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*

IEEE Transaction on Wireless Communications, Vol. 9, No. 4, April 2010
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
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
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

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

New foreign agent

Correspondent agent

Home agent
MIPv4: Control & Data Flows

Mobile Node

- Agent Solicitation
- Agent Advertisement
- Registration Request
- Registration Reply

FA

- Registration Request
- Registration Reply

HA

Correspondent Node

- User Packet
- User Packet
MIP: Triangular Routing Problem

- Mobile host
- Home agent
- Home network
- Remote host

Internet

It could be this path
MIPv6: Binding Update

Correspondent Node

Home Agent

Mobile Node

Home registration

Movement

Get care-of address

Correspondent binding procedure

Return routability procedure
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
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
Existing Handoff Results (1)

- **Smooth Handoff Approach (Layer-3, Mobile IPv6)**
  - Goal: To decrease packet loss
Existing Handoff Results (2)

- Fast Handoff Approach (Layer-3, Hierarchical Mobile IPv6)
  - Goal: To decrease handoff latency
2. Related work


- 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

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

■ 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

### 2. Related work

- **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

2. Related work
Handoff times of protocols

2. Related work
Outline

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

- HMIPv6 still suffers a long latency
  - The DAD time for LCoA and RCoA represent 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.
3. Motivation, basic idea, and system architecture

System architecture
3. Motivation, basic idea, and system architecture

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

3. Motivation, basic idea, and system architecture
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 $D_s(\alpha,\beta)$.

3. Motivation, basic idea, and system architecture

Example of $D_s(2,3)$
3. Motivation, basic idea, and system architecture

Cross-layer idea
Outline

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

4. Partner-based HMIPv6 (PHMIPv6)

Find a PN

DAD & LCoA

Pre-handoff req.
Successful scenario (2)

4. Partner-based HMIPv6 (PHMIPv6)
4. Partner-based HMIPv6 (PHMIPv6)

Partner-based HMIPv6 (PHMIPv6)
4. Partner-based HMIPv6 (PHMIPv6)

Successful case

Partner awareness Procedure

Pre-handoff request

Start handoff

BU to CN
4. Partner-based HMIPv6 (PHMIPv6)

Unsuccessful scenario (1)

![Diagram of networking scenario](image)

(a) Pre-handoff req.
(b) DAD & LCoA
4. Partner-based HMIPv6 (PHMIPv6)

Unsuccessful scenario (2)
4. Partner-based HMIPv6 (PHMIPv6)

Unsuccessful case

Partner awareness Procedure

Pre-handoff req.

MH handoff to other AP

BU to CN

DAD & LCoA

DAD & RCoA
Outline

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

<table>
<thead>
<tr>
<th>Network parameter</th>
<th>Field description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$BW_w$</td>
<td>Bandwidth of the wired backbones</td>
</tr>
<tr>
<td>$BW_{wl}$</td>
<td>Bandwidth of the wireless link</td>
</tr>
<tr>
<td>$L_w$</td>
<td>Latency of the wired link</td>
</tr>
<tr>
<td>$L_{wl}$</td>
<td>Latency of the wireless link</td>
</tr>
<tr>
<td>$S_{ctr}$</td>
<td>Average size of the control message</td>
</tr>
<tr>
<td>$n$</td>
<td>Number of hops between the MH and the router</td>
</tr>
<tr>
<td>$t_{D_{internet}}$</td>
<td>Average delay of that a packet traveling in the Internet</td>
</tr>
<tr>
<td>$t_{D_{dad}}$</td>
<td>Average delay of the DAD time</td>
</tr>
</tbody>
</table>
5. Mathematical analysis and simulation results

Mathematical analysis (2)

Total handoff time of HMIPv6
Mathematical analysis (3)

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

\[
\begin{align*}
    t_{\text{rendezvous}} &= t_{\text{solicitation}} + t_{\text{advertisement}} \\
    t_{\text{solicitation}} &= \left( \frac{S_{\text{ctr}}}{BW_{wl}} + L_{wl} \right) + n\left( \frac{S_{\text{ctr}}}{BW_w} + L_w \right) + t_{D\text{-internet}} \\
    t_{\text{advertisement}} &= \left( \frac{S_{\text{ctr}}}{BW_{wl}} + L_{wl} \right) + n\left( \frac{S_{\text{ctr}}}{BW_w} + L_w \right) + t_{D\text{-internet}}
\end{align*}
\]
5. Mathematical analysis and simulation results

Mathematical analysis (4)

- $t_{DAD\_LCoA}$ is the DAD time for the link-local CoA.

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

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

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

\[
 t_{binding\_CN} = 2 \left[ \left( \frac{S_{ctr}}{BW_{w}} + L_{w} \right) + t_{D\_internet} \right]
\]
Mathematical analysis (5)

- $t_{DAD\_RCoA}$ is the DAD time for the regional CoA.

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

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

\[
t_{binding\_ack} = \left( \frac{S_{ctr}}{BW_{wl}} + L_{wl} \right) + n\left( \frac{S_{ctr}}{BW_{w}} + L_{w} \right) + t_{D\_internet}
\]
Mathematical analysis (6)

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

\[
\begin{align*}
    t_{HMIPv6} &= t_{layer.2} + t_{rendezvous} + t_{DAD.LCoA} + t_{DAD.RCoA} + t_{binding.CN} \\
    &= t_{layer.2} + 6 \left[ \left( \frac{S_{ctr}}{BW_{wl}} + L_{wl} \right) + n \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] \\
    &\quad + 2 \left[ \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] + 2t_{D\_dad}
\end{align*}
\]
Mathematical analysis (7)

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

\[
\begin{align*}
t_{SHMIPv6} &= t_{layer.2} + t_{rendezvous} + t_{DAD.LCoA} + \min(t_{pmap}, t_{bu.HA}) \\
&= t_{layer.2} + 4 \left[ \left( \frac{S_{ctr}}{BW_{wl}} + L_{wl} \right) + n \left( \frac{S_{ctr}}{BW_{w}} + L_{w} \right) + t_{D.internet} \right] \\
&\quad + \min(t_{pmap}, t_{HA}) + t_{D.dad}
\end{align*}
\]
Mathematical analysis (8)

Let $t_{\Delta_1}$ be the time difference between $t_{\text{SHMIPv6}}$ and $t_{\text{HMIPv6}}$.

\[
 t_{\Delta_1} = t_{\text{HMIPv6}} - t_{\text{SHMIPv6}} \\
 = t_{\text{binding-CN}} + t_{\text{DAD-RCoA}} - \min(t_{\text{pmap}}, t_{HA}) \\
 \leq t_{\text{binding-CN}} + t_{\text{DAD-RCoA}} \\
 = 2 \left[ \left( \frac{S_{\text{ctr}}}{BW_{\text{wl}}} + L_{\text{wl}} \right) + n \left( \frac{S_{\text{ctr}}}{BW_{w}} + L_{w} \right) + t_{\text{D-internet}} \right] + 2 \left[ \left( \frac{S_{\text{ctr}}}{BW_{w}} + L_{w} \right) + t_{\text{D-internet}} \right] + t_{D_{-dad}}
\]
5. Mathematical analysis and simulation results

Mathematical analysis (9)

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

\[
t_{PHMIPv6} = t'_{layer.2} + t_{layer.3} - t_{overlap}
\]

\[
= t'_{layer.2} + t_{binding\_MAP} + t_{binding\_CN} - t_{binding\_MAP}
\]

\[
= t'_{layer.2} + 2 \left[ \left( \frac{S_{ctr}}{BW_{wl}} + L_{wl} \right) + n \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right]
\]
Mathematical analysis (10)

Let $t_{\Delta_2}$ be the time difference between $t_{HMIPv6}$ and $t_{PHMIPv6}$.

\[
t_{\Delta_2} = t_{HMIPv6} - t_{PHMIPv6} \\
= (t_{layer_2} - t'_{layer_2}) + t_{DAD-LCoA} + t_{DAD-RCoA} \\
= (t_{layer_2} - t'_{layer_2}) + 4 \left[ \left( \frac{S_{ctr}}{BW_{wl}} + L_{wl} \right) + n \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] \\
+ 2 \left[ \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] + 2t_{D\_dad}
\]
5. Mathematical analysis and simulation results

Mathematical analysis (11)

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

\[
t_{\Delta_2} - t_{\Delta_1} = 2 \left[ \left( \frac{S_{ctr}}{BW_{wl}} \bigg| L_{wl} \right) \bigg| n \left( \frac{S_{ctr}}{BW_w} \bigg| L_w \bigg| t_{D\text{-}internet} \right) \bigg| (t_{layer-2}, t'_{layer-2}) \bigg| 2t_{D\text{-}dad} > 0 \right]
\]
Mathematical analysis (12)

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

\[
\begin{align*}
t_{U\_PHMIPv6} &= t'_{layer\_2} + t_{layer\_3} \\
&= t'_{layer\_2} + t_{DAD\_RCoA} + t_{binding\_CN} \\
&= t'_{layer\_2} + 2 \left[ \left( \frac{S_{ctr}}{BW_{wl}} + L_{wl} \right) + n \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] \\
&\quad + 2 \left[ \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D\_internet} \right] + t_{D\_DAD}
\end{align*}
\]
Mathematical analysis (13)

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

\[
\begin{align*}
    t_{\Delta 3} &= t_{HMIPv6} - t_{U \_PHMIPv6} \\
    &= (t_{layer \_2} - t'_{layer \_2}) + t_{DAD \_LCoA} \\
    &= (t_{layer \_2} - t'_{layer \_2}) + 2 \left[ \left( \frac{S_{ctr}}{BW_{wl}} + L_{wl} \right) + n \left( \frac{S_{ctr}}{BW_{w}} + L_{w} \right) + t_{D \_internet} \right] \\
    &\quad + 2 \left[ \left( \frac{S_{ctr}}{BW_{w}} + L_{w} \right) + t_{internet} \right] + t_{D \_DAD}
\end{align*}
\]
5. Mathematical analysis and simulation results

Mathematical analysis (14)

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

\[ t_{\Delta_3} - t_{\Delta_1} = \left( \frac{S_{ctr}}{BW_w} + L_w \right) + t_{D_{internet}} + (t_{layer_2} - t'_{layer_2}) > 0 \]
System implementation

5. Mathematical analysis and Simulation results

(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.

5. Mathematical analysis and simulation results
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

![Sequence number vs. time graph](image)
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?