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# Ευφυή Κινητά Δίκτυα: Mobile Network Layer: Mobile IP and Distributed Mobility Management (DMM)

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## Motivation for Mobile IP

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- Internet started at a time when mobile computers did not exist
    - Internet today lacks mechanisms for supporting mobile users
    - IP is common base for many applications running over different networks
  - Mobile IP adds mobility support to IP
  - Key issue: Routing
    - Destination network prefix determines physical subnet
    - Change of physical subnet requires change of IP address
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## Supporting mobile nodes

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- Create routes to mobile nodes?
    - Change all routing table entries to forward packets to destination mobile node
    - Scalability issues due to number of mobile nodes and frequent location changes
  - Change IP address when mobile moves?
    - Need to modify IP address depending on location
    - Impossible to find mobile host; DNS not built for frequent updates
    - TCP connection breaks
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## Mobile IP requirements

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- Transparency
    - Mobile nodes keep IP addresses
    - Point of connection to fixed network can change
    - Communication continues after link interruption
  - Compatibility
    - Support same layer 2 protocols as IP
    - No changes to end systems and routers
    - Mobile nodes can communicate with fixed nodes
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## Mobile IP requirements (cont.)

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- Security
    - Authentication of registration messages
  - Efficiency
    - Few additional messages
  - Scalability
    - Global support for large number of mobile nodes
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## Real life analogy

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- What happens when you move to a new house?
    - Leave forwarding address to your old post office
    - Old post office forwards your mail to new post office
    - New post office delivers it to you
  - Mobile IP implements above procedure!
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## Mobile IP actors

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- Mobile Node (MN)
    - Can change point of attachment to fixed network without changing IP address (Home address is static)
    - New Care-of Address (CoA) associated with new network attachment point
  - Correspondent Node (CN)
    - Node wishing to communicate with mobile node
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## Mobile IP actors (cont.)

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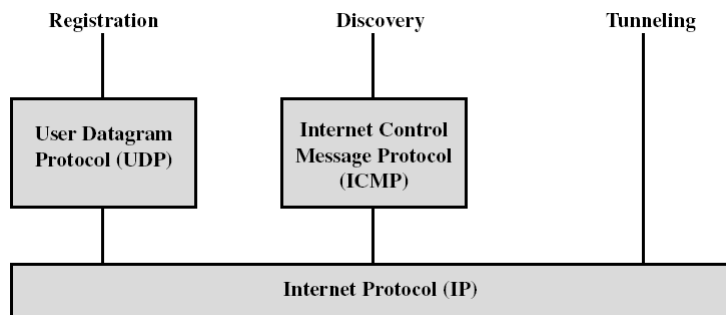
- Home Agent (HA)
    - System in home network of MN, usually router
    - Maintains current location of MN (CoA)
    - Tunnels IP packets to MN's CoA
  - Foreign Agent (FA)
    - System in foreign network, usually router
    - Receives IP packets from HA
    - Forwards IP packets to MN
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## Mobile IP mechanisms

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- Discovering the care-of address
- Registering the care-of address
- Tunneling packets to the care-of address



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## Discovering Care-of Address

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- Built on top of existing ICMP router advertisements
- Router advertisements extended to carry available CoAs: agent advertisements
- Foreign (& home) agents periodically broadcast agent advertisements
- Mobile host can choose not to wait for advertisement and send solicitation message
  - If MH doesn't hear its current CoA from foreign agent, it seeks another CoA

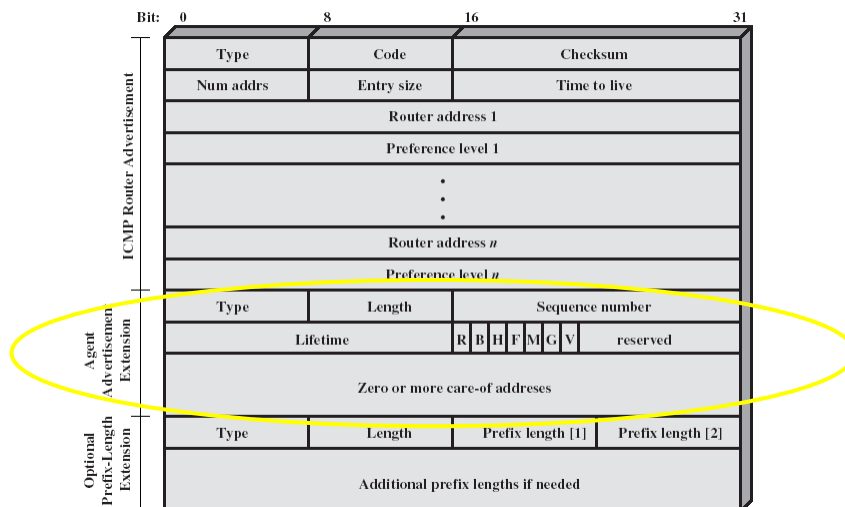
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# Agent advertisements

- Allows detection of mobility agents
- Lists one or more available care-of addresses
- Informs mobiles about special features
- Mobile node checks whether agent is home agent or foreign agent

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# Agent advertisement message



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## Registering Care-of Address

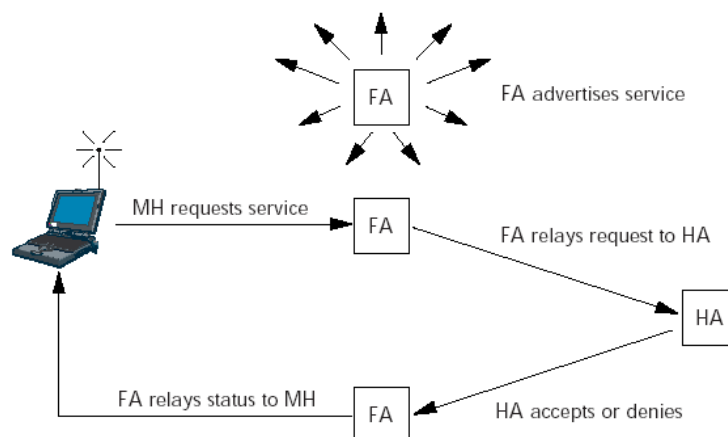
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- Once mobile host receives CoA it registers it with its home agent
    - Registration request goes through foreign agent
  - Home agent approves request and responds with a registration confirmation
    - Security is important
  - Registration has limited lifetime
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## Registering Care-of Address (cont.)

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## Securing the registration procedure

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- Home agent must be certain registration was originated by mobile node
  - Security association based on Message Digest 5 (MD5)
  - Use of timestamps or random numbers to avoid replay attacks
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## Home agent discovery

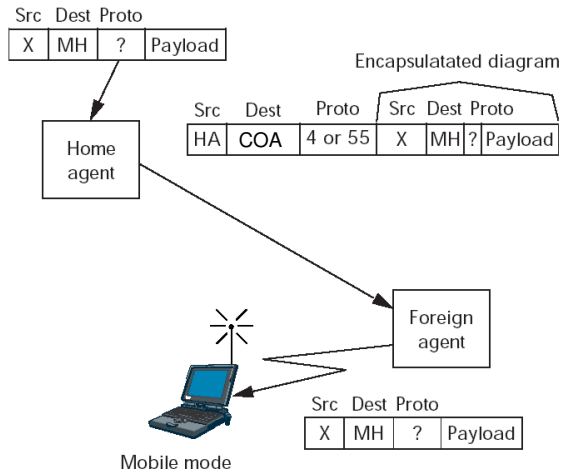
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- Agents operate both as home and as foreign agents
  - Home agents periodically send agent advertisements
  - Mobile listens to agent advertisements to determine if it is in its home network or a foreign network
  - If mobile is unable to communicate with home agent it broadcasts a home agent discovery message
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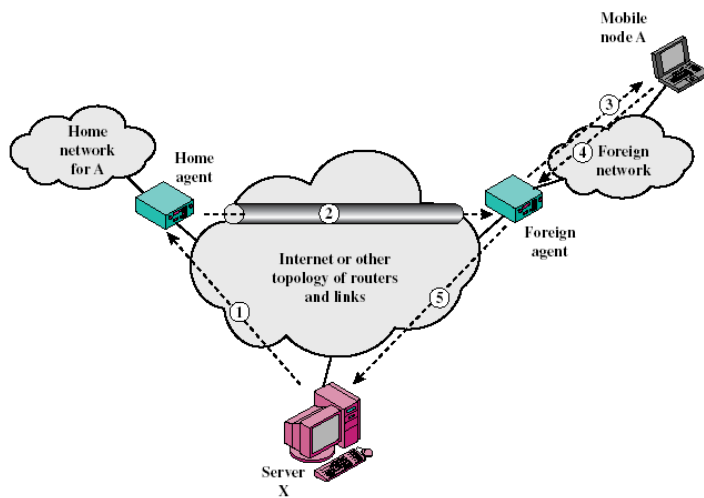


# Tunneling to the care-of-address



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# Mobile IP tunneling and response from mobile node



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## Problems with Mobile IP

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- Routing inefficiencies
    - Asymmetric routing (triangular routing)
    - Reverse tunneling
      - ◆ Solves issue with topologically correct sender addresses
      - ◆ Still inefficient since all packets (forward and reverse) go through home agent
    - Deliver care-of-address to correspondent node
      - ◆ Requires changes to end nodes that are not mobile
  - Security
    - Authentication of foreign agent
  - Packets can be lost when mobile changes network attachment point (handoff)
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## Mobile IP and IPv6

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- Mobile IP was developed for IPv4, but IPv6 simplifies things
    - Security is integrated and not an add-on; IPv6 nodes implement strong authentication/encryption
    - CoAs can be assigned using auto-configuration
    - No need for separate foreign agents; all routers perform router advertisements, which can be used instead of agent advertisements
    - A mobile node can send the CoA directly to correspondent node (route optimization)
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## IP micro-mobility

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- Micro-mobility support
    - Efficient local handover in foreign domain without involving home agent
    - Reduces control traffic on backbone
    - Needed in case of route optimization
  - Approaches
    - Cellular IP
    - HAWAII
    - Hierarchical Mobile IP
    - ... many more
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## Bigger picture: identifiers & locators

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- IP addresses serve a dual role:
    - Identifiers of host interfaces
    - Locators for topological locations used for routing IP packets
  - Above duality makes some things hard
    - Mobility
    - Multi-homing
    - Security/privacy, etc
  - Proposals to separate ID & locator: Locator/ID Separation Protocol (LISP), Host Identity Protocol (HIP), etc
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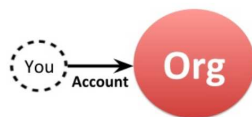
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# Identifiers

- **Decentralized identifiers (DIDs):** new type of identifier that enables verifiable, decentralized digital identity, i.e. independently of any centralized registry
- **Self-sovereign identity (SSI):** individual should own and control their identity without intervening administrative authorities

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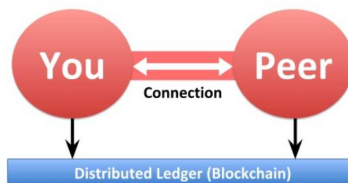
#1: Siloed (Centralized) Identity



#2: Third-Party IDP (Federated) Identity



#3: Self-Sovereign Identity (SSI)



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## Mobility and IPv6 – MobileIPv6

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- IPv6 Neighbor Discovery and Address Autoconfiguration allow hosts to operate in any location without any special support
  - No need for Foreign Agent: IPv6 Address auto-configuration allows MN to obtain a CoA in foreign network
  - Bi-directional tunneling mode
    - Does not require for the CN to support Mobile IPv6
    - Use of Reverse tunneling (for ingress filtering)
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## Mobility and IPv6 – MobileIPv6

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- Route Optimization (RO) mode
    - Requires to register the MN's current binding at the CN
    - Shortest communications path
    - Eliminates congestion at the MN's HA and home link
    - Impact of any possible failure of the HA or networks on the path to or from it is reduced
  - Dynamic Home Agent Address Discovery
    - Allows a MN to dynamically discover the IP address of a home agent on its home link
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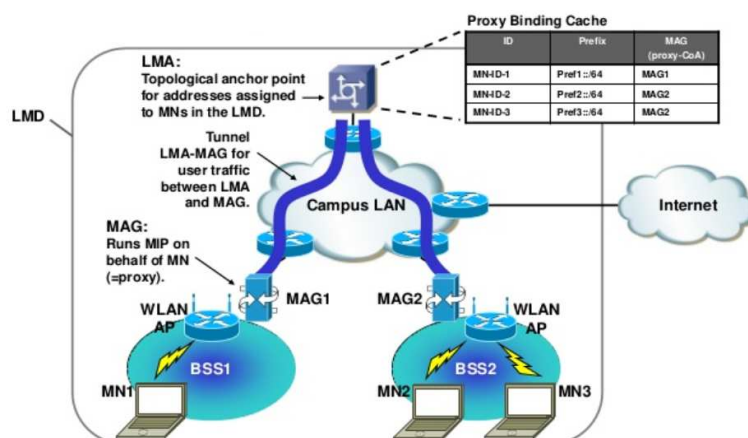
# Proxy Mobile IPv6 (PMIPv6)

- Support mobility in the network rather than on mobile devices
  - Allows operators to have tighter control on mobility
- Introduces two new entities:
  - LMA: Local Mobility Anchor
  - MAG: Mobile Access Gateway
- Two deployment scenarios:
  - WLAN-based campus network
  - 3/4G Cellular networks

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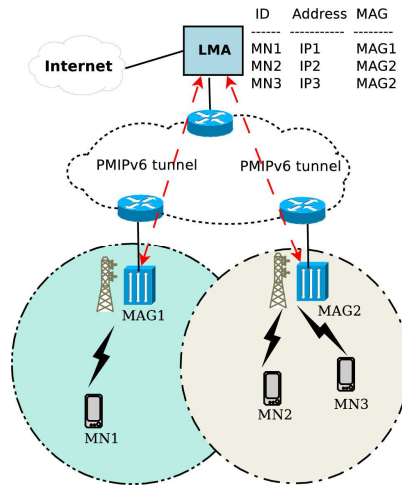
## PMIPv6 setup – WLAN-based campus

LMD: Local Mobility Domain



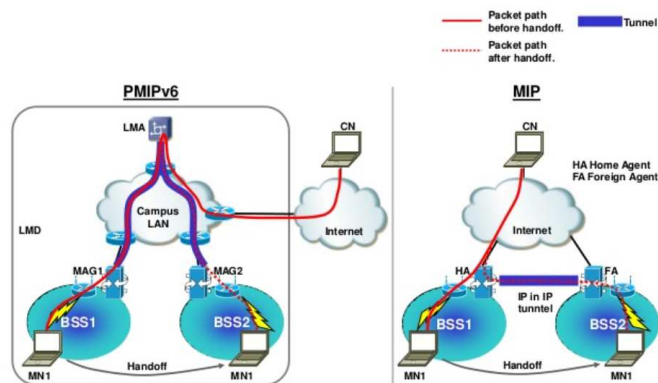
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## PMIPv6 setup – cellular network



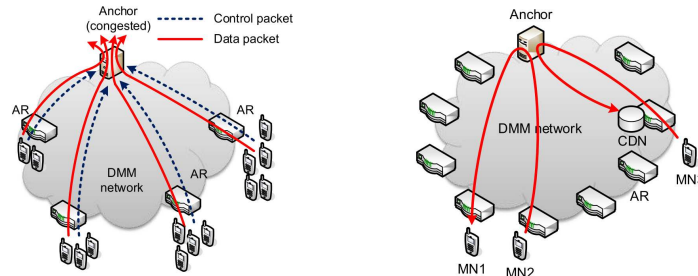
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## PMIPv6 versus Mobile IP



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## Issues with Centralized Mobility Management



- Centralized mobility management: both control and data traverse mobility anchor

Figure sources: S. Jeon et al.: DMM for the Future Mobile Networks, IEEE Access, Vol. 5, 2017

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## Distributed Mobility Management (DMM)

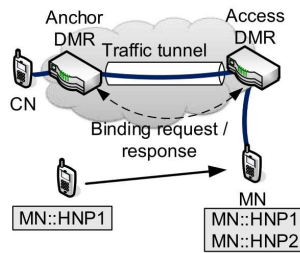
- IP mobility management functions:
  - Movement detection
  - Assignment of IP address/prefix
  - binding update
- Network-based: network performs all three functions
- Host-based: requires intelligence in MN to participate in above functions

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# Network-based mobility

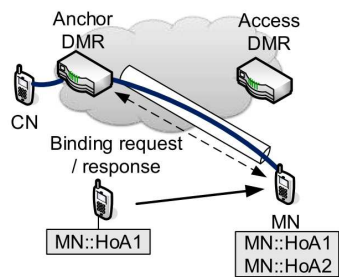
DMR: DMM-enabled router  
HNP: Home Network Prefix



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# Host-based mobility

DMR: DMM-enabled router  
HoA: Home Address

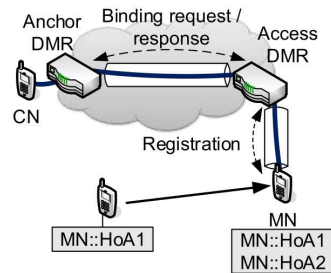


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## Semi host-based mobility

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DMR: DMM-enabled router  
HoA: Home Address



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## Distributed Mobility Management (DMM) flavors

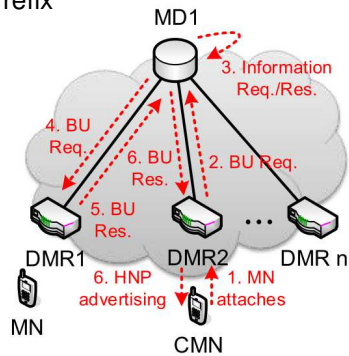
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- Separate control from data path
  - Goal is to make data path distributed
  - Control can be centralized (partially distributed) or distributed (fully distributed)
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## DMM with centralized control

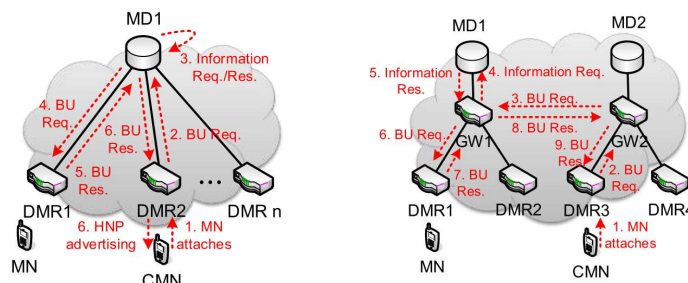
DMR: DMM-enabled router  
 MD: Mobility Database  
 BU: Proxy Binding  
 HNP: Host Network Prefix



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## DMM with centralized control (cont.)

DMR: DMM-enabled router  
 MD: Mobility Database  
 BU: Proxy Binding  
 HNP: Host Network Prefix



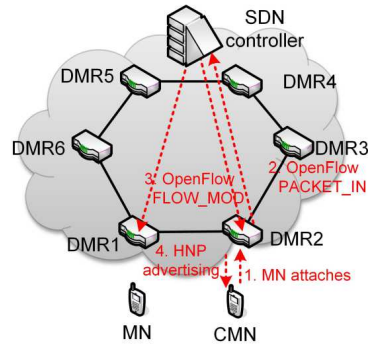
a) Single MD

b) Multiple MDs

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# DMM with centralized control & SDN

DMR: DMM-enabled router

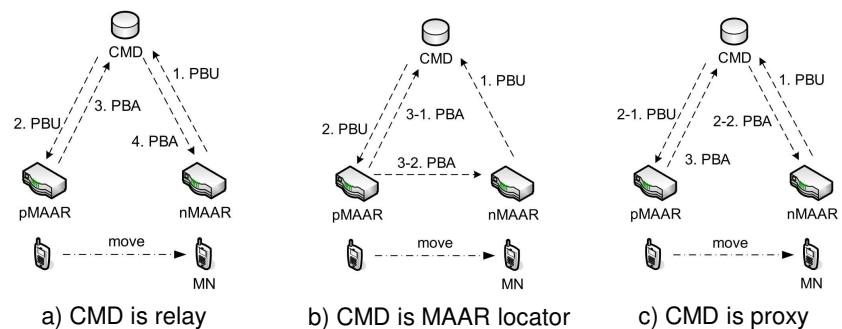


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# Network-based mobility management

PBU: Proxy Binding Update/Acknowledgement

p/nMAAR: previous/next Mobility Anchor and Access Router

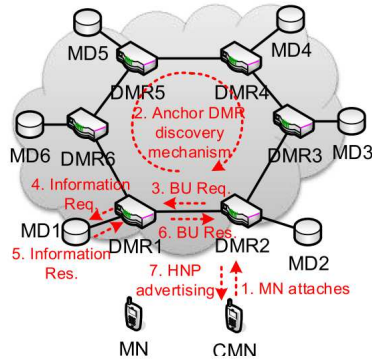


- CMD (Central Mobility Database)
  - Partially distributed mobility management
  - Only data path is distributed

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# DMM with decentralized control

DMR: DMM-enabled router  
MD: Mobility Database



- MD now distributed
- DMR: need discovery mechanisms, e.g. DHT (Distributed Hash Tables)