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A Real Time QoS Monitor Architecture Proposal for Cooperative Vehicular Platooning

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Abstract

Cooperative Platooning (Co-VP) depend enormously on their communication capacity, since the information exchanged between vehicles and infrastructure ensures the correct execution of the device 19s trajectories in most diverse scenarios. In this way, the monitoring of quality of service (QoS) plays a fundamental role in guaranteeing the system 19s safety, providing local controllers with information so that defensive actions can be taken in a timely manner when the network start to fails. In this work, we introduce the concept of a Real Time QoS Monitor (RTQM) module that can be added to devices that are part of a Co-VP application. The RTQM module performs a link quality estimation (LQE), based on the packet inter-reception time, received signal strength Indication (RSSI) and current vehicles distance. The RTQM will provide information to the local Co-VP controller allowing safety actions and enabling the network handover between different communication standards, namely between ETSI ITS-G5 and C-V2X standards.

A Real Time QoS Monitor Architecture Proposal for Cooperative Vehicular Platooning

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Abstract
Cooperative Platooning (Co-VP) depend enormously on their communication capacity, since the information exchanged between vehicles and infrastructure ensures the correct execution of the device's trajectories in most diverse scenarios. In this way, the monitoring of quality of service (QoS) plays a fundamental role in guaranteeing the system's safety, providing local controllers with information so that defensive actions can be taken in a timely manner when the network start to fails. In this work, we introduce the concept of a Real Time QoS Monitor (RTQM) module that can be added to devices that are part of a Co-VP application. The RTQM module performs a link quality estimation (LQE), based on the packet inter-reception time, received signal strength Indication (RSSI) and current vehicles distance. The RTQM will provide information to the local Co-VP controller allowing safety actions and enabling the network handover between different communication standards, namely between ETSI ITS-G5 and C-V2X standards.

Author Keywords. Cooperative Vehicular Platooning; Handover; QoS Monitor; Link Quality Estimation; Safety Maneuvers.

1. Introduction

Cyber-physical systems have evolved, enabling the creation of intrinsically connected Co-CPS capable of operating in critical scenarios and subject to the highest safety's levels. One of these scenarios is the Co-VP, that has the potential to increase the passengers and products transportations over highways, reducing collision risks and fuel consumption. The Co-VP application highly relies on the communication between vehicles to vehicles (V2V) and vehicles to infrastructure (V2I). So, given the criticality of its scope of action and the importance of the information exchanged between devices, monitoring the network QoS assumes a fundamental role in the system's safety. The fast detection of network's degradation enables a quick control systems reaction, allowing them to act to minimize damage and avoiding accidents, namely stopping the platoon in a safe way, or changing the vehicles maneuvers.

In this work, we propose a real-time QoS detection system for Co-VP (RTQM). RTQM is a modular system to be used in conjunction with existing devices, performing a link quality estimation (LQE) in the network links. It informs the controller's device about the network's condition, indicating package delay, signal strength and devices distance to keep the system's safety. The proposed RTQM will enable a network handover between different communication links, increasing the Co-VP application's safety in different scenarios. A 3D simulator integrated into a network simulator (Vieira et al. 2019), a realistic assessment of the suggested scenarios are proposed to validate the system, including two of the most used vehicle's network standards, ETSI ITS-G5 and C-V2X.

2. Context and Motivation

In the Co-VP scenarios, the communication's quality is studied in several works like in (Karoui et al. 2017), where it is possible to observe some solutions for situations where exists a drop in device's communication quality. However, most of the works presented consider only the states in which the network is normal or degraded, without indicating the detection or gradations of that state. The (Marzouk, Rodriguez, and Radwan 2018) propose a bidirectional LQE to choose the best relay option in Co-VP, but focusing on Road Side Unit (RSU) communication while ETSI ITS-G5, commonly used in Co-VP applications, uses the Decentralized Congestion Control (DCC) to check the network congestion based in the Channel Busy Rate (CBR). But those solutions do not provide any information to the device's controller, that keeps unable to perform safety actions to avoid accidents.

Some authors have studied the vertical handover (VHO), between network models or frequencies to keep the Co-VP functionality. The authors of (Khoder et al. 2020) switch between Visual Light Communication (VLC) model for LTE, while (Krupitzer et al. 2018) suggest the RSU's handover to keep the platoon stability, like an horizontal handover (HHO).

3. Real Time Quality of Service Monitor Architecture

The development of the RTQM System responds to the need for Co-VP to detect and monitor the network QoS in real-time. With the information provided by packet inter-reception time, RSSI, current vehicles distance and the number of vehicles in the network, it is possible to estimate the average packet error rate and define some safety levels. These safety levels are informed to the system's controller that will be able to carry out safety actions that prevent accidents, allowing platooning to return to regular operation when communications reestablish.

Figure 1 shows the basic architecture of RTQM, and its interconnection between vehicles and RSUs within a Co-VP application. In this scenario, the vehicles have two radios, using ITS-G5 and C-V2X and the information provided by the RTQM allows the vehicle local controller to choose between the two signals.

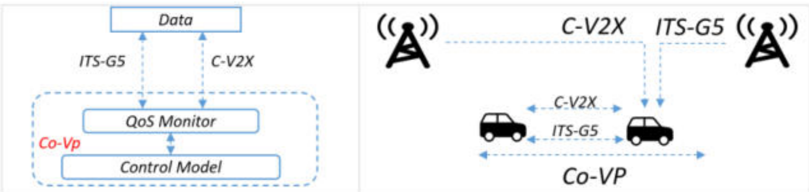

Figure 1: RTQM general View

The use of different communication models reduces the system's susceptibility to possible congestion network environments, that increase the delay between messages, as shown in Figure 2. In this figure, we demonstrate the RTQM average measurement of the delays in messages from ***car1*** to ***car2*** using ITS-G5, regarding the increase off the number of vehicles in the network. We also analyzed several communication profiles, like the Basic Service Profile (BSP), Basic Service Profile for Platooning (BSP-P), and the Custom Service Profile (CSP), defined in (Vieira et al. 2019).

If the communication deteriorates enough, RTQM inform the controller that is responsible for realize safety actions before the network completely deteriorates, preventing accidents, as demonstrated in Figure 3. This simulation was performed with Gazebo, for the a 3D simulation, integrated with Omnet ++, in CopaDrive. This simulation allows a realistic analysis of delays and other network issues. For the simulation of the ITS-G5, the Artery project framework is used, while the C-V2X communication is simulated with Simul-LTE. The integration of these components is done using the Robot Operating System (ROS) as a Broker.

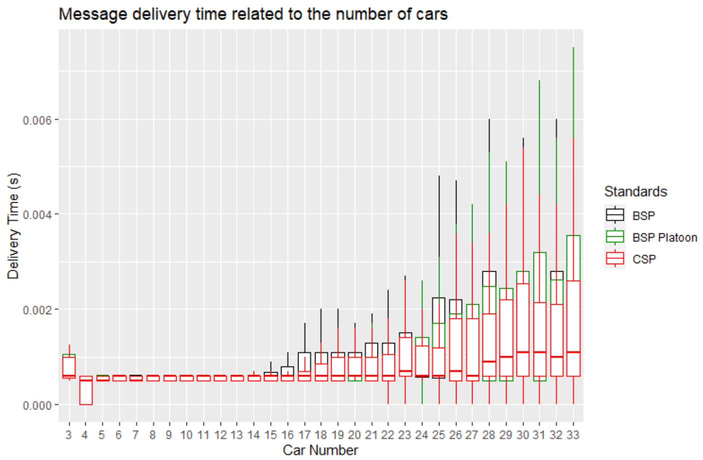

Figure 2: Delay between messages from Car1 to Car2 in ITS.-G5 scenarios

Figure 3: RTQM - Network Delay Detection

4. Conclusions

The addition of an RTQM module to a Co-VP application has potential to minimize the impacts of network issues, increasing the application's safety. Combining the ability to use two different communication standards, with the capacity to analyze the network QoS, it is believed that Co-VP applications may have increased safety. The handover between radio modules is a topic for further studies in the implementation scenario.

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