Evaluation of DSRC and LTE for V2X

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***Abstract*— Researchers are actively working on technologies that enable vehicles to communicate with each other and with surrounding devices in the environment. Currently, Dedicated Short Range Radio (DSRC) and cellular communication based approaches such as 4G/LTE and 5G are the most promising technologies for Vehicular communications (V2X). The main goal of V2X is to improve safety on the road and also provide additional convenience services for the vehicle occupants. This paper presents results of the experimental evaluation, in simulation environments, of the performance of DSRC and LTE on various quality metrics for V2X applications.**

Keywords— Vehicular communication, V2X, DSRC, 4G/LTE, Simulation.

I. Introduction

In bad weather conditions, such as when entering a dense fog area with reduced visibility, roads with snow or ice accumulation, it makes driving risky especially if drivers are not adjusting their speed to the road conditions. Careless driving in such conditions could easily result in serious deadly accidents that could involve several cars on the highway. With vehicular communication, situations like these can be prevented. Cars on the road can communicate safety messages with other cars in their surroundings to notify them about emergency conditions so accidents can be avoided. Even though the cars cannot see each other, they can communicate over a distance, and safely travel the road without an accident.

Vehicular communication provides the protocols that allow a vehicle to use a hardware module that enables it to communicate with another module or modules that can be installed on another vehicle for Vehicle-to-Vehicle (V2V), or road infrastructure for Vehicle-to-Infrastructure (V2I). It is also possible to have Vehicle-to-Pedestrian (V2P), via a system built-in or attached to mobile phones. In general, all these communication options are referred to as V2X. The communication system can be used to provide critical information to the driver, such as accident alerts, bad weather conditions, traffic information. Intelligent algorithm process the V2X information for improving safety and generating optimum routing that takes into account real-time conditions. U.S. Companies in the automotive industry and government organizations have been active in developing standards for Vehicle-safety-communication (VSC) to support Intelligent Transportation Systems (ITS) [1] for passenger safety. There are similar programs in the EU, called the Car-to-Car Communication Consortium (C2C-CC), and Japan, called the Advanced Safety Vehicle (ASV) Program [2]. Although the V2X technology exists in these countries, the actual implementation is currently available only in limited areas as special pilot studies, large scale deployments are yet to come.

This ongoing research in this field covers topics in the related to the communication types, such as the ones that are commonly known, the Dedicated Short Range Communication (DSRC) and Cellular Telecommunication (4G/LTE & 5G). Each method has its benefits and drawbacks based on different parameters such as latency, data transfer rate, range, cost, security, and market readiness. Because of the initial cost of deployment of these technologies, studies are often conducted in simulation environments in addition to limited real-world experiments with actual communication modules. Some of the tools that are commonly used for simulation include SUMO, Omnet++, Veins, and Ns-3.

II. DSRC and Wave

The IEEE 802.11 covers several wireless standards. The IEEE 802.11p WAVE is a standard that uses Dedicated Short Range Communication (DSRC) [3]. It uses 5.85-5.925GHz frequency range which is dedicated for vehicular communication to support the development of intelligent transportation systems, specifically by using V2X protocols. The DSRC provides safety and infotainment communication services. It is developed to meet the requirements of a dynamic environment such high mobility, low latency, and good communication range.

DSRC relies on radio communication transceivers mounted on vehicles as well as road side units. One of the main challenges for the DSRC technology is that the initial cost of installing the infrastructure could become expensive. Researchers evaluate the different performance parameters of the DSRC such as frequency, vehicle speed, and the number of vehicles that can be on a single channel, etc. [4]. The parameters affect the communication performance differently, so each one was evaluated against latency and the message delivery success rate. The number of vehicles on one channel, which is a measure of congestion, seems to be one of the main issues with the DSRC since having fifty or more vehicles significantly decreases the message delivery percentage and increases the latency. Even with less than fifty vehicles, when the vehicles are going at 40km/h or higher speeds, the message success rate drops to about 60% although the latency only increases a small amount, still within the standard 100ms [4].

To address the issue discussed above, which was a problem caused by a high number of vehicles communicating on the same channel, a multiple channel DSRC was proposed by

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Zhang [5], with the goal of improving message delivery success rate and latency. The system splits the allotted channel band of the WAVE into seven parts that are used for communicating different message types. The multi-channel system utilizes a cluster based formation for message delivery. It chooses one car as the head of the group and then connects it with the vehicles within a certain radius of the head vehicle [5]. The cluster is then able to communicate messages within the group very quickly. The clusters are also able to intermingle and share information, and they can be formed and modified at any time. The multi-channel system helps reduce the stress on one channel, and the cluster based formation is useful to decrease the latency for message delivery and improve the message delivery success rate.

III. Cellular Telecommunication

Due to the limitations of DSRC, researchers are exploring alternative or complementary vehicular communication technologies. Recently, there has been increasingly growing interest in the use of cellular based communication networks of 4G/LTE (long-term evolution) as well as 5G for V2X, also known as cellular-V2X (C-V2X). This technology was standardized by the 3rd generation partnership (3GPP) [6].

Cellular networks are expected to improve the performance of vehicular communication (V2X). Simulation research shows that in the LTE latency and message delivery ratio outperform that of the DSRC, across a number of parameters such as vehicle speed, range, and the number of vehicles on one channel [4]. In the simulation experiments that were conducted, the latency is found to be always within 100ms. With the increase in the number of vehicles the latency is found to increase, but it does not exceed 60ms when there are 150 vehicles in the same channel [4].

The research literature also shows that the packet delivery ratio of LTE to be better than that of the DSRC, which at its absolute best is only 80% and quickly drops down, while that of LTE reaches 95% or higher. The communication range for LTE is vastly superior over that of the DSRC, where the range for DSRC is considered to be between 300m and 1Km, while cellular radios, depending on the cell tower type and power, could have coverage to up to about 10 miles [7].

IV. Simulation Setup for Evaluation of DSRC and LTE

In this section the paper presents the approaches used for comparing DSRC and LTE for vehicular communication.

There are several software tools, such as SUMO (Simulation of Urban Mobility) [8], OMNET++ [9], and ns-3 [10] that are widely used for developing V2X simulations. For the evaluation of the DSRC vs. LTE this paper utilizes the Ns-3 software, which is a discrete network simulator that uses C/C++ programming to create networking scenarios for DSRC and LTE. For analysing the simulation results, the simulator's pure data output is imported to a different software, such as MATLAB, in order to create a visual representation of the results. Ns-3 is widely supported and contains a number of examples, tutorials, user guides, and special wiki which facilitates learning.

A. DSRC setup

For testing the DSRC performance, different tests were created with parameters such as traffic type, max latency, congestion, and range. In each scenario the packet delivery success rate is measured against each parameter. For the traffic type, it determines whether it is a highway or a city scenario where the speed greatly differs. The max latency set was one of the major factors for the packet delivery success rate. It determines the time it takes to deliver a message within a certain time and otherwise it is considered an unsuccessful message. Congestion and range measure the number of vehicles on the road and distance between the vehicles to deliver messages, respectively. The DSRC simulation output is the packet delivery success rate as a percentage at different ranges for each of the different parameters.

For the DSRC tests, the congestion tests started at 20 vehicles and increased to 160 vehicles in increments of ten. These congestion tests were also ran at three different max latencies of 10ms, 50ms, and 100ms. These latencies were chosen due to the standard being within 100ms for message delivery. The range was recorded at 200m and the tests were split into highway and city scenarios. For the range tests, the number of vehicles was set to forty for city and highway, and tested at the three different max latencies. Overall, there were six congestion tests and six range tests for a total of twelve DSRC tests (for city vs. highway test).

B. LTE setup

The parameters for the LTE code were not as flexible as the parameters for the DSRC code nor did it provide a user friendly output. The parameters tested were the latency and congestion using packet delivery success rate as a test metric. For the output, it gave a list of all of the messages received by different ports using the LTE communication standard with the packet delivery success rate attached to the message. For the comparison, the LTE and DSRC were tested in the same conditions using the congestion and latency parameters. The test for the congestion was run at the 200m range with the highway scenario at the same three latencies. Although there were only three different tests, the data for these tests provide a good comparison to the highway portion of the DSRC congestion tests.

V. Simulation Results

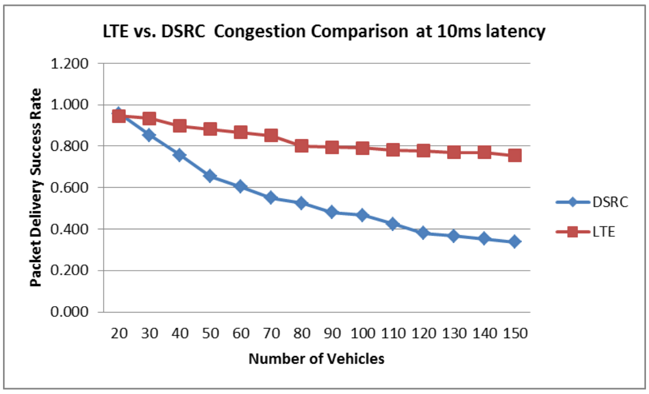

Fig. 1: LTE vs. DSRC congestion comparison at 10 ms latency

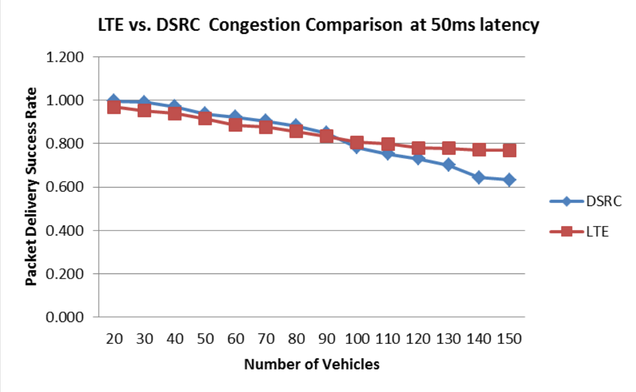

Fig. 2: LTE vs. DSRC congestion comparison at 50 ms latency

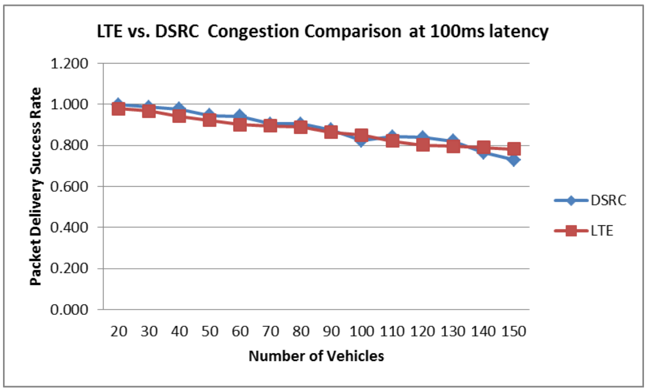

Fig. 3: LTE vs. DSRC congestion comparison at 100 ms latency

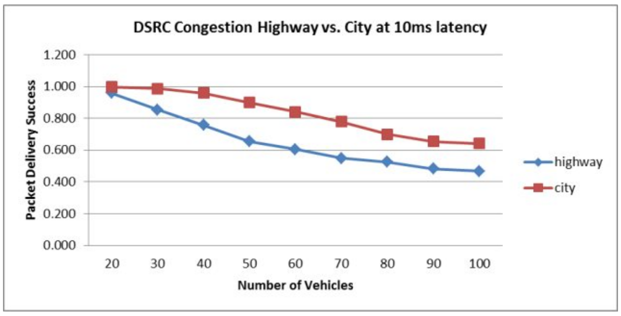

Fig. 4: DSRC congestion Highway vs. City at 10 ms latency

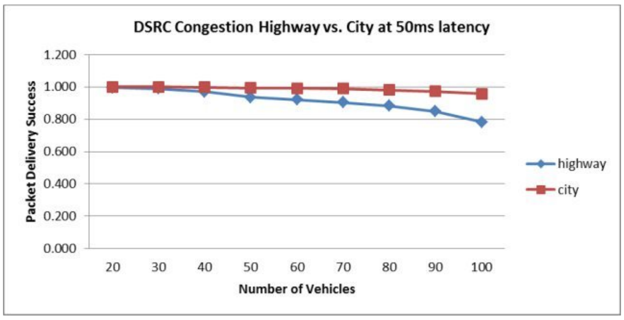

Fig. 5: DSRC congestion Highway vs. City at 50 ms latency

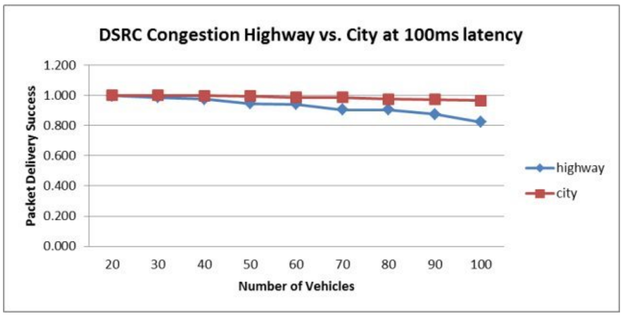

Fig. 6: DSRC congestion Highway vs. City at 100 ms latency

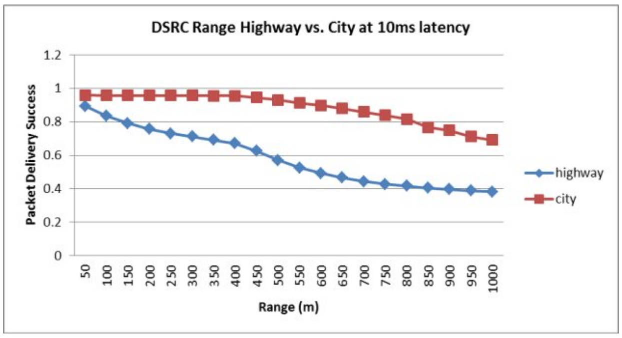

Fig. 7: DSRC Range Highway vs. City at 10 ms latency

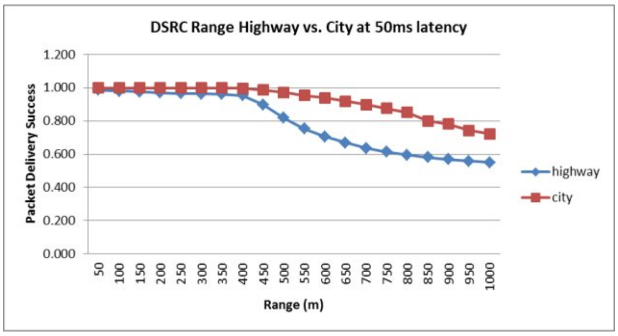

Fig. 8: DSRC Range Highway vs. City at 50 ms latency

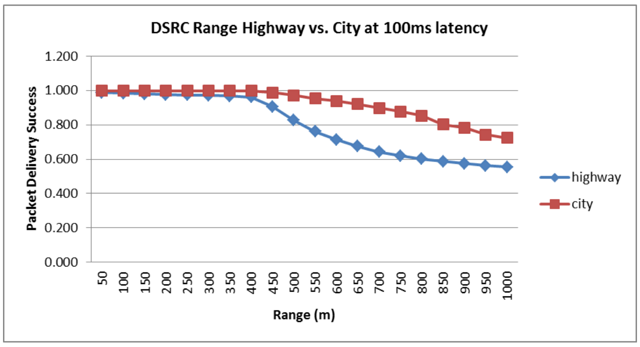

Fig. 9: DSRC Range Highway vs. City at 100 ms latency

Although the LTE tests were not as thorough as the DSRC tests, a comparison can be done on how the packet delivery success rate is affected by congestion. The LTE and DSRC data show that the LTE performs better than the DSRC at the lowest max latency, as seen in Fig. 1. The higher congestion levels decrease the packet delivery success rate. As the allowable maximum latency increases the DSRC's performance improves and comes close to that of LTE, as shown in Fig. 2 and 3. Once the maximum latency is set at the standard 100ms as shown in Fig. 3, then both have about the same level of packet delivery success rate.

For the city and highway portion of the DSRC data, the trend for all of the Figures show that DSRC modules perform better in the city where the speeds are slower than in the highway scenario. Fig. 4, 5, and 6 show the congestion comparison at the three different maximum allowable latencies. They show that as the latency increases the difference in packet delivery success rate between the two graphs shrinks.

Fig. 7, 8, and 9 demonstrate the effect of range on packet delivery success rates, comparing city against highway driving, at different maximum allowable latencies. Note that at the lowest latency of 10ms there is a significant performance degradation of the highway driving vs. city driving as the range increases. From graphs in Fig. 8 and 9, one can observe that the performances of the city and highway drving are about the same until some critical range, which is about 450 meters. After that disctance the packet delivery success rate tends to quickly drop for the highway driving compared to the city driving.

VI. Conclusion

In the recent years there have been significant advancements in the research and development of the V2X technology. The simulation results presented in this paper give clear picture that the DSRC is functional as long as we stay within its specifications, but it could still be improved to make it more robust against performance degradations under certain circumstances. The improvement to the WAVE network could be achieved using the 4G/LTE or 5G cellular networks to create a much better and more robust vehicular communication system. With the latest advancements in 5G there is high expectation for larger scale deployments of the technology to support V2X in the near future.

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