an accelerometer in it.
- For example, almost all smartphones today house an accelerometer.
- They help the phone know whether it undergoes acceleration in any direction, and it’s the reason why your phone’s display switches on when you flip it. In an industrial setting, accelerometers help engineers understand a machine’s stability and enable them to monitor for any unwanted forces/vibrations.

Applications of Accelerometer Sensors

- **Aerospace** :Accelerometers measure vibration and shock on aircraft, satellites, and spacecraft to prevent damage to equipment and maintain vehicle performance.
- **Vibration monitoring** :Triaxial accelerometers are commonly used to monitor vibration. They are compact and provide three uniaxial sensors.
- **Modal testing** : Accelerometers are used to measure the response of a structure that has been excited by an impact hammer.
- **Tilt sensing** : Accelerometers can measure static acceleration, such as the acceleration of gravity, in tilt-sensing applications.

Motion Sensors

- A motion sensor is a device that notices moving objects, mainly people.
- A motion sensor is frequently incorporated as a component of a system that routinely performs a task or else alert a user of motion in a region.
- These sensors form a very important component of security, home control, energy efficiency, automated lighting control, and other helpful systems.
- The main principle of motion sensor is to sense a burglar and send an alert to your control panel, which gives an alert to your monitoring center. Motion sensors react to different situations like movement in your living room, doors, windows being unbolt or closed and also these sensors can :

1. Activate a doorbell when someone comes close to the front door.
2. These sensors give you an alert whenever kids enter into some restricted areas in the home such as medicine cabinet, the basement or workout room.
3. Conserve energy by using this sensor lighting in empty spaces

Passive Infrared (PIR) Sensor

Ultrasonic Sensor

Microwave Sensor

Actuators :

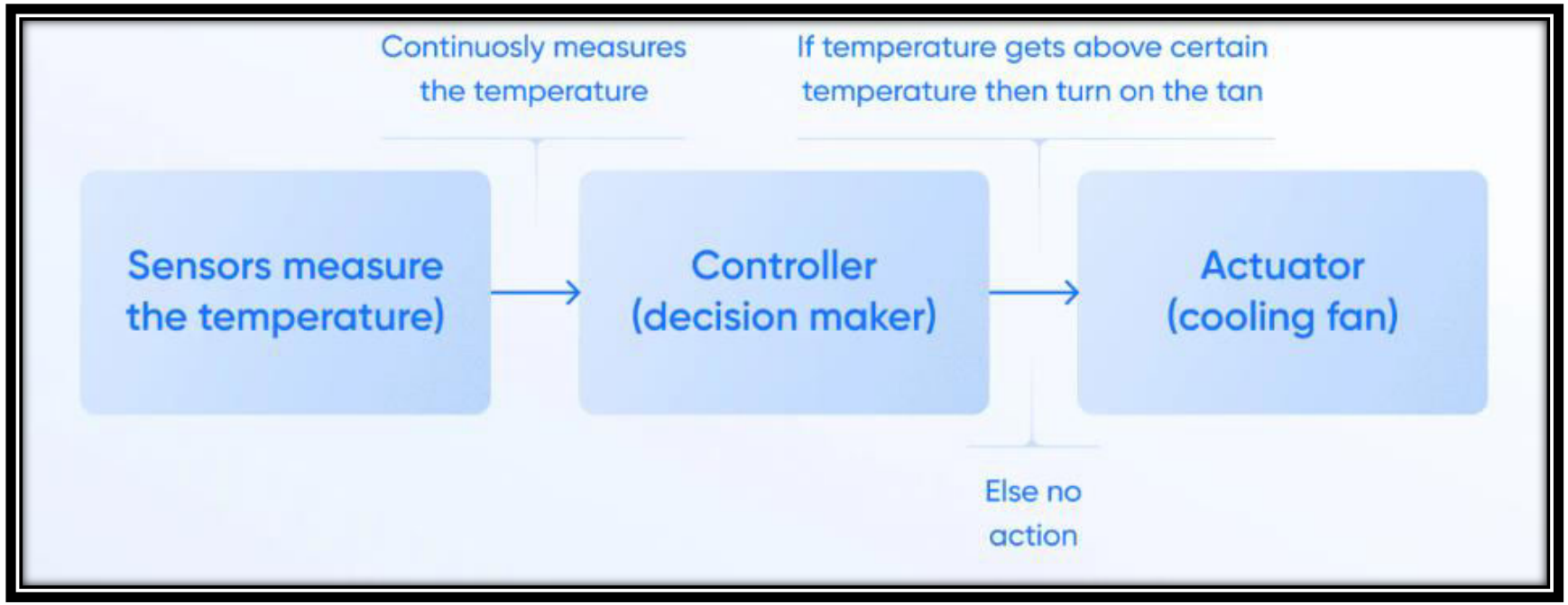
- IoT actuators are mechanical or electromechanical devices that turn energy into motion.
- They combine electrical signals with energy sources, ultimately manipulating the physical world around them.
- An actuator is a machine component or system that moves or controls the mechanism of the system.
- Actuators can open doors, close windows, raise blinds, or move objects to their intended positions.

Working Process of IoT Actuators:

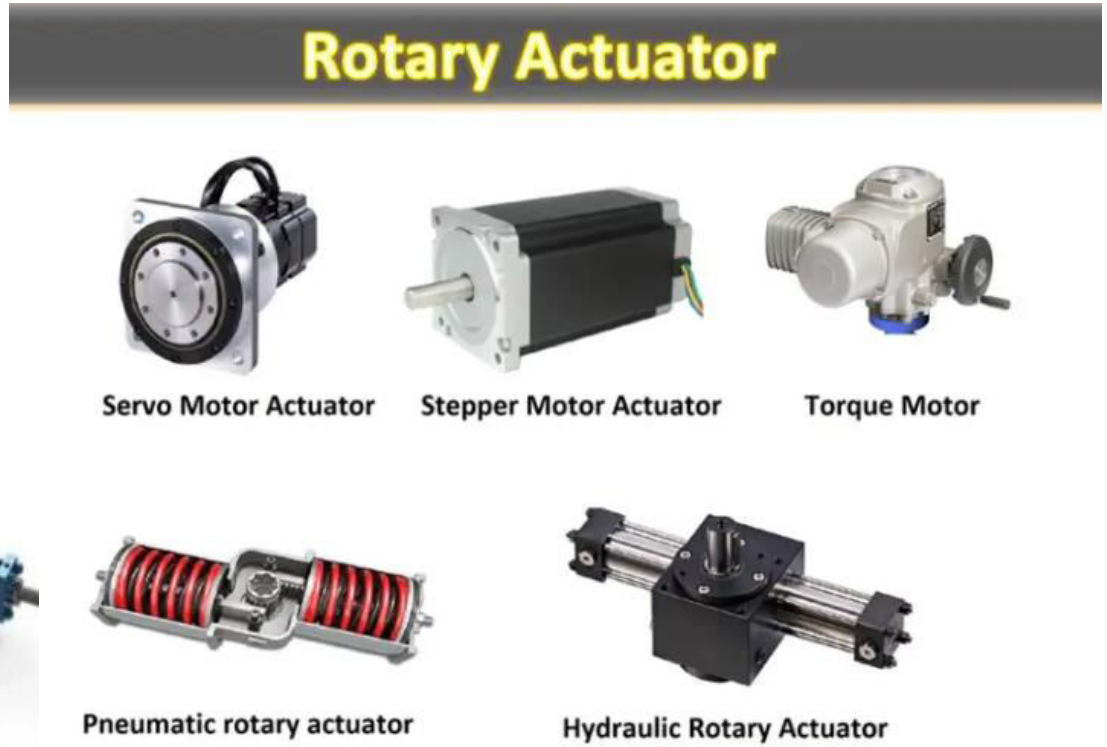
1. IoT sensors gather the data and send it to the IoT controller.

2. The controller transmits the electrical signal to the actuator.

3. The actuator interprets this signal and translates it into a physical movement.



Types of IoT Actuators



Classification of actuators based on the motion

Rotary Actuator

- Actuators that are capable of producing circular motion are known as rotary actuators.
- When considering rotational movement, it's challenging to envision any other device besides motors.
- This special device is really good at doing tasks that involve things turning around. It's like the turning part in a big machine, smoothly doing jobs that need circular motion.
- Rotary Actuator is that it can fit into many different situations.
- It works in factories, helping control how things are positioned, and in robots, making sure their arms or hands move just right.

Linear Actuators

- Linear actuators are devices that convert energy into straight-line or linear motion.
- They play a big role in various applications, such as robotics, automation, and manufacturing.
- Linear actuators are used to push, pull, lift, or position objects, providing precision and control in various industries. where linear movement is essential for operational efficiency.
- The Linear Actuator application works like a magic wand, turning round movements into straight-line motion with super accuracy.
- This special ability makes it really important in lots of areas, like making things in factories, moving robots, and even in medical and car stuff.

Classification of actuators based on the energy source

Electromagnetic Actuators

- Electromagnetic actuators are devices that convert electrical energy into mechanical motion.
- Electric motors generate force and transfer it through gears, screws, or other mechanisms to create linear or rotary movement.
- Electromagnetic actuators are commonly used in robots, aircraft, factories, and even medical equipment, these accuators offer precise control, fast response times, and clean operation.
- They're also becoming increasingly popular due to their energy efficiency and ease of maintenance.

AC and DC Servo Motor actuators

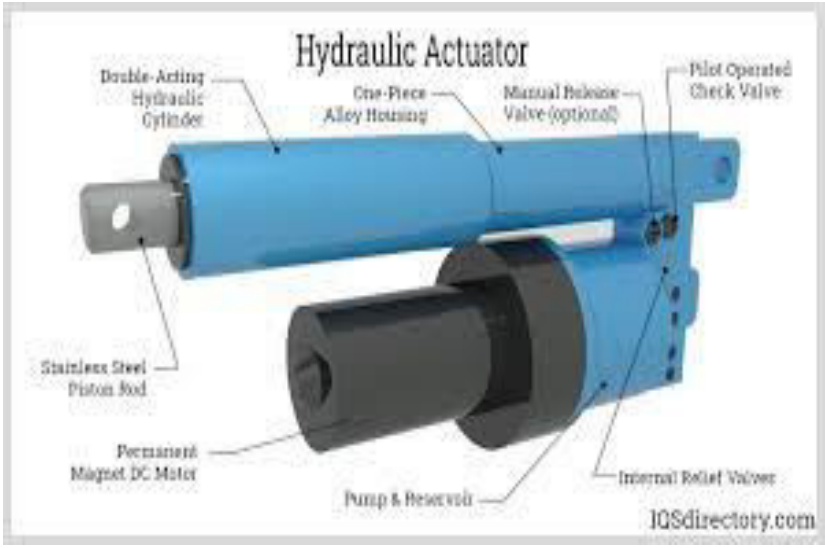
- Both AC and DC servo motor actuators are high-powered devices that convert electrical signals into controlled mechanical movement.
- AC servo motors excel in high-speed applications, while DC servo motors offer precise position control.
- Widely employed in robotics and automation, they enhance the efficiency and accuracy of various mechanical systems with their tailored capabilities

Hydraulic Actuators

- Hydraulic actuators are mechanisms that use liquid, typically oil, to generate controlled mechanical movement.

- It's like a piston inside a cylinder filled with hydraulic fluid. When pressure is applied, the fluid pushes the piston, creating linear motion.

- Hydraulic actuators find wide applications in various industries due to their ability to provide powerful and precise movement, making them essential components in machinery, construction equipment, and industrial systems.



Difference between actuators and sensors

Sensors	Actuators
The sensor reads mechanical characteristics as input data	The actuator takes command in the form of electrical signal as input.
The sensor returns electrical signal as output.	Actuator has physical movement as output
The sensor sends data about the engine to the ECU	The actuator receives command from the ECU to control the engine.
The sensor rarely uses power source to operate.	The actuator needs power source to operate
Examples of sensors are temp sensor, oil sensor, mass air flow sensor	Examples of actuators are solenoids, relays, and electronic injector pumps.

IoT boards

- IoT boards are useful when we want to prototype a new IoT project.
- The IoT market is growing rapidly and so the demand for IoT development boards.
- There are numerous development boards for different IoT devices or embedded computing products that you can use for prototyping or full-scale production.

Typical components of a Development board.

•Power circuit– Generally set up to run off of a 9V power supply

•Programming interface– Let you program the microcontroller from a computer

•Basic input – Usually buttons

•Basic output– Usually LEDs

•I/O pins– Used for motors, temperature sensors, LCD screens, etc.

Key Features That Must be Included in Your Development Board

Any development board you consider for an IoT project must include a few important features.

Processing power: This could be in the form of a CPU, microcontroller, FPGA, or other CPLD. A microcontroller comes in handy for programming your device as many manufacturers provide the IDE you need.

Wireless capabilities: This feature provides wireless communication without including an external transceiver module. Some of the common protocols include Bluetooth, Zigbee, WiFi, and others.

Scalability: This particular feature allows one to add more functionality to the development board? You may verify if the board communicates via GPIO, UART, SPI, or some other protocol; As this will determine how the board interacts with other devices.

Memory: Board memory is important. To store much data, you need built-in Flash memory. A decent board allows connecting a MiniSD or MicroSD card to enhance data storage.

Top IoT Development Board [2020-2021]

Arduino Nano 33

Arduino Nano Every

Arduino Nano 33 Ble

Arduino UNO

Teensy 4.0

Tessel 2

Onion Omega2s+

ESP32

Particle Argon

Most Popular Arduino Boards

ARDUINO NANO

MEGA 2560 REV 3

ARDUINO PRO MINI

ARDUINO UNO R3

MKR WAN 1300/1310

ARDUINO ETHERNET SHIELD 2

ARDUINO MICRO

ARDUINO DUE

NANO RP2040

UNO R4 WiFi

IoT boards will fall into any of the below categories:

1.Microcontroller-based boards:

A microcontroller development board is a printed circuit board(PCB) with circuitry and hardware designed to facilitate experimentation with a certain microcontroller boards features. The Development boards are combined with a processor, memory, chipset and on-board peripherals like LCD, Keypad, USB, serial port, ADC, RTC, Motor Driver ICs, SD card slot, Ethernet, etc. with debugging features. This will save us from messing with the connections with jumper wires and the board.

2. System on Chip (SOC) boards

System-on-a-chip (SoC) is an Integrated Circuit which houses all the critical elements of the electronic system on a single microchip. A SoC can usually have the on-chip memory, microprocessor, peripheral interfaces, , I/O logic control, etc. that are usually found inside a computer system.

3. Single-board Computers (SBC)

Single Board Computers (SBCs) offer a ready-to-use embedded platform to develop any product. This reduces the development time and cost substantially as the platform is application-ready. However, SBCs have two major constraints. These platforms cannot be scaled to accommodate latest processors in future, as the CPU and I/O sections are integrated on a single board. Secondly, customizing a SBC is impossible as the processor CPU and I/Os are already fixed.

1. **Raspberry Pi**

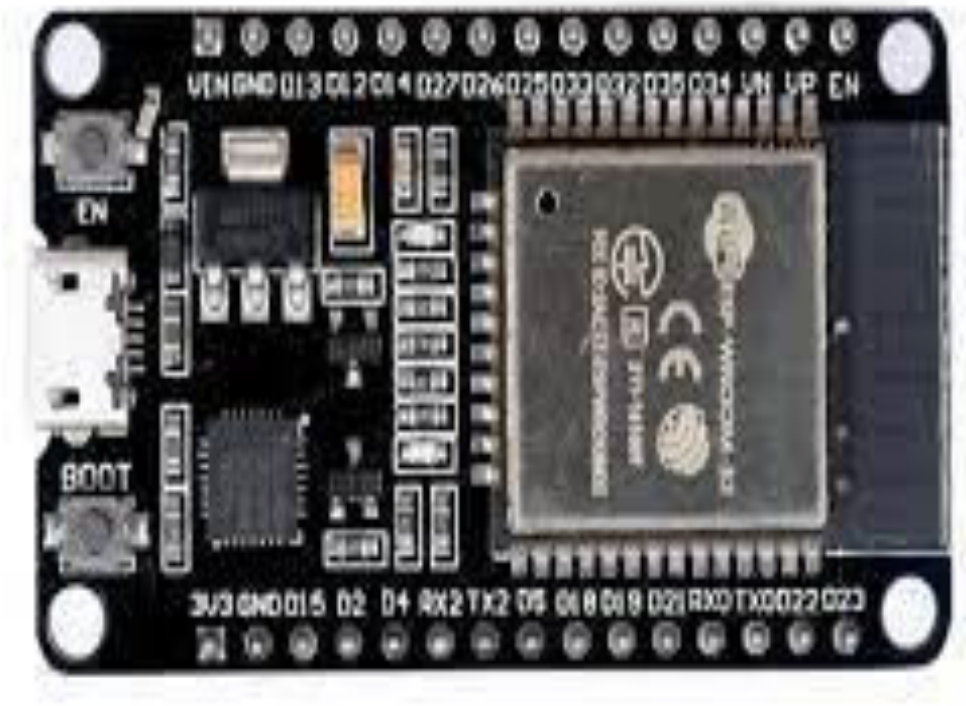
- Raspberry Pi is a much popular device used in building IoT project. The recently launched Raspberry Pi 4 includes built-in WiFi and Bluetooth making the most compact and standalone computer.
- It provides a powerful environment to install a variety of programming packages such as Python, Node.js, LAMP stack, Java and much more. Using 40 GPIO pins, and four USB ports you can connect many peripherals and accessories to the Pi.

2. Arduino:

- Arduino boards are the microcontrollers and microcontroller kit for building digital devices that can be sense and control objects in the physical and digital world.
- Arduino boards are furnished with a set of digital and analog input/output pins that may be the interfaced to various other circuits.
- Some Arduino boards include USB (Universal Serial Bus) to load programs from the personal computer.

3. ESP8266:

- This board is a low-cost board with a built-in WIFI system that enables rapid IoT project prototyping.
- It comes with several variants having specific features like memory capacity or pins number. We can use the Arduino IDE to develop IoT application.

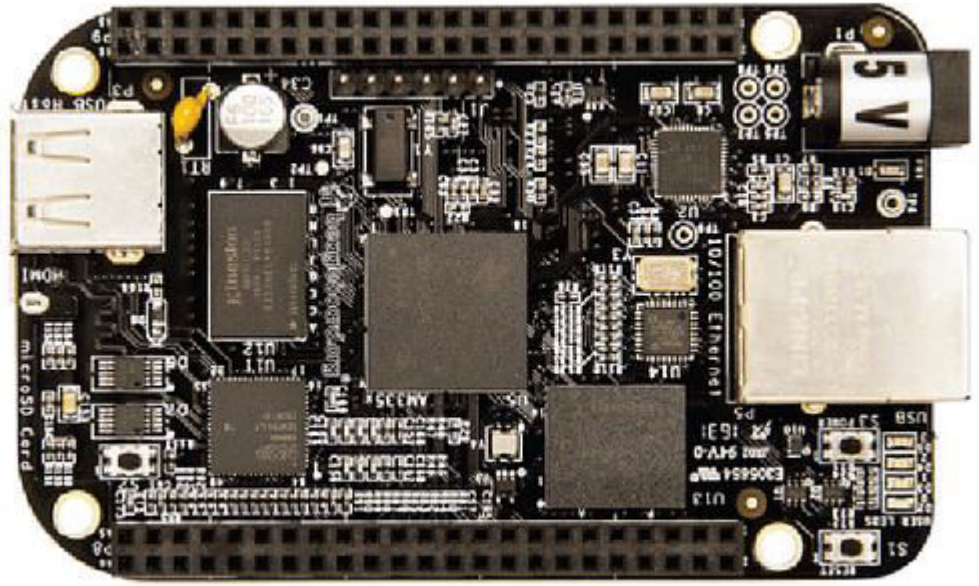


4. ESP 32

- ESP32 is a dual core low-footprint system development board powered by the latest ESP-WROOM-32 module that can be easily placed into a solderless breadboard.
- It has a pre-integrated antenna, power amplifier, low-noise amplifiers, filters, and power management module. Because of this, it’s easy to build and test circuits as well as making projects related to IoT integrating with the cloud platform.

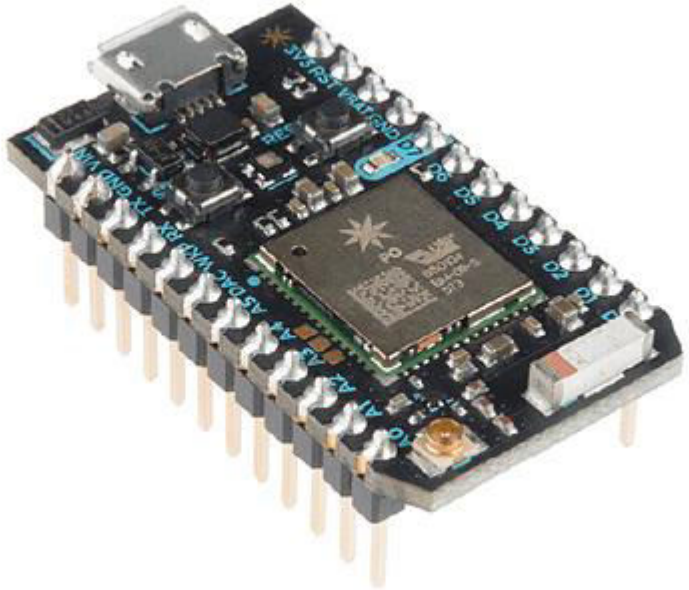
5. Beagle Bone

- The Beagle bone is a low power open-source single-board computer produced by Texas instruments. The board can boot Linux in under 10 seconds also you can start developing in less than 5 minutes with just a single USB cable.
- It is a computer installed inside of a larger electronics project. The beagle board carries two rows of GPIO (general purpose Input/Output) pins mounted along each side of the board.
- That allow it to communicate with a wide range of servos, sensors, outputs and other hardware, making it act as the brain of large & complex projects.



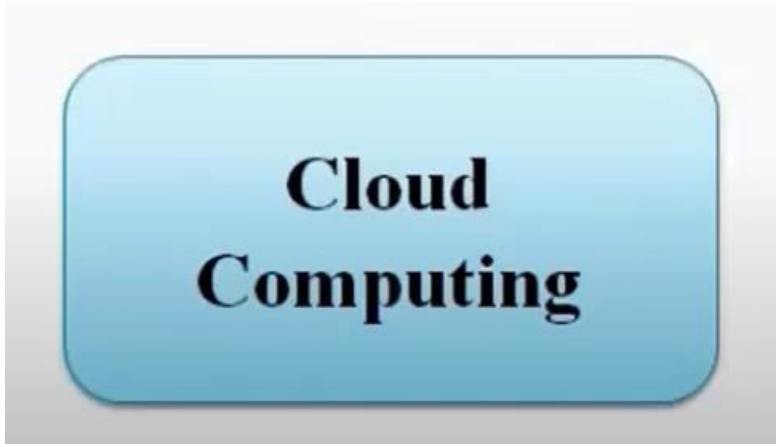
6. Particle Photon

- Particle Photon Board consists of an STM32 microcontroller, Wi-Fi, Switches, and LEDs. Simple to use, powerful, and connected to the cloud.
- Powered by a Cypress Wi-Fi chip alongside a powerful STM32 ARM Cortex M3 microcontroller, it is ideal for prototyping IoT projects.



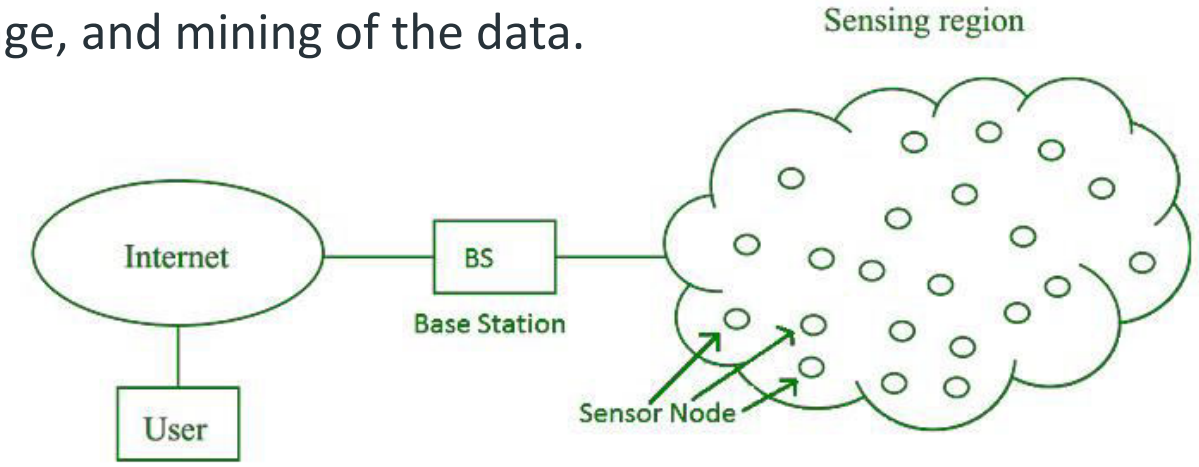
IoT Enabling Technologies

The ***Internet of Things (IoT)*** is enabled using many technologies such as



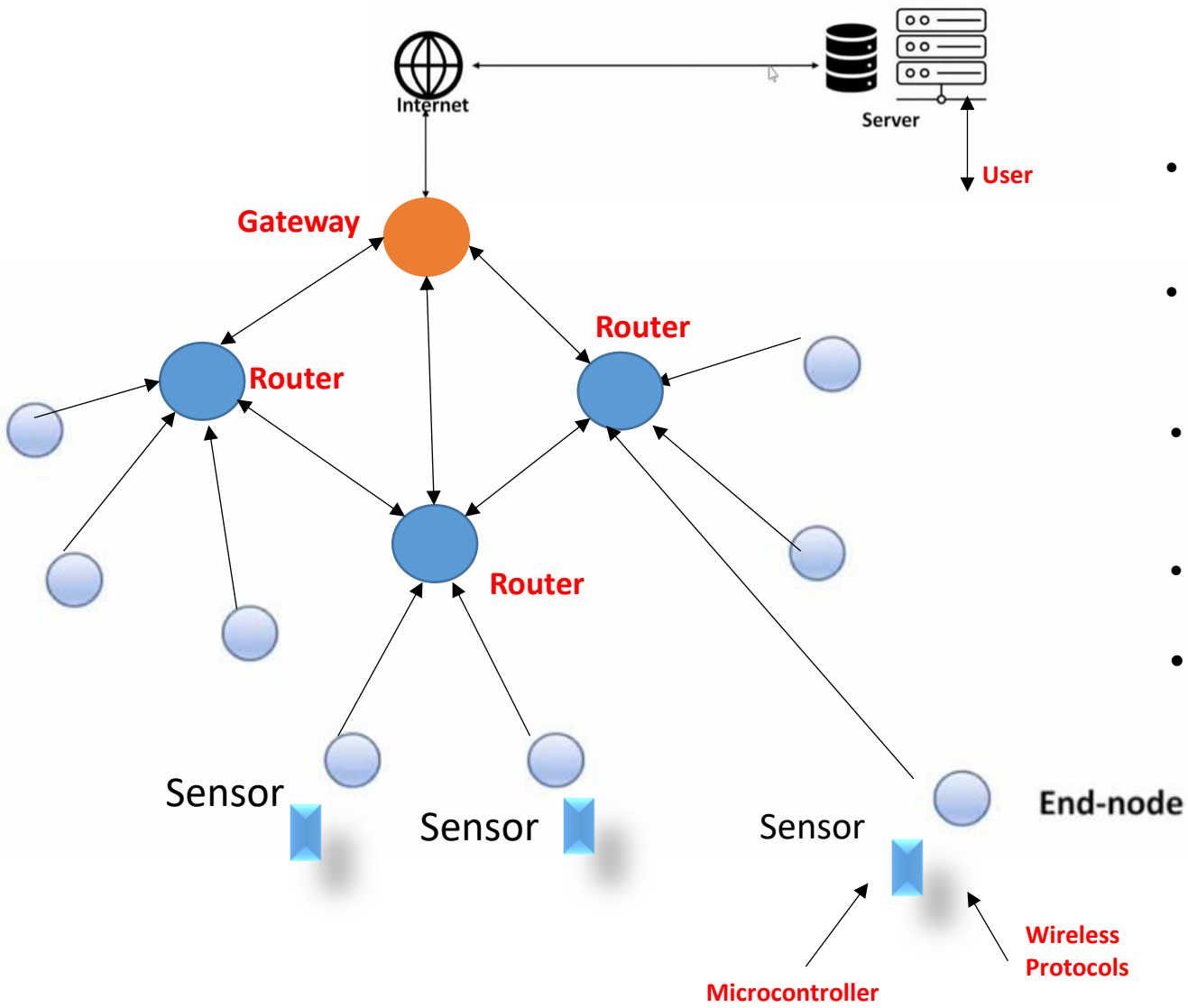
Wireless Sensor Network

- Wireless Sensor Network (WSN), is an infrastructure-less wireless network that is deployed in a large number of wireless sensors in an ad-hoc manner that is used to monitor the system, physical, or environmental conditions.
- Sensor nodes are used in WSN with the onboard processor that manages and monitors the environment in a particular area.
- They are connected to the Base Station which acts as a processing unit in the WSN System.
- The base Station in a WSN System is connected through the Internet to share data.
- WSN can be used for processing, analysis, storage, and mining of the data.



Basic architecture of WSN

- Major essential role in this architecture is end nodes.
- This end nodes are sensors which are used to capture physical data.
- That data should be transmitted to a central system. So all these end nodes are having sensor, So here this end nodes will be embedded system as well as use wireless protocol for communication.



- Sensor nodes are used in WSN with the onboard processor (microcontroller) that manages and monitors the environment in a particular area.
- That microcontroller is also attached with Wi-Fi card or Bluetooth card or Zigbee card.
- Once that physical data is measured, that will be routed to router with wireless communication.
- Now this router will be having physical data of multiple end nodes.
- So this data is given to gateway.
- Gateway will pass collected data to internet where there wil be server on which we will be storing all the physical data.
- User will be use or access the data as per application.

Basics of Wireless Sensor Networks

- A Wireless Sensor Network (WSN) comprises of distributed devices with sensors that are used to monitor the environmental and physical conditions.
- A WSN consists of a number of end nodes and routers and a coordinator.
- End nodes have several sensors attached to them. End nodes can also act as routers.
- Routers are responsible for routing the data packets from end nodes to the coordinator.
- The coordinator collects the data from all the nodes.
- The Coordinator also acts as a gateway that connects the WSN to the Internet.

WSN Network Topologies Wireless Sensor Networks (WSNs) can be organized into different network topologies based on their application and network type.

Bus Topology: In a Bus topology, multiple nodes are connected to a single line or bus. Data travels along this bus from one node to the next. It's a simple layout often used in smaller networks.

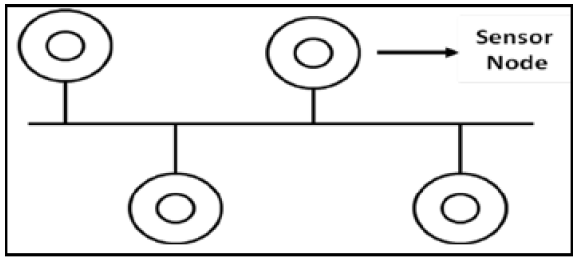


Fig. 2.1: Bus Topology

Star Topology: In Star topology have a central node, called the master node, which connects directly to multiple other nodes. Data flows from the master node to the connected nodes. This topology is efficient for centralized control.

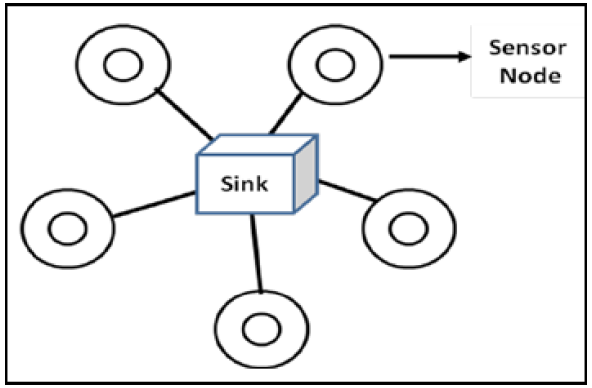


Fig. 2.3: Star Topology

Tree Topology: In Tree Topology arrange nodes in a hierarchical structure resembling a tree. Data is transmitted from one node to another along the branches of the tree structure. It's useful for expanding coverage in hierarchical deployments.

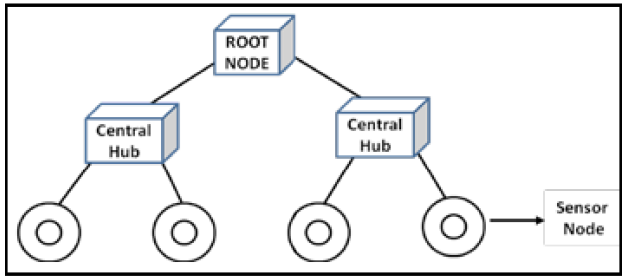


Fig. 2.2: Tree Topology

Mesh Topology: In Mesh Topology feature nodes interconnected with one another, forming a mesh-like structure. Data can travel through multiple paths from one node to another until it reaches its destination. This topology offers robust coverage and redundancy.

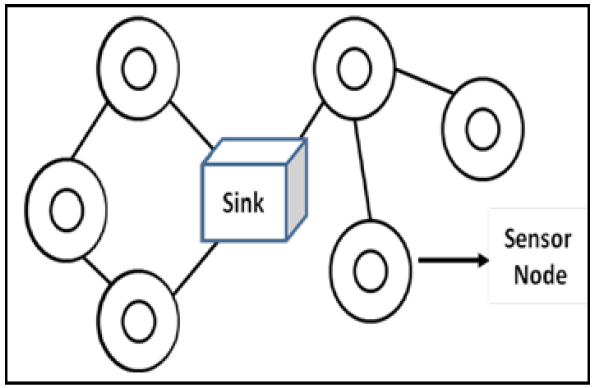
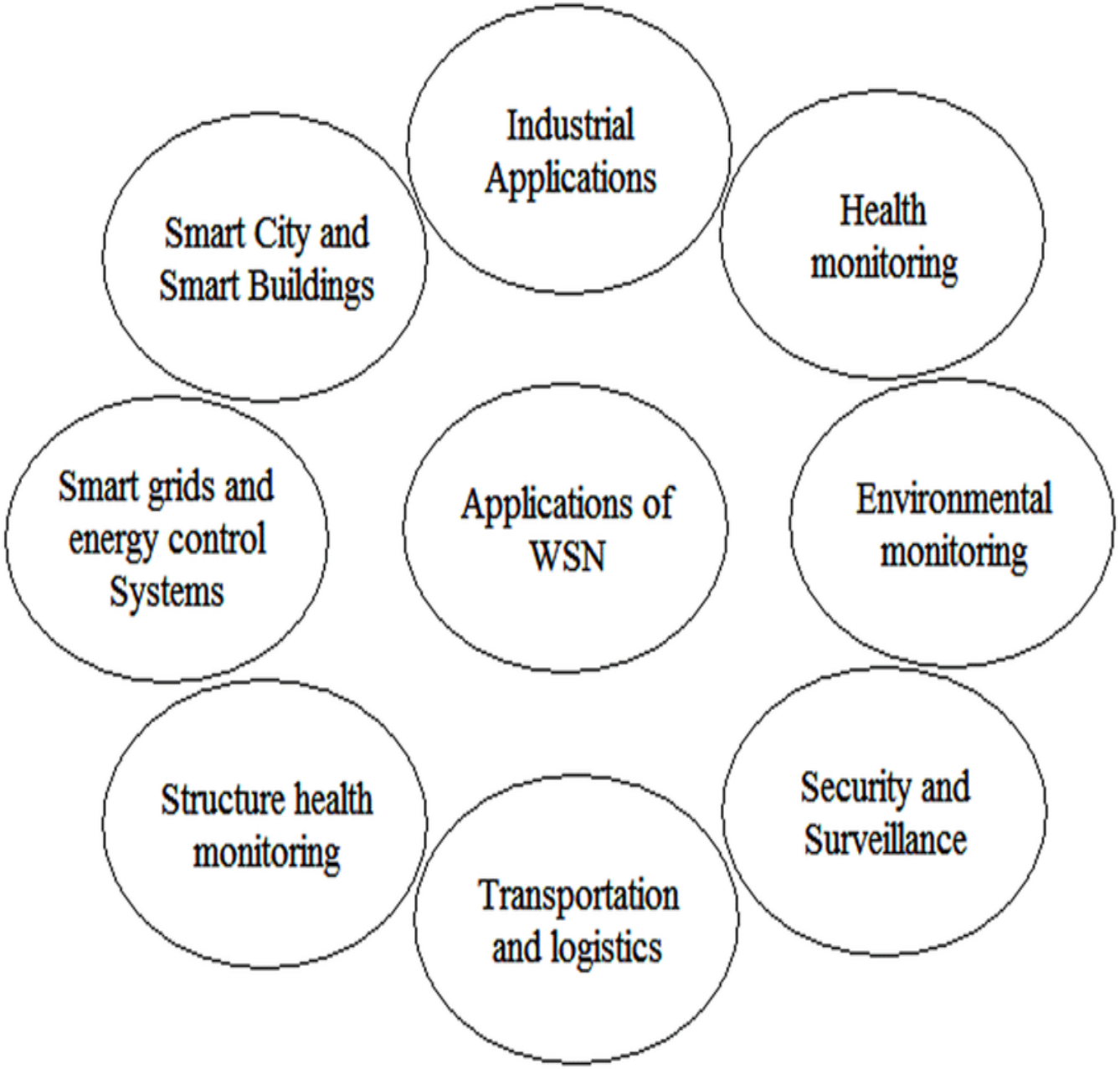


Fig. 2.5: Mesh Topology

Applications of Wireless Sensor Network



Challenges of WSN

1. **Limited power and energy:** WSNs are typically composed of battery-powered sensors that have limited energy resources. Thi makes it challenging to ensure that the network can function for long periods of time without the need for frequent battery replacements.

2. **Limited processing and storage capabilities:** Sensor nodes in a WSN are typically small and have limited processing and stora capabilities. This makes it difficult to perform complex tasks or store large amounts of data.

3. **Security:** WSNs are vulnerable to various types of attacks, such as eavesdropping, jamming, and spoofing. Ensuring the securi of the network and the data it collects is a major challenge.

4. **Scalability:** WSNs often need to be able to support a large number of sensor nodes and handle large amounts of data. Ensuri that the network can scale to meet these demands is a significant challenge.

5. **Interference:** WSNs are often deployed in environments where there is a lot of interference from other wireless devices. This make it difficult to ensure reliable communication between sensor nodes.

6. **Reliability:** WSNs are often used in critical applications, such as monitoring the environment or controlling industrial processe Ensuring that the network is reliable and able to function correctly in all conditions is a major challenge.