The Mobile Network: Mobile IPv6 Protocol

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Contents

- Motivation: Global Mobility
- Basic Mobile IP Model and Operation
- Mobility in IPv6
- Security in IPv6 Mobility.
- Optimizations: Fast handover & Hierarchical mobility

Motivation

- Growing importance of Mobile Computing
- Multiplicity of wired and wireless (sub)network technologies (GSM, GPRS, UMTS, WiFi, WiMax, Bluetooth, etc)
  - Provide mobility confined to a network technology:
    - Horizontal Handover → movement among “cells” of the same network technology
  - Mobility managed inside subnetwork (N2)
- We need Global Mobility:
  - Mobility among different administrative domains or different subnetwork technologies (Vertical Handover)
  - Implemented at network layer (N3)

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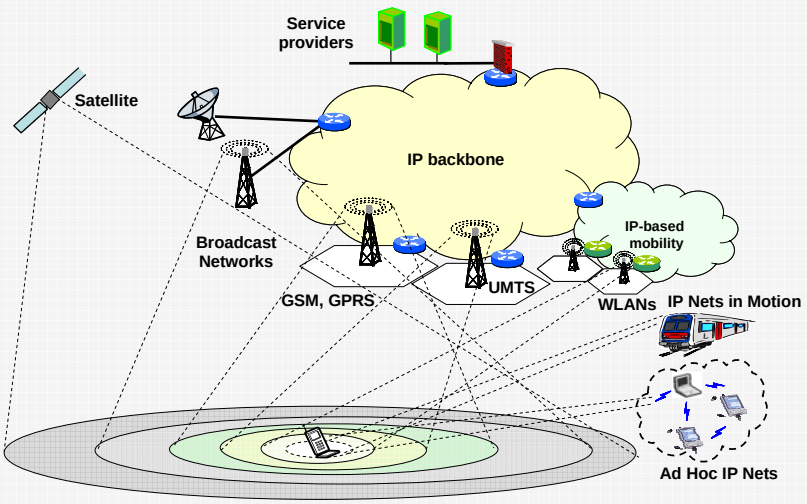
Global Mobility (I)



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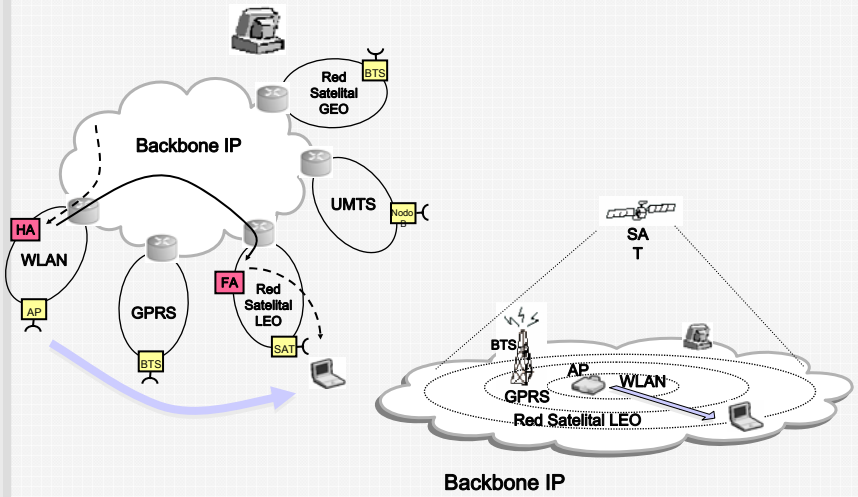
Global Mobility (II)



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Mobility vs. Portability

- Portability means changing the network connection point and still having access to the same application/services without restrictions:
  - Provided nowadays by autoconfiguration protocols (DHCP, dynamic DNS, etc), typically combined with VPN technologies
  - Requires the reinitialization of the network interface → data sessions are lost
- Mobility means changing the connexion point AND maintaining data sessions
  - Mobility requires the transparent and continuous routing of datagrams to mobile devices moving around

Mobile IP provides Mobility

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Was IP designed for Mobility?

- No, because:
  - IP addresses depend on the subnet
    - If subnet changes, the IP address must change
  - IP routing is based on subnet prefixes or aggregates that carry localization information
  - Transport protocols are aware of IP addresses
    - Identify connexions & Checksum calculation
- In summary, when a host changes its location
  - Network layer requires changing the IP address…
  - …but transport layer and applications do not allow it
- To implement mobility we have to please both of them:
  - Address duality managed at network layer: one for transport/applications and the other for routing

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IP Mobile Design Requirements

- Provide Global Mobility in network layer
  - Subnetwork independent
  - Macromobility: complements subnetwork micromobility
- Transparent to non-mobile nodes
  - No modifications in non-mobile nodes TCP/IP stack
- Transparent for applications
  - No modifications in applications/APIs (even mobile nodes)
- Transparent for network routing
  - No modifications to IP routing system
  - Mobility implemented on few new entities
- Secure signalling
  - Authentication mechanisms to avoid false redirections, DoS attacks, etc
- Simple Signalling
  - Small messages and simple protocol
- Scalability

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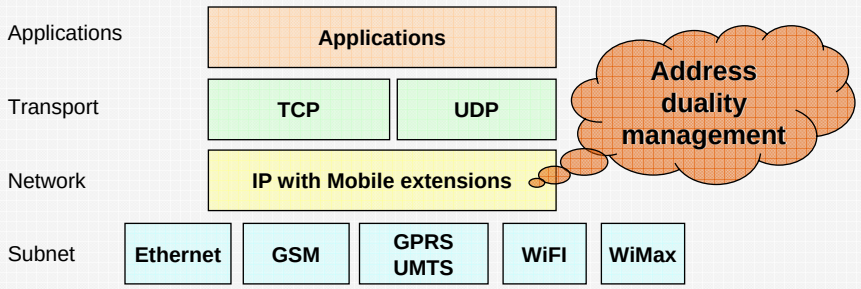
Mobile IP Architecture

- No changes at application or transport layers



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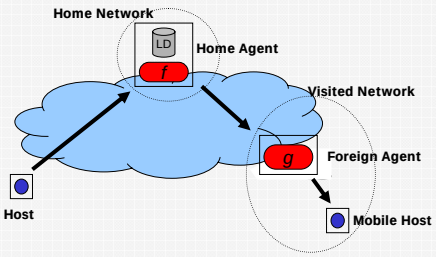
IPv4 Mobility

- Initially defined in RFC 2002:
  - IP Mobility Support, Charles Perkins, 1996
- Defines IP protocols extensions to transparently route datagrams to mobile nodes
- Address duality:
  - Home address: independent of localization
  - Care-of address: temporal and dependent of localization
- Procedures for mobile nodes to communicate its localization to local agents, that redirect (tunnel) datagrams to them when visiting networks



Functions:
f : Data Redirection
g : Forwarding
LD : Localization Directory

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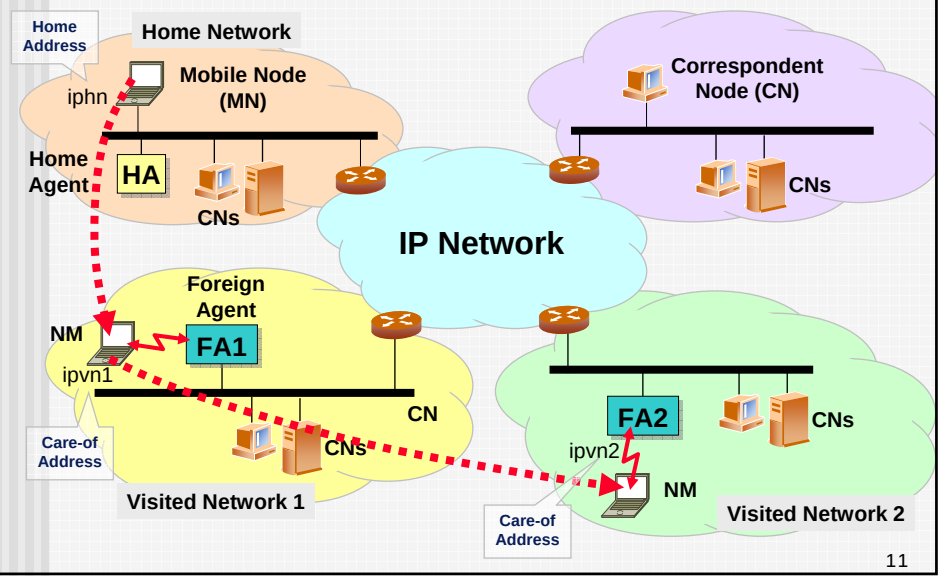
Mobile IP Scenario & Components



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New Components (I)

- Mobile Node (MN). A host or router that changes its connexion point to the network without losing their data sessions. It manages two addresses:
  - Home Address: IP address assigned to the MN when it is at Home Network. It is the one seen by applications
  - Care-of Address: temporal IP address assigned to a MN when it is attached to a visited network
- Home Agent (HA). A router on the Home Network that helps the MN by:
  - Maintaining a localization directory of the MN. Basically, a table of associations between home addresses and care-of addresses
  - Intercepts traffic destined to MN in Home Network and resends it by means of IP tunnels

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New Components (II)

- Foreign Agent (FA). A router on a visited network which provides routing services to the mobile node:
  - Detunnels and delivers datagrams to the MN that were tunnelled by the mobile node's HA.
  - In some cases, it provides the MN the care-of address and acts as a proxy between it and the rest of the network
  - Fortunately, not needed in IPv6!

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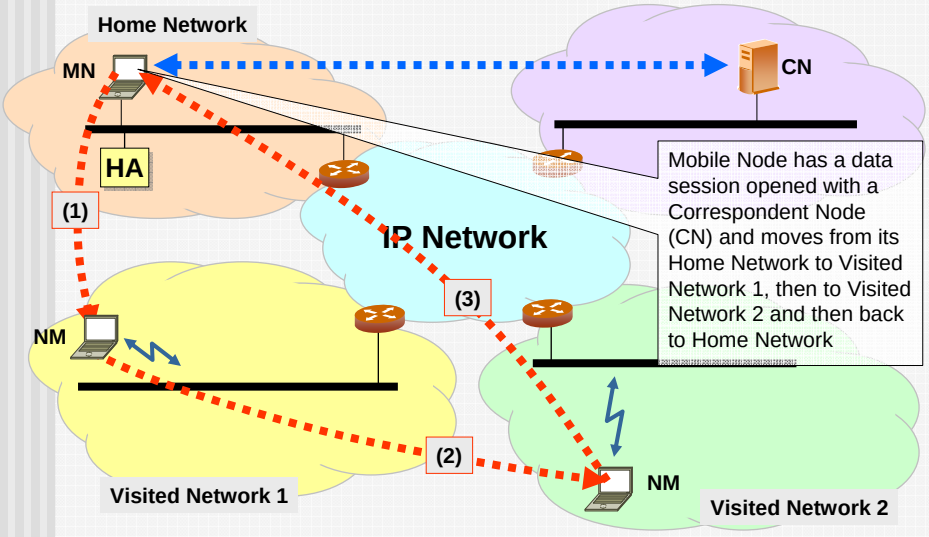
Mobile IP: Basic Operation (I)



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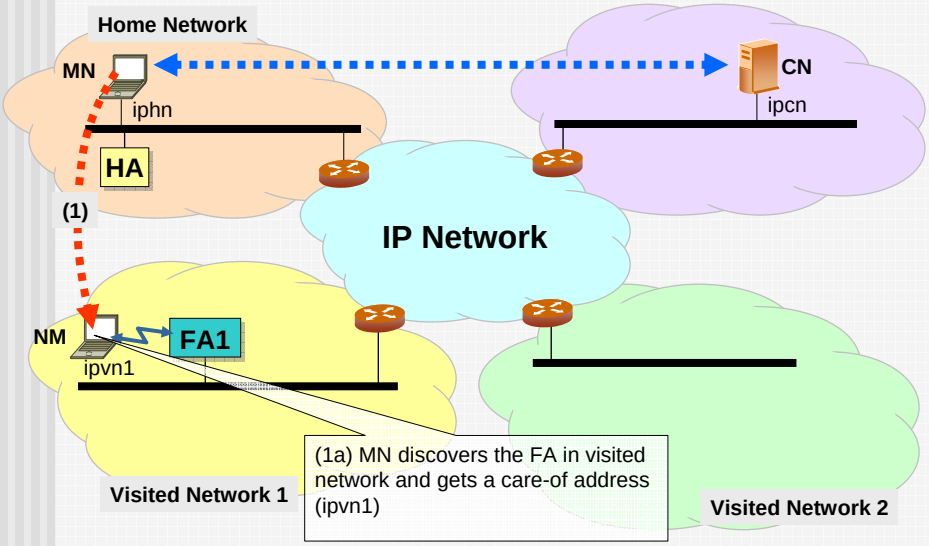
Mobile IP: Basic Operation (II)



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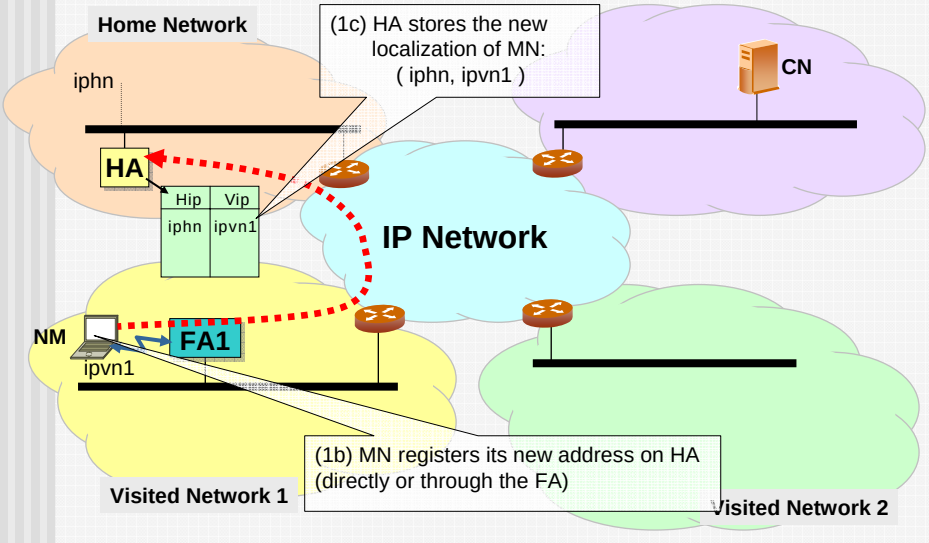
Mobile IP: Basic Operation (III)



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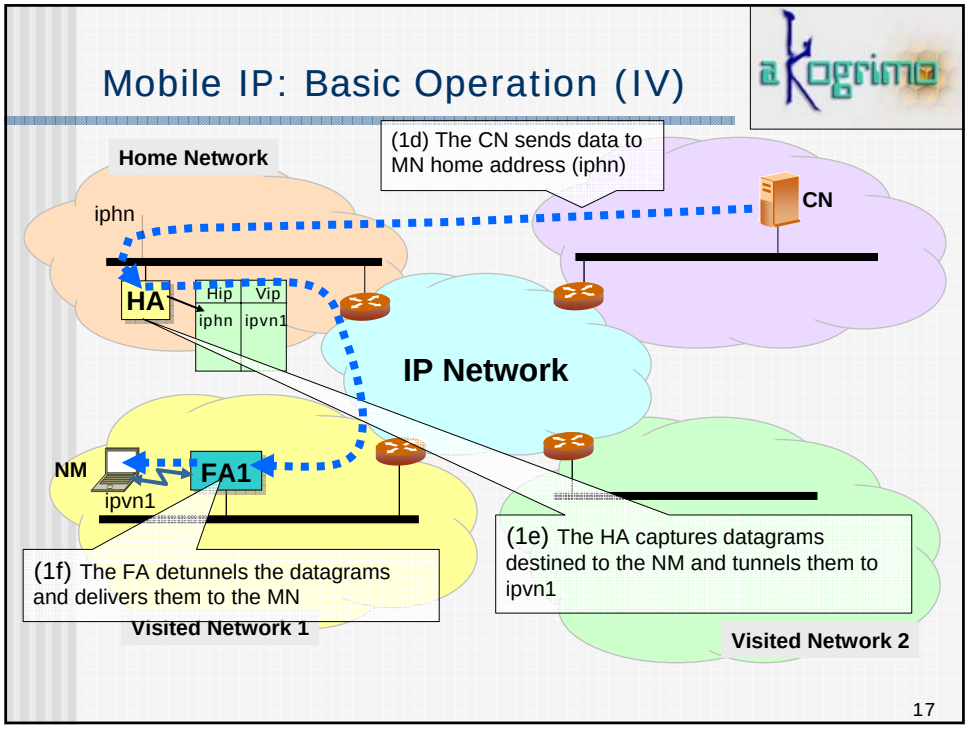
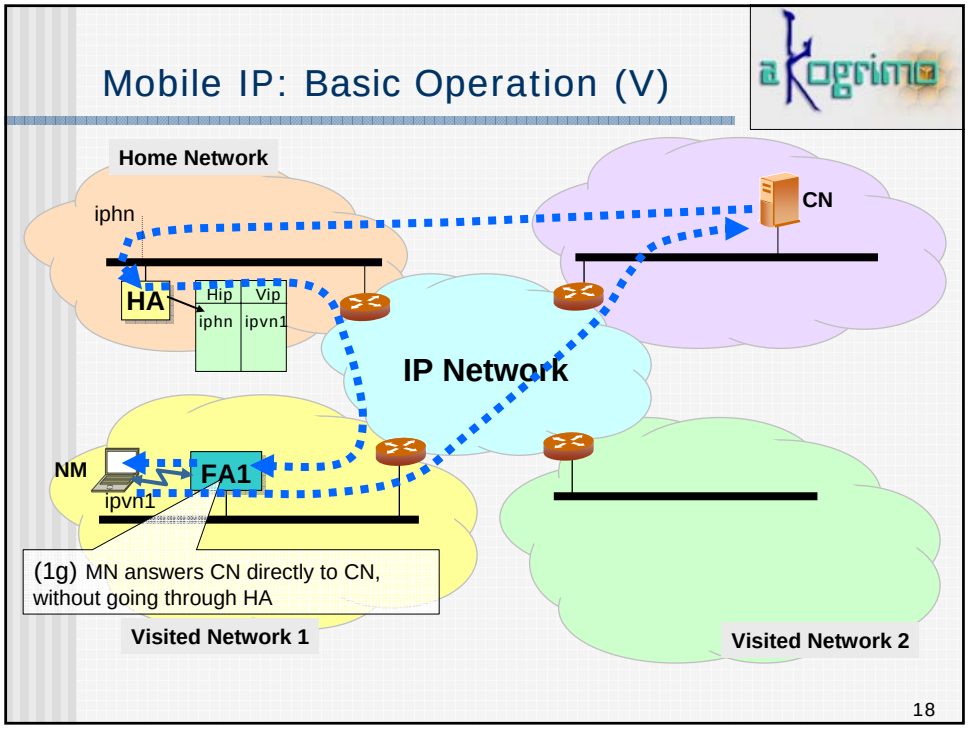
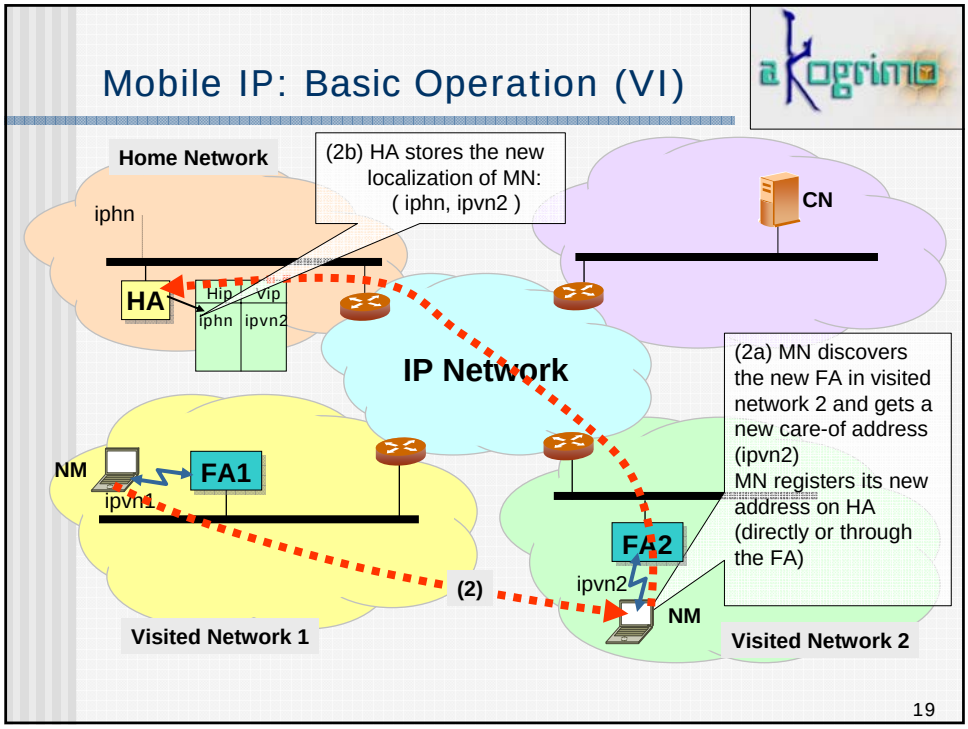
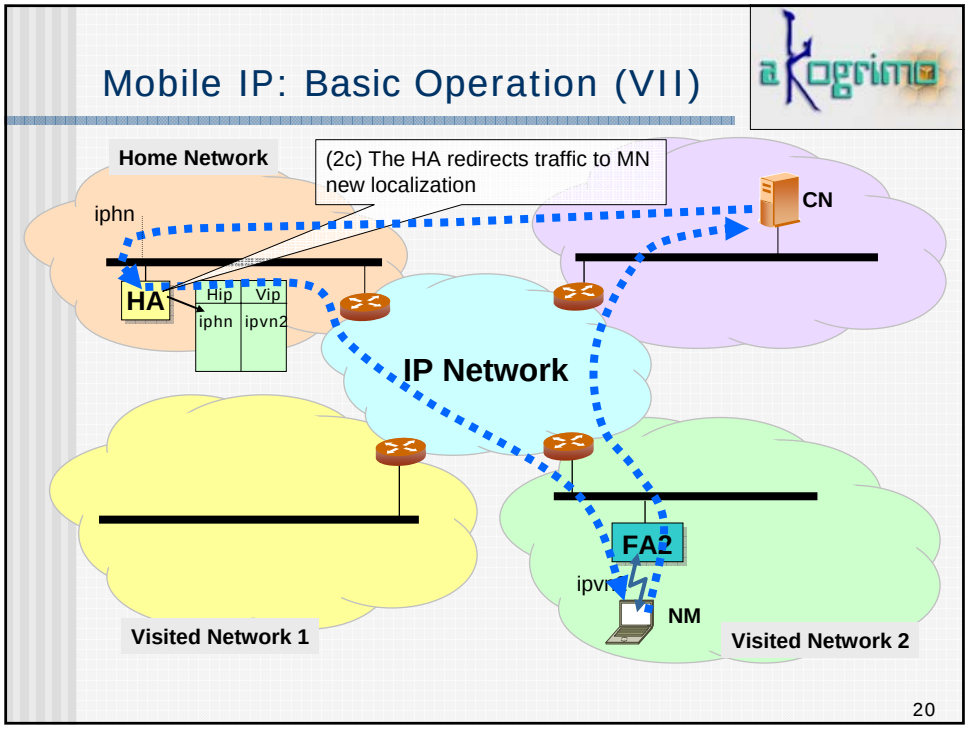
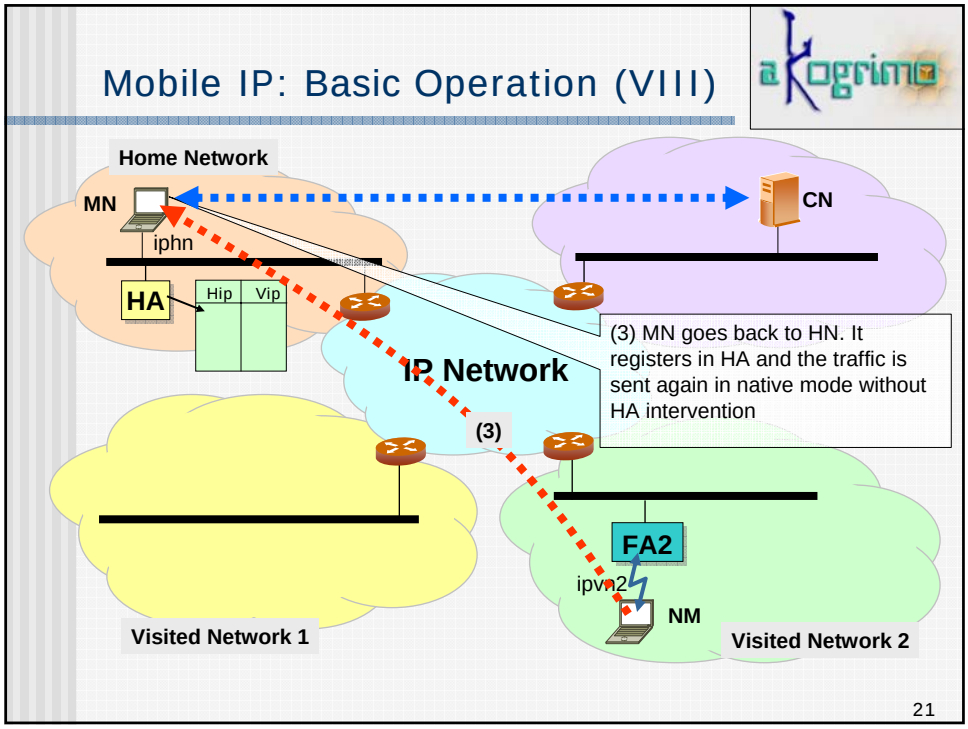
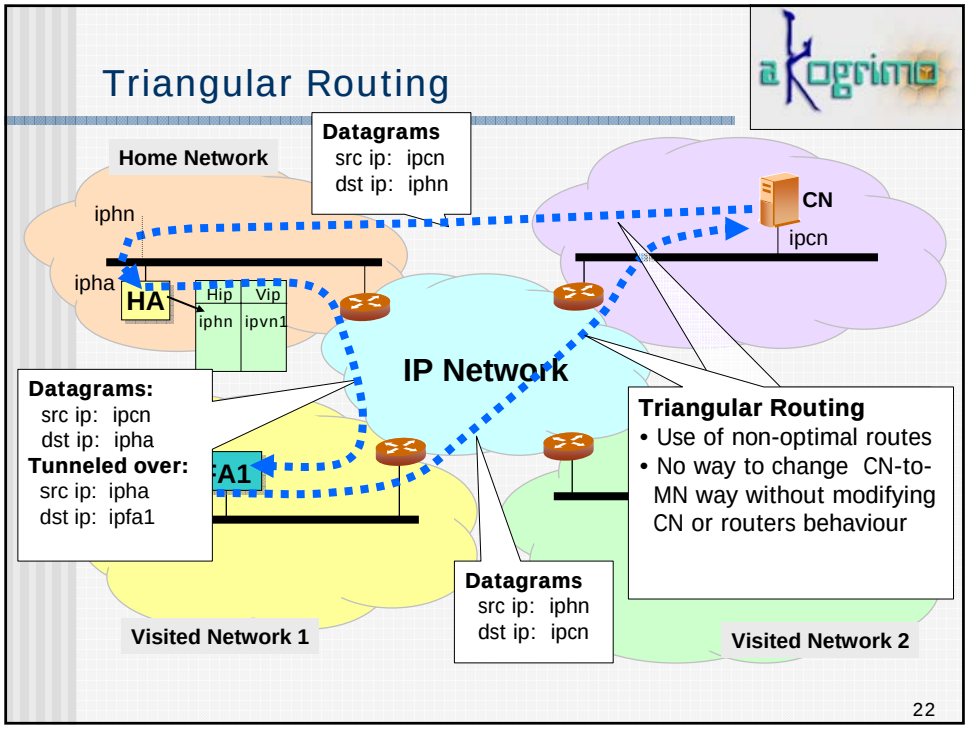

Mobile IP: Basic Operation (IV)
Home Network
(1d) The CN sends data to MN home address (iphn)
iphn
CN
HA
Hip
Vip
iphn
ipvn1
IP Network
NM
FA1
ipvn1
(1e) The HA captures datagrams destined to the NM and tunnels them to ipvn1
(1f) The FA detunnels the datagrams and delivers them to the MN
Visited Network 1
Visited Network 2
17

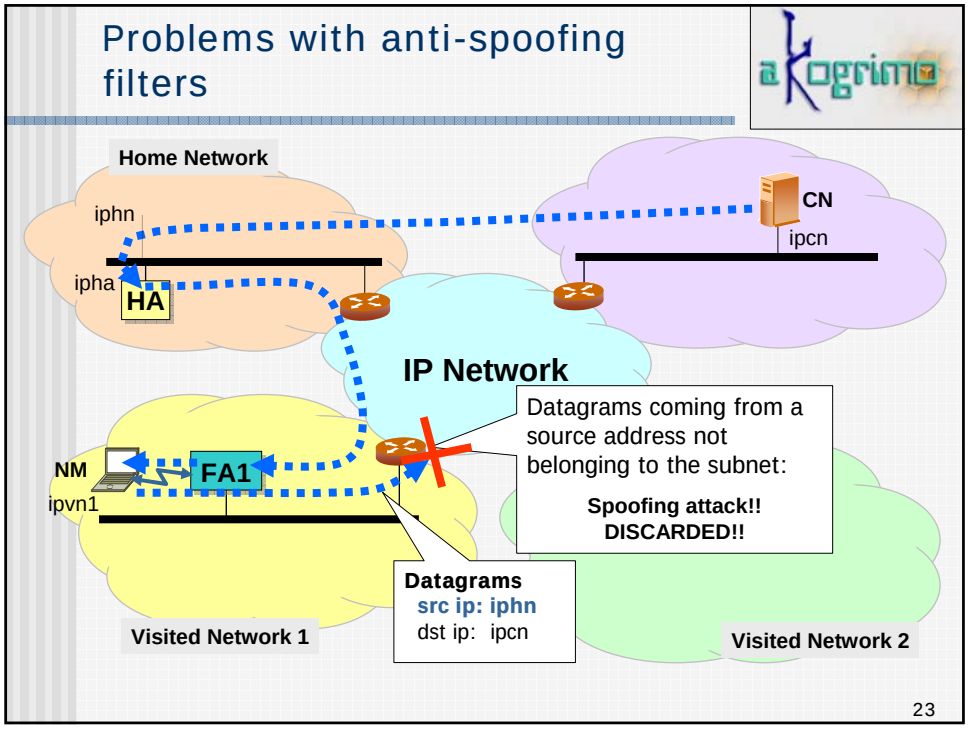

Mobile IP: Basic Operation (V)
Home Network
iphn
CN
HA
Hip
Vip
iphn
ipvn1
IP Network
NM
FA1
ipvn1
(1g) MN answers CN directly to CN, without going through HA
Visited Network 1
Visited Network 2
18

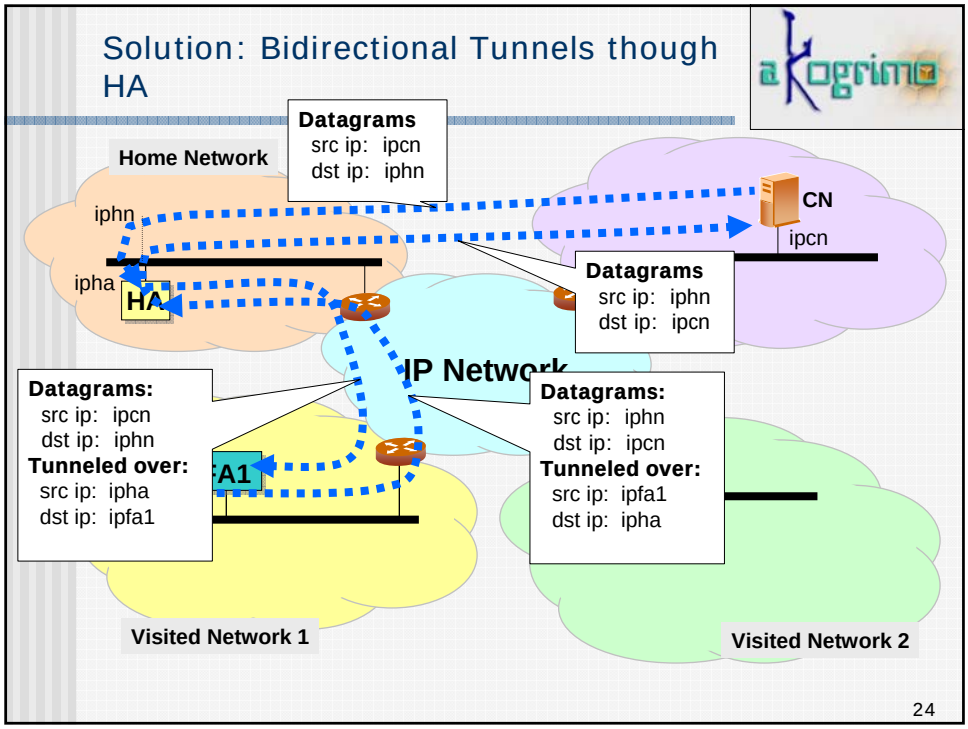

Mobile IP: Basic Operation (VI)
Home Network
iphn
(2b) HA stores the new localization of MN: (iphn, ipvn2)
CN
HA
Hip
Vip
iphn
ipvn2
IP Network
(2a) MN discovers the new FA in visited network 2 and gets a new care-of address (ipvn2)
MN registers its new address on HA (directly or through the FA)
NM
FA1
ipvn1
FA2
(2)
ipvn2
NM
Visited Network 1
Visited Network 2
19


Mobile IP: Basic Operation (VII)
Home Network
(2c) The HA redirects traffic to MN new localization
iphn
CN
HA
Hip
Vip
iphn
ipvn2
IP Network
FA2
NM
Visited Network 1
Visited Network 2
20


Mobile IP: Basic Operation (VIII)
Home Network
MN
iphn
HA
Hip
Vip
CN
IP Network
(3) MN goes back to HN. It registers in HA and the traffic is sent again in native mode without HA intervention
(3)
FA2
ipvn2
NM
Visited Network 1
Visited Network 2
21


Triangular Routing
Datagrams
src ip: ipcn
dst ip: iphn
Home Network
iphn
ipha
HA
Hip
Vip
iphn
ipvn1
CN
ipcn
IP Network
Datagrams:
src ip: ipcn
dst ip: ipha
Tunneled over:
src ip: ipha
dst ip: ipfa1
A1
Triangular Routing
• Use of non-optimal routes
• No way to change CN-to-MN way without modifying CN or routers behaviour
Datagrams
src ip: iphn
dst ip: ipcn
Visited Network 1
Visited Network 2
22


Problems with anti-spoofing filters
Home Network
iphn
ipha
HA
CN
ipcn
IP Network
Datagrams coming from a source address not belonging to the subnet:
Spoofing attack!!
DISCARDED!!
NM
FA1
ipvn1
Datagrams
src ip: iphn
dst ip: ipcn
Visited Network 1
Visited Network 2
23


Solution: Bidirectional Tunnels though HA
Datagrams
src ip: ipcn
dst ip: iphn
Home Network
iphn
ipha
HA
CN
ipcn
Datagrams
src ip: iphn
dst ip: ipcn
IP Network
Datagrams:
src ip: ipcn
dst ip: iphn
Tunneled over:
src ip: ipha
dst ip: ipfa1
Datagrams:
src ip: iphn
dst ip: ipcn
Tunneled over:
src ip: ipfa1
dst ip: ipha
Visited Network 1
Visited Network 2
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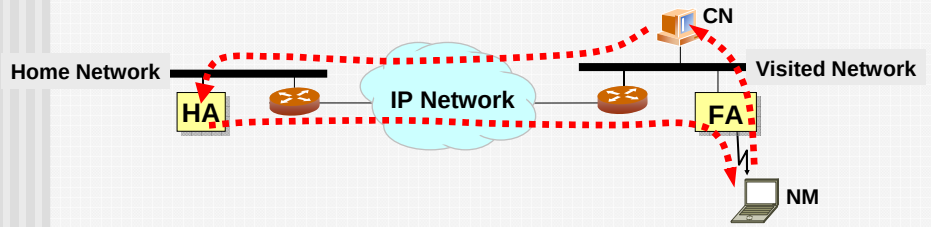
Triangular Routing

- We are using non-optimal routes:



- Solution → a mechanism to make correspondent nodes aware of the localization of mobile nodes
  - Binding Cache: a table that maintains (home address, care-of address) associations and it is updated by mobile nodes

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Mobility in IPv6 (MIPv6)

- IPv6 designed having mobility in mind:
  - included the basic functionalities to manage it efficiently…
  - …although later modifications require upgrades IPv6 implementations to fully support MIPv6
- Foreign Agents not needed:
  - MNs get care-of addresses by stateless (Router Advertisement) or statefull (DHCP autoconfiguration)
  - Greatly simplifies deployment
- Mechanisms to make correspondent nodes aware of localization of mobile nodes
  - Binding Cache database and messages to update it (Binding Update, Binding Ack, etc)
- Solves triangular routing by means of
  - Type 2 Routing Header, to avoid tunnels
  - Home Address Option, to avoid ingress filters

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Mobile IPv6 Messages and Options (I)

- Mobility Extension Header
  - Allows the sending of messages among MN, CN & HA
  - Contains one or more mobility messages:

• Binding Update • Binding Acknowledgement • Binding Refresh Request • Binding Error	**Binding Cache Management**
• Home Test Init (HoTI) • Care-of Test Init (CoTI) • Home Test (HoT) • Care-of Test (CoT)	**Return Routability Procedure**

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Mobile IPv6 Messages and Options (II)

- Type 2 Routing Header
  - A new mobility specific routing header
    - Limited to a single address
  - Defined to allow firewalls to differentiate source-routed packets (with type 0 general purpose routing header) from packets sent to mobile nodes
  - Used by correspondent nodes when sending packets to mobile nodes
    - Destination address always set to care-of-address
- Home Address Option
  - Included in IPv6 Destination Options Header
  - Used to indicate the home address in Binding Update and data packets sent by mobile nodes
    - Source address always set to care-of address (to comply with ingress filters)

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Mobile IPv6 Messages and Options (III)

- ICMPv6 Messages for Mobile IPv6
  - Used for dynamic home agent address and home subnet prefix discovery
  - Types:
    - Home Agent Address Discovery Request
    - Home Agent Address Discovery Reply
      - Use by a mobile node to dynamically discover the global address of a home agent
      - Based on the use of a Home-Agents anycast address
    - Home Prefix Solicitation
    - Home Prefix Advertisement
      - Used by a mobile node to dynamically discover the address prefix of its home link

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Mobile IPv6 Messages and Options (IV)

- Modifications to Neighbour Discovery
  - ICMPv4 Agent Advertisement and Solicitation messages do not exist in IPv6
    - Integrated in Router Advertisement/Solicitation messages
  - Home Agent Flag
    - Indicates if a router acts as a HA
  - Advertisement Interval option modified
    - Specifies how often the router sends unsolicited multicast router advertisements
    - RAs used my mobile nodes to detect whether they have moved to another link
    - RAs can be sent more frequently that every 3 seconds
  - Home Agent Information Option
    - Used to inform about HA's preference and lifetime

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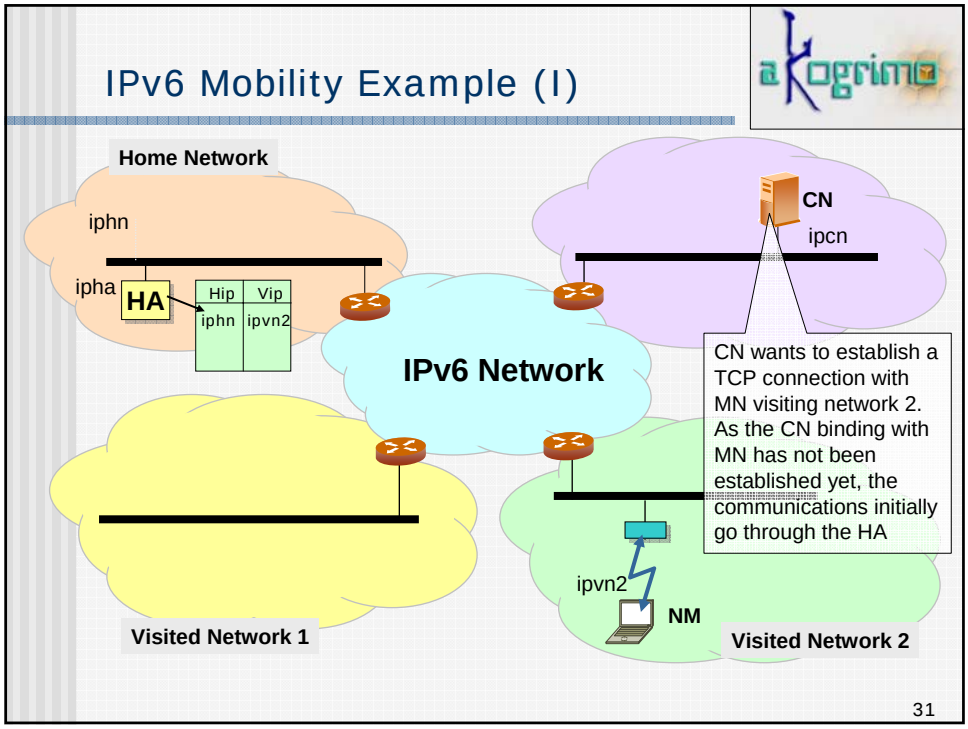
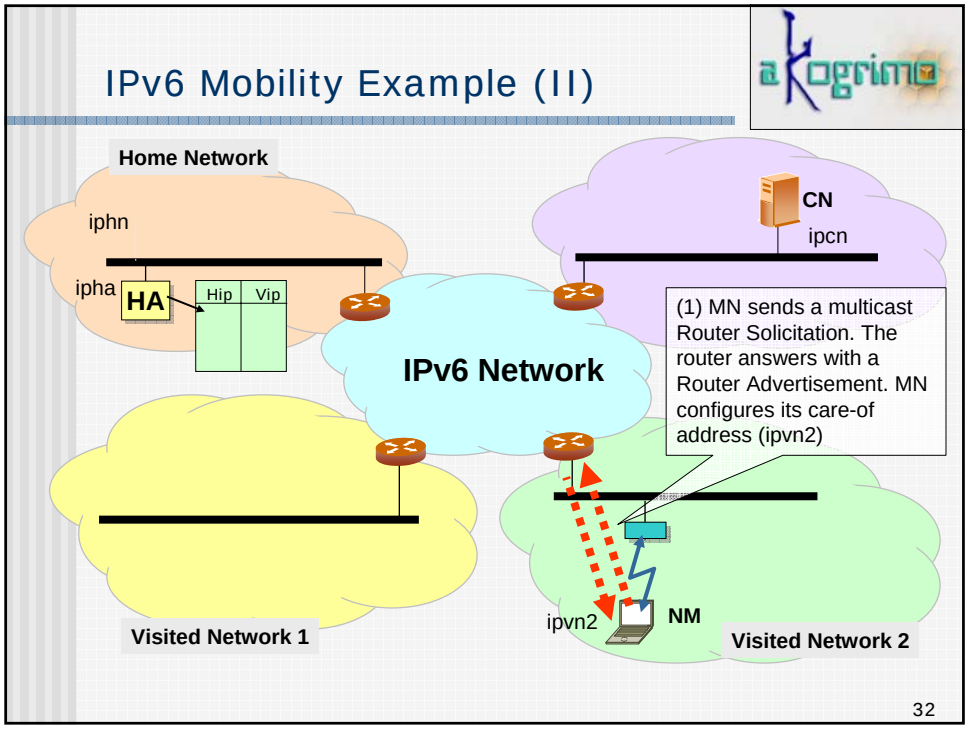
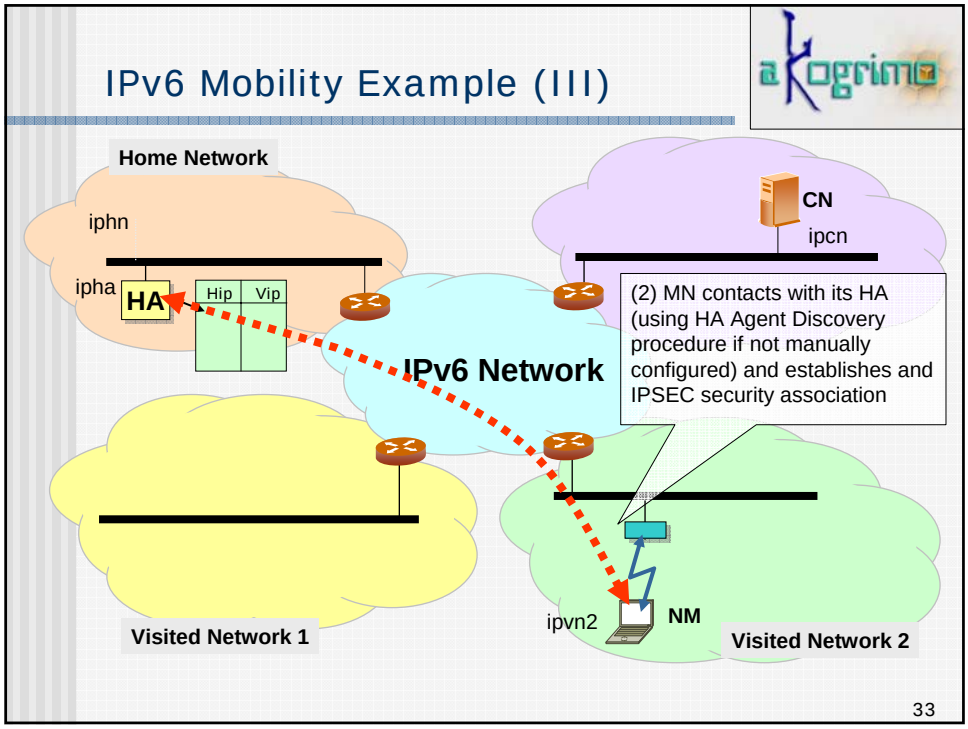
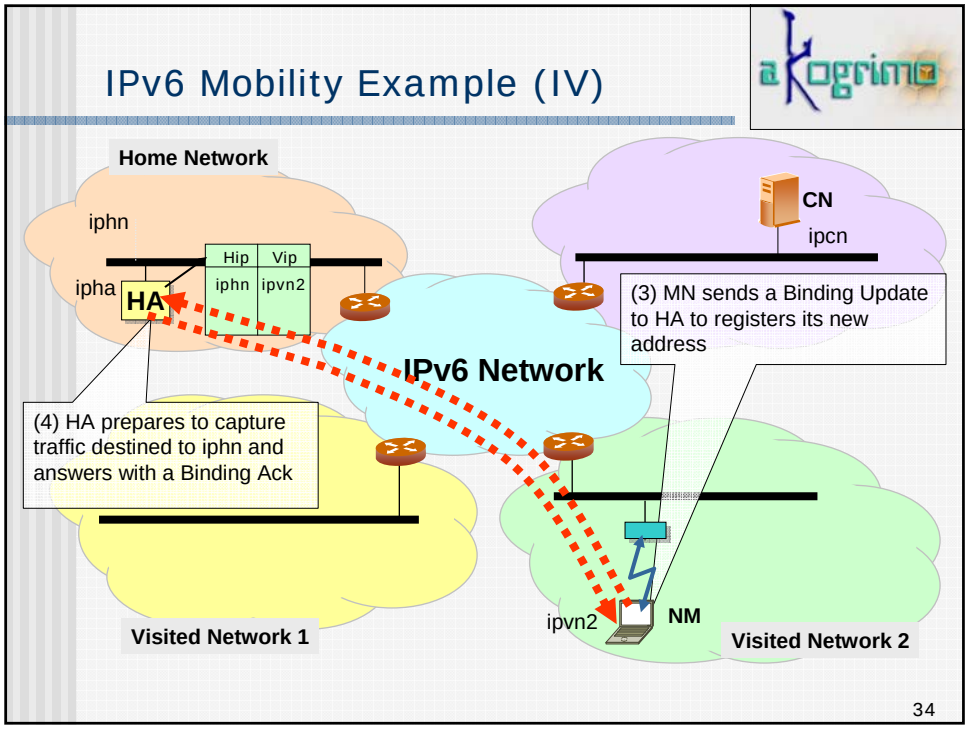

IPv6 Mobility Example (I)
Home Network
iphn
ipha
HA
Hip
Vip
iphn
ipvn2
IPv6 Network
CN
ipcn
CN wants to establish a TCP connection with MN visiting network 2. As the CN binding with MN has not been established yet, the communications initially go through the HA
ipvn2
NM
Visited Network 1
Visited Network 2
31


IPv6 Mobility Example (II)
Home Network
iphn
ipha
HA
Hip
Vip
IPv6 Network
CN
ipcn
(1) MN sends a multicast Router Solicitation. The router answers with a Router Advertisement. MN configures its care-of address (ipvn2)
ipvn2
NM
Visited Network 1
Visited Network 2
32


IPv6 Mobility Example (III)
Home Network
iphn
ipha
HA
Hip
Vip
CN
ipcn
(2) MN contacts with its HA (using HA Agent Discovery procedure if not manually configured) and establishes and IPSEC security association
IPv6 Network
ipvn2
NM
Visited Network 1
Visited Network 2
33


IPv6 Mobility Example (IV)
Home Network
iphn
ipha
HA
Hip
Vip
iphn
ipvn2
CN
ipcn
(3) MN sends a Binding Update to HA to registers its new address
IPv6 Network
(4) HA prepares to capture traffic destined to iphn and answers with a Binding Ack
ipvn2
NM
Visited Network 1
Visited Network 2
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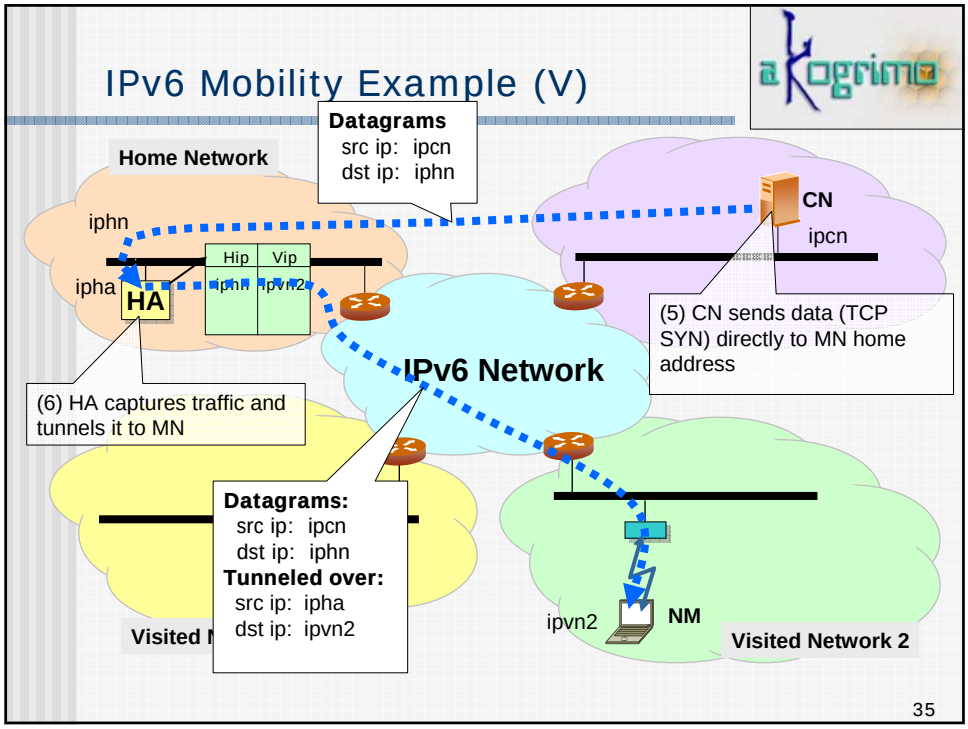
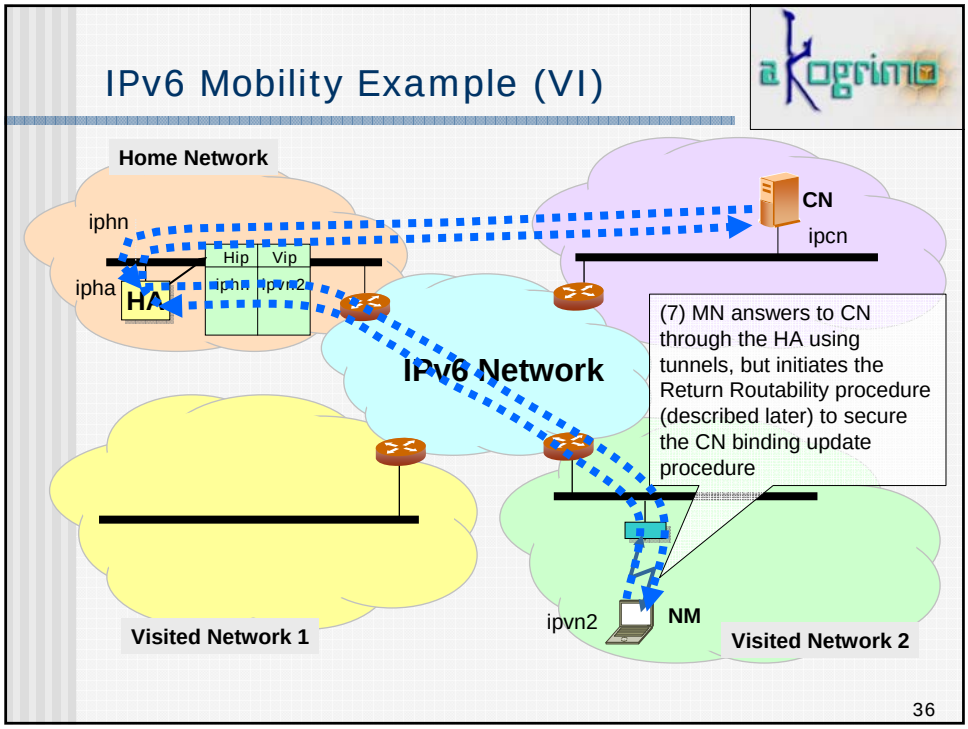
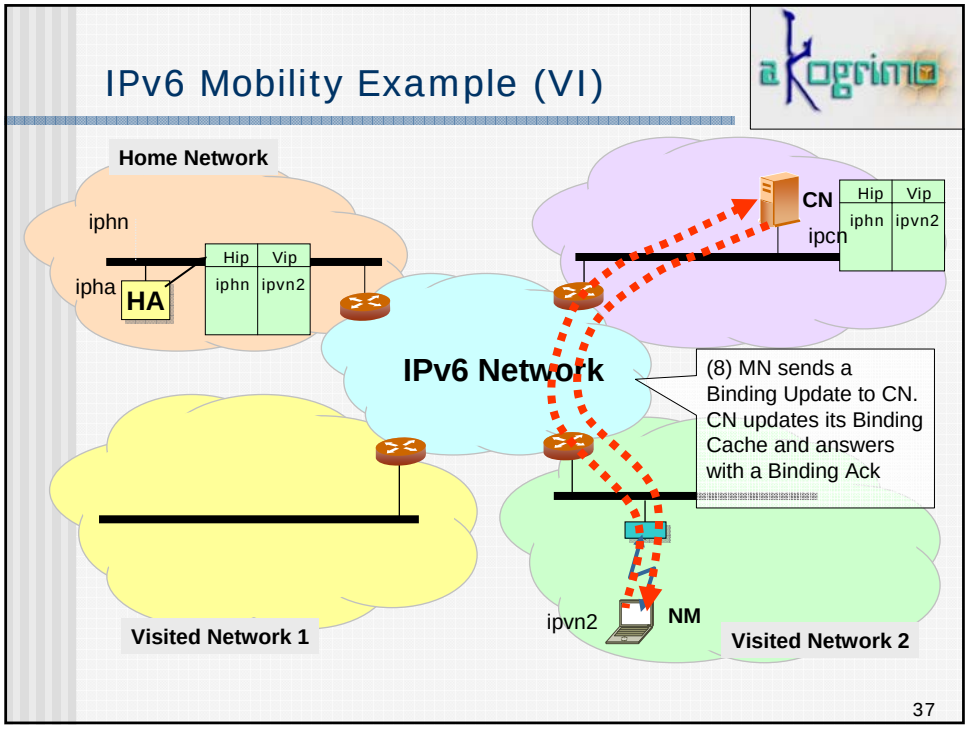
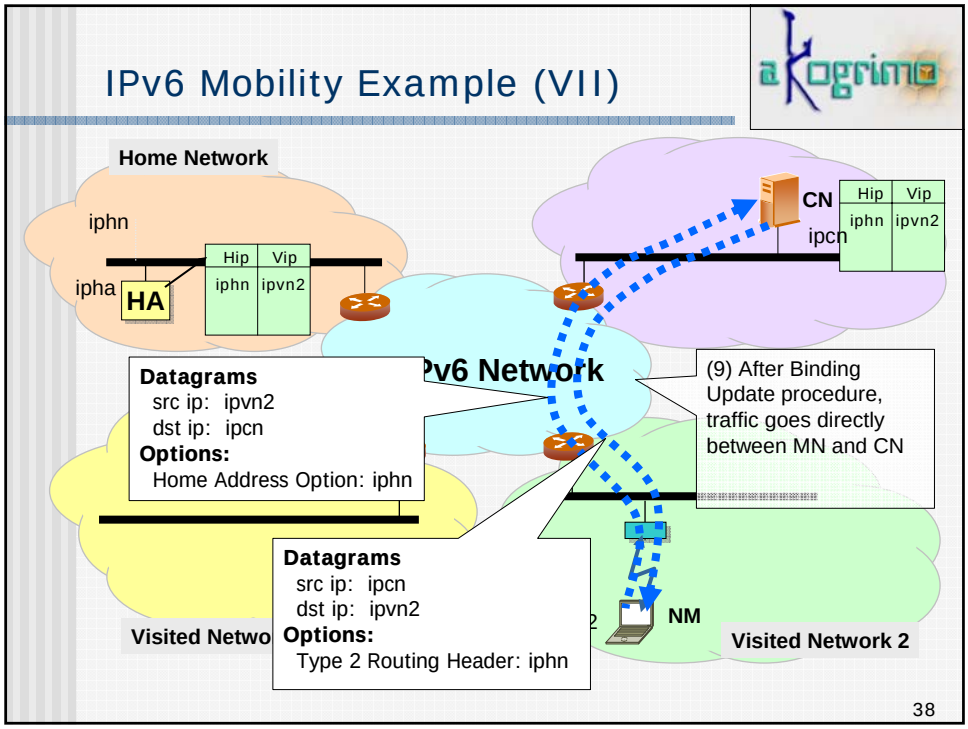

IPv6 Mobility Example (V)
Datagrams
src ip: ipcn
dst ip: iphn
Home Network
iphn
ipha
HA
Hip
Vip
iphn
ipvn2
CN
ipcn
(5) CN sends data (TCP SYN) directly to MN home address
IPv6 Network
(6) HA captures traffic and tunnels it to MN
Datagrams:
src ip: ipcn
dst ip: iphn
Tunneled over:
src ip: ipha
dst ip: ipvn2
ipvn2
NM
Visited Network 2
35


IPv6 Mobility Example (VI)
Home Network
iphn
ipha
HA
Hip
Vip
iphn
ipvn2
CN
ipcn
(7) MN answers to CN through the HA using tunnels, but initiates the Return Routability procedure (described later) to secure the CN binding update procedure
IPv6 Network
ipvn2
NM
Visited Network 1
Visited Network 2
36


IPv6 Mobility Example (VI)
Home Network
iphn
ipha
HA
Hip
Vip
iphn
ipvn2
CN
ipcn
Hip
Vip
iphn
ipvn2
IPv6 Network
(8) MN sends a Binding Update to CN. CN updates its Binding Cache and answers with a Binding Ack
ipvn2
NM
Visited Network 1
Visited Network 2
37


IPv6 Mobility Example (VII)
Home Network
iphn
ipha
HA
Hip
Vip
iphn
ipvn2
CN
ipcn
Hip
Vip
iphn
ipvn2
Datagrams
src ip: ipvn2
dst ip: ipcn
Options:
Home Address Option: iphn
(9) After Binding Update procedure, traffic goes directly between MN and CN
Datagrams
src ip: ipcn
dst ip: ipvn2
Options:
Type 2 Routing Header: iphn
NM
Visited Network 2
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Security in IPv6 Mobility

- Binding Update procedures has to be secured
- Possible Attacks:
  - Traffic theft: send false BU to attract MN's traffic and capture it
  - Bombing attack: redirect traffic from multiple MN's to someone else
  - DoS attack: deny MN to communicate with other nodes
- Security needed:
  - CN needs to authenticate a MN sending a binding update
  - MN must prove it owns both home and care-of address
  - Encryption not required
- Solutions:
  - Use certificates to assure a MN owns a home address
    - Needs a PKI infrastructure globally deployed (Difficult)
  - Light solution:
    - IPSEC between HA and MN and Return Routability Procedure

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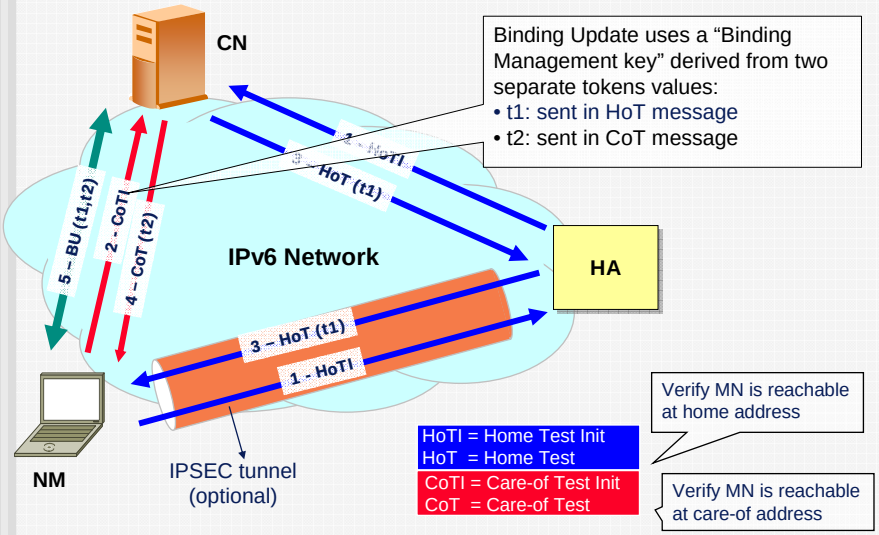
Return Routability Procedure



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MIPv6 Optimizations

- Objective:
  - reduce or eliminate signalling overhead and packet loss due to handoff delays in Mobile IPv6.
- Two main initiatives developed by MIPv6 Signalling and Handoff Optimization (mipshop) IETF Workgroup
  - **Fast Handovers for Mobile IPv6 (FMIPv6)**
    - MIPv6 extensions to reduce handover latency and packet losses by anticipating IP connectivity tasks as soon as a new link is established
  - **Hierarchical Mobile IPv6 mobility management (HMIPv6)**
    - MIPv6 extensions to allow local mobility handling to reduce the amount of signalling between the MN, CN and HA

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IPv6 Fast Handover (FMIPv6)

- Characteristics:
  - Does not depend on specific link-layer features while allowing link-specific customizations.
  - reduces packet loss by providing fast IP connectivity as soon as a new link is established.
  - It does so by fixing up the routing during link configuration and binding update, so that packets delivered to the old care of address are forwarded to the new.
  - In addition, FMIPv6 provides support for preconfiguration of link information (such as the subnet prefix) in the new subnet while the mobile node is still attached to the old subnet. This reduces the amount of preconfiguration time in the new subnet.

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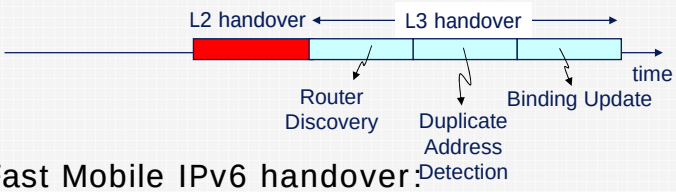
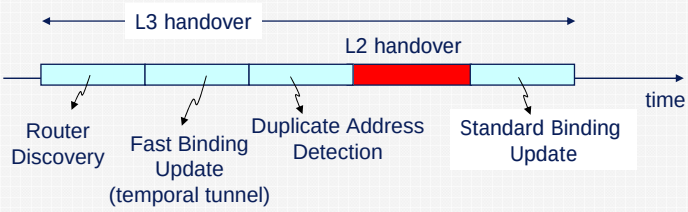
Standard vs. Fast Mobile Handover

- Standard Mobile IPv6 handover:



- Fast Mobile IPv6 handover:



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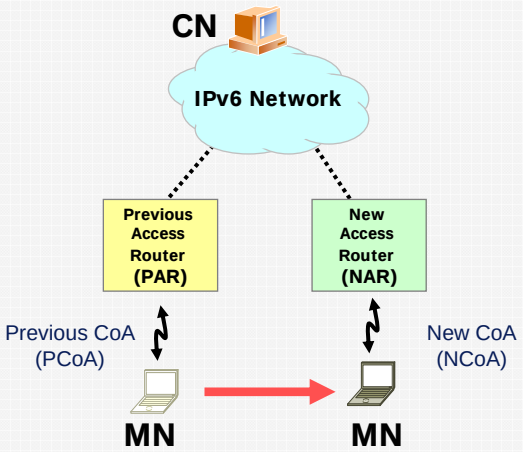
Reference Scenario for Handover



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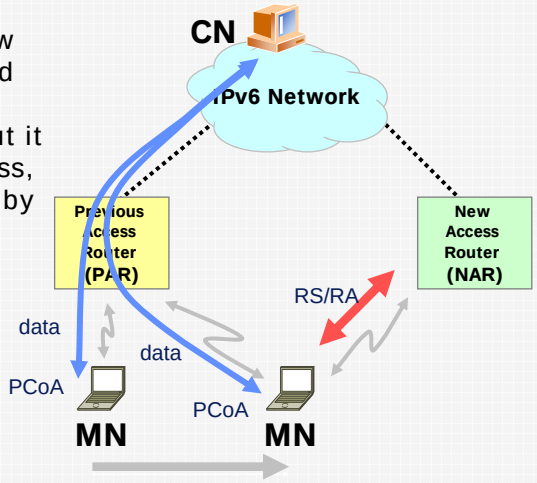
IPv6 Fast Handover Overview (I)

- MN is interchanging traffic with CN
- MN detects a new access router and requests subnet information about it (prefix, IP address, and L2 address) by means of router discovery mechanisms (RS/RA)



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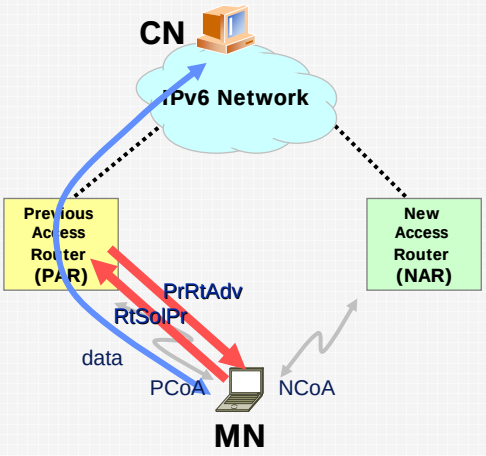
IPv6 Fast Handover Overview (II)

- MN communicates to PAR the intention to initiate a handover to NAR using messages:
  - *Router Solicitation for Proxy Advertisement (RtSolPr)*
  - *Proxy Router Advertisement (PrRtAdv)*
- MN builds a prospective new CoA (NCoA)
  - this step eliminates the latency due to new prefix discovery



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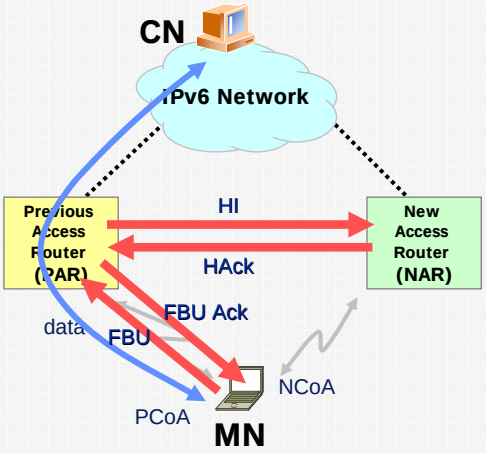
IPv6 Fast Handover Overview (III)

- MN sends a *Fast Binding Update* to PAR to request the creation of a tunnel between PAR and NAR
- PAR sends a *Handover Initiate* message to coordinate with NAR the creation of the tunnel
- After receiving the *HI Ack* message from NAR, PAR answers MN with an *FBU Ack*



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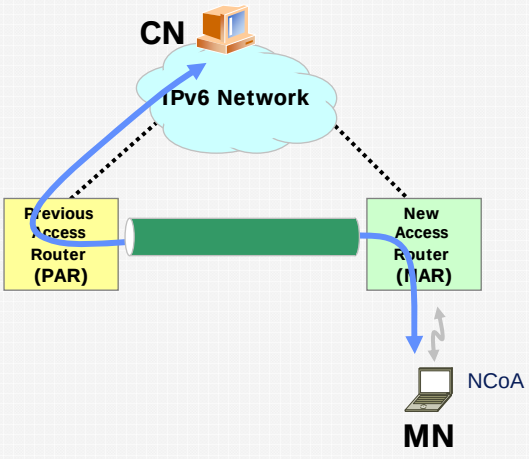
IPv6 Fast Handover Overview (IV)

- PAR and NAR set up the tunnel to carry the traffic to PCoA (the one CN sends traffic to)
- After receiving *FBU Ack* message, the MN can change definitely to the new network
- MN node must reversed tunnel the packets to CN through PAR



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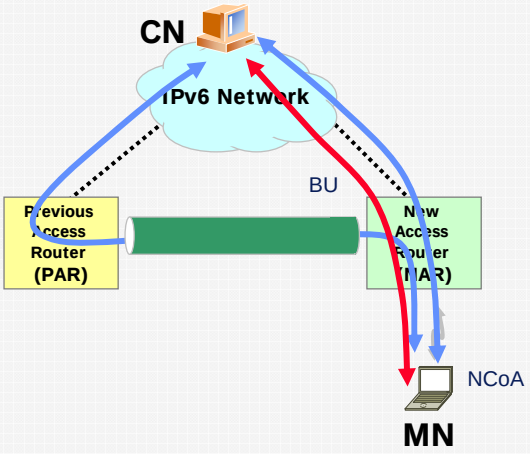
IPv6 Fast Handover Overview (V)

- MN does the standard MIPv6 Binding Update procedure to its HA and the CN to change to the optimal route between CN and MN
- As a result, the tunnel between PAR and NAR is deleted



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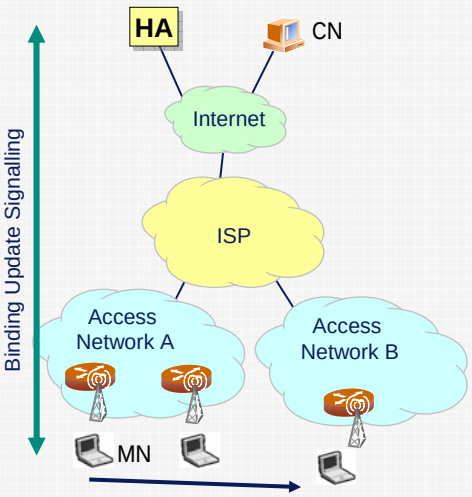
Standard MIPv6 Handover Signalling

- Every time the MN moves it has to send Binding Updates (BUs) to its Home Agent (HA) and all Correspondent Nodes (CNs) it communicates with.
- Binding Update procedure involves at least several round-trip-delays (authentication, updates, etc)
- These round trip delays will disrupt active connections every time a handoff to a new AR is performed



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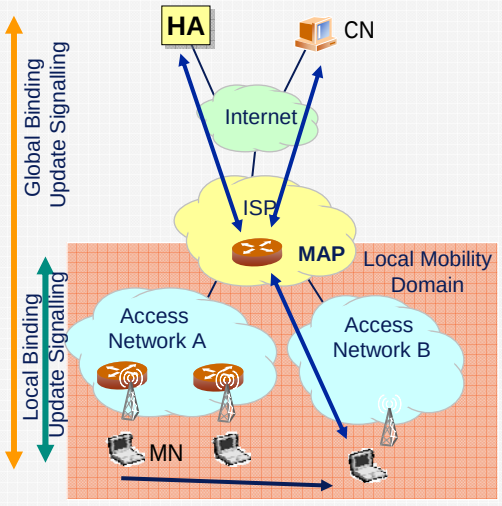
Hierarchical Mobile IPv6 (HMIPv6)

- New Mobile IPv6 node, called the **Mobility Anchor Point (MAP)** that limits the amount of Mobile IPv6 signalling outside the local domain
- MAP acts as a Local Home Agent
- MN only signals its movements inside the local mobility domain to the MAP
  - Movements are transparent for HA and CNs
  - HA and CNs send traffic to MAP



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Conclusions

- MIPv6 provides Global Mobility for IP hosts/routers:
  - Independent of subnetwork
  - Complementary to subnetwork mobility
- Mobility was compromised in IPv4:
  - lack of flexibility to define new options and messages
  - lack of key functionalities like binding caches.
- IPv6 showed to be a flexible framework protocol to develop mobility
- MIPv6 is a key element for all future All-IP wireless networks
  - Efficient and deployable protocol
  - Being integrated in 3G/4G mobile networks

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Mobile IP References

- Hesham Soliman. Mobile IPv6: Mobility in a Wireless Internet. Addison Wesley Professional, 2004.
- “Mobile IP”. William Stallings. The Internet Protocol Journal. Volume 4, Number 2, Junio 2001.
- “Mobile IP, Design Principles and Practices”. Charles E. Perkins. Addison-Wesley. 1997
- IPv6: Necessary for Mobile and Wireless Internet. ISOC Briefing Paper #14. http://www.isoc.org/briefings/014/index.html
- Request for Comments:
  - Mobility Support in IPv6 (RFC 3775)
  - Using IPsec to Protect Mobile IPv6 Signaling between Mobile Nodes and Home Agents (RFC 3776)
  - Fast Handovers for Mobile IPv6 (RFC 4068)
  - Hierarchical Mobile IPv6 mobility management (HMIPv6) (RFC 4140)

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Mobile IP References

- Relevant IETF Workgroups:
  - Mobility for IPv6 (mip6)
  - Mobility for IPv4 (mip4)
  - Mobile Ad-hoc Networks (manet)
  - Network Mobility (nemo)
  - Mobile Nodes and Multiple Interfaces in IPv6 (monami6)
  - IKEv2 Mobility and Multihoming (mobike)
  - MIPv6 Signaling and Handoff Optimization (mipshop)

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Thank you!

Questions ???

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