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# Demo

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## Abstract

The future of goods transportation will rely on increased efficiency, lower risks, and diminished delays through the use of vehicle platoons that benefit from vehicular connectivity using V2X (Vehicle to Everything) applications. This article describes a system that offers the aforementioned vehicular connectivity to platoons, based on AI-enhanced 5G for resource allocation in wireless platoon intra-communications under three scenarios (latency emergency braking, platoon wireless resource management in tunnels, V2X communications interference in a traffic congestion). Demos are described for each of the scenarios, targeting different layers, starting by the PHY (physical) layer where propagation models are implemented, then a simulation-based MAC (medium access control) layer that allows the allocation of resources to the connected User Equipments (UE) and finally a management and orchestration layer capable of monitoring and managing the radio network, offering features such as network slicing management using O-RAN (Open Radio Access Network) standards.

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# 5G network as key-enabler for vehicular platooning

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***Abstract*—The future of goods transportation will rely on increased efficiency, lower risks, and diminished delays through the use of vehicle platoons that benefit from vehicular connectivity using V2X (Vehicle to Everything) applications. This article describes a system that offers the aforementioned vehicular connectivity to platoons, based on AI-enhanced 5G for resource allocation in wireless platoon intra-communications under three scenarios (latency emergency braking, platoon wireless resource management in tunnels, V2X communications interference in a traffic congestion). Demos are described for each of the scenarios, targeting different layers, starting by the PHY (physical) layer where propagation models are implemented, then a simulation-based MAC (medium access control) layer that allows the allocation of resources to the connected User Equipments (UE) and finally a management and orchestration layer capable of monitoring and managing the radio network, offering features such as network slicing management using O-RAN (Open Radio Access Network) standards.**

***Index Terms*—5G, V2X, Platoon, Propagation model**

## I. Introduction

The 5G networks has been discussed and researched in recent years [1] [2] [3]. A highly automated driving solution, that involves computationally demanding tasks such as platoon communications, represents a pertinent real-world application that can benefit greatly from Artificial Intelligence (AI) leveraged by 5G wireless communications. This technological convergence will improve operational efficiency in vehicular platooning applications, mainly in terms of latency, reliability, interference and resource management [4]. Some practical important real-world use-cases with such stringent requirements are emergency braking or traffic management in tunnels, which will be showcased in the demonstrations section.

The proposed work contributes to V2X applications through *i*) the improvement of Ultra Reliable Low-Latency Communications (URLLC), and security/safety for vehicle platoon and in general V2X applications and *ii*) the autonomous operation/control of hundreds of platoons at the city level under smart autonomous systems, by involving coordination of platoon manoeuvres, formation, authentication, authorization. The main contribution's are as follows:

- Reliability and performance at the MAC and PHY layers, leveraging AI algorithms for wireless resources, obstacle prediction and interference detection.
- The Connected Cars Digital Twin Platform (CCDTP) that implements the V2X OBU/RSU (On-Board- and Road-Side Units) stack which is used to study the platooning use-case. The CCDTP has a backend that will support emulation off a map containing RSUs and C-V2X/LTE/5G nodes/antennas together with real or artificially generated traffic traces.
- The orchestration platform to deployment of V2X application, and a 5G RAN simulator allowing the configuration and resource allocation by enabling network slicing and platoon coordination system.

## II. Demonstrations

Our demos take advantage of improved 5G tools specifically suited for vehicle platoon communications, enhancing not only connectivity but fusing the decisions of autonomous vehicles with the radio resource allocation and PHY layer adaption via an AI mechanism for supporting V2X communications in platoon communications. This is then integrated with V2X edge computing and cloud applications considering demanding latency.

The demonstrator's main system consists of a system simulator composed of multiple components:

- CCDTP which allows to realize emulated V2X communication in the artificially generated vehicle traffic (using real vehicle trace analysis or 3D physics simulators) and feeds through the Connected Cars Service Platform (CCSP).
- Physical communication protocols.
- AI mechanisms to detect interference.
- Wireless resource management mechanisms.
- RAN simulator implementing some features of PHY layer with support for network slicing on cell capacity.
- OSS (Operations Support Systems) platform to manage and automate the network.

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### A. Demo 1: latency emergency braking

A latency emergency braking scenario is examined, wherein the platoon units adhere to protocols enabling the immediate, high-priority transmission of braking signals to all formation elements. This scenario is mainly composed of software-based components to replicate the platoon behavior, network capabilities, and management from the operator's point of view, as illustrated in Fig. 1.

The OSS tool ONAP (Open Network Automation Platform)

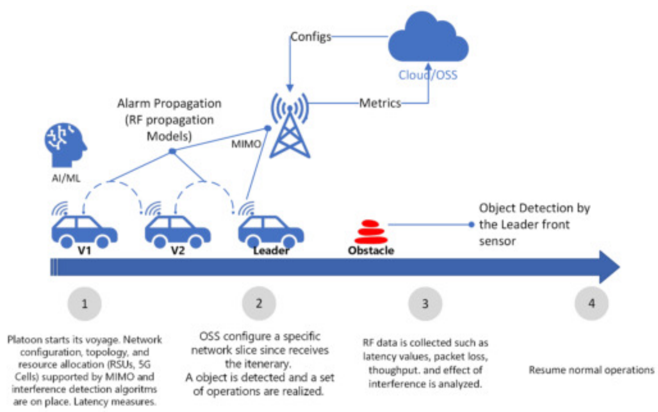


Fig. 1. Latency emergency braking demonstrator sequence

[5] is deployed on top of a Kubernetes cluster. This provides us with the ability to perform the orchestration of the network elements such as virtual or cloud-native network functions that can be a V2X application in a specific cloud region. The V2X application is purposely deployed at the edge, near the end user in order to reduce latency on the network. Also in this scenario, a RAN simulator implements the network topology schema as well as PHY and MAC layer aspects providing capabilities to create a URLLC network slice and to allocate the necessary Physical Resource Blocks (PRB). Based on Manhattan channel model, the SNR and path-losses are generated, and based on that the throughput is predicted as well as the packet loss. Those metrics serve as input to the closed-loop management system. The objective is to predict the network degradation based on the collected metrics and guarantee the QoS demanded by the platooning service. In this use case, and based on the user location the ONAP tool deploys an application near to the user which can be seen as a V2X server with the objective to reduce latency allowing the alert messages to be propagated within the platoon on time avoiding accidents for example.

The V2X MIMO channel propagation in Manhattan networks, assists on the problem of emergency braking by evaluating the probability of collision for different platoon configurations under different protocols. This helps to determine when it is useful to have the aid of a 5G base station with massive MIMO in reducing the latency of communication particularly in large platoons.

Finally, CCDTP demonstrates the manoeuvres in an emergency braking scenario and the resulting V2X communication between the emulated software stacks. The CCDTP generates platoons and road-side units (or V2X base stations) for testing V2X communication on real-map in the CCDTP. PHY layer simulators and propagation models are integrated into the CCDTP via its API for 3rd party components to reflect the effects of the environment in the communication.

### B. Demo 2: platoon wireless resource management in tunnels

This demonstration site is derived from the previous demonstrator with a single platoon and one base station. The objective is to test the reliability of communications inside a highly multipath reflective scenario under different situations. The tests will also be conducted mainly in a simulator with realistic propagation models. The main difference between this demonstrator and the previous one is the challenging communication environment due to the semi-circular tube-shaped tunnel as the communication media and the harsh conditions where the UE does not have proper LOS.

The telco OSS and the 5G RAN components in the previous scenario are derived and reused in this scenario with adaptations to meet these challenging scenario requirements. An electromagnetic propagation model is utilized for urban canyon platoon communications, extending the Manhattan model to account for multiple reflections in enclosed spaces. Striking a balance between specular reflection analysis and full electromagnetic modeling, our multi-ray tracing tool determines the multipath delay profile and environment scattering statistics. The primary aim is detecting transitions from Manhattan LOS to NLOS conditions and eventually to the tunnel, considering either an internal base station or basic Vehicle-to-Vehicle (V2V) links. This concept is illustrated in Fig. 2.

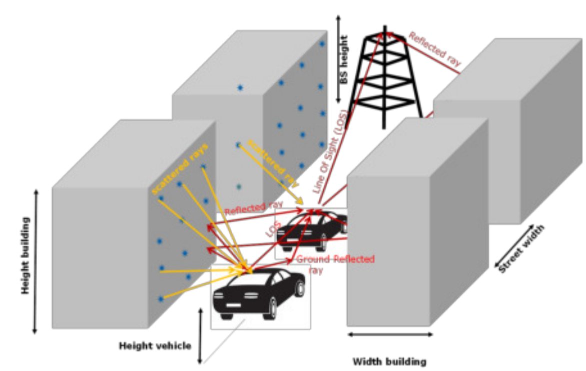


Fig. 2. V2V platoon Pathloss Model inside urban building canyon

Then, the CCDTP is used to demonstrate platoon manoeuvres and V2X communication between emulated vehicles in the tunnel. The CCDTP generates platoons and road-side units (or V2X base station) for testing V2X communication on real-map in the CCDTP. PHY layer simulators and propagation models are integrated into the CCDTP via its API for 3rd party components.

### C. Demo 3: V2X interference in a car traffic congestion

This demonstration involves a system-level simulation in a Manhattan grid network with multiple cars and/or platoons interacting with each other on the streets of the scenario using realistic propagation models from base stations located at strategic positions in the grid. Basic platoon operations will be considered such as platoon movement on a given itinerary, platoon gap and speed change.

This scenario considers a multiple cell site and platoon network in urban or dense urban environments. The objective of this scenario is to evaluate the performance of the V2V and V2X infrastructure in the presence of inter platoon and inter cell interference. Another objective is to evaluate platooning protocols and manoeuvres in challenging traffic conditions. AI algorithms are used to detect/reject interference, reduce latency, improve reliability in dense traffic conditions. Fig. 3 shows in a high level view the sequence explaining the different actions happening during the demonstration. Similar as the Demo 1, from the single base station, demonstration involves a system level simulation in a Manhattan grid network with hundreds of cars and/or platoons interacting with each other on the streets. Realistic propagation models from base stations located at strategic positions in the grid are used.

The Telco OSS and the 5G RAN for this scenario are

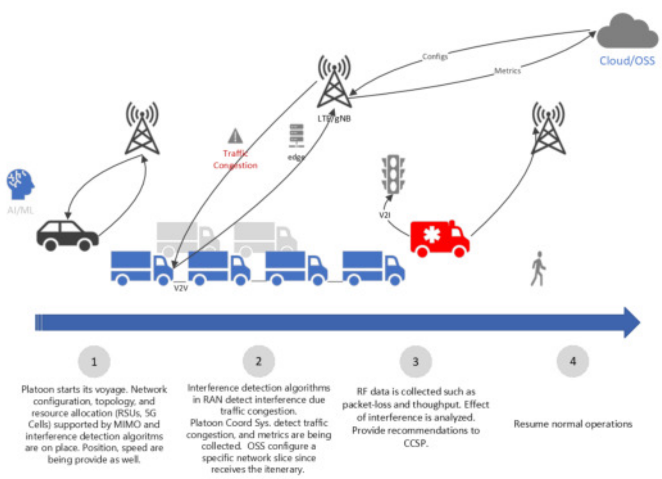


Fig. 3. Traffic congestion high-level sequence

derived from the previous demonstrators, where most of the logic is reused and adapted for this scenario. A system closed loop is in the place where network metrics are being collected from the 5G RAN simulator, based on O-RAN interfaces [6]. A platoon itinerary is also considered to prepare the network to serve the platoon service. From the Telco OSS, there's an analysis application (rApp) that detects cell anomalies or traffic congestion based on packet loss and throughput metrics. If some threshold is crossed a policy is sent via the A1 interface to the RAN where it will trigger the configuration of a slice. Additionally, a cloud-native function is deployed in an edge server based on mobility data aiming to reduce communication latency. The high-level system architecture is given in Fig. 4.

The CCDTP, generating a mix of platoons and independent vehicles, facilitates V2I and V2V communication. This platform allows real-time vehicle data to be sent to the Platoon Management Center via the CCSP, aiding in strategic platoon

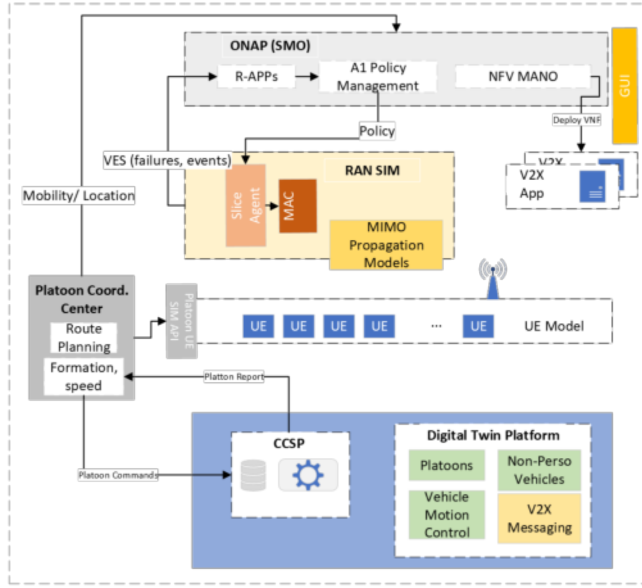


Fig. 4. High-level Architecture with all interactions of components

maneuver planning. These planned commands are then relayed back to the platoon leaders. as described in Fig. 4. Finally, the channel effects on the messaging in the CCDTP is achieved by integrating the CCDTP with the Manhattan Simulator.

## III. Conclusions

The demonstrations focused on a set of complementary mechanisms which in a holistic way improve the wireless communication reliability for V2X platooning. Starting with the PHY-layer where a set of propagation models and mechanisms to detect interference are in place to assist the different scenarios, From the management layer and based on O-RAN standards a closed-loop mechanism is in place allowing to predict degradation of the network performance, and to trigger a set of actions to improve the network reliability. Finally, the CCSP provides the virtual testing framework to test and demonstrate the operation of the platoon applications, V2X protocol stacks, platoon management and artificially producing the vehicle traffic.

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