



A Comparative Handoff Latency Evaluation in IPv6 Based Mobility Management Protocols

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Abstract— The mobility support protocols are classified into two categories; First, Host-based mobility management protocols such as Mobile IPv6, and its enhancements like FMIPv6, HMIPv6 and FHMIPv6. Secondly, Network-based localized mobility management protocols such as Proxy Mobile IPv6. This paper gives an overview to Host-based Mobility Management Internet Protocols. MIPv6 has suffered various problems like handover latency and high signaling cost etc. The FMIPv6 was introduced to reduce handover latency but it fails to reduce cost because of extra signaling between new and previous access routers. The HMIPv6 introduces a mobility anchor point (MAP) which reduces the signaling cost to a significant level by differentiating the local mobility from global mobility. So, combination of both FMIPv6 and HMIPv6 i.e. FHMIPv6 was introduced to optimize both, signaling cost as well as handover latency to a great extent.

Keywords- MIPv6, Handoff Latency, Mobility Anchor Point, HMIPv6, FMIPv6, FHMIPv6.

I. INTRODUCTION

Mobile Computing is becoming increasingly important due to the rise in the number of portable computers and the desire to have continuous network connectivity to the Internet irrespective of the physical location of the node. The Internet infrastructure is built on top of a collection of protocols, called the TCP/IP protocol suite. Transmission Control Protocol (TCP) and Internet Protocol (IP) are the core protocols in this suite. IP requires the location of any host connected to the Internet to be uniquely identified by an assigned IP address. This raises one of the most important issues in mobility, because when a host moves to another physical location, it has to change its IP address. However, the higher level protocols require IP address of a host to be fixed to identify connections. The Mobile Internet Protocol (Mobile IP) is an extension to the Internet Protocol proposed by the Internet Engineering Task Force (IETF) that addresses this issue. It enables mobile computers to stay connected to the Internet regardless of their location and without changing their IP address. More precisely, Mobile IP is a standard protocol that builds on the Internet Protocol by making mobility transparent to applications and higher level protocols like TCP.

II. IP BASED MOBILITY MANAGEMENT PROTOCOLS

Mobility management enables systems to locate roaming users in order to deliver data packets, i.e., location management and maintain connections between them when moving into a new subnet (handover management). Several protocols have been proposed for these purposes for IP mobility and are briefly presented in this section.

Definition: A handover or handoff is a movement of an MN between two attachment points, i.e., the process of terminating existing connectivity and obtaining new connectivity. Handovers in IP-based wireless Network may involve changes of the access point at the link layer and routing changes at the IP layer. Efficient mechanisms must ensure the seamless handover, i.e., with minimal signaling overhead, handoff latency, packet loss, and handoff failure and service continuity [17].

Definition: The handoff latency at an MN side is the time interval during which an MN cannot send or receive any packets during handoff and it is composed of L2 (link layer) and L3 (IP layer) handoff latencies. The L3 handoff latency is the sum of delay due to: movement detection, IP addresses configuration and binding update procedure.

A. Mobile IPv6 (MIPv6)

MIPv6 was proposed for mobility management at the IP layer and allows an MN to remain reachable despite of its movement within that IP environment.[13] Each MN is always identified by its home address (HoA). While away from its home network, an MN is also associated with a care-of address (CoA), which provides information about the MN's current location. Discovery of new access router (NAR) is performed through Router Solicitation/Advertisement (RS/RA) messages exchange. Furthermore, to ensure that a configured CoA (through stateless or stateful mode) is likely to be unique on the new link, the Duplicate Address Detection (DAD) procedure is performed by exchanging Neighbor Solicitation/Advertisement (NS/NA) messages. After acquiring a CoA, an MN performs binding update to the home agent (HA) through binding update

(BU) and binding acknowledgment (BAck) messages exchange. To enable route optimization, BU procedure is also performed to all active CNs.

However, return routability (RR) procedure must be performed before executing a binding update process at CN in order to insure that BU message is authentic and does not originate from a malicious MN. The return routability procedure is based on home address test, i.e., Home Test Init (HoTI) and Home Test (HoT) messages exchange, and care-of address test, i.e., exchange of Care-of Test Init (CoTI) and Care-of Test (CoT) messages. Although RR procedure helps to avoid session hijacking, it increases delay of the BU procedure. Fig. 1(a) represents the sequence of message flow used in MIPv6 based on stateless address autoconfiguration. Analysis of MIPv6 shows that it has some well-known disadvantages such as overhead of signaling traffic, high packet loss rate and handoff latency

B. Fast Handovers for Mobile IPv6 (FMIPv6)

FMIPv6 was proposed to reduce handoff latency and minimize service disruption during handovers pertaining to MIPv6 [3]. The link layer information (L2 trigger) is used either to predictor rapidly respond to handover events. When an MN detects its movement toward NAR, by using L2 trigger, it exchanges Router Solicitation for Proxy (RtSolPr) and Proxy Router Advertisement (PrRtAdv) messages with the previous access router (PAR) in order to obtain information about NAR and to configure a new CoA (NCoA). Then, the MN sends a Fast Binding Update (FBU) to PAR in order to associate previous CoA (PCoA) with NCoA. A bidirectional tunnel between PAR and NAR is established to prevent routing failure with Handover Initiate (HI) and Handover Acknowledgment (HAck) message exchanges. The Fast Binding Acknowledgment (FBAck) message is used to report status about validation of preconfigured NCoA and tunnel establishment to MN. Moreover, the PAR establishes a binding between PCoA and NCoA and tunnels any packets addressed to PCoA towards NCoA through NAR's link. The NAR buffers these forwarded packets until the MN attaches to NAR's link. The MN announces its presence on the new link by sending Router Solicitation (RS) message with the Fast Neighbor Advertisement (FNA) option to NAR. Then, NAR delivers the buffered packets to the MN. The sequence of messages used in FMIPv6 is illustrated in Fig. 1(b) for MN-initiated handoff of predictive mode.

A counterpart to predictive mode of FMIPv6 is reactive mode. This mode refers to the case where the MN does not receive the FBack on the previous link since either the MN did not send the FBU or the MN has left the link after sending the FBU (which itself may be lost), but before receiving a FBack. In the latter case, since an MN cannot ascertain whether PAR has successfully processed the FBU, it forwards a FBU, encapsulated in the FNA, as soon as it attaches to NAR. If NAR detects that NCoA is in use (address collision) when processing the FNA, it must discard the inner FBU packet and send a Router Advertisement (RA) message with the Neighbor Advertisement Acknowledge (NAACK) option in which NAR may include an alternate IP address for the MN to use. Otherwise, NAR forwards FBU to PAR which responds with FBack. At this time, PAR can start tunneling any packets addressed to PCoA towards NCoA through NAR's link. Then, NAR delivers these packets to the MN.

C. Hierarchical Mobile IPv6 (HMIPv6)

With MIPv6, an MN performs binding update to HA/CNs regardless of its movements to other subnets. This induces unnecessary signaling overhead and latency. To address this problem, HMIPv6 was proposed to handle handoff locally through a special node called Mobility Anchor Point (MAP) [14]. The MAP, acting as a local HA in the visited network, will limit the amount of MIPv6 signaling outside its domain and reduce the location update delay. An MN residing in a MAP's domain is configured with two temporary IP addresses: a regional care-of address (RCoA) on the MAP's subnet and an on-link care-of address (LCoA) that corresponds to the current location of the MN.

As long as an MN moves within MAP's domain or access network (AN) it does not need to transmit BU messages to HA/CNs, but only to MAP when its LCoA changes. Hence, the movement of an MN within MAP domain is hidden from HA/CNs. For inter-MAP domain roaming, MIPv6 is used rather than HMIPv6. When an MN crosses a new MAP's domain, moreover from registering with new MAP, BU messages need to be sent by the MN to its HA/CNs to notify them of its new virtual location. Fig. 2(a) presents the generic sequence of message flows used in HMIPv6 with assumption that an MN has entered into new MAP domain and MIPv6 registration procedure was already completed.

D. Fast Handover for HMIPv6 (F-HMIPv6)

Combination of HMIPv6 and FMIPv6 motivates the design of Fast Handover for Hierarchical Mobile IPv6 (F-HMIPv6) protocol in order to allow more efficient network bandwidth usage similarly to HMIPv6. Furthermore, like FMIPv6, it aims to reduce the handoff latency and packet loss. In F-HMIPv6, the bi-directional tunnel is established between MAP and NAR, rather than between PAR and NAR as it is in FMIPv6 [3]. After signaling message exchanges (between an MN and the MAP) based on FMIPv6 messages, an MN follows the normal HMIPv6 operations by sending local BU (LBU) to MAP. When MAP receives LBU with the new LCoA (NLCoA) from MN, it will stop packets forwarding to NAR and then clear the established tunnel. In response to LBU, the MAP sends local BAck (LBAck) to the MN and the remaining procedure follows the operations of HMIPv6. Fig. 2(b) illustrates a sequence of message used in F-HMIPv6 when an MN moves from PAR to NAR within MAP's domain and the MAP already knows the adequate information on the link-layer address and network prefix of each AR. This illustration is based on the assumption that an MN has entered into a new MAP domain and that MIPv6/HMIPv6 registration procedures were already completed [8].

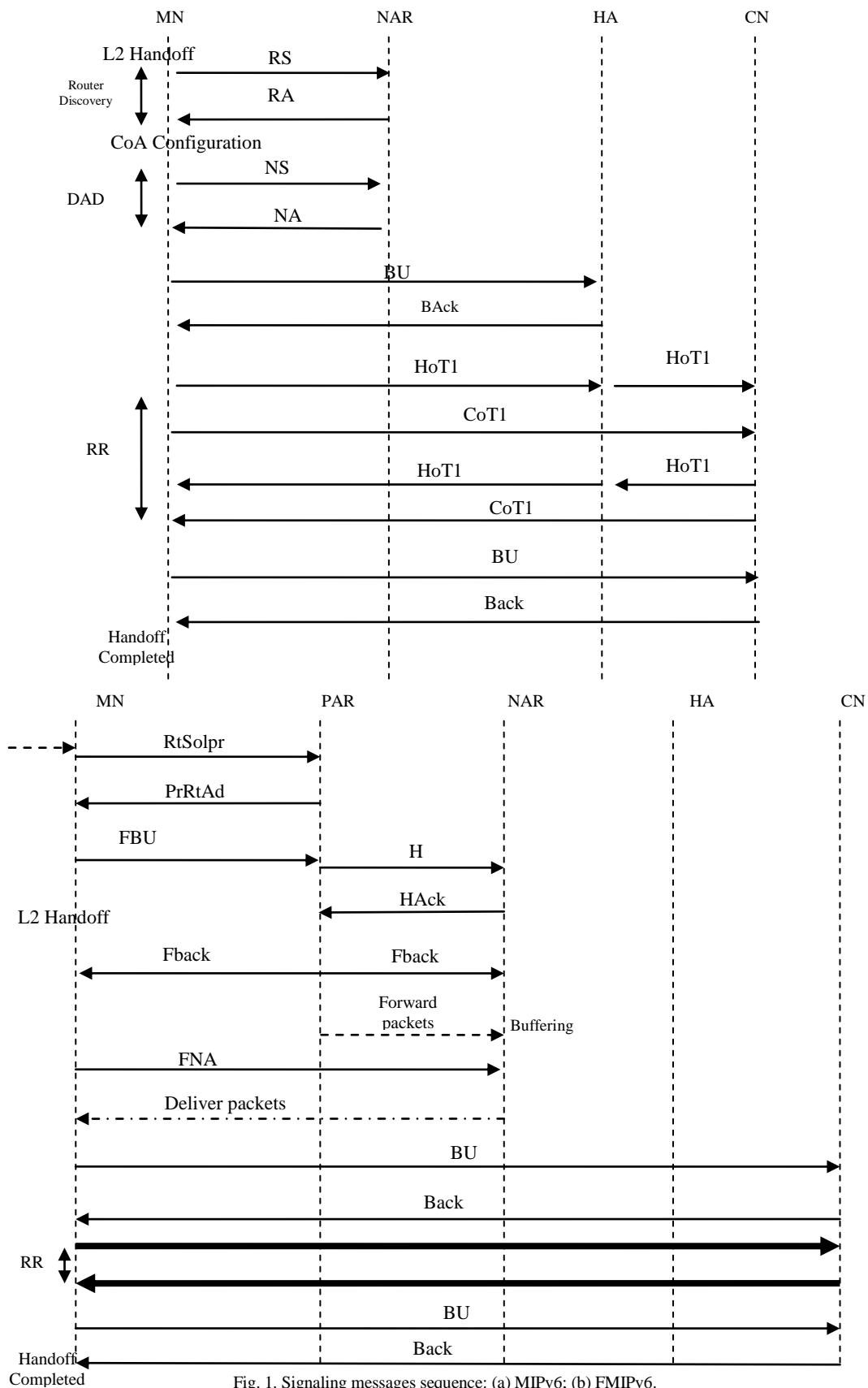


Fig. 1. Signaling messages sequence: (a) MIPv6; (b) FMIPv6.

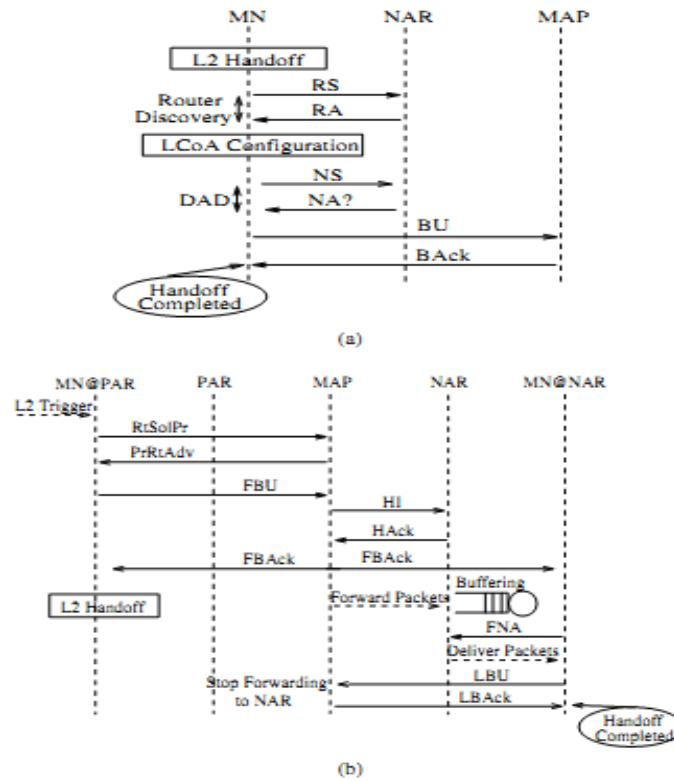


Fig. 2. Signaling messages sequence: (a) HMIPv6; (b) F-HMIPv6.

III. AN ANALYTIC FRAMEWORK FOR HANDOFF LATENCY

We define the following parameters to compute handoff latency : t_{L2} the L_2 handoff latency, t_{RD} the round-trip time for router discovery procedure, t_{DAD} the time for DAD process execution, t_{RR} the delay for an MN to perform return routability procedure and $t_{X,Y}$ one-way transmission delay of a message of size s between nodes X and Y [4]. Since the average delay needed for an MN authentication is the same for all protocols; then, it is omitted. If one of the endpoints is an MN, $t_{X,Y}$ is computed as follows:

$$t_{x,y}(s) = \frac{1-q}{1+q} \left(\frac{s}{B_{wl}} + L_{wl} \right) + (d_{X,Y} - 1) \left(\frac{s}{B_w} + L_w + \omega_q \right) \quad (1)$$

where q is the probability of wireless link failure, q the average queuing delay at each router in the Internet, B_{wl} (resp. B_w) the bandwidth of wireless (resp. wired) link and L_{wl} (resp. L_w) wireless (resp. wired) link delay. The handoff latency associated to MIPv6 is given by:

$$D_{MIPv6} = t_{L2} + t_{RD} + t_{DAD} + t_{RR} + 2(t_{MN, HA} + t_{MN, CN}) \quad (2)$$

The handoff latency for intra-AN/MAP or localized movement of HMIPv6 is obtained by replacing HA by MAP and by ignoring t_{RR} and $t_{MN, CN}$. Let Δ_{ns} be the time elapsed from the reception of FBAck on previous link to the beginning of L2 handoff when there is no good synchronization between L2 and L3 handoff mechanisms [4]. Moreover, let Δ_{lr} be the time between last packet reception through previous link and L2 handoff beginning when FBAck is received on new link. Note that, Δ_{lr} and Δ_{ns} may be equal to zero and we use this assumption in performance analysis. For fast handoff schemes, the handoff latency depends on information availability, and on which link fast handoff messages are exchanged. Hence, if information about NAR and impending handoff are available, and FBAck message is received through the previous link, handoff latency for localized or micro-mobility without an efficient buffers management for FMIPv6 and F-HMIPv6 is expressed as follows:

$$O_{FMIPv6}^1 = O_{FHMIPv6}^1 = \Delta_{ns} + t_{L2} + 2t_{MN, NAR} \quad (3)$$

If FBAck message is not received through previous link, F-HMIPv6 turns to HMIPv6 while for FMIPv6 its reactive mode is used. Then, handoff latency without efficient buffer management for FMIPv6 is expressed as follows:

$$N_{FMIPv6}^1 = \Delta_{lr} + t_{L2} + 2t_{MN, NAR} + 3t_{NAR, PAR} \quad (4)$$

The average handoff latency for FMIPv6 in terms of prediction probability is given by:

$$D_{FMIPv6}^1 = P_s O_{FMIPv6}^1 + (1 - P_s) N_{FMIPv6}^1 \quad (5)$$

Similarly, we can obtain the average handoff latency for F-HMIPv6. The predictive mode of FMIPv6 cannot perform anticipated IP-handoff for inter-AN; then handoff latency of FMIPv6 becomes same as for MIPv6. The same remark applies to HMIPv6 and F-HMIPv6.

With MIPv6 and HMIPv6, packet loss occurs during hand-off latency or service disruption latency. In fact, the number of packet loss is proportional to handoff latency. This is also the case for FMIPv6 and F-HMIPv6 if there is no efficient buffer management (BM). In fact, for fast handoff schemes there is no packet loss in theory, unless buffer overflow happens. Hence, the number of packet lost for each handoff management scheme is computed as follows:

$$P_{scheme}^{Loss, l} = \begin{cases} \max(BS_{scheme}^1 - B, 0) & \text{for efficient BM} \\ \lambda_p D_{scheme}^1 & \text{otherwise} \end{cases} \quad (6)$$

where B is the buffer size of an AR and BS_l scheme is the buffer space required at an access router for a given scheme (i.e., MIPv6, HMIPv6, FMIPv6 or F-HMIPv6).

IV. PERFORMANCE EVALUATION

Parameters and default values used in performance evaluation are given in Table I, except when wireless link delay and packet arrival rate are considered as variable parameters. The network topology [1] considered for analysis is illustrated in Fig.3,

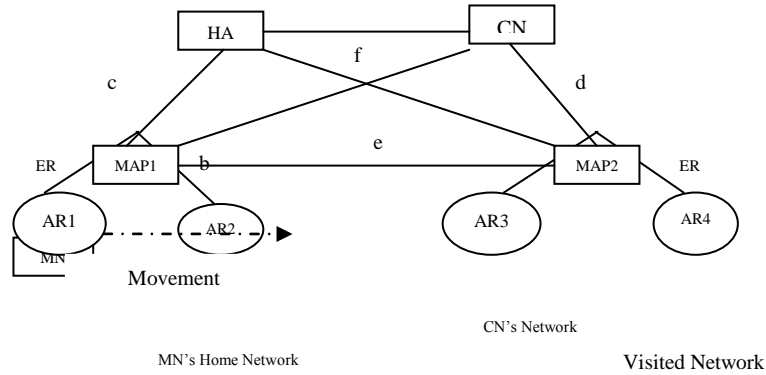


Fig. 3 Network topology used for analysis.

where ER means edge router. For protocols which do not involve hierarchical mobility management, the MAPs act as a normal intermediate (edge) router. We assume that distance (i.e., the number of hops)

TABLE I
SYSTEM PARAMETERS

Parameters	Symbols	Values
DAD delay	t_{DAD}	500ms
Router discovery delay	t_{RD}	100ms
L2 handoff delay	t_{L2}	50ms
Prediction probability	P_s	0.90
Wireless link failure probability	Q	0.50
Wired link bandwidth	B_w	100Mbps
Wireless link bandwidth	B_{wl}	11Mbps
Wired link delay	L_w	2ms
Wireless link delay	L_{wl}	10ms
Number of ARs by AN/MAP	M	2
Control packet size	s_c	96 bytes
Data packet size	s_d	200 bytes
Packet arrival rate	λ_p	10 packets/s
MN average speed	V	5.6 Km/h
Subnet radius	R	500 m

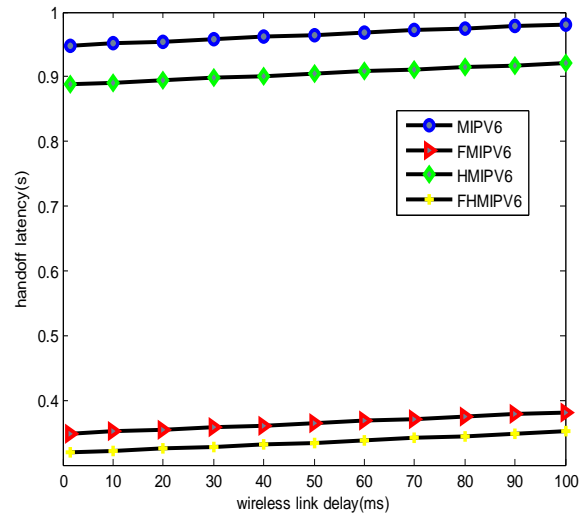


Fig. 4 Impact of wireless link delay on handoff latency.

In Fig. 4, we can see that the handover latency increases proportionally with the wireless link delay. We observe that MIPv6 and HMIPv6 have worst results among all protocols followed by FMIPv6 while F-HMIPv6 performs better than all other schemes. For MIPv6 and HMIPv6, the DAD process counts for a large portion of handoff delay. Therefore, it is important to decrease the DAD delay in order to decrease handoff latency. The optimistic DAD (oDAD) has recently been proposed to allow minimization of address configuration delay by eliminating the DAD completion time.

V. CONCLUSIONS

Mobility management is a main issue in next-generation or 4G wireless networks (NGWN/4G). Many IPv6-based mobility schemes have been proposed by IETF but they are not able to guarantee seamless roaming and service continuity for real-time applications. Moreover, Handoff Latency evaluation of these protocols is usually based on simulation approaches.

This paper proposes a comprehensive analytical Framework for IPv6-based mobility protocols like MIPv6, HMIPv6, FMIPv6 and F-HMIPv6, in order to provide analysis of the overall performance of handoff latency of these protocols. The numerical results show that F-HMIPv6 enables improvement in terms of handoff latency rather than other protocols (i.e., MIPv6, HMIPv6 and FMIPv6). However, this performance is off-set by its signaling traffic overhead and the buffer space required when compared to HMIPv6. So, it's very difficult to say which IPv6-based mobility protocol will dominate in NGWN/4G. In fact, selection of a mobility management scheme is not based solely on Handoff latency criteria, but on cost as well as profits also. Thus, until an ideal mobility management protocol is designed and deployed, mobile users still require a practical solution.

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