MIH-Assisted PFMIPv6 Predictive Handover with Selective Channel Scanning, Fast Re-association and Efficient Tunneling Management

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Abstract. In this paper, we investigate the major limitations of PFMIPv6, and explaine detailed lower layer procedures, which may significantly affect the handover performance. We propose a solution to reduce the overall channel scanning time by using IEEE 802.21 Media Independent Handover (MIH) services. MIH service is also used for efficient handover triggering and event notifications. In order to minimize the network attachment delay, we propose a fast re-association scheme for Mobile Node (MN). An efficient management of transient Binding Cache Entry (BCE) allows to eliminate out-of-order packet delivery and reduces the end-to-end delay at handover. Through the performance evaluations on OPNET network simulator, we validate that the proposed scheme provides better performance compared to PFMIPv6 and PMIPv6.

Keywords: IEEE 802.11, handover, PMIPv6, PFMIPv6, QoS, IEEE 802.21 MIH.

1 Introduction

Since most people want to continuously receive time-critical real-time multimedia services on portable devices attached to various wireless access networks, seamless secure mobility with guaranteed QoS provisioning across multiple wireless access networks is believed to be an essential feature in the next generation Internet. The QoS-guaranteed seamless multimedia service provisioning usually requires guaranteed bandwidth, limited jitter (e.g., less than 50 ms), and limited packet loss (e.g., less than 10^{-3}) during the handover.

In order to provide seamless mobile services, various mobile IP protocols, such as Mobile IPv4 (MIPv4) [1], MIPv6 [2], Fast Mobile IPv6 (FMIPv6) [3], Hierarchical Mobile IPv6 (HMIPv6) [4] and Proxy Mobile IPv6 (PMIPv6) [5], have been proposed in IETF. Especially, PMIPv6 provides the merits of network-initiated mobility that does not possess MIPv6 mobile node functionality.

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A proxy agent in the network performs the mobility management signaling on behalf of the mobile node. PMIPv6 transparently provides mobility for mobile nodes within a PMIPv6 domain, without requesting any modification in the mobile node. Recently, a fast handover mechanism for PMIPv6 has been proposed as PFMIPv6 [6] that improves the performance during handover, such as attachment to a new network and signaling between mobility agents. PFMIPv6 provides operational procedures of proactive handover and reactive handover procedures. In PFMIPv6, however, the major time consuming components, such as channel scanning for the new access network (n-AN) and re-association to the new mobile access gateway (NMAG), are not specified in detail, and are defined as out-of-scope.

In this paper, we propose MIH (Media Independent Handover)-assisted PMIPv6-based fast handovers. The channel scanning time at mobile node is reduced by providing the related information for the active channels in neighbor APs through MIH. The detailed function of MIH [7] for collections of available wireless network resources, support of handover decision making and optimized tunneling & buffering are explained. This paper also proposes a proactive authentication in advance to minimize the handover time. We explain the detailed procedure of proactive authentication using the network initiated handover procedure between PMAG (previous MAG) and NMAG. The performance of the proposed MIH-assisted PFMIPv6 predictive handover has been analyzed using OPNET simulation.

The rest of this paper is organized as follows. In section 2, related work on PFMIPv6 is briefly explained. In section 3, the PFMIPv6 predictive handover with reduced channel scanning time, pre-authentication and transient Binding Cache Entry (BCE) management is explained in detail. In section 4, the performances of the enhanced PFMIPv6 handover are analyzed, based on OPNET simulation results. Especially, the packet delivery performances in uplink and downlink are evaluated individually. Finally, section 5 concludes this paper.

2 Background and Related Work

2.1 Basic Operations in Fast Handovers for PMIPv6 (PFMIPv6)

Recently, IETF MIPSHOP working group has been developing a protocol that attempts to reduce the handover latency of PMIPv6 [6]. The protocol called fast handovers for PMIPv6 (PFMIPv6) describes the necessary extensions to FMIPv6 for operations in PMIPv6 environment. PFMIPv6 defines two modes of operation: predictive and reactive fast handovers. In predictive fast handover, a bi-directional tunnel is established between PMAG and NMAG prior to the MN's attachment to the NAR. In reactive mode, this tunnel is established after MN is attached to the new access router (NAR).

Fig.1 depicts the predictive fast handover for PMIPv6. After MN completes the scanning phase and makes a decision to which AP it will perform handover, it sends a report to the previous access network (P-AN) containing MN ID and the new AP ID. The P-AN informs the PMAG about the MN's handover to the

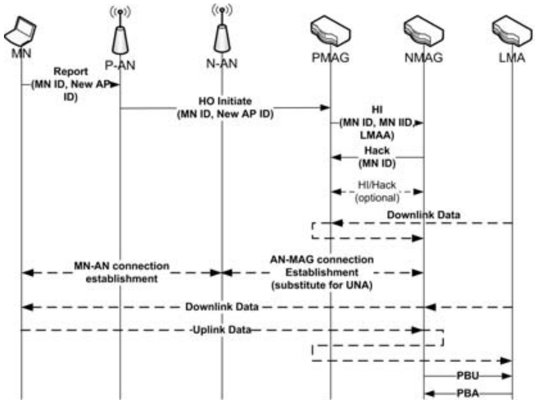


Fig. 1. Predictive fast handover for PMIPv6

new AN. PMAG sends a handover initiate (HI) message to NMAG transferring MN related context. NMAG replies with handover acknowledgement (HAck) message, and establishes a bi-directional tunnel between PMAG and NMAG. NMAG may also request PMAG to buffer the packets destined to the MN by setting U flag in HI message. The packet forwarding is restarted after HI/HAck message exchange with F flag set. Since MN doesn't participate in mobility signaling and cannot send unsolicited neighbor advertisement (UNA) to NMAG, a connection establishment notification may be regarded as a substitute for UNA. Just after the MN's attachment to the N-AN, the uplink and downlink packet flows go through the PMAG. NMAG may send proxy binding update (PBU) message to LMA, which updates MN's cache entry. After the PBU/PBA negotiation is completed, the uplink/downlink packets may be delivered through the NMAG directly.

The PFMIPv6 protocol operation may be regarded as one of the way to reduce the overall handover latency and packet loss. However, in order to minimize the overall handover latency lower layer procedures, such as channel scanning and re-association must be considered. In addition, in PFMIPv6 packet tunneling management is not optimal and may cause increase in end-to-end delay and packet out-of-order delivery.

2.2 Analysis of Limitations in PFMIPv6 Handover

The major goal of PFMIPv6 protocol is minimization of handover delay and packet loss during MN's handover. In addition, PFMIPv6 describes a context transfer related issues, so that the NMAG may acquire MN's profile not from MN or LMA, but from PMAG directly. PFMIPv6 defines two fast handover techniques: predictive and reactive. In this paper, we consider only predictive handover case and assume that MN initiates handover prior to its attachment to the new network. In order to provide a seamless handover, the access technology specific interactions must be taken into consideration. In this paper, we assume IEEE 802.11 [8] as access network technology. After MN detects that the link condition level (e.g. signal power) drops below the pre-determined threshold, it should start scanning mode. MN executes scanning on every channel and makes decision to which AP it will perform attachment. The decision is usually based on the received signal level. The scanning delay in IEEE 802.11 network may take quite long time varying from hundreds of millisecond to several seconds [9].

After MN finishes channel scanning it sends a report message to the access point with its ID and the new AP ID. In 802.11, however, MNs don't send this information directly to the access point. Instead of it, an Inter-Access Point Protocol (IAPP) is used, where the new AP sends notifications to the previous AP during the MN's re-association. This approach may not be applicable for predictive handover, since the handover process starts after MN's attachment to the new network. In addition, the HO Initiate message, which is used to inform PMAG about the MN's handover, is not defined in the specification, and is defined as out-of-scope.

PMAG has to send Handover Initiate (HI) message to NMAG containing the MN's profile information. However, it is not clear how PMAG may know NMAG's IP address, since it only receives a new AP ID and doesn't know to which MAG it belongs.

PMAG has to buffer packets destined to the MN if requested by NMAG by setting U flag in HI message. It is not defined by which criteria NMAG should request those buffered packets from PMAG. Furthermore, after handover phase is completed, MN starts sending data to NMAG, which in turn tunnels the packets to PMAG, which then tunnels those packets to LMA, which in turn delivers the packets further. This kind of routing may increase the end-to-end delay, especially if the distance between two MAGs is long. Nevertheless, NMAG may update binding by sending PBU message to LMA. The path switch in this case may induce an out-of-order packet delivery at the destination node. In addition, it is not defined what event should trigger this binding update.

Another possible problem in MAG is a neighbor queue overflow at the NMAG. A neighbor queue size is usually not large. Normally, routers consider a neighbor queue size of 3 packets [10]. This problem is caused by the new network attachment delay. The primary component of the attachment delay may be AAA authentication. The packet coming from PMAG may be delivered to NMAG, but MN may not complete the authentication phase, which may lead to buffer overflow.

3 PFMIPv6 Predictive Handover with Selective Channel Scanning, Pre-authentication, and Efficient Tunneling Management

3.1 MIH-Assisted PFMIPv6 Handover

We propose an MIH-assisted PFMIPv6 predictive handover as shown in Fig.2. When a MN initially attaches to an access network, MIH function (MIHF) of the

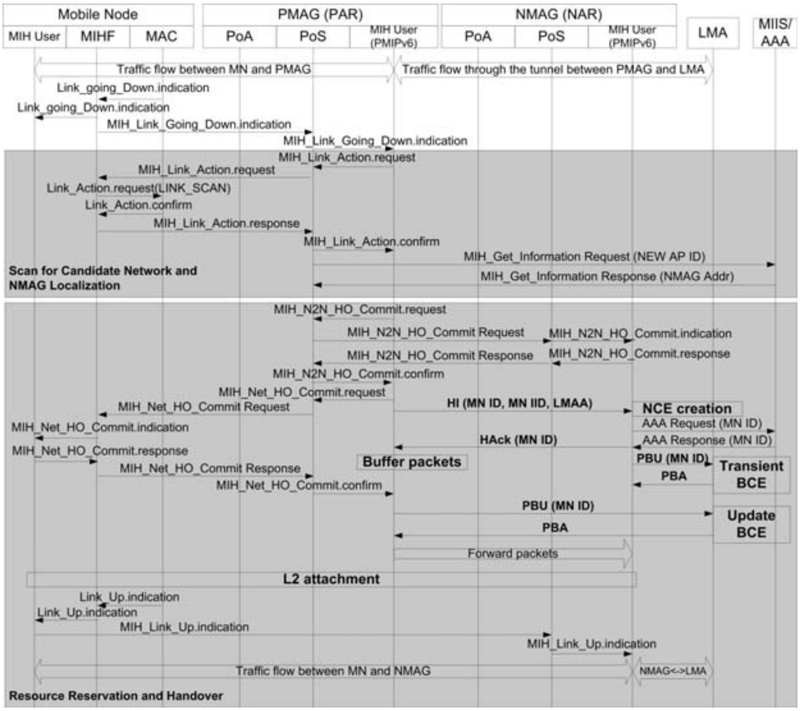


Fig. 2. Proposed MIH-assisted PFMIPv6 predictive fast handover

MN performs registration to MAG. After registration, MAG may receive event notifications from the MN. In addition, MIHF of MAG may retrieve information about the neighbor access networks to which MN may perform handover from Media Independent Information Server (MIIS). This information includes channel numbers on which neighbor access points are configured. When the link conditions deteriorate and the signal levels drops below the pre-defined threshold, a *Link_Going_Down* event is generated and delivered to the MIH Point of Service (PoS). MIH PoS sends the *MIH_Link_Action* request message commanding to start channel scanning. This command contains the channel numbers on which the MN has to perform scanning, so that the overall channel scanning time may be significantly reduced. In addition to this, any other scheme that allows data transmission during interleaving intervals of scanning may be used in order to minimize delay, such as described in [9]. There are two possible ways to execute scanning, i.e. active and passive mode. In case of passive scanning, the station “listens” every channel for the beacon frames transmitted by the neighbor APs. The scanning delay in this mode is dependent on the frequency of beacon generation. On the other hand, the frequent beacon generation may cause significant overhead. In case of active scanning, the station sends a probe request frames finding available AP. In this case the scanning time depends on the time the station has to wait for a probe response frame. In this paper, we assume that MN uses active scanning mode. Another important issue is setting the scanning threshold value, so that the handover process may be executed in proactive manner.

The result of scanning is returned to the MIH PoS. The MIH PoS then sends *MIH_Get_Information* to MIIS to request the list of possible NMAG addresses based on the AP IDs. The access point ID may be regarded as the AP's BSS ID. By this procedure PMAG may acquire NMAG's IP address.

After the scanning phase is completed, the resource reservation phase is initiated. During this phase, current PoS notifies the target PoS about the MN's handover by sending *MIH_N2N_HO_Commit* request. The target network indicates that it is ready to accept new attachment by sending *MIH_N2N_HO_Commint* response message. The current PoS now sends *MIH_Net_HO_Commit* request message to MN commanding to start a switching to the target AP. At the same moment, the PMAG sends HI message to the NMAG containing MN ID, MN interface ID (IID) and home network prefix (HNP). Since NMAG has received MN IID and HNP it can now construct MN's address and add neighbor cache entry for the MN to the neighbor cache table, so that when MN attaches to the new access network it can receive router advertisement with included HNP immediately. Since NMAG has received MN's profile information it may initiate AAA authentication for the MN in order to ensure that the MN has rights to access PMIPv6 service. This allows the MN to avoid authentication with new network during it's actual attachment.

3.2 Enhanced Management of Tunneling and Transient Binding Cache Entry (BCE)

NMAG also sends a PBU message to LMA requesting the LMA to create a transient binding cache entry (BCE). At any time instance there should be only one BCE that can forward packets in uplink and downlink direction and one that can allow forwarding only in uplink direction as it is defined in [11]. The newly created transient BCE allows only uplink packet transmission, while the old BCE allows bi-directinal transmission through the PMAG. When the MN is ready to perform switching between access networks it notifies current PoS with *MIH_Net_HO_Commit* response and undergoes L2 handover. The buffered packet from PMAG may now be delivered to NMAG, and the PMAG sends PBU message to LMA activating the previously created transient BCE, so that the packets may now be forwarded directly to/from NMAG. In PFMIPv6 specification there should be additional HI/HAck message exchange between PMAG and NMAG requesting buffered packets. However, it is not defined based on which criteria and when NMAG has to request the buffered packets from PMAG.

When the mobile node performs access network attachment, a *Link_Up* indication message is delivered to the new PoS, which indicates that the MN is ready to accept packet. From now all the packets can be forwarded through the NMAG-to-LMA tunnel directly without involving PMAG. There is also no need to update a binding cache table at LMA, since this step was already done by PMAG.

4 Performance Evaluation and Analysis

4.1 Simulation Model

We implemented PMIPv6, PFMIPv6 and the proposed MIH-assisted PFMIPv6 predictive handover scheme in OPNET [12] network simulator. The simulation topology is depicted in Fig.3. There is a single LMA and two MAGs within one PMIPv6 domain. MN performs horizontal handover from PMAG to NMAG while moving from BSS1 to BSS2. The BSS radius was set to 100 meters. IEEE 802.11b with DSSS was used as access network technology. A bi-directional 64 kbit/s PCM VoIP (RTP/UDP) session was used as application between MN and CN. In this paper, we assume that the MN moves at the pedestrian speed (10km/h). The performance of the proposed scheme was compared with PFMIPv6 and PMIPv6 in terms of mouth-to-ear delay, jitter, packet loss and Mean Opinion Score (MOS) value in uplink and downlink directions separately.

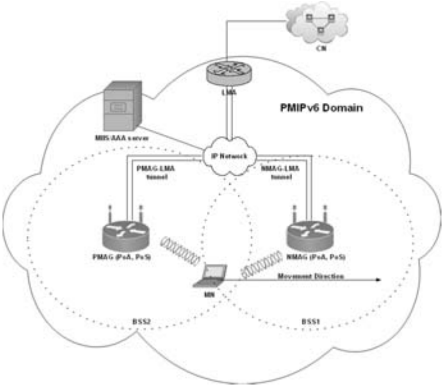
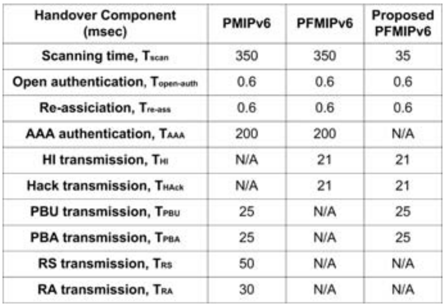


Fig. 3. Simulation topology

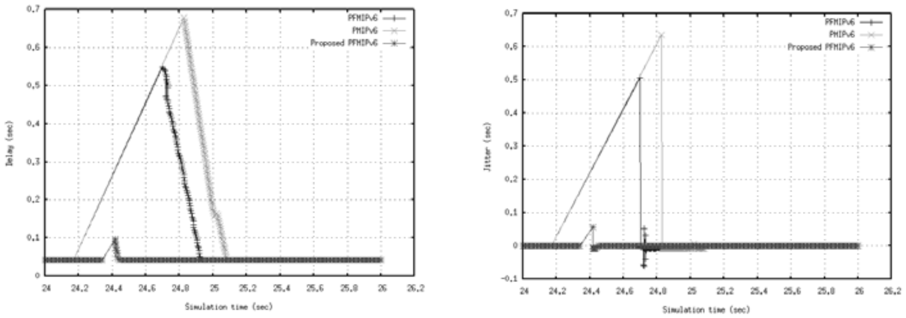


Handover Component (msec)	PMIPv6	PFMIPv6	Proposed PFMIPv6
Scanning time, T_{scan}	350	350	35
Open authentication, $T_{open\text{-}auth}$	0.6	0.6	0.6
Re-assiciation, $T_{re\text{-}ass}$	0.6	0.6	0.6
AAA authentication, T_{AAA}	200	200	N/A
HI transmission, T_{HI}	N/A	21	21
Hack transmission, T_{HAck}	N/A	21	21
PBU transmission, T_{PBU}	25	N/A	25
PBA transmission, T_{PBA}	25	N/A	25
RS transmission, T_{RS}	50	N/A	N/A
RA transmission, T_{RA}	30	N/A	N/A

Fig. 4. Handover delay components

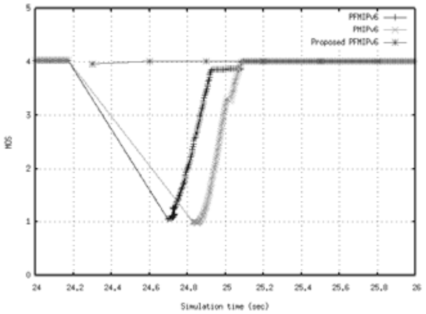
4.2 Uplink Handover Performance Analysis

The mouth-to-ear delay performance depicted in Fig.5(a) shows that the proposed PFMIPv6 can perform better than PFMIPv6 and PMIPv6. This is due to reduced channel scanning time and pre-authentication in the proposed PFMIPv6. Additionally, the packets after handover process are delivered directly to NMAG, eliminating the unnecessary routing to PMAG. Mouth-to-ear delays for PFMIPv6 and PMIPv6 are much higher than in the proposed PFMIPv6 because the packets at the MN's buffer have to wait much longer time before transmission. In case of PFMIPv6, the packets may be delivered to NMAG after attachment immediately, but in case of PMIPv6 a PBU/PBA exchange with LMA and RS/RA exchange with NMAG have to be done. Nearly at 24.7 sec. of simulation time the delay is fluctuating in PFMIPv6. This is because packets arrive out-of-order after the path switching. This also can be seen from jitter



(a) Uplink mouth-to-ear delay (sec)

(b) Uplink jitter (sec)



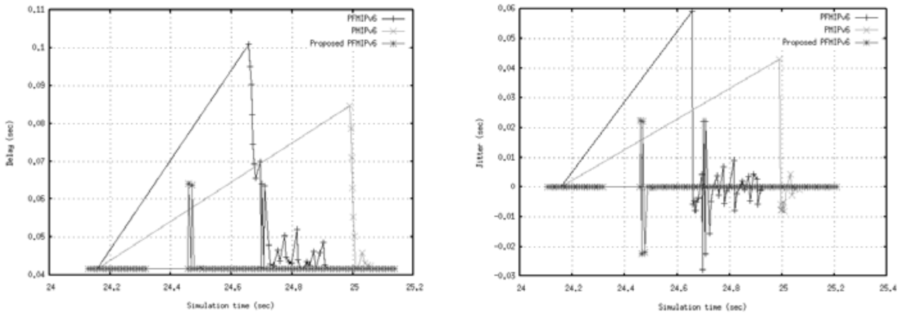
(c) Uplink MOS

Fig. 5. Uplink performance

performance depicted in Fig.5(b). The negative jitter value indicates that the packets were delivered out-of-order. There was no out-of-order packets in uplink direction in the proposed PFMIPv6 and PMIPv6 since in both cases the uplink packets were delivered directly through the NMAG-to-LMA tunnel. There was no packet loss in uplink direction. Once the handover process was started, all the packets coming from the upper layer were buffered at the MAC queue of the MN. Fig.4 shows the handover delay components.

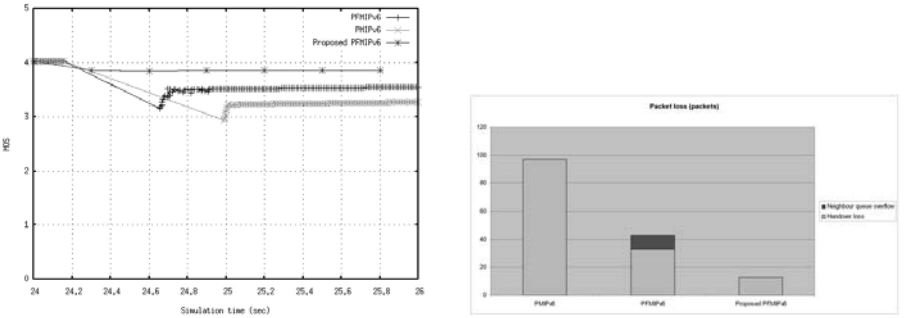
4.3 Downlink Handover Performance Analysis

The downlink performance in depicted in Fig.6. The mouth-to-ear delay in the proposed scheme was less compared to PFMIPv6 and PMIPv6. Performance of the delay also indicates that there was out-of-order packet delivery in case of the proposed scheme and PFMIPv6. This was due to the data transmission path switch. Jitter performance also indicates out-of-order packet delivery and



(a) Downlink mouth-to-ear delay (sec)

(b) Downlink jitter (sec)



(c) Downlink MOS

(d) Downlink packet loss (packets)

Fig. 6. Downlink performance

is slightly higher than 20 ms for the proposed PFMIPv6. There is a slight delay fluctuation at 25 sec. of simulation time in PMIPv6. This is due to the neighbor discovery procedure at NMAG. NMAG when receiving the first packet destined to the MN starts the neighbor discovery process. Once the MN is found, all packets may be delivered to it. The mouth-to-ear delay in PFMIPv6 is even higher than in PMIPv6. This is because the data packets during handover are forwarded through the PMAG. In case of PMIPv6, the packets are forwarded to PMAG until LMA receives PBU message sent by NMAG. The amount of packet loss, however, is much higher in PMIPv6 case compared to other schemes. The packet loss was caused by long scanning delay and access network attachment delay. In case of PFMIPv6, there was a neighbor queue overflow, which was set to four packets. The packets from PMAG were delivered to NMAG and buffered in the neighbor queue awaiting MN's attachment to the new network. In the proposed PFMIPv6 handover scheme only 13 packets were lost in downlink direction compared to 97 and 43 for PMIPv6 and PFMIPv6, respectively. The

MOS value clearly shows that the proposed PFMIPv6 handover helps to achieve much better voice quality. Even though the mouth-to-ear delay and jitter for PFMIPv6 were higher than for PMIPv6, the MOS value for PFMIPv6 showed better performance. This is because the amount of packet loss in PFMIPv6 was much less than in PMIPv6.

5 Conclusion

In this paper, we proposed an MIH-assisted PFMIPv6 predictive fast handover with reduced channel scanning time, fast re-association and transient BCE management. The proposed scheme is based on MIH services, which is providing information to reduce the overall channel scanning time. By using pre-authentication of the MN, the network attachment delay was reduced. Furthermore, handling a transient BCE allows delivery of data packets through the NMAG in uplink and downlink direction after MN's attachment immediately, i.e eliminating the unnecessary data transmission through PMAG. We compared our proposed scheme with PMIPv6 and PFMIPv6 in terms of mouth-to-ear delay, jitter, packet loss, and MOS value based on the simulation results obtained from the OPNET network simulator.

The future work will cover inter-technology fast PMIPv6 vertical handovers. The vertical handover issues for PMIPv6 will be studied deeply considering multihoming.

References

1. Perkins, C.: IP mobility support for IPv4. IETF Draft (October 2008)
2. Johnson, D., Perkins, C., Arkko, J.: Mobility support in IPv6. IETF Draft (June 2004)
3. Koodly, R.: Fast handovers for mobile IPv6. IETF Draft (July 2005)
4. Soliman, H., Flarion, Castelluccia, C., Malki, K.E., Bellier, L.: Hierarchical mobile ipv6 mobility management (HMIPv6). IETF Draft (August 2005)
5. Gundavelli, S., Leung, K., Devarapalli, V., Chowdhury, K., Patil, B.: Proxy mobile IPv6. IETF Draft (August 2008)
6. Yokota, H., Chowdhury, K., Koodli, R., Patil, B., Xia, F.: Fast handovers for proxy mobile IPv6. IETF Draft (March 2009)
7. Media Independent Handover Services: IEEE P802.21/D10.0 draft standard for local and metropolitan area networks (April 2008)
8. Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: IEEE 802.11 standard for information technology (June 2007)
9. Wu, H., Tan, K., Zhang, Y., Zhang, Q.: Proactive scan: Fast handoff with smart triggers for 802.11 wireless lan. In: INFOCOM, Anchorage, Alaska, USA, May 6–12, pp. 749–757 (2007)
10. Liebsch, M., Le, L.: Inter-technology handover for proxy MIPv6. IETF Draft (February 2008)
11. Liebsch, M., Muhanna, A., Blume, O.: Transient binding for proxy mobile IPv6. IETF Draft (March 2009)
12. OPNET Technologies Web Site, `http://www.opnet.com`