Mobility and Future Internet

Dec. 01, 2008

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Outline

- Mobile IP
- ProxyMobile IP
- Media Independent Handoff
- Site Multi-Homing by IPv6 Intermediate
- NEMO and 6LoWPAN
- Mobility in Future Internet

Mobile IP

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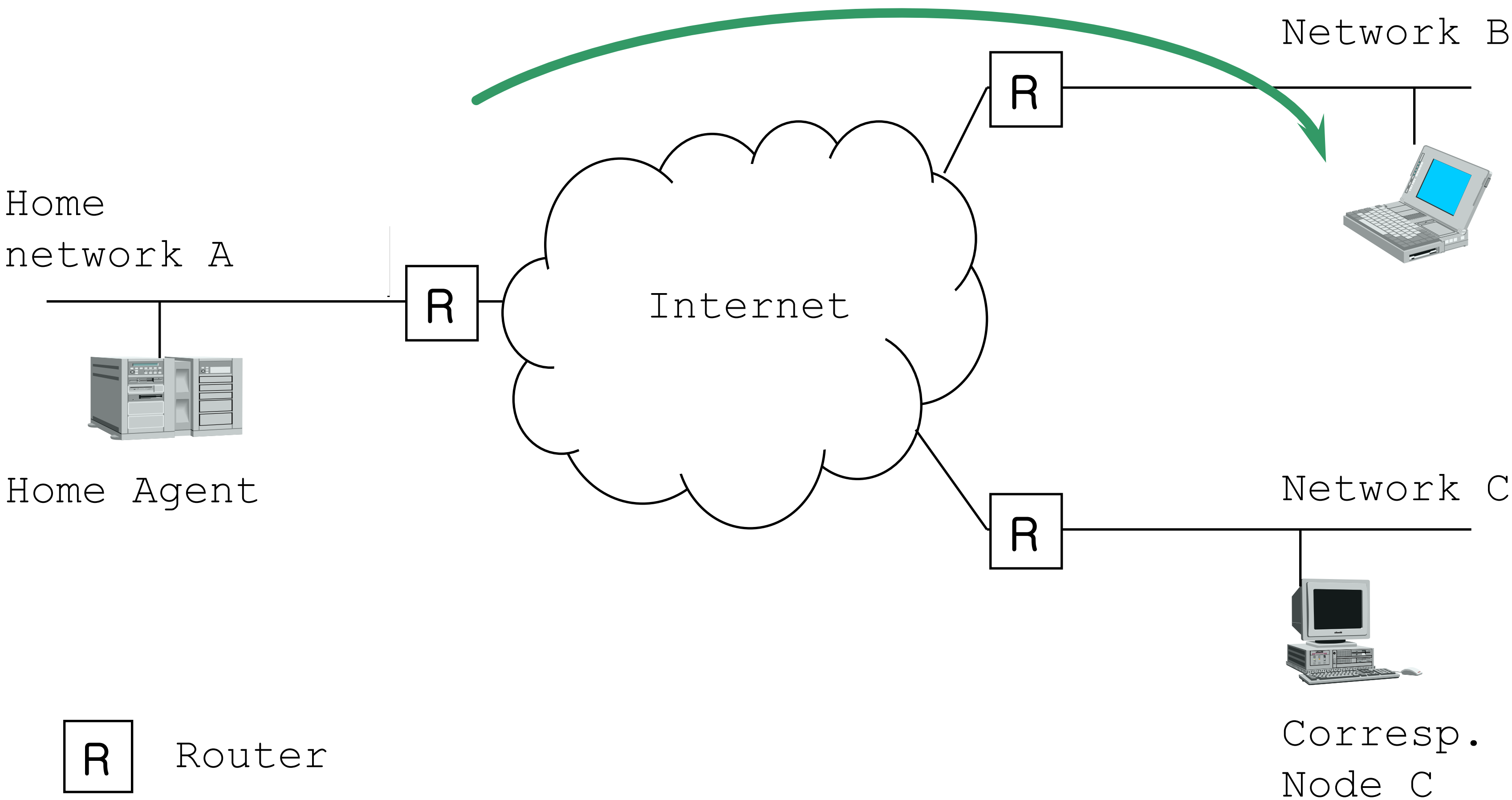
Outline

- Mobile IPv6
  - Mobile IPv6 Message
  - Mobile IPv6 Option
  - Mobile IPv6 Operation
  - Mobile IPv6 Handover
- Proxy Mobile IPv6
  - PMIPv6 Overview
  - PMIPv6 Operation Flow
  - PMIPv6 Features

Why Mobile IP

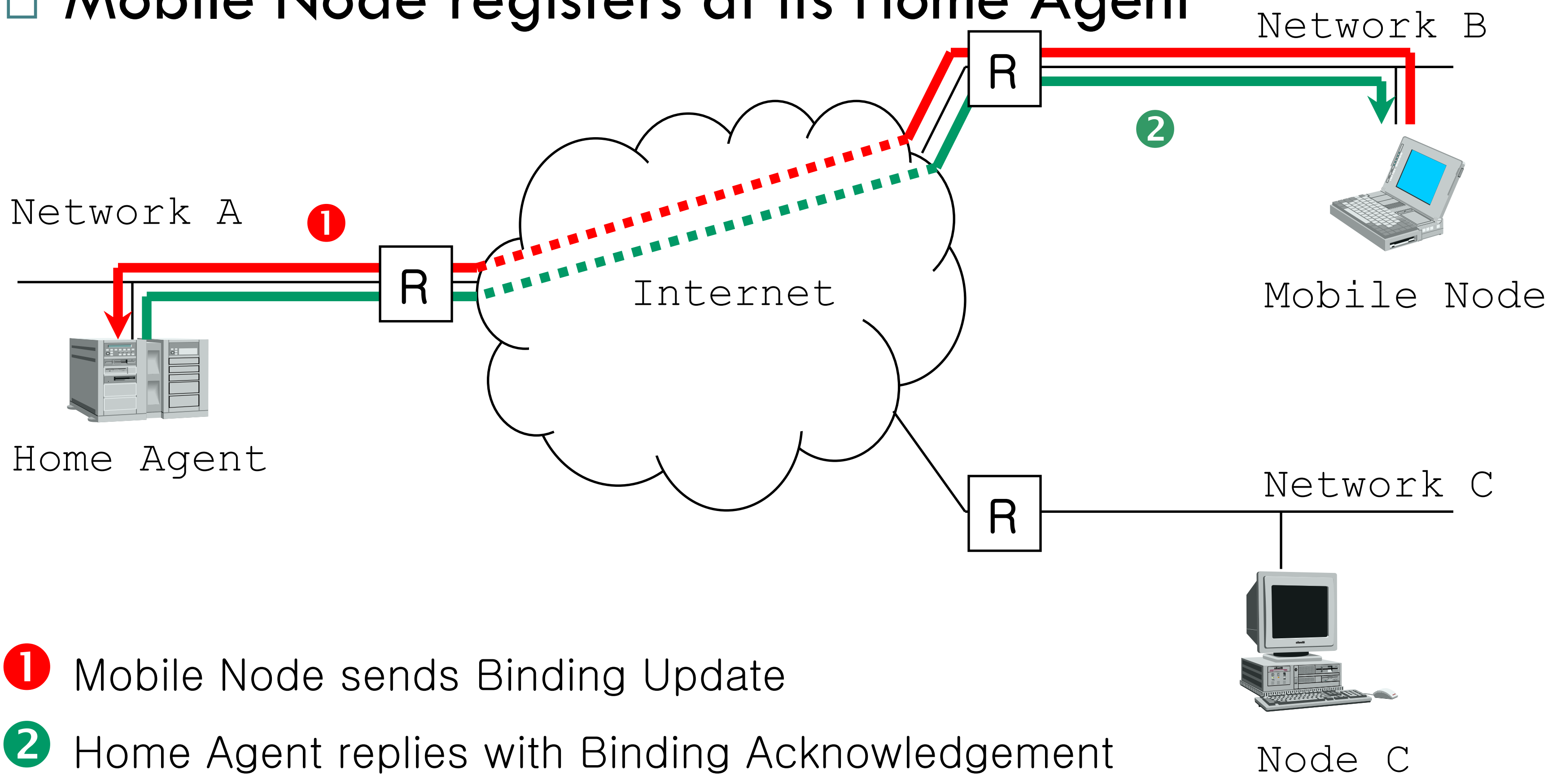
- Motivation for Mobile IP
  - TCP session needs to keep the same IP address for the life of the session
  - IP needs to change the IP address when mobile node moves to a new place
  - Consider the IP mobility problem as a routing problem
- Requirement for Mobile IP
  - Transparency
  - Compatibility
  - Efficiency and scalability

Mobile IP Operation



Mobile IP Operation

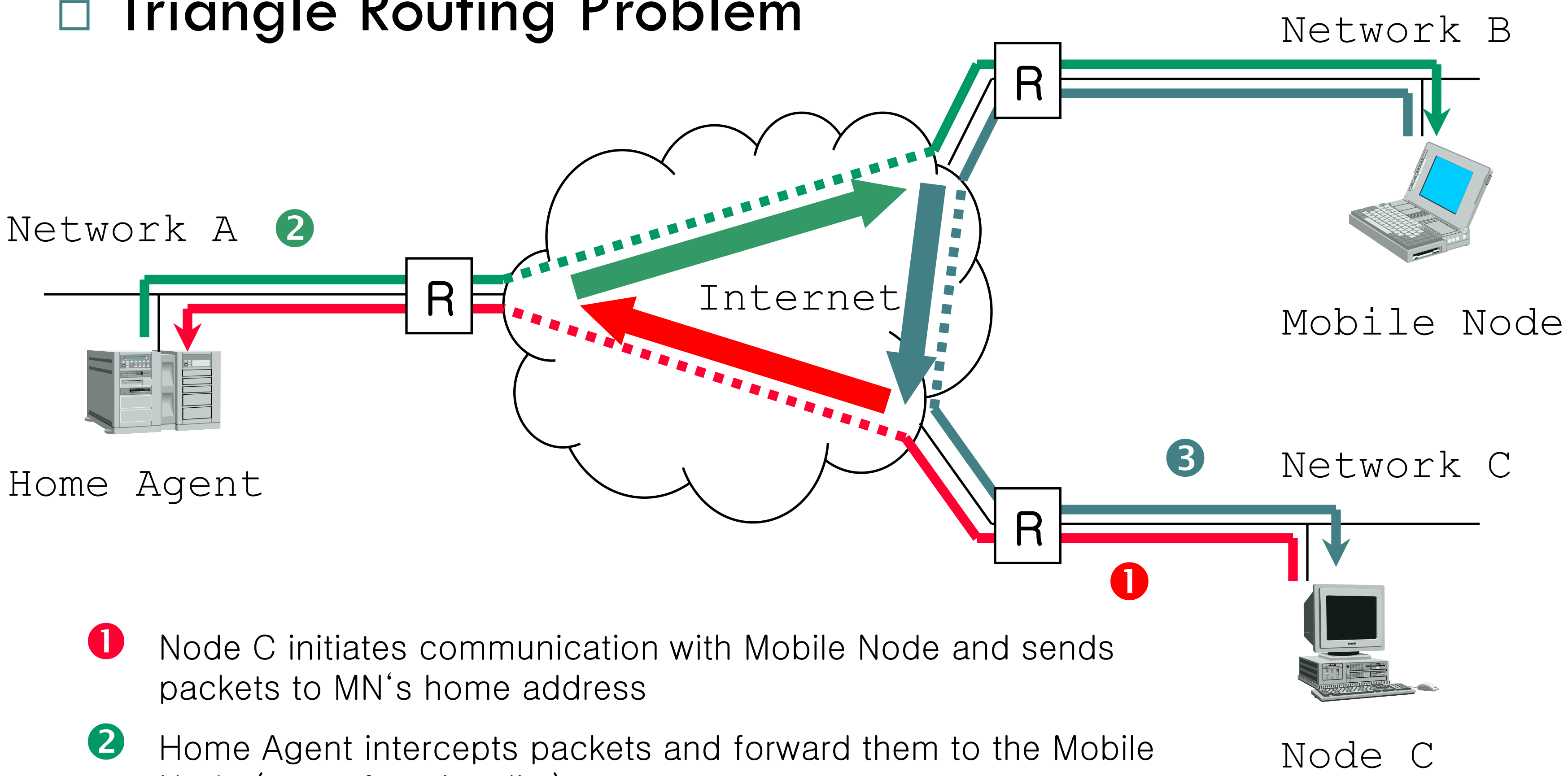
- Mobile Node registers at its Home Agent



1. Mobile Node sends Binding Update
2. Home Agent replies with Binding Acknowledgement

Mobile IP Operation

- Triangle Routing Problem



1. Node C initiates communication with Mobile Node and sends packets to MN's home address
2. Home Agent intercepts packets and forward them to the Mobile Node (proxy functionality)
3. Mobile Node replies directly to Node C

Mobile IPv6

(Mobility Support in IPv6, RFC 3775)

IPv6

- Sufficient Address Space
- IPv6:128 bits, IPv4: 32bits
- Fixed IP Header + Extension Header
- faster processing by routers
- Address Auto-configuration
- Address Renumbering

Introduction to Mobile IPv6

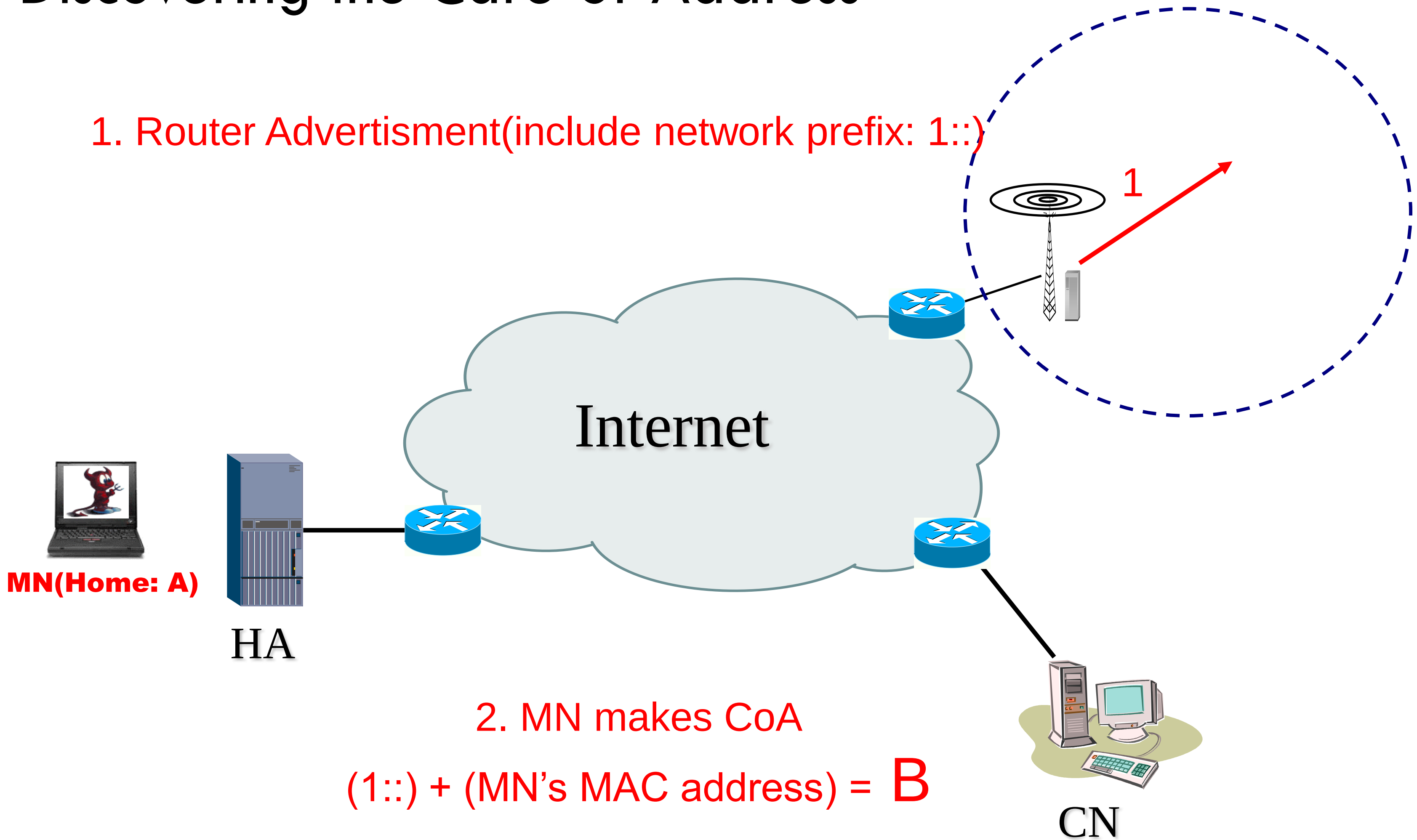
- C. Perkins et al., "Mobility Support in IPv6", RFC 3775, June 2004.
- Mobile IPv6 is intended to enable IPv6 nodes to move from one IP network to another
- Mobile Node can be contacted using it’s home address regardless of it’s current point of attachment to the internet

Mobile IPv6 Operation

- Mobile IPv6 operation can be divided in to 3 parts
  - Discovering the Care-of Address
  - Registering the Care-of Address
  - Tunneling to the Care-of Address

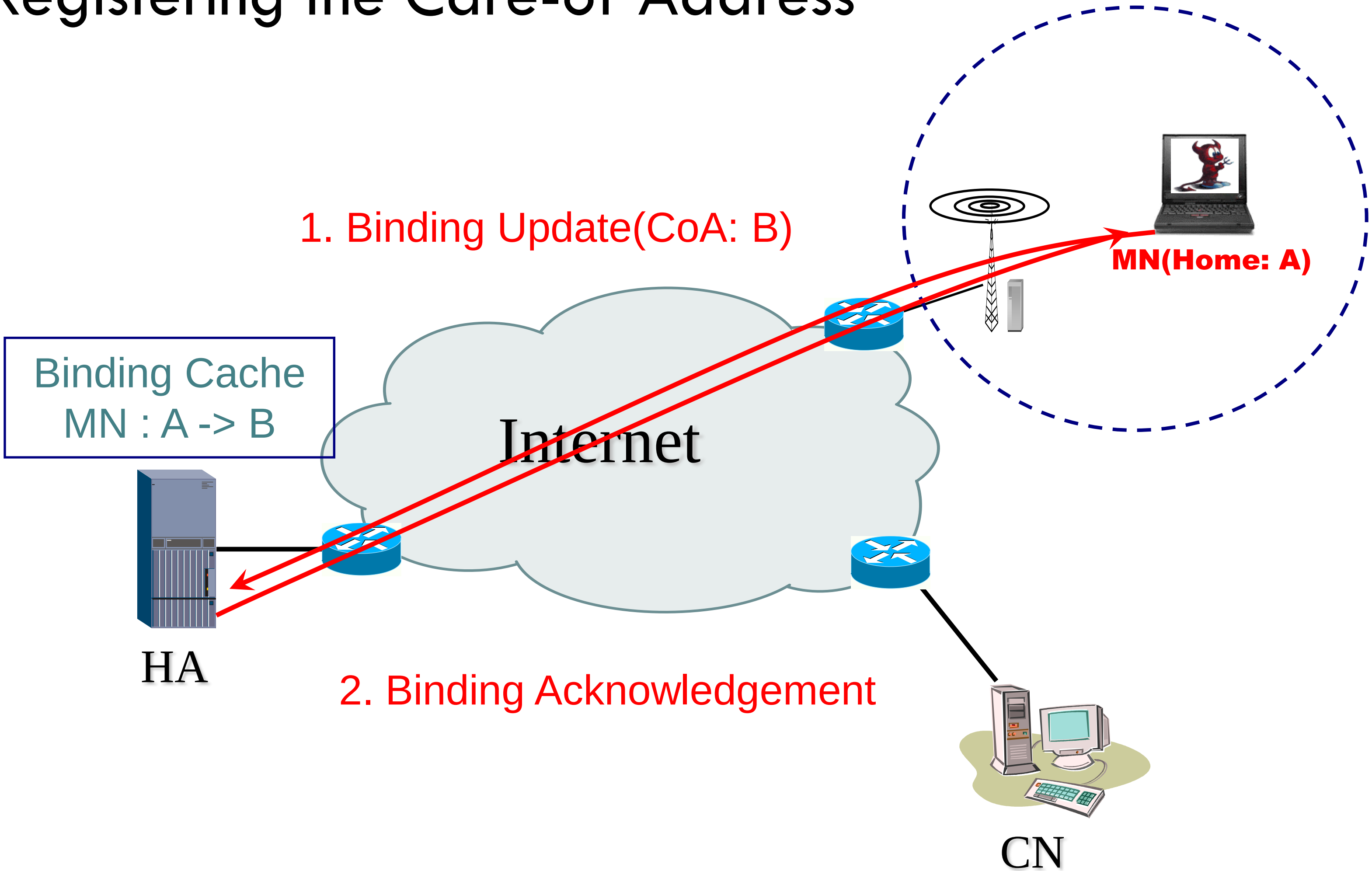
Mobile IPv6 Operation

- Discovering the Care-of Address



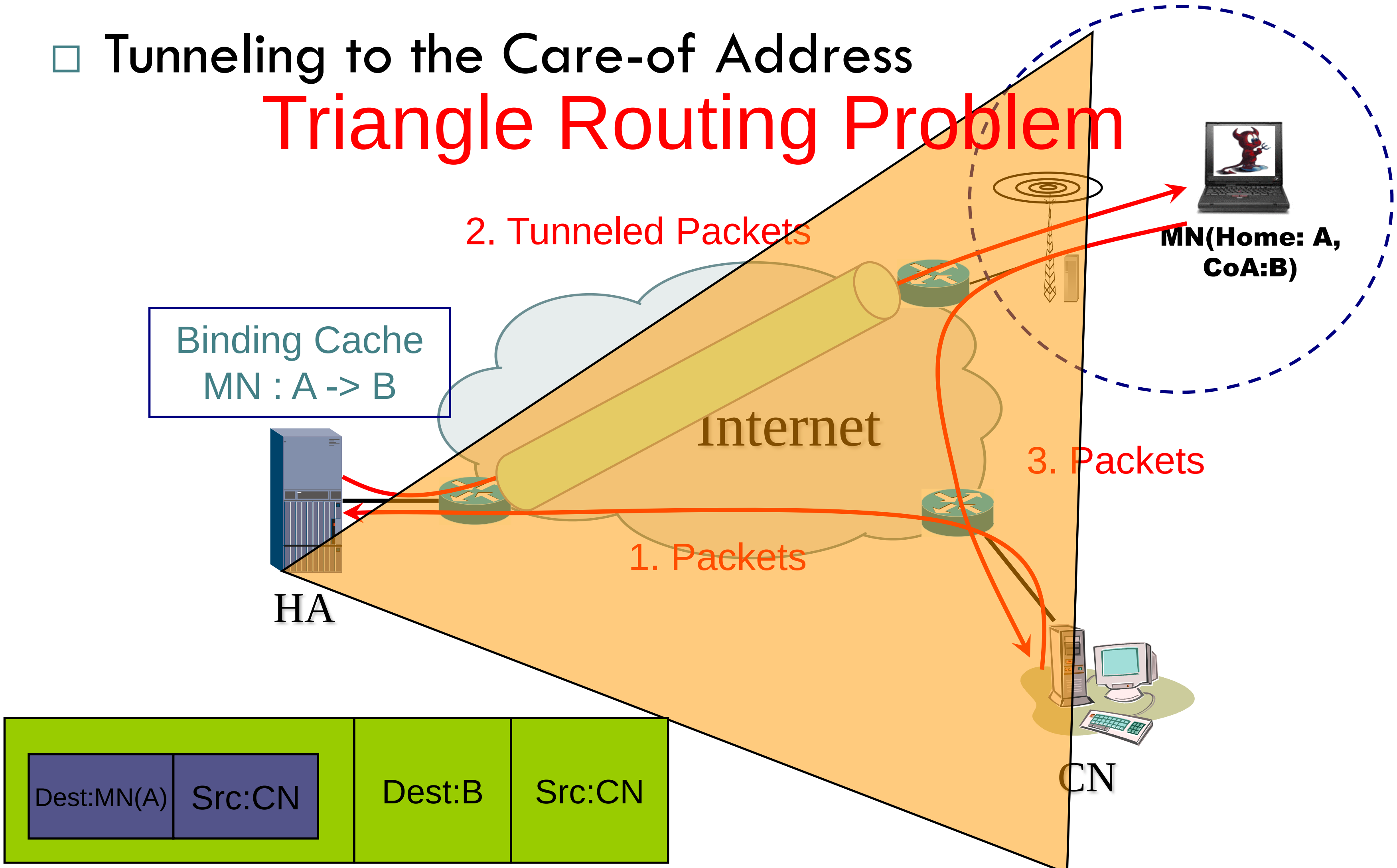
Mobile IPv6 Operation

- Registering the Care-of Address



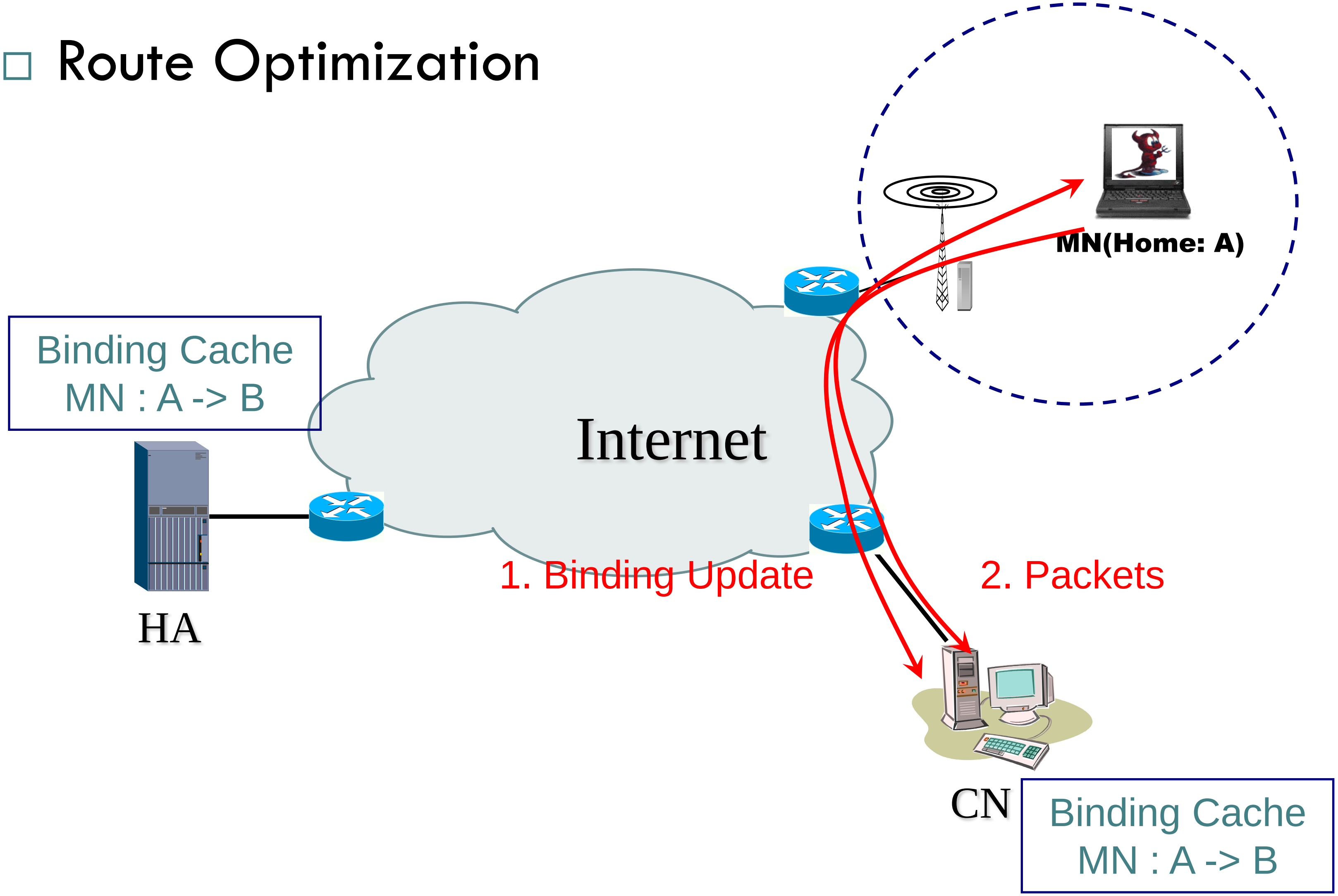
Mobile IPv6 Operation

- Tunneling to the Care-of Address



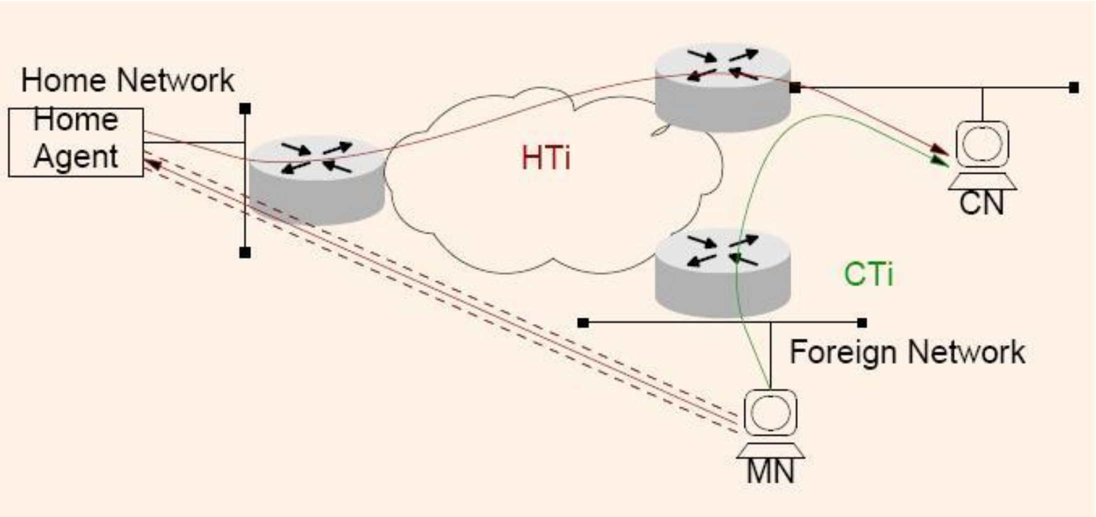
Mobile IPv6 Operation

- Route Optimization



Mobile IPv6 Operation

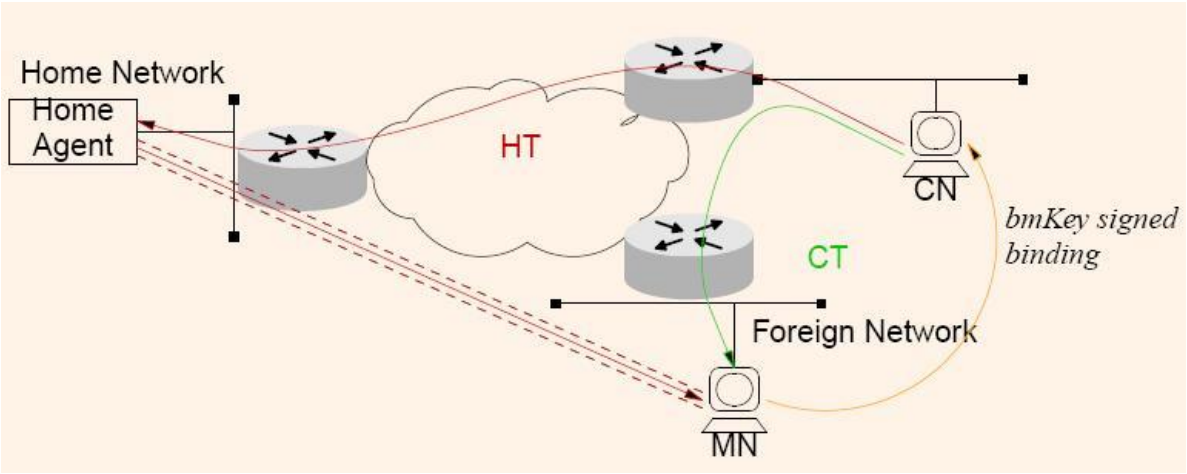
Return Routability Procedure (1)



- MN sends two messages with a cookie to CN
  - Home Test init(Hti) is send via HA
  - Care-of Test init(Cti) is send directly to CN
- CN uses pre-generated key and nonce to build two keygen tokens(Key: random number of 20 octests, Nonce: random octet string of any length)
  - Home keygentok := FIRST (64, HMAC_SHA1 (key, (HoA | nonce | "0")))
  - Care-of keygentok := FIRST (64, HMAC_SHA1 (key, (CoA | nonce | "1")))

Mobile IPv6 Operation

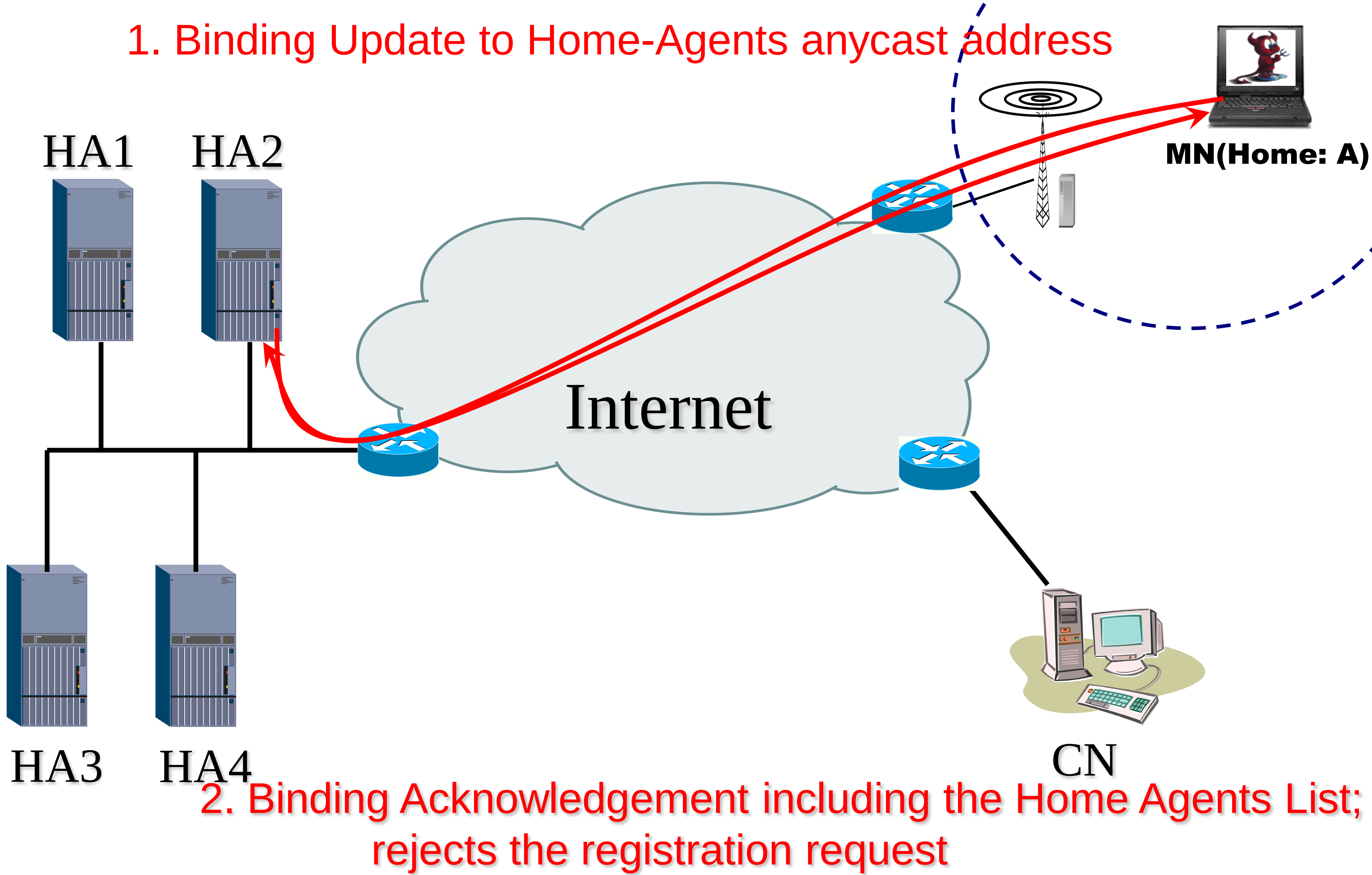
- Return Routability Procedure (2)



- CN sends keygen tokens and cookies back to MN
  - Home Test(HT) and Care-of Test(CT) messages
- MN builds binding message key
  - bmKey := SHA (home keygen token|care-of keygen token)
- MN sends binding update message signed with bmKey
- CN can proof that the MN is reachable via both paths

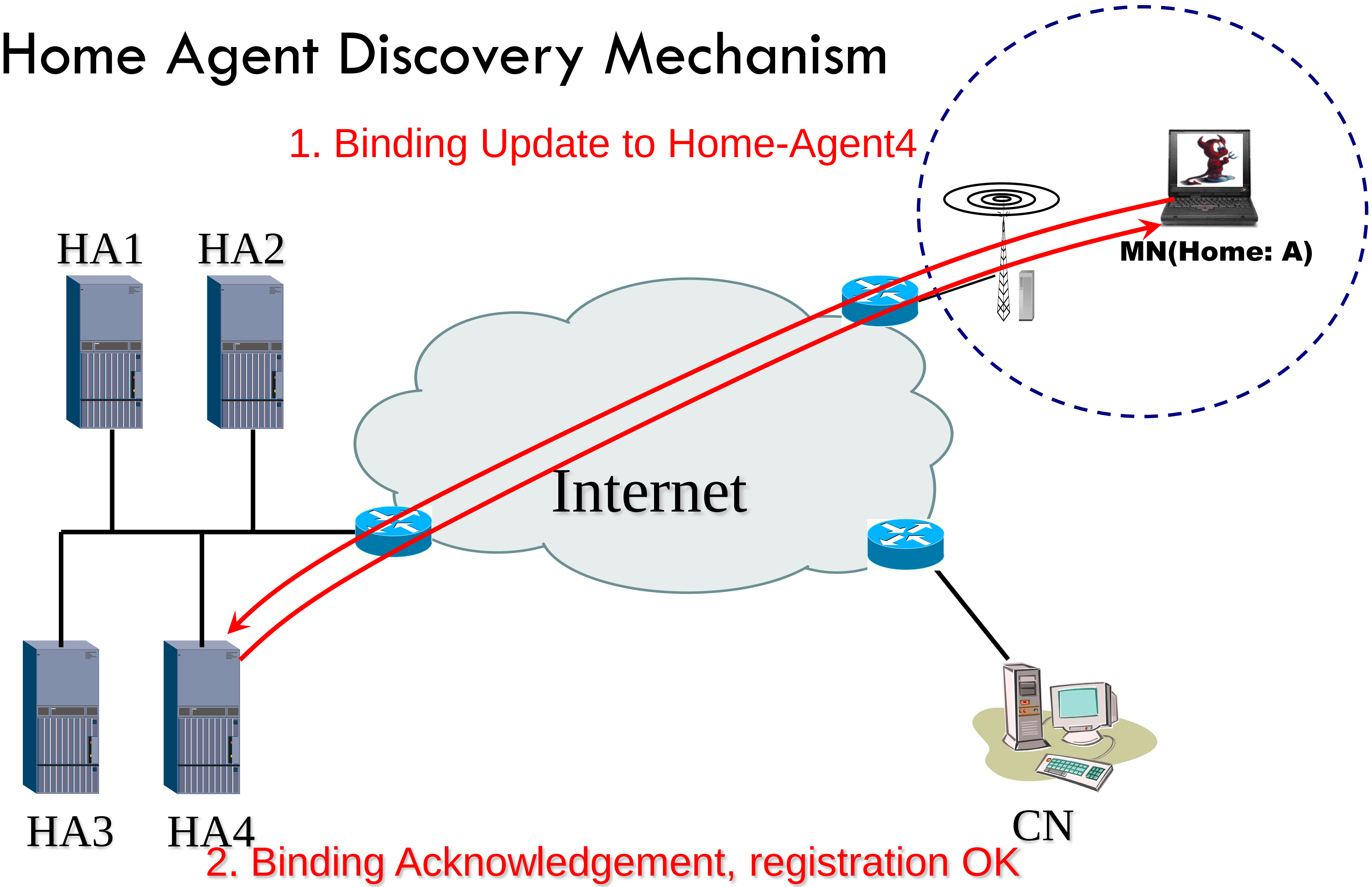
Mobile IPv6 Operation

- Home Agent Discovery Mechanism



Mobile IPv6 Operation

- Home Agent Discovery Mechanism



Mobile IPv6 Handover

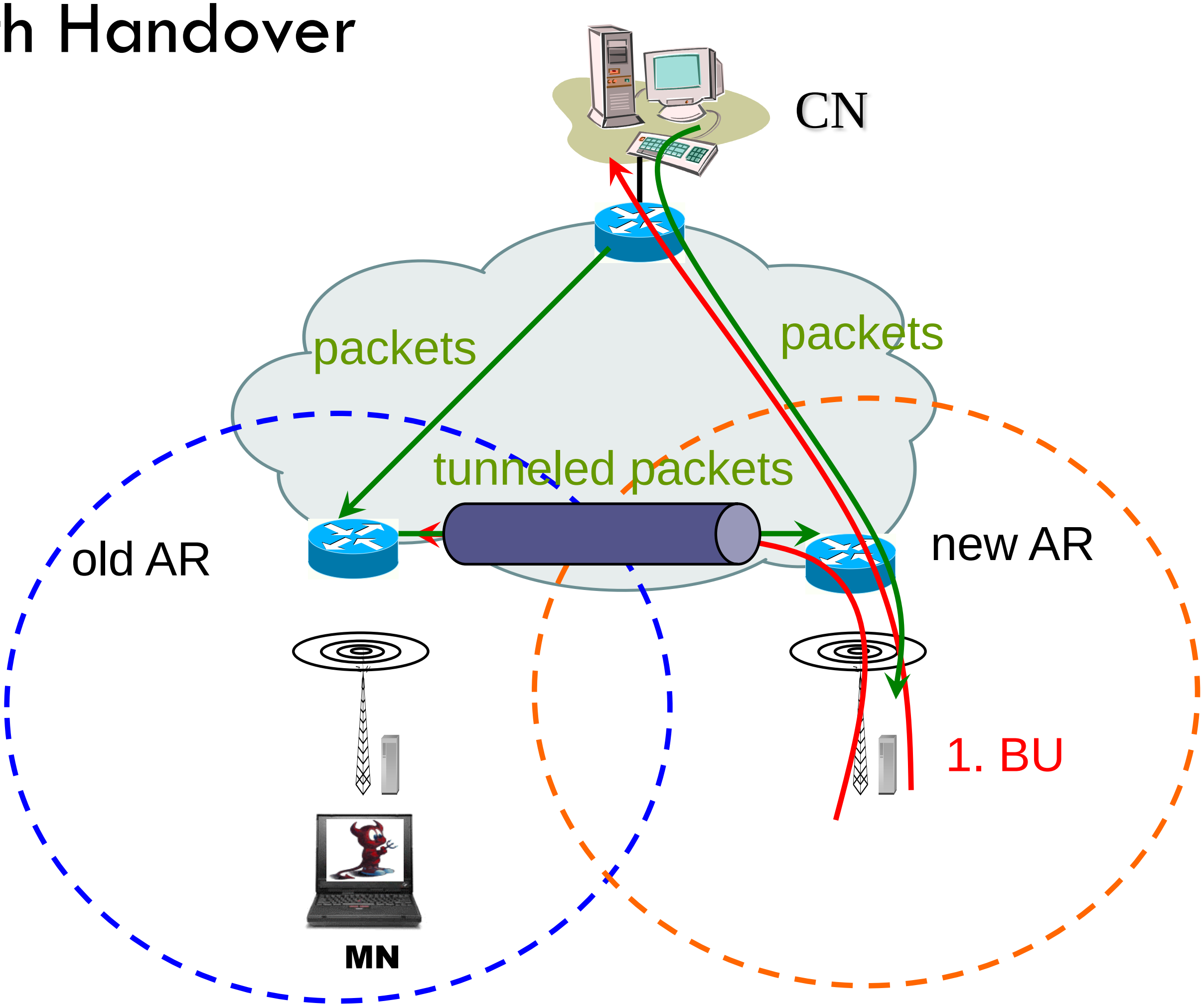
- What is a Handover?
  - Handover is the mechanism by which an ongoing connection between a Mobile Host and corresponding Access Point is transferred from Access Point to another
- When does handover occur?
  - Cell boundary crossing.
  - Weak Signal Reception.
  - Deteriorated QoS in the current cell.

Mobile IPv6 Handover

- Three kinds of handover operations
  - Smooth Handover
    - low loss
  - Fast Handover, Hierarchical Mobile IPv6
    - low delay
  - Seamless Handover
    - Both Hierarchical and Fast Handover

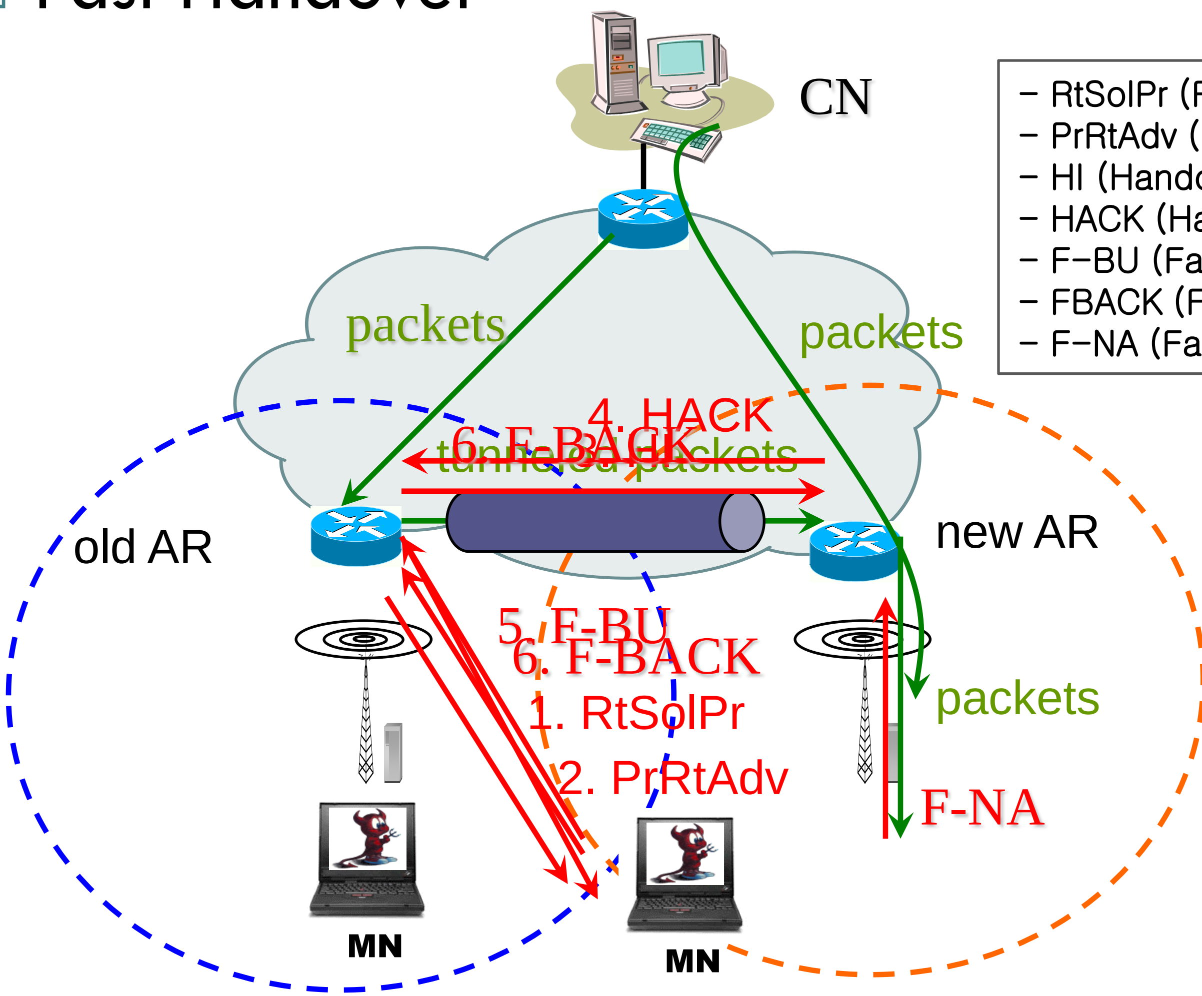
Mobile IPv6 Handover

- Smooth Handover



Mobile IPv6 Handover

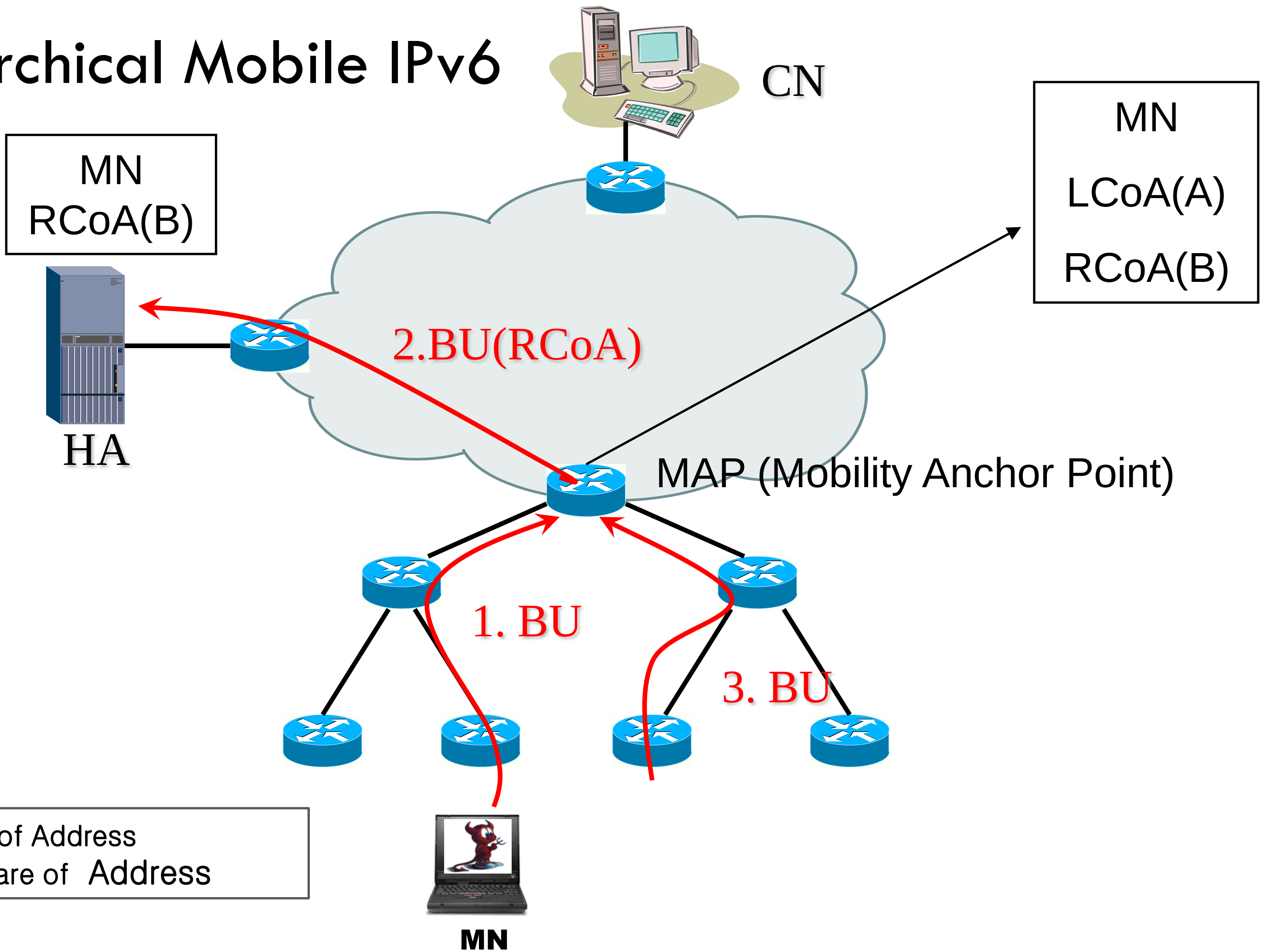
- Fast Handover



- RtSolPr (Router Solicitation for Proxy)
- PrRtAdv (Proxy Router Advertisement)
- HI (Handoff Initiate)
- HACK (Handoff Acknowledgment)
- F-BU (Fast Binding Update)
- FBACK (Fast Binding Acknowledgement)
- F-NA (Fast Neighbor Advertisement)

Mobile IPv6 Handover

- Hierarchical Mobile IPv6

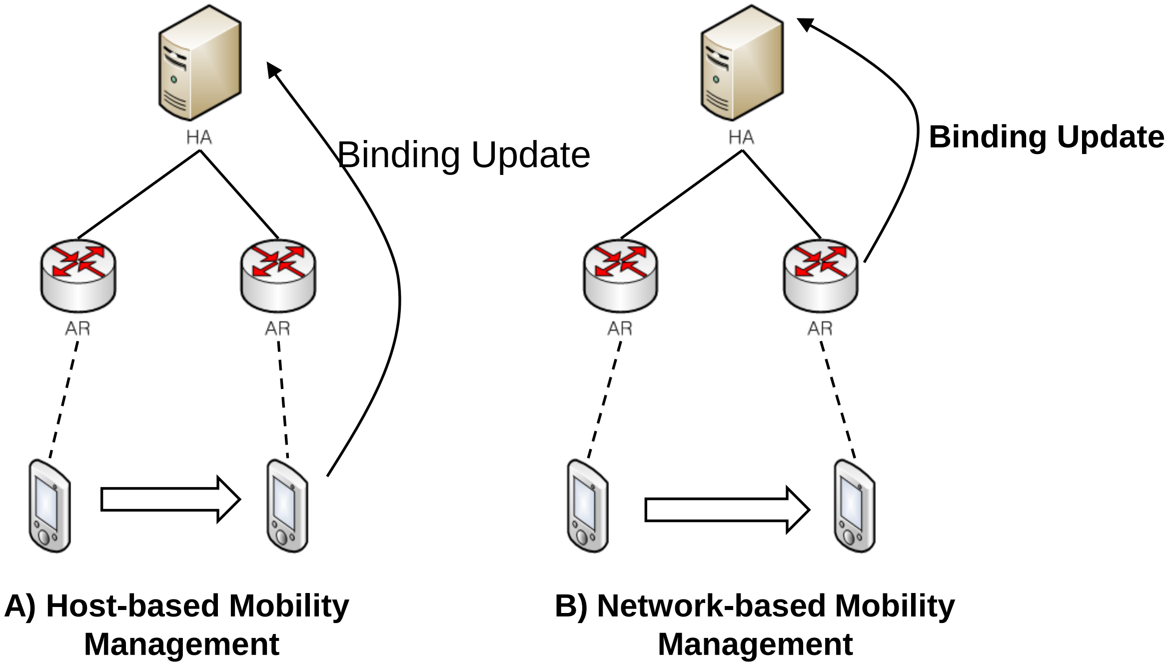


−LCoA: Local Care of Address
−RCoA: Regional Care of Address

Proxy Mobile IPV6 (PMIPv6)

Background

- Network-based Mobility
  - Mobility handled by the network, often transparent to the mobile node
  - Directly or indirectly triggered by the mobile node
- Host-based Mobility
  - Mobility handled by the mobile node
  - Full involvement of the mobile node

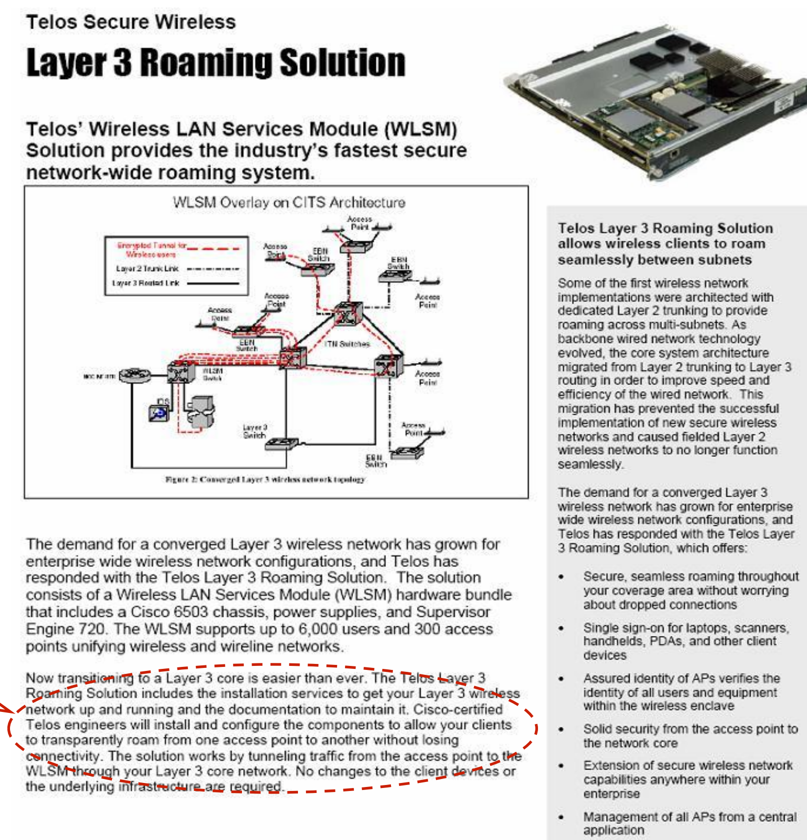


Background

- Host-based Mobile IPv4/v6 (RFC 3344/3775) has not been yet deployed that much.
  - Why host-based MIP is not deployed yet?
    - Too heavy specification to be implemented at a small terminal
      - RFC 3344 (MIPv4): 99 pages
      - RFC 3775 (MIPv6): 165 pages
    - Battery problem
    - Waste of air resource
  - No Stable MIPv4/v6 stack executed in Microsoft Windows OS
- 3GPP, 3GPP2 and WiMAX operators are now showing their STRONG interests for network-based IP mobility solution
  - They are even now deploying their non-standardized network-based IP mobility solution (not Mobile IPv4/v6!).

Background

- WLAN switch device starts to provide link specific and proprietary solution for IP handover.
  - No change in MN protocol stack required!



Telos Secure Wireless

Layer 3 Roaming Solution

Telos' Wireless LAN Services Module (WLSM) Solution provides the industry's fastest secure network-wide roaming system.

WLSM Overlay on CITS Architecture

Figure 2: Converged Layer 3 wireless network topology

The demand for a converged Layer 3 wireless network has grown for enterprise wide wireless network configurations, and Telos has responded with the Telos Layer 3 Roaming Solution. The solution consists of a Wireless LAN Services Module (WLSM) hardware bundle that includes a Cisco 6503 chassis, power supplies, and Supervisor Engine 720. The WLSM supports up to 6,000 users and 300 access points unifying wireless and wireline networks.

Now transitioning to a Layer 3 core is easier than ever. The Telos Layer 3 Roaming Solution includes the installation services to get your Layer 3 wireless network up and running and the documentation to maintain it. Cisco-certified Telos engineers will install and configure the components to allow your clients to transparently roam from one access point to another without losing connectivity. The solution works by tunneling traffic from the access point to the WLSM through your Layer 3 core network. No changes to the client devices or the underlying infrastructure are required.

Telos Layer 3 Roaming Solution allows wireless clients to roam seamlessly between subnets

Some of the first wireless network implementations were architected with dedicated Layer 2 trunking to provide roaming across multi-subnets. As backbone wired network technology evolved, the core system architecture migrated from Layer 2 trunking to Layer 3 routing in order to improve speed and efficiency of the wired network. This migration has prevented the successful implementation of new secure wireless networks and caused fielded Layer 2 wireless networks to no longer function seamlessly.

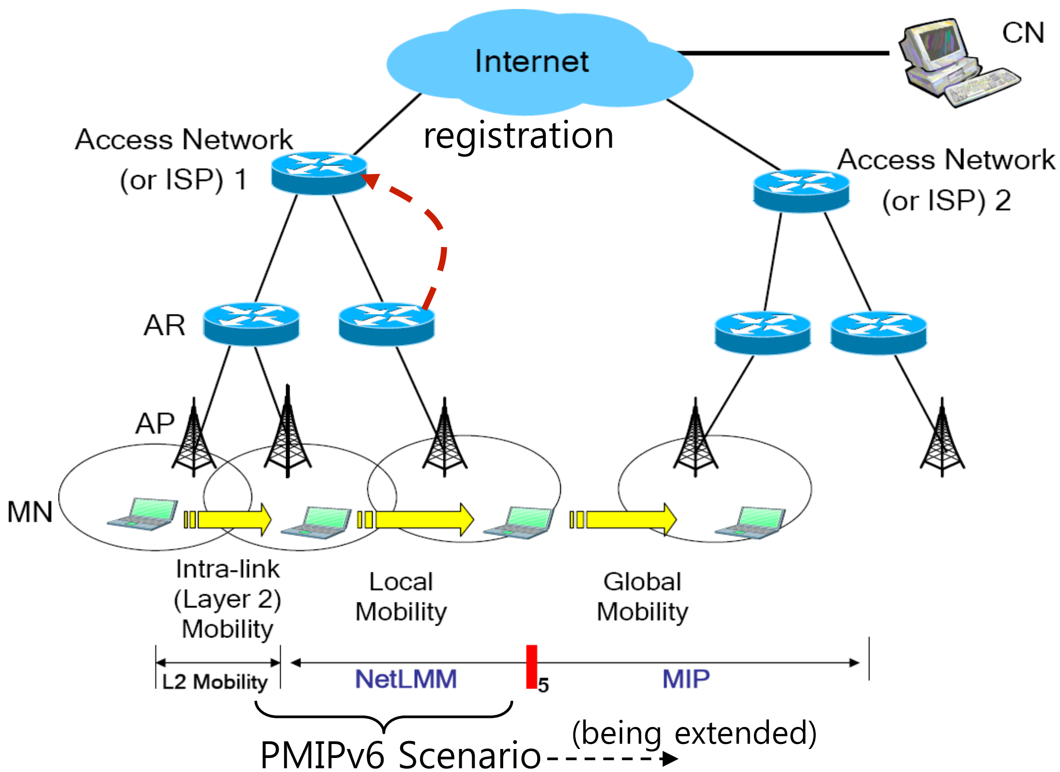
The demand for a converged Layer 3 wireless network has grown for enterprise wide wireless network configurations, and Telos has responded with the Telos Layer 3 Roaming Solution, which offers:

- Secure, seamless roaming throughout your coverage area without worrying about dropped connections
- Single sign-on for laptops, scanners, handhelds, PDAs, and other client devices
- Assured identity of APs verifies the identity of all users and equipment within the wireless enclave
- Solid security from the access point to the network core
- Extension of secure wireless network capabilities anywhere within your enterprise
- Management of all APs from a central application

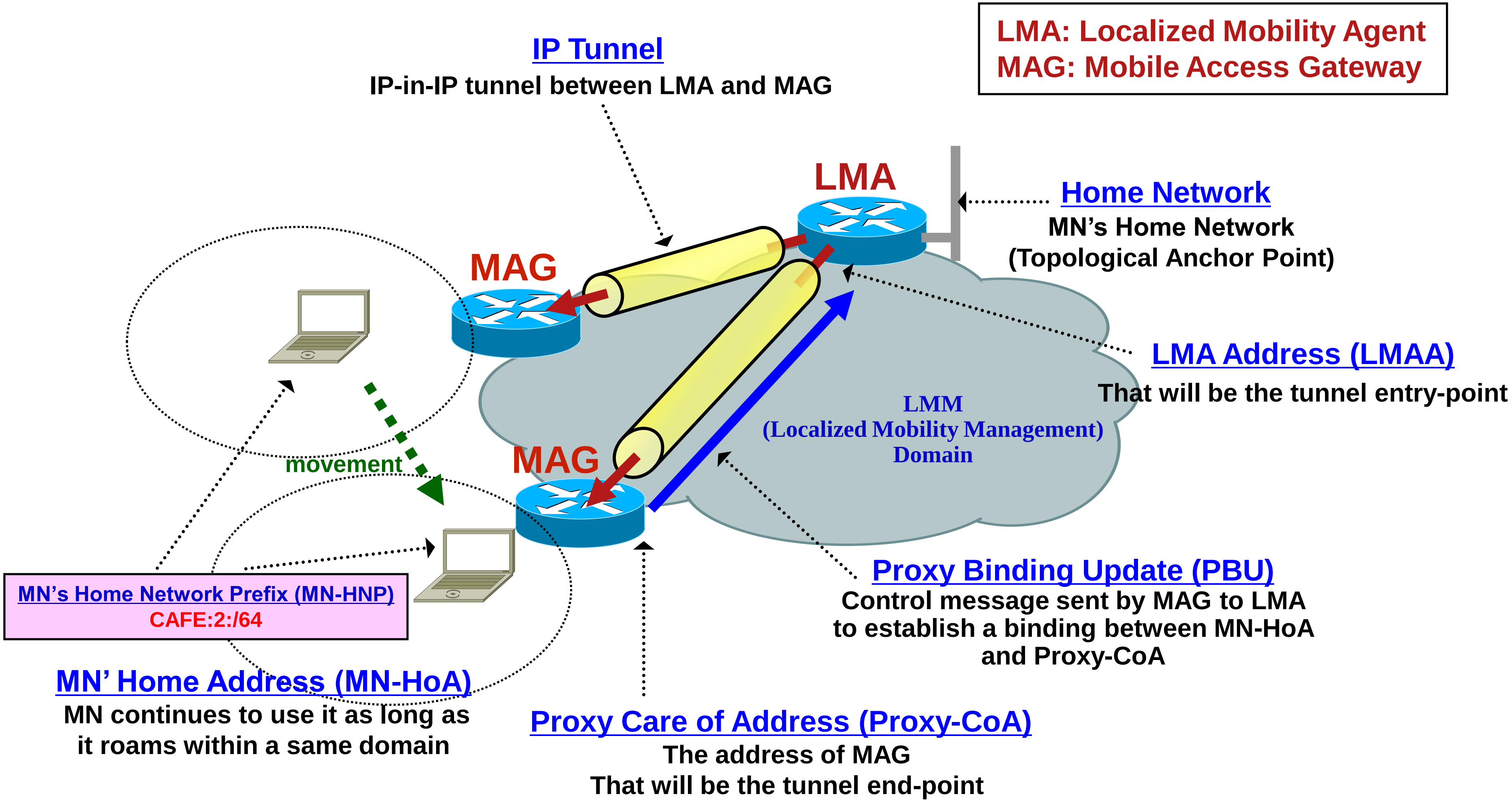
The solution works by tunneling traffic from the access point to the WLSM through your Layer 3 core network. No changes to the client devices or the underlying infrastructure are required

Goal of PMIPv6

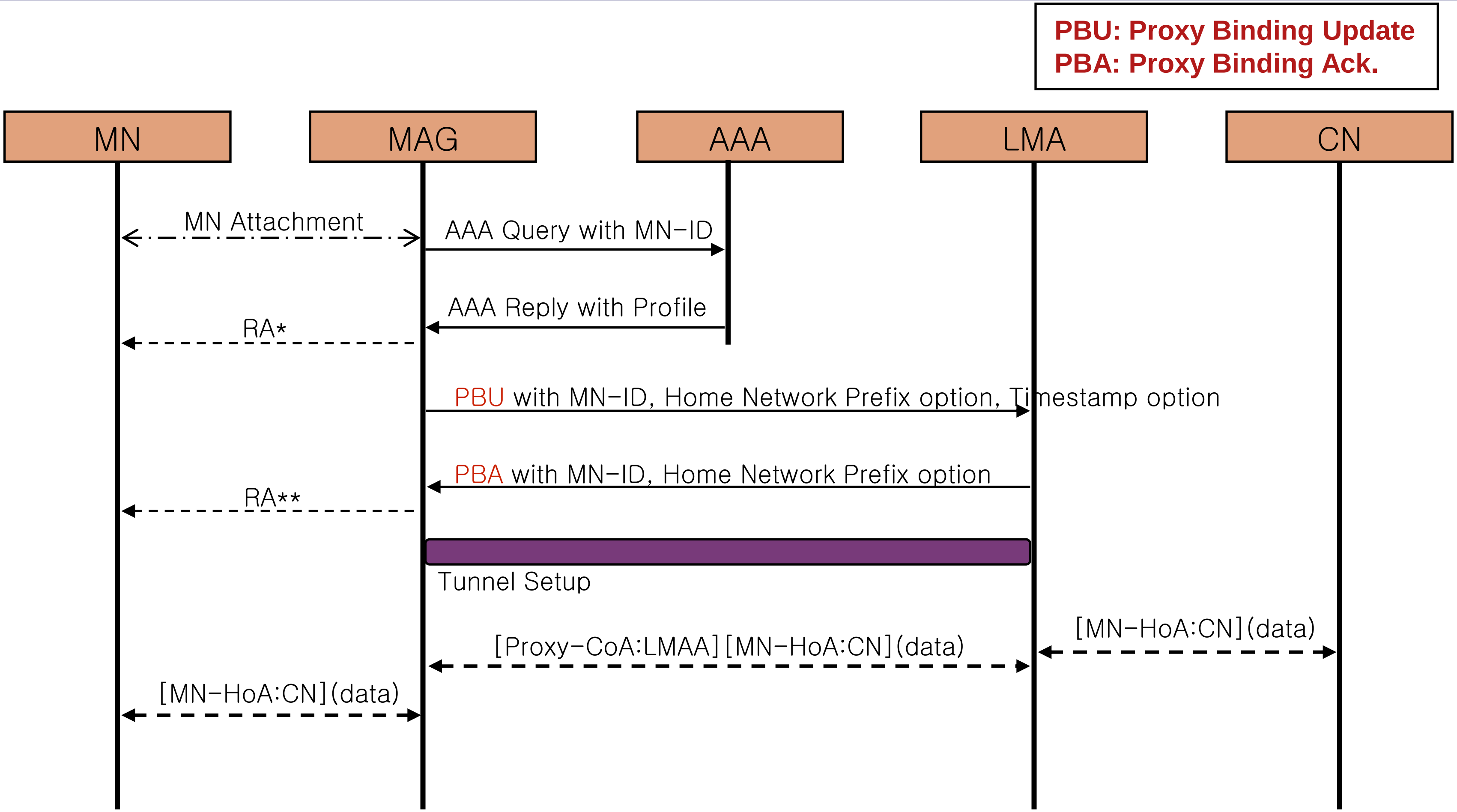
- Goal
  - This protocol is for providing mobility support to any IPv6 host within a restricted and topologically localized portion of the network and without requiring the host to participate in any mobility related signaling.



PMIPv6 Overview



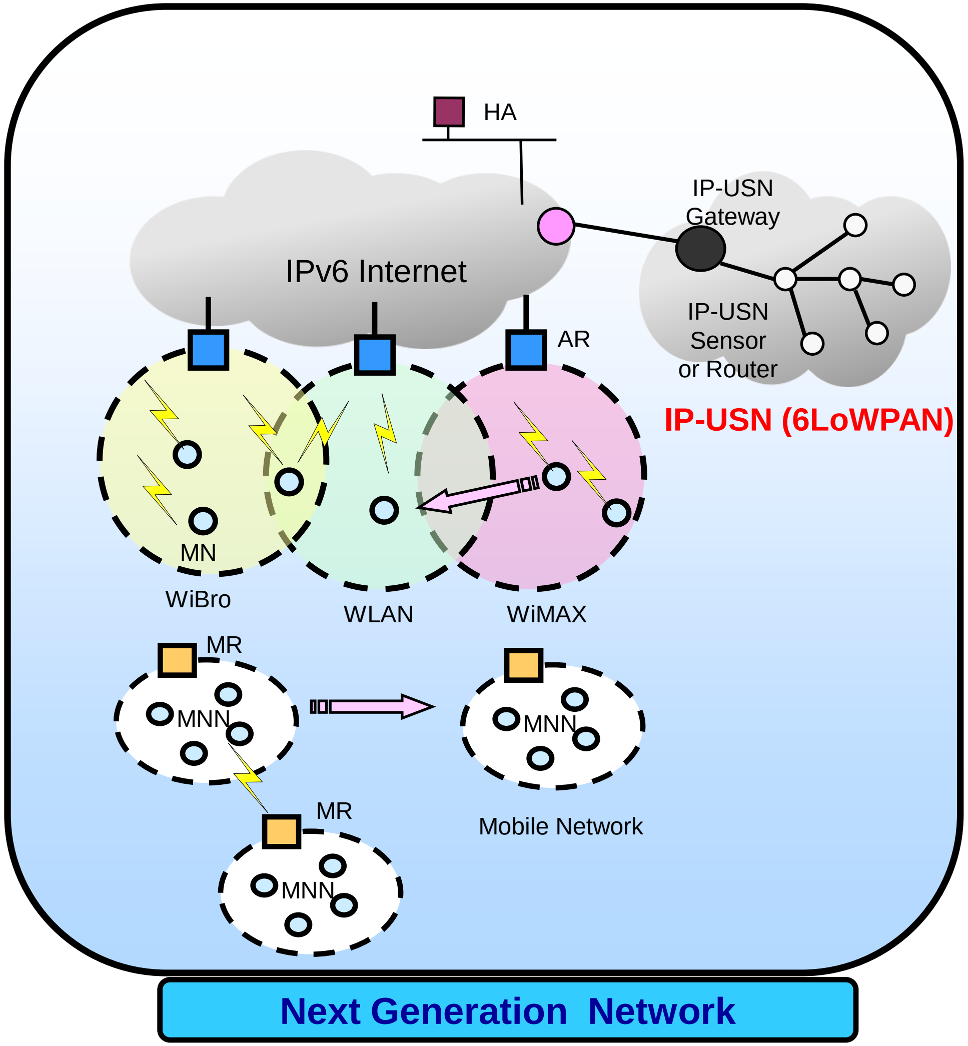
PMIPv6 Operation Flow



RA*: Router Advertisement in case of receiving MN's Home Prefix from AAA
RA**: Router Advertisement in case of receiving MN's Home Prefix from LMA

Future Mobile Network

Overview

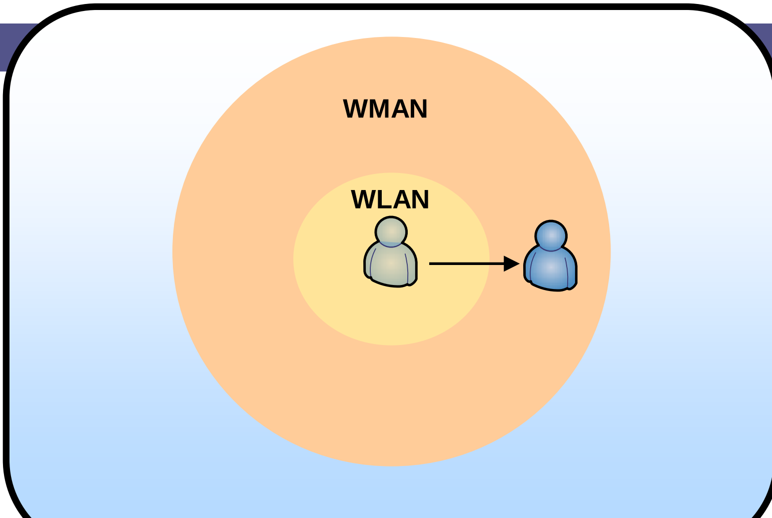


- **Mobile Network in NGN**
  - **NGN Capabilities**
    - **Basic IP Routing support**
    - **Mobility Support**
      - **Host Mobility**
      - **Network Mobility**
    - **Location management**
    - **Session control**
    - **Resource and QoS management**
    - **Security support**
  - **Network Environments**
    - **Various wireless access technologies**
      - **WiBro, WLAN, WiMAX, HSDPA…**
  - **User requirements**
    - **Seamless handover**
    - **Heterogeneous Network Interworking**
    - **Multi-Homing**
    - **User preference**

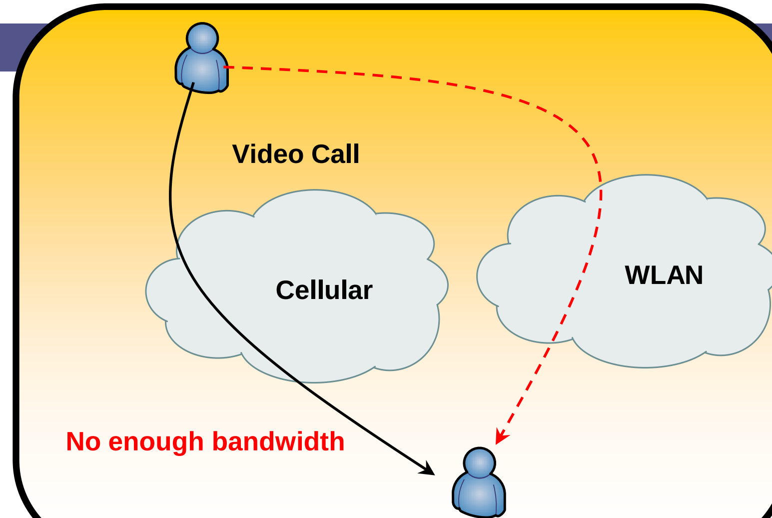
Future Mobile Network Goals

- Ubiquitous access
  - connection should be provided continually even though wireless access technologies are different with home domain
- Redundancy
  - connectivity is guaranteed as long as at least one connection to the Internet
- Load Sharing
  - traffics which are incoming and outgoing packets are transferred through more than one link
  - more efficient and possibly faster communication
- User Preference
  - choose the preferred transmission technology or access network based on cost, efficiency, policies, bandwidth requirement, delay and so on

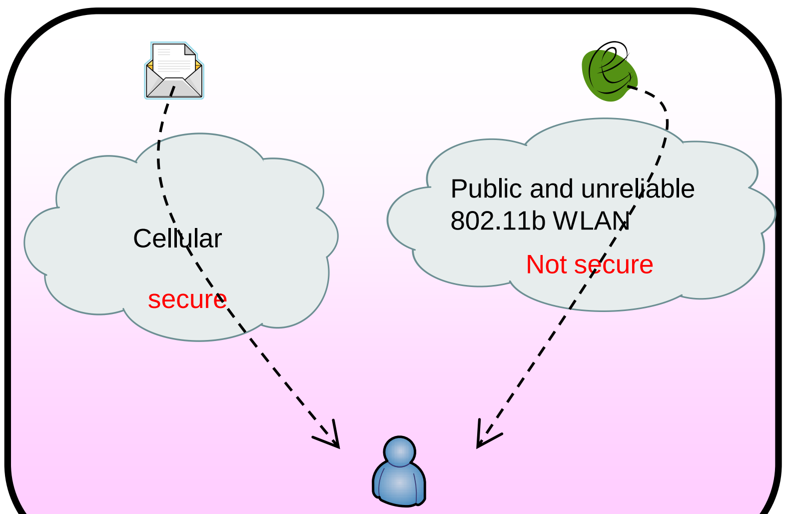
Future Mobile Network Scenarios



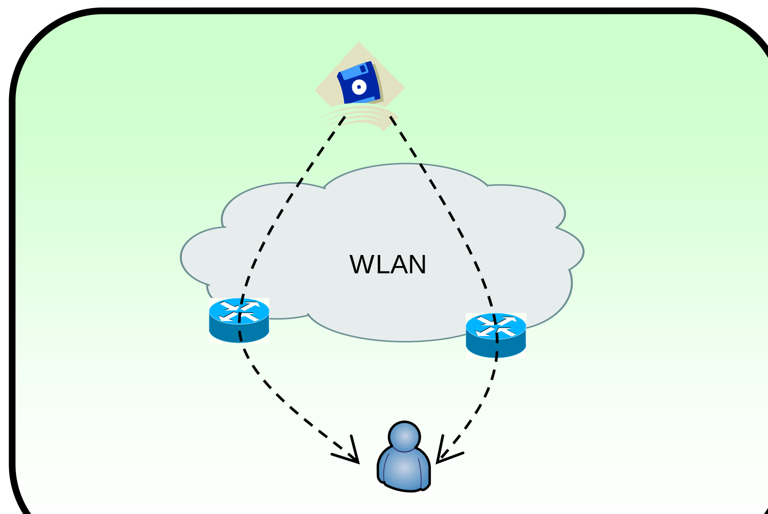
Seamless Handover



Heterogeneous Network Interworking



User Preference



Accelerate Transmission

Key Technologies

- To achieve Future Mobile Network goals, there are two key technologies
  - **MIH** (Media Independent Handoff)
    - Provide heterogeneous handover (vertical handover)
      - Across different networks
  - **SHIM6** (Site Multi-Homing by IPv6 Intermediation)
    - Provide multiple connection
    - Support ubiquitous access, redundancy, load sharing and user preference
    - No mobility function

IEEE 802.21
Media Independent Handoff

What is 802.21?

- IEEE 802.21 is being developed to facilitate smooth interaction and media independent handover between 802 technologies and other access technologies
- IEEE 802.21 offers an open interface that:
  - provides link state event reporting in real time (Event Service)
  - provides intersystem information, automatically and on demand (Information Service)
  - allows a user to control handover relevant link state (Command Service)

Why are we here?

- Work actively within relevant standard bodies in order to introduce applicable IEEE 802.21 requirements (E.g., where does IEEE 802.21 fit?)
- Update relevant 3GPP2 groups with latest development in IEEE 802.21 standards
- Request your feed back and support in the determination of the optimal placement of IEEE 802.21 Functions
- Enthuse the 3GPP2 community about the development of requirement on IEEE 802.21 technology

Definitions

- Media Independent Handover Function (MIHF):
  - MIH is a cross-layer entity that provides mobility support through well defined Service Access Points offering Event, Information and Command services
- MIH User:
  - A local entity that avails of MIHF services through the MIH Service Access Points
- MIH Network Entity:
  - A remote entity that is able to communicate with an MIHF over a transport that supports Media Independent Services

802.21 Overview

- IEEE 802.21 standard consists of:
  - An architecture that enables transparent service continuity while a mobile node (MN) switches between heterogeneous link-layer technologies
  - A set of handover-enabling functions within the mobility-management protocol stacks of the network elements and the creation therein of a new entity called the MIH Function (MIHF)
  - The definition of Media Independent Service Access Point (MIH_SAP) and associated primitives are defined to provide MIH users with access to the services of the MIHF
  - The definition of new Link Layer SAPs and associated primitives for each specific access technology

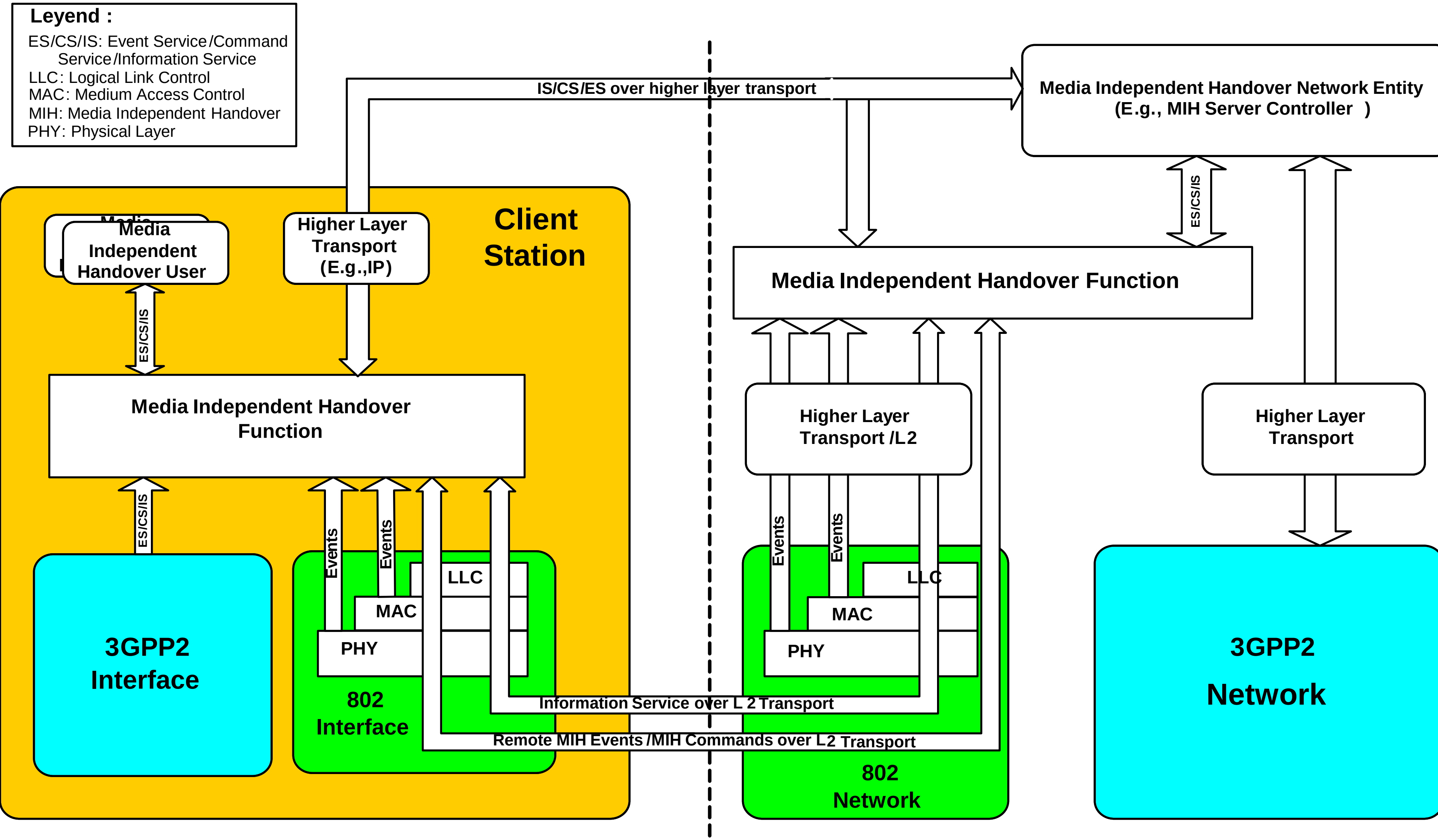
802.21 Overview (cont`d)

- The MIH Function provides three services:
  - **Event Service** detects events and delivers triggers from both local as well as remote interfaces
    - E.g. Link_available, Link_up, Link_down, etc.
  - **Command Service** provides a set of commands for the MIH users to control handover relevant link states
    - E.g. MIH_Link_Switch, MIH_Configure_Link, MIH_Handover_Initiate, etc.
  - **Information Service** provides the information model and an information repository to make more effective handover decisions. The mobile terminal obtains information from the repository using its current network points of attachment
    - E.g. list of available networks, network operator, IP version, neighbor information, etc.

Design Assumptions

- DOs:
  - Cross-layer entity interaction with multiple layers
  - Facilitate handover determination through a technology-independent unified interface to MIH users
  - Facilitate both station initiated and network initiated handover determination
- DON'Ts:
  - Does not modify existing handover principles
  - Does not mandate handover determination based on IEEE 802.21 events

Overall 802.21 Model

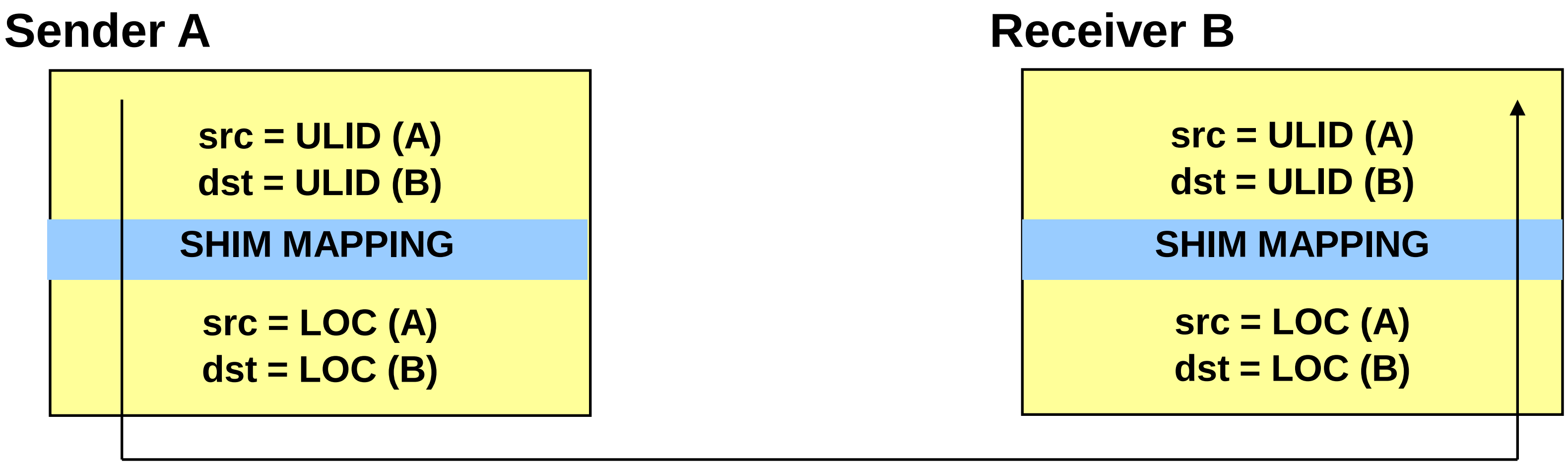


Site Multi-Homing by IPv6 Intermediation (SHIM6)

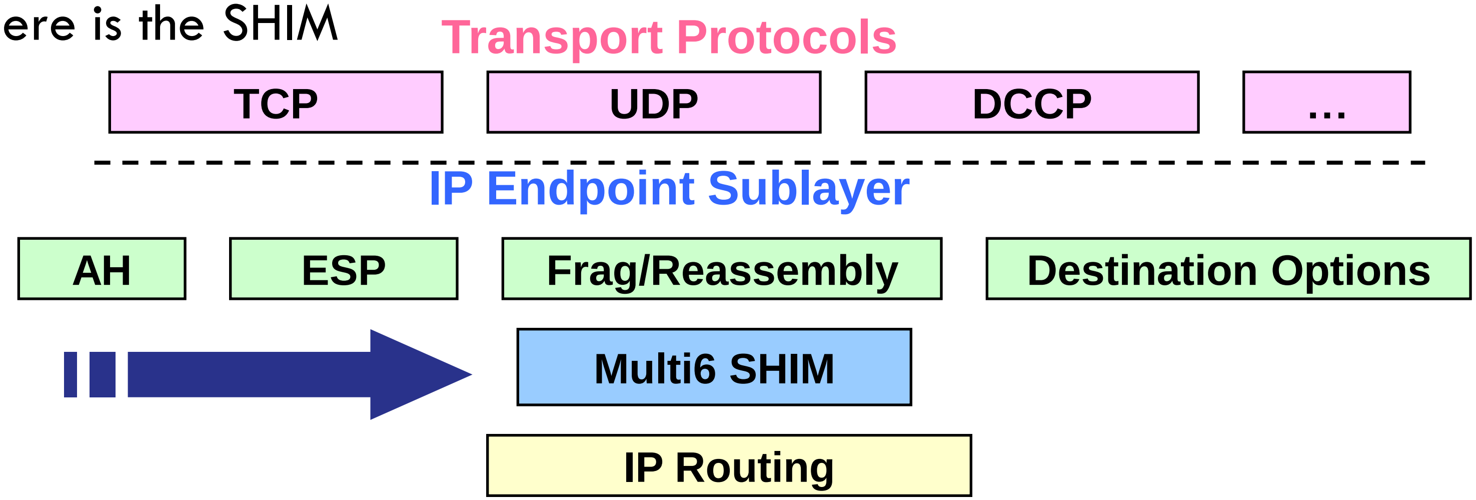
- Developed by SHIM6 WG in IETF
- Host based approach
- Features
  - ID and Locator separation
    - It is performed within host's own protocol stack
  - No new name space for Identifier
    - Support backward compatibility
  - Mapping ID and Locator and associated state information is maintained at the IP level (L3SHIM)
  - Dynamically negotiated capability
  - Support Reachability Protocol (REAP)

Layering

- ID/LOC split – Basic Approach

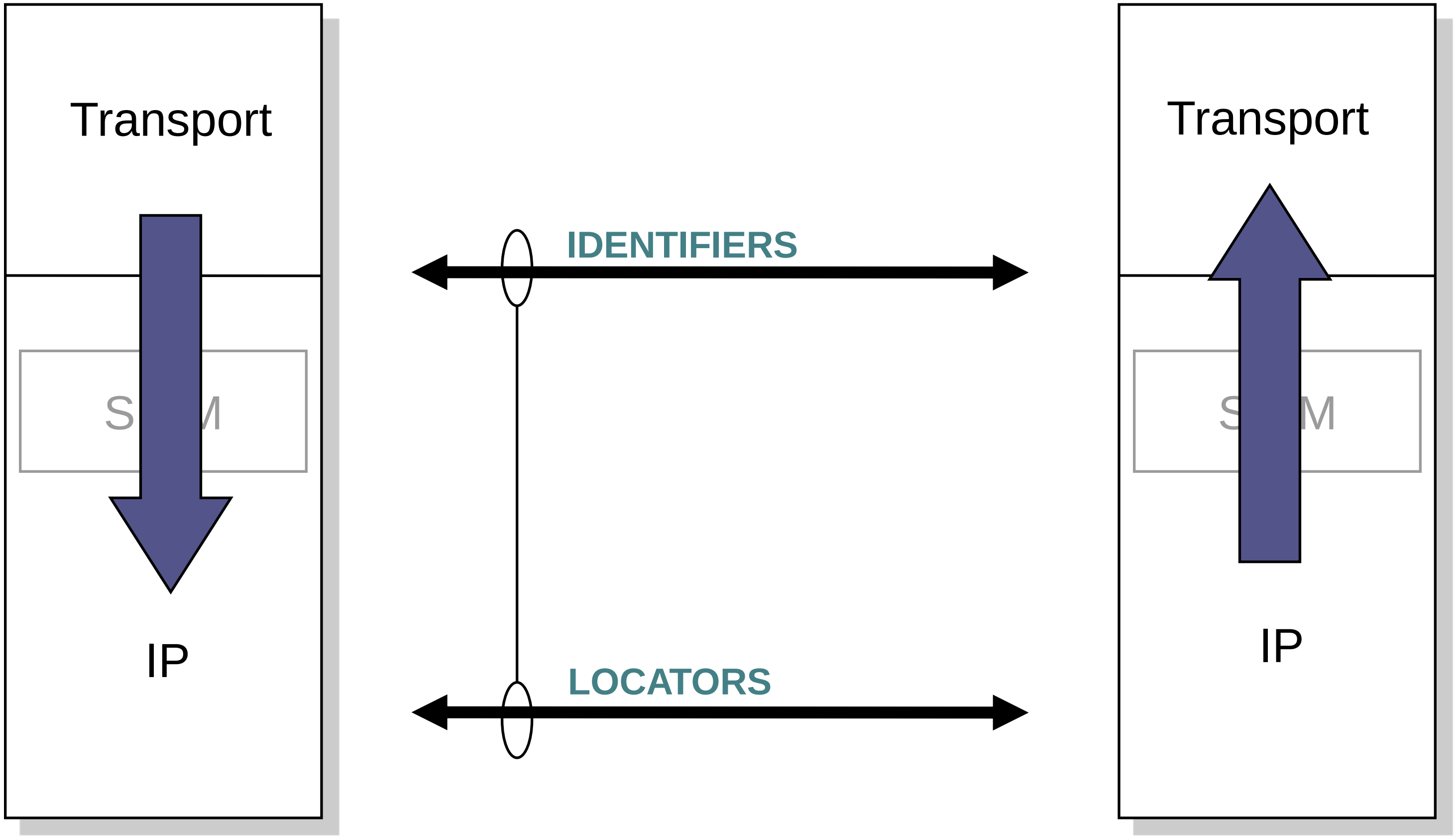


- Where is the SHIM



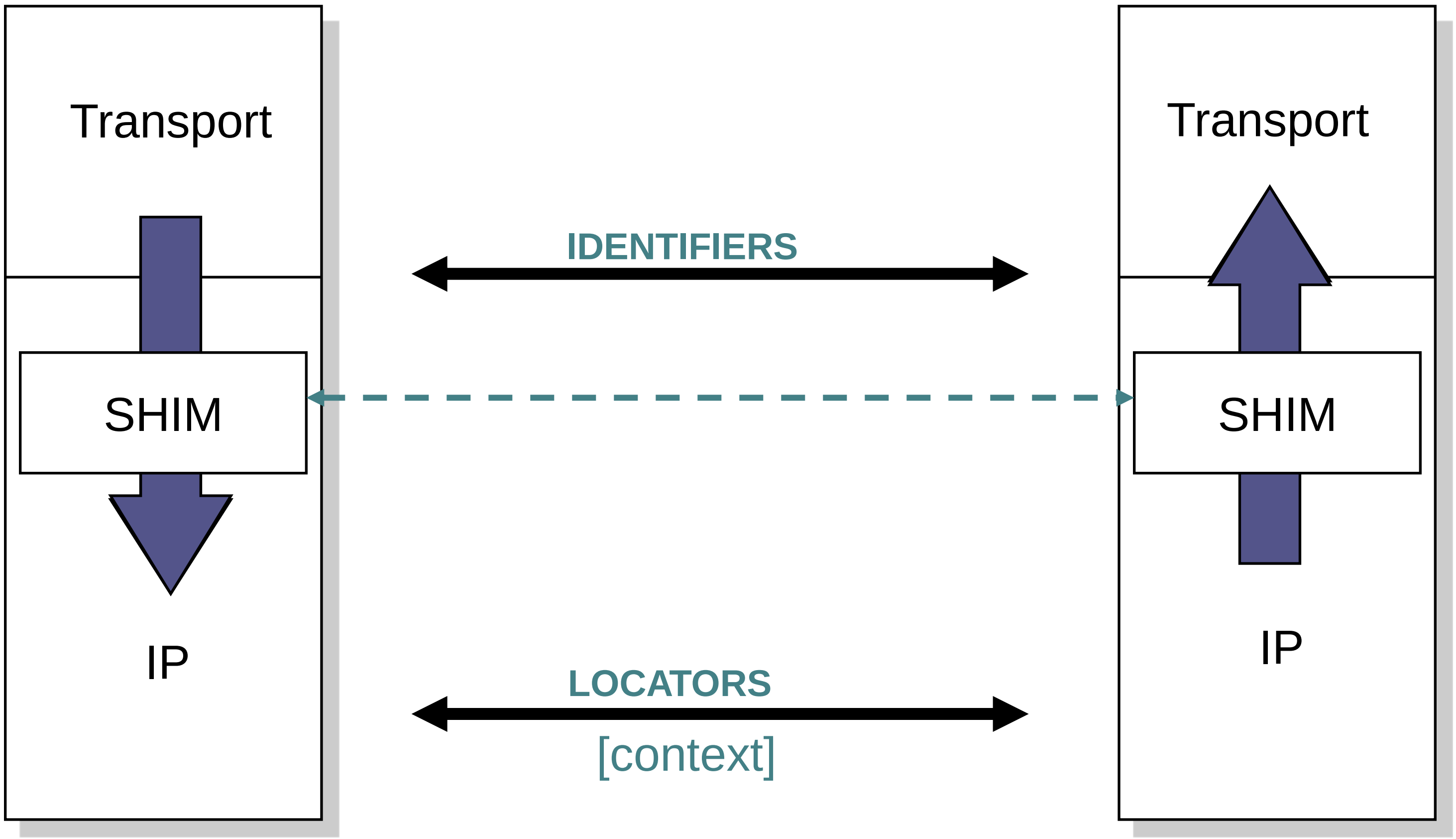
Initial Contact

No SHIM state active
Locator Selection using RFC3484
Locators and Identifiers are Equivalent



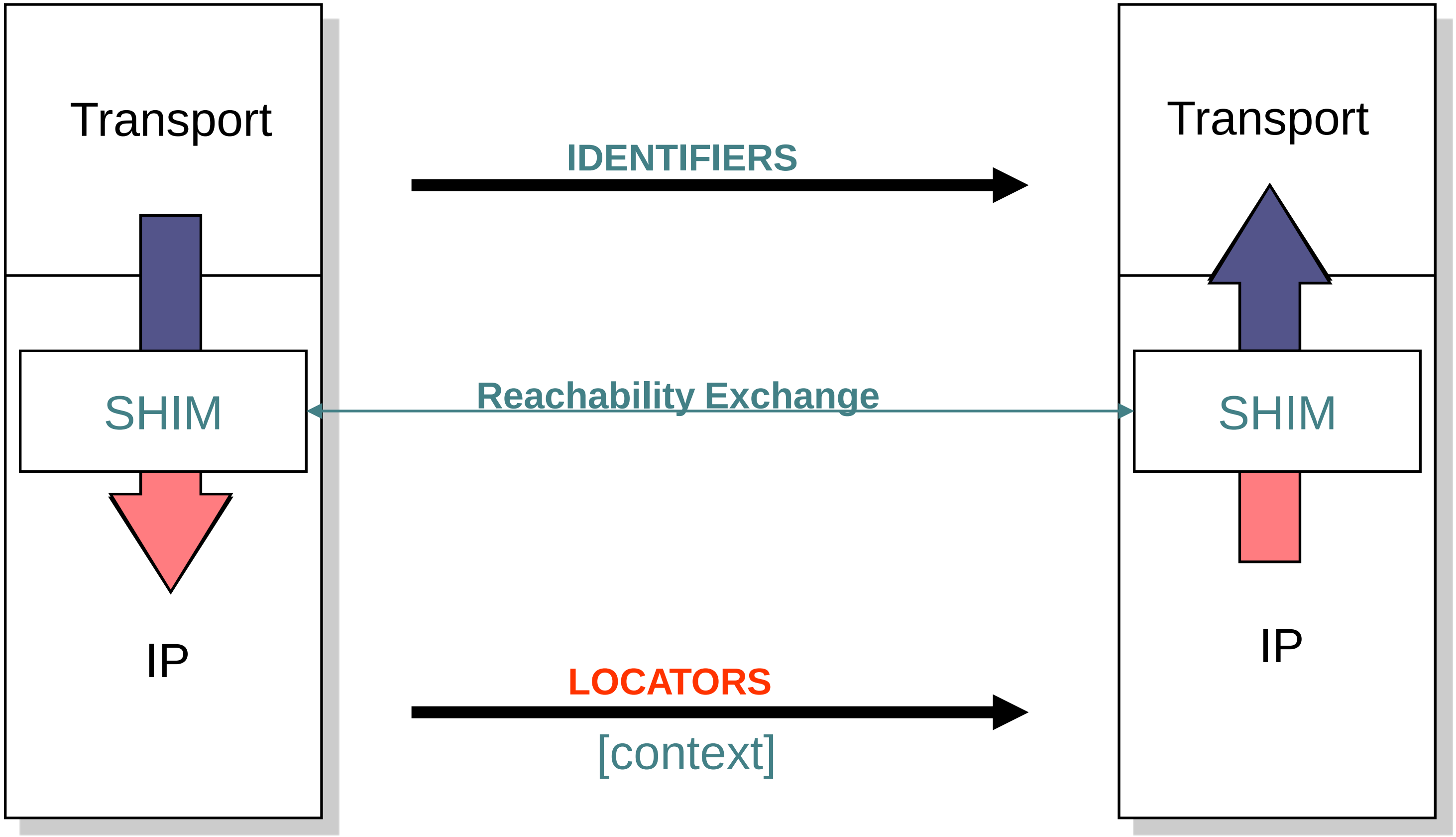
SHIM6 Activation

SHIM active
Current Locator Sets exchanged
Locators and Identifiers are Equivalent



SHIM6 Locator Failure and Recovery

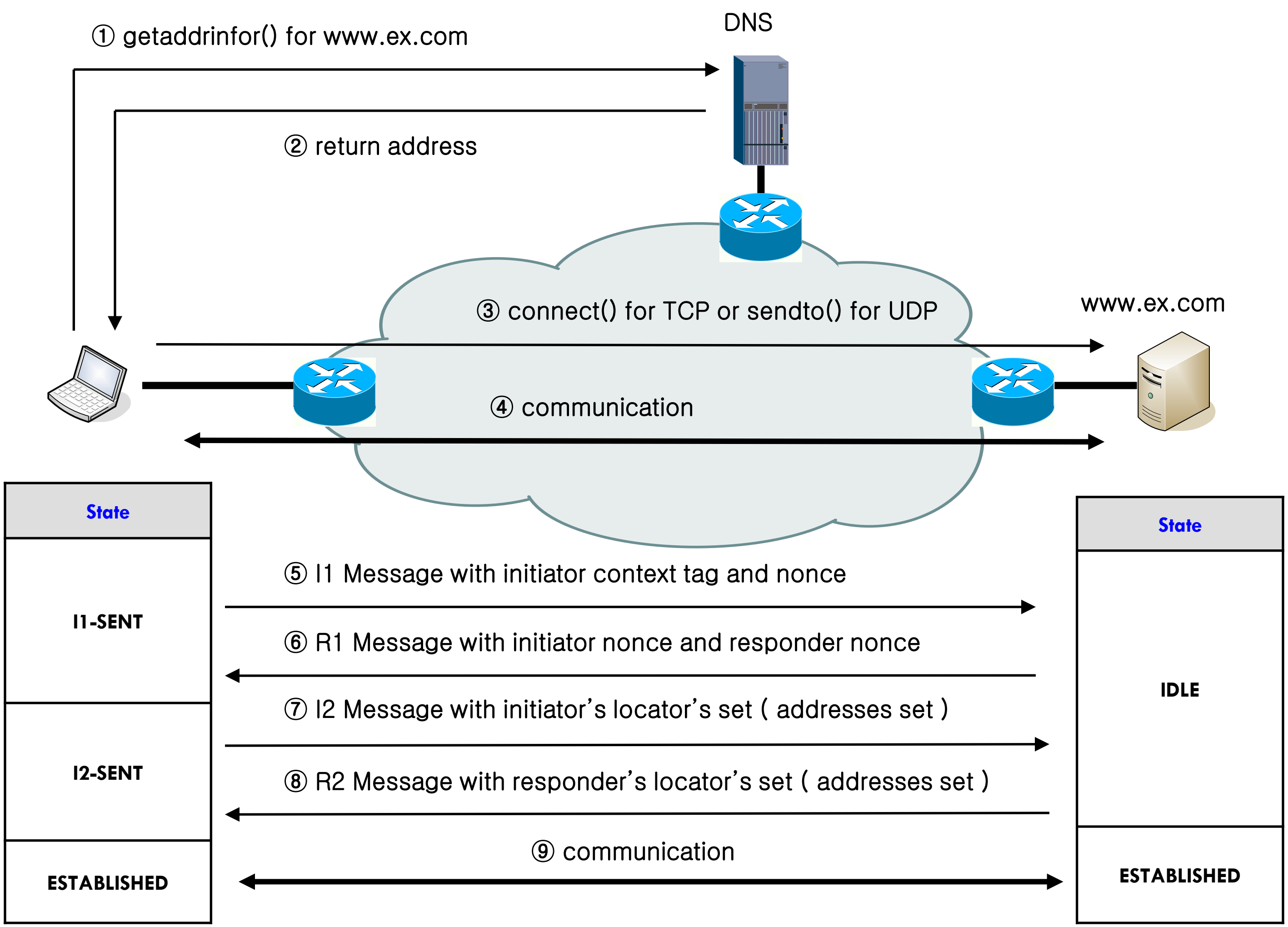
Detect locator failure
Explore for functioning locator pair
Use new locator pair – preserve identifier pair



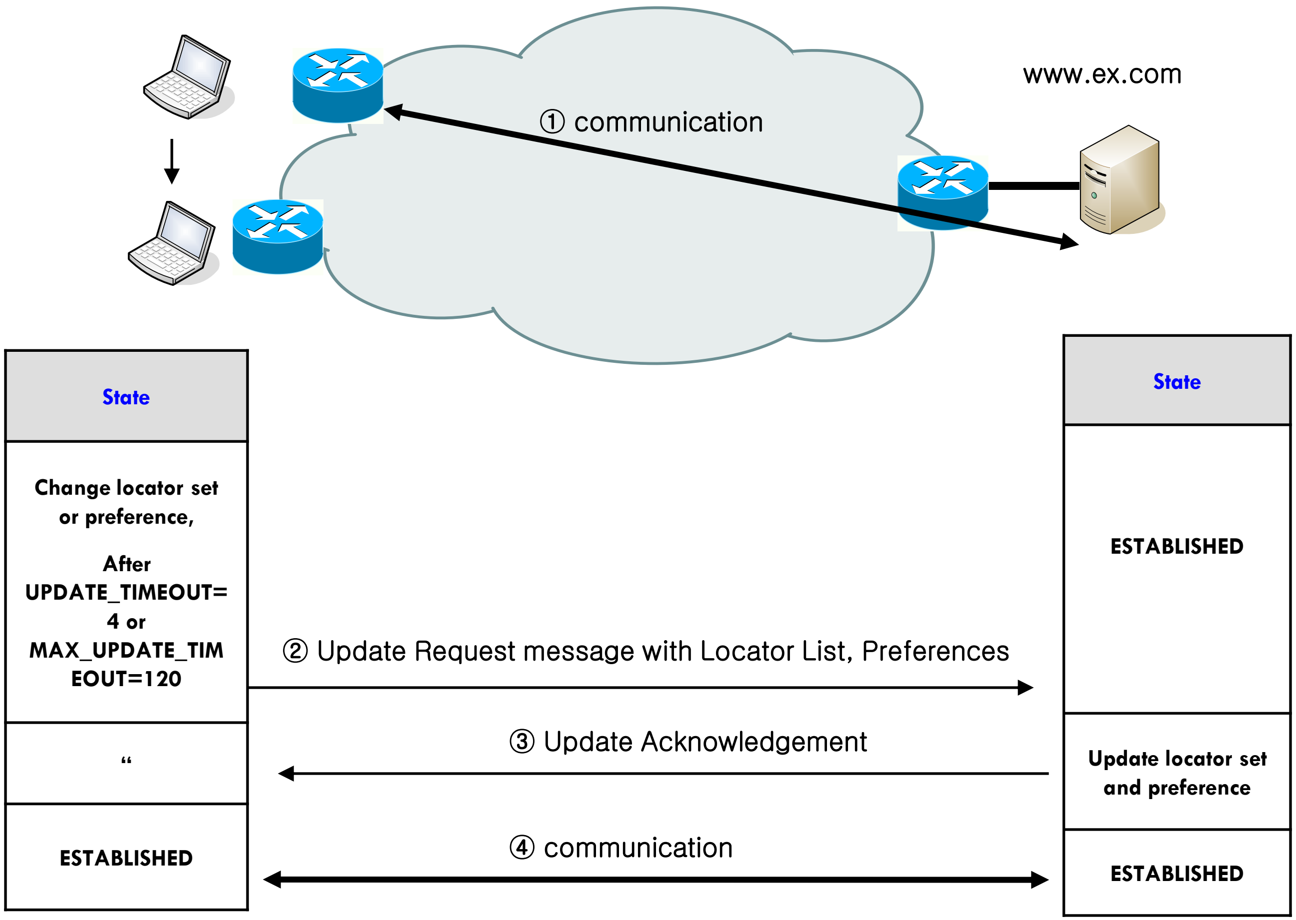
SHIM6 Control Elements

- Initial handshake (4-way) and locator set exchange
- Locator list updates
- Explicit locator switch request
- Keep alive
- Reachability probe exchange

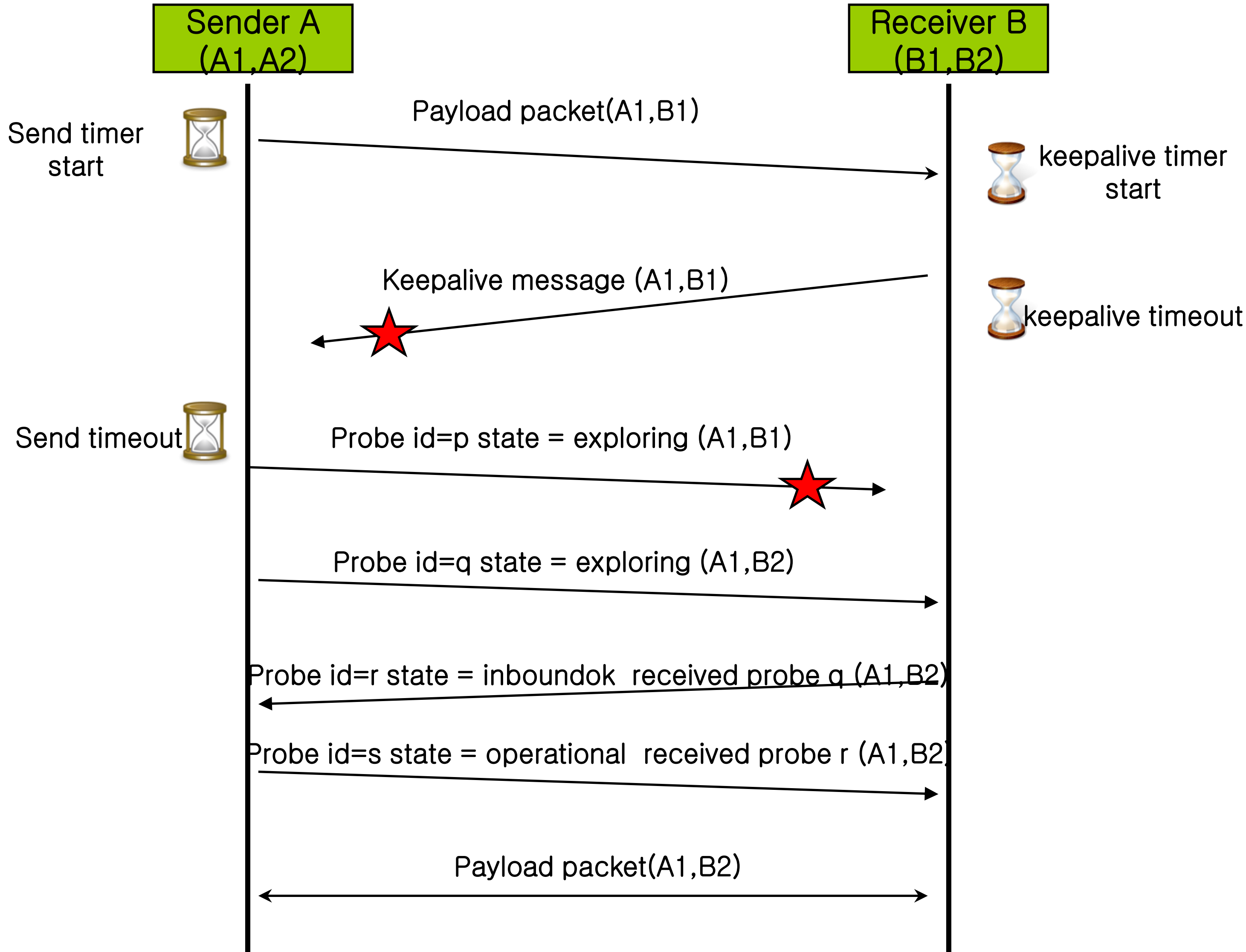
Initial handshake (4-way) and locator set exchange



locator list updates



Keep alive and reachability probe exchange



A Lightweight NEMO Protocol to Support 6LoWPAN : An Example

Introduction

- We present a scheme to support mobility for 6LoWPAN sensor nodes.
- To provide mobility for 6LoWPAN nodes, we adopt the Network Mobility (NEMO) protocol.
- If NEMO is applied in the 6LoWPAN network, even though each 6LoWPAN node is not equipped with the mobility protocol, it can maintain connectivity with the Internet through the 6LoWPAN mobile router (MR) as a network unit.
- Thus, the network mobility of the 6LoWPAN sensor nodes can be supported by an interoperable architecture between 6LoWPAN and NEMO.
- We propose a new header compression scheme for mobility headers in 6LoWPAN networks.
- Moreover, we propose a Lightweight NEMO protocol for efficient support of the 6LoWPAN network mobility.

Problem Statement of 6LoWPAN Mobility

- Even though the network mobility concept is suitable for 6LoWPAN mobility, as in the NEMO Basic Support protocol, the current 6LoWPAN packet format cannot support efficient mobility for the 6LoWPAN MR.

- To support 6LoWPAN mobility, the 6LoWPAN MR needs to send a BU message and receive a BA message from its HA. However, the 6LoWPAN packet format only defines the fragmentation and mesh routing headers.

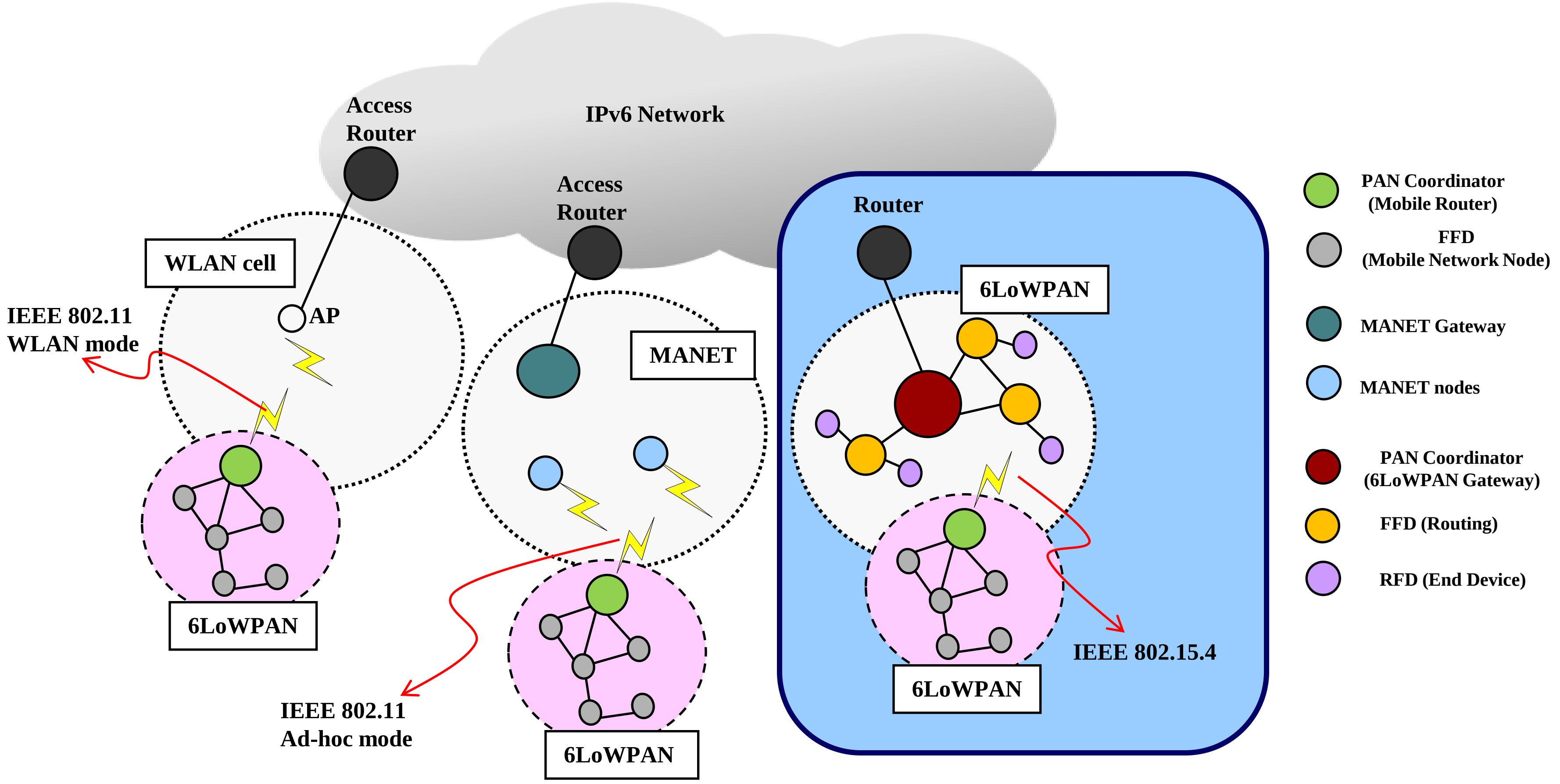
- Obviously, these messages are not sufficient to support the mobility of the 6LoWPAN MR because the structure of the 6LoWPAN packet has no solution to compress or support a mobility header for BU and BA messages.

- Therefore, we have to define a scheme to compress mobility headers in 6LoWPAN networks.

- To minimize the signaling overhead, a compressed mobility header can be used between the 6LoWPAN MR and the 6LoWPAN GW.

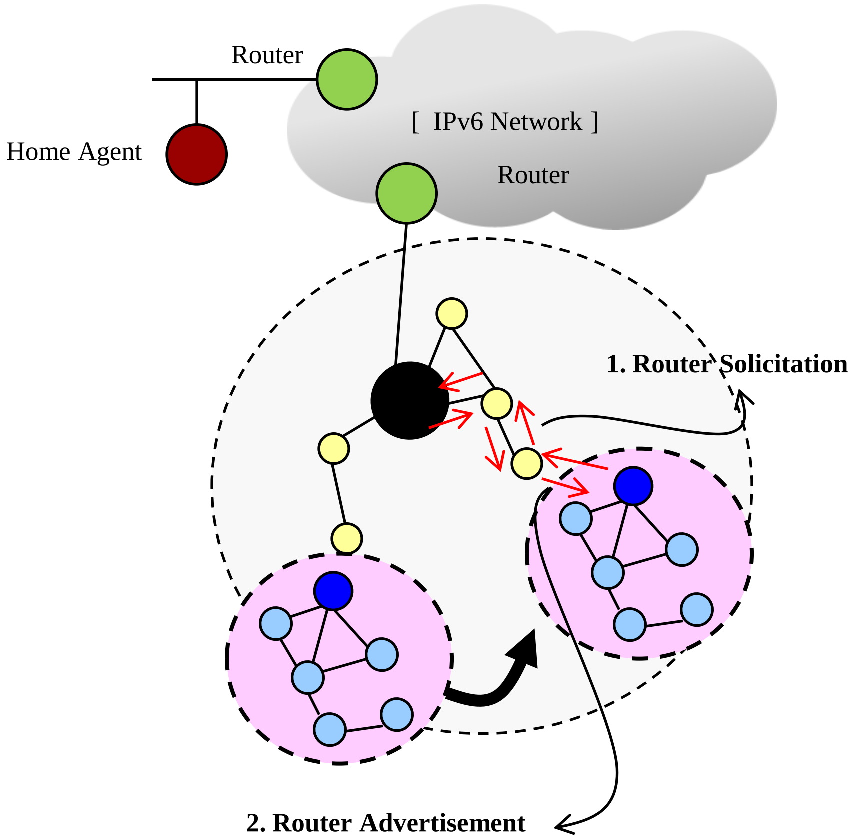
6LoWPAN network mobility for 6LoWPAN

- **Possible scenario of 6LoWPAN network mobility**

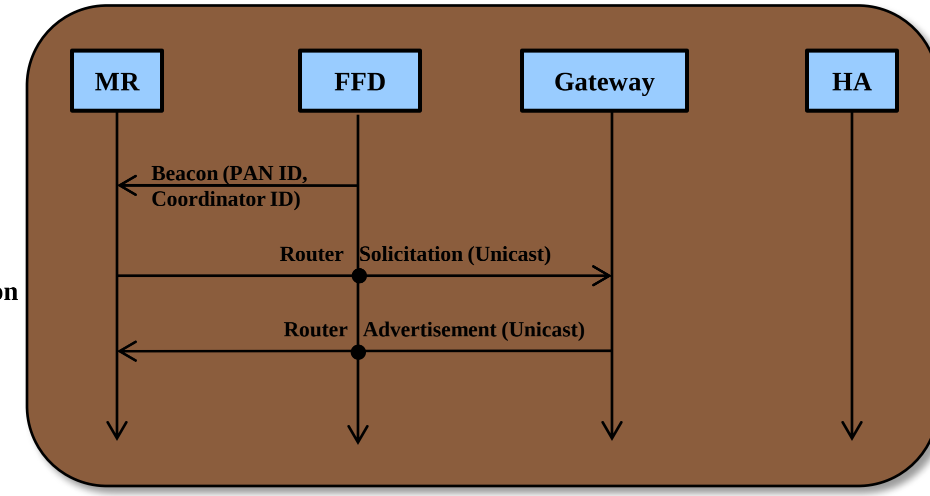


A Lightweight NEMO Protocol for 6LoWPAN :

Inter-PAN Mobility



- Full Function Device
- 6LoWPAN Mobile Network Node
- 6LoWPAN Mobile Router
- 6LoWPAN Gateway (PAN-Coordinator)



RS

(Unicast Link-local address)
SRC : MR
DST : 6LoWPAN Gateway

RA

(Unicast Link-local address)
SRC : 6LoWPAN Gateway
DST : MR

16bit-CoA option
6LoWPAN prefix option (global prefix)

Mobility in Future Internet

Mobility in the Internet

- Wireless speeds growing constantly:
  - 4G expected to achieve 40Mbps
  - WiFi up to 100Mbps
  - WiMAX up to 45Mbps
  - mmWave up to 3Gbps
  - Tera Hertz up to 10 Gbps
- *Always Best Connectivity* (ABC)

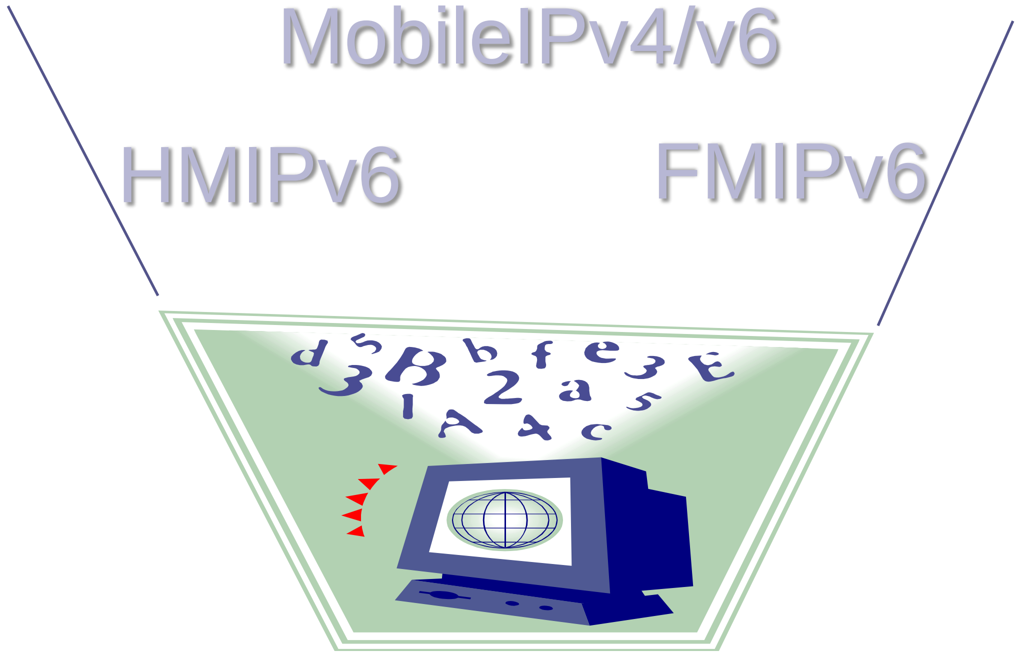
Mobility Support Problem

IP Address

Existing Solutions

- Network Layer
  - Mobile IPv4/v6, PMIPv6
- Transport Layer
  - SCTP (Stream Control Transport Protocol)
  - TCP-Migrate
- Application Layer
  - SIP (Session Initiation Protocol)
  - DNS (Domain Name System)

Many Mobile IP Variants, but…



Scalability

Manageability

Adaptability

New Trends for Mobility Support

- Identifier and Locator Separation
  - Host-based vs. Network-based approaches
  - IETF Routing and Address Problem (RoAP)
- Network-based Mobility Management
  - Proxy Mobile IPv6: Operator-friendly

Paradigm Shift (1/2)

- Traditional Wireless Mobility
  - Last hop connectivity
  - Soft handoff (horizontal, vertical)
  - Most data and services still in the wired Internet
  - Advanced ad hoc networking only in *tactical and emergency scenarios*

Paradigm Shift (2/2)

- Emerging Wireless Mobility
  - The data is collected by portable devices, and may stay on the devices for a long time:
    - Urban sensing by vehicle or people
  - New challenges
    - Distributed index to find the data
    - Data sharing via opportunistic P2P networking
    - Privacy, security, protection from attacks
    - Intermittent operations: DTN(delay tolerant network)

Directions for Future Wireless Mobility

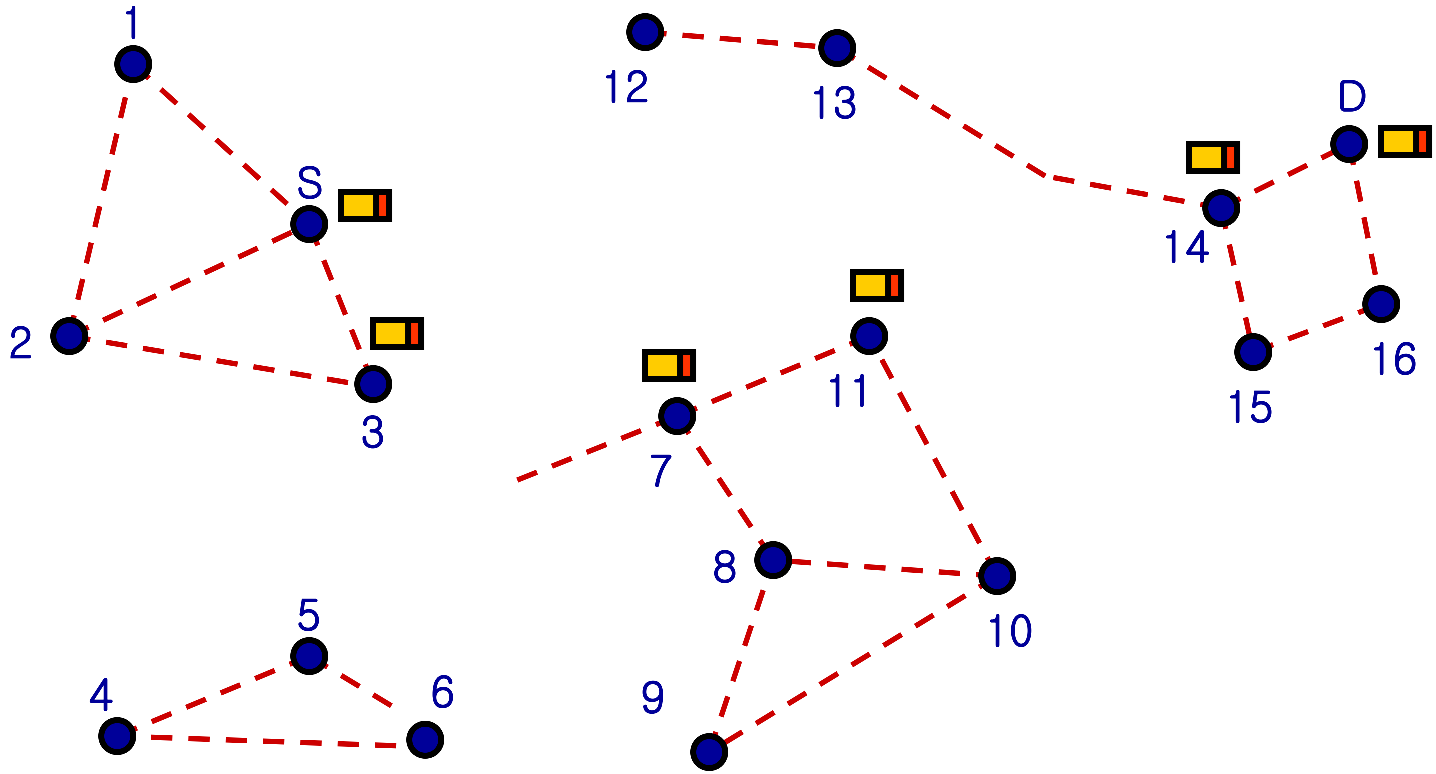
- Design for mobility requires a clean-slate approach to communication protocols in wireless networks and the Internet
- Design for mobility has direct implications on the Internet design, in-network storage and localization information being key factors
- Standards are needed for benchmarks.

A Clean Slate Approach (1/2)

- *Exploit mobility, broadcast nature, and in-network storage!*
- OSI/TCP architecture is no longer "the best"
  - MAC layer: should work on broadcast and directional transmissions
  - Network layer: Attribute-based queries, geo-location is important, resource discovery (no DNS)
  - Beyond routing: resource discovery replaces route discovery; need for binding of resources/services on the basis of names;

A Clean Slate Approach (2/2)

- Intermittent Connectivity
  - Lack of contemporaneous end-to-end paths
    - Disaster communication, Vehicular ad hoc networks
    - Ad-hoc/Sensor Networks, Inter-planetary networks



Changing The Internet Design (1/2)

- Use of storage and location information must be considered in the global routing design
- Use of location information: IPv6 can be used but we must find anonymous location information in addressing
  - Use of proxies and in-net storage
  - Privacy and security implications

Changing The Internet Design (2/2)

- Mobility creates a stronger focus on security
  - We do not know the local neighborhood!
- Opportunistic mobile routing infrastructures will become important
- Mobility changes the expectations for services (anywhere, anytime), but maintaining performance with seamless mobility is difficult.

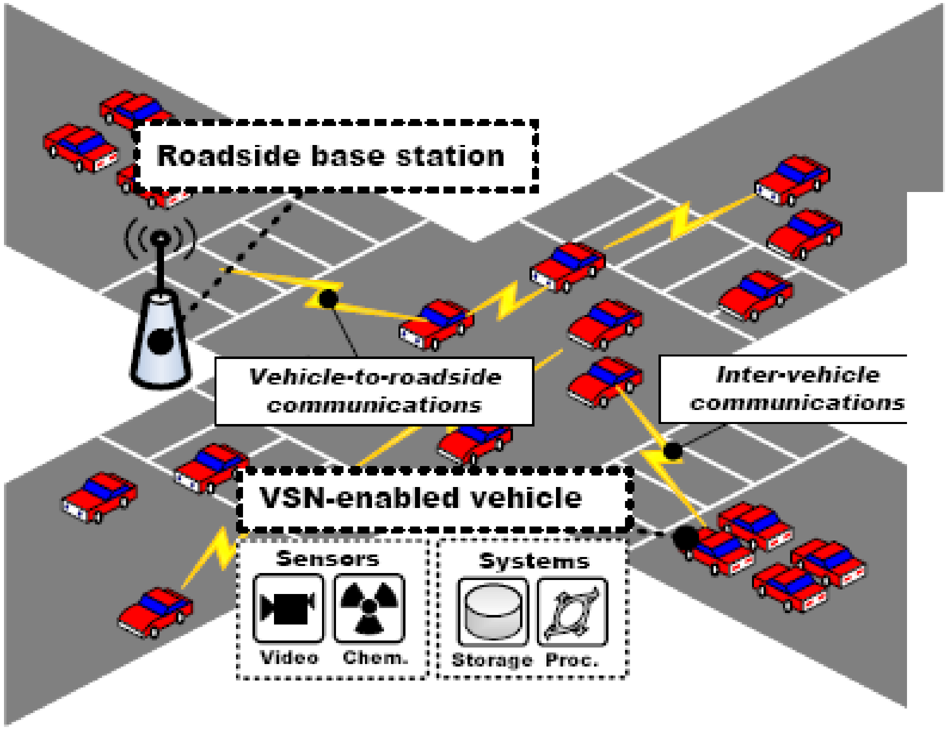
Role of Standards

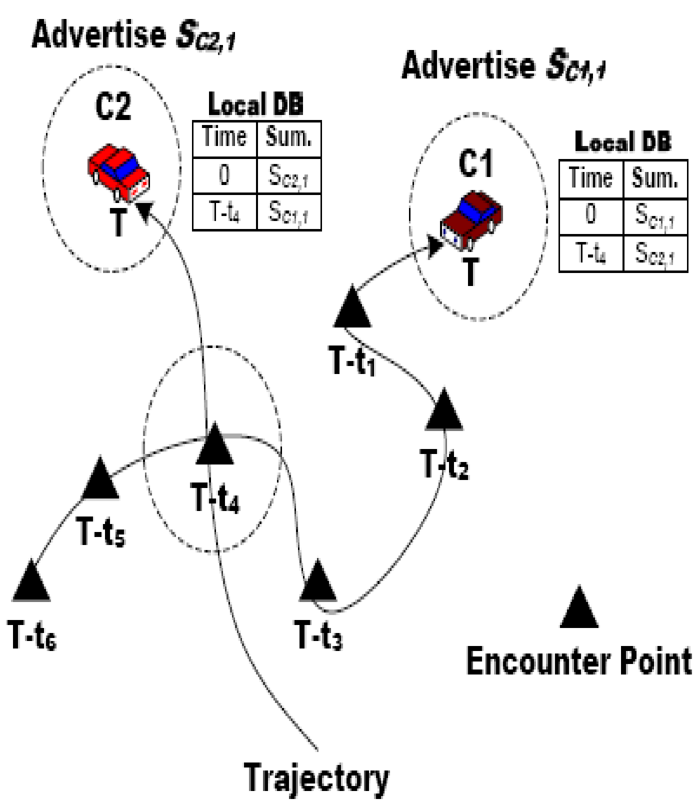
- What should be standardized?
  - Benchmarking different protocols
  - Understand dynamics of system to understand what to standardize
  - Need for a reference model capturing connectivity structures/motion patterns and spanning different scenarios and protocols.
  - Look at the “connectivity structure” of a network (dense or sparse, guidelines)

New Wireless/Mobile Applications

- Distributed
- Integrating heterogeneous infrastructure and ad-hoc networking
- Location/Energy/User behavior-aware
- Exploit mobility
- Location privacy sensitive
- Self-configurable, self-tunable, remotely manageable

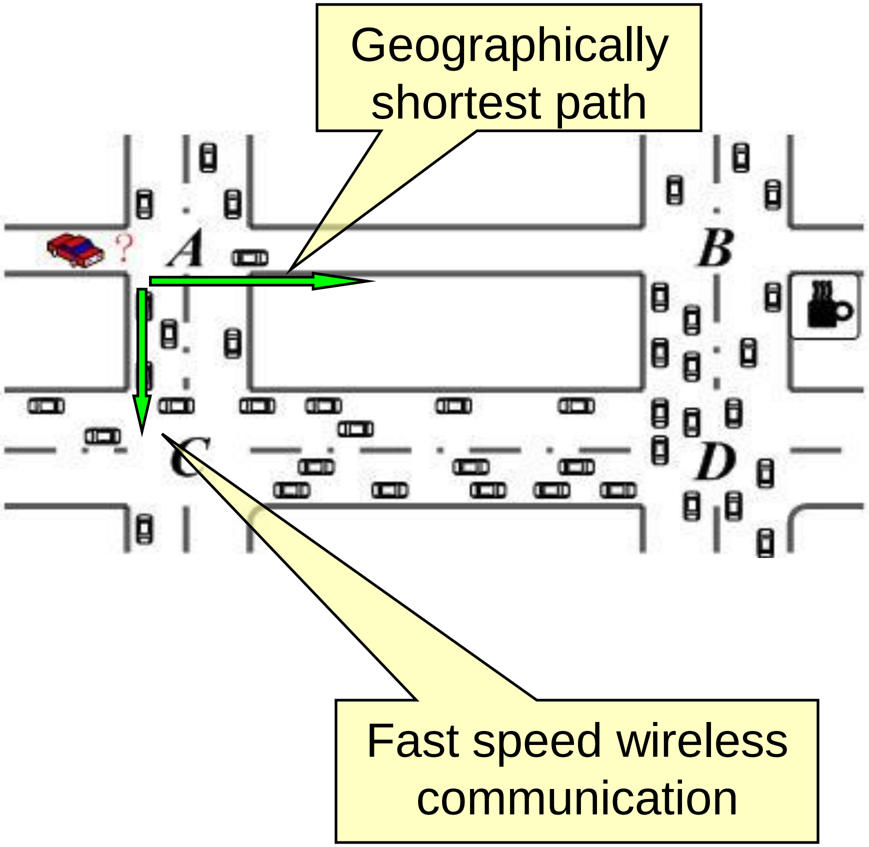
Example 1: Urban Sensing in VANETs





Example 2: Vehicle-Assisted Data Delivery

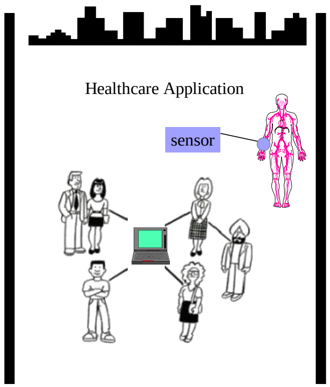
- Make use of the wireless transmission
  - Forward the packet via high density area
  - Use intersection as a opportunity to switch the forwarding direction and optimize the forwarding path

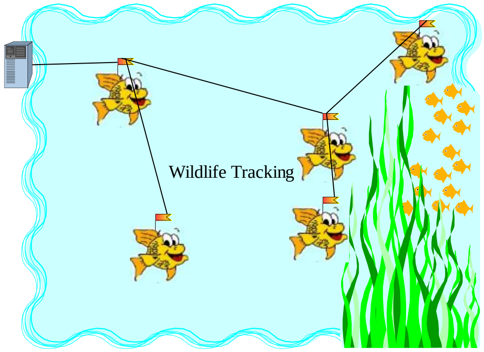


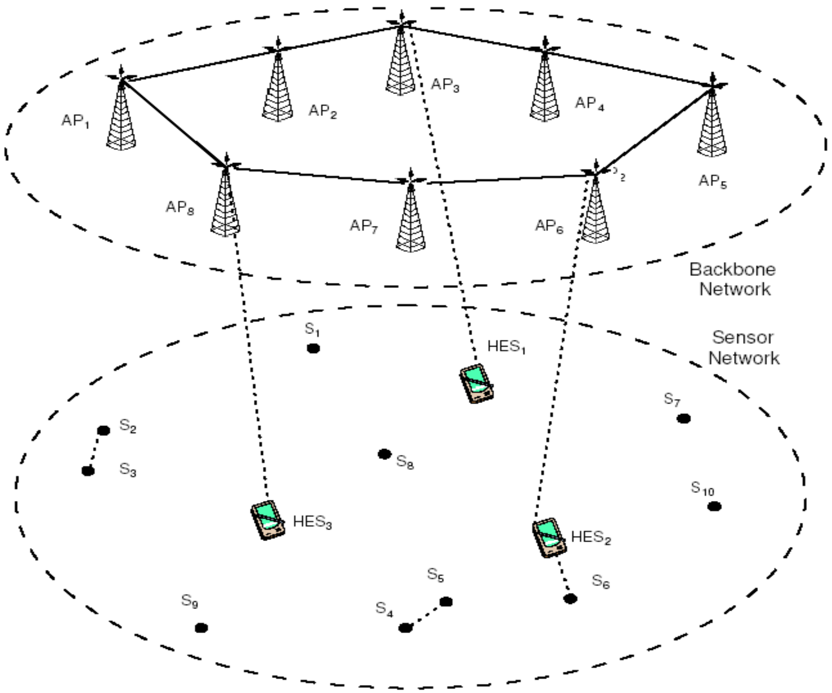
Example 3: Mobile Sensor Networks

- Applications
  - Air quality monitoring
  - Flu virus tracking

- Unique characteristics
  - Nodal mobility
  - Sparse connectivity
  - Delay/fault tolerability
  - Limited buffer/memory







Research Challenges (1/2)

- Mobile application design
  - Location-aware and mobility-exploited
- Performance and QoS
  - Delay tolerance, channel variations
- Cross-layer communication design
  - Exploit mobile application context information
- Security issues
  - Location validation and privacy, Trust management

Research Challenges (2/2)

- Mobile data management
- Fault tolerance and availability
  - In the presence of mobility
- Remote maintainability
  - Deployment, configuration, upgrade, debugging
- Application and service-oriented protocols
  - Over mobile networks

Mobility Model and Testbeds

- Flexibility in Mobility Models
  - Multiple scale models: Micro and Macro levels
  - Multi-faceted scenarios: Combines motion, data traffic, map, infrastructure
  - Trade off between accuracy and usability
- Flexibility in Testbeds
  - Heterogeneous hardware, protocols, applications
  - Broad range of motion patterns:
  - Broad range of devices: from motes to vehicles

GENI Wireless Mobility Testbeds

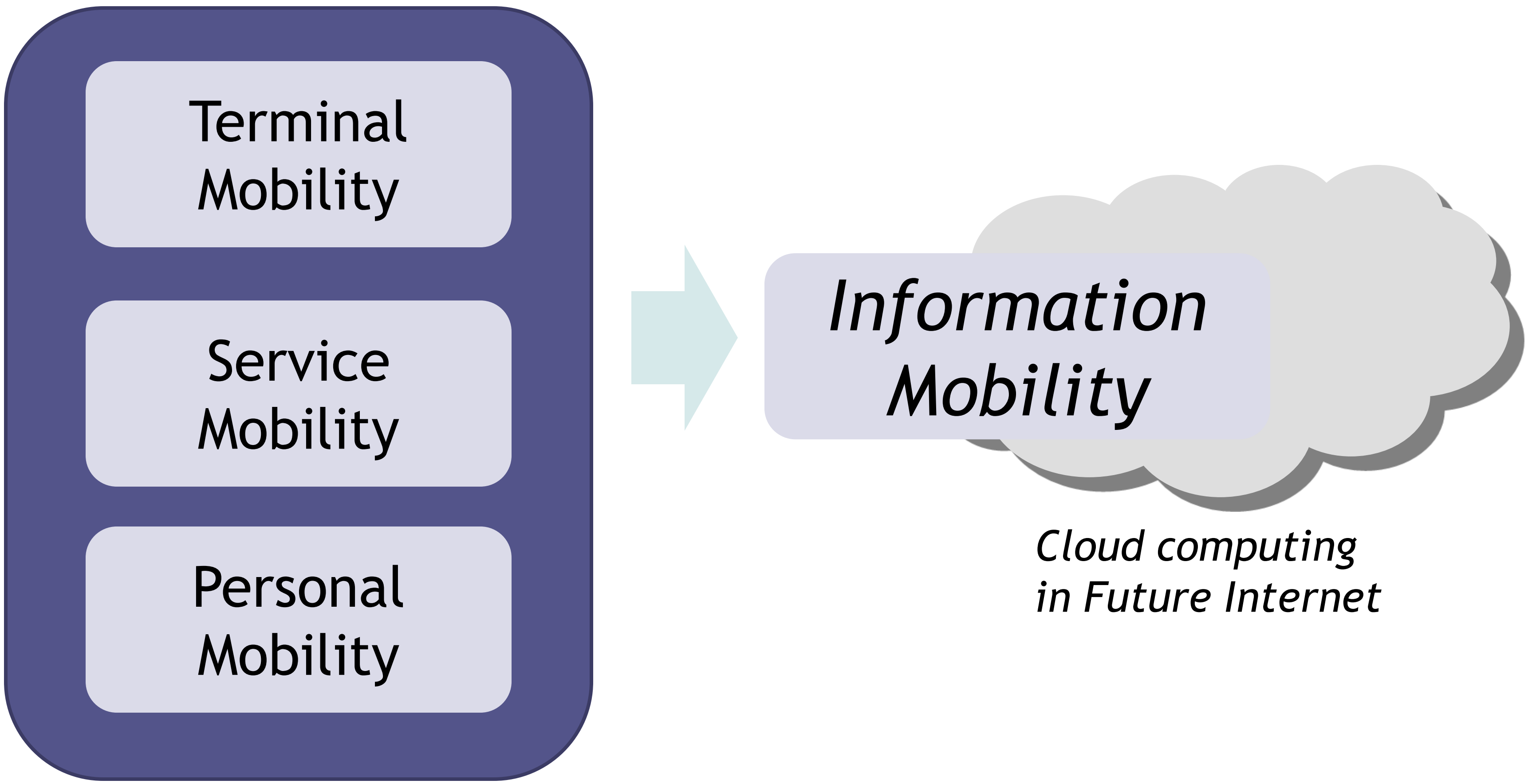
- Vehicular networks
- People to people networks
- Small scale - augmented by simulation (hybrid)
- Inter-operation

Campus Vehicular Testbed in UCLA

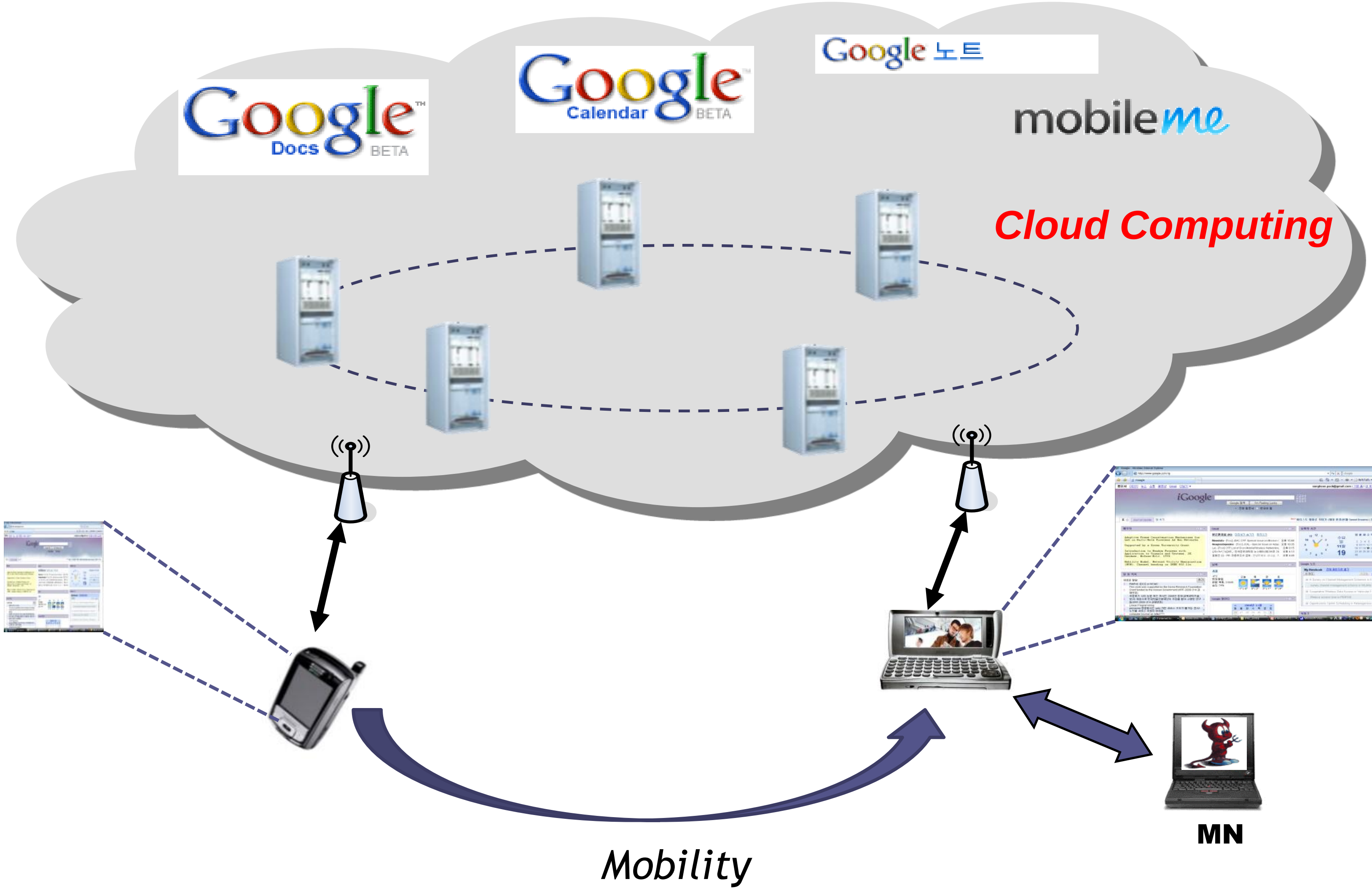
- Campus Vehicular Testbed (C-VeT)
  - A platform to support car-to-car experiments in various traffic conditions and mobility patterns
  - A shared virtualized environment to test new protocols and applications
  - Remote access to C-VeT through web interface
  - Collection of mobility traces and network statistics

shown with optional: 7" lcd / 8.7" mini keyboard

New Vision: Information Mobility (1/2)



New Vision: Information Mobility (2/2)



Conclusion

- Mobility is a key consideration in Future Internet!
  - It does not mean a connectivity issue!
  - Need reconsideration for Internet architecture!

Thank You!