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資訊工程學系
Department of Computer Science and Information Engineering,

Chapter 5:
Partner-based Hierarchical Mobile IPv6

Prof. **Yuh-Shyan Chen**
Department of Computer Science and Information Engineering
National Taipei University

A Cooperative Diversity Based Handoff Management Scheme

Tarik Taleb, *Member, IEEE*, and Khaled Ben Letaief, *Fellow, IEEE*

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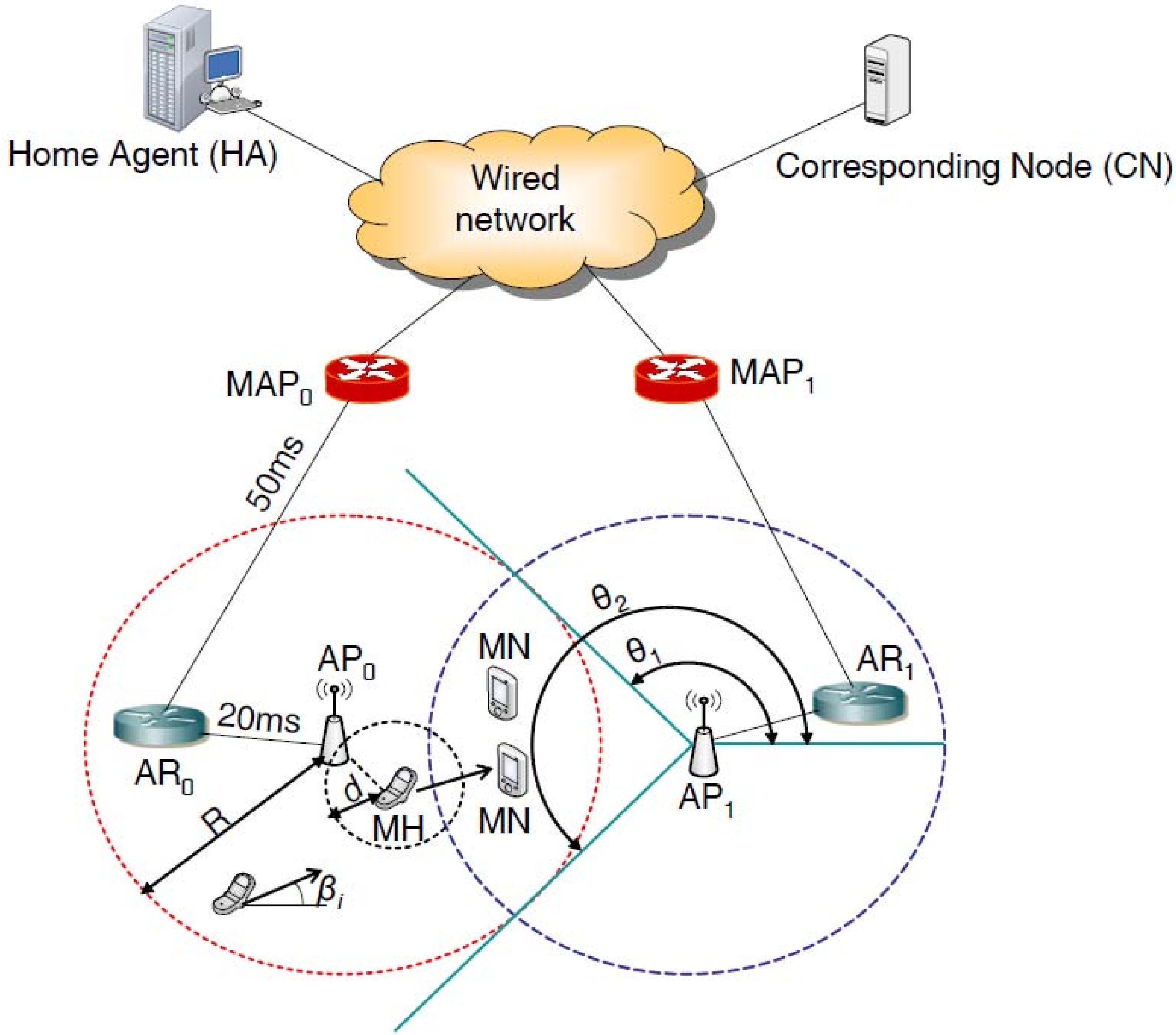
Cooperative diversity

- Cooperative diversity has emerged as a promising technique to facilitate fast handoff mechanisms in mobile ad-hoc environments.
- The key concept behind a prominent cooperative diversity based protocol, namely**, Partner-based Hierarchical Mobile IPv6** (PHMIPv6), is to enable mobile nodes anticipate handover events by selecting suitable **partners** to communicate on their behalves with Mobility Anchor Points (MAPs).

Cooperative diversity

- In the original design of PHMIPv6, mobile hosts choose partners based on their signal strength.

A **Cooperative Diversity** Based Handoff Management Scheme



PHMIPv6

- To address such shortcomings of HMIPv6 pertaining to handoff management**, Chen *et al*.** introduced the Partner-based HMIPv6 (PHMIPv6) protocol, which attempts to speed up the handoff process by initializing it prior to the entrance of the mobile node into the overlapping zone.
- PHMIPv6 serves as a pioneering work in the field of cooperative diversity, whereby a trigger scheme is used to select a Partner Node1 (PN), which carries out various steps involved in the handoff operation on behalf of a Mobile Host (MH).

Outline

1. Introduction
2. Related work
3. Motivation, our basic idea and system architecture
4. Partner-based HMIPv6 (PHMIPv6)
5. Mathematical analysis and simulation results
6. Conclusion

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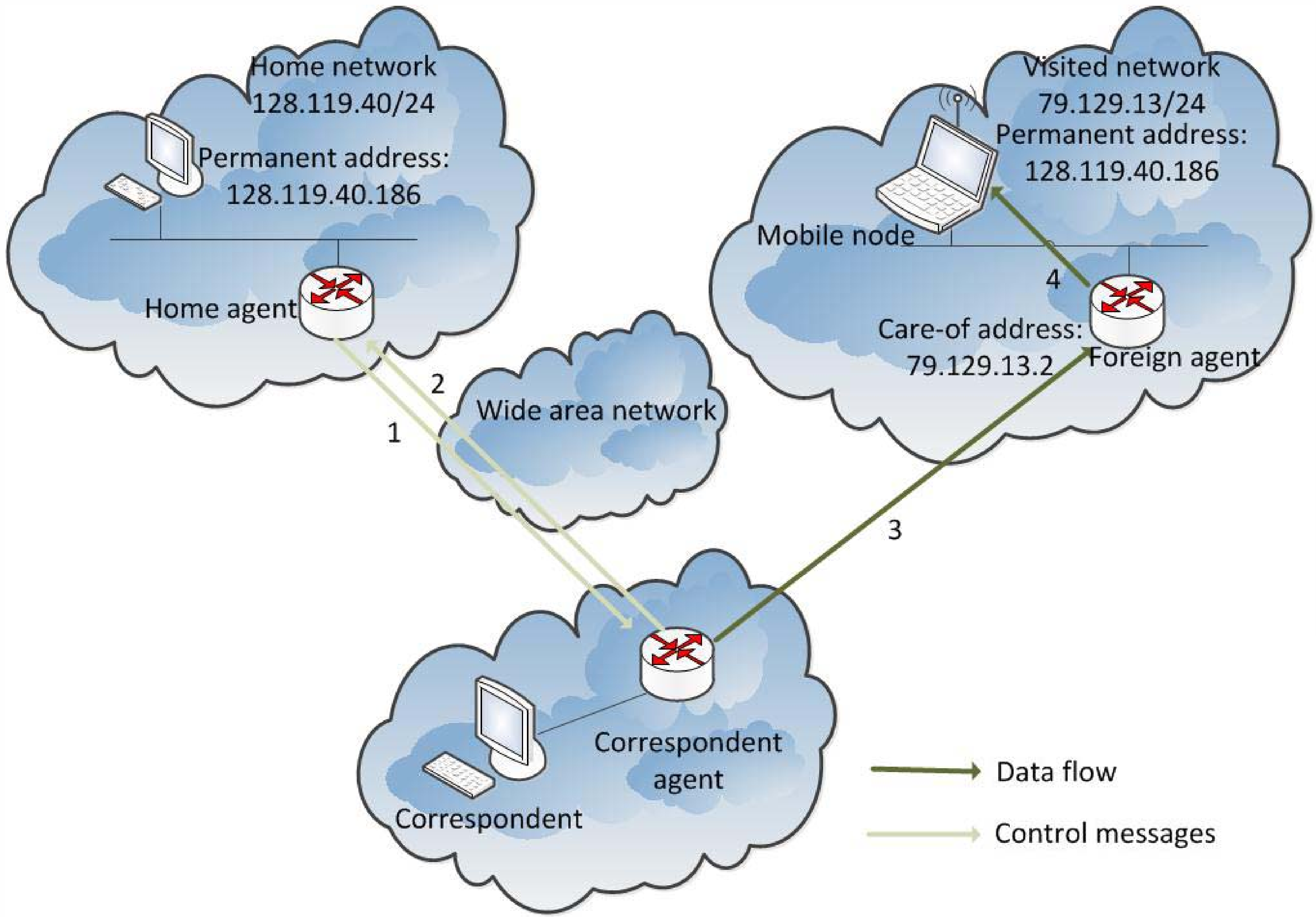
Introduction

- Mobile IPv6 (MIPv6) is used to inform the binding of its home address and current care-of-address (CoA) to its home agent.
  - MIPv6 suffers a long delay latency and high packet losses because that MIPv6 not support the micro-mobility.
- Hierarchical Mobile IPv6 (HMIPv6) is proposed by providing micro-mobility and macro-mobility to reduce handoff latency by employing a hierarchical network structure.

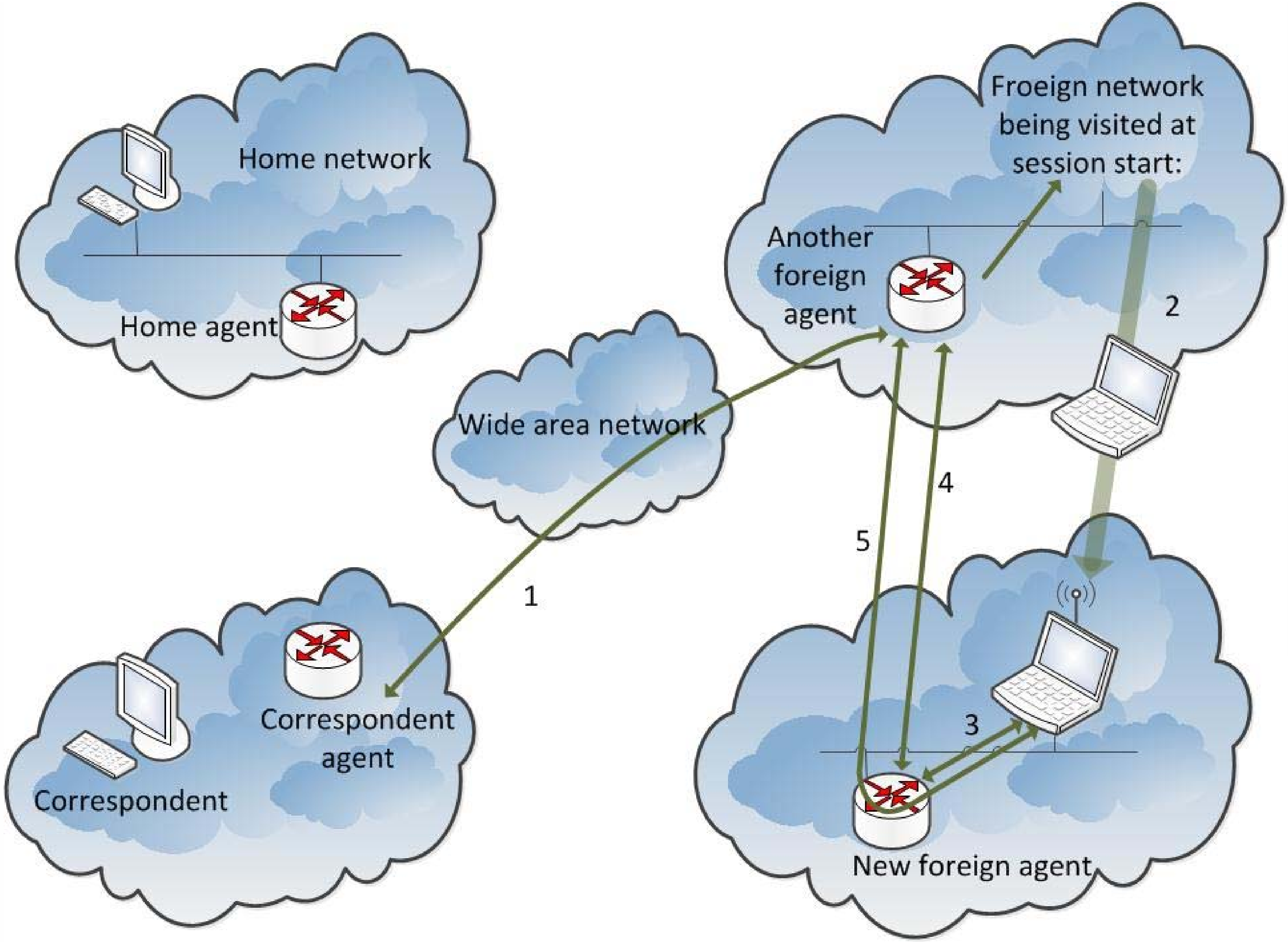
Mobile IPv6

- Mobile IPv6 allows nodes to move within the Internet topology while maintaining reachability and on-going connections between mobile and correspondent nodes.
- To do this a mobile node sends Binding Updates (BUs) to its Home Agent (HA) and all Correspondent Nodes (CNs) it communicates with, every time it moves.

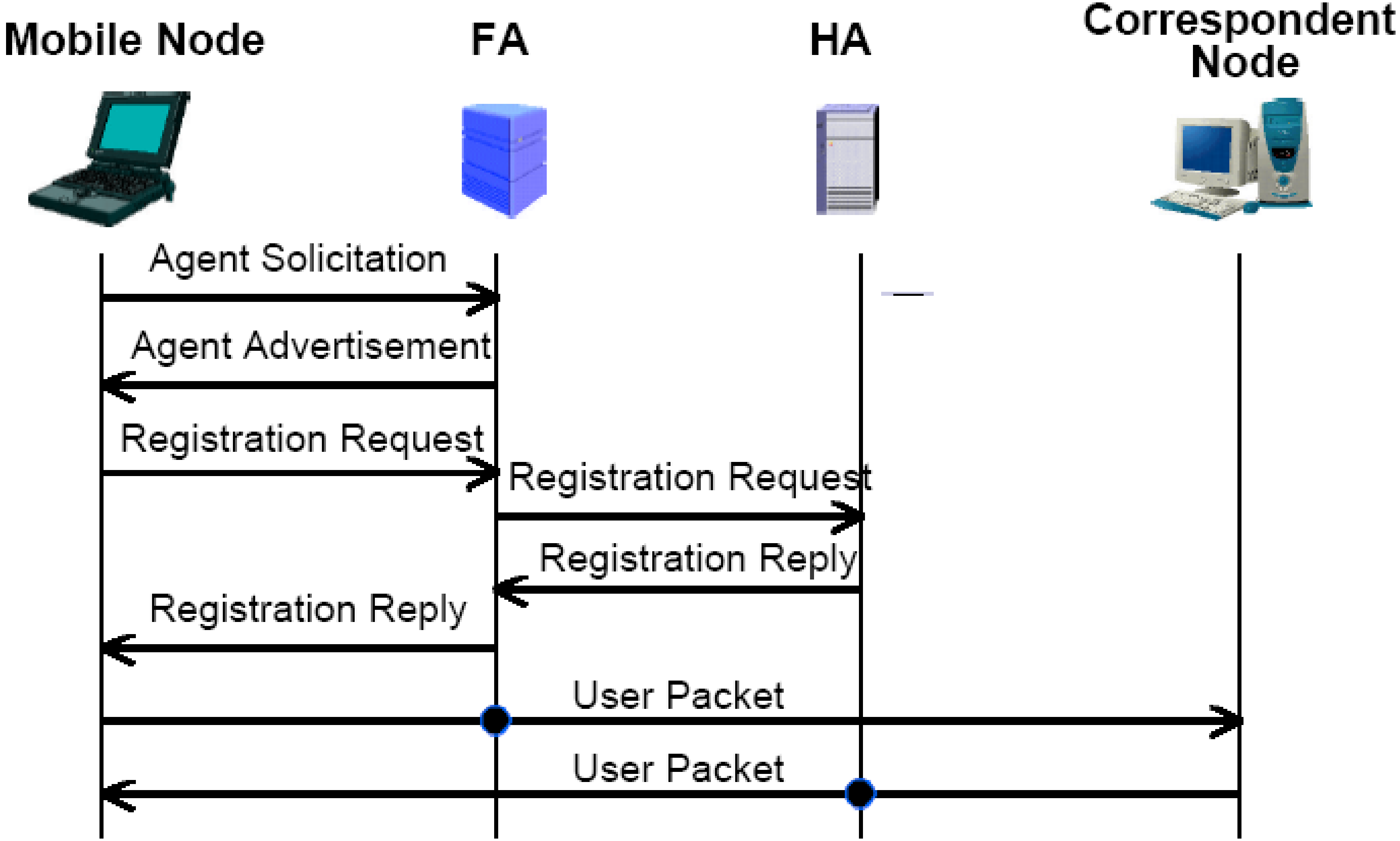
MIPv4


Home network
128.119.40/24
Permanent address:
128.119.40.186
Home agent
Visited network
79.129.13/24
Permanent address:
128.119.40.186
Mobile node
4
Care-of address:
79.129.13.2
Foreign agent
2
1
Wide area network
3
Correspondent
agent
Correspondent
Data flow
Control messages

MIPv4


Home network
Home agent
Froeign network being visited at session start:
Another foreign agent
2
Wide area network
4
5
1
Correspondent agent
Correspondent
3
New foreign agent

MIPv4: Control & Data Flows



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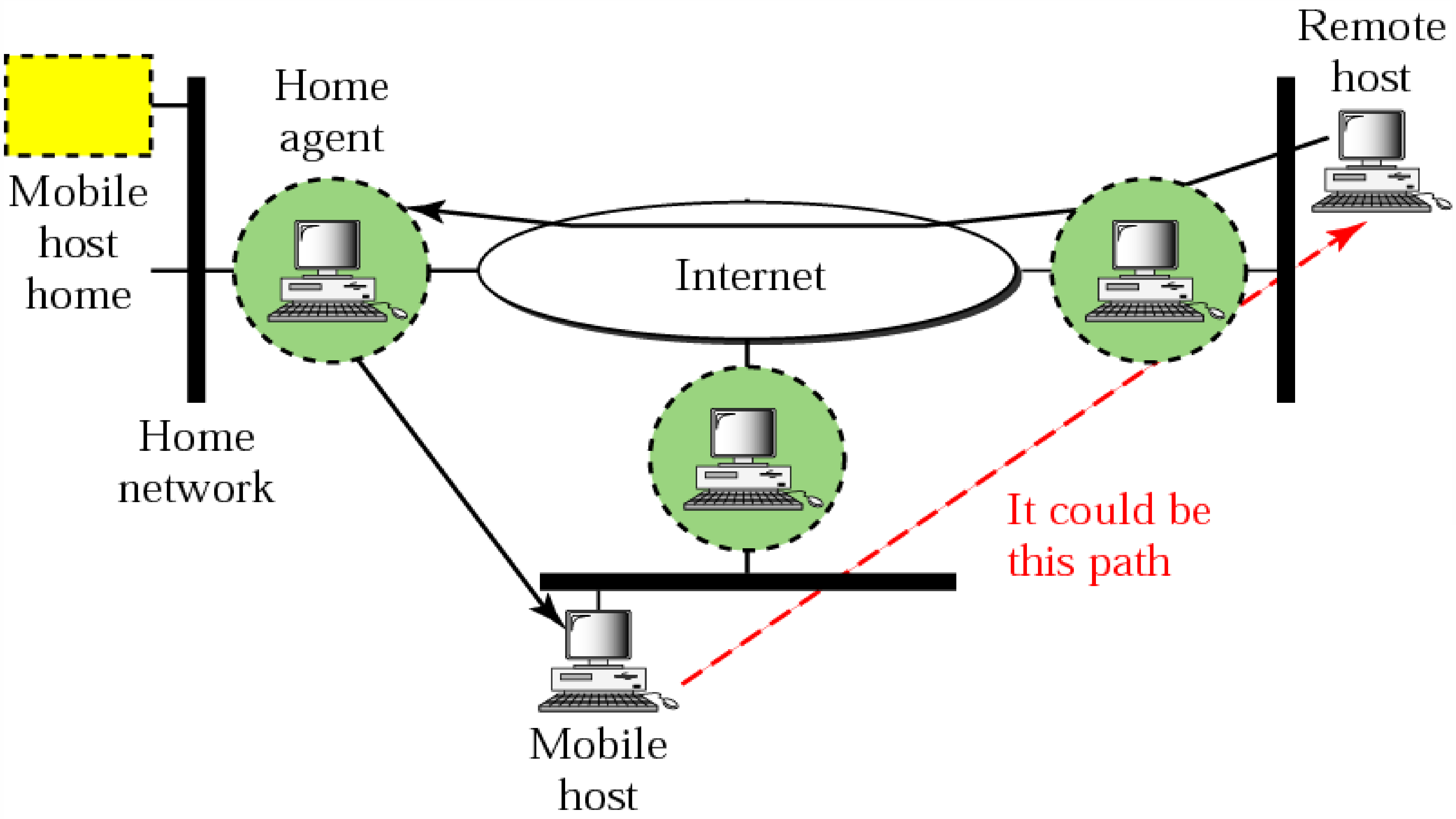
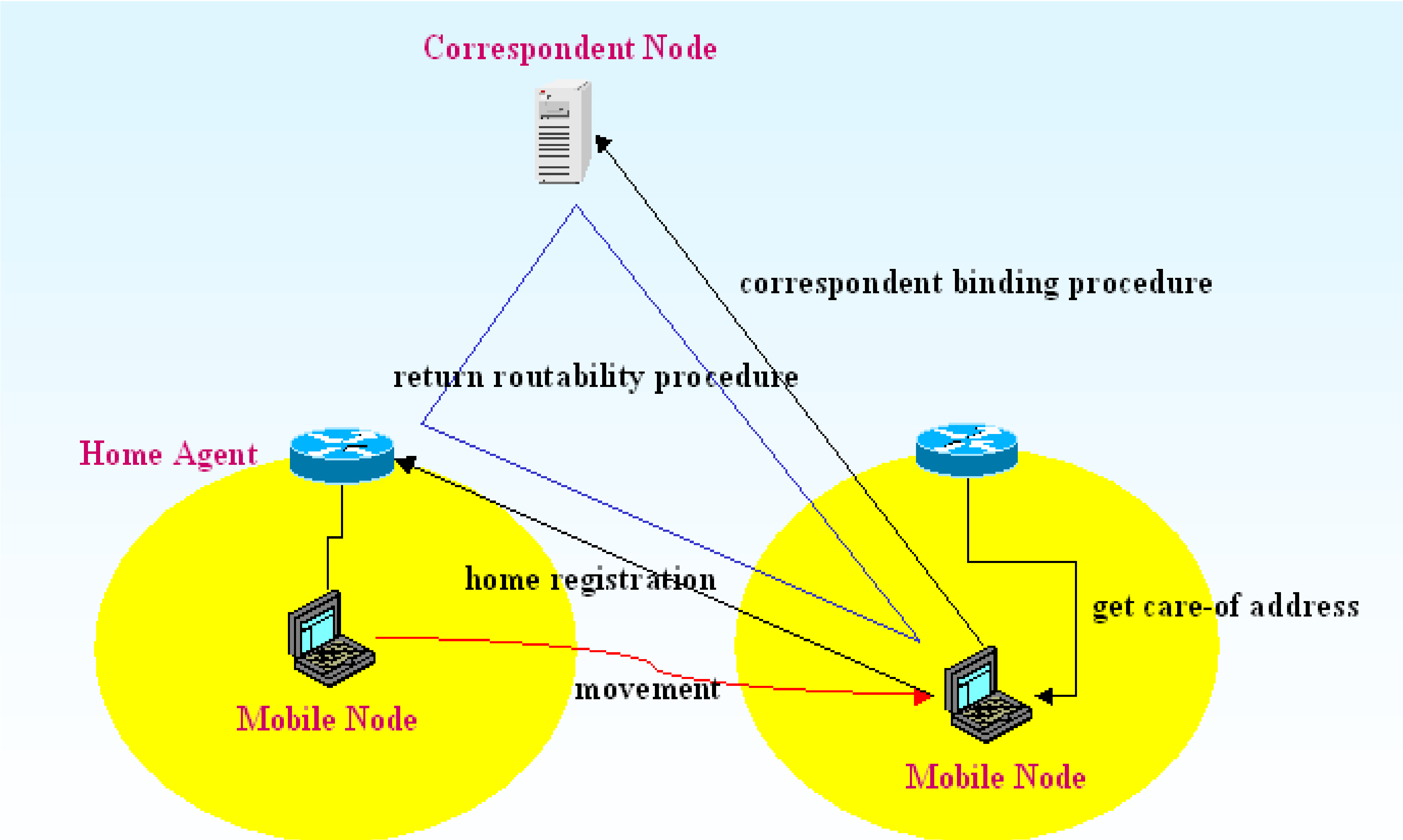
MIP: Triangular Routing Problem



MIPv6: Binding Update



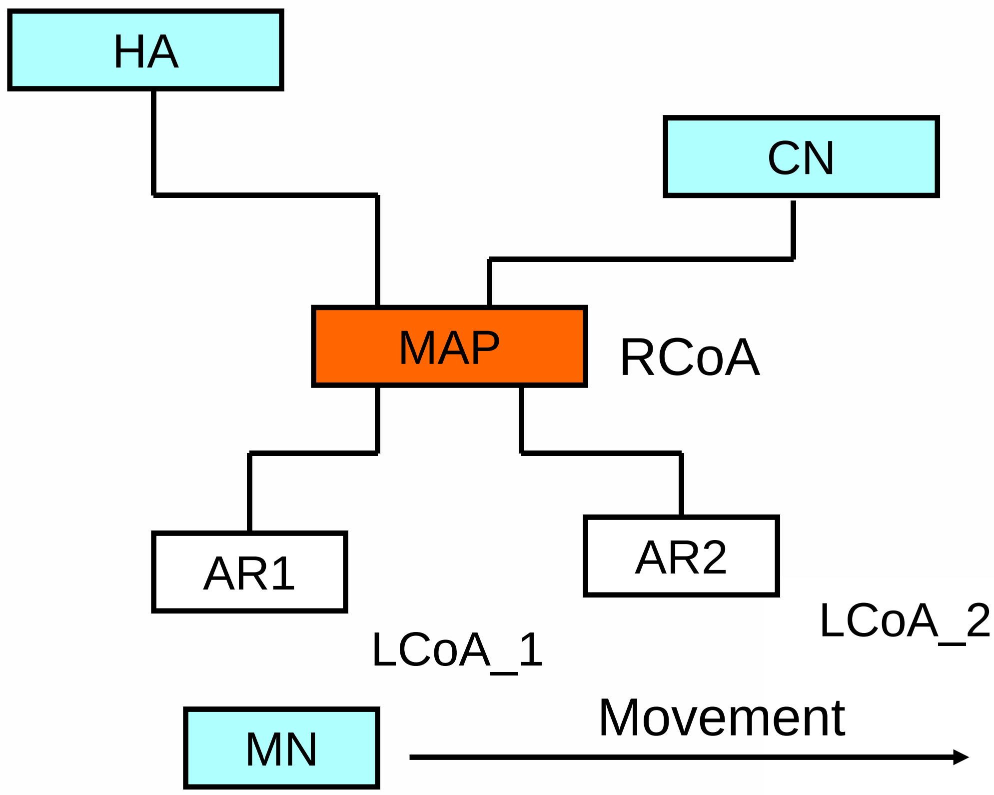
The drawback of MIPv6

- MIPv6 suffers a long delay latency and high packet losses because that MIPv6 not support the micromobility.
- Hierarchical Mobile IPv6 (HMIPV6) is proposed by providing micromobility and macromobility to reduce handoff latency by employing a hierarchical network structure.

Hierarchical Mobile IPv6 Mobility Management (HMIPv6)

- Mobility Anchor Point, is used and can be located at any level in a hierarchical network of routers, including the Access Router (AR).
- Unlike Foreign Agents in IPv4, a MAP is not required on each subnet.
- The MAP will limit the amount of Mobile IPv6 signalling outside the local domain.

Hierarchical Mobile IPv6 domain (RFC 4140)



Hierarchical Mobile IPv6 Mobility Management (HMIPv6)

- The mobile node sends Binding Updates to the local MAP rather than the HA (which is typically further away) and CNs.
- Only one Binding Update message needs to be transmitted by the MN before traffic from the HA and all CNs is re-routed to its new location. This is independent of the number of CNs that the MN is communicating with.

Mobility Anchor Point (MAP)

- A Mobility Anchor Point is a router located in a network visited by the mobile node. The MAP is used by the MN as a local HA. One or more MAPs can exist within a visited network.

Regional Care-of Address (RCoA)

- An RCoA is an address obtained by the mobile node from the visited network.
- An RCoA is an address on the MAP's subnet. It is auto-configured by the mobile node when receiving the MAP option.

LCoA (On-link Care-of Address)

- The LCoA is the on-link CoA configured on a mobile node's interface based on the prefix advertised by its default router, this is simply referred to as the Care-of- address. However, in this memo LCoA is used to distinguish it from the RCoA.

Local Binding Update

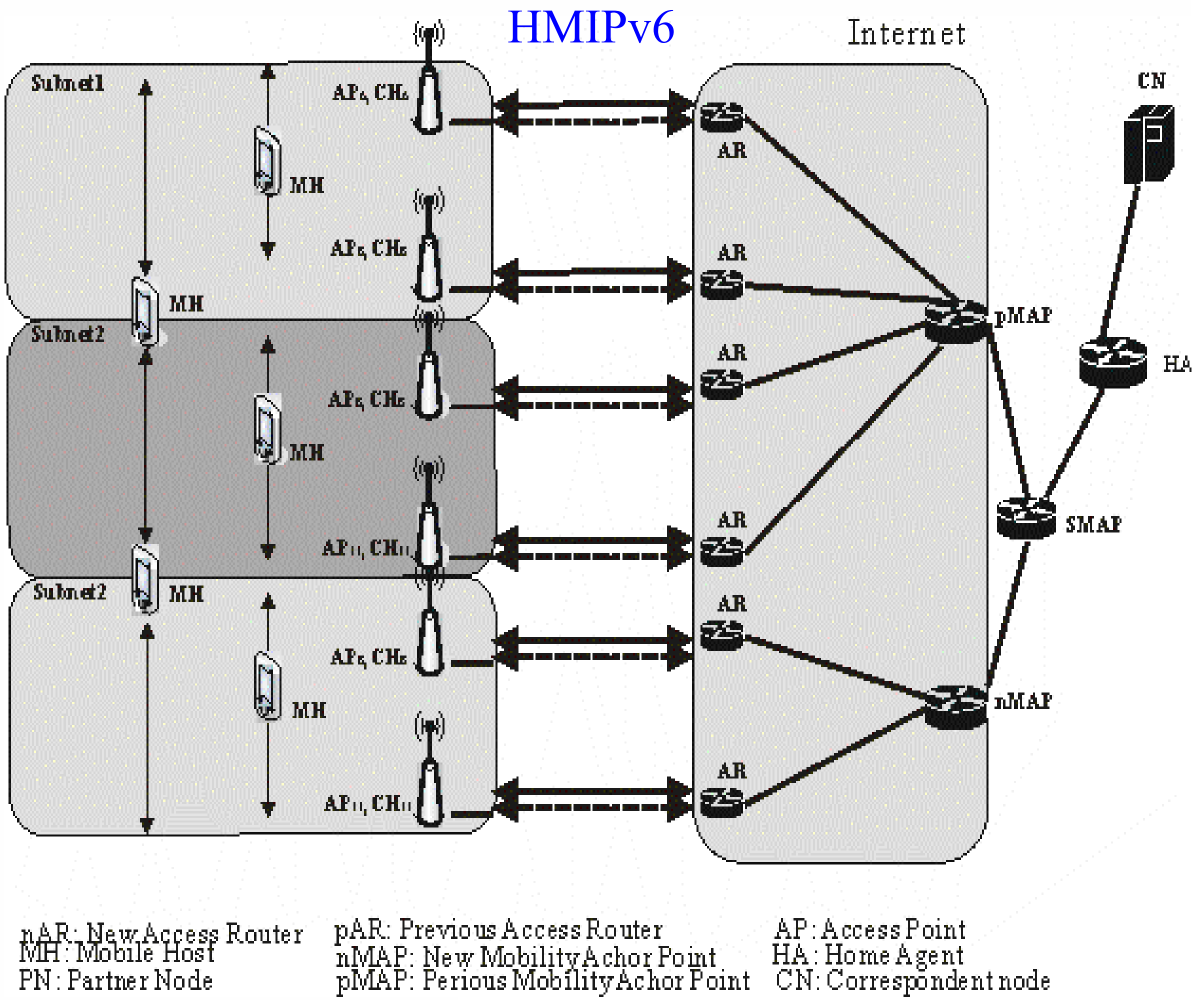
- The MN sends a Local Binding Update to the MAP in order to establish a binding between the RCoA and LCoA.

Introduction (2)

- To provide an cross-layer partner-based fast handoff mechanism for the 802.11 networks, based on HMIPv6 (PHMIPv6).
- To improve the handoff delay time by using the information of different layer and partner-node.
  - The layer-2 fast handoff (deucescan) provides the efficiency scanning utilization.
  - The partner-based fast handoff (PHMIPv6) provides for assist mobile host to perform the pre-handoff procedure by partner node.

Introduction (3)

- Cross-layer fast handoff mechanism is more efficient and important
- This work develops a new cross-layer partner-based fast handoff mechanism



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Existing Handoff Results (1)

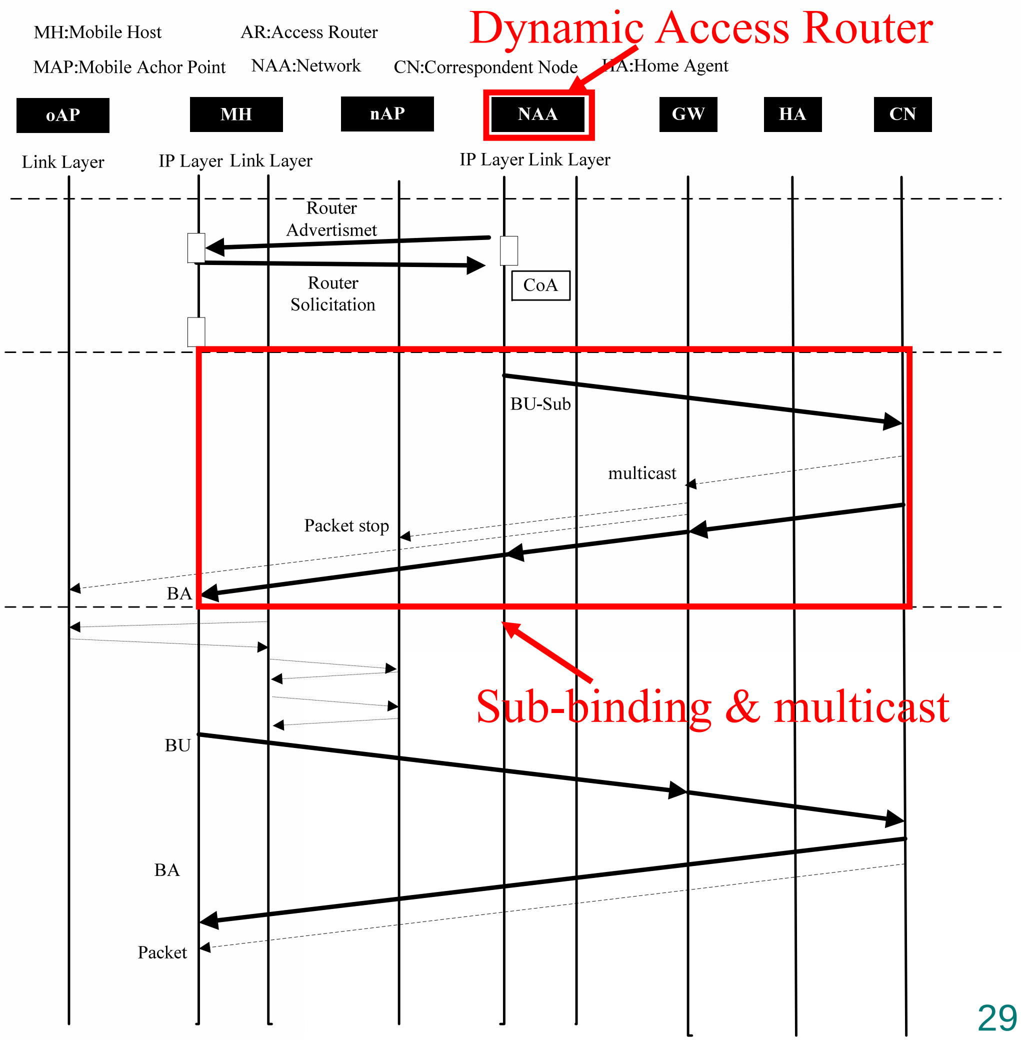
- Smooth Handoff Approach (Layer-3, Mobile IPv6)
  - Goal: To decrease packet loss
  - H.-C. Chao and C.-Y. Huang, ”Micro-Mobility Mechanism for Smooth Handoffs in an Integrated Ad-Hoc and Cellular IPv6 Network Under High-Speed Movement, ”*IEEE Transactions on Vehiclar Techology (VT)*, Vol. 52, No. 6, pp. 1576 - 1593, November 2003.
  - CE Perkins and K-Y Wang, “Optimized smooth handoffs in Mobile IP”, *IEEE International Symposium on Computers and Communications*, pp. 340 –346, July 1999.

Existing Handoff Results (2)

- Fast Handoff Approach (Layer-3, Hierarchical Mobile IPv6)
  - Goal: To decrease handoff latency
  - W.-K. Lai and J.-C. Chiu, "Improving Handoff Performance in Wireless Overlay Networks by Switching Between Two-Layer IPv6 and One-Layer IPv6 Addressing," *IEEE Journal On Selected Areas In Communications (JSAC)*, Vol. 23, No. 11, pp. 621 - 628, November 2005.
  - C.-W. Lee and L.-M. Chen and M.-C. Chen and Y.-S. Sun, "A Framework of Handoffs in Wireless Overlay Networks Based on Mobile IPv6,"*IEEE Journal On Selected Areas In Communications (JSAC)*, Vol. 23, No. 11, pp. 629 - 638, November 2005.
  - H. Soliman and C. Castelluccia and K.-E. Malki and L.Bellier, "Hierarchical Mobile IPv6 mobility management (HMIPv6)," *Internet Engineering Task Force (IETF) Internet-Draft*, June 2003

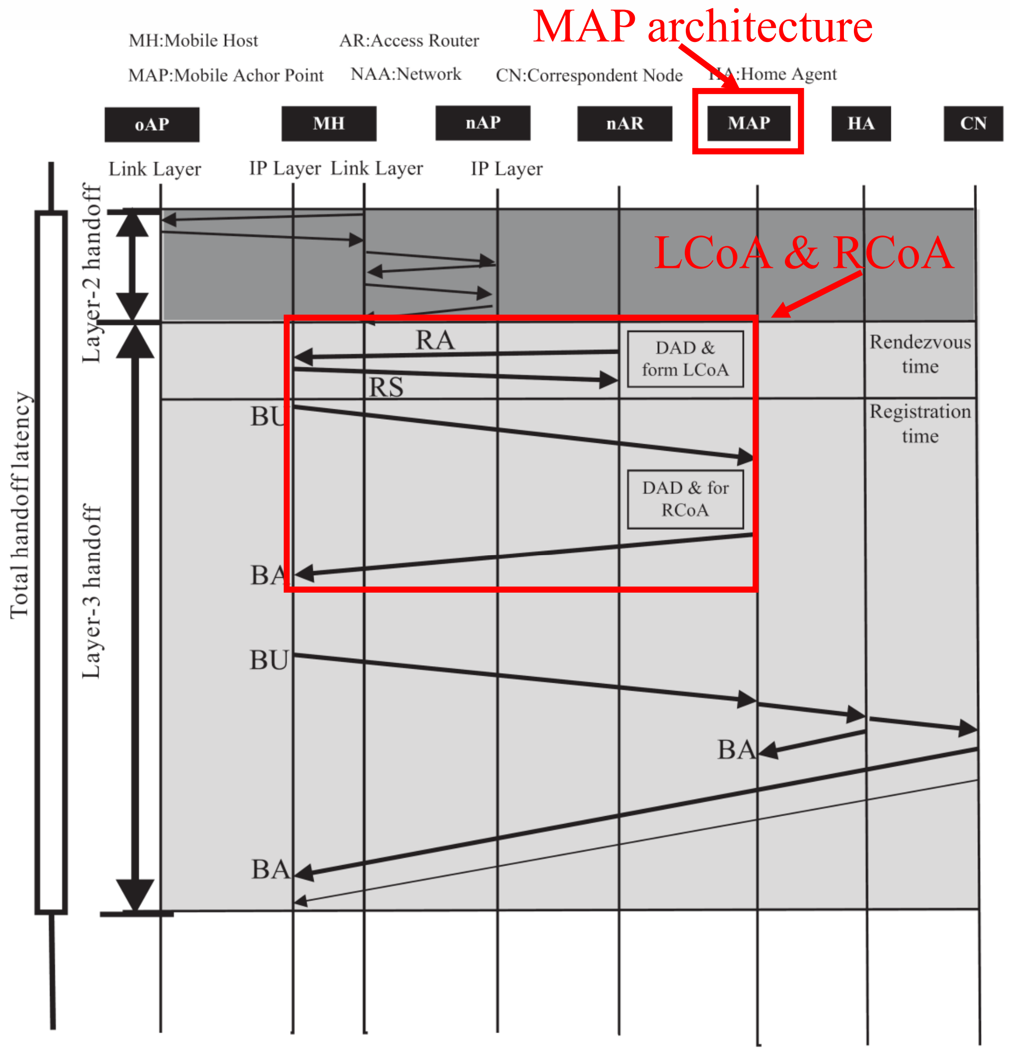
H.-C. Chao and C.-Y. Huang, "Micro-Mobility Mechanism for Smooth Handoffs in an Integrated Ad-Hoc and Cellular IPv6 Network Under High-Speed Movement, "*IEEE Transactions on Vehiclar Techology (VT)*, Vol. 52, No. 6, pp. 1576 - 1593, November 2003.

- A smooth mobile IPv6 handoff under high-speed
  - Decreasing packets loss under high-speed
  - Using dynamic access router
  - Modify BS to hold the packets
  - Using multicast to forwarding packets



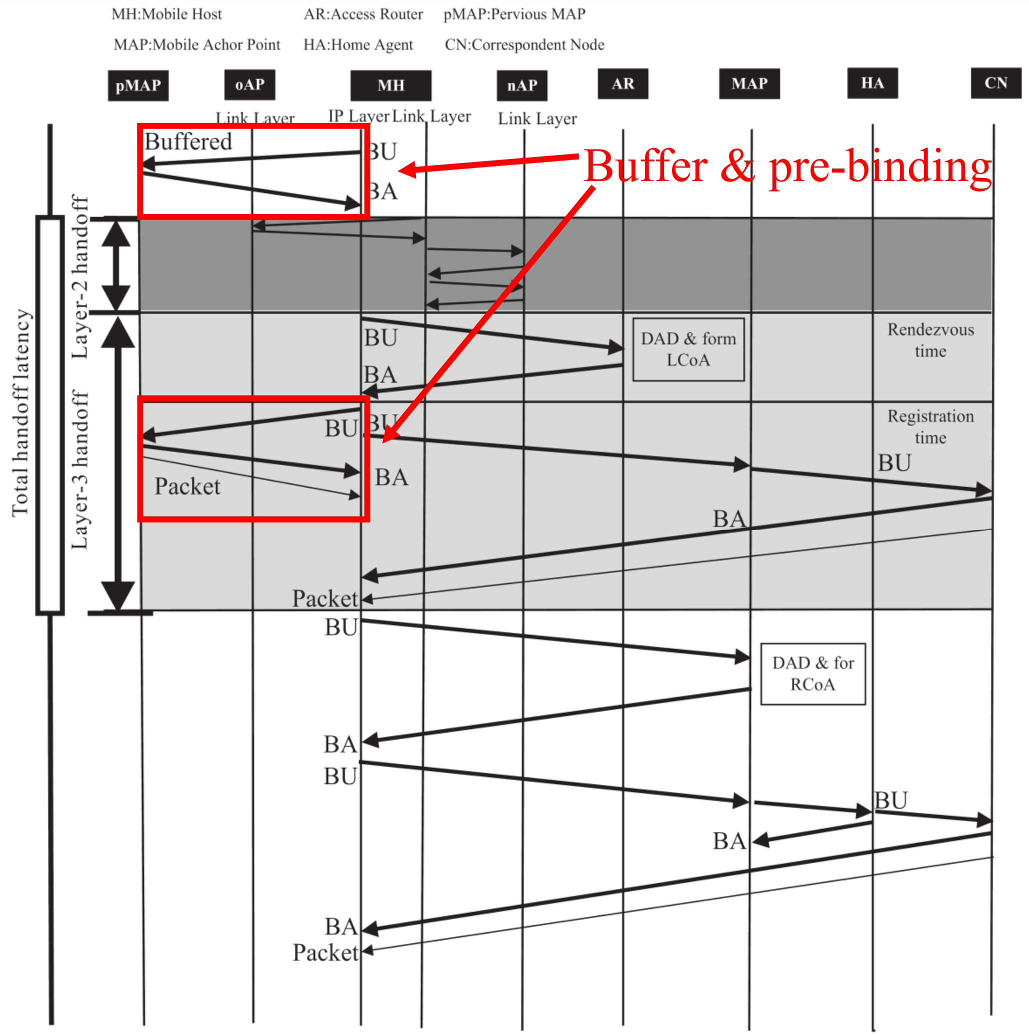
H. Soliman and C. Castelluccia and K.-E. Malki and L.Bellier, ”Hierarchical Mobile IPv6mobility management (HMIPv6), ” *Internet Engineering Task Force (IETF) Internet-Draft*, June 2003

- A hierarchical architecture mobile IPv6.
  - A hierarchical structure for mobile IPv6.
  - Add MAP for local subnet management
  - Two location address: LCoA、RCoA



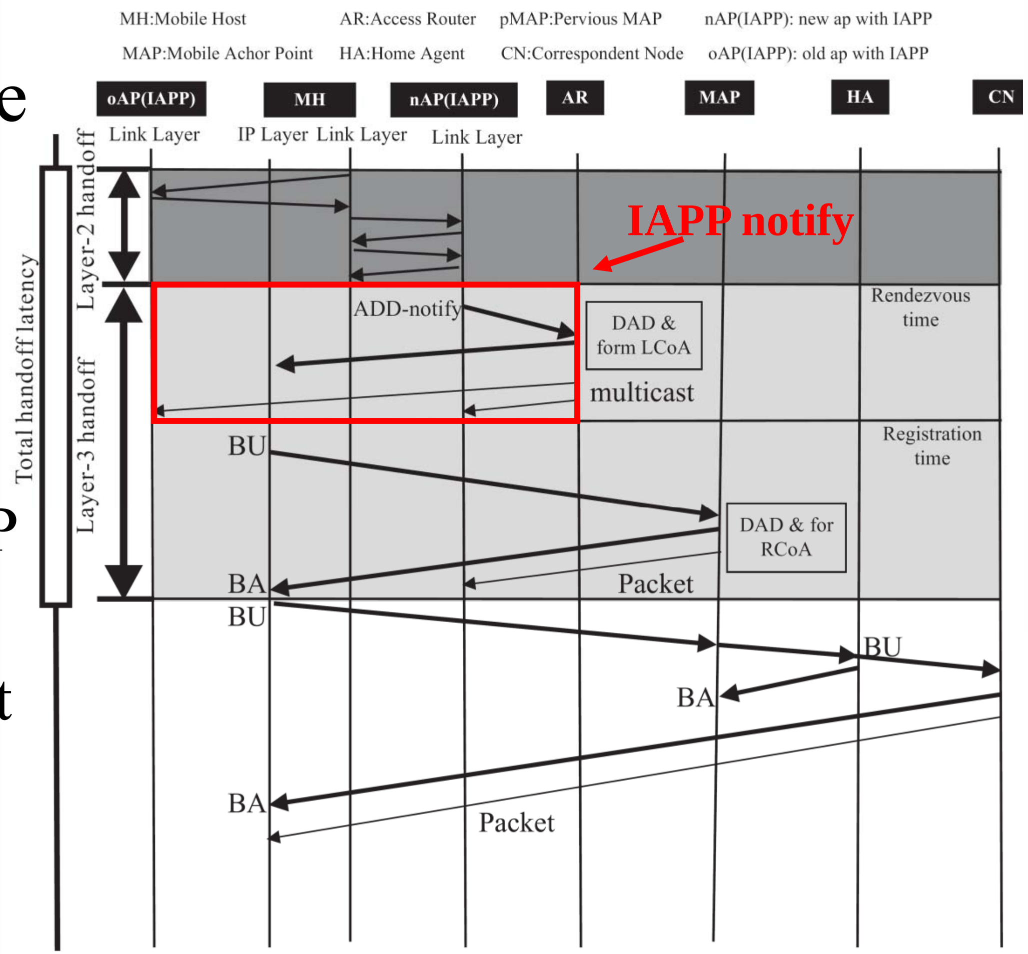
W.-K. Lai and J.-C. Chiu, "Improving Handoff Performance in Wireless Overlay Networks by Switching Between Two-Layer IPv6 and One-Layer IPv6 Addressing (SHMIPv6)," *IEEE Journal On Selected Areas In Communications (JSAC)*, Vol. 23, No. 11, pp. 621 - 628, November 2005.

- A steal-time hierarchical architecture mobile IPv6.
  - Decreasing the DAD for RCoA by pre-binding
  - Using buffer for incoming packets
  - Using pre-binding to transfer packets to current LCoA



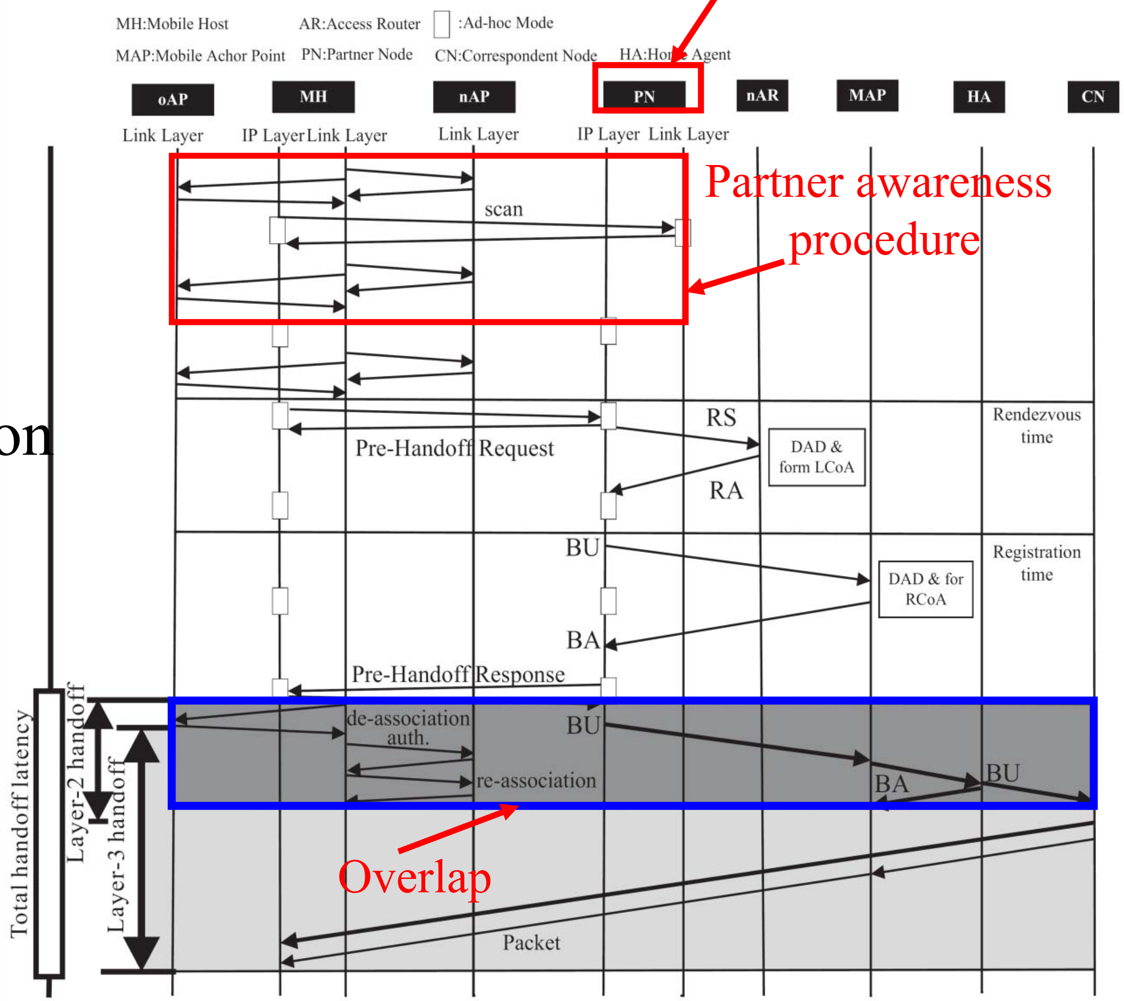
C.-W. Lee and L.-M. Chen and M.-C. Chen and Y.-S. Sun, "A Framework of Handoffs in Wireless Overlay Networks Based on Mobile IPv6 (HMIPv6+)," *IEEE Journal On Selected Areas In Communications (JSAC)*, Vol. 23, No. 11, pp. 629 - 638, November 2005.

- A hierarchical architecture for mobile IPv6+
  - Using IAPP notify to decrease the moving detecting time
  - Using ADD-notify to MAP for intranet handoff
  - Using IAPP IPv6 multicast

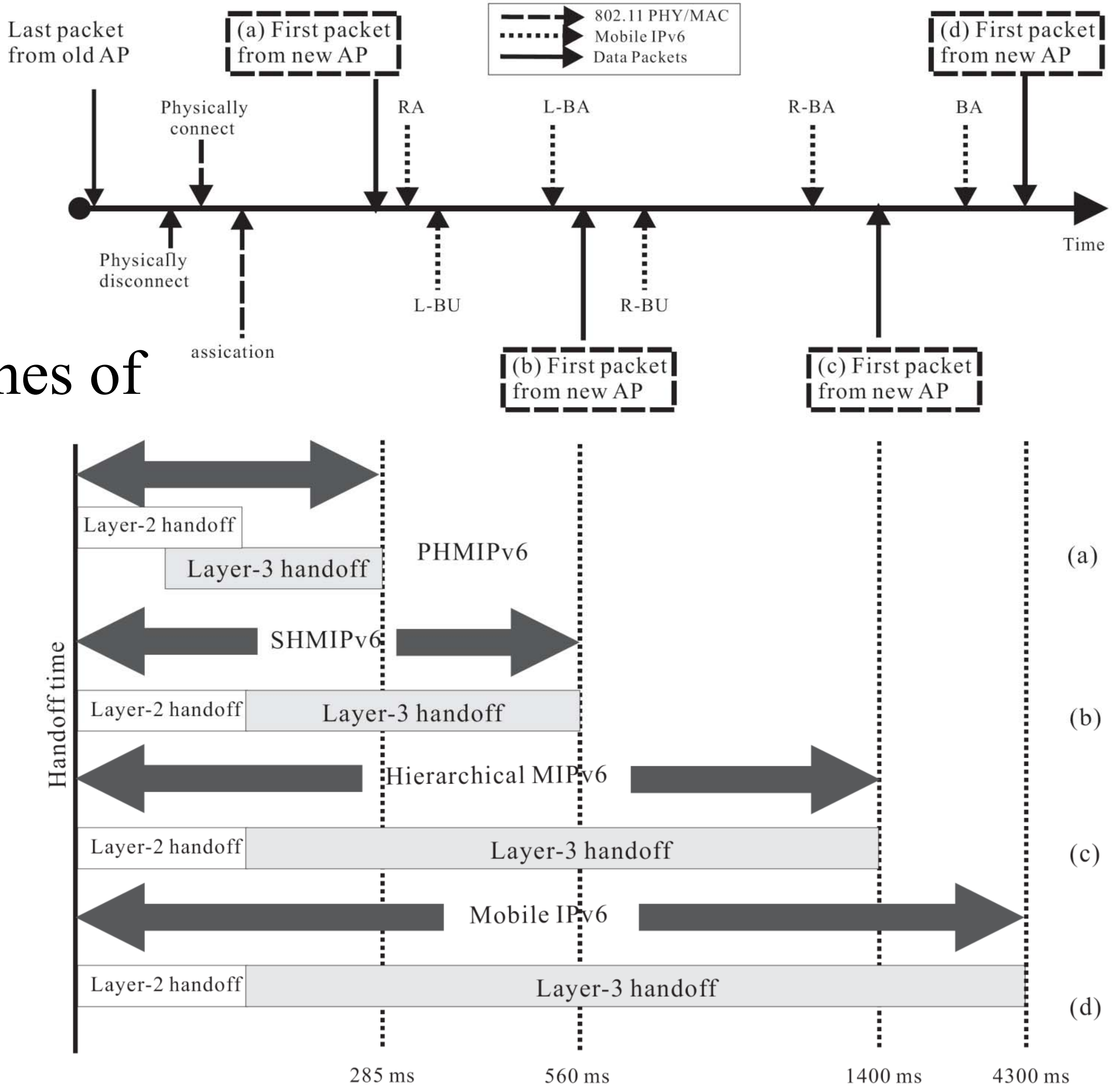


Partner based HMIPv6 (PHMIPv6)

- Cross-layer partner based fast handoff
  - Under HMIPv6 architecture
  - Using layer-2 information to enhance layer-3 handoff
  - Finding partner-node in new MAP domain
  - Decreasing the LCoA and RCoA's DAD time



Handoff times of protocols



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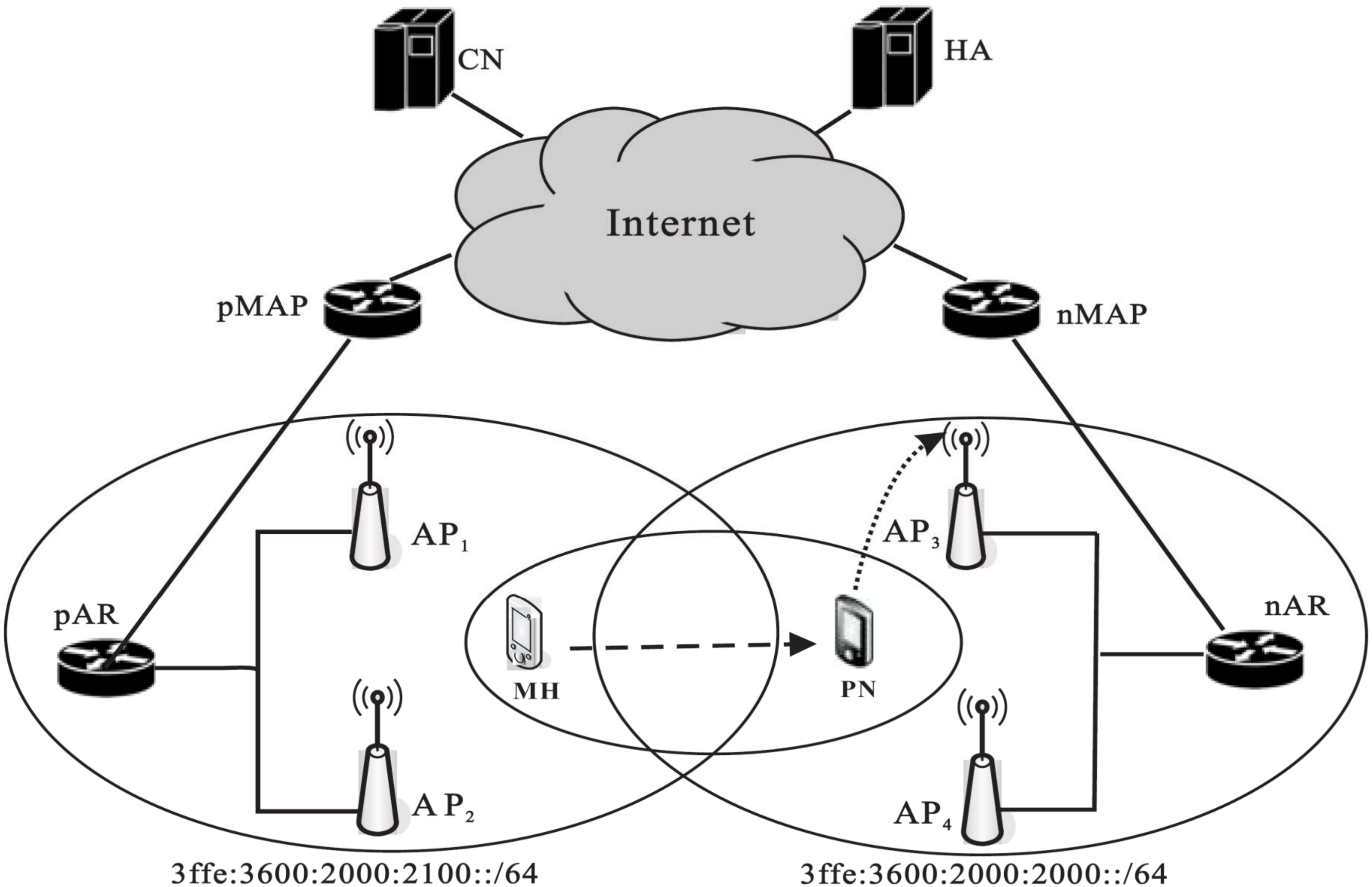
Motivation

- HMIPv6 still suffers a long latency
  - The DAD time for LCoA and RCoA represent the the main time of layer-3 handoff
  - Cross-layer fast handoff mechanism is more efficient.
- The handoff procedure of layer-3 can be pre-handoff by PN.

Definition

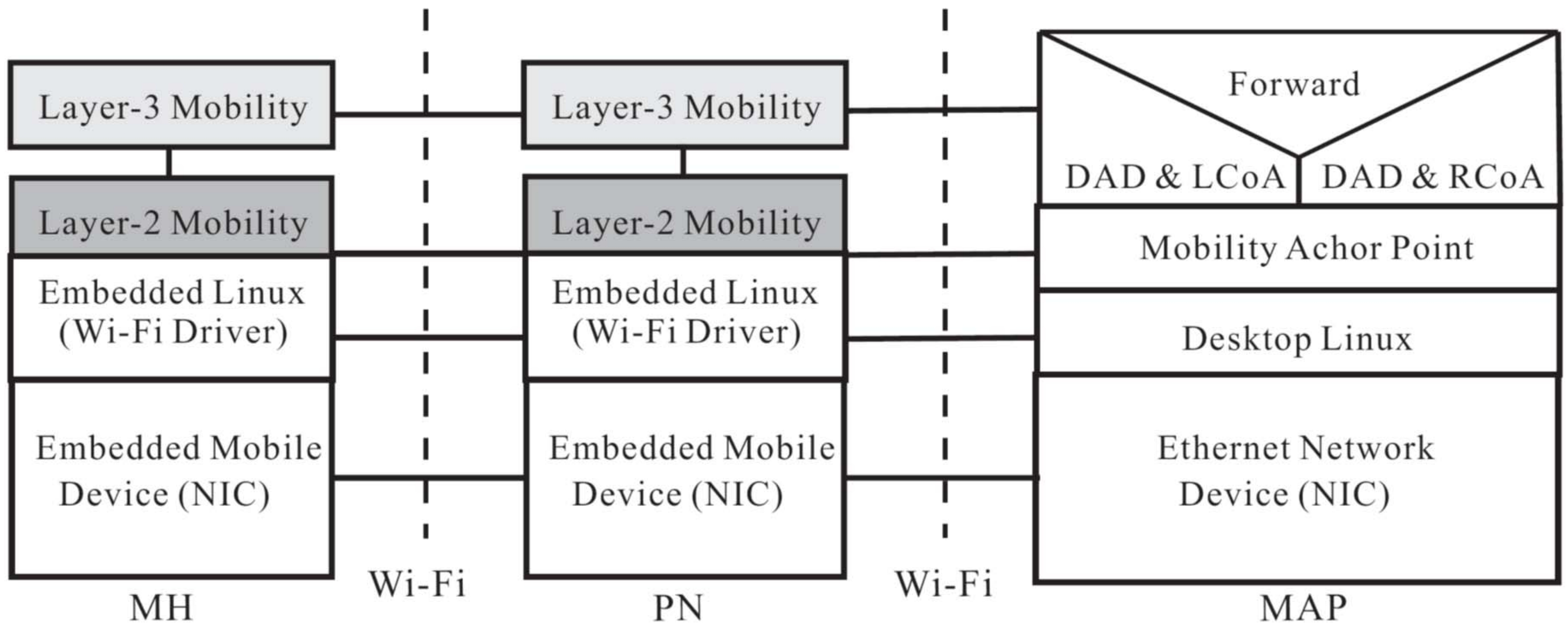
- Partner Node (PN):
  - A neighboring node of the MN, denoted as PN, where MN and PN are located in different MAP domains.
  - The PN can directly connects with IP network through AP (access point) and can directly communicate with the MN by the using ad hoc network.
  - The main task of PN is to perform the pre-handoff procedure for the MN before MN reach to a new MAP\ domain.

System architecture



PHMIPv6

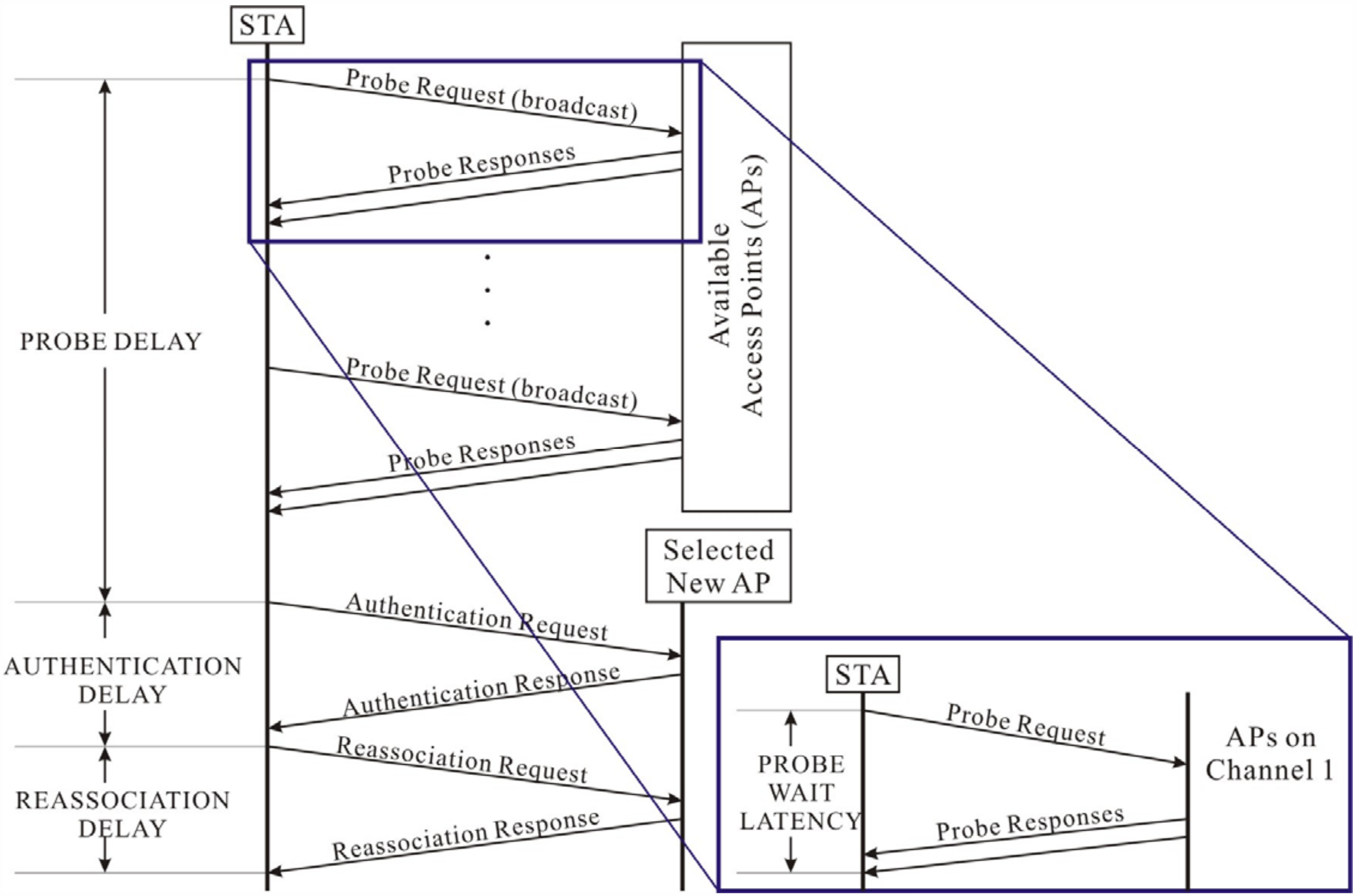
System protocol stack



Basic idea

- Using the deucescan scheme in layer-2.
  - Collecting all information of the neighbor APs.
  - Using layer-2 information to detect MH's moving.
- Using partner-based mechanism in layer-2/3.
  - Using the deucescan information to find partner node
  - Pre-handoff by partner-node for LCoA and RCoA DAD time.

Layer-2 handoff procedure in IEEE 802.11

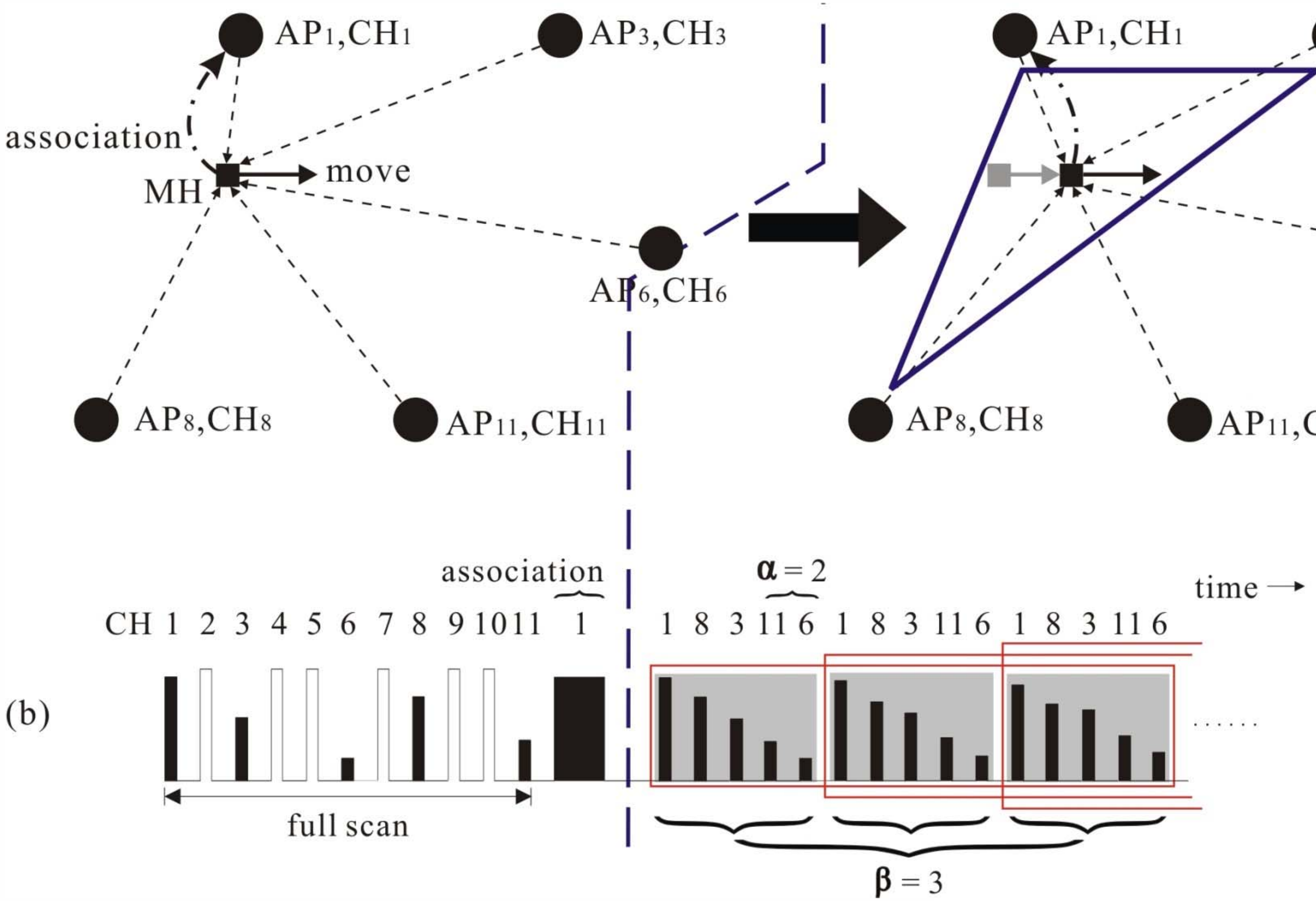


Deucescan procedure

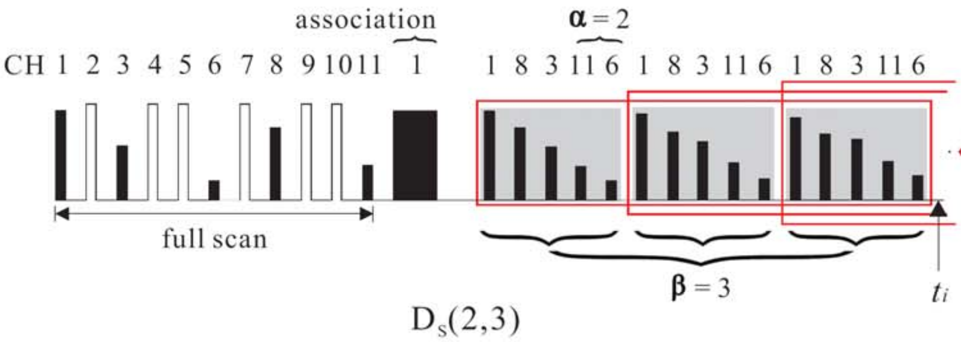
- The deuce procedure is used for confirming whether the RSS received from an MH at some place are stable by continuously probing nearby APs and judges if it needs to change the current spatiotemporal triangle.
- We denote a deuce procedure with signal strength as $D_s(\alpha,\beta)$.

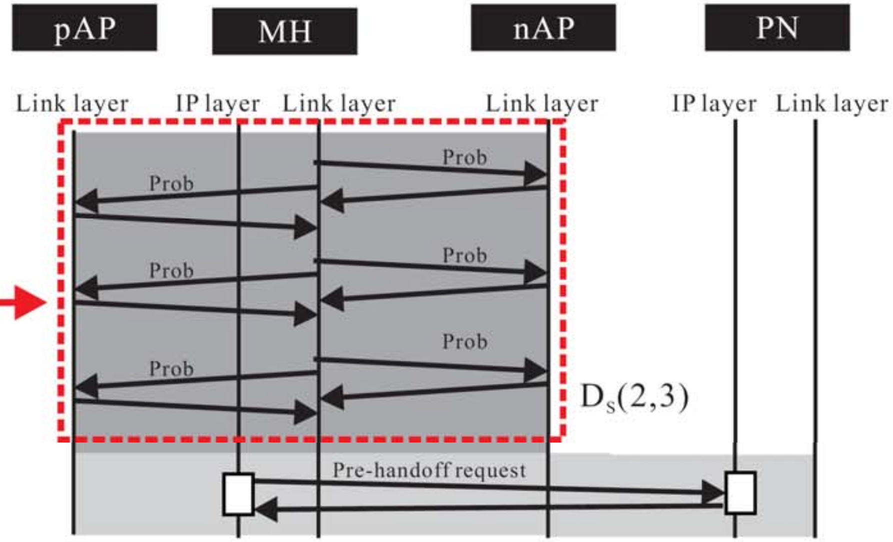
Y.-S. Chen and C.-K. Chen and M.-C. Chuang, "DeuceScan: Deuce-Based Fast Handoff Scheme in IEEE 802.11 Wireless Networks," *IEEE Vehicular Technology Conference (VTC)*, pp. 25 - 28, September 2006.

Example of $D_s(2,3)$



Cross-layer idea





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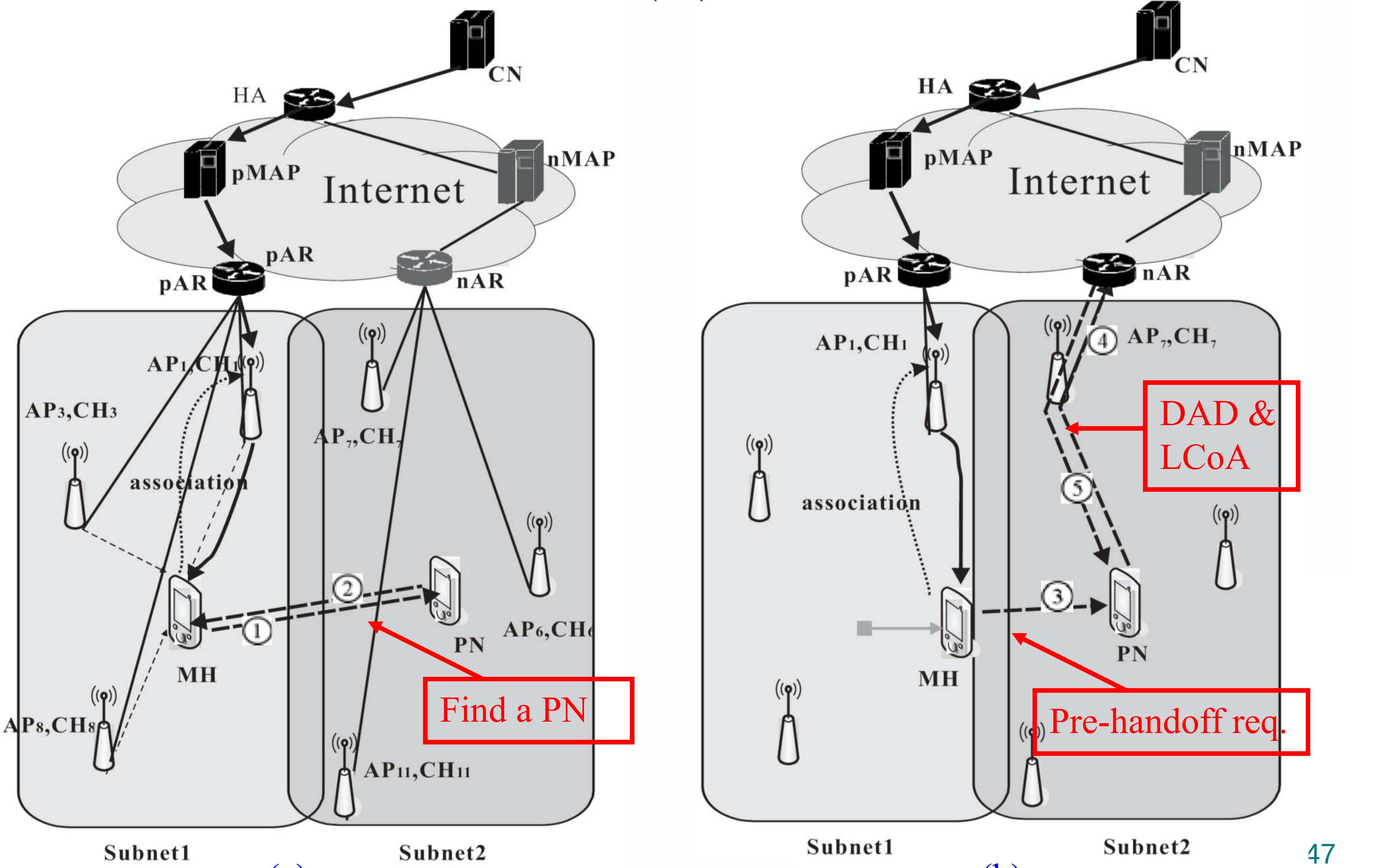
Partner-based HMIPv6 (PHMIPv6)

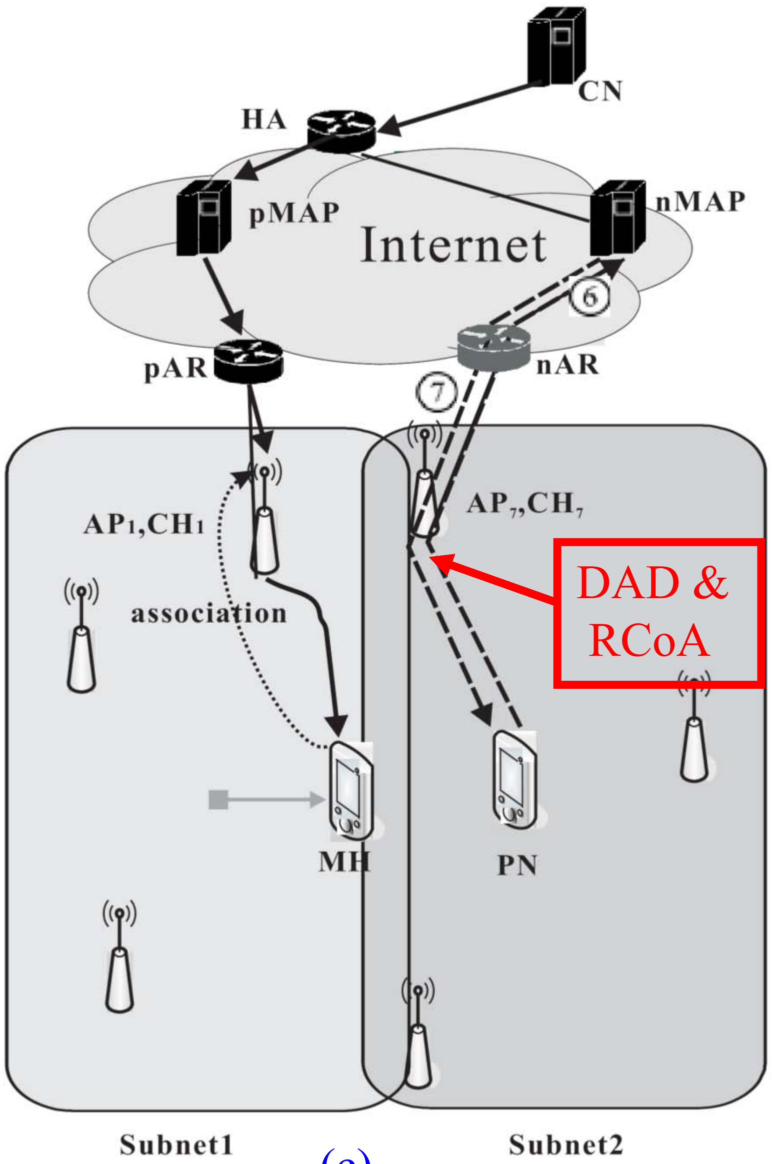
- Our key idea is to utilize the PN in new MAP domain and uses layer-2 + layer-3 approach.
- The approach has been divided into following cases:
  - Successful case: MH finds a PN in nMAP domain, and then MH switches to the same nMAP domain.
  - Unsuccessful case: MH finds a PN in nMAP domain, but MH switches to a different nMAP domain.
  - Others: If no PN is existed in the nMAP domain, MH performs the original HMIPv6 handoff protocol.

Successful scenario (1)

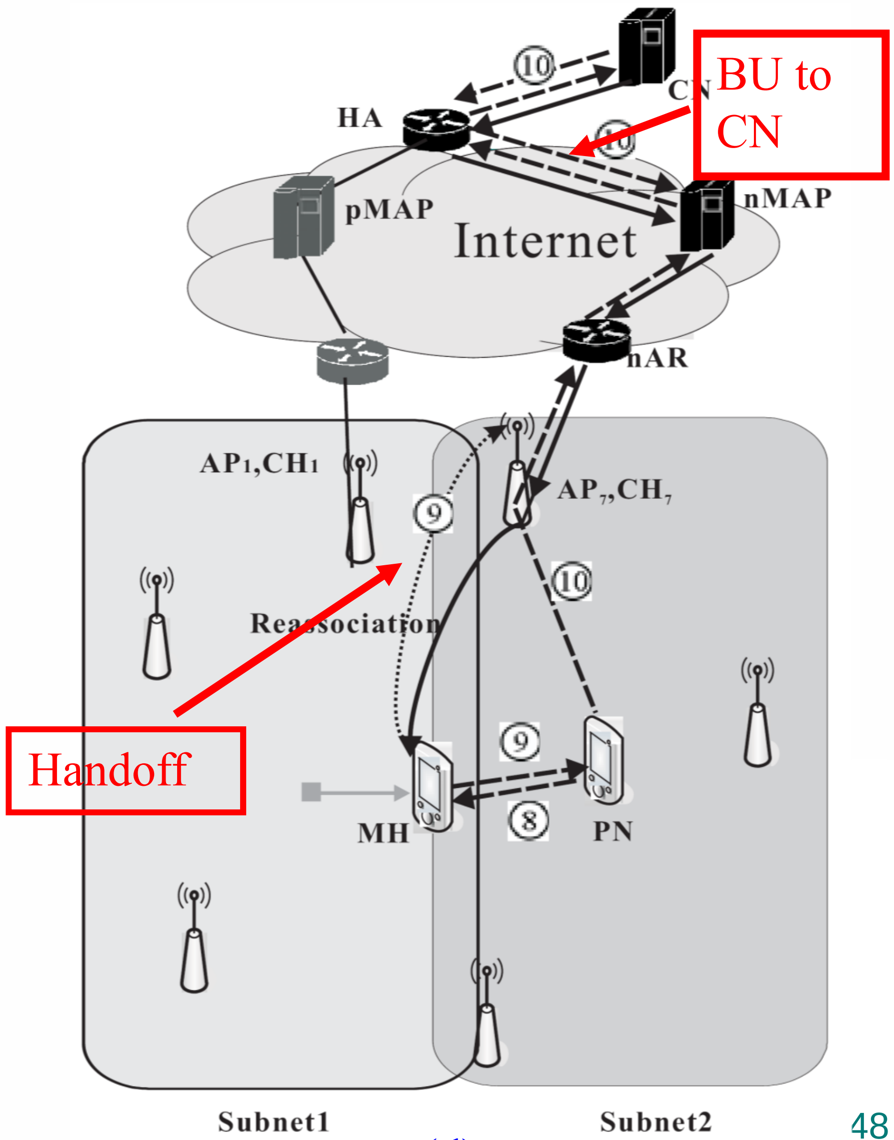


(a) (b)

Successful scenario (2)

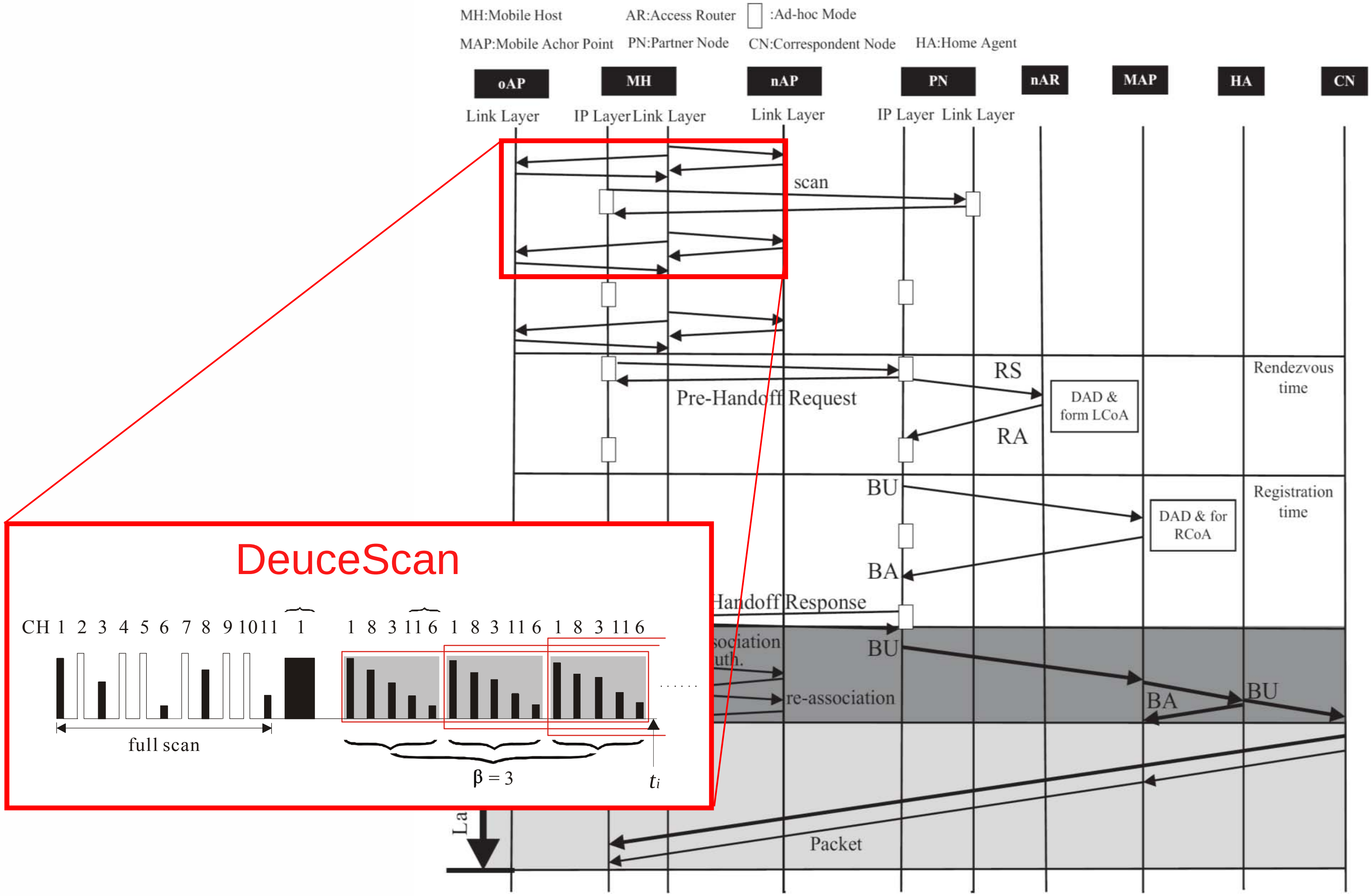


(c)



(d)

Partner-based HMIPv6 (PHMIPv6)



4. Partner-based HMIPv6 (PHMIPv6)

Successful case

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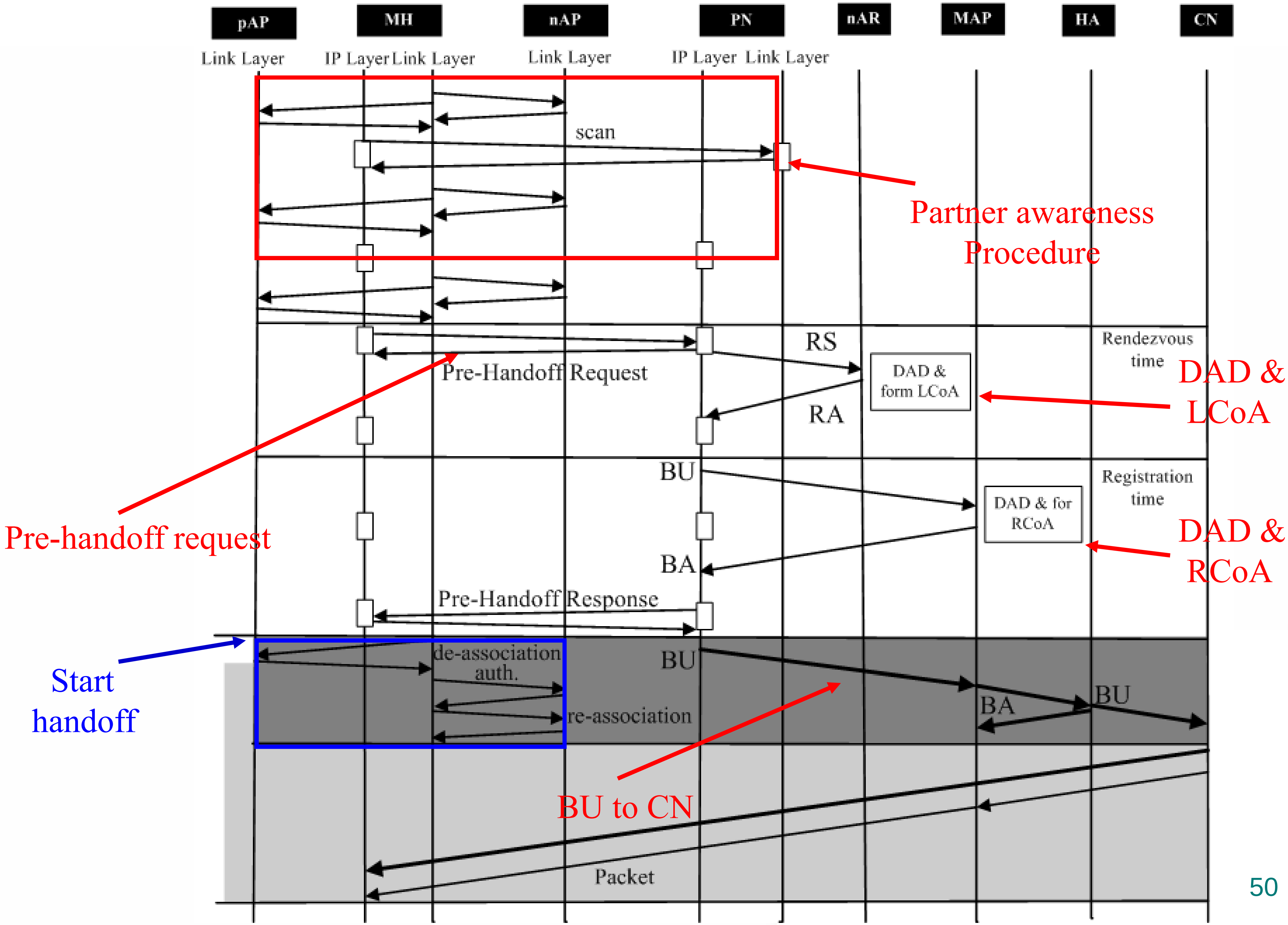
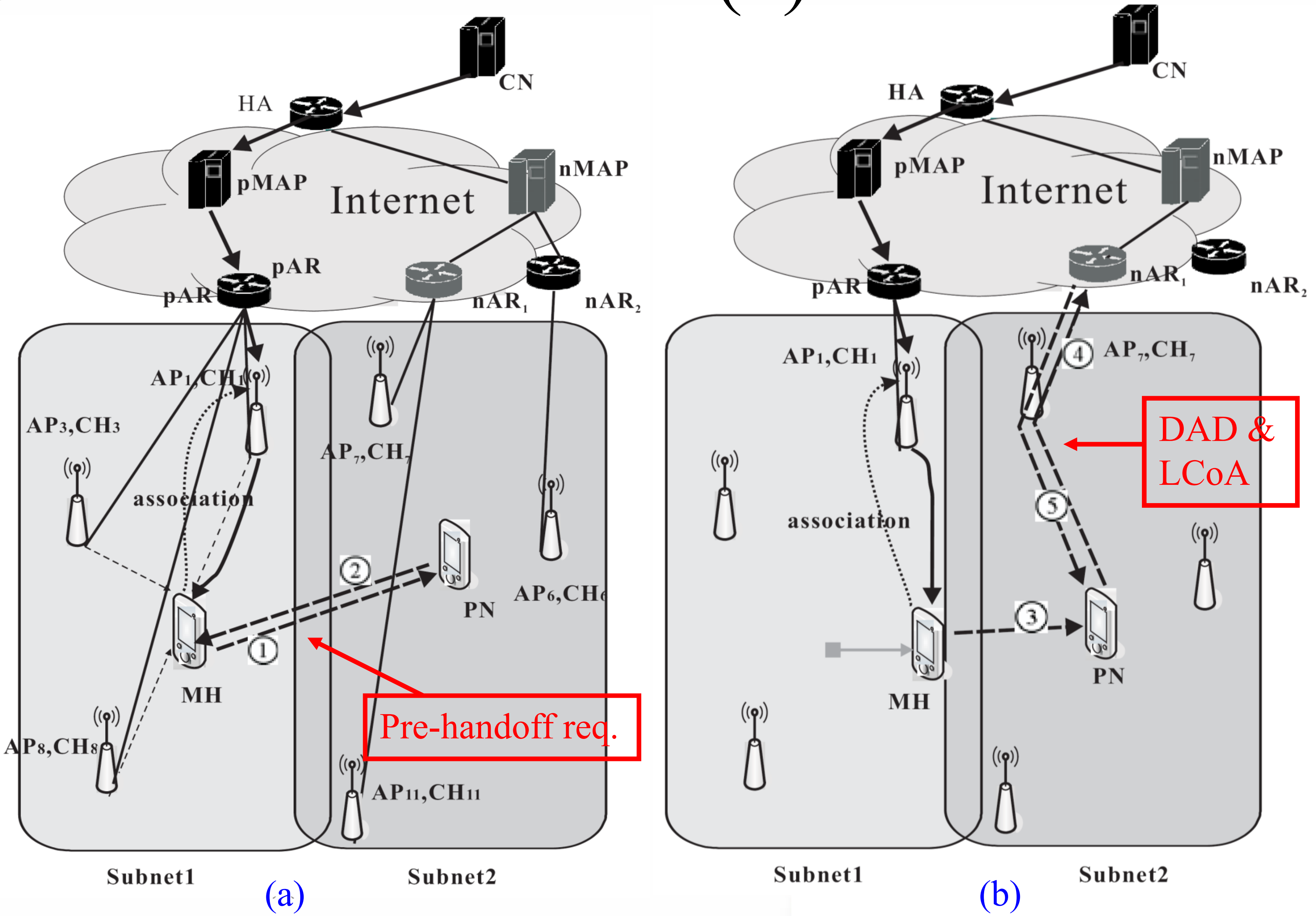
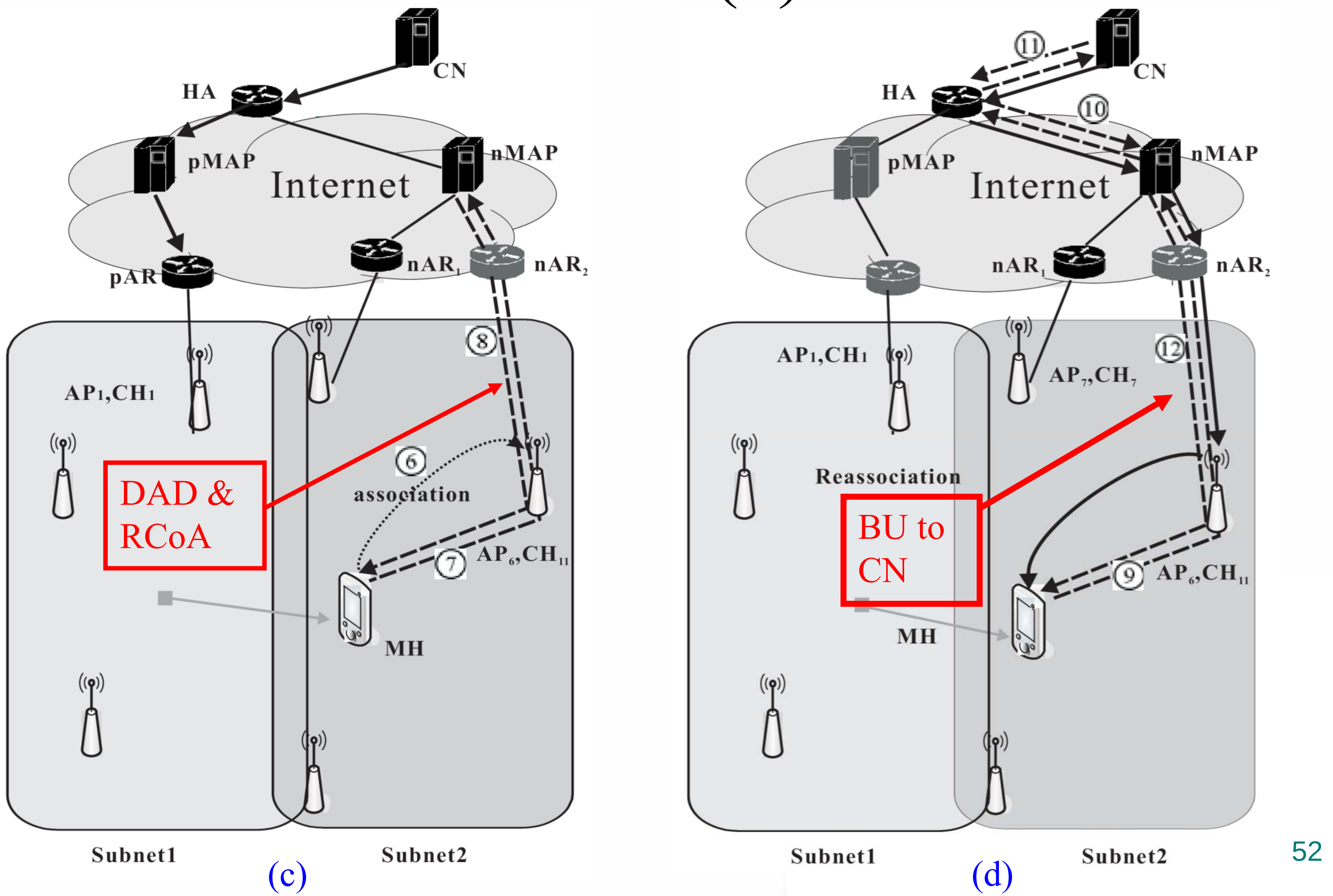
MH:Mobile Host
AR:Access Router
:Ad-hoc Mode
MAP:Mobile Achor Point
PN:Partner Node
CN:Correspondent Node
HA:Home Agent



Unsuccessful scenario (1)

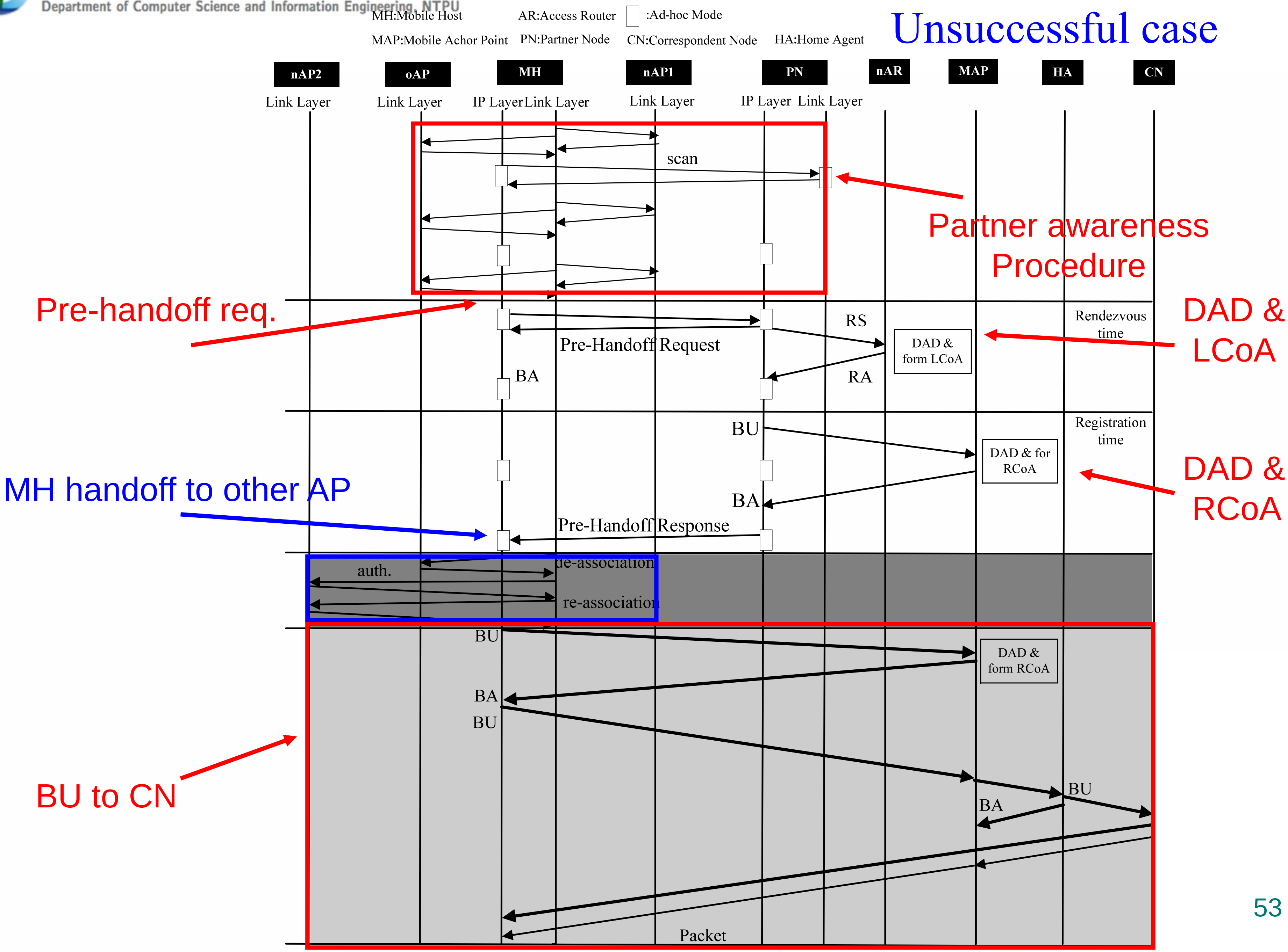


Unsuccessful scenario (2)



4. Partner-based HMIPv6 (PHMIPv6)

Unsuccessful case



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Mathematical analysis and simulation results

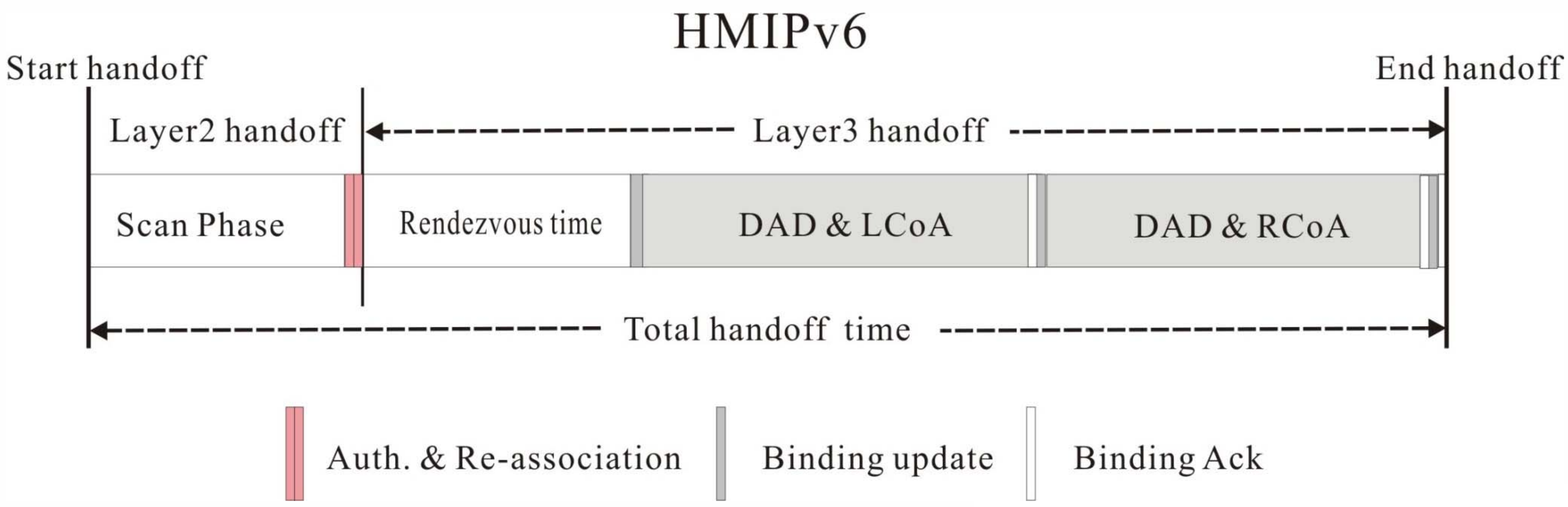
- Mathematical analysis and simulation
  - Mathematical analysis the handoff latency
- MIPv6, HMIPv6, SHMIPv6, PHMIPv6, U-PHMIPv6
  - Handoff latency
  - Handoff packet lost rate
  - Handoff jitter

Mathematical analysis (1)

- Network parameters

Network parameter	Field description
BW_w	Bandwidth of the wired backbones
BW_{wl}	Bandwidth of the wireless link
L_w	Latency of the wired link
L_{wl}	Latency of the wireless link
S_{ctr}	Average size of the control message
n	Number of hops between the MH and the router
$t_{D\_internet}$	Average delay of that a packet traveling in the Internet
t_{D_dad}	Average delay of the DAD time

Mathematical analysis (2)



Total handoff time of HMIPv6

Mathematical analysis (3)

- $t_{rendezvous}$ is the time that MH finds a new AR.

$$t_{rendezvous} = t_{solicitation} + t_{advertisement}$$

$$t_{solicitation} = \left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}$$

$$t_{advertisement} = \left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}$$

Mathematical analysis (4)

- t_{DAD_LCoA} is the DAD time for the link-local CoA.

$$t_{DAD\_LCoA} = t_{binding\_ack} + t_{D\_dad}$$

$$t_{binding\_ack} = (\frac{S_{ctr}}{BW_{wl}} + L_{wl}) + n(\frac{S_{ctr}}{BW_{w}} + L_{w}) + t_{D\_internet}$$

- $t_{binding\_CN}$ is the binding update time to CN.

$$t_{binding\_CN} = 2\left[(\frac{S_{ctr}}{BW_{w}} + L_{w}) + t_{D\_internet}\right]$$

Mathematical analysis (5)

- t_{DAD_RCoA} is the DAD time for the regional CoA.

$$t_{DAD\_RCoA} = t_{binding\_MAP} + t_{binding\_ack} + t_{D\_dad}$$

$$t_{binding\_MAP} = (\frac{S_{ctr}}{BW_{wl}} + L_{wl}) + n(\frac{S_{ctr}}{BW_{w}} + L_{w}) + t_{D\_internet}$$

$$t_{binding\_ack} = (\frac{S_{ctr}}{BW_{wl}} + L_{wl}) + n(\frac{S_{ctr}}{BW_{w}} + L_{w}) + t_{D\_internet}$$

Mathematical analysis (6)

- t_{HMIPv6} is the handoff latency of HMIPv6.

$$
\begin{aligned}
t_{HMIPv6} &= t_{layer\_2} + t_{rendezvous} + t_{DAD\_LCoA} + t_{DAD\_RCoA} + t_{binding\_CN} \\
&= t_{layer\_2} + 6\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet} \right] \\
&\quad + 2\left[\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet} \right] + 2t_{D\_dad}
\end{aligned}
$$

Mathematical analysis (7)

- $t_{SHMIPv6}$ is the handoff latency of steal-time HMIPv6.

$$
\begin{aligned}
t_{SHMIPv6} &= t_{layer\_2} + t_{rendezous} + t_{DAD\_LCoA} + \min(t_{pmap}, t_{bu\_HA}) \\
&= t_{layer\_2} + 4\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet} \right] \\
&\quad + \min(t_{pmap}, t_{HA}) + t_{D\_dad}
\end{aligned}
$$

Mathematical analysis (8)

Let t_{Δ_1} be the time difference between $t_{SHMIPv6}$ and t_{HMIPv6}.

$$\begin{aligned}
t_{\Delta_1} &= t_{HMIPv6} - t_{SHMIPv6} \\
&= t_{binding_CN} + t_{DAD_RCoA} - \min(t_{pmap}, t_{HA}) \\
&\leq t_{binding_CN} + t_{DAD_RCoA} \\
&= 2\left[(\frac{S_{ctr}}{BW_{wl}} + L_{wl}) + n(\frac{S_{ctr}}{BW_w} + L_w) + t_{D_internet}\right] + 2\left[(\frac{S_{ctr}}{BW_w} + L_w) + t_{D_internet}\right] \\
&\quad + t_{D_dad}
\end{aligned}$$

Mathematical analysis (9)

- $t_{PHMIPv6}$ is the handoff latency of our cross-layer partner-based mechanism (successful case)

$$
\begin{aligned}
t_{PHMIPv6} &= t'_{layer\_2} + t_{layer\_3} - t_{overlap} \\
&= t'_{layer\_2} + t_{binding\_MAP} + t_{binding\_CN} - t_{binding\_MAP} \\
&= t'_{layer\_2} + 2\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}\right]
\end{aligned}
$$

Mathematical analysis (10)

Let t_{Δ_2} be the time difference between t_{HMIPv6} and $t_{PHMIPv6}$.

$$
\begin{aligned}
t_{\Delta_2} &= t_{HMIPv6} - t_{PHMIPv6} \\
&= (t_{layer\_2} - t'_{layer\_2}) + t_{DAD\_LCoA} + t_{DAD\_RCoA} \\
&= (t_{layer\_2} - t'_{layer\_2}) + 4\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet} \right] \\
&\quad +2\left[\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet} \right] + 2t_{D\_dad}
\end{aligned}
$$

Mathematical analysis (11)

$t_{\Delta_2} - t_{\Delta_1}$ means that PHMIPv6 is better than HMIPv6 and SHMIPv6.

$$t_{\Delta_2} - t_{\Delta_1} = 2\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}\right] + (t_{layer-2} - t'_{layer-2}) + 2t_{D\_dad} > 0$$

Mathematical analysis (12)

- $t_{U\_PHMIPv6}$ is the handoff latency of our cross-layer partner-based mechanism (unsuccessful case).

$$
\begin{aligned}
t_{U\_PHMIPv6} &= t'_{layer\_2} + t_{layer\_3} \\
&= t'_{layer\_2} + t_{DAD\_RCoA} + t_{binding\_CN} \\
&= t'_{layer\_2} + 2\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}\right] \\
&\quad + 2\left[\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}\right] + t_{D\_DAD}
\end{aligned}
$$

Mathematical analysis (13)

Let $t_{\Delta 3}$ be the time difference between t_{HMIPv6} and $t_{PHMIPv6}$.

$$
\begin{aligned}
t_{\Delta_3} &= t_{HMIPv6} - t_{U\_PHMIPv6} \\
&= (t_{layer\_2} - t'_{layer\_2}) + t_{DAD\_LCoA} \\
&= (t_{layer\_2} - t'_{layer\_2}) + 2\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet} \right] \\
&\quad + 2\left[\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{internet} \right] + t_{D\_DAD}
\end{aligned}
$$

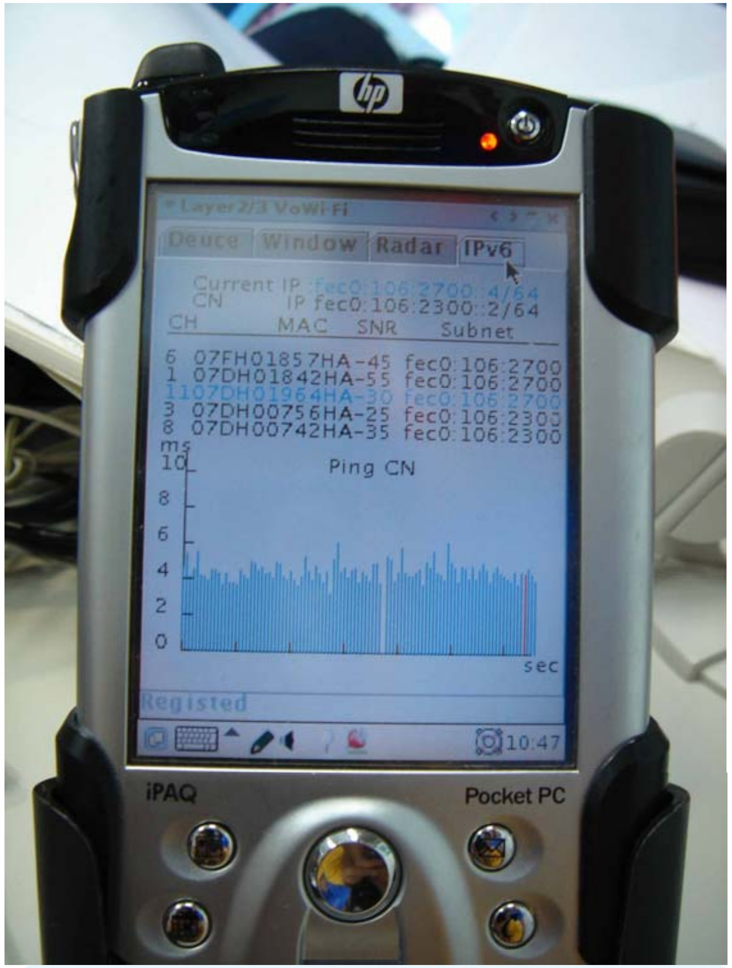
Mathematical analysis (14)

$t_{\Delta_3} - t_{\Delta_1}$ means that F-PHMIPv6 is still better than SHMIPv6.

$$t_{\Delta_3} - t_{\Delta_1} = \left[\left(\frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] + (t_{layer\_2} - t'_{layer\_2}) > 0$$

System implementation

(a) DeuceScan

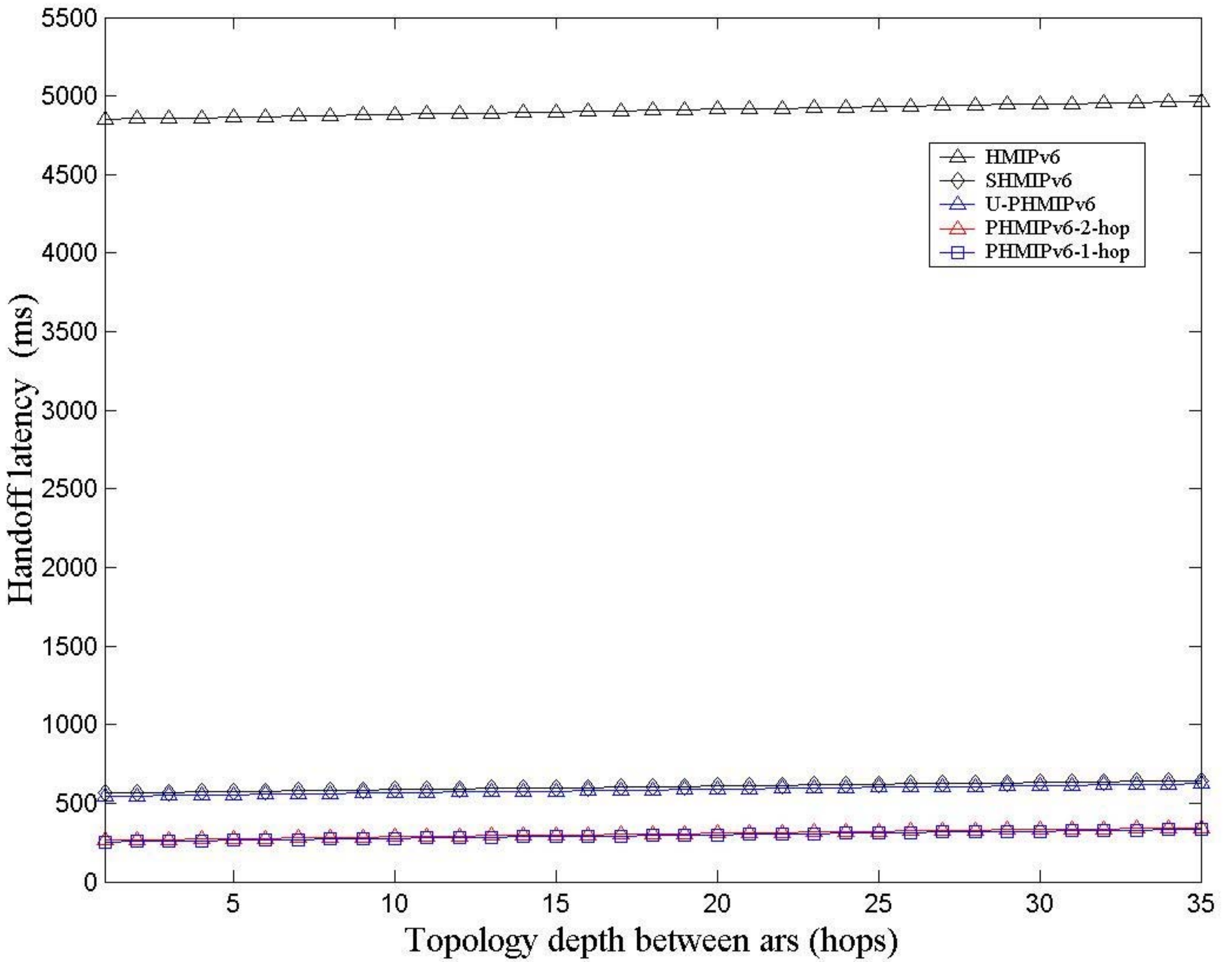


(b) Cross-layer partner-based

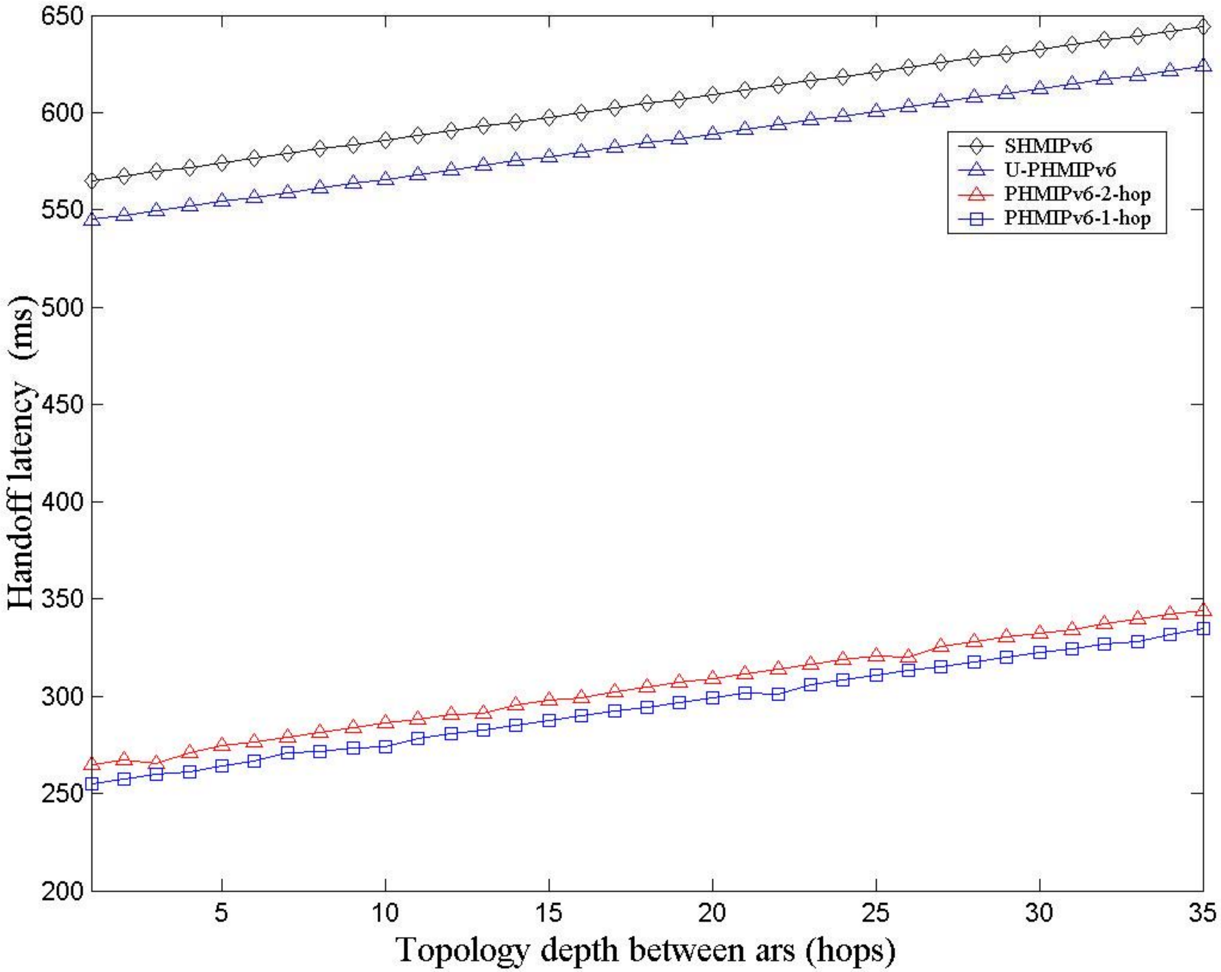
Performance metrics

- *Handoff latency* (*HL*): The handoff latency is the time that MH received last packet from the old base station and the first packet from the new base station.
- *Packet loss rate* (PLR): The packet loss rate is the percentage of the lost packets in the total packets that CN sent to MH.
- *Handoff jitter* (HJ): The handoff jitter is the variation in delay between the packets.

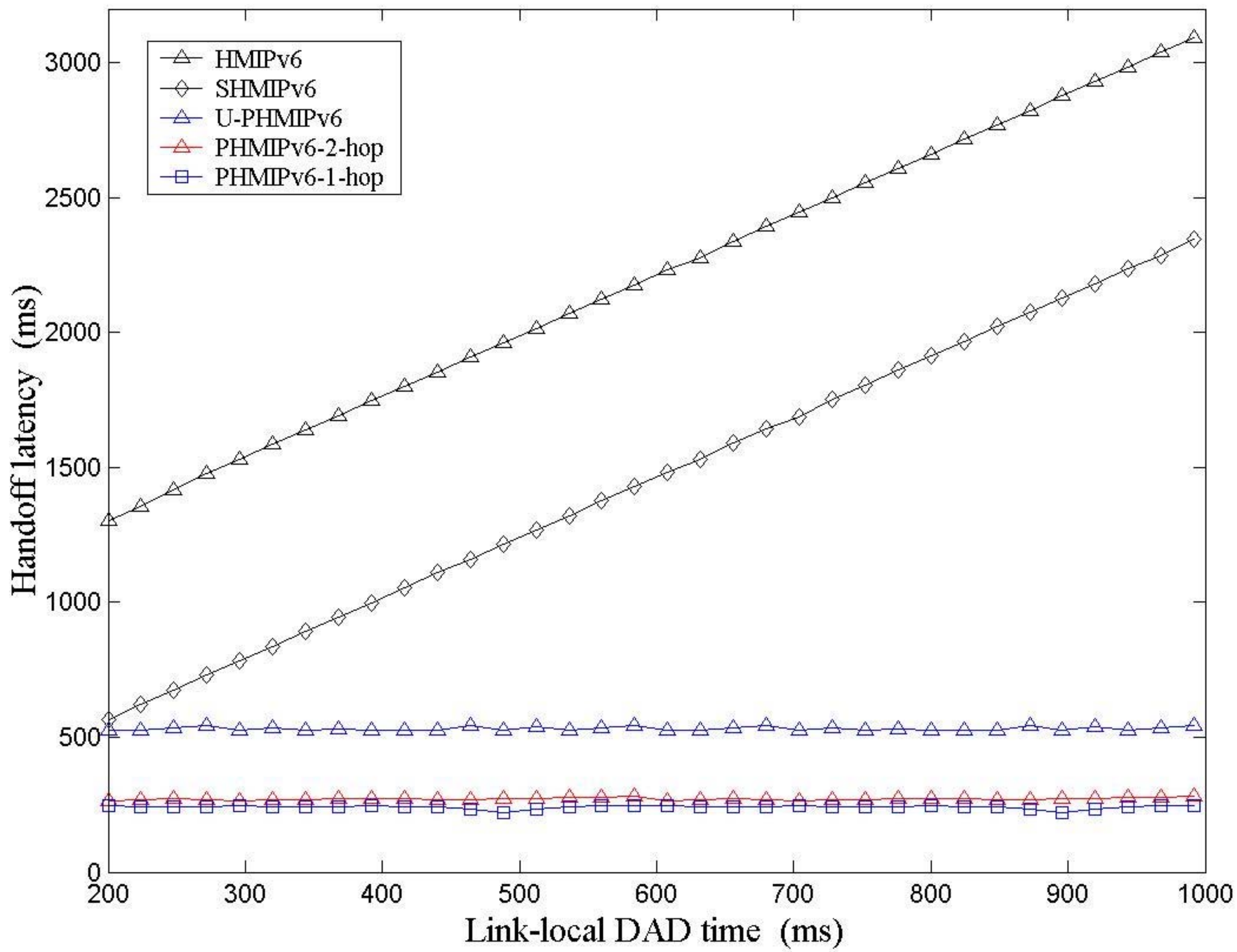
Handoff latency vs. hops (1)



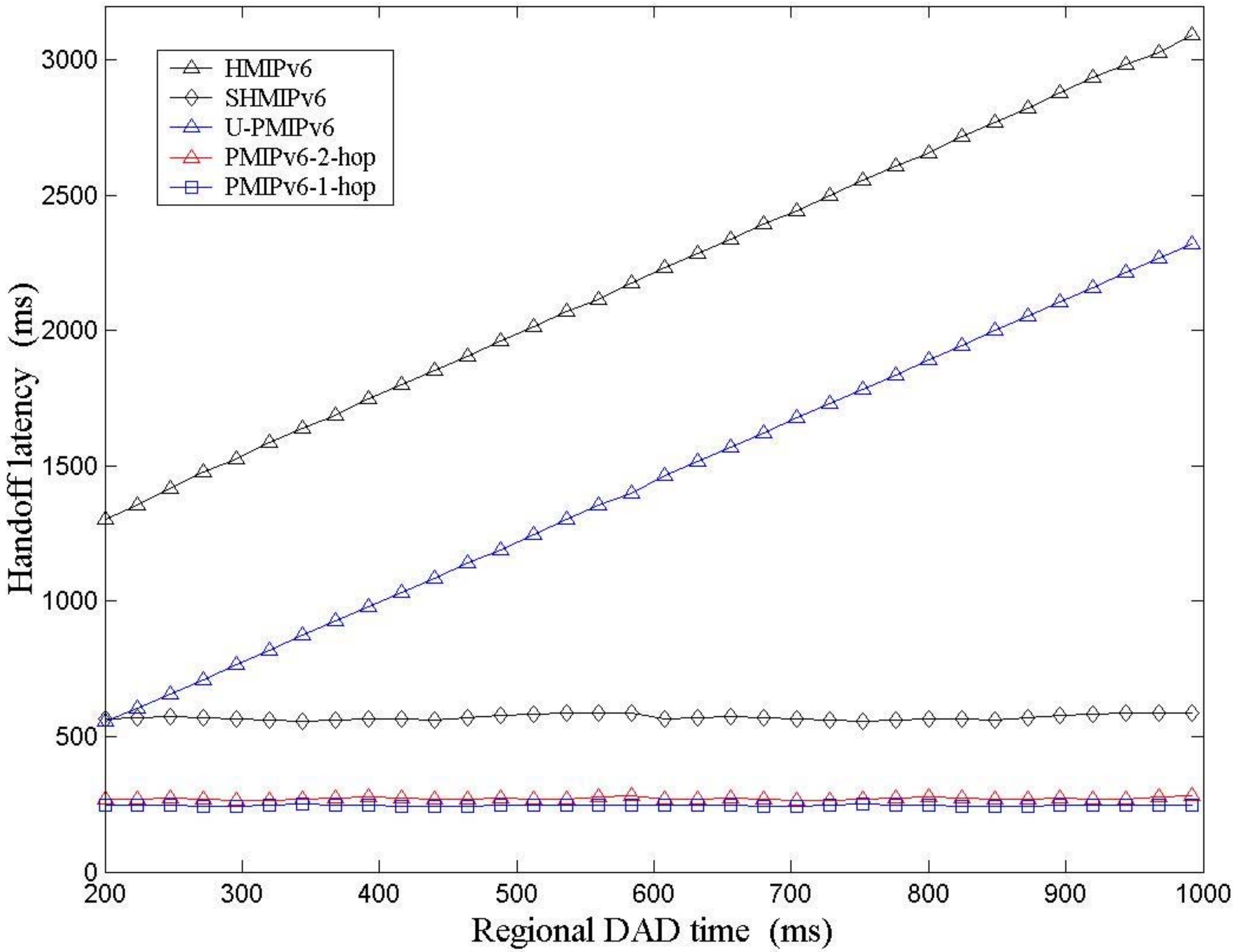
Handoff latency vs. hops (2)



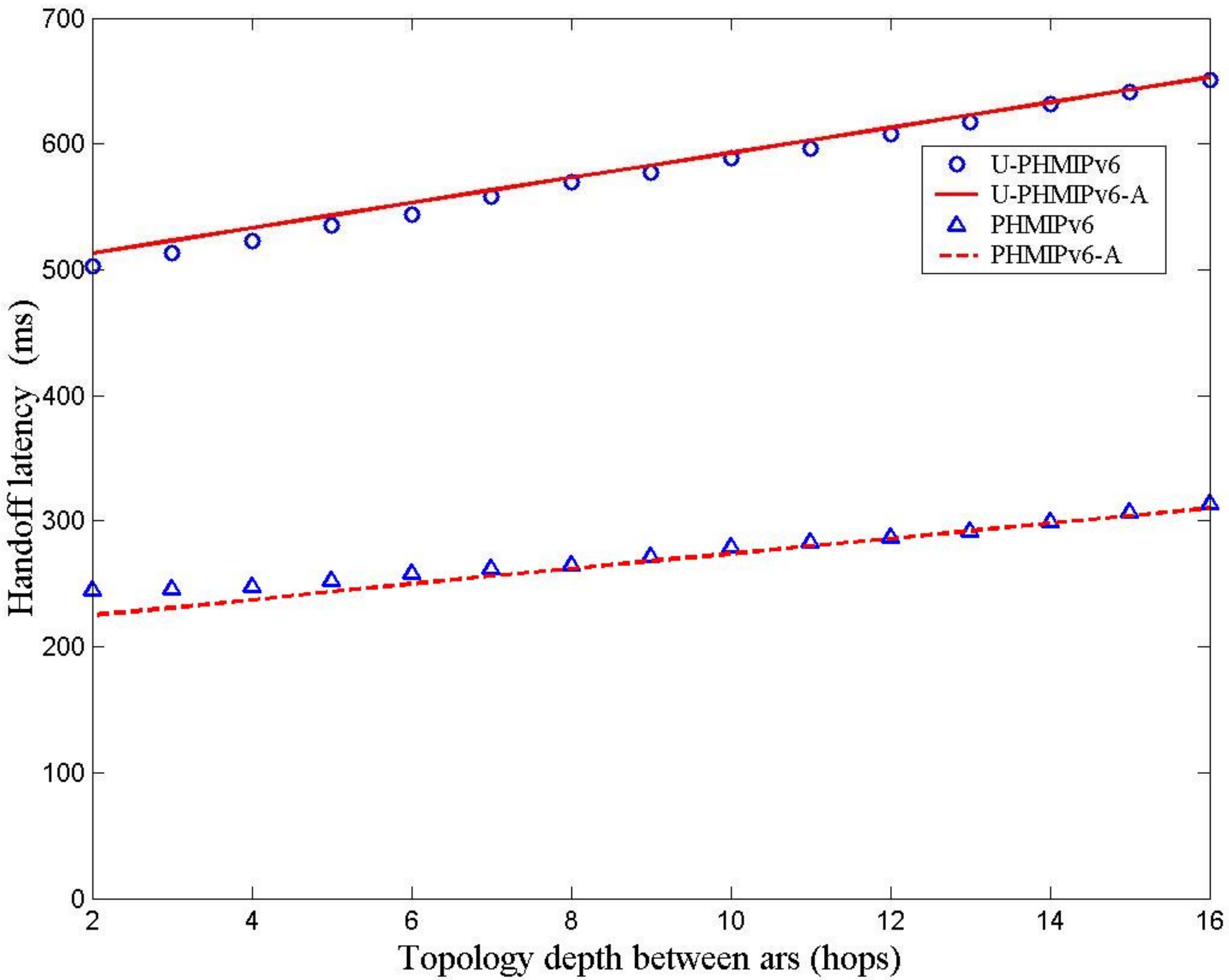
Handoff latency vs. link-local DAD time



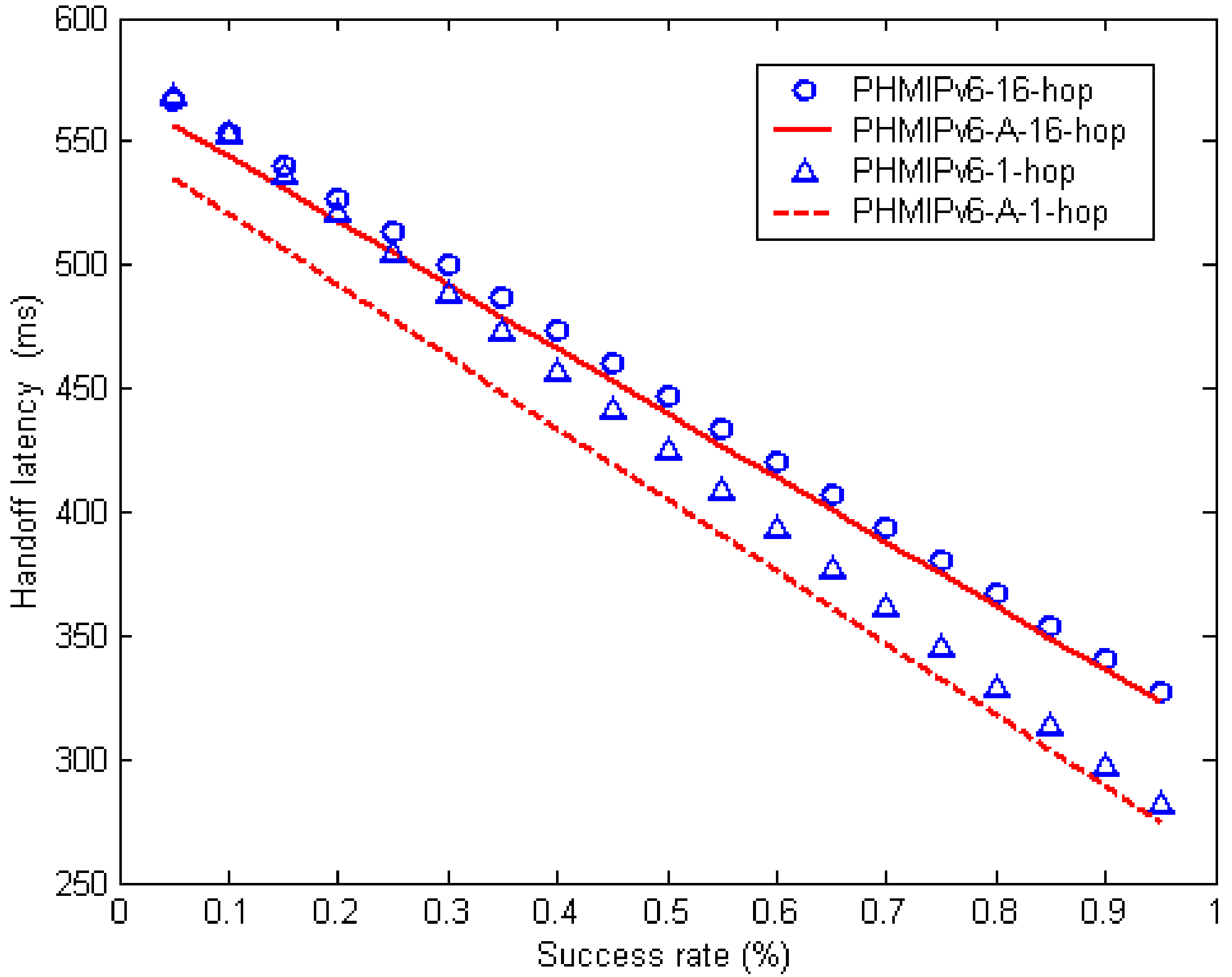
Handoff latency vs. regional DAD time



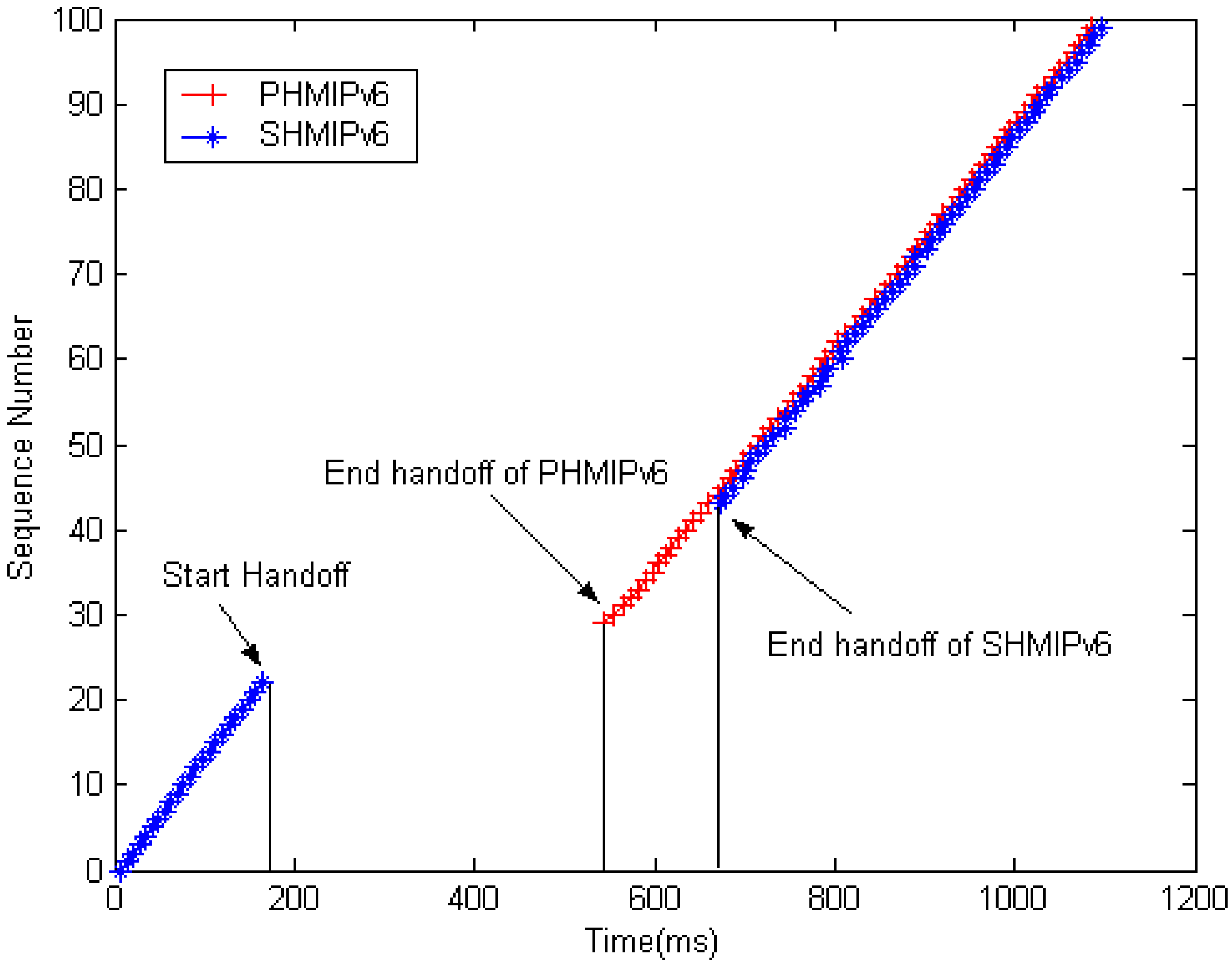
Handoff latency vs. hops (analysis)



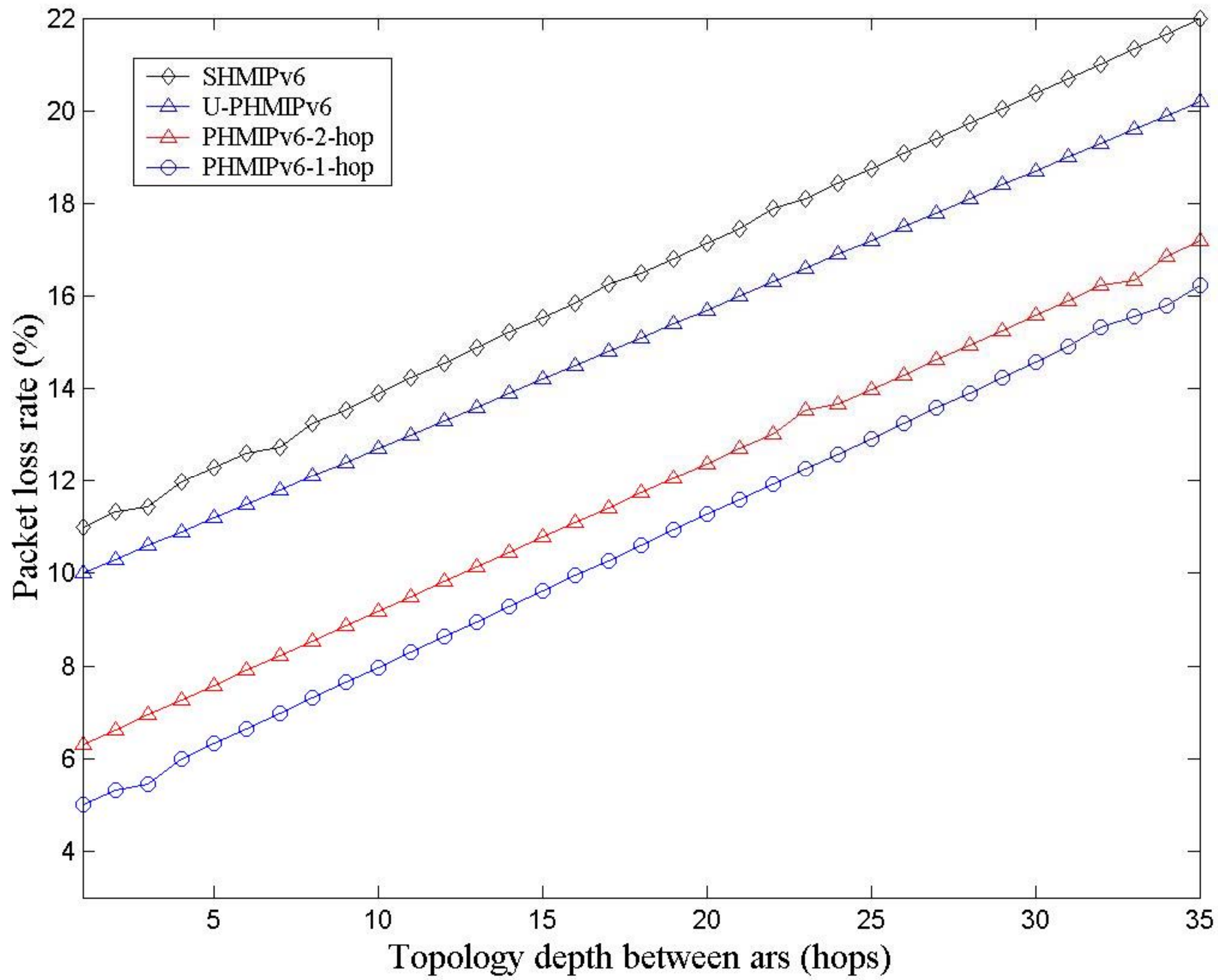
Handoff latency vs. success rate (%)



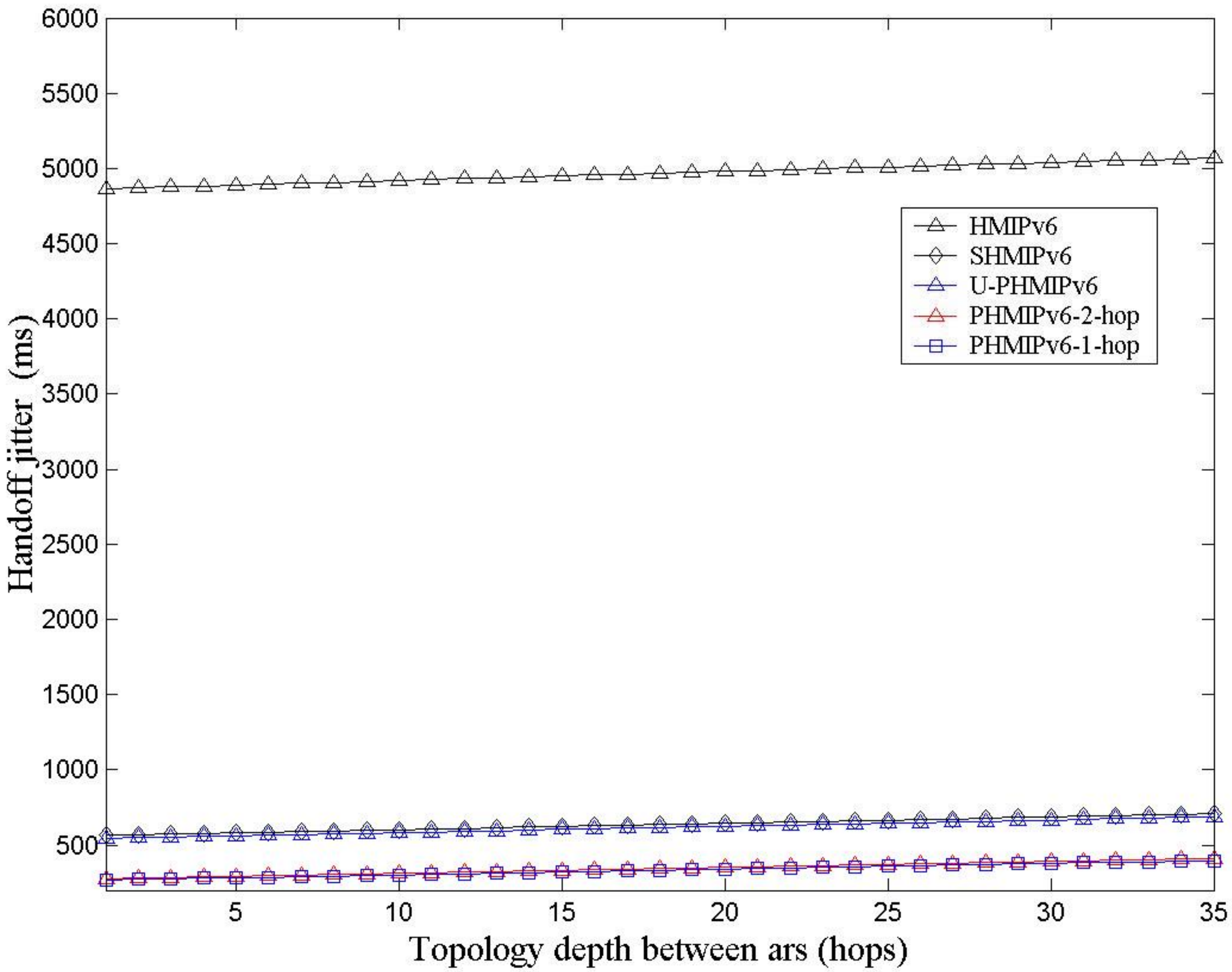
Sequence number vs. time



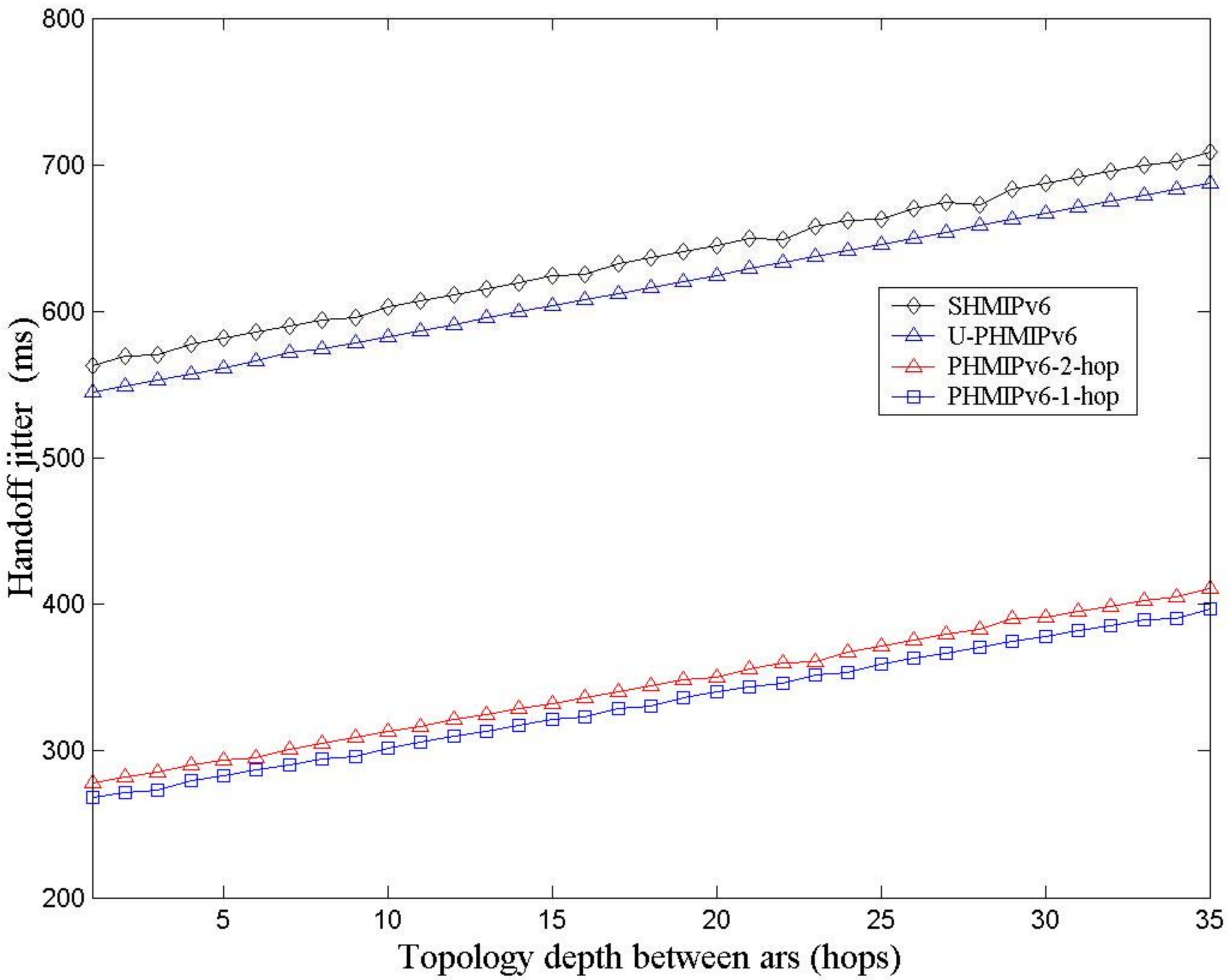
Packet loss rate (%) vs. hops



Handoff jitter vs. hops (1)



Handoff jitter vs. hops (2)



Conclusion

- We propose a handoff strategy, cross-layer partner-based fast handoff mechanism
  - Layer-2 handover using deucescan
  - Layer-3 handover using partner-based fast handoff mechanism
  - Combining the advantages of two mechanisms to decreasing handoff latency

Homework#5:

1. What's MIPv4 ?
2. What's MIPv6 ?
3. What's Hierarchical Mobile IPv6 ?
4. What's Partner-based Hierarchical Mobile IPv6 ?