### Q7)Power Saving Scheme in MAC Layer and Types of Power Saving Mechanisms

**Power Saving in MAC Layer – Overview**

The **MAC (Medium Access Control) layer** in wireless communication protocols (like IEEE 802.11) incorporates **power saving schemes** to reduce energy consumption, especially important for **battery-powered devices** (e.g., smartphones, laptops, IoT devices). It allows clients to sleep and wake up periodically without losing connectivity or data.

**Working Mechanism of Power Saving in MAC Layer**

1. **Sleep and Wake-Up Cycle**:  
   Clients enter a **low-power sleep mode** and wake up at scheduled intervals (typically aligned with **beacon intervals**).
2. **Beacon Frames**:  
   Access Points (APs) periodically broadcast **beacon frames** containing a **Traffic Indication Map (TIM)**.
3. **Traffic Indication Map (TIM)**:  
   TIM indicates if the AP has buffered data for specific clients. If the client’s ID is listed in TIM, it stays awake to retrieve the data; otherwise, it returns to sleep.
4. **PS-Poll Frame**:  
   When a client sees it has pending data, it sends a **PS-Poll (Power Save Poll)** frame to the AP, which then sends the data.

**Types of Power Saving Mechanisms**

1. **IEEE 802.11 Power Save Mode (PSM)**:
   * **Standard mode** where clients alternate between **active** and **doze** states.
   * Used in Wi-Fi networks to conserve battery.
2. **Unscheduled Automatic Power Save Delivery (U-APSD)**:
   * Part of **802.11e (QoS enhancements)**.
   * Used in VoIP and real-time apps.
   * Data is delivered **automatically** when triggered by client activity.
3. **Scheduled Automatic Power Save Delivery (S-APSD)**:
   * Also part of 802.11e.
   * **Schedules** are pre-negotiated, allowing clients to wake up at exact times to receive data.
4. **Power Save Multi-Poll (PSMP)**:
   * Introduced in **802.11n**.
   * Allows **multiple data transmissions** in a single wake period to reduce overhead and improve efficiency.
5. **Target Wake Time (TWT)**:
   * Introduced in **802.11ax (Wi-Fi 6)**.
   * Clients **negotiate with the AP** to wake up at specific times, minimizing collisions and maximizing sleep time.

**Benefits of MAC Layer Power Saving**

* Extends **battery life** of client devices.
* Reduces **network congestion** by avoiding unnecessary transmissions.
* Enhances **network efficiency** in dense deployments like IoT or smart homes.