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ORIGINAL RESEARCH ARTICLE

Early Address Detection: A Soft Vertical Handover Approach in Proxy Mobile IPv6

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ABSTRACT
This study presents an enhanced handover technique for Proxy Mobile IPv6 (PMIPv6) networks aimed at improving mobility management in heterogeneous wireless environments. The proposed scheme introduces a proactive approach where the anchor Local Mobility Anchor (LMA) obtains IP addresses for the Mobile Node (MN) before it leaves the home network, facilitating faster handovers between Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) domains. The performance of the proposed scheme was evaluated through both mathematical analysis and network simulation, comparing it with a velocity-aware handover approach. Three key metrics were assessed: handover completion probability, handover latency, and packet loss ratio. Mathematical modeling demonstrated the scheme's effectiveness in reducing handover-blocking probability and latency across various MN velocities. Simulation results, conducted using NS2.35, further established these findings, showing improvements in the number of successful handovers, reduced handover delay, and decreased packet loss compared to the velocity-aware approach. The study's outcomes indicate that the proposed scheme offers a more efficient handover mechanism, particularly beneficial for maintaining service continuity in heterogeneous network environments.

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INTRODUCTION

The explosive growth in mobile device usage and data traffic demand has created significant challenges for wireless network planning and mobility management. With mobile data, traffic is estimated to reach 49 Exabytes per month, representing a 700% increase over the past 5 years (Souza et al., 2019). Supporting seamless connectivity across heterogeneous wireless environments has become a critical issue, and this study presents an enhanced handover technique for Proxy Mobile IPv6 (PMIPv6) networks that addresses these challenges through a novel proactive approach.

The proposed scheme introduces a key innovation by enabling the anchor Local Mobility Anchor (LMA) to obtain IP addresses for Mobile Nodes (MNs) before they leave their home network. This proactive address acquisition facilitates faster handovers between Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) domains. By pre-emptively preparing for potential handovers, the system aims to reduce latency and improve service continuity in heterogeneous network environments.

Unlike existing approaches that may struggle with rapid transitions between different network technologies, our method is designed to maintain performance even at higher MN velocities. The study employs both mathematical modeling and network simulation to evaluate the scheme's effectiveness across various scenarios and metrics. By focusing on handover completion probability, latency, and packet loss ratio, we provide a comprehensive assessment of the proposed technique's capabilities in enhancing mobility management for next-generation wireless networks.

This research not only addresses current challenges in PMIPv6 networks but also anticipates the growing demands of an increasingly mobile and data-intensive technological landscape. The novel proactive approach presented here represents a significant step towards more efficient and seamless handovers in heterogeneous wireless environments, potentially improving user

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experience and network performance in the evolving world of mobile communications.

RELATED WORK

The concept used in PMIPv6 exempts mobile nodes from having to manage handovers for itself, rather, delegating that responsibility to the network elements (Gundavelli *et al.,* 2008). These elements are two: first is the Local Mobility Anchor (LMA), which serves as a topological anchor that connects a mobile node (MN) to a corresponding node (CN), via the Internet. The second is also a router called Mobility Access Gateway (MAG). An LMA can have multiple MAGs connected to it. In fact, a MAG is a wireless router that runs software that enables it to detect the presence of a mobile node (MN) and manage mobility for it, hence the name proxy (Gundavelli *et al*., 2008).

When an MN moves from one MAG (previous MAG, or pMAG, for short) to another, the pMAG will notify the serving LMA that the MN is no longer within its reach, and the LMA will first start its MN de-registration timer and also begins to buffer packets meant for the MN. If the timer runs out without receiving a message on the whereabouts of the MN, it deletes its records in its BCE and then drops all the buffered packets.

On the other hand, when a new MAG (nMAG) detects the presence of the MN either via response to its periodical beacon messages or through a *hello* message, which the MN normally sends after the maximum time it can wait for the beacon signal has elapsed, it starts the handover process by alerting the LMA of the arrival of the MN. After the exchange of Proxy Binding Update (PBU) and Proxy Binding Acknowledgement (PBA) between the LMA and the pMAG, respectively, the LMA changes the point of attachment of the MN in its Binding Update List (BUL) from the pMAG to the nMAG and starts to direct all traffic for the MN to the nMAG (Alhammadi *et al.,* 2020).

Kong et al. (2017) implemented a Fast Handover in Proxy Mobile IPv6 (FHPMIPv6), a variation of PMIPv6 that drastically reduces handover delay and allows the MN to experience little loss of packets. This approach relies on the Received Signal Strength (RSS) perceived by the MN the Layer 2 to send a report to the previous MAG (pMAG) that it is disengaging with it and is ready to connect with a new MAG which has better signal reception. The pMAG, in turn, sends a Handover Initiate (HI) to the nMAG. The nMAG, upon receiving such a message, is obliged to reply with a Handover Acknowledgement (HAck) message and send its proxy binding update to its LMA. The home LMA then sends a proxy binding acknowledgment (PBAck) to the pMAG and a PBU to the new LMA. The new LMA will then issue the MN with an IP address before sending a PBAck to the home LMA. When the home LMA receives the PBAck message, it establishes a tunnel between it and the new LMA through which the former sends packets to the latter.

Huang *et al.* (2017) introduced another mechanism that cut down signaling costs and improved handover processing by means of grouping the MNs. The central concept of this approach is that once a MAG detects the presence of an MN, it sends a handover Initiate (HI) message to all the neighboring MAGs to establish a pre–tunnel with them. Whenever an MN is detected at one of the contacted MAGs, the binding process that was begun will be completed. Although this study showed its efficacy in reducing the cost of signaling to the barest minimum, it is found wanting to establish several tunnels at once, most of which will not be used, resulting in unnecessary waste of networking resources.

Another approach that achieved much in improving the number of successful handovers in PMIPv6 is found in the work of Changzhe *et al.* (2018). In this work, an enhanced architecture of PMIPv6 called Cluster – Sensor PMIPv6 (CSPMIPv6) was used. This approach was designed to tackle the performance bottleneck in PMIPv6 by reducing the network domain into subdomains, with each subdomain having a cluster of MAGs and with each cluster being controlled by a cluster head.

The functionalities of LMAs and MAGs in CSPMIPv6 are very much the same as those of standard PMIPv6, with the major difference being that the LMA nominates a cluster head and keeps tab on its availability while the cluster head relieves the LMA of much of its responsibilities allowing the LMA to act only as a kind of overseer to its cluster heads.

The strength of this approach is that the inter–subdomain communications supervised by the LMA reduced handover latency. However, the volume of control messages exchanged in a handover consumes a lot of networking resources. The study is also limited to inter sub – domain handover. It did not consider the issue of inter-domain handover.

SYSTEM ARCHITECTURE

The Proposed System Overview

In this work, we created two networks, one Wireless Local Area Network (WLAN) and the other Wireless – Interoperability for Microwave Access (WiMAX). In the WLAN, the topology of the network consists of a central router (LMA) and other routers acting as points of attachment (MAGs), while in WiMAX, the setup consists of a Base Station (BS) that acts as a MAG and then we introduced an LMA to represent the WiMAX core unit in the network's architecture which is in control of user authentication, roaming services, network administration and provision of interface to other networks. The function of the LMA is to issue IP addresses and maintain a binding cache while the BS already has the PMIPv6 capability through its mobile—Base Station handover request/response (MOB_BSHO-REQ/RES) exchange messages. Also, the BS provides many messages that facilitate handover, such as the Uplink Channel Descriptor (UCD) and Downlink Channel Descriptor (DCD) (Ergen, 2009).

Even though network mobility schemes hide most of the complexity of moving between networks of different technologies, cross-technology handovers usually result in short, predictable disconnections during which network packets are bound to be lost (Lahby et al., 2019). We consider break-before-make handovers between networks with heterogeneous.

The Algorithm of the proposed system

1. MN joins a network afresh

2. **for** each neighboring LMA

3. aLMA send RtrSolPr to the neighboring LMAs for the MN

4. Record the received addresses in BCE

5. **end for**

6. **if** (pMAG sends a PBU)

7.Start the DeReg timer

8.Start buffering packets for the MN

9. **if** (nLMA sends MN location update)

10.Send an Acknowledgement

11.Update the BCE

12.Set up a bi-directional tunnel with nLMA

13. **endif**

14. **else if** (no update comes about, the MN and DeReg timer expires)

15. Drop all buffered packets

16. Delete MN's BCE

17. **endif**

18. **endif**

Note: We use two terms, anchor LMA (aLMA) and new LMA (nLMA), to differentiate between the one the MN is leaving its network to the one it joins.

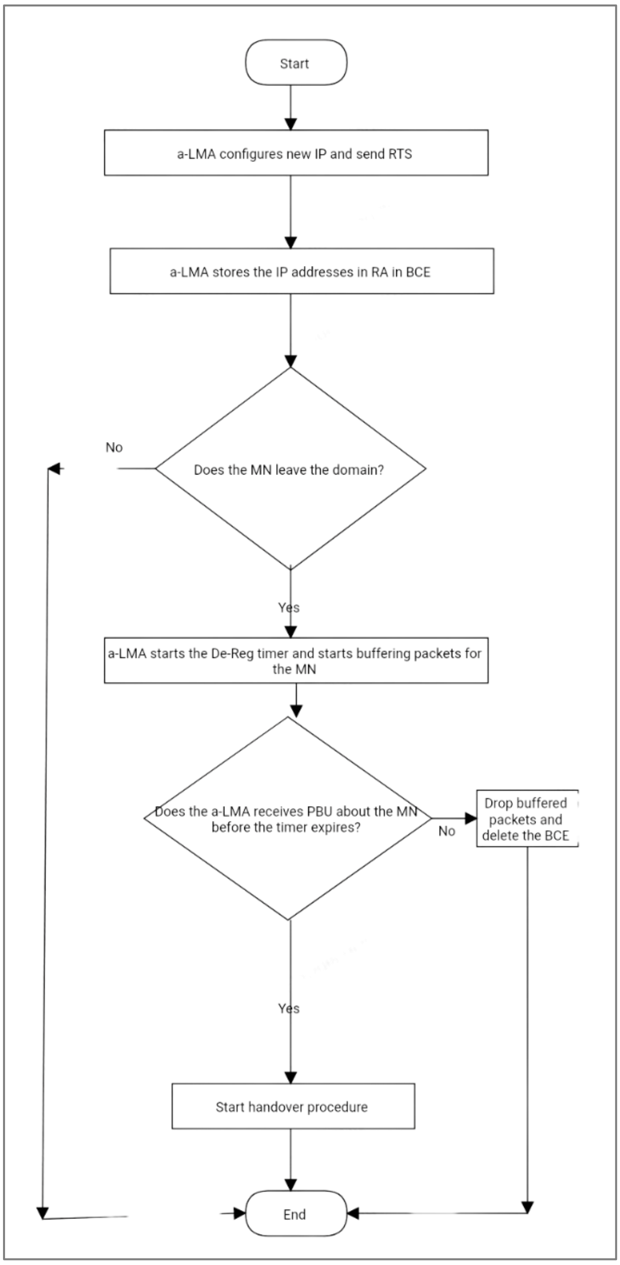

Figure 1: The process of handover in the proposed scheme

Modelling Handover in the Proposed System

The time T that is remaining before an MN moving with velocity v goes out of the coverage area of its MAG or BS is referred to as network residence residual time and can be expressed using the formula below (Khan and Han, 2014).

Figure 1 shows the process of handover in the proposed scheme. It starts with the anchor LMA; immediately after the MN joined it, it sends Router Solicitation for Proxy to all the neighboring LMAs. The anchor LMA stores all the IP addresses received from them in its Binding Chace Entry (BCE). The anchor LMA starts to buffer packets for the MN and then continues to wait for the serving MAG to alert it when the MN leaves the domain.

$$T = \frac{D_o}{v} \quad (1)$$

Where D_o is the distance between the MN and the edge of the coverage area of the MAG or BS.

However, the coverage area of the point of attachment is not a perfect circle. Also, the strength of the signal may not be evenly distributed at the edge. Thus, to normalize the signal along the borderline, we multiply the distance remaining by an index y. Hence (1) becomes:

$$T = y\frac{D_o}{v} \quad (2)$$

From the work of Aman *et al.* (2019), the handover should be triggered at (1 – y)r where r is the radius of the coverage area of the MAG. Hence, the RSS can be estimated as:

$$w_b k_1 - k_2 \log\left(1 - \frac{v}{r}\right) \quad (3)$$

where k_1 and k_2 are the antenna gain and pathloss factor, respectively, and v and r retain their previous values. The threshold can then be estimated by removing the pathloss factor and setting δ as the threshold, and we get:

$$\delta = w_b - k_2 \log\left(1 - \frac{v}{r}\right) \quad (4)$$

Once the RSS of the serving MAG or BS drops below δ, the MN would send the Link Going Down (LGD) message and proceed to scan for an available point of access.

Modelling Handover Failure Probability

Let T_E be the residence time of the MN in the network coverage area. Also, let us assume the average handover latency, T_{HO} is exponentially distributed with the cumulative function $F_T(t)$. For simplicity, we assume that T_{HO} is the only factor blocking the handover. Then, the blocking probability, according to Aman *et al.* (2019), can be expressed as:

$$Pb = \Pr(T_{HO} > T_E) = \int_0^{\infty}(1 - F(u))\int_E(u)d(u) = \frac{\mu_c[ET_p]}{1+\mu_c[ET|p]} \quad (5)$$

Where μ_c the mobility rate of the MN and, supposing that the coverage area of the network is circular, then μ_c can be calculated as follows:

$$\mu_c = \frac{2v}{\pi R} \quad (6)$$

Where v is the velocity of the moving MN π is a constant 22/7 and R is the radius of the coverage area of the network.

Model Handover Latency

Handover Latency when MN Moves from WLAN to WiMAX

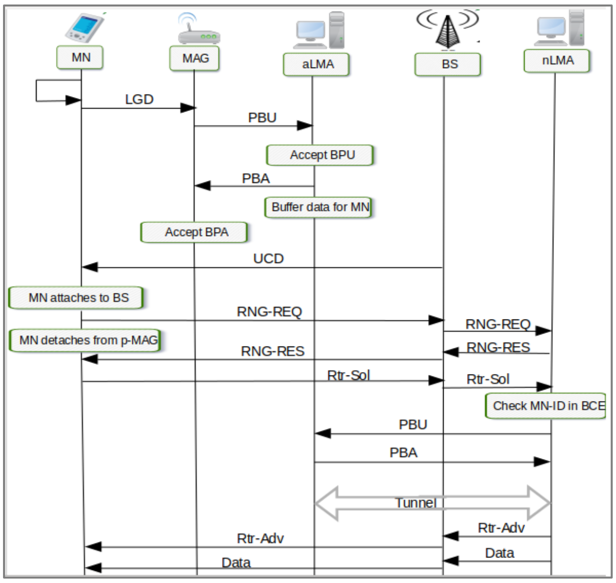

Figure 2: Signaling call flow when MN moves from WLAN to WiMAX

To estimate the handover delay, we assume the handover process to be a Poisson process, as in the work of Adamu and Lawal (2017). Let us number all the elements involved in the handover procedure when the MN moves from a WLAN network to a WiMAX network.

$N = \{1,2,3,4,5\}$

Let's assume that all external events arriving at each node is a Poisson process with arrival rate of λ and processing rate μ_i, i= 1,2, ...,5 is fixed. P= $\frac{\lambda}{\mu_i}$ is the load at the ith node, that is $i \in N$.

Also, let M_{wimax} denote the set of all messages required to be processed to complete the handover procedure while n_m is the number of m-message's transition before reaching its final destination. Let L_m be the size of the m-message in bits that is, $m \in M_{wimax}$. Also, let Δ_{wimax} denote the handover delay for the scenario when the MN is moving from WLAN domain to WiMAX domain.

$$\Delta_{HO\text{-}WiMAX} = \Delta_{pre\_detach} + \Delta_{attach} + \Delta_{location\_update}$$

$$\Delta_{HO\text{-}wimax} = \kappa + 4\mu_1^{-1} + \frac{2}{\mu_2 - 2\lambda} + \frac{2}{\mu_3 - 2\lambda} + \frac{4}{\mu_4 - 4\lambda} + \frac{3}{\mu_5 - 3\lambda} + \alpha^{-1}\sum_{m\in wimax} n_m L_m \quad (7)$$

Where $\lambda < \min\{\frac{\mu_2}{2}, \frac{\mu_3}{2}, \frac{\mu_4}{4}, \frac{\mu_5}{2}\}$ and $\alpha > 0$, and κ is the BS scanning time, and α here represents channel capacity in WiMAX network.

Proof:

Let us assume node 1 to be using M/M inf queueing model with First Come, First Serve (FCFS) discipline. Let us also divide the nodes into sets. The first set $N_{wimax} = \{1,2,3\}$ contains all the nodes during the pre-detach procedure, $N_{wimax} = \{1,4,5\}$ contains the nodes involved in the attached event, and $N_{wimax} = \{3,4,5\}$ contains all th (1) s involved in the location update procedure.

$$\Delta_{pre\_detach} = \mu_1^{-1} + \frac{2}{\mu_2 - 2\lambda} + \frac{1}{\mu_3 - \lambda} \quad (8)$$

Where $\lambda < \min \{\frac{\mu_2}{2}, \mu_3\}$

$$\Delta_{attach} = 3\mu_1^{-1} + \frac{4}{\mu_4 - 4\lambda} + \frac{2}{\mu_5 - 2\lambda} \quad (9)$$

Where $\lambda < \min \{\frac{\mu_4}{4}, \frac{\mu_5}{2},\}$

$$\Delta_{location\_update} = \frac{1}{\mu_3 - \lambda} + \frac{1}{\mu_5 - \lambda} \quad (10)$$

Where $\lambda < \min \{\mu_3, \mu_5\}$

Table 1: Routing matrix for handover in WiMAX (Proposed scheme)

	1	2	3	4	5	$\sum$
1	$\frac{1}{4}$	$\frac{1}{4}$	0	$\frac{2}{4}$	0	1
2	0	0	1	0	0	1
3	0	$\frac{1}{2}$	0	0	$\frac{1}{4}$	1
4	$\frac{3}{4}$	0	0	0	$\frac{1}{4}$	1
5	0	0	$\frac{1}{3}$	$\frac{2}{3}$	0	1

Handover Latency when MN Movesfrom WiMAX to WLAN

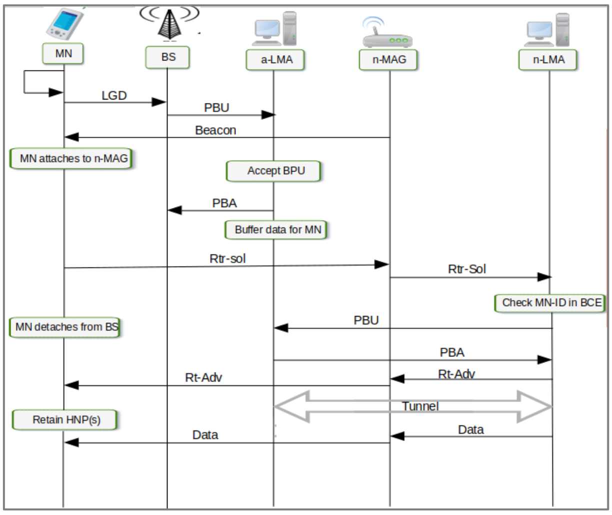

Figure 3: Signaling call flow when MN moves from WiMAX to WLAN

To determine the handover latency when the MN moves from WiMAX to WLAN lets number all the nodes involved in the handover process as we did in the case of handover when MN moves from WLAN to WiMAX.

$N = \{1, 2, 3, 4, 5\}$

Let's assume that all external events arriving at each node is a Poisson process with arrival rate of λ and processing rate μ_i, i=1,2, ...,5 is fixed. $P = \frac{\lambda}{\mu_i}$ is the load at the ith node, that is $i \in N$.

Also, let M_{WLAN} denote the set of all messages required to be processed to complete the handover procedure while n_m is the number of m-message's transition before reaching its final destination. Let L_m be the size of the m-message in bits, that is, $m \in M_{WLAN}$. Let Δ_{WLAN} denote the handover delay for the scenario when the MN is moving from Mobile WLAN domain.

$$\Delta_{HO\text{-}WLAN} = \kappa + 3\mu_1^{-1} + \frac{2}{\mu_2 - 2\lambda} + \frac{2}{\mu_3 - 2\lambda} + \frac{3}{\mu_4 - 3\lambda} + \frac{2}{\mu_5 - 2\lambda} + \beta^{-1} \sum_{m \in Mwlan} n_m L_m \quad (11)$$

Where $\lambda < min \frac{\mu_2}{2}, \frac{\mu_3}{2}, \frac{\mu_4}{3}, \frac{\mu_5}{2}\}$and $\alpha > 0$, and κ is the MAG scanning time, and β represents channel capacity at WLAN.

But,

$$\Delta_{HO\text{-}WLAN} = \Delta_{pre\_detach} + \Delta_{attach} + \Delta_{location\_update}$$

$$\Delta_{pre\_detach} = \mu_1^{-1} + \frac{2}{\mu_2 - 2\lambda} + \frac{1}{\mu_3 - \lambda} \quad (12)$$

Where $\lambda < \min \{\frac{\mu_2}{2}, \mu_3\}$

$$\Delta_{attach} = 2\mu_1^{-1} + \frac{4}{\mu_4 - 4\lambda} + \frac{1}{\mu_5 - \lambda} \quad (13)$$

Where $\lambda < \min \{\frac{\mu_4}{4}, \frac{\mu_5}{2},\}$

$$\Delta_{location\_update} = \frac{1}{\mu_3 - \lambda} + \frac{1}{\mu_5 - \lambda} \quad (14)$$

Where $\lambda < \min \{\mu_3, \mu_5$

Table 2: Routing Matrix for handover in WLAN (Proposed scheme).

	1	2	3	4	5	$\sum$
1	$\frac{1}{3}$	$\frac{1}{3}$	0	$\frac{1}{3}$	0	1
2	0	0	1	0	0	1
3	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	1
4	$\frac{2}{3}$	0	0	0	$\frac{1}{3}$	1
5	0	0	$\frac{1}{3}$	$\frac{2}{3}$	0	1

Table 2 shows the number of messages send by each node during the handover process and the nodes to which they are destined. The rows represent the sending nodes, while the columns represent the destinations.

Modelling Dropped Packets

Another critical aspect of handover is the dropped amount of packets. This has a direct link with the handover latency and, the faster the handover, the less packets lost.

Let ℓ be the total number of lost data packets, then, according to Amman *et al.* (2019):

$$\ell = \varphi \lambda_s E(s) L_{HO} \quad (15)$$

Where φ is channel capacity at either WLAN or WiMAX network, λ_s is the packet arrival rate, E(s) is the average session length, and L_{HO} is handover latency.

Simulation of the Proposed System

The simulation was carried out using network simulator 2 (NS2.35). The topology of the networks consists of a wireless Local Area Network (LAN) and a WiMAX network. The wireless LAN is assigned the radius of 300m while that of WiMAX is set at 1500m with 100 wireless nodes distributed between them, 15 of which are mobile. User Datagram Protocol (UDP) was used as the data protocol with no acknowledgment of received data, while Constant Bit Rate (CBR) was used as the running application to emulate a video streaming service. The packet transmission delay was set at 0.004s, whereas the simulation time is 240s. Drop–tail was used as a queuing type with maximum of 100 packets as its capacity, while the packet size was set as 1000 Bytes.

The mobile nodes were configured with the urban-rural mobility speed of 3m/s as in the work of Mansour rt al. (2018), while one–third of the MNs were configured with much higher speed of 5m/s to indicate our method's tolerance for higher velocities. Random waypoint was used as the type of mobility for the simulation.

DISCUSSION OF FINDINGS

Results from Mathematical Analysis

Handover Completion Probability

This is the probability that a handover will fail based on the constraints that could hamper the handover from going through, such as time and the velocity of the MN.

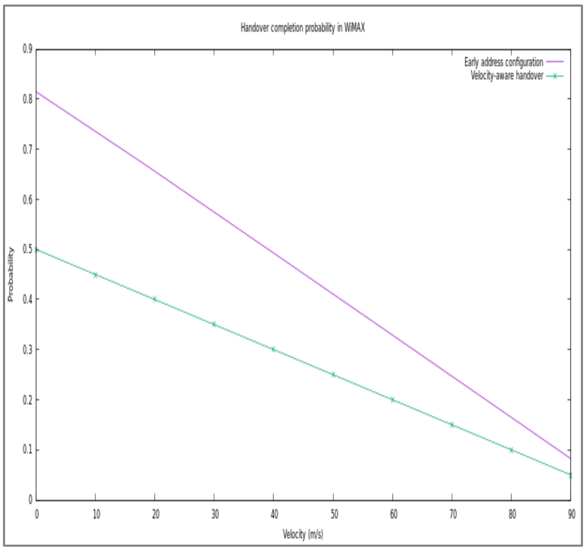

Figure 4: Comparison of handover completion probability in WiMAX

Figure 4 above shows how handover blocking probability of the two approaches in the WiMAX domain. It shows how the handover probability reduces sharply with increasing velocity. Lower probability of failure means there is a corresponding high probability of success for the handover (Gohar *et al.,* 2017).

Estimated Handover Latency

This is a result of theoretical analysis of how long the handovers last. In this case, its considered as the time between when the MN sends the LGD message to the time it obtains an IP address via a router advertisement. Factors that have a direct influence on the handover latency are the channel capacity of the new network, the number of control messages exchanged, the sizes of the messages, delays, scanning delay, and so on (Hosny *et al.,* 2019).

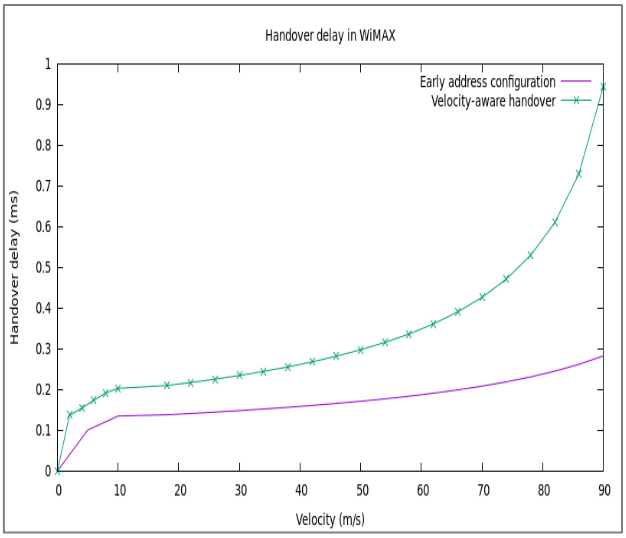

Figure 5: Handover delay in WiMAX

From Figure 5 above, it can be seen that handover period increases continuously with increasing velocity. While the delay increases sharply in the case of velocity – the aware approach, the proposed scheme indicates only a slight increase in delay with respect to increasing velocity. The graph expressed the handover delay for the WiMAX model.

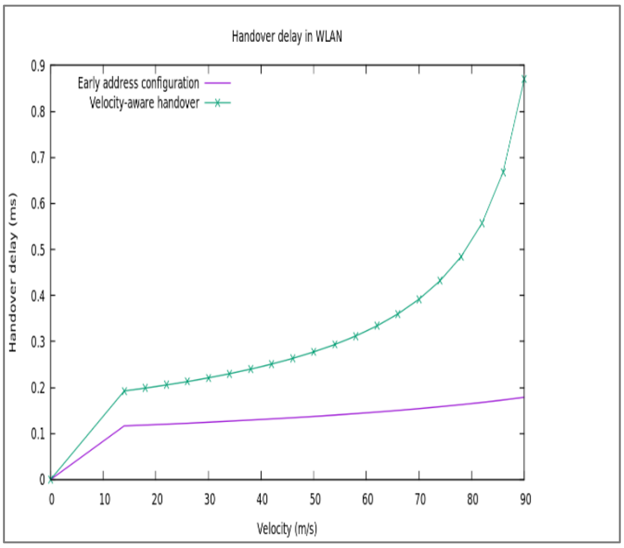

Figure 6: Handover delay in WLAN

From Figure 6, which shows the handover delay in WLAN domain, it can be seen that the graphs rise from left to right. The steep rise shows a longer handover delay in the case of a velocity–aware approach, while the proposed scheme shows only a marginal increase in delay while a less steep rise indicates less delay (Abdallah and Zurkarnain, 2017).

Dropped Packets

This metric comes as a direct result of handover and its latency. When the handover takes a long time and is inefficient, it results into loss of many data packets. The reverse is also true. Hence, following the example of Aman (2019), we take the lost packets to be the product of handover latency and packets arrival rate as well as the channel capacity.

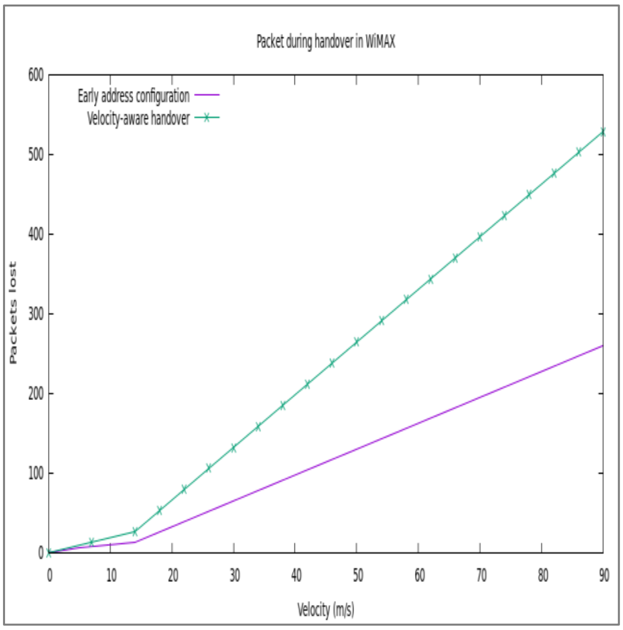

Figure 7: Dropped packets in WiMAX

Figure 7 shows the amount of lost packets during handover in WiMAX domain. It can be seen that the higher the velocity of the MN, the more packets would be lost (Hou and Wang, 2017).

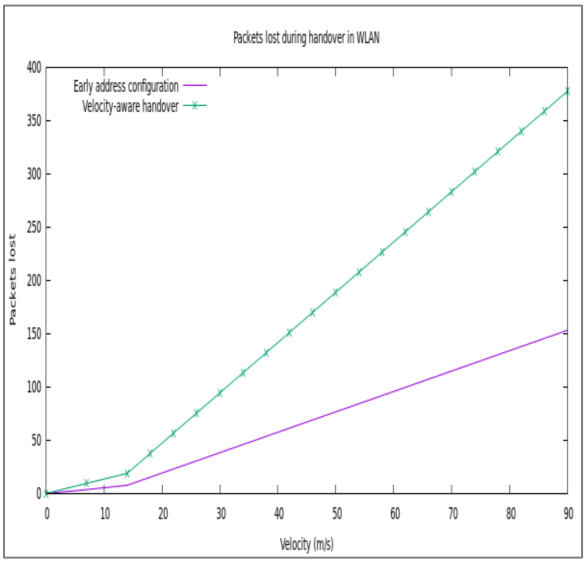

Figure 8: Dropped packets in WLAN

Figure 8 shows the packets loss by the two schemes, which increases with increase of velocity. Since packets loss is an inevitable part of handovers, the concern during design of mobility protocols should be to reduce the amount of packet loss to the minimum (Qodirov, 2018).

RESULTS FROM SIMULATION OF THE PROPOSED SYSTEM

Number of Completed Handovers

This is the amount of successful handovers during the simulation time. Too many movements of an MN will cause too many signaling messages, which takes up networking resources and time to process them, while MN moving too fast could lead to delay in handovers or even handover failure.

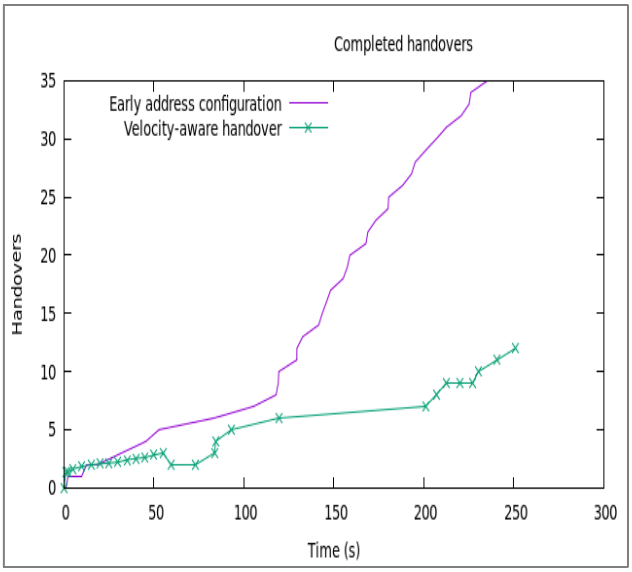

Figure 9: Number of successful handovers

The figure above indicates that the proposed scheme has achieved more completed handovers when compared to the existing one as the graph above indicated. The higher number of completed handover is an indication that the proposed system guarantees better quality of service (Goyal *et al.,* 2022).

Handover Latency

Reduction of handover delay optimizes data reception, while lengthy handover binding process incurs lengthy MN waiting time and more packets accruing to be buffered, hence increasing packet loss. The proposed scheme out-performed its counterpart in terms of recording less handover latency. This provides optimal handover latency to avoid untimely and unstable handover, all of which have a huge benefit on quality of service (Joumard *et al.,* 2019).

Figure 10 indicates that the proposed scheme records much less delay over the velocity-aware approach. It also shows the handover latency of the two schemes.

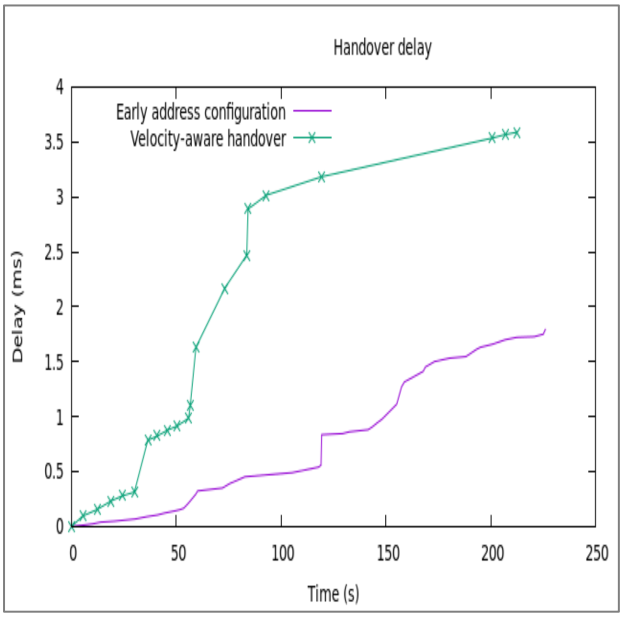

Figure 10: Handover latency

Dropped Packets Ratio

This is the ratio of all packets sent to packets dropped. Lengthy handovers lead to packets being dropped. Most of packet lost is due to serving MAG continuously sending packets while the MN is in an area with poor signal and buffer overflow. Even if it were possible to make buffers having very large sizes, packet loss would not be eliminated as the time to leave (TTL) in the packets' header may expire, causing them to be dropped from the buffer. That is why every attempt to reduce packet loss must address the time it takes to complete the handover.

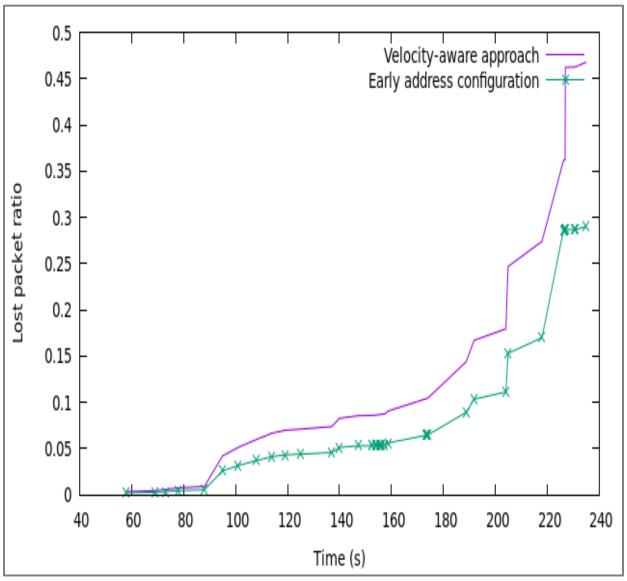

Figure 11: Lost packets ratio

Figure 11 shows the amount of dropped packets experienced by the models during simulation.

The Figure above (Figure 11) shows accrued packet loss across the simulation period. The steep rise of each graph here indicates lost packets corresponding to the time on the horizontal axis. Hence, the higher rise of velocity – the aware approach means that the method records more packet loss than the proposed method.

CONCLUSION AND FUTURE DIRECTIONS

The high increase in mobile data used every year requires continuous and adaptive measures to be taken in designing wireless networks. Proxy Mobile IPv6 (PMIPv6), which is the only network–based mobility management protocol, comes up with revolutionary approach of shifting the responsibility of mobility management from user equipment (MN) to the network elements, local mobility anchor (LMA) and mobility access gateway (MAG).

This study outlined a handover technique in Proxy Mobile IPv6 where the anchor LMA obtain IP addresses for the MN before it leaves the home network. This means whichever neighboring LMA the MN joins, it would find that its registration with the LMA there is half done. When it attaches itself to one of the MAGs of that LMA, the handover needs only to be completed. Our study was compared with another approach, Velocity – aware Handover Trigger in Two- Tier Heterogeneous Networks, where the handover decision was made based on the velocity the MN is moving with. The three metric used to compare the two approaches are number of successful handovers, handover latency, and amount of lost packets. Compared to its counterpart, our approach did better in all three parameters even though the mobile nodes in our scheme at some points travel at much faster speed.

This research did not, however, solve the problem of single–point–of–failure at the anchor LMA, a problem known with standard PMIPv6. This means whenever the LMA goes down, it takes the whole domain with it. Future works should, therefore, introduce distributed mobility management in the scheme to solve or reduce the impact of such problem.

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