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테스트베드상에서 WAVE기반 차량통신 시스템의 서비스 구현

조 웅*

Service Realization of WAVE based Vehicular Communication Systems in the Testbed

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요 약

차량통신은 IT기술과 차량산업을 결합한 대표적인 융합기술이다. WAVE 기술은 전 세계적으로 널리 채택되어 사용되어지고 있는 차량통신 표준이다. 본 논문에서는 WAVE 시스템 이용하여 실제 테스트베드상에서 구현한 서비스에 대해 소개한다. 먼저 전체적인 WAVE 시스템에 대해 간략히 살펴본 후 서비스를 구현하기 위한 테트스베드에 대해 소개하고, 테스트베드상에서 구현된 차량간통신 및 차량 기지국간통신을 이용한 다양한 응용 서비스에 대해 알아본다. 실제 응용 서비스의 구현을 바탕으로 하여 실제 시스템 구현에 필요한 사항 및 다른 분야와의 융합분야에 대해서도 논의한다.

ABSTRACT

Vehicular communication is one of representative convergence technology which combines information technology and vehicle industry. Wireless Access in Vehicular Environments (WAVE) technology is vehicular communication standard which is widely used in the world. In this paper, we introduce service realization of WAVE based vehicular communication systems in the practical testbed. We review the overall WAVE based systems in brief and introduce the testbed. Then, we investigate various applications using vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. Based on realization of systems, we discuss practical implementation issues and the convergence area of WAVE systems.

키워드

WAVE, Vehicular Communications, ITS, Application Services
WAVE, 차량통신, 지능형교통시스템, 응용 서비스

Ⅰ. Introduction

Vehicular communications provide various applications by combining information and communication technology (ICT) with road/vehicle industries, where the most representative applications are related to safety service as well as intelligent transportation systems (ITS). WAVE is a worldwide standard for vehicular communications. WAVE standard, which is referred as IEEE

802.11p, is modified version of IEEE 802.11 a/b/g, by defining the enhanced receiver sensitivity, sharp

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transmission spectrum, and increment of the maximum power. Transmission signal uses OFDM in 5.9GHz (5.835~5.925GHz) frequency band. Modulation scheme of IEEE 802.11 a/b/g and IEEE 802.11p is the same, whereas the former uses unlicensed band, i.e., ISM band, with 20MHz signal bandwidth, and the later uses licensed band with 10MHz signal bandwidth. For more details, we refer the reader to [1] and [2]. Using WAVE systems, some basic experimental measurement results are introduced in [3][4], where most of measurement results are based on simple performance test such as communication range, packet error rate (PER), link setup time, and latency.

In this paper, we introduce service realization of WAVE based vehicular communication systems, where the service is realized in the practical testbed. First, we overview the overall WAVE based communication systems. Then, the practical testbed and application services are introduced. Finally, we discuss implementation issues and the convergence areas based on the service applications.

Ⅱ. Overview of communication systems

The overall WAVE based vehicular communication systems consist of a mobile terminal, On-Board Equipment (OBE), Road Side Equipment (RSE), and ITS center/server. The mobile terminal displays information from the OBE. OBE and RSE are installed in a vehicle and road, respectively, and both OBE and RSE have the WAVE communication module which exchanges data each other. Some properties of communication module are specified in Table 1. Both OBE and RSE adopt IEEE 802.11p standard using 5.9GHz (5.835~5.855GHz) RF band. The data exchange is carried out via vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication. ITS center/server collects and manipulates data from RSE. To increase transmitter and receiver gain and transmit data reliably, omni antenna is used for both OBE and RSE, where the gain of antenna is approximately 8dBi, we use the same antenna for both OBE and RSE, and the antenna support max power of 1 Watt. Notice that the high antenna gain is achieved by sacrificing antenna beam width, i.e., the vertical beam width is approximately 15°± 2°.

Table. 1 Properties of communication module

Item	Specification
Frequency band	5.835~5.855GHz
RF output power	14dBm typical
Tx Spectrum mask	Class C
Receiver sensitivity	-85dBm with 3Mbps
Data rates	3, 4.5, 6, 9, 12, 18,24 27 Mbps
Processor	32bit MIPS 24K, 100MHz
Memory	8MB flash 32MB SDRAM DDR
MAC protocol	CSMA/CA
User data interface	10/100 Fast Ethernet
Management interface	Serial (UART)
Power	12V DC/3A

Ⅲ. Service Realization

Various applications can be realized with WAVE based communication systems, where most of applications are focusing on safety related services [5]. One of V2V applications is introduced in [6] and various safety related applications are realized and tested in several projects [7][8]. In this section, we first introduce testbed and then explain various realized services.

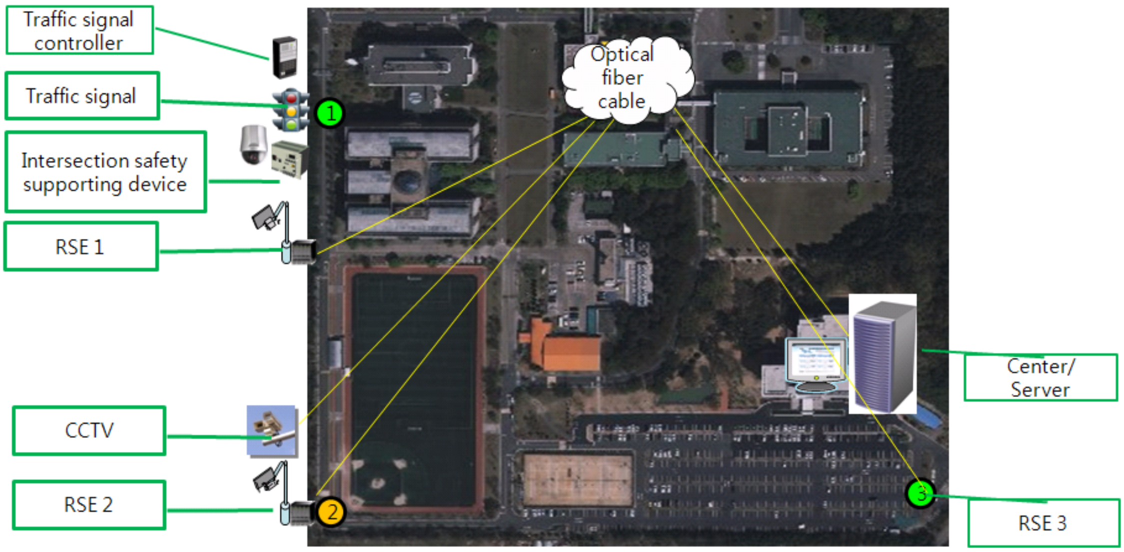

Fig. 1 Testbed of WAVE based vehicular communication systems

3.1 Testbed

Fig. 1 depicts the practical testbed using WAVE communication systems. We use 3 RSEs, and the distance between RSE and RSE is approximately 300m. Two vehicles are used for V2V communications. Each RSE and center/server is interconnected with optical fiber cable. At the location of RSE 1, we install a traffic signal, traffic signal controller, and intersection safety supporting device, which can be used for intersection safety service. At the location of RSE 2, CCTV is installed, which provides CCTV streaming service. Using the above mentioned testbed, we transmit data with 6Mbps where the modulation scheme adopts QPSK signaling. Since the distance between RSE and RSE is not so far away, approximately 12dBm EIRP (Equivalent Isotropically Radiated Power) is used for data transmission.

3.2 V2I services

Four V2I services are realized with the above testbed. Each service is working as the bellows.

Intersection safety supporting service : By locating 4 cameras at the each side of intersection, video information is provided to vehicle to support safety and protect an accident. Video information of vertical direction is transmitted to the vehicle which moves towards the horizontal direction, and vice versa.

Traffic light information service: When vehicles are stopped in the red light, the remaining time of traffic signal is transmitted to the vehicles. This service is provided by traffic signal and traffic signal controller. Fig. 2 shows an example of intersection safety supporting service and traffic light information service. Two upper pictures display the intersection information to the driver, and the right bottom picture shows the status of traffic light and remaining time of the corresponding signal.

Vehicle information collection and traffic information service: The electronic control unit (ECU) information of vehicles is collected with on board diagnostics-II (OBD-II), and this information is transmitted to server via RSE. Based on this

Fig. 2 Display example of intersection safety supporting service and traffic light information service.

information, the status of vehicle, drivers' driving habit, and traffic information of road are provided.

CCTV streaming service: When a vehicle moves toward RSE 2, RSE 2 provides the current road status using CCTV where CCTV is working on IP basis. This CCTV service is working only when a vehicle requests CCTV streaming data. With the similar operating principle, we can also provide wireless internet service by replacing CCTV with an access point.

3.2 V2V services

There are two V2V services in the above testbed. Although V2V services are provided regardless of vehicles' location, these services are realized in the testbed to demonstrate usability of V2V communication. It is worth mentioning that safety related services are more closely related to V2V communication than V2I communication.

Safety message service: When vehicles are moving and unexpected situations occurs due to emergent accident or obstacles, then the vehicles may cause sudden stop. This situation is transmitted from a front vehicle to the following vehicles in the form of safety messages.

V2V video transmission service: In this service, we equip an IP camera in each vehicle. Then, both vehicles can exchange video information using V2V communication, which is the same as peer-to-peer communication system. By applying multi-hop communications, we can transmit data to the remote vehicles.

In the above V2V services, the safety message service and V2V video transmission service are realized via broadcasting and unicasting, respectively. More detailed V2V operation is depicted in Fig. 3. In the safety message service, the sudden stop information of vehicle due to emergency status such as sudden stop of front vehicles/ abrupt obstacles or emergent severe weather condition is created in the ECU and this information is transmitted to the OBE. Then, OBE collects this data and transmits to other vehicles using antenna in the form of broadcasting or unicasting depending on the service types. This information is also displayed in the mobile terminal. At the receiver, the transmitted signal is received using antenna and delivered to the OBE. Then, the mobile terminal displays the received information using the data from OBE. Notice that ECU in Fig. 3 is replaced to IP camera for V2V video transmission service, and the video information is transmitted instead of safety messages.

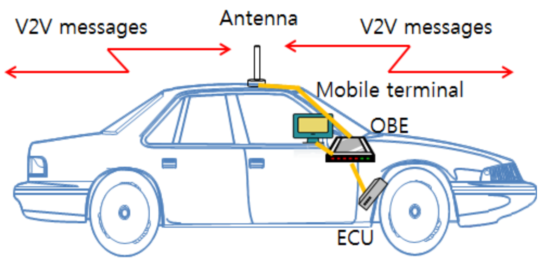

Fig. 3 V2V message transmission.

IV. Discussions

We showed some application services of WAVE based vehicular communication systems with empirical testbed. Based on the implementations in the testbed, it is observed that WAVE systems may support safety related services. However, to guarantee reliable communication services, some practical implementations issues are resolved as we indicated in [9].

There are two concerns regarding physical layer. The first one is the transmitted signal itself. In the realized systems, it is observed that the transmitted signal is not received at some specific location due to the property of RF signal. To solve this problem, we may use a relay, or we can adjust antenna pattern or the height of RSE antenna. Although this problem is directly related to physical phenomenon, it is critical to transmit signal without loss of any information. The other thing is antenna issues, i.e., location and beam pattern/gain, in vehicle. Antennas in vehicle is discussed in [10][11]. However, the antenna location for vehicular communication is not thoroughly investigated. In our implementation, the performance of communication system is somewhat different depending on the location of OBE's antenna. Although we did not consider the specific antennal location, it will be useful if we investigate the impact of antenna location in practical systems. In addition to the location of antenna, the antenna beam pattern is also critical to transmit signal by supporting reasonable antenna gain. There is tradeoff between the antenna gain and beam pattern. It will be very useful to find optimum antenna gain and beam pattern for vehicular communication especially in 5.9GHz band. By considering antenna location and beam pattern/gain simultaneously, we may provide more reliable vehicular communication links.

It is obvious that WAVE systems are one of convergence areas by combining ICT and road/vehicle industries. Besides this aspect, we can apply other areas with vehicular communications. For displaying text or video information, we use a commercial mobile terminal. However, this device may be not sufficient to support safe driving and safety related information simultaneously. It may be helpful to develop a mobile terminal which supports safety and information as well as economic satisfaction by focusing on before market. Another aspect is human machine interface (HMI) technology. In the services of this paper, we only consider the safety information which is generated by human reaction. By applying HMI technology, we may anticipate the humans' behavior in advance with human's reaction, i.e., by monitoring eye, movement of head or body continuously. Then, we can protect accident and support safe driving more efficiently, which results in the decrement of accident.

V. Conclusions

In this paper, we introduce WAVE based communication systems in the testbed. Practical implementations showed that various safety related applications can be supported by WAVE. Based on application results, we discussed some implementation issues. In addition, we suggest several convergence areas which can improve the safety level of vehicular communications. In the future work, we may provide more reliable vehicular communication links by considering the above mentioned relay and antenna issues based on practical implementation in the testbed. We may also extend convergence areas by applying HMI technology with vehicular communications, which creates various safety related services.

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References

[1] IEEE Std 802.11, IEEE standard for information technology-telecommunications and information exchange between systems-local and metropolitan area network-specific requirement, Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications, 2007.

[2] IEEE Std 802.11p, IEEE standard for information technology – telecommunications and information exchange between systems - local and metropolitan area networks - specific requirements, Part 11, Amendment 6 : Wireless Access in Vehicular Environments, 2010.

[3] W. Cho, H. S. Oh and B. J. Park, "Wireless access technologies for smart highway: requirements and preliminary results", The Journal of The Institute of Webcasting, Internet and Telecommunication, Vol. 11, No. 2, pp. 237-243, 2011.

[4] W. Cho, "Usage of RSSI in WAVE handover", The Journal of The Korea Institute of Electronic Communication Sciences, Vol. 7, No. 6, pp. 1449-1454, 2012.

[5] The CAMP Vehicle Safety Communications Consortium, Vehicle Safety Communications Project Task 3 Final Report, U.S. Department of Transportation, 2005.

[6] W. Cho, K-S. Han, H. Y. Cho, and H. S. Oh "Realization of anti-collision application using V2V communication" Proc. of Vehicular Networking Conference, pp. 1 – 5, 2009.

[7] M. Bauer, "Redefine business models as V2V and V2I converge", V2X for auto safety and mobility Europe, 2013, Feb, 2013.

[8] F. Ibrahim, "US trials, testbeds, impact in Europe", V2X for auto safety and mobility Europe, 2013, Feb, 2013.

[9] W. Cho, "Physical layer issues in vehicular communications", The Journal of The Korea Institute of Electronic Communication Sciences, Vol. 7, No. 5, pp. 1229-1234, 2012.

[10] S-J. Lee, J-H. Yoon, J-W. Lee, "Antenna design of mobile frequency band for vehicular application", The Journal of The Korea Institute of Electronic Communication Sciences, Vol. 6, No. 3, pp. 337-341, 2011.

[11] S-J. Lee, J-H. Yoon, J-W. Lee, "Construction and measurement of a T-DMB/GPS/Mobile Antenna for vehicular application", The Journal of The Korea Institute of Electronic Communication Sciences, Vol. 6, No. 5, pp. 629-636, 2011.

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