Intelligent Traffic Control System Using 5G-NR-V2X

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Abstract—Intelligent traffic control is a key tool to achieve resource-efficient and sustainable mobility solutions for V2X services. One of the most stringent requirements in the vehicular network is a safety-critical real-time system. To guarantee low latency and other diverse QoS requirements, wireless network resources should be utilized effectively. In the composite vehicular network, Machine Learning (ML) has emerged as a powerful approach to cope with the complexity of computation and can handle big data analysis. This paper provides an overview of the management of network resources through Reinforcement Learning (RL) using 5G-NR-V2X with advanced ML approaches such as Deep Reinforcement Learning (DRL) method for an intelligent traffic control system.

Keywords—5G-NR-V2X, RSU, DCC, URLLC, Deep Reinforcement Learning (DRL).

I. INTRODUCTION

European Telecommunications Standards Institute (ETSI) has defined a Decentralized Congestion Control (DCC) mechanism to mitigate the channel congestion acting on the transmission parameters (i.e., message rate, transmit power, and data rate) with performances that vary according to the specific algorithm. There are two classes of congestion control reactive and adaptive the reactive approach is represented by the DCC framework defined in ETSI and the adaptive approach is represented by the linear control algorithm. As a function of channel load (i.e., Channel Busy Ratio), both approaches control the transmission of safety messages. ML techniques can be used for different problems in the field of vehicular networks, such as traffic congestion prediction, misbehavior detection, and the design of multi-hop broadcast protocols for VANETs [1]. With traditional methods, operating parameters are set, and adaptively adjusted, but using the ML method an analytical approach is used for a system model which is already trained based on a large amount of historical data. ML algorithms are robust means for classifying and clustering large data sets due to their specific abilities such as short computing time, handling huge amounts of data, automatically detecting a pattern in data, predicting future data, and planning to collect more data [2]. 5G-NR-V2X is a valuable technology to improve vehicular safety and traffic efficiency. In this paper, we investigate some deep RL-based approaches to control traffic. The paper is organized as follows. The overview of 5G-NR-V2X is described in section II. Section III explains the DRL approach to control traffic including the platooning method to control traffic, after that we state our conclusion and future work.

II. OVERVIEW OF 5G-NR-V2X

The 5G-NR-V2X supports two modes of communications direct (PC5/Sidelink) and mobile network-based (Uu). The direct mode of 5G-NR-V2X does not require that cellular networks offer data communication service, although end-to-end use cases can be complemented by mobile networks. This is currently adopted by the automotive industry and provides an improved message delivery mechanism for Vehicle to Vehicle (V2V), Vehicle to Pedestrian (V2P), and Vehicle to Infrastructure (V2I) applications to improve road safety and traffic efficiencies in the harmonized 5.9 GHz ITS band. With both PC5 and Uu-based communication, 5G-NR-V2X will enhance autonomous driving through perception sharing, path planning, and real-time local updates. There are different ways to realize the V2I services with novel approaches of deploying Roadside Units (RSUs), including mobile RSUs, distributed RSUs, and virtual RSUs. Also, the combined use of Edge Computing together with the PC5 capability for device-to-device communication to realize the V2I services [3].

III. AI-BASED EMERGING TECHNOLOGIES FOR INTELLIGENT TRAFFIC CONTROL

To provide intelligent traffic control we need centralized resource management that should be based on deep reinforcement learning. RL is an alternative to traditional optimization techniques for managing network resources. With this centralized approach, the RSU can classify messages according to a clustering algorithm, identify different communication parameters (Average delay, Average throughput, Packets lost, Packet loss ratio, Message size, Message validity, Distance between the source and destination, type of messages, and Direction of the source message) for each cluster to minimize collisions, and broadcast such parameters to vehicles and RSUs.

A. Resource Allocation using DRL

DRL shows impressive promises in wireless resource allocation for dynamic spectrum access, power allocation, and joint spectrum in vehicular networks. The power allocation in a multi-cell network is more complicated if each cell has one base station serving multiple users and if all base stations transmit over the same spectrum, resulting in both intra- and inter-cell interference. Every base station is controlled by an RL agent, which decides how much transmit power to use to maximize the network throughput.

**Fig. 1. DRL-based resource allocation for V2I link.**

In Fig. 1 PC5 links share the resources while Uu links to improve its utilization efficiency. V2I links are designed for high data rate entertainment services while V2V links have to
support reliable transmission of safety-critical messages, formally known as packet delivery. It is hard to meet the reliability requirements of PC5 links using traditional optimization techniques due to their exponential complexity in length [4]. Using a DRL framework with agent and environment, this issue assumes that each V2I link has an orthogonal resource block (RB) and uses a fixed transmit power. Next, each PC5 transmitter must select the V2I RB to share and adjust its transmit power to avoid strong interference and ensure that both V2I and V2V links are successful [5].

**B. Vehicular Resource Management for Traffic Control**

The resource-intensive use cases like live traffic reports, require efficient resource allocation. To support these use cases, efficient and intelligent management of local and shared resources is needed. To address these issues, RL/DRL was applied to resource management. In RL/DRL-based resource management techniques there are three main resource networking, computing-caching, and energy. Networking is an entity in vehicular networks which must make an independent decision to select channel and base station (BS) to achieve maximum throughput [5]. However it is difficult due to the dynamic and unpredictability of network status. There are three issues in networking dynamic spectrum access such as collision management, Joint user association, and beamforming. The following Fig. 2 shows the RL-based applications in communication and traffic management of vehicular networks.

![Fig. 2. RL-based applications in vehicular networks.](image)

**C. DRL-based Traffic Control System**

Applying k-means ML for DCC algorithms to classify the messages at each RSU, it has three units including congestion detection, data control, and congestion control units [6]. The congestion detection unit measures the level of channel usage in order to detect congestion. The data control unit collects and filters the messages to remove the redundant messages, and then clusters the messages into four separate clusters using a k-means algorithm.

**D. 5G-NR-V2X Communication for Platooning**

A truck platoon is a convoy of trucks that are powered by electricity. Their goal is to reduce fuel consumption and CO2 emissions as well as improve road traffic capacity by traveling together on the highway. That is, truck platooning can solve traffic congestion and increase road traffic capacity, less inter-vehicle distance, and larger numbers of vehicles [8]. There is a high expectation that 5G URLLC will be applied to truck platooning since 5G provides ultra-low latency and high reliability. There are two 5G-NR-V2X use cases for truck platooning; one is communications between vehicles for platooning, and the other is communication for remote monitoring and remote operation of the platoon from a remote site. Communication requirements for these use cases can be classified into two categories; the first is low capacity and low latency communication and the second is high capacity and low latency. The first category is required for a vehicle control system, which transmits and receives information on vehicle speed and vehicle positioning. This category also requires high reliability. For platooning, a video monitoring system that transmits and receives video streams to monitor the area around the trailing vehicles is required.

**IV. CONCLUSIONS**

Machine learning methods are addressed regarding the ability to make decentralized congestion control techniques more suitable to a dynamic environment, which shows new opportunities for collision control in a vehicular environment. In this paper, we provide an overview of 5G-NR-V2X and the RL-based algorithms to control traffic which are suitable to
apply for wireless resource allocation in vehicular networks to develop an intelligent traffic control system. We explore the platooning concept in this paper which can also be a potential solution for congestion control. We investigate the existing ML-based DCC algorithm which can be a potential solution for intelligent traffic control.

V. FUTURE WORK

ML can be utilized to immediately employ in vehicular networks to overcome issues such as complexity and fast variability of wireless channels, required computational resources, need for distributed learning, coordination and cooperation through information sharing over a capacity-limited network and security. Our aim is to propose a system model which can provide cooperative traffic control using 5G-V2I data. The 5G-NR-V2X includes a new mechanism for efficient resources management, striving to better utilize the limited ITS spectrum. The co-existence of different V2X technologies, which allows 5G-NR-V2X to operate in the same channel in regions with limited spectrum allocation.

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