Mobile IPv6 Overview

Mobile IPv6 (Mobility in a Wireless Internet)
by Hesham Soliman
Addison Wesley Publisher
Contents

- Introduction
- MIPv6 Terminology
- Overview of Mobile IPv6
- Operation of Mobile node and Home agent
- Tunneling
- IPv6 Header
- BU, BA and Mobility Header format
- Movement Detection
- Returning Home
- DHAAD mechanism
- Virtual Home Links
- Route Optimization
- Receiving and Sending Route Optimized Packets
- Proxy MIPv6
Introduction

- Mobile IPv6 is for supporting mobility in IPv6
- While devices move to another place, something happens
- To maintain ongoing connections while moving, Mobile IPv6 uses the *redirection function provided by some mechanism*
- How Mobile IPv6 provides reachability and maintenance of ongoing connections without any collisions and errors
- Overview of Mobile IPv6
**MIPv6 Terminology (MN, CN, HoA)**

- **Mobile Node (MN)**
  - A node that changes its location within the Internet topology

- **Correspondent Node (CN)**
  - Any node that communicates with the MN

- **Home Address (HoA)**
  - A stable address that belongs to the MN
  - Used by CNs to reach MN
MIPv6 Terminology (Links, HA)

- Home Link
  - A link to which the home address prefix is assigned

- Home Agent (HA)
  - A router located on the home link
  - Redirects packets addressed to the MN

- Foreign Link
  - Any links (other than the home link) visited by the MN
**MIPv6 Terminology (CoA, Binding)**

- **Care-of address (CoA)**
  - An address assigned to the MN when located in Foreign Link
  - Based on the prefix of the Foreign Link combined with the MN’s interface identifier
  - Identifies the current location of the MN

- **Binding**
  - The association of the MN’s HoA with a CoA (between the stable home address and the MN’s current location)
  - Binding is refreshed or updated when the MN has a new CoA (because it has moved to a new link)
**MIPv6 Terminology (Binding Cache, BUL)**

- **Binding Cache**
  - A cache stored in volatile memory containing a number of bindings
  - Maintained by both the CN and HA
  - Contains the MN’s HoA, CoA and lifetime

- **Binding Update List (BUL)**
  - A list maintained by the MN in volatile memory
  - Maintained for the MN to know when a binding needs to be refreshed
MIPv6 Introduction Video

Content
- Introduction of terminologies in MIPv6
- Brief introduction of MIPv6 operation

Duration
- 7 minutes and 33 seconds
Mobile IPv6 Overview
Overview of Mobile IPv6 (1/2)

- MIPv6 was designed to allow an MN to be reachable and to maintain ongoing connections while changing the MN’s location
- MIPv6 uses a stable IP address assigned to MN
  - i.e. HoA (Home Address)
- The reasons for uses of the HoA
  - To be reachable by having a stable entry in the DNS
  - To hide the IP layer mobility from upper layers
Overview of Mobile IPv6 (2/2)

- In order for nodes to be reachable
  - The address should not be changed every time they move
    - the need for the HoA provided by MIPv6

- Why keeping a stable address independently of the MN’s location?
  - All CNs try to reach the MN, without knowing the actual location of the MN
Operation of Mobile Node (1/2)

- MN’s Home Address (HoA) is formed by appending an interface identifier to the prefix advertised on the Home Link

- MN operates like any other IPv6 nodes while at home
  - receives packets addressed to any of its HoAs
  - delivered via normal routing
Operation of Mobile Node (2/2)

- When the MN moves *from Home Link to the Foreign Link*
  - MN forms the CoA based on the prefix of the Foreign Link
  - MN informs the Home Agent
    - By sending *a Binding Update (BU) message*
      - BU contains the MN’s Home Address and its CoA
  - Home Agent needs to store Binding Update to forward packets to the MN
    - Binding cache contains all bindings for the Mobile Nodes
    - Each entry in the binding cache stores a binding for one home address
Operation of Home Agent (1/3)

- When the Home Agent receives the binding update
  - HA searches its binding cache to see if an entry already exists
  - If the entry already exists
    - updates that entry with the new information received
    - Otherwise, a new one is created

- Home Agent acts as a proxy for the Mobile Node on the Foreign Link
Operation of Home Agent (2/3)

To ensure this representation is understood by all nodes on the home link:

- HA sends a proxy neighbor advertisement to the all-node multicast address.
- The advertisement includes (in the target address field):
  * the MN’s home address
  * the HA’s link-layer address
- Then, packets to the MN is forwarded to the Home Agent’s Link-Layer address.
Operation of Home Agent (3/3)
Tunneling (CN->MN)

- Upon receiving a packet addressed to the Mobile Node
  - HA checks its binding cache
  - When entry is found, the packet is tunneled to the MN’s CoA
**Tunneling (MN->CN)**

- The tunnel is bidirectional and when the MN sends any packets
  - *MN tunnels them first to the HA*
  - *HA decapsulates the packet and forwards* the original one to its destination

![Diagram of Tunneling (MN->CN)]
Tunneling (Figure)
Tunneling (Transparency)

- Tunneling is required to ensure the transparency of the service provided by the Home Agent
  - To preserve the end-to-end nature of packets exchanged between the MN and CNs
- Routers must not modify the content of source and destination addresses in the IP header
  - Thereby, preserves the integrity of the packet and allows end-to-end integrity checks
- Tunneling is essential to maintain transparency for upper layers
- If the HA rewrites the destination address in the packet
  - Packet’s integrity is compromised
  - Causing the Authentication Header to fail
Practice Problem

- What is the difference between Home Address (HoA) and Care of Address (CoA)?
IPv6 Header

<table>
<thead>
<tr>
<th>Version</th>
<th>Class</th>
<th>Flow Label</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Payload Length</td>
<td>Next Header</td>
<td>Hop Limit</td>
</tr>
<tr>
<td>128 bit Source Address</td>
<td></td>
<td></td>
</tr>
<tr>
<td>128 bit Destination Address</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Version: 4-bit IP version
- Class: Traffic Class (Congestion control and non-congestion control traffic)
- Flow Label: QoS Management
- Next Header: Specifies the next encapsulated protocol.
- Hop Limit: Replaces the time to live field of IPv4
## Next Header Fields

<table>
<thead>
<tr>
<th>Value</th>
<th>Header</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Hop-by-Hop Options Header</td>
</tr>
<tr>
<td>6</td>
<td>TCP</td>
</tr>
<tr>
<td>17</td>
<td>UDP</td>
</tr>
<tr>
<td>41</td>
<td>Encapsulated IPv6 Header</td>
</tr>
<tr>
<td>43</td>
<td>Routing Header</td>
</tr>
<tr>
<td>44</td>
<td>Fragment Header</td>
</tr>
<tr>
<td>50</td>
<td>Encapsulating Security Payload</td>
</tr>
<tr>
<td>51</td>
<td>Authentication Header</td>
</tr>
<tr>
<td>58</td>
<td>ICMPv6 (Internet Control Message Protocol Version 6)</td>
</tr>
<tr>
<td>59</td>
<td>No Next Header</td>
</tr>
<tr>
<td>60</td>
<td>Destination Options Header</td>
</tr>
<tr>
<td>135</td>
<td>Mobility Header</td>
</tr>
</tbody>
</table>
Chain of the Next Header Fields

IPv6 Header
Next Header = 6
(TCP)

TCP Segment

IPv6 Header
Next Header = 43
(Routing)

Routing Header
Next Header = 17
(UDP)

UDP Segment

IPv6 Header
Next Header = 43
(Routing)

Routing Header
Next Header = 51
(AH)

Authentication Header
Next Header = 6
(TCP)

TCP Segment
### Extension Header Order

<table>
<thead>
<tr>
<th>Version</th>
<th>Traffic Class</th>
<th>Flow Label</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Payload Length</td>
<td>Next Header</td>
<td>Hop Limit</td>
</tr>
<tr>
<td>Source Address</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Address</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Header Hdr Ext Len</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hop-by-hop Options Extension Header (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Header Hdr Ext Len</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Options Header (60)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Header Hdr Ext Len Routing Type Routing Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routing Header (43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Header Reserved Fragment Offset Res</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>Fragment Header (44)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Header Hdr Ext Len</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authentication Header (51)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encapsulating Security Payload Header (50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Header</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Header Hdr Ext Len</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Options Header (60)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **For intermediate destination**: All the IPv6 nodes on the path need to process the options in this header.
- **For final destination**: For final destination.
Binding Updates and Binding Acks

- MN ensures that it has a binding with Home Agent
- If the binding is lost or the Binding Update message was not received
  - MN will be unreachable while away from home
  - Hence, a reliable protocol is required to install a binding in the Home Agent’s binding cache
  - Home Agent is required to acknowledge the Binding Update message sent by the Mobile Node
- BU and BA included in Mobility Header
**BU, BA and Mobility Header Format**

- Mobility Header is used to carry all MIPv6 messages
  - Format

<table>
<thead>
<tr>
<th>Payload protocol</th>
<th>Header length</th>
<th>MH Type</th>
<th>reserved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checksum</td>
<td>Message Data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Payload protocol field:** Indicates the type of the following header
- **Header length field:** Indicates the length of this extension header
- **Mobility header (MH) type field:**
  - Used as a switch to indicate which message is included in the mobility header
  - **Binding Update** has the MH Type value **5**
  - **Binding Acknowledgement** has the MH Type value **6**
BU Message Format

- **A (Acknowledge) flag**: Acknowledgment is required
- **H (Home Registration) flag**: Binding Update is sent to a home agent
- **L (Link-Local Address Compatibility) flag**: The home address reported by the mobile node has the same interface identifier as the mobile node's link-local address
- **K (Key Management Mobility Capability) flag**: Indicates whether the protocol used to establish a security association between the MN and HA must be rerun every time the MN moves, e.g. IPsec
- **Lifetime field**: 16-bit unsigned integer
  - The number of time units remaining before the binding MUST be considered expired
  - A value of zero indicates that the Binding Cache entry for the mobile node MUST be deleted
  - One time unit is 4 seconds
**BA Message Format**

<table>
<thead>
<tr>
<th>8bit</th>
<th>8bit</th>
<th>16bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status</td>
<td>K</td>
<td>Reserved</td>
</tr>
<tr>
<td>Sequence number</td>
<td>Lifetime</td>
<td></td>
</tr>
</tbody>
</table>

- **Status field:**
  - Success or failure of the binding
  - Value below 128 indicate success
  - Rest of the value indicate the reasons for failure

- If MN does not receive BA, MN continues to retransmit the BU
  - Until an ACK is received or
  - Until a maximum timeout value (256 sec) is reached

- After receiving the BA from the HA, the MN needs to ensure that information is stored to be able to refresh the binding
  - For this purpose, MN maintains a data structure called the *binding update list*
**Binding Cache Structure**

- **Maintained by HA and CNs**

<table>
<thead>
<tr>
<th>Home Address</th>
<th>Care of Address</th>
<th>Remaining Lifetime</th>
<th>Flag</th>
<th>Max. value of SN</th>
<th>Recent usage inform.</th>
</tr>
</thead>
</table>

- **Home Address**: HoA for the MN, searching key
- **Care of Address**: CoA for the MN
- **Remaining Lifetime**
- **Flag**: indicate whether or not "home registration" entry
- **Maximum value of the SN**: value of Sequence Number field received in previous BU (8 bits long)
- **Recent usage inform**: related to implement cache replacement policy
**Binding Update List Structure**

- **Maintained by MN**

<table>
<thead>
<tr>
<th>IP Addr.</th>
<th>Home Addr.</th>
<th>CoA</th>
<th>Interface ID</th>
<th>Initial value of Lifetime</th>
<th>Remaining Lifetime</th>
<th>Max. value of SN</th>
<th>...</th>
<th>Flag</th>
</tr>
</thead>
</table>

- **IP Address**: IP address of the node to which a BU was sent
- **Home Address**: MN’s home address
- **CoA**: MN’s CoA
- **Initial value of Lifetime**
- **Remaining Lifetime**
- **Maximum value of the SN**
- **last BU Time**
- **Retransmission State**: the time remaining until the next retransmission attempt for the Binding Update
- **Flag**: indicates that future BUs should not be sent to this destination
Movement Detection (Packet Loss)

- The MN should always inform its HA of its current location (CoA)
  - This is done by using the BU and BA messages
  - However, its HA continues to forward packets to its previous CoA until the MN updates its movement
  - This results in packet losses
Movement Detection (Procedure)

- To minimize packet losses,
  1. Detect movement
  2. Form a new care-of address
  3. Inform the HA by sending a binding update

  - Steps 1 and 2 need to be executed ASAP

- Two events for Movement Detection
  - A new prefix has appeared on link
  - The current default router has disappeared

- MIPv6 makes the minimum interval between router advertisements to 0.05 second (standard interval is 3 seconds)
Movement Detection (More Routers?)

- If a Mobile Node is located on a link that has more than one default router
  - router_1 and router_2 are connected on the same link
  - If the MN initially configures its CoA based on router_1’s advertised prefix, then receives an advertisement from router_2
  - MN might think that it has moved
    - in fact it does not!
    - How do we solve this situation?
Movement Detection (Approach)

To avoid the situation in this scenario,

- Configure all routers on the link to advertise the same prefixed
- Design a new option that should be added to the router advertisement
- This option could include a globally unique address that identifies the link
- All routers on the link would have to include this option regardless of the prefixes they advertise
Returning Home (1/2)

- When the MN returns to its Home Link
  - Inform the HA that should stop receiving MN’s packet
  - The MN must send a BU to the HA with a lifetime of zero and a CoA equal to the MN’s HoA
- MN needs to configure its Home Address to be able to send the BU
  - But, HA still assumes that it should defend the MN’s HoA, which would cause DAD to fail and prevent the MN from configuring its HoA (DAD, Duplicate Address Detection)
- To avoid DAD,
  - The MN needs to learn from HA’s MAC address
Returning Home (2/2)

- **neighbor solicitation**
  - Src add = the unspecified add (::)
  - Dst add = the HA’s solicited node multicast address
  - Target add = the HA’s global IP address

- **neighbor advertisement**
  - To the all-node multicast address

- **binding update with HA’s MAC address**
  - Src add = its home address
  - Dst add = the HA’s address
Dynamic Home Agent Address Discovery

- Mobile Node needs to locate a suitable Home Agent
  - HA’s address can be configured in the MN (with a nonvolatile memory)
- This approach has some drawbacks
  - If too many mobile nodes register with the home agent,
    - Addresses successfully change if HA address change occurs, otherwise the HA may fail or simply get overloaded
- Can be done by Dynamic Home Agent Address Discovery (DHAAD) message
- MIPv6 provides a Dynamic Home Agent Address Discovery
  - Allow MNs to discover HAs’ addresses
  - Allow HAs to *share the load between them* in cases where multiple HAs are located on the same link by utilizing a *preference* parameter
Home Agent Information Option

<table>
<thead>
<tr>
<th>8bit</th>
<th>8bit</th>
<th>16bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Length</td>
<td>Reserved</td>
</tr>
<tr>
<td>Home Agent Preference</td>
<td>Home Agent Lifetime</td>
<td></td>
</tr>
</tbody>
</table>

- preference is included in the new option
  - Home Agent Information Option
  - Included in router advertisement
- Every HA on a link keeps a list (the home agent list) containing an IP address of each HA on the link and its preference
- To communicate the information in the HA list to MNs
  - using DHAAD messages, Carried in two ICMP messages
  - DHAAD request and DHAAD reply messages
- preference
  - Default value is zero
  - Larger values indicate higher availability of the Home Agent
- Home Agent lifetime: How long a router can serve as a Home Agent
Virtual Home Links

- A DoS attack can be launched by Bad Guy sharing a link with Home Agent
  - If the home prefix is not associated to any physical link and if the home link is a virtual link, these problems can be avoided
  - The home prefix can be configured on the Home Agent and Mobile Nodes only
  - The Home Agent would not send any router advertisements for this prefix
    - Consequently, MN would never “return home”

- HA makes sure that the home address is not allocated to another node
  - Since no one else is located on the home link except Mobile Nodes and the Home Agent, no proxy neighbor advertisement would be sent on the wire
  - Bad Guy cannot launch DoS attacks on the Mobile Node’s home address
Practice Problem

What is the purpose of Binding Update and Acknowledgement messages?
**Addition Delays**

- Routing packets through the HA always adds additional delays.

![Diagram showing Mobile IPv6](image-url)
Route Optimization

- The worst-case scenario
  - MN and CN share the same link

- The best-case scenario
  - CNs were on the MN’s home link

- A problem with forcing traffic through HA
  - While it may be possible to eventually detect the failure of HA,
  - Its failure would cause the MN to lose all ongoing connections

- Route optimization is about to
  - Route packets between a MN and a CN
  - Using the shortest possible path

- MN is aware of
  - When packets are routed through the HA
  - When it receives tunneled packets addressed to its HoA

- How does a MN know if the communication with a CN lasts for a short or a long time?
  - NO concrete answer

- A “smart” MN’s implementation
  - Duration of a connection, RTT, and amount of data
Route Optimization Signaling (1/3)

- When MN receives a packet tunneled from HA
  - MN must decide whether route optimization is needed
- MN informs the CN of its current location
  - Using the binding update message
- The CN maintains a binding cache
  - Similar to the one maintained by the HA
  - BU sent to CN must not set the H-, K-, L-bits

<table>
<thead>
<tr>
<th>8bit</th>
<th>8bit</th>
<th>8bit</th>
<th>8bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload protocol</td>
<td>Header length</td>
<td>MH Type</td>
<td>Reserved</td>
</tr>
<tr>
<td>Checksum</td>
<td></td>
<td>Sequence number</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>H</td>
<td>L</td>
<td>K</td>
</tr>
</tbody>
</table>

<The binding update message format>

A (Acknowledge) flag, H (Home Registration) flag, L (Link-Local Address Compatibility) flag, K (Key Management Mobility Capability) flag:
Route Optimization Signaling (2/2)

- When a CN receives a BU from a MN
  - It creates a new entry in the binding cache
  - Updates the existing one with the new location of the MN
Two Aims of the BU

- Allow packets directly between MNs and CNs without going through the HA
- Maintain ongoing connections
  - MIPv6 defines two messages
    - New routing header type 2
    - New destination option called the home address option
- Sending Route Optimized packets to CN
Summary: Route Optimization

- When the MN sends a BU to a CN
  - Indicate the home address
    - At the home address option in the destination option’s extension header
  - After the BU, MN’s home address is stored in CN’s binding cache
  - If the A flag is set, binding acknowledgment to MN
  - MN updates binding update list
    - CN’s IPv6 address, MN’s HoA and CoA, sequence number, lifetime
  - MN uses the home address option
    - src : home address, dst : CN address
    - The home address option is essentially a disguised form of tunneling
### Sending Route Optimized Packets to CN

- **Mobility is kept transparent to upper layers**
  - When a CN receives a packet containing a home address option
  - Replaces the source address in the packet’s header with the address included in the home address option before passing the packet to upper layers

- **It is important to note that**
  - MN includes the home address option only in packets sent directly to CN
  - *i.e.*, BU was sent and accepted

- **Adding the home address option** before sending a packet

<table>
<thead>
<tr>
<th>(a) original packet</th>
<th>(b) home address option added</th>
<th>(c) final packet to be sent</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPv6 header</td>
<td>IPv6 header</td>
<td>IPv6 header</td>
</tr>
<tr>
<td>Src:home address</td>
<td>Src:home address</td>
<td>Src:care-of address</td>
</tr>
<tr>
<td>Dst:CN address</td>
<td>Dst:CN address</td>
<td>Dst:CN address</td>
</tr>
<tr>
<td>Application data</td>
<td>Dst opt header</td>
<td>Home address</td>
</tr>
<tr>
<td></td>
<td>Care-of address</td>
<td>Application data</td>
</tr>
<tr>
<td></td>
<td>Application data</td>
<td></td>
</tr>
</tbody>
</table>

**IPv6 header**
- **Src:** home address
- **Dst:** CN address
- Application data

**IPv6 header**
- **Src:** home address
- **Dst:** CN address
- Dst opt header
- Care-of address
- Application data

**IPv6 header**
- **Src:** care-of address
- **Dst:** CN address
- Dst opt header
- Home address
- Application data
Receiving Route Optimized Packets from CNs

- New routing header: Type field set to 2
- When receiving the packet
  - MN processes the routing header
  - Replacing the destination address (CoA) with the address in the routing header (home address)
- A BU Sent to CN
- The process of route optimization involves 3 distinct steps
  - Detecting that packets are tunneled by the HA
  - Sending a binding update to the CN
  - Sending packets directly to the CN and including the home address option in those packets
BU Sent to CN, and then

- When CN has not accepted the BU, CN discards packets
- To ensure the acceptance of the BU
  - MN can request an acknowledgment, A-flag in the BU
- What if CN failed?
- Binding error message
  - No binding cache entry exists for home address
  - Type field value of 7
  - Status field set to 1, 2

<Binding error message>
Why Not IP in IP Tunneling for Route Optimization?

- The basic idea behind route optimization is
  1) to hide the MN’s home address inside the packets; 2) to avoid breaking ingress filtering; and 3) to route packets to the right location in the topology

- The same effect could have been achieved by using IP in IP tunneling between MN and CN
  - Following the BU processing, a tunnel can be established between the MN and the CN

- Using tunneling between the MN and the CN

(a) Tunneled packets originating from the MN
(b) Tunneled packets originating from the CN

- Advantage: Using the existing mechanism known to Tunneling
- Disadvantage: More network bandwidth
What If MN Failed?

- MN maintains state about the nodes
  - Binding update list
- The loss of such information in MN results in
  - Different sets of information in the MN, its HA, and CNs
- If the MN loses the information
  - It immediately attempts to update its HA
- To update the current binding
  - Use a sequence number larger than the one used in its last BU message
  - If MN is not aware of the last value used, it picks a random value
Site-Local Address and MIPv6

One of the problems with site-local addresses

- MN has no way of knowing whether it is in its home site or another one

When the MN moves away from its home link, it does not know

- If the MN is in fact in the same site
  - the BU is received by the HA, and MIPv6 will work
- If the MN is in a different site, two possible outcomes
  - Another node in the same site is configured with the same site-local address as the HA; this node will receive the BU from the MN
    - However, since BUs/BAs are protected by IPsec there is no chance of confusion in this case; it will silently discard the packet
  - No node in this site is configured with the HA’s site-local address;
    - Therefore, the MN will receive an ICMP error “Destination unreachable”
MN Sending Packets

1. Receive upper layer data
2. Construct IP header
   - BUL entry exists?
     - Yes: Find CoA
     - No: Put CoA in HAO
   - BC entry exists?
     - Yes: Put CoA in RH and HoA in dst
     - No: Continue
3. IPsec needed?
   - Yes: Add AH/ESP
   - No: Proceed
4. HAO exists?
   - Yes: Swap HAO content with src address
   - No: RH type 2 exists?
     - Yes: Swap RH content with dst address
     - No: Determine next hop
     - Send packet

BUL: Binding Update List
BC: Binding Cache
CoA: Care-of address
HAO: Home address option
HoA: Home Address
RH: Routing Header
CN Received Packets

Flowchart:

1. Receive packet from link layer
2. Process IP header
   - RH type 2 exists?
     - Yes: Swap HoA with dst address
     - No: HAO exists?
       - Yes: BC entry exists?
         - Yes: Swap HoA and src address
         - No: Send binding error
       - No: IPsec needed?
         - Yes: Verify AH/ESP
         - No: Pass to upper layers
3. BC: Binding Cache
   CoA: Care-of address
   HAO: Home address option
   HoA: Home Address
   RH: Routing Header
Proxy Mobile IPv6 (PMIPv6)

- PMIPv6 is a network-based local mobility management protocol developed by the IETF (Internet Engineering Task Force).
- PMIPv6 is new Idea?
  - Absolutely No!, but new trend!. It’s a turn for the better.
  - In the handover latency aspect, PMIPv6 is a very good protocol.
- More Study and Standardization Needed
  - Route Optimization in PMIPv6
  - Fast Handover in PMIPv6
  - Cross-layering Issues
    - PMIPv6 over IEEE 802.16(e)/WiBro
    - Fast Handover with leverage of IEEE 802.21
Goal of PMIPv6

- To provide mobility without requiring the host to participate in any mobility related signaling.
PMIPv6 Overview (1/2)

■ New entities

- LMA (Local Mobility Anchor)
  ★ Home Agent for the MN in the PMIPv6 domain
  ★ Assigns MN's home prefix and manages the MN's reachability state
- MAG (Mobile Access Gateway)
  ★ Manages the mobility related signaling for a MN
  ★ Tracking the MN's attachment to the link and for signaling the MN's LMA

■ Assumptions (or Restrictions)

- Link between MN and MAG is a point-to-point link (not shared link)
  ★ Logically exclusive layer 3 link between MN and MAG
- Per-MN Prefix model
  ★ unique home network prefix is assigned to MN
- Support both Stateless and Stateful address configuration modes
PMIPv6 Overview (2/2)

**IP Tunnel**
IP-in-IP tunnel between LMA and MAG

**LMA**: Local Mobility Anchor
**MAG**: Mobile Access Gateway

**Home Network**
MN's Home Network (Topological Anchor Point)

**LMA Address (LMAA)**
That will be the tunnel entry-point

**LMM**
(Localized Mobility Management) Domain

**Proxy Binding Update (PBU)**
Control message sent by MAG to LMA to establish a binding between MN-HoA and Proxy-CoA

**Proxy Care of Address (Proxy-CoA)**
The address of MAG That will be the tunnel end-point

**MN’s Home Network Prefix (MN-HNP)**
CAFE:2:/64

**MN’ Home Address (MN-HoA)**
MN continues to use it as long as it roams within a same domain

**MN’s Home Network**
The address of MAG That will be the tunnel end-point
PBU and PBA Message Format (1/2)

■ Proxy Binding Update (PBU) Message

- A, H, L, K: RFC 3775, MIPv6 BU Reuse
- M: indicates MAP (Mobility Anchor Point) registration (HMIPv6)
- R: It is set to inform the HA, if the BU message comes from MS
- P (Proxy Registration Flag)
  - Indicates that the registration is a Proxy registration.
**PBU and PBA Message Format (2/2)**

- **Proxy Binding Update Acknowledgement (PBA) Message**

  - **K**: RFC 3775, MIPv6 BA Reuse
  - **R**: indicates that the HA that processed the BU supports the MS
  - **P (Proxy Registration Flag)**
    - ★ indicates that the HA that processed the Proxy Binding Update supports Proxy Registration.
PMIPv6 Features (1/3)

■ Home in Any Place

► Network Entry (or Handover) Procedures

★ After MN attachment, MAG gets MN’s profile
★ Obtain MN’s home network prefix information
  • Static Scheme ➔ Get it from Profile
  • Dynamic Scheme ➔ Get it from LMA via PBU/PBA
★ Now MAG has enough information to emulate MN’s home link
★ Send the RA (Router Advertisement) messages advertising MN’s home network prefix and other parameters

► MAG runs on the access router will emulate the home link on its access link.

★ MN always obtain its “home network prefix”, any where in the network.
★ It will ensure that MN believes it is at its home.
PMIPv6 Features (2/3)

- **M:1 Tunnel**
  - LMA-MAG tunnel is a shared tunnel among many MNs.
    - 1:1 relation → m:1 relation
    - One tunnel is associated to multiple MNs’ Binding Caches.
    - Life-time of a tunnel should not be dependent on the life time of any single BCE (Binding Cache Entry).

- **RA (Router Advertisement) should be UNICASTed to an MN**
  - It will contain MN’s Home Network Prefix
PMIPv6 Features (3/3)

- **LMA’s Prefix-based Routing**
  - LMA will add prefix routes to MN’s home network prefix over the tunnel.

  ![Routing State for a MN stored in LMA]

- **MAG establishes IP in IP tunnel with LMA**
  - Routing State for a MN stored in MAG

  ![Routing State for a MN stored in MAG]

- IPv6 traffic for the Mobile Node’s home prefix
  - MN-HoA::/64 via tunnel0, next-hop Proxy-CoA

  ![tunnel0]

  - Source: LMAA
  - Destination: Proxy-CoA
  - Tunnel Transport: IPv6
  - Tunnel Payload: IPv6

- Mobile Node’s IPv6 traffic
  - For all traffic from MN-HoA to destination 0::/0 route via tunnel0, next-hop LMAA

  ![tunnel0]

  - Source: Proxy-CoA
  - Destination: LMAA
  - Tunnel Transport: IPv6
  - Tunnel Payload: IPv6
PMIPv6 Operation Flow

- **MN**
  - MN Attachment
  - RA*
  - RA**
  - Optional
  - DHCP Request
  - DHCP Response
  - [MN-HoA:CN](data)

- **MAG**
  - AAA Query with MN-ID
  - AAA Reply with Profile
  - PBU with MN-ID, Home Network Prefix option, Timestamp option

- **AAA&Policy Store**
  - PBU with MN-ID, Home Network Prefix option
  - PBA with MN-ID, Home Network Prefix option
  - Tunnel Setup

- **LMA**
  - [Proxy-CoA:LMAA][MN-HoA:CN](data)
  - [MN-HoA:CN](data)

- **CN**

**Key Points**
- PBU: Proxy Binding Update
- PBA: Proxy Binding Ack.