Journal of Network and Computer Applications 46 (2014) 322–335

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

# An enhanced fast handover with seamless mobility support for next-generation wireless networks

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ARTICLE INFO

Available online 23 July 2014

*Keywords:*
Wireless networks
Mobile IPv6
Mobility management
Handoff seamlessness
Mobility model

ABSTRACT

To allow mobile node be always connected regardless of its location on the Internet, mobile IPv6 (MIPv6) is designed for next-generation wireless networks. However, this protocol has some inherent drawbacks: long handoff delay and high packet loss; unbearable for many applications. To improve the performance, mobility protocols such as Fast handovers for MIPv6 (FMIPv6), Fast handover for Hierarchical MIPv6 (F-HMIPv6), Simplified Fast handover for MIPv6 networks (SFMIPv6), are proposed by researchers. But none of them can support seamless mobility. This paper proposes an enhanced fast handover protocol with seamless mobility supports, called enhanced Seamless MIPv6 (e-SMIPv6). Bidirectional tunnels are established among access routers before actual handover; accordingly mobile users can use their previous care-of address within a new visiting network. To reduce the delay related to duplicate address detection, each access router maintains a pool of duplicate-free addresses. To minimize packet loss, access router performs bicasting for roaming node. Our proposal can minimize mobility signaling as much as possible during handoff, which presents an ideal solution for fast moving and ping-pong moving mobile users. To analyze the performance, the city section mobility model is used. Of which numerical results show that e-SMIPv6 yields better performance than FMIPv6.


## 1. Introduction

Mobile market has experienced exponential growth over the last decades. There are 6.8 billion mobile subscriptions worldwide, estimated by the International Telecommunication Union (ITU) on February 2013. The behavior of mobile users has changed considerably. Today, most of the time, smartphone is used not for talking, but for playing online games or surfing the Internet. The popularity of mobile applications imposes new requirements on wireless system, because such applications demand more network resources and improved interactivity for richer user experience. In this context, next-generation wireless networks choose all-IP-based infrastructure to support heterogeneous radio access technologies (Akyildiz et al., 2004). Internet Protocol (IP) is defined as the inter-connection protocol to integrate different wireless systems, so mobile users can perform roaming among multiple access networks, regardless of the underlying radio access technologies (Akyildiz et al., 2005; Makaya and Pierre, 2008; Mohanty and Xie, 2007). However, the advent of new value-added services, i.e. video-conference, multimedia streaming, cloud computing, makes supporting seamless mobility more challenging than ever before.

In next-generation wireless networks, mobile nodes (MNs) need to freely change their network attachment point while communicating with others. Accordingly, it is crucial for mobile operators to provide efficient seamless mobility support. *Mobility management* allows wireless system to locate roaming terminals for call or data delivery, and to maintain their network connection when they are on the move. The former aspect is called *location management*, while the latter *handoff management*. They are two important components of mobility management. *Handoff seamlessness* is defined as the ability for MNs to stay connected while roaming across different networks (Golmie, 2009), without losing ongoing connections and without disruptions in the communication (Johnson et al., 2010).

Generally, IP-layer mobility protocols are classified into two categories: *host-based* and *network-based* protocols (Al-Surmi et al., 2012). The former requires MN to detect its movement and exchange mobility signaling with the network for the purpose of maintaining ongoing session continuity, while the latter require the network to provide services to MN that cannot explicitly exchange mobility signaling with the system (Olsson et al., 2009).

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http://dx.doi.org/10.1016/j.jnca.2014.07.016
1084-8045/

The Internet Engineering Task Force (IETF) working groups have standardized several mobility protocols, such as MIPv6, Hierarchical MIPv6 (HMIPv6), FMIPv6, F-HMIPv6, Proxy MIPv6 (PMIPv6), and Fast handover for PMIPv6 (F-PMIPv6). MIPv6, HMIPv6, FMIPv6 and F-HMIPv6 are host-based protocols, while PMIPv6 and F-PMIPv6 are network-based. This paper focuses on host-based mobility management.

Our work is motivated by the following questions: How to reduce mobility signaling overhead and handover latency as much as possible? Can bidirectional tunnels be established before handover? How to completely remove the duplicate address detection (DAD) process from handover? After investigation, we found that bidirectional tunnels can be established before actual handoff. Using pre-configured tunnels, mobility signaling overheads can be minimized as much as possible during handoff. The process of DAD can be removed from handoff, on the condition that access router maintains a pool of duplicate-free care-of addresses.

The main differences of this work from previous works are that we propose an enhanced fast handover with seamless mobility support, that is called enhanced Seamless MIPv6 (e-SMIPv6) for next-generation wireless networks. Besides, we use the *city section mobility* (CSM) model to calculate mobility signaling cost, packet delivery cost, and total cost, also figure out how those costs are affected by various parameters, such as network capacity, MNs' moving speed and session arrival rate.

The remainder of the paper is organized as follows. Section 2 provides the research background and related works. Section 3 elaborates the proposed protocols: e-SMIPv6. Section 4 presents the CSM modeling and formulates different cost functions. Section 5 presents performance analysis with numerical results. Section 6 draws the conclusion mark.

## 2. Literature review

The protocol MIPv6 is designed by IETF for next-generation wireless network (Perkins et al., 2011). To be always connected to the Internet regardless of its location, MN configures a care-of address (CoA) while attached on a new link. A router at its home network, called Home Agent (HA), binds MN's home address (HoA) to its CoA. HA then intercepts MN's packets, and tunnels them to MN's new location. This incurs a triangular routing problem. To fix it, MIPv6 defines *route optimization*, in which Correspondent Nodes (CNs) maintain the same binding as HA, accordingly they can send packets to the MN via a direct routing path.

MIPv6 presents an elegant solution for global mobility management. However, it has some inherent drawbacks (Li et al., 2008; Makaya and Pierre, 2008). That is, when an MN changes its Access Point (AP), there is always a short period during which it cannot send or receive packets due to link switching and IP protocol operations. Such a period is defined as *handover latency*. Mobility management in MIPv6 presents long handover delay, significant packet loss, and high mobility signaling overhead. This is unacceptable and detrimental for real-time applications, causing user-perceptible service deterioration during handover (Kempf et al., 2003; Makaya and Pierre, 2008).

To improve the performance of MIPv6, several mobility protocols have been proposed, such as FMIPv6, HMIPv6, F-HMIPv6, simultaneous bindings for FMIPv6 (El Malki and Soliman, 2005), a novel FMIPv6 and HMIPv6 integration mechanism (Lee and Ahn, 2006), enhanced fast handover with low latency for mobile IPv6 (Li et al., 2008), simplified fast handover in mobile IPv6 networks (Van Hanh et al., 2008), an efficient scheme for fast handover over HMIPv6 (Yoo et al., 2009), seamless MIPv6 (SMIPv6) (Zhang, 2008), to name a few. These solutions can be sorted into two categories: *network architecture design* and *fast handover scheme*. This paper centers on the design of fast handoff solution.

### 2.1. Mobility management in FMIPv6

FMIPv6 reduces handover delay using link-layer trigger to anticipate the impending handoff (Koodli, 2009). It enables MN to quickly detect its movement and formulate a new CoA (NCoA) before changing its AP. Thus movement detection delay is significantly minimized during handoff. To reduce the delay regarding to binding update (BU), FMIPv6 allows Previous Access Router (PAR) to bind MN's Previous CoA (PCoA) to its NCoA. Consequently PAR can intercept MN's packets and tunnel them to MN's new location. To reduce packet loss, bidirectional tunnels are established between PAR and New Access Router (NAR) during handover. However, once MN is IP-capable on the new link, it must carry out home and correspondent registrations before using the NCoA to communicate directly with a CN (Koodli, 2009; Makaya and Pierre, 2008).

FMIPv6 supports both predictive and reactive fast handovers. The former happens when MN is able to send a Fast Binding Update message to PAR, which then establishes bidirectional tunnels and forwards MN's traffic to NAR, even before MN attaches on the new link. Reactive fast handover takes place when MN sends an FBU only after attaching to NAR (Koodli, 2009). Figure 1 shows mobility management procedure for predictive FMIPv6.

Handover starts by MN sending a *Router Solicitation for Proxy Advertisement* (RtSolPr) message to PAR to resolve some AP Identifiers to subnet-specific information. In response, PAR answers a *Proxy Router Advertisement* (PrRtAdv) message, which contains one or more [AP-ID, AR-Info] tuples. With such information, MN formulates a prospective NCoA to be used in NAR's subnet while still connected to PAR.

Soon afterwards, MN sends a *Fast Binding Update* (FBU) to PAR, which then sends a *Handover Initiate* (HI) message to NAR for setting up the bidirectional tunnels. NAR then sends a *Neighbor Solicitation* (NS) message for MN's NCoA to verify the uniqueness of the new address. The process to check whether an address is already in use is called duplicate address detection (DAD). Any node using the same IP address replies with a *Neighbor Advertisement* (NA) (Thomson et al., 2007). If NAR receives an NA, it knows that the tested NCoA is not unique. In this case, NAR needs to assign another IP address for MN, and starts the DAD process again. Once NAR makes sure that MN's NCoA is unique on its link, it sends a *Handover Acknowledge* (HAck) message to PAR, which then binds MN's PCoA to the NCoA received from NAR.

PAR then sends MN a *Fast Binding Acknowledgement* (FBAck) message on both links. Afterwards PAR intercepts MN's packets, and tunnels them to MN's NCoA. Bidirectional tunnels remain active until MN completes correspondent registration with all the CNs. When NAR receives tunneled packets from PAR, it simply buffers them.

Once receiving the FBAck, MN disconnects from PAR and initiates link layer switching. After connecting to a new AP (NAP), MN sends an *Unsolicited Neighbor Advertisement* (UNA) to NAR, which then immediately forwards the arriving and buffered packets to MN. After being IP-capable in the new subnet, MN performs home registration with HA, as well as correspondent registration with all the CNs.

There are several reasons for reactive fast handover: (1) MN did not send the FBU to PAR before disconnection; (2) the FBU is sent but lost on the wireless link; and (3) MN disconnects its physical link too earlier to receive an FBAck from PAR.

Reactive handoff starts by MN sending an *RtSolPr* message to PAR to resolve some AP Identifiers to subnet-specific information. In response, PAR replies with a *PrRtAdv* with one or more [AP-ID, AR-Info] tuples. MN then formulates an NCoA before changing its AP.

Shortly afterwards, MN initiates link-layer switching without receiving an FBAck message from PAR. Immediately after link-layer