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Inter-domain Proxy Mobile IPv6 based Vehicular Network

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Abstract

Proxy Mobile IPv6 (PMIPv6) was standardized by the Internet Engineering Task Force (IETF) NetLMM WG as a Network-based Mobility management protocol. This protocol allows the Mobile Node (MN) to maintain service connectivity while moving within the PMIPv6 domain. PMIPv6 mobility management is different from the Host-based Mobility management protocols; where the mobility signaling management is controlled by the serving network on behalf of the MN. PMIPv6 introduced new network entities to handle the signaling on behalf of the MN. However, PMIPv6 protocol can only manage the MN's reachability within a local domain (intra-domain). If the MN moves beyond the perimeter of PMIPv6 domain, the mobility support will be lost. Thus, it is an imperative need to develop PMIPv6 to support interconnecting neighboring domains, which provide MN continuous support across domains. We propose an inter-domain handover scheme to reduce the handover latency in vehicular environment. The proposed scheme utilizes the Media Independent Information Service (MIIS) to help the vehicle store information about the network that it is attached with. Furthermore, the Local Mobile Anchor (LMA) will use Fully Qualified Domain Name (FQDN).

Keywords: PMIPv6, MIIS, Mobility Management FQDN, DNS

1. Introduction

Providing seamless mobility for vehicles across wireless networks is essential for next generation networks. Normally, mobility management covers two mechanisms: location management and handover management. Location management is needed to track the vehicles location and enables packet reception. Handover management, on the other hand, is needed to keep connection active while the vehicle moves and change its point attachment. In general, mobility management research for IP-based networks mainly focuses on Mobile IPv6 (MIPv6), which has been studied extensively by both the academic and industry for the last years. MIPv6 was extended to Network Mobility (NEMO) to support mobility of moving vehicular networks [1]; the handover process of NEMO is similar to that of MIPv6. Both handover processes depend on layer 3 handover (IP layer), that's because the vehicle moves between different access routers. Layer 3 handover always includes layer 2 handover; layer 2 handover presents signal switching between different access points; for instance WiMax base station. In addition layer 2 handover does not systematically provoke layer 3 handover; only layer 2 handover occurs between two different base station domains leads to layer 3 handover. Both MIPv6 and NEMO were selected by continuous Air interface for Long and Medium range (CAML) to support host mobility and network mobility in vehicular access networks [2].

On the other hand, both MIPv6 and NEMO have the problem of long Layer 2 and Layer 3 handover latency. In order to improve handover performance, IETF introduced the development of network-based mobility protocol solution the Proxy Mobile IPv6 (PMIPv6) as the basis for further development [3]. Network-based IP mobility management is provided by PMIPv6 to support the Mobile Node (MN) mobility without requiring the MN's participation in any IP signaling.

The reducing of handover latency schemes proposed earlier is based on host-based mobility schemes [4]. In particular, MIPv6 extensions [5], Hierarchical Mobile IPv6 (HMIPv6) [6], and Fast Mobile IPv6 (FMIPv6) [7] has been proposed as experimental protocols by IETF to improve handover performance in the next generation networks with IPv6 nodes. Furthermore, it has been discovered that for handover to be seamless, timely information accurately characterizing the network conditions is needed in order for appropriate actions to be taken [8]. Hence, IEEE recently introduced the IEEE 802.21 Media Independent Handover (MIH) services standard as a unified operation during the handover process [9]. Although the standard assists in determining and initiating the handover, it leaves the specification of how to handle the handover undefined. Therefore, a reasonable and efficiency handover approach should be designed. To this end, this paper proposes a roaming mechanism between PMIPv6 domains to provide transparent and seamless inter-domain mobility management to vehicles by using IEEE 802.21 (MIH) MIIS. Both lower layers information of the available networks obtained by MIH services and the applications requirements are taken into consideration to make the handover decision. In addition the scheme also includes vehicle mobility consideration because of the vehicles characteristic of the dynamically movement along the road. The rest of this paper is organized as follows. Section 2 introduces PMIPv6 protocol and MIH protocol. In section 3 the proposed scheme is described. In 4 the performance evaluation is presented. And finally we conclude the paper in section 5.

2. BACKGROUND AND RELATED WORKS

2.1 Proxy Mobile IPv6 Overview:

The Internet Engineering Task Force designed Proxy Mobile IPv6 (PMIPv6) to support network-based IP mobility management for MNs, without requiring its involvement in any related IP-mobility functions. Mobility management in PMIPv6 is provided to MN irrespective of the presence or absence of Mobile IPv6 functionality [13].

PMIPv6 extends the signaling of MIPv6 and reuses most of MIPv6 concepts such as HA functionality. In addition it introduces two new elements known as Local Mobility Anchor (LMA) and Mobile Access Gateway (MAG) [10]. The LMA behaves similar to the HA in MIPv6 in the PMIPv6 domain and also it introduces additional capabilities required for network-based mobility management [12].

PMIPv6 supports the MN within a topological localized domain by utilizing the MAG entity. MAG organizes with the access routers and handles mobility signaling on behalf of the MN.

PMIPv6 protocol operation consists of four phases. In the first phase, MAG retrieves the MN’s profile using its current identifier. The Binding Update (BU) is the second phase, in which the MAG sends a Proxy Binding Update (PUB) request to the LMA in order to register the current point of attachment of the MN. Accordingly, a binding cache entry and a tunnel for the MN’s home prefix will be created. The third phase will be the MAG emulating the mobile node’s home interface on the access interface. Therefore, the MN will always believe it is in the home network. Fourthly, the LMA replies with a Proxy Bind Acknowledge (PBA) message with the MN’s HNP. After receiving the Router Advertise (RA) message, the MN configures its IP address by using the contained prefix. For packet routing, the LMA is able to route all received packets over the established tunnel to the MAG. The MAG forwards these packets to the MN. Additionally, the MAG will relay all the received packets over the tunnel to the LMA and then they will be routed towards the CN. Fig 1 shows PMIPv6 signaling.

While the MN is roaming in the PMIPv6 domain, the protocol ensures that the MN is eligible to obtain its home address on any access link [12] on condition that it is roaming in the same PMIPv6 domain. That is, that the serving PMIPv6 assigns a unique home network prefix, Pre-MN-Prefix, to each MN and this prefix conceptually follows the MN were ever it moves within the PMIPv6 domain [11]. As a result there is no need to perform address configuration to reconfigure a new address for the MN every time it changes its point of attachment. This in turn, optimizes handover performance by reducing the latency that is caused because of the address configuration. Also, because of the MAG network element which performs the network signaling on behalf of the MN, PMIPv6 reduces the binding update delay by reducing the round trip time, thus reducing handover latency.

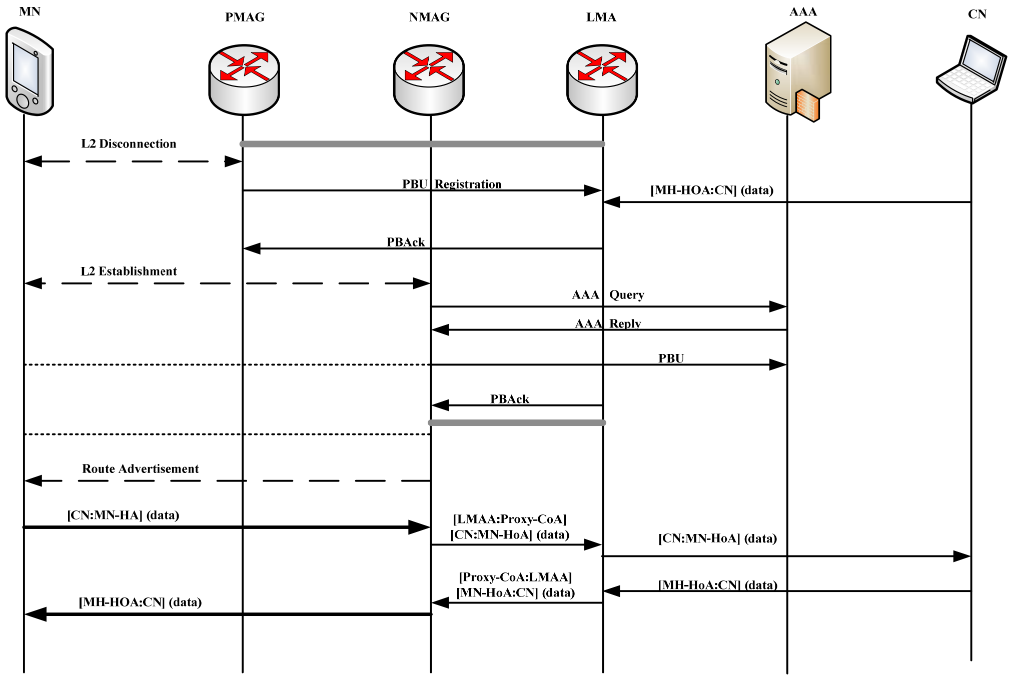

Figure 1 PMIPv6 Signaling flow

2.2 Media Independent Handover (MIH)

Media Independent Handover (MIH) specification is primitive to provide link layer information and other related information to the upper layers to optimize handover. One of the most important categories is the Event Service (MIES); it is used for the Layer 3 handover hints. Events provide the data link layer conditions to layer 3 or reflect the response of Layer 3. The representative event primitives include link going down, link down, and link going up. Layer 3 handover occurs when the vehicle changes its point of attachment after an inter-domain movement (inter-network or intra-foreign-network-movement). Inter-domain movement means that the vehicle changes its attachment point between two different networks. When layer 3 handover occurs, the vehicle will lose its IP-connectivity; it hence will lose the ongoing transmission. In addition MIH provides Command Services (MICS); it includes a set of commands that might be sent from higher layers to lower layers, and Information Services (MIIS); provides a set of information, including query/response structure to allow vehicles to discover and obtain information about available networks in a geographical area, attachment capabilities/ network point of attachment, and other information related to the network.

MIH provides these services to MIH user Service Access Point (SAP). MIH-SAP and MIH-Link-SAP serve as MIHF interfaces to L3 and above layers, in addition to lower layers (L2 and below) respectively. Fig 2 shows MIH Structure.

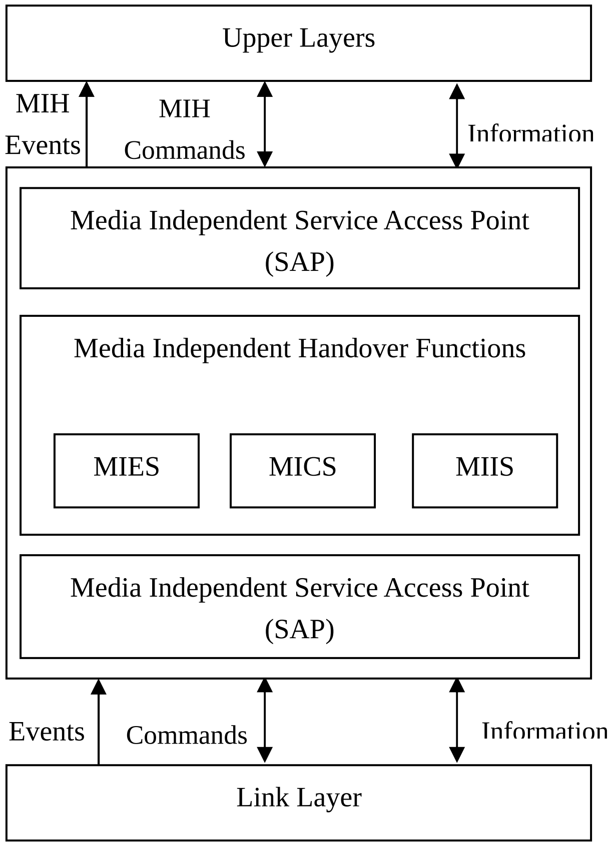

Figure 2 Media Independent Handover Structure

2.3 PMIPv6 Handover Optimization

When a mobile node moves to a new access network, it inevitably experiences packet loss or delivery latency before it receives its home network prefix advertisement from the newly attached MAG. The local handover consists of L2 detachment from previous MAG, L2 attachment to the newly attached MAG, authentication, router discovery and binding update. During this period, mobile node cannot send packets to or receive from its LMA. Recently, several fast handover mechanisms have been introduced to reduce handover latency.

In [14], retransmitting buffered packets at LMA after handover completion is suggested to avoid packet loss. It is very simple to implement but difficult to approximate the exact amount of buffered data. Hence the scheme may result in packet loss or redundant retransmission. Moreover, it does not scale well because LMA must have buffers for all the mobile nodes currently associated with it. In [15], IAPP (Inter-AP Protocol) is adopted to reduce the delay in authenticating and obtaining MN's profile. Despite this, it may experience on-the-fly packet loss between LMA and previous MAG. Moreover, since [14] and [15] assume buffers for incoming packets in the LMA, forwarding delay increases as the distance between LMA and MAG becomes longer. In [16] and [17], hybrids of PMIPv6 and FMIPv6 [7] is introduced. These schemes reduce packet loss and incoming packet delay significantly.

However, it inherits potential risks of the erroneous movement and out-of-order packet delivery problem from FMIPv6.

Most of PMIPv6 handover solutions, including those mentioned above, are derived from host-based mobility and initiated by mobile nodes. They require L2 intelligence of access network devices.

2.4 Existing Handover Schemes for Vehicular Networks

In order to provide real-time application support for Vehicular Ad-hoc Networks (VANETs) Several approaches have been proposed, Kang-Won Lee and Byoung-Sub Moon [25] proposed a scheme using Network-mobility based protocol for vehicular networks they introduced an intermediate mobile access gateway (iMAG) for supporting seamless handover for vehicles moving between different access networks although this scheme reduces the handover latency compared with host-based protocols, the total handover latency of the proposed scheme was larger than that of the conventional scheme.

Yuh-Shyan Chen [18] proposed a NEMO protocol for VANETs. On a freeway, the direction of vehicles are constrained by the roads, the car adopting this protocol can configure an IP address from the Vehicle Ad-Hoc Network (VANET) through Vehicle to Vehicle communications. The vehicle relies on the assistance of the front vehicle for processing the pre-handover procedure or it may requests for a new IP address through multi-hop relays from the car on the lanes of the same or opposite direction and reduces the handover latency and maintains the connectivity to the Internet.

Jong Min Lee [19] proposed the scheme of global mobility management (GMM) for the inter-VANET handover of vehicles. The proposed scheme supports the fast handover process using Layer 2 triggering and route optimization for packet transmission. Chung-Ming Huang [24] proposed the packet forwarding control (PFC) scheme in VANETs to select a common ahead point (CAP) as the tunnel source to forward packets. The CAP can forward packets to the Previous Access Router (pAR) and the new Access Router (nAR) with a shortest transmission path. During a vehicle handover, packets sent from the data center to vehicles can be forwarded through the CAP to the nAR directly without needing to travel through the pAR. As a result, packets can be sent through a shorter delivery path during handover in the proposed PFC scheme. However, this scheme does not work if the CAP does not exist in the middle of ARs and cannot reduce the number of Duplicated Address Detections (DADs) when the vehicle changes ARs.

M. Fazio and Mario Gerla [20] proposed a Leader-based scheme that exploits the topology of VANETs and a distributed DHCP service to guarantee fast and stable address configuration. However, it simply assumes the use of a DHCP server and suffers from the control message overhead problem since it is a proactive protocol. Additionally, it still needs the DAD when a vehicle changes the scope of its leader.

Marc Bechler [21] proposed a mobility management protocol known as (MMIP6), a communication protocol that integrates multi-hop IPv6-based vehicular Ad-hoc networks into the Internet. While the existing approaches focus on small-scale Ad-hoc networking scenarios, MMIP6 is highly optimized for scalability and efficiency. However, MMIP6 is based on the principles of Mobile IPv4 and does not provide the interoperability with previous mobility schemes such as IPv6, FMIPv6 and HMIPv6. Todd Arnold [22] also proposed the IP Passing Protocol to reduce the overhead of obtaining and configuring an IP address to under one-tenth of a second. This is done without modifying either the DHCP or the Access Point (AP) software. However, these previous schemes still do not satisfy the delay reduction to support seamless services in Vehicular Wireless Networks and Vehicular Intelligent Transportation Systems (V-Winet/V-ITS) and consider the handover delay under the imperfect prediction of the vehicle and the out-of sequence problem.

3. Proposed inter-domain Scheme

In this section we will discuss performance of our proposed scheme using Media Independent Information Service (MIIS) and how it can assist in providing suitable and sufficient information; it primitives to provide lower layer information (link layer) and other related information to the upper layers for handover optimization.

In this paper, we take the advantage of MIIS service. The key MIHF primitives define as part of MIH is used in the scheme.

We assume that the vehicle is connected with the previous BS that belongs to the first PMIPv6 domain before the handover is initiated an IP address is configured using the prefix send by the LMA.

Once the NMAG senses the vehicle link parameter using MIHF; Using MIHF which is located on the NMAG, the NMAG will send a request for information to MIIS that is located in the vehicle using MIH.

1. In our proposed method the vehicle will be able to store information of the network that it’s currently attached with; information such as (lower layer network information, profile, etc.).
2. When the New Mobile Access Gate (NMAG) senses the vehicles presence it will receive the lower layer information and send a PBA message to its LMA; upon receiving this message LMA will constrict the information that is stored in the vehicle. In addition the NMAG will receive the vehicles profile as well.
3. Form the lower layer information derived from the vehicle during the process of the network attachment. The NLMA can find the FQDN of the Previous LMA (PLMA), after that the NLMA will use the Domain Name System (DNS) to find the IP address of the PLMA.
4. The NLMA uses the FQDN of the PLMA instead of its IP address (es). The NLMA query the DNS infrastructure in order to resolve the FQDN to the PLMA IP address (es).

5. Once the IP address is maintained the NLMA will establish a tunnel with the PLMA and the information will be routed to the vehicle.
6. The vehicle will be provided with a pre-MN prefix to configure its address which will be a new IP address; using this addressing scheme provided by the PMIPv6 there will be no need to apply DAD procedure. Hence the handover latency will be reduced.

Basically Media Independent Information Service (MIIS) helps the Vehicle to obtain sufficient information of its serving LMA. The stored information will be used by the NMAG; once the NMAG senses the link of the vehicle by using MIHF it will retrieve the information from the vehicle MIIS. Then the NMAG sends a Binding Message with this information to its LMA (NLMA). This information is important for providing mobility management to the MN in the new PMIPv6 domain; in addition to the stored information the vehicle will be able to perform early scanning. MIH will allow the vehicle to select the next attachment point (new connection to MAG), on the other hand it will keep its current MAG that it is attached to update periodically.

On the other hand using the FQDN in our proposed inter-domain scheme will help in solving the address or the name of the PLMA, this will provide the NLMA the ability to discover the address of the vehicles currently serving LMA (PLMA). By obtaining the PLMA address, a tunnel will be generated between the serving LMA(s) in the inter-domain scenario and the NLMA will create a binding entry for the vehicle and the information will be routed form the PLMA to the NLMA.

Fig 3 shows the Network of our proposed inter-domain architecture, fig 4 shows the signaling flow of the proposed PMIPv6 scheme. In the proposed scheme the vehicle moves in a trajectory for a known route without changing e.g. highway.

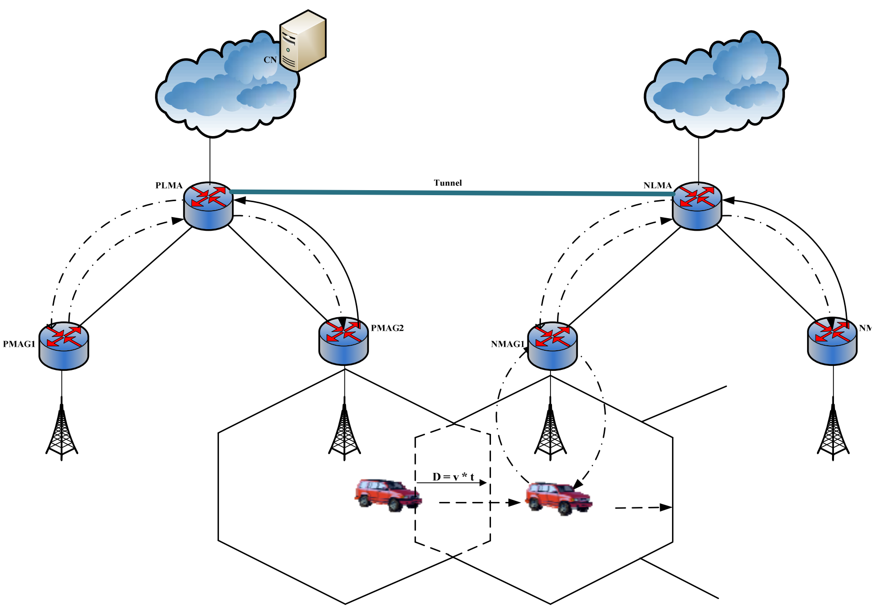

Figure 3 Proposed PMIPv6 Network architecture

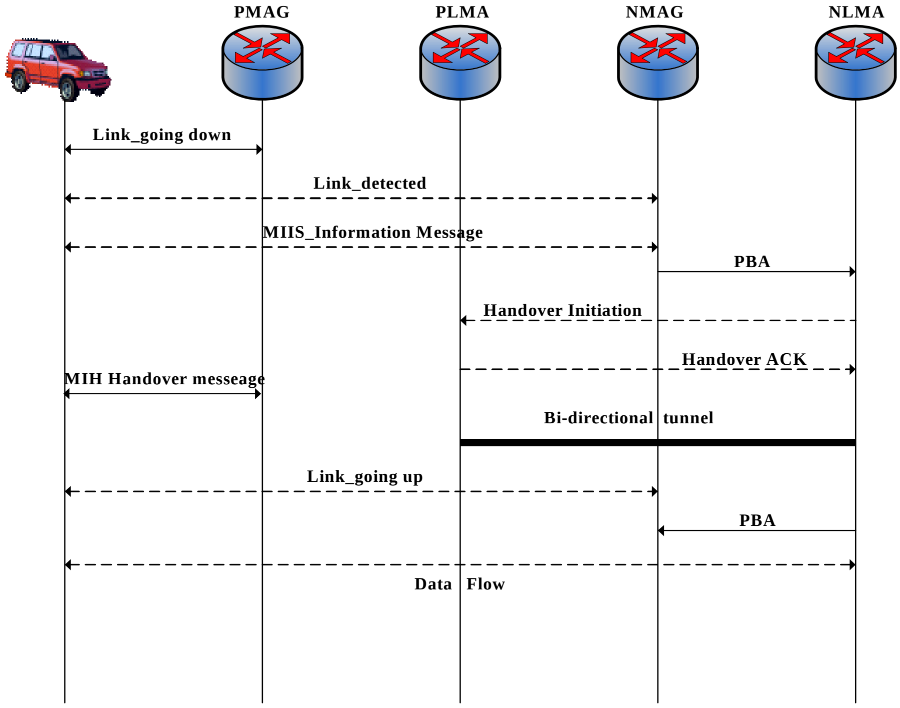

Figure 4 Signaling flow of the proposed method

4. Performance Evaluation

In this section we will numerically analyze the proposed scheme, intra-domain PMIPv6 and inter-domain PMIPv6 in terms of Handover latency.

4.1 Handover Latency

Handover latency has a significant impact on supporting real-time applications. In PMIPv6 proposed scheme, there is no need for movement detection and DAD. This is because the vehicle uses MN_pre address to configure its IP address uniquely.

PMIPv6 hand over latency is specified with time for Layer 2 handover (T_{L2}), time of the authentication latency between the MAG and PS (T_{AAA}) which is exposed as ($2 * T_{AAA}$), this is due to an intra-domain PMIPv6 handover latency, and finally the proxy binding update latency (T_{PBU}), which represents the latency involved in sending and receiving binding update messages between the MAG and its serving LMA, which is expressed as ($2 * T_{intra}$) in case of intra-domain PMIPv6 handover. Therefore, the total handover latency for intra-domain PMIPv6 given by:

$$PMIPv6_{Handover}^{intra-domain} = T_{L2} + 2 * T_{AAA} + 2 * T_{intra} + T_{RA} \quad (1)$$

Where T_{RA} represents the needed time for route advertisement.

For the inter-domain PMIPv6 handover latency case, ($\mathrm{T_{AAA}}$) and ($\mathrm{T_{PBU}}$) can be expressed as ($2 * \mathrm{T_{AAA}} + 4 * \mathrm{T_{intra}} + 2 * \mathrm{T_{inter}}$) and ($2 * \mathrm{T_{intra}} + 2 * \mathrm{T_{inter}}$), respectively. Thus inter-domain PMIPv6 handover latency is expressed by:

$$\mathrm{PMIPv6}_{\mathrm{Handover}}^{\mathrm{inter-domain}} = \mathrm{T_{L2}} + 2 * \mathrm{T_{AAA}} + 6 * \mathrm{T_{intra}} + 4 * \mathrm{T_{inter}} + \mathrm{T_{DAD}} + \mathrm{T_{RA}} \qquad (2)$$

In the proposed inter-domain scheme, since the vehicle is enabled to store the information needed such as (lower layer information, profile, etc.), pre-inter-domain Layer 3 handover process could be performed before performing the Layer 2 handover process, the NMAG retrieves the vehicles profile in addition to the lower layer information which is sent to the NLMA, the pre-tunnel will be established between the NLMA and PLMA. Furthermore the NMAG does not need to perform the authentication because the vehicle will be pre-authenticated as well as requesting for the vehicles profile from the AAA server. Therefore the inter-domain PMIPv6 handover latency for the proposed scheme is expressed by the following equation:

$$PMIPv6_{Handover}^{inter-domain} = T_{L2} + 2 * T_{intra} + 2 * T_{inter} = D_{L2} + D_{BINDING\ (PMIPv6)} \qquad (3)$$

Where $2 * T_{inter}$ equals $2 * T_{PLMA-NLMA}$ which represents the transmission of Handover Initiation (HI) and Handover Acknowledgment (H-ACK).
Route Advertisement (RA) is not calculated in our proposed scheme because of applying MIH function instead we use link-going up, link-going down. Fig 5 shows the handover latency domain.

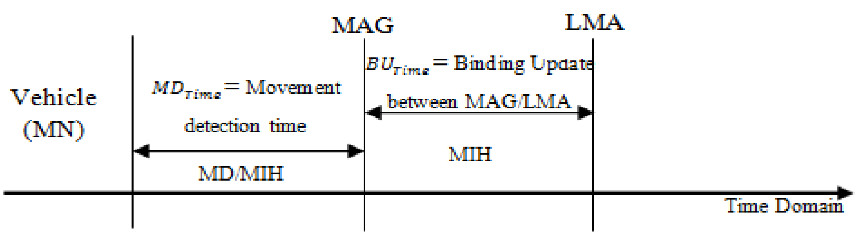

Figure 5 Handover latency time domains of the proposed Inter-domain PMIPv6

In addition the handover performance is affected by the overlapping area. This is because the high velocity of vehicles leads to the short resident connection time between two BS. Fig3 depicts the length of the overlap area (D), the overlap area is required for the vehicle to perform the handover process in the PMIPv6 domain. If the coverage of the overlapping area is too large, the coverage area of the BS will be reduced, this will result in capacity reduction of coverage. On the other hand, if it is too small, the vehicle will not have enough time for the handover process.

In our proposed inter-domain scheme, the NMAG starts the handover operation once it senses the vehicle and processes the handover within the overlapping area. Fig 6 shows the coverage overlapping length with respect to the speed of the vehicle. Here, we can notice that the handover initiation time in addition to the length of the overlapping area that is needed for completing the handover process for different velocities

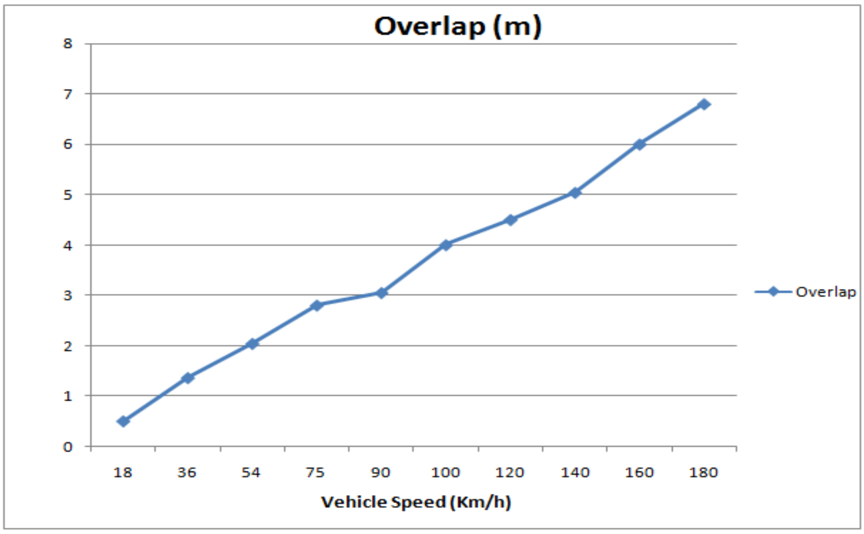

Figure 6 Relationship between the overlapping area against vehicle speed

4.2 Service Disruption Time

Service disruption time is known as the period of time when the vehicle cannot maintain active connection with the current Base Station (BS) to send and receive data packets. It usually lasts when the vehicle disconnected from its serving BS until it connects with a new serving BS link and starts sending and receiving data packets. The service disruption time of PMIPv6 is given by the following equation:

$$T_{service}^{PMIPv6} = T_{L2} + 2T_{MAG,LMA} + 2T_{MAG,vehicle} \tag{4}$$

Layer 2 handover is the time needed to perform the handover process between the vehicle and the serving BS of the serving PMIPv6 domain.

4.3 Binding Update Cost

Binding update depends on the sort of mobility management protocol and movement. Two classes of binding updates can be performed: intra-domain binding update (C_{intra}) and inter-domain bind update (C_{inter}) [23]. PMIPv6 inter-domain binding update is performed when the vehicle moves out of an LMA domain. The binding update is defined as follows:

$$C_{intra}^{PMIPv6} = 2C_{MAG,LMA} \tag{5}$$

$$C_{inter}^{PMIPv6} = 2C_{MAG,LMA} + 2C_{MN,HA} + 2C_{MN,CN} \tag{6}$$

In the proposed inter-domain scheme, we assumed that the binding update between the vehicles, HA and the CN do not occur within the inter-domain PMIPv6. Therefore, the binding update for the proposed scheme can be expressed by the following equation:

$$C_{inter}^{PMIPv6\,(proposed)} = 2C_{NMAG,NLMA} + 2C_{PLMA,NLMA} \tag{7}$$

4.4 Numerical Results

In this section, we use the parameters listed in Table 1 to calculate the handover latency for our proposed solution and compare it with i-MAG method introduced in [25].

Table 1 Parameters to calculate the performance metrics

	Notation	Default Value
Delay	T_{AAA}	30 ms
	T_{PBU}	30 ms
	T_{L2}	200-400 ms
	T_{inter}	50 ms
	T_{RA}	60
	T_{DAD}	500-1000 ms

Fig 7 shows the handover latency under different PMIPv6 domains. Notice that, the proposed inter-domain PMIPv6 solution can reduce the handover latency time compared with the proposed method in [25]. Furthermore addition the handover latency time of the proposed solution is less than the former PMIPv6 protocol.

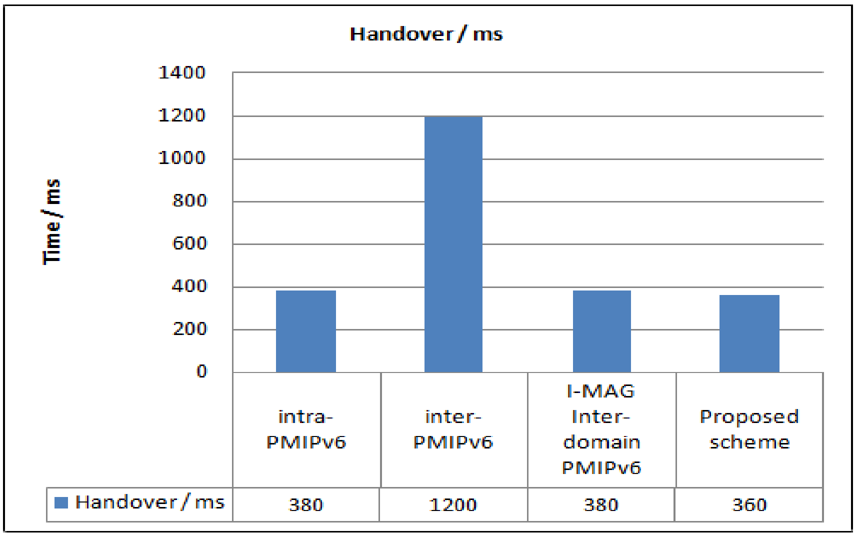

Figure 7 handover latency time of PMIPv6 vs. proposed scheme

5. Conclusion

In this paper, we proposed an inter-domain PMIPv6 handover scheme for vehicular environment. The proposed PMIPv6 handover scheme is based on MIIS information function. Using the MIH services (MIIS), the vehicle can obtain information without rout discovery or RtSolPr/PrRtAd messages. This, reduce the handover latency time due to concurrent start of L2 and L3 handover process. In this way, our scheme is suitable for a cost-effective network. Our future direction is planned to develop a mathematical model and evaluate it in different environments.

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