A HANDOVER TECHNIQUE FOR INTER- AND INTRA- DOMAIN PROXY MOBILE IPv6 IN VEHICULAR NETWORK ENVIRONMENT

Haider N. Hussain

UNIVERSTI TEKNOLOGI MALAYSIA

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HAIDER N. HUSSAIN

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To my mother and father ***Professor. Dr.*** **Noori Hussain AL-Hashimi**, whom always wanted their children to get the best education and be proud of their achievements. Their hard work, specially restless days and nights has paid them well of being proud. Thank you for your immense love, your precious, supports and for all that you have done to me. May the Blessings of Allah shower upon him.

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ABSTRACT

The provision of mobility is an essential feature of Vehicular Ad-hoc network (VANET) environments. In order to leverage mobility for wireless users, other researchers proposed an extension of MIPv6 which has been proven capable of supporting network mobility (NEMO). However, the Proxy Mobile IPv6 (PMIPv6) mobility protocol does not support seamless inter-domain vehicles handover and global mobility functionality. As a result, vehicles suffer from high handover latency and packet loss. Thus, there is a need to develop efficient inter-intra domain PMIPv6 techniques that consider the vehicular network environment for a seamless inter-domain handover. This thesis introduces an enhancement of the PMIPv6 protocol based on Media Independent Handover (MIH) known as inter-domain PMIPv6 techniques that provide seamless inter-domain handover for vehicles. Next, a handover Estimation Engine (EE) is proposed to improve the handover process, followed by an intra-domain technique to support continuous connection for vehicles crossing inter-intra domains. A series of experiments to test handover latency, communication overhead, and packet loss were conducted using highway vehicular scenarios. The findings were compared with results from other inter-intra PMIPv6 schemes. The comparison showed that the proposed techniques reduced approximately 18% of the inter-domain and 27% of the intra-domain handover latency time besides supporting continuous connection. The proposed techniques have been proven to be capable of providing inter-domain connections to resolve the global mobility support problem.

ABSTRAK

Peruntukan mobiliti merupakan satu ciri penting dalam persekitaran rangkaian kenderaan ad-hoc (VANET). Dalam usaha memanfaatkan mobiliti bagi pengguna tanpa wayar, penyelidik-penyelidik lain telah mencadangkan pernambahan terhadap MIPv6 yang telah terbukti mampu menyokong mobiliti rangkaian (NEMO). Walau bagaimanapun, protokol mobiliti Proksi MIPv6 (PMIPv6) tidak menyokong kelancaran serahan bagi kenderaan inter-domain dan fungsi mobiliti global. Akibatnya, kenderaan mengalami kependaman serahan dan kehilangan paket yang tinggi. Oleh itu, terdapat keperluan untuk membangunkan teknik inter-intra domain PMIPv6 yang cekap yang mengambil kira persekitaran rangkaian kenderaan untuk kelancaran serahan inter- domain. Tesis ini memperkenalkan penambahbaikan protokol PMIPv6 berdasarkan serahan Media Bebas (MIH) yang dikenali sebagai teknik PMIPv6 inter-domain yang menyediakan kelancaran serahan inter-domain bagi kenderaan. Seterusnya, serahan enjin anggaran (EE) dicadangkan untuk memperbaiki proses serahan, diikuti oleh teknik intra-domain untuk menyokong sambungan berterusan bagi kenderaan yang menyeberangi sesama inter-intra domain. Satu siri eksperimen bagi menguji kependaman serahan, overhed komunikasi, dan kehilangan paket telah dijalankan menggunakan senario kenderaan di lebuh raya. Hasil penemuan dibandingkan dengan keputusan dari skim PMIPv6 inter-intra yang lain. Perbandingan menunjukkan bahawa teknik yang dicadangkan dapat mengurangkan kira-kira 18% daripada inter-domain dan 27% daripada masa kependaman serahan intra-domain selain menyokong sambungan berterusan. Teknik-teknik yang dicadangkan telah terbukti mampu menyediakan sambungan inter-domain bagi menyelesaikan masalah sokongan terhadap mobiliti global.

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LIST OF ABBREVIATIONS

AAA	–	Authentication Authorization and Accounting
AN	–	Access Network
AP	–	Access Point
AR	–	Access Router
ARP / ND	–	Address Resolution Protocol / Neighbor discovery
BA	–	Binding Acknowledgement
BCE	–	Binding Cash Entry
BS	–	Base Station
BU	–	Binding Update
BUL	–	Binding Update List
CALM	–	Continuous Air Interface for Long and Medium Range
CN	–	Correspondent Nodes
CoA	–	Care-of-Address
CoT	–	Care-of Test
CoTI	–	Care-of Test Init
CS	–	Command Service
DAD	–	Duplicate Address Detection
DHCPv6	–	Dynamic Host Configuration Protocol for IPv 6
EE	–	Estimation Engine
ES	–	Event Service
FBU	–	Fast Binding Update

FMIPv6	–	Fast Mobile IPv6
FQDN	–	Fully Qualified Domain Name
GPS	–	Global Positioning System
GSM	–	Global System for Mobile communications
HA	–	Home Agent
HMIPv6	–	Hierarchical Mobile IPv6
HNI	–	Homogeneous Network Information
HNP	–	Home Network Prefix
IE	–	Information Element
IEEE	–	Institute of Electrical and Electronics Engineers
IETF	–	Internet Engineering Task Force
I-MAG	–	Intermediate Mobile Access Gateway
Interface ID	–	Interface Identifier
IP	–	Internet Protocol
IP	–	Internet Protocol
I-PMIPv6	–	Inter domain PMIPv6
IPv6	–	Internet Protocol version 6
IPv6S	–	IPv6 stack
IS	–	Information Service
ISP	–	Internet Service Provider
ITU-T	–	The International Telecommunication Union
L2	–	Layer 2
L2 trigger	–	Information from L2 that informs L3 of particular events before and after L2 handover
L3	–	Layer 3
LAN	–	Local Area Network
LCoA	–	On-Link Care of Address

LI	–	Logical Interface
LI	–	Logical Interface
LLC	–	Logical Link Control
LMA	–	Local Mobile Anchor
LMAA	–	Local Mobile Anchor Address
LMD	–	Local Mobile Domain
LTE	–	Long Term Evolution
MAC	–	Media Access Control
MAG	–	Mobile Access Gateway
MANET	–	Mobile Ad-Hoc Network
MAP	–	Mobility Anchor Point
MICS	–	Media Independent Command Service
MIES	–	Media Independent Event Service
MIH	–	Media Independent Handover
MIHF	–	Media Independent Information Function
MIH-PrefixInfo	–	Media Independent Handover Prefix Information
MIH-PrefixInfo	–	Media Independent Handover Information Prefix
MIIS	–	Media Independent Information Service
MIPv6	–	Mobile IPv6
MN	–	Mobile Node
MPR	–	Multipoint Relay
M_{BU-HA}	–	Binding Update Message Sent from MN to HA
$M_{BAck-HA}$	–	Binding Acknowledgement Message
M_{BU-CN}	–	Binding Update Message Sent from MN to CN
M_{FBU}	–	Fast Binding Update Message
M_{FBAck}	–	Fast Binding Acknowledgment Message
$M_{LBU-MAP}$	–	Binding Update Message Sent from MN to MAP

$M_{LBAck-MAP}$	–	Binding Acknowledgment Message Sent by MAP
$M_{PBU-LMA}$	–	Proxy Binding Update message sent from MAG to LMA
$M_{PBAck-LMA}$	–	Proxy Binding Acknowledgment Sent by LMA
$M_{RtSolPr}$	–	Route Solicitation for Proxy Message
$M_{PrRtAdv}$	–	Proxy Rout Advertisement Message
M_{HI}	–	dover Initiation Message
M_{HAcK}	–	Handover acknowledge
$M_S^{(HD)}$	–	IPv6 Header
nCoA	–	New Care-of-Address
NEMO	–	Network Mobility
NetLMM	–	Network-based Localized Mobility Management
NGN	–	Next Generation Networks
NIMM	–	Network Information Management Module
nLMA	–	New LMA
nMAG	–	New MAG
NUD	–	Neighbor Unreach-ability Detection
OSI	–	Open Systems Interconnection
PAR	–	Previous Access Router
PBA	–	Proxy Binding Acknowledgment
PBU	–	Proxy Binding Update
pLMA	–	Previous LMA
pMAG	–	Previous MAG
PMIPv6	–	Proxy Mobile IPv6
PoA	–	Pont of Attachment
PrRtAdv	–	Proxy Router Advertisement
RA	–	Router Advertisement

RCoA	–	Regional Care of Address
RR	–	Return Routability
RS	–	Router Solicitation
SAP	–	Service Access Points
TCP	–	Transmission Control Protocol
TLV	–	Type Length Value
TTL	–	Time To Live
UDP	–	User Datagram Protocol
V2I	–	Vehicle-to-Infrastructure
V2V	–	Vhicle-to-Vehicle
VANET	–	Vehicular Ad-hoc Networks
VMA	–	Virtual Mobility Anchor
VoIP	–	Voice over IP
WiFi	–	Wireless-Fidelity
WiMAX	–	Worldwide Interoperability for Microwave Access

LIST OF SYMBOLS

μ_c	–	Intra-Domain Crossing Rate
μ_d	–	Inter-Domain Crossing Rate
μ_I	–	Inter-Intra Domain Crossing Rate
$E(N_c)$	–	Average Number Of Intra-Cell Crossing
$E(N_d)$	–	Average Number Of Inter-Cell Crossing
$E(N_I)$	–	Average Number Of Cell Crossing Rate
$E(N_s)$	–	Average Number Of Intra-Domain Handover
$T_{(M\_latency)}$	–	Messaging Exchange
$T_{(M\_latency)}^{(PBU)}$	–	PBU Messaging Exchange
T_{L2}	–	Data Link Layer Latency
T_{WRS}	–	Delay of Delay Before Sending Initial RS Message
$T_{LU}^{(PMIPv6)}$	–	Location Registration
$M_S^{(X)}$	–	Message Size
$T_P^{(PRO)}$	–	Arrival Delay
S_{AR}	–	Connection Range
T_{RS}	–	RS Delay
T_{AAA}	–	Authentication Delay
T_{DAD}	–	Duplicate Address Detection Delay
T_{inter}	–	Inter PBU
T_{intra}	–	Intra PBU

T_{RA}	–	Route Advertisement
$T_{vehicle-MAG}$	–	Negotiation Time
$G_H^{(.)}$	–	Relative Gain for Handover Performance
O	–	Celle Overlap Area
P_f	–	Probability of Failure Handover
V	–	Velocity of the vehicle

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CHAPTER 1

INTRODUCTION

1.1 Overview

The International Telecommunication Union (ITU-T) recently, standardized Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution (LTE), for Next Generation Networks (NGN) networks, which have opened the door for deploying IP mobility support. This has laid the foundation for vehicular communications allowing vehicles to connect with the Internet while travelling roaming between networks. It is expected that Vehicular Ad-Hoc Networks (VANETs) communication will become a pressing need in the near future while providing ubiquitous connectivity over homogeneous and heterogeneous networks.

VANET mobility is different from other type's mobility, such as static mobility, in several ways. Vehicles in the vehicular network environment have high dynamic topologies, unpredictable mobility and geographically constraints. These characteristics make it difficult to apply traditional host-based or network-based mobility protocols directly to vehicular networks. As a result, mobility protocols ratified by the Internet Engineering Task Force (IETF), (i.e. Mobile IPv6 (MIPv6), Fast Mobile IPv6 (FMIPv6), Hierarchical Mobile IPv6 (HMIPv6), and NEMO (Network Mobility)) are less preferable in vehicular environments.

Both MIPv6 and NEMO were selected by the Continuous Air Interface for Long and Medium Range (CALM) group to support host mobility and network mobility in vehicular networks (Ze-qun *et al*., 2009). However, the combination of protocols did not solve the Data Link Layer and Network Layer handover latency issues experienced in vehicular environments because, these protocols produced high handover latency. This led to additional problems, such as packet loss, extensive MIPv6 functionality in IPv6 stack of the Mobile Node (MN) (Kempf, 2007a) and signaling overhead. The IETF ratified PMIPv6 designed to provide network-based IP mobility management support and the MN was not required to participate in IP mobility-related signaling (Gundavelli *et al*., 2008).

In the PMIPv6 domain, the Local Mobile Anchor (LMA) represents the Home Agent (HA) of the MN. The LMA manages the location of the MN within the PMIPv6 domain and assigns a home network prefix (HNP) to the MN. The, Mobile Access Gateway (MAG), which typically runs on the Access Router (AR), detects the movement of the MN and registers its location with the LMA. The MAG also establishes a tunnel with the LMA to forward the packets that are destined for the MN and emulates the MNs home network. Finally, the Point of Service (PoS) administers the MNs authentication and maintains the MNs profile, which is a set of parameters configured for the MN. PMIPv6 is a desirable mobility management protocol designed for telecommunication service providers as well as manufacturers. When PMIPv6 is deployed in mobile networks, manufacturers do not need to implement a mobility stack in the vehicle hardware. From a telecommunications view, they can easily manage and control the mobility services (Jong *et al*., 2009). In terms of performance, PMIPv6 generally outperforms the host-based mobility management protocols (Lee and Chung, 2010).

1.2 Problem Background

In order to provide continuity of service for a MN roaming between Access Routers (ARs), the IETF has ratified various IP-based mobility management protocols such as host-based mobility management (i.e. MIPv6, FMIPv6, and HMIPv6) (Koodli, 2005; Perkins, 2002) and network-based mobility management (i.e. PMIPv6) . Even though MIPv6 is a well-known and mature standard for host-based IPv6 mobility support, it still has several problems and drawbacks, such as high handover latency, signaling overhead, packet loss, and extensive MIPv6 functionality in the MN IPv6 stack (Al-Surmi *et al.*, 2012; Kempf, 2007b).

Host-based mobility protocols (MIPv6 and MIPv6 extensions) may partly reduce handover latency and packet loss in current mobile networks, but they cannot solve other issues related to the nature of host-based mobility. For example, host-based mobility protocols, in general and MIPv6, in particular, require host software stack changes that may not be compatible with other global mobility protocols (Soonghwan *et al*., 2009). PMIPv6 protocol was developed by IETF Network-based Local Mobility Management (NetLMM) Working Group (WG) to support IP mobility for MNs (Lee *et al*., 2011; Gundavelli, 2008). PMIPv6 provides service continuity for MNs in PMIPv6 domain without any IP mobility-related function. Currently, PMIPv6 cannot support inter-domain mobility management (global mobility management), because the PMIPv6 mobility protocol was originally designed for localized mobility management (Giaretta, 2012). There are many enhanced PMIPv6 schemes for supporting global mobility management (Giaretta, 2012; Jee-Hyeon *et al.*, 2008), but none of them can support seamless mobility for an MN, due to long inter-domain handover latency and packet loss.

The next sub-sections will discuss the issues and aspects of PMIPv6 seamless mobility management and inter-domain mobility support in greater detail.

1.2.1 Inter-Domain PMIPv6 Mobility Support

New approaches and enhancements have been developed to provide inter-domain mobility management (Lee *et al*., 2009) and they can be classified into two groups:

i. The first group aims to unify PMIPv6 protocol and global mobility management protocols, such as MIPv6 (Giaretta, 2012; Weniger *et al*., 2008).
ii. The second group expands PMIPv6 protocol, focusing on the context transfer and the handover procedures between PMIPv6 domains (Neumann *et al*., 2009; Jee-Hyeon *et al*., 2008).

Under the first approach, Giaretta (Giaretta, 2012) used PMIPv6 as a local mobility management protocol and, MIPv6 was used to support MNs inter-domain roaming between different PMIPv6 LMAs. In this approach the handover operation is similar to the handover operation of HMIPv6. However, since the MN used MIPv6 for inter-domain handover support (i.e. packet decapsulation, location update) the overall handover latency time is affected and the overall latency time increased. Another drawback of using MIPv6 to support global mobility in PMIPv6 is that it requires the MN to support MIPv6 in its mobility stack necessitating a modified MN stack that is difficult to implement. Furthermore, PMIPv6 was designed to support the MNs mobility regardless of MIPv6 support (Gundavelli, 2008). Weniger *et al*. (2008) on the other hand, assumed that PMIPv6 and MIPv6 are co-located and the transition between PMIPv6 and MIPv6 is supported without session bracking. Furthermore, the handover operation and data forwarding depends on MIPv6 priority meaning that MIPv6 has higher priority than PMIPv6 in the handover operation and data forwarding using the Binding Cash Entry (BCE). However, in this apprach the handover latency is increased because of implementation complexity and MN-HA Round Trip Time (RTT).

In the second approach, Neumann *et al*. (2009) defined a Session Mobility Anchor (SMA), Virtual Mobility Anchor (VMA) and a Steady Anchor Point in order to support seamless mobility for a MN that roamed between different PMIPv6 domains. Although Neumann's proposal offers inter-domain mobility support to MN, there was a problem. Under Neumann's proposal, the LMA played the role of both home LMA (HLMA) and the new LMA (NLMA). Consequently, LMA had to keep a Binding Cash Entry (BCE) for two kinds of MN. The first MN is the one that registered itself in this domain. As MN's HLMA, LMA keeps the BCE for MN no matter what domain the MN resided. In addition, LMA also keeps the BCE for the MN that was visiting its domain. Under Neumann's proposal, the number of BCEs increased. If there are many MN visiting the domain, the number of BCEs will become a burden for LMA and will limit the serving range of LMA. Jee-Hyeon *et al*., (2008) on the other hand, proposed a roaming mechanism to provide seamless and transparent inter-domain mobility between PMIPv6 domains. Yet, it could not support seamless service continuity during the inter-domain handover because of the long handover latency.

A Mobile Access Gateway (MAG) has no functions that support inter-domain handovers and cannot maintain communication sessions with its correspondent node. Lee *et al.*, (2007) proposed a solution that enabled a MN that lacks global mobility to support handovers between two LMA domains. In this mechanism, packet delivery cost is high because of the handover latency process. In addition, if the MN moved back into the old LMA through which it has already passed, the traffic is looped, resulting in a much higher packet delivery cost.

The approaches explained thus far have not considered the unique behavior of vehicles in vehicular network environments. All the inter-domain PMIPv6 approaches were based on a one-network topology that consisted of two PMIPv6 domains and one ISP domain.

1.2.2 Intra-Domain PMIPv6 Mobility Support

The IETF ratified Fast PMIPv6 (FPMIPv6) extension to reduce PMIPv6 control and handover latency (Yokota *et al.*, 2010). However, PMIPv6 provides fast handover only in intra-domains, not inter-domains. As mentioned in Section 1.2.1. The IETF was debating whether to go back to the MIPv6, which allows handovers in inter-intra domain PMIPv6 (Devarapalli *et al.*, 2007).

To support MN roaming between intra-inter domains, Baik *et al.* (2009) proposed an inter-domain handover approach. The basis of this approach was to switch the Authentication Authorization and Accounting (AAA) server, used for intra-domain handovers of PMIPv6, to an AAA cache server, then set the AAA cache server and communicate with other AAA cache servers in different PMIPv6 domains. In order to accomplish this multicast servers were implemented in each PMIPv6 domain, as shown in Figure 1.1. this led to long handover latency due to the time need for the MAG to send a request to obtain information about the MN from the AAA server. This approach performed poorly in vehicular network environments due to the high speed of the vehicles.

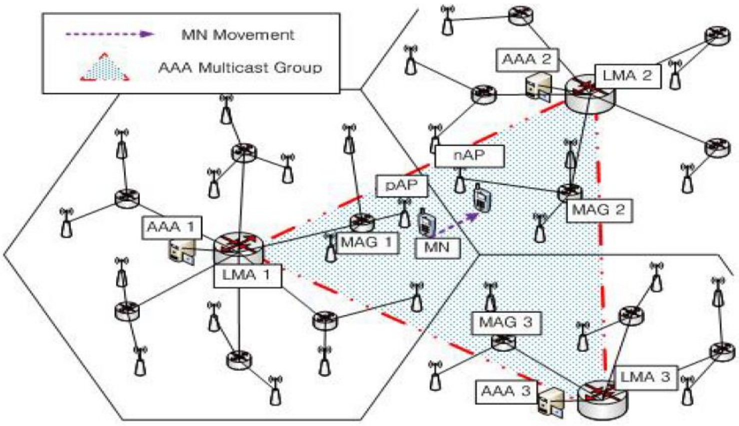

Figure 1.1 Multicast scheme in intra-domain and inter-domain (Baik *et al.*, 2009)

1.2.3 Obtaining MNs Context for Handover Triggering Support

Most inter-domain PMIPv6 mobility approaches do not consider MNs' Authentication, Authorization, and Accounting (AAA) procedures and context transfers (Lee et *al*., 2009). They assume that the New Point of Service (NPoS) will maintain authentication information for the MN and can authenticate the MN when the MN enters the new PMIPv6 domain. In addition, there is no consideration as to how AAA information regarding the MN will be obtain and shared between domains. In some cases, the MAG that the MN is attached to will ensure that the MN is always on its home network and maintains its Home Address (HA) despite being in a new PMIPv6. To achieve this, the MAG must receive the MN profile using a context transfer process. However, most of the inter-domain approaches ignore the context transfer process.

Lee *et al*. (2009) proposed an inter-domain PMIPv6 mobility protocol based on the vehicular environment that considered the context transfer issue. In this method, the authors assumed that the intermediate MAG (I-MAG) stored all the information needed in a database. However, this solution was not suitable and did not support vehicles roaming between to different networks where two PMIPv6 domains fall in different ISPs, because the new PMIPv6 domain could not receive the stored information. Furthermore, when the vehicle roamed between the PMIPv6 domains the context informaton shoud have been shared between both networks.

MIPv6 was extended to Network Mobility (NEMO) (Chen *et al*., 2009) to support the mobility of moving vehicular networks but this solution did not reduce the handover latency nor did it support the context exchange when the vehicle changed its point of attachment. Furthermore, MIPv6 extensions did not use any particular method for context transfers. In this thesis, Media Independent Handover (MIH) will be used to support context transfer in inter-domain PMIPv6 networks.

Ze-qum *et al*. (2009) proposed an application-driven handover scheme which included a PMIPv6 handover process by using IEEE 802.21 MIH services. However, in this application-driven scheme, the authors did not mention how to share the context of the vehicle when roaming between heterogeneous networks.

1.2.4 Local Mobile Anchor (LMA) Inter-domain Support

The LMA in PMIPv6 is the topological anchor point for the MNs Home Network Prefix (HNPs) and is the entity that manages the MNs binding state. The, LMA has the functional capabilities of the Home Agent (HA) (Johnson *et al.*, 2004) in addition to supporting PMIPv6 localized mobility. Therefore, the LMA is considered to be the HA of the MN within the PMIPv6 domain. In order for LMA to support MN roaming between different PMIPv6 domains, it must establish a tunnel with an anchor LMA to perform context transfers. This process reduces handover latency and packet loss for a MN moving between different domains.

Park *et al.* (2010), proposed a mechanism for establishing a tunnel between the home and visted LMA. This mechanism was based on the interaction between the home AAA and the visited AAA to exchange the information of the roaming MN. The tunnel in this mechanism was not generated until the visited LMA recived the MN information from the home AAA through the visited AAA. After this information was received, the visited LMA sent a PBU message requesting the MNs prefix from the home LMA and upon receiving the prefix, the tunnel was generated. Although, this mechanism supported generating a tunnel between the LMAs, it increased latency during the handover process resulting in packet lost. Figure 1.2 demonstrates the problem of inter-domain tunnel establishment.

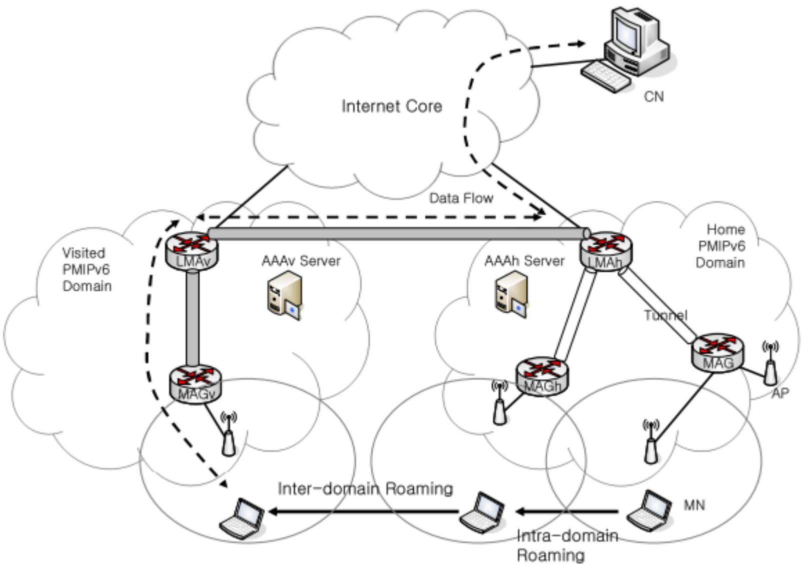

Figure 1.2 Inter-domain tunnel establishment issues (Park *et al.*, 2010)

1.3 Problem Statement

Supporting inter-intra domain PMIPv6 mobility in highway vehicular scenarios, requires the development of a seamless handover, continuous connection and efficient inter-intra domain PMIPv6 mobility techniques for highway vehicular scenarios. These mobility techniques must support inter-domain handover based vehicular network environments and reduce handover latency. Handover latency can be reduced by addressing, the problem of detachment and reattachment (disconnection/connection) with the new PMIPv6 domain when the vehicle roams between two different PMIPv6 domains. A reliable approach for network information exchange and control is needed in the vehicular network environment.

1.4 Research Questions

The purpose of this thesis is to answer the following research questions:

(1) How can support for the inter-intra domain PMIPv6 handover technique be enhanced to reduce handover latency in realistic highway vehicular scenarios,?

- (a) How can an inter-intra domain technique be developed that reduces handover latency?
- (b) How can an inter-domain handover technique be developed that bridges the gap between the deattachment and attachment of vehicles within the PMIPv6 domain,?
- (c) How can an analytical model be developed for an inter-intra domain PMIPv6 technique for vehicular network environments?

(2) How can a triggering technique be developed that increases the prediction of switching between inter-intra PMIPv6 domains?

- (a) How can the storage and information retrieval of the Data Link Layer and the Network Layer base on MIH services and Homogeneous Network Inoformation (HNI), be facilitated?
- (b) How can an handover estimation engine (EE) based on MIH information be developed?
- (c) What primitives and parameters should be considered?

(3) How can the Local Mobility Anchor (LMA) be modified to reduce the total handover latency in PMIPv6?

- (a) How can the mobility management of PMIPv6 be modified?
- (b) How can received information be resolved using the Fully Qualified Domain Name (FQDN)?
- (c) How can the tunnel be managed and generated between two LMAs for packet forwarding?

(4) How can total handover delays be measured, including triggering, selecting and transferring between LMAs?

(a) How can a network scenario be designed to simulate the vehicular environment?
(b) How can an analytical model be developed to analyze handover latency and packet loss delivered to a specified destination?
(c) How can the inter-intra domain PMIPv6 protocol be mathematically tested and compared?

1.5 Research Aim

The aim of this study is to enhance PMIPv6 protocol in order to support inter and intra domain Proxy Mobile IPv6 Protocol (handover techniques) for seamless handover, continuous connection and efficient support in highway vehicular scenarios where there was roaming between different PMIPv6 domains.

1.6 Research Objectives

The following objectives were set to improve PMIPv6 protocols to support inter-domain roaming:

(1) To enhance PMIPv6 protocol for inter-intra domain handover support by designing a handover technique that will reduce handover latency time and

support continuous connection when vehicles travel along the highway in VANET environments.

(2) To design a handover estimation engine (EE) that supports handover dissection thereby avoiding unnecessary handover processes and improving the inter-intra domain PMIPv6 handover process.

(3) To develop an inter-intra domain handover technique that support seamless mobility roaming in high speed vehicle scenarios.

(4) To evaluate the performance of the inter-intra domain PMIPv6 handover technique in terms of handover latency, packet loss, continuous connection and address configuration time.

1.7 Research Scope

This study examines an efficient inter-intra domain PMIPv6 technique that supports inter-domain and intra-domain mobility while reducing the overall handover latency in vehicular highway scenarios. To achieve inter-domain mobility support, crucial problems with the PMIPv6 based vehicular network were addressed. For instance, to address the issue of unnecessary handover, a reliable handover estimation engine is designed. The design and development of vehicular network topology, which allowed vehicles to adopt variable speeds and random motions is investigated. Mathematical models and evaluation process are required to validate the performance of the designed inter-intra techniques and topology. This study attempted the following:

(1) The analytical model of the proposed inter-intra domain PMIPv6 techniques was evaluated using Matlab 2011.

(2) This study focused on the handover process in inter-intra domain PMIPv6 based vehicular network environment.

(3) MIH services were extended in the mechanism for providing triggering information related to the Data Link Layer and to sense MN movement.

(4) This study examined vehicles moving on straight highway.

(5) The study used Data Link Layer and Network Layer information to support the handover process in the proposed protocol.

(6) This study also introduced an analytical model for inter-intra domain PMIPv6.

(7) In this study, vehicle-to-infrastructure (V2I) communication was used for the highway vehicular scenarios in which the designed inter-intra domain PMIPv6 techniques were evaluated.

1.8 Significance of the Study

This study focuses on developing an inter-intra domain PMIPv6 handover technique capable of supporting mobility in highway vehicular scenarios. The proposed inter-intra domain PMIPv6 techniques supported seamless handovers and continue connections for vehicles roaming between inter-domain and intra-domain PMIPv6 domains in vehicular environments for services that required multi-hop communication. A comprehensive solution was provided in this study based on the estimation engine (EE) that reduced the total handover latency. The proposed inter-intra domain PMIPv6 techniques modified the LMA in the PMIPv6 protocol to handle inter-domain network information and to generate a bi-directional tunnel between LMAs. In addition, the MAG was extended to support the Media Independent Handover Function (MIHF) to access stored information. A modification to the Proxy Binding Update (PBU) Message is indicated by HNI so that the LMA could understand that the vehicle was switching to a new network and would establish a bi-directional tunnel.

1.9 Research Contribution

The major contributions of this research are as follows:

1. The development of an inter-intra domain PMIPv6 handover technique for PMIPv6 protocol to support the handover process between two different PMIPv6 domains (multi-LMA domains) based vehicular networks.
2. The development of a technique for inter-intra domain handover prediction that supported continuous and seamless connections.
3. The development of an LMA extension to support information analysis that reduced the handover communication overhead.
4. The evaluation of parameters in vehicular networks, such as movement, signaling, and addressing.

1.10 Thesis Organization

The thesis is organized as follows:

Chapter 1 introduces the focus of the study including, handovers in vehicular ad hoc networks, and MIH concepts. The background of the problem was discussed, as well as the problem statement, research objectives and contributions.

Chapter 2 provides review of relevant literature involving the subject of the study including background, Media Independent Handover, problems and potential solutions. A discussion on the proposed solutions is presented along with a comparison table of the protocols.

Chapter 3 explains the research methodology used in this study. It discusses simulation setup and, problem formulation based on the literature review. It presents the mobility model and the protocol design used in this study.

Chapter 4 presents the detail analytical analysis and design of the proposed inter-intra domain PMIPv6 protocol in realistic highway vehicular environments.

Chapter 5 presents the proposed inter-intra domain PMIPv6 technique using IEEE 802.21 MIH services for vehicle global mobility support based on vehicular environments for performance evaluation. The techniques were analyzed using Matlab.

Chapter 6 presents the conclusion, describes the contributions made by this study, and suggests directions for future research.

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