

A Performance Evaluation of Cellular Network Suitability for VANET

Ho-Yeon Kim, Dong-Min Kang, Jun-Ho Lee, Tai-Myoung Chung

Abstract—Recently, a vehicular ad-hoc networks(VANETs) for Intelligent Transport System(ITS) have become able to provide the safety and convenience services surpassing the simple services such as an electronic toll collection system. To provide the proper services, VANET needs infrastructure over the country and to build a new infrastructure. Thus, we have to spend a huge sum of money, time, and human resources. In this reason, several studies have been made on the usage of cellular networks instead of new protocols. The purpose of this study is to assess a performance evaluation of the suitability of cellular network for VANET. In this paper, the result of a drive testing for the suitability of cellular networks for VANET is presented. In an experiment, The LTE(Long Term Evolution) of cellular networks was found to be most suitable among the others cellular networks.

Keywords—Vehicle communication, VANET, Cellular network

I. INTRODUCTION

THESE days, a vehicle can communicate with another vehicle and infrastructure by the dramatic development of hardware and IT convergence. These communications are able to provide an entertainment services, conveniences, and safety for drivers.

Typically, VANET is composed of Vehicle-to-Infrastructure (V2I) communication and Vehicle-to-Vehicle (V2V) communication. To use V2I communication, a Road Side Units (RSUs) must be installed. With RSUs such as 802.11 access point, vehicles can access the data stored in the RSU or even access the Internet through these RSUs [1]. However, we have to spend an enormous amount of money, times, and human resources to build a new infrastructure. In this reason, several studies have been made on the usage of cellular networks instead of new protocols [2][3]. In this paper, we perform a suitability of cellular networks for VANET through the drive testing. The rest of the paper is organized as follows. Section II introduces previous relevant works, including trend of standards for VANET, VANET components, and overview of the Wireless telecommunication technologies.

In Section III, we explain a test environment and the element of performance evaluation and discuss about the result of drive testing. Finally, we conclude this paper and introduce our future works in Section IV.

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II. RELEVANT WORKS

A. Trend of Standards for VANET

The standards organizations had been proceeding the protocol for standardized VANET. Also some countries have studied and experimented for the commercialization of VANET [4].

ISO TC204 WG16 CALM (Continues Air interfaces-Long and Medium range) is a working group for ITS. This standard is able to use the existing cellular networks, such as Wireless LAN, Dedicated Short Range Communication (DSRC), WiMAX, and etc., in VANET [5].

ETS TC ITS (European Telecommunications Standards Institute Technical Committee ITS) is organized for ITS. It consists of 700 companies and 60 countries. Telecommunication technologies have been studied and developed by the committee for V2X(Vehicle-to-Infrastructure /Vehicle/ Nomadic)[6].

WAVE (Wireless Access for Vehicle Environment) is a protocol for ITS. It is based on American Society for Testing and Materials DSRC (ASTM DSRC). This protocol combined IEEE 802.11p and IEEE 1609 into WAVE in 2004. It was completed in April 2010 and was republished in August 2011[7]. WAVE is designed to specialized VANET. Thus it provides an ad hoc mode, mobility, and high-speed data rate. A national program has been developed with the development of VANET standardization. According to the Department of Transportation in United States of America, new infrastructure will be available with a plan for ITS, it is called ITS 5 years, through a field of test in 2013. In addition, the Korean Government scheduled to construct new infrastructure for ITS until 2014 under the name of smart highway program.

B. VANET Components

Typical VANET components are as Figure 1.

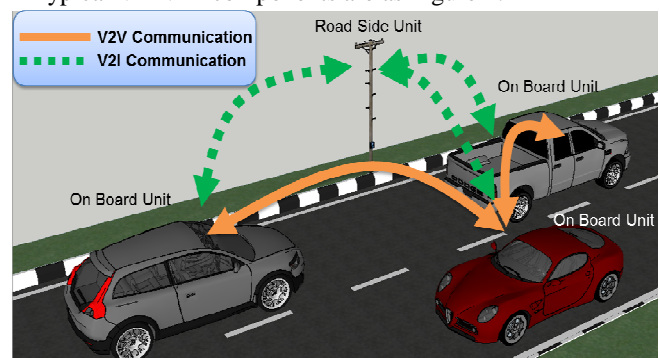


Fig. 1 Typical components of VANET

1) Components

i. OBUs(On Board Units)

OBU is one of VANET components. It is a communications modules that provides a communication network for inter-vehicle and between vehicle and infrastructure.

ii. RSUs(Road Side Units)

RSU is a communication device. Typically, RSU is installed on the road side. RSU sends a non-safety message mostly that is driver-friendly information such as traffic information, authentication messages, multimedia messages, and etc.

2) Message Types

VANET offers two types of messages. The Table I shows the type of messages[8].

TABLE I

TYPE OF SAFETY MESSAGE AND NON-SAFETY MESSAGE

Safety Message	Non-safety message
Emergency vehicle approach warning	Multimedia downloading
Intersection collision warning	Software update
Pre-crash warning	Information of Traffic jam
Slow Vehicle Warning	Danger area warning

The safety message includes an emergency message such as emergency vehicle approach warning, pre-crash warning. This message requires the short delay unlike the non-safety message because it is a matter of emergency. When the vehicle receives safety messages, it should respond to the messages quickly. Typically, the safety message is received by the vehicles around through V2V communications. However, if the safety message is required stored information in infrastructure, the safety message not only uses V2V communication, but also uses V2I communications.

The non-safety messages are convenience messages for drivers. They include multimedia information, software upgrade message, and information of traffic jam on the route. These messages are large data typically. Therefore, the non-safety message is required throughput unlike the safety message.

3) Communication Types

i. V2I Communication

V2I communication is transmission mode between infrastructure and vehicle. It includes both safety messages and non-safety messages.

ii. V2V Communication

V2V communication is used for sending an emergency message. When an accident is occurred, each vehicle transmits safety messages via V2V communications to warn other vehicles in the roadway. In special cases, the V2V communication is used for sending non-safety messages. For instance, B. Shrestha et al. studied that transmission method for receiving a received non-safety message from the RSU forwards that to the vehicles around through Bit Torrent kind of P2P(Peer-to-Peer) protocol by V2V communications[9].

C. Overview of the Wireless telecommunication technologies

VANET can use a variety of wireless telecommunication

technologies that guarantee mobility and seamless connection. Hence, in this section, we need to consider of suitability the existing wireless technologies.

1) WLAN (Wireless Local Area Network)

The advantage of WLAN(802.11n) are that hardware is cheap and has excellent infrastructure. WLAN has already been proved to satisfy V2I and V2V communications[10]. However, an early study did not consider the environment for many vehicles. This technology is applied to some high technologies such as a Multiple-Input Multiple-Output. Therefore WLAN guarantees a high transmission rate(600Mbps). However, in this case, WLAN needs 40MHz frequency bandwidth and if WLAN is applied to a cryptography, such as Wi-Fi Protected Access(WPA) or WPA Temporal Key Integrity Protocol(WPA TKIP), then it cannot guarantee the same rate of 600Mbps. In this case, WLAN operates at a low throughput rate as 802.11g mode. Furthermore, session time is extremely increased.

2) Cellular Networks

As discussed above, VANET requires an environment for many vehicles. Accordingly, we can consider the usage of cellular networks. Cellular networks provide mobility and infrastructure has already been constructed over the country. Recently, scientists and developers have made great advances in cellular networks that are able to speed up the throughput rate[11].

The cellular networks can be divided into generations. Third generation mobile telecommunications(3G) is standardized by International Telecommunications Union(ITU) in 1999. 3G provides not only voice communication but also high rate data communication. There are many kinds of 3G technologies such as International Mobile Telecommunications-2000(ITM-2000), Code Division Multiple Access 2000(CDMA2000), Wideband Code Division Multiple Access(WCDMA), and etc. After WCDMA, advanced technologies have been adopted by 3G such as High Speed Uplink Packet Access based on WCDMA. However, the mobile carriers have changed to fourth generation mobile telecommunications(4G) to satisfy the fast-growing network traffic demands that arise from a user of diversification, multimedia service of propagation.

3) WAVE

In 1999, Federal Communication Commission allocated a 5.85GHz~5.925GHz frequency bandwidth for DSRC that is used for vehicle communication such as electronic fee collection[12]. IEEE defined a new standard called WAVE that is based on ASTM DSRC and consists of IEEE 802.11p and IEEE 1609.x.

WAVE uses concise connection methods and narrow frequency bandwidth to provide mobility and seamless connection. IEEE 802.11p uses a WAVE mode for association and authentication[13]. It can communicate randomly with Basic Service Set Identifier(BSSID). Therefore IEEE 802.11p able to construct WAVE BSS(WBSS) by received beacon message alone. In addition, IEEE 802.11p uses OFDM and 10MHz frequency bandwidth instead of 20MHz for reduction of frequency for selective fading and Doppler Effect.

The Table II shows the comparison of the IEEE 802.11n, High Speed Uplink Packet Access(HSUPA), LTE and WAVE. WAVE was specially produced for VANET. Therefore WAVE is most suitable to VANET among the other wireless communication technologies, however WAVE needs a huge sum of money, time, and human resources to construct new infrastructure. Hence, we discuss the usage of cellular networks instead of WAVE.

TABLE II
 COMPARISON OF THE IEEE 802.11N, HSUPA, LTE AND WAVE

	IEEE 802.11n	Cellular Networks		WAVE (IEEE 802.11p)
		3G (HSUPA)	4G (LTE)	
Bit Rate	600Mbps	14.4Mbps	75-300Mbps	3-27Mbps
Coverage Distance	250-1Km	> 1Km	> 1Km	300-1000M
Delay	< 250ms	<100ms	< 10ms	< 100ms

Vehicles can move faster than 200Km/h. Therefore, the communication time is very short between low speed cars or the fixed location RSU and high speed cars. Hence, VANET requires a short delay and wide coverage. As shown in Table II, WLAN, 3G, 4G, and WAVE satisfy the aspect coverage and bit rate of VANET standards. However, WLAN has a considerable delay up to 250ms that is increased more when the vehicle uses the cryptography. Therefore, we ignore WLAN on the drive testing and perform 3G and 4G that satisfy every aspect of VANET requirements in theory.

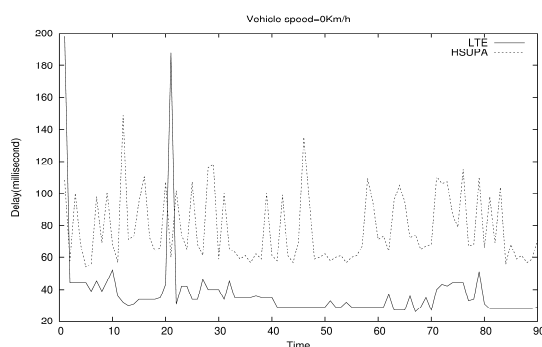


Fig. 2 3G(HSUPA) and 4G(LTE) Delay in 0Km/h

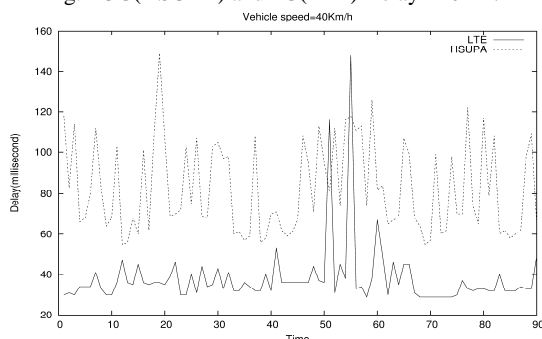


Fig. 3 G(HSUPA) and 4G(LTE) Delay in 40Km/h

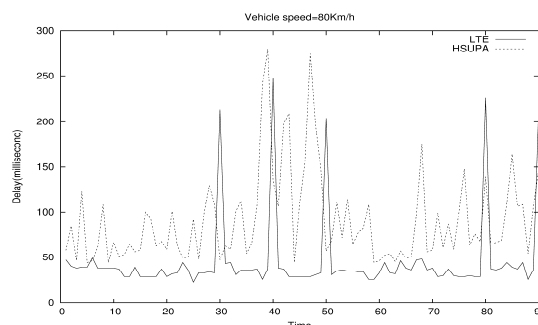


Fig. 4 3G(HSUPA) and 4G(LTE) Delay in 80Km/h

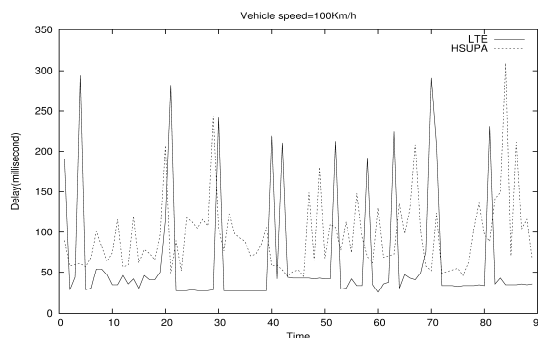


Fig. 5 3G(HSUPA) and 4G(LTE) Delay in 100Km/h

III. EVALUATION

As discussed in Section II, the important requirement is the delay in VANET. WAVE was specially produced for VANET. Therefore, WAVE is more suitable to VANET than any other wireless communication technologies. WAVE uses the WAVE mode for the short delay. However, 3G and 4G do not provide simple connection mode such as the WAVE mode or an ad hoc mode. Therefore, if cellular networks are used, the vehicle does not connect others' vehicle directly. Hence, the vehicle must be via RSU for the V2V communication. In this case, the delay will be more important, because this situation will result in a vehicle-to-infrastructure connection twice consecutively. Therefore, we perform a drive testing about the delay. The element of evaluation and the scenario are as follows:

A. The element of evaluation

The element of evaluation is the delay of every particular speed about 3G and 4G of cellular networks. Our drive testing checks the delay when the speed is 0Km/h, 40Km/h, 80Km/h, and 100Km/h using "PING". The ping is a program using an ICMP message. It checks the delay about the source-to-destination Round Trip Time(RTT). Therefore, this result was not a one-way delay. We perform the ping more than ninety times to get a reliable result. Additionally, we perform 3G(HSUPA) and 4G(LTE) at the same time, because we should consider a route

B. Scenario

1) Test bed

The Table III shows the test bed specifications. We use an android operating system for the drive testing. The 3G test bed uses a HSUPA technology and the 4G test bed uses a LTE. Also, two test beds operate the same mobile carrier.

TABLE III
 TEST BED SPECIFICATION

	3G	4G
Manufacturer	Samsung	Pantech
Model Name	SHW-M110S	IM-A800S
CPU	1GHz CPU	1.5GHz Dual Core CPU
RAM	512M	1G
Spectrum Bandwidth	2.1GHz	800MHz
OS Version	Android 2.2(Proyo)	Android 2.3(Gingerbread)

2) Test Area

A test area is Seoul in Republic of Korea where 3G and 4G networks have already been built. In this area, the 15Km drive testing is performed over the round trip in particular areas without high rise buildings at particular speeds.

C. Test Result

The Table IV shows HSUPA and LTE delay variations. As Figures 2, 3, 4, and 5 show, the delay increases abruptly when the speed of the vehicle is increased. The delay of 3G is increased to 2.6ms(3.6%), 9.6ms(11.1%), and 1.8ms(1%) according to the increased speed of the vehicle. The delay growth is 12.2ms(16%) between 0Km/h and 100Km/h. The delay of 4G is more fickle than that of 3G. The delay of 4G is increased to 1ms(2%), 7.2ms(19%), and 19.1ms(42%) according to the increased speed of the vehicle. The delay growth is 8.3ms(74%) between 0Km/h and 100Km/h. However, an average of the delay satisfies 100ms that is one of the requirements of VANET. It is suggested that 3G and 4G are suitable for VANET. However, we should remember that we used a Ping program that does not consider the operation time at the application layer. The operation time takes 20m. Thus, if we consider the operation time, such as the time for cryptography and signing a message, the 3G wireless telecommunication technology is not suitable for VANET.

TABLE IV
 HSUPA AND LTE DELAY VARIATION

Speed	4G(LTE)	3G(HSUPA)
0Km/h	36.7ms	80ms
40~50Km/h	37.7ms	82.6ms
80~90Km/h	45ms	92.2ms
100~110Km/h	64.1ms	94ms

D. The advantages and problems of LTE adoption for VANET

According to the result of the drive testing, LTE is most suitable for VANET. If LTE is used by VANET, we can gain some advantages due to the adoption of VANET.

Firstly, we can reduce the installation cost and advance the commercialization, because if we not use WAVE, we do not need RSU. Secondly, we are able to reduce the duplication of cost. Most manufacturers install a telecommunication module for calling and sending messages. If we use LTE, then, we cannot install unnecessary OBUs. Finally, LTE can be compatible with a LTE-Advanced, and if LTE-Advanced is commercialized, this network can be upgraded easily. However, friction can happen between the government, mobile carriers, and manufacturers. The network should evolve constantly, however the problem can happen in terms of the

network investment and management. Also, LTE cannot provide an ad hoc mode. Therefore, if LTE uses for VANET, V2V communications should be via the infrastructure. Therefore, WAVE and LTE will coexist for a certain period of time.

IV. CONCLUSION

In this paper, we performed a drive testing about the suitability of cellular networks for VANET. According to drive testing, the delay of LTE is 45.9ms that satisfies the requirement of VANET. Others cellular network technologies, such as HSUPA and WLAN, not satisfies to delay of requirements of VANET. Thus, LTE of cellular networks is most suitable among the other cellular networks for VAENT.

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