# A Multihoming-Based Vertical Handover Scheme

**Hee-Dong Park and Kyung-Nam Park**

**Abstract** This paper proposes a multihoming-based vertical handover scheme. Mobile nodes must have several radio interfaces to support vertical handover in heterogeneous wireless networks. In this paper, we consider each interface of a mobile node has its own protocol stack with physical, data link, and network layer. When a mobile node moves to a different type of access network, the proposed scheme can provide a mobile node with fast and seamless handover by performing layer-3 handover using its new interface while the other interface is still communicating in the old access network. This scheme uses a newly defined Proxy binding update to minimize handover delay and packet loss while a mobile node moves to a different type of access network. The proposed Proxy binding update is different from the Mobile IP binding update in that it includes home address (HoA) of the old interface instead of the new interface. The performance analysis shows that the proposed scheme can efficiently reduce vertical handover delay and packet loss.

**Keywords** Multihoming · Vertical handover · Proxy binding update · Seamless handover

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H.-D. Park
Department of Information and Communication, Korea Nazarene University, 456, Ssangyong-dong, Seobuk-gu, Cheonan-city, South Korea
e-mail: hdpark@kornu.ac.kr

K.-N. Park (✉)
Department of Multimedia, Korea Nazarene University, 456, Ssangyong-dong, Seobuk-gu, Cheonan-city, South Korea
e-mail: knpark@kornu.ac.kr

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# 1 Introduction

With the advent of diverse wireless networks and smart mobile devices, vertical handover is a key issue to support seamless communications while a mobile node moves to a different type of access network. Heterogeneous networks based on wireless local area networks (WLANs) and wireless wide area networks (WWANs) such as 3G/4G, beyond 3G/4G, and WiMAX/Wibro can combine their respective advantages on coverage and data rates. For example, WWANs such as UMTS 3G cellular networks have big coverage and low data rates, while WLANs have small coverage and high data rates. In such environment, multi-interface terminals should seamlessly switch from one access network to another in order to obtain improved performance and continuous wireless connection.

Many researches on vertical handover are being carried out and standardized in various standard organizations such as IETF, IEEE, ITU-T, 3GPP, etc. [1–6]. Especially in IETF, many IP-based mobile technologies such as Mobile IP, Fast Mobile IP, Proxy Mobile IP, etc. are considered to support vertical handover in the heterogeneous networks.

This paper proposes a multihoming-based seamless vertical handover scheme with newly defined Proxy binding update which is different from the original Binding update of Mobile IP.

# 2 Multihoming-Based Vertical Handover With Proxy Binding Update

## 2.1 Protocol Stack of a Mobile Node

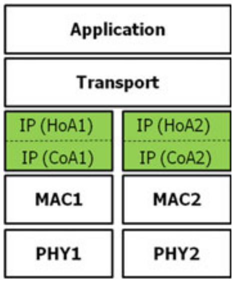
Mobile nodes must have several radio interfaces to support vertical handover in heterogeneous wireless networks. In this paper, we consider a mobile node with multiple interfaces corresponding to their access networks. Each interface has its own protocol stack with physical, data link, and network layer.

Figure 1 shows an example of protocol stack of a mobile node in the proposed scheme. The mobile node has dual interfaces which have dual PHYs, MACs, and

**Table 1** Parameters for performance evaluation

| Parameters | Definition | Value |
|---|---|---|
| $D_{HO}$ | Total handover dealy | N/A |
| $\tau$ | The interval of Router advertisements | 1 s |
| $D_{L2}$ | Layer 2 handover delay | 100 ms |
| $L_{wl}$ | Wireless link delay | 2 ms |
| $L_{w}$ | Wired link delay | 0.5 ms |
| $D_{DAD}$ | Times for duplicate address detection | 500 ms |
| $H_{AR\text{-}HA}$ | Hop-counts between AR and HA | – |

**Fig. 1** Protocol stack of a mobile node




IPs. Therefore, each interface has its own home address (HoA) and care-of address (CoA). We consider each interface of a mobile node can belong to its own access network. For example, an interface (INT-1) with WLAN has its own HoA1 and CoA1, and the other (INT-2) with 3G or 4G network has HoA2 and CoA2.

## *2.2 Handover Procedure*

Figure 2 shows the vertical handover procedure of the proposed scheme. We consider a scenario where a mobile node moves from WLAN to 3G or 4G network. AR (Access router) in Fig. 2 can be replaced by a corresponding entity according to access networks. For example, SGSN (Serving GPRS support node) in UMTS performs the role of AR.

(a) Phase 1: When a mobile node stays in the WLAN, it communicates with its home agent (HA) or correspondent node (CN) using INT-1. In Phase 1, the binding information of HA is HoA1 to CoA1. Therefore, HA intercepts the packets destined for the mobile node and tunnels them to CoA1.
(b) Phase 2: As the mobile node moves to the duplicate area between WLAN and 3G/4G network, its MIH module triggers vertical handover. In Phase 2, INT-2 receives the prefix information from New_AR in the 3G/4G network. After the mobile node associates with the New_AR by creating a CoA (CoA2), it sends a Proxy binding update message to the HA. The Proxy binding update message contains CoA2 of INT-2 and HoA1 of INT-1 instead of HoA2 of INT-2. This makes the HA to be under the illusion that the INT-1 has moved to a new access network. The INT-1, however, actually continues to receive packets in the Old_AR's coverage area (WLAN), thus packet loss can be prevented. After receiving the Proxy binding update message, HA updates the binding information and sends Proxy binding update ACK message and data packets to the mobile node through 3G/4G network. In summary, the mobile node can send and receive data packets through INT-2 in 3G/4G networks while it may also receive in-transit packets through the INT-1 in WLAN.
(c) Phase 3: After the completion of Proxy binding update, the mobile node can communicate with HA or CN through INT-2.

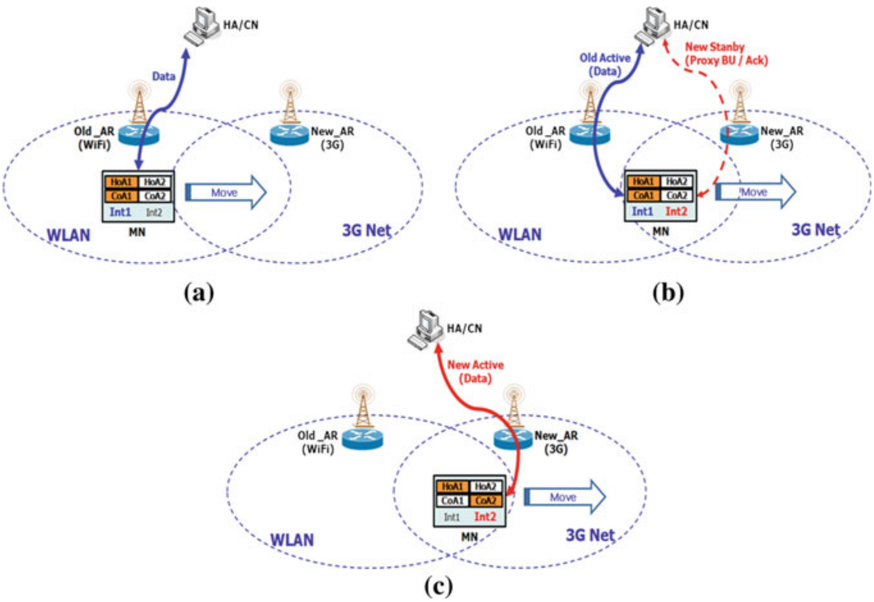



**Fig. 2** Handover procedure of the proposed scheme: **a** Phase 1, **b** Phase 2, **c** Phase 3

In the proposed scheme, Proxy binding update and Proxy binding ACK messages are introduced to support seamless vertical handover. The formats of these messages, however, are the same as those of general Binding update and Binding update ACK messages in Mobile IPv6. Yet, the proposed Proxy binding update message is different from Proxy binding update message of Proxy Mobile IPv6.

## 3 Performance Evaluation

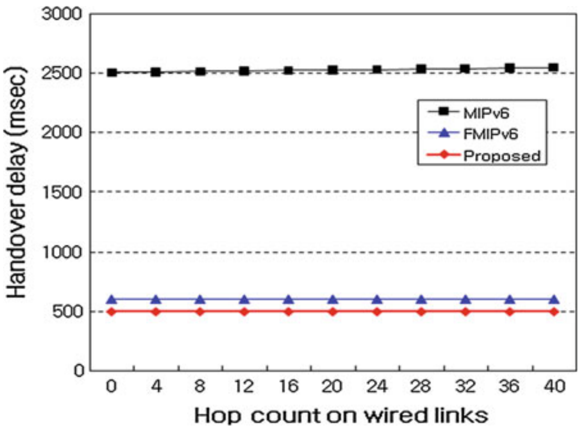
This section compares MIPv6, FMIPv6, and the proposed scheme by vertical handover delay and packet loss ratio [7].

### 3.1 Vertical Handover Delay

Vertical handover delay can be defined as the time duration between the start of layer 2 handover and reception of the first packet in a different access network after layer 3 binding update. In this paper, link delay is considered, but processing and transmission delay are not.

Handover delays of MIPv6, FMIPv6, and the proposed scheme can be represented as Eqs. (1), (2), and (3), respectively.

**Fig. 3** Vertical handover delay




$$D_{HO(MIP)} = 2\tau + 4L_{wl} + 2L_w H_{AR-HA} + D_{DAD} \quad (1)$$

$$D_{HO(FMIP)} = D_{L2} + L_{wl} + D_{DAD} \quad (2)$$

$$D_{HO(\mathrm{Pr}oposed)} = D_{DAD} \quad (3)$$

As shown in Eq. (3), handover delay of the proposed scheme is the lowest because the proposed handover is a type of 'Make-before-break' handover in network layer. Figure 3 compares their handover delays according to hop-counts between AR and HA. Handover delay of MIPv6 is proportional to wired link delay but handover delays of FMIPv6 and the proposed scheme are constant regardless of wired link delay.

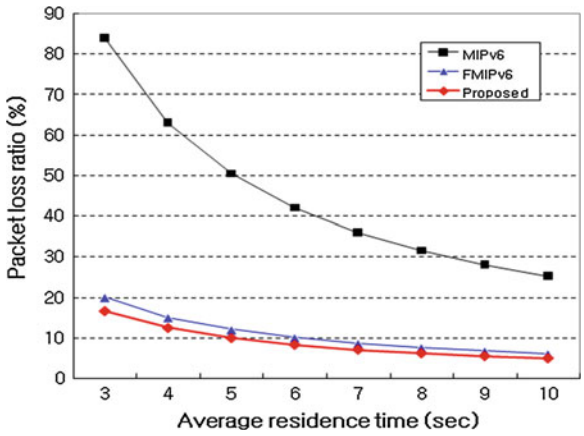
### 3.2 Packet Loss Ratio

Packet loss ratio is defined as the ratio of the number of lost packets during a handover to the total numbers of transmission packets in a cell. This can be also expressed as:

$$\rho_{loss} = \frac{D_{HO}}{t_{cell}} \times 100 \quad [\%] \quad (4)$$

where $t_{cell}$ is the average residence time in a cell. Figure 4 compares packet loss ratio during a vertical handover. As shown in Fig. 4, the packet loss ratio of the proposed handover scheme is the lowest because its handover delay is the lowest.

**Fig. 4** Packet loss ratio




# 4 Conclusions

This paper proposes a multihoming-based vertical handover scheme with Proxy binding update. When a mobile node is located in the duplicate region between two different access networks, it can send and receive data packets using multiple interfaces simultaneously, which results in a seamless handover. The proposed scheme supports 'Make-before-break' handover in network layer with Proxy binding update messages.

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