Problems and Tentative solutions in InternetCAR testing with IPv6

Keisuke UEHARA
Keio University
Graduate school of Media and Governance
5322 Endo Fujisawa
Kanagawa 252-8520 JAPAN
kei@wide.ad.jp

Hideki SUNAHARA
NARA Institute of Science and Technology
Information Technology Center
8916-5 Takayama Ikoma
Nara 630-0192 JAPAN
suna@wide.ad.jp

Jun MURAI
Keio University
Faculty of Environmental Information
5322 Endo Fujisawa
Kanagawa 252-8520 JAPAN
jun@wide.ad.jp

Abstract

Vehicle environment is a good testbed to investigate Internet mobility technologies. Based on testing of building, protocol implementation details and problems to deploy it will be clarified. This paper describes them.

InternetCAR Project had already done a testing to connect vehicles to the IPv6 Internet. Some applications includes vehicle diagnosis and teleconference, are implemented on the test system. The test system has following functions: 1) several communication media with a media switching technology, 2) MobileIPv6 function for continuous connectivity, and 3) network mobility (NEMO) [1][2] function to provide continuous Internet connectivity for an in-vehicle network.

This paper introduces problems to develop InternetCAR testing system. Our design and solutions also described.

1 Introduction and Background

At the time of the coming IPv6 era, not only computers but also many kind of appliances will be connected to the Internet. Vehicles should also be connected to the network. Networked vehicle research area referred to *telematics* is growing up rapidly. The Japanese vehicle industries shifted their telematics services to second generation in 2002. Toyota announced a new service called "G-BOOK[10]", Nissan announced "CarWings[9]" and Honda announced "Inter-Navi Premium Club[8]". These services harmonized with Internet services. In accordance with these telematics activities, a working group of the International Organization of standardization (ISO) is currently defining a networked in-vehicle computer standard based on IPv6. The group is investigating how to use IPv6 to connect in-vehicle computers to the Internet. On the other side, the Internet Engineering Task Force (IETF) has many working groups, e.g. MobileIP, MANET, NEMO, related to mobile technologies.

InternetCAR (Internet Connected Automobile Research) Project [11] [4] [7], started in 1996, is a research project to investigate applications, data architectures and network technologies about networked vehicles. From an application point of view, a probe car system [12] is tested with a Japanese nonprofit organization named Association of Electronic Technology for Automobile Traffic and Driving. A probe car system collects vehicle-side data, i.e. velocity, wiper status, etc., and gathers statistics to generate some useful information like road traffic and weather conditions. Other applications are also tested, e.g. Internet based GNSS (Global Navigation Satellite System) correction system [5]. On the networking side, this project investigates Internet mobility technologies. Several years ago, Mobile IPv4 was implemented in an in-vehicle computer to maintain connections regardless of access networks. Recently, we have moved to an IPv6-based system.

Section 2 of this paper overviews a testing which was done in the first quarter of 2002. Before designing the system, we considered three types of network models and an application model. Section 3 introduces them. We introduce InternetCAR design and implementation around IPv6

in section 4. Section 5 describes details and results of several testing whereas section 6 discusses how to improve the system. Section 7 concludes problems and tentative solutions of a networked vehicle as an IPv6 application.

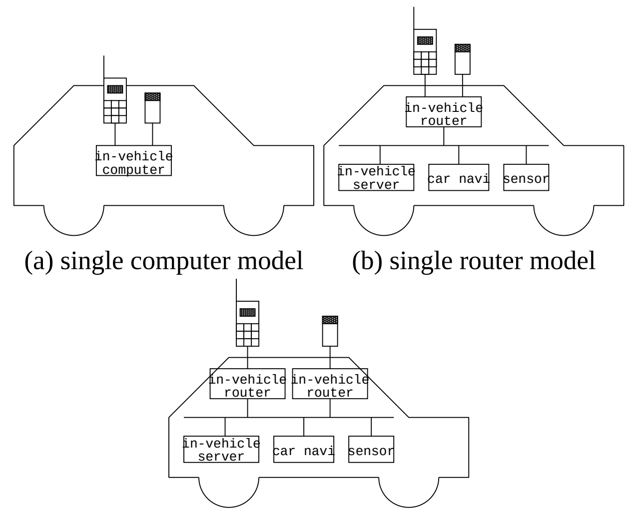
2 Testing Overview

In first quarter of 2002, we held a large scale testing with Toyota Moter Corporation, Denso Corporation and NEC Corporation. This testing included five types of sub-testings. The first one was a probe car system. About 1500 taxis in Nagoya area, a large city of Japan, were connected to the IPv4 network to collect data, such as location, velocity, wiper status and existence of passengers. A probe information center gathered data from all the vehicles to collect statistics as traffic information and weather information. The second sub-testing was a taxi business system. The data collected for a probe information system could be used to locate a taxi. A taxi control center used these data for allocation of taxis. The following three sub-testings were based on IPv6. The third one is a taxi passenger service with 70 taxis. In this sub-testing, a display with a touch panel was installed in back seats of each taxi to retrieve web information. Two types of retrieving methods, “push” and “pull”, were available, as mentioned in section 5.1. The forth sub-testing was a on-site service targeted to 70 passenger vehicles. Two applications were tested, Parking and Gas station. In a parking, an Internet payment system was used to pay parking fees. When a vehicle was entering the parking, the vehicle identifier was recorded by a local server located in the parking. Then, when the vehicle was leaving the parking, a payment transaction was initiated by a local server between a payment server and an in-vehicle computer. On the other hands, route guidance to an island and several web services are provided. The last sub-testing was a demonstration vehicle developed to investigate the future of a networked vehicle. Eleven computers, seven kinds of communication devices and other devices such as a sensor to monitor the acceleration were installed in the vehicle.

3 InternetCAR Model

3.1 Internet access models

Three types of models can be assumed when computers connected to the Internet are installed in an vehicle, The first one is the *single computer model* where a major computer like a car navigation system is connected to the Internet. The second is *the single router model* where some computers are connected to an in-vehicle network which is in turn connected to the Internet through just one router. The third one is the *multiple router model* where several routers are connecting the in-vehicle network to the Internet. Only the leading two models were actually demonstrated in the testing.



(a) single computer model (b) single router model

(c) multiple router model

Figure 1. Three models to connect a vehicle to the Internet

In our scenario, in-vehicle computers have to be connected to the Internet continuously, that is, ongoing sessions held by applications must be maintained after communication media switching regardless the communication media actually used. Media switching must also be done automatically.

3.1.1 Single computer model

In the single computer model, each computer in a vehicle has its own communication media. Each computer computer has to be identified by its own unique IP address. If three connected computers are available in a vehicle, a total of three IP addresses are used in the vehicle. But the addresses aren’t necessary related to each other. The addresses can be assigned independently.

An in-vehicle computer can have several communication media at the same time. A scenario discussed in ISO/TC204/WG16 (Working group to discuss wide and medium area communication for Intelligent Transport Systems), which is known as Communication Air interface Long and Medium range (CALM), shows a situation to switch communication media. In the scenario, an in-vehicle computer is connected through a Dedicated Short Range Communication (DSRC), when the vehicle is parked in front of the house. Then, when it goes outside, it switches to a cellular phone.

Figure 1-(a) shows an example of structure of this model.

A computer is installed to a vehicle with two types of media, a cellular phone and WiFi.

3.1.2 Single router model

In the single router model, several Internet appliances like a car navigation system, an airconditioner, an audio player, etc, are embedded in a vehicle. Passengers are also allowed to bring a PDA into the vehicle. An in-vehicle network is necessary to inter-connect these appliances. These Internet capable devices have no communication media directly connected to the Internet, thus the network deployed in the vehicle is connected to the Internet via a single in-vehicle router.

The in-vehicle router can have several types of communication media similarly to the single computer model. When the communication environment of a media is changed, the router switches to a more suitable media. Thus, all appliances in a vehicle can use the most suitable communication media regardless the current status of media.

Figure 1-(b) shows an example where a router is installed to a vehicle with two types of media, a cellular phone and WiFi. It is connected to an in-vehicle network to provide Internet connectivity to appliances.

3.1.3 Multiple router model

In these days, the cellular phone technology progresses rapidly. Some cellular phone have IP capabilities. Some of them have an IrDA or Bluetooth interface to connect with a computer. Then, we assume that cellular phones will become IP routers in the future. Multiple routers may be available in a vehicle in case passengers bring their own cellular phones into the vehicle.

According to network mobility, when multiple mobile routers are available on one mobile network, the routers must exchange some information like interface availability, capacity, statistics, etc to manage an in-vehicle network.

3.2 Information Model

Almost all InternetCAR applications use information from a vehicle like geographical location information, vehicle velocity, etc. That is the most important characteristic of vehicle applications.

Vehicle information could be used both from inside and from outside of the vehicle. Remote diagnosis applications fetch the information from outside, on the other hand, car navigation systems use it inside. InternetCAR information model provides vehicle information to both of them. If vehicle information are used outside of a vehicle, it have to be formalized. For example, vehicle velocity is represented as numbers of pulse in a vehicle. However, it cannot be

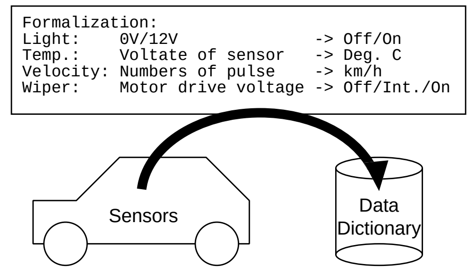


Figure 2. Information model

used outside of the car because the coefficient to convert it to more formal values like km/h is different for each type of vehicle. To solve the problem, InternetCAR information model introduces *Data dictionary* shown in figure 2. It defines how the information must be stored. For example, it defines that vehicle velocity has to be stored in km/h. Also this model is useful for in-vehicle applications. Current in-vehicle computers, i.e. a car navigation system, can be adapted to several types of sensor outputs.

4 InternetCAR design and implementation

4.1 Taxis and Passenger vehicles

In our testing, 140 vehicles are connected using the single computer model. Each vehicle has only one IPv6 computer connected to the Internet via one mobile phone (PDC-P) and one DSRC unit. The scenario is as following: 1) In the DSRC service area, the in-vehicle computer should be connected to the Internet via DSRC. 2) When the vehicle goes out of the DSRC service area, the in-vehicle computer should switch using communication media. 3) Even if communication media switching occurs, applications can communicate with their correspondents continuously. 4) Passengers, including the driver, must not care about media switching.

Two types of DSRC were used. Both of them are connected via USB. However, one of them acts as an Ethernet device, and another one acts as serial device. This means the first one has to get an IP address by stateless auto-configuration mechanism of IPv6 and the another one gets an IP address by IP6CP (sub-protocol of Point-to-Point Protocol). Both of them could sense radio strength. When a DSRC is available, the in-vehicle computer initiates to get IP address to use DSRC. On the other hand, the in-vehicle computer assumes the mobile phone is always available. An in-vehicle computer repeatedly tries to dial out when the PPP link is down.

When a DSRC is up or down, the in-vehicle computer initiates a media switching. The in-vehicle computer is running Mobile IPv6 based on internet-draft 13 [6]. So when

DSRC status is changed, a Binding Update (BU) packet is sent by the in-vehicle computer. When DSRC is available, an IP address of DSRC is used as Care-of Address (CoA). When DSRC is not available, an IP address of the mobile phone (PPP link) is used as a CoA. A Home Agent is prepared at the Internet. Home addresses are statically assigned by a network provider.

4.2 Demonstration vehicle

One special vehicle was made to investigate the single router model and to demonstrate network mobility. Eleven computers were installed and seven kinds of communication devices to provide many kinds of services. One of the computers acts as a router. It has five bi-directional communication devices: two packet cellular phones, two PHSs and WiFi. Other computers are connected to the Internet via the router. The router changes its current communication device according to communication devices availability. To provide network mobility transparently to the in-vehicle computer, we have implemented Prefix Scope Binding Update from Ernst et al[3]. When the current media is changed, a binding prefix update packet is sent to the Home Agent, located in our campus. However, there is an exception. One node, which is not the router, has a DSRC unit. When a vehicle goes into a DSRC ready area, it switches to DSRC. The node has Mobile IPv6 capabilities. Thus it can use its private communication media. The Home Agent of the node is the same as the router's. It means the system supports Local Mobile Nodes (LMNs) defined in [1].

An interface management block (IMB) works independently of the part of implementation to provide network mobility. IMB consist of a switching guidance block (SGB) and link layer management blocks (LLMBs). SGB decides what is the most suitable interface and kicks the NEMO API. Each LLMB watches an interface in charge to detect a change of its status. If necessary, a LLMB operates on an interface to establish a link. Operations are dependent on a sort of interfaces. For example, a link up operation of a LLMB for a mobile phone interface are as following: First, the LLMB dials an access point. Second, the Point-to-Point Protocol (PPP) is initiated by the LLMB. Then, an IPv6 tunnel between the router and a tunnel server is established.

4.3 Upper layer technologies

4.3.1 SNMP based system

An in-vehicle server includes Simple Network Management Protocol (SNMP) agent capability to provide in-vehicle sensor information to applications. The information is defined using Management Information Base II. Applications software, both of running on inside-vehicle and outside-vehicle, can use the information via SNMP.

In the probe car system and the taxi control system we developed, each in-vehicle server has a daemon which sends in-vehicle sensor information like vehicle velocity to a data center using a special protocol based on User Datagram Protocol (UDP). The daemon gets in-vehicle sensor information from the SNMP agent mentioned above. The reason why we used a special protocol is to reduce protocol overhead.

In a part of other applications, application server has a SNMP manager function. Health check, Vehicle diagnosis and Driving analysis servers get vehicle information using SNMP directly.

4.3.2 Other applications

Some web based applications are implemented in the testing. For example, when a vehicle goes near to the Nagoya castle, a guide to the Nagoya castle is offered to passengers. This application need a function to put URLs to a web browser in the vehicle. We implemented the function using Open Services Gateway Initiative (OMGi) Service Gateway specification.

At a shop (i.e. Gas station and Parking), the web browser in a vehicle may wonder what is the URL of the shop. We use Service Location Protocol (SLP) to put the URL. When a vehicle goes into a shop, an in-vehicle server requests the URL of the shop. Then, a shop-side SLP server reply to it.

5 Test details and results

5.1 Taxi

Seventy in-vehicle computer installed taxis were connected to the Internet using IPv6 in Nagoya area to provide three types of applications, a probe car system, a taxi control system and a location based web system. Thirty-two taxi companies joined the testing.

Figure 3. Inside taxi and DSRC Access point

In the probe car system, an in-vehicle server gets vehicle information from a velocity pulse line and a power line of wiper motor using A/D converter, position information from a GPS unit via a serial port and etc. The information

is collected once a second. An in-vehicle server sends these information using a UDP based special protocol when one of following three events is occurred. First event is short stop/trip event. A vehicle stops at a turn signal which is red. Then when the signal turns to green, it moves. It means a vehicle repeats stop and go. An in-vehicle server sends data to a probe information center when a vehicle stop/start. Second event is a long trip. When a vehicle moves 300 meter without stop, an in-vehicle server sends data. Last event is timeout. When an in-vehicle server doesn't send data during 10 minutes, it sends data. At a probe information center, it makes statistics as a traffic information on roads and a weather information to open to the public.

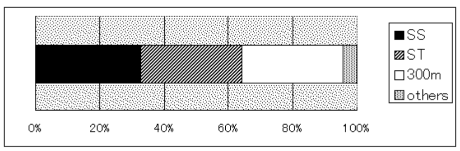


Figure 4. Communication traffic analysis

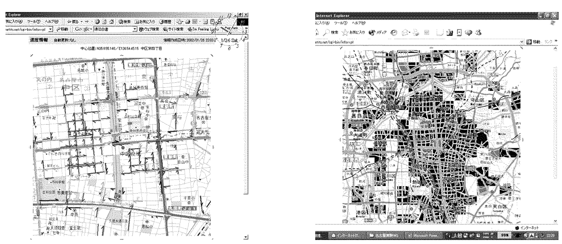


Figure 5. Example of a Web page of Traffic and Weather information

A taxi control system is constructed with a database in a probe information center. Locations and other information of taxis are collected at a probe information center. It can be used not only for a probe car system but also other applications like a taxi control system. A taxi control system is designed as a client-server system. The server is located beside a probe car center. The clients are located on taxi control centers. The server side interface is implemented as CGIs. Clients get taxi position and other information of taxis using HTTP and put the information onto a map it displays.

A location based web system is also tested using taxis. The system has two operations, "pull" and "push". In *pull* operation, when a passenger browses a web page on the InternetITS site (http://www.InternetITS.org/), information of surrounding areas like shop information and tourist information are downloaded responded the location of a vehicle. On the other hand, when a vehicle goes into a certain area which is set by InternetITS site, an application server detect that using probe information and deliver the URL using OSGi interface. That is called as *push* operation. Both of them cache web pages at the business office. Because a vehicle has only a cellular phone to be used on roads.

5.2 Passenger vehicle

In the Kawasaki area (near Tokyo), two types of on-site services are developed, Gas station guidance and Parking payment.

At a gas station, a passenger vehicle is led to a side of a gas island. When a vehicle comes into a gas station, a gas station server gets the information about the position of a fuel tap of the coming vehicle using SNMP. Then it can led the vehicle to a correct side of an island. At the side of an island, the server puts the information about color of a nozzle that should be used according to the type of oil of the vehicle. Also passenger can access to the Internet and the gas station's web site through a hot-spot during the waiting time. The left of figure 6 shows a screen dump of a gas station's page.

An Internets based payment system, named *Edy!*, is tested in a parking. Many payment systems are available on the Internet these day. *Edy!* system is constructed by three entities, a payment server, clients and shop servers. When a vehicle goes into a parking, that is recorded by a server in a parking. Then, when the vehicle goes out, a payment transaction is initiated by the server. When the payment transaction is started, a vehicle can go out from a parking. *Edy!* system use HTTP to exchange payment information among servers or a client.

Figure 6. Pages of Gas station and Parking

5.3 Demonstration vehicle

Some applications are tested using the vehicle. This section introduces four major applications.

The first one is *Vehicle diagnosis* system. An in-vehicle sensor always collects information about status of a vehicle. Then, that is stored in the server's database and it is provided as SNMP agent. In Vehicle diagnosis system, clients access to the SNMP agent directly to get vehicle statuses. Then, it show the statuses to a user.

The second one is *Health check*. The demonstration vehicle has sensors of passenger's pulses. We assume that in the face of an accident, the driver's pulse raises up. Also when the passenger get sick, it will be raise too. This system is developed to detect that situations. Pulse data is collected by a in-vehicle sensor and it store the data to its database same as Vehicle diagnosis system. Then, clients can get the information using SNMP. In our system, the data is collected periodically. But if the available communication media is not enough to transmit the data, the period becomes a long.

The third one is *Driving analysis*. This application uses a same system with Health check.

Last one is *Teleconferencing*. We use *vic* and *rat* with XCAST technology to realize teleconferencing. This system provides teleconference function to each passenger seat. When WiFi is available, it is selected by mobile route. So in this case, teleconferencing works well. However, when the route uses cellular phone, it is hard to communicate with outside of the demonstration vehicle.

6 Future work

First problem is *naming*. Many applications for vehicle want to identify a vehicle like "the vehicle in front" or "the red vehicle which is turning on a light". However, current Internet architecture has no solution for this problem.

Communication performance is very important for safety applications. Also interactive application and stream applications needs continuous communication. Currently, some solutions are proposed to provide seamless communication. These communication should be evaluated in vehicle environment.

To deploy InternetCAR, security and privacy are very important issues. We have to discuss system security with performance issue for each layer.

7 Conclusion

This paper described two architectures to connect vehicles to the Internet: the single computer model and the single router model. The single computer model is based on MobileIPv6 to provide vertical handover capabilities. On the other hand, network mobility is necessary to realize single router model.

This paper also introduced an application architecture of InternetCAR. We used SNMP to get status of vehicles. Almost all the applications we tested are using SNMP to get status of vehicles.

These architectures were tested at Nagoya and Kawasaki areas of Japan in the first quarter of 2002. A total of 141 vehicles were used in this testing. And Applications were very useful. However, some problems are realized in this testing.

Acknowledgment

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