MIPv4 & MIPv6
- Overview of IP Mobility Protocols -

February 2009

Courtesy of Youn-Hen Han
Korea Univ. Of Technology

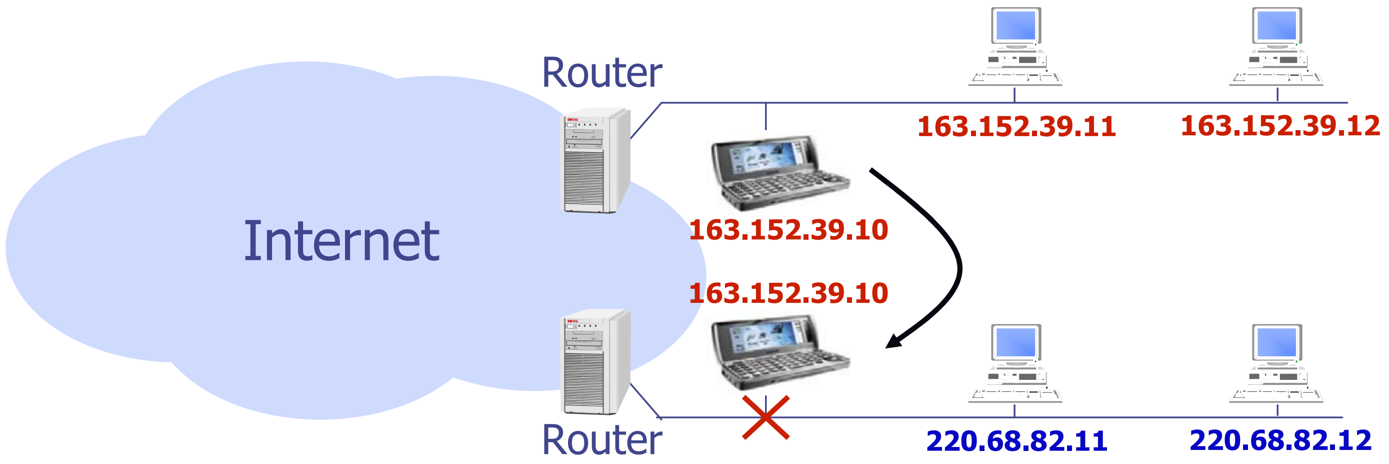
Outline

- IP Mobility - Why and What
- Mobile IPv4 (RFC 3344)
- Mobile IPv6 (RFC 3775)

- MD (Movement Detection) & DAD (Duplicate Address Detection) Optimization
- BU (Binding Update) Optimization
- Handover Latency Comparison & More Improvement
- Future Research Issues

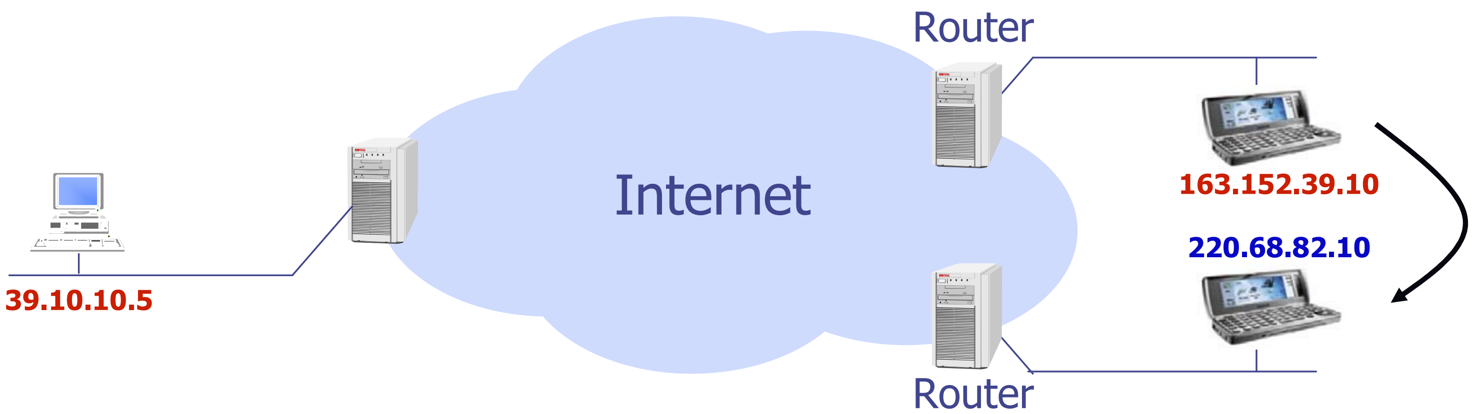
IP Mobility - Why and What

IP's Routing Model



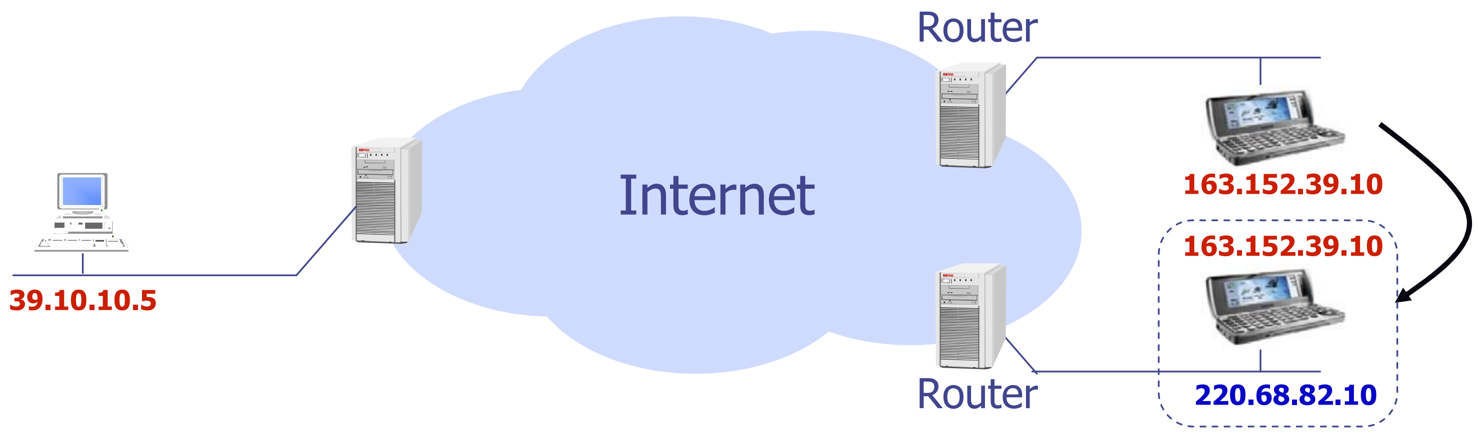
- Addresses are assigned in a topologically significant manner
- Routing based on address prefixes
- MN (Mobile Node) must be assigned a new address when it moves

IP Session Continuity



- TCP connections are defined by…
  - [Source IP, Source Port, Destination IP, Destination Port]
- MN's address must be preserved regardless of its location to preserve the on-going IP session.
- Therefore, when an MN moves,
  - Retain the MN address → Routing fails
  - Change the MN address → IP Session breaks

Solutions : Two-tier IP addressing

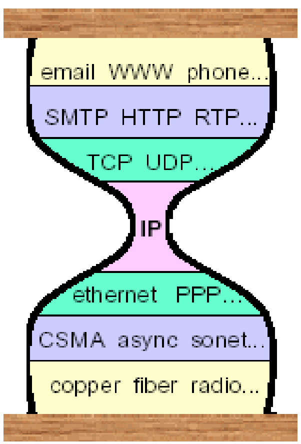


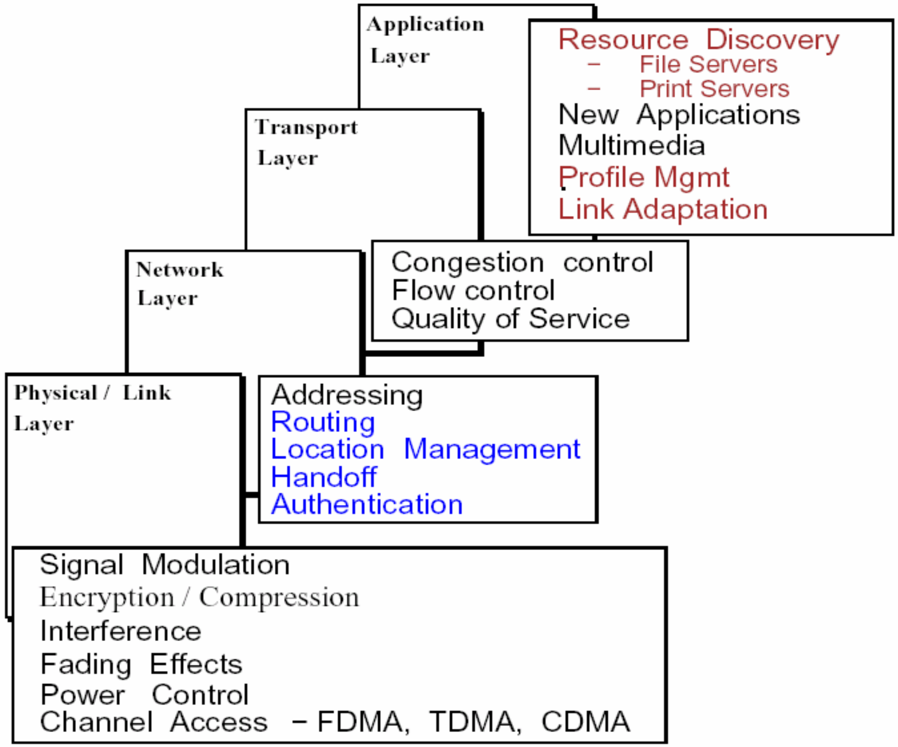
- MN keeps its static IP address, but uses a temporary a CoA(care-of address) when it moves to another subnet

HoA (Home Address) – the original static IP address – 163.152.39.10
CoA (Care-of Address) – the temporary IP address – 220.68.82.10

Why Network-layer Mobility?

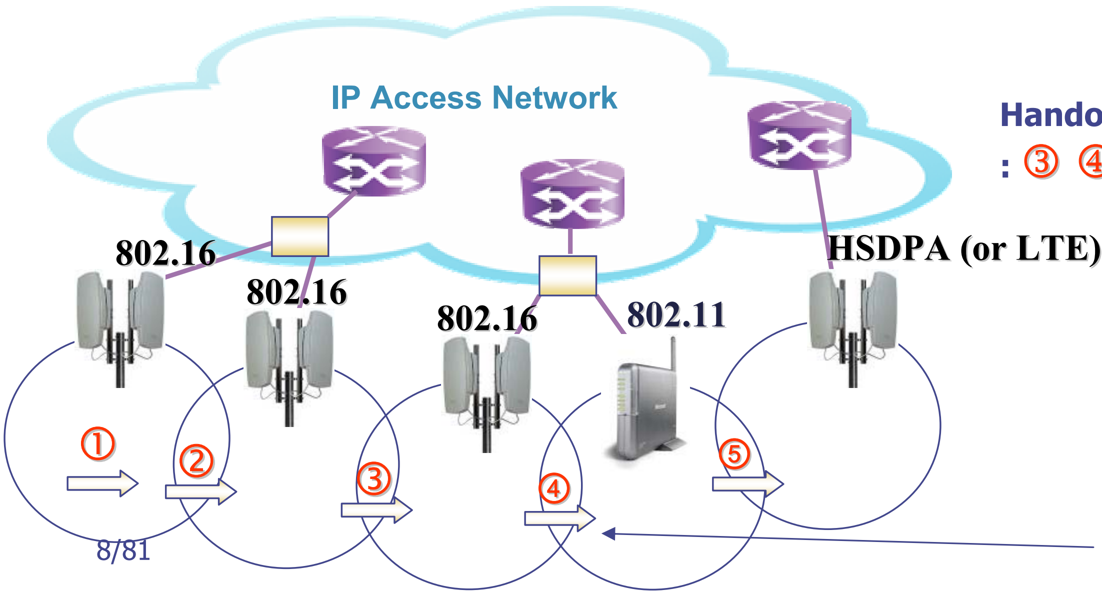
- Transport Layer/ Application Layer transparency
- Can even change physical media without breaking connections
- Mobility management is related with addressing





VHO and IP Mobility

- Horizontal Handover using one interface
  - Intra-cell Handover - ①
  - Inter-cell Handover
    - Inter-PHY/MAC Attachment Points - ②
    - Inter-PHY/MAC Attachment Points/Layer 3 Network - ③
- Vertical Handover using multi-interfaces
  - Inter-cell (Heterogeneous Cell) Handover
    - Inter-PHY/MAC Attachment Points - ④
    - Inter-PHY/MAC Attachment Points/Layer 3 Network - ⑤

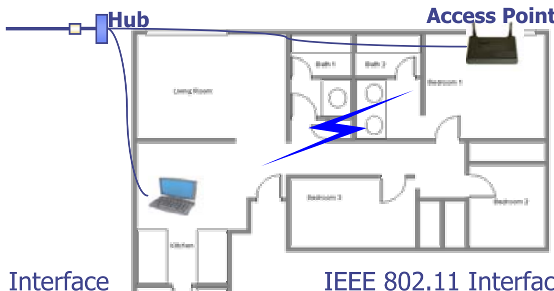


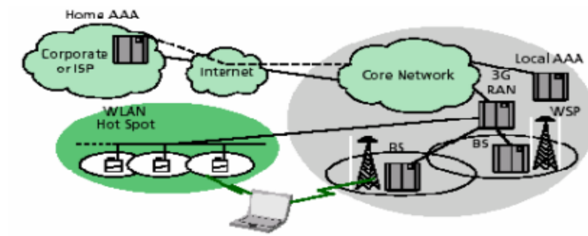
Handover requiring IP handover : ③ ④ ⑤

④ **NIC changes**

IP address and VHO Session Continuity

- Each Interface has its own L2 address (e.g., MAC) and IP configuration individually



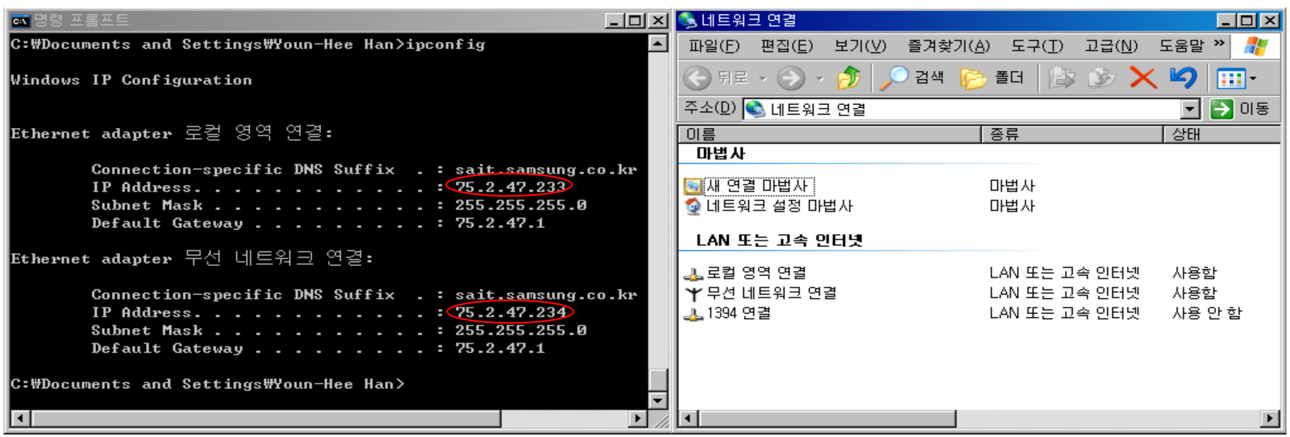


IEEE 802.3 Interface
IP Address : **A**

IEEE 802.11 Interface
IP Address : **B**

IEEE 802.11 Interface
IP Address : **C**

3GPP Interface
IP Address : **D**



IP address and VHO Session Continuity

- Conflict Relation in VHO
  - IP session continuity implies IP address preservation.
  - Multi-interfaces configures its individual IP address.

- IP Mobility resolves the conflict!!! (is it true?)
  - A new CoA (not HoA) is configured to terminal's new interface after movement
    - Each interface configures and manages its own CoA
  - Two-tier IP Addressing strategy resolves the conflict (?)
    - For session continuity, HoA is used.
    - For temporal locator, CoA is used at each interface.

  - Multi-homed MN: what CoA should use the CN to reaches the MN ?
    - Multiple CoA Binding with priority: the highest-priority CoA is used (one NIC only).

Mobile IPv4 (RFC 3344)

Mobile IPv4

- History
  - RFC 2002 (IP Mobility Support for IPv4), Oct. 1996
  - RFC 3344 (IP Mobility Support for IPv4), Aug. 2002
    - 20 Major Changes, 16 Minor Changes since RFC 2002
  - draft-ietf-mip4-rfc3344bis-06.txt (IP Mobility Support for IPv4, revised), March 2008
    - 7 Minor Changes since RFC 3344

- Major Component
  - HA – Home Agent
  - FA – Foreign Agent (usually in Router)
    - All mobility agents MUST receive addressed to the Mobile-Agents multicast group, at address 224.0.0.11
  - MN – Mobile Node

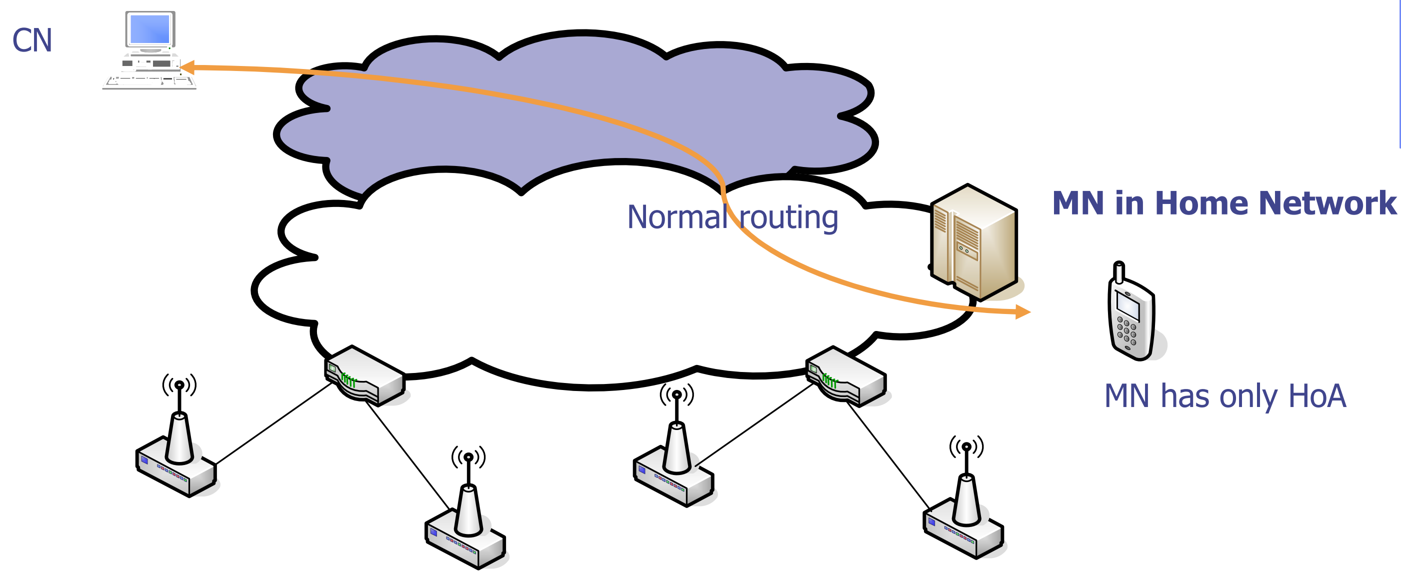
New Message and Options of Mobile IPv4

- New Signal Message related with Registration Management
  - Agent Discovery
    - Agent Solicitation/Agent Advertisement (ICMP Messages)
    - It makes use of the existing Router Advertisement and Router Solicitation messages defined for ICMP Router Discovery (RFC 1256).
  - Registration
    - Registration Request/Registration Reply (UDP Messages)

- Major Roles of MN, HA, and FA
  - MN is generally to listen for agent advertisements and initiate the registration when a change in its network connectivity is detected.
  - HA is generally to process and coordinate mobility services.
  - FA is generally to relay a registration request and reply between HA and MN, and decapsulates the datagram for delivery to MN

Mobile IPv4 Operation

- MN at Home Network



CN → MN

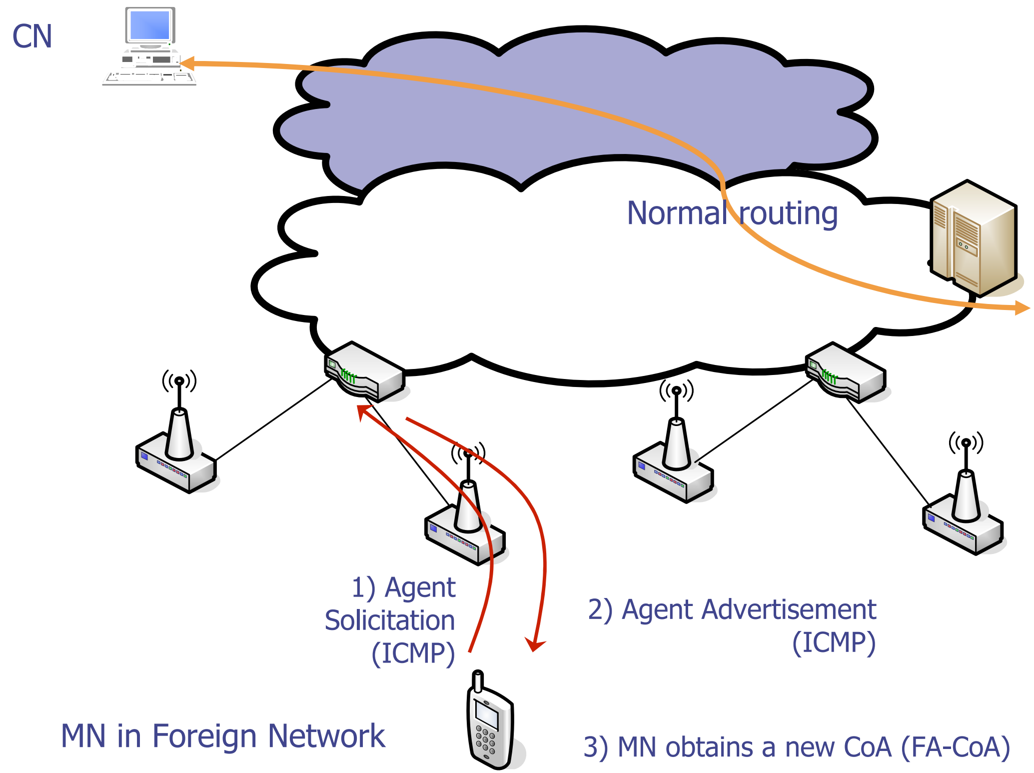
Payload	SRC: CN's Addr.	DEST: MN's HoA

DEST: CN's Addr.	SRC: MN's HoA	Payload

CN ← MN

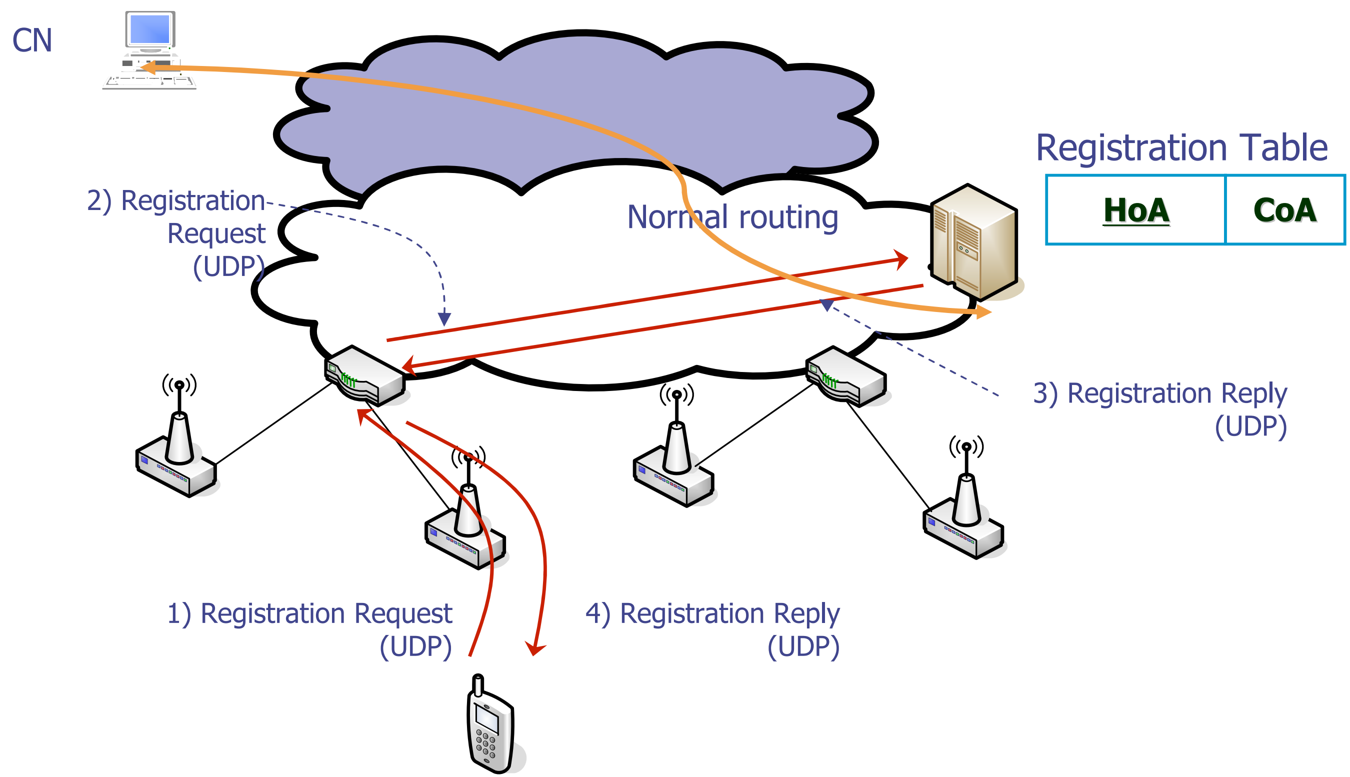
Mobile IPv4 Operation

- Agent Discovery



Mobile IPv4 Operation

- Basic Operation of Mobile IPv4: Registration



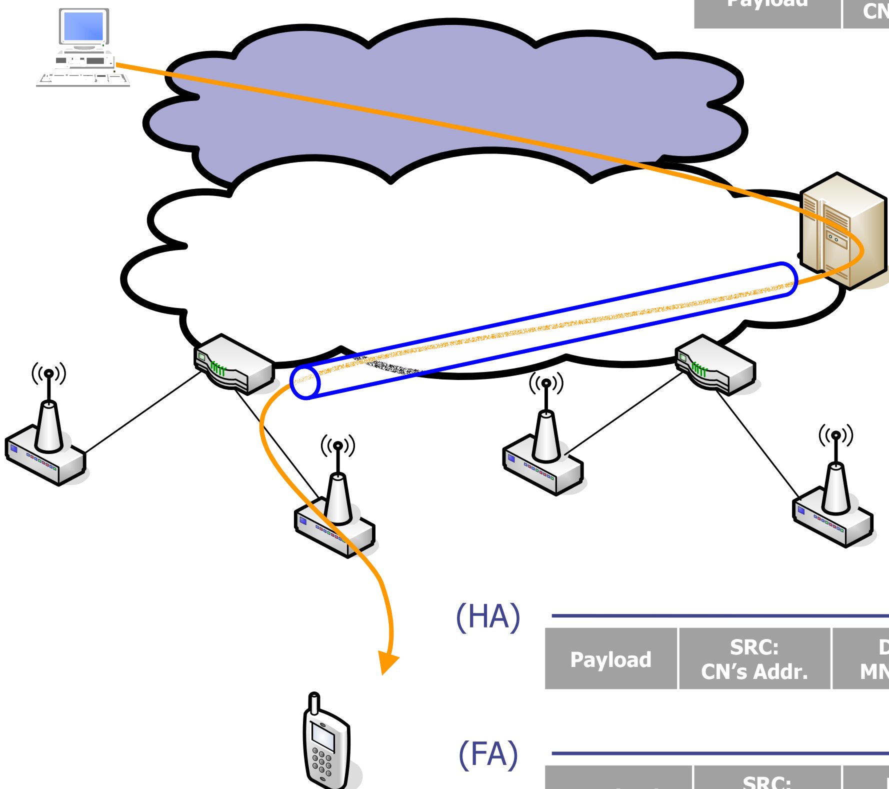
Mobile IPv4 Operation

- Basic Operation of Mobile IPv4: Tx from CN to MN

CN → (HA)

Payload	SRC: CN's Addr.	DEST: MN's HoA

CN



Registration Table

HoA	CoA

(HA) → (FA)

Payload	SRC: CN's Addr.	DEST: MN's HoA	SRC: HA's Addr	DEST: MN's CoA

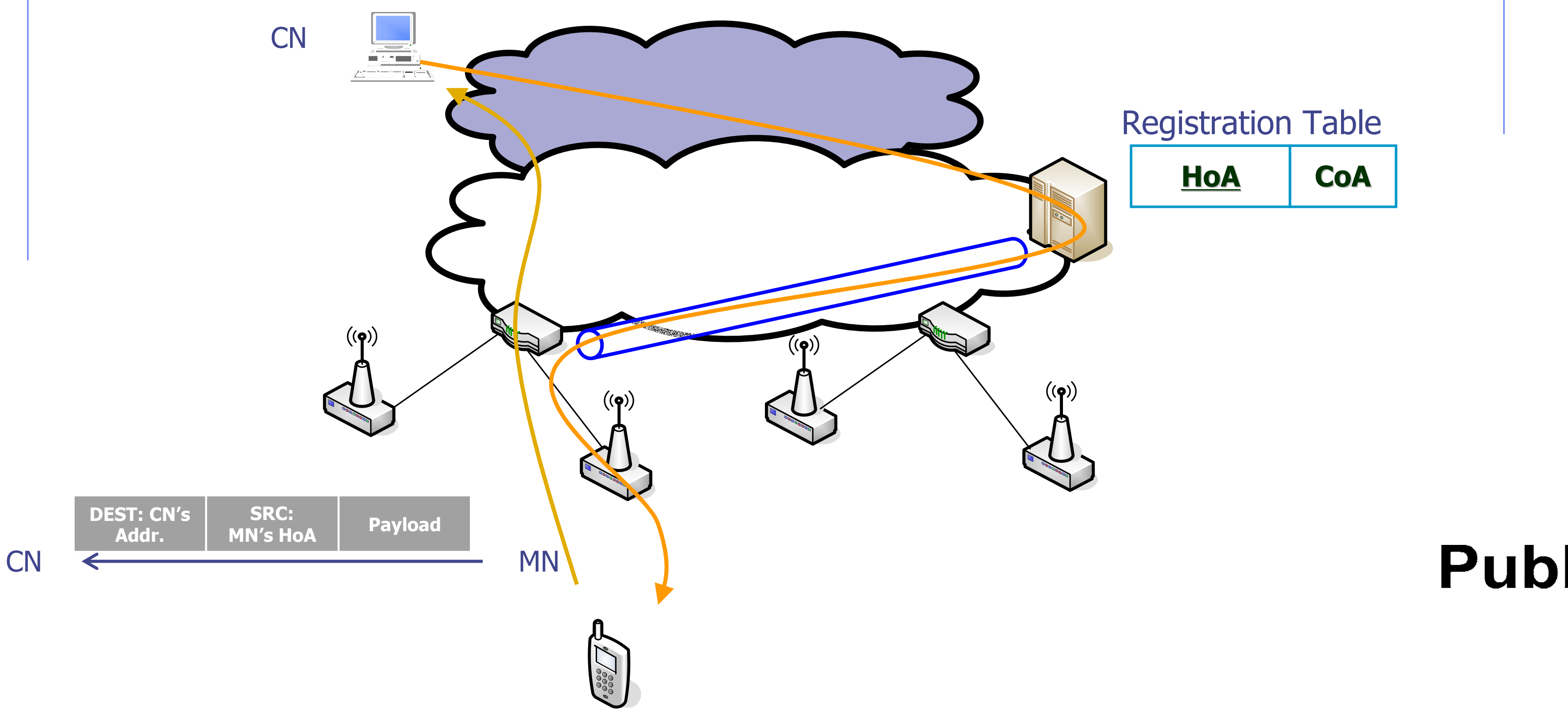
Public

(FA) → MN

Payload	SRC: CN's Addr.	DEST: MN's HoA

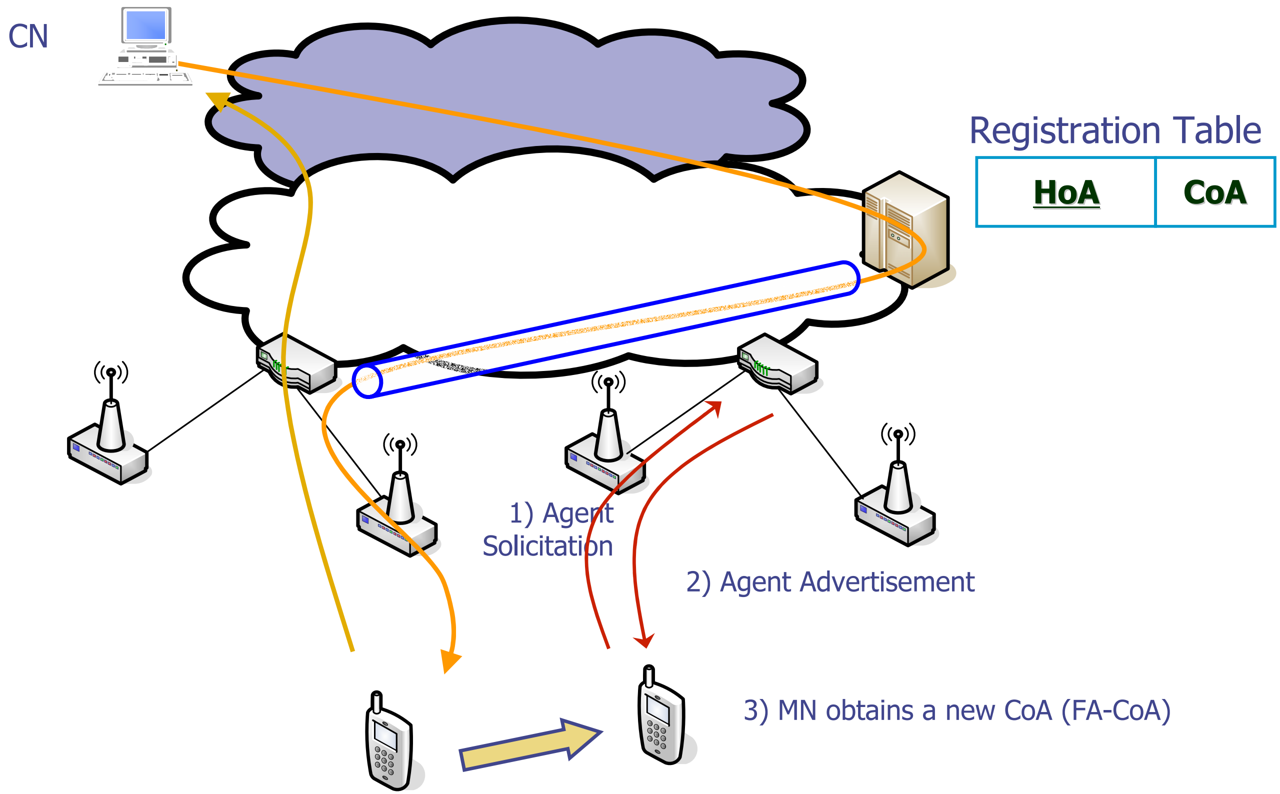
Mobile IPv4 Operation

- Basic Operation of Mobile IPv4: Tx from MN to CN



Mobile IPv4 Operation

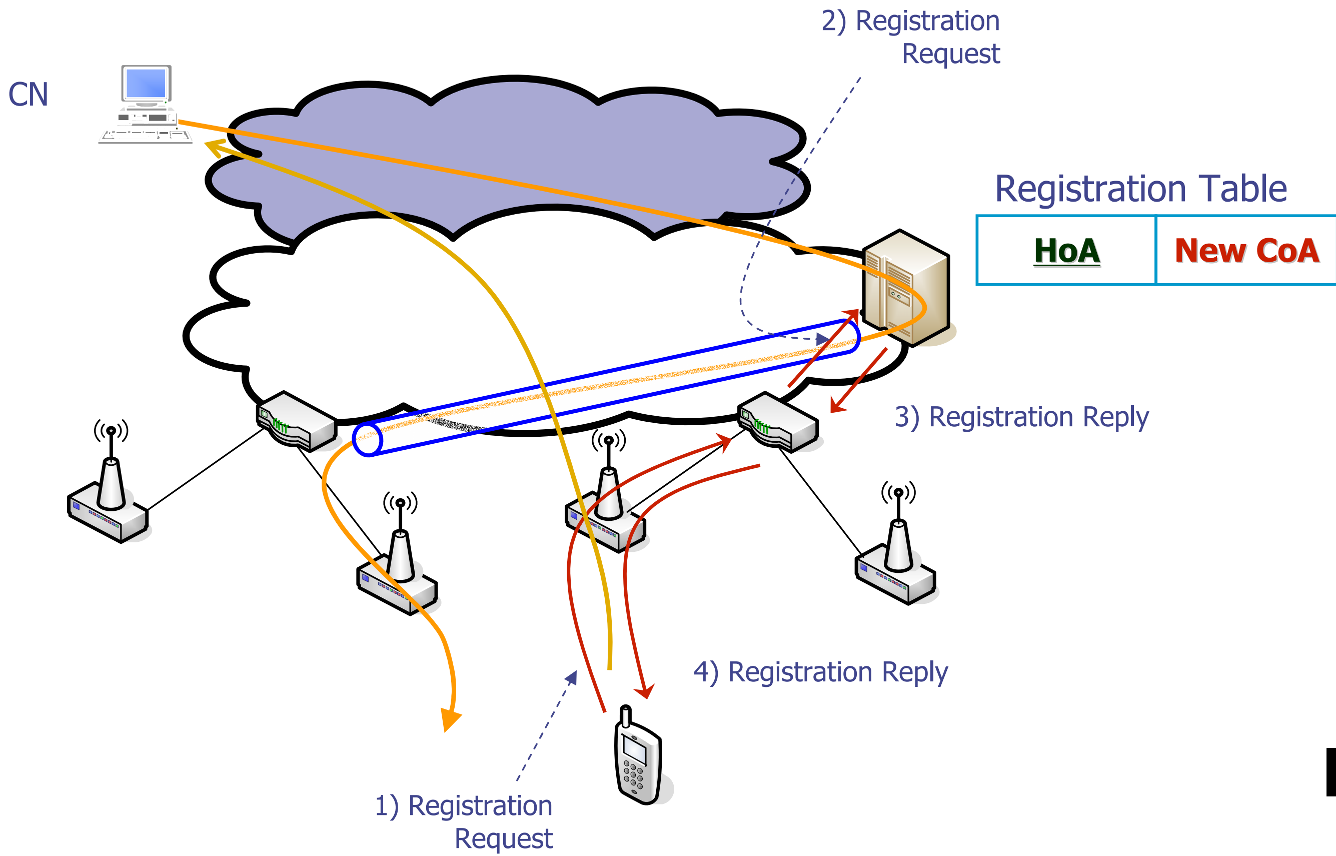
- Basic Operation of Mobile IPv4: Layer 3 Mobility – get new CoA



Publ

Mobile IPv4 Operation

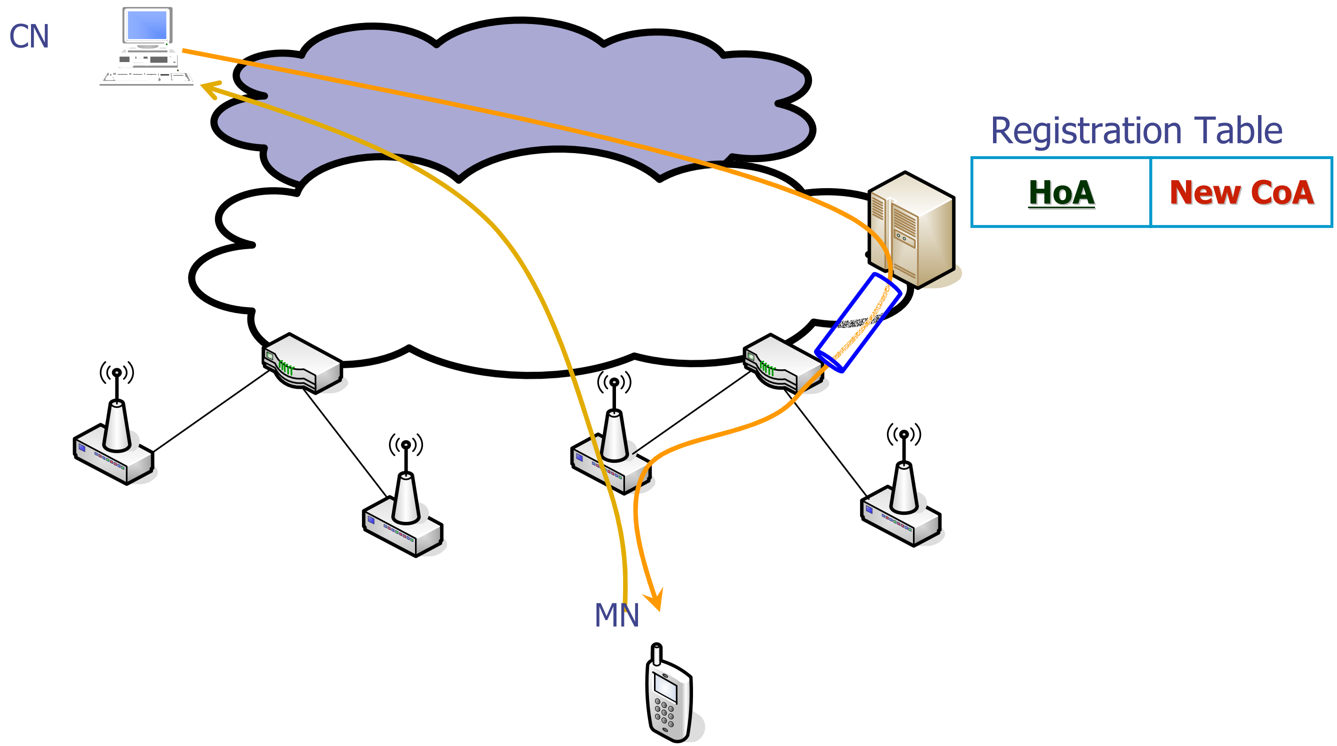
- Basic Operation of Mobile IPv4: Layer 3 Mobility – register new CoA



Publ

Mobile IPv4 Operation

- Basic Operation of Mobile IPv4: CN Tx to [Rx from] MN

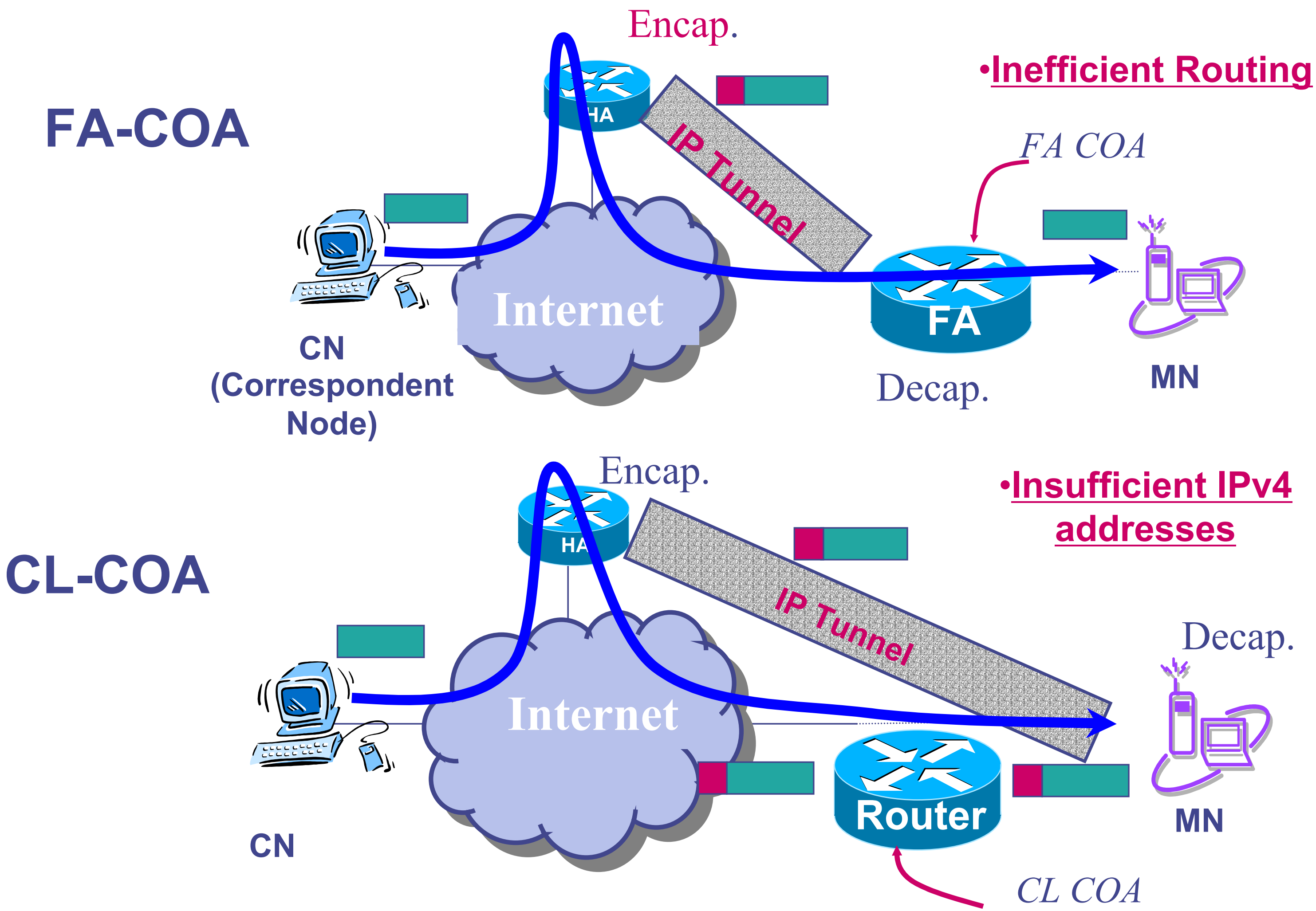


Pub

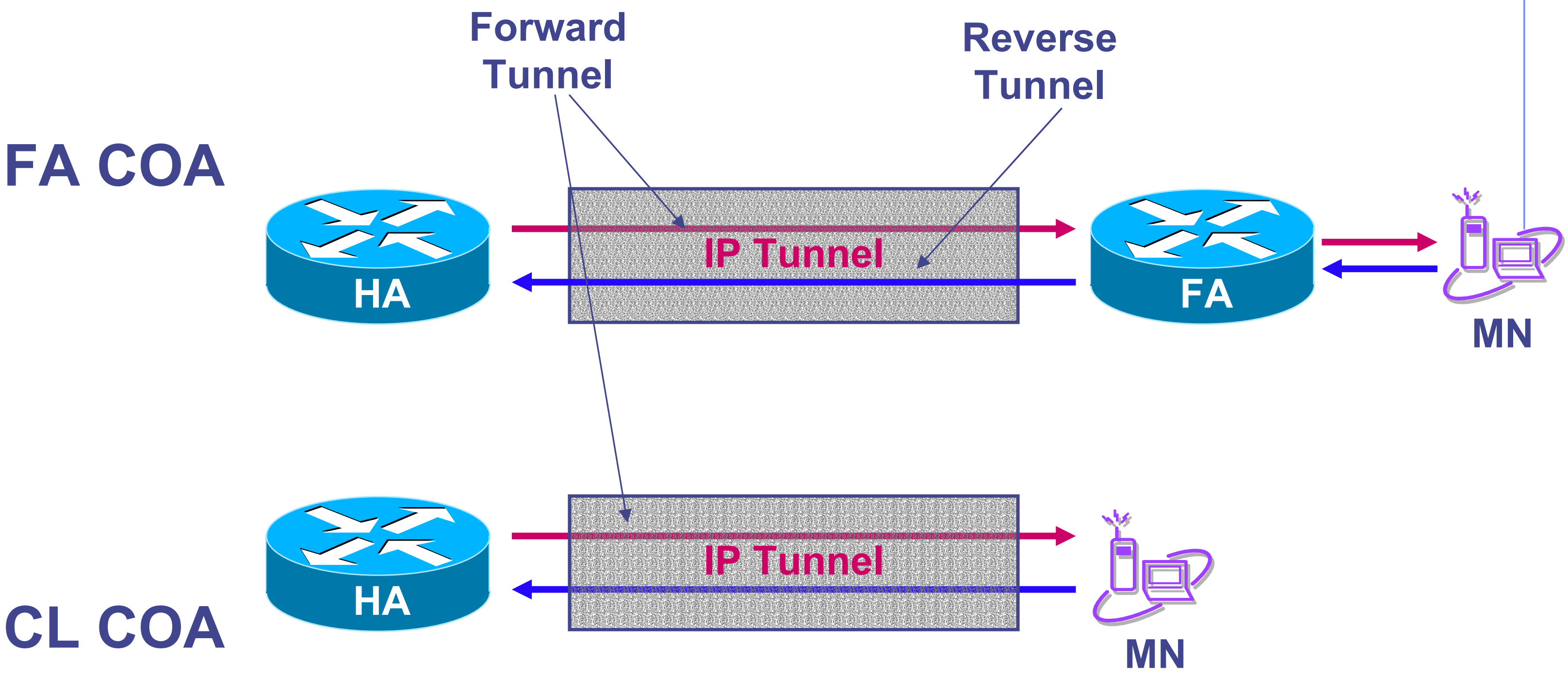
Mobile IPv4 Features

- Triangle Routing
  - CN → HA → MN, MN → CN
  - It deteriorates service of quality
  - MIP4 Route optimization
    - Not yet standardized, some research-level papers
- FA manages 'Visitor List' for visited MNs
  - It has the entry [HoA, Layer 2 (MAC) address, …]
- Two CoA Modes
  - FA-CoA (the IP address of FA)
    - MNs receive a CoA from FA
    - No duplication about new CoA
  - Co-located CoA (CL-CoA, a IP address of the Foreign Network)
    - DHCP-based CoA allocation
    - DHCP server should guarantee the uniqueness of CoA
  - FA-CoA is preferred because of the depletion of the IPv4 address space

Mobile IP: Unicast Reception (from CN to MN)



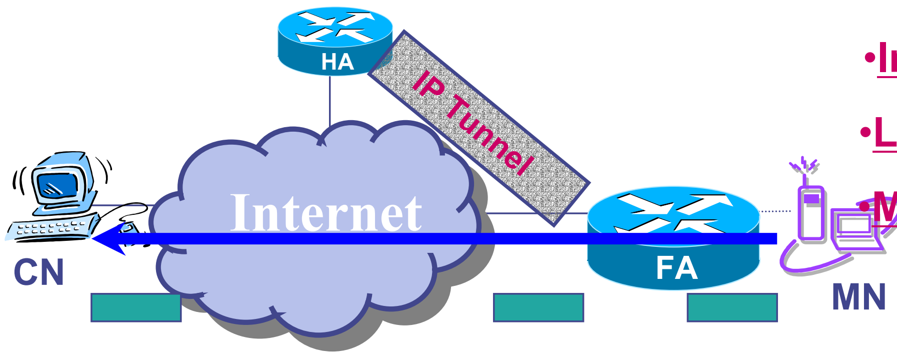
Mobile IP: Reverse Tunneling



- From CN to MN: Source address-dependent Routing

Mobile IP: Unicast Transmission (from MN to CN)

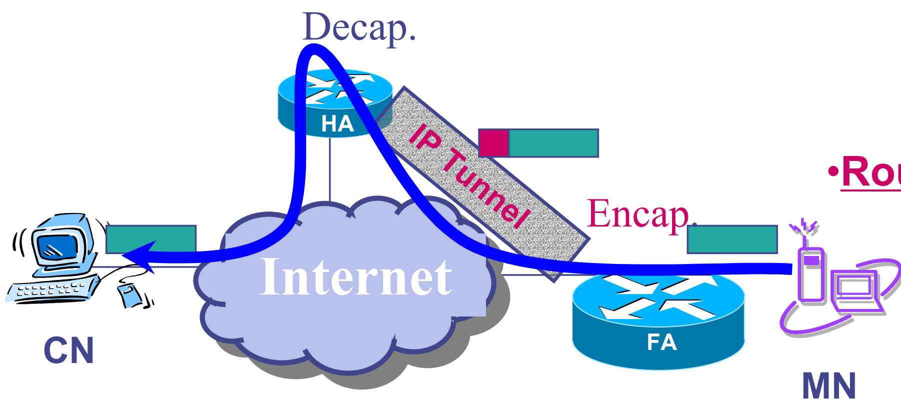
Directly



Problems

- Ingress Filtering
- Location Privacy
- Message Privacy

Via a reverse tunnel



Problems

- Routing Inefficiency

Mobile IPv4 & Ingress Filtering

- How to resolve Ingress Filtering?
  - Ingress Filtering
    - Router's packet **filtering** technique used by many Internet service providers to try to prevent source address spoofing of inbound traffic.
    - At the Foreign Network, It is not free to transmit packets with HoA as the source address
  - Solution
    - Montenegro, G., "Reverse Tunneling 2001.
    - 'T' bit
      - Support of 'Reverse Tunneling'
      - Agent Solicitation
      - Agent Advertisement
      - Registration Request
      - Registration Response

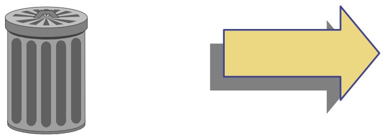
```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |        Sequence Number        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Registration Lifetime    |R|B|H|F|M|G|r|T|   reserved    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 zero or more Care-of Addresses                |
|                               ...                             |
```

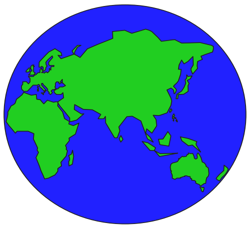
[Agent Advertisement Message Format]

  - Routers tunnels the inbound packets to HA instead of normal routing.

Mobile IPv6 (RFC 3775)

IPv6… Why IPv6? (1/2)

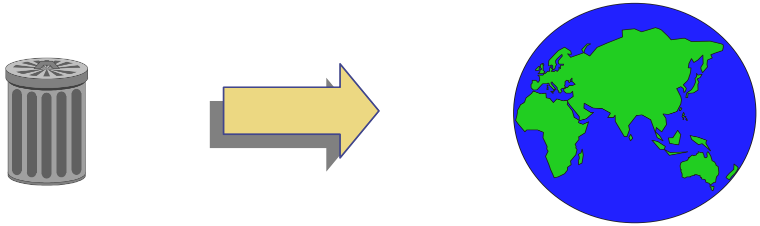




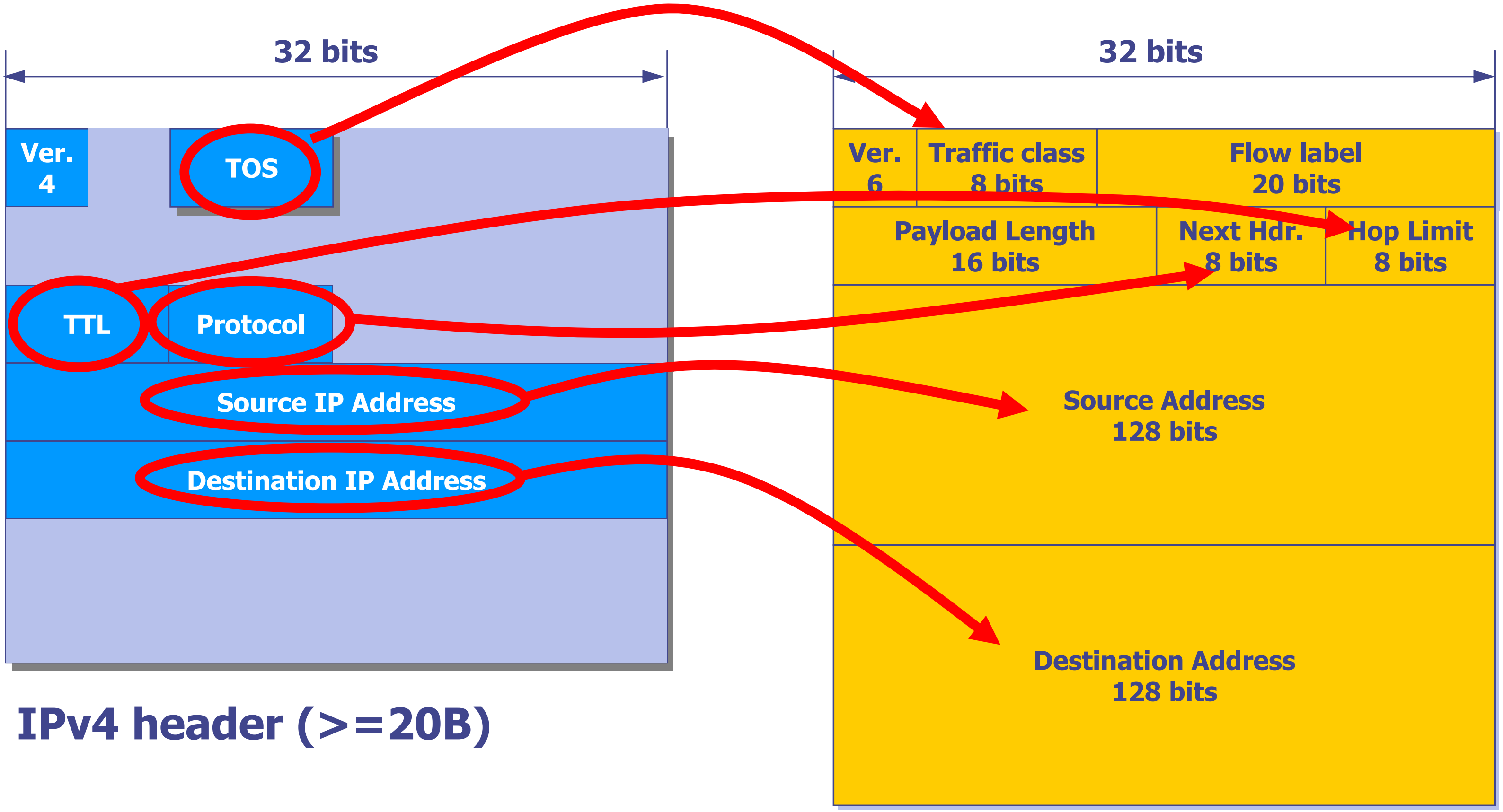
- Infinite Address Space
  - 128 bits address
- Autoconfiguration Service
  - Stateless IP address auto-configuration without DHCP
    - Network prefix + Interface ID
  - Stateful autoconfiguration
    - DHCPv6
- Neighbor Discovery
  - Discover each other’s presence and find routers.
  - Determine each other’s link-layer addresses.
  - Maintain reachability information
- Extensions Headers
  - Routing header, for route optimization
  - Destination Options header, for mobile node originated datagrams.

IPv6... Why IPv6? (2/2)

- Efficient Routing
  - Managed prefix allocation
  - The number of routing entry will be reduced at routers
- Built-in Security
- Efficient Mobility



IPv4 vs. IPv6 Header



IPv4 header (>=20B)

IPv6 header (40B)

Benefits of IPv6 Extension Headers

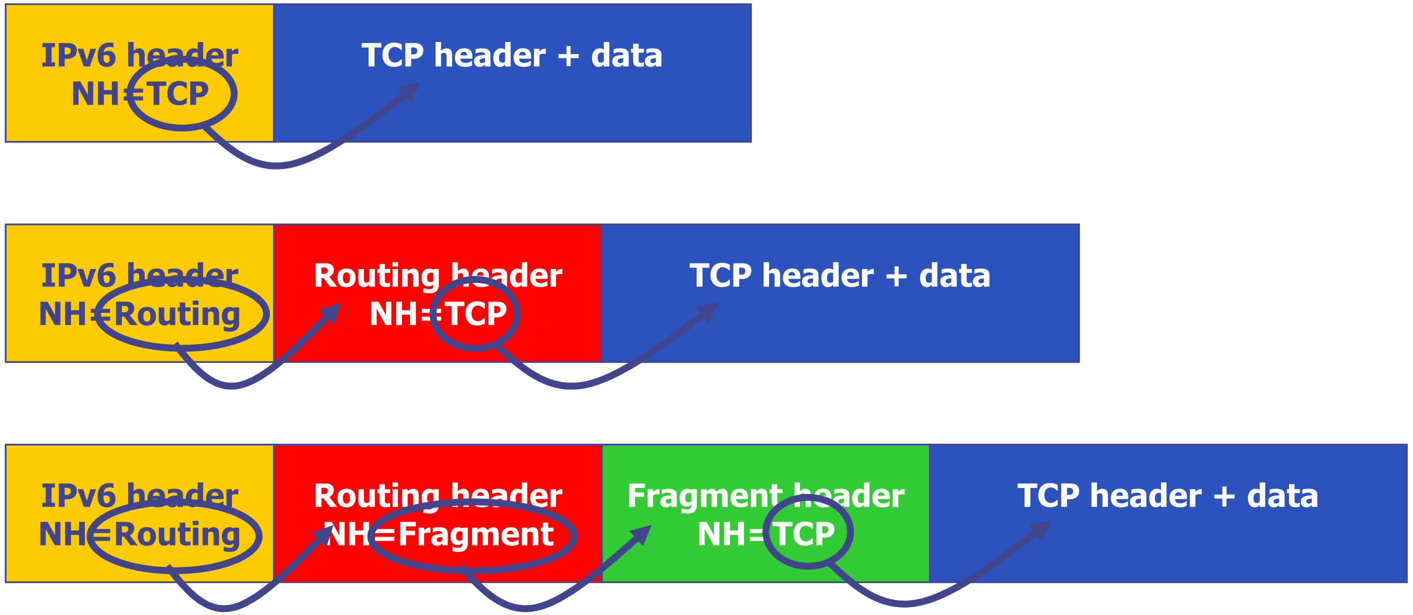
IPv4 options drawbacks

- IPv4 options required special treatment in routers
- Options had negative impact on forwarding performance
- Therefore rarely used

Benefits of IPv6 extension headers

- Extension headers are external to IPv6 header
- Routers do not look at these options except for Hop-by-hop options
- No negative impact on router‘s forwarding performance
- Easy to extend with new headers and option

IPv6 Extension Headers



IPv6 Extension Headers

Header	Previous header's NH-value
Hop-by-hop options	**0**
Destination options	**60**
Routing	**43**
Fragment	**44**
Authentication	**51**
Encapsulating Security Payload (ESP)	**50**
Destination options	**60**
OSPF for IPv6	**89**

Mobile IPv6 Features

- IPv6 Mobility is based on core features of IPv6
- The base IPv6 was designed to support Mobility
  - All IPv6 Networks are IPv6-Mobile Ready
  - All IPv6 nodes are IPv6-Mobile Ready
  - All IPv6 LANs/Subnets are IPv6 Mobile Ready
  - All new messages used in MIPv6 are defined as IPv6 Destination Options

- IPv6 Neighbor Discovery and Address Auto-configuration allow hosts to operate in any location without any special support
- No Foreign Agent.
  - In a Mobile IP, an MN registers to a foreign node and borrows its' address to build an IP tunnel so that the HA can deliver the packets to the MN. But in Mobile IPv6, the MN can get a new IPv6 address, which can be only used by the MN and thus the FA no longer exists

Mobile IPv6

- RFC 3775, Mobility Support in IPv6, June 2004
  - D. Johnson (Rice Univ.), C. Perkins (Nokia), J. Arkko (Ericsson)
  - It takes almost 4 years to make it RFC.

- Major Components
  - HA
  - MN
  - (no FA)

- From implementation's viewpoint…
  - MIPv6 is a pure network-layer protocol, while MIPv4 is an application-layer protocol (with network-layer modification).

New Message and Options of Mobile IPv6

- New Signal Message related with Binding Management
  - Binding Update (BU)
  - Binding Acknowledgement (BAck)
  - Binding Refresh Request (BRR)
  - Binding Error (BE)

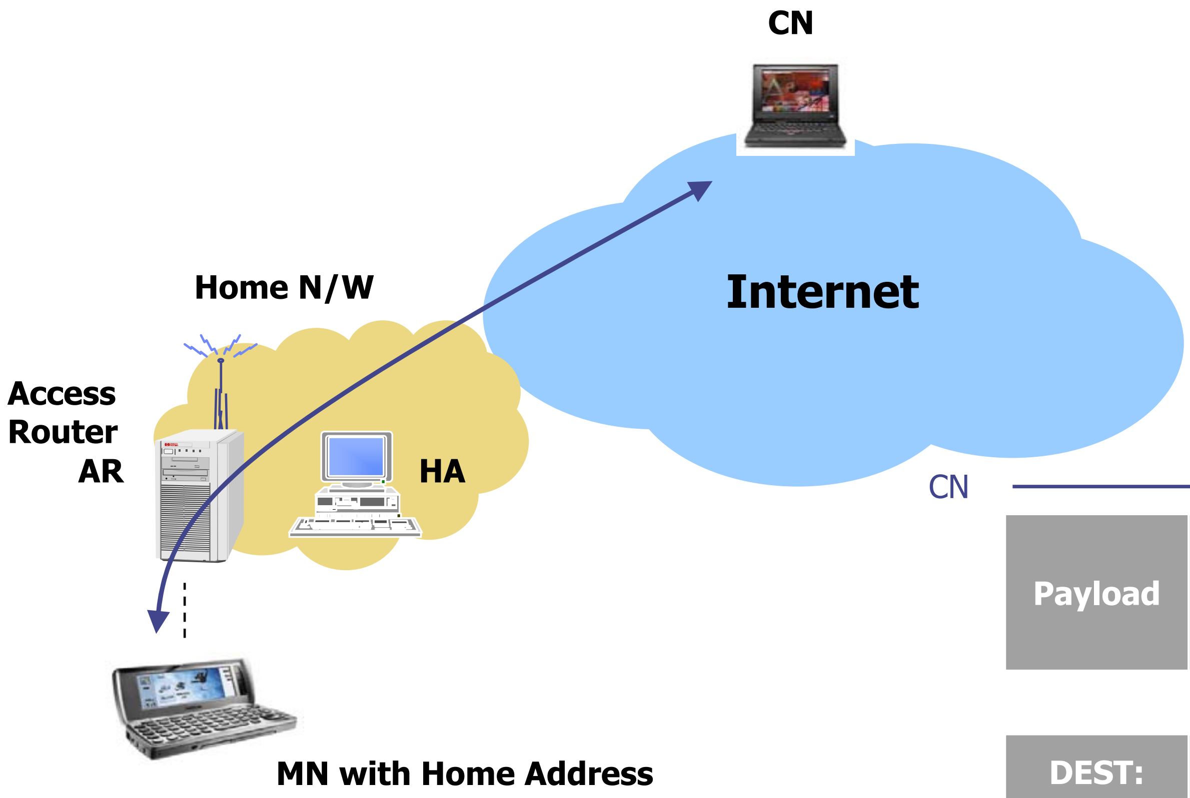
- New Signal Message related with Binding Authentication
  - Home Test Init (HoTI)
  - Care-of Test Init (CoTI)
  - Home Test (HoT)
  - Care-of Test (CoT)

- New Destination Option
  - Home Address Destination Option

- New Routing Header Type
  - Routing Header Type 2

Mobile IPv6 Operation

- MN at Home Network



CN → MN

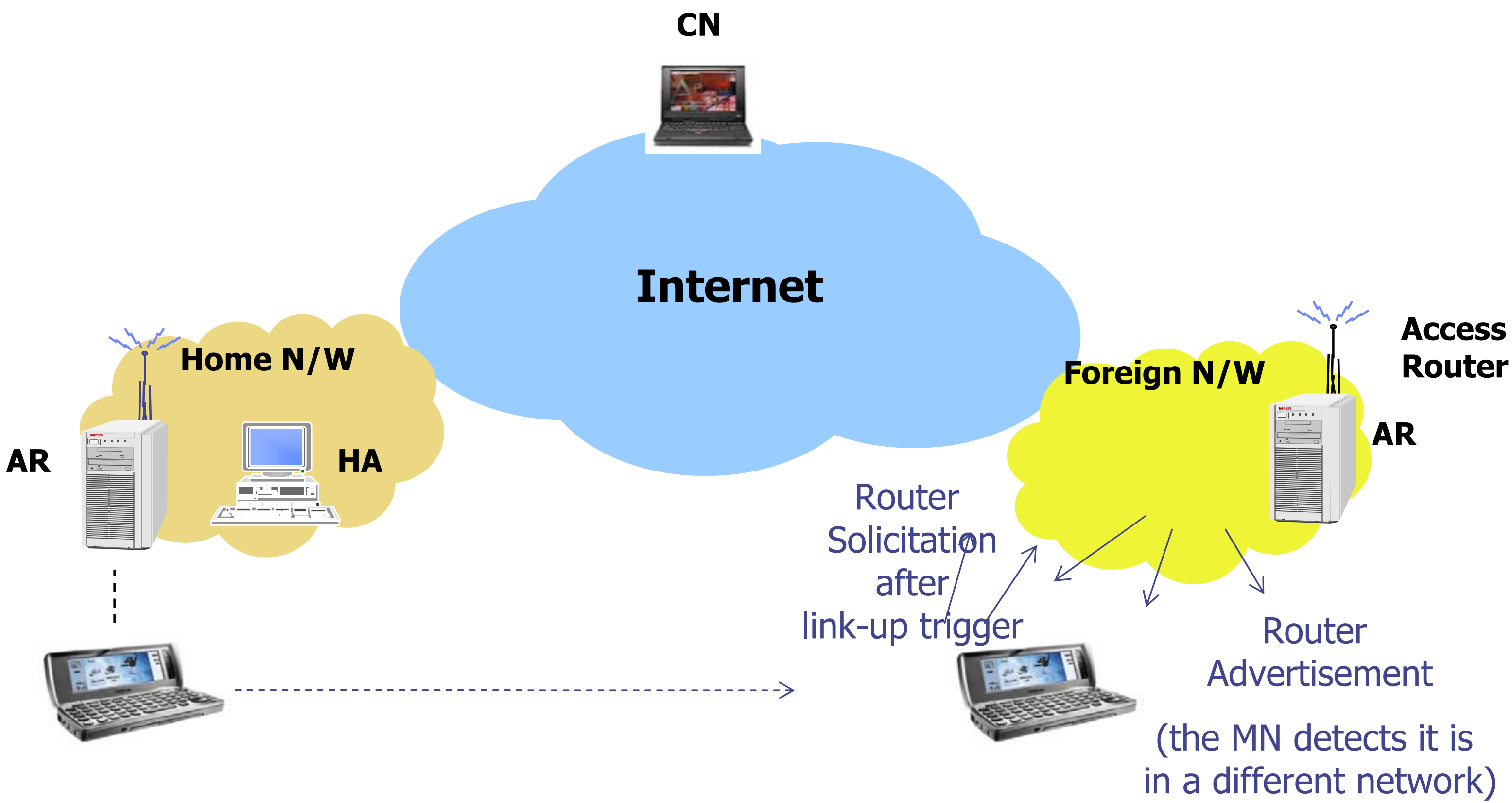
Payload	SRC: CN's Addr.	DEST: MN's HoA

DEST: CN's Addr.	SRC: MN's HoA	Payload

CN ← MN

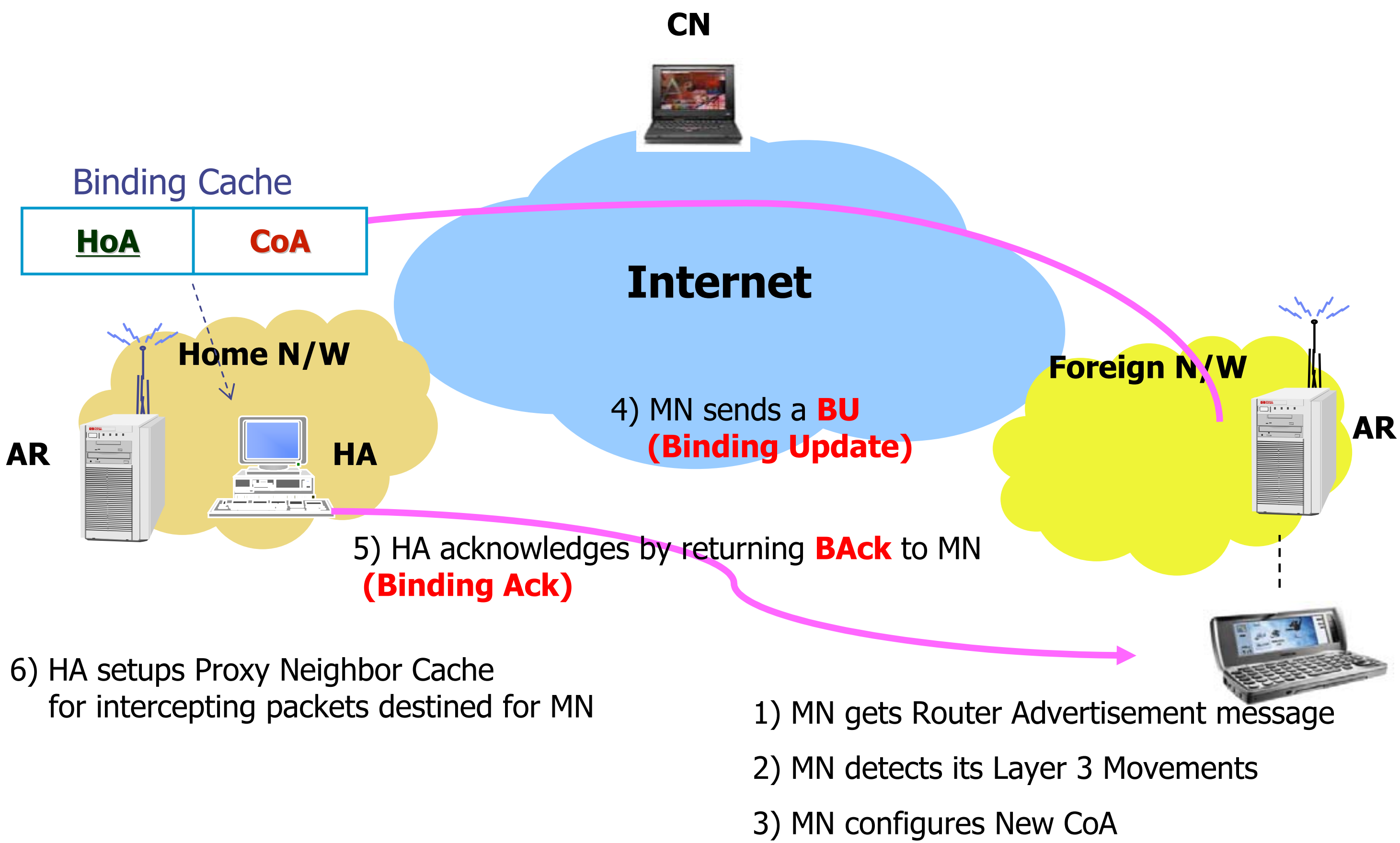
Mobile IPv6 Operation

- Router Advertisement & Router Solicitation



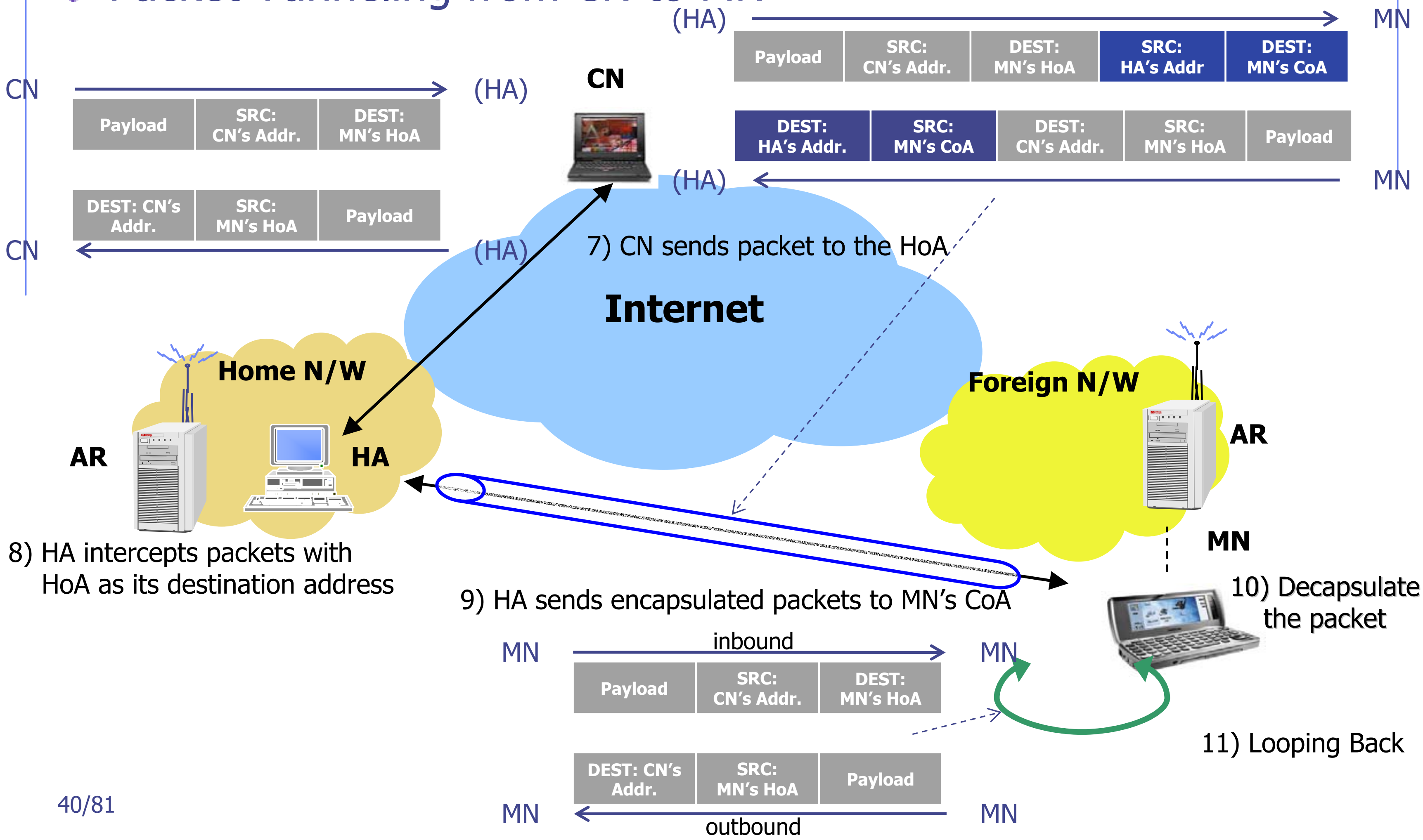
Mobile IPv6 Operation

- Movement to a Foreign Network



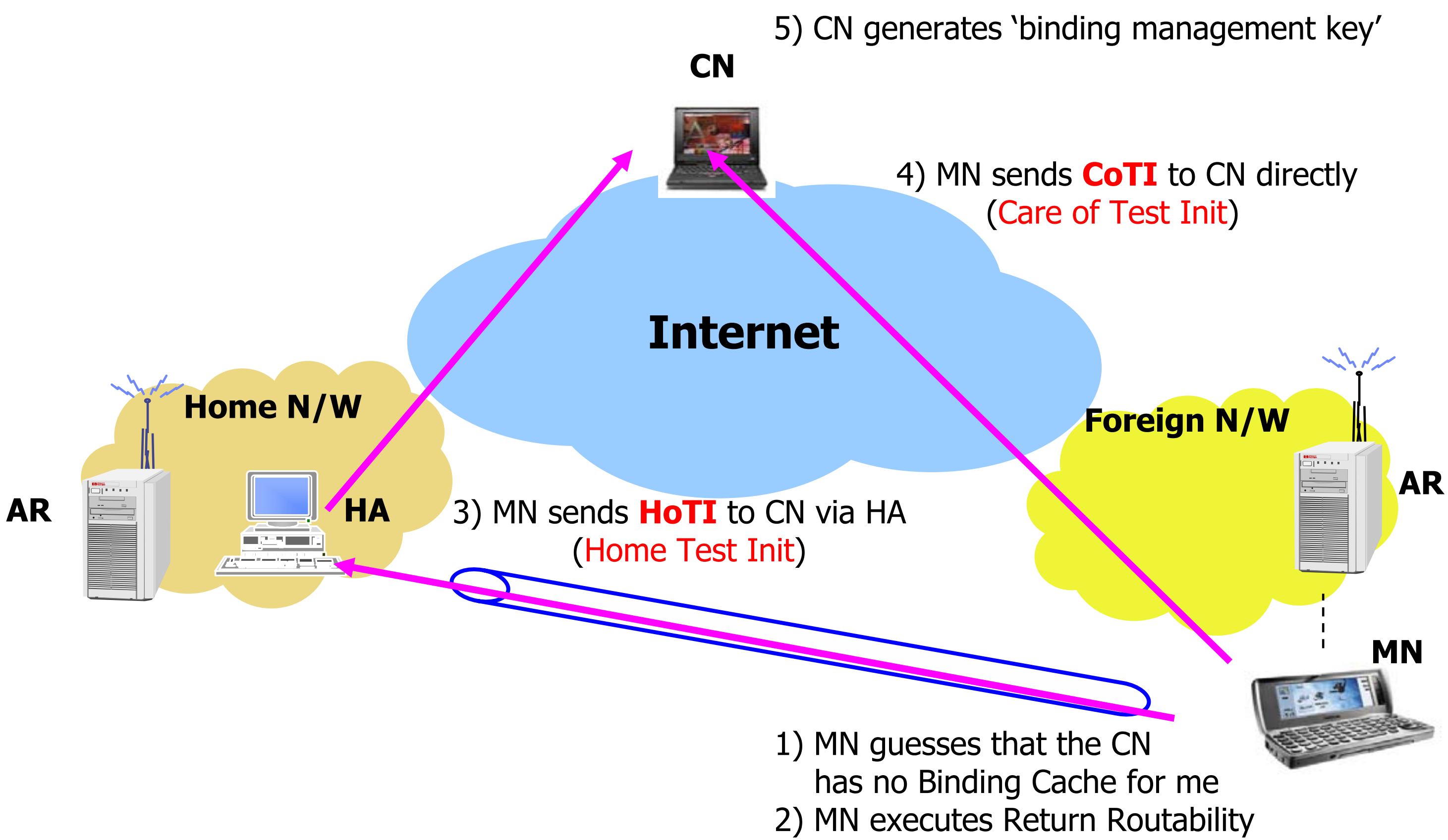
Mobile IPv6 Operation

◆ Packet Tunneling from CN to MN



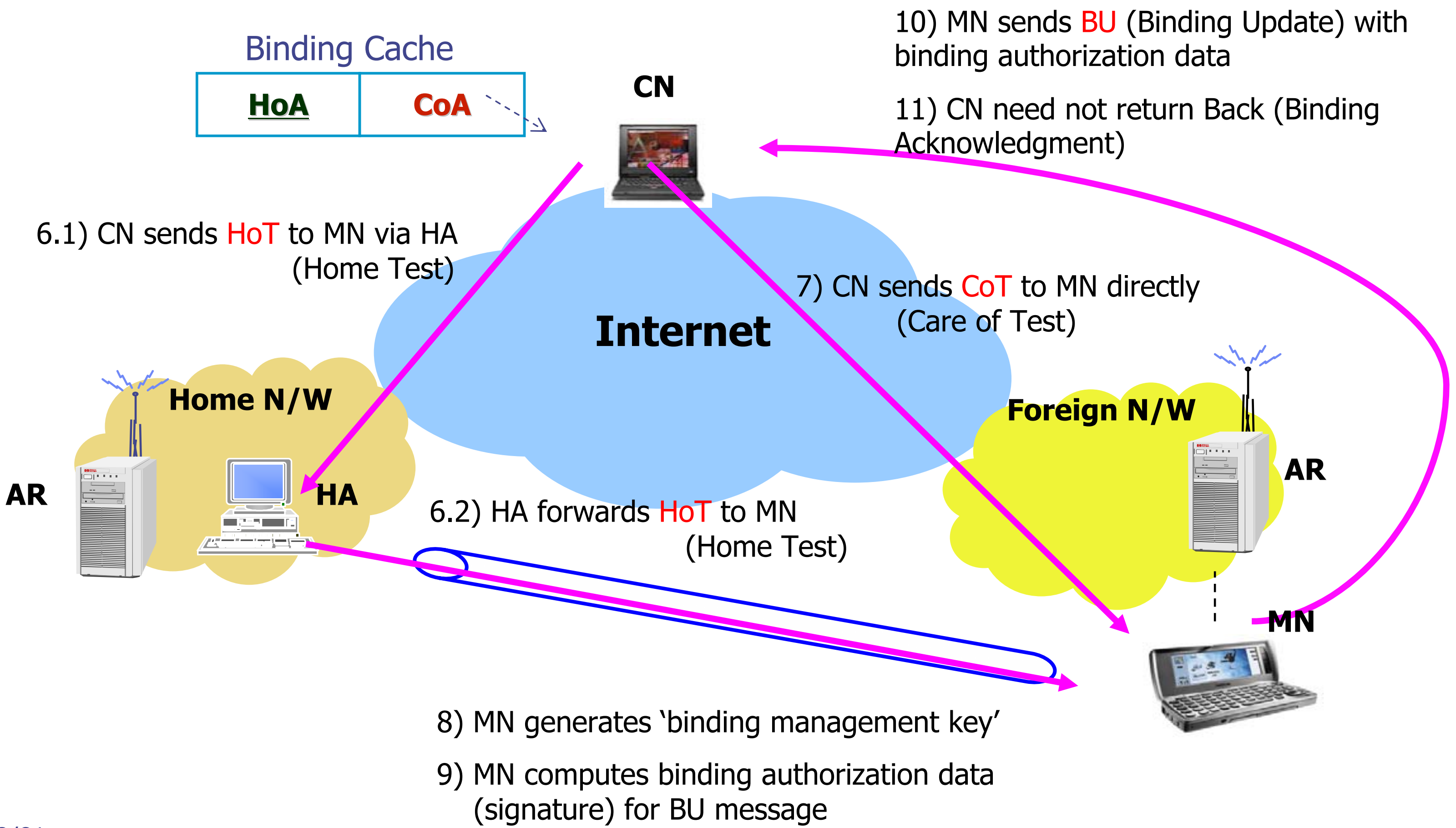
Mobile IPv6 Operation

- Return Routability with CN (setup with double check)



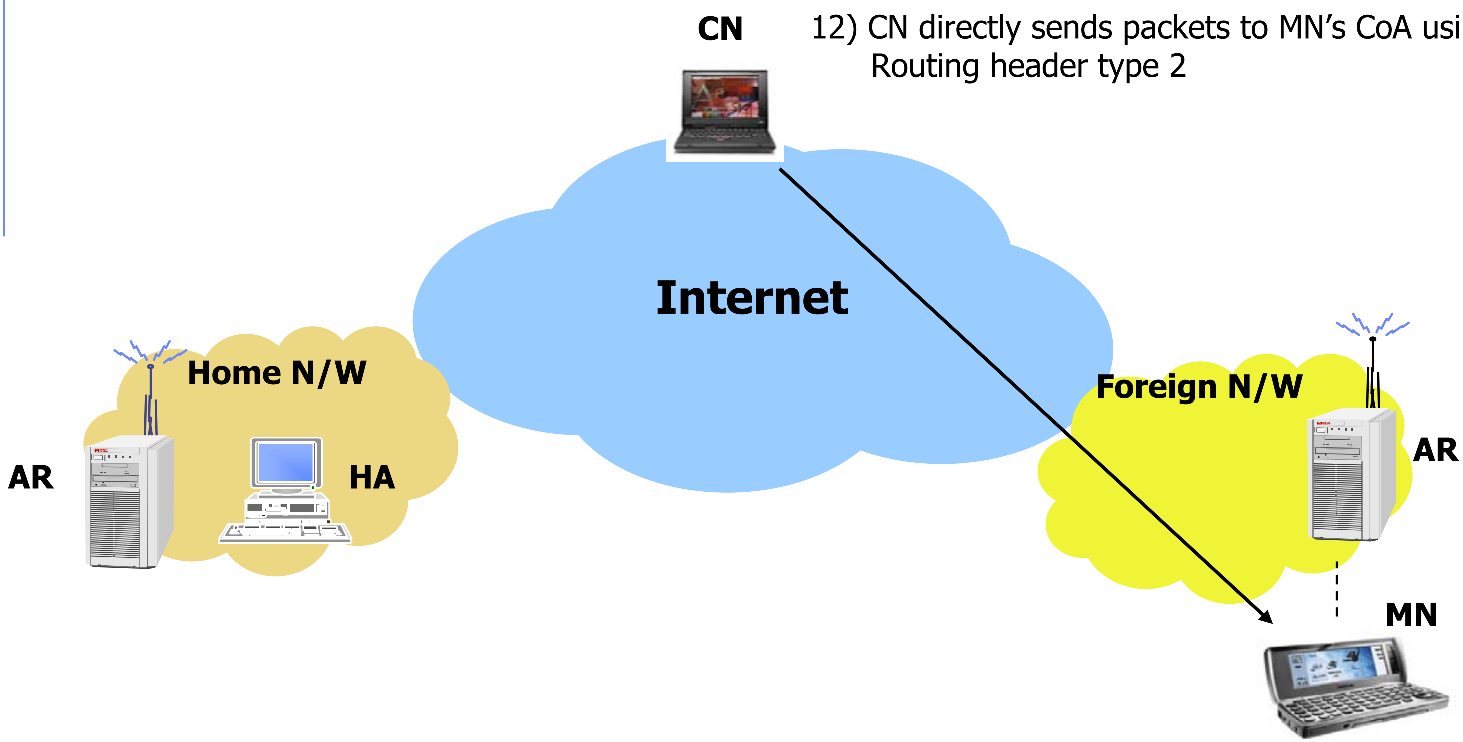
Mobile IPv6 Operation

- Return Routability with CN



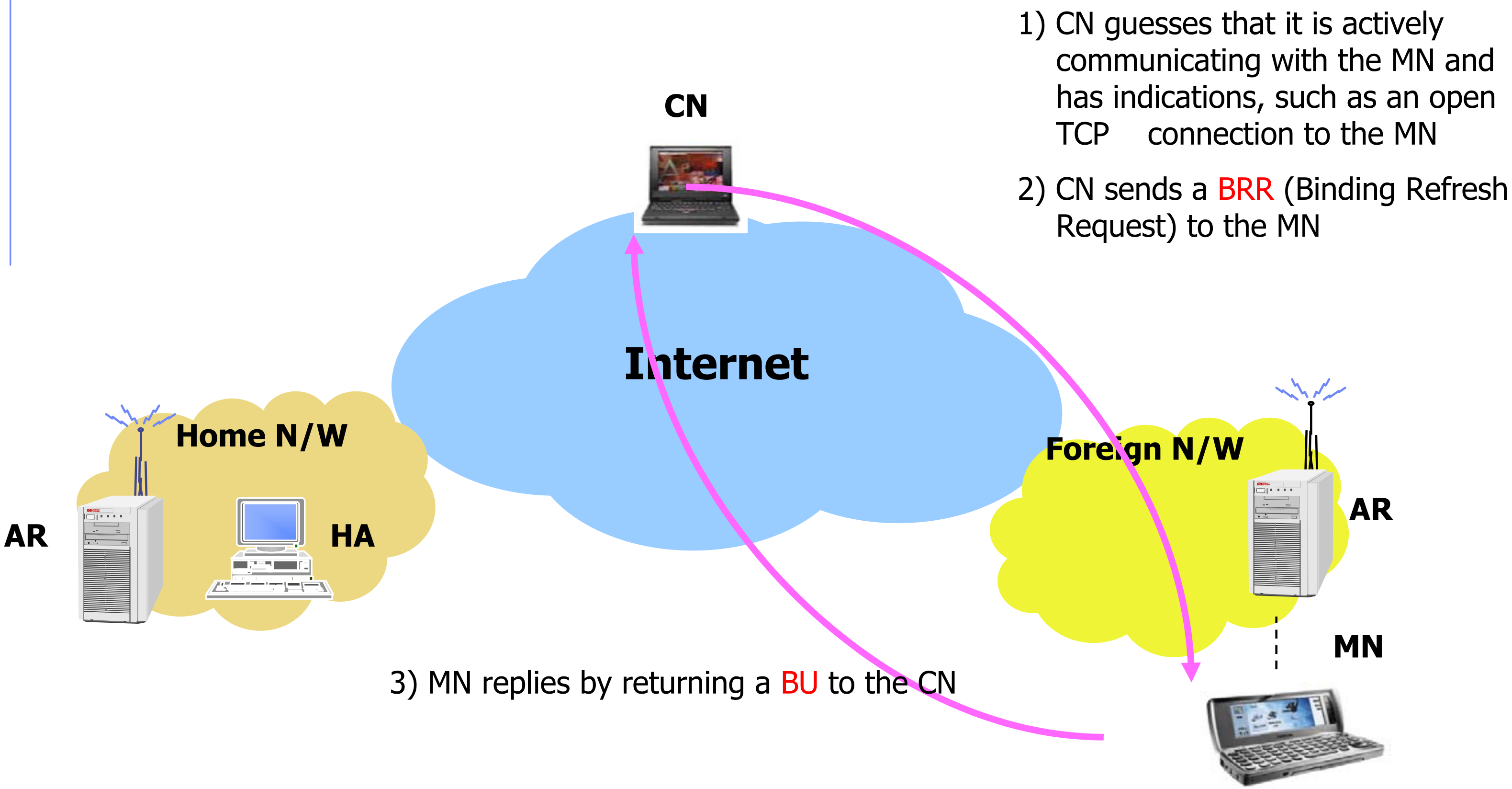
Mobile IPv6 Operation

- Route optimization after BU with CN



Mobile IPv6 Operation

- When the binding's lifetime of CN is near expiration

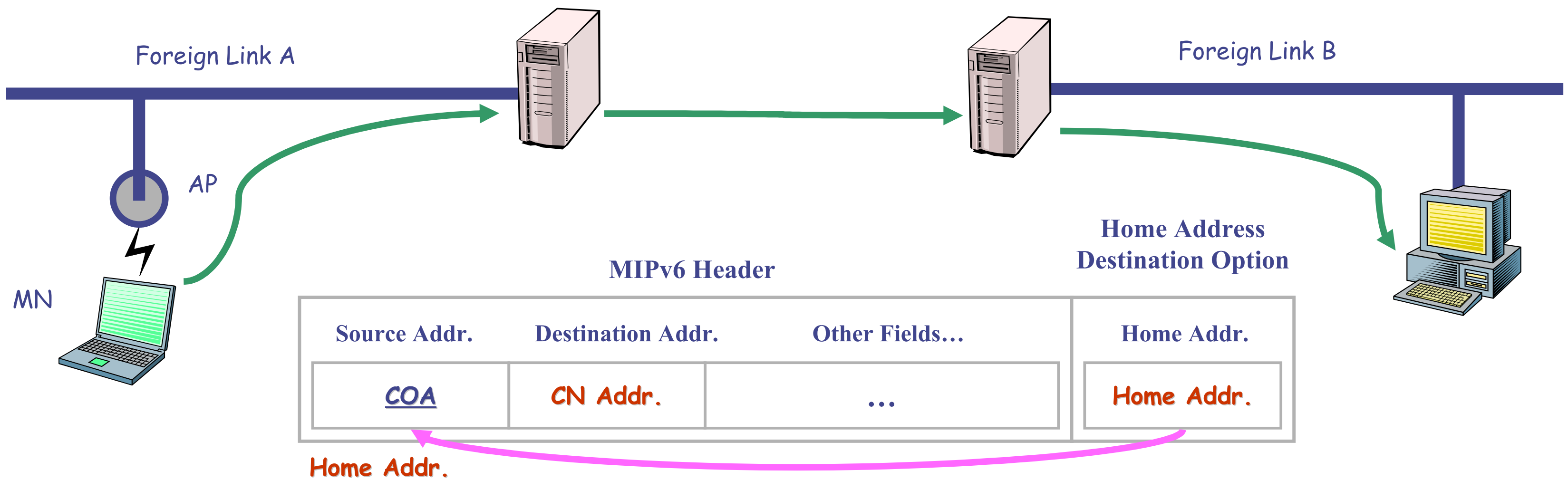


Mobile IPv6 Features

- How to make CoA?
  - Auto-configuration
    - Without DHCP
    - With DHCP
  - Duplication Address Detection (DAD) is required.
- Triangle routing avoided
- Route optimization supported
  - But, CN is required to be modified for the route optimization
- Security
  - MN ←→ HA : Strong Security (IPSec)
  - MN ←→ CN : Weak Security (Return Routability)
    - Handover latency increased

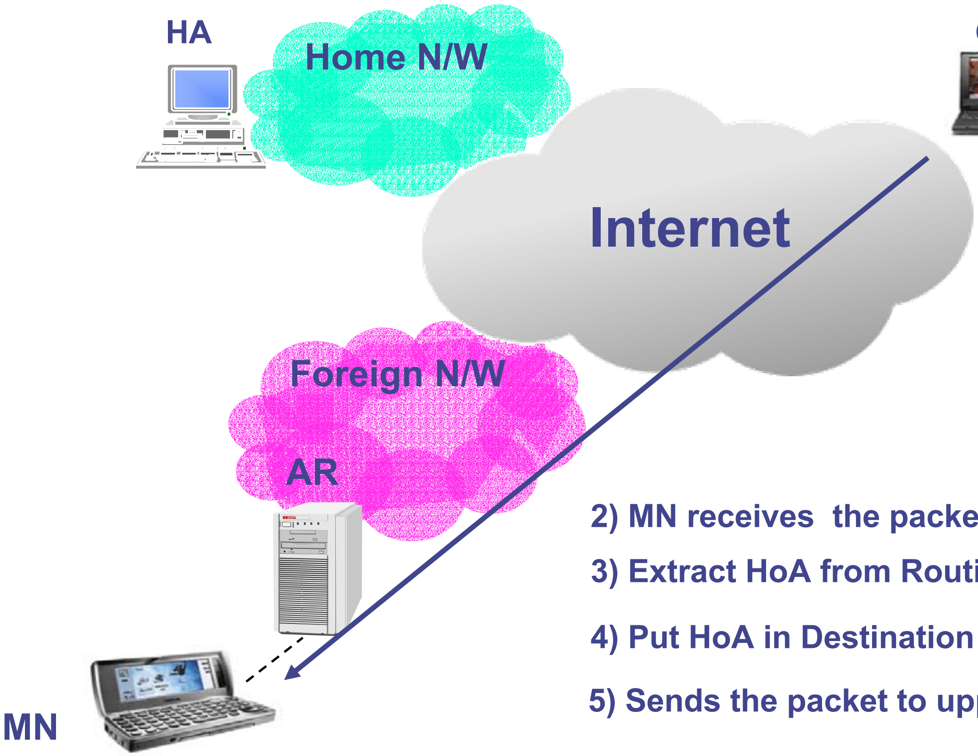
MN→CN Packet Processing

- Home Address Destination Option
  - within BU message and packets sent by MN to CN
  - Carrying Home Addr. to inform the recipient (CN) of that packet of the MN's home address
  - In every packet from MN, the followings are included
    - CoA in Source Addr. field
    - Home Addr. in Home Address Destination Option
  - making mobility transparent to upper layer
  - Ingress filtering (p.78)
    - It is not free to transmit packets with its Home Addr. As the Source Addr. field



CN→MN Packet Processing (1/2)

- Mobility is transparent over IP layer.
- The packets to and from MN (almost) always carries Home Address.



1) CN sends MN the packet with
   - CN's IP addr as src addr &
   - CoA as desn addr &
   - HoA in Routing Header

2) MN receives the packet and

3) Extract HoA from Routing Header

4) Put HoA in Destination addr. field.

5) Sends the packet to upper layer for process

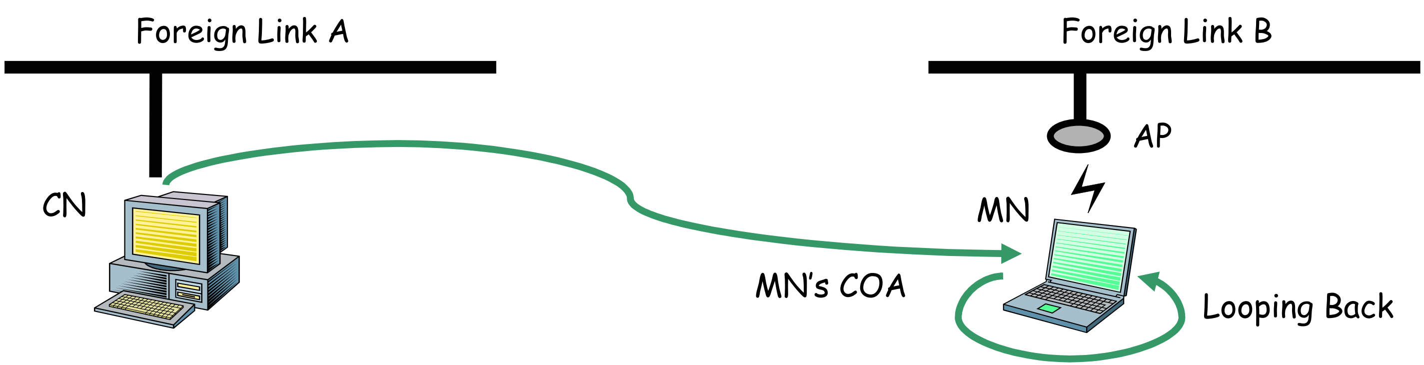
CN→MN Packet Processing (2/2)

- Packet Delivery from CN to MN using Routing Type 2

IPv6 Header … **Routing Header**

Source Addr.	Destination Addr.	Other Fields…		Type	Segment	Next Routing Addr.
CN's Addr.	MN's COA	…	…	2	1	MN's Home Addr.

Source Addr.	Destination Addr.	Other Fields…		Type	Segment	Next Routing Addr.
CN's Addr.	MN's Home Addr.	…	…	2	0	MN's COA



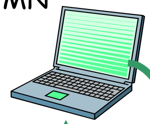
When sending Binding Error?

- Binding Error
  - MN sending packets to CN while away from home
  - CN does not have a binding cache for the sender
  - CN sends BE

IPv6 Packet Header

Source Addr.	Destination Addr.	Other Fields…
Home Addr.	CN addr.	…

MN

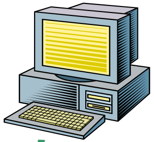


IPv6 Packet Header / **Home Address Destination Option**

Source Addr.	Destination Addr.	Other Fields…	Home Addr.
COA	CN addr.	…	Home Addr.

CN checks if there is a binding cache. If CN doesn't have…

CN



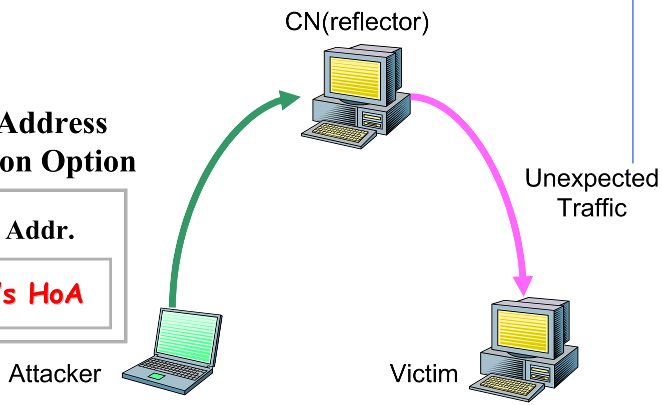
Binding Error

Source Addr.	Destination Addr.	Other Fields…	Home Addr.
CN addr	CoA	…	Home Addr.

Why Return Routability (RR)?

- Attack using Home Address Destination Option
  - Hide the attacker's identity
  - Scenario

MIPv6 Header			Home Address Destination Option
Source Addr.	Destination Addr.	Other Fields…	Home Addr.
Attacker's CoA	CN addr.	…	Victim's HoA

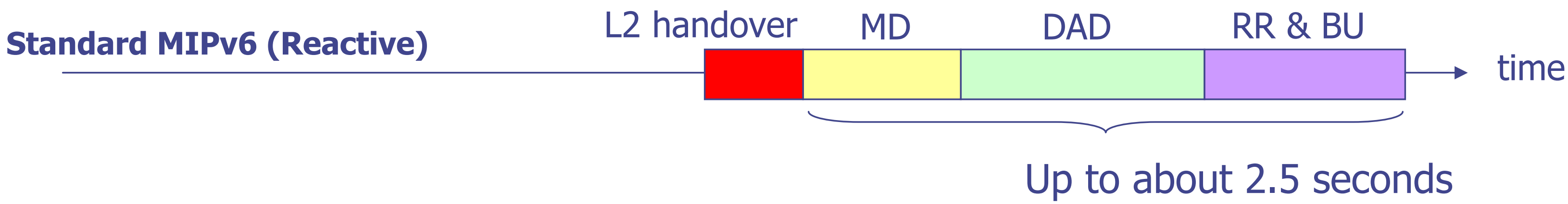


- Solution about such an attack
  - CN checks the validity of the home address
  - CN MUST process Home Address Destination Option If…
    - Case I) CN retains the binding cache for the MN's home address
      - It means that BU and BAck are exchanged, and the both BU and BAck are correctly authenticated.
    - Case II) CN retains IPSec SA(Security Association) with the MN's home address

Why Return Routability (RR)?

- Authentication for both BU and BAck between MN and CN
  - Ver.15 assumes that authentication of both BU and BA is based on the IPsec.
    - "Authentication Data assuring the integrity of Binding Updates and Binding Acknowledgement MAY, in some cases, be supplied by other authentication mechanisms outside the scope of this document (e.g., IPsec [13]). " [Mobile IPv6, Ver.15, Section 4.4]
  - Not all CNs can have the strong security association (e.g., IPsec) with a MN
    - It is 'Not Global Scale'
  - It is required to develop a universal method for the authentication for both BU and BA
  - Solution : Return Routability (since ver.18)

Handover Latency of Mobile IPv6



- Latency Components
  - MD (Movement Detection) Latency
    - How to get "Router Advertisement" fast?
  - DAD (Duplicate Address Detection) Latency
    - Constant time (1 sec.)
    - How to shorten the constant time?
  - BU (Binding Update) Latency
    - It depends on the distance between MN and HA/CN

- Mobile IPv6 is not a handover protocol, rather it is a location (and route) update and session continuity protocol.

Research Issues

- IP Mobility Core
  - Scalability
  - Fault-tolerant & Robust Service
  - Deployment & Operational Issues
- Dual-stack Mobile IP
  - Considering IPv4/v6 Heterogeneity
  - Dual-stack Terminal
- Seamless IP Handover
  - Cross-layering operation over IEEE 802.11/16 and Cellular
  - Buffer Management
  - Packet Re-ordering
  - Mobile TCP Enhancement

Research Issues

- Vertical Handover
  - IP Mobility in Heterogeneous Access Networks
  - IP Handover & IEEE 802.21 (Media Independent Handover)
  - Seamless Vertical Handover
  - TCP Improvement at Vertical Handover
- Network Mobility & Multi-homing
  - Route Optimization in NeMo (RFC 3963)
  - Deployment & Operational Issues
- Network-based IP Mobility
  - Proxy Mobile IP (PMIP)
  - New Research Cycle with PMIP