Decentralized Congestion Control for 5G-NR-V2X Sidelink

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***Abstract*— The speed, density, and channel occupancy of vehicles in vehicular networks can vary significantly. Scenario dynamics may need a large number of message exchanges as vehicle density rises, which might easily cause radio channel congestion issues. For the purpose of reducing channel congestion in cellular vehicle-to-everything (C-V2X) sidelink, ETSI ITS-G5 has defined a Decentralized Congestion Control (DCC) method that primarily affects transmission parameters (e.g, message delay, transmission power, and data rate). In this paper, the basic DCC methods are introduced and evaluated which also analyzes the current challenges and solutions for congestion control algorithms and schemes.**

Keywords—5G-NR-V2X, Decentralized Congestion Control, Intelligent Transportation Systems.

I. INTRODUCTION

Through the facilitation of V2X (vehicle-to-everything) information sharing, Collaborative Intelligent Transportation Systems (C-ITS) will aid in safe, effective, and comfortable driving [1]. For C-ITS applications, the ETSI specifies a number of message sets, including Collaboration Awareness Messages (CAM) and Decentralized Event Notification Messages (DENM). Each vehicle periodically broadcasts the CAM, which contains details on the vehicle's model, location, speed, direction of movement, and other characteristics that allow it to recognize the presence of other vehicles. When events, like an accident, are detected, DENMs are generated. Both CAM and DENM are broadcast on control channel (CCH), a channel dedicated to collaborative road safety. When the number of vehicles is great, it is easy to create congestion, which lowers the quality of communication. ETSI has improved several standards and found a solution to the congestion issue. The suggested approach uses a DCC framework to regulate the message rate, transmission power, and data rate of periodic messages (i.e., CAM) in order to lessen control channel congestion. In this paper, we first discuss the overview of DCC in section II. After that in section III we discussed the performance evaluation of DCC and analyze the performance of different DCC schemes in detail. Finally, section IV concludes the paper.

II. OVERVIEW OF DECENTRALIZED CONGESTION CONTROL

Two resource allocation options are used by New Radio (NR) for C-V2X in Rel-16: Mode 1 is a base station-centered resource allocation scheme, while Mode 2 is autonomous resource selection by the Vehicular UE (V-UE) based on a sensing mechanism [2]. Even though the autonomous resource allocation technique is quite effective, C-V2X performance suffers in scenarios with dense networks since there is more competition for the limited resources. To avoid congestion, V-UE employs two metrics: Channel Occupancy Ratio (CR) and Channel Busy Ratio (CBR). The CR value used for a certain measured CBR is determined by the Quality of Service (QoS)of the accompanying packet in terms of latency and reliability.

The core working principle of DCC is transmission rate control, which reduces congestion by lengthening the delay between CBR-based packet transmissions. This delay is determined by how ETSI distinguishes between its transmission rate control (TRC) mechanisms, DCC Reactive, and DCC Adaption. The ETSI-specified DCC Reactive approach uses a state machine with states connected to particular CBR ranges. The transmission rate is controlled by adding a delay between each packet, depending on the CBR. As shown in Table I. DCC Adaptive is a rate control mechanism based on the LIMERIC algorithm. It determines delay by an automated process.

TABLE I. ETSI ACCESS REACTIVE DCC

CBR	State	Packet	T_{off}
CBR < 0.30	Relaxed	10Hz	100ms
0.30 ⩽ CBR ⩽ 0.40	Active 1	5Hz	200ms
0.40 ⩽ CBR ⩽ 0.50	Active 2	2.5Hz	400ms
0.50 ⩽ CBR ⩽ 0.60	Active 3	2Hz	500ms
CBR ＞ 0.60	Restrictive	1Hz	1000ms

Its default setting of 68% is intended to alter the packet transmission rate such that it converges to the target CBR. DCC Adaptive better takes into account elements like fairness and stability, to avoid the occurrence of node starvation. Simultaneously ESTI has also specified methods to measure CBR and CR. Table II displays the ESTI-specified CBR-based maximum CR limits. Congestion control measures must be implemented to lower the CR if the present value exceeds the upper limit of the CBR range [3].

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

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

III. PERFORMANCE EVALUATION OF DCC METHODS

According to [4], there are various schemes for DCC performance evaluation. The core parameter to measure congestion is CBR. Simultaneously it's crucial to pay attention to factors like message latency and Packet Delivery Ratio (PDR) in order to guarantee the accurate and timely transfer of information. It should be noted that a DCC scheme that is too aggressive may degrade the overall system performance.

In order to better analyze the DCC schemes performance, this paper establishes a highway scenario to simulate according to the ESTI standard [5], where vehicles operate at high density at absolute speed of 50km/h. Vehicles are randomly mapped on the road using a Poisson distribution

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with a density of 300 veh/km, and use CBR vs. CDF to do the performance evaluation. The key parameters are shown in Table III.

TABLE III. PARAMETER TABLE

Parameter	Value
Vehicular density	300 veh/km
Road length	600 m
Number of Lanes	3 in each direction
Vehicle speed	50 km/h
Carrier frequency	5.9 GHz
Subchannel size	15 Resource Blocks
Packet size	350 Bytes
RSRP threshold	-126 dBm
RSSI threshold	-90 dB
Channel model	Winner+ B1
MCS	11
Noise figure	9 dB

We performed a simulation analysis of the DCC application with the above parameters and obtained the results in Figure I. The findings demonstrate that in the same circumstance, the DCC has a positive effect on the system CBR after commencing, lowering the CBR and alleviating channel congestion. This is due to the fact that after the DCC starts, a delay is introduced between consecutively transmitted packets according to the current CBR level, and the transmission rate of the packets is also adjusted. For more severe congestion, stricter congestion control policies will be adopted.

From the CBR results, although the DCC Reactive scheme reduces the CBR, its stability is weaker than that of the DCC Adaptive scheme. This is because the DCC Reactive scheme applies a fixed T_{off} for different states and enforces it. The strictest congestion control parameters are adopted when the CBR is higher than 60%, the transmission rate is greatly reduced, and the delay between packets is also greatly increased. Although the congestion is controlled, it is not conducive to the transmission of emergency information. In case of DCC Adaptive, it uses an algorithm to allocate delays in real time according to the CBR level, and introduce dynamic CR combined with detected information priority as the basis for measuring different states, it has better fairness and shows better performance.

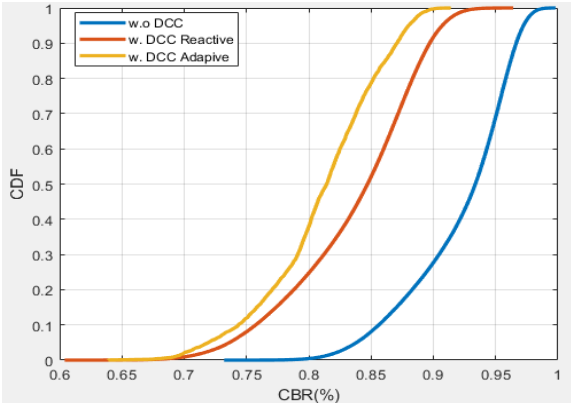

Fig. 1. DCC performance comparison.

IV. CONCLUSIONS AND FUTURE WORK

This paper has identified the operation mechanism of DCC, then established a simulation scenario compared and analyzed the performance of different DCC schemes according to relevant standards. However, this paper ignores the focus on other relevant parameters and application scenarios for evaluation. In future we wish to consider the unfairness issue as it occurs when the channel load is relatively high. At the same time, we will try to address the oscillation issue that occurs when the vehicles switch to different states rapidly due to different congestion levels.

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