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PERFORMANCE EVALUATION OF HETEROGENEOUS VANET BASED ON SIMULATION

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Abstract

With the increasing demand for public and vehicle's safety on roads, vehicular ad-hoc network (VANET) has been widely studied in recent years. Many researchers have investigated the applicability of Long Term Evolution (LTE) to support vehicular applications even though IEEE 802.11p is regarded as a suitable wireless technology for VANET. In order to overcome the limitations faced by single wireless technology, we have considered heterogeneous VANET by integrating IEEE 802.11p and LTE technologies. These two wireless technologies are popular as they are widely used and easily available. We have done the performance evaluation by using an integrated simulation framework for heterogeneous VANETs called VEINS-LTE. The results show that integration of IEEE 802.11p and LTE is suitable for heterogeneous VANETs.

I. Introduction

With the advancement of mobile technology, most of the digital equipment is connected to the internet on the move. These days, people

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spend most of their time in vehicles. In order to make the time spent by the drivers in a vehicle more pleasant and improve road traffic safety, smart vehicles based on new technology known as Vehicular Ad-hoc Networks (VANETs) have emerged. The Intelligent Transportation System (ITS) has been developed for solving modern life transportation problems [1]. Many wireless technologies such as WiFi, WiMAX, LTE, IEEE 802.11p, etc. have been proposed for VANETs. Among them, IEEE 802.11p is the most promising wireless technology, but it has some limitations. The IEEE 802.11p might fail to cover dense urban areas due to numerous vehicles and limited coverage. Another potential candidate for VANET is Long Term Evolution (LTE) which is currently the most advanced and widely available technology. Even when LTE is used instead of WLAN, high frequency of messages might overload the network and packet delays might also increase [2]. In order to overcome these limitations, we consider heterogeneous vehicular ad-hoc networks where vehicles are equipped with IEEE 802.11p and LTE communication technologies. IEEE 802.11p can be used for Vehicle to Vehicle (V2V) communication, while LTE can be used for transferring non-safety messages to the internet servers. VANET can use eNodeB instead of Road Side Unit (RSU) which makes the deployment easy and quick as LTE has high market penetration.

There are mainly two types of applications used in VANETs namely safety and non-safety applications. Safety applications in VANETS are used to send safety messages, e.g. various warning messages that support vehicles on the road by delivering information so that proper action can be taken to prevent accidents and to save people from life-threatening situations. Safety messages include events such as road accidents, traffic jams, road construction, emergency vehicle warnings, etc. Vehicles broadcast a safety message to neighboring vehicles when they encounter accidents on the road [3]. These types of safety applications require low latency and high reliability. On the other hand, non-safety applications provide efficient and comfortable driving experience for the drivers. The non-safety applications are classified into two categories, i.e., traffic management and infotainment. Traffic management applications are used to improve traffic flow and congestion control. Infotainment applications are generally used for information and entertainment purposes, providing internet access to passengers such as storage of data, video streaming, video calling, avoid traffic congestion, etc. This type of application does not require high reliability and low latency as compared to the safety applications. In our scenario, 802.11p is used for safety messages, and other infotainment application such as video streaming is performed through cellular technologies based on LTE. In this paper, we discuss the integration of both the wireless technologies. We use VEINS-LTE for performance evaluation and extension module for VEINS which adds support to LTE for simulation [4].

II. Related Work

Vehicular ad-hoc network is in its early stage of implementation and there are still many ongoing researches to improve the VANET technology. Recently, many research consortium and standardization bodies have shown interest in adopting LTE technology to support VANET applications. In [5], the authors have surveyed the feasibility of LTE technology as well as studied a number of framework and prototype implementations in vehicular networks. In this regard, the literature found in [6] studies the feasibility of LTE technology for ITS. Trichias [6] has compared LTE with IEEE 802.11p standard. However, he had used two different platforms for the study without taking into account the implementation dissimilarities. Remy et al. [7] use eNodeBs of LTE networks as a cluster management infrastructure for the VANET. In [8], Sivaraj et al. assumed vehicles with multiple interfaces, which give IEEE 802.11p and cellular network connectivity. They proposed LTE technology assisted cluster-head selection and management protocols for the IEEE 802.11p based VANETs. Cavalcanti et al. [9] proposed a system which combines WLAN with cellular technologies and this technique has been adapted to be used in VANETs. Most of the protocols have shown considerable performance improvements over the use of single access technology for the vehicular networking. Further research needs to be carried out for the feasibility of coupling and taking advantages of both the wireless technologies.

III. Heterogeneous Vehicular Ad-hoc Networks

In this section, we discuss the integration of heterogeneous vehicular ad-hoc networks. It is difficult to provide suitable ITS services only through a single wireless network due to the high mobility of vehicles and the dynamic network topology of VANETs. Thus, by integrating different wireless technologies such as LTE and IEEE 802.11p, heterogeneous vehicular ad-hoc networks are expected to be a worthy platform that can meet several demanding communications requirements of VANETs.

(a) Problem definition

The IEEE 802.11p is widely considered as communication technology for VANETs. In VANETs, the advantage with 802.11p is that it is easy to deploy with low cost using ad-hoc support as compared to LTE networks. However, it has certain limitations in dense environments such as limited radio range, short time connectivity and scalability issues [10]. The main drawback of 802.11p wireless communication technology is limited coverage in urban areas. Also, the RSUs may not be available in some parts of the country during the initial stages of deployment of the vehicular communications infrastructure.

There have been recent studies on the applicability of LTE networks in ITS services. Some of the advantages of LTE networks include large coverage, high capacity, centralized architecture, high penetration in urban area. These support broadcast and multicast communication as well. However, LTE also has some limitation before it can be fully implemented in VANETs. The MAC layer in LTE lacks efficient scheduling mechanisms for a proper mapping of vehicular traffic features. LTE cannot handle a high frequency of vehicular messages [5]. Even when LTE handles a large number of safety applications, it might lead to a significant degradation of the service quality for cellular users, i.e., non-vehicular users.

(b) Motivation

LTE provides high uplink and downlink data rates and supports maximum mobility speed of 350km/h [11]. Thus, LTE is a potential candidate to support V2I communications in VANETs providing high capacity with wide coverage for heterogeneous VANETs. LTE and 802.11p have their own advantages and disadvantages. A single wireless communication technology cannot fully support ITS services in heavy load environment and dense urban areas. During initial deployment of heterogeneous VANETs, LTE can play an important role in supporting vehicular services. Hence, we are motivated to integrate LTE and 802.11p wireless technologies for future vehicular networks. When both the technologies are integrated in heterogeneous VANETs, they can supplement the advantages of each other.

IV. Simulation

We have used the VEINS-LTE [3] as a simulation tool for the performance evaluation of LTE and 802.11p heterogeneous VANETs. VEINS-LTE combines the features of Vehicles in Network Simulation (VEINS) [12], which is a network mobility framework with SimuLTE for LTE support [13]. The SimuLTE framework allows the simulation of LTE networks and offers a detailed model of complete LTE stack with some minor abstractions. VEINS-LTE couples OMNeT++ [14] with Simulation of Urban Mobility (SUMO) version 22 [15]. OMNeT++ is a discrete event-driven network simulator and SUMO is a mobility simulator for road traffic simulation. VEINS-LTE is an integration of VEINS and SimuLTE with dynamic vehicle mobility for heterogeneous VANETs. Figure 1 shows the heterogeneous network stack used in VEINS-LTE [3]. In the figure, there is a single decision maker, which decides the type of applications below the application layer. There are two stacks for LTE network and IEEE 802.11p network below the decision maker. Both of them have a special adaptation layer where additional information is added to the packets. If an LTE-NIC receives a packet over the air, it is forwarded to the application layer, and if IEEE 802.11p NIC receives the packet, then it is forwarded to application layer via decision maker through IEEE WAVE protocol.

We considered two scenarios (urban and highway) by varying parameters such as speed and vehicle densities to reflect diverse and realistic situation. The number of vehicles increases linearly with time from 0 s to 100 s. The average speed of vehicles varies from 40 km/h in an urban scenario to 110 km/h for highway scenarios. The key parameters considered in our simulation are summarized in Table 1. In our simulation, we use IEEE 802.11p for V2V communication to send warning messages to neighboring vehicles, whenever an accident occurs. We use an LTE network for video streaming as background traffic in heterogeneous VANETs. The eNodeB communicates with the server for video streaming as shown in Figure 2. We run the simulation by increasing the traffic density from free-flow traffic (five vehicles per square kilometer) to 50 vehicles/km^2. Figure 3 shows the impact of vehicle density on throughput. In case of 802.11p, as the density of vehicle increases, the throughput decreases due to the high speed of the vehicles for highway scenario. In case of LTE, the throughput decreases slightly with increase in the density of vehicles. However, there is no significant difference between highway and urban scenario, as shown in Figure 4. Hence, integration of both the technology does not significantly affect the throughput performance.

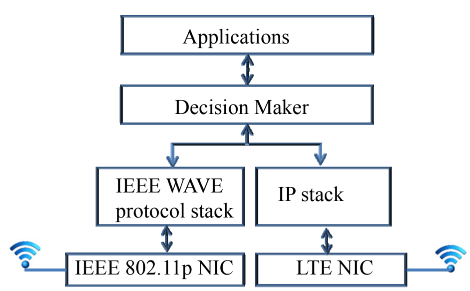

Figure 1. Protocol layers used in heterogeneous VANET.

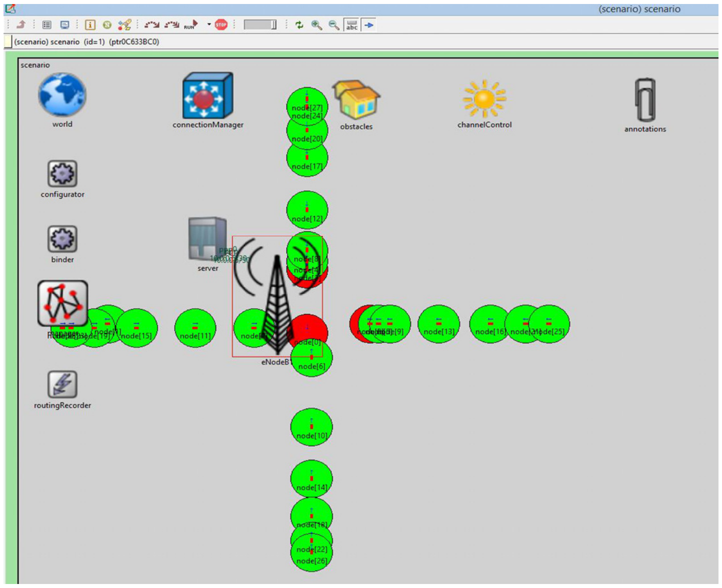

Figure 2. VEINS-LTE scenario in heterogeneous VANET.

Table 1. Simulation parameters and values

Simulation parameters	Values	
Network simulation package	OMNeT++	
Vehicular traffic generation tool	SUMO	
Simulation duration	100s	
Simulation area	20km x 20km	
Wireless protocol	IEEE 802.11p	LTE
Frequency	5.8 GHz	DL-2110MHz, UL-1710MHz
Transmission power	25dBm	UE(20dBm)/ eNB(45dBm)

The average delays of 802.11p and LTE are shown in Figure 5 and Figure 6. In case of 802.11p, the delay slightly increases with the increase in vehicle density in case of a highway due to high mobility of vehicles. Similarly, in case of LTE, there is no significant difference between the highway and urban scenarios. However, the delay slightly increases with the increase in the number of vehicles. We can observe that in both technologies, the delay is lower than 15ms which satisfies the requirement of most ITS warning and safety applications [15]. Hence, the performance evaluation results show that 802.11p gives better performance in terms of delay in urban scenario and LTE shows similar performance for highways and urban scenarios while integrating 802.11p and LTE wireless technologies for heterogeneous VANETs.

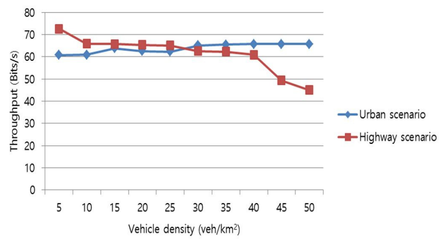

Figure 3. Throughput vs vehicle density in 802.11p.

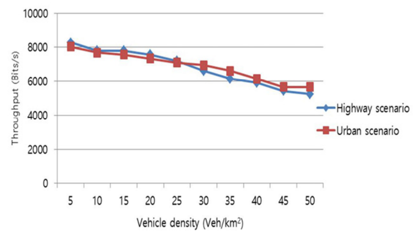

Figure 4. Throughput vs vehicle density in LTE.

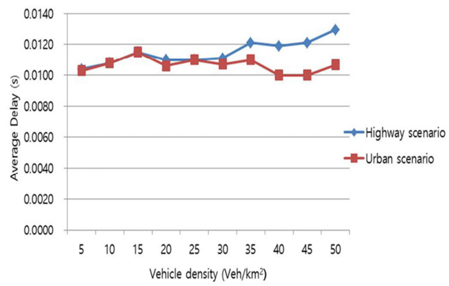

Figure 5. Delay vs vehicle density in 802.11p.

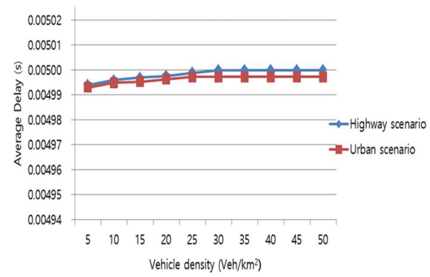

Figure 6. Delay vs vehicle density in LTE.

V. Conclusion

In this paper, we consider an integration of IEEE 802.11p and cellular LTE network as heterogeneous VANETs to boost the service quality in the transportation system. VANET faces several limitations using single wireless technology. Thus, we evaluate the performance of heterogeneous VANET by integrating IEEE 802.11p and LTE networks. We used VEINS-LTE for performance evaluation of heterogeneous VANETs. The performance evaluation results show that IEEE 802.11p gives better performance in terms of delay in an urban scenario while LTE shows similar performance for highway and urban scenarios. As for future research, we can think of heterogeneous VANET security issues as well as vehicular cloud for more robust heterogeneous VANETs.

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