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Optimised Heterogeneous Handover in Mobile IPV6 Using Enhanced Predictive Fast Proxy with Media Independent Handover (MIH) Support

Aliyu Aminu Abdulhadi[1*], Nura Mukhtar[2]

[1,2] Department of Computer Science, Umaru Musa Yaradua University Katsina, Katsina State. Nigeria.

**corresponding author: (aliyu.abdulhadi@umyu.edu.ng; ORCiD: 0009-0006-9011-861x)*

Abstract - In wireless networks, handover performance is essential for enabling real-time traffic applications. Long handover delays make it impossible for a Mobile Node (MN) to send and receive data packets, which is very undesirable for real-time applications like video conferencing and VoIP. Therefore, in order to guarantee better handover performance, decreasing handover duration is crucial. The Internet Engineering Task Force (IETF) has standardized Fast Proxy Mobile IPv6 (FPMIPv6) as an enhancement to the novel Proxy Mobile IPv6 (PMIPv6) to attain better handover performance. FPMIPv6 functions in two modes: predictive and reactive, using a link-layer triggering mechanism. The predictive mode uses link-layer triggers to improve FPMIPv6's handover performance. However, FPMIPv6 experiences packet loss, signalling overhead and unable to manage heterogeneous handovers effectively because it needs a unified Layer 2 triggering mechanism which could result in handover accomplishment either early or late. Consequently, this research, provide an incorporation between FPMPV6 with MIH by expanding its current standard services. In addition, a new predictive handover architecture that generate timely link triggers using information from adjacent network was implemented, enabling crucial handover operations to finished prior to the present link deteriorating. And used piggyback technique to reduce signalling overhead. Performance analysis using simulations indicates the pro-FPMIPv6-MIH achieved improved handover performance, particularly in decreasing handover delay, packet loss and signalling overhead.

Keywords— Handover, Mobility Protocols, Proxy Mobile IPv6, Fast Proxy Mobile IPv6, Media Independent Handover

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1. INTRODUCTION

As wireless technologies like Wi-Fi, WiMAX, LTE, and 5G have advanced, reliable service continuity and seamless mobility support have become essential for mobile nodes moving between locations. The proliferation of these technologies has led to a large growth in mobile devices with a variety of wireless communication capabilities [1]. The Mobile IPv6 (MIPv6) protocol was introduced to enable mobility across access networks on the internet.

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However, its lengthy handover latency leads to packet loss and service interruptions, significantly degrading the perceived Quality of Service (QoS) in real-time applications. IETF has released other protocol called PMIPv6 via Mobile Access Gateway (MAG) to accomplish the mobility-related operations on behalf of MNs, also it lessens handover delay and signalling cost compare with the earlier results [2]. PMIPv6 was enhanced using fast handover mechanism, recognised as Fast handover for PMIPv6. Nevertheless, handovers [3] sometimes lead to latency in link layer shifting and/or network layer mobility that could disrupt existing facilities which is inappropriate for time critical and streaming application. Smooth handovers want suitable information that exactly describe the network situations so that proper actions can be occupied. To enhance the efficiency of handover task such as beginning and effecting of fast mobile IP processes, layer 2 information is crucial to network layer and above [4]. Therefore, efficient link layer trigger mechanisms and timely link trigger firing are critical in deciding if the handover is successful and can have a considerable impact on handover performance [5]. In addition, to facilitate diverse handover, IEEE offered MIH framework (IEEE- 802.21) to be implemented in heterogeneous architecture to improve fast and seamless connection when a mobile node changes its point of attachment. Media independent handover has the capability to minimise power consumption and optimise network selections [6].

In this paper, a novel predictive handover framework is implemented leveraging neighbour network information to create appropriate link starts to ensure essential handover process is completed effectively before the current link becomes unavailable and proposes an incorporation of FPMIPv6 with media independent handover via expanding current media independent handover standards services. Furthermore, piggyback procedure to diminish the signalling overhead was used. The rest of this paper is organised as follows. Section 2 introduces PMIPv6, FPMIPv6, MIH, and examines the related work. Section 3 defines the proposed incorporation model of FPMIPv6 with media independent handover. Section 4 evaluates its performance and compares it with previous solutions, Section 5 summarises the work.

2. LITERATURE REVIEW

2.1 Overview of PMIPv6

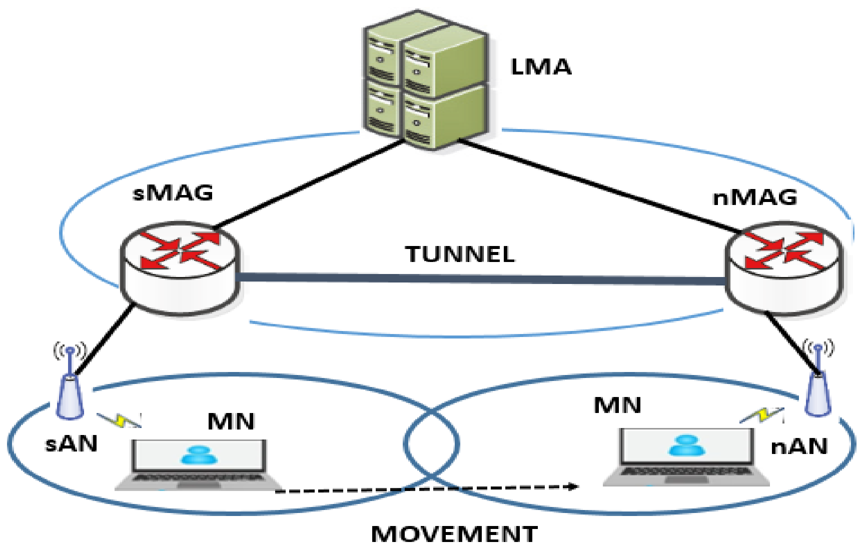
Mobility support for a Mobile Node within local domain is made possible by PMIPv6, which is effective protocol future wireless networks. By expanding MIPv6 signalling messages and utilizing Home Agent (HA) functions, PMIPv6 enables mobility without the need for host interaction, in contrast to MIPv6 [7]. In PMIPv6, the two key useful entities are the MAG and the Local Mobility Anchor (LMA). The MAG is in charge of discovering the MN movement also runs on the Access Router (AR). To transfer data packets intended for the MN, [8] it creates a tunnel with the LMA and starts mobility-related communication with the LMA on the MN's behalf. For smooth communication, the MAG also duplicates the MN's home network inside the access network. The LMA acts as the HA for an MN in a PMIPv6 domain, much as the HA in MIPv6. Its key responsibilities include allocating a Home Network Prefix (HNP) to provide continuous connectivity, managing the MN's position when it moves inside the domain, and keeping a binding cache entry for every registered MN. However, PMIPv6 has a lengthy handover because it is solely intended for local mobility management. However, since PMIPv6 is designed only for local mobility, it experiences prolonged handover delays and packet loss when MN travels to a new network or transitions between diverse technologies at high speeds [9]. Furthermore, detecting the connection and disconnection processes of an MN continue to pose challenges in numerous wireless networks, leading to increased handover latency and the inevitable loss of in-flight packets at the new MAG (n-MAG).

2.2 Overview of FPMIPv6

Serving MAG (sMAG) predicts mobile node's handover and proactively forwards data packets to new MAG (nMAG) in FPMPV6 before mobile node connects to newAN (nAN). Through eliminating the registration and authentication process of nAN, the MN can receive data packets instantly upon attachment. This drastically lowers packet loss and handover latency. A bi-directional channel is created among the sMAG and nMAG via the HO-Initiate procedure in order to accomplish this improvement. Predictive and reactive are the two modes of operation for FPMIPv6.In Predictive handover of FPMIPV6, it creates a temporary tunnel between the serving MAG and new MAG and continues forwarding packets [10] once the MN determines the Expected Signal Strength (ESS) from serving access network drops below a certain threshold. After finding a nAN via scanning neighbouring ANs, the MN notifies the sMAG with the nAN Identifier and its MN-ID. After getting report, sMAG exchanges Handover

Acknowledgment and Handover Initiate messages with nMAG to start tunnel setup. All packets intended for MN are sent from the sMAG to the nMAG via the channel. To minimise packet loss and handover latency, nMAG sends the tunnelled packets to MN [11] as soon as the MN establishes a successful linking with the nAN. This feature allows the mobile node to retrieve data upon attachment, without any delay, and supports a seamless fast handover.

Figure 1 depicts the signalling call flow for predictive handover. The procedure follows a series of steps, as outlined below.



sAN, Serving Access Network
AN, new Access Network
MN, Mobile Node
sMAG, Serving Mobile Access Gateway
nMAG, new Mobile Access Gateway
LMA, Local Mobility Anchor

Figure 1. Signalling of Fast Proxy MIPV6 [12]

a. The mobile node perceives signal strength from serving Access Network (sAN) has dropped under predefined verge. It then examines neighbouring AN then pushes mobile node id plus new access network id to sAN.
b. The serving access network pushes a Handover Signal message containing MN-id plus nAN id to sMAG.
c. Serving MAG determines nMAG based on the nAN id and drives Handover Initiate message to nMAG.
d. The new MAG responds to the serving MAG via forwarding handover Acknowledgement message.
e. A bi-directional channel is created amongst serving MAG and new mobile access gateway, allowing packets intended for the mobile node to be sent from the serving MAG to the nMAG.
f. Serving MAG send Handover Command message, signalling that handover is prepared at the network level
g. Mobile node detaches from the serving access network.
h. Mobile node attaches to nAN, which then instigates a link with nMAG
i. New MAG delivers the channelled packets to the MN
j. Uplink packets from mobile node are transmitted to sMAG through the nMAG, after which sMAG forwards them to local mobility anchor.
k. The new MAG transmits PBU message to local mobility anchor.
l. Local mobility anchor sends PBA message to nMAG.
m. Data packets towards and backwards of MN are transmitted through nMAG instead of sMAG

2.3 FPMIPv6 Problems

Fast handover specifies signalling message formats to minimise packet loss and handover time. Nonetheless, for general deployment and implementation, it needs to take certain access technologies and link-layer activities into account [12]. As a result, it still faces the following challenges.

- Events are triggered when handover is not defined. For instance, FPMIPV6 does not provide a detailed description of the procedure; instead, it only notifies of the impending handover in PMAG-initiated mode through a report message.
- An insufficient candidate network selection and discovery process may cause handover letdown.
- The absence of a comprehensive handover accomplishment process and link-layer-specific works. It also lacks application context awareness and fast authentication mechanisms, resulting in increased handover latency, packet loss, and signalling overhead—especially in mixed-network environments like Wi-Fi to LTE.
- To address these challenges, FPMIPv6 should integrate additional tools to possess diverse handovers [12, 13].

2.4 Overview of MIH

MIH is a standard developed by the IEEE 802.21 working group for transparent continuity thru group of handovers, facilitating functions and Service Access Point (SAP) towards improving handover process between different IEEE 802 systems. It establishes extensible media access independent methods and makes it easier for IP sessions to migrate between layer 2 (L2) access technologies ensuring seamless and efficient connectivity. MIH services can offer a range of signalling to improve the handover's performance. The three main 'MIH services' defined in IEEE 802.21 are Media Independent Events services (MIES), Media Independent Commands services (MICS), and Media Independent Information services (MIIS) as in Figure 2.

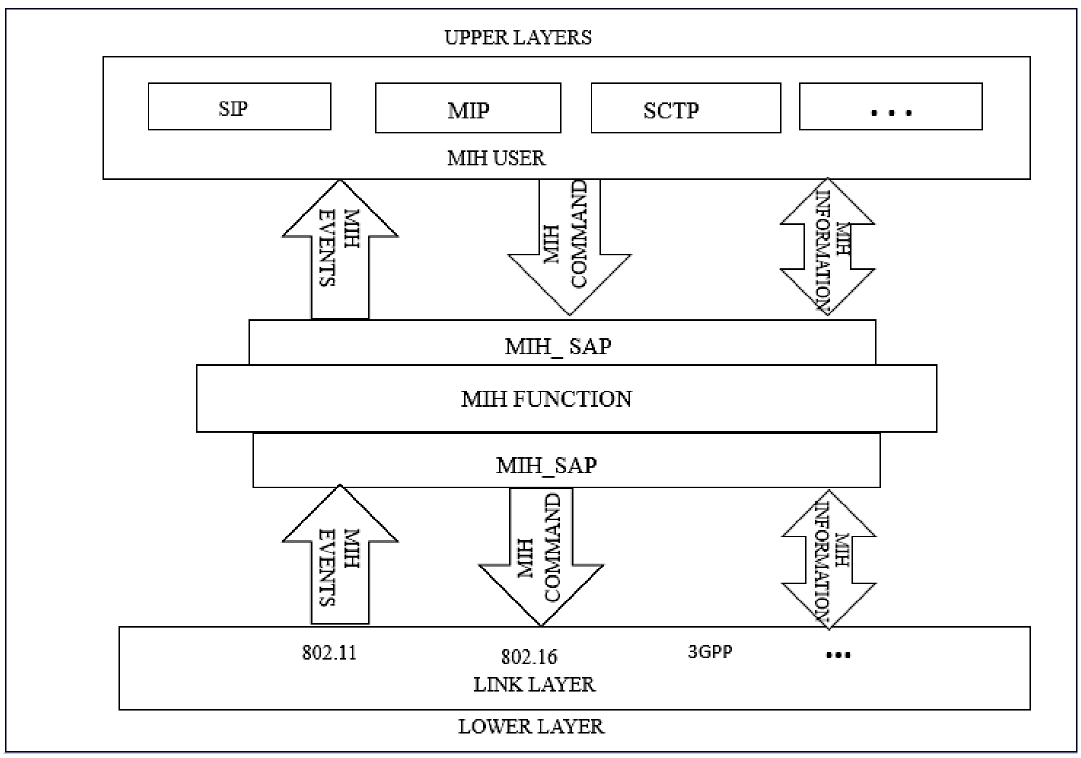


Figure 2. IEEE 802.21 MIH Standard [16]

These services were designed to improved performance of handovers. Everyone has a unique semantic associated with it [14]. The MIHU is adopted in network side and MIHF is in user side in order to report its current status to the upper layers. MIES Events services provide event organization and event clarifying which adapt dynamically to fluctuations in link quality, and characteristics. Also, it acts as a sort of L2 trigger, notifying MIH users (MIHU) at lower layer [15]. MICS command services allow Media Independent handover to manage and control link behaviour associated with mobility and handovers, including forcing an interface change or handover decisions that are made at the top and then passed down to lower layers, like Link layer are frequently transferred via commands at the remote entity or on the local device entity. Effective handover decisions and system access are made possible by a media-independent handover, which allows for the knowledge of all networks from any one Link layer network by providing details about the features and services through a MIIS [16]. Registered MIH users can access the network and information element knowledge base, as well as the associated query-response methods for information transfer, through MIIS.

Figure 2 depicts the signalling of IEEE 802.21 MIH Standard call flow. Similarly, Service Access Point interface provides facilities to upper layers whereas covering diversity L2 code of actions and locality information. All information is exchanged through three distinct types of SAPs:

a. Media Independent handover SAP – Acts as interface between MIHF plus its users, facilitating the transmission of link-layer events and the sharing of MIHF-general events.
b. Media Independent handover link service access point - provides a conceptual, media-independent interface among the MIHF and lower-layer protocol stack enabling support for various link-layer technologies through media-specific SAPs
c. Transport service across the data plane are handled by the mobile node service access point, it manages the messaging and information exchange with MIHF.

2.5 Related Works

Fast handover in a PMIPv6 context requires certain modifications to be compatible to network established mobility management. Important steps of the handover process incorporate Media Independent handover with Proxy MIPv6 are data querying, reserve accessibility checks, new L2 association formation, connection signal [17], and source discharge. A pre-registration mechanism is introduced in the resource preparation phase to minimise handover delay and buffer packets in current MAG. Nonetheless, acquiring mobile node outline from the AAA server or local mobility might lead to sudden delays. Additionally, the lack of an effective L2 initiate tool leads to packet disorder due to buffering and increased handover delay. Numerous improved approaches have been put out to address these issues, mostly utilizing pre-authentication, pre-registration, and L2 optimization to facilitate fast handover.

Moreover, in FMIPv6 environment, a predictive handover framework was presented for unbroken handovers [18] between 802.11 WLAN and WiMAX networks. To ensure that handover operations are finished before the current connection disconnects, this framework generates timely link triggers using neighbour network information. The approach first guesses the essential handover time based on the situations of the neighbouring network, via predictive connection starting mechanism, it dynamically determines optimal handover initial time to decrease handover overheads. In [19] proposed a two-phase tunnel control mechanism, to address issue of premature packet sending.

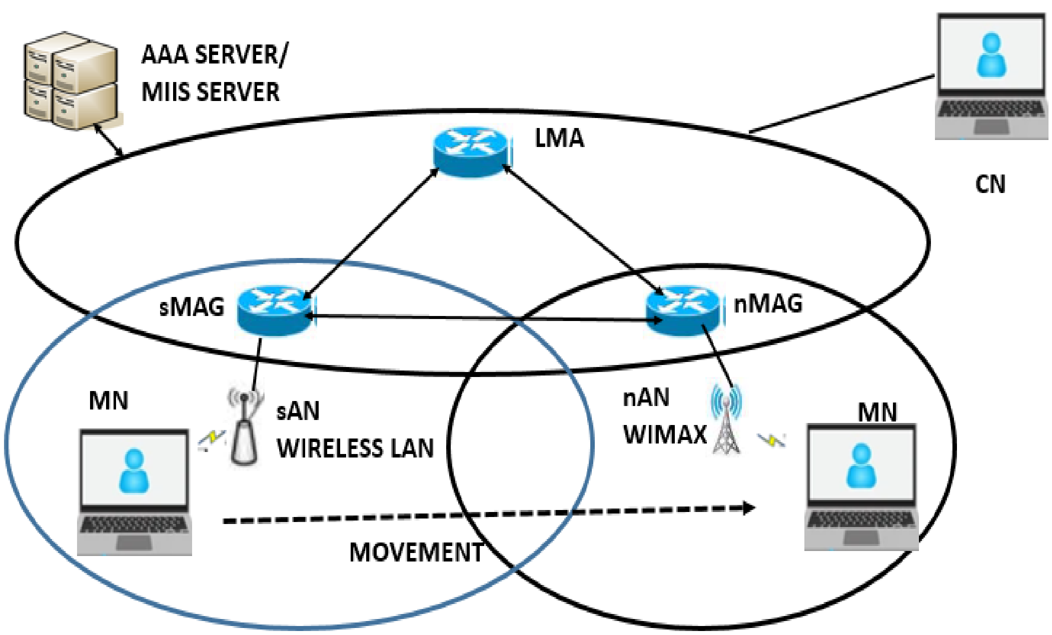
The mechanism employs media independent handover-mobile node handover candidate Request message to initiate handover, specifically via forming channel amongst sMAG and NMAG. Upon receiving response MN evaluates available options, makes handover decision for NMAG, and confirms it thru directing Commit request. Furthermore, [20] proposed a piggybacking scheme to decrease handover latency happening, nMAG can start authentication phase immediately as soon as MN travels out of the communication range of the sMAG, newMAG drives AAA request that consist of MN- Identifier to authenticate MN, sMAG send DeRegistration PBU message which piggybacks newMAG's PBU message. DeRegistration and Registration phases of sMAG and newMAG concurrently executed and effecting period of phases are corresponded which will reduce signalling overhead. On receiving DeReg PBU and PBU messages, local mobility sends a DeReg PBA and PBA messages that comprises MN home network prefix also sets up bi-directional passageway amongst LMA and current MAG.

3. RESEARCH METHODOLOGY

The proposed FPMIPv6 scheme integrates a seamless handover solution based on MIH and neighbour network information to decrease handover latency and packet loss at the network layer. Implementing this approach by the new MAG minimizes packet loss dynamically for the period of handover. Furthermore, redundant signalling messages that ask the LMA for MAG verification are removed, thereby cutting down on authentication time and optimizing the authentication process. The precise necessary handover time in the proposed design is calculated using the neighbour network characteristics. The IEEE 802.21 MIH events services continuously monitor dynamic link-layer parameters such as Received Signal Strength Indicator (RSSI), Signal-to-Noise Ratio (SNR), Link Quality Indicator (LQI) and Bit Error Rate (BER).

When the RSSI drops below a predefined threshold, it triggers an event (e.g., Link Going Down) to initiate handover preparation early. It uses historical RSSI trends and MN movement patterns to predict future degradation before actual failure. The IEEE 802.21 MIH Information Service (MIIS) Maintains a database of neighbouring networks, when MICS requests a handover, MIIS delivers this neighbour network information through a query/response mechanism, including both static data [21] and dynamic data (e.g. Quality of service conditions, , Load & congestion levels).And provides the best candidate network by using a dynamic network selection algorithm that prioritizes stable networks over short-lived high-speed links, ensures handover to a network that meets the MN's QoS requirements, reducing post-handover packet loss. MICS prioritizes handover decisions based on real-time QoS demands. And presents early network resource allocation to ensure a smoother change.

Figure 3 illustrates the core functionality of MIH that enables communication between L2 and L3. IEEE 802.21 operational assemblage presents Media Independent Handover Function positioned within the protocol stack amongst lower-layer and upper-layer. MIHF facilitates seamless handovers by providing services to both L2 and L3 through precise service access point.



MN, Mobile Node
sAN, Serving Access Network
nAN, new Access Network

sMAG Serving Mobile Access Gateway
nMAG Serving Mobile Access Gateway
LMA, Local Mobility Anchor
CN, Correspondent Node

Figure 3. Incorporated Solution Architecture of *PMIPv6* [21]

The flow diagram of the proposed FPMIPv6 scheme is presented in Figure 4, with detailed descriptions.

Step 1 - When MN receives Link Going Down result, it initiates handover preparation process from currently attached sMAG. The sMAG then sends Handover Initiation (HI) message to nMAG, prompting it to create a bi-directional channel amongst sMAG and nMAG. In response, nMAG sends Handover Acknowledgement message. After this, Forwarding Packets process begins, where nMAG buffers incoming packet from sMAG to avoid packet loss in handover.

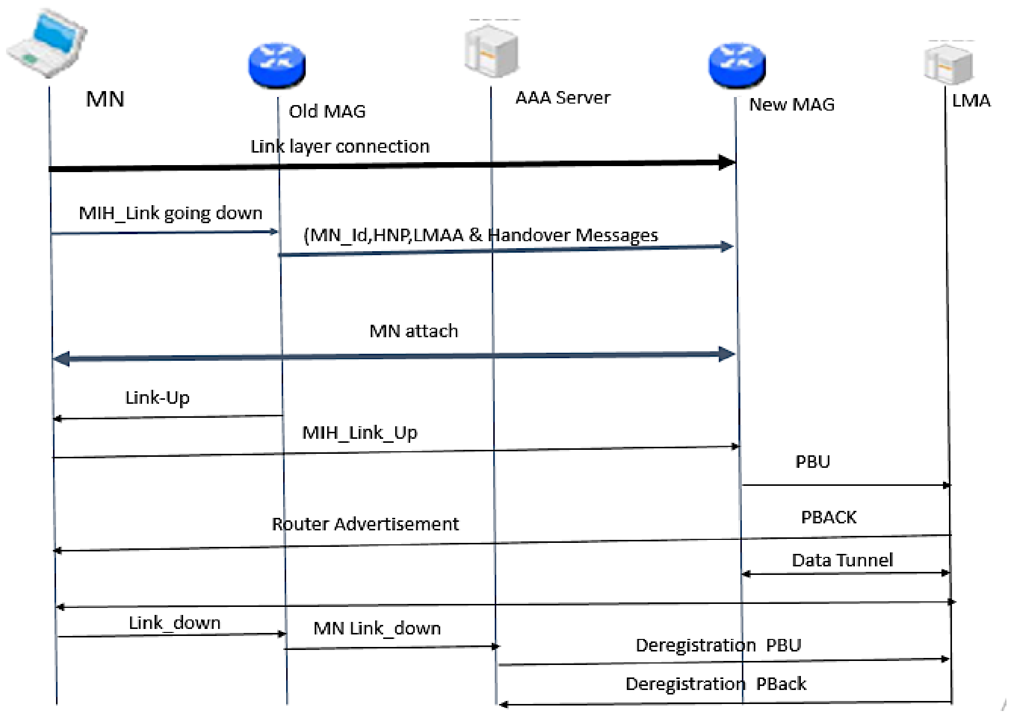


Figure 4. Proposed Fast Proxy MIPV6

Step 2 - Once identifying the mobile node connection, nMAG is in charge for authenticating the MN's uniqueness. To do so, sMAG sends MN-Id to AAA server for verification. As soon as AAA server confirms MN's uniqueness, it sends multicast message to both MAG and local mobility anchor. This message includes MN's identifier, MAG's identifier, and address formation mode, among other details. The local mobility anchor then acquires necessary information of mobile node and MAG registration

Step 3 - Upon getting MN-ID, LMA searches for MN's record in the Binding Cache Entry. If MN's record is initiate, the LMA updates it with the new MAG-ID. If no record is found, the local mobility anchor generates a novel entry for the MN in the BCE. The LMA then notifies the newMAG about the effective recording using sending past binding acknowledgement message that holds mobile node Home network prefix.

Step 4- sMAG sends DeReg PBU message to LMA to terminate its service, while newMAG assumes the role Of the sMAG.

Step 5 - Upon receiving DeReg past binding update message from sMAG, local mobility anchor sends DeReg past binding acknowledgment message, that comprises PBA with MN's Home Network Prefix. Similarly local mobility anchor creates bi-directional tunnel amongst current MAG. Using this new tunnel, local mobility anchor transfers packets to both sMAG and newMAG. The newMAG buffers these packets for MN in its New Packets Buffer (NPB), where it authorizes the series numbers of the packets. Once the handover procedure is completed, the packets in the Forwarding Packets Buffer (FPB) are transmitted before those in the NPB, ensuring that mobile node receives packet in correct order.

Step 6 - Conversely, the transmission occurs in 'partial' network region amongst LMA, newMAG, rather than directly among LMA and MN. Upon getting PBA message from LMA, newMAG begins buffering data packets arriving from LMA. Simultaneously, newMAG instructs the sMAG to stop bi-casting, and sMAG releases previous bi-directional tunnel through directing DeRegPBU message to LMA. Once Layer 2 connection is established and a CONNECTION_UP event is started, mobile node allocates to newMAG, which onwards buffered data packets to MN. This process minimizes packet loss in handover. Subsequently, normal data transfer operations resume between the MN and local mobility through bi-directional tunnel.

Step 7 - MAG notifies the mobile node of the effective registration via sending router advertisement message. Following this, entire packets of correspondent node are sent to the mobile node via the recognised bi-directional channel.

As shown in Figure 4, when Mobile Node moves out of cMAG's coverage, the cMAG receives MIH_LGD initiate. sMAG then sends DeRegistration PBU message, which includes newMAG's PBU message. This indicates that the newMAG accomplishes the registration part on behalf of the cMAG's deregistration part. As a result, the sMAG stops its service, and the newMAG takes over its role. Consequently, the DeRegistration and Registration phases for the sMAG and newMAG are performed simultaneously, with their execution times overlapping, reducing signalling overhead. Upon receiving the DeReg PBU and PBU messages, LMA sends both DeReg PBA and PBA messages, which include HNP of MN. Additionally, a bi-directional tunnel is created by LMA between itself and current MAG. After that, the LMA starts sending packets to the newMAG via the new route, where they are buffered for the MN.

4. RESULTS AND DISCUSSIONS

Using the network topology depicted in Figure 3, simulation tests were carried out to calculate performance of proposed pFPMIPv6 and FPMIPv6 schemes with an emphasis on signalling overhead, packet loss, and handover delay.

Figure 5 compares the performance of FPMIPv6 and Pro-FPMIPv6 schemes in terms of handover delay, it is observed that Pro-FPMIPv6 consistently achieves lower handover delays of 40% compared to FPMIPv6 demonstrating better enhancement in terms of seamless handover.

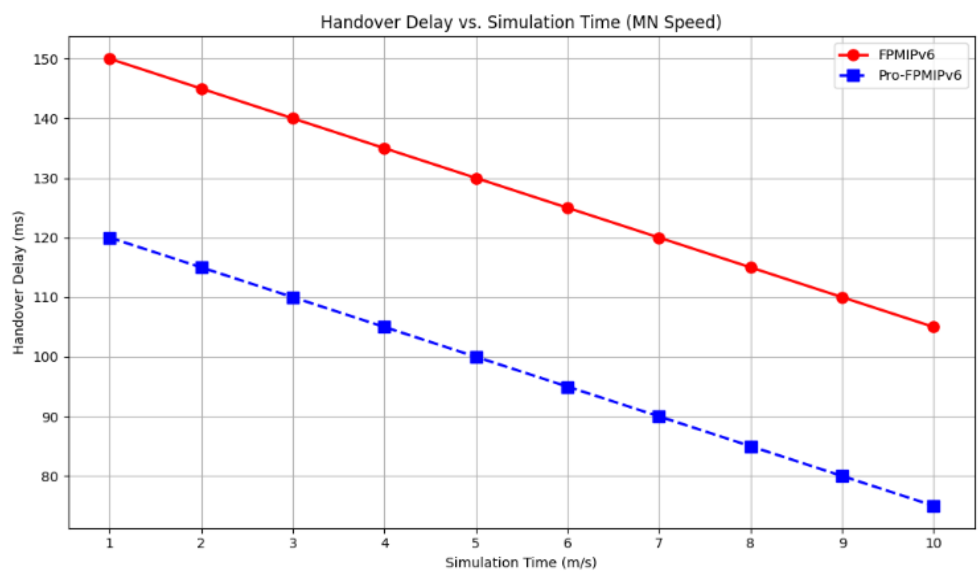


Figure 5. Handover Delay Performance Between FPMIPv6 and the pro-FPMIPv6 Schemes

4.1 Packet Loss Analysis

Packet loss is used to define miscarriage of data packets to reach their destination over a network. Figure 6 shows that Pro-FPMIPv6 provides a significant advantage of 50% over FPMIPv6 in terms of reducing packet loss during handovers.

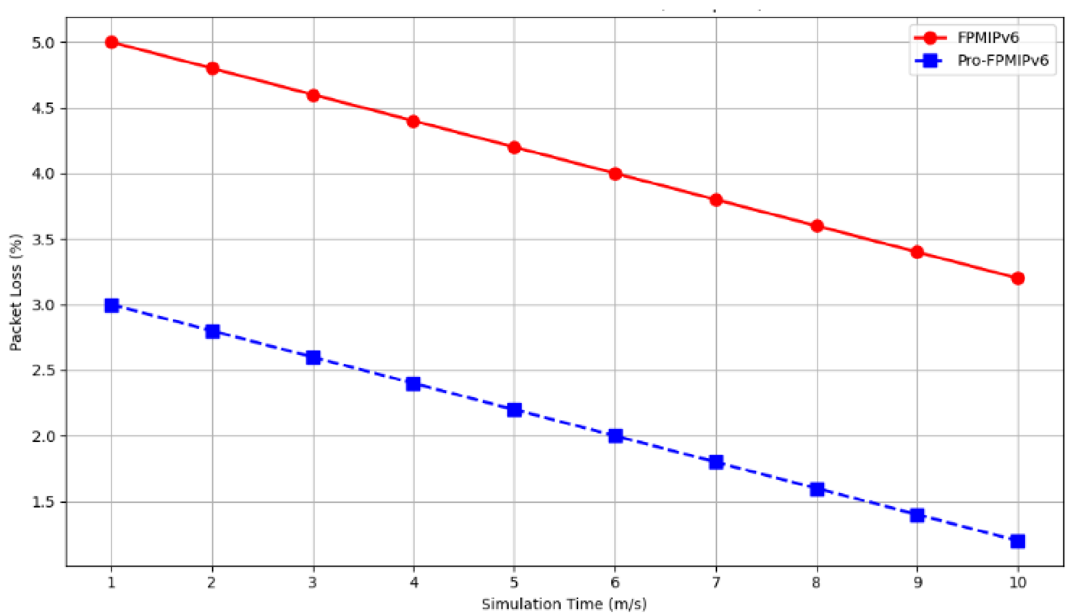


Figure 6. Packet Loss Performance Between FPMIPv6 and the Pro-FPMIPv6 Schemes

4.2 Signalling Overhead

The benefit of Pro-FPMIPv6 over FPMIPv6 in terms of signalling overhead reduction is 20% as in Figure 7, it necessitates fewer control messages during handovers.

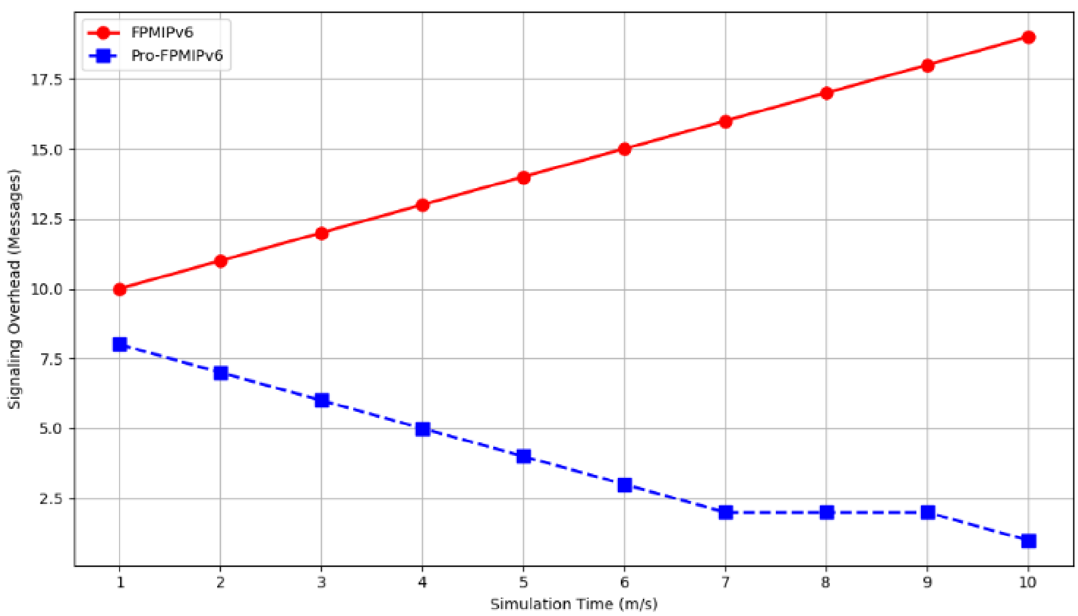


Figure 7. Signalling Overhead Performance Between FPMIPv6 and the Pro-FPMIPv6 Schemes.

5. CONCLUSION

Fast Proxy MIPv6 is being standardised by IETF to diminish handover latency and data loss in PMIPv6. Nevertheless, both late and early handover instigation can degrade the performance of FPMIPv6 rather than improve it. In this research, we proposed an incorporation of FPMIPv6 with Media independent handover via extending current Media independent handover standard services as well adopting a novel predictive handover context. This framework uses neighbour network information to provide timely link starts, ensuring that handover actions are completed before the current connection breaks. We also use a piggyback approach to reduce signalling overhead. The results of the simulation demonstrate that pPFMIPV6 overtakes standard FPMIV6 by up to 40% in latency, reduces signalling overhead by 20% – 30% and 50% in packet loss enhancement.

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AUTHOR CONTRIBUTIONS

Aliyu Aminu Abdulhadi: Conceptualization, methodology, discussion of the outcomes of the solution, validation and the preparation of the original draft
Nura Mukhtar: Writing, editing, and review

CONFLICT OF INTERESTS

The authors of this work have no conflicts of interest to report pertaining to its subject matter.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

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BIOGRAPHIES OF AUTHORS

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<tr><td></td><td>Aliyu Aminu Abdulhadi is currently with the Department of Computer Science, Umaru Musa Yar'adua University Katsina, Nigeria. His research interests include Mobility management, IoT and Artificial Intelligence (AI), Grid Computing, and performance analysis of computer and network systems. He can be contacted by email: aliyu.abdulhadi@umyu.edu.ng.</td></tr>
<tr><td></td><td>Nura Mukhtar is a lecturer at the Department of Computer Science, Umaru Musa Yar'dua University Katsina, Nigeria. His research areas of interest are machine learning, Data science, artificial immune system, Recommender system, and Bioinformatics. He can be contacted by email: nura.mukhtar@umyu.edu.ng.</td></tr>
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