An Approach To Convergence Between LTE and DSRC

Raymond Star Jyrwa[1], Debdatta Kandar[1], and Babu Sena Paul[2]

[1] Department of Information Technology, North Eastern Hill University, Shillong, India
[2] Department of Electrical and Electronic Engineering, University of Johannesburg, South Africa

Abstract. With the rapid advancements of technologies and parallel development of intelligent machines in the field of wireless communication, customer needs also arises and ubiquitous network services are expected. In order to support customer's demand there is huge need of hybrid heterogenous network. In this paper, we propose the collaboration of cellular technology like Long Term Evolution (LTE) with traditional vehicular technology i.e., the Dedicated Short Range Communication (DSRC). In this paper we proposed a LTE/DSRC hybrid architecture which can establish a bridge between LTE/DSRC communication. We proposed no changes to the already available standards but we modify some of the configurable parameters in the PHY layers. We concentrate on the OFDM modulation which is the common feature for both LTE and DSRC.

Keywords: LTE, DSRC, OFDM, VANETs, convergence.

1 Introduction

The number of vehicles in the road has increased significantly throughout the years and will increase even more in the years to come. Therefore Intelligent Transportation Systems(ITS) have become the need of the hour with the increasing number of accidents and severe traffic jams. Researchers around the world are still striving to come up with suitable solutions for efficient traffic routing and accident predictable systems. To ensure communication between the vehicles, the IEEE 802.11p WLAN standards have been formulated. According to the standards which fall under the Wireless Access Vehicular Environment(WAVE) communications the radio frequency spectrum from 5.85 to 5.925 GHz have been reserved for Vehicular communications. Although the Dedicated Short Range Communication(DSRC) protocol of 802.11p ensures high capacity for Vehicular-to-Vehicular (V2V) communication, its lacks scalability and infrastructure as well. LTE supports high moblity therefore it is very suitable for vehicular communication. From an economic point of view this cellular network infrastructure is already present and deployed on the ground and its devices are easily available in the market. In DSRC, vehicles are connected to each others through an adhoc wireless network called "Vehicular AdHoc Network"or VANET. VANETs are a subset of Mobile Adhoc Networks (MANET). It includes V2V communications and V2I communications and is an important components of ITS. VANETs follow the standards of IEEE 802.11p, they have less coverage range, hence we consider the support of LTE cellular technology to enhance the coverage range of VANETs. LTE offers wide range communication but costly backhaul infrastructure and licensed spectrum. Related background study is mentioned in Section II. The proposed LTE-DSRC architecture is mentioned in III. Results are discussed in section IV. Section V gives the conclusion.

2 Background Study

VANET applications play an important role in the world of anywhere, anytime, any communication. Applications may be of the following types 1.) Driver Service applications : Here the car can inform the driver about the surroundings, temperature, tyre's air pressure in case if there is a puncture and the nearest gas station where it can be fixed,while making a reverse turn or a u-turn etc. 2) Road Security Applications: Providing information to the driver like speed limit, or informing of the surrounding environment, and sending messages to distant cars of approaching vehicles, especially in blind curves where the driver is unable to see the approaching vehicles, information like when to over take other cars where other cars are fully aware of each other. 3) Comfort applications: Like various mode of driving for example cruise driving where the vehicle can automatically drive by sensing the car in front and make a stop if the car in the front stops. Vehicular networks by using DSRC standards provide communication in the range of 1000 m. Base station or Road side units have to be placed at regular intervals in order to provide seamless connection to the vehicles. LTE on the other hand provides communication in the range of 10Kms thereby reducing the number of required base stations. In [1] the author mentioned that LTE satisfy many of the application's demand like reliability, scalability and mobility support.The convergence of VANETS and cellular communication will enable a variety of applications in road safety. Over a long range LTE can enable VANETS to improve the scalability, throughput and lower latencies.The objective is to take advantage of the already available LTE infrastructure where LTE can support vehicular networking through the use of eNodeB in place of Road Side Units and using LTE enable On Board Units. The challenging task is delivering of real time data from one wireless technology to another efficiently without any delay and distortion in the data frames. Zeeshan Hameed Mir et al [1] analyse the performance and compared both DSRC and LTE separately with various parameters such as vehicle density, vehicle average speed and beacon transmission frequency. Both DSRC and LTE are compared in terms of delay, reliability, scalability, and mobility. The authors concluded that DSRC provides delays less than 10 ms with throughput of 10 kbps. Nabih Jaber in his paper [2] shows the possibility of combining both DSRC and Worldwide Interoperability for Microwave Access (WiMAX). They designed WiMAX tunnel using DSRC with specific changes like network entry and handover processes in the WiMAX protocol. The authors claimed to improve WiMAX communication by decreasing the number of WiMAX connections thereby reducing the traffic congestion at WiMAX base station. The road maps for future development and their challenges related to advances in VANETs is mentioned in [5] , where an overview on current research state, challenges, potentials of VANETs are mentioned. The need to deploy a heterogeneous network topology and model is mentioned in [6], based on the concept of improving the spectral efficiency per unit area. In this paper authors have proved a cost effective approach of heterogeneous networks that enhanced the capacity of LTE cellular networks. An Ubiquitous heterogeneous wireless network architecture is envisioned in [7] by integrating DSRC standards with 3GPP LTE cellular networks in order to achieve constant connectivity for ideal multimedia sessions among the clustered vehicles. F.M Abinader et.al., [8] mentioned the radio frequency spectrum of both LTE and WiFi in addition to the impacts of LTE transmissions on the WiFi, if cellular networks were to be allowed on the same unlicensed bands. It also proposes some mechanism where we can use LTE with WiFi such as the flexible spectrum access and Absolute Blank Frames of LTE.Atat et al., proposes cooperative techniques for short range (SR) collaborations to complement long range (LR) [9]. They wanted to ensure the transfer of data in the shortest time possible with the consideration of LTE network for long range links and WLAN 802.11p for short range links. The proposed cooperative shemes adapted assisted the LR networks to complement the SR networks. Beacon transmission probability in LTE and DSRC is performed in [10], the authors concluded that LTE to support beaconing for vehicular safety applications is poor according to their simulations. In LTE, the network becomes easily overloaded. Vinel et.al., compared and analyzed LTE with 802.11p and suggested that ad-hoc WAVE architecture looks more promising for vehicular safety. A framework for a vehicular network using LTE namely LTE4V2X is proposed in [11] where vehicles having both LTE and 802.11p interfaces are considered. The authors proposed a new protocol architecture and a unique frame. They proposed to use the eNodeB of LTE network to manage the clusters created in VANETs. A technique for real time video streaming of scalable video coded(SVC) over vehicle to infrastructure (V2I) are examined in [12] in which RSUs or road side units communicate with moving vehicles using IEEE 802.11p, and LTE system is used to communicate through cellular base stations. Here, three scenarios are investigated in this paper and different video transmission schemes were compared using QoS/QoE metrics for different video sequences. A heterogeneous vehicular network where LTE is the backhaul network and V2I communication is proposed in [13] in which WiFi is used for V2V communication and Ethernet for on board communication within the vehicle. A multi-interface router is introduced which has three network interfaces, LTE, WiFi, and Ethernet. The network is measured in terms of data rate , data loss ratio, delay and jitter. Imadali et.al., envisioned the use of IPv6 Internet access over LTE backhaul infrastructure in vehicular networks [14]. They considered the V2V2I communication paradigm. They also proposed that in the near future there will be two types of vehicles one equipped only with 802.11p technology called as leaf vehicles and another containing both LTE and 802.11p called as Internet Vehicles. Ali Al Sherbaz et al., proposed a Wimax-WiFi Convergence using an OFDM bridge [33]. The authors proposed not to change not to change any of the standards but to modify some of the parameters in the physical layer which are configurable.We proceed with our study using the concept mentioned in [15] and analyzing if by modifying the parameters we can bridged the gap between LTE and DSRC.

3 Proposed LTE-DSRC Architecture

The proposed architecture scenario for establishing communication in this convergent system of DSRC and LTE comes into play by transforming or adapting to the traditional scenario of Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I), where downlink communication is established between the LTE Road Side Units (RSU's) and DSRC On Board Unit (OBU). Whereas DSRC embedded vehicles can communicate with each other through DSRC-DSRC standards if they are within the coverage of 802.11p standard.The communication is such that LTE transmitter communicate with the 802.11p On board Unit in the vehicles.In our research we have considered common radio frequency spectrum in order to established communication. LTE operating in unlicensed bands is still an ongoing research work which requires careful investigation as mentioned in [8]. All the paper that have mention so far [1-4], have omitted the radio frequency (RF) difference between the two heterogenous networks. In our research we consider other physical layer parameters apart from RF since this is still an ongoing debate to allow LTE in unlicensed bands. The proposed architecture for this particular communication is shown in Figure 1. .In our proposal, we consider the works that have been done in [15] where the author proposed a convergence bridge between WiFi and WiMAX. Based on their work, we undertake some of the physical layer parameters of LTE and DSRC and made a few comparisons in Table 1.LTE uses OFDM modulation in the downlink and Single Carrier- Frequency Division Multiple Access (SC-FDMA) in the uplink whereas DSRC uses OFDM modulation both in the uplink as well as the downlink. In our research work, we considered only downlink channel as OFDM modulation is common in both technologies.

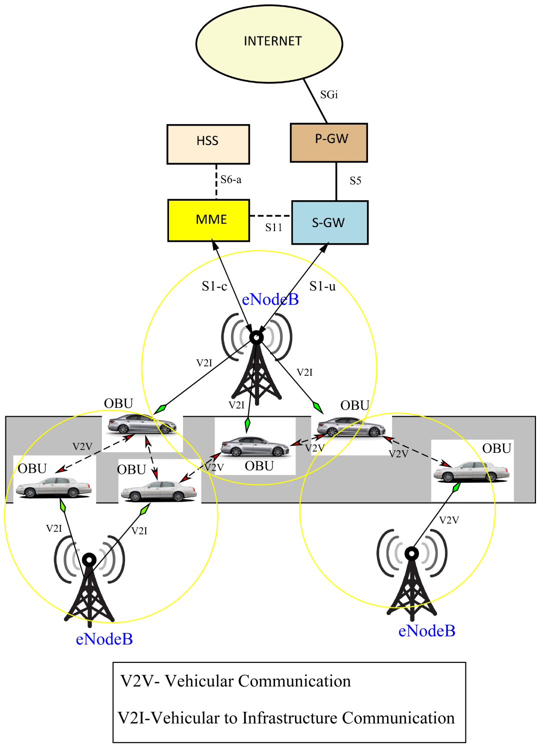


Fig. 1: LTE-DSRC converge Architecture

Table 1: Physical Layer Parameters

Features	DSRC	LTE
IFFT/FFT	64	1024
Bandwidth	10MHz	10MHz
Subcarrier spacing	156.25KHz	15KHz
Subcarriers	52	600
OFDM symbol	8ms	66.7ms
Modulation	OFDM	OFDM (downlink only)

OFDM symbols are produced by the following equation:-

$$x(t) = \sum^{k} X_k e^{j2\pi ktF_0} \tag{1}$$

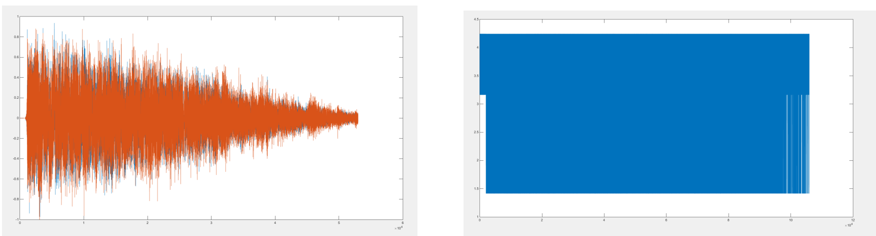
Where X_k is the data to be modulated. $e^{j2\pi ktF_0}$ is the subcarrier where X_k is modulated on. $F_0 = \frac{B}{N}$ is the subcarrier frequency , B is the bandwidth and N is number of subacrriers . k is the number of the subcarrier on which X_k is modulated. Generating this signal $x(t) = \sum^k X_k e^{j2\pi ktF_0}$ is difficult due to the large number of subcarriers . So the signal is sampled at :
Sampling interval $= \frac{1}{sampling frequency} = \frac{1}{B} = T$
L^{th} sampling instant $= LT = \frac{L}{B}$
Now $x(t) = \sum^k X_k e^{j2\pi ktF_0}$
L^{th} sample $x(L) = x(LT) = \sum^k X_k e^{j2\pi kLTF_0}$
L^{th} sample $x(L) = \sum^k X_k e^{j2\pi kL\frac{1}{B}\frac{B}{N}}$

$$L^{th} sample x(L) = \sum^{k} X_k e^{j2\pi k\frac{L}{N}} \tag{2}$$

(2) is the expression for the Inverse Fast Fourier Transform.

4 Results and Discussions

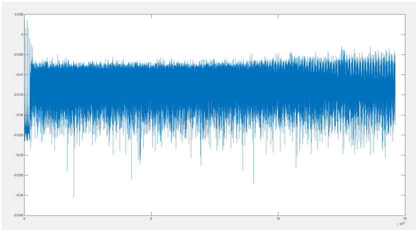
Whether it is LTE or DSRC the OFDM symbols are produced by equation (2). According to [15] convergence is a physical layer issue that cannot be solved in the MAC layer problem. We also propose not to change the standards but to modify some functions which are configurable. Simulations are performed in Matlab software where a transmitter, receiver and an ideal channel are considered. An audio signal is transmitted, where coding and modulation is performed. The data is modulated with an IFFT size of 1024 and on the receiver side the data is demodulated with an 64-point FFT. This modulation is performed on a small part of the received data. This modulation is done 16 times on all the parts in order to retrieve the entire signal and modulated using 16QAM. Figure 2a plots the data samples of the audio signal. Figure 2b plots the modulated samples. Figure 3a plots the ideal channel. Figure 3b plots the output data samples after demolutation with an FFT of size 64.



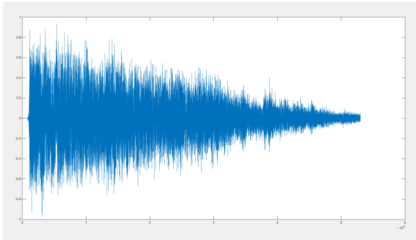
(a) Input audio data samples

(b) Modulated samples

Fig. 2



(a) Ideal Channel plot



(b) Output audio data samples

Fig. 3

5 Conclusion

Various authors compared LTE with DSRC as mentioned earlier but in this work, we addressed issues on the physical layer. Based on our study of the physical layers of both LTE and DSRC, we observed various challenging issues and differences for researchers to converge the two wireless standards. Subcarrier Spacing of LTE and DSRC is a challenging factor for such convergence approach.In conclusion we would like to consider further research on physical layer of wireless networks and to come up with better solution. We also hope that in the near future radio frequency issues of LTE in unlicensed band will be addressed.

References

1. Zeeshan Hameed Amir, Fethi Filali, *LTE and IEEE 802.11p for vehicular networking: A performance evaluation*, EURASIP Journal on Wireless Communications and Networking , 2014.
2. Nabih Jaber, Nicholas C Doyle, Keal E Tepe, *New Combined WiMAX/DSRC infrastructure design for efficient vehicular networking*, EURASIP Journal on Wireless Communications and Networking, 2012.
3. George K, Onur A, Eylem E, Geert H, Boangoat J, Kenneth L, Timothy W, *Vehicular Networking: A Survey and Tutorial on requirements, Architectures, Challenges, Standards and Solutions*, ISSN :1553-877X, DOI:10.1109/SURV.2011.061411.00019 IEEE, 2011
4. Ian F. A, David M. Gutierrez–Estevez , Elias C Reyes, *The evolution to 4G cellular systems: LTE- Advanced, Physical Communication*, pp. 217-244, ISSN: 1874-4907, doi:10.1016/j.phycom.2010.08.001, 2010
5. Elias C. Eze, Si- Jing Z, En – Jie L, Joy C. Eze, *Advances in Vehicular Ad-Hoc Networks (VANETs) : Challenges and Road – map for Future Development*, DOI: 10.1007/ s11633 – 015 – 0913 – y, pp.1-18, February 2016
6. Khandekar, A., Bhushan, N., Tingfang, J. and Vanghi, V., 2010, April. *LTE-advanced: Heterogeneous networks.* In Wireless Conference (EW), 2010 European (pp. 978-982). IEEE.
7. Sivaraj, R., Gopalakrishna, A.K., Chandra, M.G. and Balamuralidhar, P., 2011, October. *QoS-enabled group communication in integrated VANET-LTE heteroge-*

neous wireless networks. In Wireless and Mobile Computing, Networking and Communications (WiMob), 2011 IEEE 7th International Conference on (pp. 17-24). IEEE

8. Abinader, F.M., Almeida, E.P., Chaves, F.S., Cavalcante, A.M., Vieira, R.D., Paiva, R.C., Sobrinho, A.M., Choudhury, S., Tuomaala, E., Doppler, K. and Sousa, V.A. *Enabling the coexistence of LTE and Wi-Fi in unlicensed bands.* Communications Magazine, IEEE, 52(11), 2014.
9. Atat, Rachad, Elias Yaacoub, Mohamed-Slim Alouini, and Fethi Filali. *Delay efficient cooperation in public safety vehicular networks using LTE and IEEE 802.11 p.*In Consumer Communications and Networking Conference (CCNC), IEEE ,2012.
10. Vinel, Alexey. 3GPP LTE versus IEEE 802.11 p/WAVE: which technology is able to support cooperative vehicular safety applications? Wireless Communications Letters, IEEE 1.2 (2012): 125-128.
11. Guillaume Remy , Sidi - Mohammed Senouci , Francois Jan , Yvon Gourhant. *LTE4V2X : LTE for a Centralized VANET Organisation*, 2011 IEEE Globecom proceedings,2011
12. Yaacoub, Elias, Fethi Filali, and Adnan Abu-Dayya. *SVC video streaming over cooperative LTE/802.11 p vehicle-to-infrastructure communications.* Computer and Information Technology (WCCIT), 2013 World Congress on. IEEE, 2013.
13. Sadek, N. M., Halawa, H. H., Daoud, R. M., Amer, H. H., and Ali, N. A. *Heterogeneous LTE/Wi-Fi architecture for ITS traffic control and infotainment.* In Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles (ESARS), 2015 International Conference on (pp. 1-6). IEEE.2015
14. Imadali, S., Kaiser, A., Decremps, S., Petrescu, A., Veque, V. *V2V2I: Extended inter-vehicles to infrastructure communication paradigm.* In Global Information Infrastructure Symposium. IEEE.2013
15. Al-Sherbaz, Ali, Chris Adams, and Sabah Jassim. *WiMAX-WiFi convergence with OFDM bridge.* SPIE Defense, Security, and Sensing. International Society for Optics and Photonics, 2009.