A Networked Human Transporter as an Experimental Testbed of Mobile Gateway

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Abstract

The human transporter is electric powered ride which can go anywhere a human can move and is expected to be future vehicle in city areas. Nowadays, human transporter is already available as commercial products (ex. Segway) and used in city areas. We developed a networked transporter using Mobile Gateway which is capable of handling MANET and Internet mixed environments. This networked transporter is connected to other transporters, vehicles, sensors, and machines to exchange information and run applications. Once human transporters and vehicles are connected by MANET, city and town are mostly covered by network from road to sidewalk. There are several applications for human transporters including safety, entertainment, navigation, etc. We have implemented a MANET routing protocol (OLSR) and Network Mobility Basic Support protocol (NEMO) on BSD based operating system in WIDE project. These implementations are merged and modified for mobile gateway, and installed to human transporter. We introduce networked human transporter developed on Segways and its applications.

I. Introduction

As advancements of vehicles, new types of vehicle has came out. For example, the segway sold by Segway Inc. is an example of electric powered two wheeled ride. Similar ride was introduced by Toyota Inc. at Expo 2005 Aichi Japan. Toyota exhibited a future concept vehicle called the i-unit. This i-unit also has two wheel and electric power. Similarity of the segway and the i-unit is that both are capable of going to anywhere people can move, while the legacy vehicle has limited moving area, for example, it cannot come to passageway and inside buildings. In this paper, we call this new type of vehicles as ”Human Transporter”. When these human transporters are deployed in near future, our daily life will be drastically changed. We specially interested in a networked human transporter. Several technologies has been introduced and investigated to provide network connectivities to a vehicle because of highly interests from industry.

There are two key technology to achieve vehicular networks which are Network Mobility (NEMO) [4] and Mobile Ad-hoc Network (MANET). NEMO is used to provide in-vehicle networks as mobile networks which can be reachable regardless of vehicle movements. In addition, the movements are hidden to the network by the mobile routers of NEMO. Alternatively, MANET is expected to achieve vehicle-vehicle networks without any network infrastructures. Several requirements are raised for the vehicle network based on several assumptions. We have been investigating a deployable network in vehicle which support the requirements and propose a ”Mobile Gateway” for vehicle network.

In this paper, ”Mobile Gateway” is evaluated and run on demonstration system which is built on a Segway. We also explain the possible capability of the human transporter system including network design and application ideas. This paper will first introduce fundamental technology for vehicles in Section II. Then we show how to converge NEMO and MANET technology using Mobile Gateway systems, followed by related works in the area. Then the detailed implementation about the mobile gateways is described. The next section will report an experimental evaluation of vehicle-vehicle communication that takes place in a real live settings with a performance study on optimal route selection at mobile gateways. A performance evaluation on policy based routing is also conducted. Concluding observations are gathered in the final section.

II. Network Mobility and Mobile Ad-hoc Network

From the view of vehicle networks, we take a position that it is necessary to apply the network mobility support (i.e., the Network Mobility in IETF [4]) to entire in-vehicle networks in moving vehicles because only a representative mobile router needs to be mobility-aware; other individual nodes function without requiring mobility-aware functionality. Nevertheless, all in-vehicle nodes can be accessible from the Internet anywhere, anytime.

In addition, MANET is also key to establish wireless multihop networks among vehicles. Some recent work has focused on integrating MANET and the IPv6 Internet [6], [14]. However, the emphasis has been on nodes moving between mobile ad-hoc networks and the Internet with Mobile IPv6 [5] to conceal their movements.

A. Network Mobility

Network Mobility (NEMO) [4] is a technology to provide movement transparency to mobile networks. NEMO can be used to assign a permanent network prefix for in-vehicle network. NEMO is a Mobile IPv6 [5] extensions to bind a permanent prefix (called mobile network prefix) and a care-of address which a node acquires at a visiting network. Even if an automobile moves and changes its network attachment, the network in the automobile is always reachable with the same network address all the time.

Figure 1 shows configurations and operations of the NEMO basic support protocol [4]. A mobile router carries a mobile network prefix that is assigned to each vehicle. The mobile router has two network interfaces which is attached to the Internet (egress interface) and to the mobile network (ingress interface). The mobile router acquires a care-of address at the egress interface as same as Mobile IPv6. To register a binding of the mobile network prefix to the care of address , the mobile router

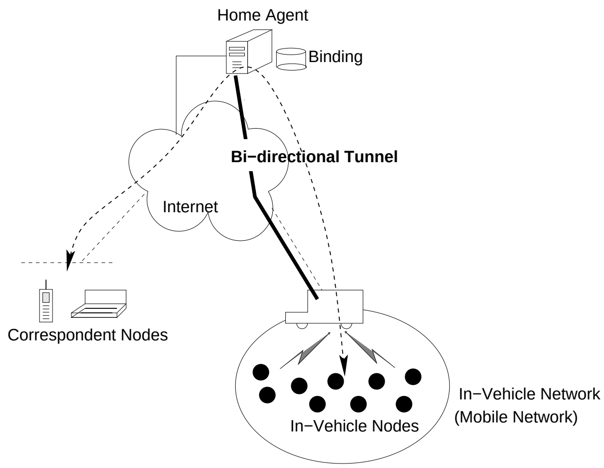

Fig. 1. The NEMO Basic Support Protocol

needs to notify its mobile network prefixe to the home agent with a mobile network prefix sub-option defined in the NEMO basic support protocol. Once the mobile router registers its binding, it establishes a bi-directional tunnel with the home agent. The NEMO basic support protocol does not support route optimization. Thus communication with a mobile network in vehicle is always through a home agent.

B. Mobile Ad-hoc Network

A Mobile Ad-hoc Network (MANET) is another key technology for vehicle networks. MANET is created dynamically when a set of nodes form a mesh routing state for their connectivity management, typically over a wireless multihop network. Even when a network topology is changed due to vehicle's movements, MANET routing protocols detect the topology changes and can recover connectivities by updating route information periodically. Many routing protocols are proposed for MANET. These protocols aim to maintain localized routing at individual nodes despite movement of intermediate nodes that causes the routing path to change. Ad-hoc On-demand Distance Vector (AODV) [12] and Optimized Link State Routing Protocol (OLSR) [2], etc. are standardized at the MANET working group. OLSR is a link state routing protocol and exchanges route information periodically among nodes inside a mobile ad-hoc network. It has an optimized flooding mechanism called Multi Point Relay (MPR) [7]. To disseminate route information, each node needs to flood route information to a network. However this flooding causes high overhead to a wireless network. Therefore, MPR provides efficient mechanism not to flood duplicated packets.

An internet gateway [14] provides global connectivity to a mobile ad-hoc network. The internet gateway is a fixed gateway attached to both the Internet and a mobile ad-hoc network. It supplies global prefix information and IPv6 global address to a mobile ad-hoc network. The internet gateway advertises prefix information and a route to the Internet. The prefix distributed by the internet gateway can be used for configuring a (topologically global) routable IPv6 [3] address for each MANET node.

III. Mobile Gateway

A. Overview

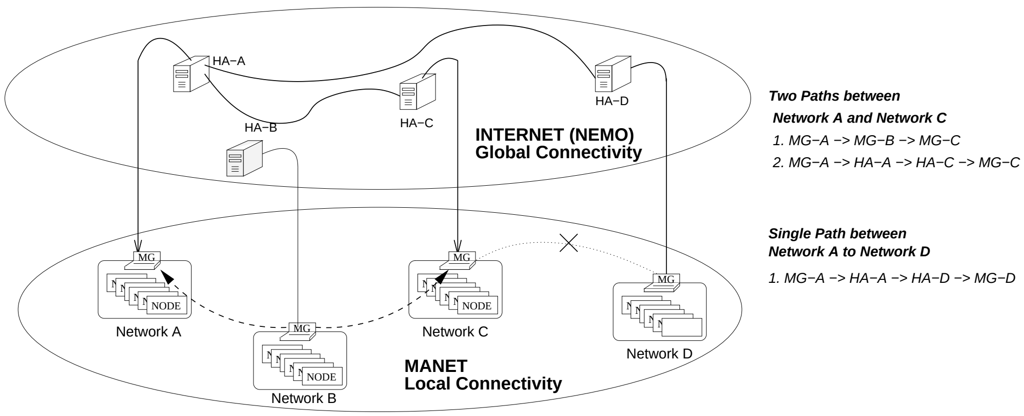

Fig. 2. Overview of Mobile Gateways

We have introduced *mobile gateways* that provide enhanced routing in addition to the mobile router support specified in the NEMO basic support protocol. This enhanced routing provides efficient vehicle-vehicle and vehicle-road communication. This contribution provides crucial routing necessary in connecting vehicles to the Internet. A mobile gateway is a nominated router from an in-vehicle nodes and is responsible for mobility and always-on Internet connectivity. The main functions of a mobile gateway are a roll of a Mobile Router of the NEMO basic support protocol and a roll of MANET Router of a MANET routing protocol.

The mobile gateway in a vehicle equips with various interfaces such as wireless WAN (ex. cellular), wireless MAN (ex. 802.16e), wireless LAN (ex. 802.11b) and MANET interface (ex. 802.11b ad-hoc mode). The mobile gateway also has an interface to connect to its in-vehicle network. All these interfaces of the mobile gateway should be configured with different radio channels and radio frequency so that packets sent by each interface does not interfere with one another.

Each mobile gateway assignes a mobile network prefix to its in-vehicle network. All nodes inside the vehicle must use the permanent address generated from the mobile network prefix for all communications. All traffic sent from the in-vehicle network to remote networks are always intercepted and routed by the mobile gateway, because the mobile gateway is a default router of all nodes inside vehicle network.

B. Multiplexed Path toward a Destination

When an in-vehicle node starts to communicate to a destination node, there are several route paths towards the destination node. Figure 2 summarizes possible paths between an in-vehicle node and a destination. The first path is used when a mobile gateway routes packets to the Internet through its bidirectional tunnel by using one of wireless WAN, MAN, LAN interfaces. The second path has MANET paths between an internet gateway and a mobile gateway. However, the mobile gateway must encapsulates all packets to the home agent. It has to route encapsulated packets to the internet gateway first and the internet gateway routes packets to the Internet (via Home Agent). This path can be utilized when the first path is not established due to out of wireless coverage areas. The third path is directly connected between end nodes over a mobile ad-hoc network. Since a mobile gateway has a prefix route of a vehicle to which a destination node is belong, it can route packets according to the prefix route without packet encapsulation. The mobile gateway can bypass its Home Agent even if the packets' source address is generated from the mobile network prefix.

The mobile gateway acquires a care-of address at an interface attached to the Internet. It then registers the care-of address to its home agent. The mobile gateway is assumed to maintain a bi-directional tunnel between the mobile gateway and the home agent all the time by using wireless WAN or MAN interface as shown in Figure 2 (denoted as path2). It may switch the interface for the Internet connectivity according to coverage of each wireless technology.

In addition, the mobile gateway run a MANET routing protocol at a MANET interface all the time so that it can acquire routes of adjacent vehicles (denoted as path1 in Figure 2). The mobile gateway exchanges only a route of a permanent prefix assigned to its in-vehicle network by a MANET routing protocol. These network route exchange are preferable in terms of route aggregatation to reduce number of routes which each vehicle manages by a MANET routing protocol. If there is an internet gateway at road sides or traffic lights , the vehicle may use the internet gateway to access to the Internet (path3 in Figure 2. In this case, the mobile gateway must use the NEMO basic support protocol to reach to a destination node. Otherwise, the packets may be rejected at the internet gateway due to ingress filtering.

C. Policy Based Routing

As described in Section III-B, a mobile gateway has various routes to deliver packets to a destination node. The mobile gateway has to determine which routes are appropriate for outgoing traffic from its in-vehicle network. The decision is made with preference information and three parameters such as bandwidth, round trip time, and hop count.

These parameters are measured during communications and route exchanges of a MANET routing protocol. The bandwidth parameter is not need to be so precise, but we use estimated bandwidth value. For example, CDMA2000 1x EvDo has 2.4Mbits/sec bandwidth in specification, but actual speed is 700K-bits/sec when we measured average bandwidth with a real NEMO basic support protocol implementation. Therefore, a mobile gateway set EvDo bandwidth as 700K-bits/sec. On the other hand, the bandwidth of a MANET path is estimated according to a link distance of a MANET path between end nodes. Each vehicle is reasonably assumed to have Global Position System (GPS) and exchange link distance information by a MANET routing protocol. If there is a link with very large distance between two vehicles, the bandwidth can be assumed to be low. Since bandwidth can not be measured in real time due to the measurement overhead, we take a position that such an estimation is reasonable for the decision. The hop count parameter is acquired by a MANET routing protocol. Most of MANET routing protocols provides the hop count for a destination to a mobile gateway.

Preference information is also introduced to prioritize the path selection depending on parameters. The information contains information of a required network of each application like delay sensitive network and stability network, etc. Preference information is sent to a destination in order to decide which path is used for vehicle-vehicle communication at the destination vehicle. It is preferable that a destination vehicle follows the same decision of the source mobile gateway.

IV. Advantages of Mobile Gateway

A mobile gateway is a simple solution but it comes with plenty of advantages for vehicle's network listed below.

- Address assignment

  A mobile gateway employees NEMO basic support protocol and acquires a mobile network prefix for its network. By using the NEMO basic support protocol, each vehicle will have a permanent network prefix for the vehicle's network. In a mobile ad-hoc network, address assignments on a mobile ad-hoc network is complicated due to no center authority to assign address and no efficient mechanism to verify address uniqueness in a mobile ad-hoc network. Therefore, a mobile gateway solves the address configuration problem of a mobile ad-hoc network in terms of permanent prefix assignment of the NEMO basic support protocol.

- Efficient communication

  When a vehicle only uses the NEMO basic support protocol, all packets are transmitted and received through a bi-directional tunnel established between a mobile router and a home agent. This becomes network bottleneck in terms of network delay and network bandwidth. On the other hand, if a vehicle only supports a MANET routing protocol, it has to transmits packets to a wireless multihop path even if the path quality become worse due to less stability and large hop counts. A mobile gateway in a vehicle enables to change the path to a destination depending on the vehicle's network environment and user's preference. It can even selects an appropriate path per flow or applications and uses multiple paths at the same time.

- Fault tolerance

  Since a vehicle is moving, network environment varies quickly. Thus, communication may stop due to out of coverage area. However, a mobile gateway always maintains multiple path to the Internet and a destination. The mobile gateway detects the path break and can re-select an alternative active path for the failed path.

- Always-on Internet connectivity

  A mobile gateway is capable to handle multiple network interfaces and multiple path to the Internet. Not only wireless WAN, MAN and LAN, but also internet gateways can be used to access to the Internet. Even if one of network interface becomes out of coverage, a mobile gateway always has alternative path to the Internet. Since many applications assume always-on Internet connectivity, this feature is necessary for vehicle's network.

- Scalability

  A mobile gateway always exchanges network routes of its mobile network prefix with other vehicles by a MANET routing protocol. This route aggregation leads scalability when a number of vehicles run on a same road and exchange routes. Without a mobile gateway, all the nodes inside a vehicle needs to exchange host route with devices of other vehicles. If hundreds of devices are installed in each vehicle, the number of routes that each vehicle manages will explode. It is clearly not efficient technique for vehicle's network.

V. Related work

There are several existing solutions to provide Internet connectivity to the MANET (e.g., [10], [13]) and to integrate Mobile IPv4 [11] and Mobile IPv6 [5] and an ad-hoc network (e.g., [1], [6], [8], [9], [14]). A DSR-based MANET is connected to the Internet with Mobile IPv6 in [9]. MIPMANET [6] integrates Mobile IPv4 and AODV utilizing *Foreign Agents* to support mobile nodes in a mobile ad-hoc network. Although Mobile IP can be integrated in our system, we focus on network mobility and not on host mobility. The approach in [14] proposes to use an Internet Gateway to connect a MANET to the Internet, by extending MANET messages for Gateway discovery and route establishment. Here, we integrate MANET routing with a mobile router for best Internet connectivity.

VI. Implementations

We have implemented the human transporter with the mobile gateway functionality. WIDE project has been developing the NEMO Basic Support protocol and OLSR manet routing protocol on BSD operating system.

A. OLSR supporting Global Connectivity

We have implemented IPv6 based OLSR and Global Connectivity on the GNU zebra 0.95-pre2 which is a routing protocol package. The GNU zebra is designed to be independent from operating systems and can run on Linux, FreeBSD, NetBSD, and MAC OS X. The OLSR implementation supports all the fundamental functions of OLSR such as HELLO message exchanges and the routing message flooding. In addition to those functions, it supports the global connectivity management that is internet gateway discovery and IP address acquisition. A manet node running this OLSR implementation can access to the Internet if an internet gateway is available nearby.

We modified the specification for IPv6 support because the RFC3626 does not define the OLSR specification for IPv6. The first modification is the use of all node multicast address (ff02::1) for message flooding. The second point is the modification of Host and Network Association (HNA) message in order to deliver IPv6 address. The original HNA message has fields for Network address and Subnetwork mask of IPv4 address, but IPv6 does not require these fields. Thus, the HNA message is redefined to have Network Prefix and Prefix length as shown in Figure3.

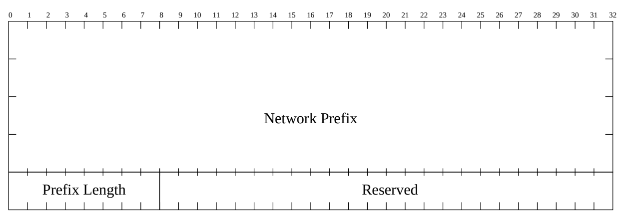

Fig. 3. HNA Message for IPv6

In this research, we defined a new OLSR message named RA message to configure global routable addresses to OLSR routers. The TLV format for OLSRv2 described in [14] is modified as an OLSRv1 message format shown in Figure 4. The message number 5 is used for this OLSRv1 message.

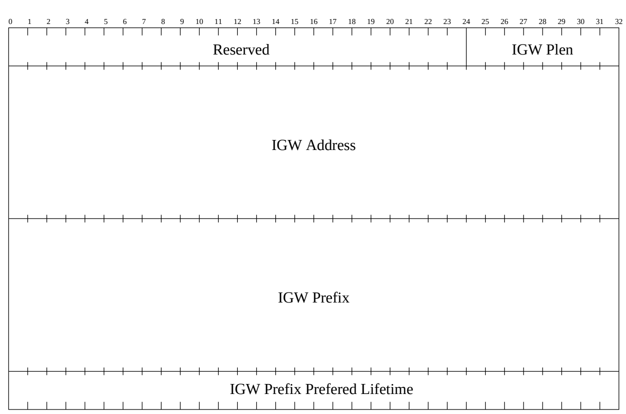

Fig. 4. Internet Gateway Advertisement Message Format

The routers which are configured as Internet gateways advertise RA messages on all network interfaces configured to send

RA messages. Routers generate global routable prefixes from the global address of the network interface and store it into the IGW Prefix field of the RA message. The IGW Plen field stores the prefix length of the advertised network prefix. The IGW Address is for the Internet gateway's routable address in the network. The IGW Prefix Preferred Lifetime field indicates the valid lifetime of the advertised prefix. The RA messages interval is 5 seconds by default.

When receives RA messages, Manet nodes generate global addresses from the advertised global prefixes and EUI-64 Interface ID generated from MAC addresses of received network interfaces. The next hop node address for the Internet gateway is configured as the default route.

B. NEMO Basic Support

WIDE project has been implementing Mobile IPv6 and the NEMO Basic Support protocol called SHISA on BSD based UNIX systems such as FreeBSD, NetBSD. The SHISA software is released as an open source programs and widely used at both industry and academic areas. It contains kernel extensions and program daemons for all functionalities of Mobile Node, Mobile Router, Correspondent Node, and Home Agent.

Each mobile router carries a mobile network prefix by the NEMO basic support and also advertises the prefix by the OLSR program. All the traffic carried by the NEMO is tunneled to the Home Agent by IP-in-IP encapsulation.

C. Applications: message distribution

As an application used on a networked transporter, we implemented a flooding based messenger system. The flooding messenger is designed as one-to-one communication tool. This tool is run on WEB browser. The user interface of flooding messenger is shown in Fig 5. All the messages are displayed with random move on the browser. In addition to this gimmick, newly received messages are displayed with the bigger font size and old messages are with smaller. Therefore, a user can know which message is fresh based on the font size.

This messenger consists of an input module and an output module. The input module requires a CGI script and http daemon to work on each client node. They are used for sending messages to other mobile nodes, which are equipped on Network Transportors. For sending messages, accessingf local CGI script with users' browsers and filling some forms are required. Output module requires a message daemon(msgd) to output received messages for small web format(swf) which is accessed by browsers and for displaying dynamic page on users' browser.

VII. Segway Network

In this research, we construct a mobile network on Segways. Figure 6 shows the overview of the segway network. On each Segway, there is a network that has a /64 address block includes three computers. Two of the three computers are called

Fig. 5. User Interface of Flooding Messenger

mobile network nodes which are located inside of the mobile network. PDA is one mobile network node as a user application equipments for the music streaming service and the voice communication with other segway user equipments. Another mobile network node is an IPv6 camera that provides segway driving video streaming. To provide network reachabilities for the two mobile network nodes, a PC router called ”mobile gateway” is mounted on the segway. OLSR daemon is running on the mobile gateway to announce the mobile network prefix to the MANET using HNA messages. On two mobile nodes, a PDA and an IPv6 camera, the link-local address of the mobile gateway is configured as the default route, and they communicate with other mobile network nodes on other segways via the mobile gateway.

Figure 7, 8, 9, 10 show the equipments installed on Segways. A laptop PC on which BSD system is installed works as a mobile gateway. A PDA is mounted near the handle so that users can easily operate it. These two devices have own batteries and it is not necessary to equip additional power supply devices. An IPv6 camera is set on the front section of the Segway so that it can provide driving video streaming of the Segway. Since no build-in battery system is available on IPv6 cameras, an external DC 12V battery is set on the Segway.

VIII. Experimental Evaluation

We installed a mobile gateway running SHISA and OLSR programs on two segways. Since an internet-gateway was prepared on the roadside, all the segways can access to the Internet through the internet-gateway. The experimental environment is shown in Figure 11.

Our test environment consists of two different networks, the Internet and the ad-hoc network. There is a client PC with a global address 2001:200:10::2 on the internet side, and there are three OLSR routers on the ad-hoc networks, i.e two mobile

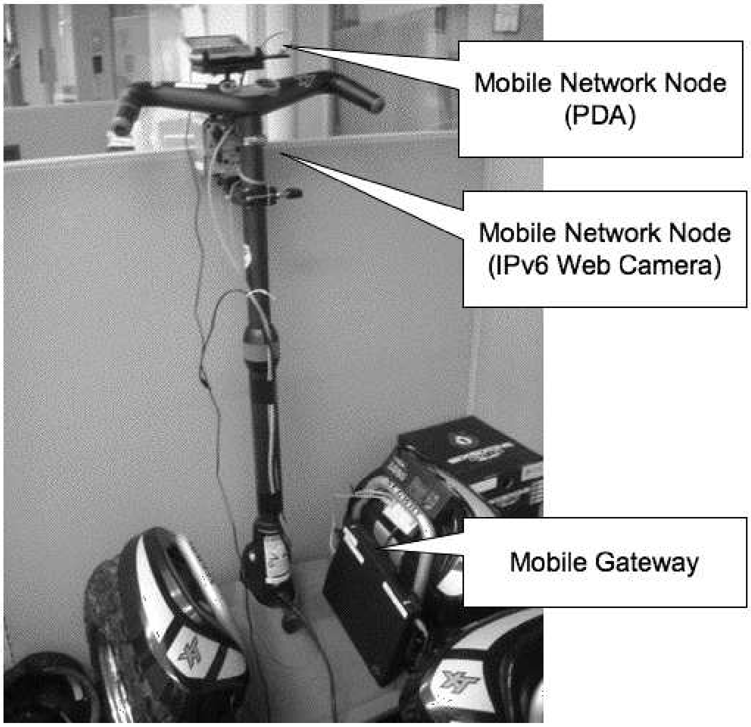

Fig. 6. Segway Network Overview

gateways and one Internet gateway. Each OLSR routers have one pre-configured site local scope address from the prefix fec0::/64, and mobile gateways receive a router advertisement from the Internet Gateway. When Mobile gateways get the router advertisement, they set the default routes to the next hop for the Internet gateway. On Segway A, there is a network with a prefix 2001:200:1::/64 which includes a PDA with a global address 2001:200:1::2. Through the experiment, we unilized the default OLSR configurtion except for the hello interval value set to 1 second.

TABLE I
EQUIPMENTS ON SEGWAY

CPU	OS	Memory	Wireless device
CoreDuo 1.66Ghz	FreeBSD5.5	1GB	Melco inc. WLI-PCM-L11GP
CoreDuo 1.40Ghz	NetBSD6.1	640MB	Melco inc. WLI-PCM-L11GP
PentiumIII 1.06Ghz	NetBSD2.0	640MB	Intersim Prism 2.5 Melco inc. WLI-PCM-L11
XScale 416Mhz	OpenBSD3.9	64MB	-

The equipments on each segway are listed in Table I. The IBM ThinkPAD is basically mounted on each segway. The access router is also IBM ThinkPAD with Intel Pentium M 1.4 Ghz CPU and 256M memory. The internet gateway is connected to

Fig. 7. Mobile Gateway

Fig. 8. PDA

Fig. 9. IPv6 Camera

Fig. 10. 12V Battery for IPv6 camera

both the ad-hoc network by the 802.11b and the Internet by wired 100Mbps link.

We measured RTT values from the PDA on Segway A network to the PC on the Internet with ICMP. We utilized ping6 program to send ICMP packets. The ICMP packets are forwarded to the mobile gateway from the PDA, and when the mobile gateway lost the route to the Internet gateway, it causes the packet losses.

First, packets from the PDA is forwarded to the mobile gateway on the Segway A, and then to the PC on the Internet through the mobile gateway on the Segway B and the Internet gateway. Then Segways moved toward the Internet gateway keeping the distance to each other. During the movement, the connection via Segway B switched to the direct connection of Segway A and the Internet gateway.

The figure 12 shows the graph of RTT through this experiment. The first seven packets to the PC was forwarded by the mobile gateway on Segway B except for one dropped packet, thus the hopcount for the destination from the PDA is 4. Then

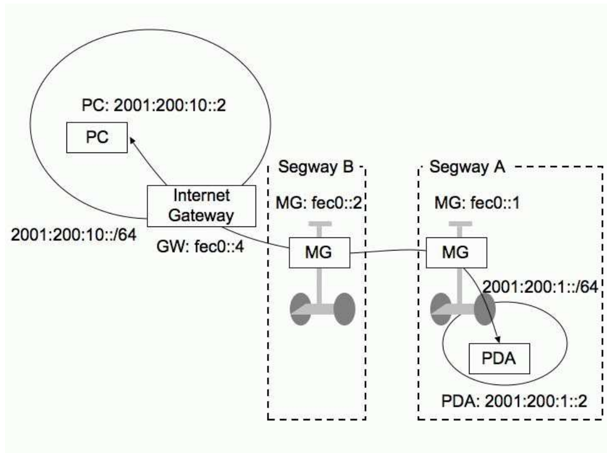

Fig. 11. Experimental Environment

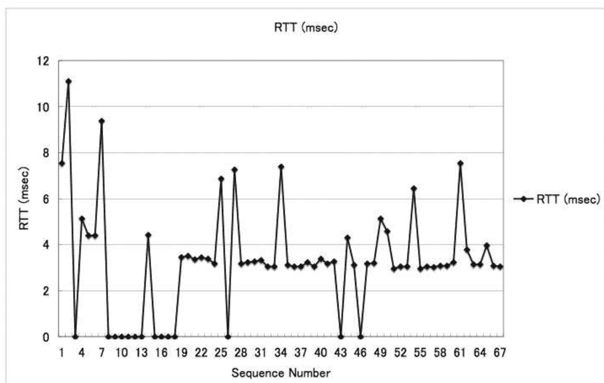

Fig. 12. Result

the connection kept 4 hops after lost six packets. After the second packet drop period, the mobile gateway on Segway A was directly connected to the Internet gateway until the connection between Segway A and the Internet gateway had lost.

There are two causes for the packet losses during the toplogy change. The first one is the lost of the routes because of the outage from the wireless coverage, and second one is concerned with the Neighbor Cache with asymmetric links. In case there are asymmetric links, the node which receives Neighbor Solicitation packets from the other node creates a neighbor cache entry even when the routing protocol decides that the route for the destination is 2 hops. BSD systems transfer data packets according to the neighbor cache with unavailable links rather than available routes in the routing table, and it causes the packet losses. Some architecture to configure the preference between the neighbor cache and the routing table is necessary.

IX. Conclusion

In this paper, we show how to coordinate vehicle network environment for vehicle to vehicle communication by using gateways and a MANET routing protocol. Three essential issues are addressed with the assumption that the number of vehicles will become high in some scenarios. These are limited route connectivity and flooding overhead, lack of session continuity and lastly lack of scalability. The warp network established by gateways is proposed to support the efficient management of vehicle networks. As our future work, we will evaluate our system and conduct some experimental work with real vehicle networks.

References

[1] M. Benzaid, P. Minet, and K. Al Agha. A framework for integrating Mobile-IP and OLSR ad-hoc networking for future wireless mobile systems. In *Proceedings of the 1st Mediterranean Ad-Hoc Networks workshop (Med-Hoc-Net)*, September 2002.

[2] T. Clausen and P. Jacquet. Optimized Link State Routing Protocol OLSR. Request for Comments (Experimental) 3561, Internet Engineering Task Force, October 2003.

[3] S. Deering and R. Hinden. Internet Protocol, Version 6 (ipv6) Specification. Request for Comments (Proposed Standard) 1883, Internet Engineering Task Force, December 1995.

[4] V. Devaraplli, R. Wakikawa, A. Petrescu, and P. Thubert. Network Mobility (NEMO) Basic Support Protocol (proposed standard). Request for Comments 3963, Internet Engineering Task Force, January 2005.

[5] D. Johnson, C. Perkins, and J. Arkko. Mobility support in IPv6. Request for Comments (Proposed Standard) 3775, Internet Engineering Task Force, June 2004.

[6] U. Johnsson, F. Alriksson, T. Larsson, P. Johannson, and G. Maquire Jr. MIPMANET - Mobile Ip for Mobile Ad hoc Networks. In *Proceedings of First Annual Workshop on Mobile Ad Hoc Networking and Computing (Mobihoc)*, August 2000.

[7] A. Laouiti, A. Qayyum, and L. Viennot. Multipoint Relaying: An Efficient Technique for Flooding in Mobile Wireless Networks. In *Proceedings of the 35th Annual Hawaii International Conference on System Sciences (HICSS'2002)*, 2002.

[8] H. Lei and C. E. Perkins. Ad Hoc Networking with Mobile IP. In *Proceedings of 2nd European Personal Mobile Communication Conference*, September 1997.

[9] D. A. Maltz, J. Broch, and D. B. Johnson. Quantitative Lessons From a Full-Scale Multi-Hop Wireless Ad Hoc Network Testbed. In *Proceedings of the IEEE Wireless Communications and Networking Conference*, September 2000.

[10] G. Cirincione M.S. Corson, J.P. Macker. Internet-based mobile ad hoc networking. In *IEEE Internet Computing, Vol.3, No. 4*, pages 63–70, Jul 1999.

[11] C. Perkins. IP Mobility Support. Request for Comments (Proposed Standard) 2002, Internet Engineering Task Force, October 1996.

[12] C. Perkins, E. Belding-Royer, and S. Das. Ad hoc On-Demand Distance Vector (AODV) Routing. Request for Comments (Experimental) 3561, Internet Engineering Task Force, July 2003.

[13] A. Striegel, R. Ramanujan, and J. Bonney. A protocol independent internet gateway for ad-hoc wireless networks. In *Proceedings of Local Computer Networks (LCN 2001)*, Tampa, Florida, Nov 2001.

[14] R. Wakikawa, J. Malinen, C. Perkins, A. Nilsson, and A. Tuominen. Global Connectivity for IPv6 Mobile Ad Hoc Networks (work in progress, draft-wakikawa-manet-globalv6-05). Internet Draft, Internet Engineering Task Force, March 2005.