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# The Backward Fast Media Independent Handover for Proxy Mobile IPv6 Control Scheme (BFMIH-PMIPV6) over Heterogeneous Wireless Mobile Networks*

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Proxy Mobile IPv6 (PMIPv6) is a networked-based handover protocol for the IP layer, *i.e.*, the layer 3 mobility management protocol. The fast handover control scheme can be integrated into PMIPv6 to improve handover latency. Since the handover performance of the predictive mode is better than that of the reactive mode, an issue should be considered is how to have a handover control scheme that can let MN have the higher chance of being in the predictive mode to improve the handover. In this work, the Backward Fast Media Independent Handover Control Scheme for Proxy Mobile IPv6 (BFMIH-PMIPv6) is proposed. The BFMIH-PMIPv6 integrated fast handover and IEEE 802.21 Media Independent Handover (MIH) Services with PMIPv6 to improve the handover performance over the heterogeneous wireless network. The proposed BFMIH-PMIPv6 can start handover preparation earlier to let MN have the higher chance of being in the predictive mode and build the tunnel in advance to reduce the packet loss situation and handover latency. Through the simulations for performance analysis, it shows that the proposed BFMIH-PMIPv6 can have better handover performance in terms of handover latency, packet loss rate, and throughput.

***Keywords:*** proxy mobile ipv6, fast handover, media independent handover, handover, handover latency

## 1. INTRODUCTION

With the rapid development of mobile nodes and radio access technology, wireless networks are evolving towards the all-IP network for "anywhere, anytime" accessing from Internet without interruption. One of the most important issues for all-IP mobile networks is mobility management, *i.e.*, continuous accessing from Internet [1, 2]. When a mobile node (MN) moves from one network to another, it needs some processing for MN to detach from the previous network and attach to a new network to maintain its connectivity to Internet, which is referred as handover. During the time period of handover processing, which is called handover latency, MN is isolated from the network.

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Handover latency includes the delay of layer2 (L2) attachment, movement detection, duplicate address detection, and the mobility signaling. Therefore, some transmitted packets, which are destined to MN, may be lost if the handover latency is long. Mobile IPv6 (MIPv6) was designed to tackle issues in mobility management for handover between sub-networks [3]. Although MIPv6 provides mobility management for MNs, it suffers from several drawbacks, such as long handover latency and high packet loss. Additionally, a lot of signaling and protocol processing are embedded in MN using MIPv6. To reduce the signaling overhead of MN for mobility management and optimize the handover procedure, a network-based mobility management protocol, which is called Proxy Mobile IPv6 (PMIPv6), has been discussed and developed by Internet Engineering Task Force (IETF) [5]. The target of PMIPv6 is to achieve L3 handover without the participation of MN in the exchange of messages between MN and its home agent. However, since PMIPv6 is essentially based on MIPv6 with the similar functionality to manage MN's handover, it still has problems of long handover latency and high packet loss during handover.

There were several control schemes for PMIPv6 to relieve the handover latency and signaling cost. However, these schemes still experience problems of some packet loss and inefficient packet transmission during handover [6-8]. The fast handover [9], which is developed in Mobile IPv6, provides handover preparation to reduce handover latency. The fast handover can be integrated into PMIPv6 to improve the handover performance with modified messages exchanging.

To provide continuous session continuity in a heterogeneous environment, *e.g.*, the handover between 4G cellular network and WiFi network, IEEE 802.21 Media Independent Handover (MIH), was proposed [6]. IEEE 802.21 MIH has shown satisfactory performance by handling the entire lower layer signaling. In order to reduce the handover latency over heterogeneous networks, IEEE 802.21 MIH and the fast handover control scheme can be integrated into PMIPv6 to improve the handover performance [8, 10, 11]. Two issues that should be tackled for improving the performance of PMIPv6 are as follow.

1. Two modes that exist in the fast handover control scheme are the predictive mode and the reactive mode. If handover preparation is finished before MN disconnecting from the previous network domain, the fast handover is in the predictive mode; otherwise, it is in the reactive mode. The handover performance of the predictive mode is better than that of the reactive mode. Thus, how to design a handover control scheme that can let MN have the higher chance to be in the predictive mode is an issue to be tackled.
2. When the fast handover is integrated with PMIPv6, MN can be in the predictive mode or the reactive mode during handover. MN is in the predictive mode if the handover preparation is ready. It means that MN still connects to previous mobile access gateway (PMAG) domain when the tunnel between PMAG and new mobile access gateway (NMAG) is established. Otherwise, MN is in the reactive mode. The handover performance of the predictive mode is better than that of the reactive mode. Thus, how to have a handover control scheme that can let MN have the higher chance of being in the predictive mode to improve the handover performance is the 2nd issue to be tackled.

In this paper, a Backward Fast Media Independent Handover control scheme for Proxy mobile IPv6 (BFMIH-PMIPv6) is proposed to tackle the aforementioned 2 problems. In the proposed BFMIH-PMIPV6, in order to let handover preparation be finished before MN disconnecting from the PMAG's domain, a mechanism that can start handover preparation earlier is used to let MN have the higher chance of being in the predictive mode. Usually, MN starts to prepare for handover after LINK_GOING_DOWN (LGD) is triggered. LGD is a L2 event that will be triggered when the currently connected signal strength is below the predefined threshold. In our proposed BFMIH-PMIPV6 scheme, handover preparation is started when MN detects signal from the new network, *i.e.*, a new access point (NAP) in NMAG's domain. Therefore, handover preparation processing gets more time to finish before MN disconnecting from PMAG's domain. That is to say, the proposed BFMIH-PMIPV6 focuses on earlier handover preparation to let MN have more time to prepare handover. In addition, the handover process is similar to the traditional fast handover based scheme, whose handover starts after LGD triggered. In this way, MN can have a higher chance to be in the predictive mode. In addition, the fast handover control scheme always provides buffering MN's packets in PMAG or NMAG to avoid packet loss. If PMAG or NMAG cannot provide buffering or buffering will become a heavy load because multiple MNs transmit video streaming data and these video streaming data should be buffered during handover, buffering packets become unsuitable. Instead of using the buffering mechanism, our proposed scheme provides a multicast/bicast mechanism to reduce the handover latency.

The rest of the paper is organized as follows: Section 2 overviews PMIPv6, fast handover, IEEE 802.21 MIH, and related works. Section 3 presents the proposed Backward Fast Media Independent Handover control scheme for PMIPv6 (BFMIH-PMIPv6). Section 4 shows the performance analysis of the proposed BFMIH-PMIPv6 schemes. Finally, Section 5 has the conclusion remarks.

## 2. PRELIMINARY

This Section has a brief introduction of PMIPv6, Fast handover, IEEE 802.21 MIH, and related research of fast handover for PMIPv6.

### 2.1 Proxy Mobile IPv6 (PMIPv6)

Proxy Mobile IPv6 [5, 10] is a protocol for building a common technology that is independent with the mobile core networks, accommodating various access technologies such as WiMAX, 3GPP and WLAN based access architectures. The main elements of PMIPv6 include Local Mobility Anchor (LMA) and Mobile Access Gateway (MAG). LMA acts as the home agent (HA) for MNs in a PMIPv6 domain. It is the topological anchor point for MN's home network prefix (HNP) and is the entity that manages MN's binding state. Meanwhile, MAG is a function on an access router that manages the mobility-related signaling for MNs to attach with its access link.

When MN enters into the PMIPv6 domain, MAG receives a router solicitation (RS) message from MN. Then, MAG performs the access authentication based on MN's link layer identifier. After successful authentication by the AAA server in the PMIPv6 domain, MAG gets MN's profile and then sends a proxy binding update (PBU) message, which contains the identifier of MN, to LMA. After the success of binding, LMA updates MN's Proxy Care of Address (CoA) with IP address of the MAG. MAG then sends a router advertisement (RA) message to MN in order to advertise MN's HNP. Finally, MN is able to configure an IP address and uses the tunnel between MAGs and LMA to send or receive packets. After the attachment procedure is complete, MN's IP address, *i.e.*, MN-HoA, is not changed while it moves within the PMIPv6 domain. Fig. 1 depicts the operational and message flow chart in the PMIPv6 domain.

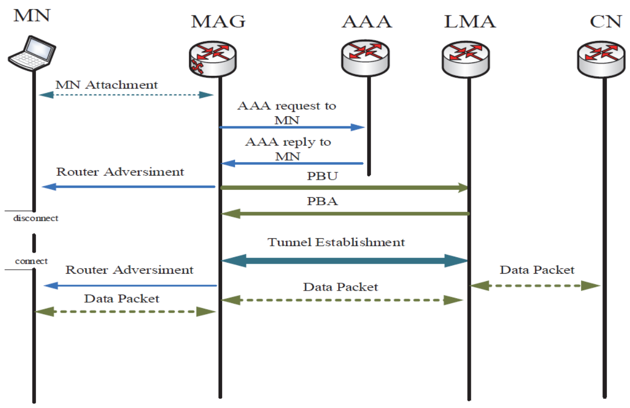


Fig. 1. The operational and message flow chart of PMIPv6.

### 2.2 Fast Handover for PMIPv6 (FPMIPv6)

FPMIPv6 protocol has been designed to mainly deal with the handover latency and packet loss issues when MN roams in a PMIPv6 domain [10]. By using the variable Received Signal Strength (RSS) of MN, FPMIPv6 predicts that MN's handover is imminent. In the predictive mode, MN is initially connected to PAP, which is in the PMAG domain. When L2 trigger occurs, MN informs PMAG to make handover preparation. Then, PMAG sends a HI message involving MN's HNP to NMAG and then NMAG responses with a Handover Acknowledge (HACK) message. After HI/HAck messages are exchanged, a bidirectional IP tunnel is established between PMAG and NMAG. When the tunnel establishment is finished, MN disconnects with PMAG and switches to NMAG. NMAG can send the router advertisement message with MN's HNP with querying LMA. After MN gets the router advertisement message, MN gets its HNP and finish the handover process. In this way, the handover latency can be reduced.

### 2.3 IEEE 802.21 Media Independent Handover (MIH)

IEEE 802.21 MIH is a layer 2 handover mechanism that optimizes handovers between heterogeneous wireless network systems [6, 18, 19]. IEEE 802.21 MIH may assist handovers between IEEE 802 systems and cellular systems with information exchanging and define commands/events to make the handover decision. MIH protocol defines the frame structure for exchanging messages between MIH functional entities. MIH function

(MIHF) provides asynchronous and synchronous services through well-defined Service Access Point (SAPs) for link layers and MIH users. In the case of a system with multiple network interfaces of arbitrary types, MIH users use the event service, command service, and information service provided by MIHF to manage, determine, and control the state of the underlying interfaces. These services provided by MIHF can help upper layers with maintaining service continuity, service adaptation to various quality of service, battery life conservation, network discovery, link selection, *etc.* The information enables effective system access and effective handover decisions. The handover procedure can be mobile-initiated or network-initiated.

### 2.4 Related Work

PMIPv6 still has the same weakness with MIPv6. It also suffers from handover latency and data loss. There are several enhanced approaches that have been proposed to adapt the network-based mobility management such as (1) bi-casting and (2) smart buffering and (3) load balancing. In [12], authors proposed to incur minimal packet loss and handover latency. It is achieved by using a signal strength prediction algorithm that estimates the viability of a link when the handover is imminent. The numerical result shows that the solution can improve the performance of PMIPv6. Authors in [13] introduced an Enhanced Bi-casting Proxy Mobile IPv6 (EB-PMIPv6) scheme that not only minimizes packet loss and handover delay but also efficiently utilizes network resources by executing the bi-casting operation. In addition, it is achieved using the signal strength prediction algorithm to predict the link when a handover is about to happen.

The smart buffering methods were proposed for avoiding data traffic loss. Authors in [14] proposed the scheme that PMAP played a role for proactive buffering all data traffic without considering the target point of attachment and MN detachment time. The key point of smart buffering is that MN need not to be involved in performing the buffering process. As a result, the packet loss ratio has reached its minimum level. However, this scheme will cause some signal traffic overhead because of adding signaling messages to identify NMAG as well as performing the buffering and forwarding procedures between NMAG and PMAG. The other buffering mechanism proposed is to resolve handover latency and packet loss problems [15]. This work revealed the Out-of-Order Packet (OoOP) problem and proposed a scheme using last packet marker to notify the end of data delivery in the old path and buffering to handle the OoOP problem in PFMIPv6. Since some new mobility messages are used to inform both PMAG and NMAG the last transmitted packet through the old path and the new path respectively, it incurred infrastructure cost and processing overhead.

Authors in [16] proposed the load balancing in PMIPv6 domain using IEEE 802.21 Media Independent Handover (MIH) protocol, in which they defined (1) the algorithm that the overloaded MAG can learn about the load status of the candidate MAGs and (2) the handover signaling to operate the load balancing scheme in the PMIPv6 network. Hence, this work can reduce the average queuing delay at the cost of more handovers of MNs. In [17], authors proposed the PMIPv6 control scheme that exchange messages with several candidate NMAGs for handover preparation, for which a proper one is selected as the NMAG using some criteria. Thus, it can help MN select the most suitable MAG to switch. Therefore, the handover delay can be reduced.

Contrary to previous works, this work studied the case how to let handover preparation be finished before MN disconnecting from PMAG. The proposed mechanism can reduce the handover latency and buffer MN's packets in PMAG or NMAG to avoid packet loss. In the next Section, we describe the main principles of the proposed BFMIH-PMIPv6 mobility management control scheme that integrate network-based PFMIPv6 with IEEE 802.21 MIH framework over heterogeneous wireless mobile networks.

## 3. THE PROPOSED BFMIH-PMIPV6 METHOD

In the predictive mode of PFMIPv6, handover preparation starts from receiving MN's Link_Going_Down message and PMAG exchanges HI/Hack messages with NMAG to build a tunnel. If the handover preparation cannot be finished and MN disconnects from PMAG, MN would be in the reactive mode. In order to improve the chance for MN to be in the predictive mode, handover preparation should be started earlier. When MN receives new signal strengths from NAPs, MN can use L2 information such as probe message to trigger NMAG for starting handover preparation. In this way, when the handover preparation is finished, MN still connects to PMAG's domain. It is the goal of the proposed BFMIH-PMIPv6 control scheme.

The main idea of the proposed BFMIH-PMIPv6 control scheme is as follows. The new access point (NAP) can retrieve MN's information when it receives MN's probe request message, including network prefix and link layer address. The NAP then immediately starts to forward the messages to its connected NMAG after NAP receives MN's information. Based on the received information, NMAG can send a request for building a tunnel to PMAG in advance.

In contrast with the regular handover processing, our proposed BFMIH-PMIPv6 allows MN to send the handover preparation message before it receives the Link_Going_ Down message. The operational and message flow chart of our proposed scheme is depicted in Fig. 2.

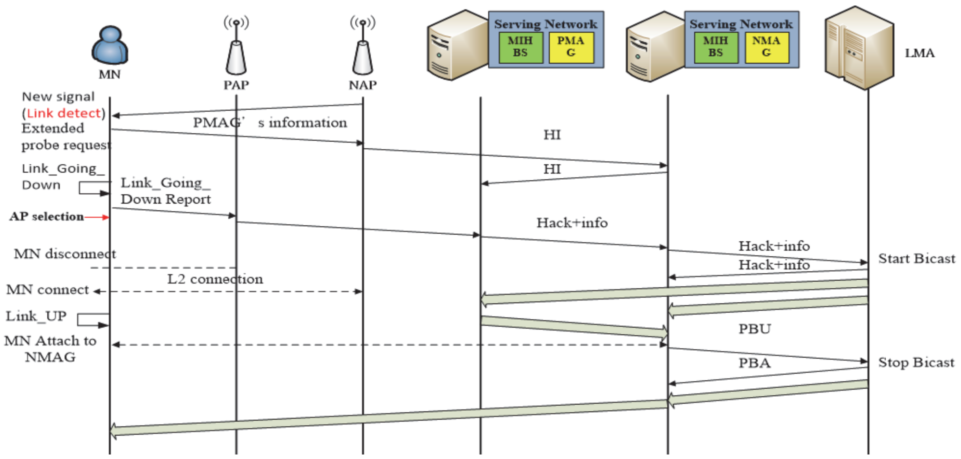


Fig. 2. The operational procedure and message flow chart of the proposed backward handover scheme.

The handover procedure is introduced in more detailed as follows:

**Step 1:** While MN is still associated with PAP/PMAG and detects the NAP/NMAG(s) availability by receiving beacons, MN then sends a Handover_Backward_Request message, which includes its PMAG's information and MN's MAC address, to those NAPs/ NMAGs.
**Step 2:** NAP receives and forwards the Handover_Backward_Request message to NMAG. NMAG retrieves PMAG IP address and MN's MAC address. Then, NAMG sends the HI message to PMAG.
**Step 3:** When MN receives the LINK_GOING_DOWN (LGD) message, MN sends the LGD report to PAP/PMAG to indicate that it will switch to a new network, which has the strongest signal among the available ones. PMAG then sends the Hack message to LMA, which forwards the Hack message to NMAGs. Then, the tunnel is built between PNMAG and NMAG. Meanwhile, LMA sends bi-cast packets to both PMAG and NMAG.
**Step 4:** MN disconnects from PMAG's domain and reconnects to NMAG's domain. After NMAG detects MN's presence, NMAG sends PBU to LMA. When LMA receives the PBU message, it stops bi-cast and responses the PBA message. From now on, packets destined to MN will be sent to NMAG. Finally, the handover process finished.
The proposed BFMIH-PMIPv6 scheme has the following advantages:

**Higher chance to be in the predictive mode:** In order to a high probability of handover in the following time, the main factor is that MN should have enough staying time for handover preparation. The staying time is related to the LGD timing, MN's moving speed and the distance between LGD and disconnection. The handover preparation depends on the message exchanging of HI/HAck between PMAG and NMAG. In the traditional fast handover control scheme, handover preparation usually starts when LGD occurred. If the stay time is longer than the handover preparation, *i.e.*, in the predictive mode, MN can successfully make the handover. Otherwise, MN will be in the reactive mode and have the longer handover latency. In our proposed method, the handover preparation starts when the new signal of a NMAG is detected. Therefore, the handover preparation starts earlier and the handover preparation time is longer than the traditional method. As a result, our proposed scheme has a better chance to make a successful handover.

**Quick response for handover request:** In our proposed scheme, the request of tunnel establishment, *i.e.*, sending the HI message, has been sent to PAR earlier. Thus, when MN sends a LGD message to PMAG, PMAG can send the response message, *i.e.*, Hack message, to NMAG immediately. With the quick response time, the chance of being in the predictive mode can be improved.

**Exception consideration of sudden disconnection:** When an L2 trigger occurs MN may lose connection with PMAG due to the decreased signal strength. If MN does not have enough time for handover preparation, the handover latency would be increased because it falls into the reactive mode. In our proposed scheme, when LGD occurs, the Hack message passes through LMA to inform that MN is possible to switch to NMAG.

If MN suddenly disconnects from PMAG, since packets have been transmitted to both PMAG and NMAG with the help of bi-casting, it can avoid too much packet loss during handover. Additionally, packets sent to PMAG can be forwarded to NMAG through the established tunnel. As a result, the failure occurrence of incomplete handover preparation can be reduced.

In summary, the handover performance of the predictive mode is better than that of the reactive mode. In order to let handover preparation to be finished before MN disconnecting from PMAG's domain, *i.e.*, having handover in the predictive mode, handover preparation should be started earlier but not too early. The proposed BFMIH-PMIPv6 scheme can let MN have the higher chance to be in the predictive mode.

## 4. PERFORMANCE ANALYSIS

In this section, the performance of PFMIPv6 and the proposed BFMIH-PMIPv6 scheme is evaluated, for which the comparison is in term of handover latency and packet transmission path.

### 4.1 Handover Latency

The handover latency of PFMIPv6 (denoted as $T_{HO\text{-}PFMIPv6}$) consists of the time intervals for (1) MN making L2 report to connect with NAP (denoted as $T_{MN\text{-}NAP}$); (2) NAP making L2 connection with NMAG (denoted as $T_{NAP\text{-}NMAG}$); (3) NMAG sending PBU to LMA (denoted as $T_{NMAG\text{-}LMA}$); (4) LMA sending back PBA (denoted as $T_{LMA\text{-}NMAG}$); (5) NMAG sending Router Advertisement to NAP (denoted as $T_{NMAG\text{-}NAP}$) and (6) NAP forwarding packets to MN (denoted as $T_{NAP\text{-}MN}$). The time sequence of the handover processing is depicted in Fig. 3, in which:

$$\begin{aligned} T_{HO\text{-}PFMIPv6} &= T_{MN\text{-}NAP} + T_{NAP\text{-}NMAG} + T_{NMAG\text{-}LMA} + T_{LMA\text{-}NMAG} + T_{NMAG\text{-}NAP} + T_{NAP\text{-}MN} \\ &= 2T_{MN\text{-}NAP} + 2T_{NAP\text{-}NMAG} + 2T_{NMAG\text{-}LMA} \end{aligned} \tag{1}$$

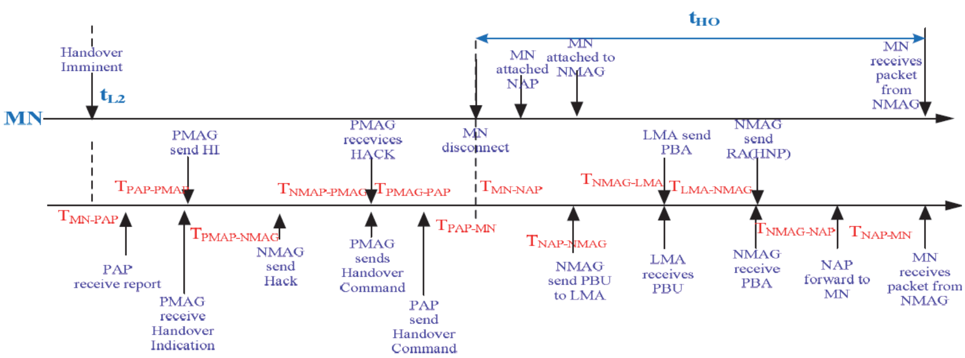

Fig. 3. The handover latency of the fast handover for PMIPv6.

The handover latency of the proposed BFMIH-PMIPv6 scheme (denoted as $T_{HO\text{-}BFMIH\text{-}PMIPv6}$) depends on two situations, which are depicted in Fig. 5: it can consist of the bigger value of (1.a) the time interval of LMA sending bi-cast to NMAG (denoted as

$T_{LMA\text{-}NMAG}$) and (1.b) the time interval of MN making L2 report to connect with NAP (denoted as $T_{MN\text{-}NAP}$) and NAP making L2 connection with NMAG (denoted as $T_{NAP\text{-}NMAG}$), (2) NMAG sending Router Advertisement to NAP (denoted as $T_{NMAG\text{-}NAP}$) and (3) NAP forwarding packets to MN (denoted as $T_{NAP\text{-}MN}$). The time sequence of handover processing for the proposed BFMIH-PMIPv6 is depicted in Fig. 4. Therefore,

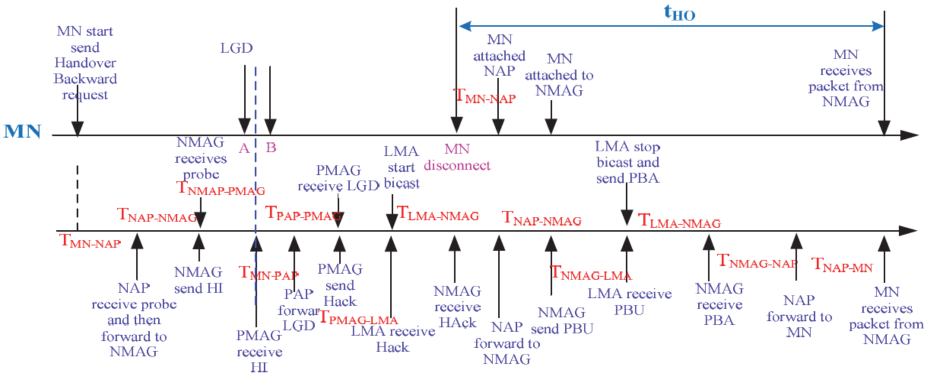


Fig. 4. The handover latency of BFMIH-PMIPv6.

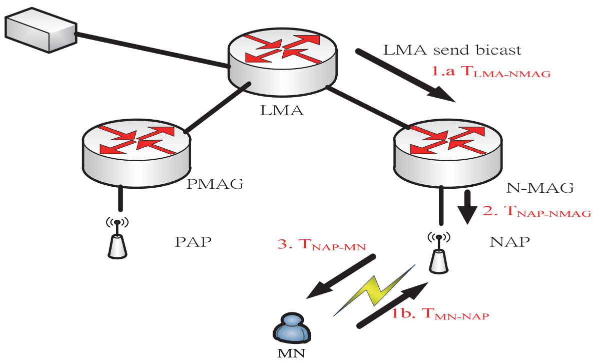


Fig. 5. The two situations of handover latency for BFMIH-PMIPv6.

$$T_{HO\text{-}BFMIH\text{-}PMIPv6} = \max\{T_{MN\text{-}NAP} + TN_{NAP\text{-}NMAG},\ T_{LMA\text{-}NMAG}\} + T_{NMAG\text{-}NAP} + T_{NAP\text{-}MN} \quad (2)$$

**Case 1:** If $T_{MN\text{-}NAP} + TN_{NAP\text{-}NMAG} > T_{LMA\text{-}NMAG}$

$$\begin{aligned} T_{HO\text{-}BFMIH\text{-}PMIPv6} &= T_{MN\text{-}NAP} + TN_{NAP\text{-}NMAG} + T_{NMAG\text{-}NAP} + T_{NAP\text{-}MN} \\ &= 2T_{MN\text{-}NAP} + 2T_{NAP\text{-}NMAG} \end{aligned} \quad (3)$$

The difference of Eqs. (1) and (3) is $(2T_{MN\text{-}NAP} + 2T_{NAP\text{-}NMAG} + 2T_{NMAG\text{-}LMA}) - (2T_{MN\text{-}NAP} + 2T_{NAP\text{-}NMAG}) = 2T_{NMAG\text{-}LMA} > 0$.

**Case 2:** If $T_{MN\text{-}NAP} + TN_{AP\text{-}NMAG} < T_{LMA\text{-}NMAG}$

$$T_{HO\text{-}BFMIH\text{-}PMIPv6} = T_{LMA\text{-}NMAG} + T_{NMAG\text{-}NAP} + T_{NAP\text{-}MN} \quad (4)$$

The difference of Eqs. (1) and (4) is $(2T_{MN\text{-}NAP} + 2T_{NAP\text{-}NMAG} + 2T_{NMAG\text{-}LMA}) - T_{LMA\text{-}NMAG} + T_{NMAG\text{-}NAP} + T_{NAP\text{-}MN} = T_{LMA\text{-}NMAG} + T_{NMAG\text{-}NAP} + T_{NAP\text{-}MN} > 0$

As a result, the handover latency of the proposed BFMIH-PMIPv6 scheme is always less than that of the traditional fast handover of PMIPv6.

### 4.2 Packet Transmission Path for Handover Analysis

In PMIPv6, upon a handover, packets will be sent from LMA to PMAG. When the tunnel is built between PMAG and NMAG, packets will be forwarded from PMAG to NMAG. Then, packet transmission in PMIPv6 during handover is expressed as follows: (1) the packet delivery path for MN = the path from LMA to PMAG (denoted as $D_{LMA\text{-}PMAG}$) + the path from PMAG to NMAG (denoted as $D_{PMAG\text{-}NMAG}$). Therefore, the packet delivery path for PFMIPv6 during handover is equal to $D_{LMA\text{-}PMAG} + D_{PMAG\text{-}NMAG}$.

In BFMIH-PMIPv6, NMAG receive packets directly from LMA by bi-casting. Therefore, the packet delivery path of BFMIH-PMIPv6 is equal to $D_{LMA\text{-}NMAG}$.

## 5. SIMULATION

This Section presents the performance analysis, which is based on the comparison of our proposed BFMIH-PMIPv6 scheme with (1) the fast handover control of PMIPv6 scheme (FMIP-PFMIPv6) with the predictive/reactive modes; (2) PFMIPv6 with NAP/NMAG selection for loading consideration, which is called LC-FMIH-PFMIPv6 [17], over the predictive/reactive modes and (3) the original PMIPv6. The comparison is in term of handover latency, packet loss ratio and throughput. The simulation configuration is based on NS2 (ns-allinone2.29) [20-22] and depicted in Table 1.

**Table 1. Parameter values used in the BFMIH-PMIPv6 simulation.**

| Parameter | Value |
|---|---|
| ***Network Topology*** | |
| WiFi cell coverage | 50m |
| Routing protocol | DSDV |
| Wire Conection delay | 15ms |
| Wire Conection bandwidth | 100Mbps |
| Wire Conection queue type | DropTail |
| ***WiFi Configuration*** | |
| Number of Mobile Nodes | 1 |
| Number of Base Station | 3 |
| Beacon interval | 0.1 s |
| MinChannelTime | 0.02 s |
| MaxChannelTime | 0.06s |
| RXThresh | 5.25089e-10 (50m coverage) |
| CSThresh | 0.95* RXThresh |
| pr_limit_ | 1.005 |
| ***Mobility Model*** | |
| MN Velocity | Variable from 10m/s to 60m/s |
| Path | Straight line |
| ***Application Model*** | |
| Type | Constant Bit Rate (CBR)/ UDP |
| Packet size | 512 bytes |
| Data Transfer Period (or Data Rate) | Variable from 0.01 second per packet to 0.1 second per packet |

### 5.1 Handover Latency Analysis

Figs. 6 and 7 depict the comparison of handover delay. In Fig. 6, BFMIH-PMIPv6, Predictive FFMIH-PMIPv6 and Predictive LC-FMIH-PMIPv6 generate the better performance because the handover preparation is finished before MN disconnects with PMAG. BFMIH-PMIPv6 slightly outperforms Predictive FFMIH-PMIPv6 and Predictive FMIH-PMIPv6 because the proposed BFMIH-PMIPv6 has the earlier handover preparation and a shorter packet delivery path, *i.e.*, bi-casting from LMA. If the handover preparation is not finished before MN disconnects with PMAG, the proposed BFMIH-PMIPv6 and LC-FMIH-PFMIPv6 will enter into the reactive mode. Thus, the proposed BFMIH-PMIPv6 and LC-FMIH-PFMIPv6 generate the second better performance than the original PMIPv6. It is because the original PMIPv6 just works on L3 handover without L2 and tunnel supported.

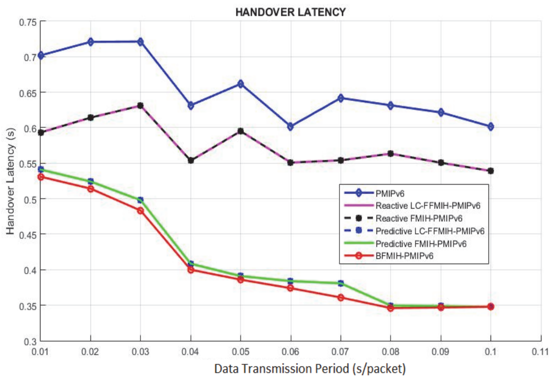


Fig. 6. The comparison of handover latency based on the data transmission period.

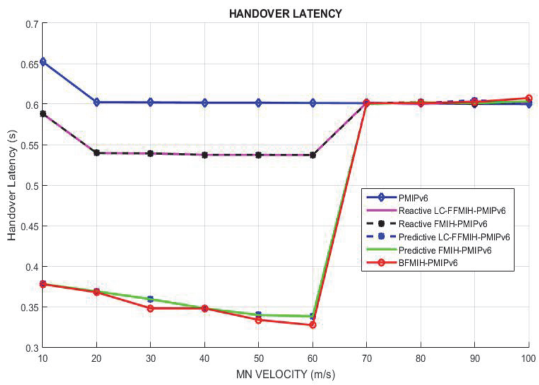


Fig. 7. The comparison of handover latency based on the MN's velocity.

According to Fig. 7, the proposed BFMIH-PMIPv6, Predictive FFMIH-PMIPv6 and Predictive LC-FMIH-PFMIPv6 have the better performances when MN's velocity is varied from 10m/s to 60m/s because of their handover preparation mechanisms. When

MN's velocity is higher than or equal to 70m/s, all of the schemes' performance become similar because of the failure support of tunneling. Thus, all of the schemes' performances are equal to the original PMIPv6's performance.

### 5.2 Packet Loss Analysis

Referring to Fig. 8, packet loss ratio is influenced by MN's velocity. When MN velocity is slow, the handover preparation can be successful and packets can be sent through tunnel. When MN's velocity becomes higher than or equal to 30m/s and less than 60m/s, the proposed BFMIH-PMIPv6 has less packet loss than the FFMIH-PMIPv6 and LC-FMIH-PFMIPv6. It is because that the proposed BFMIH-PMIPv6 has longer staying time in PMAG to make handover preparation successful. When MN's velocity is higher than or equal to 70m/s, the handover preparation is failed and the tunnel cannot be used for all fast handover based schemes. Therefore, the performance of the fast handover based schemes are similar to that of the original PMIPv6.

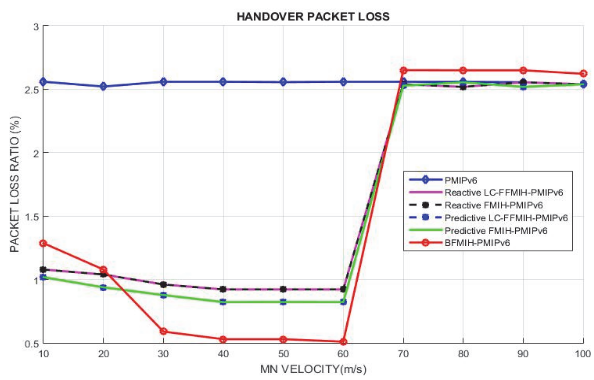

Fig. 8. The comparison of handover packet loss based on the MN's velocity.

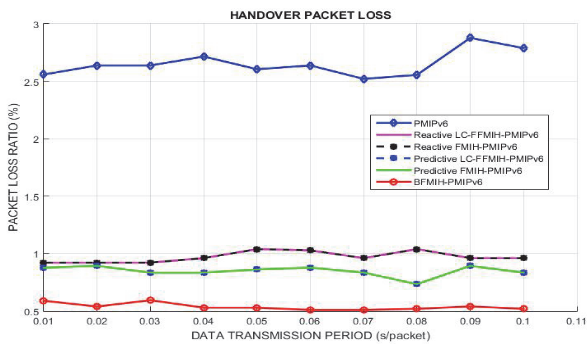

Fig. 9. The comparison of handover packet loss based on the data transmission period.

Fig. 9 shows the influence of various data transmission rates for the packet loss rate, in which MN's speed is set as 30m/s. The packet loss ratio is not significantly affected in the data transmission period. When the number of transmitted packets is decreased, the number of dropped packets would be reduced as well. Therefore, when we vary the data transmission period from 0.1 s/packet (10 packet/s) to 0.01 s/packet (100 packet/s), all of these schemes' performance intuitively keep the same packet loss ratio.

### 5.3 Throughput Analysis

Fig. 10 depicts the comparison of handover throughput based on various velocities of MN. The proposed BFMIH-PMIPv6 has the better throughput performances than the others when MN's velocity is varied from 10m/s to 60m/s because of their handover preparation mechanisms. When MN's velocity is higher than or equal to 70m/s, all of the schemes' performance become similar with the original PMIPv6.

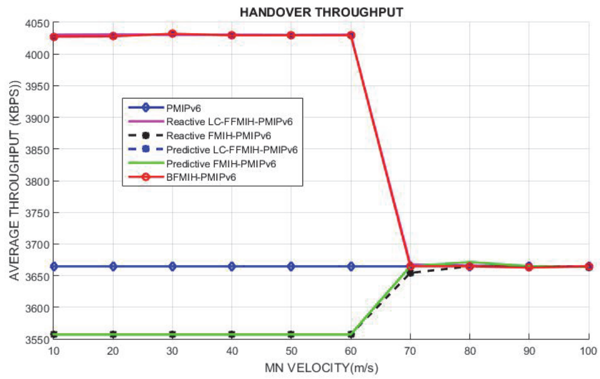


Fig. 10. The comparison of handover throughput based on MN's velocity.

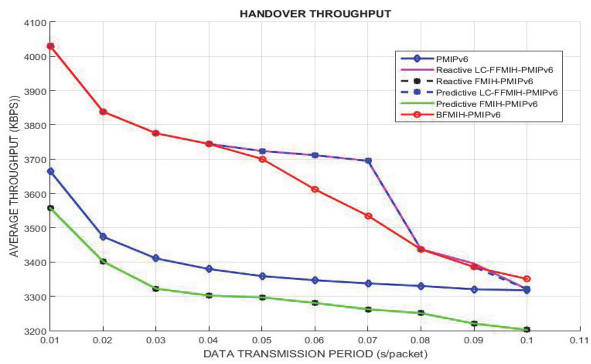


Fig. 11. The comparison of handover throughput based on the data transmission period.

Referring to Fig. 11, the higher data transmission period results in the better throughput. The proposed BFMIH-PMIPv6 has better throughput than all other control schemes. It is because our proposed scheme has a less packet loss rate and handover latency. Therefore, no matter how data transmission rate is, the throughput is better than all other schemes.

## 6. CONCLUSION

In this paper, we have proposed and analyzed a Backward Fast Media Independent Handover for Proxy Mobile IPv6 Control Scheme (BFMIH-PMIPv6) over Heterogeneous Wireless Mobile Networks to improve handover performance. The proposed BFMIH-PMIPv6 scheme is analyzed to show that it has the better performance than that of the normal PMIPv6 in terms of the following issues: (1) the handover latency can be reduced comparing with the PMIPv6 because the proposed scheme makes MN have better chance to be in the predictive mode and (2) the packet loss and throughput can be improved. Performance analysis and simulation results shown the proposed handover control scheme has lower latency, lower packet loss and better throughput than the fast handover of PMIPv6 and PMIPv6. In future work, we will apply our proposed control scheme in VANET over the SDN environment.

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