The Impact of Packet Priority Transmission on 5G-NR-V2X Communications

Sawera, Jiawei Tian, and KyungHi Chang*
Dept. of Electronic Engineering, Inha University,Incheon, Republic of Korea.
saweraaslam265@gmail.com, tianjiawei@inha.edu, and khchang@inha.ac.kr*

***Abstract*—5G New Radio Vehicle-to-Everything (5G-NR-V2X) technology enhances road safety and efficiency by facilitating communication among vehicles, roadside infrastructure, and pedestrians. A major challenge within V2X networks is the decreasing Packet Reception Ratio (PRR) associated with higher vehicle densities. This paper proposes a potential solution to tackle this challenge through the implementation of Prose Per Packet Priority (PPPP) in simulations to overcome the impact of vehicle congestion on PRR within Vehicle-to-Vehicle (V2V) network. This paper analyzes the influence of vehicle congestion on the reliability of V2V communication, which is a crucial aspect for ensuring safety and optimizing traffic flow efficiency. The application of PPPP demonstrates a noteworthy improvement in communication reliability, indicating its effectiveness in mitigating packet loss within specific traffic environments. This highlights the potential of Packet Priority Transmission as a practical solution to address real-world communication challenges in the context of 5G-NR-V2X networks.**

Keywords—5G-NR-V2X, V2V communication, vehicle density, packet loss, Prose Per Packet Priority.

I. INTRODUCTION

As numbers of connected vehicles are increasing rapidly, efficient management of traffic flow is crucial to preventing congestion. Intelligent Transportation Systems (ITS) and Vehicle-to-Everything (V2X) communications are key to making transportation work better and safer [1]. The advent of 5G-NR-V2X sidelink communications stands out as a significant solution, enabling direct and reliable communication between nearby vehicles without the necessity of a base station or a cellular network. Despite its advantages, communication within 5G-NR-V2X sidelink networks presents challenges due to the dynamic nature of vehicular traffic and the potential for congestion which leads to a reduction in PRR [2].

In the presence of a substantial number of vehicles, the potential for congestion escalates, consequently compromising communication quality. This leads to congestion and reduces PRR, managing traffic flows efficiently is crucial to prevent congestion. In V2V communication, Cooperative Awareness Messages (CAMs) and Decentralized Environmental Notification Messages (DENMs) are important messages for road safety. CAMs, which are sent out regularly, share vital details such as a vehicle's location, speed, and acceleration. These details are key for keeping roads safe and traffic moving smoothly. DENMs are also important for dealing with dangerous situations on the road. Both CAMs and DENMs are sent over a special channel called the Control Channel (CCH), which is used specifically for cooperative road safety [3]. PPPP prioritizes the transmission of vital messages, thereby diminishing the chances of missing key safety information. It allocates higher priority to urgent messages.

This research investigates the scenario when PPPP can make 5G-NR-V2X communications more reliable, which is crucial for keeping our roads safe as the traffic get congested. We first discuss the overview of Packet Priority Transmission in section II. After that in section III we discuss the performance evaluation of varying PPPP settings on the PRR in dense vehicle networks in detail by changing different parameters setting. Finally, section IV concludes the paper.

II. OVERVIEW OF PACKET PRIORITY TRANSMISSION

PPPP is a communication protocol designed to manage and prioritize data transmission in 5G-NR-V2X technology. The purpose of Packet Priority Transmission is to address challenges related to network congestion and PRR, especially in scenarios where many connected vehicles are communicating simultaneously. Table I displays Channel Busy Ratio (CBR) based maximum Channel Occupancy Ratio (CR) limits. Congestion control measures must be implemented to lower the CR if the present value exceeds the upper limit of the CBR range [4].

TABLE I. CBR-BASED MAXIMUM CR LIMIT AND PACKET PRIOTIY

CBR	Priority 1-2	Priority 3-5	Priority 6-8
$0 \le CBR \le 0.30$	No limit	No limit	No limit
$0.30 < CBR \le 0.65$	No limit	0.03	0.02
$0.65 < CBR \le 0.80$	0.02	0.006	0.004
$0.80 < CBR < 1$	0.02	0.003	0.002

The protocol operates by assigning different levels of priority to individual data packets based on their content and urgency. PPPP ensures that critical messages, such as emergency alerts, accident warnings, or important traffic information, receive higher priority compared to less time-sensitive data. By prioritizing these crucial messages, PPPP aims to enhance the stability of the 5G-NR-V2X communications, ensuring that essential information reaches its destination promptly and without compromise, even in congested network conditions.

III. PERFORMANCE ANALYSIS

In this study, the main goal is analysis of Packet Priority Transmission in 5G-NR-V2X communications, specifically under conditions of high vehicle density. The primary goal is evaluating the PRR, a crucial metric in 5G-NR-V2X communications. PRR is essential for assessing the reliability of 5G-NR-V2X communications, where timely and accurate transmission of information is critical for safety and efficient traffic management. Our approach is to examine the impact of PPPP in maintaining or enhancing PRR, while being cautious to avoid an overly aggressive application that might disrupt the system's overall performance.

For this purpose, we used a simulator named LTEV2Vsim in 3GPP standard. Highway scenario is used to evaluate the PRR performance in sidelink communications [5]. Table II presents parameters and their corresponding values for the simulation. Key attributes include the packet size of 1000 bytes, a subchannel size defined by 10 resource blocks, a range of awareness spanning 200 meters for vehicles in communication, and an average vehicle speed of 120 km/h

* Address Correspondence to Prof. KyungHi Chang

with a standard deviation of 7 km/h indicating speed variability. Additional parameters include subcarrier spacing at 15 kHz, a keep probability of 0.4, periodicity set at 0.1 seconds, a sensing threshold of -126 dBm.

TABLE II. LIST OF PARAMETERS USED IN SIMULATOR

Parameter	Value
Scenario	3GPP Highway
Road Length	2000 m
Road Width	4 m
Vehicle Speed	120 km/h
Carrier Frequency	6 GHz
Bandwidth	20 MHz
Packet Size	1,000 Bytes
Size of Subchannel	100 Resource Blocks
Subcarrier Spacing	15 kHz
MCS for NR	5
Antenna Gain	3 dBi
Noise Figure	9 dB

This scenario is designed to reflect realistic traffic conditions with a vehicle density of 100 and 200 vehicles per kilometer. The simulation's main goal is to investigate the effects of varying PPPP settings on the PRR in dense vehicle networks. Figure 1 shows the PRR with respect to distance for two different PPPP values, 2 and 5, across two vehicle densities, 100 and 200 vehicles per kilometer.

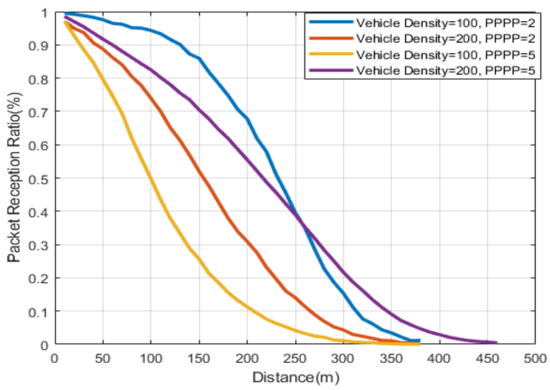

Fig. 1. PRR varying vehicle density and PPPP.

At vehicle density = 100 vehicles per kilometer, higher PPPP (Normal Priority), leads to a lower PRR, when distance increases. This effect is due to higher vehicle densities, which leads to a rise in the CBR, resulting in a more congested network environment that reduces the PRR even further.

Conversely, the lower PPPP (High Priority), leads to a higher PRR by giving priority to important messages. For both vehicle densities (100 and 200), the PRR starts higher at shorter distances, indicating a better packet reception. However, as distance increases, the reception ratio decreases, more so for a higher vehicle density.

Overall, the curves representing the PRR performance by using two different PPPP values indicate that when vehicle density is 100 vehicles per kilometer and PPPP is set 2 (High Priority), it gives better performance of PRR over distance as compared to other curve line, which is also representing 100 vehicle density per kilometer with PPPP value 5. In other case, when PPPP is set 5 (Normal Priority), vehicle density of 200 vehicles per kilometer gives better PRR over distance as compared to other curve line, which is also representing 200 vehicles per kilometer with PPPP value of 2, because in high vehicle density, CBR also increases which leads to limited CR.

IV. Conclusions

In conclusion, we analyze the effect of varying PPPP settings on the PRR in dense vehicle networks. The simulation results show that a higher PPPP value of 2 enhances PRR over distance with 100 vehicles per kilometer, whereas a normal PPPP value of 5 performs better in higher vehicle densities of 200 vehicles per kilometer. This is because, in areas with more vehicles, the CBR goes up, which limits the CR. It shows that it is essential for maintaining stable communication in ITS under the high congested traffic flow.

Acknowledgment

This work was supported by the Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (No. 2021-0-01140, Development of ultra high-speed V2X communication-based autonomous driving service technologies).

References

[1] Garcia, Mario H. Castaneda, et al., "A tutorial on 5G NR V2X communications," *IEEE Communications Surveys & Tutorials*, vol. 23, no. 3, pp. 1972-2026, Feb. 2021.

[2] Lucic, Michael C., et al., "Leveraging intelligent transportation systems and smart vehicles using crowdsourcing: An overview," *Smart Cities*, vol. 3, no. 2, pp. 341-361, May. 2020.

[3] Tian J., Islam A. and Chang K., "A hybrid power-rate management strategy in distributed congestion control for 5G-NR-V2X sidelink communications," *Sensors*, vol. 23, no. 15, pp. 6657-6672, Jul. 2023.

[4] Nasrin Taherkhani, and Samuel Pierre, "Prioritizing and scheduling messages for congestion control in vehicular ad hoc networks," *Computer Networks*, vol. 108, pp. 15-28, Oct. 2016.

[5] V. Todisco, S. Bartoletti, C. Campolo, A. Molinaro, A. O. Berthet and A. Bazzi, "Performance analysis of sidelink 5G-V2X mode 2 through an open-source simulator," *IEEE Access*, vol. 9, pp. 145648-145661, Oct. 2021.