

# Optimized handover delay in Proxy Mobile IPv6 using IEEE802.21 MIH Services

Linoh Magagula and H. Anthony Chan

**Abstract**— Recent trends are showing fast convergence of mobile and wireless communication networks with internet services to provide ubiquitous access to network users. It is envisioned that these next generation wireless networks will be supported by an all-IP based infrastructure with the support of heterogeneous wireless access technologies such as UMTS, WLAN, WiMax, etc. These heterogeneous access networks differ in many properties and characteristics such as data rates, coverage, and capacity, as well as mobility, QoS and security requirements. Since these networks are complementary to each other, their integration will empower mobile users to be connected to the all-IP based infrastructure using the best available access network during roaming. However, mobility management across these heterogeneous wireless networks poses a great challenge, particularly, in issues of handover including reducing handover delay. The different characteristics of these networks demand for superior mobility management schemes for providing seamless handover with minimal handover delay. Hence, the widely proposed host-based mobility management protocols where the mobile node is involved in mobility-related signaling may not be ideal for the future wireless networks. This paper, therefore, proposes a network-based mobility management framework, based on Proxy Mobile IPv6, to reduce handover delay by optimizing the authentication delay. The framework incorporates IEEE802.21 to facilitate the handover across the networks. We show through analysis of the signaling procedure that the proposed mechanism performs better than the basic Proxy Mobile IPv6 and host-based mobility management schemes such as HMIPv6.

**Index Terms**—Authentication delay, Handover delay, Mobility-related signaling, Proxy Mobile IPv6.

## I. INTRODUCTION

**N**EXT generation wireless networks (NGWN) will be supported by an all-IP based infrastructure [1] with the support of heterogeneous wireless access technologies. Thus, mobile users will be able to roam across this IP-based heterogeneous wireless network without any noticeable disruption to ongoing communication flows. The network layer is the choice for convergence of the heterogeneous wireless networks in the all-IP vision [1].

However, roaming across these networks which have different properties and characteristics requires superior

mobility management techniques to support seamless handover with negligible handover delay to avoid disruption of active services. More so, NGWN will support real-time multimedia applications which are inherently intolerant of handover delays. Network layer based mobility management protocol, Mobile Internet Protocol (MIP), has been proposed and standardized by IETF to provide transparent node mobility support across networks [2].

Generally, in MIP a mobile node (MN) is identified by its home address, regardless of its current point of attachment in the internet [3]. When away from home, the MN is associated with a care-of-address (CoA). Unfortunately, the base MIP causes significant delays due to its triangular routing, its effect on protocol overhead, and end-to-end delay thereby affecting the handover performance. Thus, improvements were made and incorporated in a newer version of MIP called Mobile IPv6 (MIPv6) [4] to optimize some of the drawbacks. For example, MIPv6 addresses the triangular routing problem among other improvements and capabilities. Triangular routing problem is where the MN in a foreign network can directly reach a correspondent node (CN) while the CN can only reach the MN through a home agent (HA) resulting in a long triangular route.

It has been discovered that mobility can be more efficiently handled if the mobility management is divided into global mobility management and localized mobility management. Thus, Hierarchical Mobile IPv6 (HMIPv6) [5] and Fast Handover for Mobile IPv6 (FMIPv6) [6], which are extensions to MIPv6, have been proposed as the experimental protocols by IETF for efficient localized mobility management for MNs. MIPv6 is best suited for global mobility management. These experimental extensions have been standardized to optimize MIPv6's performance in terms of reducing the handover delay and hence service degradation during the handover period. Other localized-mobility management protocols such as Cellular IP and HAWAII have also been proposed by other standards development organizations. The main goal of these localized mobility management protocols is to reduce handover delay by localizing registration [7] so that seamless service continuity can be achieved during roaming across wireless networks. Handover delay is mainly due to delays caused by discovery, configuration, authentication, and binding update procedures associated with a mobility event [8].

Most of the currently proposed mobility schemes are host-based, that is, the MN is directly involved in mobility-related signaling. However, to accommodate mobility-related signaling, the conventional signaling messages are extended resulting in heavier messages. These extended messages take a longer period to process and to reach their destination

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Linoh Magagula is with the Communications Research Group, University of Cape Town, Private Bag, Rondebosch, 7701, Cape Town, South Africa (email: linohm@crg.ee.uct.ac.za and linohm@yahoo.com; phone: (021) 650 2813; fax: (021) 650 3465).

H. Anthony Chan is a professor in the Department of Electrical Engineering, University of Cape Town, Private Bag, Rondebosch 7701, South Africa (email: h.a.chan@ieee.org)

since they have to first traverse the error-prone air link between the MN and the default access router of the network, hence effectively increasing the handover delay. Thus, there are still some challenges pertaining to reducing handover delay with the currently proposed host-based localized-mobility management schemes.

This paper, therefore, proposes the utilization of a network-based localized mobility management scheme, Proxy Mobile IPv6 (PMIPv6) [9], which is currently being standardized by IETF, in place of the widely proposed host-based localized mobility management schemes. More so, PMIPv6, by its specification, reduces the mobility related signaling path, hence the handover latency, by eliminating the MN from mobility-related signaling.

However, in network-based mobility management schemes, handover latency is affected significantly by authentication mechanisms that control network access [10]. Thus, this paper proposes an IEEE802.21 assisted PMIPv6 framework to reduce the authentication delay, and hence effectively reducing the handover delay. An analytical performance evaluation comparison of basic PMIPv6 and the proposed IEEE802.21 enhanced PMIPv6, as well as a host-based HMIPv6 is presented. The analysis focuses on a MN that roams between subnets within the same PMIPv6 domain. Of note is that this paper deals with the conceptual operational and functional theory of the framework. A follow up paper dealing with the performance evaluation based on simulation results will be formulated soon.

The rest of the paper is organized as follows: Section II reviews some related work. Section III briefly presents HMIPv6 operation and its approach to reducing handover delay. Section IV introduces the functional and operational architecture of PMIPv6. IEEE 802.21 Media Independent Handover services are summarized in Section V while Section VI presents the analytical handover performance evaluation comparison. Section VII concludes the paper.

## II. RELATED WORK

The challenge in NGWN mobility management is reducing handover delay. Since handover delay is comprised of different delay-causing components, different works have proposed to reduce the handover delay by reducing the different delay components. [11] proposes the use of a proactive correspondent registration/binding mechanism for PMIPv6 route optimization between the correspondent node and media access gateway. Notably, route optimization is not specified in the draft PMIPv6 standard. [12] proposes to use PMIPv6 that relies on a so called rich set of informational resources to reduce handover delay, in particular, the components due to movement detection and binding updates. However, the informational resources are not clearly defined and furthermore, reduction of authentication delay is not addressed.

Notably though, is that network-based localized mobility management has recently emerged and a protocol is yet to be standardized, hence most works propose and utilize host-based localized mobility management schemes. In [13] the handover procedure in FMIPv6 is optimized by using IEEE802.21 MIH services. In particular, the delay due to radio access discovery and candidate access router discovery

is tackled. [14] proposes a framework that is based on Fast Handover for Hierarchical Mobile IPv6 and Optimistic Duplicate Address Detection. However, most host-based mobility management schemes do not address the reduction of handover delay by reducing the authentication delay component.

## III. HIERARCHICAL MOBILE IPV6

HMIPv6 is designed to handle local mobility of an MN, thus effectively reducing the handover delay due to changing of points of attachment by performing local registration. It supports the maintaining of service continuity during roaming between the MN and its correspondent nodes (CN), as well as the home agent (HA). The HMIPv6 domain introduces a mobility anchor point (MAP) to manage the movement within the local domain, ultimately improving the handover speed. In fact, the MAP more or less behaves like a local HA and is closer to the MN than the actual HA is.

CNs communicate with an MN which is in the HMIPv6 domain via the MAP. The MN in the HMIPv6 domain can be reached through a Regional Care-of-Address (RCoA) which is usually the MAP address. The MAP, like an HA, encapsulates the packets addressed to the MN and tunnels them to the associated on-Link Care-of-Address (LCoA) of the MN.

HMIPv6 is able to reduce handover delay by registering the changing LCoA to the MAP instead of the HA and CNs which are usually further away compared to the MAP. Furthermore, only one registration needs to be carried out, irrespective of the number of CNs. As long as the MN stays inside the HMIPv6 domain, the RCoA does not change, and only the LCoA, which is managed by the MAP, changes. Thus, the MN's mobility remains transparent to the CNs it is communicating with.

## IV. PROXY MOBILE IPV6

PMIPv6 is a network-based localized mobility management scheme. A typical PMIPv6 domain is shown in figure 1 below.

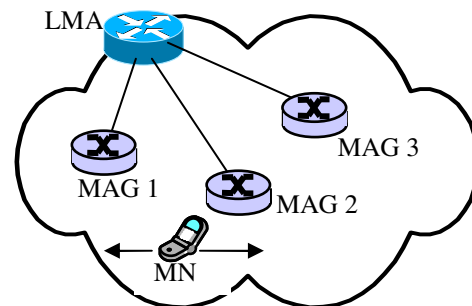


Fig.1. Proxy Mobile IPv6 domain

The PMIPv6 domain introduces two new network functional entities called Local Mobility Agent (LMA) and Mobile Access Gateway (MAG). The LMA behaves like the HA of the MN in the PMIPv6 domain and also has additional capabilities required for network-based mobility management. Just like the MAP in a HMIPv6 domain, it is the topological anchor point for the MN's home network prefix and is the entity that manages the MN's binding state

[9]. The MAG, on the other hand, handles all mobility-related signaling on behalf of the MN. It tracks the movement of the MN, authenticates it after attachment and initiates the required mobility signaling on behalf of the MN. Like in any other localized mobility management domain, an MN in a PMIPv6 domain can be reached by a CN outside the domain via the topological anchor point, LMA.

In a nutshell, PMIPv6 operation consists of: attachment and authentication, binding update and acknowledgment, MAG's emulation of the MN's home interface on the access link, IP address configuration, duplicate address detection (DAD), and packet routing. The PMIPv6 protocol ensures that the MN maintains the same home address configuration as long as it is in the domain. That is, the PMIPv6 specification supports a Per-MN-Prefix model [9] whereby a unique home network prefix is assigned to each MN and no other node shares an address from that prefix. Thus, IP address configuration and DAD are mostly relevant only when the MN node enters the PMIPv6 domain.

The air link interface between the MN and the point of attachment or AR (which normally implements the MAG functionality) is without any mobility related signaling overhead. Thus, the mobility signaling path is reduced, hence effectively reducing the handover delay.

Furthermore, PMIPv6 does not necessarily need any mobility stack implementation in a MN in its domain. This increases the range of MNs that could be accommodated in a PMIPv6 domain since it caters for any MN irrespective of its mobility stack, whether it has it or not. On the other hand, host-based mobility management schemes require the addition of relevant mobility management functionality on the MN's IP stack. Apart from limiting the range of MNs that can be accommodated, host-based mobility management schemes create software complexity and demand more processing from the MN which unfortunately has very limited resources.

## V. IEEE802.21 SERVICES

The IEEE802.21 [15] working group has created a framework that defines a Media Independent Handover Function (MIHF) which assists with seamless handover across heterogeneous link-layer technologies thus providing better performance to users during mobility events across heterogeneous networks. Basically, IEEE802.21 (Media Independent Handover) technology defines information exchanges that provide topological and location related information of service networks, timely communications of wireless environment information, and commands that can change the state of the wireless link. It is logically located between layer 2 and layer 3 in the protocol stack of both the MN and network. IEEE802.21 supports the cooperative use of both MN and network infrastructure for making vertical handovers. The MIHF provides services to the upper layers through a unified interface, the Service Access Point (SAP), which hides the heterogeneity of the access technologies. The lower layer protocols communicate with the MIHF through media dependent SAPs.

The MIHF has three functional components that are designed to provide services to assist with seamless

handover across the heterogeneous networks.

1) Media Independent Event Service (MIES): offers service to upper layers by reporting the dynamically changing lower layer events. These events are reported only to upper layer mobility protocols (MIH users) that have registered for a particular set of events and hence get alerted as those events happen. Some commonly defined events include "link up", "handover imminent", etc. which are based on reports on packet loss, data rates, etc. The MIH users would then act based on receiving these notifications.

2) Media Independent Information Service (MIIS): basically provides static information about characteristics and services of the serving and neighboring networks to both higher and lower layers. Examples include network type, channel information, security information, etc. The information is made available via both lower and upper layers through a query/response mechanism. To ensure transparency to the access technologies, this information is represented by using standard formats. With the necessary information an MN may discover available neighboring networks and communicate with elements within these networks a priori to optimize handover.

3) Media Independent Command Service (MICS): This service is provided to the upper layers to enable them to control the functions of the lower layers. The MICS commands are used, for example, to execute higher layer mobility and connectivity decisions to the lower layer. Example MICS commands are "poll", "scan", "configure", etc. This service provides commands for both MN-controlled and network-controlled handovers.

So, basically IEEE802.21 performs a report mechanism that conveys useful mobility-related information to entities where a decision is made to cause a command to be executed at some specific network elements to facilitate seamless handover. Hence, the handover process is facilitated by the information provided from the network to the MN, in addition to the information that the MN collects from the lower layers. This cooperative information exchange enhances handover optimization.

## VI. ANALYTICAL COMPARISON OF HANDOVER DELAY PERFORMANCE

### A. Proxy Mobile IPv6

The basic signaling call flow diagram of handover in PMIPv6 is shown in figure 2 below.

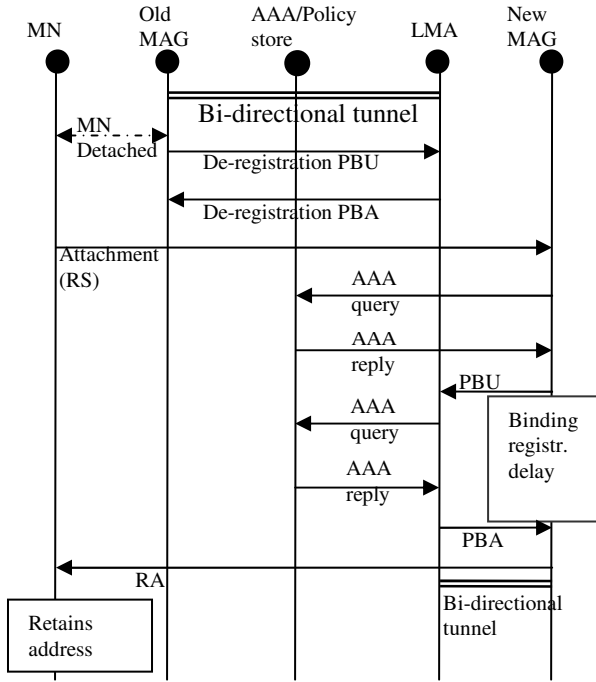


Fig.2. Signaling Call Flow of MN handover in PMIPv6 domain

Notably, from the above figure, the binding registration messages (Proxy Binding Update (PBU) and Proxy Binding Acknowledgement (PBA)) are initiated by the MAG, which is a network element, as opposed to HMIPv6 where the same signaling is initiated by the MN as will be observed later.

For clarity, the round-trip signaling call flow diagram showing the handover latency components of an MN attaching to a new MAG during handover in a basic PMIPv6 domain is shown in figure 3.

Evidently, from figure 3, the handover delay in PMIPv6 is due to many processes that take place during handover: the attachment notification delay due to the packet from the point of attachment (PoA) that informs the MAG of an MN's attachment ( $D_{ATTACH}$ ), the authentication delay (query (Q) and reply (R) messages) due to the MAG verifying if the attaching MN is eligible for network-based mobility management service ( $D_{AUTH} = D_Q + D_R$ ), another authentication delay whereby the LMA verifies the authenticity of the MAG sending the PBU ( $D_{AUTH\_2} = D_{Q2} + D_{R2}$ ), the proxy binding registration delay ( $D_{BINDING} = D_{PBU} + D_{PBA}$ ) whereby the MAG performs mobility-related signaling to the LMA on behalf of the MN, the router advertisement delay ( $D_{RA}$ ) whereby the MAG advertises the necessary information, some of which is obtained from the LMA, for the MN to be able to configure its address in the domain and to know its default access router, the actual IP address configuration delay ( $D_{CONF}$ ) and the duplicate address detection delay ( $D_{DAD}$ ) which is appreciable only when the MN first enters the PMIPv6 domain. DAD is for checking if the local IP address configured by the MN is not already configured by another MN in the same MAG link.  $D_{CONF}$  is also mainly relevant

when the MN enters the PMIPv6 domain. Once the MN has entered and is roaming inside the domain,  $D_{CONF}$  is not relevant since according to the PMIPv6 specification, the MN continues to use the same address configuration.

These delays are inevitable in a PMIPv6 domain during MN attachment although they can be optimized or reduced. They contribute to the overall handover latency during the handover process, in particular L3 handover, between MAGs in a PMIPv6 domain. Hence, real time multimedia communication which a MN might be having with a CN may be interrupted due to the handover latency which normally results in packet losses.

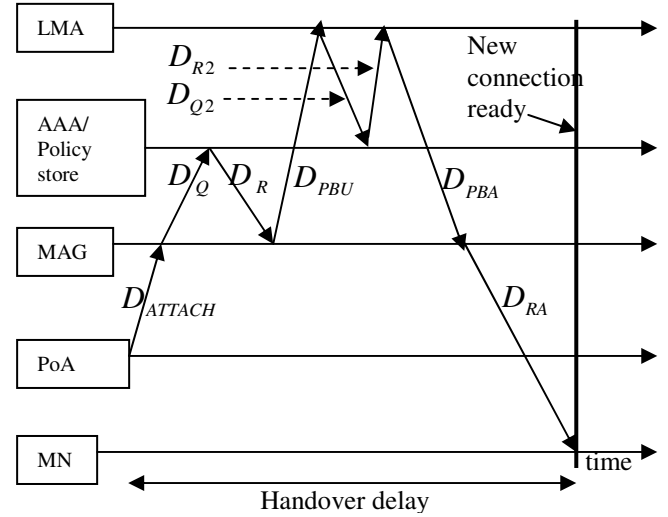


Fig.3. PMIPv6 Signaling call flow showing handover delay

It should be noted that the handover latency is automatically reduced in PMIPv6 compared to that in host-based localized mobility management schemes by virtue of having the MN not involved in mobility-related signaling. That is, the binding updates delay is shorter in PMIPv6 since it is carried out by a MAG instead of the MN which is usually further away from the LMA than the MAG is in a PMIPv6 domain. Also, since in a PMIPv6 domain, the MN keeps its address as long as it is inside the domain, the IP configuration delay is irrelevant and DAD delay is not appreciable compared to host-based mobility management where these processes are performed completely anew every time a MN changes its access subnet within the same domain.

Thus, overall handover delay in basic PMIPv6 is the sum of the individual component delays:

$$D_{PMIPv6} = D_{ATTACH} + D_{AUTH} + D_{AUTH\_2} + D_{BINDING} + D_{RA} \quad (1)$$

$D_{CONF}$  and  $D_{DAD}$  have been considered non-appreciable since we assume that the MN is already roaming in the PMIPv6 domain. In fact, according to [9], the MAG can learn the MN's link-local address by snooping at the DAD messages sent by the MN for establishing the link-local address uniqueness on the access link. Subsequently, at each handover, the MAG can obtain this address from the LMA to ensure link-local address uniqueness (since LMA is assumed to have the overall knowledge of the PMIPv6 domain) and change its own link-local address, if it detects a

collision. Thus, delay due to  $D_{DAD}$  can be considered negligible thus irrelevant in a PMIPv6 domain.

For comparison reasons, a signaling call flow diagram of handover in a HMIPv6 domain (host-based localized mobility management scheme) is shown below.

### B. HMIPv6

Figure 4 below shows a basic signaling call flow diagram for a host-based localized mobility management scheme, HMIPv6.

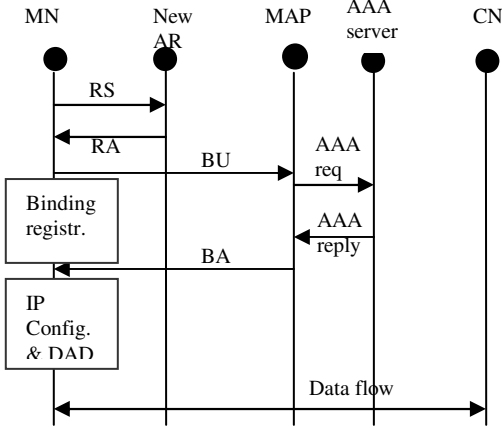


Fig.4. HMIPv6 domain handover signaling call flow

It can be immediately observed from the above figure that the MN is directly involved in mobility-related signaling. Therefore, the binding registration time is longer in a host-based localized mobility management scheme than it is in a network-based localized mobility management scheme. That is,  $D_{BIND\_HMIPv6} > D_{BINDING}$ . Also, movement detection delay ( $D_{MD} = D_{RS} + D_{RA}$ ) and  $D_{DAD}$  are known to be long and time-consuming operations that can degrade handover performance significantly in host-based mobility management schemes as mentioned in [16]. Therefore,  $D_{MD} > D_{ATTACH}$ , where  $D_{ATTACH} \approx D_{RS} \approx D_{RA}$ . Thus, the handover delay is longer in HMIPv6 than in PMIPv6:

$$D_{HMIPv6} = D_{MD} + D_{BIND\_HMIPv6} + D_{AUTH} + D_{CONFIG} + D_{DAD} \quad (2a)$$

where  $D_{BIND\_HMIPv6} \approx D_{PBU} + D_{PBA} + 2D_{ATTACH}$  and  $D_{MD} \approx 2 \times D_{ATTACH}$  (in terms of PMIPv6 delays) since according to [9] the MAG in PMIPv6 only sends the router advertisement (RA) after completing the binding registration with the LMA, unlike in HMIPv6 where RA is sent back to MN before binding registration. Thus, handover delay in HMIPv6,  $D_{HMIPv6}$ , in terms of PMIPv6 delays' symbols:

$$4D_{ATTACH} + D_{BINDING} + D_{AUTH} + D_{CONFIG} + D_{RA} + D_{DAD} \quad (2b)$$

Furthermore, a HMIPv6 mobility stack is added in the MN's protocol stack.

### C. IEEE802.21 assisted PMIPv6

With IEEE802.21 MIH services, the MN and the PMIPv6 domain network elements, in particular the MAG/AR, are informed about some parameters necessary in handover decision prior to the actual handover process. Our proposed IEEE802.21 assisted PMIPv6 scheme exploits the services of the MIH function to reduce handover delay, in particular, the access authentication delay component which can cause a significant delay in network-based mobility management handovers.

The motivation to use MIH services to reduce handover delay is that with these services, some operations can be performed prior to the handover process while the MN is still connected to the old MAG link. Thus, when the handover is eventually performed, there will be fewer delay-causing phases executed. For example, the authentication delay is dealt with by enabling the new MAG to authenticate the MN ahead of time. Security issues may have to be considered but are unfortunately outside the scope of this paper.

We propose that the MN and MAG/AR utilize the MIIS specification of IEEE802.21 to know of their heterogeneous neighboring networks' characteristics and capabilities by requesting from information elements at an information server (which comprises of a policy store and AAA server). The information server is assumed to be located at the LMA in this paper as shown in the figure 5 below.

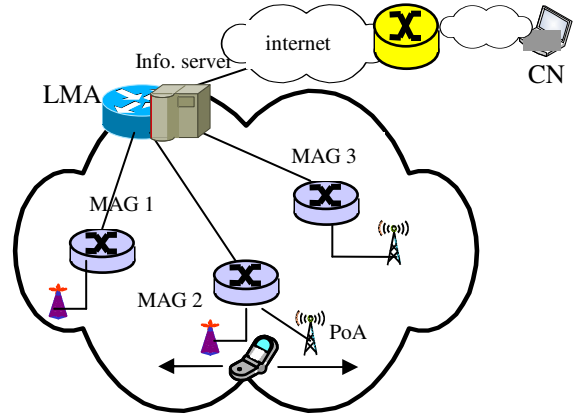


Fig.5. IEEE802.21 enabled PMIPv6 domain and Mobile Node

The information stored include static information such as the roaming agreements, network types, service level agreements, etc. while dynamic information include data rate, security information, etc. In our scheme, we propose the inclusion of layer 3 information such as proxy CoAs of neighboring ARs/MAGs in the MIIS specification. Furthermore, the list of candidate MAGs in the PMIPv6 where a roaming MN can attach is included. Also, stable identities of already attached MNs in the PMIPv6 domain are included in the information server. Thus, each MAG in the PMIPv6 domain is always up-to-date about its neighboring environment. That is, a MAG uses the MICS service as per the MIH protocol as specified in the IEEE 802.21 draft [15] to get information by requesting from information elements in the information server.

The dynamic network information is constantly updated in the information elements of the information server by the

MIES service as the environment changes. These MICS and MIES services are triggered by different events such as MN attachment or detachment events.

Furthermore, as the handover decision parameters from the environment and information server get below or above certain predefined thresholds, the MAC layer of the MN and/or MAG informs the MIES. The MIES then alerts the relevant handover decision engines about the imminent handover and at the same time update the information server. Maintenance of the information server is very feasible since it falls under a PMIPv6 domain which is localized and possibly under a single administrative management.

Thus, when a MN is handed over from an old MAG to a new MAG within the same PMIPv6 domain, the new MAG would easily obtain information about the attaching MN. In fact, the new MAG would have authenticated the MN in the policy store when it first discovered the MN's identity from the list of the PMIPv6 domain's attached MNs in the information server. This process is triggered by an MIES event based on dynamic changes of the environment (e.g. attachment/detachment of MNs) among other things. An L2 trigger at the MN sends the MN identity to the MAG which in turn simply verifies having authenticated the identity ahead of time during the MN's attachment to previous MAGs. Hence, the authentication delay is eliminated during the actual handover process.

Thus, using the same symbol definitions, the handover delay of our proposed scheme shows a significant improvement and is:

$$D_{PMIPv6\_802.21} = D_{BINDING} + D_{RA} \quad (3)$$

A typical signaling call flow for the IEEE802.21 assisted PMIPv6 is as shown in figure 6 below. However, for simplicity, the details of the involved specific MIH primitives are not shown in the figure. Instead, they are collectively shown as MIH info. updates. Similarly, for the same reason, the specific MIH handover messages' primitives are not shown in the figure.

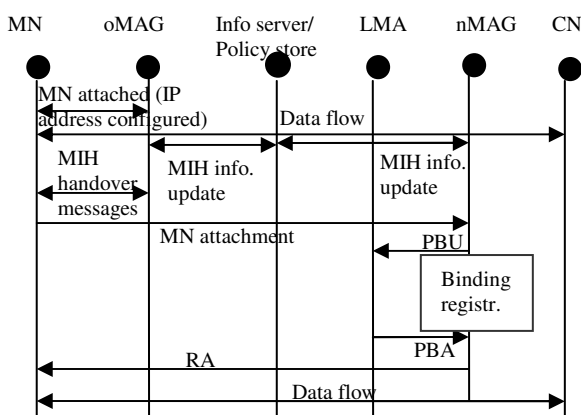


Fig.6. Signaling call flow for IEEE802.21 assisted PMIPv6.

## VII. CONCLUSION

In this paper, we present a mechanism which improves the PMIPv6 handover process with the assistance of IEEE802.21 MIH services. In particular, the MIIS is utilized and layer 3 information of neighboring access MAGs as well

as a list of all attached MNs identities is included in the service. This ensures that neighboring MAGs have information about each other as well as a list of attached MNs in the domain hence helping PMIPv6 to tackle the issue of access authentication in advance. In our proposed mechanism, the handover delay is significantly improved by removing the authentication phase from the actual handover process. Moreover, the mere utilization of a network-based mobility management scheme, PMIPv6, already reduces the handover delay by eliminating the MN from mobility-related signaling.

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**Linoh A. Magagula** received his Master of Science degree in Telecommunication and Information Systems at the University of Essex, England, in 2005. He is currently a PhD candidate in the Department of Electrical Engineering, University of Cape Town. His current research interest is mobility management in next generation wireless networks.

**H. Anthony Chan** (M'94-SM'95) received his PhD in physics at University of Maryland, College Park in 1982 and then continued post-doctorate research there in basic science. In 2004, he joined University of Cape Town as professor in the Department of Electrical Engineering. He is distinguished speaker of IEEE CPMT Society.