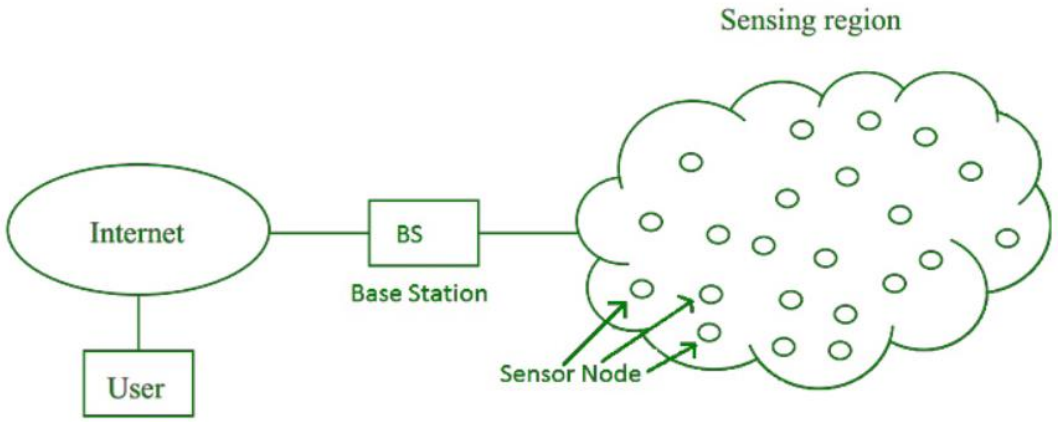
UNIT-III

1. A. Explain the fundamentals of Wireless Sensor Networks (WSNs).

Wireless Sensor Networks (WSNs) -

A **Wireless Sensor Network (WSN)** is a group of **small wireless devices** (sensor nodes) that **collect information** like **temperature, humidity, or motion** and **send it wirelessly** to a main device (sink node).



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1. Main Parts of WSN

1. **Sensor Nodes** – Small devices that:
    - **Sense data** (e.g., temperature, air pollution).
    - **Process data** using a small computer (microcontroller).
    - **Send data** wirelessly to the main device.
2. **Sink Node (Base Station/Gateway)** – A powerful device that:
    - **Receives data** from sensor nodes.
    - **Sends data** to a computer or cloud for analysis.
    - **Manages network communication.**

3. **Network System** – Helps nodes **connect and share data wirelessly**.

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2. Features of WSN

- **Works Wirelessly** – Uses Wi-Fi, Bluetooth, Zigbee, or LoRa.
- **Uses Less Power** – Works on small batteries.
- **Self-Organizing** – Can adjust if some nodes stop working.
- **Sends Data Automatically** – Collects and sends data without human help.

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3. Network Types (Architecture)

- **Flat Topology** – All nodes send data directly to the sink.
- **Hierarchical Topology** – Nodes form groups (clusters), and one node (cluster head) sends data to the sink.
- **Hybrid Topology** – Mix of both flat and hierarchical for better performance.

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4. How Data is Sent (Protocols)

- **MAC Protocols** – Prevents data collision (e.g., TDMA, CSMA).
- **Routing Protocols** – Finds the best way to send data (e.g., LEACH, AODV).

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5. Problems in WSN

- **Battery Runs Out Fast** – Needs power-saving methods.
- **Data Security** – Data must be protected from hackers.

- **Works with Many Nodes** – Must handle thousands of devices.
- **Node Failure** – Network should still work if some nodes fail.

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6. Uses of WSN

- **Environment Monitoring** – Checks air pollution, temperature, water quality.
- **Healthcare** – Used in smartwatches and health monitoring devices.
- **Smart Farming** – Helps with automatic irrigation.
- **Factories & Industries** – Tracks machines and prevents failures.
- **Military & Security** – Used for surveillance and security systems.

Conclusion

Wireless Sensor Networks **help in many areas** like **healthcare, farming, industries, and security**. They **collect and send data automatically**, making work easier. But they also face **problems like battery life and security**, which need improvement.

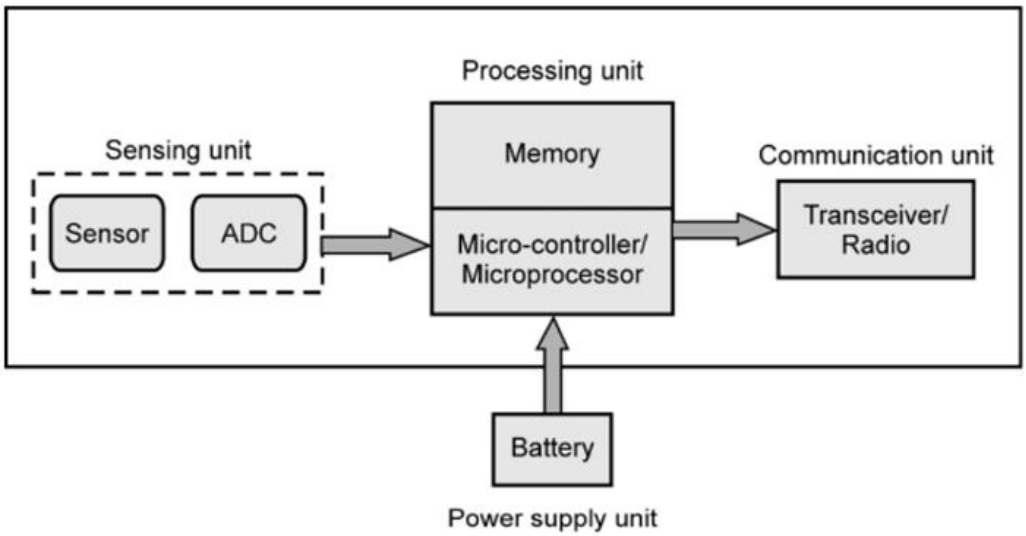
b) Differentiate between Wireless Sensor Network (WSN) vs. Adhoc Network [L2,CO4] [6M]

Feature	Wireless Sensor Network (WSN)	Ad hoc Network (MANET)
What it is?	A network of small sensor devices that collect and send data.	A network of mobile devices that communicate without wires.
Main Use	Used for sensing and monitoring (e.g., weather, health, military).	Used for communication between mobile devices (e.g., army, disaster areas).
Device Type	Small, low-power sensor nodes.	Powerful mobile devices like phones and laptops.
Power Usage	Uses very little power to last long.	Uses more power because devices communicate often.
Data Flow	Data goes from many sensors to one central device.	Devices talk to each other directly.
Mobility	Mostly fixed or slow-moving sensors.	Devices move around a lot.
Size of Network	Many small sensors (large network).	Fewer mobile devices (small network).
Communication	Short distance, uses multi-hop (one sensor passes data to another).	Longer distance, direct or multi-hop communication.

2 a) Establish on the architecture of Sensor Node Architecture . 6M

Sensor Node Architecture

A **sensor node** is like a small device used in networks to collect and share information. It has 4 main parts:



1. **Sensing Unit**:

    - It measures things like temperature or humidity from the environment using **sensors**.
    - The sensors send the data as **signals** which are then turned into digital data by a **converter**.
2. **Processing Unit**:
    - A small **microcontroller** works here to process the data from the sensors and control the node.
    - The processed data is stored in **memory**, which can be external storage like **flash memory**.
3. **Communication Unit**:
    - This part allows the sensor node to talk to other nodes.
    - It uses things like **radio waves**, **light**, or **infrared** to send data wirelessly.
4. **Power Supply Unit**:
    - This part gives the sensor node power to work.
    - Most power is used when sending data.
    - Replacing batteries can be difficult, so it's important to manage energy well.

Key Points to Remember:

- **Sensing Unit** measures things from the environment.
- **Processing Unit** handles data and stores it.
- **Communication Unit** sends data to other nodes.
- **Power Supply Unit** gives energy to the node.

b) Identify the key issues related to sensor networks. [L3,CO4] [6M]

 Energy Problems:

- Sensors use batteries that run out fast.
- It’s hard to charge or replace them in remote areas.

 Too Many Nodes:

- Having too many sensors makes communication slow and hard to manage.

 Security Problems:

- People can steal or change data.
- Hackers can flood the network or send fake data.

 Data Problems:

- Too much data wastes energy.
- Data from sensors might not match, causing mistakes.

 Connection Problems:

- Sensors can stop working or move, breaking the network.

 Slow Communication:

- Routing data takes time because the network keeps changing.

 Deployment Problems:

- It’s hard to place sensors in tough spots.
- Sensors can break or get tampered with.

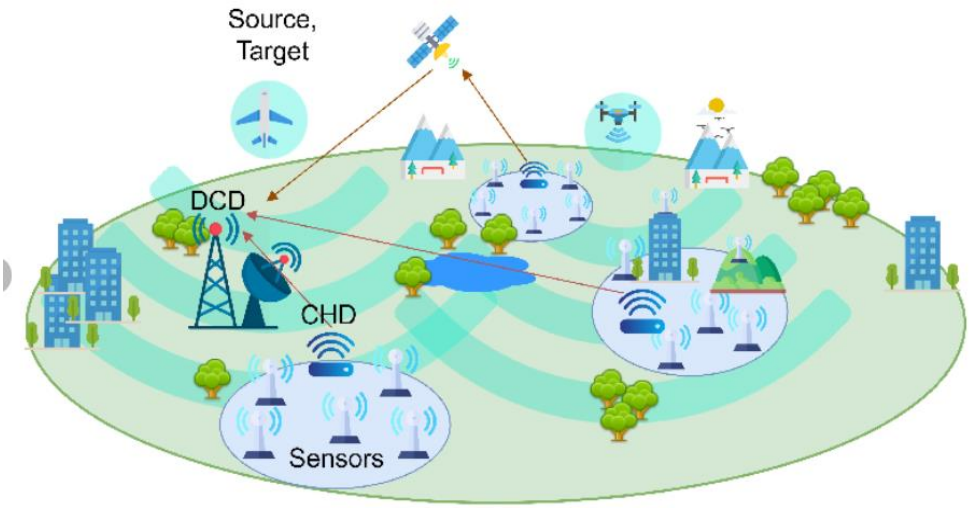
 Delay Problems:

- Some applications need quick data, but delays can happen because of slow connections.

Types of Wireless Sensor Networks (WSNs)

Wireless Sensor Networks (WSNs) are used for monitoring different environments and conditions. Here are the main types of WSNs:

1. **Terrestrial WSNs**

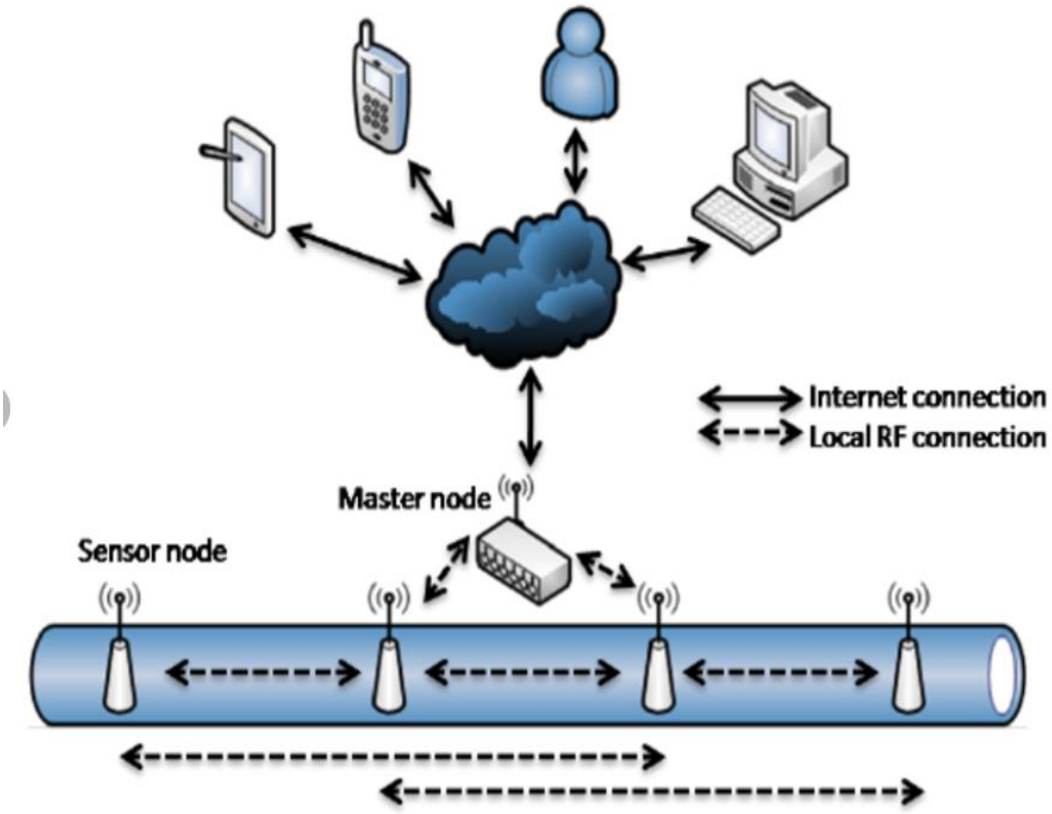


Typical structure for terrestrial WSN deployed to localize UAVs.

   - **What they do**: These sensors are placed on land to monitor things like temperature, humidity, and motion.
   - **How they are placed**:
     - **Random placement**: Sensors are scattered randomly in the area.
     - **Planned placement**: Sensors are placed in an organized pattern.
   - **Challenges**: Sensors use a lot of battery, so methods like using solar power, saving energy, and sending data in shorter bursts are used.

2. **Underground WSNs**

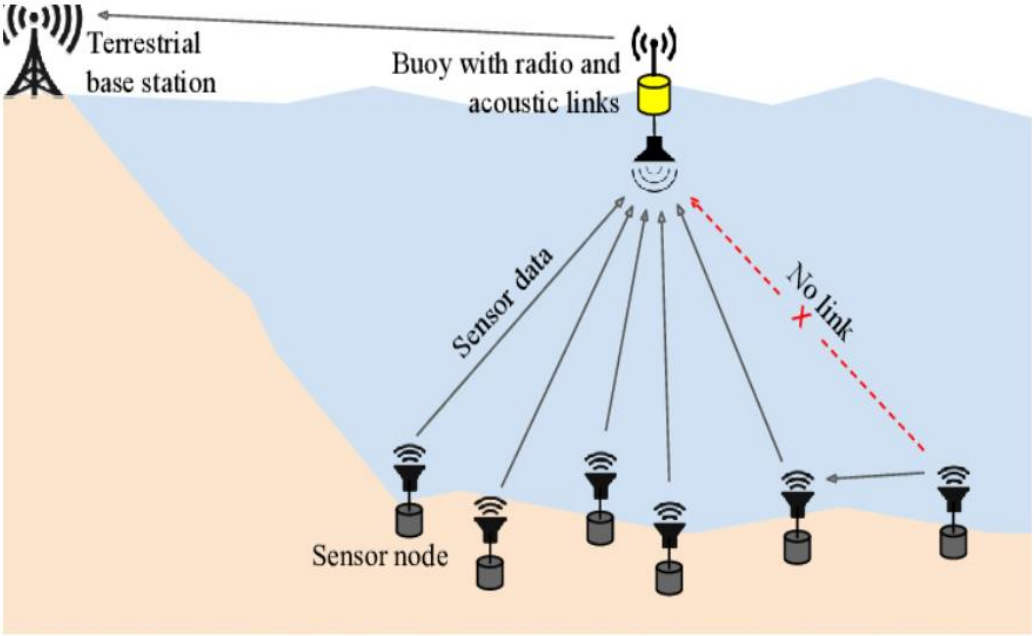
- **What they do**: These sensors are placed underground to monitor things like soil moisture and temperature.
- **Challenges**:
  - Signals have a hard time traveling through soil and rocks.
  - It's expensive to install and maintain these sensors.
  - It's hard to recharge the sensors because they're buried underground.



General schematic of the proposed Underground Wireless Sensor Network (UWSN) for a pipeline monitoring system.

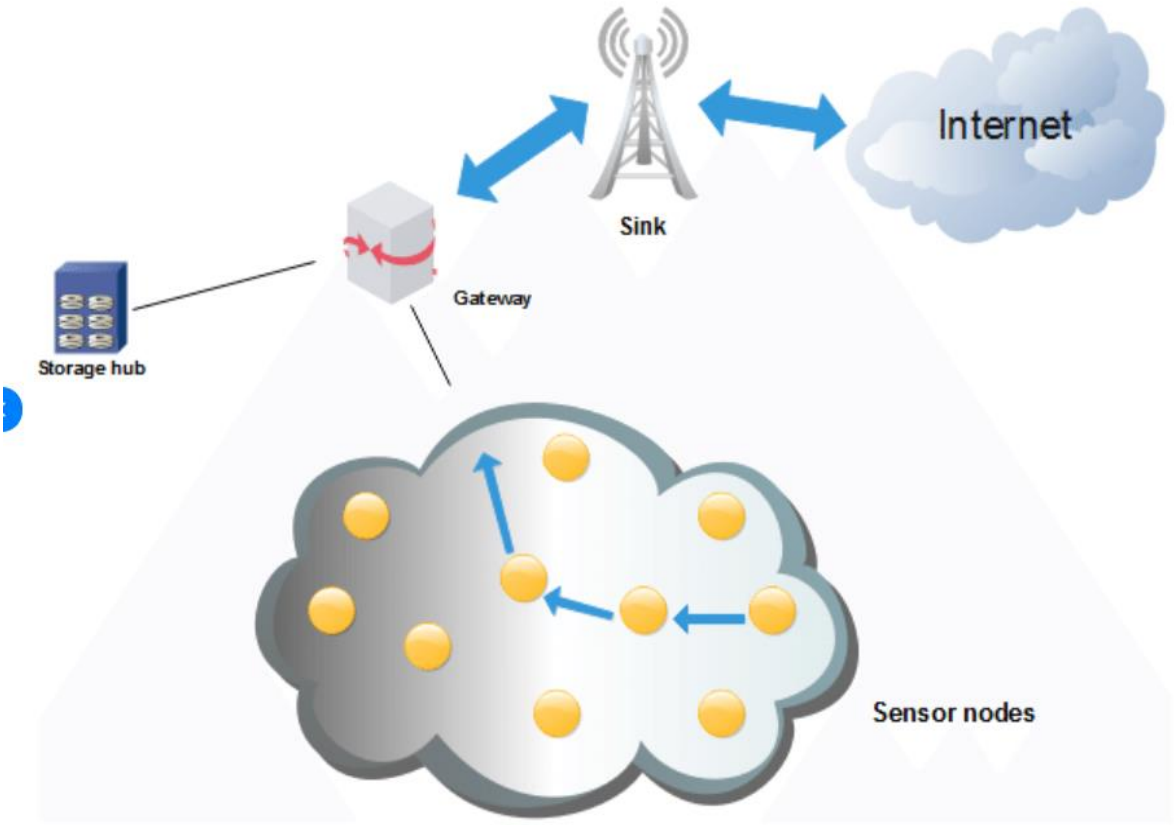
3. **Underwater WSNs**
   - **What they do**: These sensors are placed underwater to monitor water quality, temperature, and marine life.
   - **Challenges**:

- They use sound waves for communication, which are slow and can lose strength.
- The sensors are expensive because they need special equipment to work underwater.



Underwater wireless sensor network deployment with sensor nodes on the sea bed and a surface buoy used as the gateway node.

4. **Multimedia WSNs**



Wireless Multimedia Sensor Network (WMSN)

- **What they do**: These sensors capture and send images, videos, and sounds for monitoring and tracking.
- **Challenges**:
  - They use a lot of energy because sending images and videos requires a lot of power.
  - They need high-speed data transfer (lots of bandwidth).
  - Data needs to be compressed, and the quality of the data needs to be good.

5. **Mobile WSNs**

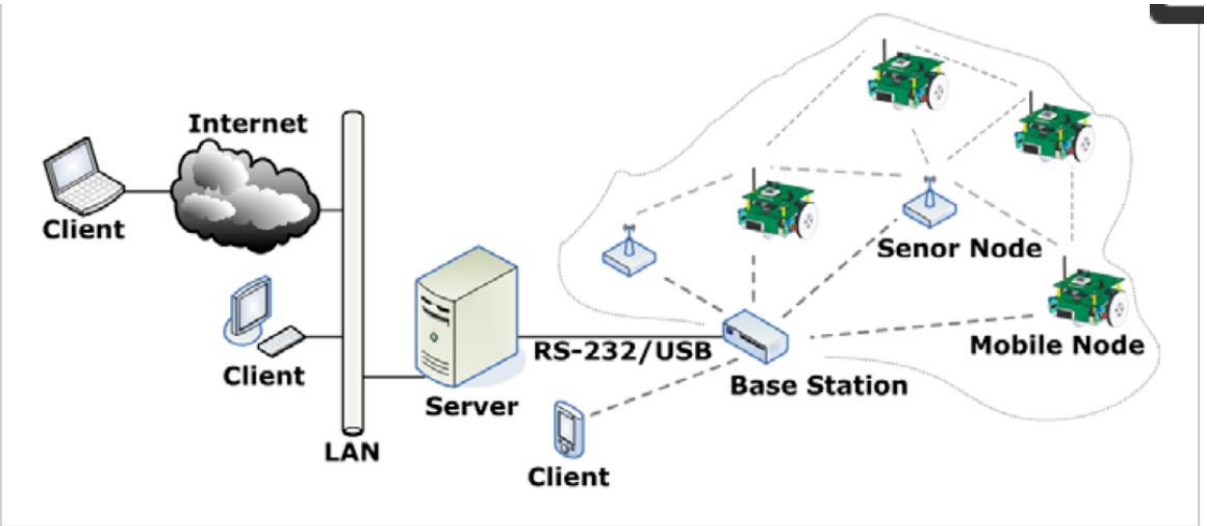


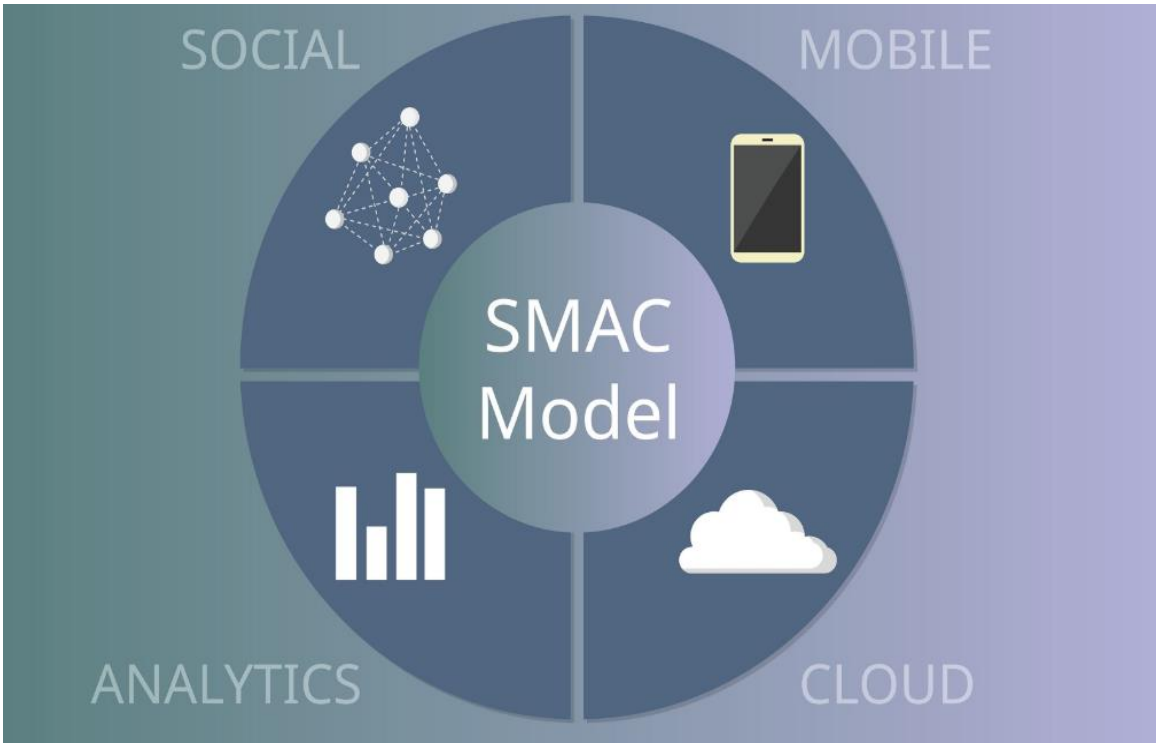
Figure 1. The system architecture of a mobile sensor network.

- **What they do**: These sensors can move around and create their own network.
- **Challenges**:
  - Routing (sending data between sensors) needs to change because the sensors are moving.
  - Managing energy becomes harder because the sensors move.
  - The network setup and maintenance are more difficult because the sensors change positions.

4 Classify the various MAC protocols used in wireless sensor networks. 12M

1. **Self-organizing MAC (SMACS):**
   - Nodes communicate without a central controller.
   - They find their neighbors, assign time slots, and use channels without interference.

- Power is saved by turning off the transceiver when idle.



2. **Eavesdrop and Register (EAR) Protocol:**
    - Mobile nodes connect with stationary ones.
    - Mobile nodes use a registry to remember nearby nodes.
    - Messages like "Mobile Invite" help establish connections.
3. **Hybrid TDMA/FDMA:**
    - This method combines Time Division (TDMA) and Frequency Division (FDMA) to avoid interference.
    - Each node gets a time slot to communicate and uses a different frequency for each cluster.

4. **Low Duty Cycle Protocols:**

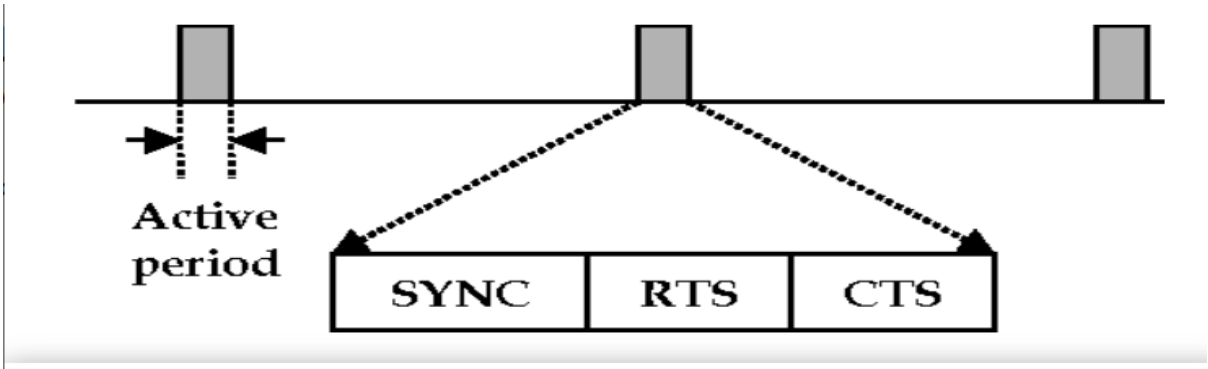
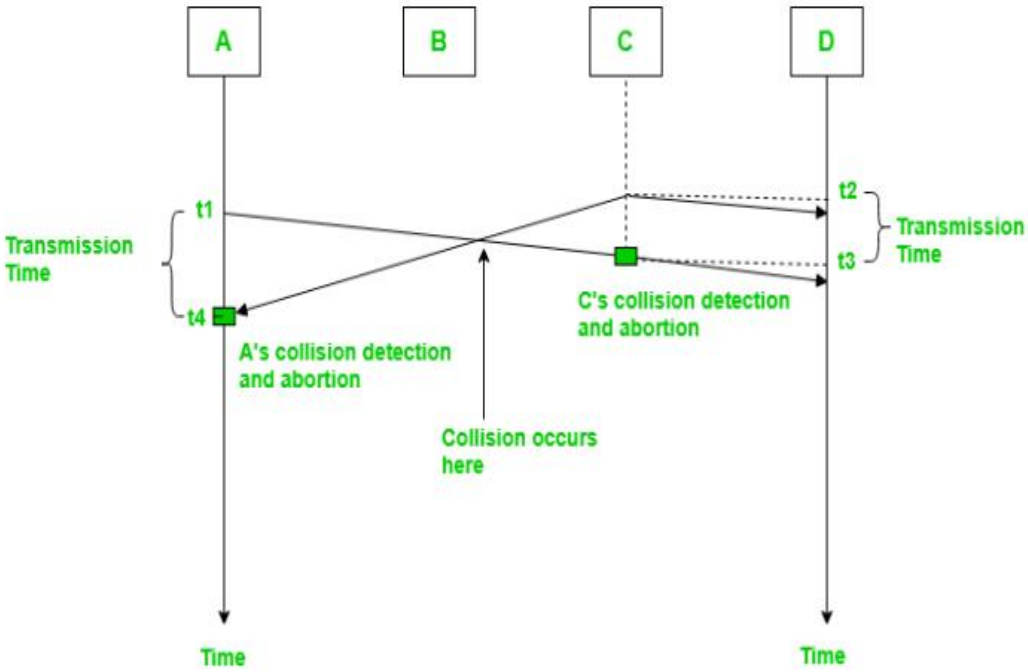


Fig. 4. S-MAC synchronous periodic wake-up scheme.

   - Nodes spend most of their time sleeping to save power.
   - They wake up periodically to check for communication.

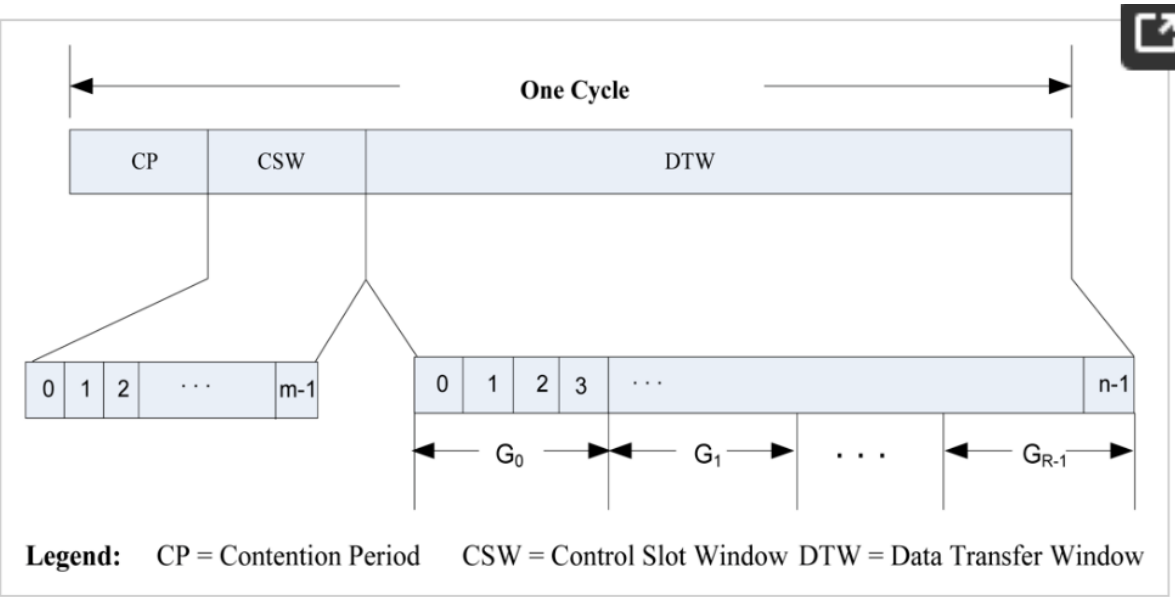
5. **CSMA-based MAC Protocols:**

   - Nodes compete for the channel using random back-off times.
   - Examples include S-MAC, T-MAC, and B-MAC.

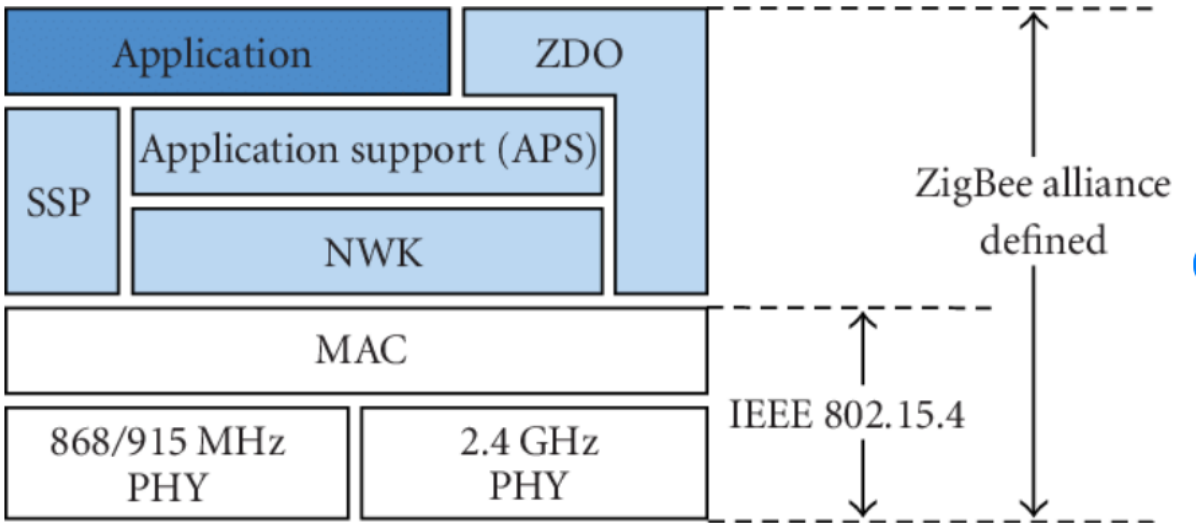


6. **Schedule-Based MAC Protocols:**

- Nodes follow a strict schedule for communication to avoid collisions.
- Examples include LEACH and TRAMA protocols.



7. **IEEE 802.15.4 and Zigbee:**
   - IEEE 802.15.4 is a standard for low-power, low-data-rate communication.
   - Zigbee uses IEEE 802.15.4 for building low-power, self-healing networks.



IEEE 802.15.4 and ZigBee.

5 a) Design Challenges in Sensor Networks:

1. **Random Deployment and Self-Organization**:
    - Sensor nodes are placed randomly without a planned structure.
    - They must figure out how to connect and work together without any help from humans.
2. **Energy Efficiency and Battery Limitations**:
    - Sensor nodes use batteries that can't be recharged or replaced easily.
    - To save energy and make the network last longer, we need to use less power.
3. **Infrastructure-less and Distributed Operation**:
    - There is no central control in the network.
    - Each node must handle tasks like sending data and fixing problems on its own.
4. **Cost Constraints**:
    - The nodes must be cheap because there are many of them.
    - But they also need to work well and last long.
5. **Localization and Positioning**:
    - Knowing where each sensor is located is important.
    - GPS might not work well because it uses too much battery or doesn't work in some areas.
6. **Security and Privacy Concerns**:
    - Sensor networks can be attacked (e.g., someone stealing the data).

- We need to keep the data safe and make sure no one can tamper with the nodes.

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b) CSMA-based MAC Protocols in Sensor Networks:

1. **S-MAC (Sensor-MAC)**:
   - This protocol makes nodes sleep during idle time to save energy.
   - They only wake up when they need to send or receive data.
2. **T-MAC (Timeout-MAC)**:
   - Nodes decide when to sleep based on the amount of data being sent.
   - They also use a handshake (RTS/CTS) before sending data to avoid collisions.
3. **D-MAC**:
   - All nodes wake up at the same time to receive data.
   - This protocol doesn't use handshakes like RTS/CTS.
4. **B-MAC (Berkeley-MAC)**:
   - Nodes listen for the channel at regular intervals.
   - If the channel is free, they send a preamble and then the data.
5. **X-MAC**:
   - The sender keeps sending small preambles until the receiver responds.
   - This saves energy by not sending extra preambles once the receiver replies.

6. **Wise-MAC**:
    - Nodes listen at different times but follow a synchronized pattern.
    - The sender sends a wake-up preamble so the receiver can get the data efficiently.