A Hybrid Network/Host Mobility Management Scheme for NGNs

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Abstract— **Next Generation Networks are becoming more and more converged. Like the System Architecture Evolution (SAE) which encourages Fixed Mobile Convergence. It is a packet switched network which connects different radio access technologies. With this heterogeneity, mobility management becomes an issue as the goal is to always achieve seamless mobility. However, various access technologies support different layer 3 schemes, such as PMIPv6 which is network-based and MIPv6 which is host based. With the heterogeneity that the SAE adopts, there are several deployment scenarios where PMIPv6 will interact with MIPv6. We propose a hybrid network/host mobility management scheme which will allow the user to roam amongst networks supporting either protocol.**

Index Terms – global mobility management, network-based mobility management, proxy mobile ipv6, EPC.

I. INTRODUCTION

The 3GPPs desire to provide a competitive wireless access technology in the years 2010-2020 has led to the standardization of the System Architecture Evolution (SAE). This standardization has two major objectives. One objective is to design a new access technology -Long Term Evolution (LTE), based on Orthogonal Frequency Division Multiplexing (OFDM) radio technology which inherently increases data rates, reduces end-to-end latency for real time applications and lowers set-up times when new connections are made. Secondly, to create an all IP packet core network, the Evolved Packet Core (EPC), an access independent core designed not only to support 3GPP radio technologies, but also non-3GPP radio access technologies such WIMAX, WLAN and CDMA2000.

With support of all these access technologies, the Mobile Node (MN) should be able to roam between them without having to re-establish the connection or lose the connection at any point. That means suitable quality-of-service at all times independent of the access technology attached too. Thus with this heterogeneity, several challenges arise in the choice of network architecture design and mobility protocol [18]. It has been realized that mobility is more efficient when mobility management is divided into local mobility management and global mobility management. Subsequently MIPv6 is more effective when used as a global mobility management protocol. The IETF has standardized host-based protocols FMIPv6 and HMIPv6 which are optimizations of MIPv6 to efficiently improve localized mobility management for mobile users. These optimizations include reducing delay, packet losses and signaling overhead incurred during handover. With host-based schemes, the MN contains an IPv6 stack which involves the MN in mobility related signaling. The IETF later standardized a local mobility scheme, PMIPv6 which is a localized network-based mobility scheme. PMIPv6 is an extension of MIPv6, and contains network entities such as the Local Mobility Anchor (LMA) and Mobile Access Gateways (MAGs) which handle all mobility related signaling on behalf of the MN. This means the MN need not contain an IPv6 stack since all signaling is managed by the MAG. Contrast to MIPv6; PMIPv6 is best suited for localized mobility management. However, PMIPv6 is access specific, meaning the access technology has to have network entities with MAG functionality, while MIPv6 is generic to any access and preferred for global mobility.

Two mobility approaches were specified by the 3GPP for the EPC for mobility between 3GPP and non-3GPP access networks, namely the network-based mobility protocol PMIPv6 [14] and GTP and client-based based mobility protocols Dual-Stack Mobile IPv6 (DSMIPv6) [11] and Mobile IPv4. Since one of the crucial goals of the EPC is to provide seamless mobility across numerous access technologies, some access technologies provide network-based solutions while others provide host-based solutions. So it is crucial to investigate how these protocols behave when they are interworked together.

The rest of this paper is organized as follows: section 2 will provide related works similar to the work presented here; section 3 provides a brief background of mobility management protocols. Section 4 identifies interworking scenarios of how these protocols would be deployed while section 5 identifies issues when these protocols interact. Section 6 gives a concise background on the SAE and section 7 presents the proposed work. Section 8 provides preliminary results obtained from the simulations done and finally section 9 provides future work and concludes the paper.

II. RELATED WORK

Kang-won Lee at. al. [8] proposed an interworking scheme between PMIPv6 and MIPv6 which enables the Mobile Node to move from a PMIPv6 domain to a non-PMIPv6 domain (which supports MIPv6) and vice versa. Their scheme consists

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of four sections namely: integrated functional architecture for LMA and HA, common lookup key, Home Network Prefix (HNP) allocation mechanism and a handover procedure between a PMIPv6 domain and MIPv6 domain. Their implementation combines the binding cache of the LMA and HA. So any updates destined for either the LMA or HA will be recorded in the integrated binding cache. They use the MN-HoA as the common lookup key in the cache and in order to distinguish between the entries, they use a bit which when it is equal to 1 is a proxy binding, else a MIPv6 binding is recorded which is similar to our implementation.

Yan et. al. [20] designed and implemented a Hybrid MIPv6/PMIPv6 based Mobility Management Architecture. Localized mobility is handled by PMIPv6 while global mobility is handled by MIPv6. In their design, the HA logically co-exists with the LMA and the AAA server is deployed to provide the necessary authentication. The allocation of the HNP in PMIPv6 is adopted and the HoA is a specific address belonging to the allocated HNP. Since the binding cache lookup keys for MIPv6 and PMIPv6 are different, they hybrid scheme always creates two different binding cache entries in the home HA/LMA which corresponds to the PMIPv6 and MIPv6 separately. This implementation uses one binding cache which distinguishes the entries using the P-bit. They proposed a hybrid+ scheme which builds on to the hybrid scheme. The scheme incorporates a protocol selection algorithm, which takes into account the mobility characteristics of MN and network conditions. The hybrid scheme is similar to the work mentioned above.

Gou et. al. [5] proposed a LMA/HA discovery mechanism that would be used when MIPv6 domain interworks with PMIPv6. In their proposed scheme, there are multiple collocated LMA/HAs in the PMIPv6 domain. When the MN moves between the two domains, it should be able to choose the correct LMA/HA for binding management or packets designated for the MN will be dropped. In their implementation the LMA communicates with the AAA server to obtain the MN-HoA. However, their proposal concentrates on the MN identifying the correct LMA/HA while moving between two domains.

H. G. Kim et. al. [6] proposed a network-based globalized mobility scheme for different IP access networks. They improve the existing global mobility management issues in MIPv6 by reducing the handover delay using a Label Switched Path (LSP) of Multi Protocol Label Switching (MPLS). For local mobility, PMIPv6 is used and for global mobility, the Mobility Information Control Server (MICS) is used. This means that fast location registration through the Multi Protocol Label Switching Label Switching Path (MPLS LSP) is possible. Their implementation includes MPLS which adds additional network entities and they look at roaming between PMIPv6 domains. And our scheme looks at interacting PMIPv6 and MIPv6 in the EPC.

III. OVERVIEW OF LAYER 3 MOBILITY MANAGEMENT SCHEMES

A. *Mobile IPv6*

Mobile IPv6 was designed to allow MNs to be reachable anywhere while maintaining ongoing sessions when they move about within a topology [1]. When the MN attaches to the home link of the HA, it bootstraps its parameters with the HA in order to gain connectivity. After successful registration, the MN obtains a HoA which it will use while in the home network. However, when the MN moves into a foreign network, it obtains a care-of-address from the prefix of the Access Router in the foreign network which is used away from home. The MN sends an binding update to the HA informing it of its new address and any packets destined for the MN are redirected by the HA to the new address of the MN. However, packets can also be sent to the MN directly from the correspondent node, bypassing the HA. This is known as route optimization.

B. *Proxy Mobile IPv6*

Proxy Mobile IPv6 [16] as illustrated in Fig.1 is a localized network-based mobility management scheme designed to reduce complexity in the MN. With PMIPv6, the MN doesn't require an IPv6 stack as any mobility management signaling is handled by the network. It consists of Local Mobility Anchor (LMA) and Mobile Access Gateways (MAG). The LMA forms a topological anchor point for the MN Home Network Prefixes (HNP). The MAG tracks the MNs movements and encompasses the function that manages the mobility related signaling on behalf of the MN.

When the MN enters a Proxy Mobile IPv6 domain and attaches to the access link, it sends a router solicitation message to the MAG. The MAG then communicates with the AAA or policy server to authenticate the MN. After successful authorization, MAG sends a proxy binding update (PBU) message including the MNs location to the LMA. Upon receiving the PBU, the LMA responds with a proxy binding acknowledgement (PBA) which includes the MN HNP. At this time, a bidirectional tunnel is set-up between the LMA and MAG for packet delivery. Packets from the correspondent node are passed to the LMA which directs the packets to the relevant MAG in the bi-directional tunnel. Upon reception of packets, the MAG sends a Router Advertisement to the MN and the packets are sent. When the MN moves to another location out of reach with the current MAG, the new MAG registers with LMA to save the new location of the MN and packets are then relayed via the new MAG.

IV. INTERWORIKING SCENARIOS

Three interworking scenarios have been identified:

A. *Hierarchical*

In this scenario, PMIPv6 is used as a network-based local mobility management protocol whereas MIPv6 is used as a global mobility management protocol. MIPv6 is used when the MN roams across different access networks whereas PMIPv6 is used for mobility within an access network. The

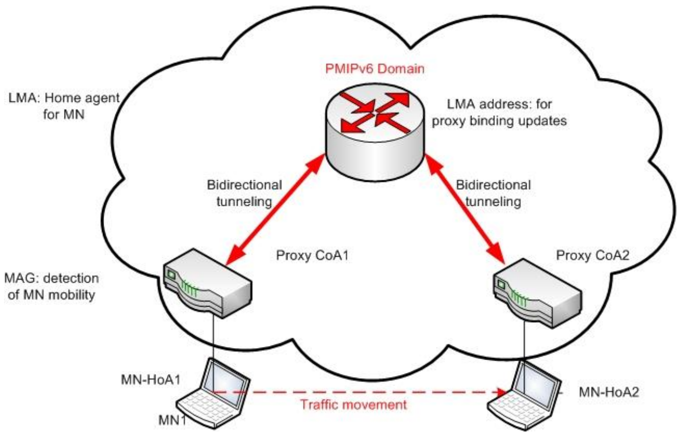

Figure 1: PMIPv6 Architecture

MN-HoA managed by the PMIPv6 domain is registered as a CoA by the MN at the HA. Therefore the HA has a binding cache entry for MIPv6-HoA that points to the MN-HoA which is managed in the PMIPv6 domain.

B. Co-existence

Here, some MNs handle they own mobility by using MIPv6 while others rely on the network to manage their mobility, hence using PMIPv6. There may be a mutual mobility anchor which acts both as a MIPv6 Home Agent and a PMIPv6 Local Mobility Management (LMA). However, the HA and LMA nodes can be separated which will not have an impact on the mobility of the nodes.

C. Transition

A MN moves between different access networks, some supporting a network-based solution (PMIPv6), others supporting a host-based solution. Hence, the MN is moving from an access network supporting PMIPv6 to another access network supporting MIPv6. Subsequently, the MN home link is the PMIPv6 domain. This means that the MIPv6-HoA is equal to the MN-HoA (i.e. the address managed by PMIPv6 domain). This scenario has sub-scenarios depending on the MIPv6 Home Agent and the PMIPv6 domain. One sub-scenario for example, can be a MN moving from an access network where PMIPv6 is supported to another visited PMIPv6. When the MN moves into a visited PMIPv6 domain the MN hands over to the visited MAG and obtains a different IP address which is managed by the visited LMA and registered as a MIPv6 CoA.

V. INTERWORKING ISSUES

Some interworking issues have been identified by the IETF NetLMM WG [3], who drafted the scenarios. No real issues have been identified for the Hierarchical and Transition scenarios. However for the co-existence scenario, a number of concerns have been raised. PMIPv6 is comparable to MIPv6 as it adopts its fundamental functionality as well as its messages. Despite the similarity, certain issues arise when the two protocols interact.

Firstly, In MIPv6, the lookup key in the Binding Cache is the HoA of the MN; it excludes the MN-ID in the Binding Cache Update Message to the Home Agent as defined in [1]. However for PMIPv6, the Proxy Binding Update contains the MNs HNP and MN-ID. The HoA is not included in the message as it might not be known by the MAG and subsequently the LMA. The lookup key for the LMA Binding Cache is therefore the HNP or the MN-ID as defined in [16]. This means that the lookup keys for MIPv6 and PMIPv6 registrations are different. This means as the MN moves from its home network (PMIPv6 domain) to a foreign network (MIPv6 domain), the BU sent by the MN will not be recognized by the HA as an update of Proxy Binding cache entry which included in the HNP and MN-ID. Consequently, a new BU entry is created. This suggests that the HA and LMA will always create two different binding cache entries meaning that the session will be dropped.

Secondly, When the MN moves from a foreign MIPv6 network into a PMIPv6 domain, the MN bootstraps its parameters with the MAG and after successful authentication, sends a PBU to the LMA. The LMA updates its Cache with an entry including the MAG address and responds with a PBA. The MAG emulates the MN home link and once the MN has detected this, it sends a de-registration BU to it's HA. It is essential to ensure that the MIPv6 de-registration does not delete the PMIPv6 registration.

Thirdly, a race condition between a PBU and BU might occur, since the former uses timestamps while the latter uses sequence numbers. Re-ordering of registration messages are handled by different mechanisms for both MIPv6 and PMIPv6. For the former, Binding Update Messages are sent by the MN to the HA and ordered by sequence numbers while the latter uses Proxy Binding Update Messages sent by the MAG and ordered by timestamps. Other threads such as a compromised MAG and wrong use of HA/LMA after handover also arise, but are out of the scope of this paper.

VI. SYSTEM ARCHITECTURE EVOLUTION

The System Architecture Evolution (a.k.a Evolved Packet Core) is a simplified flattened network architecture which consists of an Evolved Packet Core (EPC), and an Evolved Universal Terrestrial Radio Access Network (UTRAN).The EPC is an IP based core network with support for packet switch traffic only including voice. Fig. 2 depicts a simplified architecture of the SAE. The core architecture of the SAE consists of the following functional entities:

Mobility Management Entity (MME): Is in charge of all control plane functions in the EPC and provides mobility to the MN. Other functions include security, session handling and location management.

Serving Gateway (S-GW): Is a user plane node which connects the core to different radio access technologies. It serves as a local mobility anchor, which suggests that packets will be routed from this point to support intra E-UTRAN (LTE) mobility and mobility with 3GPP networks.

Packet Data Network Gateway (PDN GW): Is a user plane node which connects the user to the Internet. It is responsible

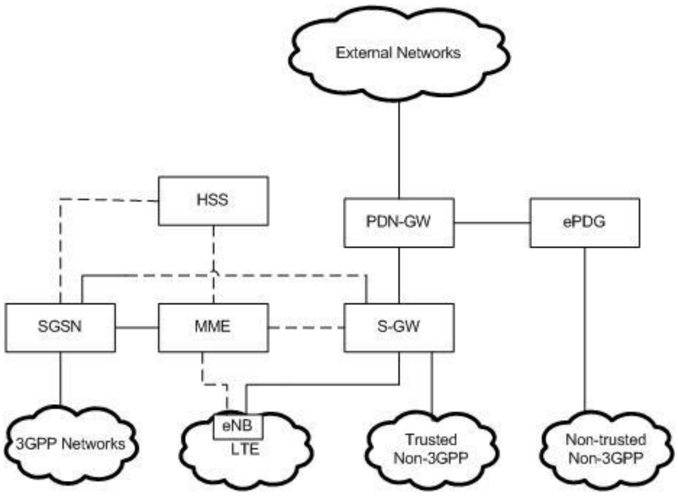

Figure 2: Simplified Architecture of SAE

for several IP functions which include address allocation, policy enforcement, packet classification and routing. In terms of network-based mobility management (PMIPv6), the PDN-GW acts as the LMA and the ePDG (which functions as a security mechanism for non-trusted networks) and S-GW as MAGs. On the contrary, when host-based mobility management (DSMIPv6) is supported, the PDN GW acts as a HA for the MN. Since the PDN GW acts as either LMA or HA depending on the mobility protocol, it becomes evident that when the two protocols interact, the LMA and HA would be collocated in the PDN GW.

VII. PROPOSED INTERWORKING SCHEME

A. Mutual Binding Cache

For interworking between PMIPv6 and MIPv6, we propose a mutual binding cache to be shared between the LMA and HA. Since the LMA and MAG do not explicitly know the HoA of the MN, we propose that the LMA discover the HoA of the MN using the DHCPv6 server present in the network. We assume that Stateful Address Configuration is supported on the home link (PMIPv6 domain) of the MN. Hence, the LMA can obtain the address configuration from the DHCP server located on the home link by typical DHCP mechanisms [15]. Evidently, the MN HoAs are configured from the Home Network Prefixes. In order to support Stateful Address Configuration using DHCP, the DHCP relay agent service must be supported by all MAGs [15]. The HNP is shared between the LMA and HA which entails that there is an interaction between the LMA and HA. When the MN enters a foreign network, it must acquire authorization to use network resources. During the security association with the HA/LMA, the MN will suggest a HoA which it used in the PMIPv6 Domain or alternatively the HA will contact the DHCPv6 server to obtain the MNs HoA as described in [19].

B. Common Lookup key

Given a mutual binding cache, a common lookup key is required to search the cache for update entries.

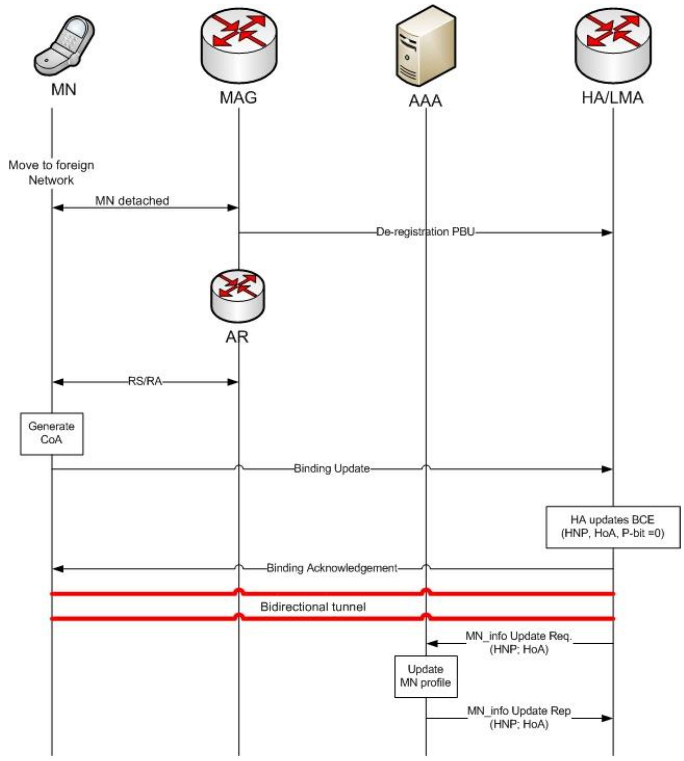

Figure 3: PMIPv6-MIPv6 (MN moves out of PMIPv6 Domain)

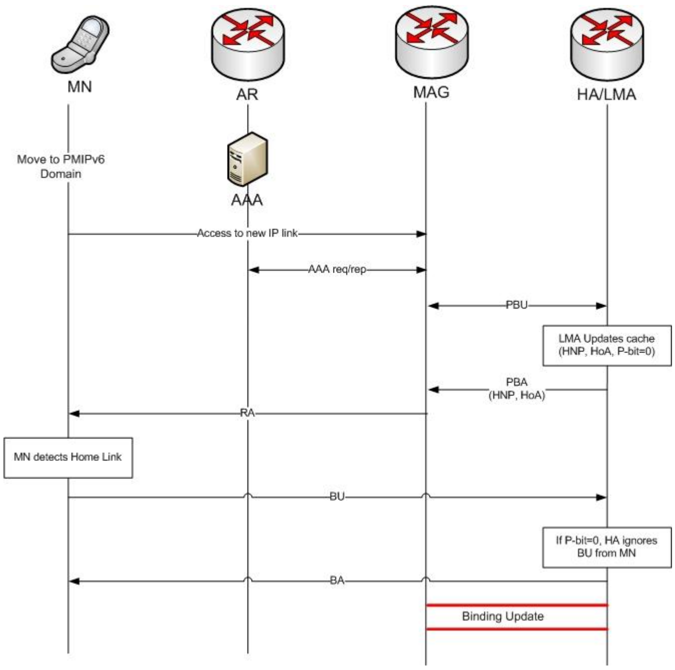

Figure 4: MIPv6-PMIPv6 (MN moves into PMIPv6 Domain)

Because PMIPv6 is an extension to MIPv6; the Binding cache entries do not differ much, however for PMIPv6 the lookup key is either the MN-HNP or MN-ID whereas for MIPv6 it is the MN-HoA. This poses a serious problem, since we have a

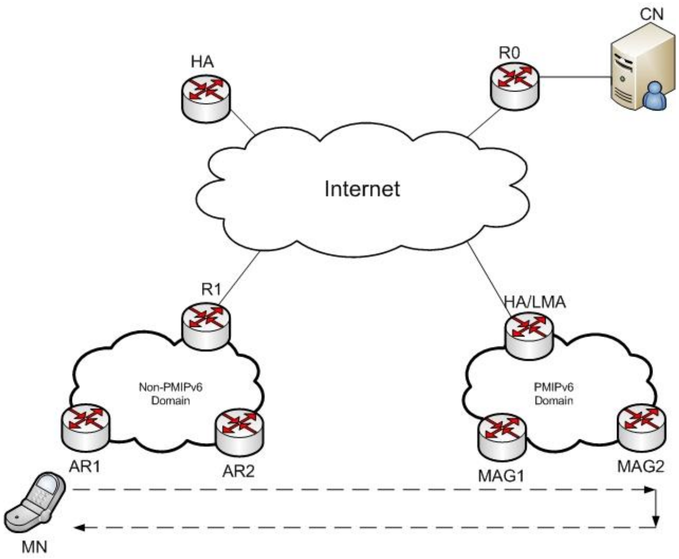

Figure 5: Simulation Set-up

mutual cache with different keys. So we propose to use the HoA as a common look-up key in the Mutual Binding Cache.

As mentioned before, the LMA and MAGs do not explicitly know the MN HoA, however they can use DHCP mechanisms in the initial attachment to discover the address and thus will implicitly know the address. As a result, both the LMA and the HA will know the MN-HoA which is then used as the common key. In order to distinguish between a Proxy Binding Update and a Binding Update, we use the P-bit which is in the PMIPv6 mobility header. When the P-bit is one, it means that the entry is a Proxy Binding Cache (PMIPv6); else it is a Binding Update (MIPv6).

C. Mobility from PMIPv6 Domain to non-PMIPv6 Domain

Like the solution in [8], the handover call flows are similar. Figure 3 illustrates the handover between a PMIPv6 Domain to a non-PMIPv6 Domain. When the MN first entered the PMIPv6 domain, the LMA created a Binding Cache Entry setting the P-bit to 1. When the MN moves out of the PMIPv6 domain, a MAG sends a de-registration PBU to the LMA and upon reception, starts a BCE-delete timer as defined in [16]. Meanwhile, the MN determines that it has entered a foreign network and sends a Router solicitation message and the Access Routers replies with a Router Advertisement message. The MN then sends a registration BU to the HA. Upon reception of the message, the HA is able to find the MN BCE in the mutual binding cache using the MN-HoA, updates the cache and cancels the BCE-timer. The HA responds with a BA and sets the P-bit to 0 and updates the Accounting, Authorization and Authentication (AAA) server.

D. Mobility from non-PMIPv6 Domain to PMIPv6 Domain

Figure 4 illustrates a handover between a non-PMIPv6 Domain to a PMIPv6 Domain. When the MN enters a PMIPv6 domain and attaches to a MAG. The MAG tries to authenticate the MN by communicating with the AAA server. Upon the MNs approval, the MAG sends a PBU message to LMA. The LMA replies with PBA which includes the MNs HNP and HoA. Since this is a PBU, the LMA sets the P-bit to 1 in the MNs binding cache entry. The MAG sends a RA message and a bi-directional tunnel between the MAG and LMA is created. As soon as the MN realizes that its' at home, it sends a de-registration BU to HA, however the HA ignores this message since the P-bit is set to 1.

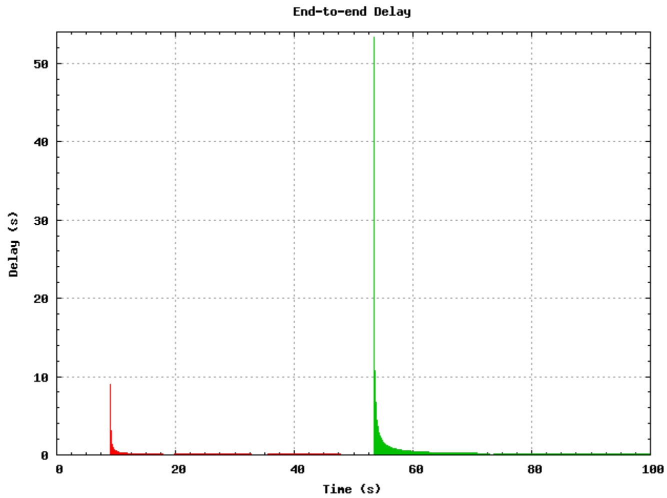

Figure 6: End-to-end delay in Hierarchical scenario

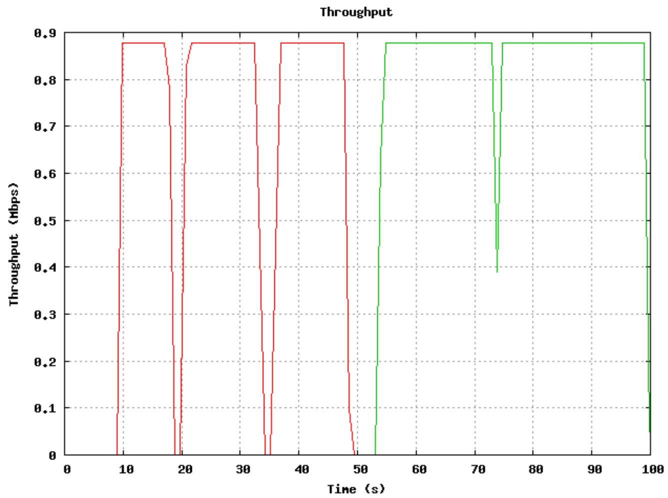

Figure 7: Data rate in the hierarchical scenario

Table 1: Handover Latency between routers

	Handover Latency (s)
HA→AR1	2.0
AR1→AR2	2.71
AR3→MAG1	5.60
MAG1→MAG2	0.65

VIII. PRELIMINARY RESULTS

The simulation setup used is illustrated in Fig. 5. The simulator used is NS-2 with NIST mobility package [12]. The access network in this scenario is IEEE802.11 with a data rate of 11Mb. The coverage area for each access router or MAG is about 50m and the MN is moving with a speed of 5 m/s.

However it must be noted that these parameters are subject to change. Note that, due to simulator shortcomings, the HA is also a Base-Station node. At present, the HA/LMA acts as a LMA node only. As such, the Hierarchical scenario was simulated, where MIPv6 was used for global mobility and PMIPv6 for localized mobility as shown in Fig. 5. Shown in Fig. 6 and 7 are some results obtained when the MN moves from a MIPv6 (red) to a PMIPv6 Domain (green). Fig. 6 shows the end-to-end delay as the MN traverses. When the MN switches to the PMIPv6 domain, a very high delay is obtained due to the change in protocol. However, in real applications the initial packets obtained with high delays would be discarded. Fig 7 shows that the throughput at the MN peaks at 0.9 Mbps, and finally Table 1 shows the handover latencies throughout the network.

IX. CONCLUSION AND FUTURE WORK

We have shown that there are deployments scenarios where PMIPv6 and MIPv6 will interwork. Examples of such deployments are in the System Architecture Evolution which consists of various access networks all connected to a packet core network. Although PMIPv6 is an extension of MIPv6, these protocols differ slightly especially in the structure of the binding caches. We have shown that the Interworking between these protocols is non-trivial and have proposed a hybrid network/host interworking scheme to allow these protocols to interact smoothly. PMIPv6 is used for network localized mobility management whereas MIPv6 is used as a global mobility management protocol. Several results of the interaction have been shown. Future work includes finalizing the interworking of the HA/LMA implementation in NS-2 and an analytical survey of the results. A comparative survey will also be done to compare the proposed work to the hierarchical scenario as well as the pre-mentioned protocols. And because, both protocols still suffer from high handover latencies, we will therefore try to reduce delays.

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BIOGRAPHY

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