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# A Comparative Study of Handoff Schemes in Vehicle to Infrastructure using Mobile WiMAX

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***Abstract*– With the increase in user mobility, there is need for seamless handover when mobile applications and services are being used especially in the context of vehicular Ad-Hoc networks (VANET), in order to enhance the user experience thus affecting the quality of service. This paper looks at VANET with WiMAX with a vehicle moving at speeds of up to 120 km/h. Real time applications like Voice over Internet protocol (VoIP) and Video conferencing have stringent requirements on delay. The network layer that is being considered in this case is IPv6. In the case of VoIP this affects echo and speech overlap in the system. In order for services requiring low delays, various handoff schemes have been proposed which includes FMIPv6 and HMIPv6 which deal with latencies due to movement anticipation and care of address configuration, and signaling delays respectively. A simulation study is done in order to evaluate the handoff latency using fast hierarchical handover for Mobile IPv6, of which different handoff times are observed.**

***Index Terms*– Handoff Latency, Fast Handover, VANET and WiMAX**

## I. INTRODUCTION

THE growing number of mobile users has resulted in a demand for high speed and bandwidth applications and services. In order to provide a wider coverage in metropolitans, mobile WiMAX is a suitable candidate. VoIP and video streaming have stringent delay requirements in order for system to have optimum performance. A typical WiMAX infrastructure has a number of base stations and when mobile users move from one base station to another, Handoff occurs. When vehicles are considered moving at high speed, there are huge latencies which are experienced by the user as they move from one base station coverage area to another, this is mostly due to conventional handoff process inherent to Ipv6.

This latency has an adverse effect in the communication process resulting in the break in the reception of a complete termination of the whole session [1]. The purpose of this study was to analyse the performance of the WiMAX network in terms of handoff latency, packet loss and throughput during handoff with emphasis on using FHMIPv6.

## II. RELATED WORKS

There are several works which have been carried out in the area of handoff latency optimisation and in particular that of VANET. In [2] mobile IP handover reduction is done using seamless handover architecture, the goal was the reduction of handover delay in the IP layer. Seamless mobility means the ability of a mobile user move freely between the various base station as well as other networks. The key in seamless handover is for the mobile user to stay connected without losing the ongoing session.

The studied [3, 4] latency in two-way communication of VoIP in WLAN and handoff latency of VoIP in mobile IPv6 (MIPv6).This involved studying three different voice coding schemes namely G711,G723.1 and G729 to determine the effects on the handoff latency and the quality of service parameters were packet loss, throughput and delay. The objective was to look at the performance of VoIP during handoff in MIPv6 as well as looking at the reduction of the handoff delays and packet loss which occurred during the handoff process by using Fast MIPv6 (FMIPv6). And lastly to analyse and compare the performance of VoIP in both MIPv6 and FMIPv6. It is shown that in MIPv6, the different codecs do have significant effect on the handoff latency. Also for all codecs in the case of MIPv6, there was a drop in the throughput during handoff since no packets were received by the mobile node (MN) at that time. Mobile Node(MN) and Mobile station(MS) are being used interchangeably in the rest of this paper.

When the case of FMIPv6 was considered, no packet loss was observed during handoff time for all the three codecs. And it was also observed that the handoff latency was due to the forwarding of packets from previous access router (PAR) to new access router (NAR). There was no significant drop in throughput for FMIPv6 when compared with the case of using MIPv6. Thus when average throughput was considered, FMIPv6 scheme achieved a higher system performance because no packet loss was observed during the handoff times. The study concluded by stating that, overall FMIPv6 manages to reduce the handoff latency significantly. This results in providing seamless mobility and therefore improving the performance of VoIP applications.

Another significant study [5], handover blackout duration of layer 3 (L3) mobility management schemes are looked into. Various management protocols included Hierarchical MIPv6 (HMIPv6) and FMIPv6. A simple analytical comparison was done on all the presented protocols. This was done by using four inter-domain handover scenarios with different delays between the entities involved. This showed that the handover performance could greatly be improved when the basic protocol were to be extended by additional functionality. The study showed that the tunneling of packets during handover significantly reduces the blackout time during which the MN is not able to receive packets. In the analysis, it was observed that the best performance in terms of handoff delay was shown by the pure FMIPv6 protocol in its predictive version and SMIP, a combination of HMIPv6, FMIPv6 and bi-casting. It was further shown that the handoff delay in the inter-domain scenarios further depended on the constellation of the participating entities. Thus not only communication delays between MN, home agent (HA) and correspondent node (CN) played a major role, but also the delays between previous access router (PAR), new access router (NAR), previous MAP (PMAP) and new MAP (NMAP).

The proposal in [6] exploits the domain name system (DNS) to develop a mobility management such that the function of mobility management is transparent.

## III. HANDOFF PROCESS

In WiMAX, handoff (HO) is defined as the set of procedures that enable an MS to migrate from the air interface of one BS to the air interface of another [14]. The handoff, also known as handover consists of different stages:

- Cell selection.
- Handoff decision and initiation.
- Synchronisation to the target BS.
- Ranging with the target BS.
- Termination of context with previous BS.

### *A. Cell selection*

MS uses information that is acquired from a decoded MOB_NBR-ADV message obtained from a neighbour BS. It may also make a request to schedule scanning intervals or sleep-intervals, this is in order for the neighbour BS to be evaluated in handover to potential target BS. The cell reselection process may not occur in conjunction with any specific contemplated HO decision.

### *B. HO Decision and Initiation*

Handover begins when an MS decides to handover from a serving BS to another target BS. This decision is brought about by either the MS or the serving BS. This is indicated by either the MOB_MSHO-REQ message which is the notification by the MS or the MOB_BSHO-REQ which is from the serving BS.

### *C. Synchronization to Target BS*

In this stage, the MS synchronises to the downlink transmission of the target BS and obtains the downlink (DL) and uplink (UL) transmission parameters. If the MS had received a neighbour advertisement message, MOB_NBR-ADV which includes the target BSID, physical frequency, DCD and UCD [7], this process is shortened. If the target BS had previously received HO notification from serving BS over the back-bone, then target BS may allocate non-contention-based Initial Ranging opportunities.

### *D. Ranging with the target BS*

The process that follows after the synchronisation is ranging. This stage consists of several processes which exist between the MS and the target BS. The purpose is to communicate the characteristics of the transmission link.

### *E. Termination of Context with Previous BS*

This is the final step in the handover process. Termination of MS context can be defined as serving BS termination of context of all the connections belonging to the MS and the context associated with them such as information in queues, ARQ state machines, counters, timers, header suppression information is all discarded. An MS can cancel the handover process at any time before the expiration of the resource-retain time interval after transmission of the MOB_HOD-IND message.

## IV. HANDOFF SCHEMES

Handoff in a mobile network consists of components that are encountered at the physical/Mac and at the Network layer. Network layer handoff results when the mobile station shifts to a different Access Service Network (ASN) from its current one. To enhance mobility in mobile IPv6 (MIPv6), Fast Mobile IPv6 (FMIPv6) is combined with Hierarchical MIPv6 (HMIPv6) to form Fast Hierarchical MIPv6 (FHMIPv6).When it comes to FHMIPv6, a tunnel is established between MAP and NAR as opposed to between PAR and NAR. When it is implemented in such a manner, the MS communicates the FMIPv6 messages with MAP and PAR. In FHMIPv6 no new messages are created, instead the FMIPv6 messages are utilised.

### *A. Layer 2 and layer 3 handovers*

With reference to mobility management, a handover describes the movement of a mobile node between different points of attachments in a network. The points of attachments are access points (AP) or could be base stations depending on the particular investigated network. For example Global System for mobile communication (GSM) was designed to handover a mobile phone from one base station to another. There are several causes which could trigger this, one of the factors being the degradation in the quality of the wireless link which is indicated by the received signal strength indicator RSSI.

When IP is used on top of the radio link, the change in the access points during handover results in a change in IP addresses. This is illustrated in Fig. 1.

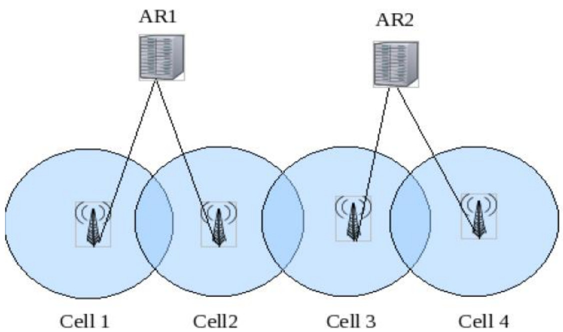


Fig. 1: Layer 2 vs. Layer 3 handovers

Each base station has a specific cell coverage area which can vary in size depending on the radio technology being used and the transmit power that is applied. The antenna system will also affect the coverage area, whether it is an omni-directional antenna or sectored system. For instance in GSM systems the upper limit of 35 km for a single cell is used, they could also be as small as 100meters. Technologies like code division multiple access (CDMA) have cells which vary in size depending on the number of users and the transmitted power.

From the fig.1 it can be seen that the handoff between cell 1 and cell 3 results in a change in the location of the mobile node within the topology. This results in both the IP layer and a link-layer handoff to takes place. This illustrates how IP layer handoff takes place resulting from the link-layer handoff. The IP layer handoff however is not always triggered by the layer 2. A typical case could be a multi-homed mobile node having two different physical interfaces [8], one can be a cellular link whilst the other being an ethernet link.

## V. HANDOVER IN MIPV6

This section presents the review of the mathematical treatise in relation to handover in Mobile IPv6 as shown in [15]. L3 handover is caused when there is a change in a MN's location in the network topology regardless of the cause which could be a trigger from the layer 2 or interface change. Because of this change, the mobile node needs to inform the CN and the HA. However the break in layer 2 still exists. This can be referred using (1).

$$\delta_t = \delta_i + \delta_l \qquad (1)$$

Where: $\delta t$ is the time during which the MN is unable to send or receive packets.

$\delta i$ is the time during which the MN cannot send or receive packets due to mobile IPv6 actions.

$\delta l$ is the time during which the node is unable to send or receive packets due to the link-layer handover.

What is essentially required is the elimination of the $\delta_i$. The MN does this by sending a router solicitation (RS) message to the new router. There are several causes which indicate to the mobile node that it should send the RS message:

- When the router advertisement (RA) interval has lapsed and the mobile node has not received any router advertisement.
- When the L3 receives a trigger from the L2 indicating that handoff has taken place.
- When the MN receives the RA, it configures a new care of address. The movement detection delays can be summarised by (2).

$$\delta_{mv} = \delta_{rs} + \delta_{ra} + \delta_{coa} \qquad (2)$$

Where: $\delta_{mv}$ is the time required for the MN for detection that it has moved,

$\delta_{rs}$ *is* the time it take for router to receive the RS message.

$\delta_{ra}$ is the time just after $\delta_{rs}$ and ends when the MN receives router advertisement.

$\delta_{coa}$ is the time it takes for the MN to configure a new care of address and then test it using duplicate address detection (DAD) for duplication.

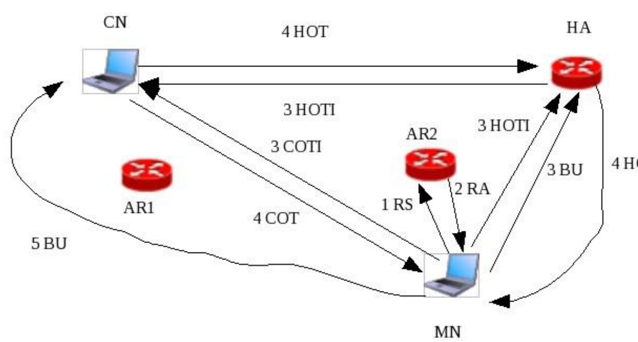


Fig. 2: Mobile IPv6 handover time [15]

$\delta_{bu}$ is the time taken for the mobile node to update its HA and the CNs. This time depends on the delay incurred by packets which are sent between the MN and the HA (HOTI/HOT and binding update to the home agent), the delay which is incurred between the HA and the CN (HOTI/HOT) and the delay between the MN and the CN (for COTI/COT and the binding update). It can be said that the HOTI/HOT messages always take more time than the COTI/COT messages. This can be expressed as shown in (3).

$$\delta_{mn-ha-cn} >= \delta_{mn-cn} \qquad (3)$$

Where: $\delta_{mn\text{-}ha\text{-}cn}$ is the time it takes a message to travel between the MN and the CN through the home agent (HOTI/HOT messages).

$\delta_{mn\text{-}cn}$ is the time it takes the same message to travel directly between the mobile and correspondent nodes (COTI/COT/BU).

Where the binding update reaches first before the HOTI at the home agent, it will allow for the return routability test to work. Thus;

$$\delta_{bu} = \delta_{mn-ha-cn} + \delta_{mn-cn} \tag{4}$$

From which the total handover time $\delta_{ho}$ can be calculated as:

$$\delta_i = \delta_{ho} = \delta_{mv} + \delta_{bu} = \delta_{rs} + \delta_{ra} + \delta_{coa} + \delta_{mn-ha-cn} + \delta_{mn-cn} \tag{5}$$

The major delay components in (5) are caused by DAD delays ($\delta_{coa}$) and the random delay used by the MN and router before an RS/RA is sent respectively.

## VI. HANDOVER OPTIMIZATION

From the discussions in the previous section, it can be seen that there is need for the reduction of packet losses which arise out of mobile IPv6. These delays are caused by the following factors: the delays which occur between the MN and its HA. Also the delays which are associated with movement detection. There are different mechanisms that have been adopted in order to address the delay issues. These schemes can be used independently or could be combined in order to address certain aspects which cause delays which in turn affect the performance of mobile IPv6 handovers.

### *A. Fast Handovers for Mobile IPv6*

This is known as FMIPv6, it can also be called as fast handoff. FMIPv6 is concerned with minimising delays which are associated with movement detection and mobile IPv6 signaling delays between the mobile node and home agent/correspondent nodes [9].

### *B. Hierarchical Mobile IPv6*

HMIPv6 was designed in order to allow movement of the mobile nodes within a particular domain without the need to update their home agents or the correspondent nodes every time they moved. Only one binding update is is sent to a Mobility Anchor Point (MAP) which is located in the visited network. The aim of HMIPv6 is in order to reduce the number of messages to one at the same time maintaining an optimal route to the mobile node. Routing can be optimised by having a home agent close to the mobile node while the number of signals sent by the mobile node is reduced. A MAP can be considered as a local home agent which is located in the visited network. Upon visiting the new network, the mobile node discovers the IPv6 address of the MAP.

## VII. RESULTS AND DISCUSSION

The WiMAX forum identified several applications that are capable of running on mobile WiMAX based systems considering performance metrics including latency. This is summarised in [10]. The guidelines help to assume a quality user experience. It must be noted that the latency for VoIP needs to be below 50msec for good performance, however at least values below 160 msec can suffice.

This section is a presentation of the results that were obtained from the various scenarios which were simulated using Omnet++ 4. The result looks at the two cases of optimised and non-optimised. Optimised in this context means the application of the handoff schemes in order to reduce the handoff latency [11]. The results for the optimised case do not include the DAD which was seen to be the major contributor towards the latencies. The scheme that was used in this case to evaluate the performance was a combination of FMIPv6 and HMIPv6 to form FHMIPv6.

Under both cases of the optimised and non-optimised, the simulation was furthermore divided into two scenarios. Movement of a MN within the same MAP/ASN domain, known as Intra ASN handoff and the movement of the MN between two MAP domains and ASN, known as Inter ASN handoff [12,13].

The performance metric Latency was evaluated at the speeds at which the MN moved at which are 120 km/h, 20km/h and 5 km/h. The performance results are finally summarised, the different graphs show the result that was obtained.

### *A. Case 1: Network without optimization*

Corresponding node, CN0 sends traffic (data) to the mobile node MS0. The Home agent is embedded within the base station and the source traffic type was a constant bit rate (CBR).For simulation purposes, 500Bytes per second were being sent to the mobile station, MS0. This first case is not optimised because standard mobile IPv6 was being used when handoff took place. During handover, the MN is disconnected from the serving base stations (access router). There are no packets that can reach the mobile nodes during the handoff interval. This case is as shown in Fig. 3.

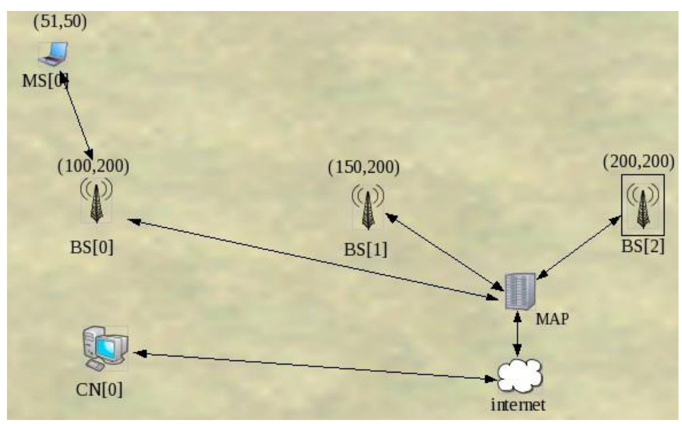


Fig. 3: Network structure without MAP

### *Case 2: Network with Optimisation*

The second scenario involved the optimised case as shown in fig.4. This is the implementation of the fast handoff scheme using FHMIPv6. Even in this scenario, observations were made for the two cases of Inter MAP/ASN and Intra MAP/ASN handover and the results compared. In Fig. 4, the position of the mobility anchor point is shown.

The implementation of the MAP can either be integrated with the base station or can be outside the BS, this is largely a matter of choice by the operator and the environment in which the network is being set up.

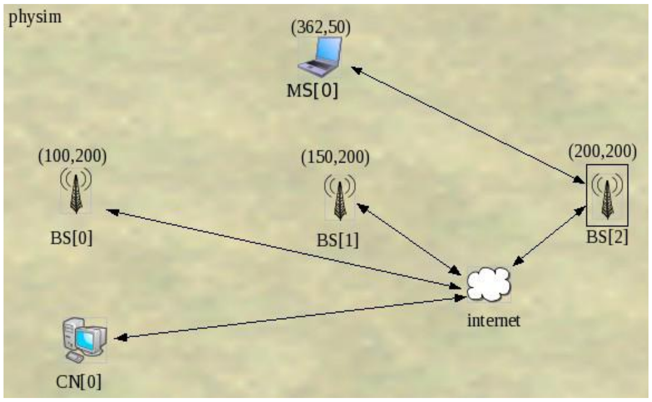


Fig. 4: Network structure with MAP included

For this simulation, a two level hierarchy was used. Each base station had an integrated MAP, for inter MAP observation. And there was one MAP implemented which was one stage up the hierarchy, so in total the FHMIPv6 was a two tier.

## *B. Handoff Latency*

The network set up involved three base stations, and the mobile station was initially attached to base station 1, which meant that by the time it got attached to the third base station, the mobile node would have under gone a total of two handovers. The handovers are between base stations BS0 and BS1, and BS1 and BS2 (see fig.3 and fig.4). Fig.5 depicts the graph for a mobile station at a selected speed of 120 km/h.

The network parameters were as follow:

- BS to BS -50km, operating Frequency 2500 MHZ.
- BS height 32 m,cell radius 35 km, Overlap -10km.
- BS max power 43 dBm, mobile terminal power 23dBm.
- Link capacity for backbone was set to 1Mbps, delay of 1ms.

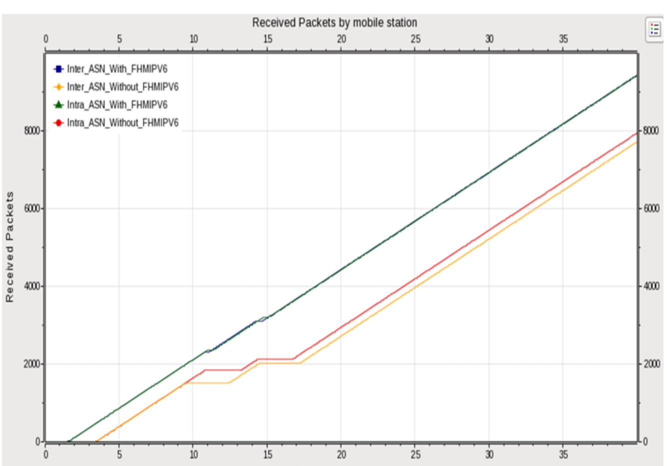


Fig. 5: Received packets vs simulation time at 120 km/h

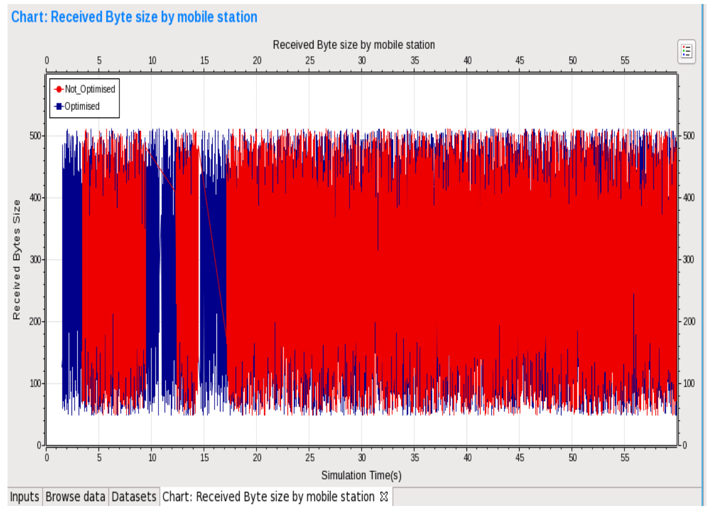


Fig. 6: Received Packets during handoff for optimized and non optimized cases

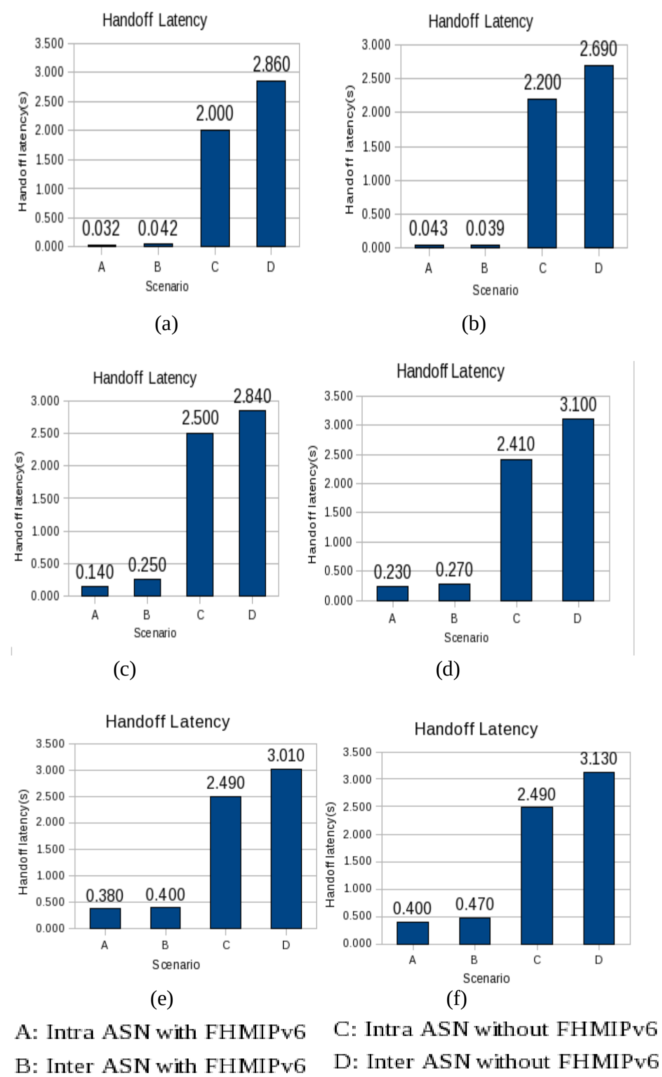


Fig. 7: (a) Handoff at 120 km/h from BS0 and BS1 (b) Handoff at 120 km/h from BS1 and BS2 (c) Handoff at 20 km/h from BS0 and BS1 (d) Handoff at 20 km/h from BS1 and BS2 (e) Handoff at 5 km/h from BS0 and BS1 (f) Handoff at 5 km/h from BS1 and BS2

TABLE I
SUMMARY OF THE HANDOFF LATENCIES

| CATEGORY | SPEED(KM/H) | HANDOFF LATENCY(s) 1st HANDOFF | 2nd HANDOFF |
|---|---|---|---|
| Inter ASN without FHMIPv6. | 120 | 2.86 | 2.69 |
| Intra ASN without FHMIPv6. | 120 | 2 | 2.2 |
| Inter ASN With FHMIPv6. | 120 | 0.042 | 0.039 |
| Intra ASN with FHMIPv6. | 120 | 0.032 | 0.043 |
| Inter ASN without FHMIPv6. | 20 | 2.84 | 3.1 |
| Intra ASN without FHMIPv6. | 20 | 2.50 | 2.41 |
| Inter ASN with FHMIPv6. | 20 | 0.25 | 0.27 |
| Intra ASN With FHMIPv6. | 20 | 0.14 | 0.23 |
| Inter ASN without FHMIPv6. | 5 | 3.01 | 3.13 |
| Intra ASN without FHMIPv6. | 5 | 2.49 | 2.49 |
| Inter ASN with FHMIPv6. | 5 | 0.40 | 0.47 |
| Intra ASN With FHMIPv6. | 5 | 0.38 | 0.40 |

The flat part of the graph in Fig. 5 is the moment during which handoff was taking place. It is observed from the graph the flat part is more prominent when a handoff scheme is not used in both the intra and inter ASN handoff. Fig. 6 shows the received packets during handoff with the graph showing no packets received during handoff for the non-optimised case and the optimised case receives packets during the same time interval.

It was observed that there was remarkable reduction in the handoff latency with the most being at speeds of 120 km/h, this is summarized in Table I. It is seen that as the speed increases, the handoff time between the base stations also reduces. Fig. 7 compares the various handoff at the investigated speeds when the handoff schemes are applied.

## VIII. CONCLUSION

Mobile IPv6 was designed with mobility in mind, however, handoff delays are still encountered when it is used hence affecting services which are real-time based. Several proposals have been made in order to deal with the issue of handoff latency which includes FMIPv6 and HMIPv6. FMIPv6 was designed to deal with handoff latencies which are mainly caused by movement anticipation and the Care of address configuration. HMIPv6 was designed to deal with handoff latencies which deal with signaling with the aim of reducing the number of signaling messages. In order to achieve this , HMIPv6 introduces the Mobility Anchor Point ( MAP ) which acts as a local home agent in the visited base station by the mobile node. Thus the mobile node does not have to send a BU to it home agent every time it makes a movement but instead only sends one BU to the MAP. In order to have good optimisation, a combination of the two mentioned handoff scheme was investigated which is termed FHMIPv6, whose overall effect is that it benefits from both FMIPv6 and HMIPv6.

This paper investigated handoff latency in vehicle to infrastructure and WiMAX. The vehicle is moving at a speed of 120 km/h which is considered as vehicular speed. WiMAX, IEEE 802.16e was used as the standard for communication between the vehicles, in this case the mobile node, with the infrastructure which consisted of WiMAX base station. The performance metric investigated was handoff latency. When the metrics were compared with speeds of 20 km/h and 5 km/h, it was observed that the handoff latency increased with the reduction in the speed with the handoff scheme applied, without the application of the handoff scheme, the difference was minimal.

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