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Performance analysis of WAVE communication under high-speed driving☆

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Abstract

Although WAVE (Wireless Access in Vehicular Environments) is a technology designed for the high-speed mobile environments, WAVE communication performance in a real road environment is highly dependent on the surrounding environments such as moving vehicles, road shape, and topography. In particular, when a vehicle moves at high speed, the location of the vehicle and its proximity to the road-side device are rapidly changed and thus affect communication performance. Accordingly, we build a performance evaluation system based on the WAVE-LTE network cooperative operation. We also analyzed the performance differences based on external environmental factors, such as information volume and velocity, from the data acquired through actual vehicle tests.

Keywords: ITS; IEEE 802.11p; WAVE; LTE; Performance test

1. Introduction

Traffic accidents that occur frequently on the road have become a serious social problem. Table 1 shows a report from the U.S. Department of Transportation in 2015. According to the report, the number of fatal crashes increased by 7% from 2014 to 2015. Furthermore, the number of total crashes increased by 3.8% [1,2]. According to studies, the cause of traffic accident can be divided into human, vehicle, and environment factors. The traffic accidents are mostly caused by a human carelessness such as smartphone use, drinking, drowsiness, and taking drugs. However, these human factors cannot be eliminated easily through driver safety training [3].

In many countries, research institutes, and companies are working to reduce them by using various methods and techniques. In particular, the C-ITS (Cooperative-Intelligent Transport Systems) integrates the advanced technologies such as ICT and sensor technology with components of the transportation system such as vehicles, roads, and pedestrians. Further, it provides a real-time traffic information and services to drivers via a vehicle-centered network. In this context, V2X (vehicle-to-everything) technology for enhancing stability and convenience has come under the spotlight. Most of the developed vehicular communication technologies are based on WAVE standard [4]. As in the general communication systems, WAVE also has limited overall communication capacity and uses the frequency band of 5.9 GHz. The straightness of radio waves is strong. Because of its characteristics. In the road environment, there are always obstacles of various sizes (vehicles, road facilities, road shapes, and terrain, etc.) around the communication device. It is difficult to ensure LOS (line-of-sight) communication. Thus signal distortion and signal output attenuation can occur frequently. However, most V2X services provide services requiring strict real-time properties such as forward collision warning, road safety service, and emergency stop. It is necessary to send all V2X messages with a probability of 99.999%. About 1600 bytes of a message must be transferred

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Table 1
Number of Police-Report crashes, by crash severity.

Type	2014	2015	Change	%change
Fatal crashes	30,056	32,166	+2,110	+7%
Non-fatal crashes	6,034,000	6,264,000	+230,000	+3.8%
Total crashes	6,064,000	6,296,000	+232,000	+3.8%

with ensuring an end-to-end waiting time of less than 5 ms. Relative speeds of up to 500 km/h should be supported in highway environments. Each service can have various transport parameters depending on service requirements and amount of information. Therefore, to implement the V2X service on the actual road, it is necessary to grasp the communication characteristics and limits according to the transmission parameters on the road. In particular, WAVE is a technology designed for high-speed mobile environments. However, when the vehicle moves at high-speed, the surrounding environment rapidly changes according to the speed of the vehicle. Since this change affects the communication performance, various performance tests of the actual vehicle environment are necessary to provide a highly reliable communication service by applying them to the actual road environment [5–7].

Owing to its high cost and time consumption, the performance test of V2X was substituted with simulations in most of previous studies. Moreover, these experiments were conducted in stationary vehicles, not considering the effect of speed in actual measurements. Therefore, this method does not fully reflect the actual situation.

In this research, we built a test bed for effective performance testing in a high-speed running environment, to analyze factors affecting V2X communication performance. In addition, communication characteristics according to changes in communication parameters (data rate, packet size, velocity) were measured through actual vehicle tests and the communication delay, communication distance, success rate of transmitted packets, and RSSI (Received Signal Strength Indicator) are analyzed.

2. Test bed

To construct a high reliable performance measurement system, a few things are to be considered when sending test results to the server. IEEE 802.11p limits the amount of data transfer and is a disadvantage in that as the network load increases, the throughput degradation speeds up rapidly. Therefore, when sending the test results to the server through WAVE, packet loss and transmission delay can occur, which can affect the results of the performance analysis.

Fig. 1 shows the network topology of the V2X performance measurement system. This network topology distributes the communication load and guarantees a reliable data transmission through the WAVE-LTE network cooperative operation [8]. This system consists of the analysis server, RSU (Road-Side Unit), and OBU (On-Board Unit). Because the RSU is a fixed infrastructure, Ethernet is used as the communication interface with the server. Because the OBU is installed in the vehicle, problems such as IEEE 802.11p can occur when using wireless LAN. Therefore we used LTE for more accurate performance analysis. The analysis server notifies the start and end of the test and monitors and records the measured performance test results. The server can control the test scenarios of RSUs and OBUs through Ethernet and LTE. It collects the test results and provides the performance analysis result using the GPS (Global Positioning System) in real time.

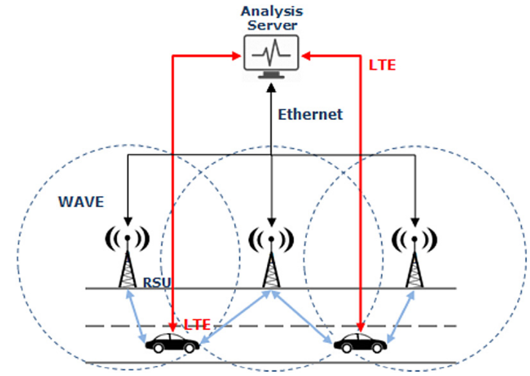

Fig. 1. Network topology.

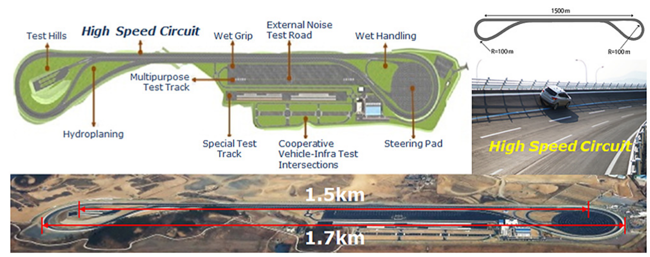

Fig. 2. ITS high-speed circuit of KIAPI.

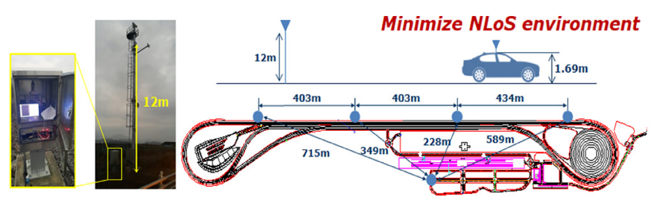

Fig. 3. RSU installed on the road side.

Performance tests should be executed at faster speeds, like speeds on an expressway. Therefore we built a V2X performance measurement system on KIAPI (Korea Intelligent Automotive Parts Promotion Institute)'s ITS high-speed circuit in Daegu, Korea. Fig. 2 shows the KIAPI ITS (Intelligent Transport Systems) high-speed circuit. a vehicle can maintain a steady speed of over 100 km/h on this circuit. This circuit is Autobahn simulation Open road with guaranteed LOS and Minimized multipath fading.

In the performance measurement system, the installation position of the communication module and the antenna are important factors that affect the communication performance. As shown in Fig. 3, the RSU is installed at about 12 m from the ground to ensure LOS with the OBU. The network is designed to minimize NLoS (Non-Line-of-Sight) environment with the