Design of Gateway for In-vehicle Sensor Network

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Abstract – The advanced information and communication technology gives vehicles another role of the third digital space, merging a physical space with a virtual space in a ubiquitous society. In the ubiquitous environment, the vehicle becomes a sensor node, which has a computing and communication capability in the digital space of wired and wireless network. An intelligent vehicle information system with a remote control and diagnosis is one of the future vehicle systems that we can expect in the ubiquitous environment. However, for the intelligent vehicle system, many issues such as vehicle mobility, in-vehicle communication, service platform and network convergence should be resolved. In this paper, an in-vehicle gateway is presented for an intelligent vehicle information system to make an access to heterogeneous networks. It gives an access to the server systems on the internet via CDMA-based hierarchical module architecture. Some experiments was made to find out how long it takes to communicate between a vehicle's intelligent information system and an external server in the various envrionment. The results show that the average response time amounts to 776ms at fixec place, 707ms at rural area and 910ms at urban area.

Keywords: Vehicle Gareway, In-vehicle Sensor Network, Intelligent Vehicle Information System, Web-based Control, Vehicle Remote Control

1 Introduction

The ubiquitous computing environment representing the future society requires the intelligent vehicle to provide a driver with his or her vehicle diagnosis and management at any time and any where. The existing remote vehicle control systems mainly using RF communication within a close range do not support cooperation with the outer heterogeneous networks and thus have a trouble with extending to various on-line vehicle information services [1-3]. Moreover, it is not enough for mobility of vehicle services and has a weakness for security because of a short range wireless communication with low frequency [4-6]. Lots of researches on remote monitor and management systems on the Internet have been done but have mainly focused on the remote control target systems at fixed place. In addition, it does not consider a service mobility which is strongly demanded for the intelligent vehicles, because of its legacy of wired communication [7-9].

In this paper, we present a vehicle gateway for the intelligent vehicle sensor network system. It collects vehicle's status information such as position, speed, altitude, temperature, battery state and inclination from the in-vehicle sensor network and controls vehicle's actuators such as horn, headlamp and door. In addition, the gathered vehicle's status information is transmitted to external network via the protocol conversion. The in-vehicle sensor network is based on CAN(Controller Area Network) protocol which is a digital serial wire communication network for vehicles. Specially, we proposed a cut and call back protocol so that it can allow a bidirectional connectivity between control server and vehicle gateway.in CDMA mobile network

The remainder of paper is organized as follows. A design of the vehicle gateway is explained in section 2 and experiments and performance analysis of the vehicls gateway proposed in this paper discussed in section 3. Finally, some conclusion remark will be made in section 4.

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2 Vehicle Gateway

2.1 Network Model

The main role of vehicle gateway is to translate and execute control commands received from the control server. It cooperates with the in-vehicle sensor network to help the remote vehicle diagnosis and management performed. It also provides in-vehicle drivers with useful information that is sent from the control server.

The vehicle gateway in the intelligent vehicle allows context collected from sensor nodes within and around the vehicle to be offered to the external heterogeneous networks. The control server gives vehicle status information to the clients on the external network and transfers the request message of vehicle management from the clients to the vehicle gateway. Implementing both the vehicle gateway and control server in the vehicle needs large scale and high performance server. It also needs a wireless internet protocol to guarantee dynamic connection with external network at high speed like mobile IP based on IPv6.

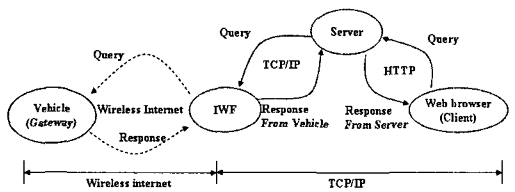

Figure 1. Network Oriented Server-Client Model.

Instead, we present a network oriented server-client model shown in Fig. 1. While the vehicle gateway is placed in the vehicle and the control server is located on the external network. The model gives a mobility of service to a vehicle, communicating data packet over the CDMA based mobile network.

2.2 Software Architecture

Fig. 2 shows the software architecture of the vehicle gateway proposed in this paper. It consists of a wireless communication manager, a server-gateway security manager, a command filter, core engine and other application programs for in-vehicle drivers.

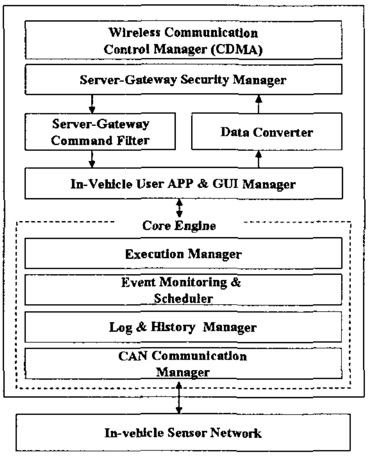

Figure 2. Software Architecture of Vehicle Gateway.

Fig. 3 shows the cut and call back protocol proposed in this paper. Generally, the existing mobile data communication network such as CDMA does not support two-way network connection in the mobile environment. For the two-way network connection, the cut and call back mechanism requires the caller identification service. If the control server requests a connection to the vehicle gateway, the vehicle gateway will identify the caller identification of the control server.

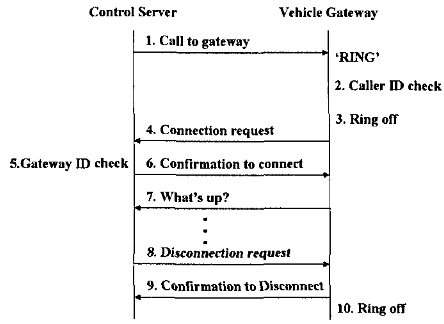

Figure 3. Cut and Call Back Protocol.

3 Evaluation

3.1 Experimental Environment

Fig. 4 shows the test envrionments of the vehicle gateway system proposed in this paper. It consists of the sensor nodes, actuator nodes and the vehicle gateway in a vehicle, which are connected by CAN (Controller Area Network) network. Besides, the vehicle gateway is connected to the Internet via CDMA mobile communication network. The gateway has a role of collecting vehicle status data from in-vehicle sensor network and converting network protocol to connect the in-vehicle network with the external network.

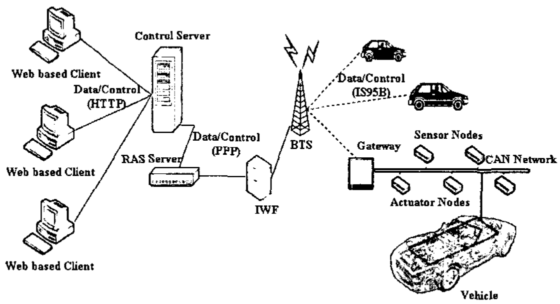

Figure 4. The Vehicle Gareway Test Environment.

3.2 Performance Analysis Model

For performance evaluation, the web based vehicle control system can be modeled as shown in Fig. 5. The round trip time is defined as time taken for a web client to receive a response from a sensor node in the sensor network since its request.

Let T_{cs} be communication latency between a web client and control server when web client request a service, T_{sg} be one between the control server and the vehicle gateway, and T_{gn} be one between the vehicle gateway and a sensor node in the in-vehicle sensor network. T_{rtt}, which is a round trip time between a web client and a sensor node, can be defined as follows:

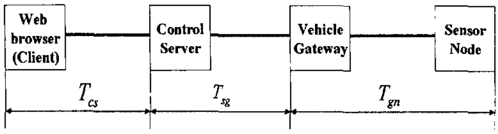

Figure 5. Performance Analysis Model.

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

T_{cs} = *Client to server response time*

T_{sg} = *Server to gateway response time*

T_{gn} = *Gateway to sensor node respone time*

The communication latency T_{cs} between web client and control server is given as follows:

$$T_{cs} = \tau_{cproc} + \tau_{javadown} + \tau_{csdealy}, \quad (2)$$

τ_{cproc} = *Client processing time*

$\tau_{javadown}$ = *Java applet download time*

$\tau_{csdealy}$ = *Client to server propagation delay*

The communication latency T_{sg} between the control server and the vehicle gateway includes the performance factors such as execution latency of the control server and the network traffic, which is difficult to estimate. T_{sg} is given as follows:

$$T_{sg} = \tau_{sproc} + \tau_{cutback} + \tau_{stdelay}, \quad (3)$$

τ_{sproc} = *Server processing time*

$\tau_{cutback}$ = *Cut and call back delay*

$\tau_{sgdelay}$ = *Air space data propagation delay*

T_{gn} is the communication latency between the vehicle gateway and a sensor node in the in-vehicle sensor network and given as (4). In the equation (4), P_d is a delay time taken to process data frames at the vehicle gateway. R_m is the worst-case latency time taken for a sensor node to transfer data frames to the vehicle gateway via CAN network.

$$T_{gn} = P_d + R_m \quad (4)$$

P_d can be defined as follows:

$$P_d = \tau_{scan} + \tau_{debo} + \tau_{nproc}, \quad (5)$$

τ_{scan} = *Input – scan cycle time*

τ_{debo} = *Input filter / Debounce time*

τ_{nproc} = *Software processing time*

R_m is the worst-case latency time taken to load the sensor data on the CAN network since storing the sensor data into the CAN stack. It is, in turn, defined as the equation (6), where q_m is a worst-case queuing time and *Cm* is the maximum transmission time for a transmission data. Therefore, R_m is defined as follows:

$$R_m = q_m + C_m \quad (6)$$

q_m shown in equation (7) is the sum of the block time B_m, which is the delay time by other lower priority transmission frames than the given priority m frame, and the waiting time by the higher priority frames [10-12].

$$q_m = B_m + \sum_{\forall \in hp(m)} \left\lceil \frac{q_m + J_j + \tau_{bit}}{T_j} \right\rceil C_j \quad (7)$$

B_m = *Blocking time of lower priority message*

$hp(m)$ = *Set of higher priority messages than message m*

q_m = *Queuing delay of* $hp(m)$

J_j = *Jitter of given task J*

τ_{bit} = *Bit time*

T_j = *Period of given task J*

C_j = *Worst – case computation time of given task J*

The maximum transmission latency, C_m, for a transmission frame to be completely loaded on the CAN network is the sum of the stuff bit time, overhead bit time and transmission data bit time as shown in equation (8).

$$C_m = \left(\left\lceil \frac{34 + 8S_m}{5} \right\rceil + 47 + 8S_m \right) \tau_{bit} \quad (8)$$

3.3 Experimental Results

The communication latency for the web based remote vehicle diagnosis and management is analyzed in the mobile environment. The communication time is measured at fixed place, highway around rural area with vehilce a speed of 100km/h and downtown with vehicle a speed of 30kmk/h. The implemented vehicle gateway and the in-vehicle sensor network are installed in the testing vehicle which is shown in Fig. 6. going through the experimental areas. The round trip time T_{rtt} between a web client and sensor nodes are measured.

As shown in Fig. 7, the round trip time at the fixed place is shorter and better stable than others because it does not have the handover delay time for the CDMA and depends only on the mobile communication network traffic in that area. On the other hand, the experimental results at the rural and urban area are seriously fluctuated because of the frequent handover of the CDMA. Specifically, the round trip time at the urban area is longer and more fluctuated than other area. It is because there is busy network traffic and frequent handover with Pico cells about 200m of radius.

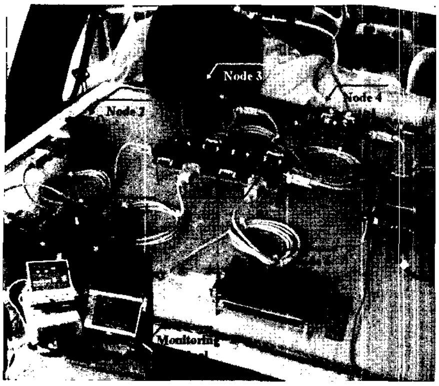

Figure 6. The Vehicle Gateway Test Environment.

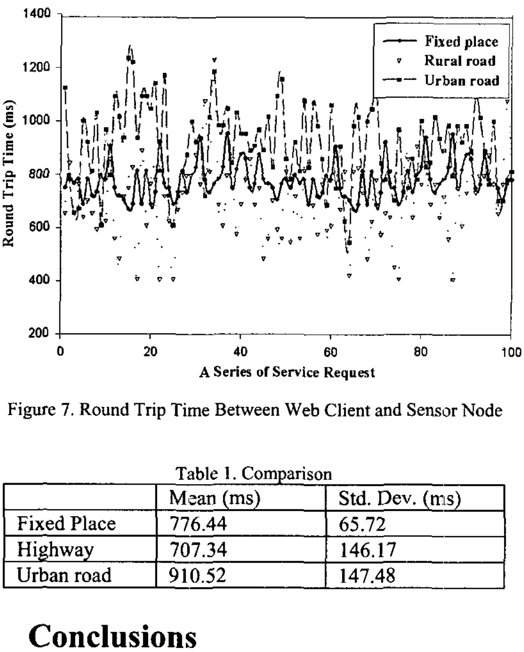

Figure 7. Round Trip Time Between Web Client and Sensor Node

Table 1. Comparison

	Mean (ms)	Std. Dev. (ms)
Fixed Place	776.44	65.72
Highway	707.34	146.17
Urban road	910.52	147.48

4 Conclusions

The existing web-based remote diagnosis and management system is only for the target system at fixed place. It is unsuitable for vehicles because it does not consider the mobility of target system.

In this paper, we present the vehicle gateway for the intelligent vehicle in the ubiquitous computing environment. The proposed vehicle gateway allows in-vehicle drivers and web clients to have an access to the vehicle at any time and any where.

The performance evaluation of the vehicle gateway with web based remote control system is performed at various environments. The experimental results show that the average round trip time amounts to 766ms at fixed place, 707ms at rural are and 910 ms at urban area.

The round trip time at various mobile environments has very differnt values because it has different notwork specificity. Therefore, the dual mode protocol switching algorithm is our future work. It allows the vehicle gateway to access external network with the most suitable network procotol followed by mobile network environment.

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