WAVE Communication Technology

Hyun Seo Oh, Sang Woo Lee, Woong Cho, Hyun Kyun Choi, Han Byeog Cho
Vehicle Networking Research Team, ETRI
Gajeong-no 138, Yusung-gu, Daejeon, Korea, hsoh5@etri.re.kr

Abstract

We introduce Vehicle Multi-hop Communication (VMC) project, which has a research goal to achieve vehicle to vehicle and vehicle to infrastructure communication technology for Smart Highway and vehicle safety. VMC provides seamless fast radio link between vehicle and infra system or among vehicles by applying for WAVE technology with handover. ETRI has developed on-board equipment (OBE) and road side equipment (RSE), intersection safety system (ISE) and server. Its radio performance has been evaluated by testing it in highway environments.

Keywords: WAVE, handover, Smart Highway

1. Introduction

Recently, V2V/V2I communication technology is highly recognized as a means to provide advanced ITS and vehicle safety applications. Its related projects have been actively studied in USA and European countries. WAVE technology is IEEE standard which consists of IEEE 802.11p and 1609 software stacks and its distinct features to support high mobility and low latency, and V2V communication capabilities. Thus it has unique features compared with the existing DSRC and WLAN, 2G/3G cellular system.

In 2007, ETRI has launched VMC project to achieve core technologies in V2V and V2I communication and has successfully developed WAVE based vehicle communication system and have tried field testing in highway environments. In this paper, we will introduce V2V/V2I communication system and its important features in detail, and discuss performance evaluation in terms of radio coverage and data rate, latency and handover in highway environments.

2. WAVE Communication Technology Development

ETRI have developed WAVE based vehicular communication system to provide vehicle to vehicle(V2V) and vehicle to infrastructure communication(V2I). WAVE based communication system consists of on-board equipment (OBE) and road-side equipment (RSE), additionally intersection safety equipment (ISE) and server system as shown in figure 1.

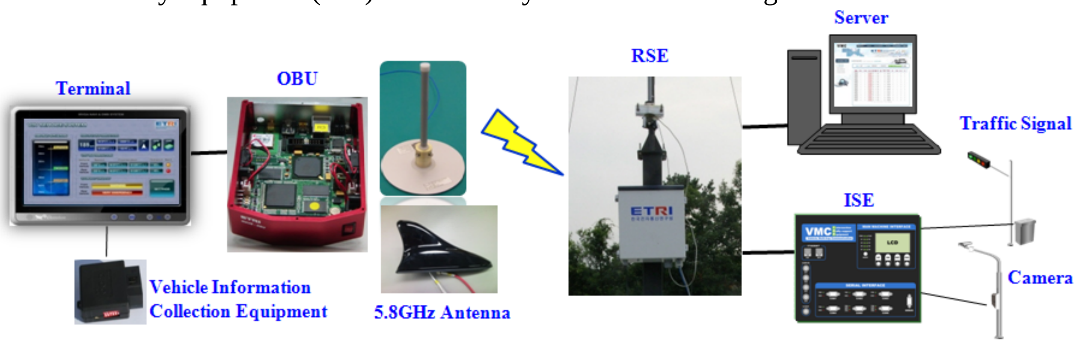

Figure 1: WAVE based vehicular communication system

OBE is vehicle mounted equipment which has UMPC (Universal Multi-purpose PC) and OBU(On-Board Unit). UMPC is used as service platform to implement V2V and V2I based applications. OBU is connected to UMPC via USB or Ethernet port, and RF signal is connected to roof mounted vehicle antenna. Vehicle Information Collection Equipment is connected to terminal to monitor ECU status of vehicle. RSE (Road Side Equipment) provide radio connection to OUB and wired connection to Sever and ISE which send traffic signal status and intersection situation by camera image. The radio access technology as shown in table 1 provides 27 Mbps data rate in

10MHz channel spacing and supports both IP packet and WSMP packet between OBU and RSE. Also handover technology to support seamless radio link is implemented by using RSSI based radio channel selection.

Table 1: Radio Access Specification

Item	Spec.
RF frequency	5.835~5.895GHz
RF power	Maximum 23 dBm
Channel bandwidth	10MHz
Modulation	OFDM(BPSK, QPSK,16QAM, 64QAM)
Data rate	3,4.5,6,9,12,18,24,27Mbps
MAC	CSMA/CA(optional: time slot based CSMA/CA)
Networking protocol	IPv4, WSMP(WAVE safety message protocol)
Handover	RSSI based channel selection

OBU and RSE has V2V/V2I communication module which consist of MODEM and MAC, and routing functionality. And it basically meets IEEE 802.11p and 1609.3 & 4 standard. Modem and MAC hardware function are implemented by FPGA and MAC and routing are implemented by ARM processor. OBE configuration is shown in Figure 2 and its important features are as follows.

- *Processor : ARM 940T CPU*
- *OS : Nucleus real-time OS*
- *Synchronization : GPS time (GPS module included)*
- *12 Volt power supply*
- *External Interface : USB, RJ45 Ethernet, RS232C x 2 port*

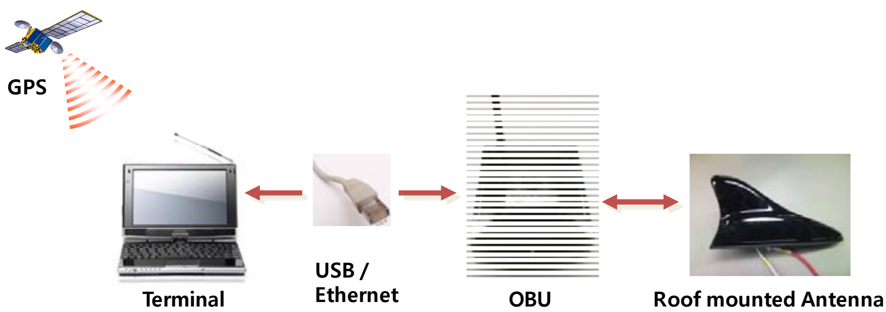

Figure 2: OBE system configuration in vehicle part

RSE has the same functions as OBU except for server networking. IPv4 protocol is used for server networking and 10 dBi directional patch or omni-directional antenna may be used for RSE. ISE has built in 4 cameras to monitor the road situation in the intersection area and moving image from ISE is transferred to RSE, and to OBE via 5.8 GHz radio. Moving image of OBE will be informed to vehicle driver to recognize the approaching left and right road situation in intersection road.

3. Performance Test in Highway Environments

WAVE based communication system has been tested in laboratory and outdoor highway test road in high speed driving environment since 2008. We have tested radio coverage and data rate, and packet latency in highway driving condition as a measure of performance. 5 OBEs and one RSE are used to measure the performance in vehicle to vehicle communication and vehicle to infrastructure communication.

- Radio Coverage

  Radio coverage is the maximum radio range to be able to transfer the packet between the transmitter and the receiver. WAVE is able to support 3, 4.5, 6,9,12,18,24,27 Mbps data transmission and more SNR is needed as data rate is increased. Maximum data rate is about 1 km in case of BPSK modulation(3Mbps) and

QPSK modulation (6Mbps), 500m in case of 16QAM (12Mbps) , several ten meters in case of 64QAM modulation (27Mbps). Radio coverage is highly related to modulation orders because high order modulation needs higher SNR value than low order modulation.

- Data Rate

Data rate depends on vehicle mobility and interferences. 16QAM (12Mbps) is the highest modulation to be used in high mobility environments and 27 QAM (27Mbps) may be used at fixed condition. As the numbers of user are increased, the user data rate is linearly decreased. We tested user data excluding packet overhead for 32 user activation. According to testing, the average data rate is 50~60% of maximum data rate due to packet overhead. For example, the average data of 16QAM is 6~9Mbps for unicasting and broadcasting.

- Packet Latency

Packet latency is a processing time or time delay which packet will be delivered from the transmitter to the receiver. We added loop function mode which the received packet will be re-transmitted without packet reception. The packet latency is several milliseconds in single user. However, packet latency will be increased as the users are increased.

- Handover

WAVE communication technology has a hot spot concept as like WLAN. Smart Highway needs a seamless radio link between OBE to RSE. We developed fast handover technology to support seamless radio link, which OBE scans two radio channels in adjacent RSEs and switches the new radio channels by comparing the received signal levels. We installed five RSEs in highway and verified WAVE handover technology. And handover time is negligible because GPS time is used for synchronization.

4. Conclusions

We have developed WAVE based communication system and verified its performance through field test. Specially, WAVE handover technology is new and important technology for ITS application. We expect this system will be commercialized in a near future and contribute a big growth in the future ITS and vehicle safety.

References

[1] "VMC Technology Development", research final report, ETRI, Feb., 2011.

Acknowledgments

This work has been supported by IT R&D Program of MKE/KEIT [2007-F-037-01, Vehicle Multi-hop Communication (VMC) Technology Development]