Demonstration System supporting Host and Network Mobility

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1 Introduction

Intelligent Transportation Systems (ITS) is comprised of a number of technologies such as information processing, communications, control, and electronics. By applying these technologies to our transportation system, ITS promotes the advanced automobile navigation technology, safe driving, and tolling system such as the Electronic Toll Collection System (ETC). ITS is assumed to be deployed all over the world. Therefore, ITS needs a common communication infrastructure. The Internet is one of the communication infrastructure deployed all over the world. We have been working on ITS on the Internet named "Internet ITS" since 1996 [2]. The particulars about the advantages of the Internet are shown at papers[1] and [4].

When an automobile attaches to the Internet, it is necessary to make use of mobility supports. While communicating actively, any nodes can not move around on the Internet without mobility supports. Therefore, a number of mobility protocols are proposed and standardized at the Internet Engineer Task Force (IETF). We have been researching how to apply these mobility protocols to the common communication infrastructure for automobiles. As the consequence of these researches, we demonstrated an example of the mobile network system for automobiles at the "The Workshop for Internet and Automobile". This workshop was held in KEIO University at March 12th, 2003. and was coordinated by WIDE project, the Internet ITS project and Association of Electronic Technology for Automobile Traffic and Driving (JSK).

In this paper, we first describe the expected mobile Internet environment and scenarios of our demonstration. Then, we show detailed network configurations of this demonstration system at Section 4. We explain experiments on the demonstration system and show results. Finally we give conclusion of this demonstration.

2 ITS meets the Mobile Internet

2.1 The Mobile Internet

Mobile devices are expected to promise an integral part of the future Internet due to a rapidly growing number of mobile devices with high computer resources. These mobile devices including automobiles need a certain mobility support to move in the Internet. Although several mobility protocols have been proposed and almost been standardized, each mobility protocols has different features. There are two types of mobility protocols: Host mobility and Network mobility. Host mobility is for a mobile host to hide movements of the mobile host from the Internet. Mobile IPv6 [3] is designed to support this host mobility and almost standardized at IETF. Network Mobility (NEMO) protocol conceals movements for a network which moves entirely. NEMO has been discussing at the NEMO working group at IETF. Although several solutions for NEMO are proposed at IETF, we use our original solution [5] for this demonstration system.

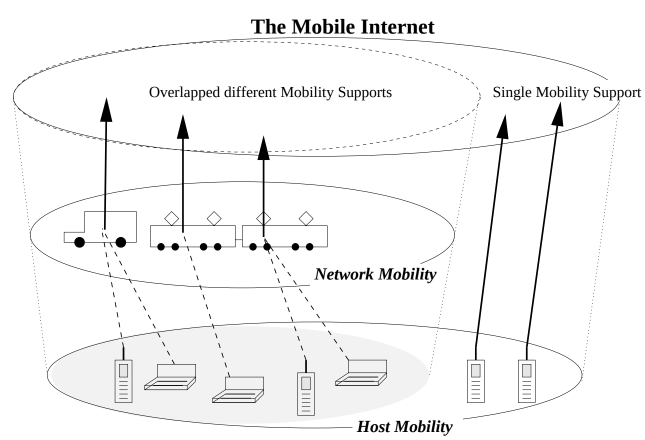

Figure 1: Overlapped Mobility Supports

The relationship between these mobility supports are illustrated on the Mobile Internet in Figure 1. The mobile Internet is comprised of two mobility layers: the network mobility and the host mobility layer. A mobile host accesses to the mobile Internet through either a mobility layer or multiple mobility layers. The network mobility layer is expected to employ for automobiles, trains, any kinds of vehicles. Each vehicles connects to the Internet with the network mobility support. On the other hand, the host mobility layer is used for mobile phones, sensor devices, handhelds devices, and so on. Most of these mobile devices connect to the Internet with a host mobility support, but some of the devices may access to the Internet through the network mobility layer. For example, a passenger brings her/his Mobile IPv6 capable mobile phone to a train supporting network mobility. It is precise to happen that different mobility support layers are overlapped each other. Thus, it is necessary to consider coordination of different mobility layers. Once an automobile becomes an Internet available spot, it can say that ITS obtains a common communication infrastructure. In conjunction with the deployment of ITS, the Internet also gets larger coverage areas by means of Internet capable automobiles.

2.2 Demonstration Scenarios

This section explains assumed scenarios of the demonstration. The main goal of this demonstration is to show that automobiles can be connected to the Internet permanently and can become a network available spot for mobile hosts. At this demonstration, we showed coordination of protocols for automobile's network mobility and mobile devices' host mobility. We also gave demonstration of interface switching systems.

Automobiles are connected to the Internet with network mobility support. All devices attached to automobiles such as build-in devices and visiting devices are connected to the Internet with network mobility support. In addition, automobiles switch their network interfaces depending on network environments. For example, when network connectivity is cut off due to out of a network service range, automobiles switch to an active network interface. This enables automobiles to connect to the Internet permanently. All hosts attached to automobiles can also acquire permanent Internet connectivity. On the other hand, each driver or passengers has their mobile devices such as a mobile phone and a laptop computer. These devices are connected to the Internet with host mobility support. Therefore, the devices can moves in the Internet without notice of their movements. When the devices are on the automobiles, they are connected to a network laid in automobiles.

These scenario is one example of the mobile Internet. As described in Section 2., automobiles are treated as a mobile devices moving around the mobile Internet and a service area to provide network connectivity to the mobile Internet.

3 Network Configurations

Figure 2. is the network configuration of the demonstration system. Each digit prefix in the figure is omitted the upper prefix value such as “3ffe:501:100c”. (eg. b240::/64 indicates 3ffe:501:100c:b240:: with prefix length 64.) Both Demo-Network and Lab-Network were managed by Fast-Ethernet. We needed to prepare IPv6 network at Demo-Network, because Demo-Network was not IPv6 ready. Hence, IPv4-IPv6 tunneling was used to lay IPv6 network from Lab-Network. Demo-Network and Lab-Network were connected by Gigabit-Ethernet.

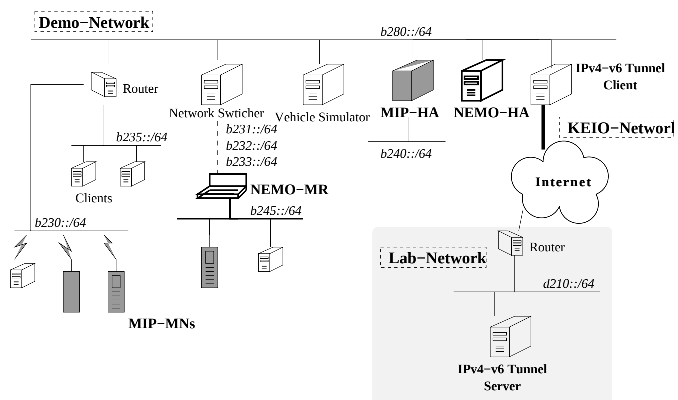

Figure 2: The Demonstration Network Overview

Mobile IPv6 Configuration

A Home Agent (MIP-HA) was configured at Demo-Network to run Mobile IPv6 on the demonstration system. MIP-HA was assigned 3ffe:501:100c:b240::/64 network prefix as a home prefix of Mobile Nodes (MNs). All the MNs had a home address generated by the home prefix. The MNs register their bindings to MIP-HA whenever they move to foreign networks which are 3ffe:501:100c:b245, b235, b230::/64 network and the home network.

Mobile Network Configuration

A Home Agent (NEMO-HA) was set up at Demo-Network as well as MIP-HA. NEMO-HA was configured as a default router of the mobile network prefix (3ffe:501:100c:b245::/64). A Mobile Router (MR) configured its mobile network prefix to an ingress interface and sent router advertisements to the ingress interface. MR was changed its attaching point to the Internet automatically by network switcher described in Section 4.4.

4 Experiments

4.1 Nested Mobility

Nested Mobility is known as the situation when there are more than one level of mobility supports as described in Section 2. There are two cases for nested mobility. The first situation is when a MN attaches to a mobile network. The other situation is when a MR attaches to another mobile network. At this demonstration, we demonstrated the first situation. MNs were possible to attach to the mobile network and acquired a care-of address. The MN could operate registering the binding according to Mobile IPv6 without any changes.

Figure 3. is the screen dump of a client program which dumps the binding cache database on MIP-HA. The Home address field displays a home address of each MNs, and the CoA field displays a care-of address. The Lifetime field and the Seq field shows the lifetime and the sequence number value of each binding entries. The Flags fields indicates the flags set in a binding update. 'A-flag' means Acknowledge flag and 'H-flag' means home registration. If a MN is located at a mobile network, the entry is emphasized with a different color.

The nested mobility was completely succeeded to operate on the demonstration network. A MN could visit a mobile network and keep connections open even at the mobile network, because our NEMO protocol is designed to cooperate with Mobile IPv6. During being at the mobile network, the MN was unaware of the automobile's movements because MR concealed the movements from the MN.

4.2 Multiple Network Interfaces Support

Multiple network interfaces support is requisite for mobile hosts and routers, because there is no network access services covered all over the world. Therefore, mobile nodes/routers must change the network access interface depending on network environments. For example at our demonstration, MNs had two network interfaces such as IEEE 802.11b and 802.3. MNs could switch the available network interface connecting to the Internet as occasion demands. When MNs were attached to the mobile network, they selected the IEEE 802.3 network interface. At any other place, they used the IEEE 802.11b network interface to keep the Internet connectivity. As a result, the MNs could switch network interfaces triggered by in and out of the mobile network. The more advantages of multiple network interfaces support can be found at [6]. As a result, the MNs can keep Internet connectivity all the time by means of switching network interfaces.

4.3 Sensor Nodes running Mobile IPv6 as Application

Sensor nodes were used to collect automobile information. A Mobile IPv6 implementation was ported to these sensor nodes. The Mobile IPv6 implementation has been implemented by us at KEIO university since 2000. Once sensor nodes have Mobile IPv6 functionalities, it can be addressed by unique identification (i.e. home address) regardless of their location. Thus, installation of Mobile IPv6 to sensor devices reduces a number of configuration changes caused by their movements. This is big advantage for embedded devices, because a user could place these sensor devices without any network configurations.

We prepared 3 Mobile IPv6 capable embedded devices as sensor nodes placed in a vehicle's network. These sensors were remotely controlled by UDP packets. Correspondent nodes accessed the sensor nodes, processed information, and expressed the information as graphic charts.

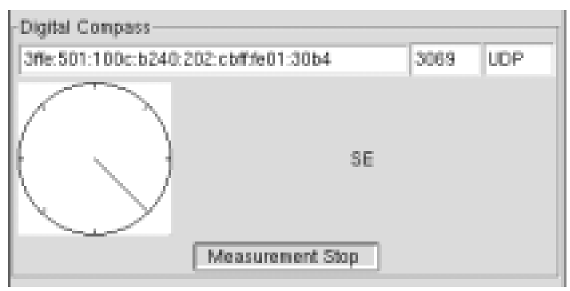

Figure 4: Screen Dump of Digital Compass at Correspondent Node

The first sensor had functionality to sense vehicle direction. The information was sensed by Digital Compass (*G*eosensory RDCM-802). Figure 4 is the screen dump of this sensor information. The address in the figure is the home address of this sensor node. The sensed information was expressed as the compass image. Whenever the sensor detects direction changes, the pointer of the compass always tracks the current direction. The second sensor could sense status of accelerator and brake. These information was sensed by 2-Axis Accelerometer (*A*nalog

```
  Home Address          /           CoA          / life / seq /flags
=========================================================================
3ffe:501:100c:b240::1    /    3ffe:501:100c:b230::1    / 1200 / 112 / AH
3ffe:501:100c:b240::1    /    3ffe:501:100c:b245::1    / 1122 /  20 / AH  <- Nested Mobility
...
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Figure 3: Screen Dump of Mobile IPv6 Binding Cache

Devices ADXL202JE). The third sensor measured temperature of a car and a driver system. We used a Thermometer sensor (National Semiconductor LM35DZ). All the sensed information is accessed by Mobile IPv6 and displayed at client programs at correspondent nodes.

4.4 Network Switcher and Simulator

In demonstrating the movement of the network, a vehicle simulator and a network switcher were prepared. The vehicle simulator simulates vehicles movements and sends a UDP packet containing vehicle id, speed, moving direction, and location information in longitude and latitude per second to the network switcher.

A map was divided into small cells to simulate vehicles moving across different networks. Each cell size was defined using longitude and latitude information binded to the map to pseudoly create ranges of the each cells. Each cell size was defined with respect to each vehicles speed in the simulator so that the vehicle would move from a cell to another within a preferable time in showing the demonstration. Each cells was assigned a different IPv6 network prefix. The MR attached to the network switcher would receive a Router Advertisement with a different prefix for each cell.

When the network switcher detects the vehicle moving out from the previous cell based on the location information received from the simulator, it would start sending a different Router Advertisement with the new prefix. Since the MR receives a different prefix, it detects the movement of the vehicle in the simulator and starts movement process.

5 Conclusion

This paper discuss the demonstration system given at the workshop for Internet and Automobile. The demonstration was build with Mobile IPv6, the NEMO protocol, and simulators. All the mobility protocols were working predictably through the demonstrations network tested with implementations. The demonstration also shows possibility of the mobile Internet and gives reality to it, since the Internet capable automobile is treated as just an application of mobile computing.

At this demonstration, we only treated Mobile IPv6 and the NEMO protocol, but there are still many technologies for the mobile Internet. We keep researching on the mobile Internet technologies and will give same kinds of demonstration to show their possibilities.

6 Acknowledgments

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