Proceedings of the 2009 IEEE International Conference on Systems, Man, and Cybernetics
San Antonio, TX, USA - October 2009

Development of Telematics Communication System with WAVE DSRC

Kang-Chiao Lin
Service-Oriented Network System Department
Information & Communications Laboratories
Industrial Technology Research Institute
Hsinchu, Taiwan, R.O.C.
kcling@itri.org.tw

Chun-Huang Lin
Service-Oriented Network System Department
Information & Communications Laboratories
Industrial Technology Research Institute
Hsinchu, Taiwan, R.O.C.
andersonlin@itri.org.tw

***Abstract*—Vehicular wireless communication for emergent or critical informational event's notification is more and more important although ITS and telematics' services are not ready. DSRC (Dedicated Short Range Communication) equipment is under developed up to now, and WAVE (Wireless Access in Vehicular Environment) is one of the DSRC standards that is currently been standardized. In this paper, we first propose an architecture of demonstration system in telematics. Then we introduce two demonstration scenarios, the Congestion Avoidance System (CAS) and the Emergency Alert System (EAS), about transferring traffic information by WAVE/DSRC. This telematics' field-trial demonstration system is composed of OBU in vehicle, RSU on roadside and LTS on remote site. This demonstration system uses WAVE short message protocol (WSMP) to send alert pictures and messages from vehicle to vehicle (i.e. V2V mode) and traffic information between vehicle and road-side unit (i.e. V2R mode).**

***Keywords*—Telematics, DSRC, IEEE 1609**

I. INTRODUCTION

TELEMATICS OF ITS becomes a more and more important technology nowadays. Some simulation or evaluation systems of telematics have been proposed in literatures [14][15][16]. Since the high probability of vehicle accidents, it leads to a huge loss of life and economy around the world. Most of the accidents are due to unawaring of the real traffic condition nearby. Once drivers know that an emergent traffic condition just occurred in front of their vehicles, they would be able to avoid accident easily by changing to other way or just slowing down the speed. The technology of propagating traffic information among vehicles is WAVE/DSRC. Using the new WAVE/DSRC technology, drivers get important traffic information conveniently and drive more safely. Drivers could receive the real-time traffic information near their vehicles. When the traffic is jammed due to an accident, the drivers can avoid it by the aid of getting this traffic information. Since there is not enough time to re-send emergency messages, it is not sufficient for using the TCP/IP protocol to transfer these messages. So we need a quick-responding protocol stack for transmitting emergent messages. This protocol stack of IEEE standard is under standardization [13], and it consists of IEEE 802.11p [1] for the WAVE PHY and MAC layer, IEEE 1609 [2]–[5] for the WAVE MAC, network layer, above layer, and security functions.

In this paper, we propose a telematics' system and two demonstration scenarios about transferring traffic information by WAVE/DSRC technology. One scenario is the Congestion Avoidance System (CAS) and the other is the Emergency Alert System (EAS). The rest of this paper is organized as follows: In section II, we introduce demonstration architecture and equipments. The two scenarios, Congestion Avoidance System (CAS) and Emergency Alert System (EAS), will be introduced in section III and IV, respectively. Section V is our conclusion about this demonstration system. Finally, some future works are given in section VI.

II. ARCHITECTURE AND EQUIPMENTS

A. Architecture

In this demonstration system we use WAVE/DSRC technology to achieve the safety information transmission. The WAVE/DSRC is used between vehicle and road-side unit (V2R), vehicle to vehicle (V2V) respectively.

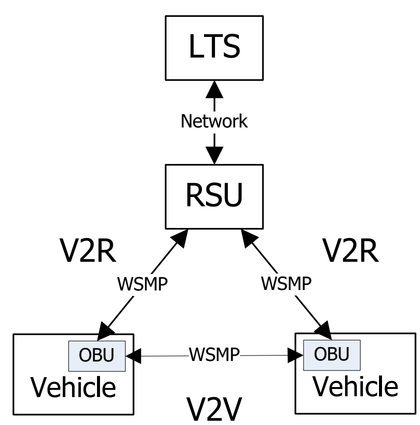

Figure 1. The architecture of our telematics system.

The architecture of our hybrid telematics system and the characters are shown in Fig. 1. The details of these characters are described below:

978-1-4244-2794-9/09/$25.00 ©2009 IEEE

1) LTS: Local Traffic Server (LTS) is a specific regional traffic information server. It provides traffic information such as traffic jams at certain road sections or crossroads within the region. LTS server maintains the traffic information of a region, and sends these information to the RSU. RSU is connected to the LTS through infrastructure network.

2) RSU: Road-Side Unit (RSU) is a server that broadcasts traffic information to vehicles by using WAVE/DSRC technology. The traffic information is within a specific small region such as a crossroad or a small section of road and is sent from the LTS that is responsible for this dedicated region. RSU is connected to LTS by infrastructure network and broadcasts information by WAVE/DSRC to the vehicles near itself. Besides sending traffic information, RSU receives vehicle Probe Message which contains speed and location data of the vehicle nearby. Thus RSU can determine traffic condition of local area, and feedback this information to the LTS server.

3) Vehicle: There is an On-Board Unit (OBU) on vehicle. It can receive traffic information from RSU. The wireless connection between OBU and RSU is using WAVE short message protocol (WSMP) of WAVE/DSRC. OBU can also transfer alert information from one vehicle to others using WAVE short message (WSM). There is also a navigation platform in OBU to provide navigation service for driver. The traffic information that received from RSU can be shown on the display screen of navigation platform. The details will be described in paragraph II.C.

B. Equipments

1) WAVE-BOX: WAVE-BOX is a device that can communicate with each other through WAVE/DSRC technology. RSU and OBU both need to send/receive information by WAVE/DSRC. These two units need a WAVE-BOX respectively. Currently our system uses the control channel (CCH) for sending traffic information and alert messages, termed WSM (WAVE short message) in the WAVE standard.

Following is the packet transportation capability test result of our WAVE-BOX. Due to the characteristics and application of WAVE/DSRC, we use Packet Delivery Rate (PDR) as major performance index for the WAVE-BOX [6]-[10]. The definition of Packet Delivery Rate (PDR) is the ratio of successful received packet number to total sent packet number (i.e. 1000 WSM packet). We send 1000 WSM packet from RSU to Vehicle (OBU) and send 1000 WSM packet from Vehicle (OBU) to RSU every time. Every WSM packet has 1024 bytes payload. We send packets with variable data rate and variable transmitter output power level under fixed distance between RSU and OBU. It's obvious that distance between RSU and OBU and transmitter output power level are critical parameters influencing PDR. In this testing, we ignore the effects from weather. All of the testing procedures are executed on sunny day.

According to the data of Fig. 2~4 shown below, Packet Delivery Rate (PDR) becomes better while distance from RSU to Vehicle (OBU) getting closer within 200 meters. Packet Delivery Rate (PDR) of higher transmitter output power (e.g. 12 dBm) is better than lower transmitter output power (e.g. 6 dBm). Packet Delivery Rate (PDR) of lower data rate (e.g. 6 Mbps) is better than higher data rate (e.g. 27 Mbps).

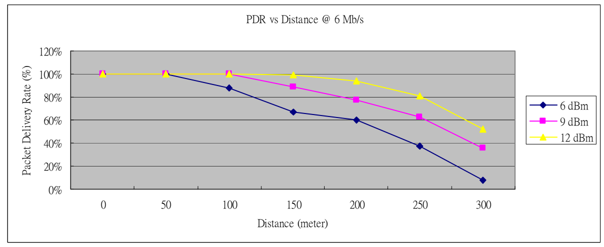

Figure 2. PDR vs Distance @ 6 Mbps

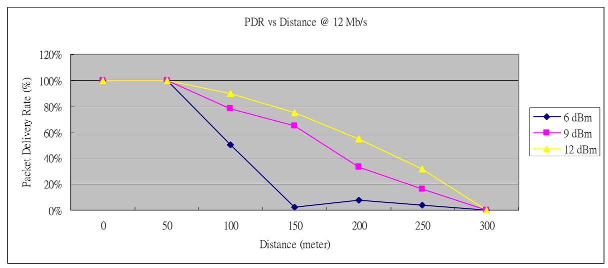

Figure 3. PDR vs Distance @ 12 Mbps

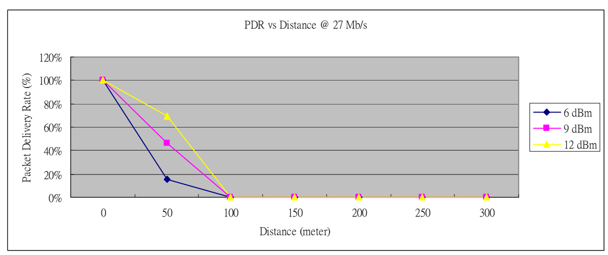

Figure 4. PDR vs Data Rate @ 27 Mbps

2) Road Side Unit: Fig. 5 shows the equipments in a RSU. We use a personal computer as a RSU server. The RSU server is connected to a WAVE-BOX by ethernet. When RSU needs to send information, the RSU server sends it to WAVE-BOX in UDP format. Then WAVE-BOX converts it to WSMP format and radios it out. WAVE-BOX can also receive WSMP information and then convert it to UDP format for RSU Server receiving.

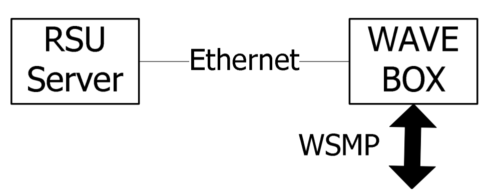

Figure 5. The equipments of RSU.

3) On-board Unit: Fig. 6 shows the equipments in an OBU. We use a Portable Navigation Device (PND) as an OBU client. PND is also connected to a WAVE-BOX by ethernet. When OBU receives WSM information at the WAVE-BOX, it is converted to common UDP format and is sent to the PND. After receiving the UDP mssages of traffic event information, PND can display the traffic alert or picture on the front screen. The PND can also send UDP information to the WAVE-BOX. Then the WAVE-BOX converts the UDP information to WSM format and transmits it.

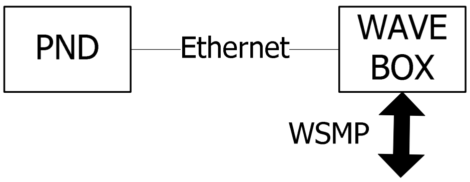

Figure 6. The equipments of OBU in vehicle.

C. *Software architecture on PND*

There are two types of information should be handled by PND. First type is WSM information from RSU or OBU. Second type is picture captured by the built-in camera in other PND. To achieve these functions, we designed software architecture on PND as Fig. 7.

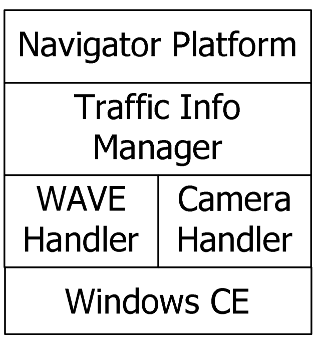

Figure 7. The architecture of software on PND.

Our PND is Windows CE[11] based system. Following are functional modules of this system.

1) Navigator platform: This platform can provide navigation service to driver. The platform can show traffic information or alert picture on the navigation map. It also allow driver to arise an alert and send it to other vehicles. This navigator platform use Windows IPC[12] to communicate with the Traffic Info Manager module described bellow.

2) Traffic Info Manager: The traffic info manager receives information sent from WAVE handler and drops the re-sent information which has been received already. Whenever driver arises an alert displayed on the screen of navigator platform, the traffic info manager handles it and sends it out through WAVE handler module. While dealing with alert information, traffic info manager could drive the camera module to capture alert picture at the same time. The navigator platform only displays the traffic information that maintained by traffic info manager.

3) Camera module: During EAS scenario, the camera module is responsible for taking picture while traffic info manager needs to capture picture of an alert. This camera is a built-in module in PND.

4) WAVE Handler: The WAVE handler deals with the WAVE interface. Traffic info manager can send and receive UDP packets which is converted to WSM in WAVE-BOX through this interface.

D. *Traffic information format*

In this section we define the format of all traffic information string in our system. The data format of our information string is defined as Fig. 8.

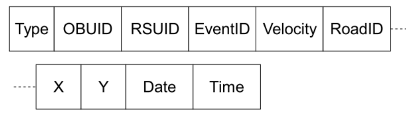

Figure 8. Traffic information format in air.

The description of traffic information format is stated below:

1) Type: It indicates the type of information. The size is 1 byte. Our traffic information can be divided into three types: (1) LTS traffic information which is provided by LTS. (2) V2V alert traffic information which provided by other vehicle. (3) Probe data which provided by all OBU on vehicles.

2) OBUID: It indicates the ID of OBU. Every OBU has a unique ID. Type of this is an integer.

3) RSUID: It indicates the ID of RSU. Every RSU has a unique ID. Type of this is an integer.

4) EventID: The traffic event ID indicates a specified traffic event information. Type of this is an integer.

5) Velocity: It indicates the driving speed of vehicle. This information field is created only in probe data. Type of this is an integer.

6) RoadID: It indicates the GIS location ID of road. We can use this ID to show where the traffic event occurred. Type of this is an integer.

7) X: GIS Longitudinal coordinate which the event exactly occurred. Type of this is a float.

8) Y: GIS Latitudinal coordinate which the event exactly occurred. Type of this is a float.

9) Date: It indicates the date of this information. The type is YYYY-MM-DD.

10) Time: It indicates the time of this information. The type is HH:MM:SS.

III. CONGESTION AVOIDANCE SYSTEM (CAS)

In this section, we introduce about Congestion Avoidance System (CAS). In this scenario, drivers can get traffic information about cars congestion event on the road, thus are able to avoid congestion event by simply changing their driving path.

A. local traffic information processing

We first explain how RSU sends local traffic information to vehicle and collects probe data from vehicles. The traffic information in LTS server is provided by probe data of vehicles. The data flow of local traffic information processing is shown in Fig. 9.

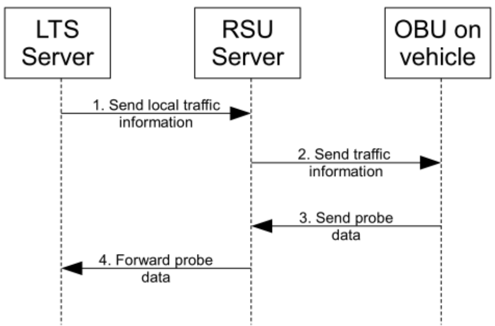

Figure 9. Local traffic information processing flow.

Fig. 9 shows how an OBU receives information from RSU and LTS, and how to send probe data to RSU and LTS. Following is operations during this processing:

1) Send local traffic information from LTS to RSU: LTS sends local traffic information of a specified area to some RSU. The data link between LTS and RSU is shown in Fig. 1. LTS sends traffic information to RSU while getting new information from infrastructure network or probe data.

2) Send traffic information from RSU to OBU: RSU broadcasts all traffic information by WAVE/DSRC technology. The time interval between information is one second in our system. When a vehicle approaches a RSU, OBU can receive all of the traffic information and display the traffic information on the front screen of PND to driver.

3) Send probe data from OBU to RSU: After receiving traffic information from RSU, OBU sends probe data to RSU immediately. The probe data contains the speed and location of this vehicle.

4) Forward probe data from RSU to LTS: After receiving probe data from vehicle, RSU forwards this data to LTS server immediately. RSU just pass the data to LTS without any processing. This probe data can help LTS server to produce local traffic information such as a traffic jam at a crossroad within the region nearby.

B. CAS DEMO scenario

The demonstration scenario in the crossroads of congestion avoidance system (CAS) is shown in Fig. 10.

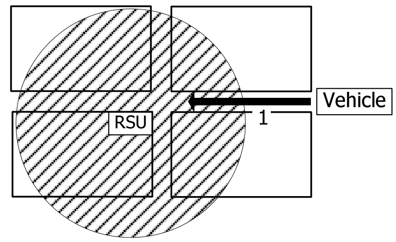

Figure 10. CAS demonstration scenario.

In Fig. 10 arrow 1, A vehicle with 50~60km/hr speed is going into the effective radio coverage (about 250 meters) of a RSU. Within the coverage of RSU, OBU on vehicle can receive local traffic information such as congestion at the next two crossroads. After receiving this traffic information on the navigator platform, the driver of this vehicle can avoid that congestion by bypassing this crossroads in advance. The traffic information displayed on navigator platform is shown in Fig. 11.

Figure 11. Traffic congestion information on navigator platform.

The navigator platform also shows other two traffic information which occurred on VICTORS WAY in Fig. 11. Each triangle icon shows there is a different kind of accident occurred at that position.

IV. EMERGENCY ALERT SYSTEM (EAS)

In this section, we introduce Emergency Alert System (EAS). When the driver on sender vehicle A finds an accident, he (or she) can send an alert message to the vehicles nearby through WAVE short message (WSM). Once a vehicle B receives this message, the OBU on vehicle B can send request message immediately to request a picture of this accident. The OBU on the vehicle A receives request message and captures picture of this accident. The OBU on the vehicle A then sends the picture to the OBU on the requester vehicle B. The details of these two operations are described below.

A. Send alert information processing

The data flow of sending alert message is shown in Fig. 12.

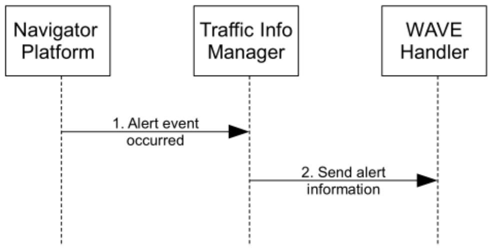

Figure 12. Flow of sending alert information.

1) Alert event occurred: When driver on the vehicle A finds an accident occurred, he can push an icon on the screen of navigator platform.

2) Send alert information: When the traffic info manager on the vehicle A receives this alert, it will produce alert information and send this alert out. The information of this alert contains the position of vehicle A. When other vehicle (e.g. vehicle B) receives the alert message, An alert icon will be shown at the position of vehicle A on navigator platform . After receiving this alert message, traffic info manager of vehicle B will send picture request message to vehicle A in order to get alert picture.

B. Request accident picture processing

Data flow of accident picture processing is shown in Fig. 13.

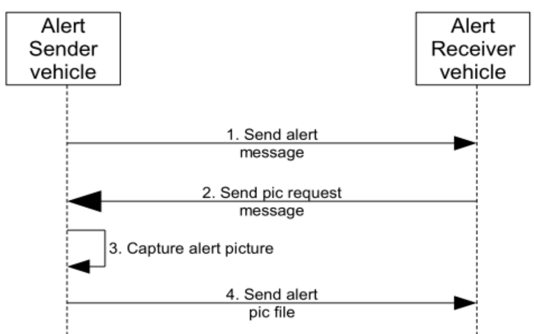

Figure 13. Flow of accident picture processing.

Fig. 13 shows how receiver vehicle (B) can get the accident alert picture from alert sender vehicle (A). We introduce operations during this processing in the following:

1) Send alert message: The driver of alert sender vehicle (A) sends an alert message out while finding an accident occurred. The alert receiver vehicle (B) will receive an alert message.

2) Send pic request message: After received alert message from nearby alert sender (A), the program on PND of vehicle B will send the pic request message to request this accident picture. This request message contains OBU ID of vehicle B.

3) Capture alert picture: The Traffic info manager on the alert sender vehicle (A) will use camera module to capture alert picture after receiving a pic request from vehicle B. There is a camera module in the PND and it can capture alert picture. After capturing, OBU on vehicle A will send this picture to the alert receiver vehicle (B) in next operation step. This picture is saved in JPEG format.

4) Send alert pic file: After capturing and saving alert picture file, OBU on vehicle A will send it to the alert receiver vehicle (B). We use WSM to transmit this picture file directly. When the transmitting operation is complete, the driver in the alert receiver vehicle (B) can see this picture on the screen of navigator platform.

C. EAS DEMO scenario

We also demonstrate the Emergency Alert System (EAS) in CVPC Dec. 3-5, 2008. We combined EAS with CAS scenarios. Thus we demonstrated EAS scenario just after CAS scenario. The demonstration environment of EAS is shown in Fig. 14.

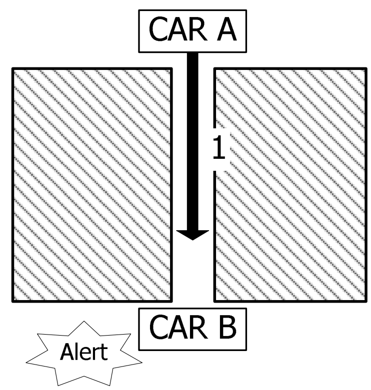

Figure 14. EAS DEMO scenario.

When CAR A approach CAR B by arrow 1 in Fig. 14, the driver on CAR A will see the alert information which comes from the CAR B through WAVE/DSRC. After driver on CAR A found this alert, he realizes that there is an alert condition occurred. He can avoid it by changing to drive in other way or slowing down. He can touch the triangular icon of this alert to see the alert picture. The screen on navigator platform is shown in Fig. 15.

Figure 15. Alert information shown on navigator platform.

Fig. 15 shows an alert information on navigator platform. Alert information is shown by a red triangle icon with an exclamation mark on the map. When drivers push this icon, they will see the description about this alert information as Fig. 16.

Figure 16. Alert information description shown on navigator platform.

After pushing the "Photo" button on the below right of navigator platform, driver can see the alert picture as Fig. 17.

Figure 17. Alert picture shown on navigator platform.

Fig. 17 shows the received alert picture. Driver can see this picture and be notified of the current situation. The image is a small jpeg file. The size of this jpeg file is about 7~8Kbytes that can be transfer in less than 10 wsmp packets which the max size of a wsmp packet is 1024 bytes. This feature should using the SCH to achieve. In the future we will implement streaming feature like this using SCH.

V. CONCLUSION

We have demonstrated two scenarios for the application of WAVE/DSRC system. One is CAS and the other is EAS. The driver can get traffic information in CAS scenario. The driver can also get alert information and picture in EAS scenario. In this paper, we also introduce our system architecture, design and equipments. Telematics technology is well designed to improve safety and efficiency of driving.

VI. FUTURE WORKS

In the future, we'll test packet transportation capability in dynamic mode. The original static test will be executed with vehicle speed as 50km/hr to 100km/hr. We also want to extend the sensitive range of WAVE/DSRC signal from 200 meter (now) to 500 meter. The delay time of WSM transportation and total reaction time in every demonstration scenario will also be measured and reported in the future.

We will focus on group management of vehicles and research on how to communicate with much more vehicles. We also try to combine with different kinds of networks to provide more useful services.

In our system design, there could be many vehicles receiving alert messages simultaneously. This processing could have a huge amount of data transmitted at a short period of time. We will try to improve performance of this process in the future.

We also notice a problem that when a message packet is lost during transfer, WAVE/DSRC has problem for recovering it. So we need a reliable data transfer scheme which will be developed in the future.

REFERENCES

[1] IEEE 802.11p/D5.0 Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, November 2008

[2] IEEE P1609.1, Trial-Use Standard for WAVE-Resource Manager, October 2006

[3] IEEE P1609.2, Trial-Use Standard for WAVE-Security Services for Applications and Management Messages, July 2006

[4] IEEE P1609.3/D1.0, Draft Standard for WAVE-Networking Services, December 2008

[5] IEEE P1609.4/D1.0, Draft Standard for WAVE-Multi-channel Operation, December 2008

[6] ARIB TR-T16 Version 1.0, DEDICATED SHORT-RANGE COMMUNICATION SYSTEM TEST ITEMS AND CONDITIONS FOR MOBILE STATION COMPATIBILITY CONFORMATION, September 9th 2001

[7] ARIB TR-T17 Version 2.0, DSRC APPLICATION SUB-LAYER TEST ITEMS AND CONDITIONS FOR MOBILE STATION COMPATIBILITY CONFIRMATION, May 25, 2004

[8] ARIB STD-T75 Version 1.0, DEDICATED SHORT-RANGE COMMUNICATION SYSTEM, September 9th 2001

[9] ARIB STD-T88 Version 1.0, DSRC APPLICATION SUB-LAYER, May 25, 2004

[10] Jared Dulmage, Minko Tsai, Mike Fitz, Babak Daneshrad, "COTS-based DSRC Testbed for Rapid Algorithm Development, Implementation, and Test", Demonstrations of WiNTECH 2006 co-located with MobiCom 2006

[11] Windows CE, http://www.microsoft.com/windowsembedded/en-us/products/windowsce/default.mspx

[12] Windows IPC, http://msdn.microsoft.com/en-us/library/aa365574(VS.85).aspx

[13] IEEE 1609 Working Group, http://vii.path.berkeley.edu/1609_wave/

[14] Tsutomu Tsuboi, Jun Yamada, Naoki Yamauchi, Masato Hayashi, "Dual Receiver Communication System for DSRC," Future Generation Communication and Networking, vol. 1, no. 1, pp. 459-464, 2008 Second International Conference on Future Generation Communication and Networking, 2008.

[15] Hayashi, M.; Fukuzawa, S.; Ichikawa, H.; Kawato, T.; Yamada, J.; Tsuboi, T.; Matsui, S.; Maruyama, T., "Development of Vehicular Communication (WAVE) System for Safety Applications," Telecommunications, 2007. ITST '07. 7th International Conference on ITS , vol., no., pp.1-5, 6-8 June 2007

[16] J.M.H. Elmirghani, B. Badic, Y. Li, R. Liu, R. Mehmood, C. Wang, W. Xing, I.J. Garcia Zuazola1, and S. Jones, "IRIS: An Intelligent Radio-Fibre Telematics System," in Proc. 13th World Congr. & Exhi. on Intelligent Transport System & Services, London, UK, Oct. 2006.