Improvement of FMIPv6 handover performance using MIH and timely link layer triggers

Sabelo Dlamini, *MIEEE*; Mqhele Enock-Hershal Dlodlo, *MIEEE*
Department of Electrical Engineering
University of Cape Town, Private Bag, Rondebosch, 7701
Tel: +27 650-2813, Fax: +27 650-3465
email: dlaminis@crg.ee.uct.ac.za; mqhele.dlodlo@uct.ac.za

Abstract- The Mobile IPv6 for Fast Handovers (FMIPv6) solution aims at reducing the handover latency and packet loss experienced in MIPv6. It achieves this reduction by applying fast movement detection and fast binding update procedures. However, handover latency in this FMIPv6 solution is still not sufficient for active ongoing real-time and time-sensitive applications. In fact, this latency results in packet loss hence cause service disruption during the handover period. We propose to address this drawback by using predictive link layer triggers in conjunction with IEEE 802.21 Media Independent Handover (MIH) services to facilitate an enhanced FMIPv6 handover. The obtained simulation results show that the proposed scheme enhances handover performance in terms handover latency and packet end-to-end delay.

Index Terms— Handover latency, link-layer triggers; Least Mean Square; MIH

I. BACKGROUND

Among many proposed mobility management solutions, Mobile IPv6 (MIPv6) [1] has been proposed as the standard to solve the problem of mobility. It does this by redirecting packets for the mobile node (MN) to its current location. In MIPv6 the period during which the MN looses connectivity with its current link until the time it receives the first packet after connecting to the new link is known as handover latency. The overall handover latency in MIPv6 consists of Layer 2 (L2) handover latency and Layer 3 (L3) handover latency. L2 handover latency is the period when the MN is disconnected from the air-link to the current Access Router (AR) until the time it connects to the air-link of the new AR [1]. In L3 handover, there are latencies incurred due to the processes of movement detection, Care-of-Address (CoA) configuration and Binding Updates (BU). The handover latency incurred by MIPv6 is intolerable for time sensitive and real-time traffic [2], since the MN is not able to send or receive traffic during this interval.

Various protocols have been proposed to optimize handover latency in MIPv6 e.g. Fast Handovers in MIPv6 (FMIPv6) [2] being one of them. FMIPv6 protocol has been designed to reduce handover delays incurred due to movement detection, Care-of-Address (CoA) acquisition and binding update (BU) events. This is done with the aid of anticipation based Layer 2 (L2) trigger information as well as by obtaining the subnet prefix information from the New Access Router (nAR) while the MN is still connected to its current/old Access Router (oAR). In order to form a new CoA, FMIPv6 relies on the oAR to resolve the network prefix of the nAR based on the L2 identifier reported from the MN.

The anticipation mechanism specified by FMIPv6 suffers from the problem of timing hence it may cause the handover process to start earlier or later than the actual handover. This reduces the certainty about the MN's movement. Also sudden degradation of the wireless link during the handover initiation phase may cause the MN to lose connectivity with the oAR. In this case, if the handover anticipation time is large, then the MN may not have sufficient time for new CoA (NCoA) configuration while being attached to the oAR's link. Consequently, there would be long handover latencies.

II. RELATED WORK

Timely execution of handover decision plays a vital role in handovers, particularly in heterogeneous networking environments. Various handover solutions have been proposed to reduce handover delays, but there are still issues that need to be addressed in this area. Song et al. in [3] identifies the issues that are affecting the handover latency in the predictive mode of FMIPv6. It shows that the ambiguous link layer triggering timing, the lack of assistance from the network layer entities, and the inefficient interaction between the link layer and the network layer are the primary causes of large handover latency.

The work by Pyo et al. in [4] proposes a prediction algorithm to counteract the problem of timely link layer triggering. Pyo et al. uses Fast Exponential Smoothing, while Xiaoyu in [5] use FFT the prediction algorithm to predict the decay of the received signal strength. Different prediction schemes have been used as prediction algorithms such as Neyman-Pearson in [6] and artificial intelligence in [7]. In this paper we are going to use Least Mean Square which is defined in [8]. However, any other prediction algorithm can be used to provide the RSS prediction capabilities in the scheme.

As it is always desirable to have a standardized method to handle mobility across heterogeneous networks in a efficient manner. The MIH was designed to be such standard that can be used across different heterogeneous networks to provide seamless handovers. In this paper MIH is going to be adopted for heterogeneous network discovery and selection.

The link layer triggers are used to communicate link layer events to the network layer and the layers above. Link layer events include the anticipation and execution of a host association and disassociation with the current link. The link layer triggers have been well defined in [9] and [10]. There are numerous schemes that have been proposed to provide more definitive L2 triggers to reduce handover delays in FMIPv6. References [11] and [12] use the MIH services to provide timely L2 triggers.

The work in reference [13], also MIH Information Service to obtain the information that helps it predict the target cell for the MN. They use this information to advance the Link Going Down trigger in order to prepare for the handover in advance. The issue with this work is that it uses GPS based information which can be resourceful to an MN compared to our proposed scheme. In addition to this after generating the Link Going Down trigger in advance they do not take into consideration the timing impact that may cause handover to be generated to early.

III. MOTIVATION

The goal of this work is to propose a predictive handover scheme. This scheme will use the IEEE 802.21 for network discovery and the most optimal prediction algorithm to timely generate the L2 triggers. This will be used to ensure that all the L2 triggers are executed at the right time and increase the probability of FMIPv6 to be executed in a proactive mode. This will be done by estimating the required handover time for given neighbour network conditions. Then using the predictive L2 triggers the handover will be started at a time that is dynamically calculated to minimize the handover latency.

IV. PROPOSED SCHEME

This section outlines the operations of the proposed scheme. The first part defines the implementation of the proposed scheme in the MN. The second part previews the operation of the scheme in facilitating the handover process.

Our proposed scheme employs the cross-layer approach to enhance FMIPv6 handover performance. Figure 1 below illustrates the architectural framework of the proposed scheme. The basic idea of the scheme involves utilization of both link layer and network layer information to facilitate the handover process.

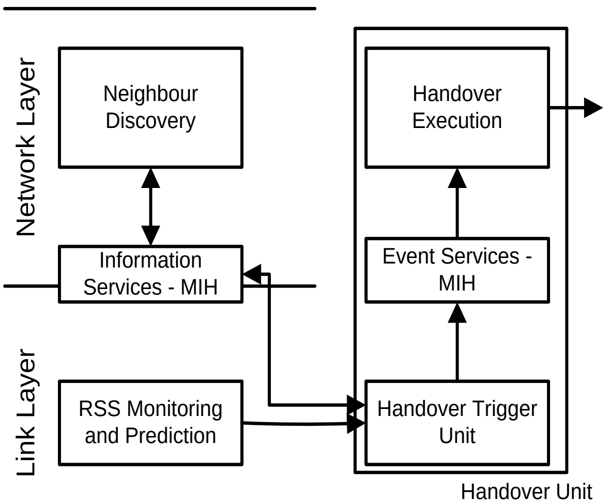

Figure 1: System Architecture

As can be observed in Figure 1, the proposed scheme consists of 4 cooperating modules to improve handover performance. The modules' functions are briefly discussed next.

The Neighbour Discovery module collects and stores both dynamic and static network layer information. The information include e.g. neighbouring PoAs addresses, authentication information etc. This module utilizes the MIIS functionality of the MIH services to achieve its aim, which involves providing information that will facilitate network selection.

The Handover Trigger module gets the information from the Neighbour Discovery module and processes it based on defined prediction algorithms and thresholds, which ensure timely triggering of the handover process. Since network conditions are very dynamic, the operations of the Handover Trigger module also rely on the latest link layer information it gets from the RSS Monitoring and Prediction module to make timely and well-informed handover triggering decisions. Based on the information the Handover Trigger has obtained from the Neighbour Discovery and RSS Monitoring and Prediction module, it estimates the delay associated with either horizontal or vertical handover. In effect, the Handover Trigger module is able to estimate the appropriate time to start the handover process. We implement an LMS prediction algorithm to ensure that the Handover Trigger efficiently performs its function.

The RSS Monitoring and Prediction, on the other hand, concentrates on obtaining dynamic link layer information that has an impact on handover decisions, in particular the dynamic RSS. It observes the behavior of the RSS with respect to same dynamically set threshold and sends the output to the Handover Trigger module as required.

Finally, the Handover Execution module, executes the command it receives from the Handover Trigger module. In fact, the Handover Execution module implements FMIPv6, which is triggered to timely start the handover procedures at the handover initiation time estimated or predicted by the handover triggers module. Figure 2 below shows a flow chart that illustrates the basic operation principle of our proposed scheme as explained above.

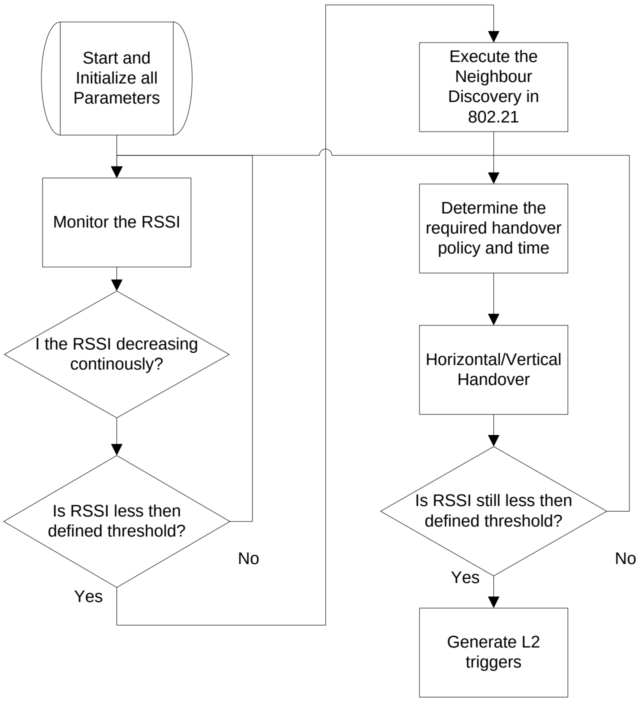

Figure 2: Proposed Scheme Flow Chart

As can be seen from Figure 2 above, after initialization, the RSS Monitoring and Prediction continually observes the RSS with respect to dynamically set threshold. The threshold is dynamically set based on the current network condition. For example, if the conditions are poor, the threshold is correspondingly and proportionally increased. Likewise, when the conditions are good, the threshold is correspondingly and proportionally reduced. In effect, the RSS Monitoring and Prediction module, predicts the next set threshold on the current network conditions or RSS.

The outcome of the RSS Monitoring and Prediction is then passed on to the Handover Trigger module. The Handover Trigger module also gets network-related information from the Neighbour Discovery module. Based on this information, the Handover Trigger module determines the most suitable network to handover to, i.e. whether is horizontal or vertical handover, as well as the expected time the handover will take. The Handover Trigger module constantly checks the inputs from the Neighbour Discovery and RSS Monitoring and Prediction modules to ensure that it is always up-to-date in the estimation it makes, otherwise a rollback to the handover events is also possible.

After the estimation of the time required for the handover as well as the type of handover required, it sends a command for handover initiation to the Handover Execution module in a timely manner to ensure that the handover starts and finishes as per estimation, hence ensuring minimal handover and packet loss.

The implementation of the cross-layer scheme to optimize the performance of the FMIPv6 has been outlined. Also the details of each component and its relation to other modules in terms of the operation to reduce the handover delay in FMIPv6 handover.

V. Simulation Results

In this section the performance of the proposed scheme is evaluated through simulations. The handover delay, packet loss and the end-to-end packet delay is analyzed for the proposed scheme. The proposed scheme is compared with FMIPv6.

Figure 3 shows the simulation setup, which is set in area of 3000 by 3000 meters in the ns-2 simulator platform with the NIST mobility module. In the simulation the TCP traffic is used to evaluate the handover delay and packet loss, and the UDP traffic is used to evaluate the end-to-end packet delay. The packet intervals are fixed to 0.05s for all simulations. The wired link between the router and the gateway are 100Mb with link delays of 30ms. The MN moves linearly from AP1 towards BS2 past BS1 at a constant speed of 1m/s, effectively experiencing two handover; AP1-to-BS1 vertical and BS1-to-BS2 horizontal handover, and on its return trip it then makes four handovers. These handovers are shown in Figure 4.

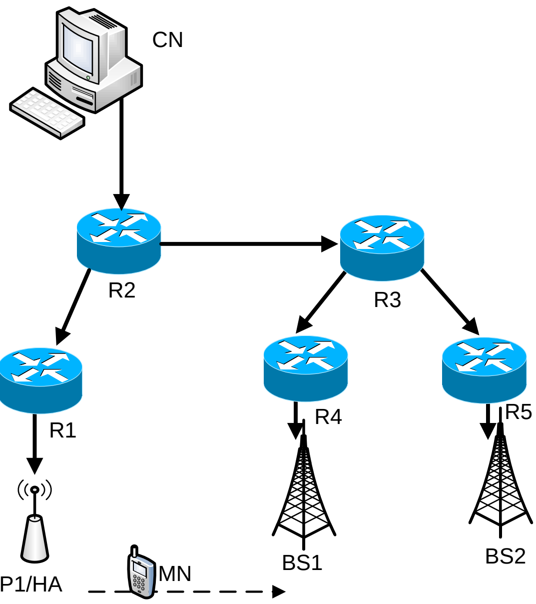

Figure 3: Simulation Setup

Figure 4 depicts the handover delay performance obtained when our proposed scheme is incorporated in FMIPv6 and when it is not. For clarity in the diagram, we shifted the graph obtained by our proposed scheme upwards in the Packet ID scale, to avoid the graphs from appearing on top of each other.

Figure 4: Handover Latency

As can be observed, the gaps in the graphs represent the handover periods and correspond to the handover delays. Thus, around 50s a vertical handover from WiFi to WiMax was experienced and the handover delay encountered in our proposed scheme was about 3.18s while that obtained for FMIPv6 was about 3.21s. In the second gap is the horizontal handover which is discussed below and the other subsequent handovers in the return trip of the MN.

The horizontal handover though was about 0.4s, shown in Figure 5, in our scheme while it was 7.7s for FMIPv6. The reason for longer handover delay in FMIPv6 can be attributed to the fact that it was not well prepared for the handover and that it had to perform the handover procedures sequentially, e.g. scanning which its value varies and contribute much of the time in the handover process. Our scheme on the other hand reduces this processing delay due to preparedness by early prediction and accurate estimation of the time to start the handover process while the MN is still connected to the old network.

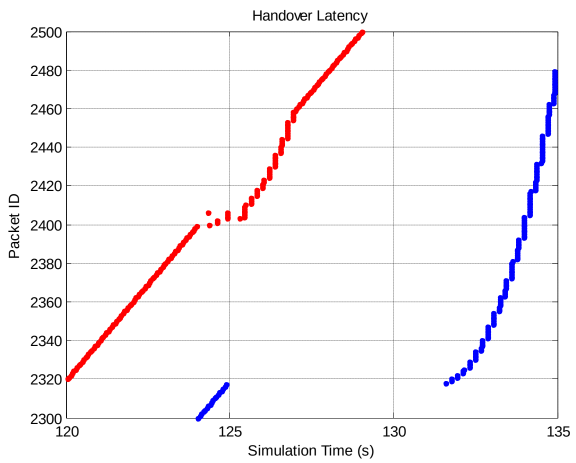

Figure 5: Proposed Scheme Handover Delay

In addition to the time that the MN is not able to send or receive traffic, the handover delay there is also packet loss which also contributes to service disruption during the handover. Packet loss is defined as the number of packets that were lost due to the handover of the MN. This factor highly depends on the timing of handover processes and the optimal utilisation of resources such as the packet buffer in the NAR.

Furthermore, the arrival pattern of packets is dependent on many factors, including application characteristics, network queuing behaviours, etc. Hence, packets may arrive at the NAR before the MN is able to establish its link there. These packets will be lost unless they are buffered by the NAR. Similarly, if the MN attaches to the NAR and then sends an FBU message, packets arriving at the PAR until the FBU is processed will be lost unless they are buffered.

This is evident if the handover is executed too early, because the packets start to be redirected to the NAR buffer from the PAR early. This causes buffer overloading and then the packet loss. On the other hand, if the handover is generated too late, the handover process may be in the risk of failure. As our proposed scheme defines the timing of the handover events, it provides optimal utilisation of the NAR buffer. This allows enough time for packet retransmission and reduction of packet loss. It can be shown in Table 1 that our proposed scheme has been able to reduce packet loss regardless of the handover delay. In each handover case the proposed scheme has been able to reduce the packet loss compared to FMIPv6.

Table 1: Packet Loss

Packet Loss				
Handover	1	2	3	4
Proposed	91	7	6	7
FMIPv6	92	51	76	60

The time it takes for a packet to move from the source to the destination also plays a vital role in providing uninterrupted service during the handover. In this case we also analysed the performance of our proposed scheme based on the time it takes for a packet to move from the CN to the MN, and how this is affected during the handover period. When calculating packet end-to-end delay each packet is traced from the CN to the MN and then the time it took the packet to reach the MN is recorded. Figure 6 and Figure 7 display the packet delays in FMIPv6 and in the proposed scheme, respectively. The packet delay is the time it takes for the packet to move from CN to MN. As each wired link has the delay time of 0.03s between the node and the distance from the CN to the PAR is equal to two hops the sum of the delay is 0.06s plus some negligible 802.11 latency. Also in the NAR the wired hops introduce the delay of 0.03s which adds up to 0.09s plus the negligible 802.16 latency. This packet delay does not remain constant it change during the handover. The handover affects the packet delay through packet buffering, re-ordering, redirection and TCP re-transmission during or after the handover.

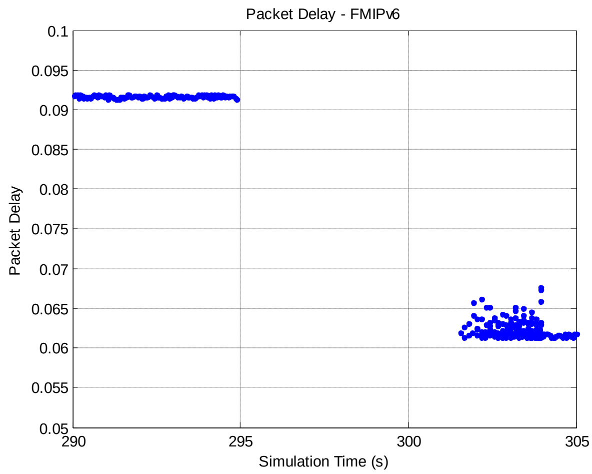

Figure 6: Packet Delay FMIP

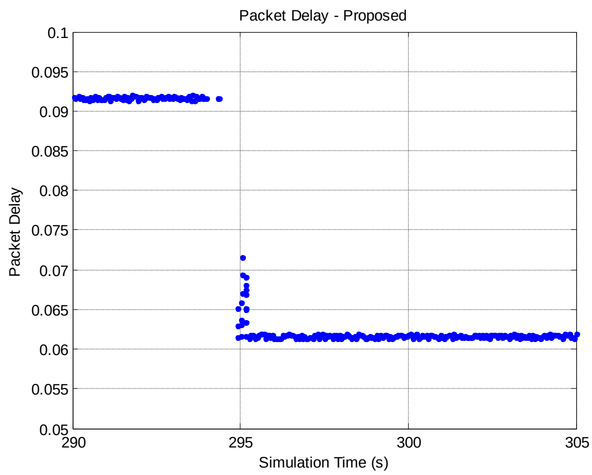

Figure 7: Packet Delay Proposed

The aim of the scheme is to overcome these factors that affect handover. In Figure 6 and Figure 7 the packet end-to-end delay is observed. The average packet delay to reach the MN while it is connected to BS1 is 0.092s. The factors contributing to this delay are defined above. As the MN moves back towards AP1 it experiences a handover at around 295s. The handover occurs earlier in the proposed scheme, but it also finishes earlier. This allows for optimal buffer as the MN receives the buffered data packets as soon as it connects to the NAR. This reduces packet congestion and buffer overload which may lead to packet loss. In FMIPv6, there is much utilisation of the buffer. This causes packet re-ordering and buffer congestion which subsequently lead to packet loss. This even causes the packets that are sent to the MN when it has already connected to the NAR to be delayed as the system will still be dealing with the buffered packets.

The proposed scheme, on the other hand, has been able to overcome the packet delay challenge. It can be noted that during the handover period there are fewer packets that took more than the average packet delay of 0.062s to reach the MN when it is connected to the NAR. This demonstrates the improved handover performance of the proposed scheme during handover. The proposed scheme has been able to reduce the effects of packet buffering, re-ordering, redirection and TCP re-transmission during or after the handover.

VI. Conclusion and Future Work

The FMIPv6 reduces the long handover latency and high packet loss of MIPv6 by fast movement detection and fast binding update. But it suffers from uncertain additional anticipation time imposed by link layer trigger, especially for delay-constrained real-time traffic such as VoIP. We utilize use predictive link layer trigger with information from the MIH's information services to overcome this challenge.

In this paper we proposed scheme to optimize the performance of FMIPv6 during the handover. The proposed scheme is implemented in ns-2 and the results obtained are shown and discussed. The results have shown that the proposed scheme performs much better than the current FMIPv6 protocol. The proposed scheme achieves much shorter handover latency, lower packet loss and lower end-to-end delay. The proposed scheme has been able to reduce the effects of packet buffering, re-ordering, redirection and TCP re-transmission during or after the handover.

VII. References

[1] D. Johnson, C. Perkins and J. Arkko "Mobility Support in IPv6", RFC 3775, June 2004

[2] R. Koodli, "Mobile IPv6 Fast Handovers", IETF RFC 5268, July 2009

[3] Yilin Song, Min Liu, Zhongcheng Li, Qi Li "Handover Latency of predictive FMIPv6 in IEEE 802.11 WLANs: A cross Layer Perspective" International Conference on Computer Communications and Networks, 2009

[4] S. Pyo and Y. Choi, "A Fast Handover Scheme Using Exponential Smoothing Method" , February 2009

[5] Xiaoyu Cheng, Duyan Bi "Real-time Adaptive link layer Trigger based Cross Layer Fast Handoff Mechanism in 802.11 WLANs" International Conference on Communication Software and Networks, 2009

[6] Tara A. Yahiya, Hakima Chaouchi "An Optimized Handover Decision for Heterogeneous Wireless Networks" PM2HW2N, October, 2009

[7] Jing Nie, Liaoyuan Zeng, Jiangchuan Wen "A bandwidth Adaptive Fuzzy Logic Handoff in IEEE 802.16 and IEEE 802.11 Hybrid Networks" International Conference on Convergence Information Technology, 2007

[8] S. Haykin and B. Widrow, "Least-Mean-Square Adaptive Filter Theory," John Wiley & Sons, Inc., 2005

[9] IEEE Std 802.21^{TM} , Amendment 1: Security; Part 21:Media Independent Handover Services. 17 Nov. 2009. URL: https://mentor.ieee.org/802.21/dcn/09/21-09-0179-00-0sec-tentative-ieee-21a-document structure-1.doc

[10] Vivek Gupta, David Johnson"A Generalized Model for Link Layer Triggers," Intel Corporation. March 2004

[11] Yong-Sung Kim, et al."Seamless handover support over heterogeneous networks using FMIPv6 with definitive link layer triggers," Springer Science+Business Media B.V. 2007

[12] S. Woon, N. Golmie, Y.A. Sekercioglu, "Effective Link Triggers to Improve Handover Performance", IEEE PIMRC06, pp.1-5, 2006

[13] Inwhee Joe and MinChul Shin "A Mobility-based Prediction Algorithm with Dynamic LGD Triggering for Vertical Handover" IEEE CCNC 2010
[14] The Network Simulator - ns-2, http://www.isi.edu/nsnam/ns/

Sabelo Dlamini (S'09) completed his BScEng (Computer) degree at the University of KwaZulu Natal in 2007. He joined the Communications Research Group at the University of Cape Town as a Telkom Centre of Excellence student where he is currently working towards his MScEng (Elec) degree. His research interests are in Mobility Management in the Next Generation Wireless Networks.

Mqhele Enock-Hershal Dlodlo, (M'88) he is an Assoc. Prof., at the University of Cape Town, He completed his PhD at Delft University in 1996. He researches on wireless personal communication systems and applications. Prof. Dlodlo's international experience spans maintenance engineering, curriculum design, teaching, research, heading departments and faculties between 1980 and 2004. He is a 2003 Fulbright Visiting Scholar alumnus.