An Enhanced Bicasting Scheme for Proxy Mobile IPv6 with Buffering

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Abstract- Research trends in mobility management depict that handover delay and packet loss minimization are parameters of utmost importance in an endeavor to formulate a mobility management solution that offers seamless handovers as a mobile node changes points of attachment. This is largely driven by the requirement to offer uninterrupted real-time services to mobile users. It has also been noted that there is a current and future anticipated rapid increase of mobile data traffic volumes with the introduction of new innovative IP-based services. This thus calls for mobility management solutions that will be able to scale with the rapid traffic increase while still achieving seamless handovers. This paper introduces an enhanced Bicasting Proxy Mobile IPv6 (EB-PMIPv6) scheme that incurs minimal packet loss and handover delay while also efficiently utilizing network resources such as backhaul bandwidth and network elements' buffer space by executing the bicasting operation in a timely and accurate manner. This is achieved by using a signal strength prediction algorithm that estimates the viability of a link when a handover is imminent. The paper further provides an in-depth discussion of the proposed solution. The model of the solution has been implemented on the Network Simulator 2 (ns-2) and its performance is analyzed in regard to packet loss, handover delay. The results indeed show that the solution optimizes the performance of PMIPv6 handovers whilst also ensuring efficient network resources utilization, thus making it a much more scalable bicasting solution for PMIPv6.

Index Terms—bicasting, network resources, seamless handovers

I. INTRODUCTION

PMIPv6 has been standardized by the Internet Engineering Task Force (IETF) through the Network-based Localized Mobility Management group (NetLMM). [1] PMIPv6's fundamental foundation is based on MIPv6. It extends the MIPv6 signaling and reuses many of its concepts such as the home agent (HA) which is an anchor point in MIPv6. In PMIPv6, as opposed to MIPv6, the mobile node is relieved of any mobility related signaling. The mobile access gateway (MAG) performs the signaling on behalf of the mobile node [2]. There is also no necessity to modify the mobile node's protocol stack to support PMIPv6. It also features a considerable reduction of signaling overheads on the air interface of the radio access network compared to the MIPv6 variants. There is also a reduction in processing and resource utilization at the mobile node thus improving the battery life. [2]

Due to the advantages just highlighted, PMIPv6 has gained a lot of popularity and has already been adopted by the WiMAX forum and has been recommended in some of the Third Generation Partnership Project (3GPP) frameworks such as the Evolved Packet Core (EPC). [3] [4] On this account, many researchers have put their efforts in proposing, modeling, and testing extensions to the PMIPv6 in order to attain the goals set for network based localized mobility management protocols such as PMIPv6 in [5].

In the next generation wireless networks, handovers should be seamless. Thus, packet loss and handover delay should be minimized such that quality of service does not degrade. Bicasting PMIPv6 (B-PMIPv6) is one of the solutions that achieve low packet loss and handover delay during a PMIPv6 handover. However, B-PMIPv6 has a problem on inefficient utilization of backhaul bandwidth and network elements' buffer space due to transmission of duplicate packets during a PMIPv6 handover. Therefore, there is a need to enhance B-PMIPv6 such that it efficiently utilizes network resources.

The contribution of this paper is the design of an enhanced B-PMIPv6 that not only strives to achieve seamless handovers by lowering handover delay and packet loss but also efficiently utilizes network resources. The network resources of interest are the backhaul bandwidth and the network elements' buffer space. This solution is largely motivated by the need to design bicasting-based PMIPv6 extension that will scale with the increase in mobile data volumes due to the introduction of more bandwidth hungry IP-based applications as well as new broadband radio access technologies, such as the Long Term Evolution (LTE).

The rest of the paper is organized as follows: Section II highlights the work that was reviewed and related the research carried out. Section III gives an in-depth description of the proposed solution. In section IV, the simulation setup that was used to test the model of the solution is discussed. Performance results and their analyses are discussed in section V. The paper is concluded in section VI.

II. RELATED WORK

Due to the strict requirements (e.g. required jitter, end to end delay, etc) needed by real-time mobile services, researchers have put much effort in proposing PMIPv6 extensions to enhance its performance. Among these extensions, Fast handovers for PMIPv6 (FPMIPv6) has been standardized by the IETF, and it minimizes packet loss and handover delay by performing predictive handovers as opposed to the reactive handovers in PMIPv6. [6] Furthermore, S. Ryu *et al* [7] proposed an enhanced FPMIPv6 scheme whereby a Proxy Binding Update (PBU) is sent to the Local Mobility Anchor (LMA) as soon as all the required information is available and hence resulted into an even faster handover for PMIPv6.

PMIPv6 as is does not perform optimally for real-time applications due to a substantial amount of packets lost during a handover. In PMIPv6, packet redirection from the previous point of attachment (Previous Mobile Access Gateway (PMAG)) to the next point of attachment (Next Mobile Access Gateway (NMAG)) is effected after successful Layer 2 handover (scanning and re-association and authentication) to the next point of attachment since it uses a reactive approach as opposed to a predictive approach. Thus, in the time span from disconnecting from PMAG to connecting to NMAG, packets are sent to PMAG unnecessarily as the packets will ultimately not reach the mobile node through PMAG. Furthermore, in-flight packets can be lost since the mobile node does not instruct the PMIPv6 that a handover is imminent. [1]

Ji-In *et al* in [8], and [9] also proposed a bicasting based PMIPv6 (B-PMIPv6) scheme that duplicates packets to the current and candidate (subsequent) points of attachment when the signal strength degrades to a certain set threshold namely the Link Going Down (LGD) power level. This solution also proves to minimize handover delay and packet losses. However, this solution utilizes a significant amount of network resources (backhaul bandwidth and buffer space) since it delays to stop bicasting. The Motorola LTE Whitepaper [10] also commended bicasting based schemes for lowering packet loss, but also raised a concern on the inefficient utilization of network resources. Thus, it would be essential to determine in a timely and accurate manner as to when to start and stop bicasting as shown in Fig. 1.

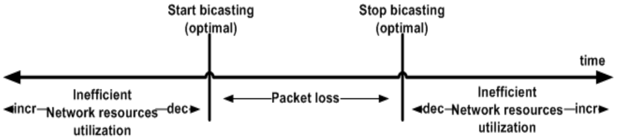


Figure 1. Bicasting analysis timeline

If bicasting starts too early or delays to stop, a significant amount of backhaul bandwidth is required. Also, if bicasting delays to start or stops prematurely, packet loss occurs.

Ji-In *et al* in [11] further improved B-PMIPv6 and proposed a partially bicasting PMIPv6 (PB-PMIPv6) which attains very low packet losses, handover delays, and minimized the network resources utilization. However, the solution may fall prey of stopping bicasting prematurely as the stop bicasting trigger is not accurately timed. This could result in stopping to deliver packets to the mobile node even though the signal strength is still strong enough for the mobile node to receive packets without errors.

III. PROPOSED ENHANCED BICASTING FOR PMIPV6

In order to solve the problems stated in Section II, this paper proposes an enhanced bicasting scheme for PMIPv6 (EB-PMIPv6). The proposed scheme achieves lower handover delay and packet loss for PMIPv6 while efficiently utilizing network resources. The EB-PMIPv6 employs timely link layer triggers that are used to accurately execute the bicasting process, handoff and a predictive layer 3 handover (binding updates). The use of timely triggers aids this solution to evade the loss of in-flight packets which results from a loss of packets just after the mobile node losses connectivity (i.e. Link is Down (LD)) from the previous point of attachment (Previous Mobile Access Gateway (PMAG)). These triggers are also used to lower the handover delay by redirecting the flow of packets destined to the mobile node at the Local Mobility Anchor (LMA) to the candidate point of attachment (Next Mobile Access Gateway (NMAG)) in advance by performing a layer 3 handover (Proxy Binding Update and Proxy Binding Acknowledgement) proactively. Lastly, we use the triggers to quicken the layer 2 handover (scanning, authentication and re-association) by forcing the mobile node to disconnect from the point of attachment as soon as the signal strength drops below the threshold for receiving packets successfully. This enables the mobile node to scan and re-associate at the earliest possible time to the next point of attachment.

EB-PMIPv6 re-uses of the signal strength thresholds (boundaries) identified in the document by the National Institute of Standards and Technology (NIST) Seamless and Secure in [12] which apply in wireless networks as shown in Fig 2 below.

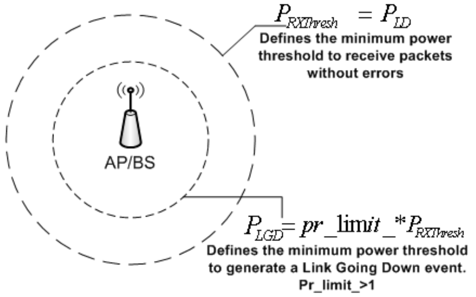


Figure 2. Signal strength thresholds/boundaries

The proposed solution performs modifications on the LMA and MAG side of the PMIPv6 architecture. Starting with changes on the MAG side, over and above the thresholds adopted from Fig. 2, EB-PMIPv6 defines two other thresholds at two signal strength (power) levels that are equally spaced from P_{LGD} by a small offset Δ_p.

$$P_{T1} = P_{LGD} + \Delta_P \quad (1) \qquad P_{T2} = P_{LGD} - \Delta_P \quad (2)$$

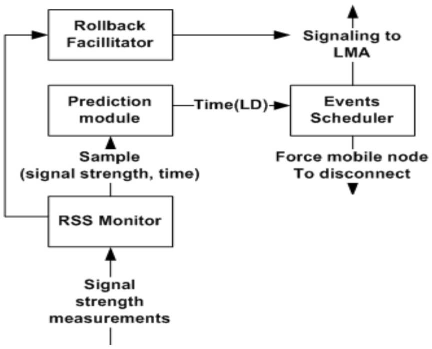


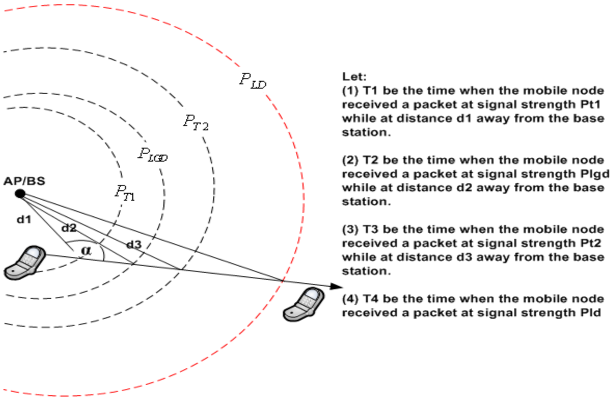
Figure 3 EB-PMIPv6 Architecture (MAG side)

Fig. 3 shows the architecture of the proposed solution on the

MAG side. The Received Signal Strength (RSS) Monitor starts monitoring the signal strength once it decays to threshold P_{T1}. During RSS monitoring, the RSS Monitor, records the power level of the packet received and the corresponding time as the signal decays to P_{T1}, P_{LGD} and P_{T2}. The RSS Monitor also alerts the Rollback facilitator module if the signal strength then increases instead of decaying. Once the signal strength deteriorates to P_{T2}, the recorded tuples (*power level, time*) collected are passed to the prediction module.

The Prediction module uses the samples passed by the RSS Monitor to predict the viability of the decaying link. The prediction algorithm used here is adopted from a link breakage prediction algorithm used in [13] for a dynamic source routing protocol. The prediction module estimates the amount of time left before the link actually breaks which we call link viability. Knowing the link viability, we can then timely and accurately execute the start bicasting and stop bicasting events. The viability is also used to know as to when to trigger a redirection of the flow of packets at the LMA from PMAG to NMAG. The output of the prediction module is the time at which the Link down (LD) event is estimated to going to be, which is when the mobile node will no longer successfully receive packets (Below signal strength $P_{RXThresh}$ (P_{LD})).

In order to describe the prediction algorithm, we consider a scenario whereby a mobile node moves away from an access point (AP) or base station (BS) which is collocated with the MAG as shown in Fig. 4.



Let:
(1) T1 be the time when the mobile node received a packet at signal strength Pt1 while at distance d1 away from the base station.

(2) T2 be the time when the mobile node received a packet at signal strength Plgd while at distance d2 away from the base station.

(3) T3 be the time when the mobile node received a packet at signal strength Pt2 while at distance d3 away from the base station.

(4) T4 be the time when the mobile node received a packet at signal strength Pld

Figure 4. Mobile node movement, and signal strength

The prediction algorithm uses the tuples passed by the RSS Monitor. These are ($P_{T1}, T1$), ($P_{LGD}, T2$) and ($P_{T2}, T3$) (Refer to Fig. 4). The propagation model used is the two ray ground reflection which considers both the direct path and a ground reflected path and is more accurate than the Free Space propagation model for longer distances whereby direct line of sight is not the only means of propagation. The power received by a mobile node at a distance *d* away from a base station or access point as per the two ray ground reflection propagation model is as shown in (3) below.

$$P_{received}(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \qquad (3)$$

Where P_t, G_t, h_t are the power transmitted by the AP/BS, gain and height of the AP/BS transmitter antenna respectively. G_r and h_r are the gain and the height of the mobile node's receiver antenna. *L* is the system loss.

From Fig. 4 above, we deduce equations that lead us to the estimation of the time when the signal strength will be at P_{LD} beyond which the mobile node will no longer be able to receive packets successfully. For simplification of (4), (5), (6) and (7), we let $t_2 = T2 - T1$, $t_3 = T3 - T1$ and $t = T4 - T1$. Our assumption is that the mobile node will maintain its velocity from the time the signal decays from P_{T1} till the link is broken.

Time	Power level (Signal Strength)
T1	$P_r = P_{T1} = \frac{kP_t}{d_1^4}$ (4)
T2	$P_r = P_{LGD} = \frac{kP_t}{(d_1^2 + (vt_2)^2 - 2d_1 vt_2 \cos\alpha)^2}$ (5)
T3	$P_r = P_{T2} = \frac{kP_t}{(d_1^2 + (vt_3)^2 - 2d_1 vt_3 \cos\alpha)^2}$ (6)
At Link Down	$P_r = P_{LD} = \frac{kP_t}{(d_1^2 + (vt)^2 - 2d_1 vt \cos\alpha)^2}$ (7)

Where $k = \frac{G_t G_r h_t^2 h_r^2}{L}$

In solving for *t*, after carrying out mathematical substitutions and eliminations of unknown variables such as the mobile node velocity the solution is of the form $at^2 + bt + c = 0$ which is a quadratic equation. The constants *a*, *b* and *c* are as shown by (8), (9) and (10) below.

$$a = t_2 \beta \sqrt{P_{LD} P_{LGD}} \qquad (8)$$

$$b = \sqrt{P_{LD}} \left(\sqrt{P_{T1}} - \sqrt{P_{LGD}} - t_2^2 \beta \sqrt{P_{LGD}} \right) \qquad (9)$$

$$c = t_2 \left(\sqrt{P_{LGD} P_{LD}} - \sqrt{P_{T1} P_{LGD}} \right) \qquad (10)$$

Where $\beta = \frac{t_2 \left(\sqrt{P_{T1} P_{LGD}} - \sqrt{P_{LGD} P_{T2}} \right) + t_3 \left(\sqrt{P_{LGD} P_{T2}} - \sqrt{P_{T1} P_{T2}} \right)}{\left(t_2 t_3^2 - t_2^2 t_3 \right) \sqrt{P_{LGD} P_{T2}}}$

From the solutions of the quadratic equation, we consider the positive one since we are interested in a future prediction. Thus, $t = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$ which is an approximate time left before the link actually goes down (breaks). Therefore, the time estimate as to when the link will be down (LD) is as given by (11).

$$Time\ (LD) = T4 = T1 + t \qquad (11)$$

The Events scheduler passes signaling messages to the LMA and the mobile node. These signaling messages instruct the LMA and mobile node the time at which they have to carry out certain commands. The signaling message sent to the mobile node instructs the mobile node to disconnect from the point of attachment with degrading signal strength. This aids the mobile node to start the layer 2 handover (scanning new channels, authentication, and re-association) to the new point of attachment at the earliest possible time. Thus, the mobile node is forced to disconnect at time $Time\ (LD)$ since there is no need for the mobile node to continue to remain attached when the signal strength is below the receive threshold P_{LD} or $P_{RXThresh}$.

The Events scheduler also sends a signaling message to the LMA to perform pre-registration on behalf the mobile node and setup a route to the candidate point of attachment (between LMA and NMAG) when a handover is imminent. This is done to perform a predictive layer 3 handover. The expressions below show how performing a predictive handover lowers the handover delay of PMIPv6. Therefore the proposed solution also performs predictive handovers thus lowering the handover delay.

$$t_{PMIPv\ 6} = t_{L2-L3} + t_{PBU} + t_{PBA} + t_{MN\_HNP\_Adv}$$

$$t_{\Pr edictive\_PMIPv\ 6} \approx t_{MN\_HNP\_Adv}$$

t_{L2-L3} is the time for Layer 2 to notify Layer 3 of the mobile node's attachment. t_{PBU} and t_{PBA} accounts for the delay of the proxy binding update from the MAG and the proxy binding acknowledgement from the LMA. And, $t_{MN\_HNP\_Adv}$ is the delay incurred for the router advertisement that contains the home network prefix for the mobile node to configure the same home address throughout the PMIPv6 domain. In the case of predictive PMIPv6, the binding update process and pre-registration for the mobile node between the NMAG and the LMA is done in advance and hence technically the mobile node is in advance attached to the next MAG. It should however be noted that the total handover delay during which the mobile node is unable to receive any packets includes the layer 2 handover latency.

Furthermore, the events scheduler sends the LMA the message which instructs the LMA as to when to start and stop bicasting so that bicasting is executed in a timely and accurate manner. Unlike the previously proposed solutions, the times to start and stop bicasting are correlated to the rate of signal strength decay. To minimize the loss of in-flight packets, our solution stops sending packets to PMAG ahead of the time when the link will be down as shown by (12). This is also considered to be a stop bicasting time.

$$t_{stop\_bicasting} = time(LD) - \{t_{LMA-PMAG} + t_{PMAG-MN}\} \quad (12)$$

This hence increases the probability that the last packet sent to PMAG by the LMA is received by the mobile node just before signal strength decays beyond P_{LD}. Thus, at this time, a route from LMA to PMAG is cleared. Bicasting starts marginally before stopping bicasting. This is so that the bicasting duration is very short so as to minimally use double the amount of backhaul bandwidth. This is by a time margin Δ_t . $(\Delta_t \geq 0)$

$$t_{start\_bicasting} = time(LD) - \{t_{LMA-PMAG} + t_{PMAG-MN} + \Delta_t\} \quad (13)$$

Lastly we discuss the modifications on the LMA side for the proposed solution. The solution's architecture is shown on Fig. 5. The classifier classifies and routes the signaling messages appropriately to either the Bicasting Trigger Generator or the Pre-routing update facilitator. The Pre-routing update facilitator ensures that the mobile node is pre-registered and sets up a route between LMA and NMAG in advance and that the mobile node is pre-inserted into the NMAG binding cache list. Lastly, the Bicasting Trigger generator generates triggers to start and stop bicasting triggers. The Bicasting engine is responsible for carrying out the actual duplication of packets and then encapsulates them in an IP-in-IP tunnel to both the PMAG and NMAG during the bicasting period. Thus during bicasting, a mobile node has two simultaneous bindings in the LMA binding cache entry list associating it to PMAG and NMAG. Packets destined for the mobile node that arrive at NMAG (Next (Candidate) MAG) during the layer 2 handover are buffered at NMAG and sent to the mobile node as soon as it attaches.

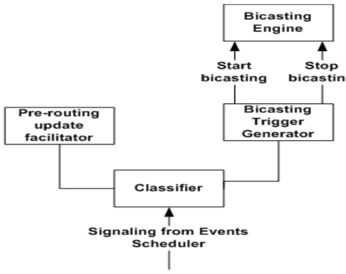


Figure 5. EB-PMIPv6 Architecture (LMA side)

The overall flow of signaling messages and operations that have been discussed in detail are collectively shown in the message sequence chart in Fig 6 below.

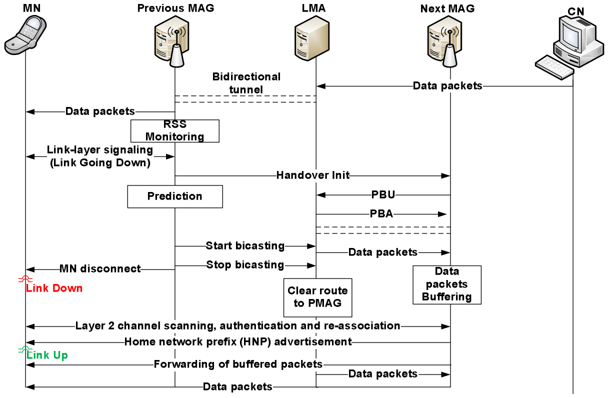


Figure 6. EB-PMIPv6 Message sequence chart

IV. SIMULATION SETUP

Now, we discuss how the EB-PMIPv6 model was simulated and tested for proof of concept purposes. We used the Network Simulator 2 (ns-2) to simulate EB-PMIPv6 handovers since the simulator already has a working and tested PMIPv6 model. The simulation was set up as shown in Fig. 7 below. The network configuration was done on a TCL script while the implementation of the model was done using C++.

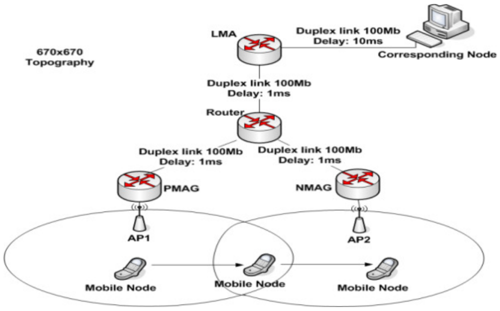


Figure 7. Simulation setup

For comparison purposes, simulations were performed for four schemes, namely (1) the PMIPv6 as it is, (2) the proposed EB-PMIPv6, and (3) Bicasting PMIPv6 (B-PMIPv6) [8, 9], and (4) Partially Bicasting PMIPv6 (PB-PMIPv6) [11]. For uniformity, each simulation ran for 60 seconds. At 0.5 seconds a corresponding node (CN) starts sending constant bit-rate (CBR) packets of size 1000 bytes every 0.001s (CBR packet interval) over User Datagram Protocol (UDP) to the mobile node (MN) to emulate a real-time traffic stream. Thus, the CN is the traffic source whereas the MN is the traffic sink. A very short CBR packet interval of 0.001s was used in the simulations so as to approximate the handover delay accurately as packets are received by the mobile node just before the link goes down on PMAG and as soon as the link is up on NMAG. At 1sec, MN begins to move at a uniform speed so as to perform a handover from PMAG to NMAG. CBR traffic is stopped at 59.5sec. And, at 60 sec the simulation halts. The links' respective bandwidth allocations and delays were as indicated in Fig. 7. Other parameters of the simulation were varied to test and evaluate different performance metrics.

V. RESULTS AND PERFORMANCE ANALYSES

In this section, we discuss and analyze the performance results obtained from simulating different scenarios using each of the mobility management schemes. For the result presented in Fig. 8, in addition to the simulation parameters outlined in section IV, to simulate a handover from PMAG to NMAG, at 1 sec, the MN began to move from PMAG to NMAG at the velocity of 30m/s. Data used to plot the graph in Fig. 8 was extracted from the simulation trace output from the interval 12.5 seconds to 15.5 seconds within which the handover occurs. The break in reception of packets indicates the duration whereby the MN was not able to receive packets from PMAG and handing over to NMAG which we refer to as the handover delay. It can then be observed that B-PMIPv6, and EB-PMIPv6 attain a much shorter handover delay than PMIPv6 because they employ a predictive handover mechanism as opposed to the reactive mechanism used by PMIPv6. Furthermore, for B-PMIPv6 and EB-PMIPv6 the MN is able to receive packets through PMAG till the signal strength reaches the receive threshold and immediately after attaching to NMAG. It should however be observed that for B-PMIPv6, the MN receives duplicate packets which depicts an inefficient backhaul link usage, and networking infrastructure.

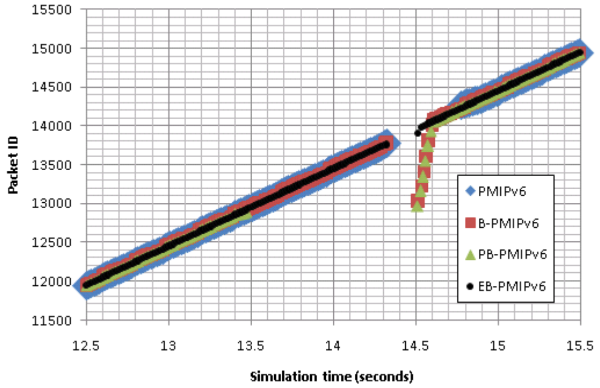


Figure 8. CBR packets received by MN

On the other hand, even though PB-PMIPv6 also uses a predictive handover mechanism, the MN takes a much longer time without receiving packets. This is primarily due to the operation of PB-PMIPv6; whereby the scheme stops routing packets to PMAG as soon as a bidirectional tunnel is established between the LMA and the NMAG. This is done regardless of whether the signal strength is still strong enough to deliver packets from PMAG to MN without errors. Thus, it is observable that PB-PMIPv6 can incur even longer handover delays at lower MN speeds (e.g. pedestrian speeds). However, it can perform better at higher MN speeds. It can further be observed that the utilization of the buffer on NMAG aids B-PMIPv6, PB-PMIPv6 and EB-PMIPv6 to incur lower packet loss after redirecting packets at the anchor point (LMA) to NMAG during the handover before the mobile node re-attaches to the network. Lastly, since PMIPv6 redirects packets to NMAG after MN attaches to NMAG a significant amount of packets are dropped on PMAG.

Secondly, in Fig. 9, we assess the NMAG buffer space utilization which is required by the schemes to alleviate packet loss when the mobile node cannot receive packets from neither PMAG nor NMAG during the handover.

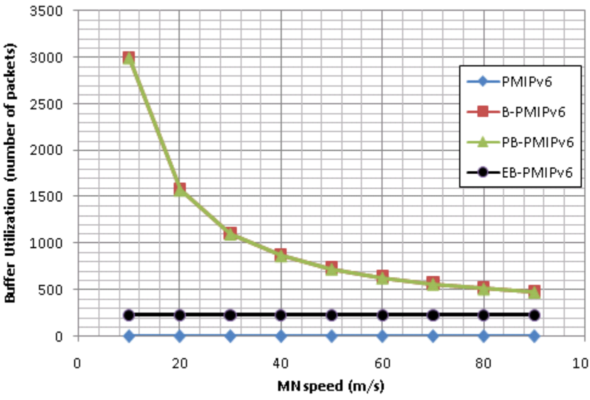


Figure 9. NMAG Buffer Utilization

Starting with PMIPv6, this scheme does not utilize the buffer on NMAG since packets are only redirected to NMAG after a successful handover since a reactive approach is used. Our proposed solution; EB-PMIPv6 utilizes much less buffer space than B-PMIPv6 and PB-PMIPv6 which lowers the chances of buffer overflows if a large number of mobile nodes simultaneously perform a handover requiring packet buffering to lower packet loss. It can also be seen that the number of packets buffered is almost constant regardless of the speed of the mobile node. This is because the duration in which packets need to be buffered is constant. This is the time in which the mobile node performs the layer 2 handover (channel scanning, re-association and authentication). This also shows that through using optimized layer 2 handover mechanisms, the buffer utilization can further be reduced conserving the buffer space which is not an unlimited resource. On the other hand, B-PMIPv6 and PB-PMIPv6 utilize more buffer space, with PB-PMIPv6 utilizing slightly less buffer space. It is also observable than the lower the MN speed the more buffer space is required to alleviate packet loss. This is because the lower the mobile node's speed, the longer the time it will take the MN to attach to NMAG which is the element which buffers the packets.

Lastly, the paper presents a result obtained in evaluating the schemes for packets dropped on PMAG which results from routing packets to PMAG (misrouting) when the MN is no longer attached to PMAG or just before the MN moves out of PMAG's coverage area (loss of in-flight packets). We thus use the graph in Fig. 10 below to assess the inefficient utilization of the backhaul bandwidth since packets dropped by PMAG due to the above mentioned reasons ultimately do not reach the MN and hence utilize the backhaul bandwidth unnecessarily.

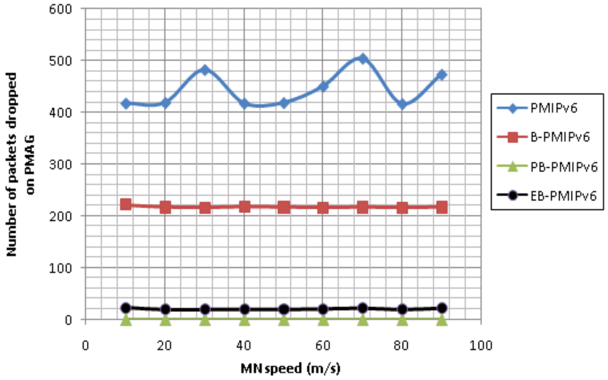


Figure 10. Packets dropped on PMAG

From Fig. 10, it can be observed that PMIPv6 incurs the highest packet drops on PMAG. And, this is primarily due to its usage of a reactive handover approach whereby packets are routed to PMAG until the MN attaches to NMAG. Thus, during the handover, packets are continuously sent to PMAG even though they will not reach MN through PMAG. B-PMIPv6 also incurs high packet drops on PMAG because bicasting which sends packets to both PMAG and NMAG only stops after the MN has attached to NMAG. Thus, packets are also sent to PMAG unnecessarily and hence utilize the backhaul bandwidth inefficiently. However, B-PMIPv6 incurs a lower packet loss compared to PMIPv6 because B-PMIPv6 handover delay is much shorter than that of PMIPv6.

Our solution, EB-PMIPv6 incurs a low packet loss on PMAG because the scheme stops routing packets destined for MN to PMAG as soon as the signal strength drops below the receive threshold ($P_{RXThresh}$) since the packets will ultimately not reach the MN. Thus, EB-PMIPv6 utilizes the backhaul bandwidth much more efficiently. PB-PMIPv6 attains no packet drops on PMAG since the scheme stops sends routing packets to PMAG way in advance which aids it to use the backhaul bandwidth efficiently. But, this in turn affects the MN negatively since the MN stops receiving packets though PMAG even though the signal strength is still strong enough to deliver packets, thus creating a realizable glitch in the service being consumed by the MN.

VI. CONCLUSION

In this paper, an enhanced bicasting scheme for PMIPv6 (EB-PMIPv6) has been proposed and its operation has been discussed in-depth. The proposed scheme's performance has been compared to other bicasting schemes for PMIPv6 (B-PMIPv6 and PB-PMIPv6) and the classical PMIPv6 in regards to packet loss and handover delay. And, the results indeed show that EB-PMIPv6 attains low handover delay and packet loss. Furthermore, EB-PMIPv6 strikes a balance between attempting to attain a seamless handover by reducing packet loss and handover delay; and utilizing network resources (backhaul bandwidth and buffer space) much more efficiently than other bicasting schemes. This is attained regardless of the speed of the mobile node which is variable that is difficult to determine from the network-side. Overall, the proposed scheme performs better regardless of the mobile node speed since it monitors the signal strength so as to execute the handover operations and bicasting in a timely and more accurate manner.

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