

WAVE, WiMAX and LTE-V2V Technologies for Vehicular Communication: A Comparative Performance Evaluation

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Abstract

The exponentially increasing traffic on the road highways is creating safety issues for the vehicles. It is a challenge to make the highways safe and secure against traffic congestion and road accidents, which may happen due to a continuous rise in both traffic density and speed of the vehicles. It is imperative to devise vehicular communication technologies to ensure a reliable and powerful driving support system for the safety and efficiency of road transportation. Vehicular communication technologies are being designed to make early detection of the perilous situation and exchange the information among the vehicles, which may be used for issuing the warnings to the drivers and /or navigational aids. In addition, non-safety applications of vehicular networks are being embedded in the vehicles for the purpose of infotainment and the comfort of the passenger. In this paper, we present a comparative performance evaluation of three technologies- WAVE, WiMAX, and LTE-V2V with the aim to examine their relative strength in a dynamic vehicular environment. The impact of node density, node speed and beacon transmission frequency on the throughput, delay and packet delivery ratio is analyzed. Through numerical results, LTE-V2V is shown to outperform the other two alternatives in terms of throughput and delay.

Keywords: - V2V Communication, WAVE, WiMAX, LTE based vehicular network.

INTRODUCTION

Since in most areas, vehicles are being evolved by integrating more features into it, it becomes a center of attraction for people to have it, which results in a greater number of vehicles on the road. As the growth in vehicle density leads to the probability of more accidents may happen, it is highly important to consider their safety too. For Road safety purpose, vehicles collect and share useful information by communicating with other vehicles in proximity and the infrastructure as well. Dedicated Short Range Communication (DSRC) relies fundamentally on standards-based interoperability among devices from different manufacturers [1]. DSRC can be used to share message for safety purpose.

Apart from the safety application, there are various kinds of non-safety application, which improves passenger comfort by providing multiple facilities such as web browsing and video streaming media downloading, email applications etc.

Vehicle to Everything (V2X) Communication helps to communicate not only with another vehicle but also with the infrastructure by introducing it with other existing networks. The existing network helps to extend the range and enhance the performance in terms of high data rate, high throughput, less delay etc. For Intelligent Transportation System (ITS) application, Federal Communication Commission (FCC) has allocated the licensed spectrum of 75MHz bandwidth in the 5.9 GHz band (5.850-5.925 GHz). This 75 MHz bandwidth is further classified into two categories in which six 10MHz channel (a.k.a. Service Channel SCH) are reserved for traffic efficiency and infotainment applications, and one 10MHz channel (a.k.a. Control Channel CCH) is mainly dedicated for safety purpose such as broadcasting short message and communication management for road safety applications. The remaining 5MHz is reserved for the guard band.

In this paper, we are focusing on the delivery of non-safety message by using different radio technology, namely WAVE (IEEE802.11p), WiMAX (IEEE802.16e) and LTE technology. To analyze their performance, a discrete-event network simulator NS-3 (version 3.30) is being considered for evaluation.

From the simulation study, some parameters are being observed, such as throughput, Packet Delivery Ratio (PDR) and end-to-end delay by varying node density, beacon transmission frequency and the node speed under a similar environment.

The rest of the paper is organized as follows. Section II is devoted to the introduction part of each technology in detail. All the related work and literature survey is done in Section III. Section IV tells all about the simulation scenario and their results. At last, we conclude the paper in Section V.

VEHICULAR NETWORK

The characteristics of VANET, such as highly dynamic topology, frequent connection-disconnection network, time-varying vehicle density, heterogeneous communication range and others, makes it distinctive from MANET. To deal with it, highly secure and stringent technology is needed.

Though DSRC makes it possible by providing a highly secure communication channel and frequent connection within proximity and makes the connection highly reliable and efficient, integration with the existing network enhances the capability of secure and convenient connection to cover a wide range.

A. IEEE 802.11p (WAVE)

DSRC uses IEEE802.11p Wireless Access for Vehicular Environment (WAVE) standard at the PHY and MAC layer, and due to this, DSRC is also popular as WAVE standard. The presence of IEEE 1603 family standard including resource manager (1609.1), security services (1609.2), network layer services (1603.3), multichannel operation (1609.4) with the PHY layer standard (IEEE802.11a/b/p) and other radio technologies (e.g. UMTS etc.) provides a firm and secure connection between vehicles.

For Network and transport layer, it also supports TCP/UDP protocol and internet protocol (e.g. IPv4/IPv6). For safety messages, it utilizes Wave Short Message Protocol (WSMP), and for general packet transmission, TCP-IP protocol coexists in the layer.

The spectrum in which it works is already mentioned above. Due to the coexistence of multiple protocols in the layer, it can support safety and non-safety applications at a time.

B. IEEE 802.16e (Wi-MAX)

WiMAX based Vehicular network can also be a better option for non-safety application such as media streaming, web browsing, email, VoIP etc. It operates in a 2.3GHz and 2.5GHz frequency band. It mainly consists of two standards, i.e., for fixed station IEEE802.16d and for mobile station IEEE802.16e.

In the WiMAX-based network, the WiMAX tower station (Base Station) has direct access to the internet, resulting in better throughput, high data rate, and low latency for non-safety application. The performance analysis of the WiMAX-based vehicular network for safety application is still an open issue. The WiMAX based vehicular network can be set up as shown in Fig. 1.

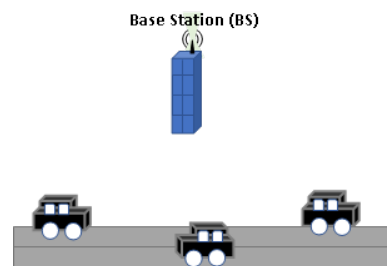


Fig. 1: WiMAX-based vehicular network

C. LTE

The LTE standard by 3GPP is a 4G cellular standard, which offers high data rate, high bandwidth, ultra-low latency to the users. In LTE based vehicular network, vehicles can communicate to other vehicles within proximity distance as well as with the infrastructure through eNodeB stations. LTE network basically comprises of two components: E-UTRAN and EPC network. E-UTRAN is mainly responsible for the radio communication between any kind of UE (e.g., mobile phone, vehicle etc.) and the EPC unit with the help of the eNB base station.

In E-UTRAN, eNB plays an important role to allow UE to transmit any packet. EPC basically act as a bridge between E-UTRAN and external network such as the internet. In LTE based vehicular network, vehicles can communicate with each other using the PC5 interface (a.k.a. Side-link). It allows devices present in proximity to communicate directly rather than all the way through the base station.

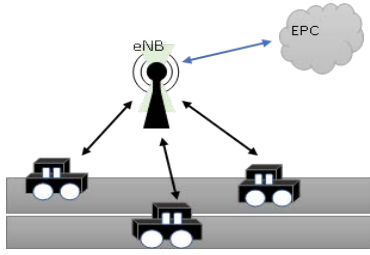


Fig. 2: LTE based vehicular network

Hereby, D2D communication may help to extend the coverage area of any existing technology/connectivity, act as a relay node to pass the information, fast transfer of important files by providing high throughput and least delay and also can act as a source of internet connectivity by connecting to the internet network directly.

REVIEW OF THE RELATED LITERATURE

In 2010, Msadaa et al. [2] compared 802.11p and Mobile WiMAX based V2I communication networks using QualNet 4.5 Simulator for non-safety application. He observed that WAVE is better suited for low traffic loads and offer very short latencies even at high vehicle speed, whereas WiMAX offers not only large radio coverage and high data rates but even low delays too.

In 2013, Araniti et al. [3] had been analyzed the strength and weakness of LTE for vehicular communication analytically. He said that as LTE provides a high data rate and low latency for mobile users, it also supports a high penetration rate, high-speed terminal, and large coverage range for Vehicular Communication. It perfectly fits in high bandwidth demands and QoS-sensitive requirements such as infotainment applications, but for safety applications, still, it is an open issue.

In 2014, Mir et al. [4], [5] provided a detailed study of both standards by considering a variety of parameter settings and concluded that for sparse network, IEEE 802.11p is more suitable, though it offers some difficulties in the dense network due to increase the no. of vehicles. Whereas LTE technology performs better than IEEE 802.11p in every condition, but due to the higher cellular network traffic load, it is very challenging to obtain stringent delay requirements.

In 2015, Abd-Elrahman et al. [7] proposed a novel framework for V2V failure (a.k.a. dead-ends) recovery using Device to Device (D2D) communications. In 2017, Kim et al. [6] suggested that V2I communication is better for safety message delivery at intersections as compare to V2V communication. Since the infrastructure can have a LOS connection with the vehicles present

at the intersections, it results in better safety message delivery with low latency and less packet loss.

In 2013, Mojela et al. [8], [10] investigated the performance of the network of using a combination of Wi-Fi for inter-vehicle communication and WiMAX for the vehicle to infrastructure communication. He observed that vehicles with Wi-Fi connection provide reliable and high bandwidth while connected, whereas WiMAX bandwidth fluctuates for NLOS but significantly affects the average bandwidth.

In 2015, Tiwari et al. [9] analyzed the performance of the network using WAVE and WiMAX for VANET. He observed that WiMAX provides better results for small packet size by contributing less packet loss ratio and high QoS. Whereas, as the packet size increases, WAVE outperforms WiMAX by providing less delay.

SIMULATION SCENARIO AND RESULTS

In this section, we present the simulation model and analyze the numerical results. Performance is evaluated in terms of packet delivery ratio, throughput and end to end delay. Vehicle density, beacon transmission frequency and vehicle speed are used as the independent parameters.

A. Simulation Scenario

For creating the simulation model, we use the network simulator NS3 (version 3.30), which is an open-source, discrete event network simulator. The parameters are set in the simulator and observed by varying the node velocity, beacon transmission frequency and node density. The system parameters used are listed in Table I.

In the case of WAVE, all the layers are being set up using the available library in NS3 and integrated together to perform the simulation. For the PHY layer, the transmission power is set to 25dBm. The receiver sensitivity and energy detect threshold is set to -83dBm and -86dBm, respectively.

For WiMAX-based vehicular network, the available library in NS3 integrates features necessary for a WiMAX network such as PHY OFDMA, PMP and TDD modes using the available helper class. The simple priority-based scheduler is set during the simulation.

The modulation scheme is set as 16 QAM with $\frac{1}{2}$ code rate. The mobility scenario is kept the same as WAVE to analyze the actual behavior of the network. In the case of WiMAX-based vehicular

network, packets are being transmitted and received via the base station.

In the case of LTE based vehicular network, one eNB station is considered. In this network, the vehicles tend to transmit the packets in the uplink, and eNB tends to transmit packets in the downlink in a broadcast manner. The cell operates at the downlink frequency band of 2110MHz (RBs) and uplink frequency band of 1710MHz (50RBs).

Table I Simulation Parameter				
Simulation Parameters	Values			
Mobility	RandomWayPoint			
Loss Model	Two Ray Ground			
Simulation Time	50sec.			
Data Rate	2Mbps			
Transmit Max. Delay	10ms.			
Packet Size	200 bytes			
Node Velocity	20, 40, 60, 80 m/sec.			
Beacon Tx. Frequency	1, 4, 8, 10, 20Hz.			
No. of Nodes	25, 50, 75			
	WAVE	WiMAX	LTE	
Frequency	5.8 GHz	3.5GHz	DL 2110 MHz	UL 1710 MHz
Channel Bandwidth	10MHz	10MHz	10MHz	
Transmission Power	25dBm	20dBm	eNB (40dB m)	UEs (20dB m)
Propagation loss Model	Nakagami fading model	Friis	Friis	
Data rate/ RB allocation	6Mbps	27.948 Mbps	DL (50), UL (50)	
Scheduler	-	FCFS scheduler	Round Robin	
Noise Figure	-	7.0dB	eNB (5.0)	UEs (7.0)

B. Simulation Results

In this section, we have shown the effect of varying each parameter which has been discussed earlier. During this analysis, the Beacon Tx frequency is taken as a common parameter and graphs are plotted between the measured parameter Vs the beacon Transmit frequency.

Impact of Node Speed

In the case of WAVE, throughput ranges over 0 to 40 kbps. Fig. 2(a) and 2(b) depict that increase in node speed doesn't affect the throughput. It remains independent of the varying speed from 20m/s to 80m/s. No delay is shown in the result, and all packets are received at the receiver end (by

the node within range). It is observed that even if the propagation loss is exponential with respect to the time, it still does not affect the delay.

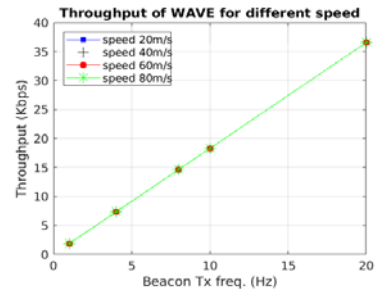


Fig. 3(a) Throughput for WAVE for varying speed

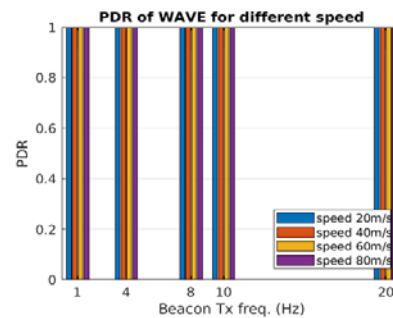


Fig. 3(b) PDR of WAVE for varying speed

In the case of WiMAX, Fig. 3(a) depicts that the throughput lies in the range of 5-120 Kbps, and the increase in node speed doesn't have much effect on the throughput till the beacon Tx freq. vary from 1 to 10 Hz., but for 20 Hz beacon Tx freq. the throughput is higher for speed 40m/sec and lowest for speed 80m/s. Fig. 3(b) shows that the delay lies in the range of 35-50msec. and for 20Hz beacon Tx freq., the exerted delay is the least, and for 1Hz beacon Tx freq., the delay is maximum as compared to others.

But if we observe, the effect of speed on the delay is not much, as it is higher for 20m/s and lower for 40m/s. Figure 3(c) reveals that the packet delivery ratio is 100% and the increase in speed doesn't have much effect on the PDR.

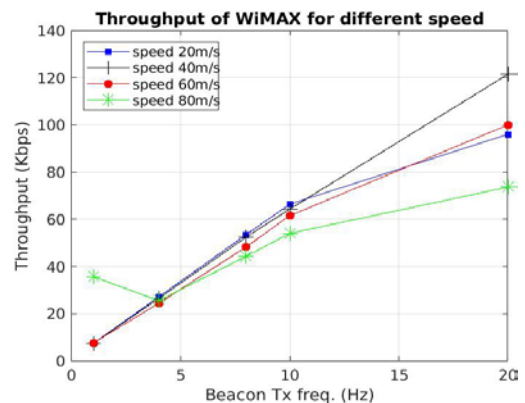


Fig. 4: (a).Throughput of WiMAX-based vehicular network for varying speed

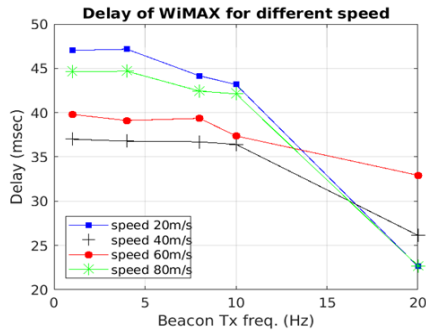


Fig. 4 (b) Delay of WiMAX-based vehicular network for varying speed

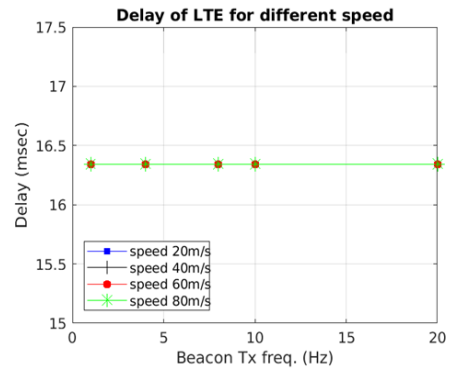


Fig. 5 (b) Delay of LTE based vehicular network for varying speed

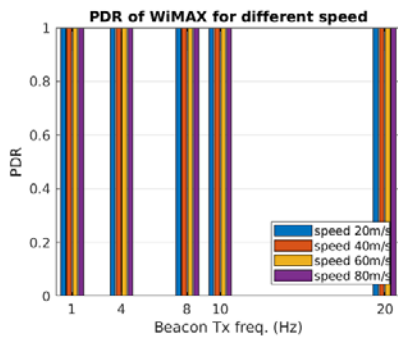


Fig. 4 (c) PDR of WiMAX based vehicular network for varying speed

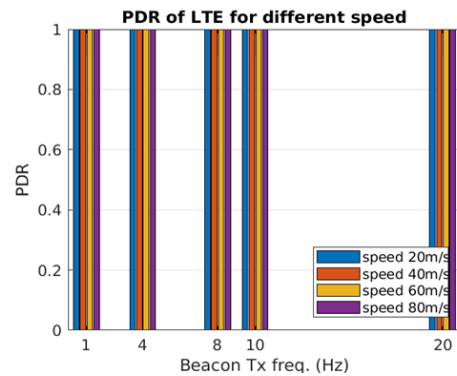


Fig. 5 (c) PDR of LTE based vehicular network for varying speed

In the case of LTE based vehicular network, the impact of node speed is negligible in the case of throughput, delay and PDR, as well as shown in Figure 4(a), 4(b) and 4(c). It is found from this graph that throughput lies in the range of 250-400 kbps and is higher for 20 Hz beacon transmit frequency (More transmission of packets in less time), whereas lower for 1Hz beacon transmit frequency (when beacon transmission interval is higher).

The delay lies in less than 20ms and remains constant for all beacon freq. It can be observed from these results that LTE outperforms the WAVE as well as WiMAX in terms of throughput and delay while increasing the speed of nodes.

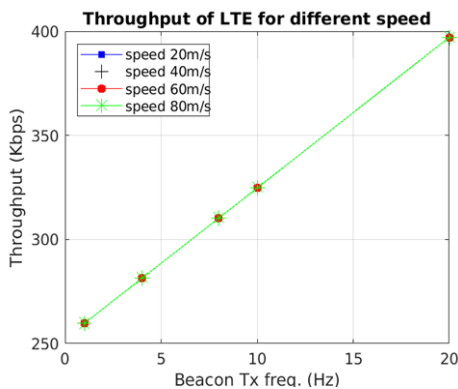


Fig. 5 (a) Throughput of LTE based vehicular network for varying node speed

Impact of varying Node Density

In the case of WAVE, Fig. 5(a) and 5(b) shows the results, and it can be observed that throughput lies in the range of 0-40 kbps, and it remain the same even if the node density increases from 25 to 75 nodes. No delay is exerted by this network, and all packets are successfully received by the nodes present in the range.

From the past researchers work, it is known that the coverage area for WAVE is around 1Km, and if the background data is not being considered, the effect of propagation delay doesn't show any effect on its performance.

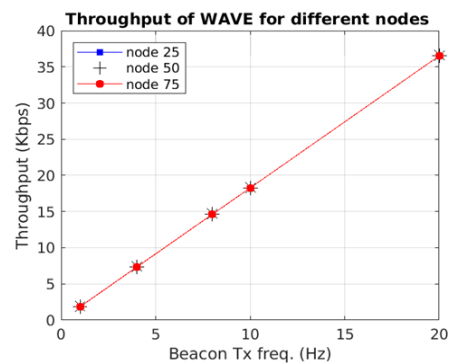


Fig. 6 (a) Throughput of WAVE for varying node density

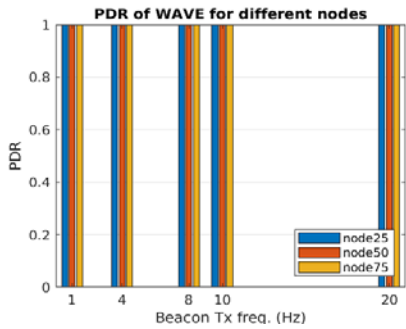


Fig. 6 (b) PDR of WAVE for varying node density

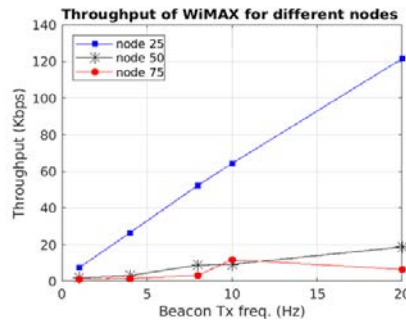


Fig. 7 (a) Throughput of WiMAX-based vehicular network for varying node density

In case of WiMAX based vehicular network, the Fig. 7(a) depicts that the maximum throughput for 25 nodes lies in the range of 120 kbps for 20 Hz beacon transmit frequency. As the node density increases, the throughput keeps decreasing less than 20Kbps. From Fig. 7(b), it can be observed that the delay can be increased up to 80msec. and inconsistent for 50 nodes and the least delay is around 40msec for 25 nodes.

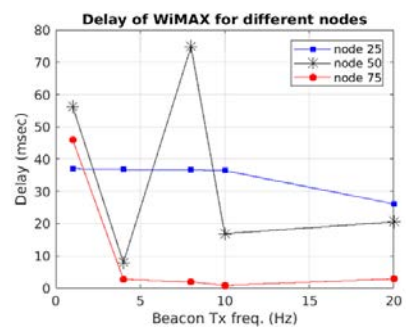


Fig. 7 (b) Delay of WiMAX based vehicular network for varying node density

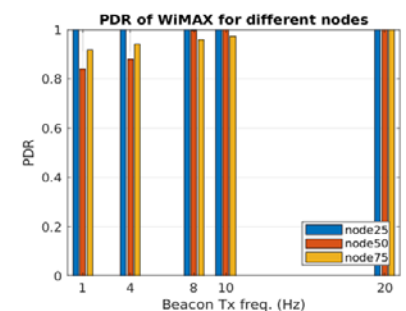


Fig. 7 (c) PDR of WiMAX-based vehicular network for node density

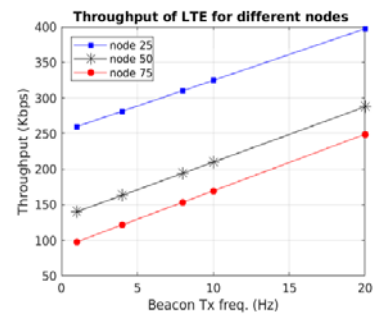


Fig. 8 (a) Throughput of LTE based vehicular network for varying node density

As the node density increases from Fig. 7(c), the PDR decreases for lower beacon Tx frequency such as 1, 4, 8 and 10 Hz. But for 20Hz beacon Tx freq., PDR is still 100%. Thus, it can be analyzed from the results that WiMAX shows satisfactory results for low density by providing throughput around 120Kbps and delay less than 40msec, but as the node density increases, it shows poor results.

In case of LTE based vehicular network, from Figure 8(b), it can be observed that the throughput keeps decreasing with the increase in the node density and lies in the range of 100-400Kbps. Fig. 8(b) and (c) depicts that the delay also increases with increase in the node density, but still it is less than 30ms, whereas the PDR is 100% and the effect of node density is negligible. From these results it can be observed that LTE outperforms other two technologies by providing higher throughput and least delay even for higher density.

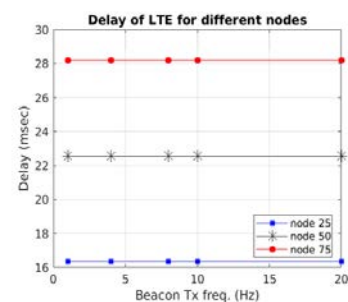


Fig. 8 (b) Delay of LTE based vehicular network for varying node density

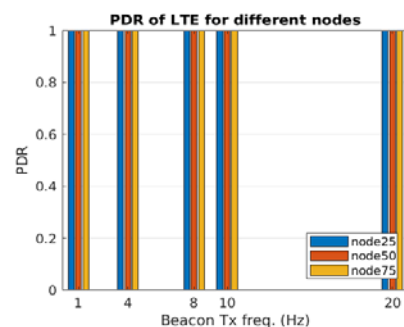


Fig. 8 (c) PDR of LTE based vehicular network for varying node density

CONCLUSION

In this paper, a comparative performance evaluation of three potential candidate technologies available for the dissemination of non-safety messages in vehicular communication was presented. It was observed that in terms of throughput and delay, LTE outperforms the other two. The resulting throughput lies in the range of 100- 400Kbps, and delay is less than 30ms for up to 75 nodes. In the case of WiMAX-based vehicular network, the throughput lies in the range of 1-150Kbps, and delay is less than 80ms for up to 75 nodes. WiMAX also provides satisfactory results for less no. of nodes and for the high speed of nodes around 80m/s. Hereby it can be treated as a better candidate in the absence of LTE, whereas The WAVE offers the throughput in the range of 1-50 kbps for short-range communication. The results presented are useful to examine the potential and readiness of the competitive technologies for application in V2V communication. The study is particularly useful for intelligent transportation systems, which are being deployed in smart cities the world over.

REFERENCES

1. Kenney, John B. "Dedicated short-range communications (DSRC) standards in the United States." *Proceedings of the IEEE* 99, no. 7 (2011): 1162-1182.
2. Msadaa, Ikbal Chammakhi, Pasquale Cataldi, and Fethi Filali. "A comparative study between 802.11 p and mobile WiMAX-based V2I communication networks." In 2010 fourth international conference on next generation mobile applications, services and technologies, pp. 186-191. IEEE, 2010.
3. Araniti, Giuseppe, Claudia Campolo, Massimo Condoluci, Antonio Iera, and Antonella Molinaro. "LTE for vehicular networking: a survey." *IEEE communications magazine* 51, no. 5 (2013): 148-157.
4. Mir, Zeeshan Hameed, and Fethi Filali. "LTE and IEEE 802.11 p for vehicular networking: a performance evaluation." *EURASIP Journal on Wireless Communications and Networking* 2014, no. 1 (2014): 89.
5. Mir, Zeeshan Hameed, and Fethi Filali. "On the performance comparison between IEEE 802.11 p and LTE based vehicular networks." In 2014 IEEE 79th vehicular technology conference (VTC spring), pp. 1-5. IEEE, 2014.
6. Kim, Woosong, and Eun-Kyu Lee. "LTE network enhancement for vehicular safety communication." *Mobile Information Systems* 2017 (2017).
7. Abd-Elrahman, Emad, Adel Mounir Said, Thouraya Toukabri, Hossam Afifi, and Michel Marot. "A hybrid model to extend vehicular intercommunication V2V through D2D architecture." In 2015 International Conference on Computing, Networking and Communications (ICNC), pp. 754-759. IEEE, 2015.
8. Mojela, Lerotholi S., and Marthinus J. Booysen. "On the use of WiMAX and Wi-Fi to provide in-vehicle connectivity and media distribution." In 2013 IEEE International Conference on Industrial Technology (ICIT), pp. 1353-1358. IEEE, 2013.
9. Tiwari, Priyanka, and Rajendra Singh Kushwah. "Traffic analysis for VANET using WAVE and WiMAX." In 2015 International Conference on Communication Networks (ICCN), pp. 343-346. IEEE, 2015.
10. Singh, A. and Singh, B. "A Study of the IEEE802. 11p (WAVE) and LTE-V2V Technologies for Vehicular Communication." In 2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM), pp. 157-160. IEEE, 2020.
11. Mir, Zeeshan Hameed, and Fethi Filali. "On the performance comparison between IEEE 802.11 p and LTE based vehicular networks." In 2014 IEEE 79th vehicular technology conference (VTC spring), pp. 1-5. IEEE, 2014.
12. Song, Yoo-Seung, and Hyun-Kyun Choi. "Analysis of V2V broadcast performance limit for WAVE communication systems using two-ray path loss model." *ETRI Journal* 39, no. 2 (2017): 213-221.
13. King, Heather, Keith Nolan, and Mark Kelly. "Interoperability between dsrc and lte for vanets." In 2018 IEEE 13th International Symposium on Industrial Embedded Systems (SIES), pp. 1-8. IEEE, 2018.
14. Kim, Woosong, and Eun-Kyu Lee. "LTE network enhancement for vehicular safety communication." *Mobile Information Systems* 2017 (2017).