Cross-Layer Design for Mobility in Wireless Networks

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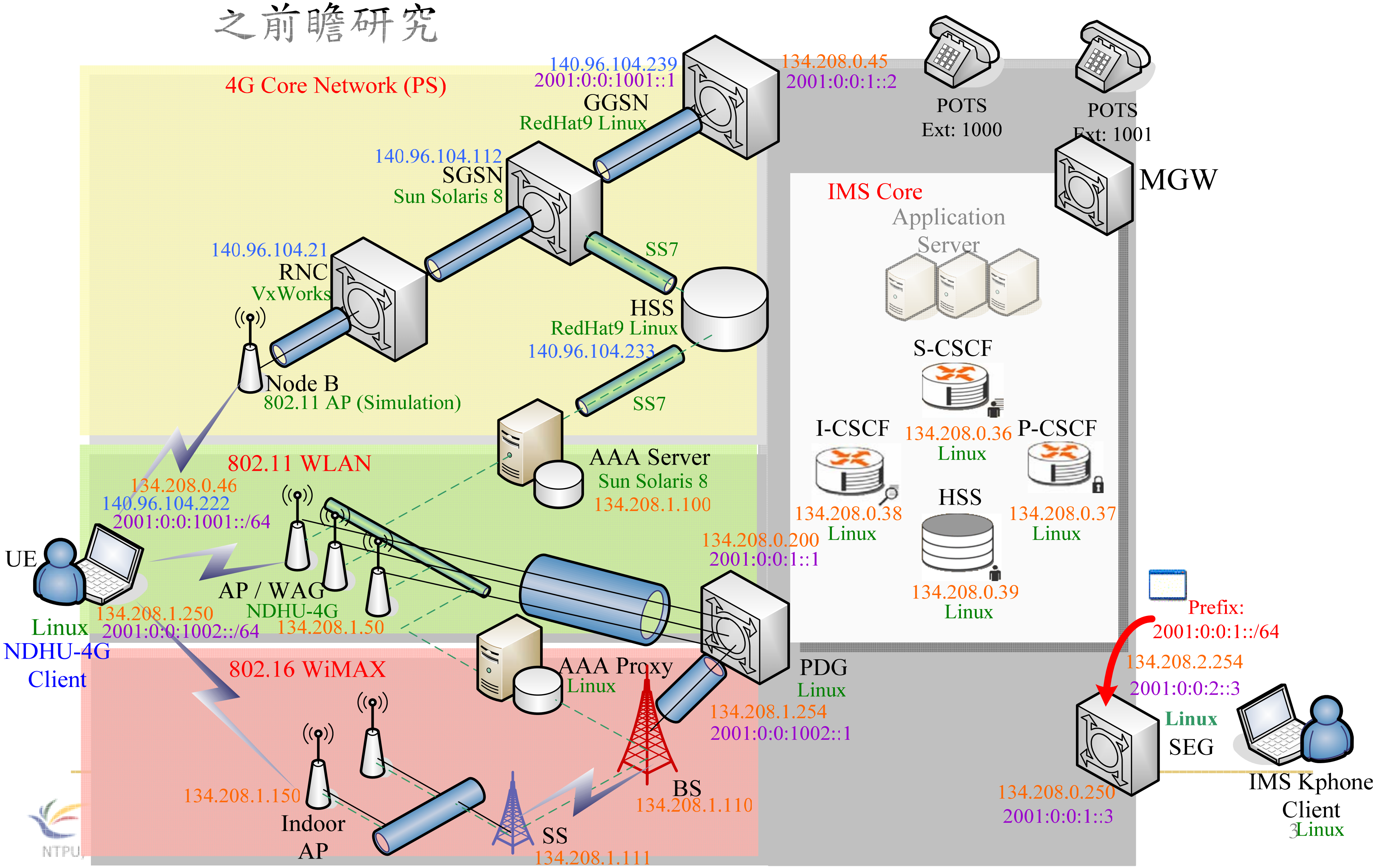
Outline

- Introduction
- Four recent results
  1. Layer-2 Handoff
     - DeuceScan: Deuce-based fast handoff scheme in IEEE 802.11 wireless networks (IEEE Trans. on VT, 2008, IEEE VTC 2006-fall)
  2. Cross-Layer Handoff
     - (**Layer 2 + 3**) Cross-layer partner-based fast handoff mechanism for IEEE 802.11 wireless networks (IEEE VTC, 2007-fall)
     - (**Layer 2 + 3**) A Cross-Layer Partner-Assisted Handoff Scheme for Hierarchical Mobile IPv6 in IEEE 802.16e Systems (is submitted to IEEE ICC, 2008)
     - (**Layer 4 + 7**) SmSCTP: SIP-based MSCTP scheme for session mobility over WLAN/3G heterogeneous networks (IEEE WCNC, 2007)
- Conclusion

電信國家型計畫：All-IP Cross-Layer 4G行動通信研究－子計畫四：全-IP 跨層mobility和session管理之前瞻研究

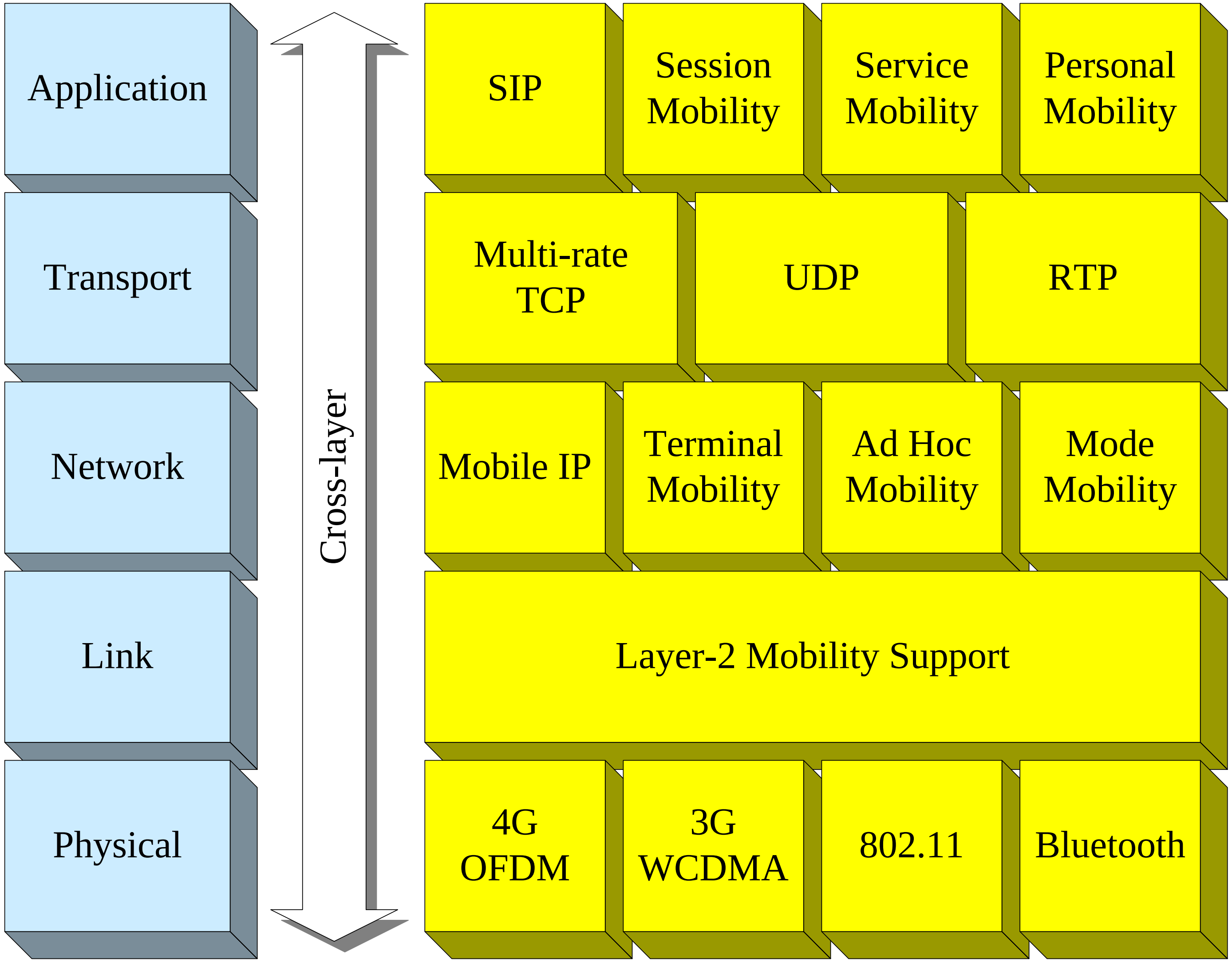


Introduction

- Cross-layer design methodologies hold great promise for providing reliable and high quality end-to-end performance in wireless communications.

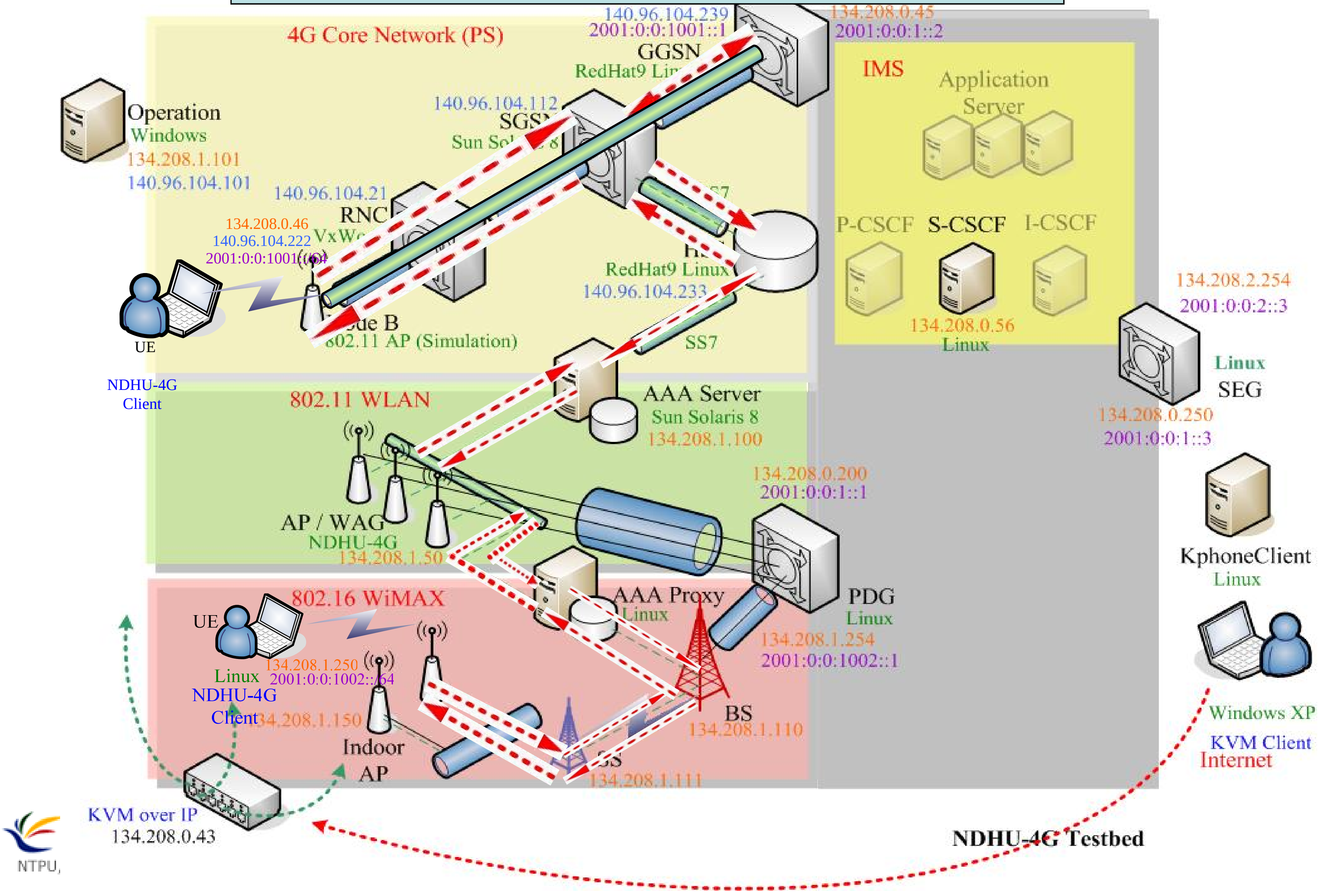
- Cross-layer design for mobility
  - The idea of cross-layer is to use the low-layer information to assist mobility management.
  - To minimize the packet loss and handoff delay time during switching different access networks.

Introduction

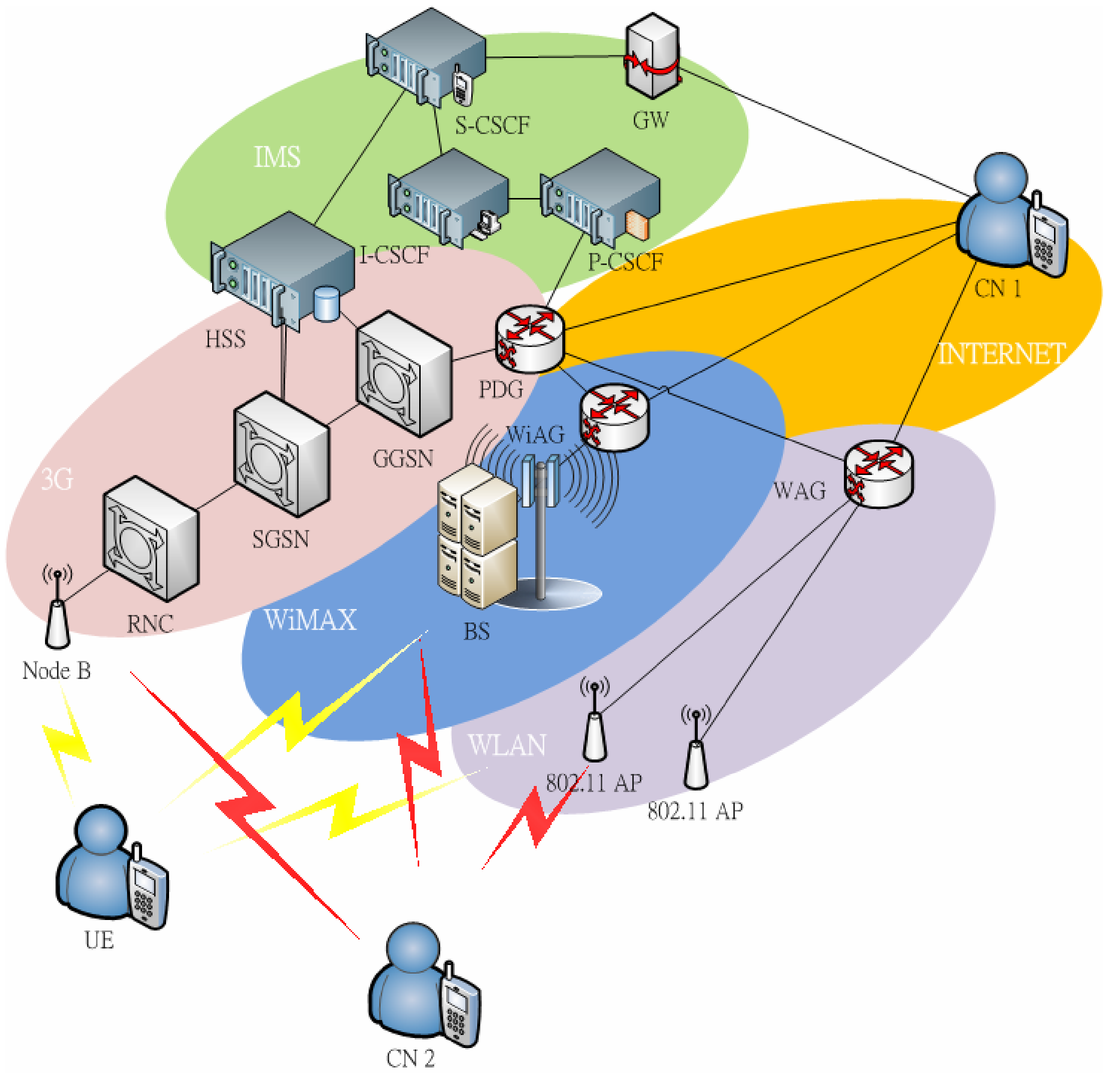


4G Testbed + IMS

1.從4G Core Network 換到802.16 WiMAX
2.從802.16 WiMAX 換到802.11WLAN



WiMax/WLAN/UMTS Seamless Handoff



Part I. Layer-2 Handoff:
DeuceScan: Deuce-Based Fast Handoff Scheme in IEEE 802.11 Wireless Networks

IEEE Trans. on Vehicular Technology, March, 2008.

Outline

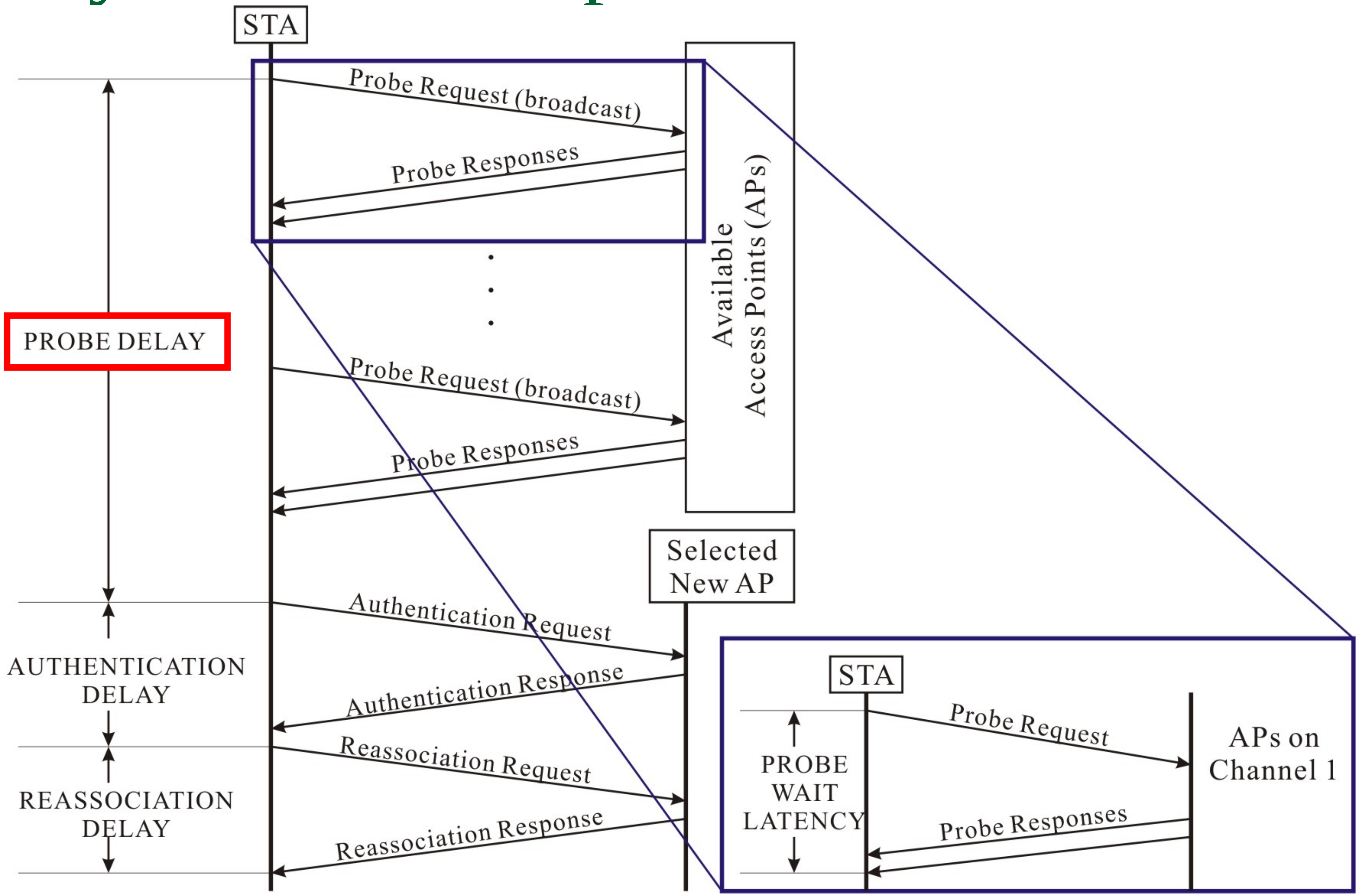
- Background
- Related work
- DeuceScan: Deuce-based fast handoff scheme using spatiotemporal graphs
  - Spatiotemporal graphs
  - Deuce procedure with signal strength
  - Deuce procedure with variation of signal strength
- Simulation results
- Summary

Background

- The entire delay time of a handoff is divided into probe, authentication, and re-association delay time. The probe delay occupies most of the handoff delay time.

- In IEEE 802.11 Std., MH needs to perform a full scan (11 channels) operation during a handoff procedure, and it wastes much time.

Layer-2 handoff procedure in WLAN



Motivation

- In this paper, we proposed a fast handoff scheme, called DeuceScan, to reduce the probe delay (MAC layer) for 802.11-based WLANs.
  - Our DeuceScan scheme utilizes spatiotemporal graph to provide the spatiotemporal information for making better handoff decisions to exactly search for the next AP.
  - Our DeuceScan scheme is a pre-scan approach, and two factors of signal strength and variation of signal strength are both considered in our DeuceScan scheme.

Related Works

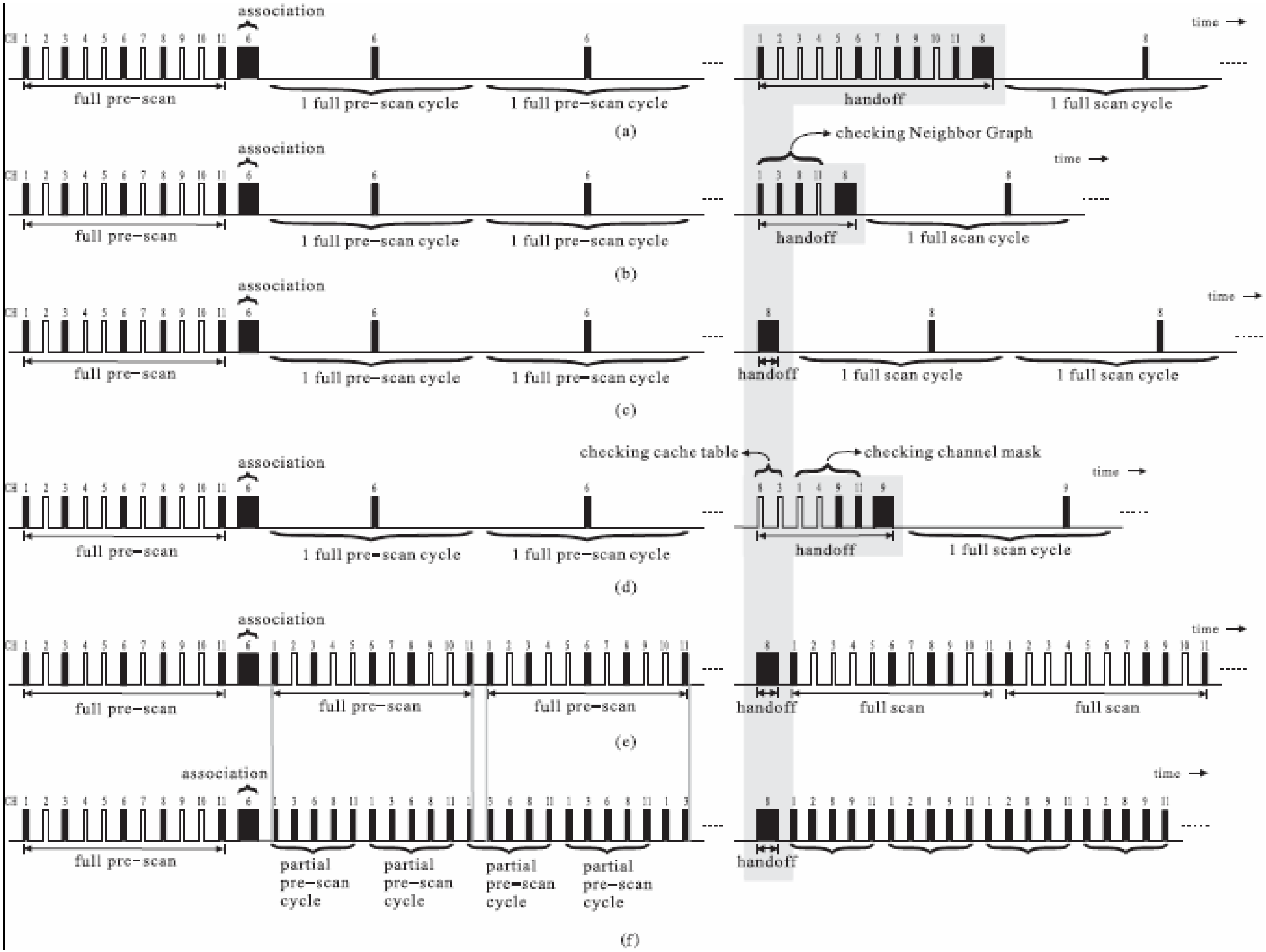
- For reducing the probe delay time scheme
  - Partial scan scheme
    - M. Shin *et al.*, "Improving the Latency of 802.11 Hand-offs using Neighbor Graphs", ACM MobiSys, Jun. 2004.
    - S. Shin *et al.*, "Reducing MAC Layer Handoff Latency in IEEE 802.11 Wireless LANs", ACM MobiWac, Sep. 2004.
  - Pre-scan scheme
    - I. Ramani *et al.*, "SyncScan: Practical Fast Handoff for 802.11 Infrastructure Networks", IEEE INFOCOM, Mar. 2005.
  - Location-based scheme
    - C. C. Tseng *et al.*, " Location-based Fast Handoff for 802.11 Networks", IEEE Communication Letters, Apr. 2005.

Related Works

- Partial scan scheme (selective scanning)
  - By using a dynamic channel mask in the selective scanning algorithm, scanning a subset of eleven channels can be used as a generic solution.
- Pre-scan scheme
  - MH continuously scans the channel before handoff.
- Caching scheme
  - The AP cache consists of a table which uses the MAC address of the current AP as the key.
  - This list is automatically created while roaming.

Comparisons of different methods

	IEEE Standard	Neighbor graph	Selective scan		SyncScan	Location based	DeuceScan
			Cache hit	Cache miss			
Pre-scan	No	No	No		Yes	No	Yes
Probe action	Full scan	Partial scan	No	Partial scan	No	No	No
Handoff latency	Slow	Medium	Fast	Medium	Fast	Fast	Fast
Extra device	No	No	No	No	No	Yes	No
Memory cost	*1*	$O(n \times M)$	$O(n)$	$O(n)$	$O(N)$	$O(N \times M)$	$O(n \times M)$



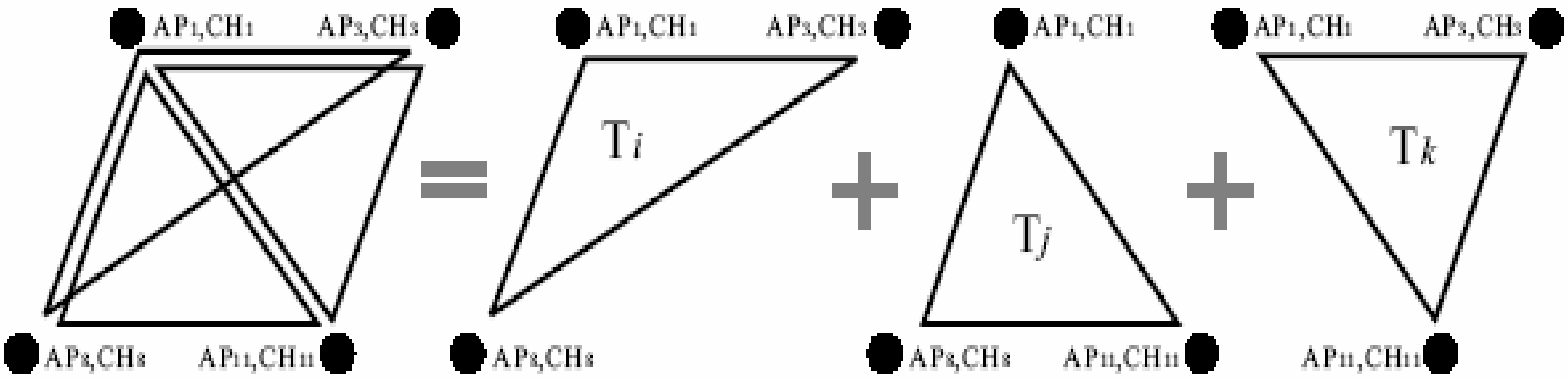
association
time
full pre-scan
1 full pre-scan cycle
handoff
1 full scan cycle
(a)
checking Neighbor Graph
(b)
(c)
checking cache table
checking channel mask
(d)
full scan
(e)
partial pre-scan cycle
(f)

DeuceScan: Deuce-based fast handoff scheme using spatiotemporal graphs

- Spatiotemporal graphs
- Deuce procedure with signal strength
- Deuce procedure with variation of signal strength

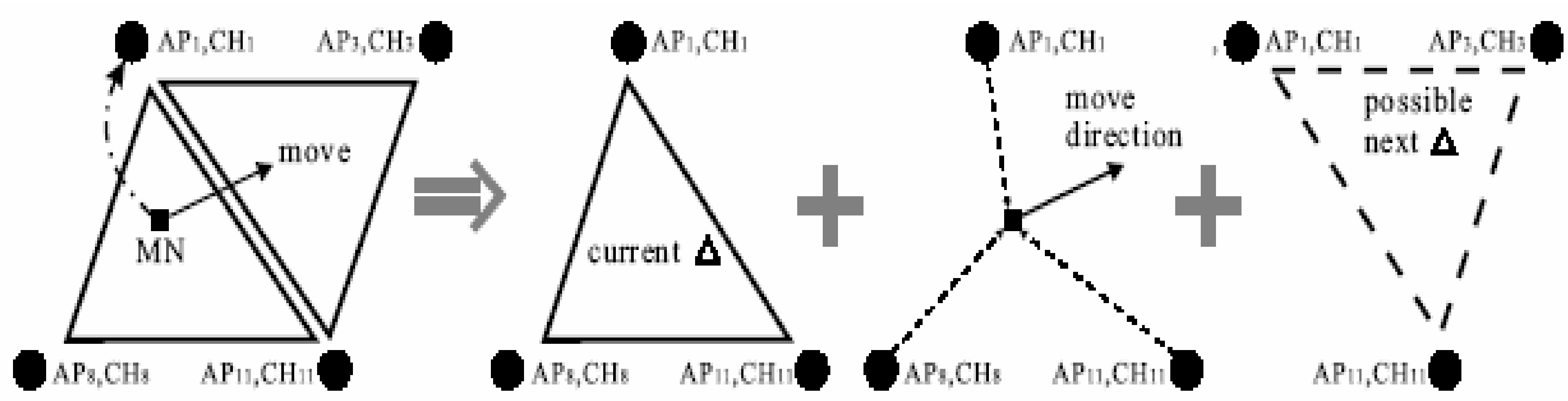
Spatiotemporal graphs

- Composed of a lot of spatiotemporal triangles which are established at distinct time and places.
- Each MH will possess its own individual spatiotemporal graph.



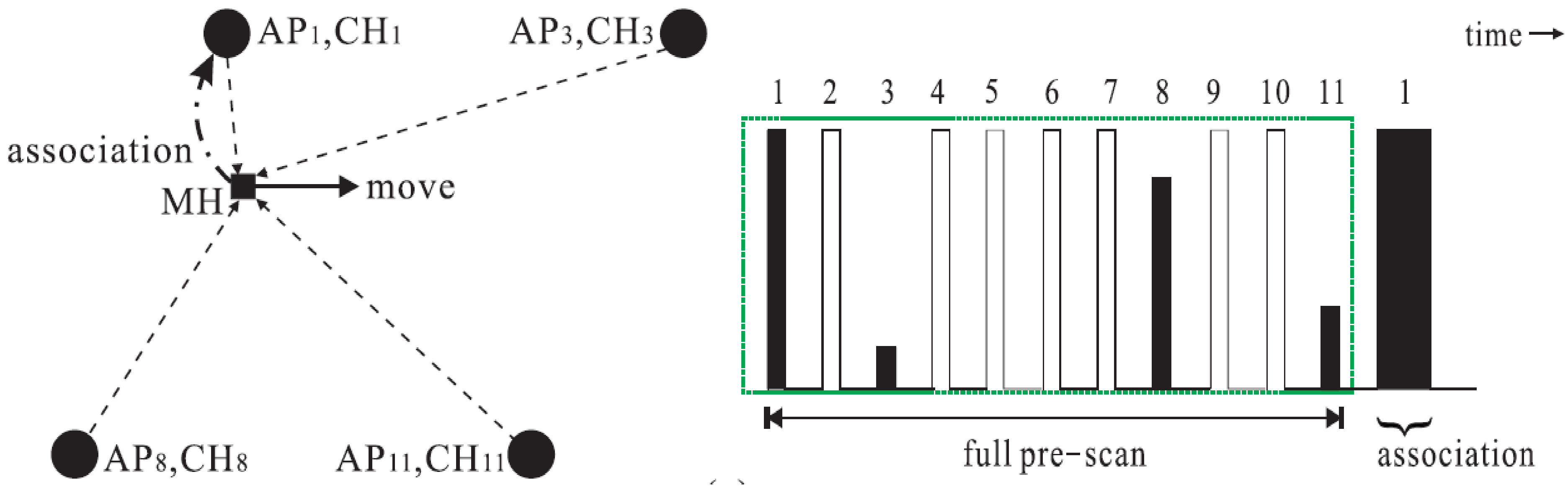
Spatiotemporal graphs

- The current triangle presents the first three closest APs near an MH.
- MH's moving direction is known by variation of RSS.



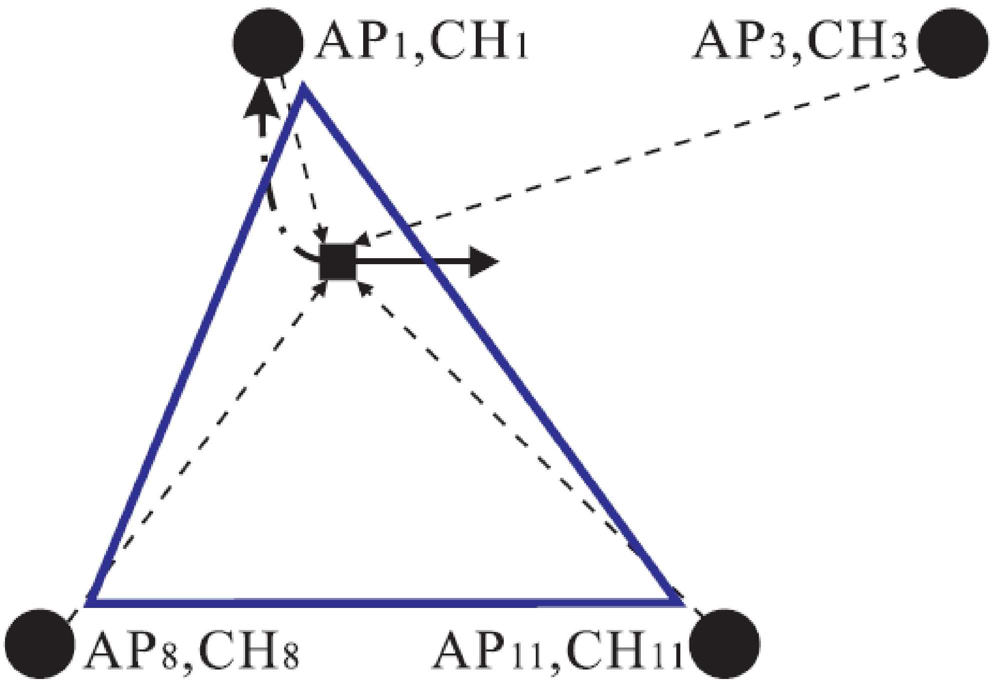
Example of construction of spatiotemporal graphs

- The full pre-scanning operation needs to be performed if an MH enters a new location.



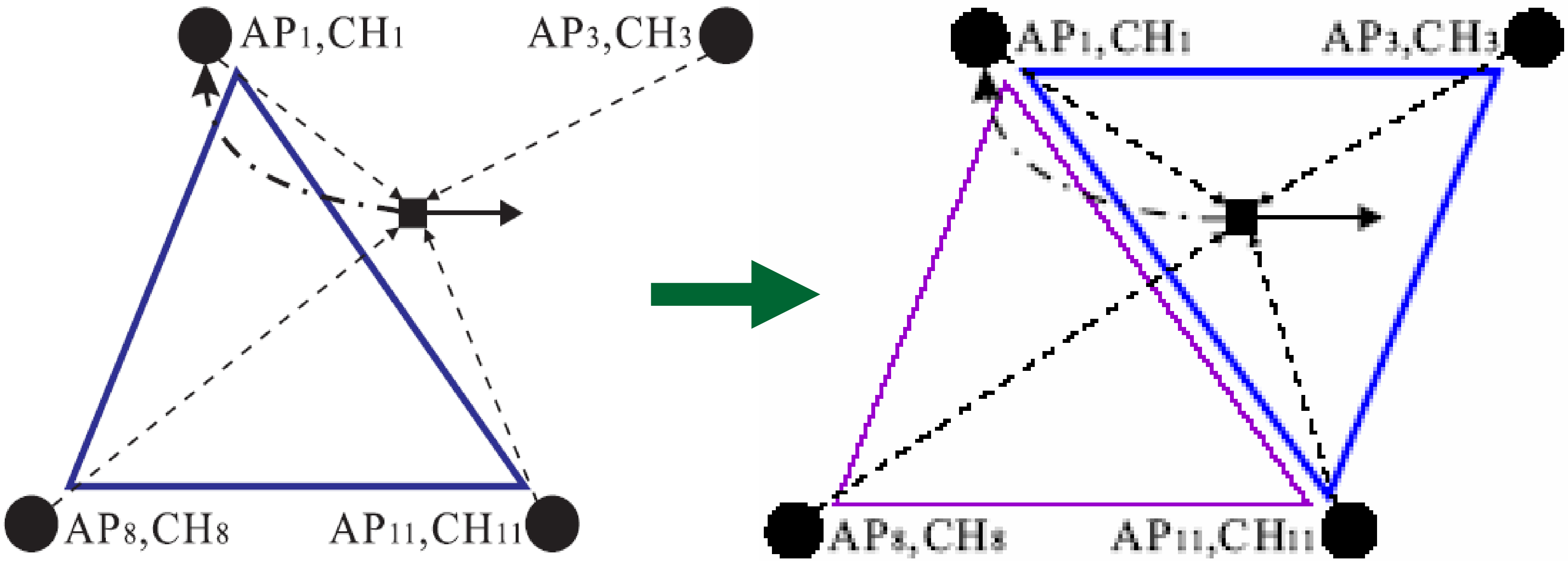
Example of construction of spatiotemporal graphs

- A triangle is constructed by three APs, AP_1, AP_8, and AP_{11}.



Example of construction of spatiotemporal graphs

- Construct a new spatiotemporal graphs



DeuceScan fast handoff scheme

- To reduce the layer-2 handoff latency which utilizes spatiotemporal graphs to provide spatiotemporal information for making better handoff decisions to exactly search for the next AP.
- Adopting two factors of received signal strength and variation of received signal strength.

Deuce procedure with signal strength

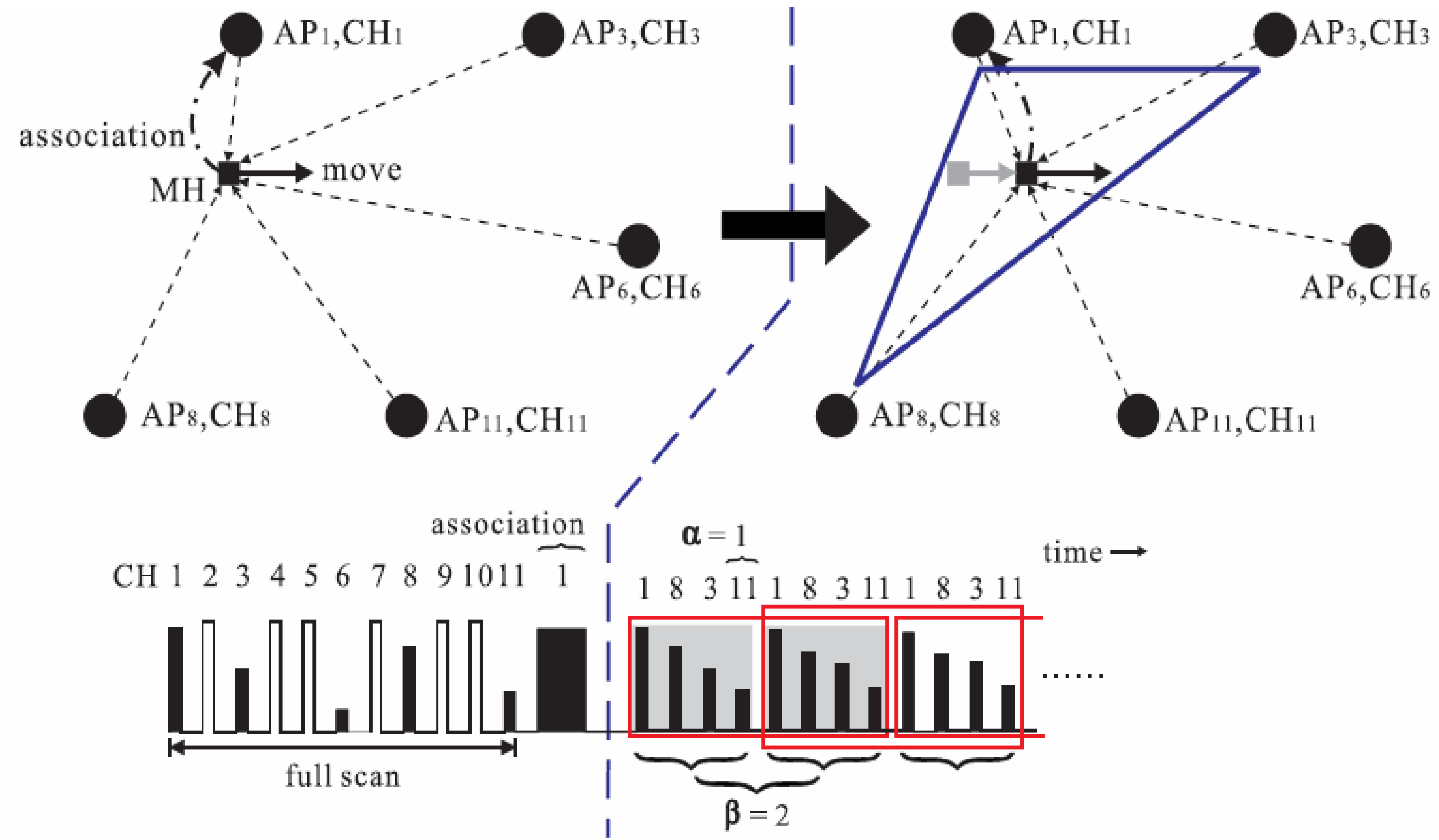
- The deuce procedure is used for confirming whether the RSS received from an MH at some place are stable by continuously probing nearby APs and judges if it needs to change the current spatiotemporal triangle.

- We denote a deuce procedure with signal strength as $D_S(\alpha, \beta)$.

Deuce procedure $D_S(\alpha, \beta)$

- We select the APs which have the larger α+3 strong RSS receiving from the MH to form a scan cycle, and this presents that there are still α APs for selecting if the full scan has a mistake.
  - $\alpha + 3 < 11$ (partial pre-scann)
- Successive β scan cycles form a deuce window.
  - It is stable means that the RSS magnitude order in each scan cycle of a deuce window are the same.

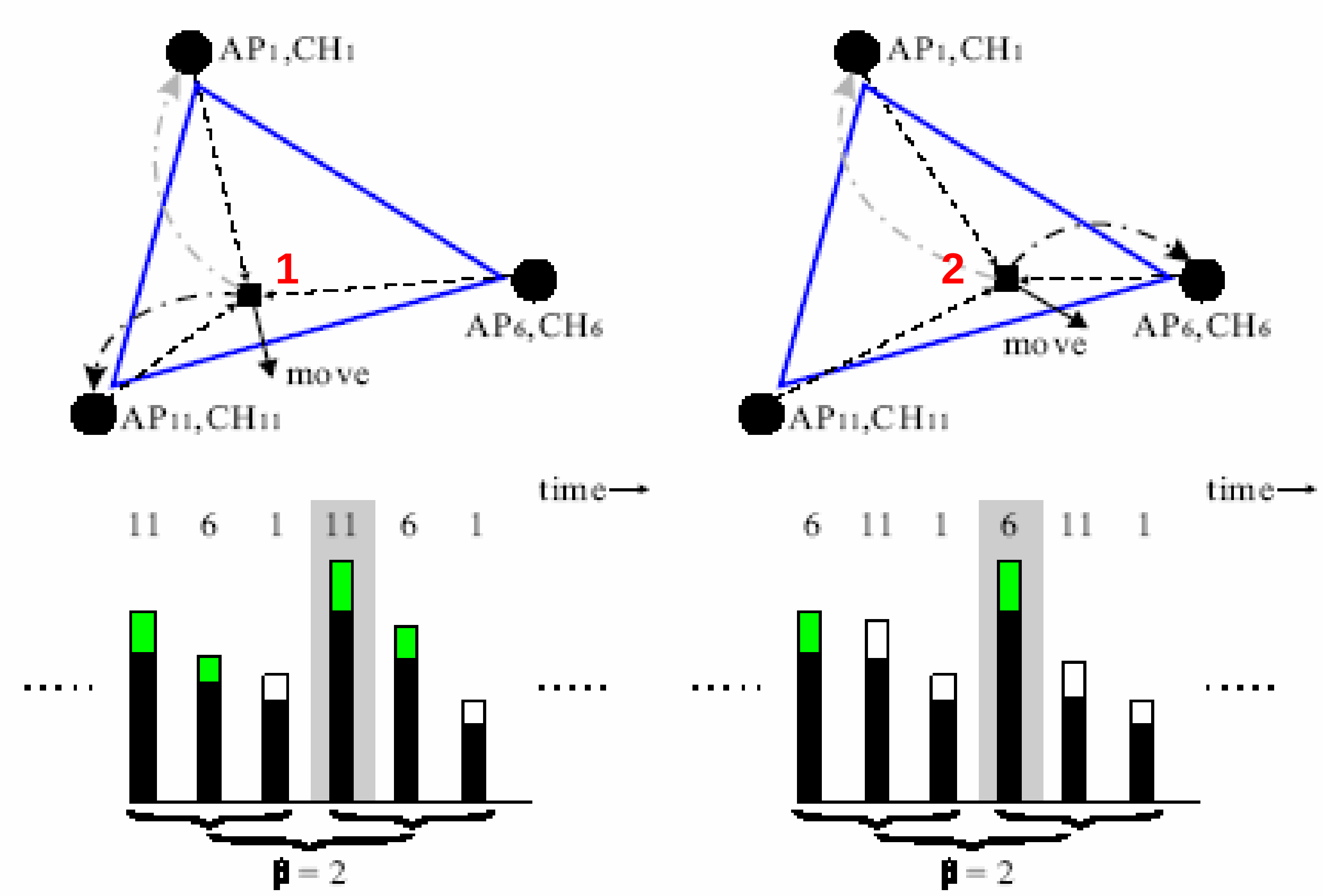
Example of $D_S(1,2)$



Deuce procedure with variation of signal strength

- When the variation of successive two RSS of an AP is positive, the MH moves away from this AP.
- An MH can be aware of its moving direction (to be close to or to be distant from some APs) and determine which is the next AP when handoff.
- We denote a deuce procedure with variation of RSS as $D_V(\alpha, \beta)$.

Example of $D_V(1,2)$



DeuceScan procedure

- **Step 1:** When the MH turns on, it performs a full scan, and selects a best AP (with the strongest RSS) to associate with, denoted as AP_{cur} and S_{APcur}. Then the MH enters deuce procedure with α and β.
- **Step 2:** Set integer $i = 1$. The MH probes AP_{cur} to get S_{APcur} in a scan cycle C_i, and judges whether $S_{APcur} < S_h$, where S_h is a pre-defined threshold for handoff. If ”NO” then jump to Step 2, and if ”YES” then jump to Step 3.
- **Step 3:** Let $i = i+1$. The MH probes AP_{cur} to get S_{APcur} in a scan cycle C_i, and determines whether $S_{APcur} < S_h$. If ”NO” then jump to Step 2, else jump to Step 4.
- **Step 4:** If $i = \beta$, the MH decides to handoff and jump to Step 5, else jump to Step 3.

DeuceScan procedure

- **Step 5:** Here denotes the two best APs with the first two strongest RSS in a scan cycle C_i as AP_{1st} and AP_{2nd}, and their RSSs are $S_{AP1st} > S_{AP2nd}$. Besides, the symbol SD is a pre-defined small constant used for computing the variation of two RSSs. If $SAP1st$ - $SAP2nd < S_{\Delta}$ then jump to Step 7, else jump to Step 6.

- **Step 6:** The MH reassociates to AP_{1st} . Jump to Step 2.

- **Step 7:** If Δ_{AP1st} and Δ_{AP2nd} both increase, the MH reassociates with AP_{1st} . If Δ_{AP1st} and Δ_{AP2nd} both decrease, the MH reassociates with the AP_{2nd}. If Δ_{AP1st} increase and Δ_{AP2nd} decrease, the MH reassociates with the AP_{1st} . If Δ_{AP1st} decrease and Δ_{AP2nd} increase, the MH reassociates with the AP_{2nd}. Jump to Step 2.

Simulation results

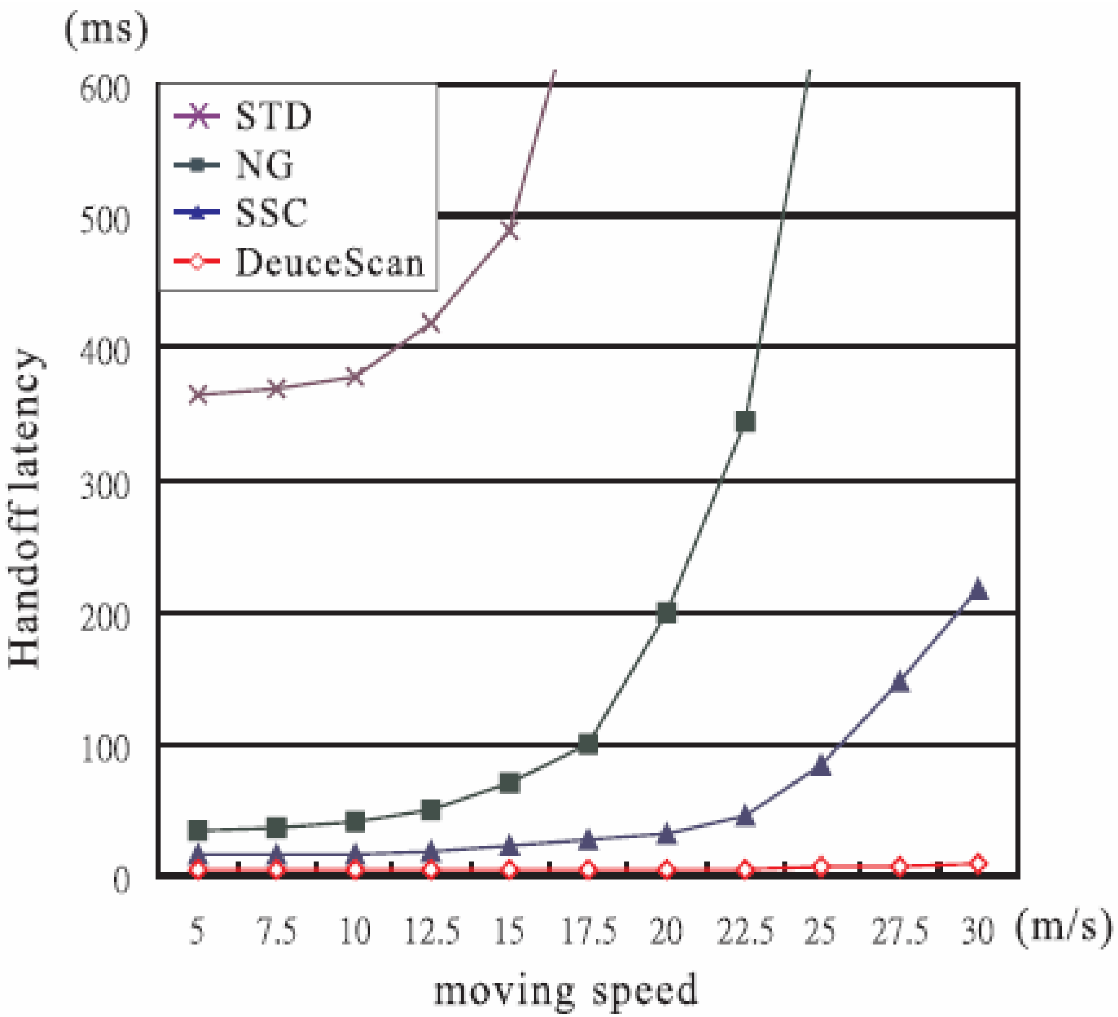
- Simulator: NCTUns 3.0
- The simulation parameters

Parameter	Value
Number of mobile hosts	500
Number of access points	100~200
Network region	1000 m $\times$1000 m
Radio propagation range	100 m
Mobility of mobile hosts	5~30 m/s
Pause time of mobile hosts	10 sec

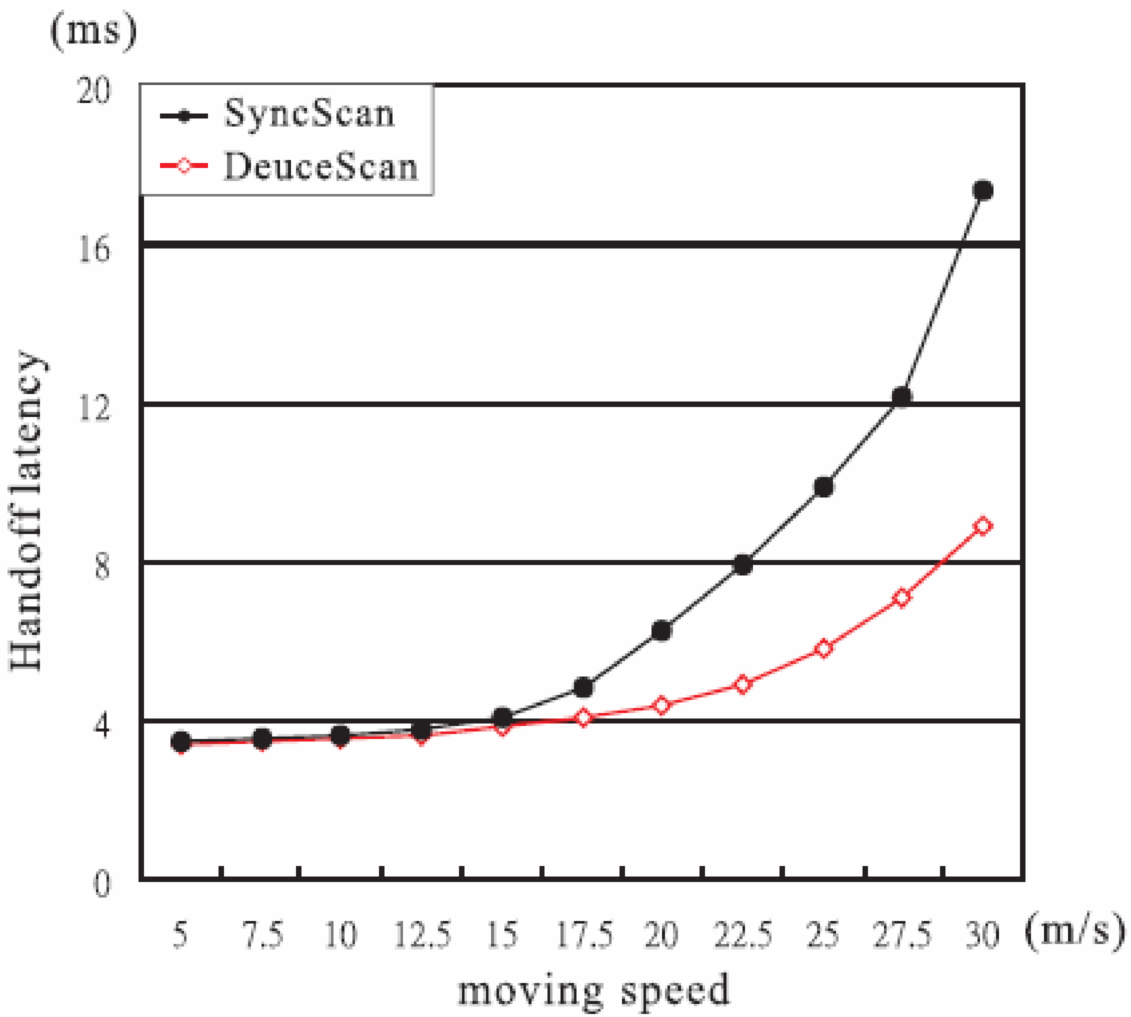
Performance metrics

- Handoff latency
  - A delay time between an MH moving its association from one AP to another.
- Packet loss
  - The number of all lost packets during handoff of an MH.
- Link quality
  - The average received signal strength of an MH during a period of time.

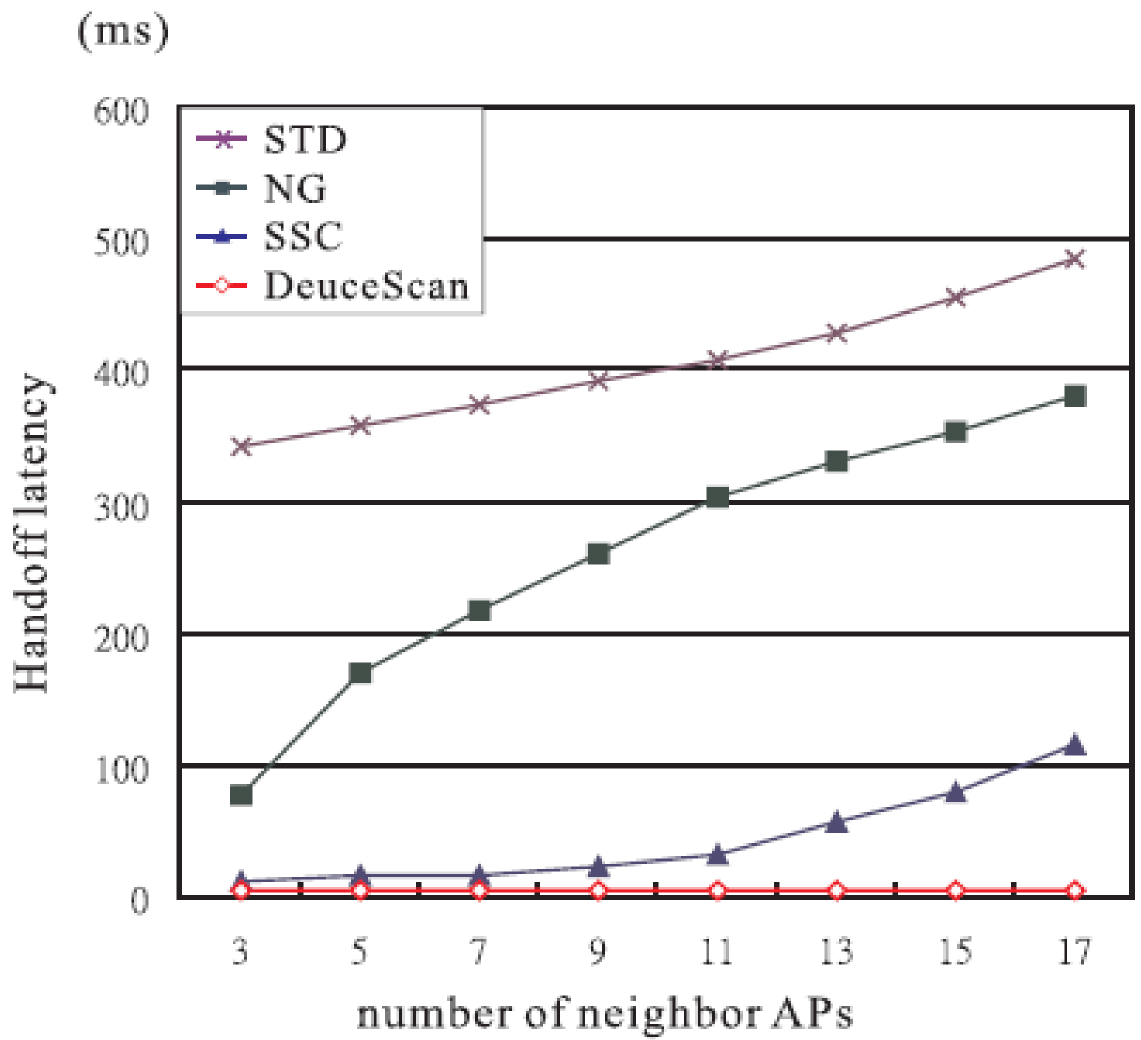
Handoff latency



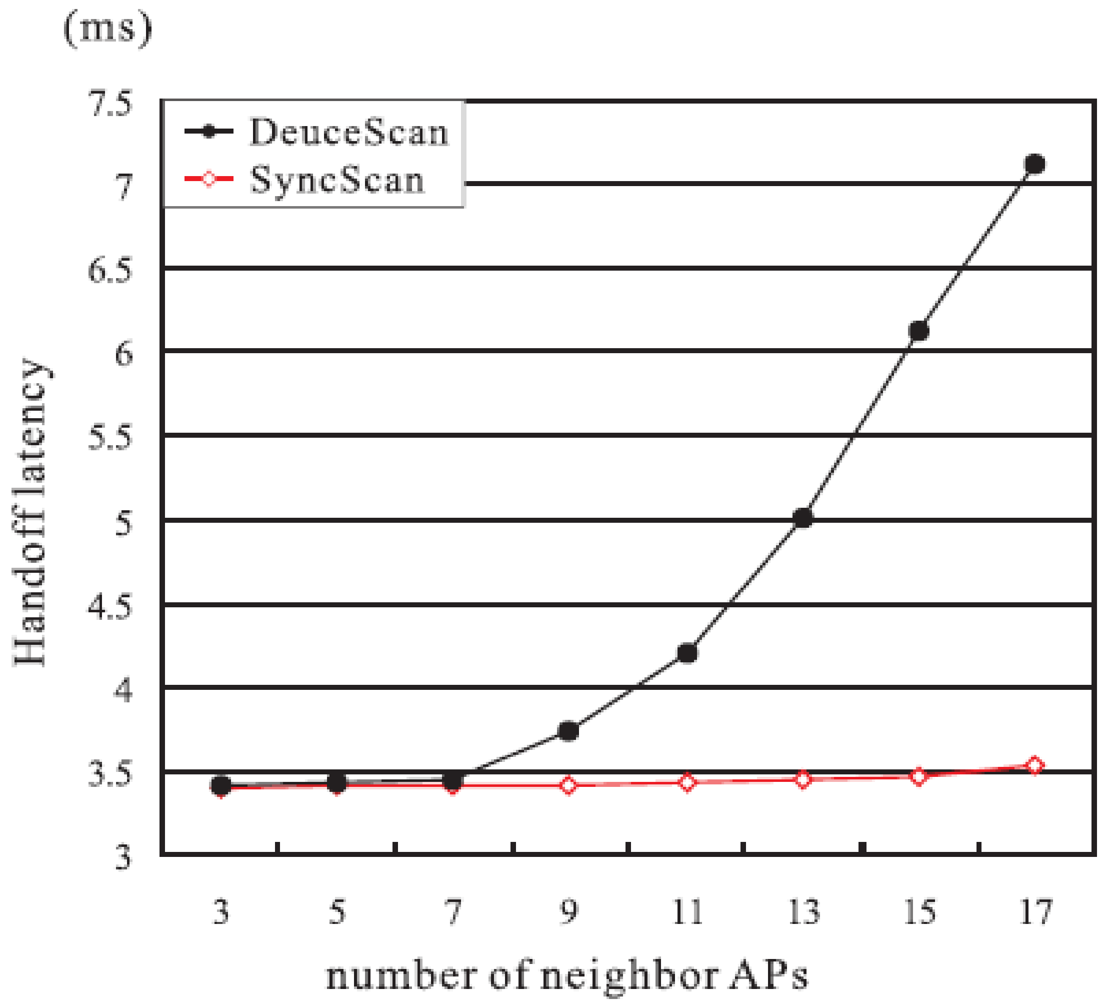
Handoff latency



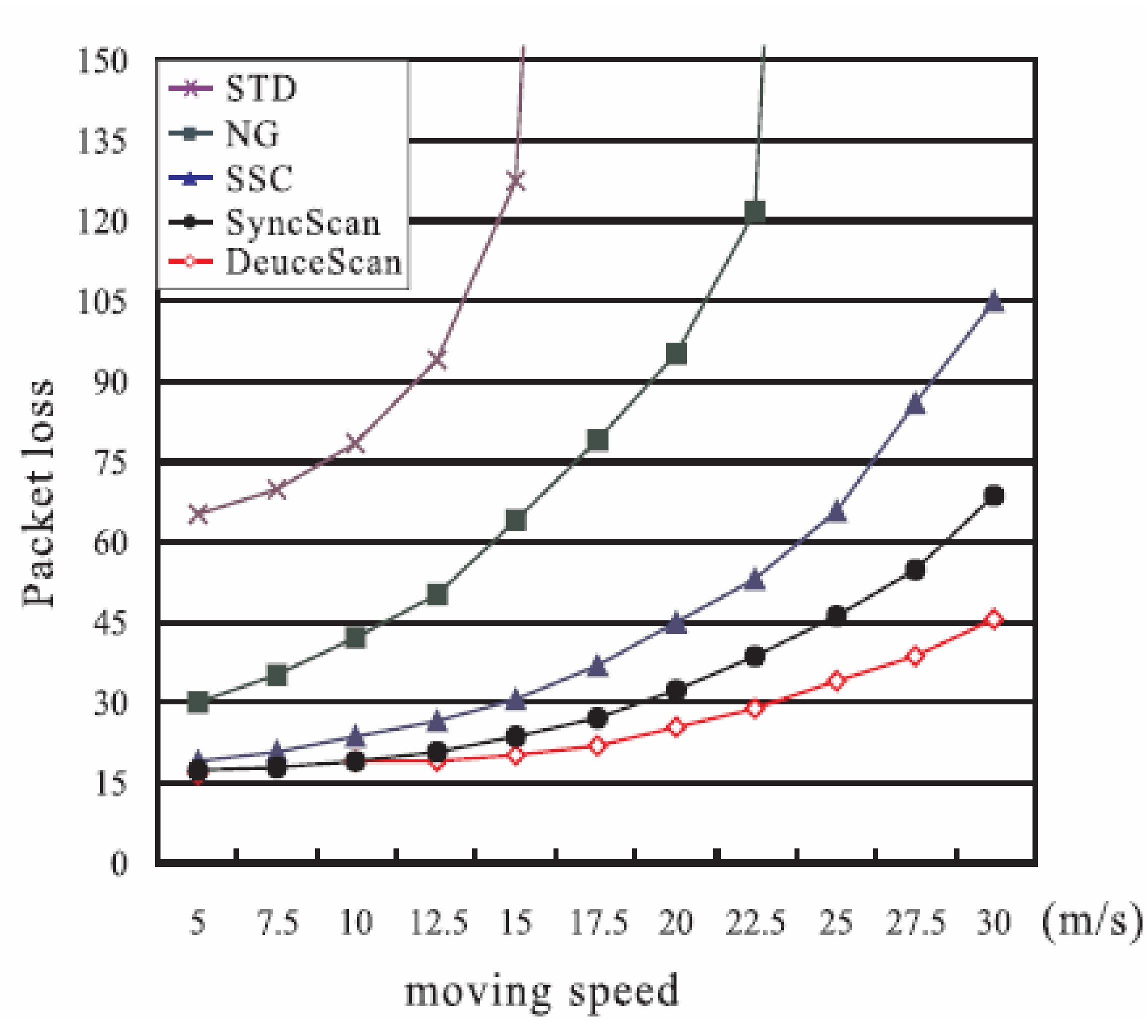
Handoff latency



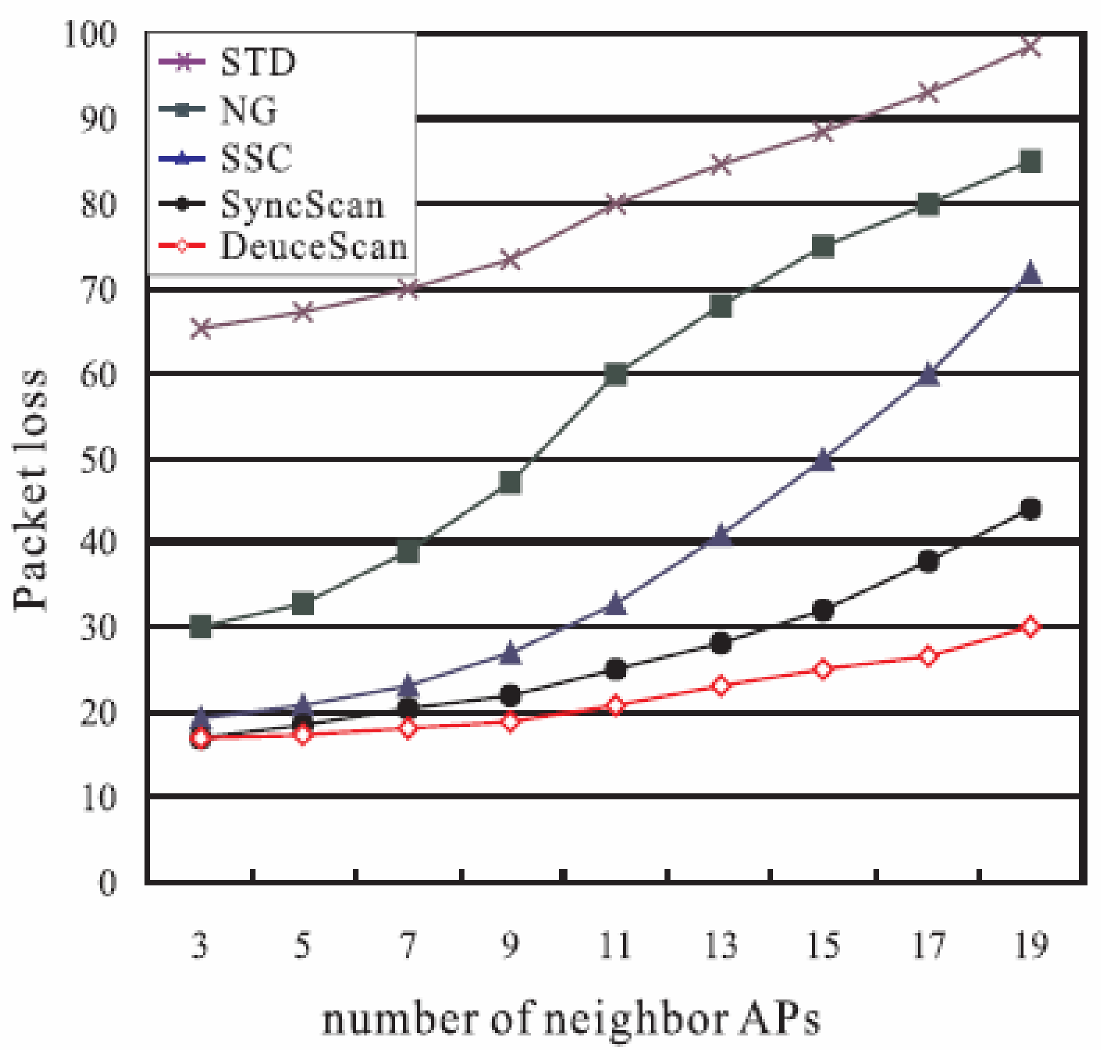
Handoff latency



Packet loss

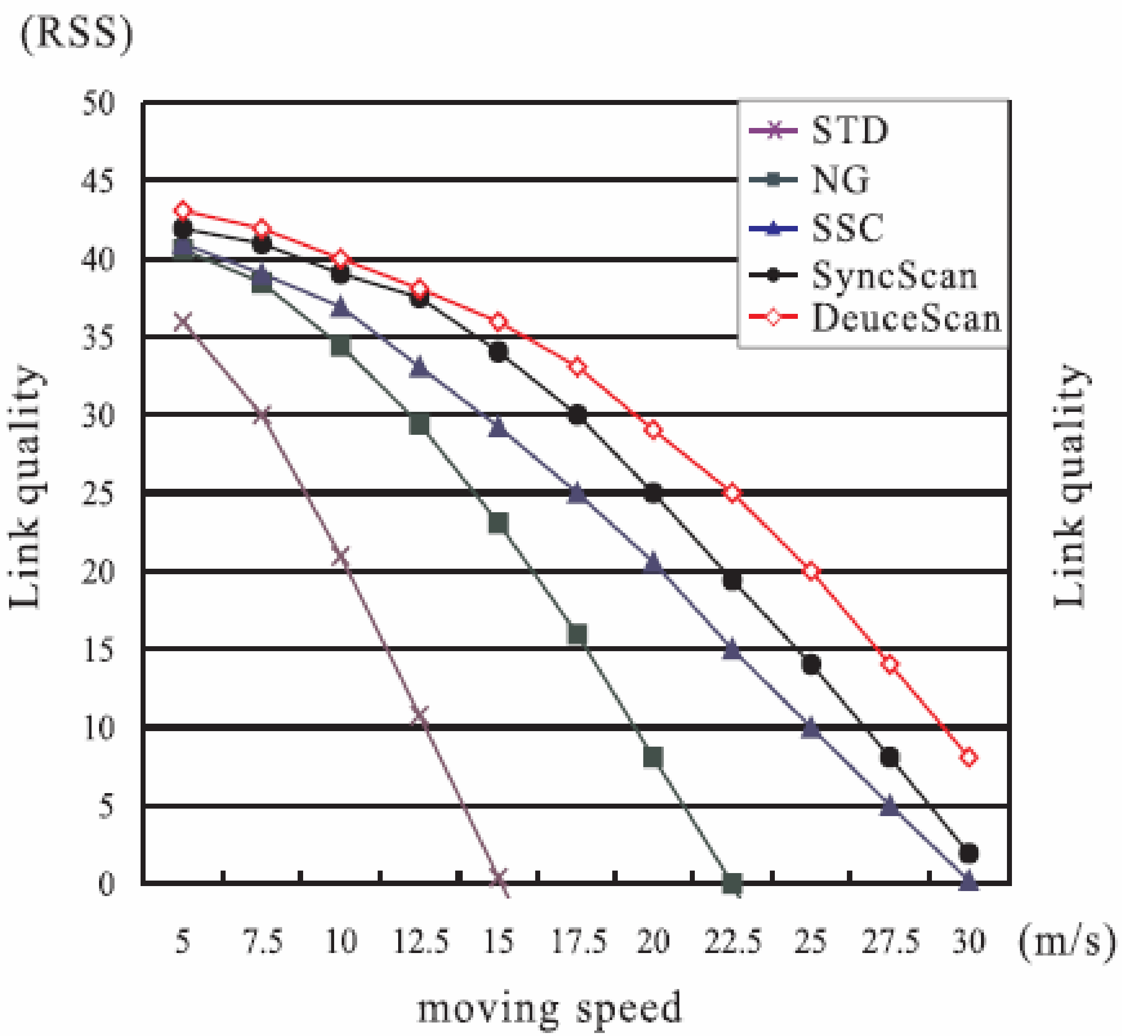

STD
NG
SSC
SyncScan
DeuceScan
150
135
120
105
90
75
60
45
30
15
0
Packet loss
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30
(m/s)
moving speed

Packet loss



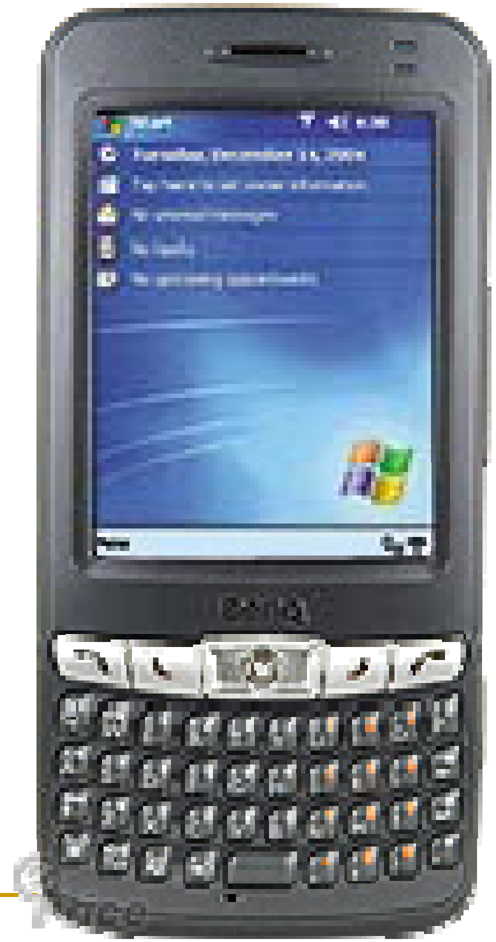
STD
NG
SSC
SyncScan
DeuceScan
Packet loss
100
90
80
70
60
50
40
30
20
10
0
3
5
7
9
11
13
15
17
19
number of neighbor APs

Link quality



Windows CE Platform (Hardware-BenQ P50)

- Processor : Intel PXA 272 416MHz
- RAM: 64MB Flash ROM及64MB Mobile SDRAM
- OS: Microsoft Windows Mobile 2003 Pocket PC Phone Edition Second Edition
- Connectivity: Bluetooth, WLAN, USB1.1, IrDA, GPRS, and SDIO
- GSM/GPRS 850 / 900 / 1800 / 1900 MHz) smart phone，Wi-Fi 802.11b



Summary

- This paper presents a new fast handoff scheme, called DeuceScan, to reduce the probe delay for WLANs.
- A spatiotemporal approach is developed in DeuceScan scheme to utilize spatiotemporal graph to provide the spatiotemporal information for making better handoff decisions to exactly search for the next AP.

Part II: Cross-Layer Partner-Based Fast Handoff Mechanism for IEEE 802.11 Wireless Networks

IEEE Vehicular Technology Conference 2007 Fall (VTC2007-Fall), Baltimore, Maryland, USA, 1-3 October, 2007.

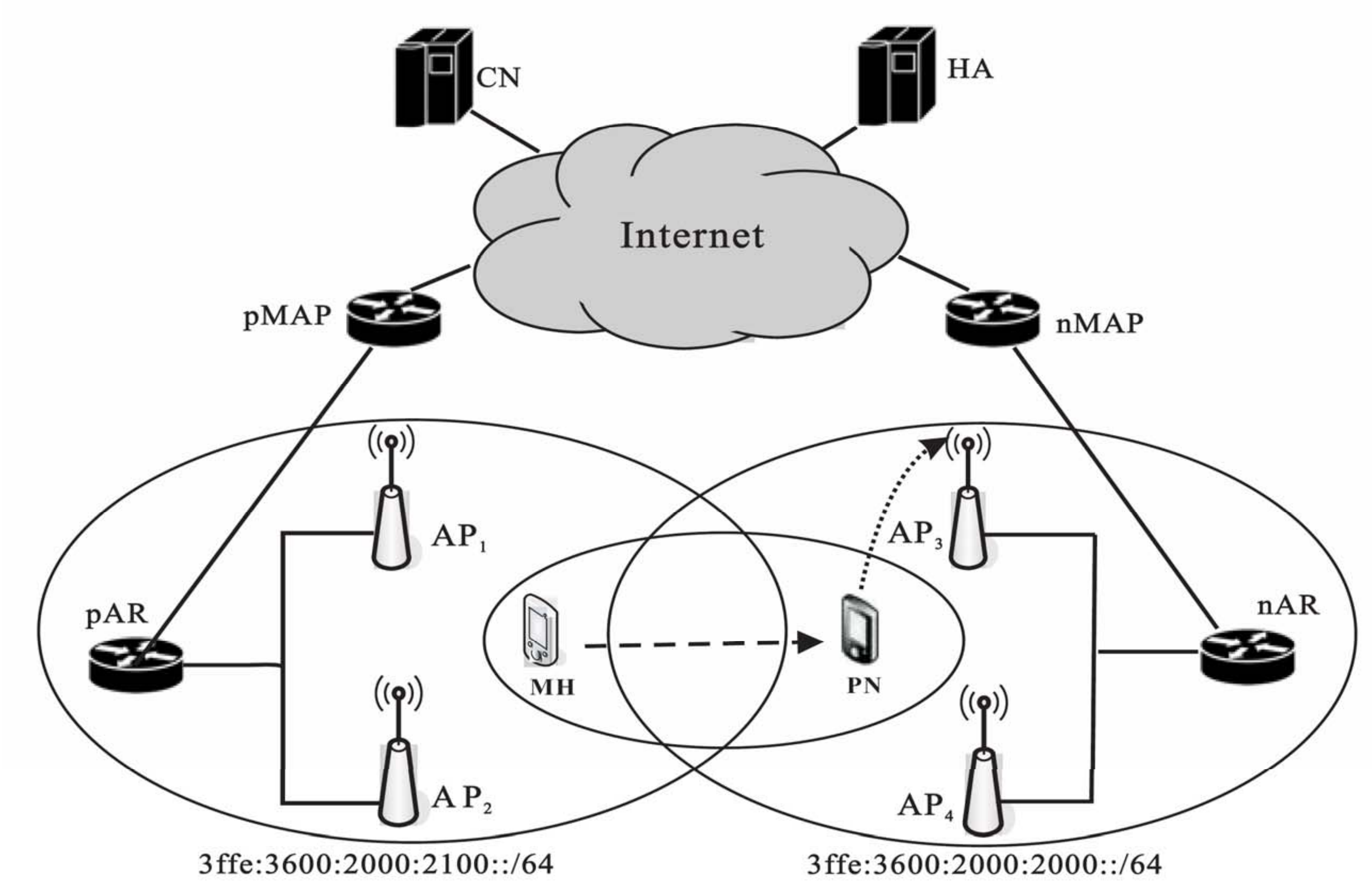
Outline

- Background
- Related work
- Partner-based HMIPv6 (PHMIPv6)
- Mathematical analysis and simulation results
- Brief summary

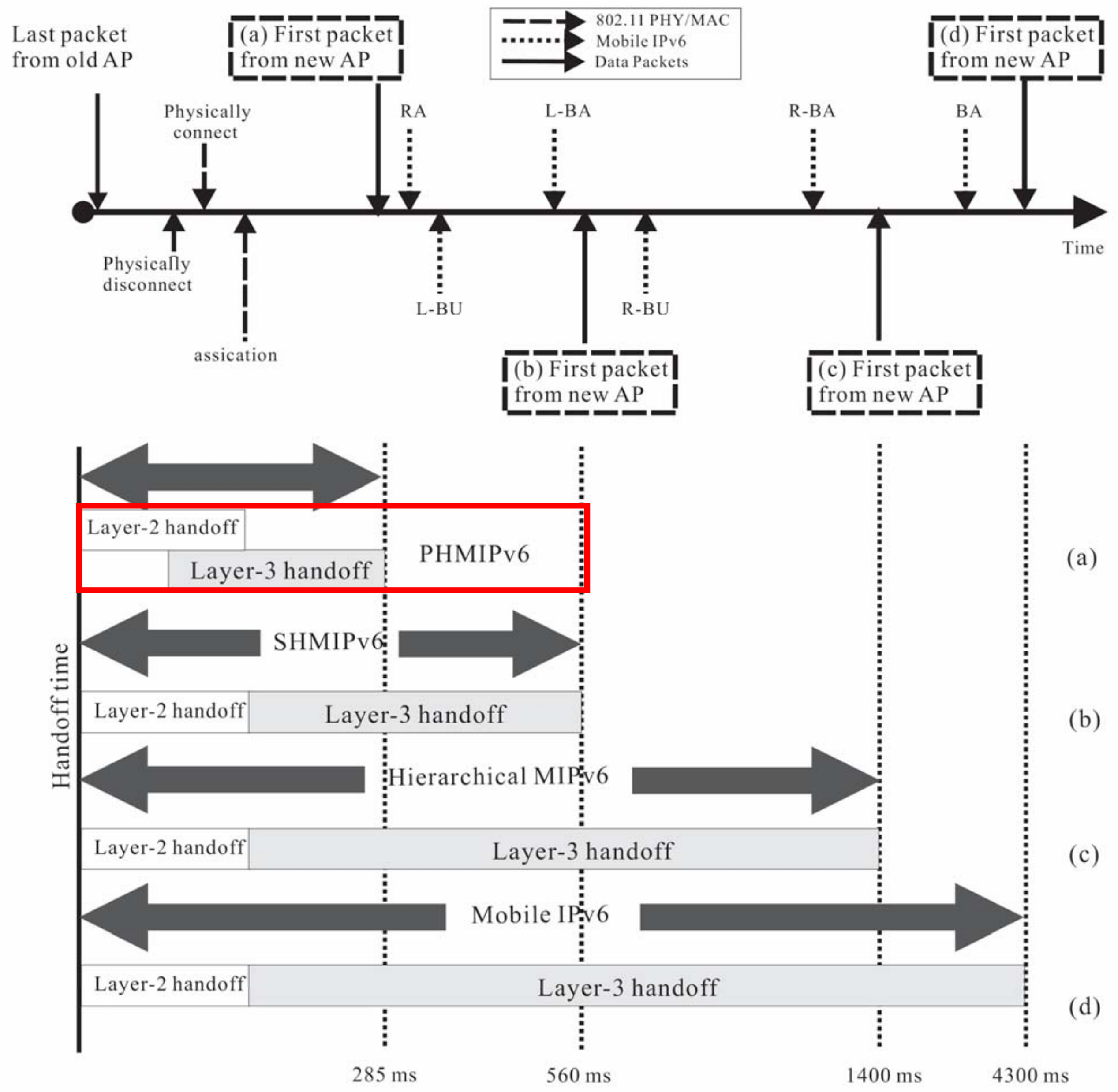
Background

- 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.

System architecture (HMIPv6)



Related work



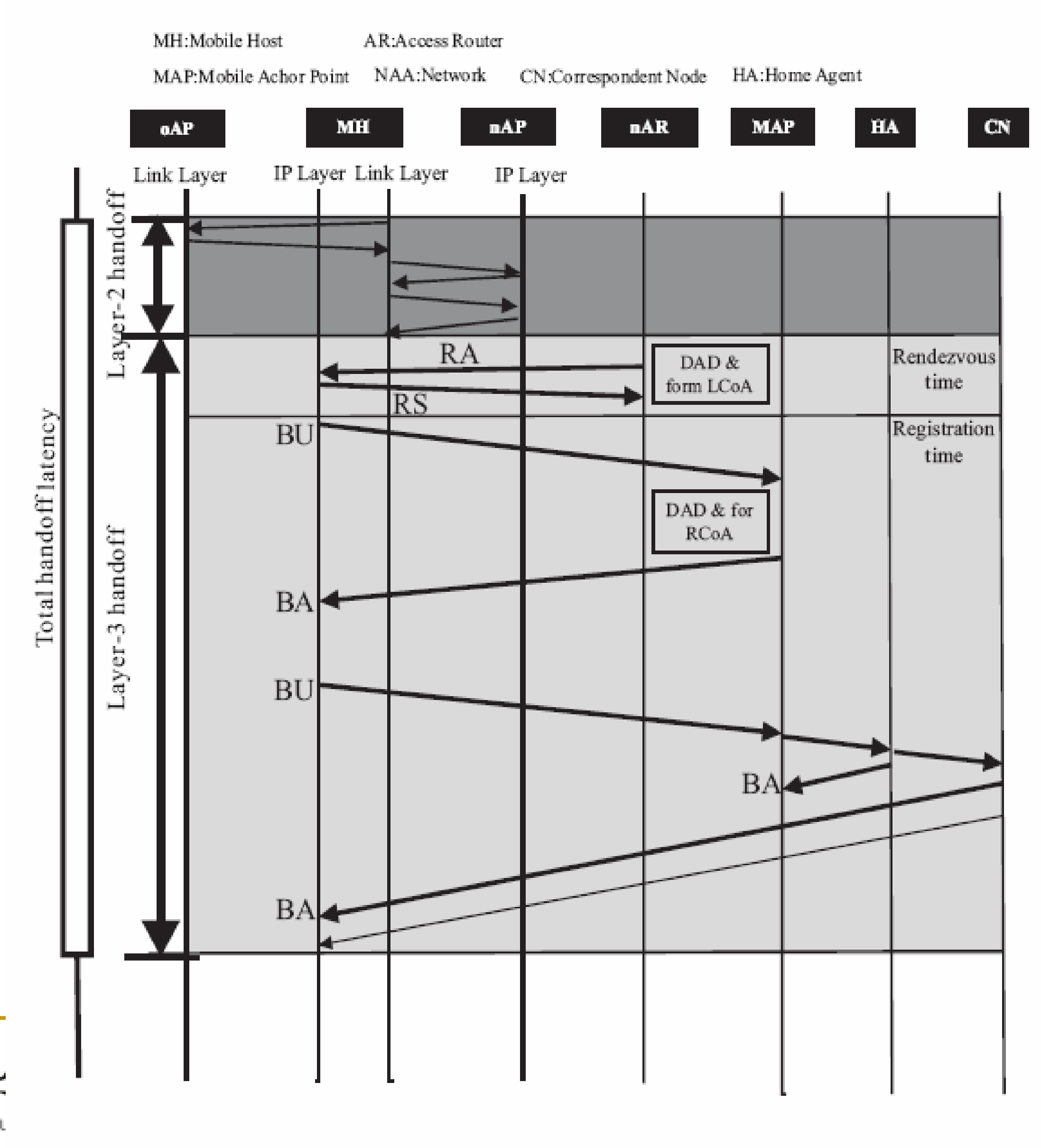
Motivation

- 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.
  - Cooperative works by PN

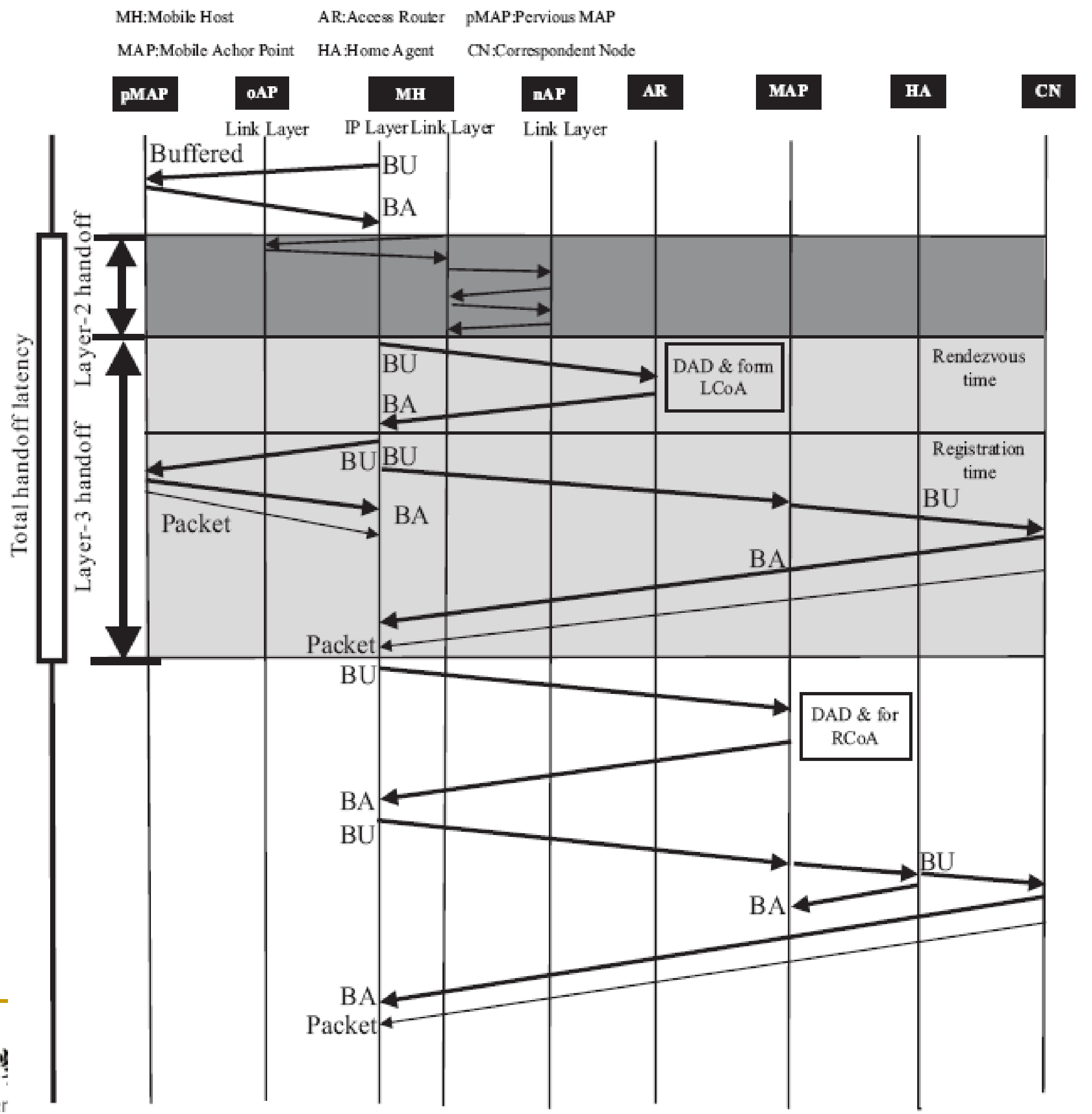
Partner based HMIPv6 (PHMIPv6)

- 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.

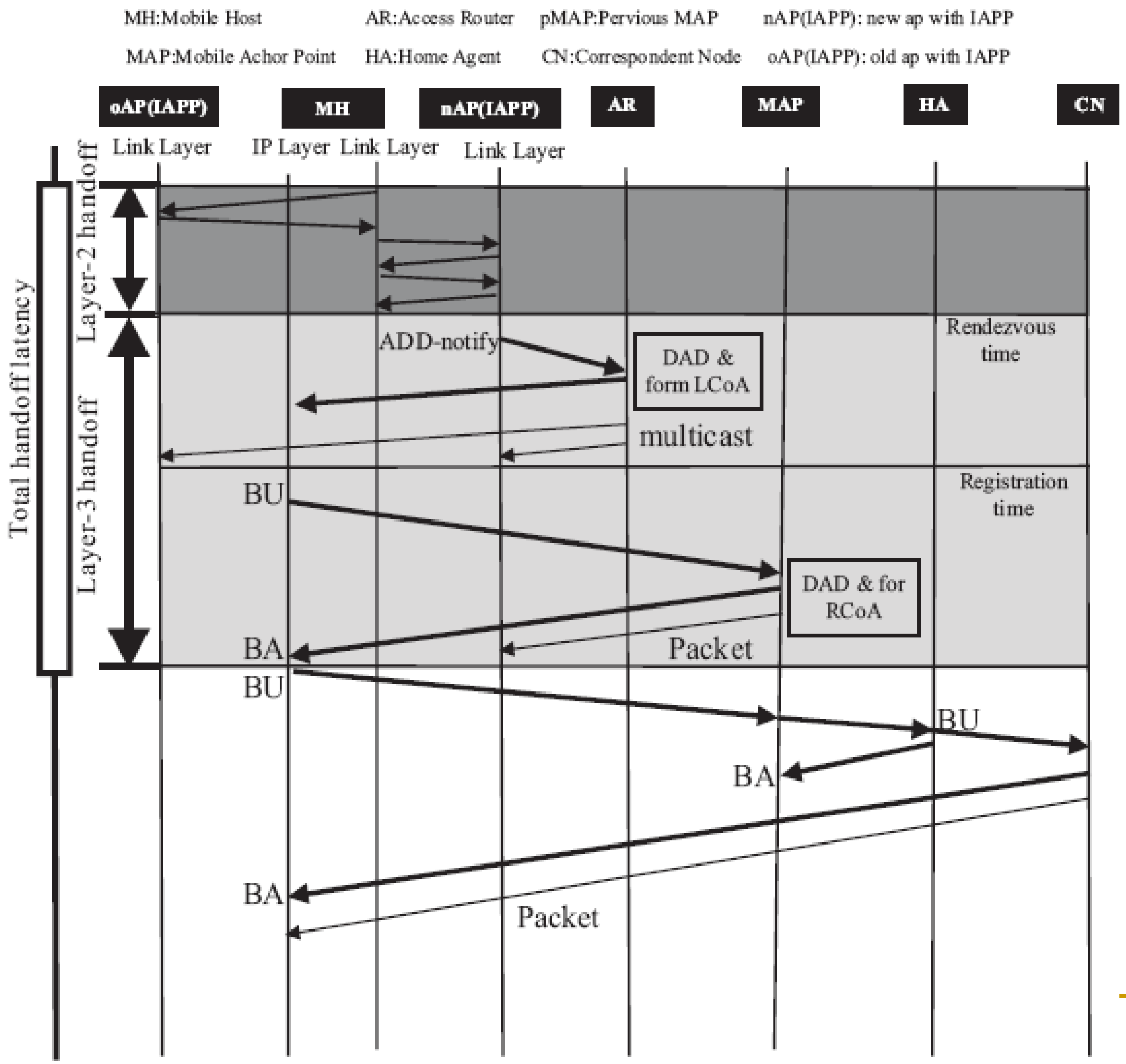
Handoff of HMIPv6



Handoff of SHMIPv6

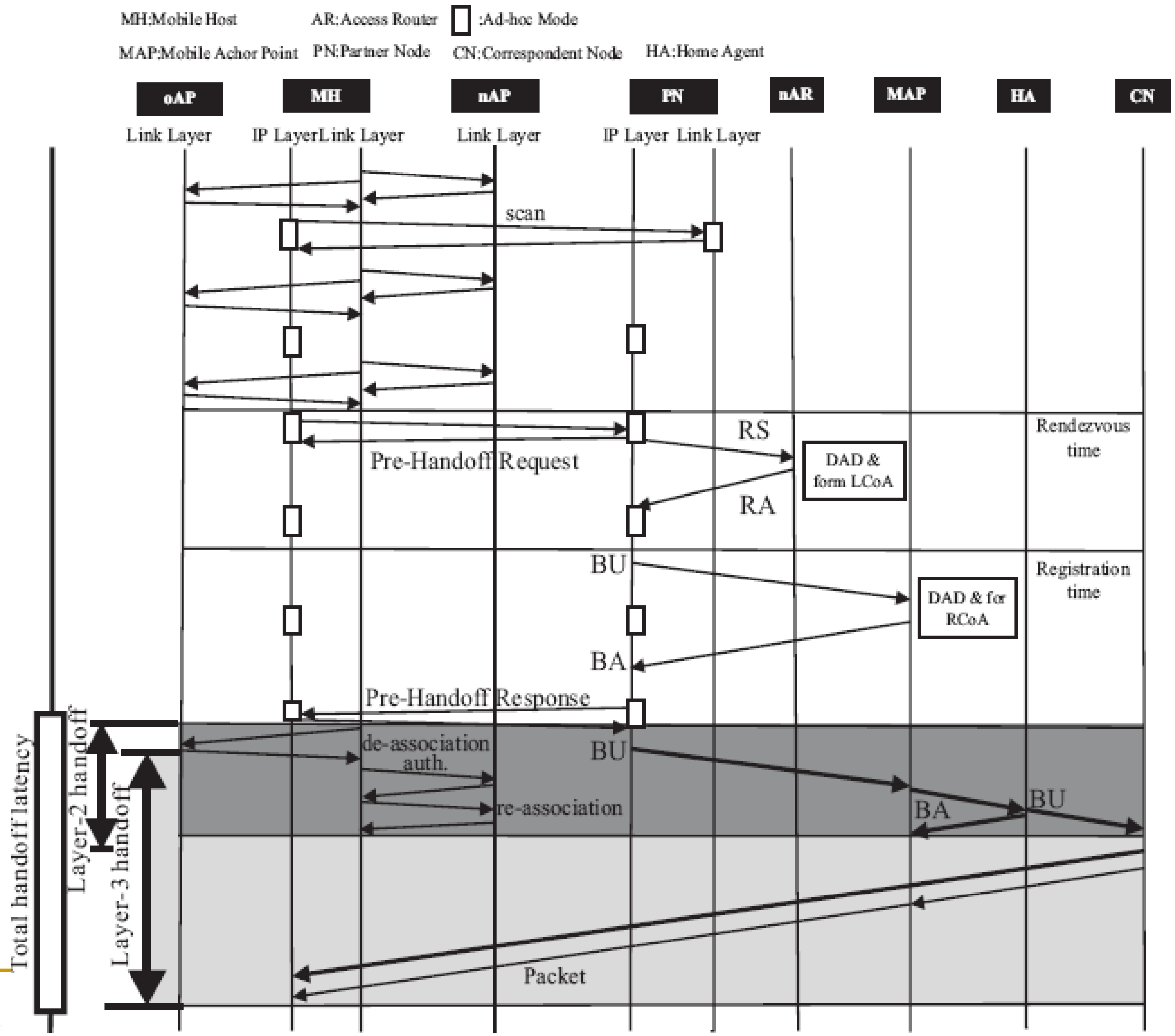


Handoff of HMIPv6+



NTPU, Department of C

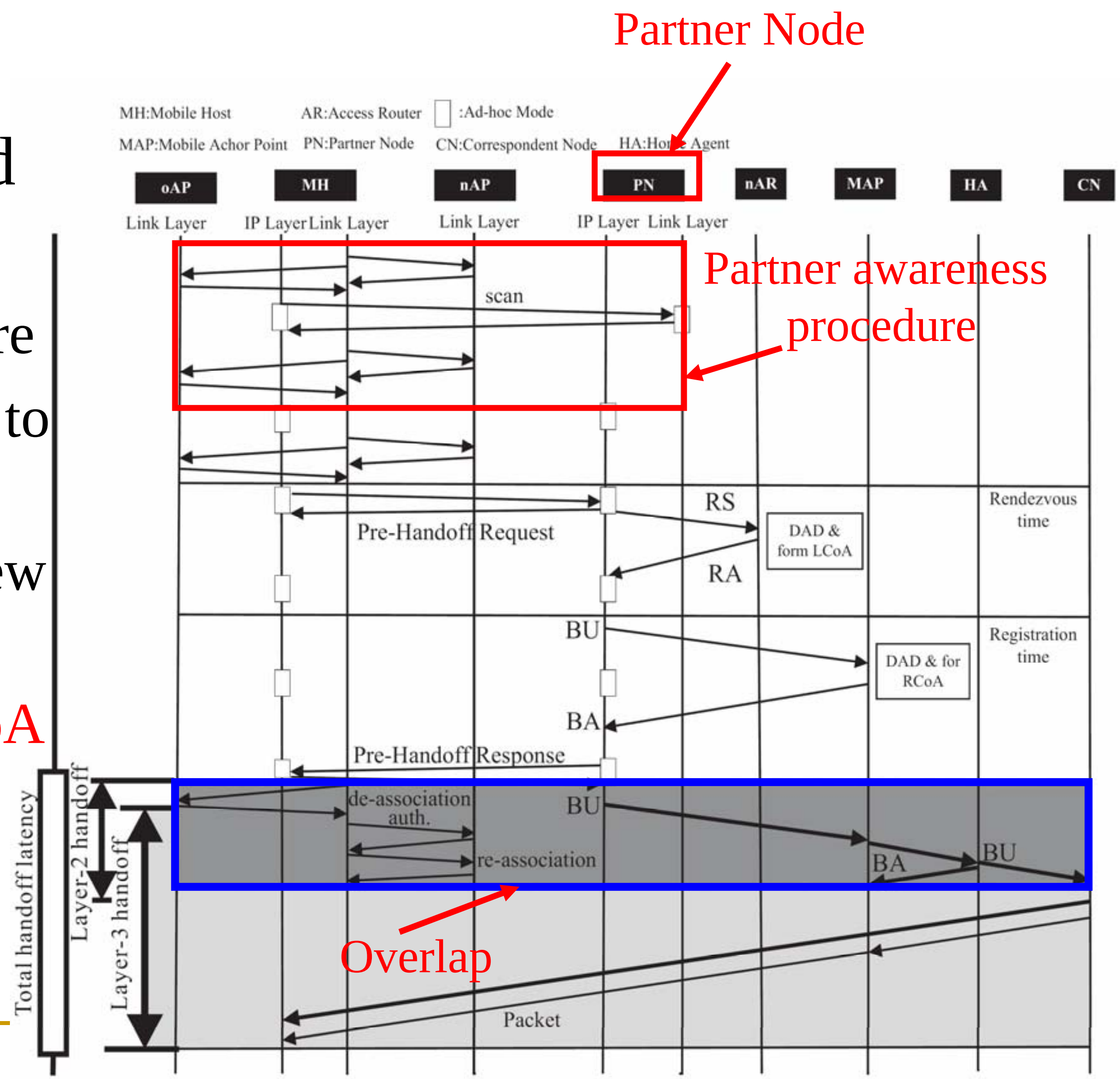
Ours



MH:Mobile Host
AR:Access Router
:Ad-hoc Mode
MAP:Mobile Achor Point
PN:Partner Node
CN:Correspondent Node
HA:Home Agent
oAP
MH
nAP
PN
nAR
MAP
HA
CN
Link Layer
IP Layer Link Layer
Link Layer
IP Layer Link Layer
scan
RS
Pre-Handoff Request
DAD &
form LCoA
RA
Rendezvous
time
BU
DAD & for
RCoA
Registration
time
BA
Pre-Handoff Response
de-association
auth.
BU
re-association
BA
BU
Packet
Total handoff latency
Layer-2 handoff
Layer-3 handoff

Partner based HMIPv6 (PHMIPv6)

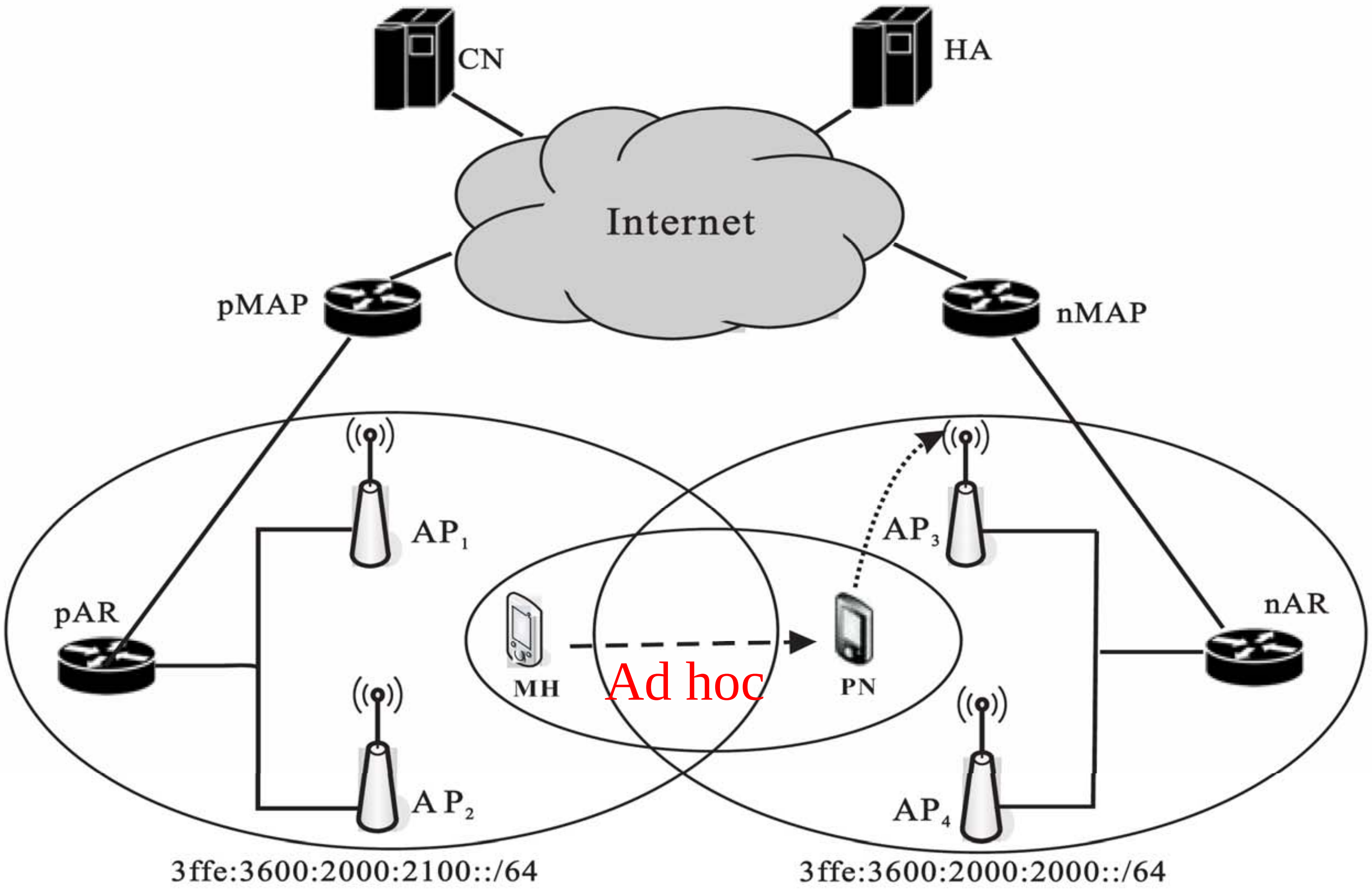
- Cross-layer partner based fast handoff
  - Under HMIPv6 architecture
  - Using layer-2 information to enhance layer-3 handoff
  - Finding partner-node in new MAP domain
  - To reduce the LCoA and RCoA's DAD time



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.

Cooperative Partner Node (PN)



Basic idea

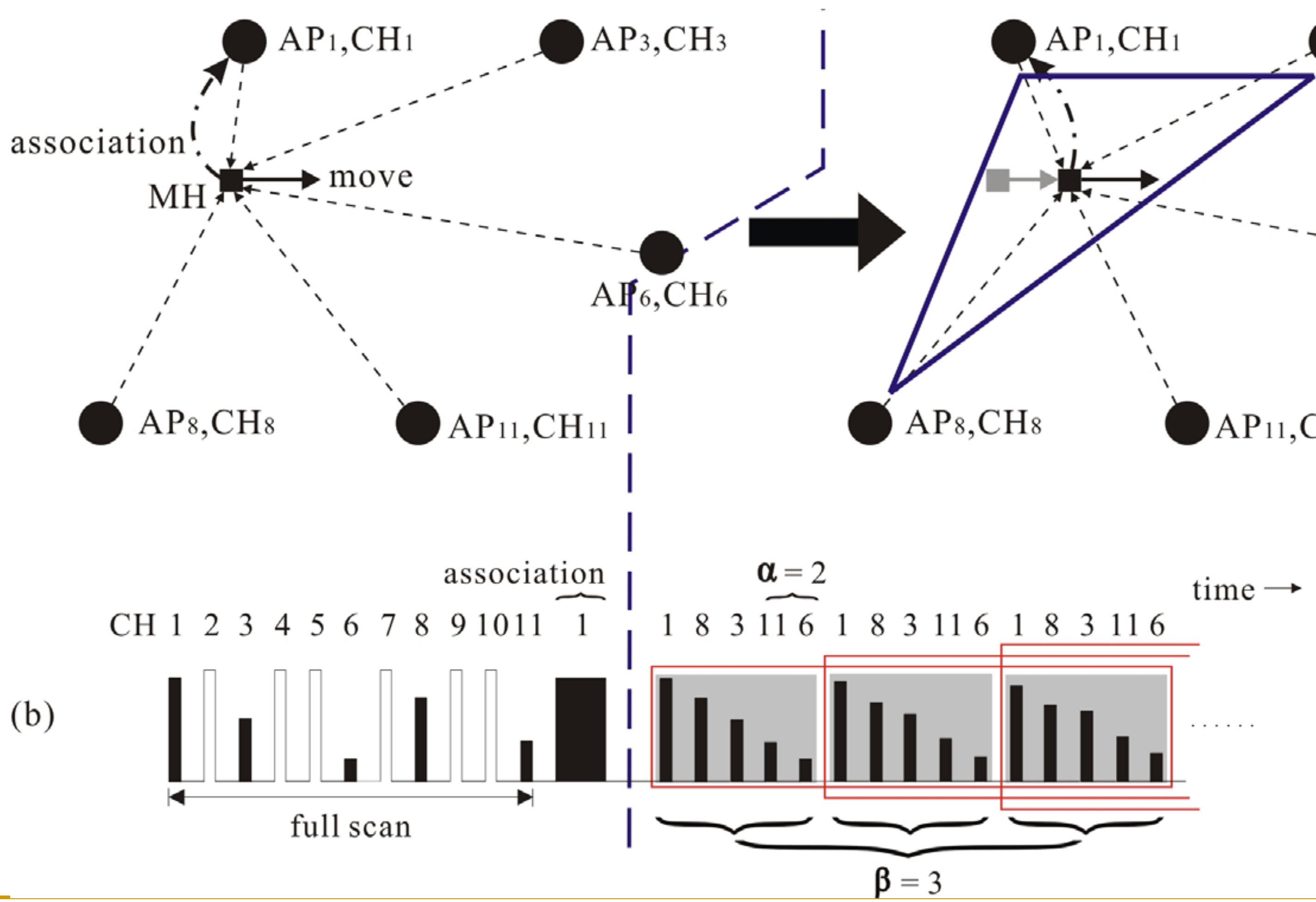
- Using the Deucescan scheme in layer-2.
  - Collecting all information of the neighbor APs.
  - Using layer-2 information to detect MH's moving.
- Using partner-based mechanism in layer-2/3.
  - Using the deucescan information to find partner node
  - Pre-handoff by partner-node for LCoA and RCoA DAD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

Deucescan procedure

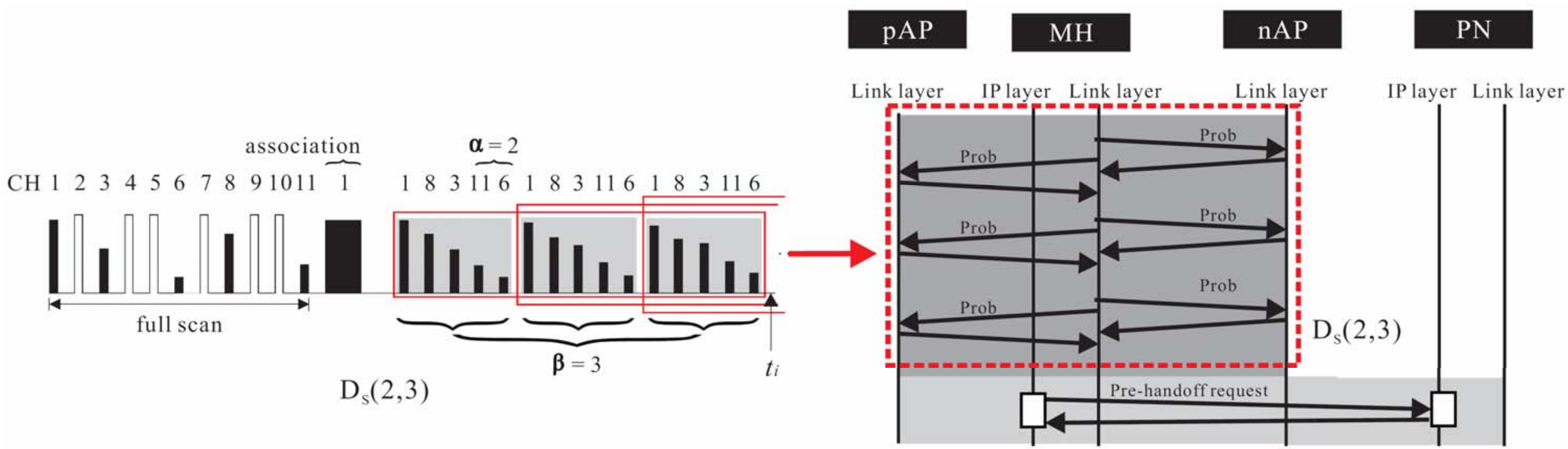
- The Deuce procedure is used for confirming whether the RSS received from an MH at some place are stable by continuously probing nearby APs and judges if it needs to change the current spatiotemporal triangle.
- We denote a deuce procedure with signal strength as $D_s(\alpha, \beta)$.

Y.-S. Chen and C.-K. Chen and M.-C. Chuang, "DeuceScan: Deuce-Based Fast Handoff Scheme in IEEE 802.11 Wireless Networks," **IEEE Trans. on Vehicular Technology**, March 2008.

Example of $D_s(2,3)$



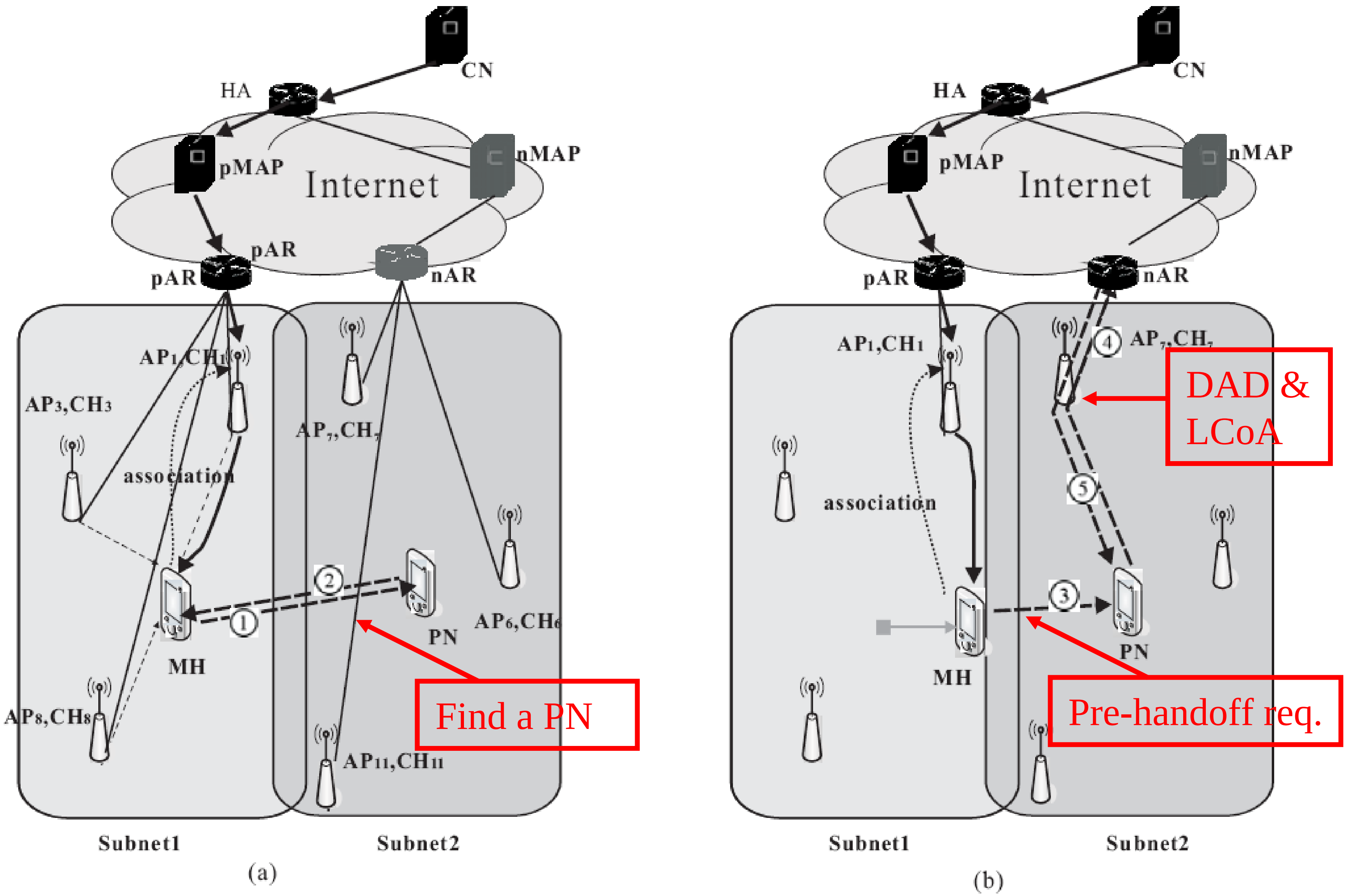
Cross-layer idea



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 cooperative scenario



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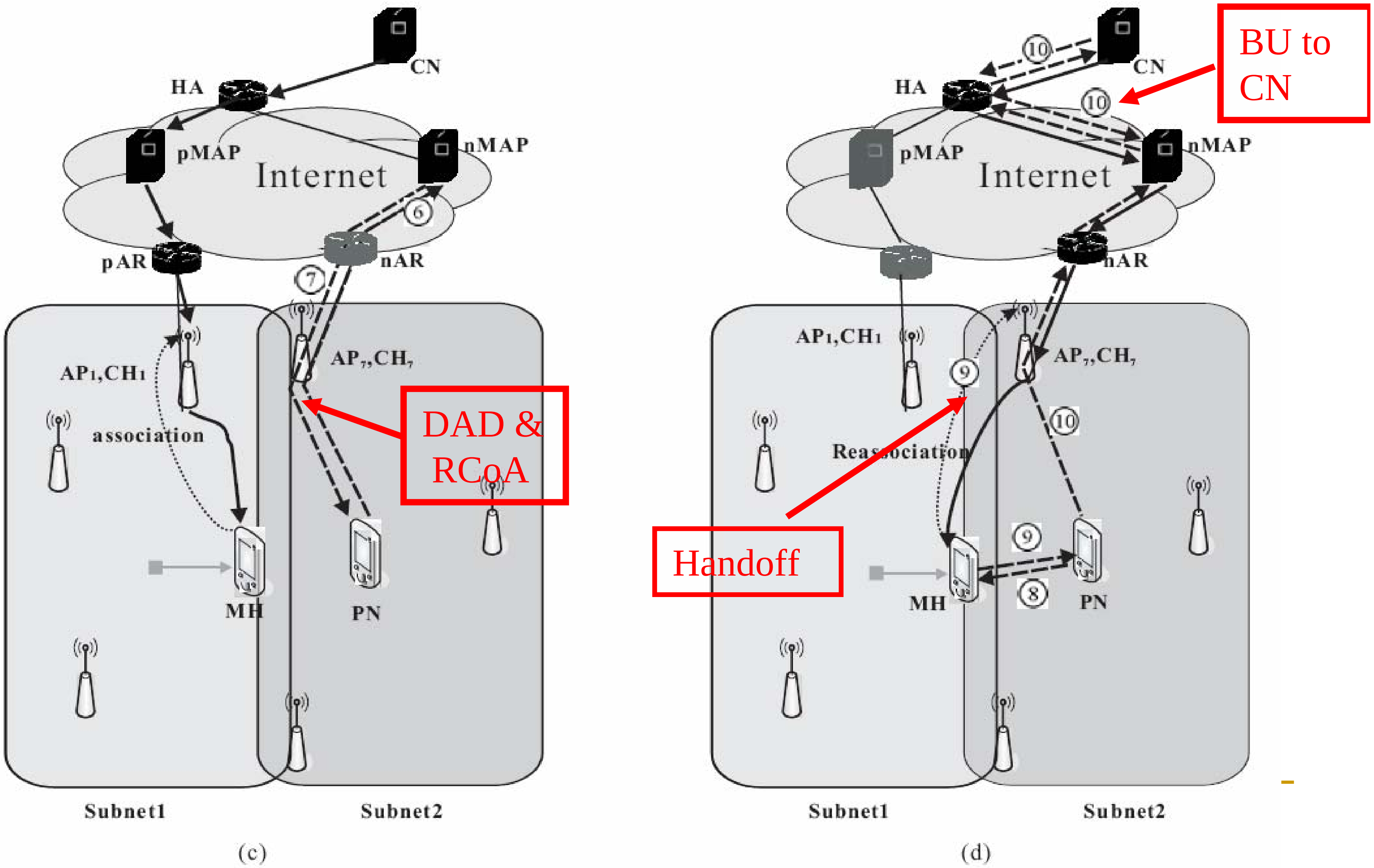
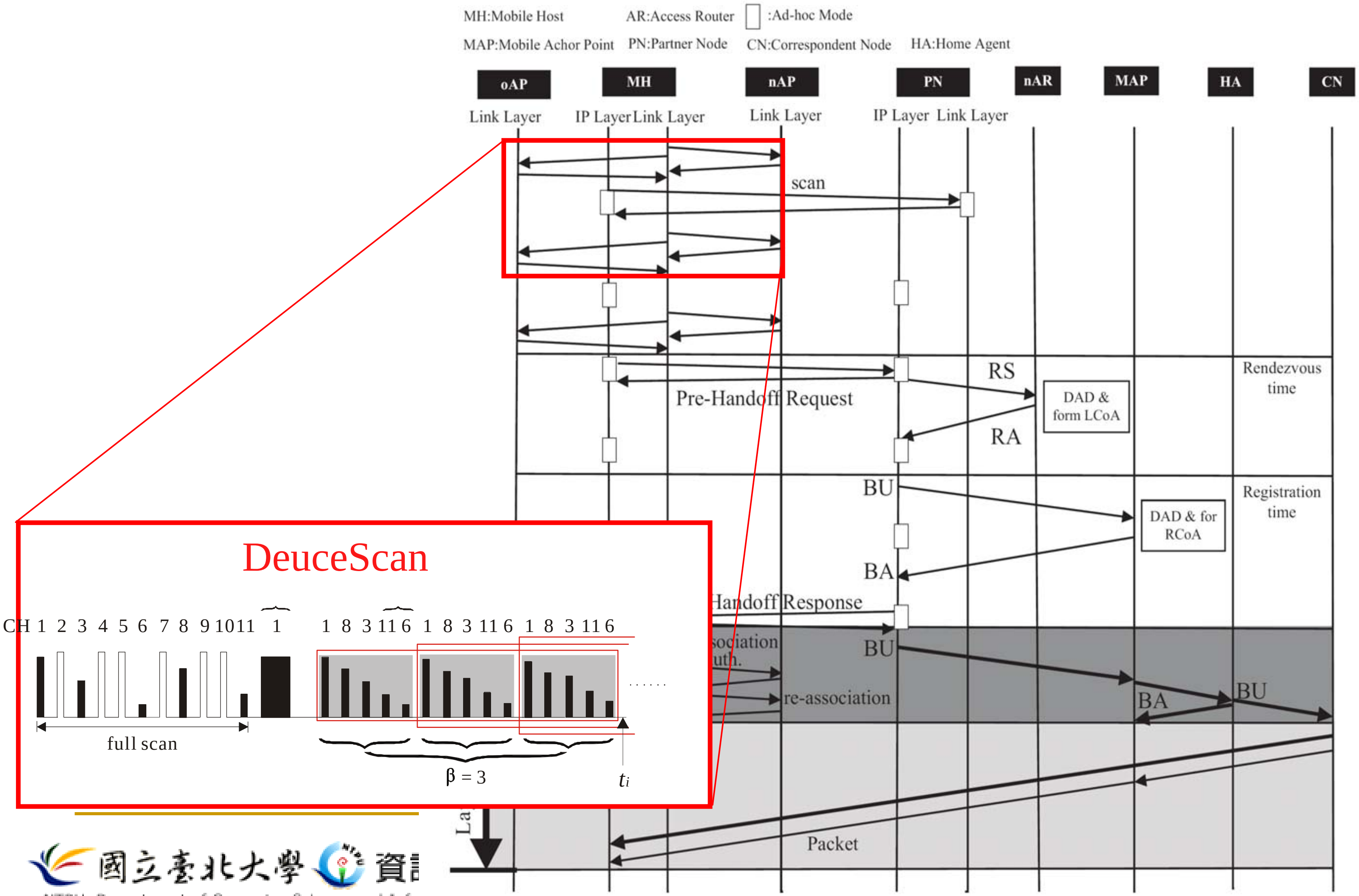
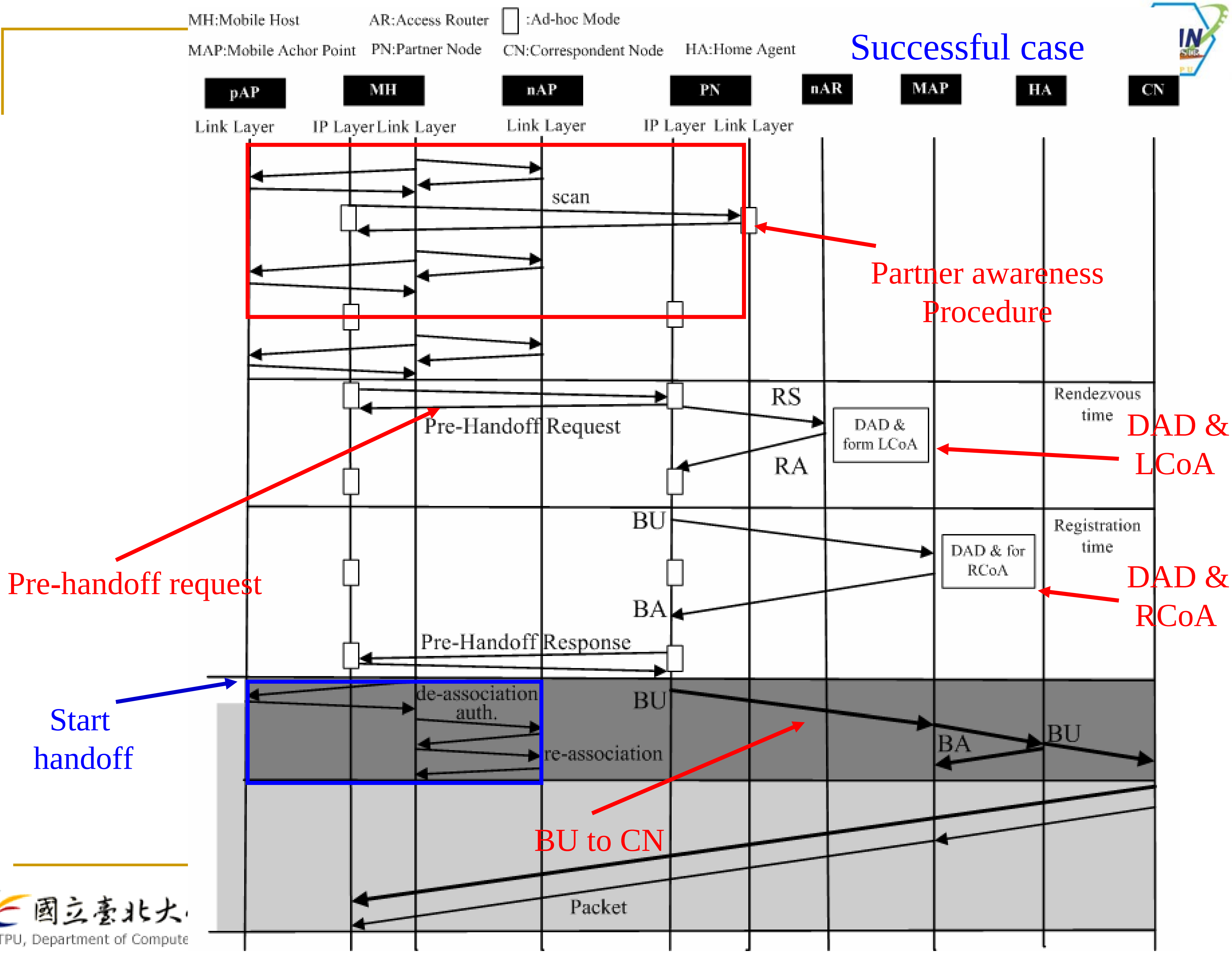


CN
HA
pMAP
nMAP
Internet
pAR
nAR
AP1,CH1
AP7,CH7
association
DAD & RCoA
MH
PN
Subnet1
Subnet2
(c)
BU to CN
Reassociation
Handoff
(d)

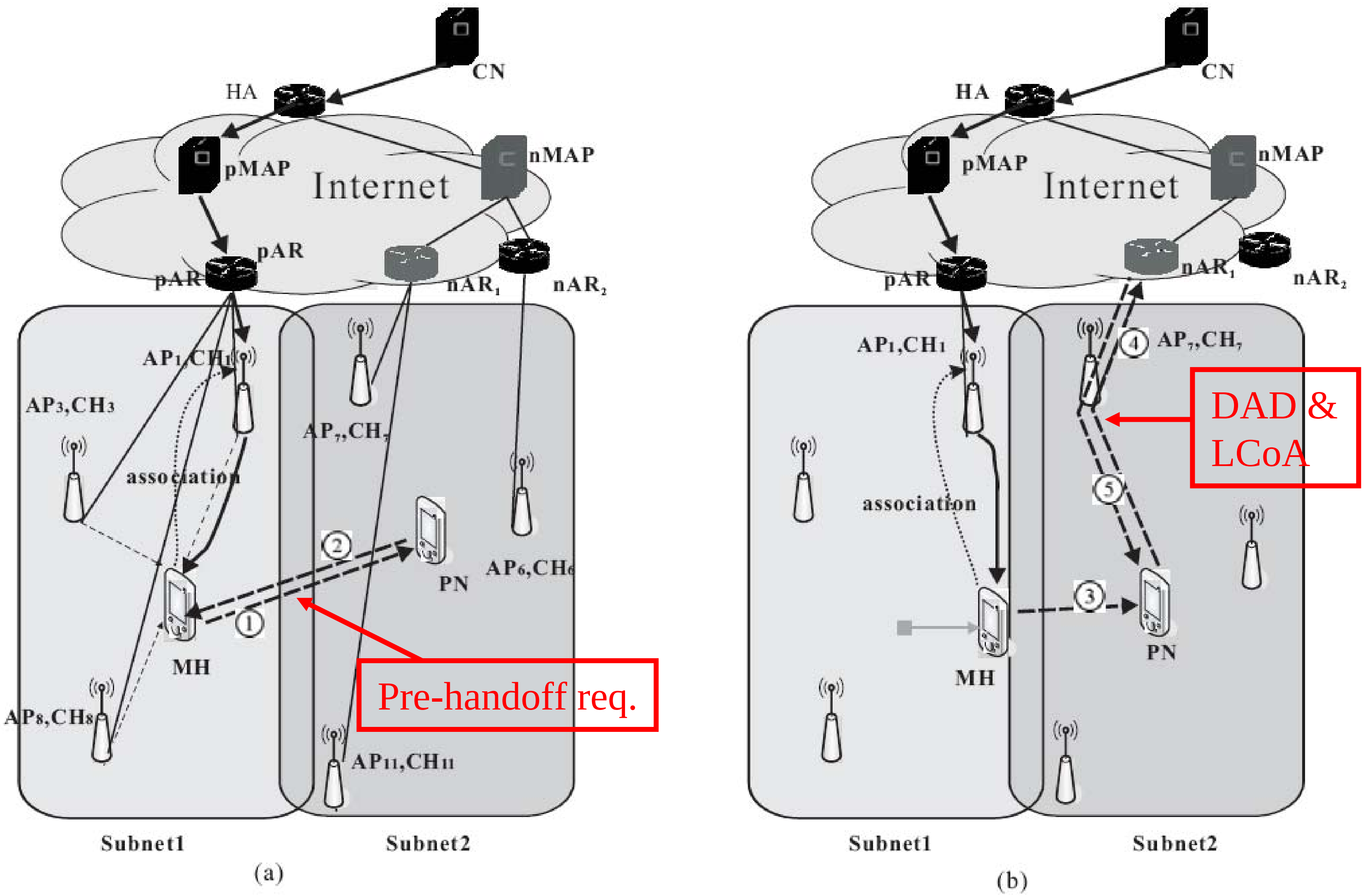
Partner-based HMIPv6 (PHMIPv6)



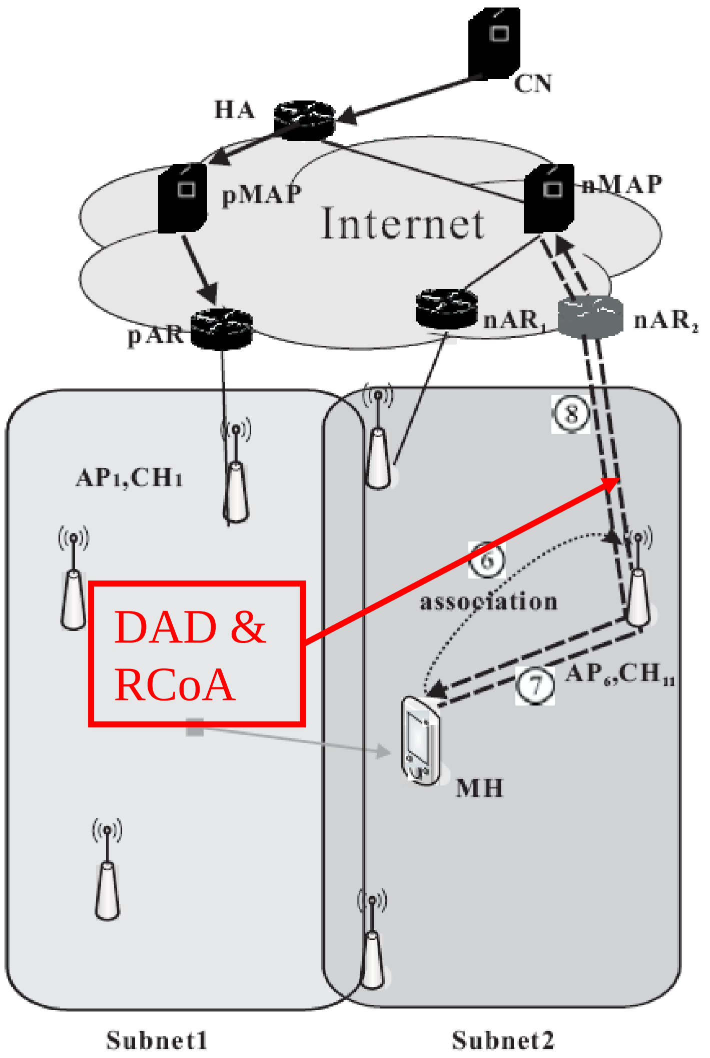
Successful case

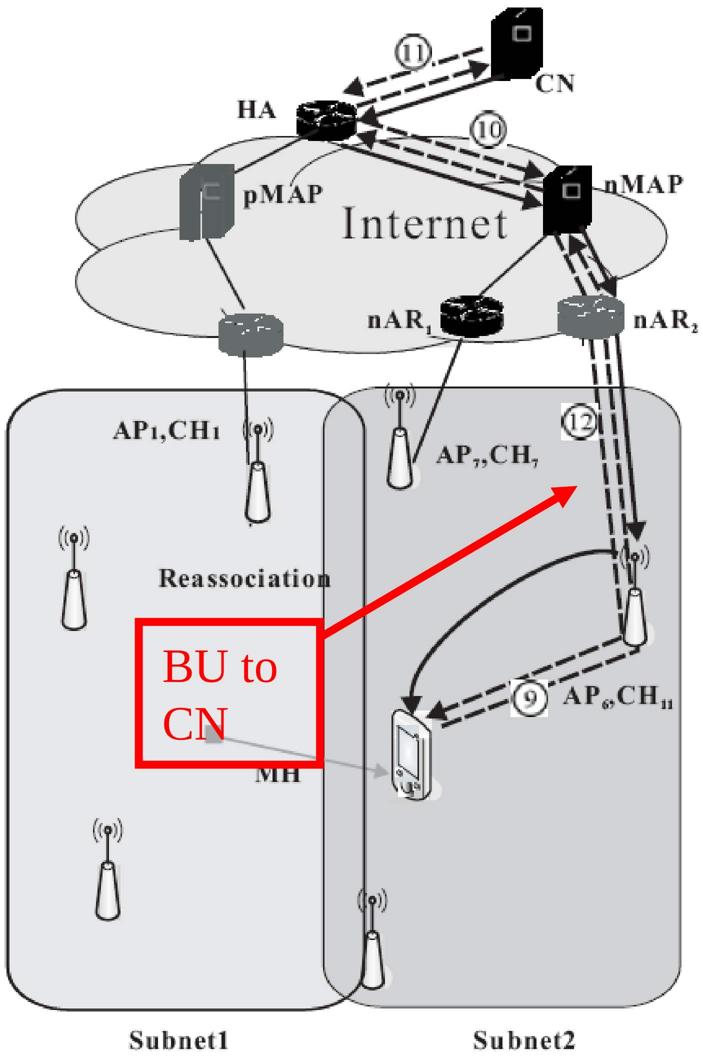


Unsuccessful scenario

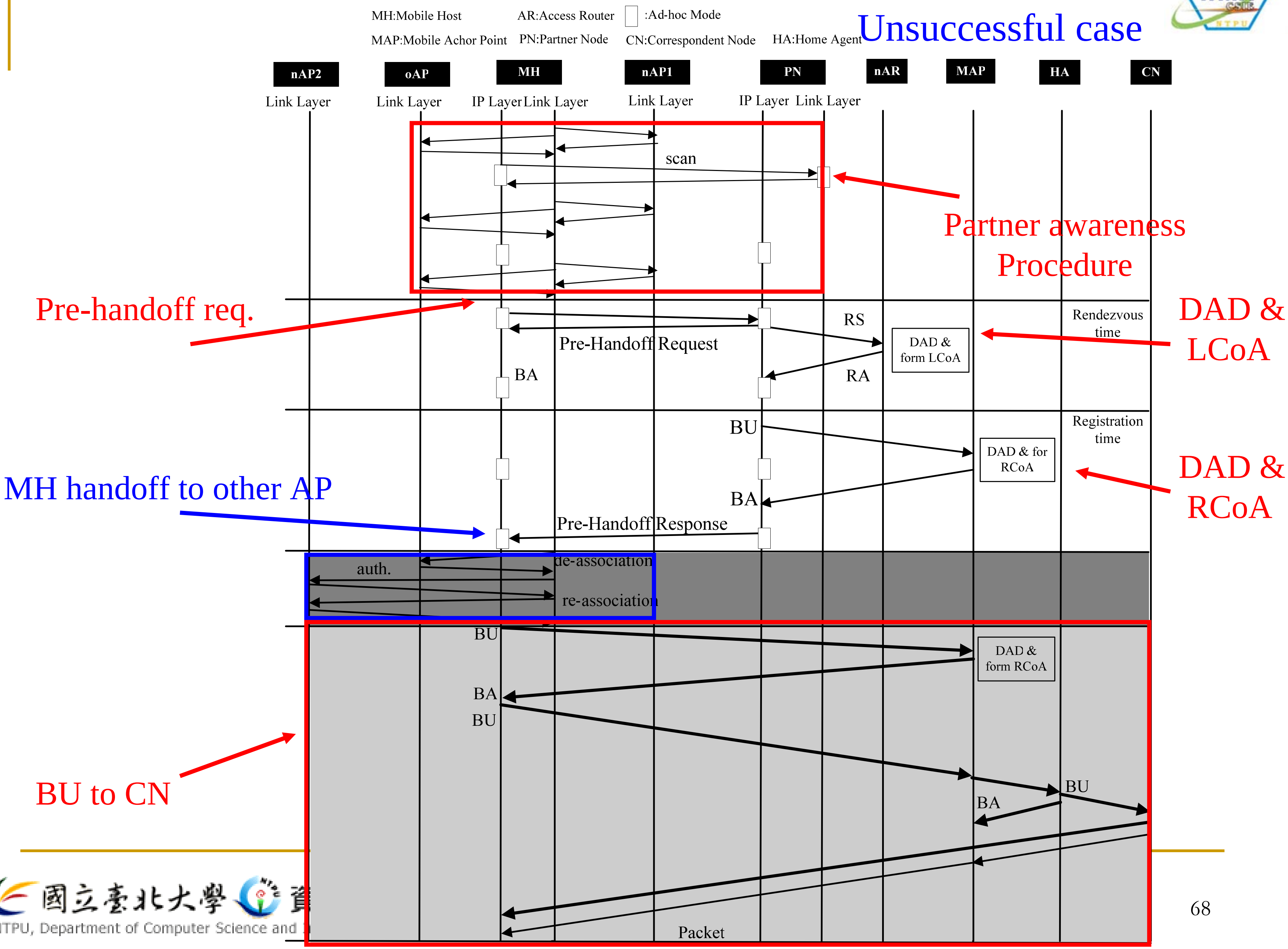


Cont.


CN
HA
pMAP
nMAP
Internet
pAR
nAR_1
nAR_2
AP1,CH1
8
6
association
DAD &
RCoA
7
AP_6,CH_{11}
MH
Subnet1
Subnet2
(c)


11
CN
HA
10
pMAP
nMAP
Internet
nAR_1
nAR_2
AP1,CH1
12
AP_7,CH_7
Reassociation
BU to
CN
9
AP_6,CH_{11}
MH
Subnet1
Subnet2
(d)

Unsuccessful case



Mathematical analysis/simulation results

- Mathematical analysis and simulation
  - Mathematical analysis the handoff latency

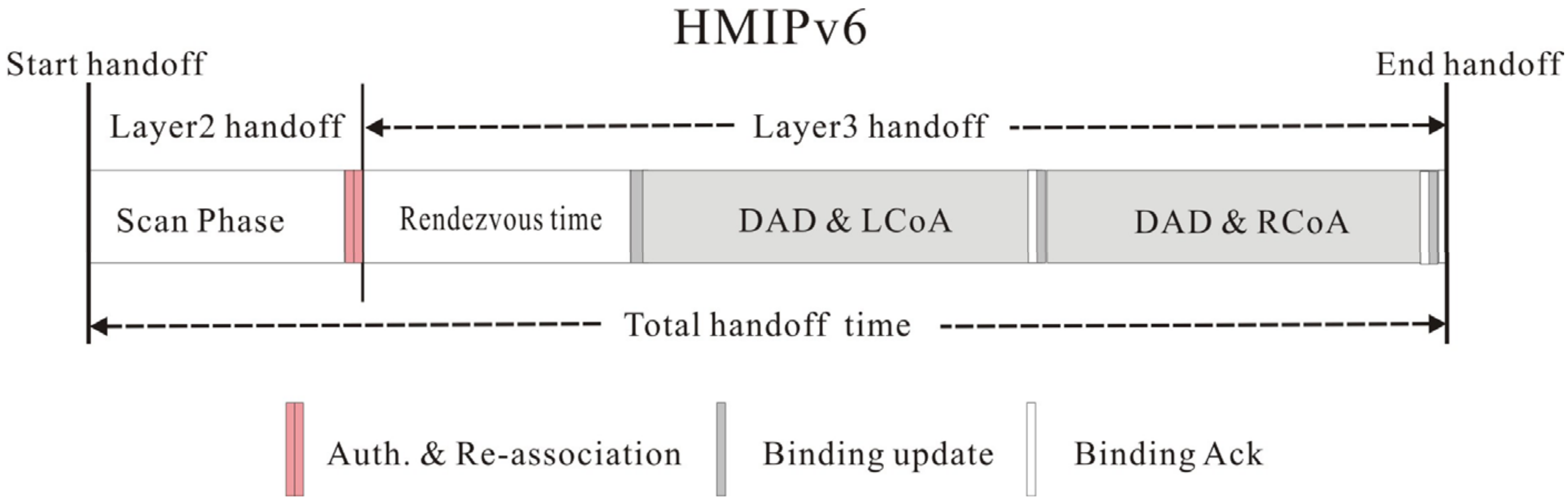
- MIPv6, HMIPv6, SHMIPv6, PHMIPv6, U-PHMIPv6
  - Handoff latency
  - Handoff packet lost rate
  - Handoff jitter

Mathematical analysis

- Notations

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



Total handoff time of HMIPv6

Mathematical analysis

- 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

- $t_{SHMIPv6}$ 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

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

$$
\begin{aligned}
t_{\Delta_1} &= t_{HMIPv6} - t_{SHMIPv6} \\
&= t_{binding\_CN} + t_{DAD\_RCoA} - \min(t_{pmap}, t_{HA}) \\
&\leq t_{binding\_CN} + t_{DAD\_RCoA} \\
&= 2\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}\right] + 2\left[\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}\right] \\
&\quad + t_{D\_dad}
\end{aligned}
$$

Mathematical analysis

- $t_{PHMIPv6}$ 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

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

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

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

Mathematical analysis

- $t_{U\_PHMIPv6}$ 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

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

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

Mathematical analysis

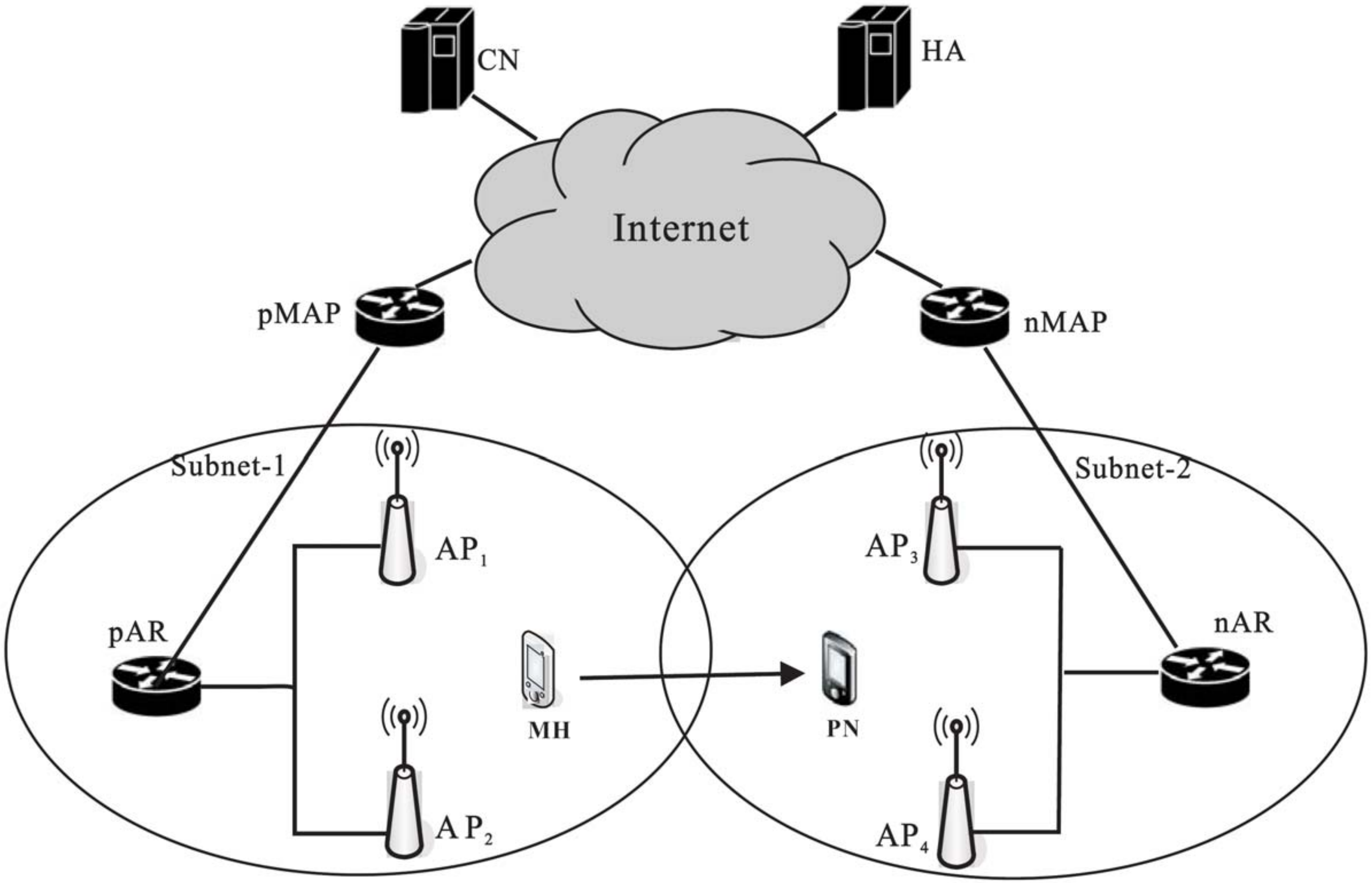
$t_{\Delta_3} - t_{\Delta_1}$ means that U-PHMIPv6 is still better than SHMIPv6.

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

$$\text{If } \; t'_{layer\_2} < \left[\left(\frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] + t_{layer\_2}$$

$$t_{\Delta_3} - t_{\Delta_1} > 0$$

PHMIPv6 test-bed



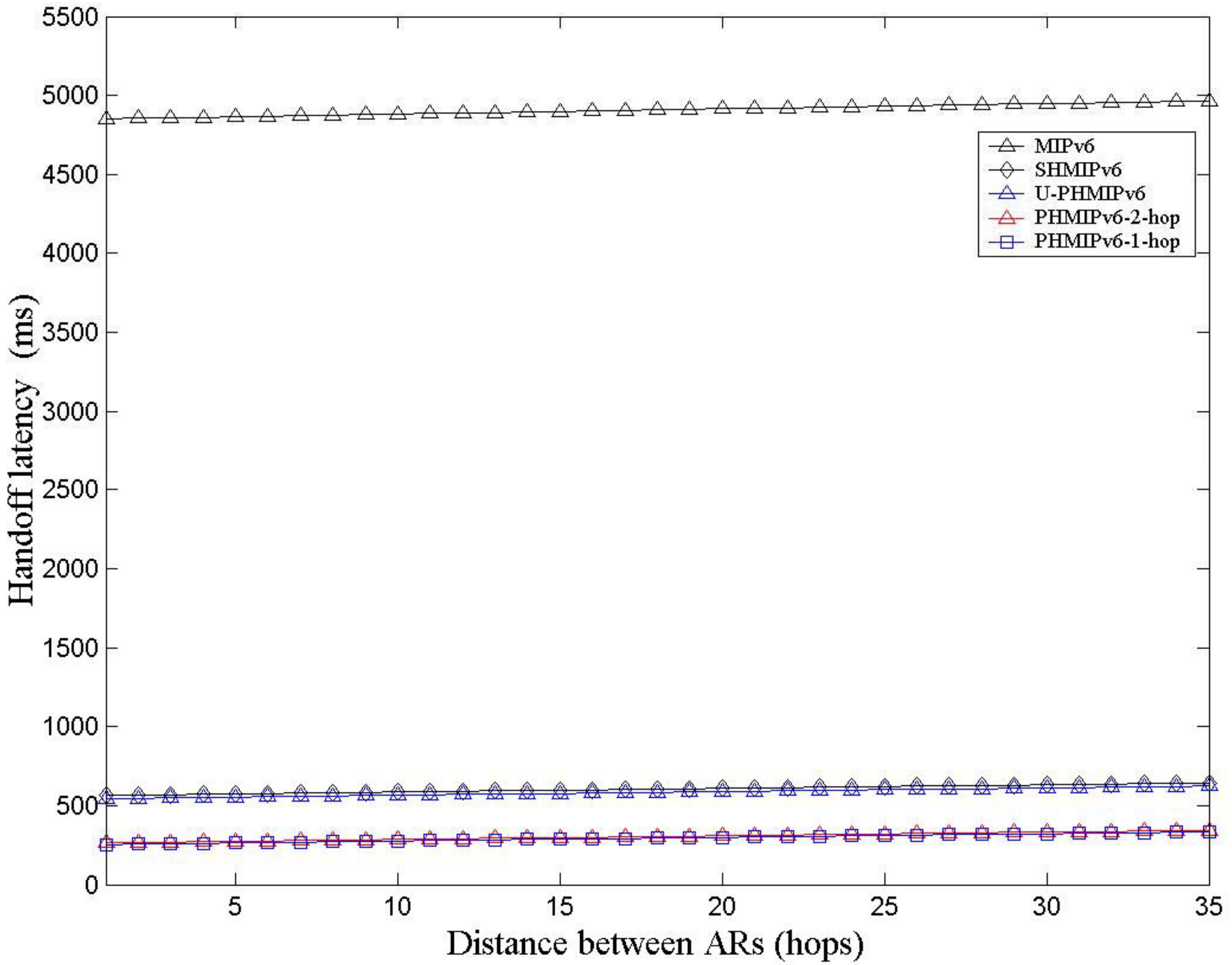
Performance metrics

- *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.

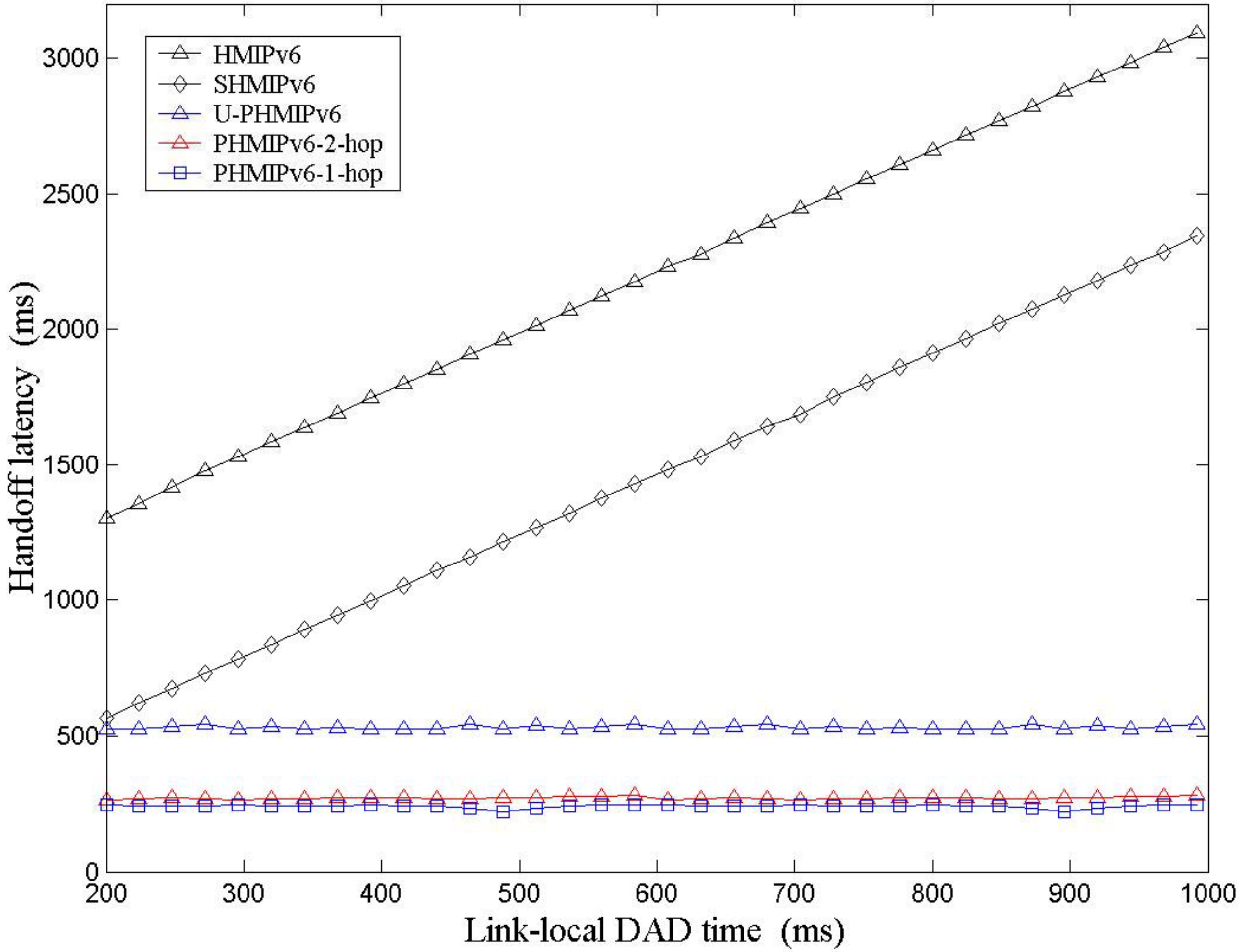
- *Handoff jitter* (HJ): The handoff jitter is the variation in delay between the packets.

Handoff latency



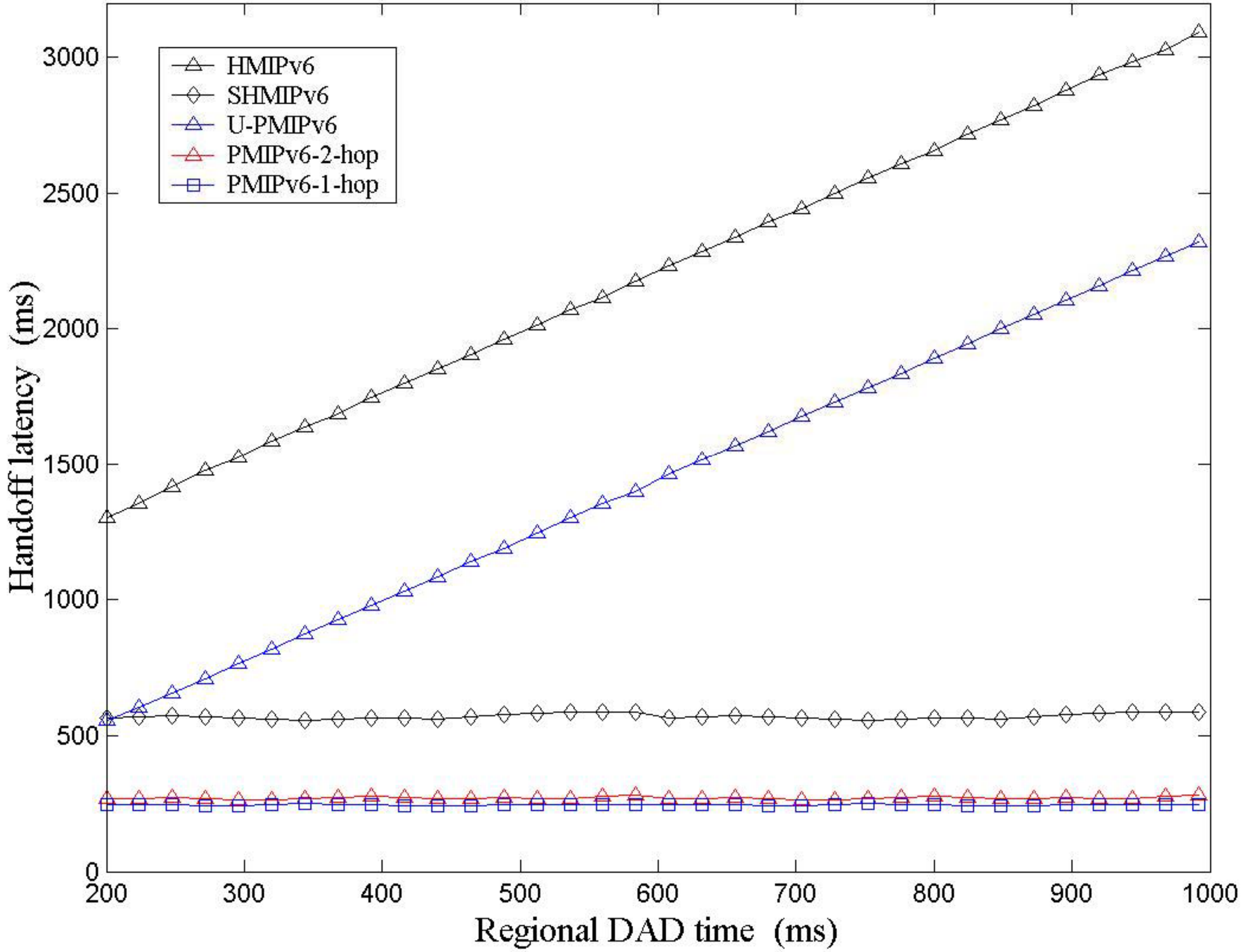
Handoff latency vs. hops

Handoff latency



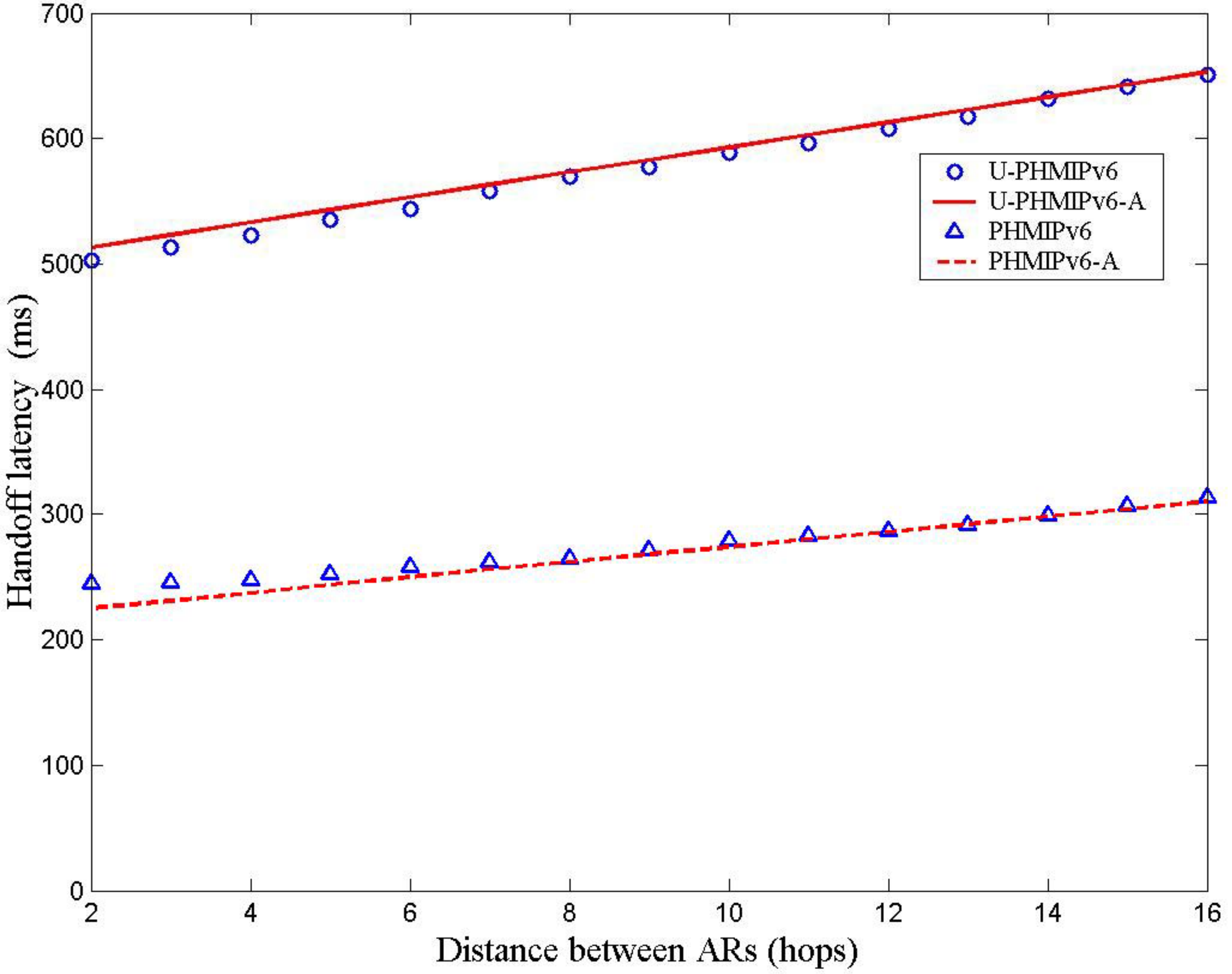
Handoff latency vs. link-local DAD time

Handoff latency

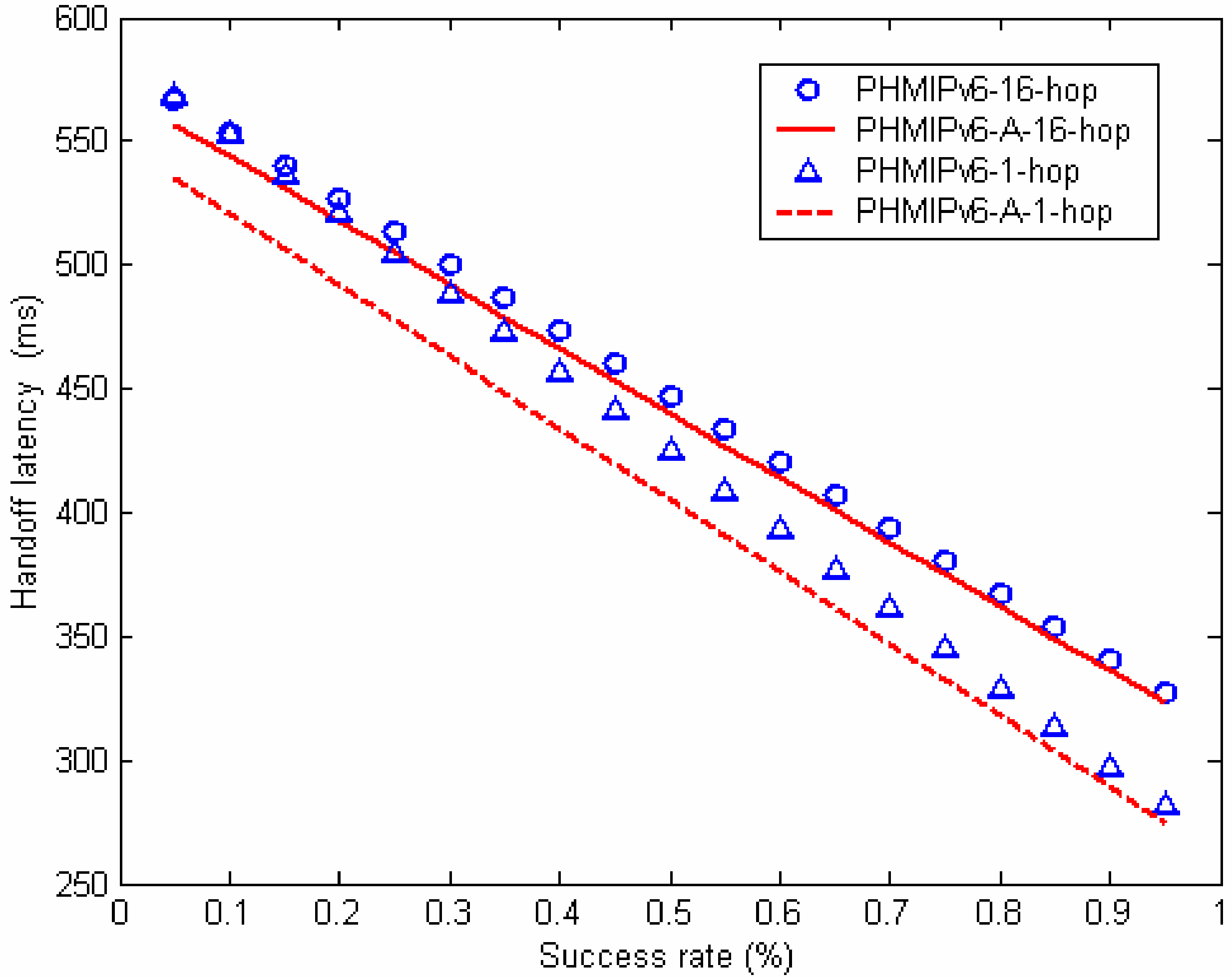


Handoff latency vs. regional DAD time

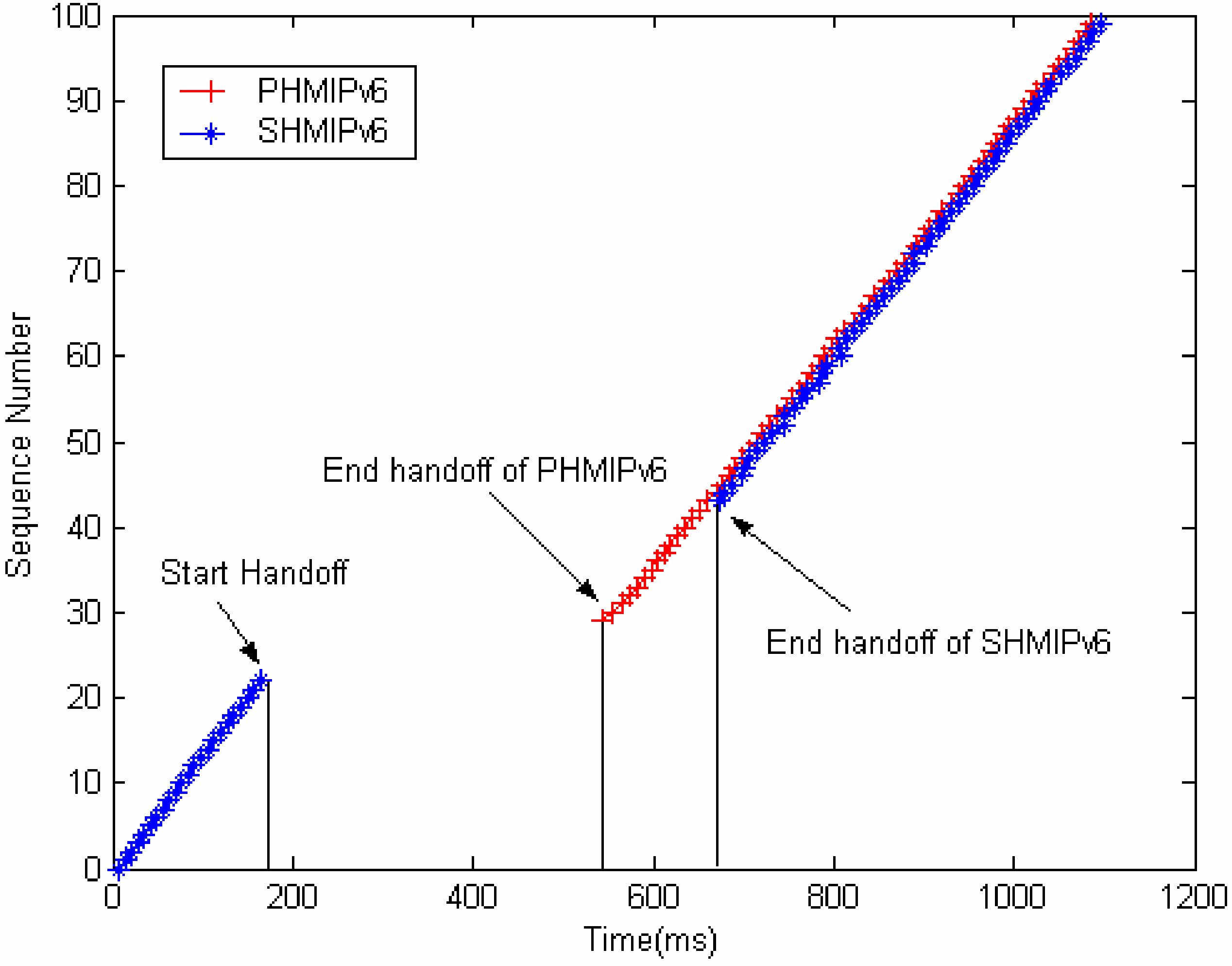
Handoff latency (analysis)



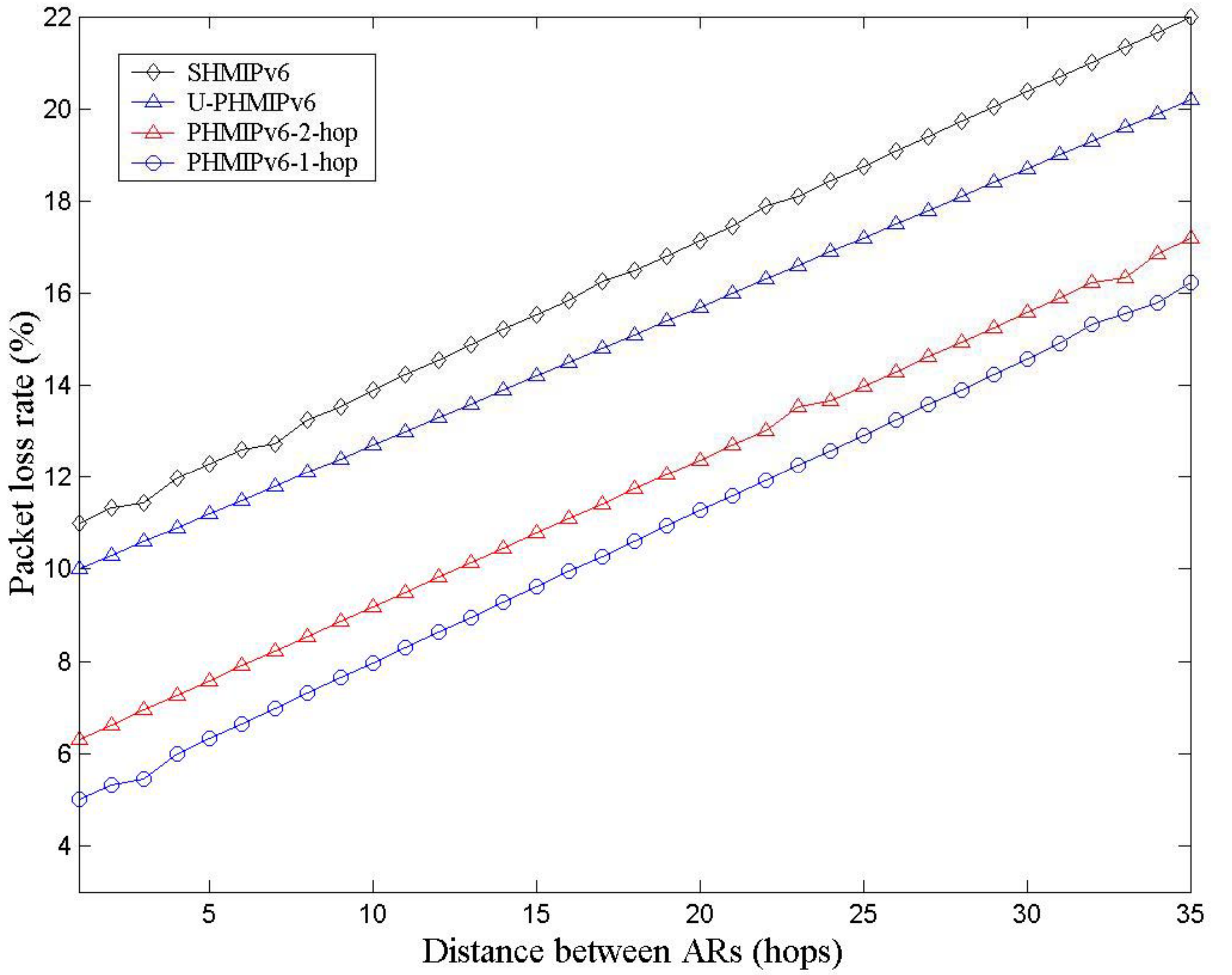
Handoff latency



Sequence number

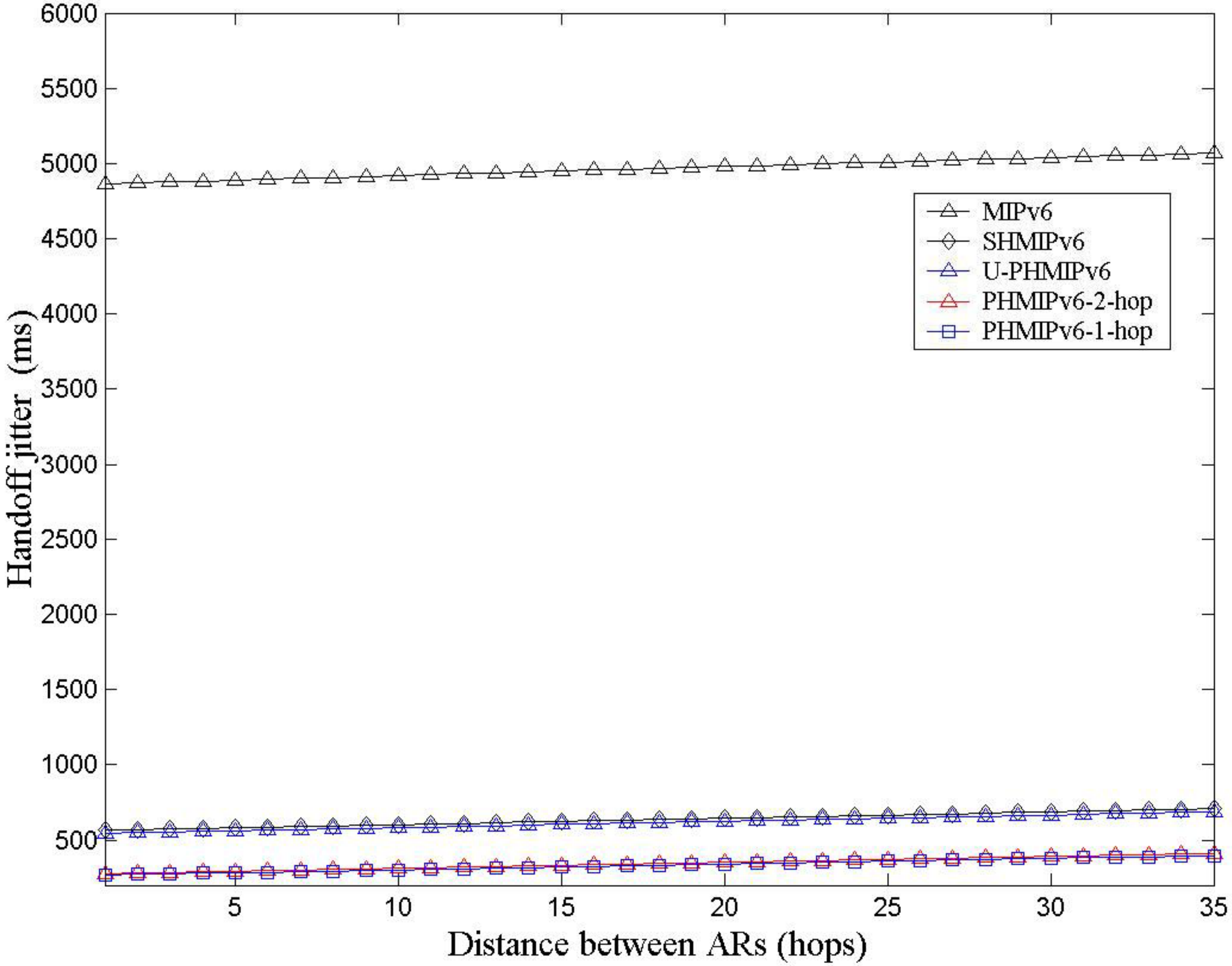


Packet loss rate



Packet loss rate vs. hops

Handoff jitter



Handoff jitter vs. hops

Mobileheroes

2005

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Candidate-AP Detection Function

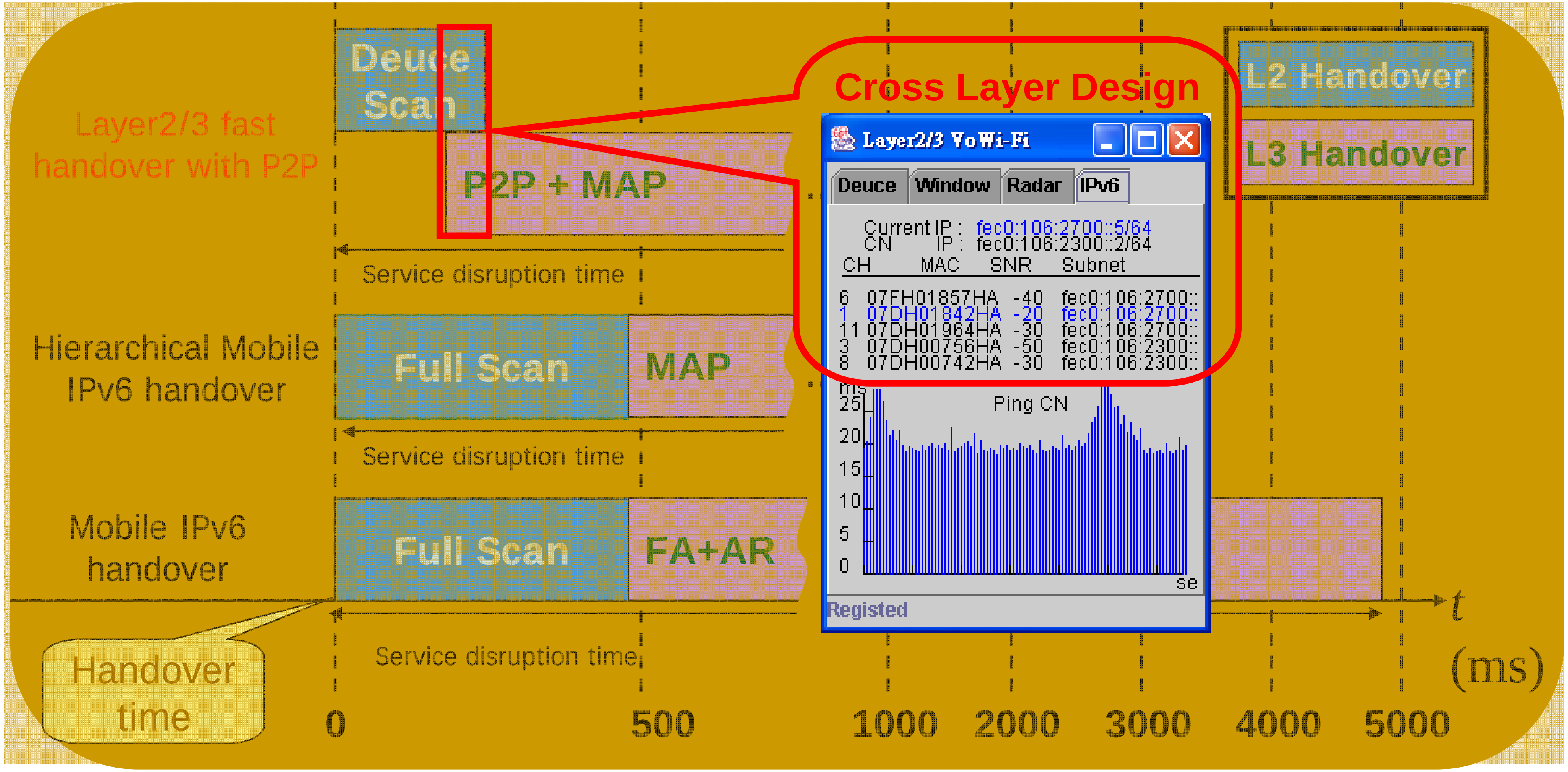
- To provide useful information to cross layer-2/3 handoff scheme
  - DeuceScan
  - HMIPv6 + P2P
- To identify possible candidate APs
  - To utilize signal strength (variation) and moving history

System implementation

(a) DeuceScan

(b) Cross-layer partner-based

Comparisons of Handoff Latency



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得獎證明

無限夢想行動家 蕭煒翰 吳昆霖 謝博在 呂振瑋 君

作品：Layer-2/3 Fast Handoff Mechanism for VoWi-Fi

參加由經濟部工業局委託工研院電通所舉辦之

『打造無限夢想行動家 2005通訊大賽』

Play Tech組 成績優異

經評選核定 榮獲優等獎

特此證明

財團法人
工業技術研究院
電腦與通訊工業研究所

INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE
財團法人 工業技術研究院 電腦與通訊 工業研究所
COMPUTER & COMMUNICATIONS RESEARCH LABORATORIES

所長 林寶樹

中 華 民 國 九 十 四 年 十 月 八 日

Part III: A Cross-Layer Partner-Assisted Handoff Scheme for Hierarchical Mobile IPv6 in IEEE 802.16e Systems

is submitted to **IEEE ICC 2008**, May 19-23, 2008. Beijing, China.

Outline

- Introduction
- Related Work
- Basic Idea and System Architecture
- Partner-Assisted HMIPv6 (P_HMIPv6)
- Mathematical Analysis and Simulation Results
- Conclusions

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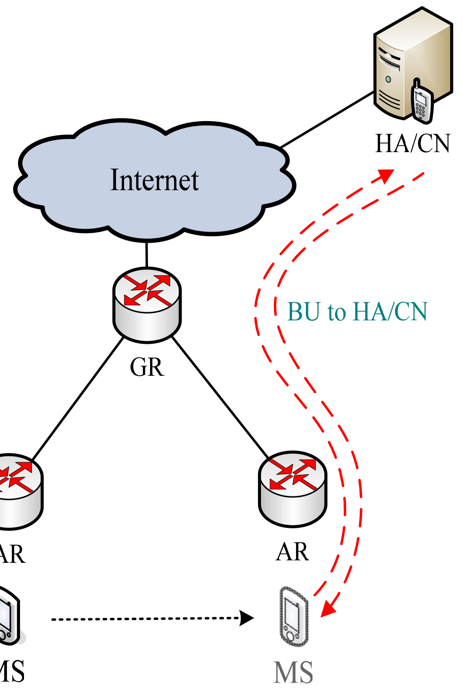
Introduction

- Worldwide Interoperability for Microwave Access (WiMAX)
  - IEEE 802.16-2004 standard
    - High bandwidth
    - Large transmission range
  - IEEE 802.16e standard
    - Support mobility for mobile station (MS)
    - Channel information and Mobile stations' handoff parameters are exchanged by BSs.

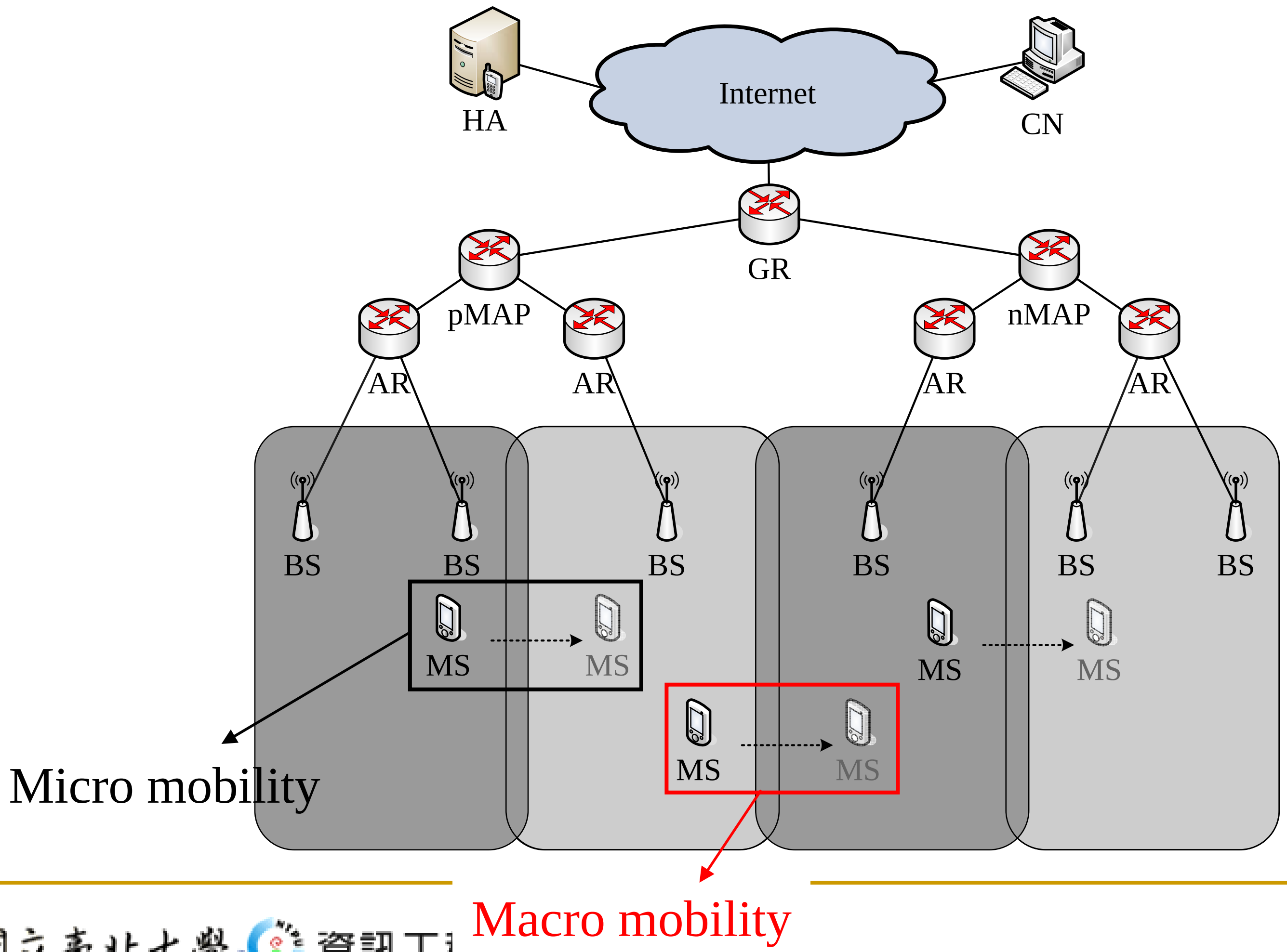
Introduction

- 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 loss because MIPv6 doesn’t support the micro-mobility.



- Hierarchical Mobile IPv6 (HMIPv6) is proposed by employing a hierarchical network structure to provide micro-mobility for reducing handoff latency.

Introduction



Introduction

- Providing a cross-layer partner-assisted handoff mechanism based on HMIPv6 in IEEE 802.16e systems
  - The IEEE 802.16e provides an efficiency handoff mechanism by exchange some useful handoff parameters over the backbone network.
  - The partner-assisted handoff (P_HMIPv6) defines a partner station (PS) to assist mobile station (MS) to perform the layer 3 pre-handoff procedure.

Outline

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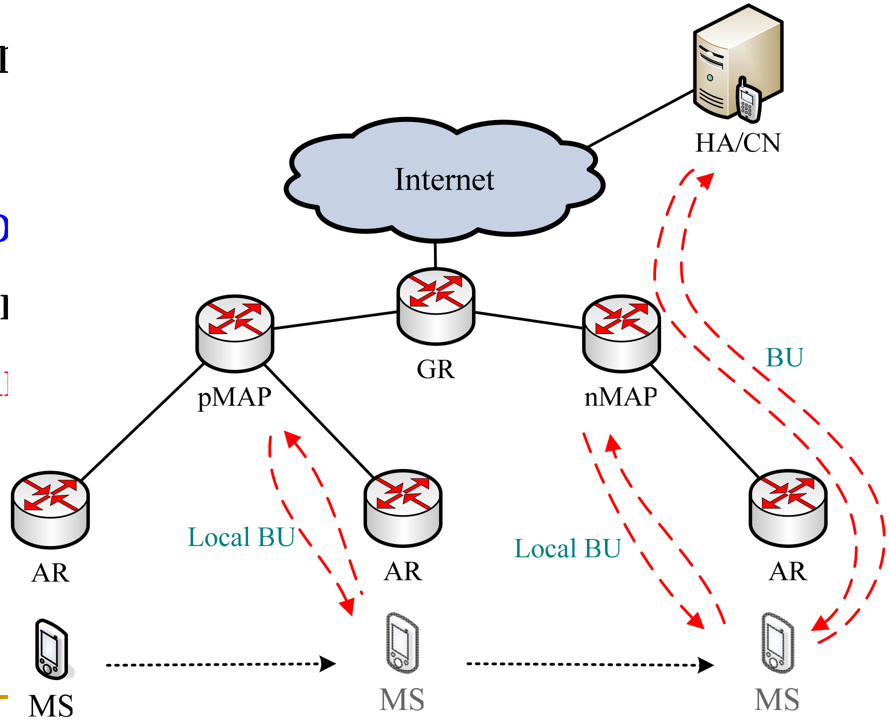
Existing Handoff Results

- HMIPv6 (RFC 4140)
  - provide a hierarchical architecture to reduce the time of binding update
  - H. Soliman, C. Castelluccia, K. E. Malki, and L. Bellier. "Hierarchical Mobile IPv6 Mobility Management (HMIPv6)". Internet Engineering Task Force (IETF), RFC-4140, August 2005.
  - Adding MAP (Mobile Anchor Poi
    for local mobility management
  - Two Care-of address: LCoA、RCo
  - Suffering large handoff latency in mac
    mobility because of two DAD procedu



Existing Handoff Results

- Existing cross-layer (layer 2 + layer 3) handoff approach in IEEE 802.16e system
  - H.-J. Jang, J.-H. Jee, Y.-H. Han, and J. Cha. "Mobile IPv6 Fast Handovers over IEEE 802.16e Networks". *Internet Engineering Task Force* (*IETF*), *Internet-draft*, January 2007.
    - layer 2 trigger defined in IEEE 802.21
  - M. Shim, H. Kim, and S. Lee. "A fast handover mechanism for IPv6 based WiBro system". *IEEE International Conference on Advanced Communication Technology*, February 2006.
    - Integrating layer 3 message into the layer 2 messages
    - Reducing the out-of-order problem

Existing Handoff Results

- Existing cross-layer (layer 2 + layer 3) Handoff Approach
  in IEEE 802.16e system
  - Y.-W. Chen and F.-Y. Hsieh. "A Cross Layer Design for Handoff in 802.16e Network with IPv6 Mobility". *IEEE Wireless Communications and Networking Conference*.
    - Integrating some FMIPv6 messages into the layer 2 messages
    - Overlapping the layer 2 handoff time and the time of the tunnel establishment
  - J. Park, D.-H. Kwon, and Y.-J. Suh. "An Integrated Handover Scheme for Fast Mobile IPv6 Over IEEE 802.16e Systems". *IEEE Vehicular Technology Conference 2006 Fall* , pp. 1 - 5, September 2006.
    - Solving the problems of the imprecise L2-trigger generation time
    - The L3 handoff is always initiated at the network side.

Existing Handoff Results

- Other layer 3 handoff approach
  - Goal: pre-executing layer 3 handoff procedure to reduce handoff latency and 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 Vehicular Technology*, pp. 1576 - 1593, November 2003.
  - Y.-S. Chen, W.-H. Hsiao, and K.-L. Chiu. "Cross-Layer Partner-Based Fast Handoff Mechanism for IEEE 802.11 Wireless Networks". *IEEE Vehicular Technology Conference 2007 Fall* , October 2007.

Motivation

- HMIPv6 suffers a long latency for real-time service in macro mobility
  - DAD time for LCoA and RCoA occupies the the main time of layer-3 handoff
- Partial handoff procedure of layer-3 can be pre-executed before the layer 2 handoff.

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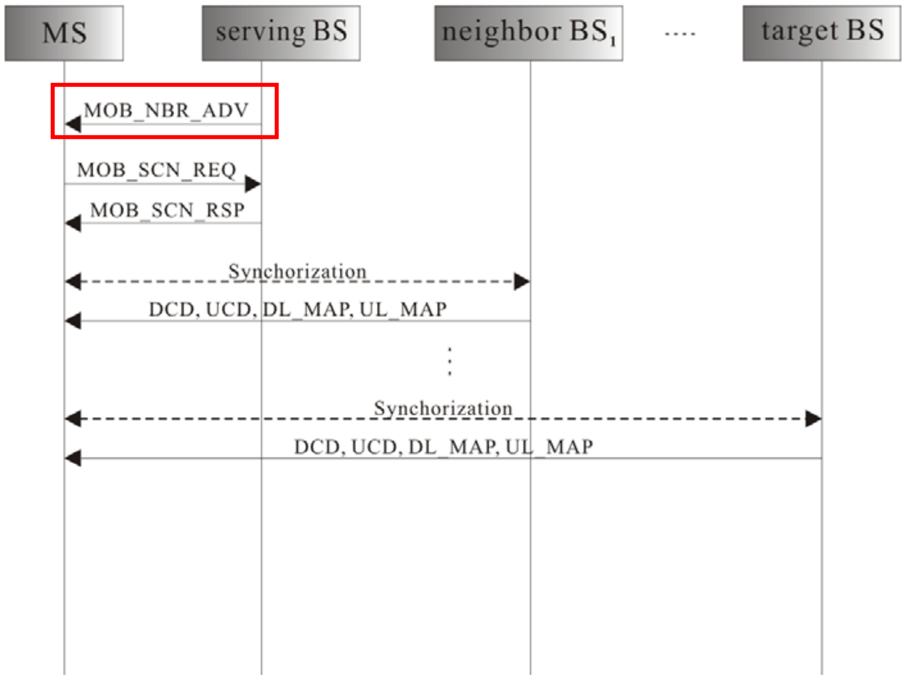
IEEE 802.16e Handoff Procedure

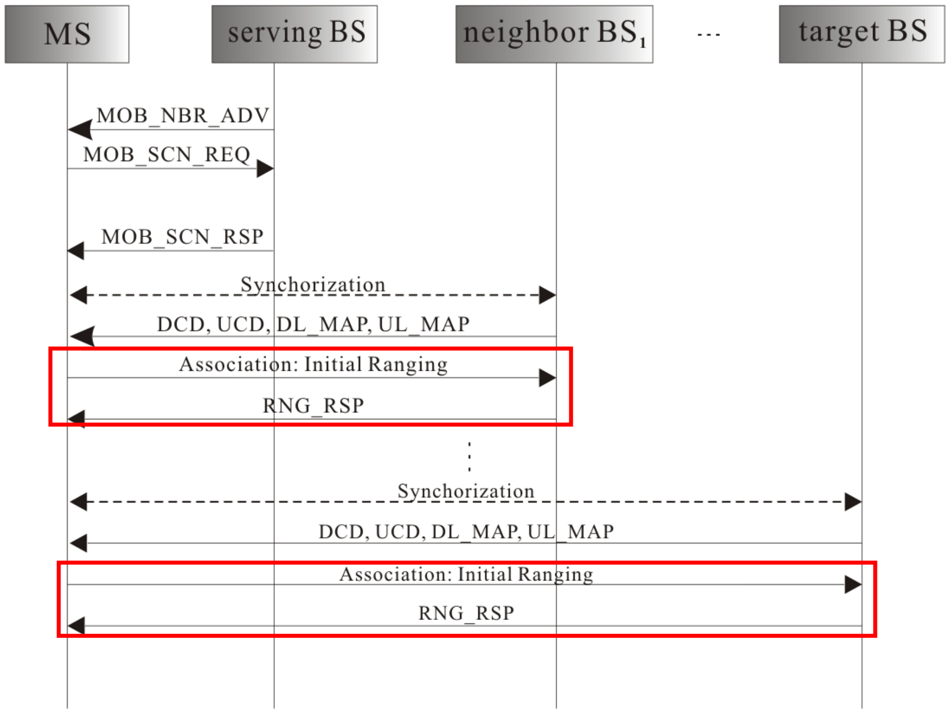
- Cell reselection
- Handoff decision and initiation
- Synchronization to target BS
- Handoff ranging
- Termination of MS context

Cell Reselection

without association

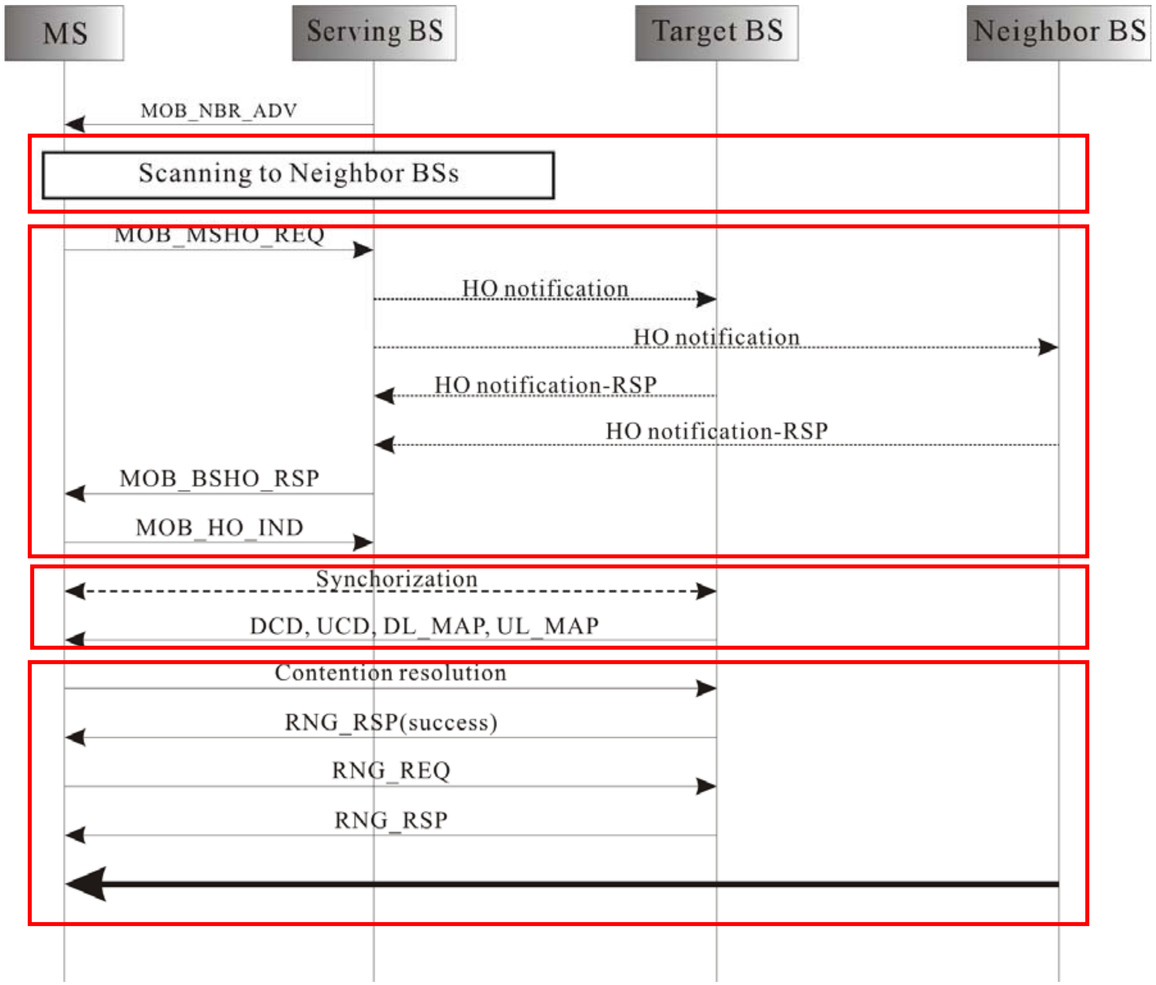


Scanning with association

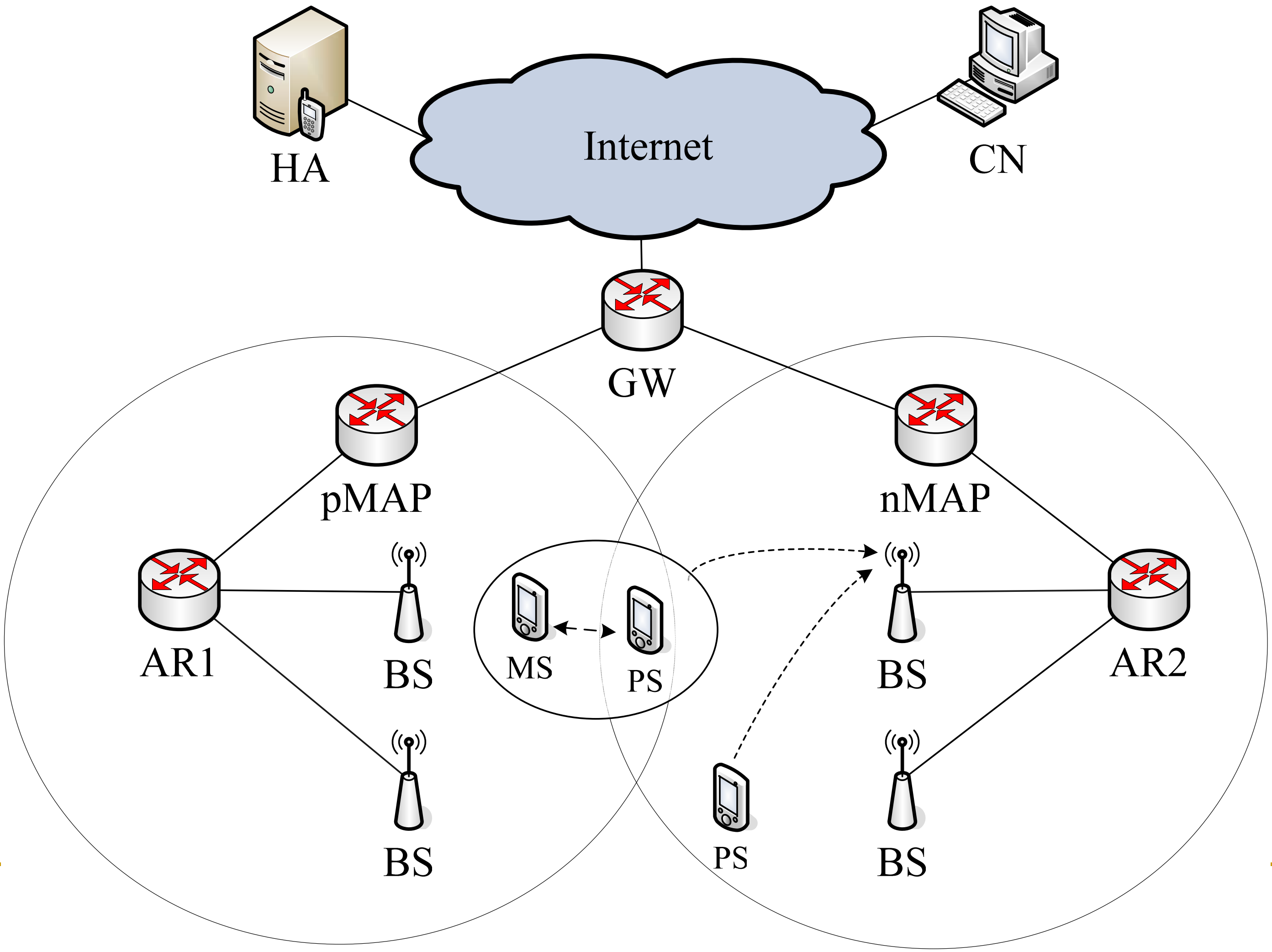


Handoff Procedure

- Cell reselection
- Handoff decision and initiation
- Synchronization to target BS
- Handoff ranging



System Architecture

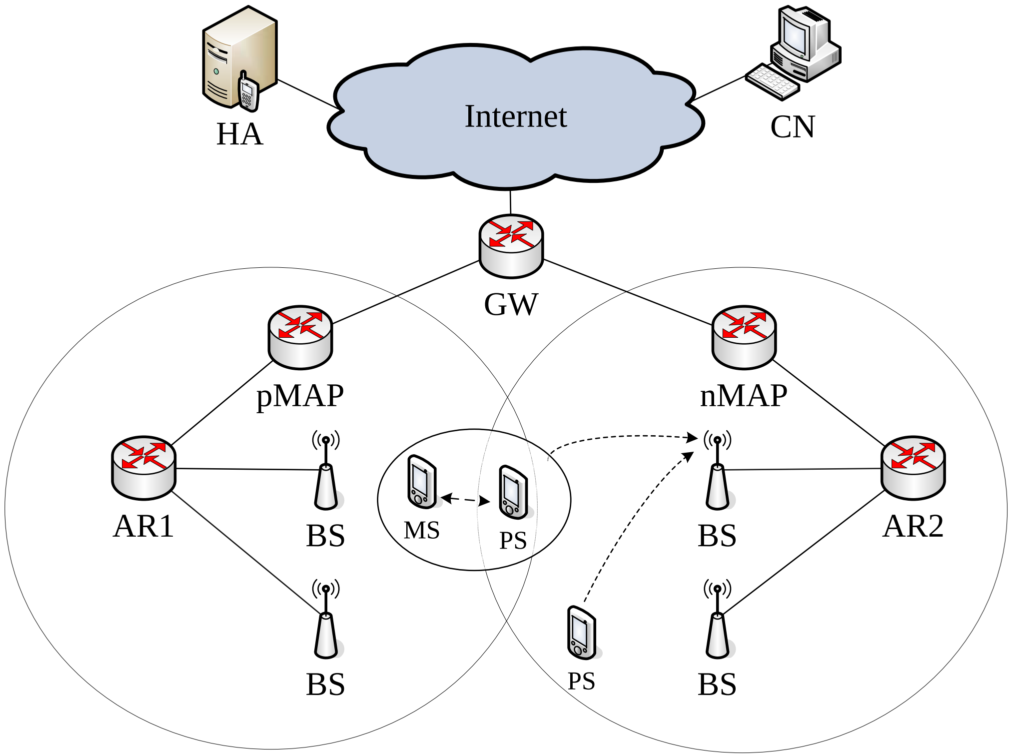


Assumption and Definition

- Assumption
  - PSs have the functionality of the relay station (RS) defined in IEEE 802.16j relay task group
  - PS can directly connect to IP network through a base station (BS) and can directly communicate with the MS.
- Partner Station (PS):
  - A neighbor MS of the MS, denoted as PS, where MS and PS are located in different MAP domains.
  - Main task of PS is to perform the pre-handoff procedure for the MS before MS perform actual layer 2 handoff to a new MAP domain.

Challenges

- Partner discovery
  - Before the layer 2 handoff decision
  - Handoff decision by PSs
  - With assistance of multiple PSs
- Pre-handoff procedure
  - Process of multiple local binding update messages for the same MS in nMAP



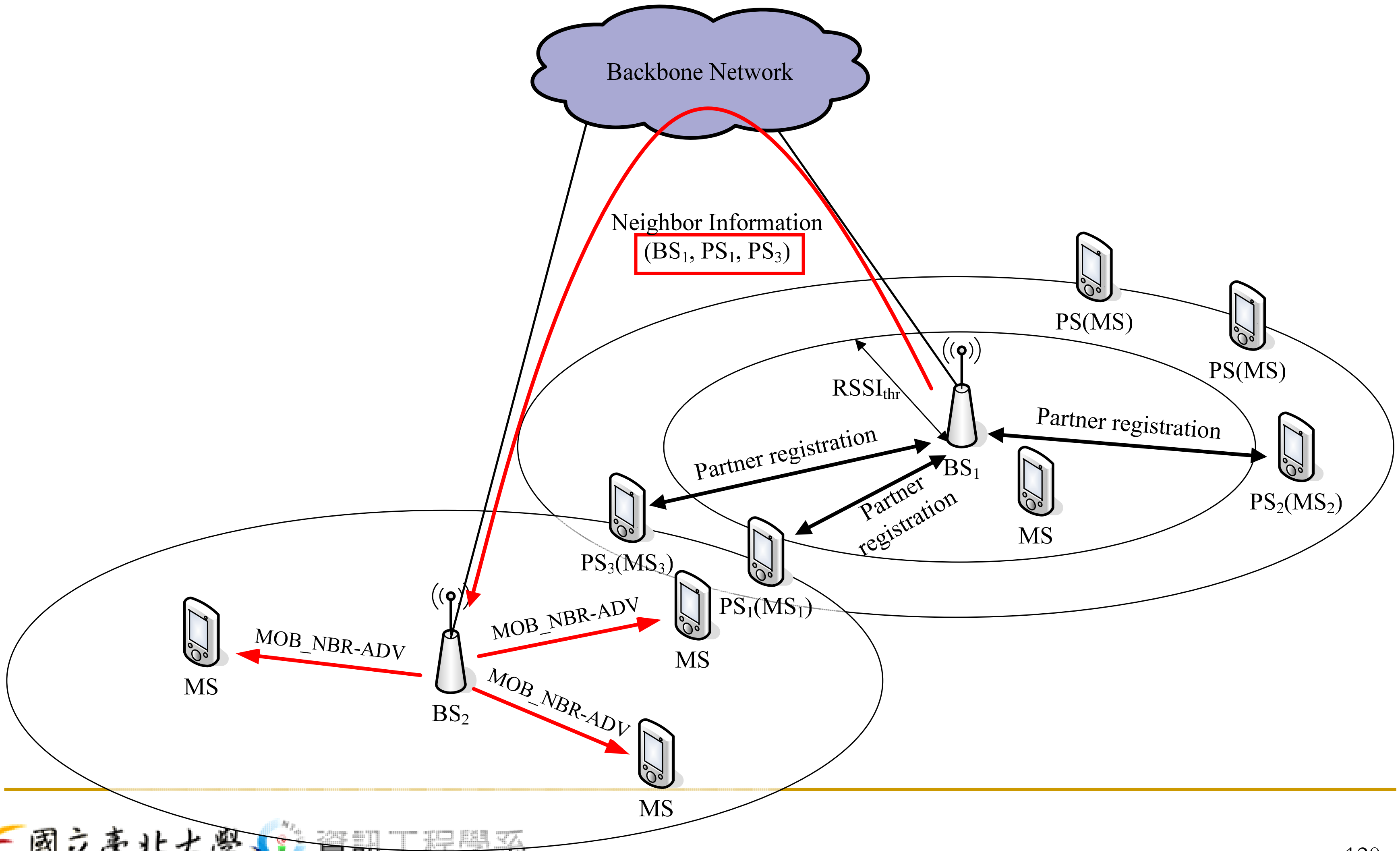
Basic Idea

- Using the IEEE 802.16e scanning procedure in layer-2.
  - Through the backbone network to get the neighbor BSs' and PSs' channel information and some layer 3 handoff parameters
  - Finding the multiple appropriate PSs to initial the pre-handoff procedure.
- Using partner-assisted handoff mechanism in layer-3.
  - Pre-handoff by partner station for LCoA and RCoA DAD and binding with LCoA and RCoA.

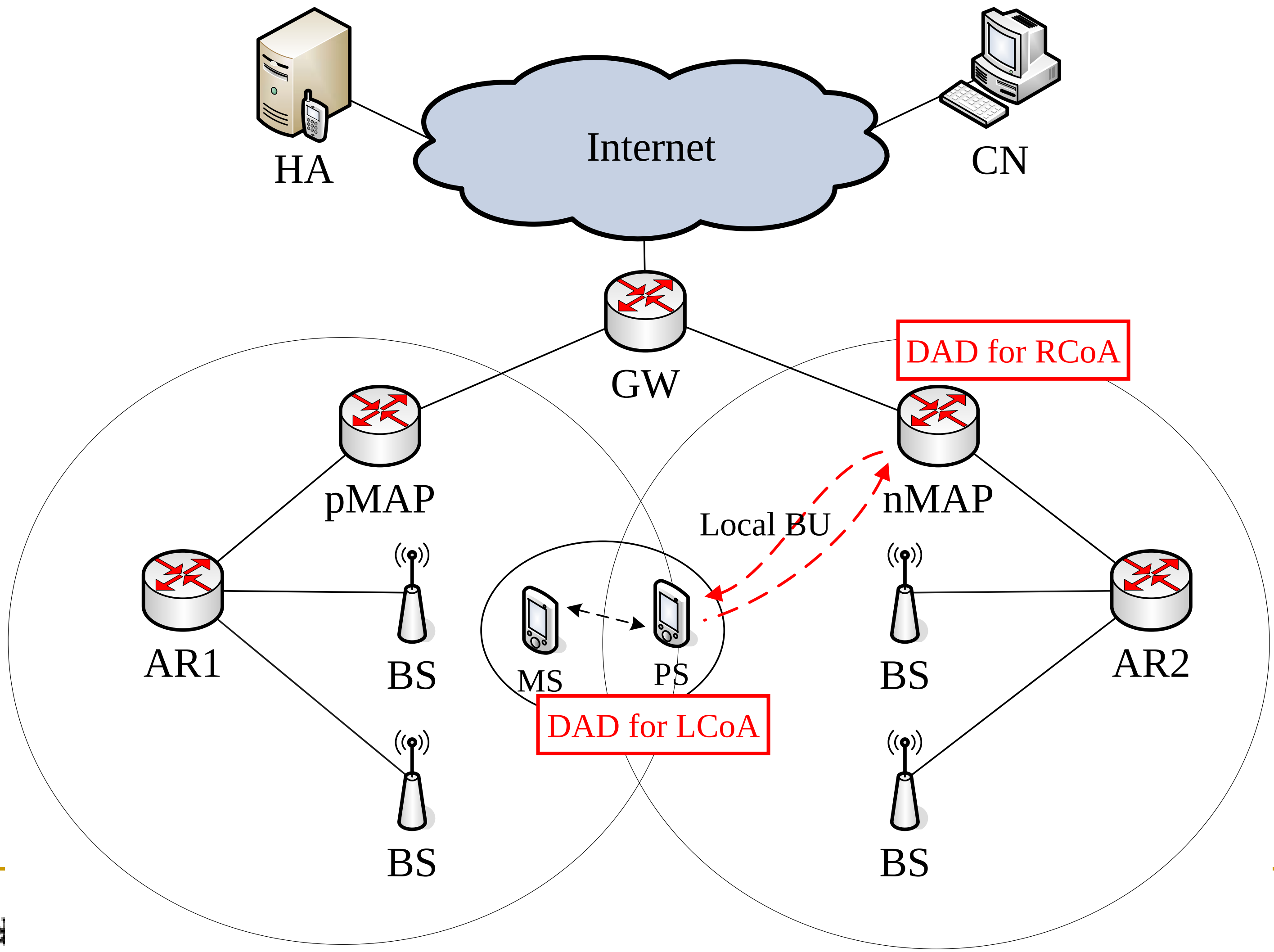
Conditions to Become a PS

- The MS is static.
- The RSSI of the BS downlink to the MS must less than $RSSI_{thr}$ to ensure that the MS is nearly in the boundary of the neighbor BS's coverage.
- The MS must perform neighbor BS scanning to ensure its locality and to report the scanning result to its serving BS.

Becoming a PS



Partner-Assisted Handoff Mechanism



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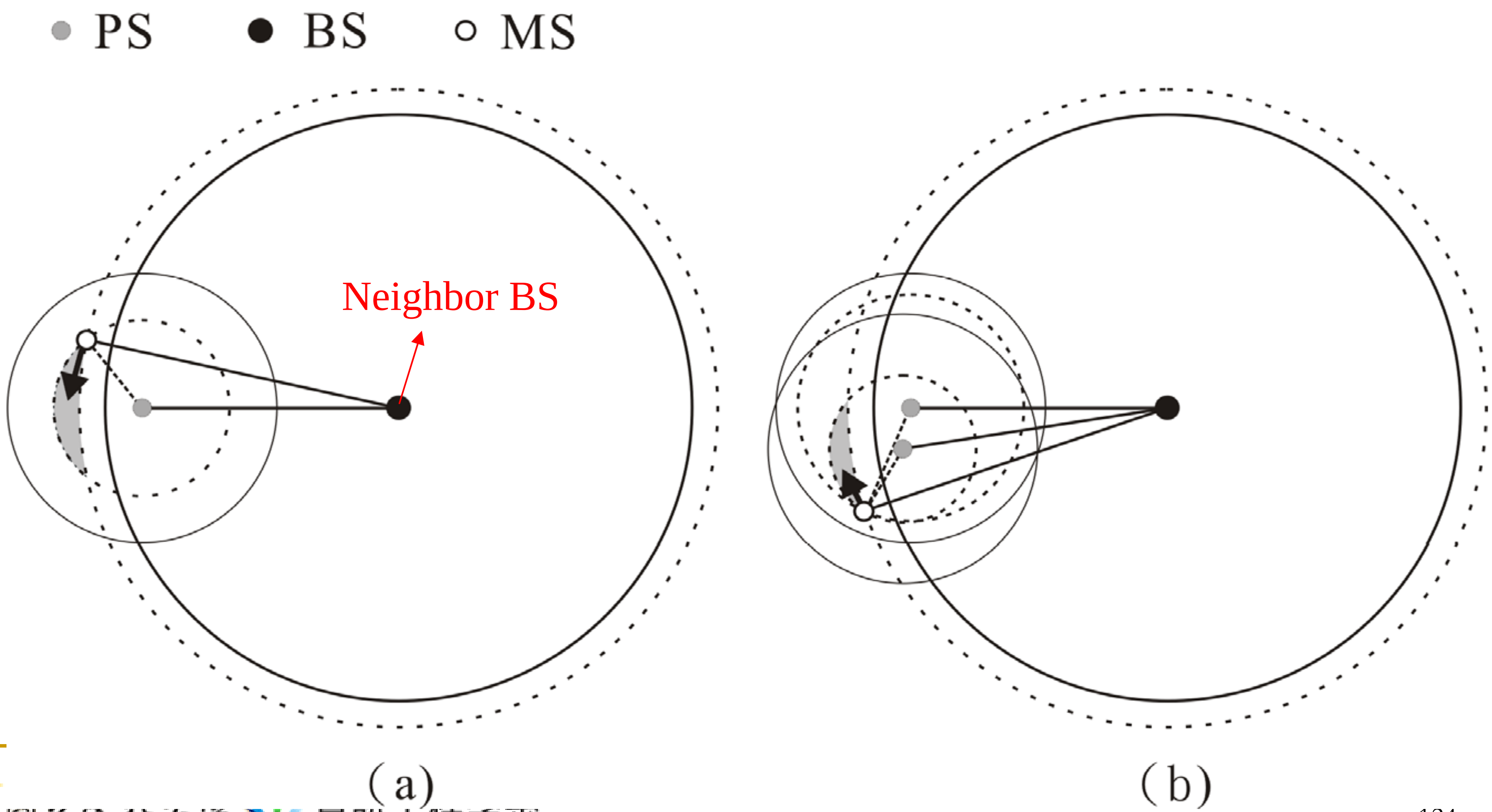
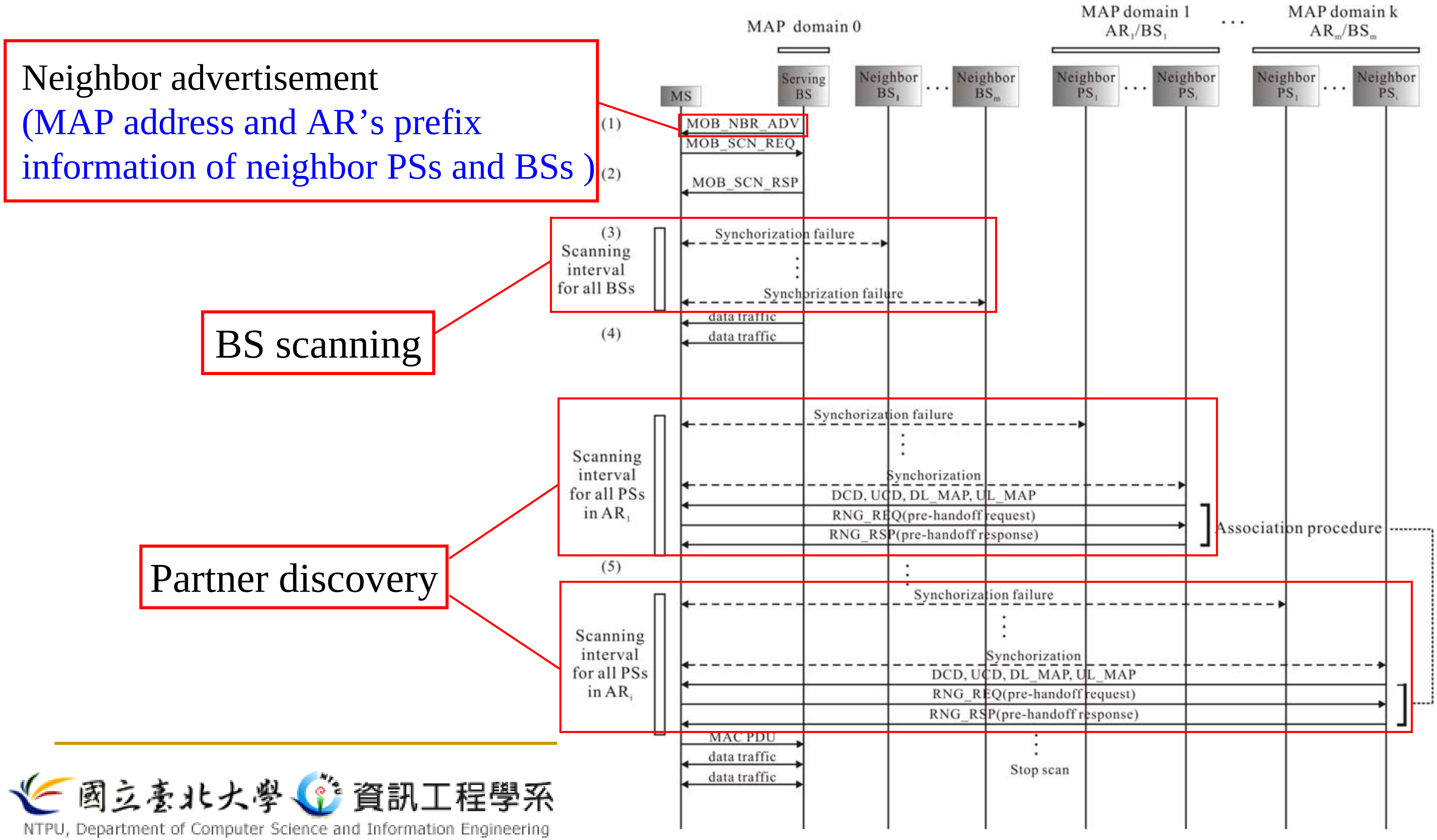
Partner-Assisted HMIPv6 (P_HMIPv6)

- Our key idea is to get the assistance of the PS in new MAP domain by combining layer 2 + layer 3 messages.
  - Partner discovery
  - P_HMIPv6
    - Successful case: The MS finds PSs in nMAP domain, and then the MS switches to the nMAP domain.
    - Unsuccessful case 1: The MS finds PSs in nMAP domain, but the MS switches to a different nMAP domain.
    - Unsuccessful case 2: The MS finds PSs in nMAP domain, and the MS switches to the nMAP domain but not in the same AR's subnet.

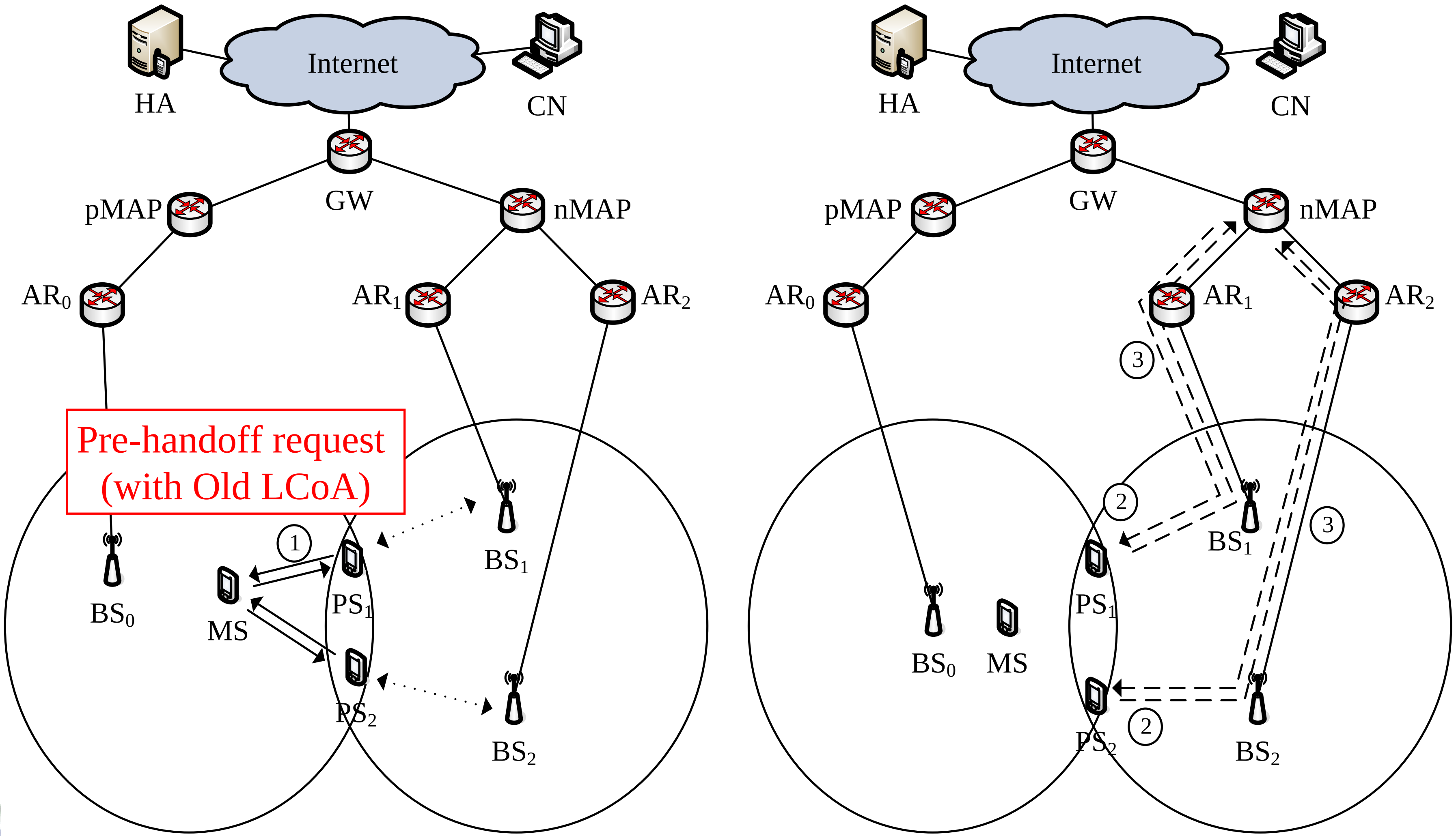
Target BS Selection with Assistance of PSs' RSSI



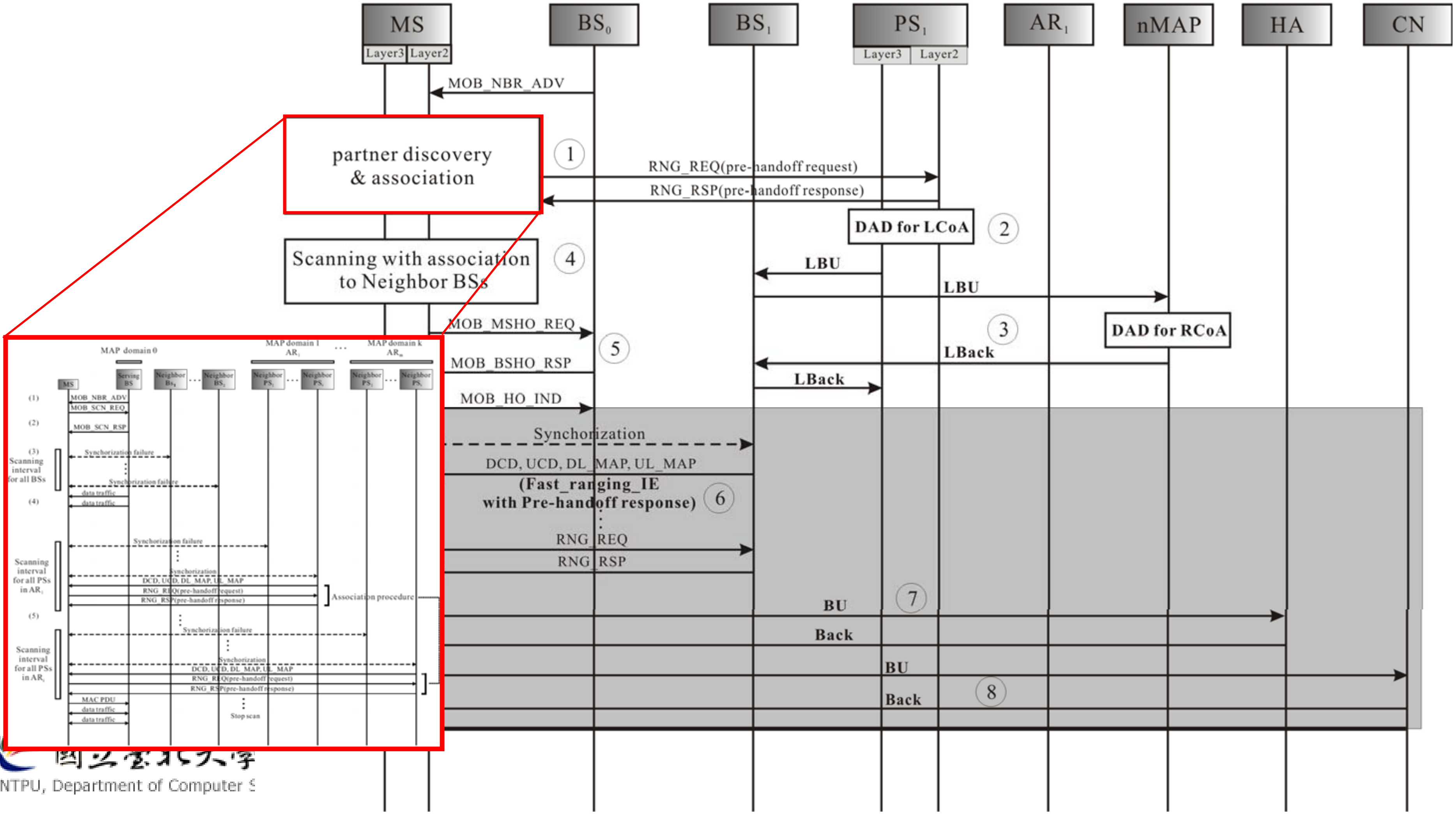
Partner Discovery



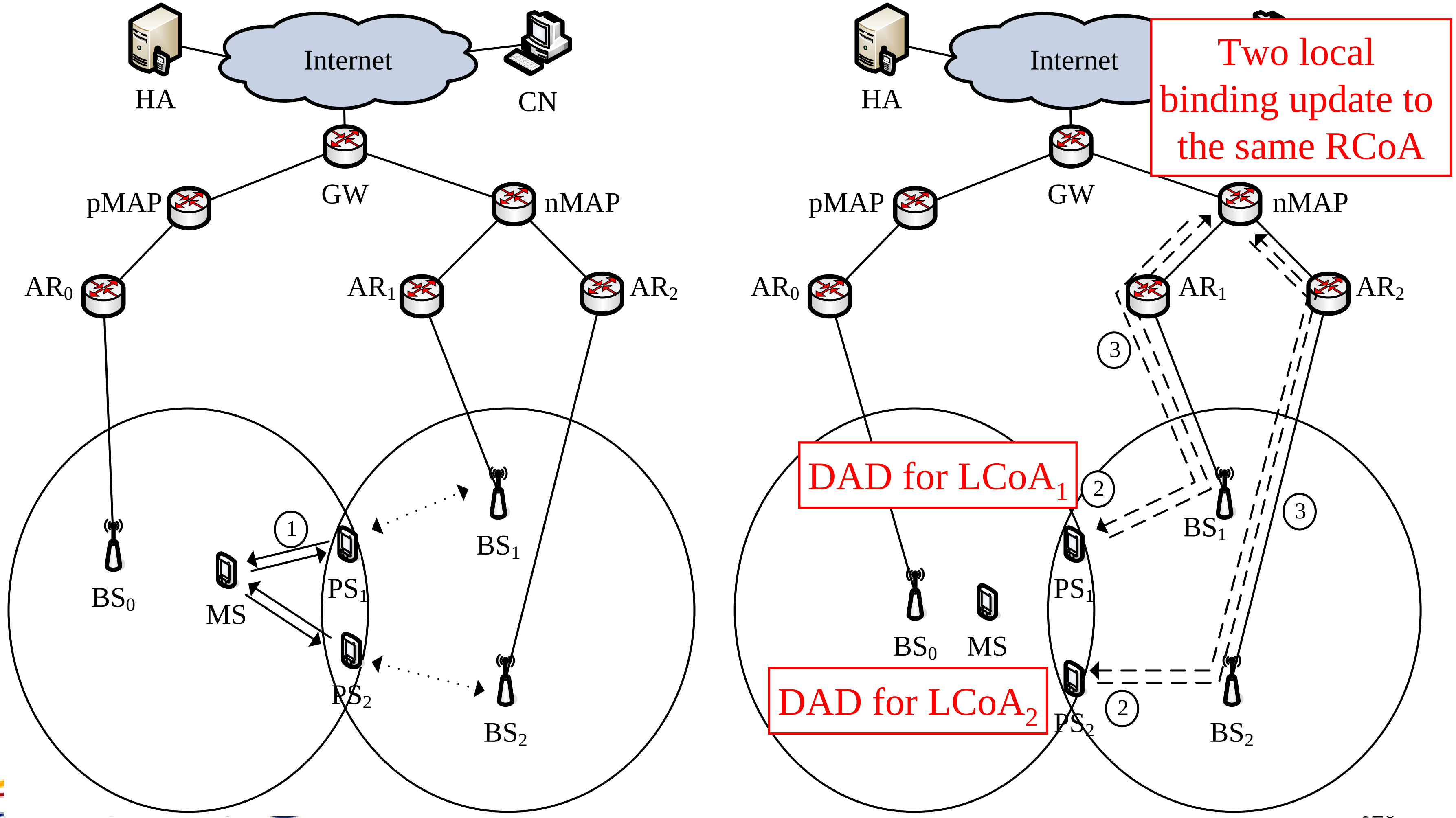
Successful Scenario



Partner discovery



Successful Scenario

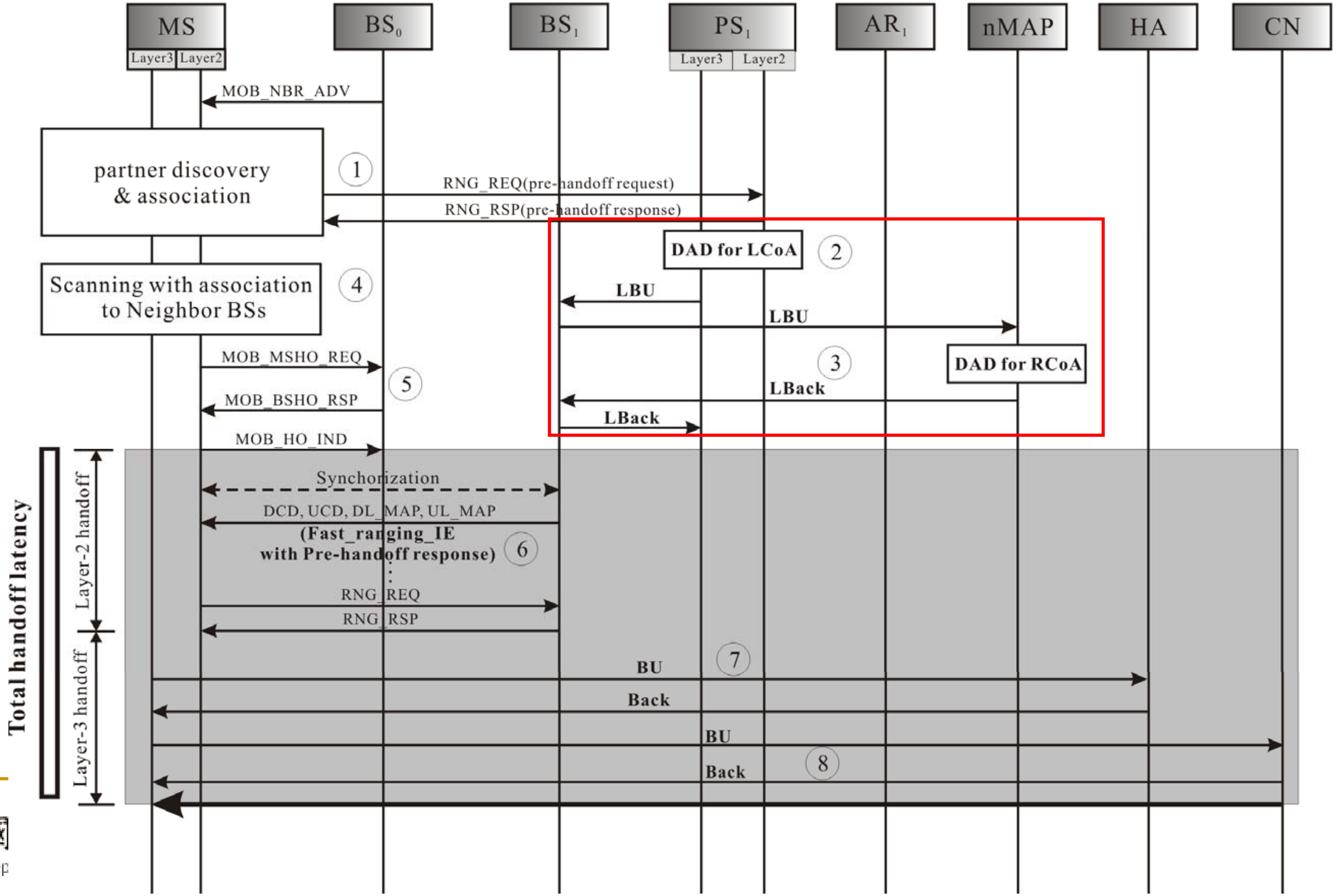


Modified local binding update message

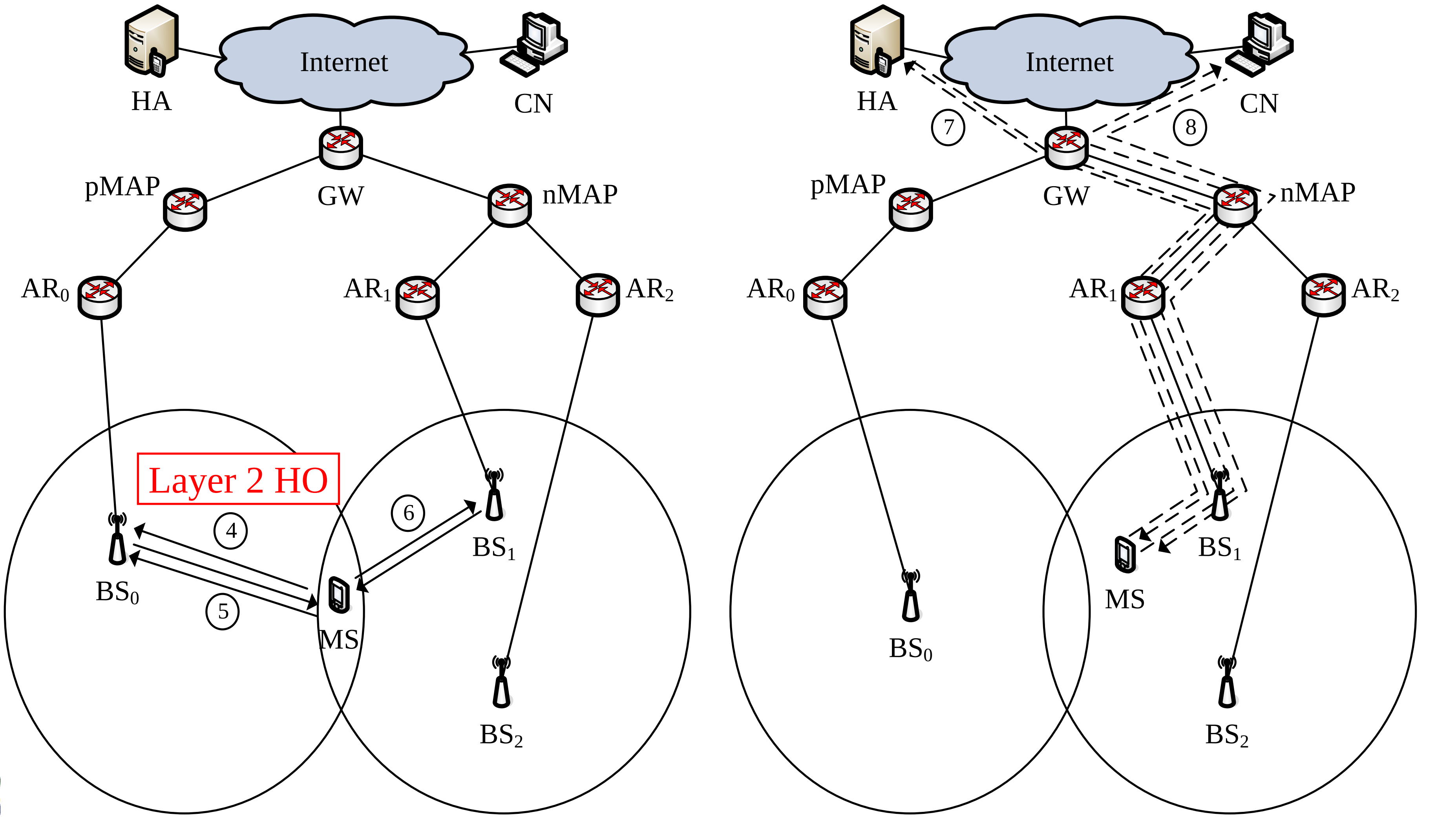
- Pflag
  - This binding update message is sent by PS.
  - The binding is temporary.
  - To support multiple LCoA bind the same RCoA
- Old LCoA of the MS in mobility option
  - Check multiple binding update message is sent for the same MS

							Sequence #
A	H	L	K	M	P	Reserved	Lifetime
Mobility options							

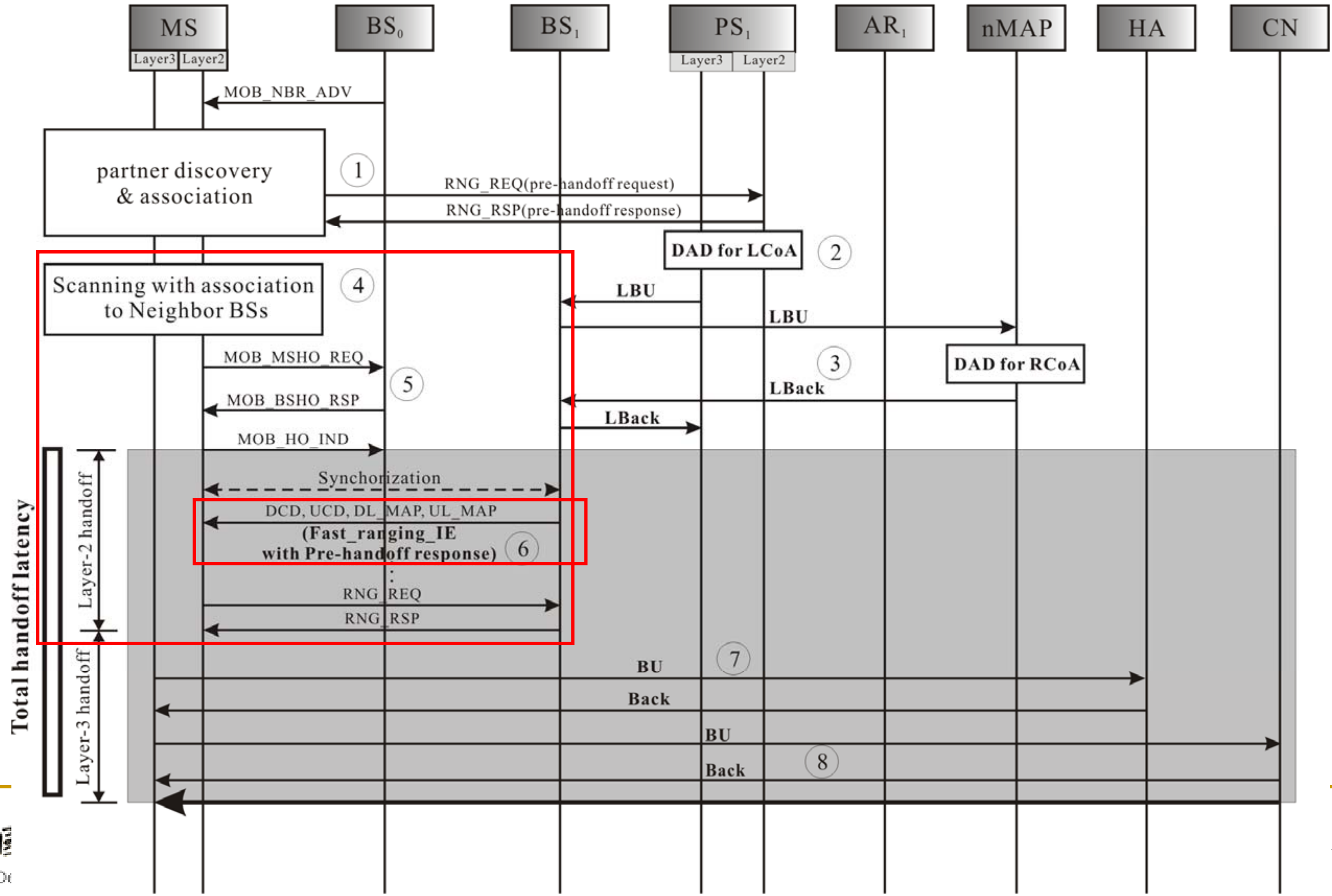
Successful case



Successful Scenario

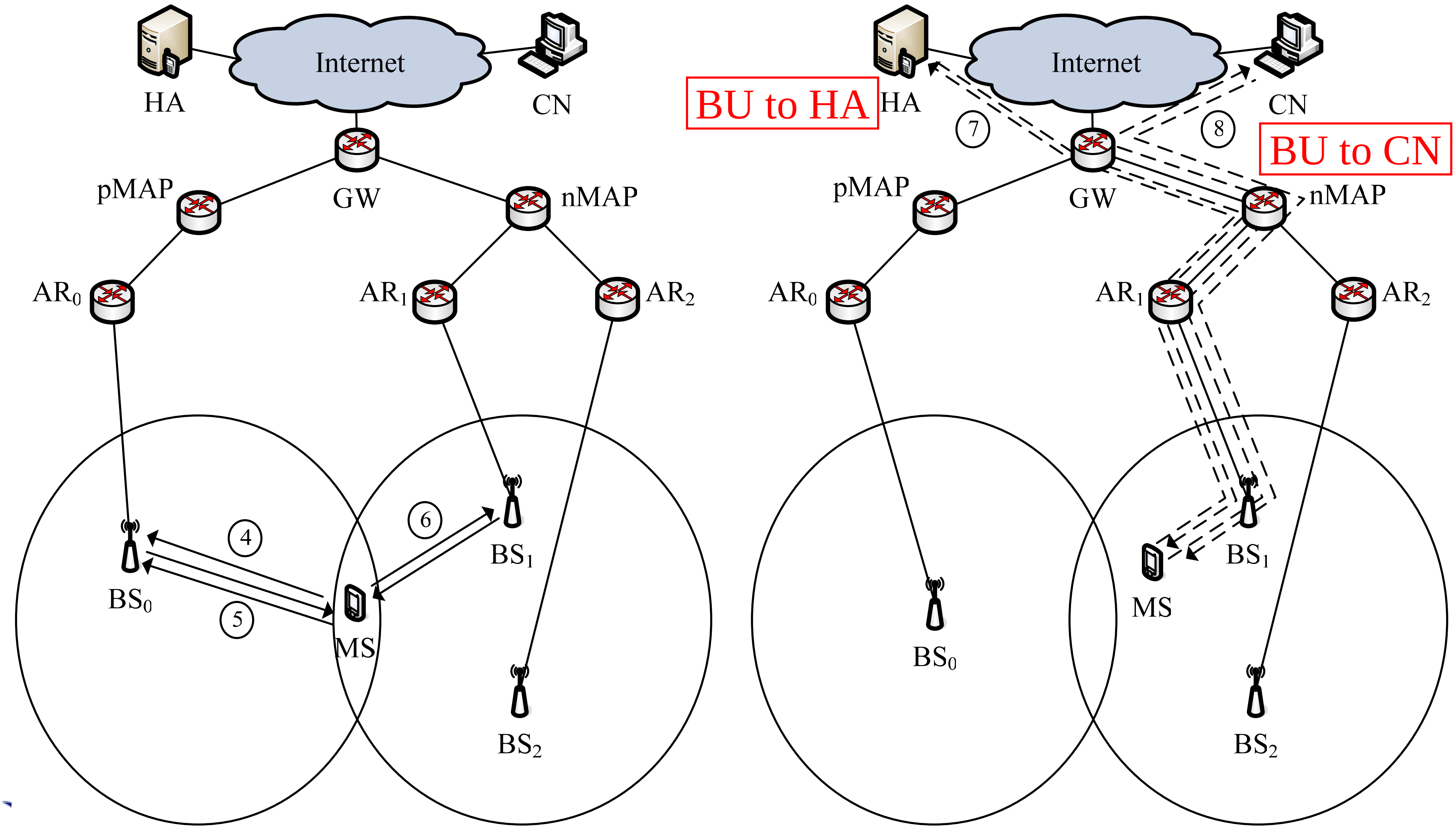


Successful case

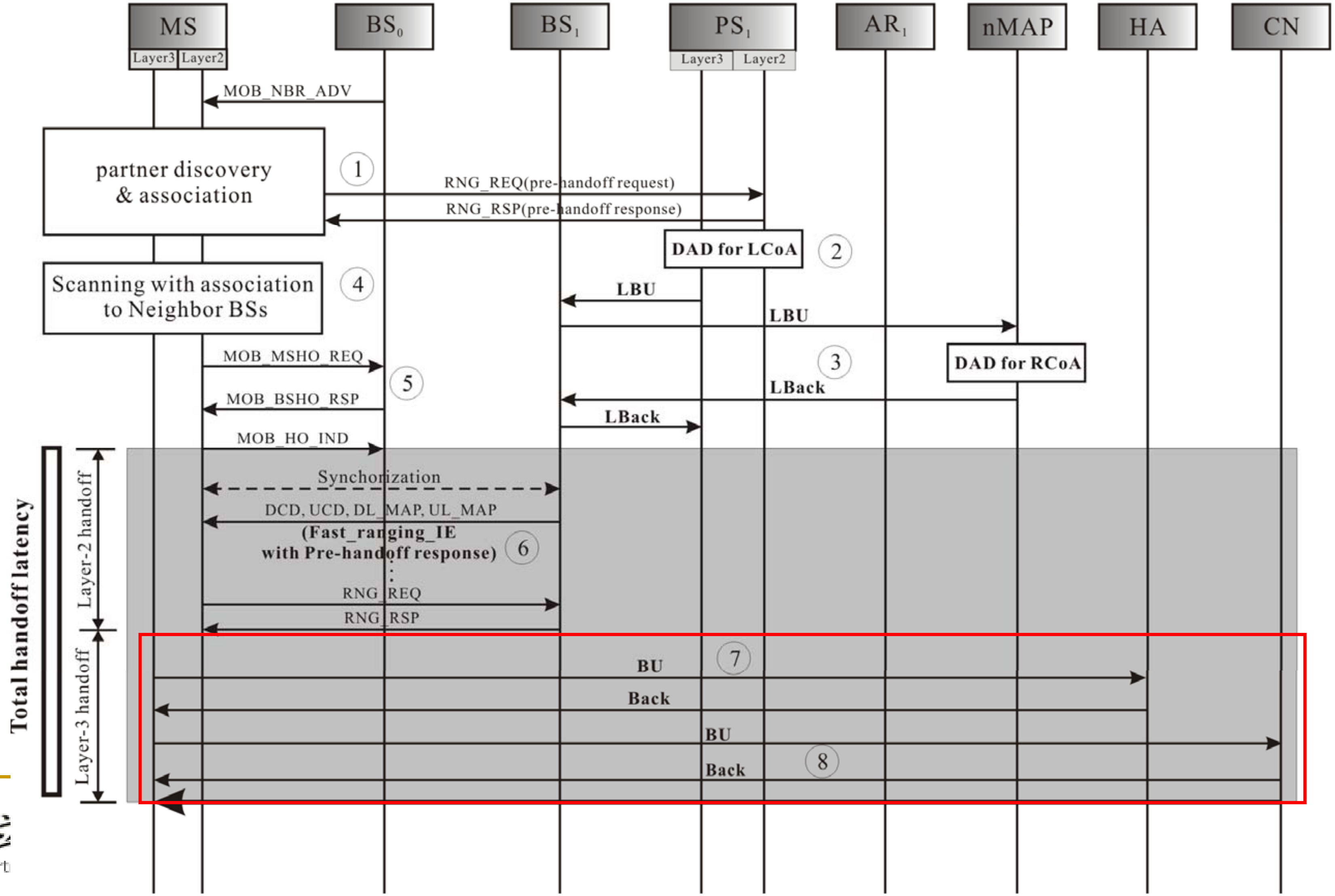


NTPU, De

Successful Scenario



Successful case



Outline

- Introduction
- Related Works
- Basic Idea and System Architecture
- Partner-Assisted HMIPv6 (P_HMIPv6)
- Mathematical analysis and simulation results
- Conclusions

Mathematical Analysis and Simulation Results

- HMIPv6, P_HMIPv6, U_P_HMIPv6 case 2
- Mathematical analysis
  - Handoff latency
- Simulation results
  - Handoff latency
  - Handoff packet loss
  - Handoff jitter

Mathematical Analysis (1)

- Network parameters

BW_{wired}	Bandwidth of the wired backbones
BW_{wimax}	Bandwidth of the wimax link
L_{wired}	Latency of the wired link
L_{wimax}	Latency of the wireless link
S_{ctr}	Average size of the control message
n	Number of hops between the MS and the access router
$t_{D\_internet\_MAP}$	Average delay of that a packet travelling in the Internet between AR and MAP.
$t_{D\_internet\_HA}$	Average delay of that a packet travelling in the Internet between AR and HA.
$t_{D\_internet\_CN}$	Average delay of that a packet travelling in the Internet between AR and CN.
t_{D_DAD}	Average delay of the DAD time

Mathematical Analysis (2)

- The $t_{movement\_detection}$ is the time of the MS detects the target AR's subnet.

$$t_{movement\_detection} = t_{solicitation} + t_{advertisement}$$

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

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

Mathematical Analysis (3)

- t_{LBU} is the time of the PS or MS performs the local binding update to the MAP, which includes the DAD time of RCoA.

$$t_{DAD\_LCoA} = t_{DAD\_RCoA} = t_{D\_DAD}$$

$$t_{LBU} = t_{binding\_MAP} + t_{binding\_MAP\_ack} + t_{D\_DAD}$$

$$\begin{aligned} t_{binding\_MAP} = & \, t_{binding\_MAP\_ack} \\ & = \left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet\_MAP} \end{aligned}$$

Mathematical Analysis (4)

$$t_{BU\_HA} = t_{binding\_HA} + t_{binding\_HA\_ack}$$

$$\begin{aligned} t_{binding\_HA} &= t_{binding\_HA\_ack} \\ &= \left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet\_HA} \end{aligned}$$

$$t_{BU\_CN} = t_{binding\_CN} + t_{binding\_CN\_ack}$$

$$\begin{aligned} t_{binding\_CN} &= t_{binding\_CN\_ack} \\ &= \left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet\_CN} \end{aligned}$$

Mathematical Analysis (5)

- t_{PS} be the time of PS performing the pre-handoff procedure.

$$
\begin{aligned}
t_{PS} &= t_{DAD\_LCoA} + t_{LBU} \\
&= t_{DAD\_LCoA} + t_{binding\_MAP} + t_{binding\_MAP\_ack} + t_{D\_DAD} \\
&= 2\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) + t_{D\_internet}\right] + 2t_{D\_DAD}
\end{aligned}
$$

Mathematical Analysis (6)

$$t_{HMIPv6} = t_{layer\_2} + t_{movement\_detection} + t_{DAD\_LCoA} + t_{LBU} + t_{BU\_HA} + t_{BU\_CN}$$
$$= t_{layer\_2} + 8\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) \right]$$
$$+ 2t_{D\_internet\_MAP} + 2t_{D\_internet\_HA} + 2t_{D\_internet\_CN} + 2t_{D\_DAD}$$

$$t_{P\_HMIPv6} = t_{layer\_2} + t_{layer\_3} - t_{movement\_detection} - t_{PS}$$
$$= t_{layer\_2} + t_{binding\_HA} - t_{binding\_CN}$$
$$= t_{layer\_2} + 4\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right) \right]$$
$$+ 2t_{D\_internet\_HA} + 2t_{D\_internet\_CN}$$

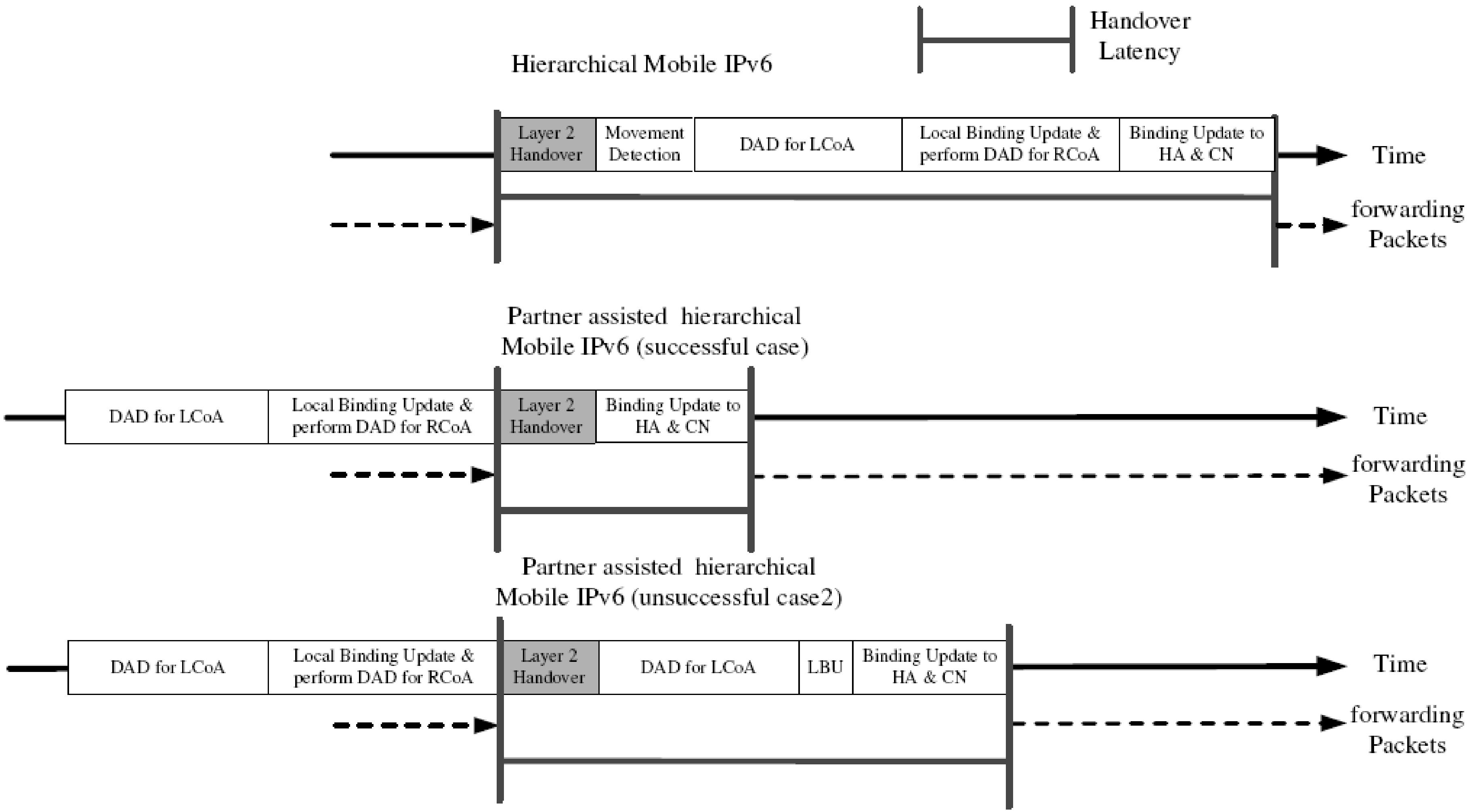
Mathematical Analysis (7)

$$
\begin{aligned}
t_{\Delta_1} &= t_{HMIPv6} - t_{P\_HMIPv6} \\
&= t_{movement\_detection} + t_{DAD\_LCoA} + t_{LBU} \\
&= 4\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right)\right] \\
&\quad + 2t_{D\_internet\_MAP} + 2t_{D\_DAD}.
\end{aligned}
$$

$$
\begin{aligned}
t_{U\_P\_HMIPv6} &= t_{layer\_2} + t_{layer\_3} - t_{movement\_detection} - t_{D\_DAD} \\
&= t_{layer\_2} + 8\left[\left(\frac{S_{ctr}}{BW_{wl}} + L_{wl}\right) + n\left(\frac{S_{ctr}}{BW_{w}} + L_{w}\right)\right] \\
&\quad + 2t_{D\_internet\_MAP} + 2t_{D\_internet\_HA} + 2t_{D\_internet\_CN} + t_{D\_DAD}
\end{aligned}
$$

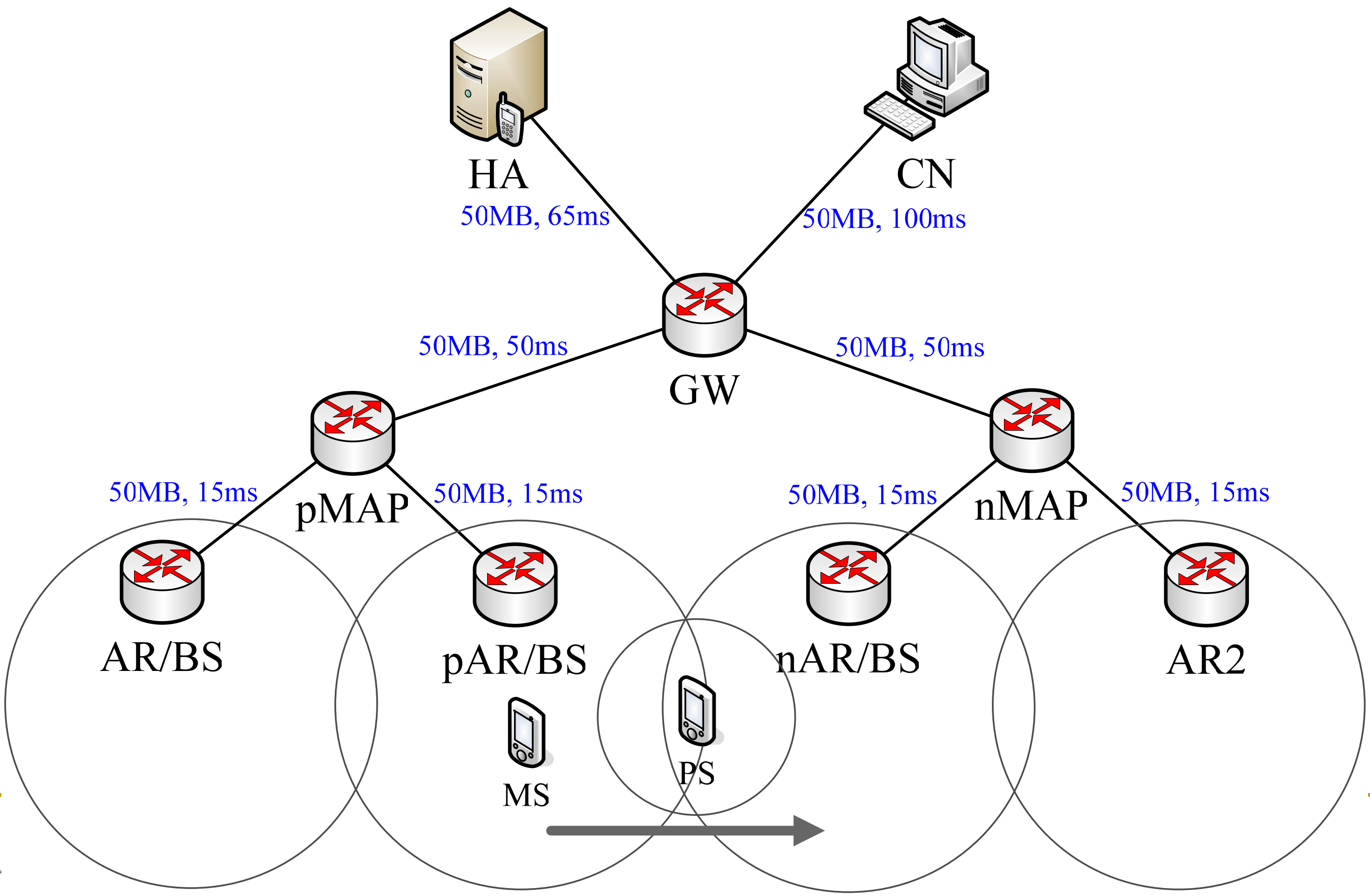
$$
\begin{aligned}
t_{\Delta_2} &= t_{HMIPv6} - t_{U\_P\_HMIPv6} \\
&= t_{movement\_detection} + t_{D\_DAD}
\end{aligned}
$$

Handoff Latency Comparison



P_HMIPv6 Network Scenario

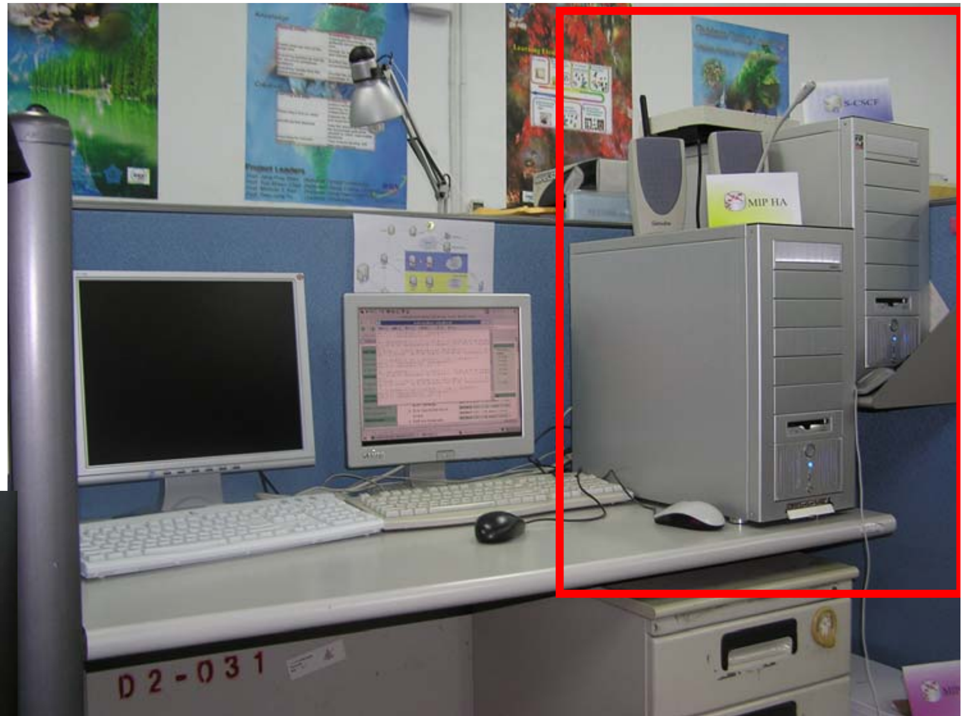
Ns-2 2.29 + mobiwan 2.28 + NIST wimax module (802.16e)



Our Testbed environment

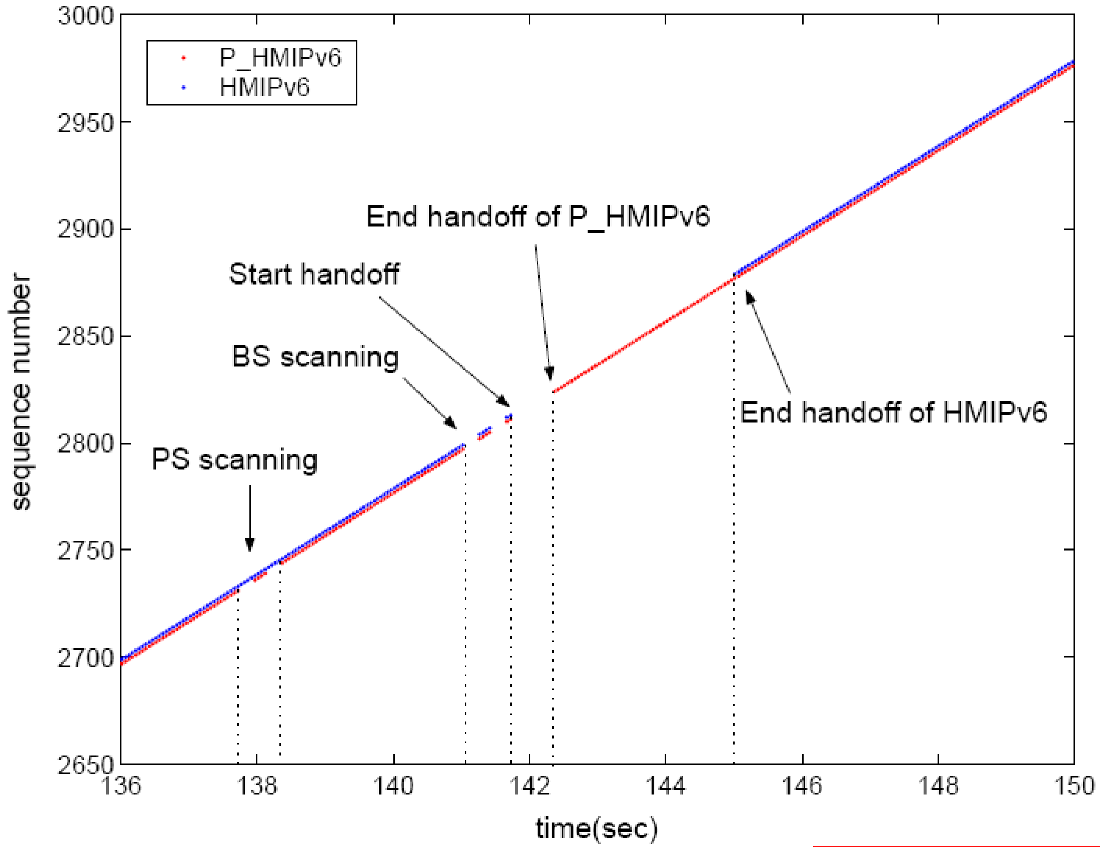
MN

CSCF server &
SmSCTP CN



MIP HA

Sequence Number vs. Time



Latency(msec)	L2 HO	MD	LCoA DAD	BU_MAP & RCoA DAD	BU_HA	BU_CN
P_HMIPv6	88	-	-	-	268	340
HMIPv6	88	68	1000	1057	268	340

- Network parameters

BW_{wired}	Bandwidth of the wired backbones
BW_{wimax}	Bandwidth of the wimax link
L_{wired}	Latency of the wired link
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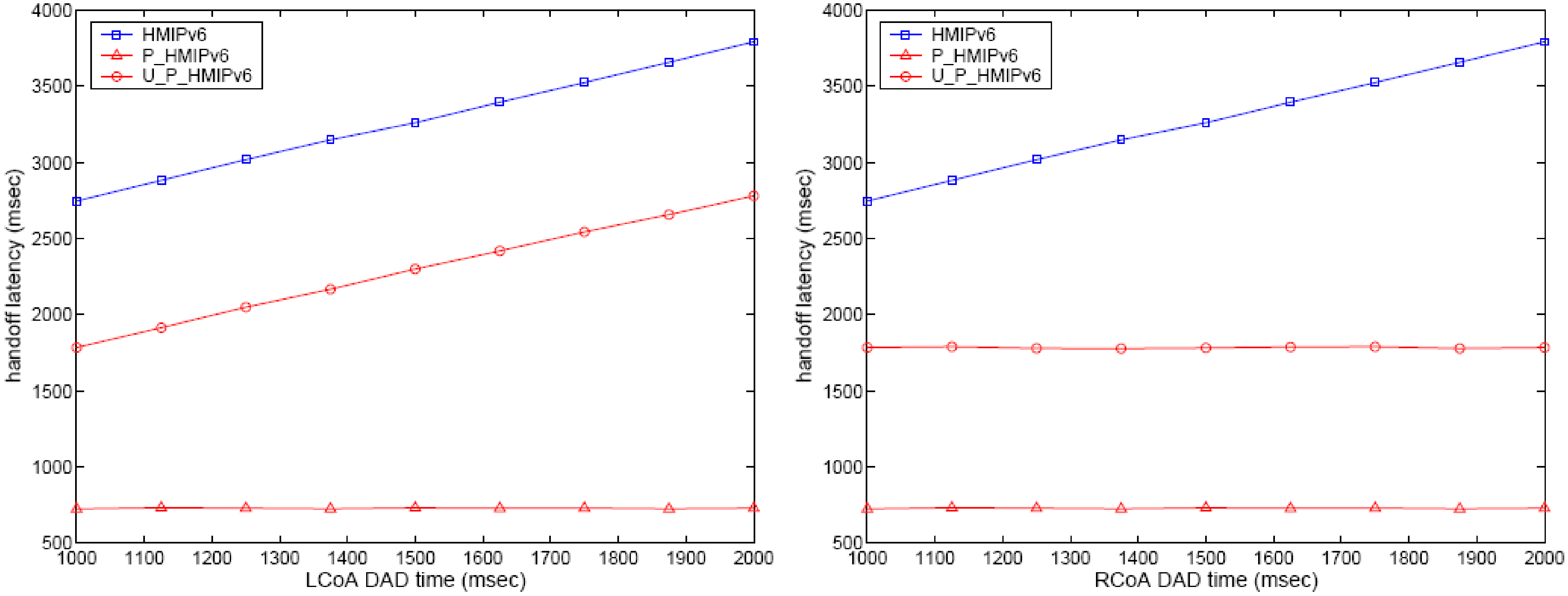
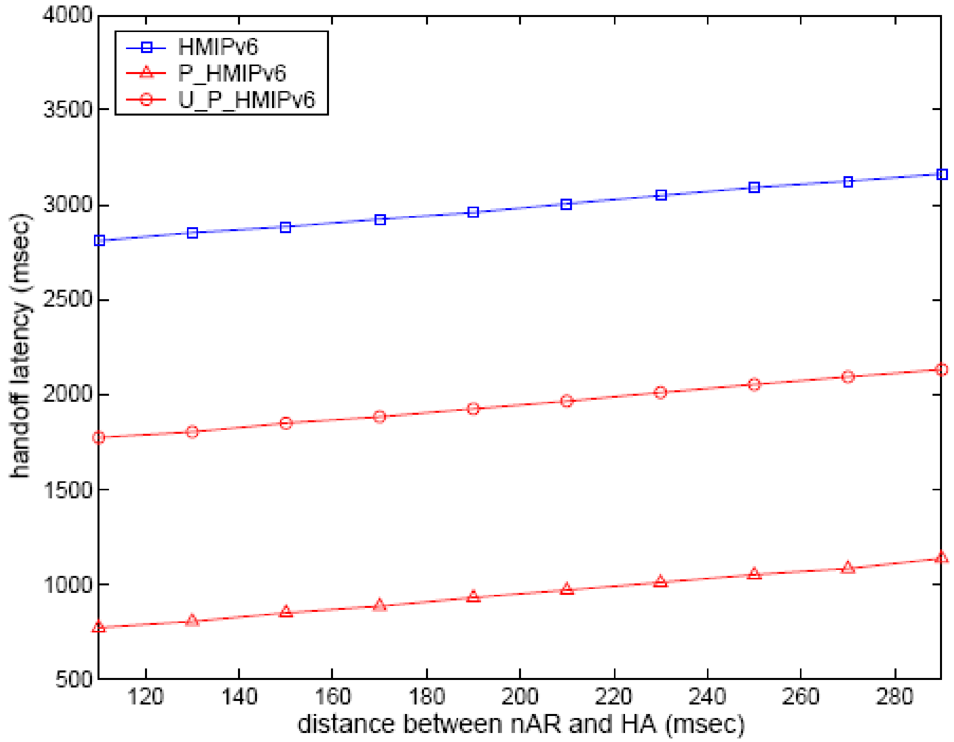
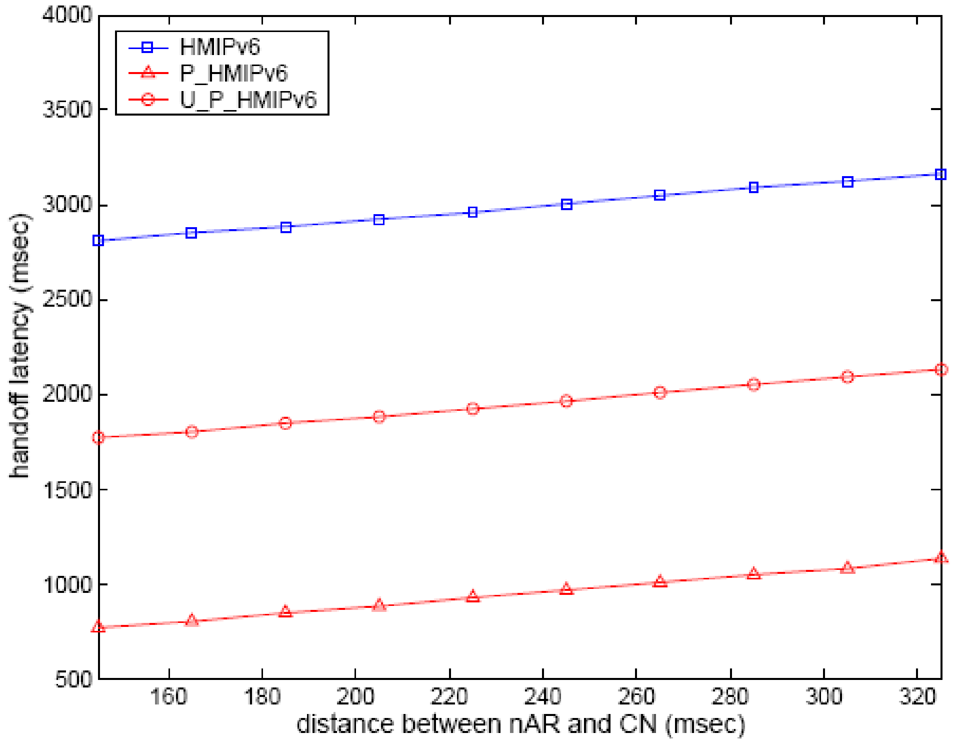
t_{D_DAD}	Average delay of the DAD time

Handoff Latency vs. DAD time

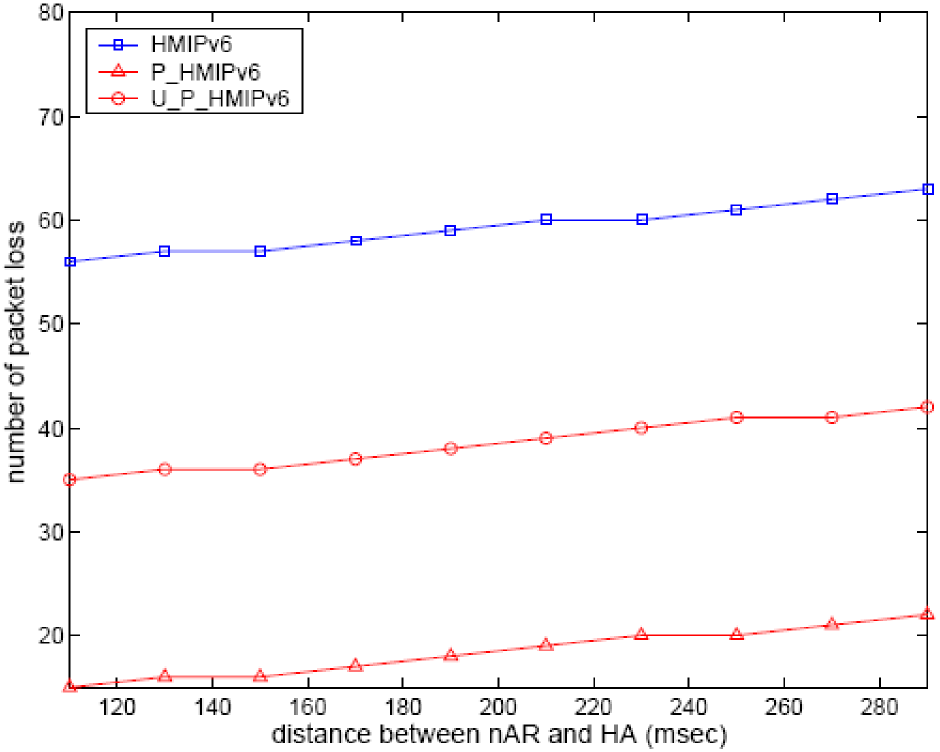


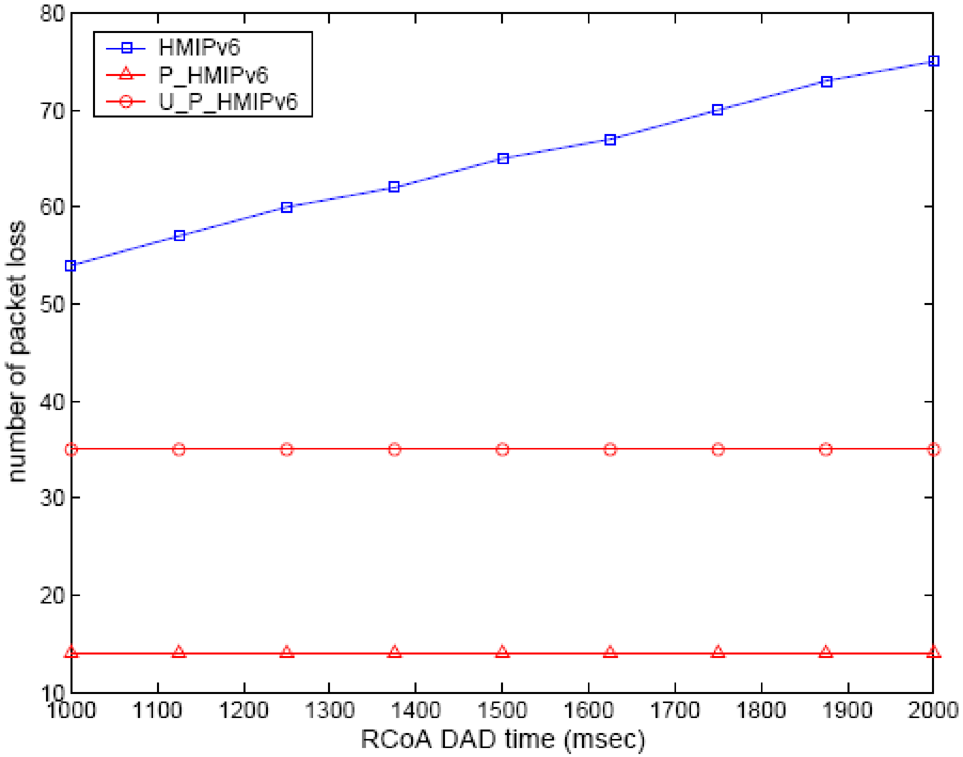
Handoff Latency vs. Distance to HA and CN



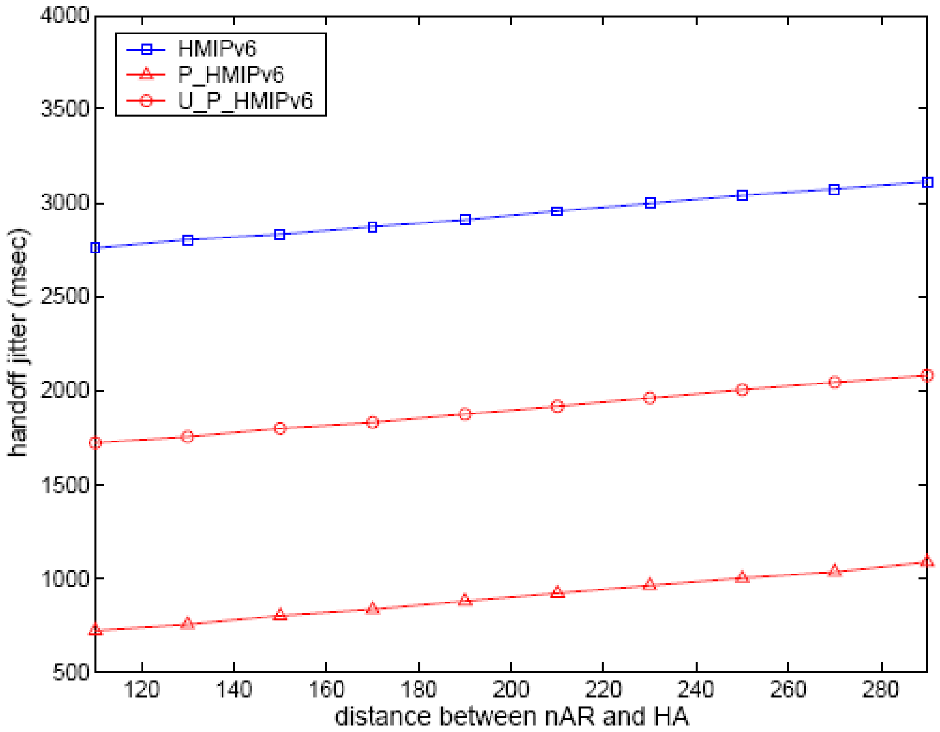


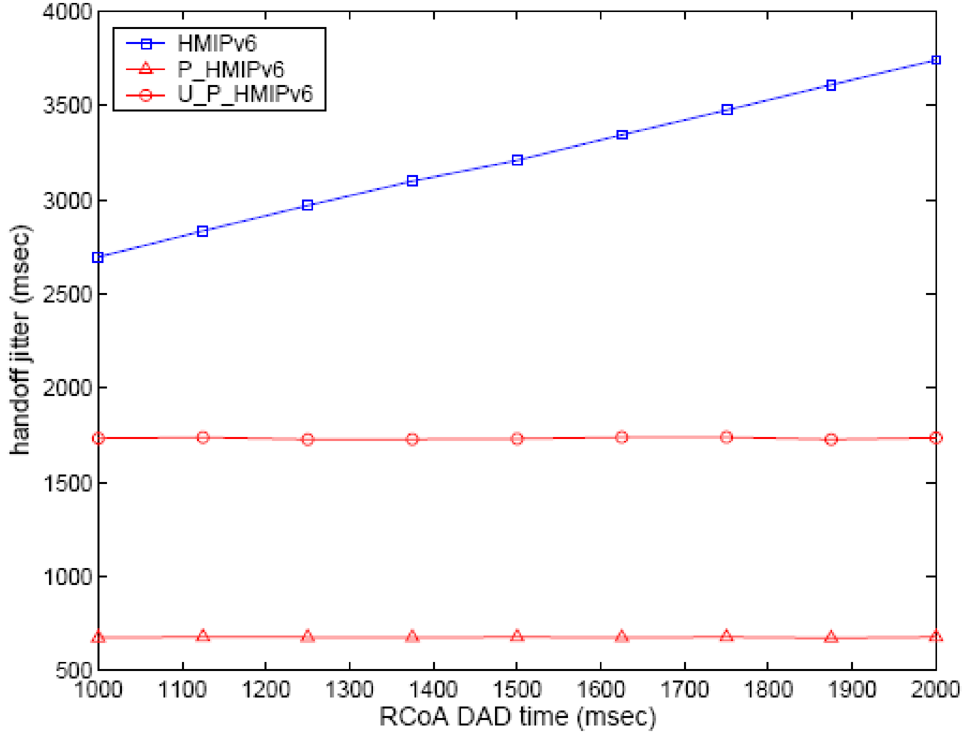
Packet Loss vs. Distance to HA and Packet Loss vs. RCoA DAD Time





Handoff Jitter vs. Distance to HA and Handoff Jitter vs. RCoA DAD Time





Outline

- Introduction
- Related Work
- Basic Idea and System Architecture
- Partner-Assisted HMIPv6 (P_HMIPv6)
- Mathematical Analysis and Simulation Results
- Conclusions

Conclusions

- We propose a handoff mechanism, cross-layer partner-assisted handoff mechanism, for HMIPv6 in IEEE 802.16e system.
- With the assistance of the PSs, the MS can confirm the validation of the LCoA and RCoA before finishing the layer 2 handoff procedure.
- The P_HMIPv6 can substantially reduce the handoff latency and packet loss compared to HMIPv6 in IEEE 802.16e.

Part IV: SmSCTP: SIP-based MSCTP Scheme for Session Mobility over WLAN/3G Heterogeneous Networks

IEEE **WCNC 2007**, 11-15 March 2007, Hong Kong.

在 4G 環境中 (WLAN-UMTS) 中, 設計出以 SIP-based MSCTP 策略之跨層設計 (跨第四層及第七層合作) 的軟性換手機制, 以達到session mobility over 4G networks 的目標

Outline

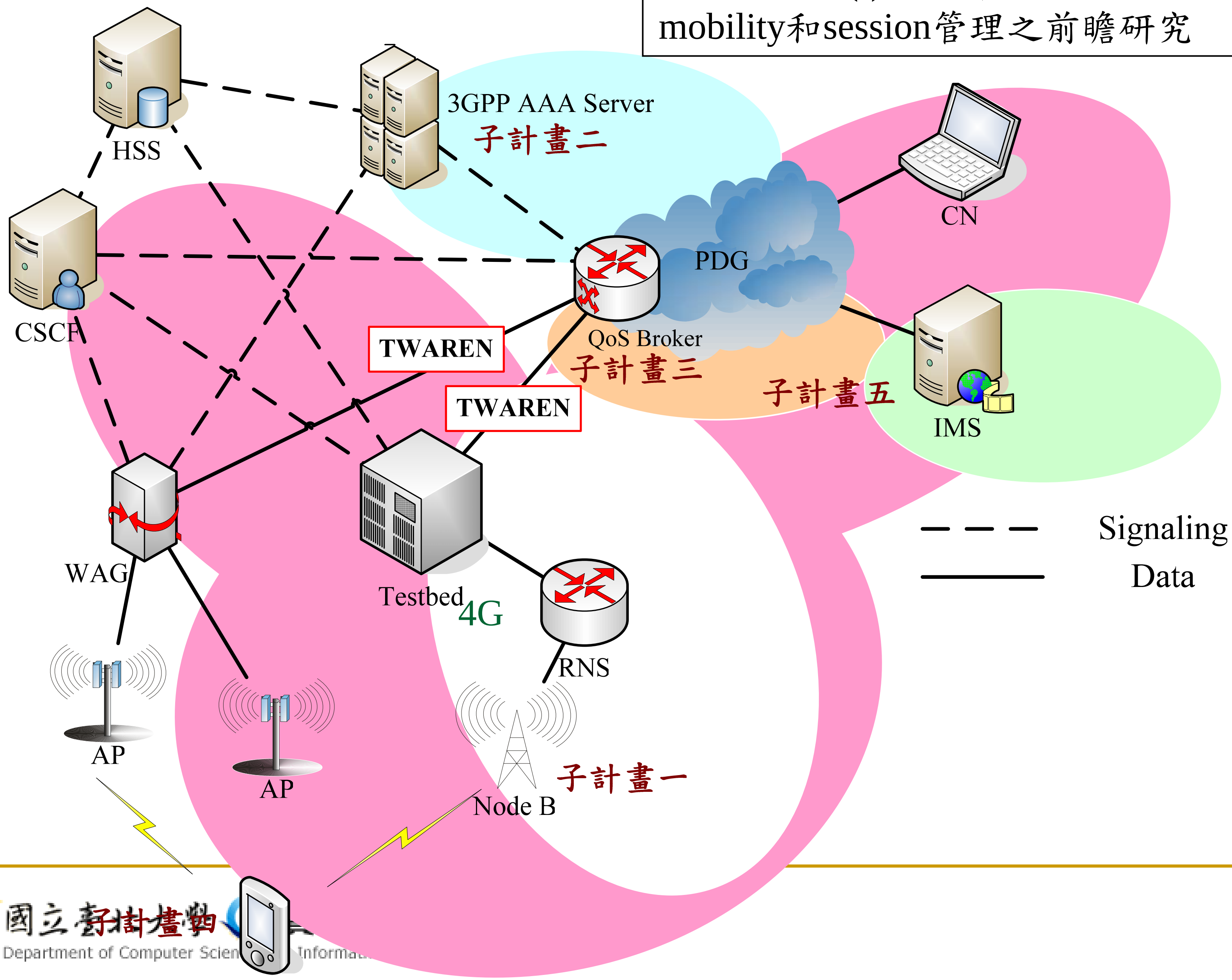
- Introduction
- Related Work
  - SIP re-INVITE Mechanism
  - Mobile SCTP Re-Configure Mechanism
- SmSCTP Mechanism over Heterogeneous Network
- Performance Analysis
- Conclusion

Introduction

- The fourth-generation network is proposed a heterogeneous network
  - GPRS, UMTS, WLAN, HSDPA, and WiMAX
- The handoff problem is became a important issue in the heterogeneous network.
  - Long delay time may makes the connection unstable
- Lots of signaling message may cause the system overhead
- Fleeting-Location-Collapse (FLC) problem

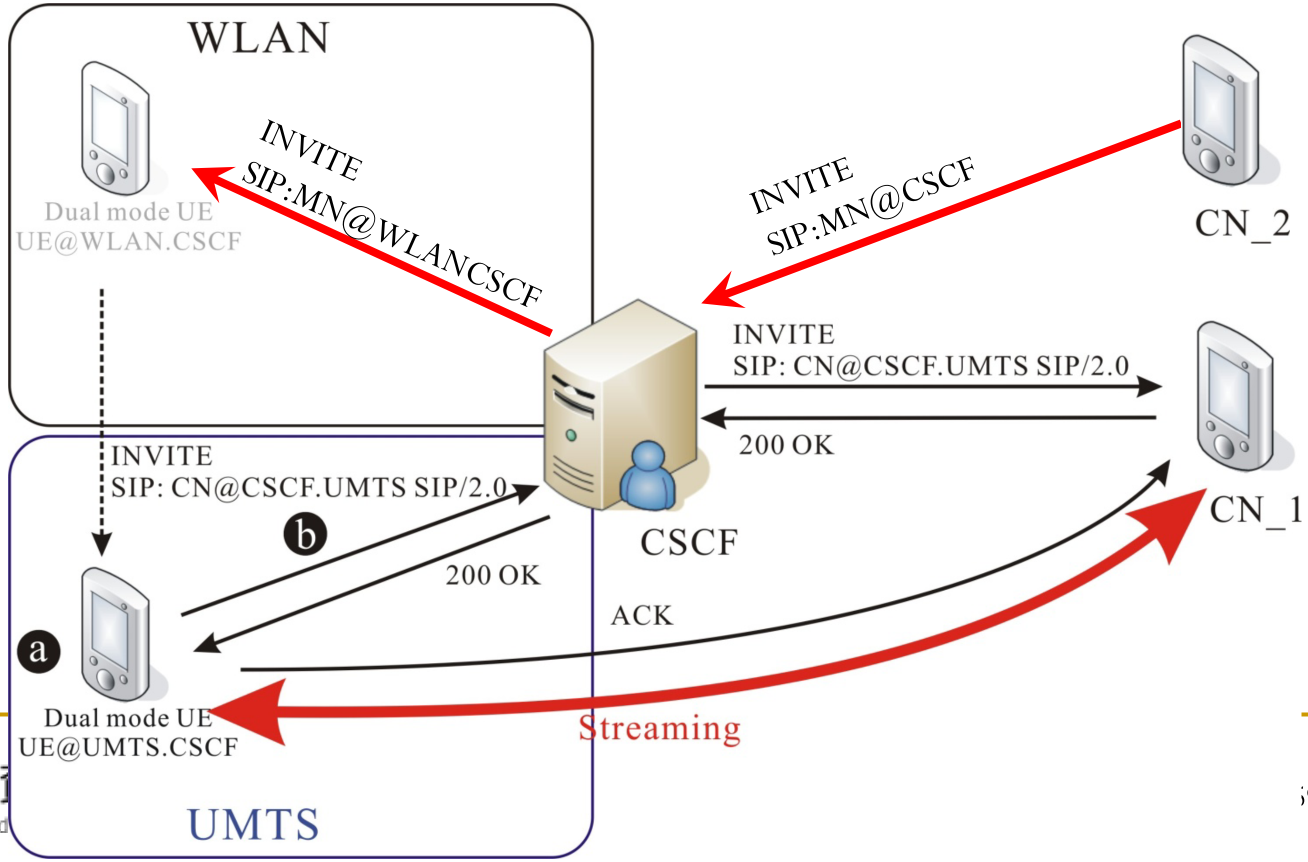
4G Testbed

電信國家型計畫：All-IP Cross-Layer 4G行動通信研究(I)—子計畫四：全-IP 跨層mobility和session管理之前瞻研究



Fleeting-Location-Collapse (FLC) Problem?

- Incoming message be forwarded to incurrent location when the MN is handing off to new location.



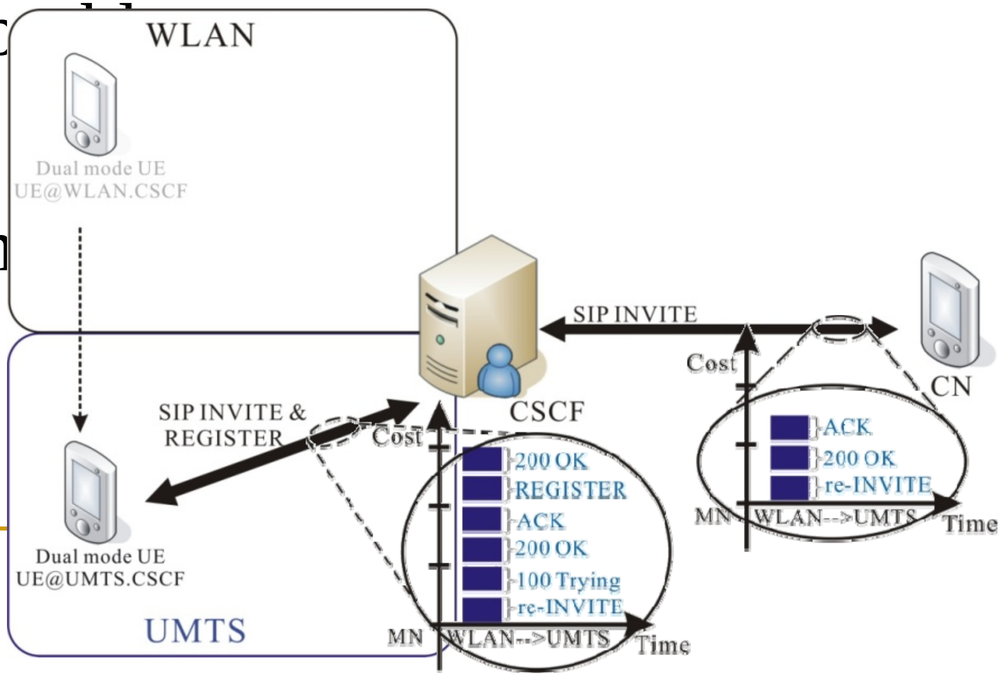
Contribution

- By cross layer design, we can provide a stable, low delay time and low signaling message cost model.
  - SmSCTP is layer 4+layer 7
  - Uses new signaling message to control handoff procedure

- Our solution can also solve *fleeting-location-collapse (FLC)* problem

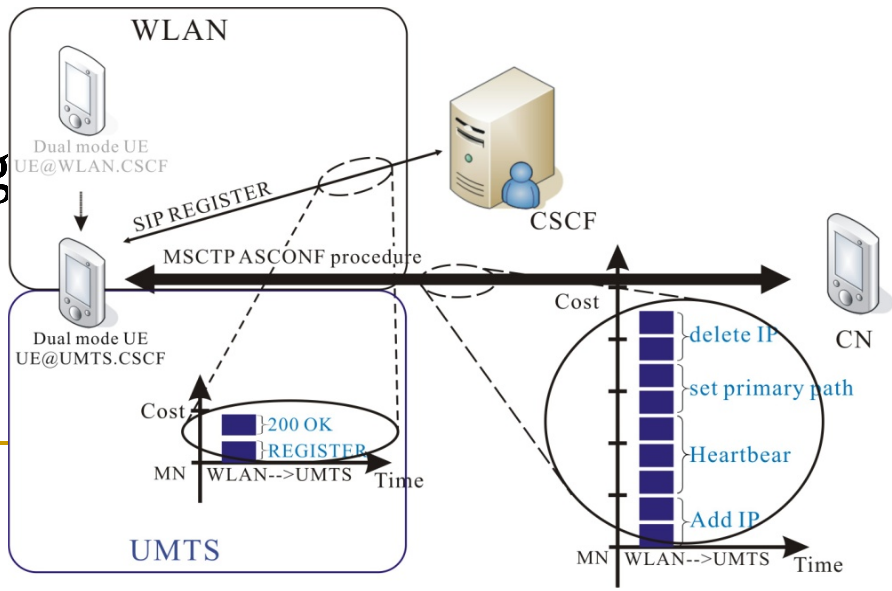
Two Traditional Approach-
SIP re-INVITE Scheme

- In 3GPP TS 23.228 V7.0.0, SIP has been selected to be the main signaling protocol
- In pure SIP environment
  - The re-INVITE scheme is adopted to solve session mobility p
  - Signal IP mode
  - Has FLC problem

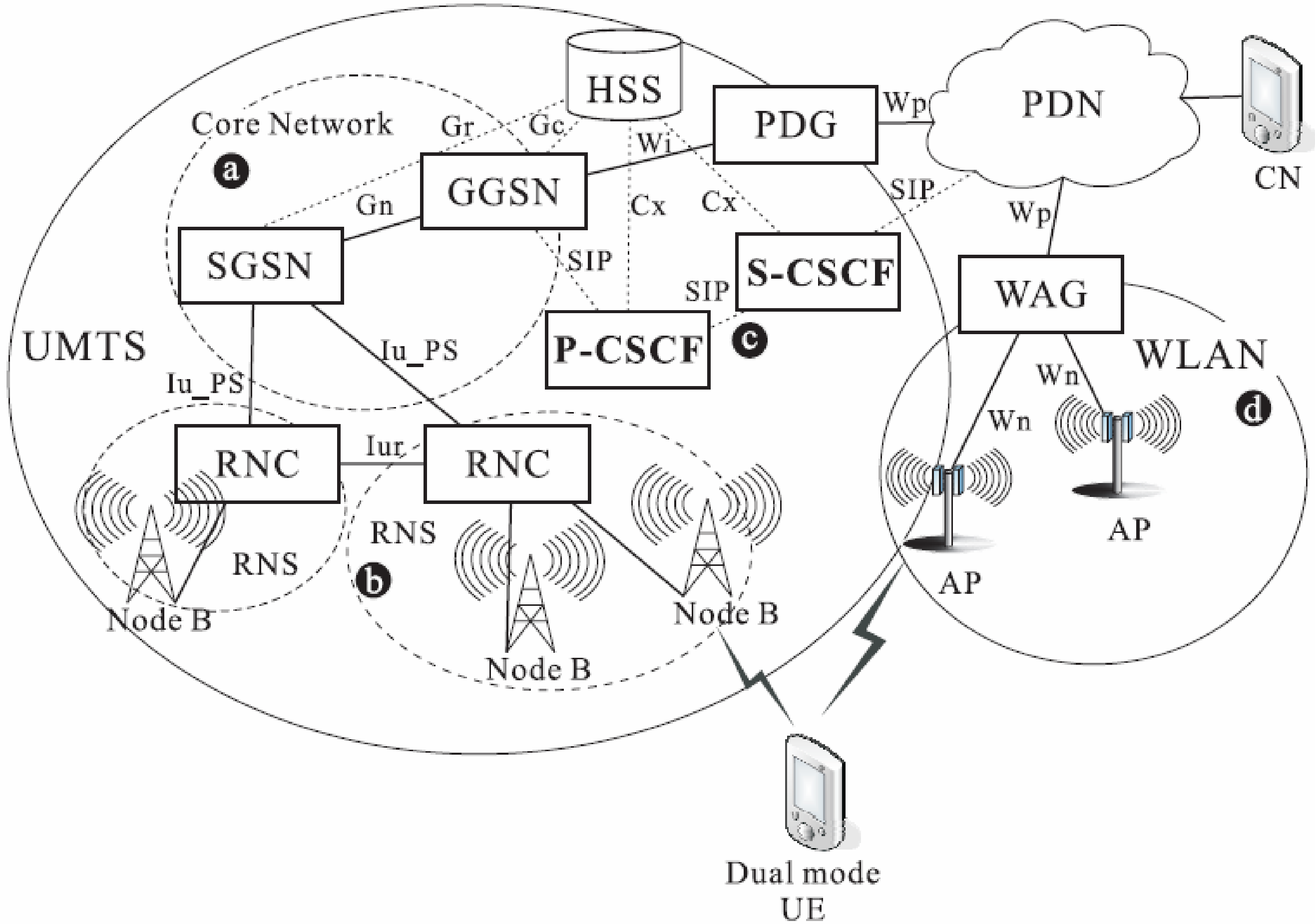


Two Traditional Approach- Mobile SCTP Re-Configure Mechanism

- An alternative new transport layer protocol is proposed by IETF standard transport protocol (RFC2960)
  - Stream Control Transmission Protocol
    - Multihoming- allows each pairs end-point to set up a set of connections that can be thought different interface.
    - *Heartbeat* message
- Mobile SCTP
  - Dynamic Address Reconfig
  - Also has FLC problem



System Model



UE: User Equirement
SGSN: Serving GPRS support node
RNC: Radio Network Controller
PDG: Packet Data Gateway
RNS: Radio Network System

GGSN: Gateway GPRS support node
PDN: Packet Data Network
WAG: WLAN Access Gateway
CSCF: Call Session Control Function
CN: Correspondent Node

SmSCTP Mechanism over Heterogeneous Network

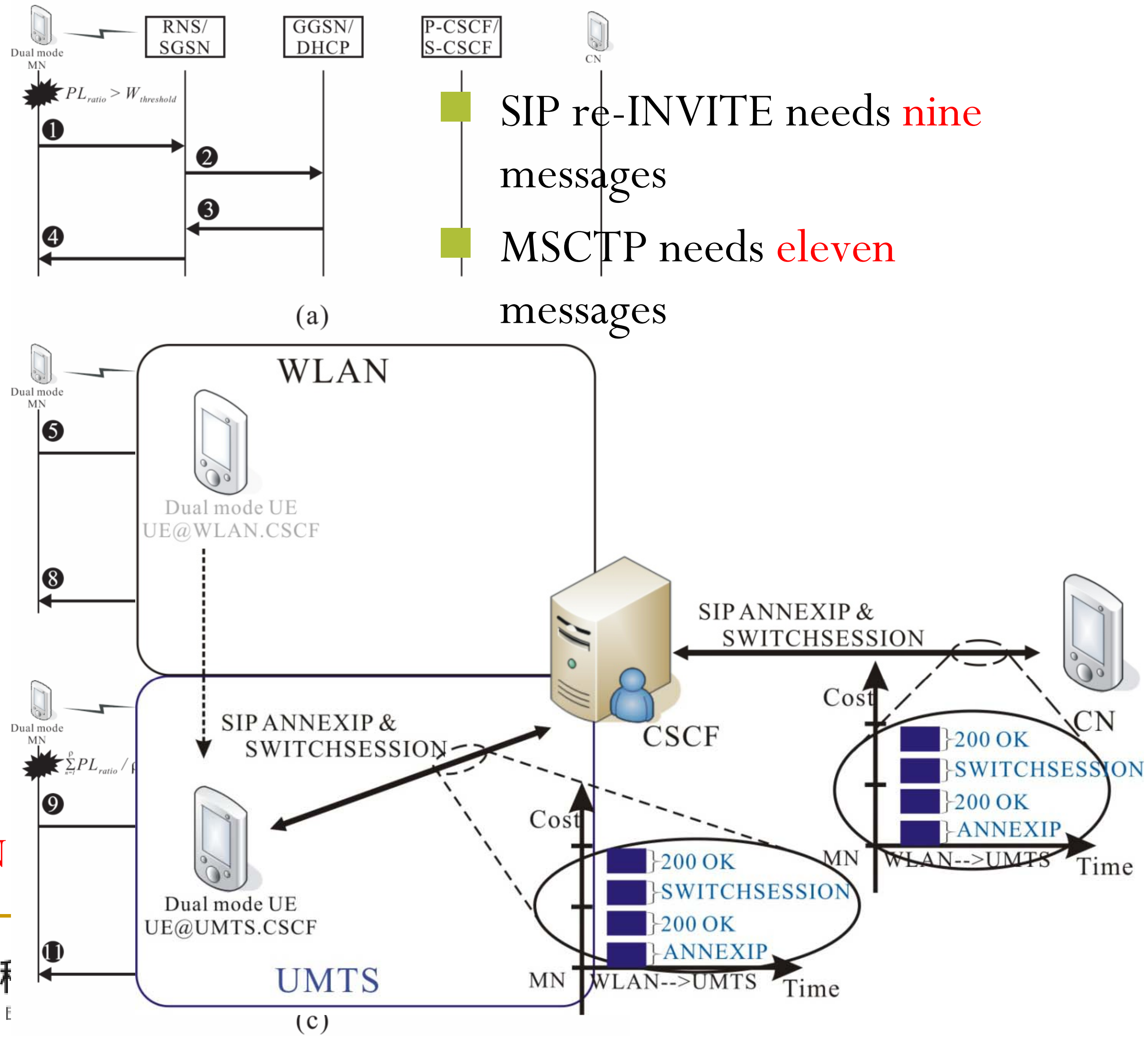
- Cross layer design
  - Layer 7 SIP and layer 4 MSCTP
  - Concise handoff procedure
- SmSCTP adopts active mode to quickly notify the CN about the network status.
- Two new signaling message
  - ANNEXIP
  - SWITCHSESION
    - Solving FLC problem

Message Flow for SmSCTP

UMTS PDP Context Procedure

ANNEXIP

SWITCHSESSION



- SIP re-INVITE needs nine messages
- MSCTP needs eleven messages

Signaling Message Cost

- SIP re-INVITE

$$\Psi_{SIP} \approx nCMR * [5C_{req} + 4C_{res}]$$

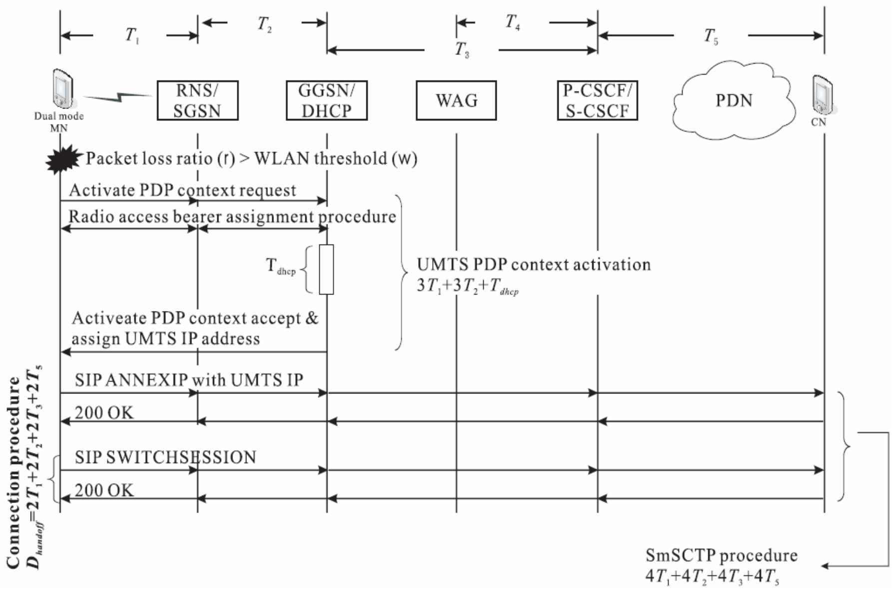
- MSCTP

$$\Psi_{MSCTP} \approx nCMR * [7C_{req} + C_{res} + 3cost_{hb}]$$

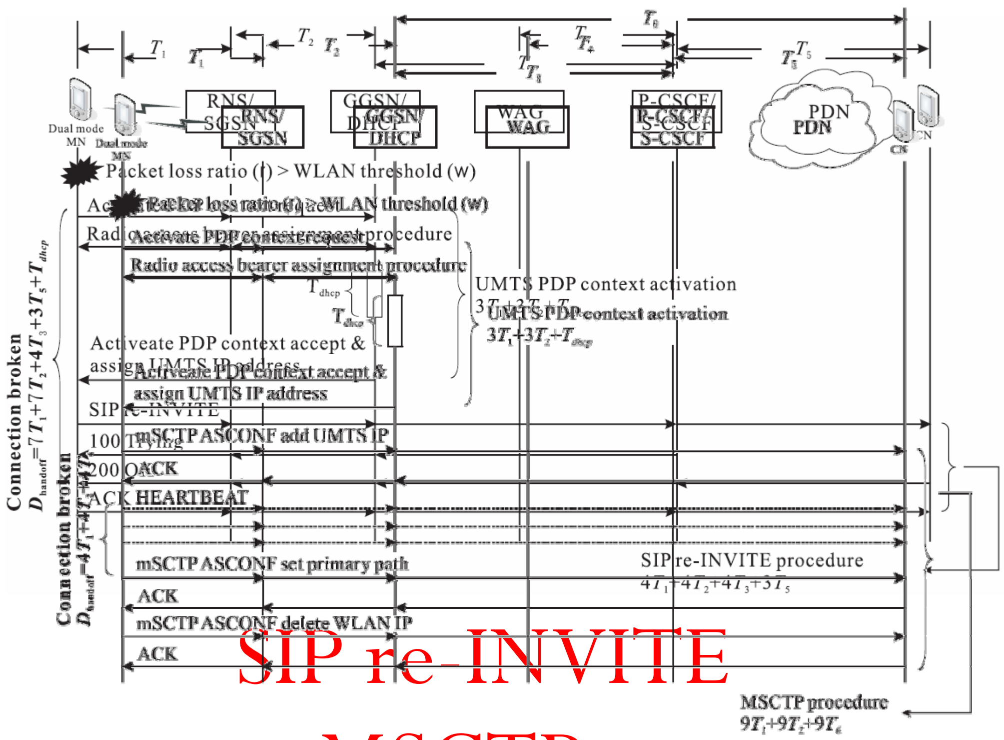
- SmSCTP

$$\Psi_{SmSCTP} = 2CMR * (n+1) * (C_{req} + C_{res})$$

Delay Time Analysis



SmSCTP



SIP re-INVITE

MSCTP

Delay time

- SIP re-INVITE

$$D_{SIP} \approx nCMR * (4T_1 + 4T_2 + 4T_3 + 3T_5 + D_{PDP})$$

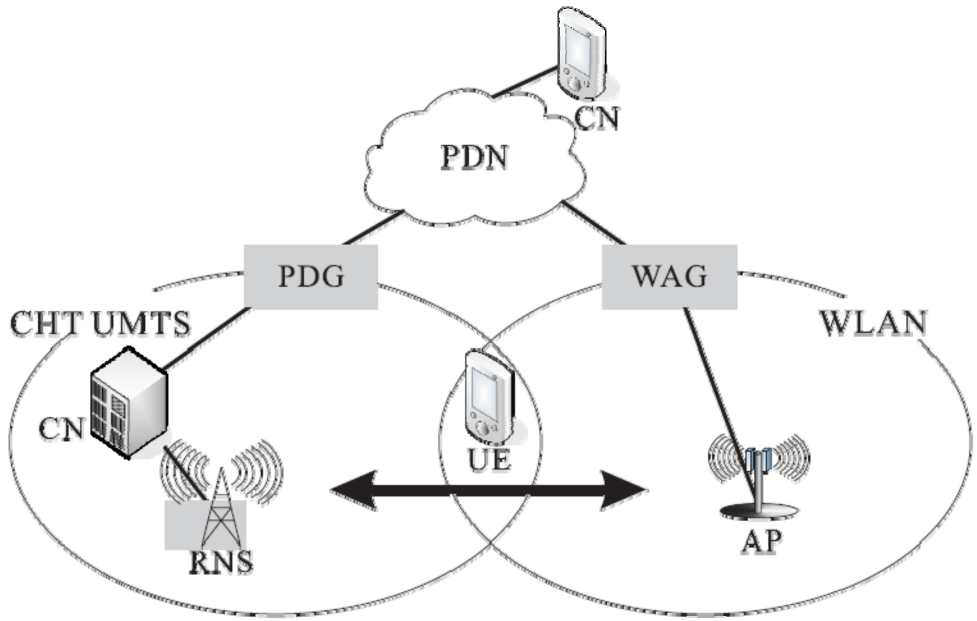
- MSCTP

$$D_{MSCTP} \approx nCMR\,[4T_1 + 4T_2 + 4T_6]$$

- SmSCTP

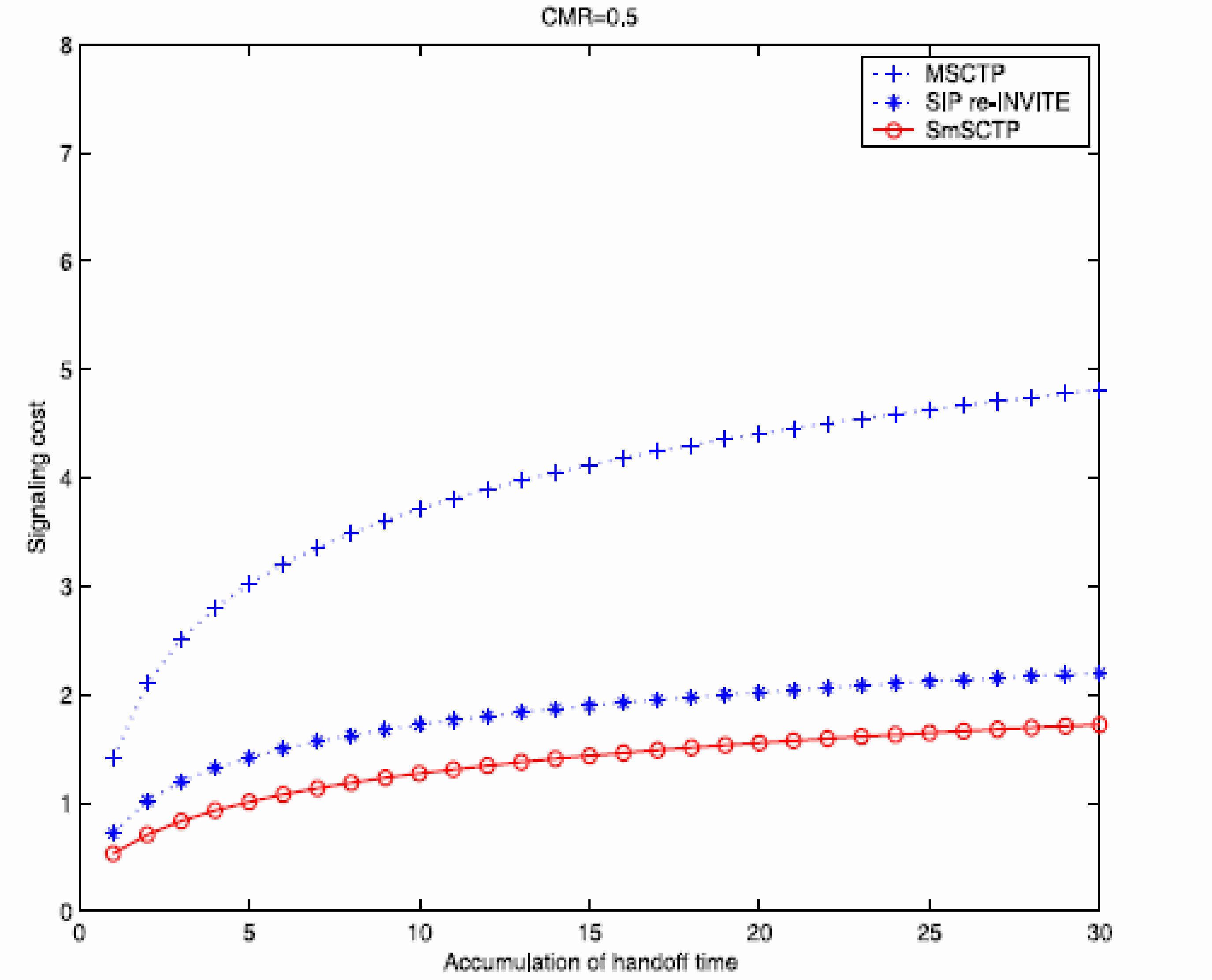
$$D_{SmSCTP} = nCMR(2T_1 + 2T_2 + 4T_3)$$

SmSCTP Testbed

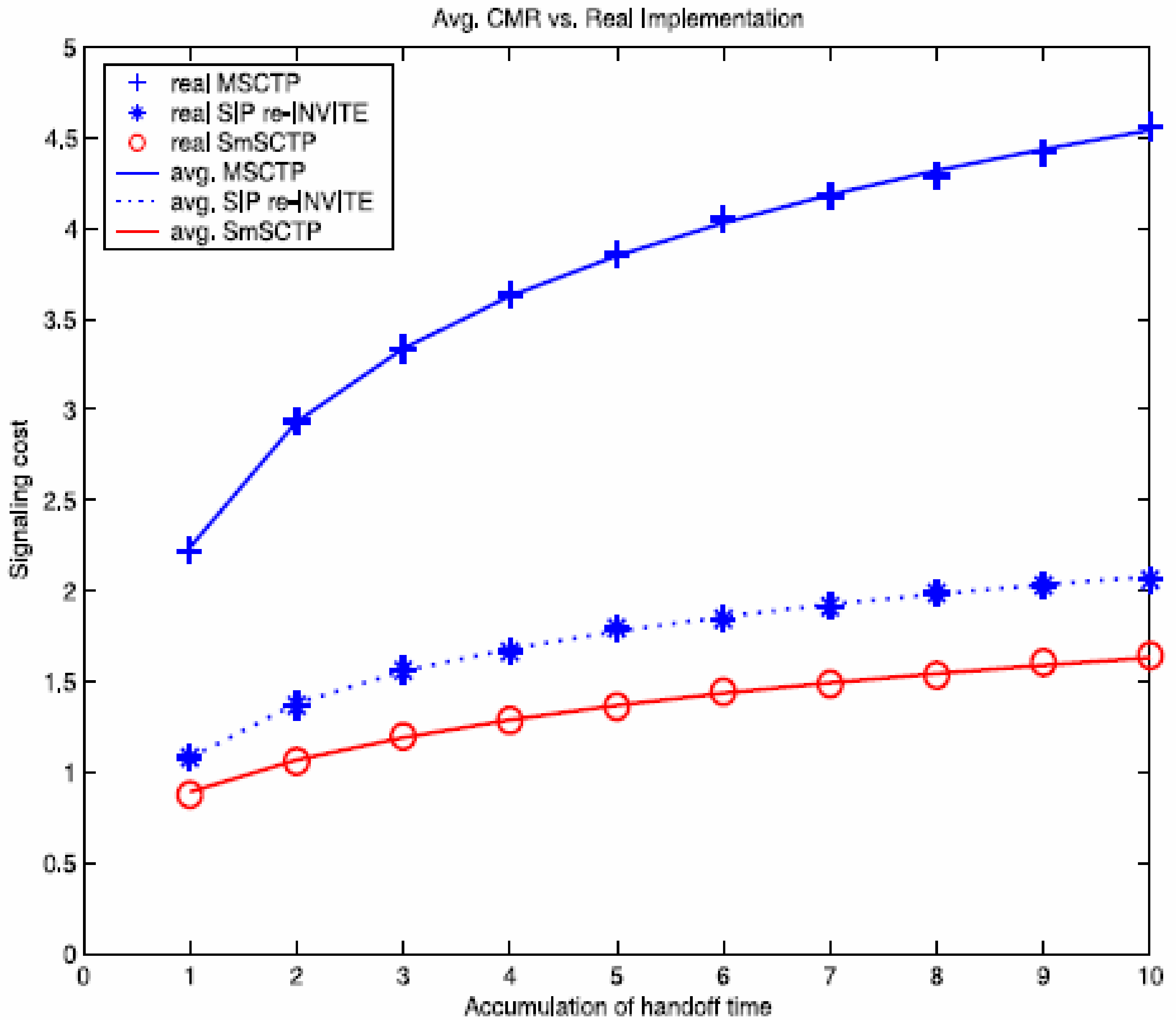


- UMTS
  - Chunghwa Telecom Co. in Taiwan
  - 384kpbs
- WLAN
  - WiFi
- UE
  - Kphone

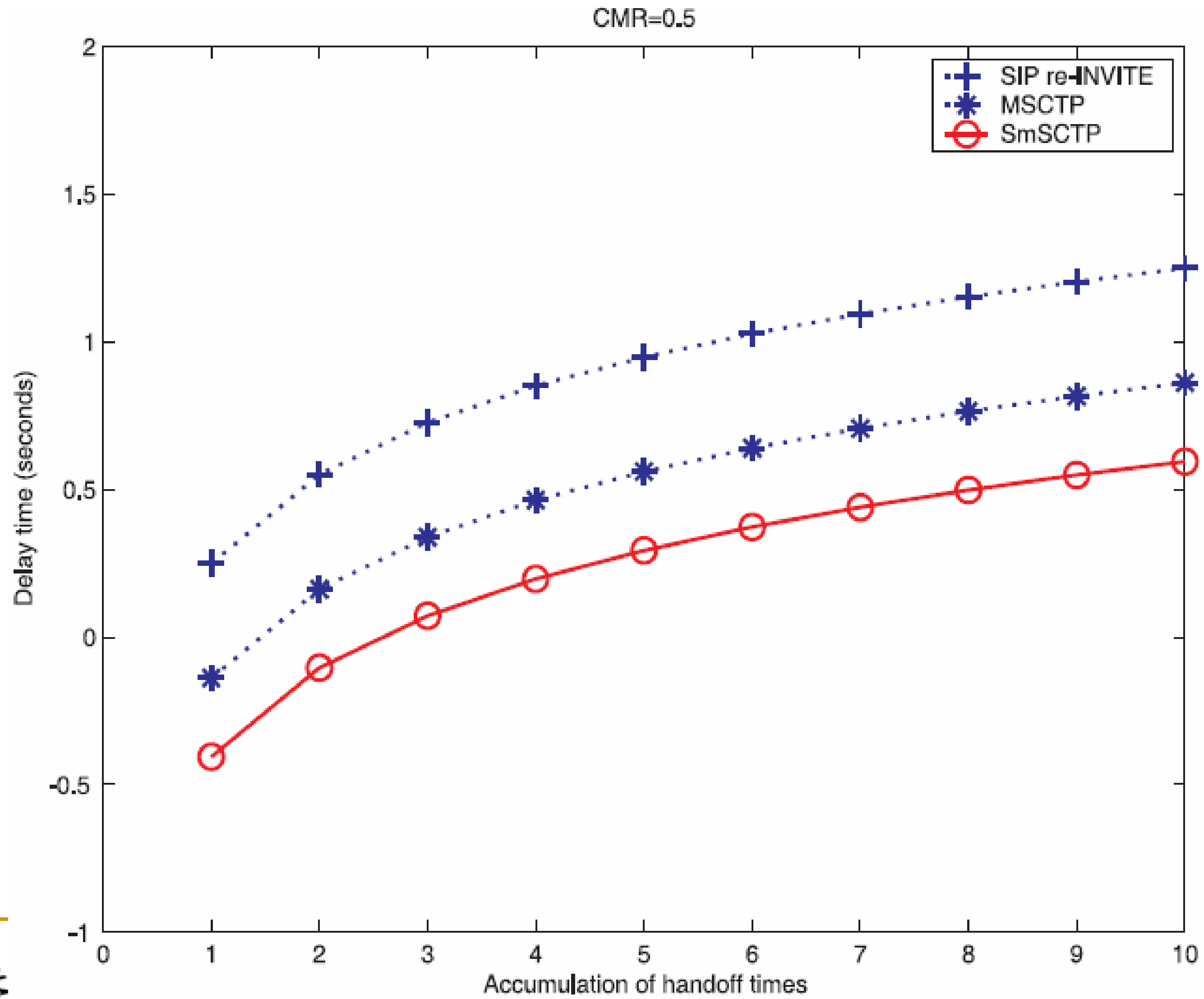
Performance Analysis-
Signaling Cost (CMR=0.5)



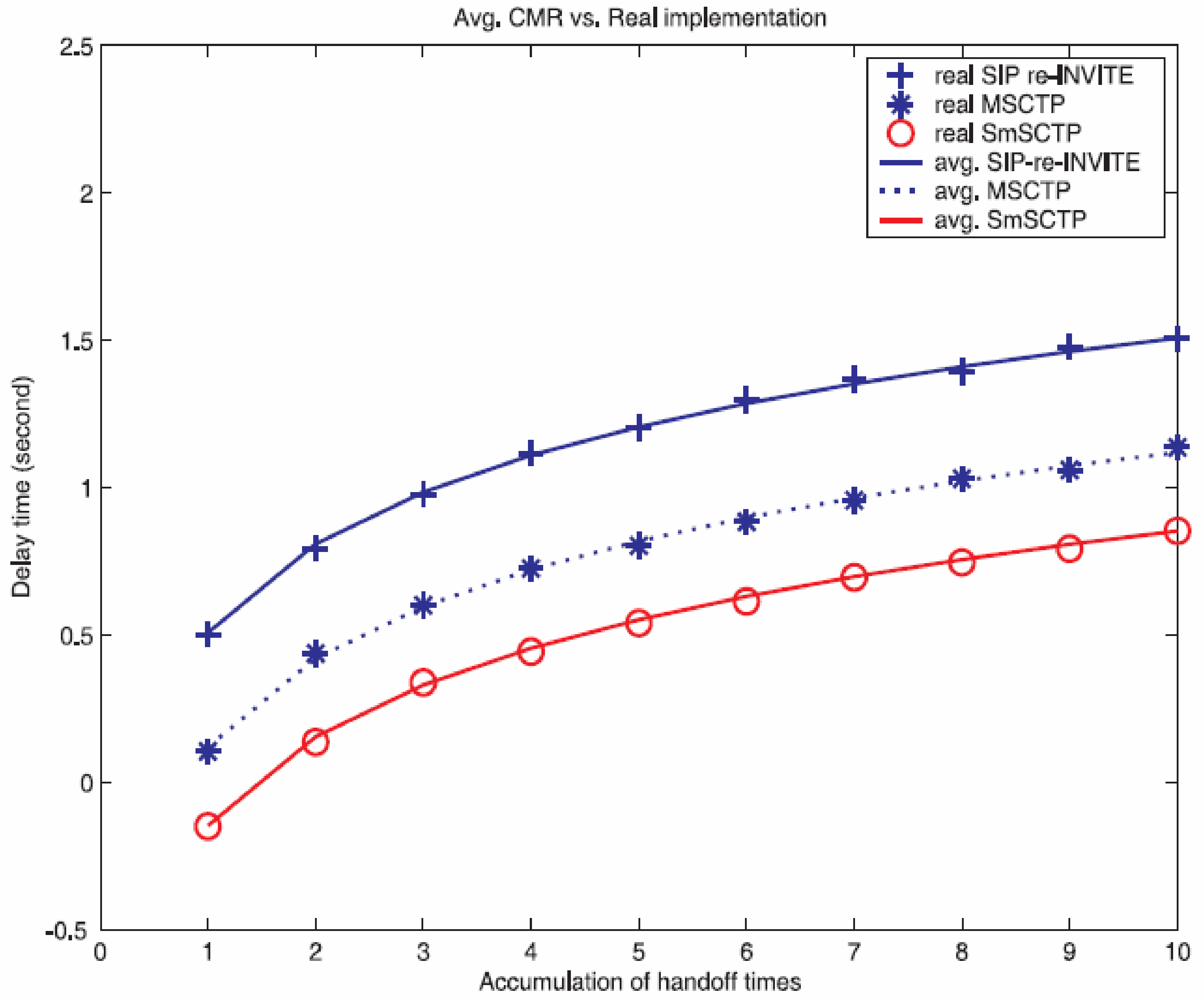
Performance Analysis-
Signaling Cost (implementation results vs. Avg. CMR)



Performance Analysis-
Handoff Latency (CMR=0.5)



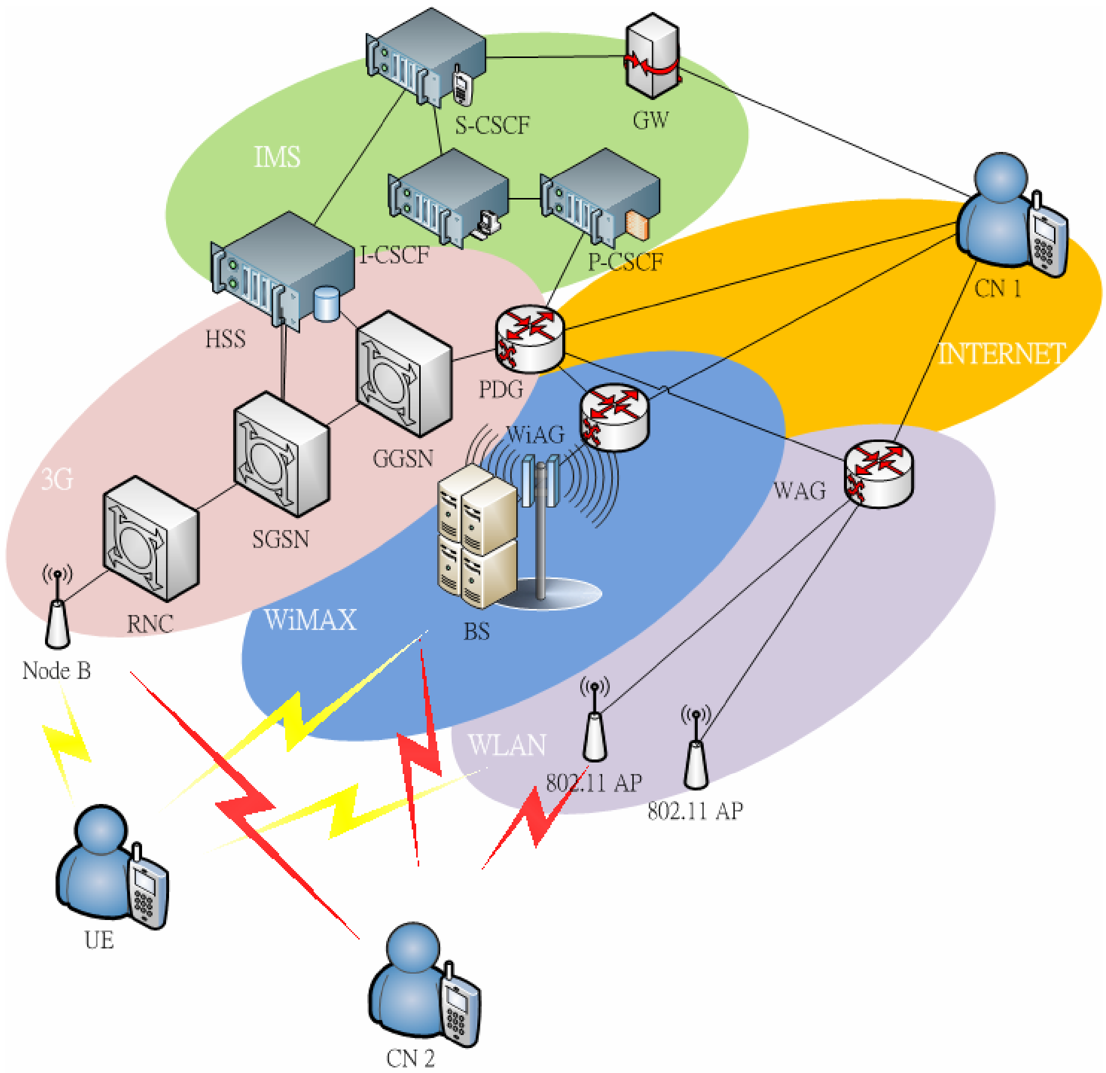
Performance Analysis-
Handoff Latency (implementation results vs. Avg. CMR)



Conclusion

- We introduce our cross layer scheme, SmSCTP, over WLAN and 3G UMTS heterogeneous network.
- By new signaling (SWITCHSESSION), our scheme can solve FLC problem
- In the mathematical analysis and implementation result, we verify that our SmSCTP scheme offers a low latency and signaling message cost

WiMax/WLAN/UMTS Seamless Handoff

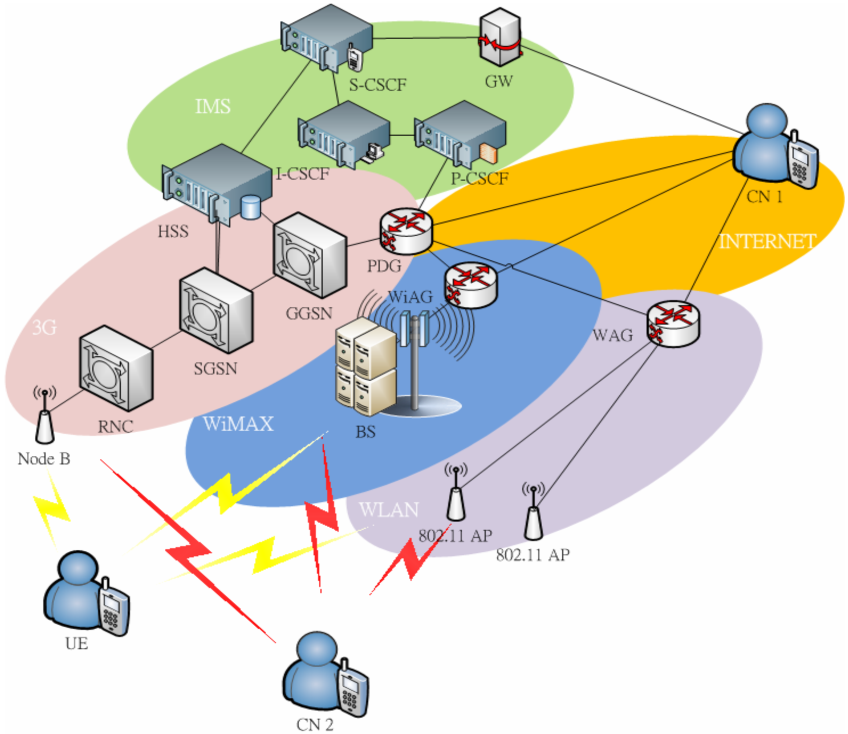


All-IP Cross-Layer 4G行動通信研究

All-IP Cross-Layer Mobility and Session Management計畫成果

計畫目標

- 在UMTS/ WLAN/WiMAX異質網路(4G)環境下提供無縫隙換手機制
- 跨層資訊(cross-layer)整合研發以達到無縫隙換手之目的
- 減少系統控制負擔增加系統穩定性
- 減少換手延遲時間增加可靠度提供
- 與其他子計畫具整合能力



計畫成果

- 跨層式SIP-based 多-IP無縫隙換手機制
- 達到UMTS/WLAN/WiMax間無縫隙換手

工作展望

- 研發認知式(cognitive-based)換手機制
- 研發機制整合location-aware/IMS

Multi-IP 原始碼下載網站

(http://203.68.111.118/4G/)

Q&A

- Prof. Yuh-Shyan Chen
  - My e-mail
    - yschen@mail.ntpu.edu.tw
  - URL:
    - http://www.csie.ntpu.edu.tw/~yschen/