Module 5

Q. Cellular IP

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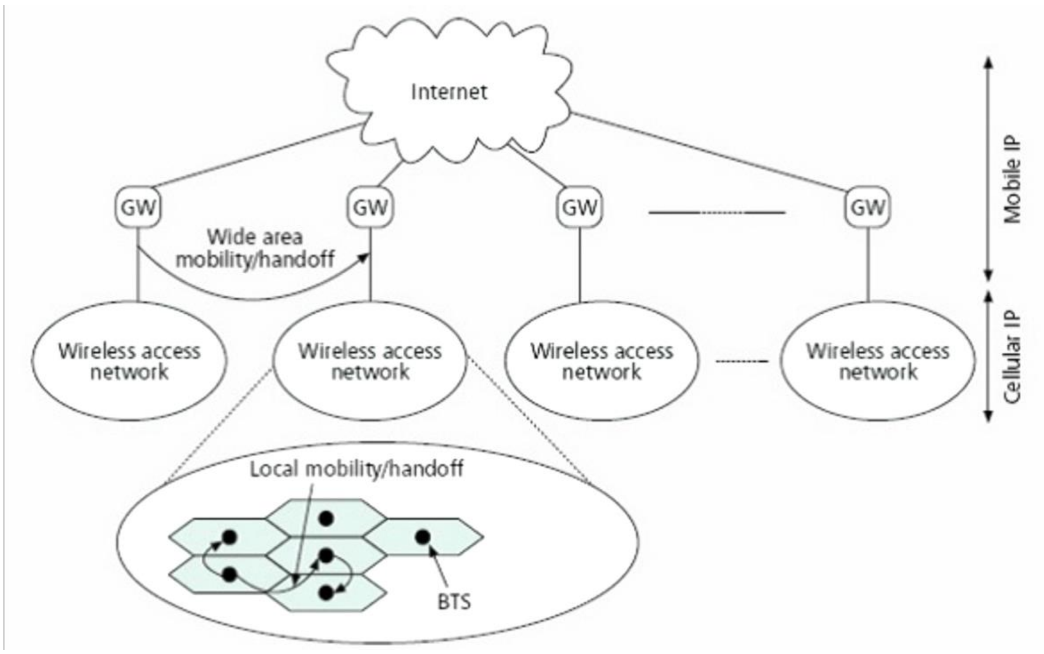
1. What is Cellular IP?

Cellular IP is a **mobility management protocol** that allows **mobile hosts (MHs)** to maintain seamless internet access while moving at high speeds. It is designed to support fast handoff and low-latency data transfer, especially in environments where Mobile IP alone is not efficient.



2. Purpose of Cellular IP

- To provide **efficient mobility support** in wireless networks.
- To **extend Mobile IP** functionality with better **handoff mechanisms** and **reduced signaling overhead**.
- To ensure **low-latency delivery** of data packets during mobility, particularly for fast-moving mobile users.

3. Major Components of Cellular IP Architecture

1. **Mobile Host (MH):**
   a. A device (like a phone or tablet) moving within the network and requiring internet connectivity.
2. **Base Station (BS):**
   a. Acts as a **Cellular IP node**.
   b. Communicates wirelessly with MHs.

   c. Routes packets within the cellular network using **hop-by-hop routing**.
   d. Periodically transmits **beacon signals** to allow MHs to determine the nearest base station.
3. **Gateway (GW):**
   a. Connects the **Cellular IP network** to the **Internet or external IP network**.
   b. Serves as an **exit/entry point** for data packets moving between internal and external networks.

4. How Cellular IP Works

- **Beaconing & Discovery:**
  - Base stations emit **beacon signals** regularly.
  - Mobile Hosts use these signals to identify the **nearest base station** to connect to.
- **Packet Routing:**
  - All IP packets from an MH are routed from the current BS to the GW using **shortest path routing**.
  - BSs maintain a **routing cache** which maps MH IP addresses to the neighboring node from which packets were last received.
  - These mappings are used to **forward downlink packets** from the GW to the MH.
- **Route Cache Maintenance:**
  - MHs periodically send **control packets** to refresh and maintain their routing entries.
  - This ensures routes do not expire while the user is active.
- **Paging Mechanism:**
  - For idle MHs not actively transmitting data, **paging caches** are maintained.
  - These caches allow the network to reach the MH with minimal signaling overhead.

5. Handoff in Cellular IP

- MHs monitor signal strength from nearby BSs.
- When signal drops, the MH **tunes its radio** to a new BS and sends a **Route Update Packet**.
- This triggers the creation of a new **routing path** to the MH via the new BS.
- During handoff:
  - Both **old and new routes** may remain active temporarily.
  - This is called **semi-soft handoff**, which helps reduce **packet loss** and **handoff latency**.
- The old route is deleted after a timer expires if no packets use it anymore.

7. Use Cases of Cellular IP

- High-speed mobile networks like in trains or vehicles.
- Wireless metropolitan area networks.
- Networks requiring **fast handoff** and **low signaling overhead** (e.g., VoIP or video streaming on mobile).

Q. What is Micro Mobility?

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Micro Mobility refers to the **mobility management** within a **limited or local area network**, such as a campus, city block, or organizational wireless network. It handles **frequent and small-scale movements** of a mobile device (Mobile Host – MH) **within a single administrative domain** without interacting with the global internet mobility protocols.

Why is Micro Mobility Needed?

In traditional mobility systems like **Mobile IP**, even a small movement (e.g., between nearby access points) requires:

- Contacting the **Home Agent (HA)**
- Registering every handoff globally

This leads to:

- **High latency**
- **Signaling overhead**
- **Packet loss during handoffs**
- Poor user experience, especially for **real-time services** (VoIP, video streaming, etc.)

Hence, **Micro Mobility** is introduced to:

- Minimize delays and signaling overhead
- Improve **handoff speed and reliability**
- Avoid unnecessary communication with distant Home Agents
- Support **real-time and continuous service** during frequent local movements

Approaches to Micro Mobility

There are **two main approaches** to micro mobility:

1. Routing-Based Approaches

These approaches rely on **modifying the routing paths** within the local domain to deliver packets to the new location of the mobile node.

- **How it works:**
    - Local routers maintain **dynamic routing entries** for each mobile node.
    - When the mobile host moves, routing updates are done **locally**.
    - No need to inform the Home Agent of every movement.

- **Examples:**
    - **Cellular IP**
    - **Handoff-Aware Wireless Access Internet Infrastructure (HAWAII)**
- **Advantages:**
    - Fast handoff
    - Low signaling load
    - Efficient for local movements
- **Disadvantages:**
    - Scalability can be a concern due to per-host routing

2. Tunnel-Based Approaches

These use **tunneling mechanisms** to forward packets from a fixed point (local anchor or gateway) to the current location of the mobile node.

- **How it works:**
    - A **Mobility Anchor Point (MAP)** is set inside the local domain.
    - The mobile host registers only with the MAP.
    - When the mobile node moves, the MAP **tunnels** the packets to the new point.
- **Examples:**
    - **Hierarchical Mobile IP (HMIP)**
    - **Low Latency Handoff in Mobile IPv6 (Fast MIPv6)**
- **Advantages:**
    - Reduces signaling beyond the local network
    - Maintains compatibility with Mobile IP
- **Disadvantages:**
    - Adds tunneling overhead
    - May increase path length

Comparison Table: Micro Mobility Approaches

Approach	Mechanism	Key Feature	Examples	Overhead
Routing-Based	Per-host routing updates	Fast local handoff	Cellular IP, HAWAII	Low to Medium
Tunnel-Based	Local tunneling from anchor	Avoids global signaling	HMIP, Fast MIPv6	Medium

Q. Short Note on IPv6

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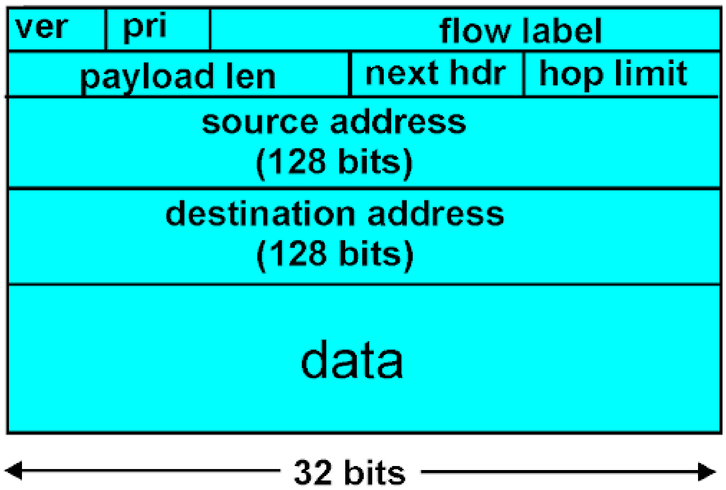

IPv6 (Internet Protocol version 6) is the **next-generation Internet Protocol** designed to replace the current version, **IPv4**, due to the exhaustion of IPv4 addresses.

Key Features of IPv6:

1. **128-bit Addressing**:
   a. Allows **3.4×10^{38} unique IP addresses**, compared to only 4.3 billion in IPv4 (32-bit).
   b. Written in **hexadecimal** and separated by colons (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334).
2. **Simplified Header Format**:
   a. More efficient routing due to a streamlined header with fewer fields.
3. **No Need for NAT**:
   a. Due to a massive address space, **Network Address Translation (NAT)** is not required.
4. **Built-in Security**:
   a. **IPSec (Internet Protocol Security)** is integrated, offering better security features by default.
5. **Auto-configuration**:
   a. Supports **stateless address auto-configuration (SLAAC)**, allowing devices to generate their own IPs.
6. **Improved Mobility and Multicasting**:
   a. Enhanced support for **mobile networks** and **multicast communication**.

Need for IPv6:

- **Address depletion** in IPv4.
- Growth in **IoT, mobile devices**, and internet-connected systems.
- To ensure **scalability**, **security**, and **efficiency** of the future internet.

Q. How IP Mobility is Achieved in Wireless Networks

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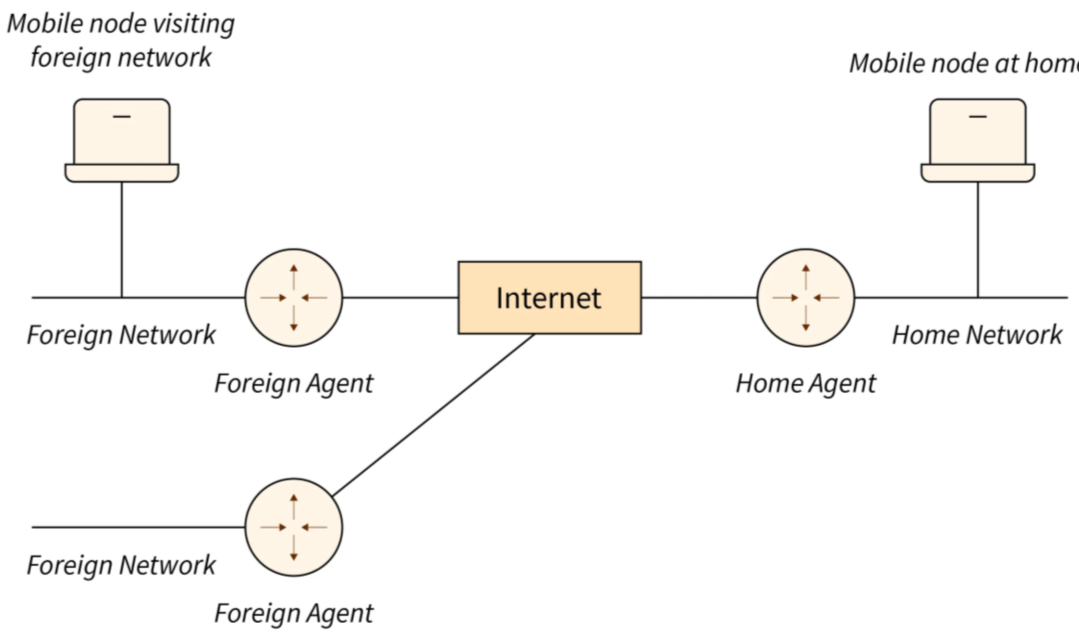
IP mobility refers to the ability of a mobile device (Mobile Host, MH) to maintain ongoing internet connections while moving across different IP networks or subnets, without changing its IP address or losing connectivity.



Key Techniques to Achieve IP Mobility:

1. Mobile IP (MIP)

Mobile IP is the foundational protocol developed by the IETF to support IP mobility.

- **Home Agent (HA):** A router in the mobile node's home network that keeps track of the mobile node's current location.
- **Foreign Agent (FA):** A router in the visited network that provides routing services to the mobile node while it's away from home.
- **Care-of Address (CoA):** A temporary IP address assigned to the mobile node when it's in a foreign network.

Working:

- The MH moves to a new network and registers its CoA with its HA.
- The HA intercepts packets destined for the MH and tunnels them to the CoA.
- The MH can also use **reverse tunneling** to send packets back.

2. Hierarchical Mobile IP (HMIP)

- Reduces signaling overhead and handover latency.
- Introduces **Mobility Anchor Point (MAP)** between the HA and the FA to handle local mobility.

3. Fast Handover for Mobile IP (FMIP)

- Predicts movement and prepares the new CoA before actual handover.
- Reduces packet loss and handover delay.

4. Proxy Mobile IP (PMIP)

- Mobility is managed by the network (not the mobile node).
- Used in LTE and Wi-Fi networks to provide seamless handover without requiring changes in the mobile device.

Mobility Support in IPv6 (Mobile IPv6)

- Mobile IPv6 simplifies the process by eliminating the need for a Foreign Agent.
- The MH itself configures a new CoA and registers it with the HA.
- Uses **Route Optimization** to improve performance by allowing direct communication between MH and CN (Correspondent Node).

Use of Tunneling:

- Tunneling is commonly used to maintain a consistent IP address.
- Encapsulation allows data to be sent to a mobile node regardless of its current point of attachment.