Οικονομικό Πανεπιστήμιο Αθηνών
Τμήμα Πληροφορικής

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

Εαρινό Εξάμηνο 2024-25

Βασίλειος Σύρης

Motivation for Mobile IP

- 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

Supporting mobile nodes

- 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

Mobile IP requirements

- 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

Mobile IP requirements (cont.)

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

Real life analogy

- 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!

Mobile IP actors

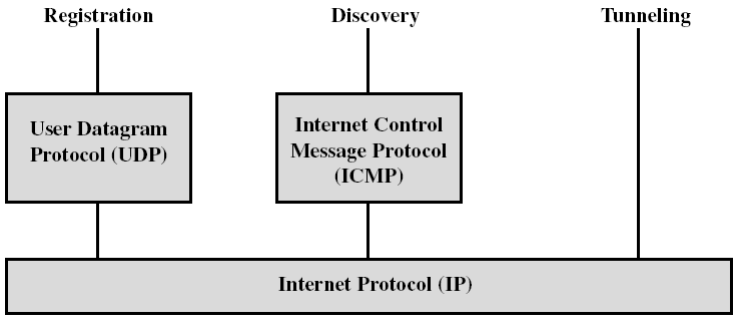
- Mobile Node (MN)
  - Can change point of attachment to fixed network without changing IP address (Home address is static)
  - New Care-of Address (CoA) associated with new network attachment point
- Correspondent Node (CN)
  - Node wishing to communicate with mobile node

Mobile IP actors (cont.)

- 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

Mobile IP mechanisms

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



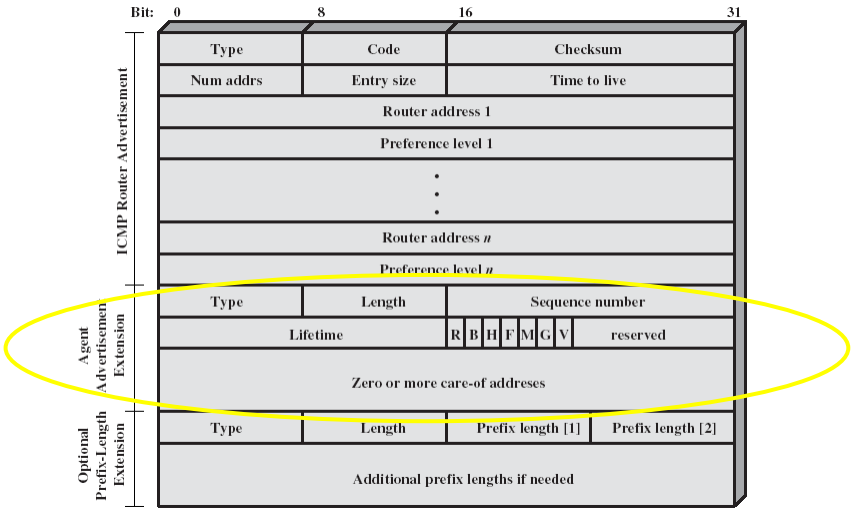
Discovering Care-of Address

- 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

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

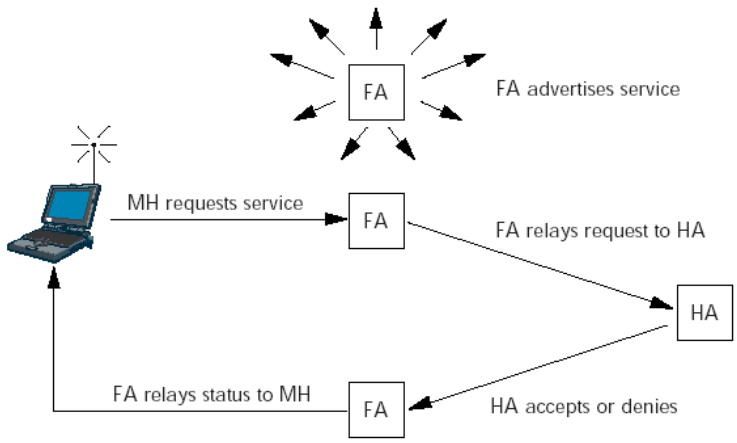
Agent advertisement message



Registering Care-of Address

- 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

Registering Care-of Address (cont.)



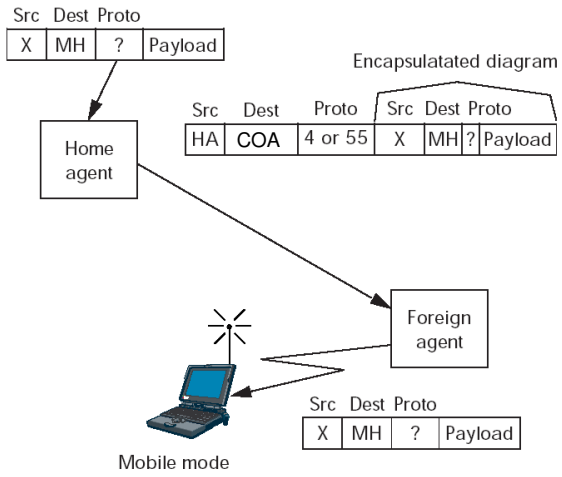
Securing the registration procedure

- 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

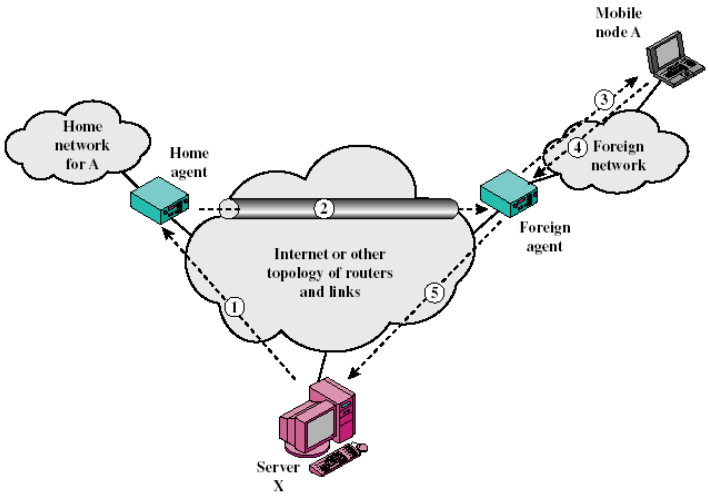
Home agent discovery

- 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

Tunneling to the care-of-address



Mobile IP tunneling and response from mobile node



Problems with Mobile IP

- 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)

Mobile IP and IPv6

- 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)

IP micro-mobility

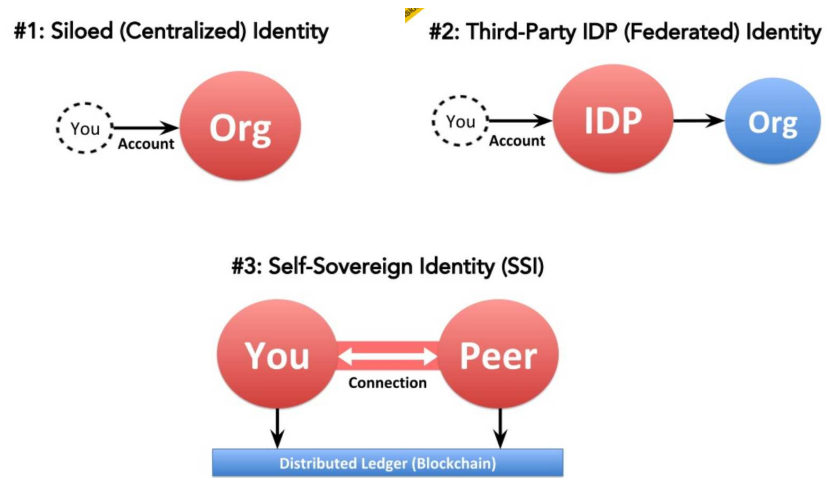
- Micro-mobility support
  - Efficient local handover in foreign domain without involving home agent
  - Reduces control traffic on backbone
  - Needed in case of route optimization
- Approaches
  - Cellular IP
  - HAWAII
  - Hierarchical Mobile IP
  - … many more

Bigger picture: identifiers & locators

- 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

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



Mobility and IPv6 – MobileIPv6

- 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)

Mobility and IPv6 – MobileIPv6

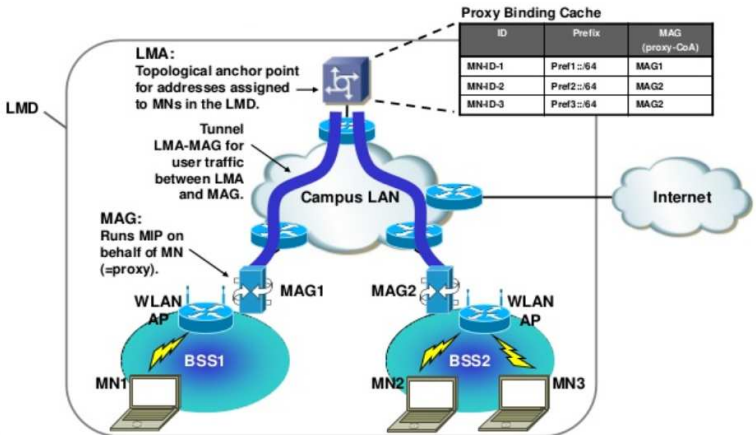
- Route Optimization (RO) mode
  - Requires to register the MN's current binding at the CN
  - Shortest communications path
  - Eliminates congestion at the MN's HA and home link
  - Impact of any possible failure of the HA or networks on the path to or from it is reduced
- Dynamic Home Agent Address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

Proxy Mobile IPv6 (PMIPv6)

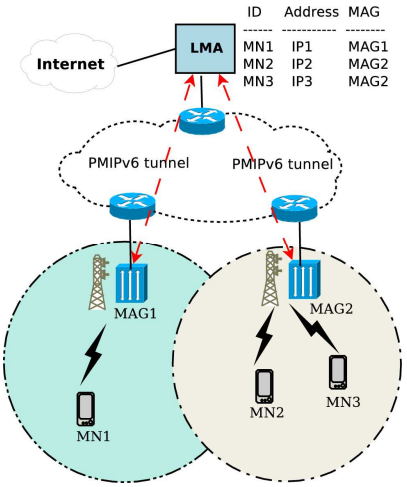
- Support mobility in the network rather than on mobile devices
  - Allows operators to have tighter control on mobility
- Introduces two new entities:
  - LMA: Local Mobility Anchor
  - MAG: Mobile Access Gateway
- Two deployment scenarios:
  - WLAN-based campus network
  - 3/4G Cellular networks

PMIPv6 setup – WLAN-based campus

LMD: Local Mobility Domain



PMIPv6 setup – cellular network



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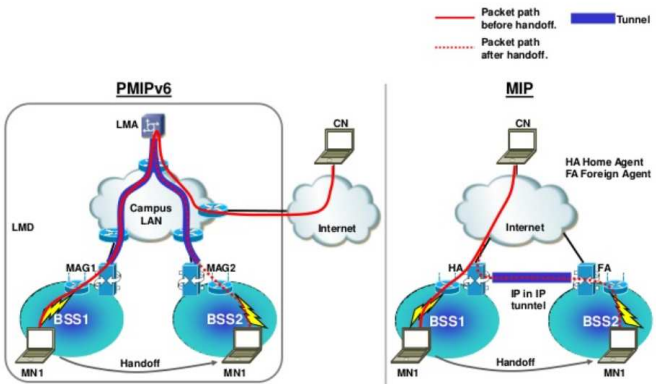
PMIPv6 versus Mobile IP



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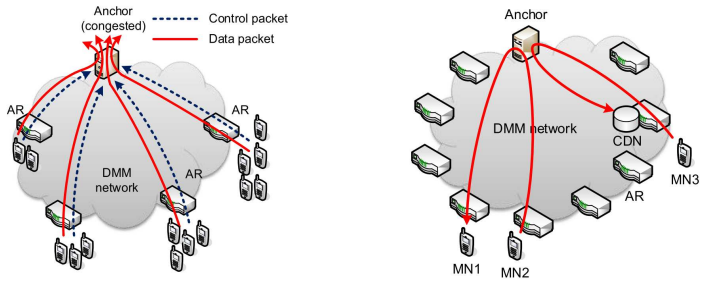
Issues with Centralized Mobility Management



a) Single point of failure

b) sub-optimal routing

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

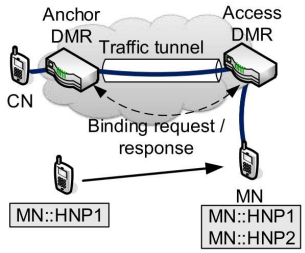
Figure sources: S. Jeon et al.: DMM for the Future Mobile Networks, IEEE Access, Vol. 5, 2017

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

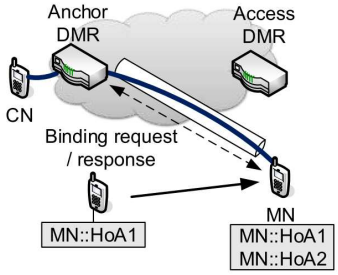
Network-based mobility

DMR: DMM-enabled router
HNP: Home Network Prefix



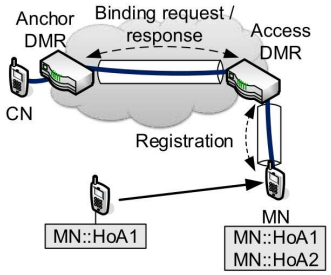
Host-based mobility

DMR: DMM-enabled router
HoA: Home Address



Semi host-based mobility

DMR: DMM-enabled router
HoA: Home Address

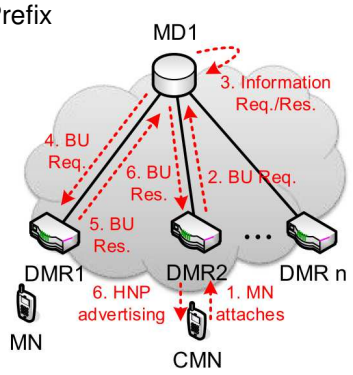


Distributed Mobility Management (DMM) flavors

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

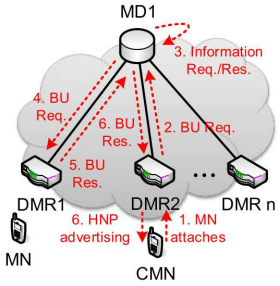
DMM with centralized control

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

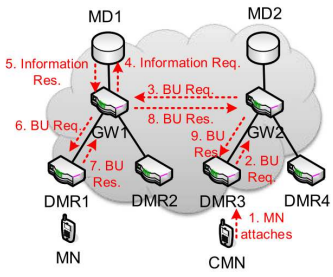


DMM with centralized control (cont.)

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



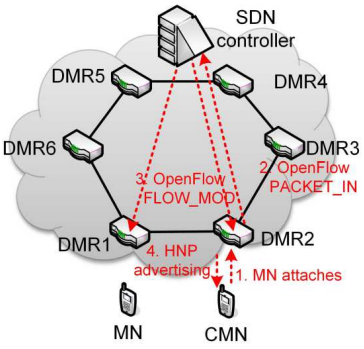
a) Single MD



b) Multiple MDs

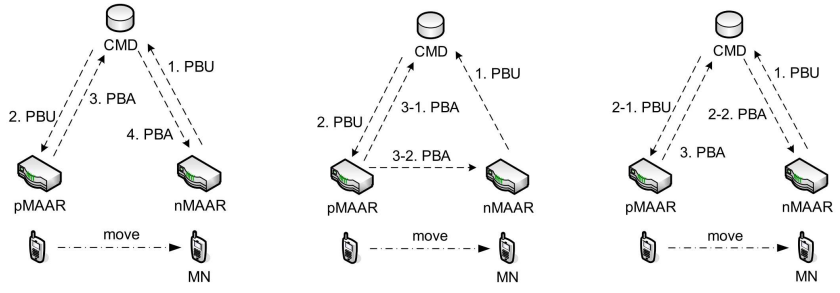
DMM with centralized control & SDN

DMR: DMM-enabled router



Network-based mobility management

PBU: Proxy Binding Update/Acknowledgement
p/nMAAR: previous/next Mobility Anchor and Access Router

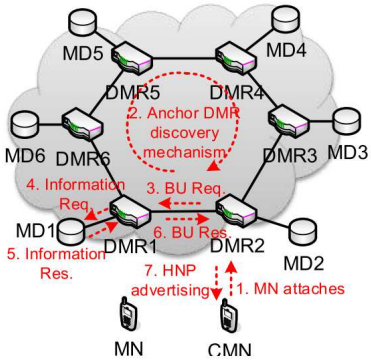


a) CMD is relay b) CMD is MAAR locator c) CMD is proxy

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

DMM with decentralized control

DMR: DMM-enabled router
MD: Mobility Database



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