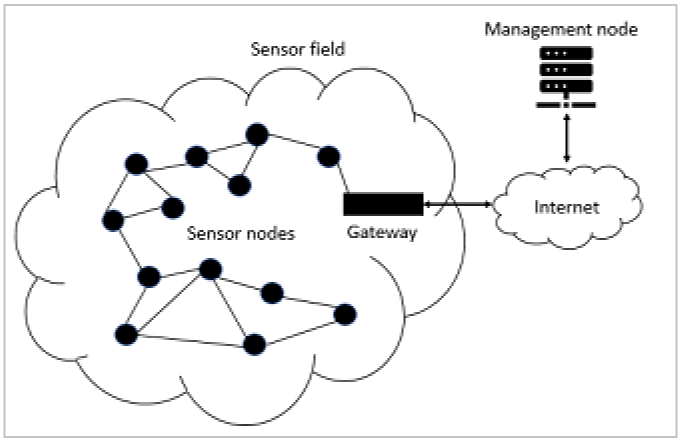
## UNIT-II
# Sensor Networks

**1Q. Define a Sensor Network and explain its role in IoT applications.**

- A sensor network commonly referred to as a Wireless Sensor Network (WSN) is a collection of sensor devices, which are tiny, autonomous electronic units equipped with sensors.




- These sensor nodes are spatially dispersed in a specific area (or) environment.
- Each sensor node can sense data, processing it locally and communicating wirelessly with other nodes (or) a central system.
- The sensor network gathers information, cooperates to transmit it efficiently and delivers the data to a base station (or) gateway for further processing and analysis.

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**2Q. What are the main differences between sensors and actuators? Give examples of each.**

- **Types of Sensors**

  Sensors are devices that detect changes in physical, chemical (or) biological conditions and convert these changes into electrical signals for processing and analysis. There are various types of sensors designed to measure specific phenomena such as temperature, pressure, motion, and light etc. each type of sensor plays a crucial role in enabling precise data collection for diverse applications across industries such as healthcare, environmental monitoring, industrial automation and smart homes.

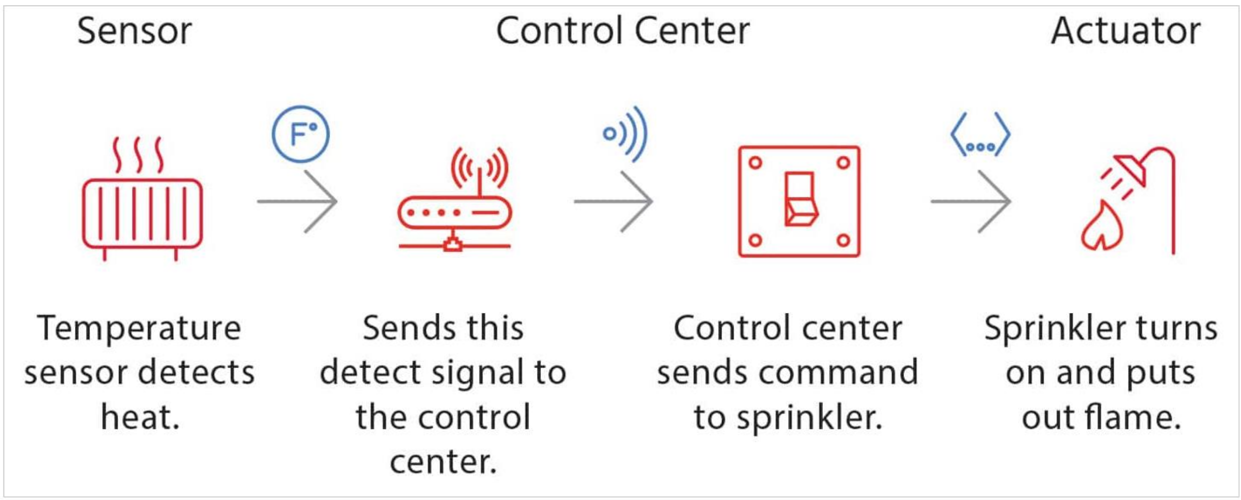
  **Temperature Sensors:** Measure the temperature of the environment (or) object.
  **Ex:** Thermocouples, Resistance Temperature Detectors, thermistors, Infrared sensors.
  **Pressure Sensors:** Measure the pressure of gases (or) liquids.

**Ex:** Piezoelectric Sensor, Capacitive Pressure sensors.
**Humidity Sensors:** Measure the moisture content (or) relative humidity in the air.
**Ex:** Capacitive humidity sensors, Resistive humidity sensors.
**Proximity Sensors:** Detect the presence (or) absence of an object (or) measure the distance to an object without physical contact.
**Ex:** Infrared sensors, ultrasonic sensors, capacitive and inductive sensors.


**Light Sensors:** Measure the intensity of ambient light.
**Ex:** Photodiodes, Phototransistors, Light Dependent Resistors (LDR).
**Motion Sensors:** Detect movement (or) velocity of objects.
**Ex:** Passive Infrared (PIR) sensors, accelerometers, gyroscopes.
**Gas Sensors:** Detect the presence and concentration of gases in the air.
**Ex:** Electrochemical sensors, Metal Oxide Semiconductor (MOS) sensors.
**Sound Sensors:** Detect sound waves and convert them into electrical signals.
**Ex:** Microphones, Acoustic sensors.
**Chemical Sensors:** Detect specific chemicals (or) changes in chemical composition.
**Ex:** pH sensors, ion- selective electrodes.
**Force and Load Sensors:** Measure mechanical force, weight (or) load.
**Ex:** Strain gauges, load cells.
**Displacement Sensors:** Measure linear (or) angular position, displacement (or) rotation.

**Ex:** Potentiometers, hall-effect sensors.
**Accelerometers:** Measure acceleration forces, which can be static (gravity) (or) dynamic (movement).
**Ex:** MEMS accelerometers.

- **Types of Actuators**
  Actuators are devices that convert electrical signals (or) control inputs into physical motion (or) mechanical action, enabling systems to interact with and affect their environment.




- **Electrical Actuators:** Convert electrical energy into mechanical motion.
  **Ex:** Electric motors, solenoids
- **Hydraulic Actuators:** Use pressurized fluid (oil or water) to create mechanical motions.
  **Ex:** Hydraulic motors, Hydraulic cylinders.
- **Pneumatic Actuators:** Use compressed air to generate motion.
  **Ex:** Pneumatic motors, Pneumatic cylinders.
- **Thermal (or) Magnetic Actuators:** Use heat expansion of materials (bimetallic strips) to create movement (or) use magnetic forces to create motion.
  **Ex:** Thermal actuators, magnetic actuators.
- **Piezoelectric Actuators:** Use piezoelectric effect to produce precise movement by applying voltage to special materials.
- **Shape Memory Alloy (SMA) Actuators:** Use special alloys that change shape when heated.

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**3Q. Describe the working principles of various sensors and actuators.**

1. **Example and working of temperature sensor**
   **Example:** NTC Thermistor (Negative Temperature Coefficient)
   **Working:** A thermistor's resistance changes with temperature. For an NTC thermistor, resistance decreases as temperature increases. This change in resistance is measured by the sensor circuit and converted into a temperature reading.
   **Use Case:** Measuring ambient temperature in HVAC.
2. **Example and working of motion sensor (PIR Sensor)**
   **Example:** Passive Infrared (PIR) sensor.
   **Working:** PIR sensors detect infrared radiation emitted by warm objects like humans (or) animals. When a warm body moves within the sensor's field of view, the sensor detects a change in infrared levels, triggering an output signal.

1. **Example and working of electric actuator.**
   **Example:** Brushed DC motor
   **Working:** When DC voltage is applied to the motor terminals, current flows through the windings creating a magnetic field. This magnetic field interacts with the permanent magnets in the motor, producing a force that causes the rotor to spin, and converting electrical energy to mechanical rotary motion.
   **Use Case:** driving wheels in robotics.
2. **Example and working of hydraulic actuator.**
   **Example:** single- acting hydraulic cylinder.
   **Working:** Pressurized hydraulic fluid is pumped into the cylinder chamber, pushing the piston rod outward. This converts fluid pressure into linear mechanical force, moving (or) lifting heavy loads.
   **Use Case:** Excavator arm movement.

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**4Q. What are the key features of Arduino development boards, and how do they support IoT prototyping?**

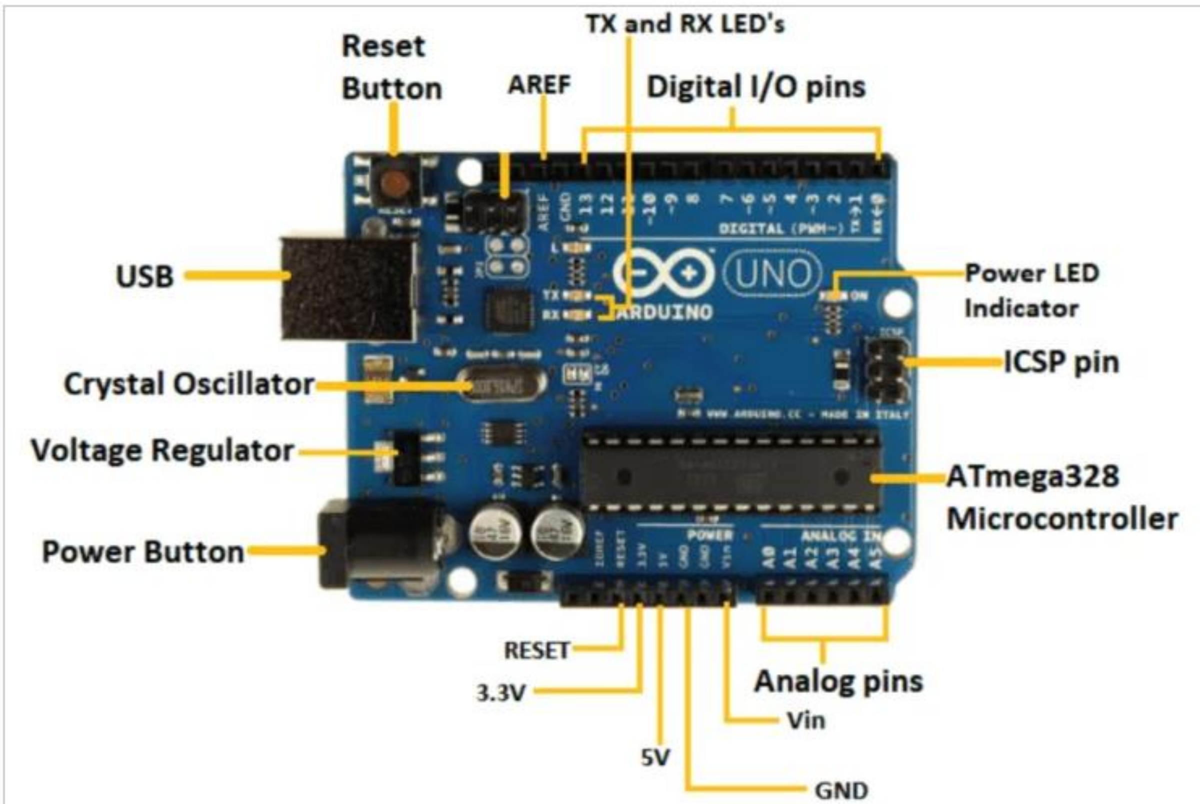
- **IoT Development Boards: Arduino IDE and Board Types**
  IoT development boards like those supported by the Arduino platform are widely used for building and prototyping IoT applications due to their simplicity, flexibility and open-source nature.
  The Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are microcontroller based platforms that allows developers to write, compile, and upload code (C/C++) to various boards using the Arduino IDE (Integrated Development Environment).

- **Arduino IDE**
  Arduino IDE is the software used to write, compile and upload code to Arduino boards.
  Features:

- Simple and beginner –friendly interface.
- Based on C/C++ programming.
- Include serial monitor for debugging and communication.
- Has a wide collection of built-in libraries for sensors, motors, display etc.

**Components of Arduino IDE:**

- **Editor window:** Where you write your code
- **Verify/Compile Button:** Checks for errors in code.
- **Upload Button:** Sends code to the connected board.
- **Serial Monitor:** displays data received from the Arduino board.
- **Library Manager:** Allows you to install additional libraries.




- **Common Arduino Board Types**

1. **Arduino Uno**
   **Microcontroller:** ATmega 328P
   **Digital I/O Pins:** 14 (6 can be PWM)
   **Analog Inputs:** 6
   **USB Type:** Standard USB-B
   **Best For:** Beginners, basic projects, education.
2. **Arduino Mega 2560**
   **Microcontroller:** ATmega 2560
   **Digital I/O Pins:** 54 (15 can be PWM)
   **Analog Inputs:** 16

**USB Type:** Standard USB-B
**Best For:** Projects needing more I/O pins like 3D printers (or) large displays.

3. **Arduino Nano**
   **Microcontroller:** ATmega 328
   **Digital I/O Pins:** 14 (6 can be PWM)
   **Analog Inputs:** 8
   **USB Type:** Mini USB
   **Best For:** Compact Projects where space is limited.
4. **Arduino Leonardo**
   **Microcontroller:** ATmega 32u4
   **Digital I/O Pins:** 20
   **Analog Inputs:** 12
   **USB Type:** Micro USB
   **Special Feature:** Can emulate a keyboard (or) mouse.
5. **Arduino Due**
   **Microcontroller:** ARM Cortex-M3 (32-bit)
   **Digital I/O Pins:** 54
   **Analog Inputs:** 12
   **USB Type:** Standard USB-B
   **Best For:** High-speed applications, complex computation.
6. **Arduino MKR Series**
   **Purpose:** Designed for IoT with built-in connectivity
   **Variants:** MKR1000 (Wi- Fi), MKR GSM 1400 (GSM), MKR NB 1500 (NarrowBand IoT)
   **Features:** Compact, includes crypto chip for security

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**5Q. Explain about Raspberry Pi development kit.**

- **Raspberry Pi Development Kit**
  Raspberry Pi is a compact, low-cost, single-board computer developed by the Raspberry Pi foundation with goal of promoting computer science education and enabling accessible computing.
  Unlike traditional microcontrollers, the raspberry Pi can run full operating systems such as Raspberry Pi OS (formerly Raspbian), Ubuntu and others on Linux.
  It comes equipped with essential computing components, including a processor, RAM, USB ports, HDMI output, GPIO pins and network interfaces, making it a versatile platform for a wide range of projects and applications.
  Despite its small size, the Raspberry Pi is powerful and capable of performing multiple tasks simultaneously. It can browse the internet, steam media, executing programming scripts and connect to a variety of peripherals and sensors via its General-Purpose Input/ Output (GPIO) pins.
  These features make it ideal for building IoT systems, smart home devices, robotics projects, media centers and even lightweight AI and ML applications.

**Features:**
**CPU:** ARM Cortex-based processor (Quad- core in Rpi4)
**RAM:** 2GB/4GB/8GB (Depending on model)
**Storage:** MicroSD card (acts as hard disk)
**Connectivity:** Wi-Fi, Bluetooth, Ethernet
**Ports:** USB, HDMI, Audio, Camera Serial Interface (CSI), Display Serial Interface (DSI)
**40- Pin GPIO Header:** Used to connect sensors, LEDs, motors, etc.
**Camera and Display Support:** CSI port for camera, DSI port for touch screens.


- **Programming Language Supported:**
  - Python (most popular for IoT)
  - C/C++
  - JAVA
  - NODE.JS
  - Scratch (for beginners)

- **Networking Capabilities**
  Raspberry Pi can connect to the internet via Wi-Fi, Ethernet, and USB dongles.
  It can serve as web server,(Flask, Node.Js, Apache)
  MQTT (Mosquitto for IoT messaging)
  Cloud Client (Send sensor data to AWS, Azure, etc.)

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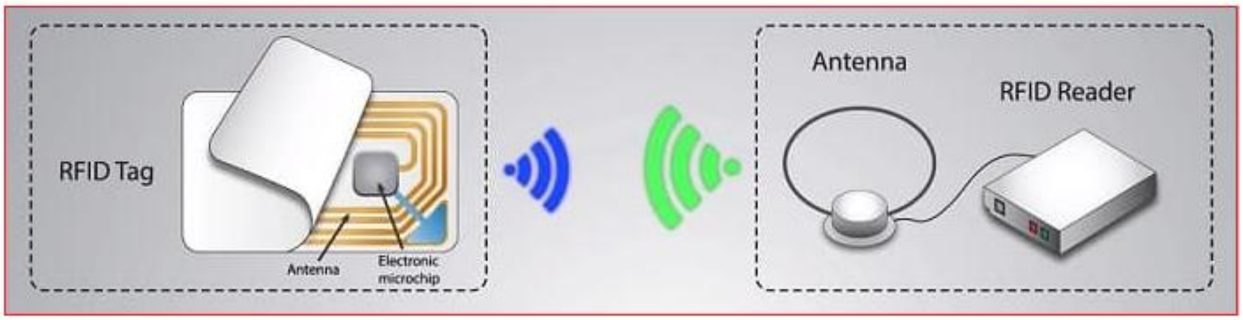
**6Q. Explain the components and working principle of an RFID system.**

- **RFID Principles and Components**
  Radio Frequency Identification (RFID) is a wireless technology that uses radio waves to automatically identify and track objects, animals (or) people. It consists of RFID tags, which store unique identification information and RFID readers that transmit signals to detect and read data from these tags.




Unlike traditional barcodes, RFID reader does not require Line- of –sight (or) manual scanning, the tag only needs to be within the reader's range to be detected. This capability makes RFID highly efficient for applications such as inventory control, access management, asset tracking, and supply chain logistics due to its speed, accuracy, and ability to read multiple tags simultaneously.

**Principle of RFID**

The core principle of RFID involves communication between a tag and a reader via radio waves.

- The RFID reader sends a radio signal.
- The RFID tag, when it receives this signal, responds by sending back stored data.
- The reader receives the signal and passes the data to a computer system for processing.

**Main Components of an RFID system**

An RFID system consists of three main components:

**RFID Tag (transponder):** It is a microchip attached to an antenna and embedded in a label, card (or) object.

**RFID Reader (Interrogator):** The reader sends out radio signals to detect and communicate with tags within its range.

**Antenna:** The antenna transmits the RF signal from the reader to the tag and receives the response.

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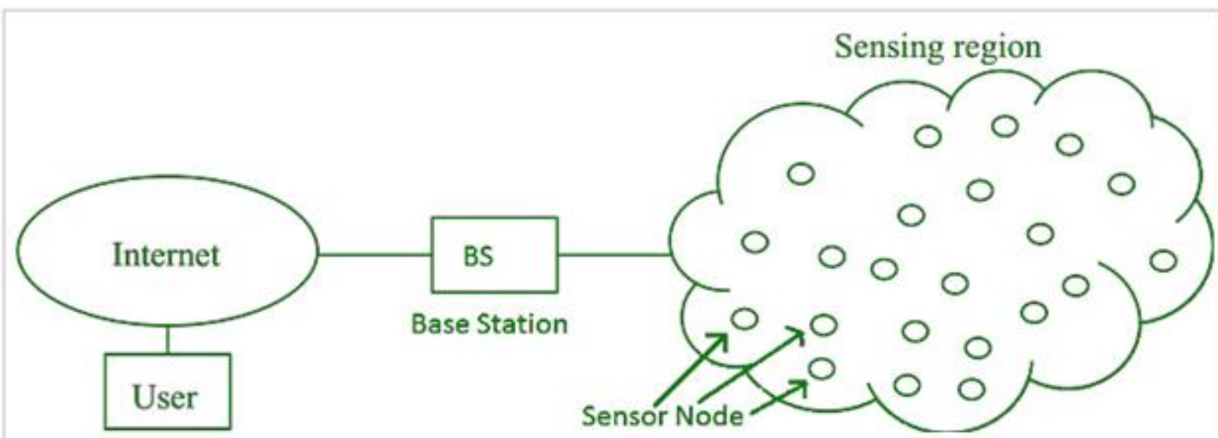
## 7Q. Discuss the historical evolution and significance of Wireless Sensor Networks (WSNs)

Wireless Sensor Networks (WSNs)

**History and Context**

- Wireless Sensor networks (WSNs) are systems composed of numerous autonomous sensor nodes that are spatially distributed to monitor environmental (or) physical conditions, including temperature, sound, pressure, motion and pollutants.
- These sensors collect data and wirelessly transmit it to a central base station where the information is processed and analyzed.
- The nodes in a WSN typically consist of sensing units, microcontrollers, power sources (batteries) and communication modules.
- Their design emphasizes energy efficiency, scalability and adaptability, especially deployed in large scale (or) remote environment.
- The concept of WSNs has evolved significantly since the 1980s, initially driven by military needs foe battlefield surveillance.
- The rise of the IoT has accelerated the integration of WSNs into everyday technologies, making them foundational components of smart systems that require real-time monitoring and data-driven responses.




**Evolution**

- **1960s- Early Concepts:** The roots of WSNs lie in military applications.
- **1980s-** The defense Advanced Research Projects Agency (DARPA) introduced the idea of Distributed Sensor Networks.
- **1990s-** The birth of WSNs
- **2000s-** Commercial Expansion
- **2010s-** IoT integration.

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## 8Q. Explain about node in a WSN.

### The Node

- In a WSN, a node often referred to as a sensor node is the fundamental unit that enables the network to function effectively.
- Beyond sensing, the node is also capable of processing the collected data locally, performing tasks such as filtering, aggregation (or) simple analysis before transmission.
- The sensor continuously monitors environmental parameters and it converts raw data into usable form.
- The microcontroller at the node analyzes and compresses the data.
- To conserve energy, nodes switch off components when idle.

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## 9Q. Describe different communication protocols used for connecting nodes in a WSN.

Connecting Node

- In a WSN, "Connecting Nodes" refers to the process of establishing communication links between individual sensor nodes to enable data exchange and cooperation with the network.
- Connecting nodes also involves organizing the network topology and managing routing protocols to optimize communication efficiency, conserve energy and maintain network reliability.
- Multi-hop communication is a key feature, where data packets are relayed through multiple intermediate nodes until they reach the destination.

How nodes are Connected

1. **Wireless Communication:** Nodes connect wirelessly using radio signals. Ex: Zigbee, Bluetooth, Wi-Fi, LoRaWAN, 6LoWPAN.
2. **Multi-hop Communication:** Since individual nodes have limited transmission range, data often passes through multiple intermediate nodes before reaching the sink (or) base station.
3. **Routing Protocols:** Algorithms decide how data how data travels through the network. Routing can be done through flat routing; hierarchical routing and location- based routing.

Types of Connections Between nodes

**Data Link:** Nodes within each other's radio range communicate directly.
**Indirect Link (Multi-hop):** Nodes out of direct range forward data through intermediate nodes.
**Cluster – Based:** Nodes from groups (Clusters), each cluster has a leader node that aggregates data and communicates with the sink.

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Networking Node

- Networking nodes in a Wireless Sensor Network (WSN) refers to the systematic organization and communication processes among individual sensor nodes that enable the network to function as a unified system.
- It involves establishing protocols for data routing, ensuring nodes can send and receive information effectively and coordinating their activities to maintain network stability.

Concepts in Networking Nodes

1. **Network Topology:** The arrangement (or) structure of nodes and their communication paths within a WSN.
   **Star topology:** All nodes connect directly to a central node (Sink).
   **Tree Topology:** Nodes from hierarchical connections like branches.
   **Mesh Topology:** Nodes are interconnected with multiple paths.
   **Clustered Topology:** Nodes are grouped into clusters.
2. **Routing Protocols:** Protocols govern how data is transmitted across nodes to reach the sink efficiently.
   **Data- Centric Routing:** Data is requested (or) routed based on the content.
   **Hierarchical Routing:** Uses clusters (or) layers to reduce energy consumption.
   **Location- Based Routing:** Uses geographical location information to route data.
   **Multi- Path Routing:** Uses multiple paths for liability and load balancing.
3. **Communication Models**
   **Single – hop Communication:** Nodes send data directly to the sink.
   **Multi– hop Communication:** Data is forwarded by intermediate nodes to the sink.
4. **Network Management**
   It includes node deployment, addressing, synchronization and fault tolerance.

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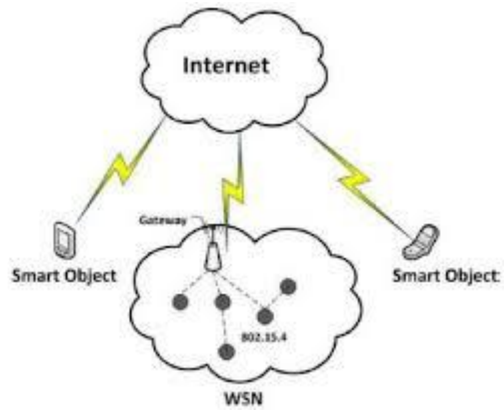
**10Q. How do WSNs integrate with IOT systems to support real-time data collection and decision making.**

WAN and IoT

- Wireless Sensor Networks (WSNs) form a fundamental building block of the IoT by serving as the primary data collection layer.
- By capturing real-world information in real-time, WSNs provide the critical inputs that allow IoT systems to understand and interact with their environmental effectively.
- IoT leverages WSNs to connect and manage a vast array of smart devices across different domains including smart homes, healthcare, agriculture and industrial automation.
- IoT platforms aggregate then sensor data collected by WSNs, analyze it using cloud computing and AI, and enabled automated responses (or) user interactions.




Why WSNs are Crucial for IoT

- **Real-Time data collection:** WSNs enable continuous, automated data gathering from remote (or) inaccessible areas.
- **Scalability:** They allow thousands of sensors to be deployed and networked for large- scale IoT systems.
- **Energy Efficiency**: WSNs are using low power devices suitable for long term monitoring.
- **Flexibility:** Wireless nature allows easy deployment and reconfiguration.
- **Distributed Intelligence:** Sensor nodes can perform local processing, reducing data volume sent to central system.

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