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Design and Evaluation of Telematics User Interface for Ubiquitous Vehicle†

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Abstract In the ubiquitous computing environment, a ubiquitous vehicle will be a communication node in the vehicular network as well as the means of ground transportation. It will make humans and vehicles seamlessly and remotely connected. Especially, one of the prominent services in the ubiquitous vehicle is the vehicle remote operation. However, mutual-collaboration with the in-vehicle communication network, the vehicle-to-vehicle communication network and the vehicle-to-roadside communication network is required to provide vehicle remote operation services. In this paper, an Internet-based human-vehicle interfaces and a network architecture is presented to provide remote vehicle control and diagnosis services. The performance of the proposed system is evaluated through a design and implementation in terms of the round trip time taken to get a vehicle remote operation service.

Key Words : Ubiquitous Vehicle, Remote Operation, Ubiquitous Computing, Vehicular Network, Ubiquitous Telematics

1. Introduction

Advanced network technologies have extended a vehicle's function from a means of transportation to means of communication. In the ubiquitous computing environment, the vehicle will play a role as a mobile sensor node with autonomous computation and communication capability in the network space. Thus, the vehicular communication becomes one of the key technologies to monitor and control the ubiquitous vehicle remotely. Recently, many researchers in vehicular communication focus on seamless vehicular safety communication technology under different protocols and networks [1-3]. However, there are many challenges involved in constructing an advanced vehicular network. This is because the network environment for vehicular communication is quite different from existing network environments. Vehicular communication is exposed to poor and dynamic environments such as high mobility, frequent topology change, lack of a centralized entity and high traffic density of vehicles in urban areas [4].

DSRC (Dedicated Short Range Communication) is designed for vehicular communication such as vehicle-to-vehicle and vehicle-to-roadside networks [5]. However, it is primarily aimed at vehicle-to-roadside communication with a slow vehicle speed because it is based on IEEE 802.11a. Most researches on Internet-based remote operation systems focus on the system in the fixed place, and thus do not consider the service's mobility [6-7].

In this paper, an Internet-based human-vehicle

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interface is proposed for vehicle remote operation with consideration for the vehicle's environment. It can monitor and control moving vehicles remotely at anytime and anywhere via a web browser. The performance of the proposed system is evaluated in terms of round trip time from the service request to the receipt of response from the vehicle depending on its speed and location.

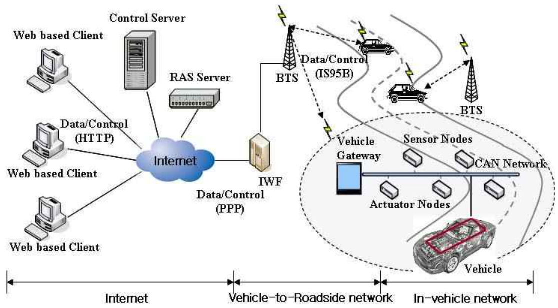
This paper is organized as follows. Section 2 introduces the related work. The Internet- based human-vehicle interface are explained in section 3. The performance evaluation is presented and analyzed in section 4. Finally, section 5 contains concluding remarks.

2. Related Work

Internet-based vehicle remote operation is one of the Man-to-Machine Interface (MMI) technologies that controls and diagnoses a target system in a remote place using standard web browser based technology. The advantage of Internet-based remote operation is that a target system can be controlled via a web browser irrespective of client's computing platform, requiring only that it be connected to the Internet. Researches on the existing vehicle remote operation system have been mainly focused on local area wireless communication [8]. However, their control methods do not consider security, extensibility or mobility of the services. The existing system is only for a stationary target system at fixed place and thus unsuitable for moving vehicles because it does not consider the mobility of target system [9-11]. On the other hand, vehicular communication has several different characteristics from traditional network communication such as mobility of nodes, frequent topology change, high density of nodes and short link time. However, due to these characteristics the conventional network communication approach cannot be applied to vehicular communication [12].

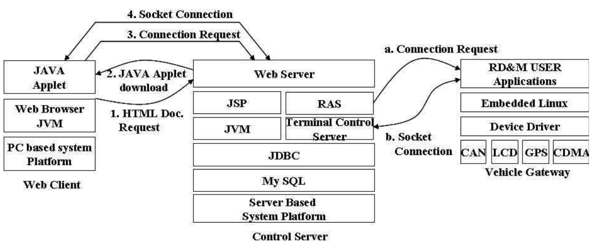
3. Human-vehicle Interfaces for Ubiquitous Telematics

Figure 2 shows the network configuration for vehicle teleoperation based on network-oriented server-client model proposed in this paper. The in-vehicle network consists of the sensor nodes, actuator nodes and the vehicle gateway. They are connected to a Controller Area Network (CAN). The vehicle-to-roadside network for data exchange between the vehicle and the control server is based on the CDMA mobile infrastructure.



<Fig. 1> Network configuration for vehicle remote operation

The control server is the core unit offering the web-based remote vehicle management services to web clients as well as in-vehicle drivers. The structure of the control server consists of a web server, security manager, a server-gateway communication manager, a language converter, a core engine and a data-base. The web server provides a web client with a web-based interface. The RAS (Remote Access Service) server, which is controlled by server-gateway communication manager, is responsible for secure connection and access control between the control server and the vehicle gateway. The security manager consists of a client authentication manager for web clients and the server-gateway security manager for drivers. The language converter, which exchanges information among the different types of networks, has the role of converting the HTTP protocol packet format on the web client side into the point-to-point (PPP) protocol format on the vehicle gateway side and vice versa. The core engine consists of a gateway manager, an event and history manager and a data-base manager. The gateway manager is in charge of managing the connection request, the gateway configuration and the information transmission and reception. The event and history manager has the role of event analysis, control command trans-mission and execution, a received data analysis and log file generation. Finally, the database manager deals with log files about event history and in-formation about vehicle gateways stored in the database.

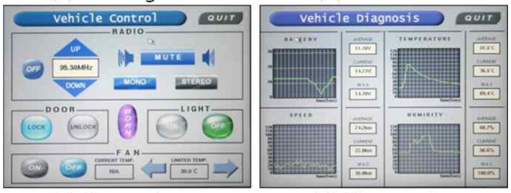


<Fig. 2> System architecture for Internet-based vehicle remote operation

Figure 2 shows the system architecture for the Internet-based vehicle remote operation. The im-plemented system consists of a web client, a control server, a vehicle gateway and an in-vehicle network. To support Internet-based vehicle remote operation, the control server is based on the JAVA platform that consists of MySQL, JDBC (Java Database Connectivity), JVM (Java Virtual Machine) and JSP (Java Server Pages).

We have implemented two types of vehicle remote operation interfaces. One is for in-vehicle drivers provided by the vehicle gateway. The other is for web users provided by the control server. Figure 3 shows a capture of remote operation interfaces for in-vehicle diagnosis and control services, which are provided to drivers by the vehicle

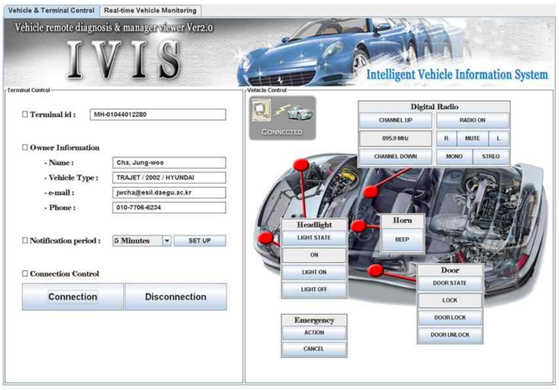
(a) Manager (b) Position



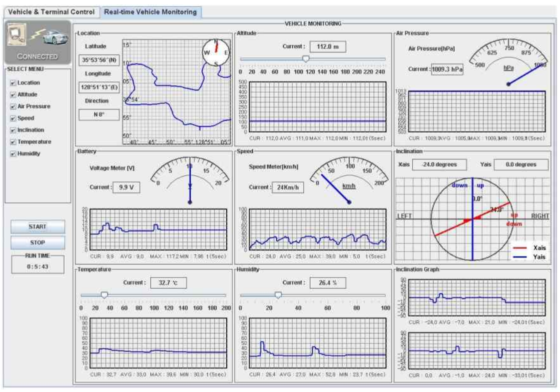
(c) Control (d) Diagnosis

<Fig. 3> In-vehicle remote operation services

gateway. Using these services, the in-vehicle driv-ers can monitor the vehicle status and control actuator.



(a) Remote Vehicle Control



(b) Remote vehicle monitoring

<Fig. 4> Web-based remote operation services

The web-based vehicle remote operation services are designed as shown in Figure 4. Web users can monitor and control moving vehicles at a remote location through collaboration with the control server, the vehicle-to-roadside network, the vehicle gateway and the in-vehicle network. The web-based vehicle remote operation services are provided with remote vehicle status information such as position, speed, altitude, temperature, battery state and inclination of the vehicle. It also offers the control of actuators such as doors, head lamps, horns and digital radios in the vehicle at remote location place.

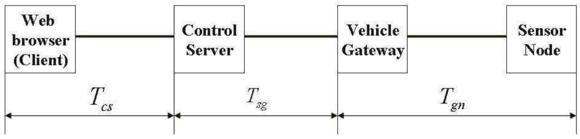
4. Performance Evaluation

In this section, we focus on the round trip time between the web-based client and the in-vehicle gateway to evaluate the performance of the proposed system. The round trip time is defined as time taken for a web client to receive a response from a sensor node in the in-vehicle sensor network since its request. Thus, the Internet-based vehicle remote operation system can be modeled as shown in Figure 5. Based on the performance analysis model, the round trip time (T_{rtt}) can be calculated as follows:

$$T_{rtt} = T_{cs} + T_{sg} + T_{gn}, \qquad (1)$$

where T_{cs} is a communication latency between a web client and a control server, T_{sg} is one between the server and a vehicle gateway, and T_{gn} is one between the gateway and a sensor node In the in-vehicle network.

Table 1 shows the experimental results for T_{sg}. It is measured with the time taken to make a complete connection between the control server and the vehicle gateway. When the control server requests a connection to the vehicle gateway using the cut and



<Fig. 5> Performance analysis model

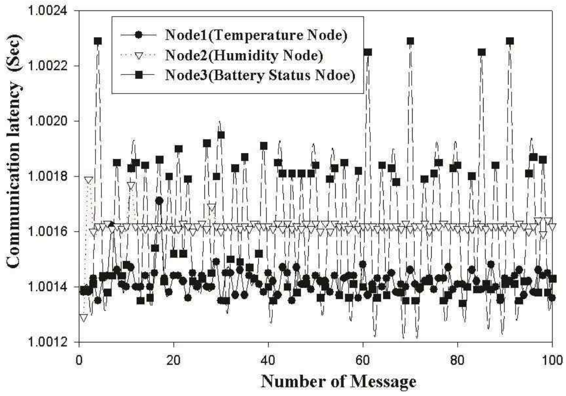
callback protocol, the result shows that the average communication latency is 10.302sec and the standard deviation is 0.821ms.

<Table 1> Connection delay time between the control server and vehicle gateway (sec)

Link Direction	Min.	Max.	Avg.	Std. Dev.
Server to Gateway	8.76	12.123	10.302	0.821
Gateway to Server	4.064	7.905	5.068	1.131

On the other hand, when the vehicle gateway requests a connection to the control server, it does not use the cut and call back protocol. It reduces the communication latency by about 50 %. The results show that the average communication latency is 5.608sec and the standard deviation is 1.131sec. The delay time due to the CCB protocol includes the time to verify a caller's identification and make a call back to the control server.

Figure 6 shows the results of T_{gn} that is the communication latency between the gateway and the sensor node based on the master-slave communication model. In this experiment, the bit rate of CAN network is upto 1M bps and all the transmission data has a fixed priority. Three sensor nodes are connected to the CAN network. Every sensor node transfers its sensing data to the vehicle gateway in charge of master node at every one second. The master node has the highest priority and each slave node has its own priority in order. The average communication latency between sensor nodes and the vehicle gateway is 6.669ms. The slave node1 with temperature sensor has the lowest communication latency among sensor nodes because its highest priority results in the shortest waiting time. The slave node3 with battery sensor is the longest in the latency and the largest in the range of fluctuation because of its lowest priority.



<Fig. 6> communication latency between in-vehicle gateway and sensor nodes

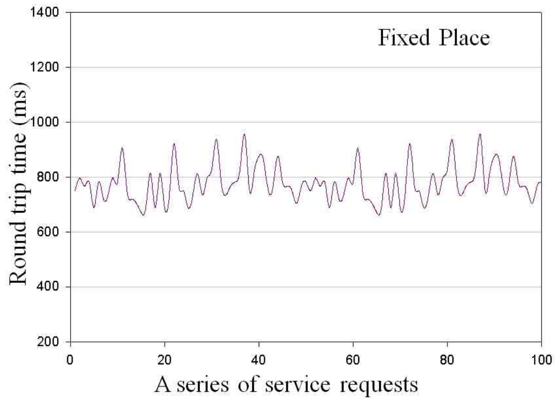
The round trip times for the web based remote vehicle diagnosis and control service are measured in the mobile environment. The vehicle gateway and the in-vehicle sensor network are installed in a testing vehicle. The round trip times are observed in various circumstances of the testing vehicle. That is, it is measured when the testing vehicle stops at a place, moves on a highway, and moves in a downtown.

The experimental results show that the average round trip time of stationary vehicle at a place amounts 776.44ms and the standard deviation is 65.72ms as shown in Figure 7(a). Figure 7(b) shows the round trip time when the testing vehicle runs on a highway with the speed above 100 km/h. The average round trip time of the moving vehicle on the highway is 707.34ms and the deviation is 146ms. Figure 7(c) shows the results of round trip time when the testing vehicle moves through a downtown at the speed of 30 km/h. The average round trip time of the moving vehicle in the downtown is 910.52ms and the standard deviation is 147ms. Consequently, the round trip time of stationary vehicle is shorter and more stable than others because it does not take the handover delay time of cellular network and depends only on the mobile communication network traffic in that area. On the other hand, the experimental results of moving vehicle are seriously fluctuated because of the frequent handover of the CDMA. Specifically, the round trip time of the moving vehicle in a downtown is longer and more fluctuated than other area. It is because there is busy network traffic and frequent handover with pico cells at about 200m of radius.

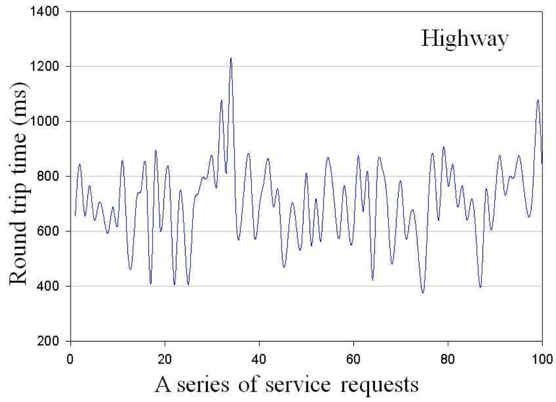
5. Conclusions

A vehicle will be considered a mobile terminal or a node in the mobile network. However, there are many challenges on the path realizing an advanced vehicular network because of the nature of vehicular networks, such as the vehicle's poor and dynamic communication characteristics.

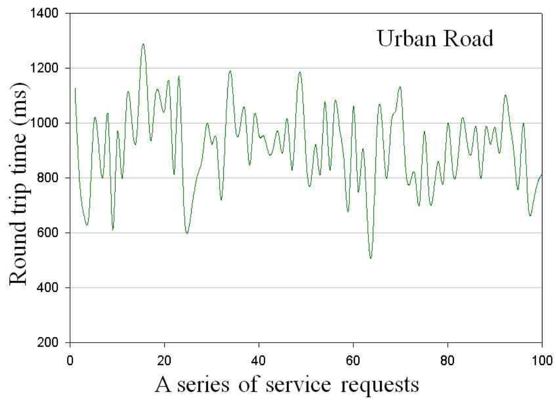
In this paper, Internet-based service system architecture is presented for the vehicle remote operation based on the mobile infrastructure. We also have demonstrated web service applications for vehicle remote operation. The web services exploit collaboration of heterogeneous networks such as vehicle-to-roadside communication networks based on mobile infrastructure, in-vehicle communication networks and the Internet. The proposed Internet-based vehicle remote operation services allow in-vehicle drivers and web users to have access to the vehicle at anytime and anywhere. Moreover, residing in the Internet and separated from the vehicle, the control server can be easily connected to the several other networks and provides several types of services. The mobile infrastructure such as GSM and CDMA can be used for the Internet-based vehicle remote operation system to provide wireless vehicle services.



(a) Round trip time of stationary vehicle



(b) Round trip time of moving vehicle on highway



(c) Round trip time of moving vehicle in downtown

<Fig. 7> Round trip time between web client and sensor nodes

The performance evaluation of the Internet-based vehicle remote operation is performed in various environments. The experimental results show that the average round trip time amounts to 766ms in the stationary vehicle, 707ms in the moving vehicle on a highway and 910ms in the moving vehicle in a downtown. These results depend on the environment and information throughput of the mobile infrastructure. The proposed system is not suitable for the real-time remote vehicle control such as remote driving, engine control and other real-time system controls because the response time is little bit too long to meet real-time requirements. However, the proposed system would be extended to be used for real-time vehicle control if it is implemented on mobile infrastructure providing higher throughput.

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