

Efficient Mobility Management Scheme to Support Highway Environment

Daewon Lee

*Division of General Education, Seokyeong University, Korea,
daelee@skuniv.ac.kr*

Abstract

With the explosion of wireless technologies, variable types of mobility are presented. To provide seamless communication and mobility management, IP based mobility management protocols are proposed. One of them, to provide inter/intra/inner vehicle communication, the vehicles' mobility management is studied that called VANET (vehicular ad hoc network). However, the mobility of vehicular results in short lived connections to access router (AR), affecting the availability of IP services in VANET. The most critical issue consists of the design of scalable routing algorithms that are robust to frequent path disruption caused by vehicles' mobility. With the navigation information that one of vehicles' mobility features, we are classified into intra highway mobility and global mobility management mobility. Furthermore, we propose efficient mobility management scheme based on route prediction in VANET. Experimental analysis shows that proposed mobility management protocol reduces handoff latency, signaling costs and packet loss.

Keywords: *Vehicular Ad Hoc NETWORK (VANET), intra highway mobility, NETWORK MOBILITY (NEMO), binding update*

1. Introduction

With the explosion of wireless technologies, variable types of mobile devices are provided with wireless interface can access Internet anytime and anywhere. To provide seamless communication and mobility management, IP based mobility management protocols are proposed [1-2]. Depending on environment of usage, variable types of mobility are presented. For example, personal mobility, network mobility, sensor mobility, vehicles' mobility and so on.

To provide personal mobility, mobile IPv6 (MIPv6) is designed between wireless IPv6 networks by IETF. Using MIPv6, nodes are possible to access wireless IPv6 networks without changing their IP address. However, if mobile host (MH) moves frequently, MIPv6 results in high handoff latency and high signaling costs to update the MH's location [1]. Thus, many mobility management protocols have been proposed to improve handoff performance and reduce signaling overhead. Thus, many mobility management protocols have been proposed to improve handoff performance and reduce signaling overhead. And, if several MHs move to identical route continuously, MIPv6 results in same handoff latency and same signaling costs for each MH. To support network mobility, the IETF NEMO working group proposed network mobility basic support protocol [2] extending MIPv6. NEMO is designed to support the movement of a mobile network consisting of several mobile nodes where nodes move together as a group, as in a train, car, plane, ship, etc. And, to provide seamless communication and mobility management on vehicle communication, the vehicles' mobility management is studied on network environment that called VANET (vehicular ad hoc network) [3]. In VANET, the mobility can be classified inter vehicle between vehicle and other IP network, intra

vehicle between vehicles and inner vehicle between vehicle and other component within vehicle.

However, the inter vehicle mobility results in short lived connections to access router (AR), affecting the availability of IP services in VANET. The most critical issue consists of the design of scalable routing algorithms that are robust to frequent path disruption caused by vehicles' mobility [4-5]. Typically, vehicle mobility has several characteristics. They will be shown at section 3. With the navigation information that one of vehicles' mobility characteristics, we classify into intra highway mobility and global mobility management mobility. Furthermore, we propose efficient mobility management scheme based on route prediction in VANET. Handoffs in intra highway mobility are managed locally and transparently to CH, while global mobility is managed with Mobile IPv6. Experimental analysis shows that proposed mobility management protocol reduces handoff latency, signaling costs and packet loss.

The rest of paper is organized as follows. In Section 2, we discuss previous works on mobile management protocols. Section 3 explains the environment that we are focused on. In Section 4, we describe the operation of proposed protocol. Section 5 shows numerical analysis between basic NEMO protocol and proposed protocol. Finally, Section 6 concludes this paper.

2. Related Works

2.1. Mobility Management Schemes

The Mobile IPv6 protocol is specified by the IETF IP Routing for Wireless/Mobile hosts working group [1]. However, MIP suffers from several well-known weaknesses such as handoff latency or signaling overhead, that have led to macro/micro mobility schemes. Thus, many mobility management protocols such as HMIPv6, HAWAII, CIP, IDMP, etc have been proposed to improve handoff performance and reduce signaling overheads. Hierarchical Mobile IPv6 (HMIPv6) [6] is most famous micro mobility management protocol. It presents a n-level hierarchical mobility management architecture for IPv6. HMIPv6 defines a domain as the highest level of hierarchical architecture. A domain is an arbitrary structure, as ISP network, campus network, or a single LAN. A domain is connected to the rest of internet via one or several interconnection routers that is called mobility anchor point (MAP). HMIPv6 separates local mobility from global mobility management. Using n-level hierarchical architecture, HMIPv6 improves handoff performance that becomes reducing packet loss and signaling overhead. It doesn't fix anything on router and it is flexible and scalable.

However, the train moves at 60km/h, MH moves rapidly across many domains that is the highest hierarchy in HMIPv6 architecture. It causes macro handoff continuously. HMIPv6 has better performance than MIPv6, but it can't tolerate movement with vehicle. Therefore, we are focused on the movement with vehicle such as automobile on highway

2.2. Network Mobility (NEMO)

The NEMO protocol maintains the session continuity for all the group of MHs [2, 7], when the mobile network (MN) is constructed with MHs and it dynamically changes its point of attachment on the Internet. It also manages connection for all MHs it has as it moves. In RFC 3963 [16] the NEMO protocol has been proposed and standardized to support network mobility. NEMO is based on IPv6, all signaling messages such as binding update (BU) and binding acknowledgement (BA) are extended Mobile IPv6 messages. The BU and BA messages have an additional flag R bit to signal the mobile router (MR). In NEMO, explicit and implicit mode is proposed. In the explicit mode, several mobile network prefix options (at least one) should be included in a BU message.

In the implicit mode, instead of including mobile network prefix, the HA decides mobile network prefix owned by the MR.

2.3. Vehicular Ad Hoc Network (VANET)

Vehicular ad hoc network(VANET) is proposed for the access to drive thru Internet and IP based applications. VANET services are supported by roadside ARs that connected to external IP networks [3]. However, the VANET suffers from asymmetric links due to variable transmission ranges caused by mobility, obstacles, and dissimilar transmission power, which make it difficult to maintain the bidirectional communications and to provide the random mobility required by most mobile IP devices. Furthermore, the vehicle's mobility results in short lived connections to the ARs, affecting the availability of IP services in VANETs. And, more challenge issues are come for seamless communications through multi hop VANETs, because of proposing the infrastructure to vehicle to vehicle (I2V2V) communications for infotainment applications, such as IP-based services and drive thru Internet access [4-5].

First, due to the dynamic network topology of VANET, vehicles transfer their active connection through different IP networks. Thus, the on-going IP sessions are affected by the change of IP addresses, which causes the session disconnections. Second, additional complexity may be added due to links variability during V2V communications and the presence of asymmetric links caused by irregular transmission ranges between network infrastructure and VANET devices [8, 9].

3. Highway Environment

3.1. Mobility of Vehicles

In general, almost all devices in a vehicle are provided seamless communication. However, when the vehicle moves with high speed, the MH and MR in the vehicle could not grantee seamless communication. To guarantee seamless communication environment, we must consider its features.

The mobility of vehicle has several characteristics.

- (1) Heterogeneous network (*i.e.*, GPS, WLAN, WIBRO, LTE/3g, Bluetooth, *etc.*) is available.
- (2) A vehicle has moves the random mobility as a person.
- (3) A vehicle has the group mobility with other mobile devices in the vehicle.
- (4) Also, vehicle has the group mobility with other vehicles going same way.
- (5) A vehicle must move on route that is consisted of geographical structure.
- (6) The vehicle's movement pattern can be predicted by the navigation.
- (7) On highway or expressway, the random mobility is disappeared and the group mobility is remaining.

By these characteristics, the vehicle's movement path can be predicted. Therefore, this paper is based on two assumptions that are as follow:

Assumption 1.

The navigation must be used, and the vehicle's own path is set before departure.

Assumption 2.

The network structure of highway or expressway is virtualized as a single subnet or multiple subnets.

3.2. Highway Mobility

The highway environment is constructed with fixed route that is consisted with partial route and it is geographically connected. In this paper, focused highway organization consists of subnets. We organize geographically distributed subnets into a logical highway organization. Therefore, MH/MR that moves within a highway that is in physical subnet i , but it is logically in highway organization. The focused highway organization is shown at Figure 1. In example, highway organization is consisted of subnets. It is organized geographically distributed subnets into single logical domain that called highway organization. And, the highway home AR is proposed to manage MHs/MRs within the highway organization.

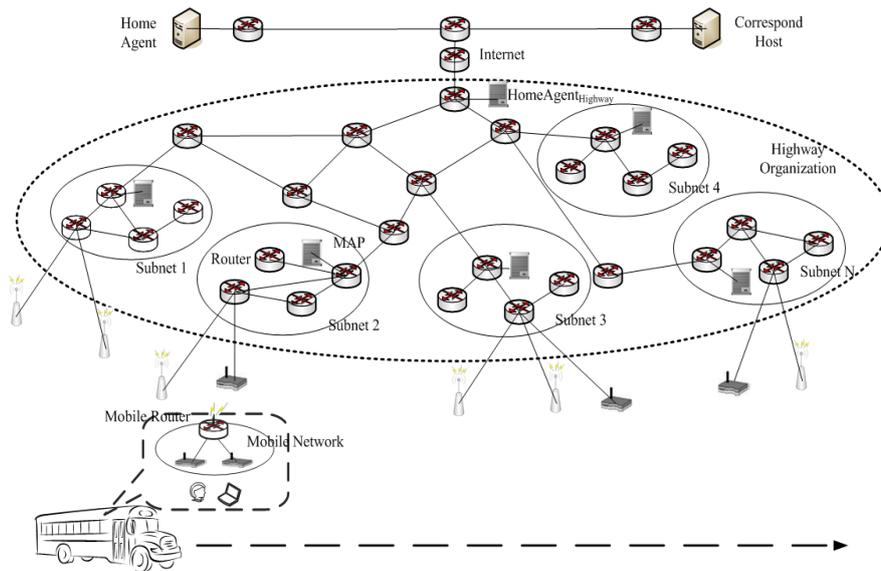


Figure 1. Example of Highway Organization

4. Highway Mobility Management Protocol

The proposed highway mobility management scheme is consisted of four phases as following: 1) Route Predictions phase, 2) Pre-registration phase, 3) Registration phase and 4) Packet delivery phase.

4.1. Protocol Overview

Table I shows the route prediction algorithm. MHs/MRs request to the navigation making out new route path. After receiving route path, MHs/MRs starts the route prediction algorithm that describes at table 1. The route_path is consisted of partial_path1 to partial_pathn. Each partial_pathi is verified that there is highway by bool_operator. The bool_operator checks distance and velocity of each route_pathi. And then, if there is one or more partial_pathi that includes the highway send pre_registration to highway home AR.

Table 1. Route Prediction Algorithm

```

Route_Predictor()
Initialization Status;
Get Route_Path Form The Navigation;
Begin;
For Each_Path;
    If Bool_Operator() Is Equal To True Then
        Send Pre_Registration() To Highway Home Ar;
    End If
End For
End;

Bool_Operator()
{
    If (Distance > 5 Km)                                Return
True;
    If (Current Speed > 60 Km)
Return True;
    Return False;
}
Pre_Registration()
{
    Send Current Host Id Of Mh;
}

```

4.2. Pre-Registration Phase

When the highway home AR receives request of pre-registration (), it starts the pre-registration phase. This phase performs the IP configuration. It checks received MH/MR's host id that is available to use. If the host id is unusable, new host id is selected from pool of idle IP. And it is set up as a reserved host IP. Then, the reserved host IP is broadcasted to all ARs in highway organization.

Table 2. Registration Algorithm

```

Highway_Home_Ar()
Begin;
If Receive Pre-Registration() Then
    Do Ip Configuration();
    Send Prefix Of Highway Home Access Router
Address;
    Send Reserved Host Id;
End If
Broadcast Reserved Host Id To All Ars In Highway
Organization
End;
Ip Configuration()
{
    Do Duplicate Address Detection (Dad);
    If Current Host Id Of Mh Is Duplicated Then
        Discovery Available Host Id;
        Set Reserved Host Id(Available Host Id);
    Else
        Set Reserved Host Id(Current Host Id Of Mh);
    End If
}

```

4.3. Registration Phase

Figure 2 shows the call-flow of registration. This call-flow is consisted two parts (pre-registration phase, after handoff phase). After handoff, the MH/MR does not have to register its new CoA to new AR. Also, the MH/MR sends only one BU to its HA when it joins into highway organization.

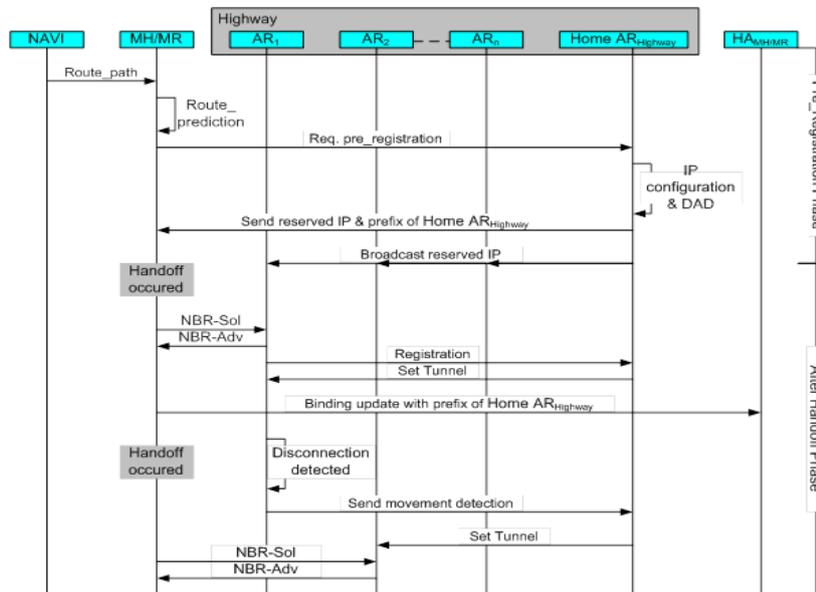


Figure 2. Call-Flow of Registration

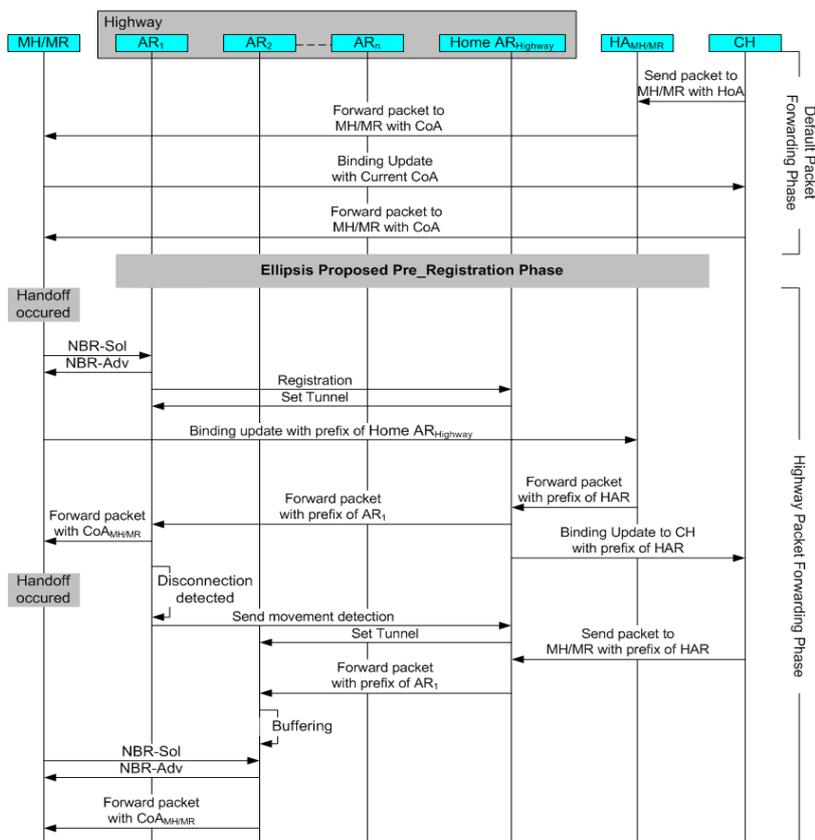


Figure 3. Call-Flow of Packet Delivery

4.3. Packet Delivery

Figure 3 shows the packet delivery call-flow. This call-flow is consisted of two parts. The one is a default packet forwarding phase at out of highway organization. The other is the highway packet forwarding phase when the MH/MR is attached in highway organization.

5. Numerical Analysis

5.1. Signaling Cost and Packet Delivery Cost

We analyze the performance of proposed scheme with respect to following metrics: location update signaling cost $C_{binding_update}$, packet delivery overhead cost $C_{packet_delivery}$. To calculate these metrics, we follow a methodology similar to [8] to calculate the probability that a vehicle moves across i service areas. We have chosen the MANET centric NEMO scheme [8] for comparison purposes. We define the costs parameters used for the performance analysis as follows:

$C_{binding_update}$: The cost of BU/BA,

$C_{packet_delivery}$: The cost of additional IP tunneling header,

$T_{handoff_delay}$: The period time due to handoff and IP configuration,

N : The number of network service areas(or AR),

$f_{sa}(t)$: general distribution of service area residence time,

$$f_{sa}(t) = \frac{1}{\mu}$$

μ : the rate of service area crossing,

v : the average velocity of MH/MR (vehicle),

π : the direction of MH/MR (vehicle),

L : the average length of sessions,

λ_I : the average rate of inter session arrival time,

ρ_s : the session to mobility ratio,

$f_{sa}(\lambda_I)$: the Laplace transform of service area residence time distribution,

$\alpha(i)$: the probability of crossing i service area,

$$\alpha(i) = \begin{cases} 1 - \frac{1}{\rho_s} [1 - f_{SA}^*(\lambda_I)], & \text{if } i = 0 \\ \frac{1}{\rho_s} [1 - f_{SA}^*(\lambda_I)]^2 [f_{SA}^*(\lambda_I)]^{i-1}, & \text{if } i > 0 \end{cases} \quad (1)$$

where the session to mobility ratio ρ_s and the Laplace transform of the service-area residence distribution $f_{sa}(\lambda_I)$ can be found in [9]. Furthermore, derivation details of (1) can be found in [10] and references therein. The location update signaling cost per handover BU is obtained according to the number of hops the signaling messages have to reach the home agent in default case such as NEMO, and the highway home AR in highway organization case that proposed. It is calculated as follows:

$$BU^{NEMO} = (n \times \omega + d_{HA})U^{NEMO}, \quad \text{if default} \quad (2)$$

$$BU^{Proposed} = (n \times \omega + d_{HighwayHomeAR})U^{Highway}, \quad \text{if handoff within a highway} \quad (3)$$

U : the size of BU/BA,

$d_{HA}/d_{Highway_HA}$: the number of hops,

n : the number of links,

ω : the relative weight of packet transmission on wireless link compared with wired link,

The total location update signaling cost C_{BU} (bytes \times hops), incurred by a vehicle moving across several service areas is calculated as follows:

$$C_{binding_update} = \sum_{i=0}^{\infty} i \times BU \times \alpha(i) \quad (4)$$

where BU is replaced by (2, 3), accordingly. Also, C_{BU} goes to 0 in highway case.

The delivery overhead cost per packet PD accounts for extra information and extra links traversed when delivering a data packet from a server to the vehicle. It is computed as follows:

$$PD^{NEMO} = d_{CH} + H(d_{HA} + n \times \omega) \quad (5)$$

$$PD^{Proposed} = d_{CH} + H(d_{HighwayHomeAP} + n \times \omega) \quad (6)$$

where d_{CH} is the distance to the CH, and H is the size of the tunneling IP header.

The total packet delivery cost C_{PD} (bytes \times hops) considers the number of active hosts m in the in-vehicle network and the average session length L (packets). L depends on downloading data rate γ , packet size S , and intersession arrival rate λ_I . Thus, C_{PD} is calculated as follows:

$$C_{packet_delivery} = m \times PD \times L \quad (7)$$

where PD is replaced by (5, 6), accordingly.

Total cost CT is obtained by adding the total location update and total packet delivery cost of each scheme. Therefore,

$$C_{Total} = C_{binding_update} + C_{packet_delivery} \quad (8)$$

5.2. Numerical Analysis

In this section, we demonstrate some numerical results. Table III shows parameters used in our performance analysis [8, 11]. For simplicity, we assume that the distance between mobility agents is fixed and is the same.

Table 3. Numerical Analysis Parameter

Parameter	D	A	ω	N
Value	10000 0	1200k m^2	3	2
$1/\lambda_i$	N	D_{ha}	$D_{highwayhome}$	D_{ch}
10s- 800s	50	10- 15hops	3-6hops	15- 20hops
U^{nemo}	$U^{highway}$	P	V	H
124byt es	124byt es	124byt es	30- 1100km/H	40byt es

Figure 4 shows that proposed scheme achieves lower BU cost compared with basic NEMO. When ρ becomes larger, a different result is observed. The result of Figure 5 with longer session lengths is compared with mobility, where different session varies by length $v = 60\text{Km/h}$, and $(1/\lambda_I) = 800\text{s} - 10\text{s}$. It is also impacted that the reducing packet

loss on proposed scheme, comes at the cost of a 28.4% increase of BU signaling cost when compared with basic NEMO. Different downloading data rates ($\gamma = 200 \text{ Kb/s} - 4\text{Mb/s}$) and session arrival rates ($1/\lambda_l = 600\text{s.}$) are studied at fig. 6. Figure 5 shows that the packet delivery cost naturally increases for longer data sessions with high velocity. Proposed scheme outperforms basic NEMO on cost of packet delivery. Based on the fig. 6, it is observed that the packet overhead is increased with similar rates on the basic NEMO. Because packets are affected by the multiple encapsulation, when the highway home AR to subnet AR tunnel is employed.

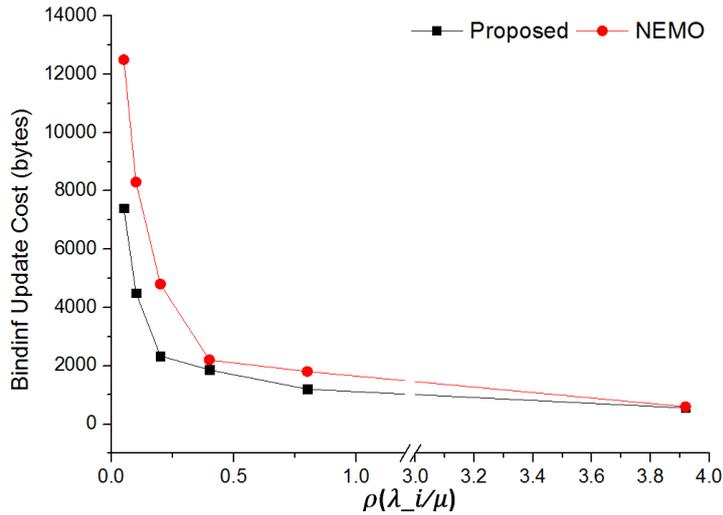


Figure 4. Signaling Overhead Comparison

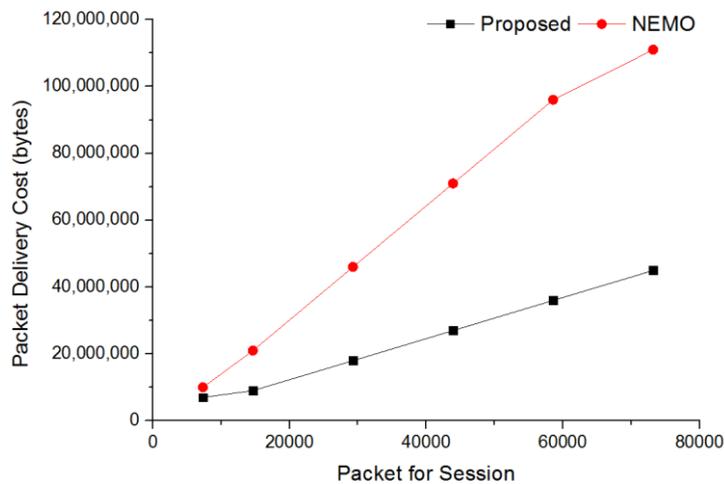


Figure 5. Packet Delivery Comparison

6. Conclusions

In this paper, we focus on network mobility management to provide reliable communication within the vehicle that move in fast moving area such as a highway. The most critical issue consists of the design of scalable routing algorithms that are robust to frequent path disruption caused by vehicles' mobility. Due to the characteristics of vehicle, we try to solve the problem. In this paper, we are classified into intra highway mobility and global mobility management with the navigation information. Furthermore, we propose efficient mobility management scheme based on route prediction in VANET. Proposed mobility management scheme has several advantages. First, proposed

management scheme reduces handoff latency, since handoffs within the highway are managed locally such as handoffs within a single domain. This causes additional advantages increasing handoff speed and minimizes packet loss during transition. Second, it reduces the signaling overhead by BU that each MH/MR initiates. In this paper, the BU within the highway, the home AP of highway sends the BUs to each MH/MR's HA and their CH. It means the MH/MR doesn't have to send the BU within the highway. On point of HA/CH, MH/MR stays in the highway. Through the numerical analysis based on the discrete analytic model shows that proposed scheme has superior performance than the basic NEMO scheme within the highway.

Acknowledgments

This Research was supported by Seokyeong University in 2013.

References

- [1] C.D. Scott and R.E. Smalley, "Diagnostic Ultrasound: Principles and Instruments", *Journal of Nanosci. Nanotechnology*, vol. 3, no. 2, (2003), pp. 75-80.
- [2] Johnson, David, C. Perkins and J. Arkko, "Mobility support in IPv6", No. RFC 3775, (2004).
- [3] Devarapalli and Vijay, "Network mobility (NEMO) basic support protocol", No. RFC 3963, (2004).
- [4] Li, Fan and Y. Wang, "Routing in vehicular ad hoc networks: A survey", *Vehicular Technology Magazine, IEEE* 2.2 (2007): 12-22.
- [5] Mahmoud, E. Mohamed and X.S. Shen, "PIS: A practical incentive system for multihop wireless networks", *Vehicular Technology, IEEE Transactions*, vol. 59, no. 8, (2010), pp. 4012-4025.
- [6] Lu and Ning, "Capacity and delay analysis for social-proximity urban vehicular networks", *INFOCOM, 2012 Proceedings IEEE*, (2012).
- [7] Soliman and Hesham, "Hierarchical mipv6 mobility management (hmipv6)", draft-ietf-mobileip-hmipv6-06, (2002).
- [8] Jemaa and I. Ben, "Validation and evaluation of NEMO in VANET using geographic routing", *10th International Conference on Intelligent Transport System Telecommunications-ITST 2010*, (2010).
- [9] Chakravorty, Rajiv and I. Pratt, "Performance issues with general packet radio service", *Communications and Networks*, vol. 4, no. 4, (2002), pp. 266-281.
- [10] Xie, Jiang and I.F. Akyildiz, "A novel distributed dynamic location management scheme for minimizing signaling costs in Mobile IP", *Mobile Computing, IEEE Transactions*, vol. 1, no. 3, (2002), pp. 163-175.
- [11] Pack and Sangheon, "An adaptive network mobility support protocol in hierarchical mobile IPv6 networks", *Vehicular Technology, IEEE*, vol. 58, no. 7, (2009), pp. 3627-3639.
- [12] Lee, Jong-Hyouk, T. Ernst and N. Chilamkurti, "Performance analysis of PMIPv6-based network mobility for intelligent transportation systems", *Vehicular Technology, IEEE*, vol. 61, no. 1, (2012), pp. 74-85.

Authors



Daewon Lee, received his B.S. in division of Electricity and Electronic Engineering from Soonchunhyang University, Asan, ChungNam, Korea in 2001. He received his M.E. and Ph.D. degrees in Computer Science Education from Korea University, Seoul, Korea in 2003 and 2009. He is currently a full time lecturer in the Division of General Education at SeoKyeong University in Korea. His research interests are in IoT, Mobile computing, Distributed computing, Cloud computing, and Fault-tolerant systems.