2018 4th International Conference on Systems, Computing, and Big Data (ICSCBD 2018)

Low Latency of Vehicular Communication in 5G

Weiqi Xiang

Nanjing University of Science and Technology, Nanjing 210094, China.

xiangweiqi@njust.edu.cn

Keywords: vehicular communication; V2X; latency; 5G NR.

Abstract: To expand the wireless communication system to automotive industry, LTE completed supporting the vehicle-to-everything (V2X) communication. The advanced V2X services (eV2X services) are categorized into four useful scenarios: vehicular platooning, advanced driving, extended sensors and remote driving, their common feature is the need for low latency. Even some scenarios have harsh requirements for latency, such as the communication scenario that emergency trajectory alignment between users supporting V2X application needs 3ms end-to-end delay. Although the 3ms delay requirement is demanding, for autonomous driving, this is the basic requirement for safe driving. In this article, we analyze the latency characters of the existing vehicular communication, and propose a feasible to meet the latency requirement to support the vehicular communication in 5G new radio (NR).

1. Introduction

Intelligent Transportation System (ITS) contains two technologies: Dedicated Short Range Communication (DSRC) and V2X. For nearly a decade, DSRC based on IEEE 802.11p has been searched, and It seems to have an advantage in local V2X communication[1],[2],[3]. However, Research on cellular networks over the past few years has shown that cellular networks has advantage on already available infrastructure, longer range, higher data rates and lower end-to-end latency, and that it can be integrated into Internet of Things (IoT). Thereby, the evolution of cellular networks has enabled Long Term Evolution (LTE) to become the preferred communication technology for V2X[4],[5]. A relevant aspect of advanced V2X applications is the Level of Automation (LoA), LoA are: 0 – No Automation, 1 – Driver Assistance, 2 – Partial Automation, 3 – Conditional Automation, 4 – High Automation, 5 – Full Automation. In the extreme scenes, the performance requirement of V2X is required that the max end-to-end latency is as low as 3ms and the reliability is as high as 99.999%[6]. [7][8] analyzes the latency of LTE, the result show that the minimum latency cannot meet the extreme needs of 3ms and cannot meet the universal needs of 10ms. Even 1ms delay request in Ultra Reliable Low Latency Communication (URLLC) [9]. In this article, we first analyze the latency characteristics of LTE V2X, then analyze the latency characteristics of NR V2X, and then propose measures to reduce the delay.

2. The Latency of LTE V2X

The vehicular communication in cellular communication has two ways of resource allocation: Centralized distribution and distributed distribution. The two distribution methods lead to two different lantency analysis methods. In this paper, we analysis the latency of centralized distribution, i.e. Autopilot-related data is transmitted through the air interface (Uu interface). Unless otherwise stated, LTE V2X or NR V2X refers to the mode of centralized allocation.

When data arrives, and the vehicle has no sidelink grant to send the data, the latency for sendind the data is consists of following component which is described by Table 1, the total latency of LTE-V2X is up to 19.5 transmission time interval (TTI). TTI is the basic unit of time scheduling, representing the minimum data transfer time. And TTI in LTE is equal to 1ms, so the data of LTE-V2X need 19.5ms to transmit. it is obviously not able to meet the 3ms requirement. The TTI length

  DOI: 10.25236/icscbd.2018.020

is related to the carrier spacing, as the carrier spacing becomes larger, the TTI length becomes smaller, thereby reducing the delay. And the time of transmitting data is fixed value (i.e. 1 TTI), it is obviously unreasonable. For example, in LTE, sending 1024bit costs 1ms, and sending 1bits also cost 1ms, this is what we don't want to see. We hope that the smaller the length of the message sent, the less time it takes.

Table 1. Latency component of LTE-V2X based on SR/BSR

Component	Description	Time
	Average waiting time for PUCCH (5 TTI SR period)	2.5 TTI
a	UE sends Scheduling Request (SR) on PUCCH	1 TTI
b	eNB decodes Scheduling Request and generates the Scheduling Grant	3 TTI
c	Transmission of Scheduling Grant	1 TTI
d	UE Processing Delay (decoding of grant + L1 encoding of UL data)	3 TTI
e	UE sends BSR	1 TTI
f	eNB decodes BSR and generates scheduling grant	3 TTI
g	Transmission of scheduling grant	1 TTI
h	UE processing delay and transmission (decoding scheduling grant + L1 encoding of data)	4 TTI
Total		17+2.5 = 19.5 TTI

3. The Latency of NR V2X

In 5G NR, there are 4 carrier spacing: 15kHz, 30kHz, 60kHz,120kHz, and the corresponding time slot length is 1ms, 0.5ms. 0.25ms, 0.125ms, we also introduce non-slot to reduce transmission time.

3.1 Control Plane Latency

Control plane latency is evaluated from *RRC_INACTIVE* state to *RRC_CONNECTED* state. The process required for the user to switch from the idle state to the active state is shown in Figure 1. The latency does not include waiting time for DL/UL subframe to align the understanding of the delay parameters without waiting time. The latency of transmitting the Physical Random Access Channel (PRACH) preamble is related to its format.

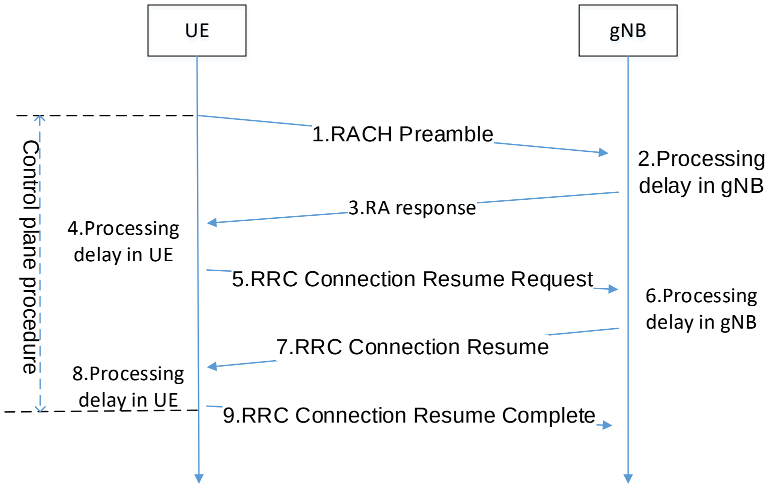
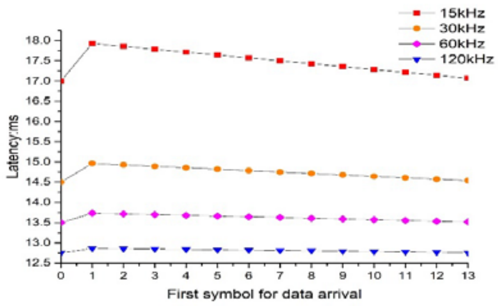


Figure 1. Control plane procedure

The delay is mainly composed of two parts, i.e. the UE capacity and transmission time. For the UE, the delay determined by the UE capability is immutable, the latency determined by transmission time can be reduced. It takes 1TTI to transfer data each time. And 1TTI equals 1ms in current vehicular communication based on cellular communication, regardless of the size of the transmitted data. In NR V2X, we can use the broadband, i.e. the larger carrier spacing, to reduce the TTI, thus reducing the delay. In NR V2X, we even use non-slot to further reduce the delay, Transmission time does not necessarily contain 14 Orthogonal Frequency Division Multiplexing (OFDM) symbols (OS), it can also be 2OS, 4OS, 7OS or 14OS. In our simulation, the preamble length takes 1ms. With my simulation, i.e. Fig.2 and Fig.3, shorten TTI (i.e. increasing carrier spacing) and using non-slot can reduce the latency of control plane (CP) latency.



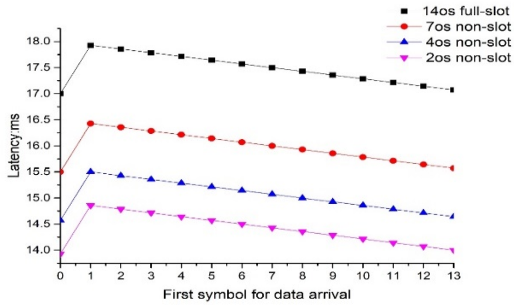


Figure 2. the CP latency with different carrier spacing   Figure 3. the CP latency with non-slot or full slot

3.2 User plane latency

The latency elements in V2X are configured latency and transmission latency.

Configured latency is the time duration for vehicular to be allocated resource from eNB. The latency components generally consist of the following:

1) Average waiting time for PUCCH;

2) Scheduling Request (SR) transmission: $t_{SR} = 1symbol$;

3) eNB decodes SR and generates the scheduling grant for BSR: $t_{BS,rx} = 1slot$;

4) Scheduling grant transmission: $t_{grant} = 1symbol$;

5) UE processing delay (decoding of grant + L1 encoding of UL data): $t_{ue,tx} = N_2 = T_{proc,2} symbols$;

6) BSR transmission: $t_{BSR} = 1symbol$;

7) eNB decodes BSR and generates scheduling grant: $t_{BS,rx} = N_1 = T_{proc,1} symbols$;

8) Transmission of scheduling grant for data transmission: $t_{grant} = 1symbol$;

9) UE processing delay: $t_{ue,rx} = N_2/2 = T_{proc,2} / 2symbols$;

Transmission latency is the time duration for the data from being transmission to being receiving. V2X has not feedback (i.e. ARQ/NARQ) to reduce the latency, and the UE has right to choice to retransmission by wireless channel quality. The latency components generally consist of the following:

1) UE encode the data: $t_{ue,tx} = N_2/2 = T_{proc,2} / 2symbols$;

2) Data transmission: $t_{data} = 1slot$;

3) eNB receiving the data and decode data: $t_{BS,rx} = N_1 / 2 = T_{proc,1} / 2symbol$;

In NR, the scheduling period for Physical Uplink Control Channel (PUCCH) is no longer a fixed value, i.e. 10 slots, it has multiple value (e.g. 4slots,8slots, and so on). However, in order to have a clearer latency comparison with LTE V2X, we still take the original scheduling period. In the actual simulation process, there are also considerations for slot alignment. Data arrival occurs at any other slots and any symbols, when the number of OFDM symbols required in the data transmission duration is less than the available remaining OFDM symbols in the available slot for transmission, the UE should wait until the arrival of the first available symbol of the next slot. For example, if the data transmission duration is assumed to use 10 OFDM symbols, but the remaining available OFDM symbols in the current slot is 5 OFDM symbols, the data transmission will not be triggered in the current slot and needs to wait 5 symbols for the next available slot. From the simulation results, the latency of NR V2X is significantly better than the latency of LTE V2X, and the carrier spacing of 60kHz reaches the highest requirement of V2X for latency (ie 3ms).

Table 2. The latency of UP for NR V2X with differrent carrier spacing

	Latency(ms)			
Carrier spacing	Full slot	Non-slot		
		7OS	4OS	2OS
15kHz	9.107	7.607	6.964	6.607
30kHz	6.080	3.830	3.723	3.438
60kHz	2.330	2.205	2.080	2.027

The latency result of table 1 is contain configured latency and transmission latency, but the UE has only the transmission latency without configured latency in the case of existing resources. With the using of semi-persistent scheduling (SPS), in most cases, latency only contains transmission latency. Fig. 4 and Fig. 5 is simulated basing on the grant-free, and Fig. 5 uses 15kHz carrier spacing. From the simulation results, the larger the carrier spacing, the smaller the latency, and 60kHz carrier spacing reach the latency requirement (1ms) of Ultra Reliable Low Latency Communication (URLL). And also, If the evaluation is for *K* OFDM symbol length non-slot, then non-slot based scheduling is used. And the data transmission will require *K* OFDM symbols, applying non-slot can significantly reduce latency, 2OS non-slot delivers 3dB benefits compared to 14OS full-slot.

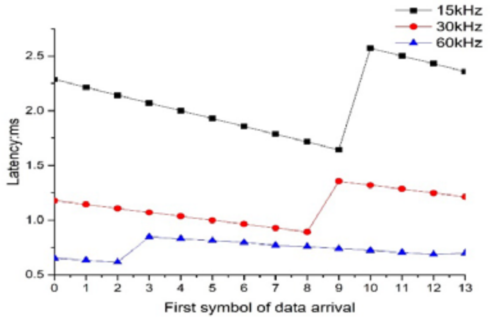


Figure 4. the UP latency with different carrier spacing

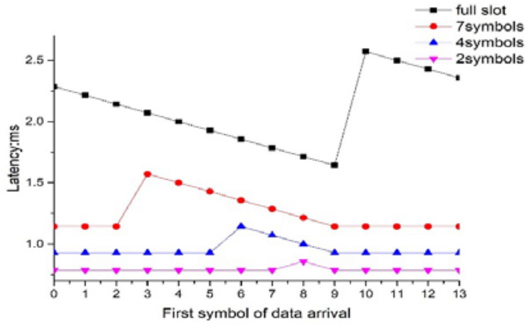


Figure 5. the UP latency with non-slot or full slot

Acknowledgments

The paper gives exhaustive explanation of the latency of vehicular-to-everything communication based on cellular communication by air interface. To meet the requirement in V2X that the latency of 3ms. Increasing the carrier spacing, i.e. shorten TTI length, and applying the non-slot (7OS, 4OS, 2OS) make the latency meet performance requirement.

References

[1] Zubair Amjad et al., "Low Latency V2X Applications and Network Requirements: Performance Evaluation", In IEEE Intelligent Vehicles Symposium (IV), 2018 IEEE Conference on (pp. 220 - 225)

[2] Luoto, P., Bennis, M., Pirinen, P., Samarakoon, S., Horneman, K. and Latva-aho, M., 2017, June. "Vehicle clustering for improving enhanced LTE-V2X network performance." In Networks and Communications (EuCNC), 2017 European Conference on (pp. 1-5). IEEE.

[3] Sikora, Axel, and Manuel Schappacher. "A highly scalable IEEE802. 11p communication and localization subsystem for autonomous urban driving." Connected Vehicles and Expo (ICCVE), 2013 International Conference on. IEEE, 2013.

[4] Chen, S., Hu, J., Shi, Y., Peng, Y., Fang, J., Zhao, R. and Zhao, L., 2017. "Vehicle-to-Everything (v2x) Services Supported by LTE-Based Systems and 5G." IEEE Communications Standards Magazine, 1(2), pp.70-76.

[5] Chen, S., Hu, J., Shi, Y. and Zhao, L., 2016. "LTE-V: A TD-LTE Based V2X Solution for Future Vehicular Network." IEEE Internet of Things Journal, 3(6), pp.997-1005.

[6] 3GPP TS 22.186," Enhancement of 3GPP support for V2X scenarios", Sep. 2018.

[7] 3GPP TS 36.881," Study on latency reduction techniques for LTE", Jun. 2016.

[8] RP-150465, New SI proposal: Study on Latency reduction techniques for LTE, Ericsson, RAN#67, March 2015.

[9] Report M.2410," Minimum requirements related to technical performance for IMT-2020 radio interface(s)", ITU-R, 11/2017