The Journal of Systems and Software 83 (2010) 1644–1650

Contents lists available at ScienceDirect

The Journal of Systems and Software

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

Performance Evaluation of Fast Handover in Mobile IPv6 Based on Link-Layer Information

Mohamed Alnas *, Irfan Awan, R.D.W. Holton

Mobile Computing, Networks and Security Research Group, School of Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK

ARTICLE INFO

Article history:
Received 9 November 2009
Received in revised form 18 January 2010
Accepted 30 March 2010
Available online 15 June 2010

Keywords:
Mobile IPv6
Fast Handover
Mobility Management
Link-Layer Information
Handover Latency

ABSTRACT

Handover latency is the primary cause of packet loss resulting in performance degradation of standard Mobile IPv6. Mobile IPv6 with fast Handover enables a Mobile Node (MN) to quickly detect at the IP layer that it has moved to a new subnet by receiving link-related information from the link-layer; furthermore it gathers anticipative information about the new Access Point (AP) and the associated subnet prefix when the MN is still connected to the previous Corresponding Node (CN).

This paper proposes an enhancement to Fast Mobile IPv6 handover (FMIPv6), based on link layer information, we also present performance evaluations in terms of the packet loss and handover latency using evaluation models.

1. Introduction

The fast development of wireless technologies has resulted in a movement towards total mobility. Mobile IP provides mobility to mobile users and terminals while they are changing their point of attachment during handovers from a previous wireless access network to a new access network. This mobility is managed within the network layer through Mobile IP extensions where mobile connectivity can be supported while the MN is roaming between different wireless access networks. However, which are still several technical barriers such as long handover periods and packet loss have to be overcome before wide deployment of the Mobile Internet Protocol (Yegin et al., 2000).

IPv6, next generation Internet protocol, is designed to satisfy the requirements emerging from mobile environment. It has not only provided a large address space for the potential increase in the number of mobile users, but also introduced a mobility management mechanism called Mobile IPv6 that allows for mobility (Johnson et al., 2004).

Mobile IPv6 is a network layer solution for node mobility. It makes a MN perform handovers between different Access Routers (ARs) while preserving IP communications.

Mobile IPv6 specification defines how a MN can maintain connectivity to the internet when its AP changes from on AR to another one. It allows a MN to communicate with other nodes (stationary or mobile) after changing its link-layer point of attachment from one IP subnet to another, yet without changing the MN's 1Pv6 address. A MN is always addressable by its home address, and packets may be routed to it using this address regardless of the MN's current point of attachment to the Internet (Mishra et al., 2003; Chen and Zhang, 2006).

During handover procedure, there is a time period in which a MN cannot send or receive packets, because of the link switching delay. This period of time known as handover latency, it is the primary cause of packet loss. Moreover; there is a high Mobile IPv6 handover delay because of the agent discovery and registration periods, eventually Mobile IPv6 handover can cause significant performance degradation, especially in large scale mobility environments (Draft IEEE Standard for Local and Metropolitan Area Networks: Media Independent Handover Services; Leung et al., 2008).

In this paper we propose the use of link-layer information, and the link-layer trigger to enhance the overall performance towards fast handover in Mobile IPv6.

1.1. Mobile IP Handover

In standard Mobile IP, a handover occurs whenever a MN moves between two foreign agents (FAs). In fact, an FA periodically broadcasts agent advertisement messages that carry essential information for MNs to establish a successful connection with the FA. Thus, when the MN enters an overlap region between two FAs, it may receive multiple agent advertisements from the old and new FA. The MN ensures that it has been released from the old FA (oFA),

* Corresponding author.
E-mail addresses: M.J.R.Alnas@bradford.ac.uk (M. Alnas), I.U.Awan@bradford.ac.uk (I. Awan), D.R.W.Holton@bradford.ac.uk (R.D.W. Holton).

0164-1212/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.jss.2010.03.080

and then it sends a registration request message to the new FA (nFA). This registration request message is constructed using the agent advertisement message received from the nFA (Hsieh et al., 2003).

When the nFA receives this request, it assigns a new Care-of-Address (nCoA) to the MN, then; MN sends a registration request message to its Home Agent (HA) to associate its home address with the new allocated CoA. After that, a HA acknowledges this request by sending a secured registration reply message to the MN. This registration process involves handover latency, and therefore data sent by a CN to the MN may be delayed and even lost.

The FMIPv6 is an enhancement to Mobile IPv6, proposed by the Internet Engineering Task Force (IETF) that provides seamless handover in Mobile IPv6 networks (Kim, 2005). Layer 2 (L2) trigger information from the MN is used to obtain a valid nCoA while it is still connected to the previous link, and then a bidirectional tunnel is established between the old Access Router (oAR) and the new Access Router (nAR) in order to reduce packet loss during the handover (Yokota et al., 2002).

1.2. Handover Management

Handover management enables the network to maintain a user's connection as the MN continues to move and change its AP to the network. The processes of handovers involve initiation, where either user, network agent, or the changing network conditions identify the need for handover.

Then; new connection generation, where the network must find new resources for the handover connection and perform any additional routing operations (Montavont and Thomas, 2002).

Under network-controlled handover or mobile assisted handover, the network generates a new connection, finding new resources for the handover and performing any additional routing operations. For mobile-controlled handover, the MN finds the new resources and the network approves. The final stage is data-flow control, where the delivery of the data from the old connection path to the new connection path is maintained according to agreed upon service guarantees (Yegin et al., 2000).

2. Related work

Fast handovers for Mobile IPv6 (Koodli, 2005) is proposed to reduce the handover latency by executing those time consuming processes when a MN is still present on the current link with the help of timely generated L2-trigger. The L2-trigger is generated from the link layer to indicate that the MN will be likely to perform a L2 handover soon. Upon receiving L2-trigger, MN initiates FMIPv6 handover procedure and completes the CoA configuration before L2 handover (Fig. 1).

This leads to waste of time, because there is no way to know which one accrue first either L2 or L3 handover after the completion of new CoA.

Several extensions (Johnson et al., 2004) have been proposed to improve the performance of FMIPv6, but these studies did not consider reducing the anticipated handover delay that limits the time for the MN to perform fast handover procedure in predictive mode. In addition (Montavont and Noel, 2003), all of these enhancements issue more signaling messages during this critical period; therefore these proposals are inappropriate for high-speed MN movement.

An MN detects that it has moved to a new subnet by analyzing the Router Advertisement (RA) periodically sent by the AR (Montavont and Thomas, 2002). MN can also request an AR to send a RA by sending a router solicitation. The information contained in the RA will allow MN to create an nCoA. As specified in IPv6 (Yegin et al., 2000), MN first needs to verify the uniqueness of its link-local address on the new link. MN performs Duplication Address Detection (DAD) on its link-local address. Then, it may use either stateless or stateful address auto configuration to form its nCoA. Once it has obtained the nCoA, it may perform DAD for it. However, DAD takes quite a long time with respect to the handover latency.

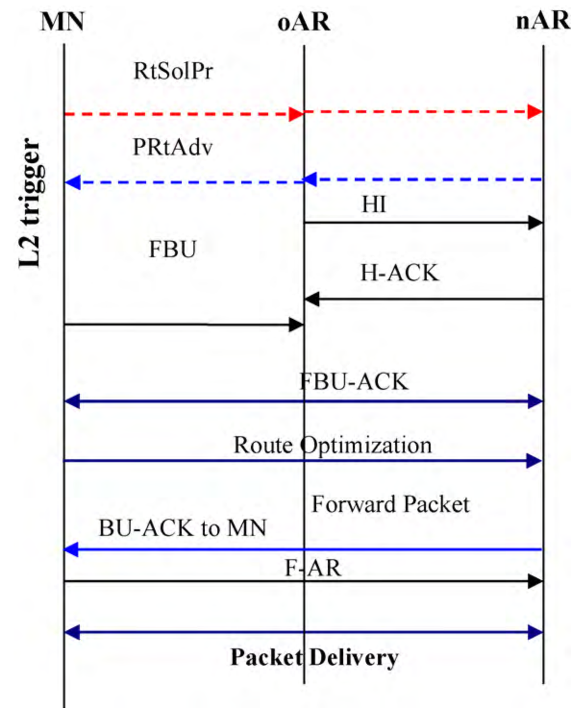

Fig. 1. Message exchange during handover.

In order to perform DAD, the MN has to send one or several neighbour solicitation(s) to its new address and wait for a response for at least 1 s. This implies important additional time to handover latency. For this reason, MN should perform DAD in parallel with its communications, or choose not to perform it.

A modification to the FMIPv6 protocol proposed in (Neighbor Discovery for IP Version 6 (IPv6)) using extra Binding Update (BU) to reduce tunneling time between oAR and nAR. Pre-BU and Pre-Binding Acknowledgement messages are exchanged between MN and (HA/CN) before the Fast BU message is sent to the oAR. Thus, the reverse tunnel between oAR and nAR need not be established.

However, other issues could arise, because two new signaling messages are issued during the critical time of the fast handover procedure, this method could extend the fast handover delay, easily leading to fast handover failure.

An Early Binding Fast Handover (EBFH) (Kim and Kim, 2006), in which an MN performs an early fast BU with its current AR before a trigger that signals MN is closed to handover. The FMIPv6 initiates movement detection through a link-going-down trigger, whereas EBFH completes its BU for the nCoA before the link-going-down trigger.

The idea of EBFH is to provide a fast handover for fast-moving nodes. If the MN moves at high speed, it is turn to the FMIPv6. This requires that, EBFH issues many signaling messages before the link-going-down trigger, so it consumes a large amount of network performance and creates significant useless overhead.

Mobile IPv6 handover proposal (Yegin et al., 2000) from Sun Microsystems addresses latency and packet losses issues associated with Mobile IPv6 handover. This proposal allows a CN to send IPv6 BU with multiple CoA. These include the CoA of the MN's current location as well as the CoA of other APs in the neighborhood that the MN may handover to. This neighborhood is established on a per mobile basis and is based on the network layout and the direction the CN is moving in.

A new message proposed in (Chen and Zhang, 2006), the Router Solicitation for Proxy Advertisement (RtSolPr) message, is utilized by the MN and sent to its current AR to request this information about likely candidate APs. The response by the present AR is called a Proxy Router Advertisement (PRtAdv) messages, containing the neighbouring router's advertisement (including its prefix). As the MN receives this information, it can immediately formulate a prospective new CoA for the new AR, while still present on the old AR's link.

FMIPv6 tries to reduce handover delay by providing fast IP connectivity as soon as MN attaches to a new subnet. To realize this, MN must launch the passive or active scanning process to discover the available AP (Shin and Arbaugh, 2003). According to the probe results, AR provides MN with the corresponding subnet prefix information, and then MN could generate an nCoA when it is still connected to its current subnet. To minimize packets loss, a bidirectional tunnel is set up between oAR and nAR.

Utilizing this tunnel, oAR forwards the packets destined to MN's old CoA to its nCoA, MN could also continue to send packets to CN through oAR. Such tunnel remains active until MN completes a BU with its CNs. However, there are two mains shortcomings in the FMIPv6 protocol.

First; MN could'nt receive or send the data during the probe phase, while it lasts minimum 350 ms (Ramani and Savage, March 2005) furthermore, MN must spend time to re-switch the channel and re-associate with its oAP to exchange the messages with oAR;

Second; DAD process could not be completely avoided if MN's nCoA is not validated by the nAR before MN disconnects with its oAR.

3. Layer 2 Handover

The handover preparation procedure begins when MN moves into the overlapping radio coverage area of two adjacent subnets, it needs to perform a layer 2 handover to bring to an end the association with the oAP and re-associate with new one (Yokota et al., 2002).

This will require some steps such as detection, authentication and re-association with the nAP. Only, after these procedures will finish, higher layer protocols can proceed with their signaling procedure, such as layer 3 router advertisements. Once the MN finishes layer 2 handover and receives the router advertise from the AR, it should begin to obtain a new CoA address (Malki and Soliman, 2005).

4. Anticipated Handover

In anticipated handover, a handover is initiated when either the MN or the oAR have predictive information about the next point of attachment to which the MN will move to (Neighbor Discovery for IP Version 6 (IPv6)). If the MN has such information, or it chooses to force a handover to a new subnet, it sends a Router Solicitation for Proxy (RtSolPr) to the oAR, and receives a Proxy Router Advertisement (PRtAdv) in response, providing the MN with the L2 information, such as the subnet prefix, link quality, measured bandwidth and available attachments status required for the MN to establish a new CoA on the new subnet (Kim, 2005).

When oAR receives an indication from L2 that the MN will be moving or RtSolPr indicating that the MN wants to move, the oAR exchanges messages with nAR in order to obtain or validate the new CoA for the MN. The oAR sends a Handover Initiate (HI) message to the nAR. The HI message contains the requested new CoA on the new subnet.

When the nAR receives HI, it does the following:

- If the HI message does not have a new CoA, it allocates a new CoA.
- If the HI message contains a proposed new CoA, the new AR validates the new CoA.

The nAR replies to the oAR with a Handover Acknowledgement (H-ACK) message containing either the new CoA that allocated with nAR or an indication whether the new CoA proposed by the oAR is valid.

5. Proposed Scheme

The FMIPv6 protocol enables a MN to quickly detect at the IP layer that it has moved to a new subnet by receiving link-related information from the link layer (Chen and Zhang, 2006); furthermore it gathers anticipation information about the new AP, and the associated subnet prefix when the MN is still connected to the previous subnet, the overall messages exchange described bellow:

1. MN will initiate L3 handover by sending RtSolPr message to the oAR, if L2-trigger is received at the mobile-initiated handover, on contrary, the oAR will send PRtAdv to the MN, if the L2-trigger received at the network-controlled handover.
2. MN checks the neighbour cache to determine the link-layer address of the next hop node. The neighbour cache also has an associated state with each neighbour entry.
3. A neighbour is considered reachable if it has recently received confirmation that packets sent to the neighbour have been received.

   This is achieved in different ways, either the receipt of a neighbour advertisement from the neighbour in response to a neighbour solicitation sent by the MN or a hint from upper layer protocols (Kim, 2005).
4. A MN obtains a new CoA in time that still connected to the oAR, before the actual handover occurs, it performs that by receiving a RA included the visited network information from the nAR.

   The oAR will validate the new CoA and sends a HI message to the nAR to establish bidirectional tunnel process between oAR and nAR.
5. The new AR will respond with H-ACK message.
6. MN sends a fast binding update (FBU) to the oAR to update its binding cache with the MN's new CoA.
7. When MN receives a PRtAdv, it has to send FBU-ACK message prior to disconnect its link.
8. After the oAR receives FBU, it must verify that the requested handover is accepted as it was indicate in H-ACK message.
9. The oAR starts forwarding packets addressed for the old CoA to the nAR and sending BU-ACK with fast access router F-AR to the MN.

5.1. Performance Analysis

In this section, we evaluate the performance of the proposed fast handover in Mobile IPv6 (FMIPv6) based link-layer information algorithm. We compare our algorithm against a standard Mobile IP and previous Mobile IPv6. The performance metrics for comparison include the handover latency, packet loss, throughput and handover delay.

5.2. Handover scenario

For the simplicity we assume that there is no change in direction while the MN moves inside the overlapping area. The best possible handover point occurs at position A as shown in Fig. 2.

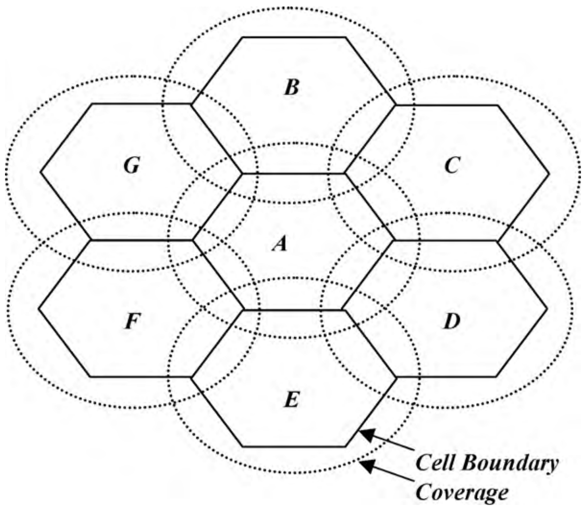

Fig. 2. Overlapping coverage area.

The coverage area can be defined in terms of signal strength; the effective coverage is the area in which MNs can establish a link with acceptable signal quality with the AP. The coverage radius defined as the distance from an AP to its coverage boundary. The cell radius is the distance from an AP to its cell boundary (Table 1).

5.3. Procedure

In the FMIPv6 protocol, when an MN is aware of its movement towards nAR through an L2-trigger, the MN must perform a fast handover procedure. Then, after connecting to the nAR, the MN immediately sends Fast Neighbour Advertisement (*F-NA*) message without the need for route discovery in order to advertise its presence, so that arriving and buffered packets can be forwarded to the MN.

Finally, as in the MIPv6 protocol, in order to complete the handover, the MN must perform home registration with the HA and correspondent registration, including a return routability procedure and BU with the CN.

A fast handover procedure starts when a MN sends an *RtSolPr* message, and ends with the MN receiving Fast Binding Acknowledgement (*FB-ACK*) message on the previous link. In this proposal we use Pi-Calculus to describe the system of making fast handover in Mobile IPv6 based on link layer Information as following:

$$\begin{aligned} System \overset{Def}{\equiv} & \dot{a}\left\langle b\right\rangle (MN(t1,\ s1)|nCN|oCN|HA) \\ & \rightarrow \dot{a}\left\langle b\right\rangle (MN(s1, t1)|\bar{s}1, t2, s2, nCN|oCN) \\ & \rightarrow \dot{a}\left\langle b\right\rangle (MN(t2, s2)|oCN|nCN|HA) \\ & \rightarrow \dot{a}\left\langle b\right\rangle (MN(t2, s2)|nCN) \\ & \cong System \end{aligned}$$

where each of these entities makes the following actions.

Table 1
Simulation parameter.

Simulation parameter	Value
Simulator	Ns-allinone-2.31
Network range	600 m × 600 m and 1000 m × 1000 m
Transmission range	25 m
Mobile nodes	7 and 12
Traffic generator	Constant bit rate
Band width	2 Mbps
Packet size	512 bytes
Packet rate	10 packet per second
Simulation time	900 s

MN will communicate with both old CN (*oCN*) and new CN (*nCN*) to make a successful fast handover.

$$\begin{aligned} MN(s, t, g, l) \overset{Def}{\equiv} & s \cdot nCN(s, t, g, l) \\ & +|Register\ (HI, DiregReq, DisassReq, oCoA, H \cdot Add)| \cdot oCN \\ & |\overline{HI}\langle BU, H \cdot Add\rangle| \cdot nCN \\ & |\overline{nCoA}\langle LinkInformation, TimeToLife, NetworkPrefix\rangle| \cdot MN \\ & |nCoA(Ack) \cdot \overline{Register}\langle H.Ack\rangle| \cdot MN \end{aligned}$$

MN will send a Disassociation Request (*DisassReq*) to the oCN to let it knows that MN will make a handover to nCN:

$$\begin{aligned} oCN(g, l) \overset{Def}{\equiv} & l \cdot CN(g, l) \\ & +|Register(CoA, DiregRep, DisassRep, LinkIdeH \cdot Add)| \cdot MN \\ & |\overline{CoA}\langle LinkInformation, TimeToLife, NetworkPrefix\rangle| \cdot MN \\ & |CoA(Ack) \cdot \overline{Register}\langle Ack\rangle| \cdot oCN \end{aligned}$$

where the CN always uses two processes to communicate with the MN, called Gain and Loss (G, L), including all of other requirements.

$$\begin{aligned} oCN(g, l) \overset{Def}{\equiv} & l \cdot oCN(g, l) \\ & +|(\nu w)\bar{x}\langle w\rangle, \bar{w}\langle y1\rangle, \bar{w}\langle y2\rangle, \bar{w}\langle y3\rangle, \ldots, \bar{x}\langle w\rangle, \bar{w}\langle yn\rangle| \cdot MN \\ & |\bar{w}\langle y1\rangle, y1\langle z1\rangle, y1\langle z2\rangle, y1\langle z3\rangle| \cdot MN \\ & |\bar{w}\langle y1\rangle, (Ack)\ \bar{\nu} w(Ack)| \cdot oCN \end{aligned}$$

Upon the verification of the variables, nCN will send the Acknowledgment (*ACK*) to confirm it is acceptance, then oCN will start sending buffered packet to nCN distend to the MN.

$$\begin{aligned} nCN(g, l) \overset{Def}{\equiv} & g \cdot CN(g \cdot l) \\ & +|Register\ \ (nCoA, RegRep, AssRep, LinkIde, H \cdot Add)| \cdot MN \\ & |\overline{HI}\langle BU, H - Ack\rangle\ | \cdot oCN \\ & |\overline{nCoA}\langle LinkInfo, TimeToLife, Netorkprefix\rangle| \cdot MN \\ & |nCoA\ (Ack) \cdot \overline{Register} \cdot \langle Ack\rangle| \cdot nCN \end{aligned}$$

$$\begin{aligned} nCN(g, l) \overset{Def}{\equiv} & g \cdot CN(g \cdot l) \\ & +|(\nu w)\ \bar{x}\langle w\rangle, \bar{w}\langle y1\rangle, \bar{w}\langle y2\rangle, \bar{w}\langle y3\rangle, \ldots, \bar{x}\langle w\rangle, \bar{w}\langle yn\rangle| \cdot MN \\ & |\bar{\nu}(a), a\langle u1\rangle, a\langle u2\rangle| \cdot oCN \\ & |\bar{w}(y1), y1\langle z1\rangle, y1\langle z2\rangle, y1\langle z3\rangle| \cdot MN \\ & |\bar{w}(y1) \cdot (Ack) \cdot \overline{\nu w} \cdot \langle Ack\rangle| \cdot nCN \end{aligned}$$

Next, HA have four operations which called, Switch, Talk, Gain, Loss (S, T, G, L), to exchange and communicate between both entity MN and CNs:

$$\begin{aligned} HA(s, t, g, l) \overset{Def}{\equiv} & t \cdot HA(s, t, g, l) \\ & +|(BU, nCoA, RouterCache, LocationUp, DisRep)| \cdot nCN \\ & |DisRep\langle Buffer, CacheEntey, CoA\rangle| \cdot HA \end{aligned}$$

$$\begin{aligned} HA(s, t, g, l) \overset{Def}{\equiv} & t \cdot HA(s, t, g, l) \\ & +|x(w), w(y1), w(y2), w(y3), \ldots, x(w), w(yn)| \cdot nCN \\ & \left|\bar{w}\langle yi\rangle \cdot \bar{x}(y)\right| \cdot HA \end{aligned}$$

In this stage HA will get multi input from both, MN and oCN, before the handover executed to the nCN:

$$\begin{aligned} \bar{x}a|xu \cdot \bar{y}u|xu \cdot \bar{z}u \ & \rightarrow \bar{y}a|xu \cdot \bar{z}u \\ & (and\ ,\ or) \\ & \rightarrow xu \cdot \bar{y}u|\bar{z}a \end{aligned}$$

MN will send and receive packets (from/to) nCN and HA:

$$\bar{x}a|xu \cdot \bar{y}u \rightarrow \left\{\frac{a}{u}\right\}(\bar{y}u) = \bar{y}a$$

Value a being sent for the communication between the input and output:

$$\begin{aligned} & a(\bar{x}) \cdot \bar{c}(x)|(ub) \cdot \bar{a}b \\ & (ub) \cdot (a(x) \cdot \bar{c}x|\bar{a}b) \end{aligned}$$

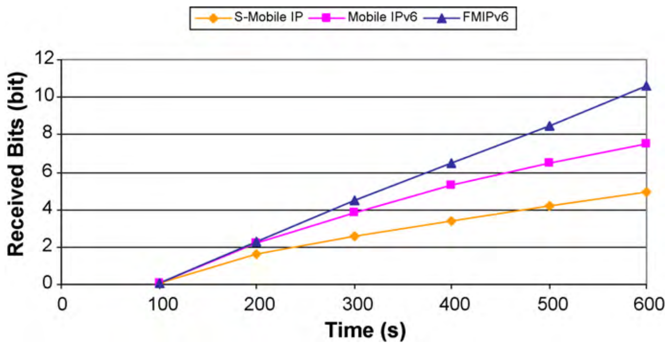

Fig. 3. Handover behavior.

We can see that b has transition between the components, because of:

$$a(x) \cdot \bar{c}x | \bar{a}b \rightarrow \bar{a}b$$

Then, we get

$$(ub) \cdot (a(x) \cdot \bar{c}x | \bar{a}b \rightarrow (ub) \cdot \bar{a}(b))$$
$$In \quad general \quad b \notin fn(P)$$

Finally, MN handover is:

$$a(\bar{x}) \cdot P | (ub) \cdot \bar{a}b \cdot Q \rightarrow (ub) \cdot P\left(\frac{b}{x}\right) Q$$
$$P = a(x)\,(fx = Y, \quad then \quad T + if \quad x = Z \quad then \quad S)$$

This is the actual communication of the Mobile IP handover. When the MN used channel $\bar{a}$ to passing values b between all the entities, oCN, nCN and its local HA.

6. Simulation setup

We use the network simulator CIMS NS-2 version ns2-allinone-2.31 as a simulation tool in order to simulate FMIPv6 handover.[1] It supports routers set in order to reduce unsolicited RA intervals and the addition of the RA interval option as defined in the MIPv6 draft. This will enable CN support for route optimization.

The MN connects to the CN using the ns-2 IEEE 802.11 wireless LAN model. The results were obtained using 7 MNs moving between different neighbouring at speed of 40 m/s, and the overlap area is 25 m.

Fig. 3 shows an example of the uplink MN to CN transmission behavior with six handovers in the unit time of all three schemes Standard Mobile IP (S-Mobile IP), Mobile IPv6 and FMIPv6.

The result graphs show the transmission bit rate of each handover protocol. Handover delay periods are known in both S-Mobile IP and Mobile IPv6, although Mobile IPv6 received more data than that of S-Mobile IP, but both of them show inherent handover delay, this is because of their registration period. On the other hand, FMIPv6 handover shows the highest transmission rate without any delayed period. This is because FMIPv6 uses multi-homing and buffer procedure, which provides fast and accurate data transmission.

Throughput is an important performance metric that measures the transmission ability of a network. The average throughput is calculated as the mean volume of data that is actually delivered to the destination within each time unit. The overall throughput graph for different rates given in Fig. 4, it shows that the throughput increases as the sending rate increases; FMIPv6 performs better than Mobile IP. The reason is that the handover time 3 s does not

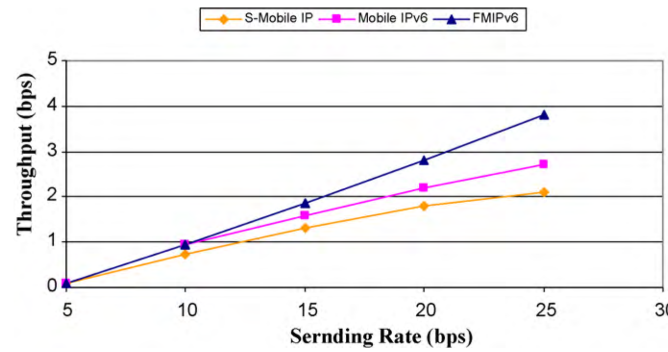

Fig. 4. Throughput vs rate.

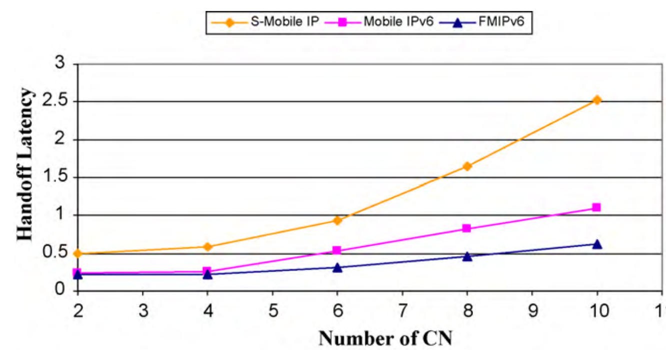

Fig. 5. Impact of simultaneous station on handover latency.

depend on sending rate and the inter-arrival of packets reaches the average value since there is no compensation for packets lost of S-Mobile IP.

Moreover, the reason for the throughput increase is that more packets are sent overall, although the number of packets lost increases as the sending rate increases. Since the number of packets lost is smaller in FMIPv6 as we have seen in instantaneous throughput graph FMIPv6 performs slightly better compared to both Mobile IPv6 and S-Mobile IP.

Figs. 5 and 6 show the increase in the handover latency and the packet loss due to an increase in the number of MNs sharing the wireless channel. The gained results for up to 10 MNs point out that the dominating factor of the handover latency is the wired link delay for a small number of MNs.

As can be seen, FMIPv6 approach performs better in terms of the handover latency and packet loss, although the fast handover protocol is designed to minimize the packet loss and the latency during a handover, a worse performance is observed with respect to S-Mobile IP and Mobile IPv6 protocol when the channel availability arises. Under high load conditions, the additional signaling

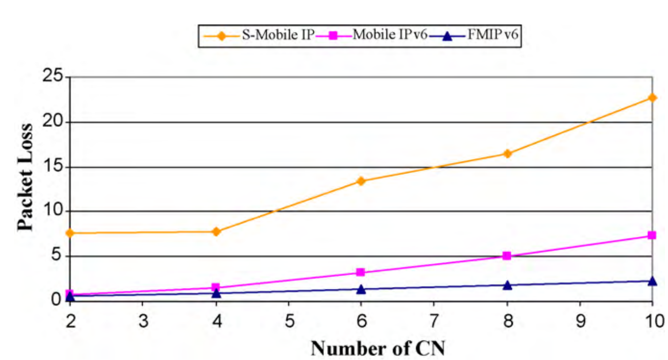

Fig. 6. Impact of simultaneous station on packet loss.

[1] http://tagus.inesc-id.pt/~pestrela/ns2/.

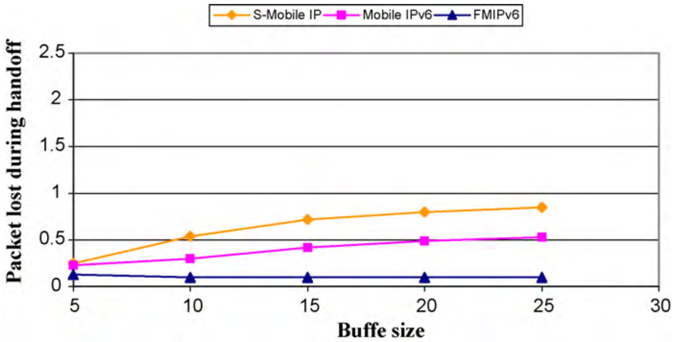

Fig. 7. Packet loss vs buffer size.

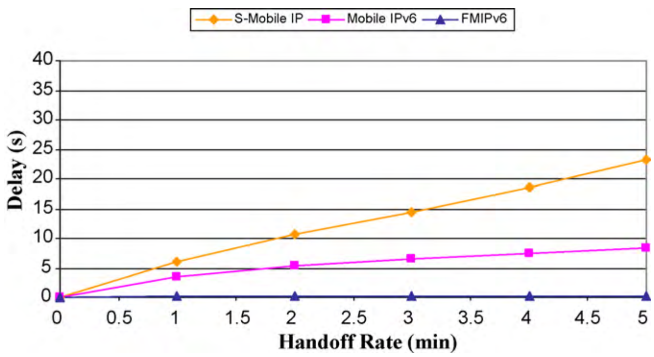

Fig. 8. Total handover delay.

messages of fast handover schemes in the local domain result in reaching earlier the saturation level on the wireless channel.

The number of packets lost depends both on the size of buffer used to store packets for potential handovers and the sending rate as seen in Fig. 7. The number of packets lost is increasing for S-Mobile IP since no buffer is used and increases as the sending rate increases since more packets are sent while MN is unable to receive them during handover.

On the other hand, the number of packets lost decreases as buffer size increases for FMIPv6. This means that the packet loss can be totally eliminated if the buffer size is chosen large enough. Furthermore, this buffer size can be adjustable to the sending rate since the number of packets lost increases as sending rate increases for constant buffer size.

Fig. 8 shows the uplink MN to CN handover delay of S-Mobile IP, Mobile IPv6 and FMIPv6 over handover rate.

Total handover delays versus handover rate shows how the handover delay of each handover protocol reacts when scale of mobility varies, the total handover delays of S-Mobile IP and Mobile IPv6 increase as expected, in contrast, FMIPv6 handover does not incur any delay irrespective of the handover rate. This is due to the fundamental difference between FMIPv6 handover registration procedure and other schemes procedures.

Handover delay of S-Mobile IP and Mobile IPv6 becomes more significant as handover rate increases. As we can see handover delay and handover rate product directly affects the end-to-end throughput and packet loss. Thus, S-Mobile IP and Mobile IPv6 cannot be a proper handover approach in large scale mobility environments. On the other hand, FMIPv6 does not affect any significant throughput decrease nor packet loss by keeping handover delay zero regardless of handover rate.

The partially better behavior for Mobile IPv6 is a consequence of the higher wireless load of the fast handover approach. A higher number of signaling messages sent via the wireless medium yields to a higher channel access delay and higher collision rate, resulting in a lower bandwidth achieved.

7. Conclusion

In this paper, we proposed an enhanced fast handover scheme in Mobile IPv6 by utilizing the link-layer information. In our scheme, we analyzed the performance by simulating the proposed scheme in IST-CIMS NS-2 to get the fast Mobile IPv6 handover performance results in terms of handover latency and packet loss.

We always prepare the new link connection on available network interface whenever the MN detects a new available network. As can be seen, FMIPv6 approach performs better in terms of the handover latency and the packet loss, although the fast handover protocol is designed to minimize the packet loss and the latency during a handover, a worse performance is observed with respect to S-Mobile IP and Mobile IPv6 protocol when the channel availability arises.

This approach can reduce the handover latency as well as can prevent the packet loss. For future work it would be interesting to explore the algorithm for some other mobility models in IPv6 network using neighbours information. We also plan to evaluate the performance of fast Mobile IPv6 in Wimax networks.

References

Chen, H.F., Zhang, J., April 2006. Prep-binding of fast handovers for mobile IPv6. Draft-chen-mipshop-fast-handovers-prep-binding-02.txt. IETF.
Draft IEEE Standard for Local and Metropolitan Area Networks: Media Independent Handover Services, IEEE P802.21/D00.01, July 2005.
Hsieh, R., Zhou, Z.G., Seneviratne, A., 2003. S-MIP: a seamless handoff architecture for mobile IP. In: INFOCOM 2003, Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies, vol. 3, IEEE, 30 March–3 April, pp. 1774–1784.
Johnson, D., Perkins, C., Arkko, J., 2004. Mobility support in IPv6. RFC 3775.
Kim, Y.S., September 2005. Performance comparison of mobile IPv6 and fast handovers for mobile IPv6 over wireless LANs. In: Proceedings of IEEE Vehicular Technology Conference (VTC 2005-Fall), pp. 807–811.
Kim, H., Kim, Y., 2006. An early binding fast handover for high-speed mobile nodes on MIPv6 over connectionless packet radio link. In: Seventh ACIS International Conference on Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing (SNPD'06), pp. 237–242.
Koodli, R., July 2005. Fast handoffs for mobile IPv6. RFC 4068. IETF Network Working Group.
Leung, K., Devarapalli, V., Chowdhury, K., Patil, B., February 2008. Proxy mobile IPv6. Draft-ietf-netlmm-proxymip6-11.txt.
Malki, K., Soliman, H., July 2005. Simultaneous bindings for Mobile IPv6 fast handovers. IETF draft-elmalki-mobileip-bicasting-v6-06-txt.
Mishra, A., Shin, M., Arbaugh, W., 2003. An empirical analysis of the IEEE 802.11 MAC layer handoff process. ACM Computer Communication Review (April).
Montavont, N., Noel, T., 2003. Analysis and evaluation of mobile IPv6 handovers over wireless LAN. ACM Journal on Mobile Networks and Applications (MONET) 8 (November (6)).
Montavont, N., Thomas, 2002. Handover management for mobile nodes in IPv6 networks. In: IEEE Communications Magazine, August 2002. Louis Pasteur University, CNRS, Strasbourg.
Neighbor Discovery for IP Version 6 (IPv6), IETF Draft IPv6-2461bis-10. Work in Progress, June 2007.
Ramani, I., Savage, S., March 2005. SyncScan: practical fast handoff for 802. 11 infrastructure networks. In: Proceedings of the IEEE Infocom Conference, Miami, FL.
Shin, M., Arbaugh, W., 2003. An empirical analysis of the IEEE 802.11 MAC layer handoff process. ACM Computer Communications Review 33 (April (2)).
Yegin, A., Parthasarathy, M., Williams, C., September 2000. Mobile IPv6 neighborhood routing for fast handoff. Internet Draft, draft-yegin-mobileip-nrouting-00.txt. Work in Progress.
Yokota, H., Idoue, A., Hasegawa, T., Kato, T., 2002. Link layer assisted mobile IP fast handoff method over wireless LAN networks. In: Proceedings of the 8th Annual International Conference on Mobile Computing and Networking, pp. 131–139.

Mohamed Alnas received his BSc from Sabha University, Libya (2004) and MSc in Distributed Computing (Computer Science) from USM University, Malaysia (University of Science Malaysia), (2006). He served for one year as a lecturer in the Computer Science Department, Naser Nationalism University, and as an employee at L.T.T Communication Company, Libya. He joined Performance Engineering and Networks Research Group, University of Bradford in 2008 as a PhD student.

Irfan Awan received his BSc from Gomal University, Pakistan (1986), MSc (Computer Science) from Qaid-e-Azam University, Pakistan (1990). He served for three years as a lecturer in the Computer Science Department, BZ University Pakistan and then joined Performance Modelling and Engineering Research Group, University of Bradford in 1993. He received his PhD from the Department of Computing, Bradford University, UK (1997). During his PhD studies, he developed cost effective

approximate analytical tools for the performance evaluation of complex queueing networks.His research mainly focused on service and space priorities in order to provide quality of service and to control the congestion in high speed networks. In 1998 and 1999, he spent summer terms with the Performance Modelling Group, University of Bradford. In 1999 he joined the Department of Computing, University of Bradford as a Lecturer and is a module coordinator for "Concurrent and Distributed Systems" and "Intelligent Network Agents".His recent research lies in developing analytical tools for the performance of mobile and high speed networks. He has been a member of organising committees for several IFIP workshops held in Ilkely, Bradford. He is also a member of Programme committees for several international conferences and reviewer of several international journals. He has completed PGCHEP from the University of Bradford in 2002 and is a fellow of HEA. He is also member of BCS, IEEE and UK Simulation Society

Rob Holton is a lecturer in the School of Computing, INformatics and Media, University of Bradford, UK. He is also a Director of Postgraduate Research. Dr Holton's expertise lies in formal modelling of computational systems. From early work in modelling production cells he has investigated a range of applications and is currently focussing on interactive systems such as web services.