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Link level performance comparison between LTE V2X and DSRC

Jinling Hu[1], Shanzhi Chen[1], Li Zhao[1], Yuanyuan Li[1], Jiayi Fang[1], Baozhu Li[2*], Yan Shi[2]

1. State Key Laboratory of Wireless Mobile Communications, China Academy of Telecommunications Technology, Beijing 100191, China
2. State Key Laboratory of Networking and Switching Technology, Beijing University of Posts and Telecommunications, Beijing 100876, China

* Corresponding author, Email: tiger_1984@bupt.edu.cn

Abstract: Applications of VANETs (Vehicular Ad hoc Networks) have their own requirements and challenges in wireless communication technology. Although regarded as the first standard for VANETs, IEEE 802.11p is still in the field-trial stage. Recently, LTE V2X (Long-Term Evolution Vehicular to X) appeared as a systematic V2X solution based on TD-LTE (Time Division Long-Term Evolution) 4G. It is regarded as the most powerful competitor to 802.11p. We conduct link level simulations of LTE V2X and DSRC (Dedicated Short-Range Communication) for several different types of scenarios. Simulation results show that LTE V2X can achieve the same BLER (Block Error Ratio) with a lower SNR (Signal Noise Ratio) than DSRC. A more reliable link can be guaranteed by LTE V2X, which can achieve the same BLER with lower receiving power than DSRC. The coverage area of LTE V2X is larger than that of DSRC.

Keywords: LTE V2X, DSRC, link level simulation, frequency offset estimation, VANET

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1 Introduction

Vehicular Ad hoc Networks have attracted much attention from academia and industry recently owing to the broad range of new applications of wireless communication technologies. Existing V2V (Vehicle-to-Vehicle) direct communication together with V2I (Vehicle-to-Infrastructure) communication use wireless data communication between vehicles and between vehicles and RSUs (Road-Side Units). This can significantly decrease the number of accidents on the roads. All kinds of applications are emerging. Lane departure warning and assistance, cooperating safety systems and emergency vehicle routing are examples of applications[1].

These traffic safety related systems indicate an increased number of requirements and challenges for wireless communication. The unpredictable behavior of wireless channels needs to be overcomed. In addition, developers must cope with fast vehicular movement, rapid topology changes in vehicular networks, and strict timing and reliability requirements. Timing requirements can be deduced from the fact that it is only relevant to communication about an

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upcoming dangerous situation before the situation is a fact, and perhaps can be avoided (e.g., report a probable collision before the vehicles collide)[2]. One thing we need to consider is how shared channels should be fairly divided among vehicle nodes. This is accomplished through MAC (Medium Access Control) mechanism. A lot of attention has been devoted to improving MAC performance by introducing different QoS (Quality of Service) classes[3]. The MAC layer is unlikely to need many different service classes. However, to ensure that time-critical communication tasks meet their deadlines, the MAC mechanism must first provide a strict and finite access time to the channel. Once channel access is successful, different coding strategies, retransmission schemes, and diversity techniques can be used to finish the required correctness and robustness. Information delivered after the deadline is not only useless but also wastes time and precious resources, and poses severe consequences for traffic safety. This problem has also been pointed out in Ref. [4].

Many wireless technologies can provide the wireless access required by vehicular Ad hoc communications. These technologies include cellular networks (3G and 4G), traditional Wi-Fi, IEEE 802.11p, and even infrared communications[5,6]. Owing to their small communication range, traditional Wi-Fi and infrared communications are not appropriate for supporting high mobility and frequent topology changes[5]. Although people can use cellular networks, they suffer from low rates, high costs, and long latencies. In these technologies, although IEEE 802.11p as the first standard specifically for vehicular networks has arisen, it has obvious weaknesses such as hidden node problems, unbounded delays, low reliability and intermittent V2I connectivity[7-10]. From an industrial perspective, the wide deployment of IEEE 802.11p network infrastructure requires huge investments. A lot of effort has been made by using LTE as a promising wireless technology to support vehicular communications[11,12].

Owing to its high penetration rate, high data rate, large coverage, and comprehensive QoS supporting, LTE has inherent advantages in supporting V2I communications. However, LTE faces severe challenges when being applied in V2V communications for the following reasons: the heavy load caused by safety-related and periodic messages strongly influences LTE capacity and potentially disadvantages traditional applications, and its centralized mode has no support for V2V communications[7]. Extending LTE with direct communications between vehicles will be a promising solution, because cellular and Ad hoc communications are suggested to be complementary[13,14].

Vehicular networks mainly provide safer, more comfortable driving and traffic efficiency; however, if we do not ensure the reliability (error probability) of a system supported by a PHY (Physical) layer, the benefits of vehicular networks cannot be exploited and utilized. We need to investigate the characteristics of the PHY layer of LTE V2X and DSRC to evaluate their BLER performance. In this paper, we conduct a link level evaluation between LTE-V2X and DSRC by using an extensive simulation. By the evaluation based on simulation, we derive that the performance of the PHY layer of LTE V2X is obviously superior to that of DSRC with regard to simulation parameters such as different traveling velocities and different packet sizes.

The rest of the paper is organized as follows: A comparison between LTE V2X and DSRC on the physical level is discussed in section 2, which includes the coding scheme and frequency offset estimation algorithm. In section 3 we conduct a simulation and performance evaluation between LTE V2X and DSRC in all kinds of scenarios including different relative velocities and a fast fading model. Concluding remarks and future work are given in section 4.

2 Comparison between LTE V2X and DSRC

In the section, we mainly focus on a comparison between LTE V2X and DSRC on the physical level. In the next section, we conduct link level simulations on LTE V2X and DSRC to evaluate their link performances in different scenarios.

2.1 DSRC

The US FCC (Federal Communication Commission) allocated 75 MHz of the spectrum for V2V and V2I communications. The main purpose is to enable safety-related applications in vehicular networks to improve traffic conditions and prevent accidents (traffic safety). There are two types of channels in DSRC, each of them with a 10-MHz bandwidth: the SCH (Service Channel) and the CCH (Control Channel). SCHs are available both for safety and non-safety use, and CCHs are restricted to safety communications only. Applications for vehicular communications can be placed in three main categories: traffic safety, traffic efficiency and value-added services (e.g., infotainment/business)[15-17].

The DSRC band is a free yet licensed spectrum. Because the FCC does not charge a fee for spectrum usage, it is free. However, we should not confuse this with the unlicensed bands at 900 MHz, 2.4 GHz, and 5 GHz, which are also free for use. These unlicensed bands place no restrictions on the technologies other than some emission and co-existence rules. On the other hand, usage of the DSRC band is more restricted. FCC rulings regulate usage within certain channels and limit all radios to be compliant with a standard. In other words, although DSRC is limited in transmission power with regard to the unlicensed band, one cannot develop a different radio technology (e.g., one that uses all 75 MHz of the spectrum) in the DSRC band. These DSRC usage rules are referred as “license by rule.”

2.1.1 Physical layer architecture

The physical layer standard is made up of two sublayers: the PMD (Physical Medium Dependent) sublayer and PLCP (Physical Layer Convergence Protocol) sublayer. The PMD sublayer defines the parameters to establish the signal, such as channel coding, modulation, and demodulation. On the other hand, the PLCP sublayer deals with interference between different PHY layers and makes sure that the MAC layer receives the data in a common format, independent of the particular PMD sublayer. Through the correspondent SAPs (Service Access Points), the PLCP communicates with the PMD sublayer and MAC layer.

2.1.2 Coding scheme: convolutional code

In DSRC, convolutional code is used. This is also called NSC (Nonsystematic Convolutional) codes.

2.1.3 DSRC frequency offset estimation algorithm

For the DSRC receiver, there are two steps to estimate and correct frequency errors. The detailed steps can be seen in Algorithm 1.

Algorithm 1 DSRC frequency offset estimation

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1: The short training sequences (for coarse frequency offset estimation) and the long training sequence (for fine frequency offset estimation) are utilized in the PLCP preamble to correct the frequency error, and the integer and non-integer parts of the frequency error can be corrected at the same time;
2: Four pilot subcarriers of every OFDM symbol are used for carrier phase tracking to alleviate the residual frequency error and phase noise.
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The short training sequence is defined as 1.6 us, and the FFT/IFFT period for the 10-MHz bandwidth is 6.4 us in IEEE 802.11p protocols. Because the phase offset of the neighboring short training sequence is limited to π, the maximum frequency error estimation of the 10-MHz DSRC can be two times the subcarrier spacing, theoretically. Though the fixed frequency error $X = 40$ ppm (236 kHz) for DSRC is higher than the subcarrier spacing of 156 kHz, the fixed frequency error of 236 kHz is lower than the theoretical maximum frequency error estimation of 312 kHz of the 10-MHz DSRC. Then, the frequency compensation can be based on the estimation of the frequency error. The fixed frequency error of 40 ppm (236 kHz) can be compensated with short and long training sequences simultaneously for the integer and non-integer parts of the frequency error.

2.2 LTE V2X

LTE V2X based on TD-LTE 4G is a systematic V2X solution. LTE V2X consists of two modes: LTE-V-Direct and LTE-V-Cell. Compared with IEEE 802.11p, LTE-V-Direct is a new distributed architecture. It changes the TD-LTE physical layer and attempts to provide high-reliability improvements, short-range direct communication, and low latency by maintaining commonality. By leveraging the centralized architecture, LTE-V-Cell optimizes RRM (Radio Resource Management) to better support V2I communications. LTE-V-Direct and LTE-V-Cell work together with each other to provide promising V2X solutions.

2.2.1 Frame structure

Fig. 1 shows the frame structure of LTE V2X. In the frame structure, there are 14 TTIs (Transmission Time Intervals), in which four DMRS (Demodulation Reference Signals) and one GP (Guard Period) are included, and the rest are data symbols.

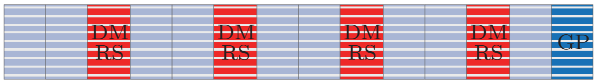

Figure 1 Frame structure of LTE V2X

For V2V, the data frame structure of D2D defined in 3GPP TS 36.211 and 3GPP TS 36.212 is reused: there are 14 symbols in one TTI that lasts 1 ms, and the last symbol is used as a guard period.

In PSSCH/PSCCH/PSDCH of 3GPP Rel 12/13 D2D, there are two DMRSs per PRB, and the interval time of the DMRS is 0.5 ms. When the speed of the mobile terminal is high, such as 140 km/h, and the signal's center frequency is 6.0 GHz, the coherence time (about 0.277 ms) of the signal will be lower than the current time interval of DMRS (about 0.5 ms). Hence, the demodulation performance of the data will fall sharply owing to poor channel estimation and a consequential lack of channel information. There is a consensus that DMRS density in the time domain should be increased to four symbols.

2.2.2 Coding scheme: Turbo code

In LTE V2X, we use turbo code which is one of the most powerful types of FEC (Forward-Error-Correcting) channel codes. The best-known convolutional codes are mostly nonsystematic. However, systematic convolutional codes are used in turbo encoders (i.e., the encoder's input bits appear at the output). Unlike nonsystematic code, a systematic code word can be divided into data and parity components. Turbo codes are produced by using the parallel concatenation of two RSC (Recursive Systematic Convolutional) encoders. This is one of the most interesting characteristics: that it is not just a single code, but is also in fact a combination of two codes that work together to achieve a synergy. It would be impossible by merely using one code by itself. In particular, a turbo code is formed from the parallel concatenation of two constituent codes separated by an interleaver. Each constituent code may be any type of FEC code used for conventional data communications. Although the two constituent encoders may be different, in fact they are normally identical. The interleaver is a critical part of the turbo code. It is a simple device that changes the order of the data bits.

2.2.3 LTE V2X frequency offset estimation algorithm

For the DSRC receiver, there are six steps to estimate and correct the frequency error. The detailed steps can be seen in Algorithm 2.

3 Simulation and performance evaluation

We conducted extensive link level simulations of LTE V2X and DSRC using our simulator coded in MATLAB by CATT, and analyzed a comparison and performance evaluation of the two links based on the simulation results (i.e., SINR-BLER and the receiving power with BLER). Our simulation assumptions are based on the parameters listed in Tab. 1, and all assumptions were agreed to during the NGMN V2X task force F2F meeting[14,18,19] in September 2016. For frequency errors in Tab. 1, we set the values based on the maximum allowable deviations these two systems can tolerate. Extensive simulations were conducted for the urban case with relative speeds of 30 km/h and 120 km/h and the freeway case with relative speeds of 280 km/h and 500 km/h. Only the performance metrics of BLER are compared in this paper. We will compare some other performance metrics in the future. In addition, in all figures, fix CFO means a fixed central frequency offset, and rand CFO means a random central frequency offset.

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Algorithm 2   LTE V2X frequency offset estimation
1: Timing detection by searching the peak of channel estimation transformed to the time domain, $\rightarrow d$;
2: Local DMRS sequence is transformed to the time domain, $\rightarrow P(n)$;
3: Sequence shift of sequence in Step 2 according to timing in Step 1, $\rightarrow \widetilde{P}(n) = P(\mathrm{mod}(n+d, N))$;
4: Received DMRS symbol is transformed to the time domain, $\rightarrow r(n)$;
5: Correlation is done for sequence in Step 3 and Step 4;
6: Frequency offset is estimated by comparing the angle difference of first half and second half of sequence in Step 5.
   $f = \frac{1}{2\pi\Delta t \tan^{-1}}\left\{\sum_{n=0}^{N/2-1}\widetilde{P}(n)r(n)\right\} \times \left\{\sum_{n=0}^{N/2-1}\widetilde{P}(n+\frac{N}{2})r(n+\frac{N}{2})\right\}$
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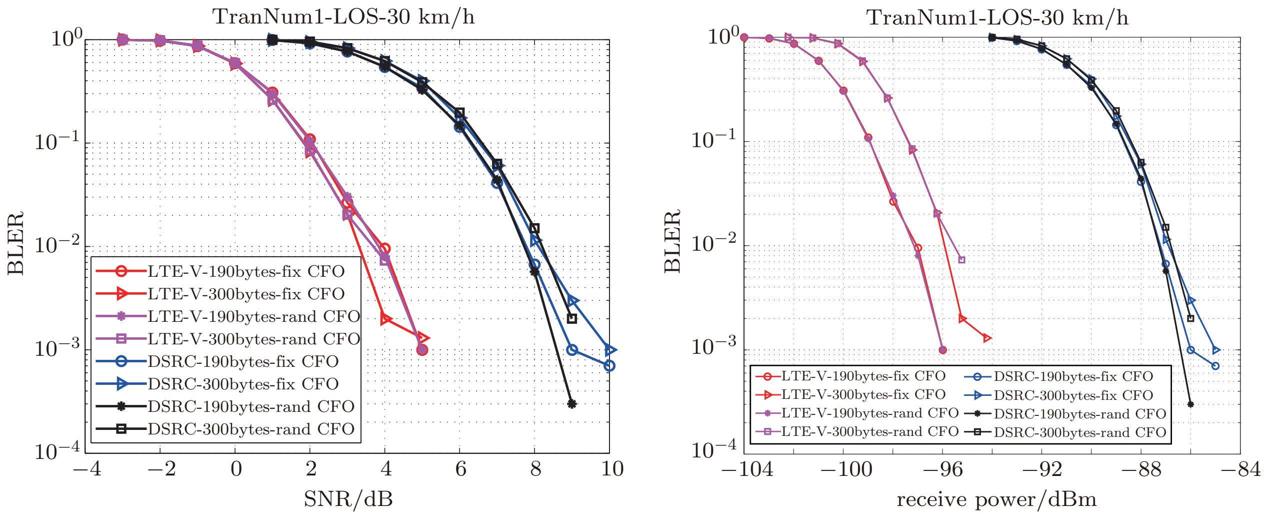
Fig. 2 shows a link level performance comparison between LTE V2X and DSRC when the relative speed is 30 km/h for the urban case with LOS[20]. Fig. 2(a) shows various BLERs for LTE V2X and DSRC with packet sizes of 190 B and 300 B, and fixed and random frequency errors, respectively, when the SNR is increasing. It is seen that the curves of BLERs are very close about different packet sizes and different types of frequency errors for LTE V2X and DSRC for different SNRs. This indicates that packet sizes and frequency-error types cannot affect BLERs of LTE V2X and DSRC under the same SNR because we used the same coding rate and better frequency offset estimation algorithm. We observe that a higher SNR is needed for DSRC than LTE V2X to achieve the same link level performance. Fig. 2(b) shows various BLERs of LTE V2X and DSRC with packet sizes of 190 B and 300 B, and fixed and random frequency errors respectively, when the received power is increasing. It is seen that the curves of BLERs are very close about different packet sizes and different types of frequency errors for DSRC, but BLERs are very different for different packet sizes of LTE V2X, and different types of frequency errors cannot cause performance differences. We observe that a higher received power is needed for 300 B than 190 B to achieve the same link level performance for LTE V2X.

Fig. 3 shows a link level performance comparison between LTE V2X and DSRC when the relative speed is 120 km/h in the urban case with LOS. Compared to Fig. 2, Fig. 3 have the same tendency yet a worse performance. This indicates that relative speed affects the BLERs of LTE V2X and DSRC in the urban case with LOS. Under the same SNR and receiving power, a larger relative speed causes larger BLER (i.e., worse performance). This is because that when the relative speed becomes larger, the Doppler effect becomes larger, and the frequency offset correction is more seriously affected.

Fig. 4 shows a link level performance comparison between LTE V2X and DSRC when the relative speed is 30 km/h in the urban case with NLOS[20]. It is seen that compared to Fig. 2, there are clear and obvious differences between the BLERs for LTE V2X and DSRC. This indicates that different fast fading models affect the BLER significantly in the urban case under the same velocity. In more detail, for LTE V2X, in Fig. 2(a) when the SNR is -3 dB, the BLER is 1. When the SNR is 4 dB, the BLER is 0.01. In Fig. 4(a) when the SNR is -7 dB, the BLER is 1. When the SNR is 12 dB, the BLER is 0.01. The ratio of the BLER to the SNR is larger in the urban case with LOS than in the urban case with NLOS. We can deduce that to achieve the same link level performance, a higher SNR is needed for the urban case with NLOS than the urban case with

Table 1 Link level simulation parameters for LTE V2X and DSRC

parameters	LTE-V2X	DSRC
modulation & coding rate	QPSK, 1 transimssion w/o segmentation, 1/2 coding rate	QPSK, 1/2 coding rate (i.e., 6 Mbit/s)
carrier frequency	5.9 GHz	5.9 GHz
fast fading model	ITU LOS/NLOS	ITU LOS/NLOS
frequency error	$X = 0.3$	$X = 40$
noise figure	9 dB	9 dB
number of antennas	1TX and 2RX antennas	1TX and 2RX antennas
time synchronization	ideal time synch	ideal time synch
performance metric	SNR vs. BLER; receiving power vs. BLER	SNR vs. BLER; receiving power vs. BLER
scenarios	urban case and freeway case	urban case and freeway case
absolute speed	15 km/h, 60 km/h, 140 km/h and 250 km/h	15 km/h, 60 km/h, 140 km/h and 250 km/h
relative speed	30 km/h, 120 km/h, 280 km/h and 500 km/h	30 km/h, 120 km/h, 280 km/h and 500 km/h

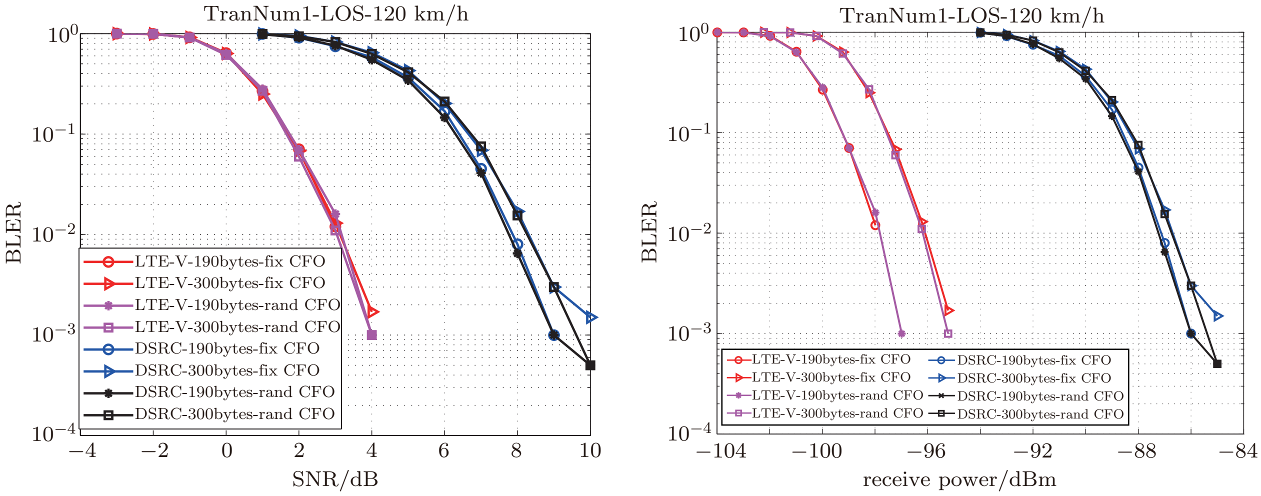


(a) (b)

Figure 2 Link level performance comparison between LTE V2X and DSRC (urban case: LOS; relative speed 30 km/h). (a) SNR-BLER; (b) receiving power-BLER

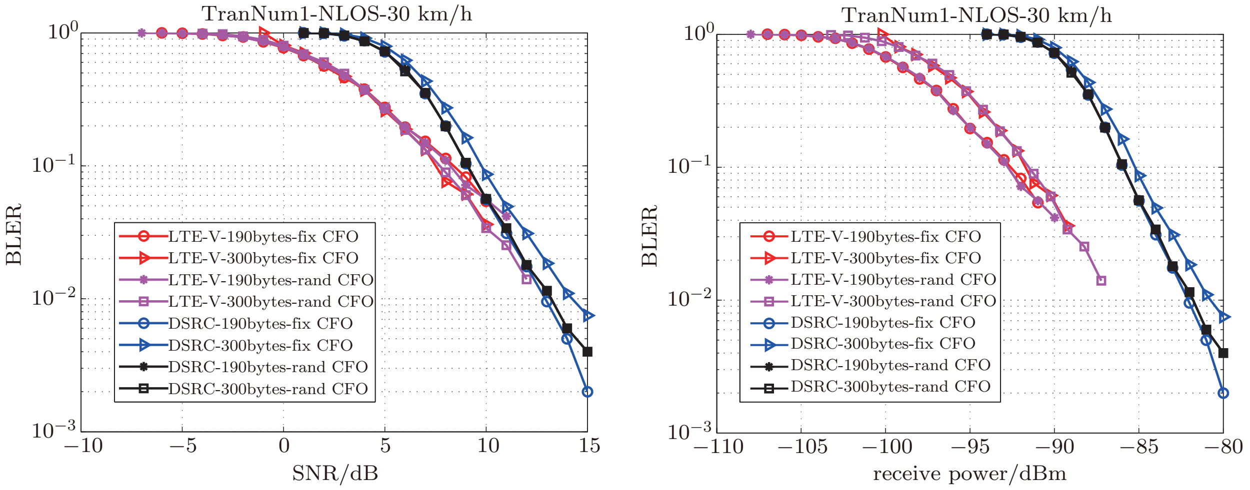
LOS. The same conclusion is reached for the DSRC. This situation occurs because in the NLOS scenario, obstructions from buildings and other objects affect the transmission equality of the signal, and then affect the link performance. It can also be seen that LTE V2X can achieve the same BLER with a lower receiving power than DSRC, and that the coverage of LTE V2X is larger than DSRC under the same velocity.

Fig. 5 shows a link level performance comparison between LTE V2X and DSRC when the relative speed is 120 km/h in the urban case with NLOS. From this figure, we can obtain the same conclusion in Fig. 4 compared to Fig. 3. Note that in Fig. 4(a) and Fig. 5(a), when the SNR is 10 dB, the performance gap between LTE V2X and DSRC is small. Compared to DSRC (156.25 kHz), subcarrier spacing of LTE V2X (15 kHz) is smaller. In the NLOS scenario, because there is no LOS path that can offer a frequency offset correction, LTE V2X is more sensi-



(a) (b)

Figure 3 Link level performance comparison between LTE V2X and DSRC (urban case: LOS; relative speed 120 km/h). (a) SNR-BLER; (b) receiving power-BLER



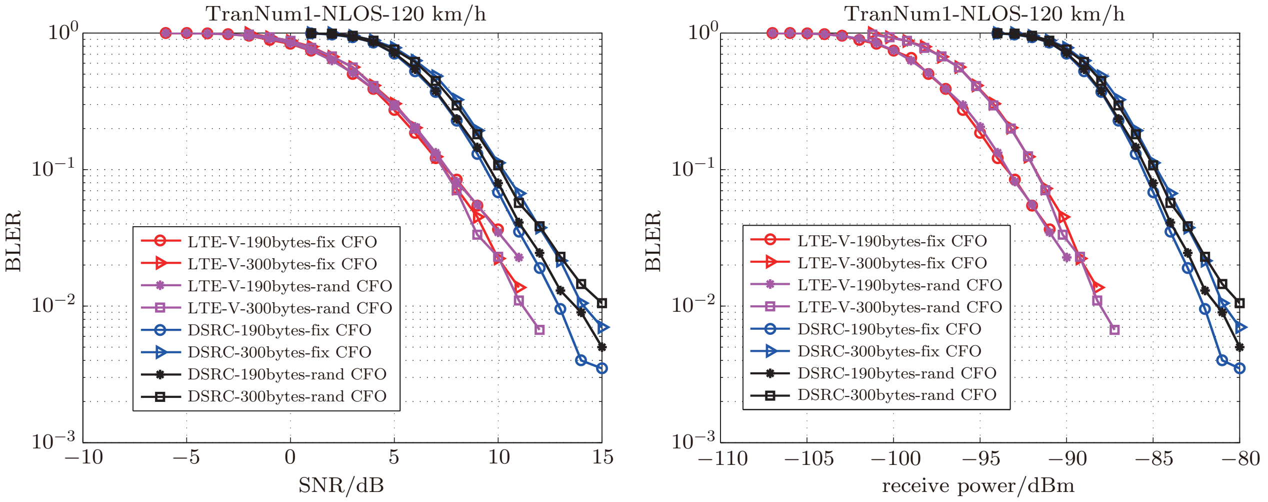
(a) (b)

Figure 4 Link level performance comparison between LTE V2X and DSRC (urban case: NLOS; relative speed 30 km/h). (a) SNR-BLER; (b) receiving power-BLER

tive to frequency offset effects than DSRC. Moreover, for LTE V2X, the channel estimation is less accurate. These two reasons result in the phenomenon that the curves of LTE V2X and DSRC are very close.

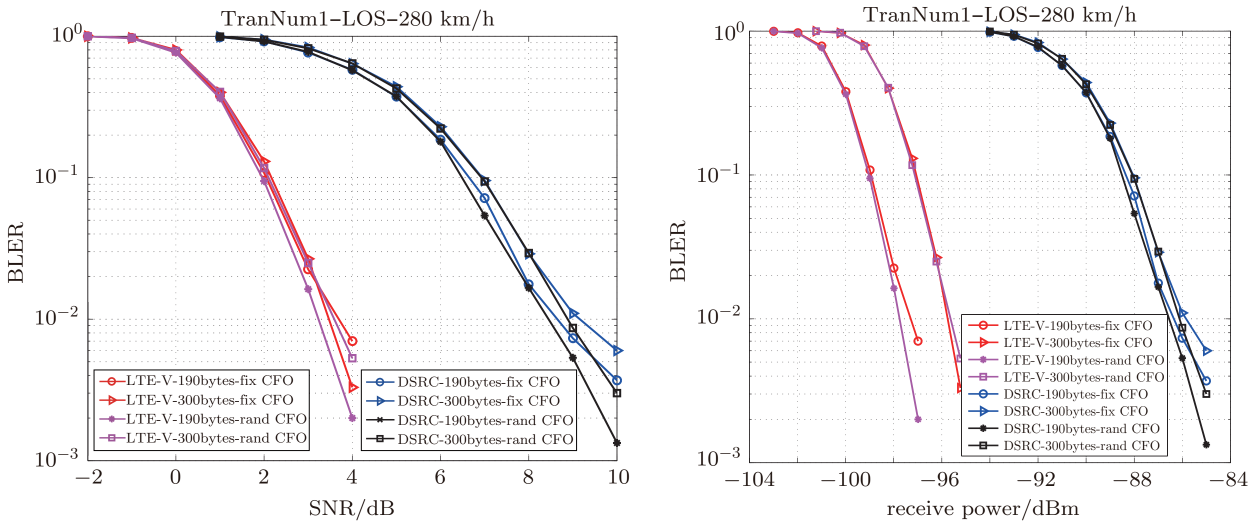
Fig. 6 shows a link level performance comparison between LTE V2X and DSRC when the relative speed is 280 km/h in the freeway case with LOS. As depicted in Fig. 2 and Fig. 3, we can see that DSRC needs a larger SNR and receiving power to obtain the same BLER as LTE V2X in the freeway case with LOS. However, compared to Fig. 2 and Fig. 3, the performances of LTE V2X and DSRC in Fig. 6 do not obviously decline. This is because the frequency offset estimation for LTE V2X is very accurate and when the relative speed is 30 km/h, channel fading is more serious. This indicates that under a larger relative velocity in the freeway case, LTE V2X and DSRC can obtain the same performance in the LOS scenario.

Fig. 7 shows a link level performance compari-



(a) (b)

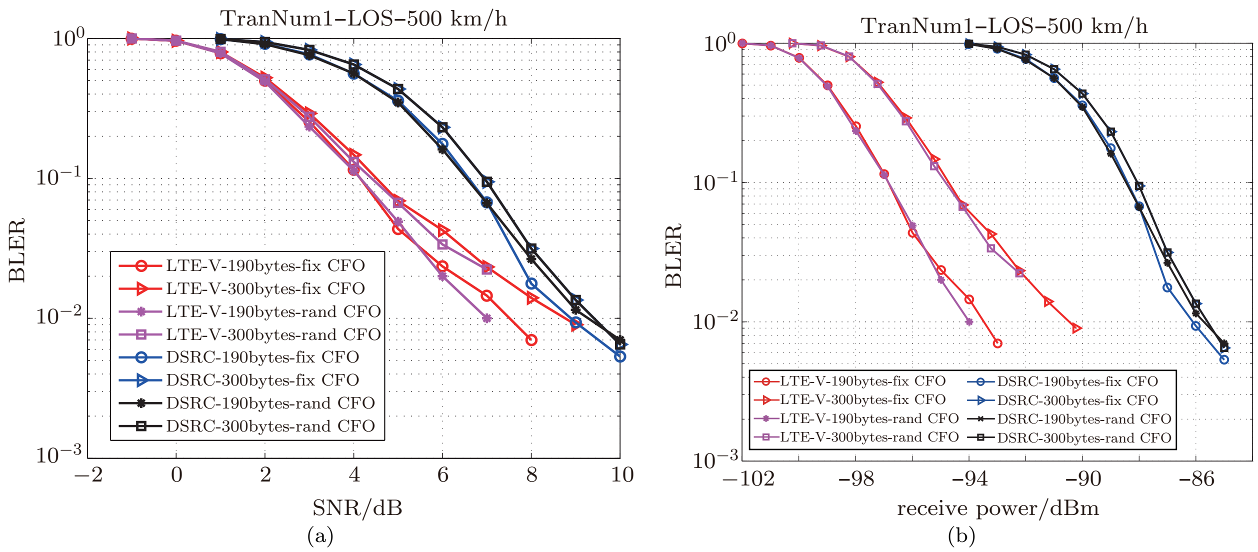
Figure 5 Link level performance comparison between LTE V2X and DSRC (urban case: NLOS; relative speed 120 km/h). (a) SNR-BLER; (b) receiving power-BLER



(a) (b)

Figure 6 Link level performance comparison between LTE V2X and DSRC (freeway case: LOS; relative speed 280 km/h). (a) SNR-BLER; (b) receiving power-BLER

son between LTE V2X and DSRC when the relative speed is 500 km/h in the freeway case with LOS. We can see that in the SNR interval (i.e., [−2, 4] dB and [1, 10] dB) in Fig. 6(a), LTE V2X and DSRC can cause larger BLERs when the relative velocity is 500 km/h than when the relative velocity is 280 km/h, especially for LTE V2X. Obviously, the angle of slope of LTE V2X is much smaller than that of DSRC. Thus, for LTE V2X, a larger SNR is needed to obtain the same BLER under a very high relative velocity. Similar to Fig. 2(b) and Fig. 3(b), Fig. 6(b) and Fig. 7(b) show that LTE V2X needs a larger receiving power to achieve the same BLER under the same velocity. Thus, if a large packet needs to be sent, a shorter distance is needed under the same sending power. In reality, the relative velocity 500



(a)

(b)

Figure 7 Link level performance comparison between LTE V2X and DSRC (freeway case: LOS; relative speed 500 km/h). (a) SNR-BLER; (b) receiving power-BLER

Table 2 Comparison of SNR between LTE V2X and DSRC (BLER = 0.1)

BLER = 0.1	DSRC_SNR minus LTEV2X_SNR (dB)				results range (dB)
scenarios	190 B/fixed CFO	300 B/fixed CFO	190 B/rand CFO	300 B/rand CFO	
30 km/h/LOS	4.2	4.7	4.3	4.8	[4.2, 5.0]
120 km/h/LOS	4.7	5.0	4.6	5.0	
280 km/h/LOS	4.6	4.7	4.5	4.8	
500 km/h/LOS	2.5	2.5	2.3	2.6	[2.3, 2.6]
30 km/h/NLOS	1.0	2.3	1.3	1.3	[1.0, 2.8]
120 km/h/NLOS	2.1	2.7	2.1	2.8	

km/h is rarely seen. Thus, we only compare the situation as a reference.

As shown in Tab. 2, for both LOS and NLOS transmission scenarios of the MCS (Modulation and Coding Scheme) configurations, we observe that a higher SNR is needed for DSRC than LTE V2X to achieve the same link level performance (BLER = 0.1). For example, the SNR of DSRC is about 4.2 dB to 5.0 dB higher than that of LTE V2X in LOS scenarios with relative speeds of 30 km/h to 280 km/h. The difference between the SNR of DSRC and LTE V2X decreases, but the SNR of DSRC is about 1.0 dB to 2.8 dB higher than that of LTE V2X in NLOS scenarios with relative speeds of 30 km/h to 120 km/h. However, at a relative speed of 500 km/h, the link level performance in LOS scenarios is degraded, and the SNR of DSRC is still about 2.3 dB to 2.6 dB higher than that of LTE V2X. Therefore, LTE V2X can achieve the same BLER with a lower SNR than DSRC, and a more reliable link can be guaranteed by LTE V2X.

In Tab. 3, for both the LOS and NLOS transmission scenarios of the MCS configurations, a higher receiving power for DSRC is needed to achieve the same link level performance (BLER = 0.1). It can be observed that the receiving power of DSRC is about 8.9 dBm to 10.7 dBm higher than that of LTE V2X in the LOS scenarios with relative speeds of 30 km/h

Table 3 Comparison of receiving power between LTE V2X and DSRC (BLER = 0.1)

BLER = 0.1	DSRC_RX_Power minus LTEV2X_RX_Power (dBm)				results range (dB)
scenarios	190 B/fixed CFO	300 B/fixed CFO	190 B/rand CFO	300 B/rand CFO	
30 km/h/LOS	10.2	8.9	10.3	9.1	[8.9, 10.7]
120 km/h/LOS	10.7	9.1	10.6	9.2	
280 km/h/LOS	10.6	8.9	10.5	9.0	
500 km/h/LOS	8.5	6.6	8.3	6.8	[6.6, 8.5]
30 km/h/NLOS	7.0	6.5	7.3	5.5	[5.5, 8.1]
120 km/h/NLOS	8.1	6.9	8.1	7.0	

to 280 km/h. In the NLOS scenarios, the difference between the receiving power of DSRC and LTE V2X decreases, but the receiving power of DSRC is about 5.5 dBm to 8.1 dBm higher than that of LTE V2X in the NLOS scenarios with relative speeds of 30 km/h to 120 km/h. However, at a relative speed of 500 km/h, the link level performance in the LOS scenarios is degraded, and the receiving power of DSRC is still about 6.6 dBm to 8.5 dBm higher than that of LTE V2X. Therefore, LTE V2X can achieve the same BLER with a lower receiving power than DSRC, and the coverage area of LTE V2X is larger than that of DSRC.

From the aforementioned simulations and analysis, we can see that LTE V2X performs better than DSRC. The reasons from a theoretical perspective are:

- Four-column DMRS can improve the performance in the high Doppler case resulting from the vehicles' high traveling velocities;
- Because an FDM mechanism is utilized in LTE V2X, the granularity of resources in the frequency domain is a subchannel. The noise has less impact on LTE V2X than DSRC in the time domain;
- Turbo code outperforms convolutional code, as mentioned in section 2.

4 Conclusion and future work

In order to evaluate the link level performances of LTE V2X and DSRC, extensive simulations were conducted in an urban scenario and freeway scenario. The simulations included many kinds of relative velocities and fast fading models. Based on these simulations, we can see that LTE V2X can achieve the same BLER with a lower SNR than DSRC. A more reliable link can be guaranteed by LTE V2X, and LTE V2X can achieve the same BLER with a lower receiving power than DSRC. The coverage area of LTE V2X is larger than that of DSRC.

In this paper, the modulation mode used in DSRC was QPSK. To round things out, in the future, we still need to conduct a link level simulation comparison between LTE V2X and DSRC in which BPSK is used. Based on these two simulation comparisons, we can fully understand the link performance between LTE V2X and DSRC. To validate the accuracy of the simulation results, we also need to conduct real experiments between LTE V2X and DSRC in terms of the simulation scenarios mentioned above.

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About the authors

Jinling Hu got her master's degree from Beijing University of Aeronautics and Astronautics, in 1999. She is the deputy chief engineer at Datang Wireless Mobile Innovation Center, where she works on research of key technologies in next generation mobile communications. (Email: hujinling@catt.cn)

Shanzhi Chen received his Ph.D. degree from Beijing University of Posts and Telecommunications (BUPT), China, in 1997. He joined Datang Telecom Technology & Industry Group in 1994, and has been serving as CTO since 2008. He was a member of the steering expert group on information technology of the 863 Hi-Tech Research and Development Plan of China from 1999 to 2011. He is the director of State Key Laboratory of Wireless Mobile Communications, and the board member of SMIC (Semiconductor Manufacturing International Corporation). He devoted his works to the research and development of TD-SCDMA 3G industrialization and TD-LTE advanced 4G standardization. He received 2001 and 2012 National Awards for Science and Technology Progress, China, the 2015 National Award for Technological Invention, China, and the 2014 Distinguished Young Scholar Award of National Natural Science Foundation, China. His current research interests include network architecture, 5G mobile communication, and IoT (Internet of Things).

Li Zhao received her master's degree from Beijing University of Posts and Telecommunications (BUPT) in 2004. She is currently an engineer at Datang Wireless Mobile Innovation Center. Her current research interests focus on vehicular networking and cellular high layer protocol. (Email: zhaoli@catt.cn)

Yuanyuan Li received her M.E. degree from Beijing Institute of Technology in 2009, and joined CATT this year. She has been working on GPP LTE/LTE-A at RAN1 working group. She focus on LTE-V2X technology and related algorithm development. (Email: liyuanyuan@catt.cn)

Jiayi Fang received his M.Sc. degree from the University of Electronic Science and Technology of China in 2004, and joined CATT this year. He has been working on 3GPP LTE/LTE-A at RAN1/RAN2 working group from Release 8 since 2008. He is currently a senior technical manager of CATT, focus on LTE-V2X technology. (Email: fangjiayi@catt.cn)

Baozhu Li [corresponding author] received his B.E. and M.E. degrees from University of Jinan, China. He is a Ph.D. student in Beijing University of Posts and Telecommunications, China. His research interest is vehicular Ad hoc networks. (Email: tiger_1984@bupt.edu.cn)

Yan Shi received her Ph.D. degree from Beijing University of Posts and Telecommunications (BUPT) in 2007. She is currently a member of the research staff of the State Key Laboratory of Networking and Switching Technology, BUPT. Her current research interests include network architecture evolution, protocol design and performance optimization of future networks, mobile computing and vehicular network, especially mobility management technology. (Email: shiyan@bupt.edu.cn)