Improving Mobile IPv6 Handover in Wireless Network with E-HCF
Anne Wei, Gouzhi Wei, Benoit Geller

To cite this version:
Anne Wei, Gouzhi Wei, Benoit Geller. Improving Mobile IPv6 Handover in Wireless Network with E-HCF. IEEE Vehicular Technology Conference, Sep 2008, Calgary, Canada. pp.5-9, 10.1109/VETECF.2008.294. hal-01229104

HAL Id: hal-01229104
https://hal-ensta-paris.archives-ouvertes.fr/hal-01229104
Submitted on 16 Nov 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Improving Mobile IPv6 Handover in Wireless Network with E-HCF
Anne Wei‡, GouZhi Wei* and Benoit Geller‡§
*Université Paris XII, 61 avenue du Général de Gaulle, 94030 Créteil, France
† Conservatoire National des Arts et Métiers, 292, rue Saint-Martin, 75003, Paris, France
‡ SATIE – ENS Cachan, 61 avenue du Président Wilson, 94235 Cachan Cedex, France
§ LEI – ENSTA, 32 boulevard Victor, 75015 Paris Cedex, France
Email: anne.wei@cnam.fr

Abstract—Mobile IP allows a mobile node to maintain a continuous connectivity to the Internet when moving from one access point to another. However, due to the link switching delay and to the Mobile IP handover operations, packets designated to mobile nodes can be delayed or lost during the handover period. This paper presents a new control function called Extended Handover Control Function (E-HCF) in order to improve the handover performance in the context of Mobile IPv6 over wireless networks. With an analytical model and some OPNET simulations, we show in this paper that our solution allows to provide low latency, low packet loss to the standard handover of Mobile IPv6.

Index Terms—Mobile IPv6, Performance and Handover operations

I. INTRODUCTION

The need to keep an "everywhere and at any time" connection with Internet has been more and more demanded in recent years with the success of IEEE 802.11 and of IEEE 802.16 wireless networks standards. A growing number of 802.15/802.11 based wireless networks has been deployed in campuses, hotels, airports and companies as access networks to the Internet. The mobility support has thus become one very hot research subject. However, the continuous Internet connectivity and the correct routing of packets were not guaranteed when users change their access points to Internet with classical protocols. To resolve these problems, the Mobile IPv4 (MIPv4) and Mobile IPv6 (MIPv6) protocols [1, 2] were respectively published by the Internet Engineering Task Force (IETF).

Based on MIPv6, the main standards by the IETF are the Hierarchical Mobile IPv6 (HMIPv6) and the Fast Handover for MIPv6 (FHMIPv6). HMIPv6 introduces a Mobility Anchor Point (MAP) who acts somehow like a local Home Agent (HA) for the visiting Mobile Node (MN). The concept of MAP can limit the amount of signaling required outside the MAP’s domain [5, 7]. FHMIPv6 [8] can reduce the packet loss by providing fast IP connectivity as soon as a new link at the Link Layer is established. The network uses a Link Layer trigger to launch either Pre-Registration or Post-Registration handover operations. Besides of these main proposals, there has been some approaches for providing the lossless handover and minimizing the handover delay [9–12, 14]. In [9], a Pre-Handover Signaling (PHS) protocol is proposed in order to support the triggering of a predictive handover and to allow the network to achieve accurate handover decisions by considering different constraints such as Quality-of-Service (QoS), user profile and mobile node service requirements. In [10], a Hierarchical Network-layer Mobility Management (HNSM) framework is described in which an integrated IP-layer handover solution provides an optimized network connectivity. Also, a Competition based Soft Handover Management (CSHM) protocol [11] and a Multi-path Transmission Algorithm (MTA) [12] have been presented to decrease packet loss during a handover. Furthermore, the IEEE 802.11f standard including the Inter-Access Point Protocol (IAPP) enables the Access Points (APs) to communicate with each other, so that the Mobile IPv6 handover is improved at the Link Layer [14].

The goal of this paper is to optimize the Mobile IPv6 handover procedure by using a new function named Extended Handover Control Function (E-HCF). Based on our paper [3], the principle of the Handover Control Function (HCF) is that, according to the mobile node’s scanning result and the HCF router database, the HCF router can both pre-decide a mobile node’s new access point and a new IP address. So the mobile node can send Binding Update message when it is still connected with its previous access point. Contrarily to a standard MIPv6 handover for which the Detection Address Duplication (DAD) deteriorates dramatically the handover latency (see below), the HCF approach avoids any IP address collision without the use of DAD. In this context, we propose the E-HCF which not only inherits of the advantages of the HCF, but also allows communications between some extra-HCF routers. Moreover, the E-HCF can buffer the packets during the handover process in order to reduce the packet loss. The remainder of the paper is thus organized as follows: Section II presents our Extended Handover Control Function (E-HCF) architecture and the associated operations. Section III deals with the performance of the E-HCF handover in terms of handover latency and packet loss. Regarding the standard handover of MIPv6, Our numerical and simulation results show that the E-HCF handover reduces significantly both the latency and the packet loss. Finally, some conclusion and future works are mentioned in Section IV.

This work was supported in part by the international project PRA-SIP under Grant SIP04-03.
II. EXTENDED HANOVER CONTROL FUNCTION
FOR MOBILE IPV6

A. E-HCF overview

Generally speaking, a handover consists of a Link Layer handover and of a Network Layer handover. The Link Layer handover includes a Discovery phase (scanning the channels to discover an available Access Point), an Authentication phase, and a Re-association phase, whereas the Network Layer handover is concerned by a Router Discovery phase, a Detection Address Duplication (DAD) phase, a Binding Update phase and a Binding Acknowledgement phase respectively. As displayed on Figure 1, the standard MIPv6 handover latency has been estimated to a maximum value of 1290 ms [7]. This long latency is not acceptable for real time applications such as video and audio. If we analyze each phase during the Network Layer handover (Router Discovery, DAD, Binding Update and Binding Acknowledgement), we can note that the DAD latency costs almost 1000 ms and has a heavy weight on the global handover latency. As a result, in order to reduce the total handover latency, we now develop a procedure to avoid any DAD operation during handover procedure.

![Figure 1. Standard MIPv6 Latency](image1)

We introduce a local intelligent entity called Extended Handover Control Function (E-HCF) which should be capable of controlling its attached Access Routers (ARs), Access Points (APs) and Mobile Nodes (MNs). As shown on Figure 2, linked directly with its ARs, each E-HCF router reserves beforehand a list of all available IP local addresses. The E-HCF router also generates and updates periodically a second list which records the used ARs/APs/IP addresses. By comparing these two lists, the E-HCF router can find a potential duplicate IP address (collision) in its domain. Then, this E-HCF router can withdraw this potential duplicate IP address or can ask a concerned sub-node to change its IP address. In this way, the E-HCF router enables to insure an unique IP address to a MN without DAD.

Furthermore, an E-HCF router could exchange both some local information with its ARs/APs/MNs and some external information with other E-HCF routers. To realize our E-HCF proposal, we propose six new messages: MN Request (MNReq), MN Reply (MNRep), HCF Request (HCFReq), HCF Reply (HCFRep), Connection Established Information (CEInf) and Handover Finished Confirmation (HFCOn) messages (for the detailed information about the formats of these messages see [15]).

For the mobile IPv6 protocol and IEEE 802.11/802.16 networks context, a MN surveys periodically the received signal strength. When the signal strength drops below a predefined threshold, the MN must discover and connect itself to a new available AP for granting its communication with its correspondence. It reports to its E-HCF router (via its attached AR/AP) some AP’s Basic Service Set IDentifier (BSSID) and signal strengths that it were probed. Based upon the reported information, the AR/AP’s loading and the MN’s Quality of Service (QoS) requirements, the E-HCF router decides which AP, the MN shall associate with and notifies the MN about the new AR/AP information, such as a new AP’s BSSID, an AR interface address, a sub-network prefix and an IP address. Consequently, the MN can configure its new Care-of-Address (CoA) and can take care of the Binding Update process even if it is still attached with its previous AR/AP. An E-HCF router can guarantee that the new IP address is unique thanks to the knowledge of its lists. If a MN moves to another domain, the E-HCF original router guarantees the new IP address by exchanging some data with the new E-HCF router. Moreover, in order to minimize the packet loss during a handover, an E-HCF router stores packets into a buffer until the MN is really attached to the new IP address. The entire handover procedure is displayed on Figure 3.

![Figure 2. Architecture of Extended Handover Control Function (Router is an Access Router; E-HCF is an E-HCF router)](image2)

![Figure 3. E-HCF Procedure (E-HCF original router is an attached router with an E-HCF function; the E-HCF distant/remote router is a router with who an E-HCF original router can communicate)](image3)
B. E-HCF Procedure

We first recall that HCFReq/HCFRep messages are used between E-HCF routers for extra-domain handovers. Each E-HCF router must record and update its database periodically. This database helps to decide an unique new IP configuration in order to adapt for MN movements without the DAD phase during a handover.

As illustrated on Figure 3, the E-HCF procedure is composed of the following steps:

- Moving in the network, if the threshold of the received signal strength is overstepped, the MN begins to probe the neighbor AR/AP’s information, including the signal strength, some IP addresses, AP’s BSSIDs, AR interface addresses and the sub-network prefix. Then the MN sends a MNReq message to its E-HCF original router (via its AR/AP) to report this information.
- Receiving the MNReq message, the AR stops to forward all the packets sent to the MN and forwards them to its E-HCF original router in order to avoid the packet loss during the handover procedure.
- Receiving the MNReq message, the E-HCF original router decides to which AR/AP the MN will be associated. The choice of the AR/AP is mostly based on database obtained with periodic exchange messages from an E-HCF router to another (HCFReq and HCFRep messages) or with periodic exchange messages from ARs/APs/MNs. For example, if the number of registered MNs in one AR or AP has reached a limit, the E-HCF original router will not attach the MN to this saturated AR or AP. After making the previous decision, the E-HCF original router sends to the MN a MNRep message which consists of a new AP’s BSSID, an AR interface address, a sub-network prefix and a new IP address.
- With the MNRep message, the MN can obtain its new CoA and configure it automatically.
- The MN sends a CEInf message to its E-HCF original router to confirm its new attachment.
- After receiving the CEInf message, the E-HCF original router transfers the buffered packets to the MN’s new CoA. Then, the E-HCF original router sends an HFCOn message to end the handover procedure.
- The MN can then exchange Binding Update (BU) and Binding Acknowledgement (BA) messages with its home agent and its correspondent node.

As shown in the E-HCF procedure, a MN can obtain its new CoA before it really attaches to its next AR/AP. Moreover, any DAD latency (about 1000 ms) is avoided. Thus, the E-HCF approach allows the reduction of both the traditional handover latency and the packet loss. The handover performance is thus optimized compared to a traditional approach.

III. E-HCF PERFORMANCE ESTIMATION

The E-HCF performance estimation has been evaluated in terms of the total handover latency and of the packet loss with an analytical model. This model allows us to compare our E-HCF handover with the standard handover of the MIPv6 protocol.

A. E-HCF Latency Analysis

According to the handover procedure on Figure 3, we cite the following latency notations to estimate the handover latency:

- \( L_{\text{EHCF}} \): Total handover latency with the E-HCF approach.
- \( L_{\text{scan}} \): Latency due to the MN’s original scanning of its neighbour AR/AP’s information.
- \( L_{\text{MNReq}} \): Latency for a MN to send a MNReq message to its E-HCF original router.
- \( L_{\text{dec}} \): Latency necessary to an E-HCF router to decide which AR/AP the MN should be attached (including the short delays to send an HCFReq message and to receive an HCFRep message).
- \( L_{\text{MNRep}} \): Latency for an E-HCF router to send a MNRep message to the MN.
- \( L_{\text{CEInf}} \): Latency necessary for a MN to auto-configure its new CoA.
- \( L_{\text{conf}} \): Latency due to the fact that an E-HCF router sends buffered packets and a HFCOn message.
- \( L_{\text{BU/BA}} \): Binding Update/Binding Acknowledgement latency.

The overall E-HCF handover latency \( L_{\text{EHCF}} \) can be summed as following:

\[
L_{\text{EHCF}} = L_{\text{scan}} + L_{\text{MNReq}} + L_{\text{dec}} + L_{\text{MNRep}} + L_{\text{CEInf}} + L_{\text{conf}} + L_{\text{BU/BA}}
\]

As this \( L_{\text{EHCF}} \) depends upon the mobile link bandwidth and the computation capacity of each entity in the wireless network, we summarize the parameter values used in our numerical analysis in Table I.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel scan time</td>
<td>50 ms</td>
<td>MIPv6 standard</td>
</tr>
<tr>
<td>BU/BA latency</td>
<td>140 ms</td>
<td>MIPv6 standard</td>
</tr>
<tr>
<td>Wireless link bandwidth</td>
<td>5.5 Mb/s</td>
<td>IEEE 802.11b</td>
</tr>
<tr>
<td>Wireless link bandwidth</td>
<td>2 Mb/s</td>
<td>UMTS</td>
</tr>
<tr>
<td>Wireless link bandwidth</td>
<td>130 kb/s</td>
<td>GPRS</td>
</tr>
<tr>
<td>Wireless link bandwidth</td>
<td>9 kb/s</td>
<td>GSM</td>
</tr>
<tr>
<td>AR computation capacity</td>
<td>20 Mb/s</td>
<td>general router</td>
</tr>
<tr>
<td>MN computation capacity</td>
<td>10 Mb/s</td>
<td>PC computation capacity</td>
</tr>
<tr>
<td>MNReq message size</td>
<td>72 byte</td>
<td>E-HCF approach</td>
</tr>
<tr>
<td>MNRep message size</td>
<td>45 byte</td>
<td>E-HCF approach</td>
</tr>
<tr>
<td>HCFReq message size</td>
<td>45 byte</td>
<td>E-HCF approach</td>
</tr>
<tr>
<td>HCFRep message size</td>
<td>45 byte</td>
<td>E-HCF approach</td>
</tr>
<tr>
<td>CEInf message size</td>
<td>45 byte</td>
<td>E-HCF approach</td>
</tr>
<tr>
<td>HFCOn message size</td>
<td>24 byte</td>
<td>E-HCF approach</td>
</tr>
</tbody>
</table>

B. Numerical Results of the Total E-HCF Latency

With the parameters of Table I, we give a latency comparison between the standard handover latency and the E-HCF latency according to equation (1). These latencies are functions of the wireless link bandwidths (WiFi, UMTS, GPRS and GSM) and of the computation capacity. For example, the
Latency can be numerically estimated as following: with a 10 Mbit/s computation capacity, a MN needs 57.6 μs to generate a 72-byte MNRQ message, whereas, 28.8 μs are required for an Access Router. Putting this 72-byte message on a 9 kbit/s GSM network, requires about 64 ms, so that the global of L_{MNRQ} is about 64 ms.

On Figure 4, the standard MIPv6 handover latency (1290 ms) is the first figure displayed on the left. The rest of the figures are the E-HCF handover latencies based on WiFi, UMTS, GPRS and GSM link bandwidths. We note that the various E-HCF latencies are not really different when link bit rates vary from 150 kbit/s to 5.5 Mbit/s. If the link bit rate drops to 9 kbit/s (GSM), the E-HCF handover latency raises up to 450 ms. As a result, the wireless link bandwidth has an important influence over the overall handover procedure. Let us focus on the E-HCF latency with the IEEE 802.11b wireless networks. The average of the E-HCF handover latency is about 200 ms. This value of 200 ms is validated by our simulation results on OPNET illustrated on Figure 5.

![Fig. 4. E-HCF handover latencies as a function of wireless link bandwidths](image1)

![Fig. 5. E-HCF handover latency by simulation](image2)

Although the latency reduction from 1290 ms to 200 ms is significant, the value of 200 ms is still too long to support a real-time application in wireless networks. This is due to the number of channel scans. As a result, we propose a fast E-HCF method in which a MN can immediately request its E-HCF router without probing for the connection information, if the threshold of the received signal strength is overstepped. The E-HCF router then decides the next attached point. Our simulation results show that the average of the fast E-HCF latency can drop to 100 ms.

### C. E-HCF Loss

In terms of packet loss with the E-HCF approach, packets can be stored into a buffer during the handover (see subsection II-B). Figure 6 illustrates the comparison of packet loss rates between the E-HCF approach and the MIPv6 standard. The upper curve represents the number of lost packets with the MIPv6 standard (38 packets received out of 100 emitted packets), whereas the bottom curve with E-HCF approach (68 packets received out of 100 emitted packets). This gives a typical 30% gain with the E-HCF approach.

![Fig. 6. Comparison of loss rates between the E-HCF approach and the MIPv6 standard by simulation](image3)

### IV. Conclusion

In order to improve the handover performance for the Mobile IPv6, this paper studies an original E-HCF approach which allows to collect and store some link and network data. Regarding the classical Mobile IPv6 handover performance, our numerical results validated by simulations show that the E-HCF approach enables to decrease both the total handover latency and the packet loss significantly.

We focused on the handover performance at the Network Layer. We now are interested to also improve the handover performance at the Link Layer with a ”graph” solution. Our future goal aims at improving the handover performance both at the Network Layer for the Mobile IPv6 and at the Link Layer for IEEE 802.11 networks with a cross-layer proposal.

### References

[16] J. Bournelle and M. Laurent-Marknavicius, "Adaptation et implementa-