LTE-V2X System Performance Based on Urban-Low Speed Environment

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Abstract —Vehicular Ad Hoc Networks (VANETs) is an important field of study nowadays. VANETs attracts attention of vehicles communication researcher due to its potential to improve vehicle road safety, enhance traffic and travel efficiency, and provide convenience and comfort for passengers and drivers. Due to the fact that modern life, especially when travelling in vehicles, is in need for high throughput, this paper investigates the Block Error Rate (BLER) and throughput performance of vehicle-to-Infrastructure (V2I) communication between LTE node and vehicles in urban-low environment using two different stochastic channel model used urban-low areas because urban-low speed areas is the common road situation for a large number of users require connection with LTE node. Vehicle-to-Infrastructure - Urban (V2I-U) is used in urban areas and Vehicle-to-Infrastructure – Urban Small intersection (V2I-US) channel model, used as a reference model, has the largest maximum excess delay near to the 3GPP Extended Vehicular A (EVA) channel model. The performed simulation is done at low speed, 40 km/h in 10 MHz bandwidth for the 2.6 GHz carrier frequency. Results show that V2I-U meets the highest value in the throughput that reaches 20 Mbps as those obtained from the EVA one without huge effect on the BLER. This result can be attributed to the fact of using Line-of-Sight (LoS) which leads to less dispersion of the frequency and less doppler frequency shift.

Index Terms—LTE, V2X, stochastic channel, BLER, VANETs

I. INTRODUCTION

Modern life is characterized by continuous movement, that is, people are in endless continuous movement. Consequently, staying connected online and while moving became a demand for today's life which includes intelligent transportation. By applying a large number of sensors in the communication area, intelligent transportation that needs, dependable, high wireless data rate communication in order to be able to serve different environmental issues such as: vehicles' moving, climate, temperature and traffic situation which needs a robust system to be used in the communication process [1].

Intelligent transportation System (ITS) is as major modern applications that requires continuous internet connection to allow mutual connection between anything exists in the traffic load. With the increase number of vehicles with the increasing wireless demand and increasing use of sensors, the importance of road safety, broadcasting the traffic situation, and enhance the Internet connectivity is becoming more important [2]. However, to satisfy these issues, a high good network configuration and access links are needed [3].

Aiming at utilizing the advantages that LTE gives when applied at vehicle's communication V2x and Long-Term Evolution (LTE) were combined. The combination stands for (LTE-V2X) where X represents the type of communication such as Vehicle to Vehicle (V2V) communication, Vehicle to Infrastructure (V2I) communication and Vehicle to Pedestrian (V2P) communication [4]. The communication is performed by either peer to peer which is called Device-to-Device (D2D) transmission, or indirectly by using the main base station to gather all data and resend it again as shown in Fig. 1.

Future mobile communications will thus basically face two distinct groups of users; the first are the indoor users that demands high data rate communication for static communication between user and the access point [5], and the second are the outdoor moving users with large number of users need high data rate connection while moving where LTE-V is the solution to deliver high rate and meet the wireless demand [6].

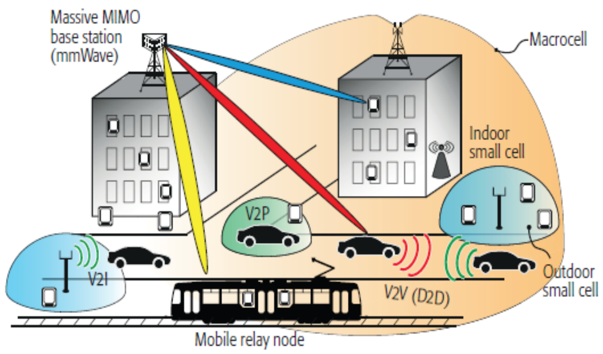

Fig. 1. Future mobile network in an urban area [1]

The challenging issue for LTE-V2x is the high change rate in channel characteristics due vehicles' fast movement. This fast movement causes Doppler effects, including frequency error and Inter-Carrier Interference (ICI) which is attributed to shorter coherence time that causes higher Doppler shifts, broader Doppler spread, and insufficient channel estimation. LTE can overcome by using high gain antennas to avoid hidden nodes and optimizes the channel response by using different aspects like generating OFDM signals [7]. Additionally, LTE can overcome this problem by using more reference signal to

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reduce the time interval between reference signal sequences, and reference signal structure to increase frequency offset compensation range [8].

The rest of this paper is organized as follows: Section II illustrates the literature review of this study, and gives the overview about the importance of this work among other literature. Section III discusses the proposed system model of LTE-V2x. The following section, section IV addresses BLER and throughput performance results for the use of two stochastic channel model used in V2I and their analysis with respect to EVA channel model as a reference model. Finally, Section V presents concludes of this paper.

II. LITERATURE REVIEW

Several studies as Maskulainen, *et al*. [9] investigated the performance and possibilities of exploiting beamforming in LTE-V2x. Whereas, the performance is compared to the conventional Maximum Ratio Combining (MRC) and LTE codebook precoding Minimum Mean Square Error (MMSE) receivers. It depends on enhancing the throughput of the LTE-V2x system by using the narrow beamforming concept. The comparison between using LTE and IEEE802.11p in V2x systems is performed in [10], the use of LTE-based vehicular system is simulated to support the V2V communication for the safety of vehicles and pedestrians. Where, experimental results reveal that IEEE 802.11p based V2V communication when compared to LTE is unstable in the N-LoS conditions, while the cellular-based performs is better in transmission reliability, but has a larger latency than IEEE 802.11p.

The comparison between the two networks used in V2x is also performed in [11]-[13] to motivate the system to achieve the most stringent link-level communication requirements of V2x cooperative driving. They simulate Long Term Evolution Advanced (LTE-A) as a systematic and integrated V2x solution comparing to IEEE 802.11p, LTE-V-Direct is suitable for short range direct communication, low latency and high reliability improvements focusing on communication between vehicles and Road Side Units (RSUs) commonly referred to as V2I communication in a multi-lane freeway scenario the study here is to determine the maximum number of vehicles that can be supported when coverage is provided by the LTE-A network. A top-down approach to create a realistic simulation scenario for joint IEEE 802.11p and Long Term Evolution (LTE) performance evaluations is presented in [14]. The scenario allows the investigation of different use cases considered for ITS.

All the aforementioned studies discuss the LTE-V link in the system and link level performance. It is important to know that the study of the LTE link in V2I communication is essential in both system and link level, especially for the radio channel on the physical layer because of the moving antennas at the transmitter and receiver for low and high speed moving [15]. Because of this the study of channel characteristics in physical layer is very important which is the main advantage of this study. The importance of the channel characteristics study comes from the V2I channel characteristics that affected by large scattering due to the large multipath signals comes from the surrounding objects [16].

Another importance of this study is the study of strong LoS communication because of the low antenna heights used in V2I and short path communication links.

One of the main issues that this study aims to discuss and differs from other literatures is the choice of the best time-variant and frequency selective channel performance to overcome the high Doppler spread due to the moving objects.

Motivated by all the challenges that V2x faces that mentioned before like the QoS of the LoS communication and the channel characteristics, LTE is generally used in V2x. Using LTE can extend the coverage area of V2x application like V2V and V2N, thus makes the commercial use of these systems more reliable. Besides, the link performance of IEEE 802.11p is degraded according to the hidden node and multipath signals where these issues in LTE is avoided [17].

This paper aims to investigate the performance of LTE-V2x system in urban-low speed environment by using Vehicle-to-Infrastructure - Urban (V2I-U) and Vehicle-to-Infrastructure – Urban Small intersection (V2I-US) channel models which both of them have a maximum excess delay near to the 3GPP Extended Vehicular A (EVA) channel model which is used as a reference model in this paper. All these types of stochastic channel model used in V2I communication to have the response of BLER and the throughput of the communication link with the use of two common baseband modulation which are Quadrature Phase Shift Keying (QPSK) and 64-Quadrature Amplitude Modulation (64-QAM).

III. SYSTEM MODEL AND METHODOLOGY

The system proposed is shown in Fig. 2. The figure shows the block diagram of the basic simulation flow of V2I channel model. The simulation proposed starting by assuming that the vehicle travels with low velocity of 40 km/h on a road consisting of LTE nodes along the road with the use of QPSK and 64-QAM as modulation types at 2.6 GHz. The transmitted data are passed to the three channel models and reaches the receiver where it makes the down-conversion process and calculating the BLER and the throughput.

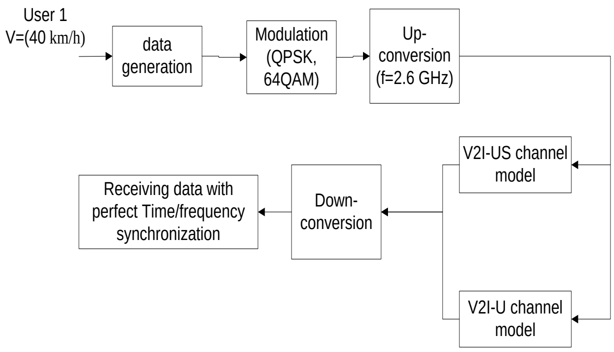

Fig. 2. System model

As recommended by 3GPP or the International Telecommunications Union (ITU), a classical approach to evaluate the link level performance of a cellular network in computer simulations is done by using a stochastic reference channel model, Basically, these models consist of a tapped delay line channel abstraction and a Doppler shift according to the relative speed between TX and RX. However, the given propagation characteristics in vehicular communication lead to different Doppler characteristics and distribution of scatters compared to cellular communication.

In this paper, two times-variant and frequency-selective channel models for V2I-communication are used with one channel model used as a reference. Each model is defined by a set of paths characterized is by an individual delay and relative pathloss, maximum Doppler shift and individual Doppler spectrum shape. Furthermore, the TX-antenna heights are 6.1 m, the LTE carrier frequency fc = 2.6 GHz is used in the proposed simulation study and relative velocity v = 40 km/h is used to compute the Doppler shifts of the channel models used.

The reference channel model is the 3GPP Extended Vehicular A (EVA) that represents the propagation channel between a based station and a vehicular user that is characterized by a large maximum excess delay related to the V2I channel models. Vehicle-to-Infrastructure - Urban Small intersection (V2I-US) is the first channel model used compared with EVA. It represents a small intersection scenario in an urban environment with the maximum excess delay of τ_max = 700 ns which is considered relatively small compared to the EVA reference where its τ_max = 2510 ns. The second one the Vehicle-to-Infrastructure - Urban (V2I-U) which represents the propagation characteristics that is typical to urban street, where static sources of reflection and scattering are in direct proximity to the course of the street. This kind of channel model is usually used in dense road traffic situations and thus many potential mobile scatters in the nearby area exist.

Table summarizes the simulation parameters. As typical setup utilized by many network operators, a system bandwidth B = 10 MHz, and the carrier frequency is set to fc = 2.6 GHz. This band is chosen because of the high free space loss and the large Doppler shifts compared to the typical 800 MHz or 1800 MHz bands making this setup more challenging. Single Input Single Output (SISO) antenna configuration is used in this simulation to simplify the studied (tested) scenario. Accordingly, the modulation used is QPSK and 64-QAM because their features fit in most of wireless communication and has low error rates. Moreover, an MMSE channel estimation in combination with a Zero Forcing equalizer is used in the RX In other words, time and frequency synchronization are assumed to be perfect as the Table I below shows simulation parameters for the LTE link simulator

TABLE I: THE SIMULATION PARAMETERS AND VALUES

Simulation parameter	Values
System bandwidth	10 MHz
Carrier frequency	2.6 GHz
Antenna type	SISO
Modulation	QPSK, 64-QAM
Time/frequency synchronization	Perfect
Antenna height	6.1 m
Velocity	40 km/h
Code rate	0.44
Channel Types	EVA, V2I-US, V2I-U

The process starts from initializing the simulation parameters and determining the channel characteristics. After that, the system operates when the velocity reached 40 km/h to satisfy urban-low mobility scenario between Tx and Rx. Then, the system calculates the BLER response for different values of SNR while applying LTE. Finally, the simulation stopped at 35 dB to satisfy high SNR values. The simulation process is repeated to calculate the BLER and throughput for all types of channel models under study. Every time the channel is changed, the Doppler frequency and frequency taps of the channel are changed to satisfy the channel model used. The correlation between the channel and the transmitted signal is performed where Inter-symbol Interference (ISI) would not adversely affect the system performance.

IV. SIMULATION RESULTS AND DISCUSSION

The first simulation result is performed when applying the V2I-US channel model with QPSK and 64-QAM modulation schemes with 0.44 code rate for both, the receiver RX uses MMSE channel estimation in combination with a Zero Forcing equalizer.

The comparison between the EVA reference channel model and the BLER results obtained from the LTE link level simulator when applying the V2I-US channel model against different values of SNR is shown in Fig. 3. The figure shows that the standard cellular channel model which is represented here by EVA model is dropping steeper with increasing SNR when compared to BLER. This is because of a more detailed modeling of channel properties related to time and frequency dispersion.

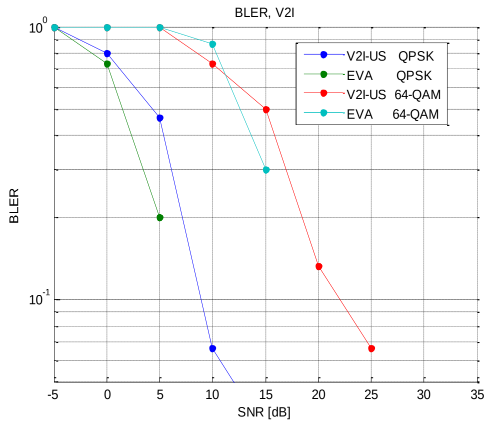

Fig. 3. BLER performance evaluation of V2I-US channel model

The results for the V2I-US model shown in Fig. 3 shows that the BLER falls below 10-1 threshold with approximately 9 dB SNR when using QPSK and 22 dB SNR when using 64-QAM for 0.44 code rate used.

Accordingly, this leads to conclude that the BLER performance of low speed scenario, with the use of the V2I-US channel model, is nearly the same for low and high values of SNR with 2 dB difference compared to EVA BLER performance.

The throughput performance of the V2I-US channel model is shown in Fig. 4. In this figure, the throughput of the V2I-US using QPSK reaches the same values of the EVA channel at 20 dB SNR with 7 Mbps. While the throughput of the V2I-US using 64-QAM reaches the value of the EVA throughput at 30 dB SNR with an extremely increased throughput value that approached 22.5 Mbps which is close enough to the throughput that is obtained from EVA channel.

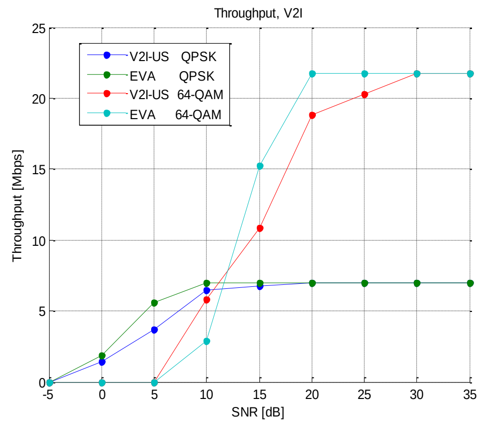

Fig. 4. Throughput performance evaluation of V2I-SS channel model

Fig. 5 shows simulation results for the V2I-U channel model. Due to the strong LoS multipath component and smaller Doppler offset, the BLER result shows lower performance degradation when compared to the EVA reference channel model at the same threshold value with 1 dB and 0.5 dB, differences are required for QPSK and 64-QAM, respectively.

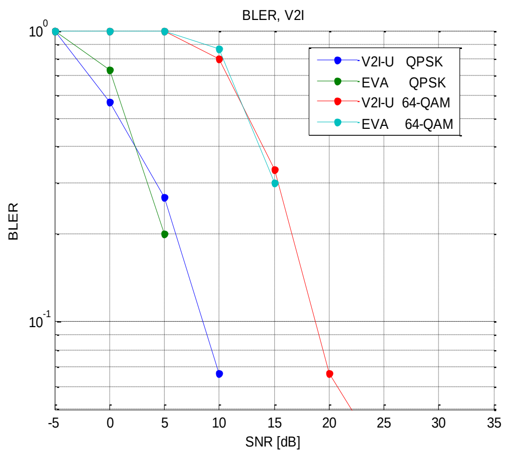

Fig. 5. BLER performance evaluation of V2I-U channel model

The throughput performance results for all two V2I channel models are compared in Fig. 6 using 64-QAM. The figure shows that the performance achieved by the V2I-U channel model is slightly better when compared to V2I-US channel models with 20 Mbps for the V2I-U channel which greater by 1000 kbps than the V2I-US. Slight quantitative differences for the BLER of all three channel models can be observed for SNR values of 10 dB and above. This does not significantly influence the throughput which converges to 23 Mbps at 30 dB, which is the maximum throughput that can be obtained. The best performance within the V2I-U environment can ultimately be explained by the dominant direct path and less severe frequency dispersion.

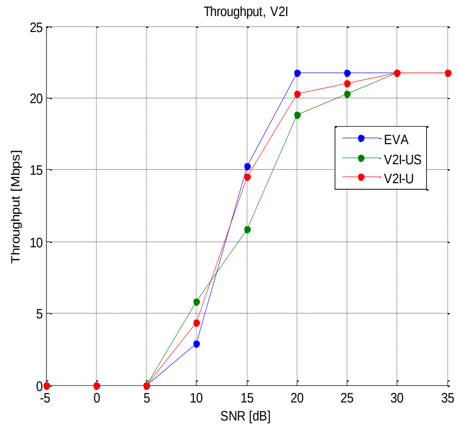

Fig. 6. Throughput performance evaluations of all channel models using 64-QAM

V. Conclusion

The goal of this paper is to make a full overview and a practical simulation of the use of LTE networks in V2I communication in order to evaluate the effect of using two stochastic channel models by simulating the BLER and throughput of the system. The simulation results show that the LTE network offered better network throughput at 23 Mbps for the EVA reference channel model using 64-QAM. The throughput obtained from the V2I-U is nearly 22 Mbps and it is the best values obtained from all other channel models used in this paper. The improved performance within the U environment can ultimately be explained by the dominant direct path and less severe frequency dispersion. There are several possible future works for additional examination like using OFDM as a multiple access for MIMO configuration.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

Saif H. Alrubaee and Mohammed A. Altahrawi have prepared and analyzed the data; Mahamod Ismail has reviewed the research; Bara B. Burhan has modified the paper organization and outline. All authors have approved the final version.

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REFERENCES

[1] S. Schwarz and M. Rupp, "Society in motion: Challenges for LTE and beyond mobile communications," *IEEE Communications Magazine*, vol. 54, no. 5, pp. 76-83, 2016.

[2] Y. L. Tseng, "LTE-advanced enhancement for vehicular communication," *IEEE Wireless Communications*, vol. 22, no. 6, pp. 4-7, 2015.

[3] C. Wang and M. Deng, "Promoting TD-LTE technology to V2X applications to improve traffic safety and efficiency," *Modern Science & Technology of Telecommunications*, vol. 9, pp. 40-46, 2014.

[4] N. A. K. Khani, Z. Chen, and F. Yin, "Single value SRS (SV-SRS) feedback control method for LTE uplink transmission," *JCM*, vol. 9, no. 2, pp. 171-179, 2014.

[5] Y. Li, Y. Cao, H. Qiu, L. Gao, Z. Du, and S. Chen, "Big wave of the intelligent connected vehicles," *China Communications*, vol. 13, no. 2, pp. 27-41, 2016.

[6] W. Li, X. Ma, J. Wu, K. S. Trivedi, X. L. Huang, and Q. Liu, "Analytical model and performance evaluation of long-term evolution for vehicle safety services," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 3, pp. 1926-1939, 2016.

[7] K. Zhou and N. Nikaein, "Random access with adaptive packet aggregation in LTE/LTE-A," *EURASIP Journal on Wireless Communications and Networking*, vol. 2016, no. 1, p. 36, 2016.

[8] J. Liu, X. Tan, C. Huang, and X. Ji, "An enhanced feasible adaptive scheduling algorithm for 3GPP LTE-Advanced system," *Journal of Communications*, vol. 11, no. 1, pp. 64-70, 2016.

[9] I. Maskulainen, P. Luoto, P. Pirinen, M. Bennis, K. Horneman, and M. Latva-aho, "Performance evaluation of adaptive beamforming in 5G-V2X networks," in *Proc. European Conference on Networks and Communications (EuCNC)*, 2017, pp. 1-5.

[10] Z. Liu, Z. Liu, Z. Meng, X. Yang, L. Pu, and L. Zhang, "Implementation and performance measurement of a V2X communication system for vehicle and pedestrian safety," *International Journal of Distributed Sensor Networks*, vol. 12, no. 9, p. 1550147716671267, 2016.

[11] H. Cao, S. Gangakhedkar, A. R. Ali, M. Gharba, and J. Eichinger, "A 5G V2X testbed for cooperative automated driving," in *Proc. Vehicular Networking Conference (VNC)*, 2016, pp. 1-4.

[12] S. Chen, J. Hu, Y. Shi, and L. Zhao, "LTE-V: A TD-LTE-based V2X solution for future vehicular network," *IEEE Internet of Things Journal*, vol. 3, no. 6, pp. 997-1005, 2016.

[13] P. Luoto, M. Bennis, P. Pirinen, S. Samarakoon, K. Horneman, and M. Latva-aho, "System level performance evaluation of LTE-V2X network," in *Proc. European Wireless 2016; 22th European Wireless Conference*, 2016, pp. 1-5.

[14] A. Möller, J. Baumgarten, Z. H. Mir, F. Filali, and T. Kürner, "Realistic simulation scenario for hybrid LTE/IEEE 802.11 p vehicular communication," in *9th European Conference on Antennas and Propagation (EuCAP)*, 2015, pp. 1-5.

[15] P. Chen, W. Ma, and L. Zhang, "Spectrum resources sharing between LTE-V and DSRC," *ZTE Technology Journal*, no. 3, p. 11, 2018.

[16] P. Li, Y. Jia, M. Feng, C. Ye, F. Chen, and H. Fan, "A real-time software defined radio platform for LTE-advanced heterogeneous networks," *Journal of Communications*, vol. 11, no. 3, pp. 263-275, 2016.

[17] S. H. Sun, J. L. Hu, Y. Peng, X. M. Pan, L. Zhao, and J. Y. Fang, "Support for vehicle-to-everything services based on LTE," *IEEE Wireless Communications*, vol. 23, no. 3, pp. 4-8, 2016.

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