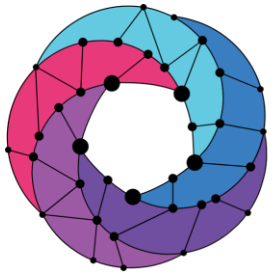

Open Source MANO by ETSI

Deploying a V2X Stack in Edge Environments for Improving Mobility Safety

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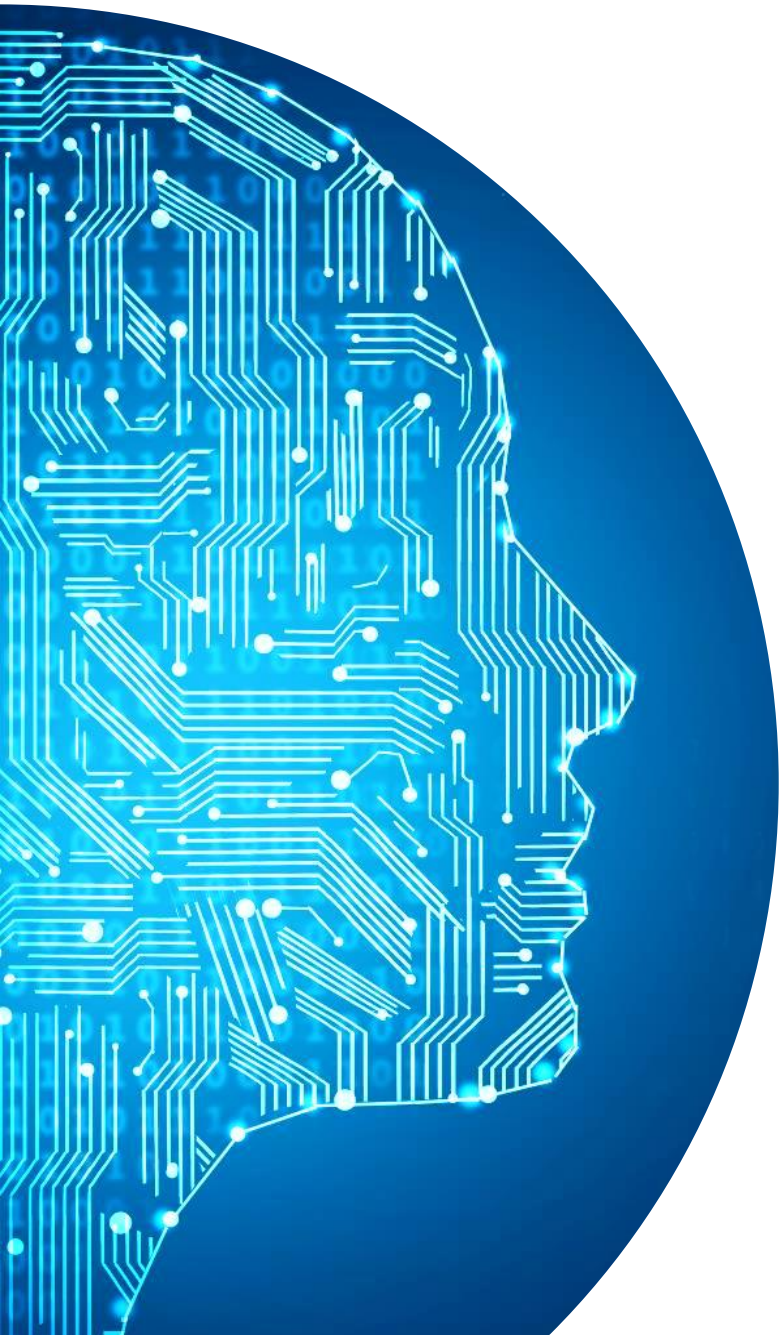

Agenda

- Key Takeaways
- V2X Background & Challenges
- i2CAT V2X solution
- Demo 1: Deployment of V2X Stack via OSM
- Demo 2: Validation in a Real Environment
- References

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Key Takeaways

This proof-of-concept (PoC) introduces the use of V2X technology as a key enabler for a vulnerable road user (VRU) protection system. The proposed solution fully benefits from the use of edge computing to deploy a V2X stack based on the ETSI ITS-G5 protocol. This solution implements an abstraction interface between vehicles and V2X applications (e.g., risk detector) to prevent accidents and mitigate risks.

- The PoC builds the V2X components from scratch following the ETSI ITS-G5 standard by using python as programming language and open-source tools such as MQTT, GPSd.
- The V2X stack is packaged as a Helm Chart to be deployed as a cloud-native service following the Kubernetes Native Function (KNF) paradigm supported by OSM.
- To enable V2X message isolation, the PoC uses Multus CNI as a networking manager tool. Multus CNI configures virtual isolated networks by implementing VLANs tags associated to each one of the different Road-side Units (RSUs).
- OSM is used to manage the lifecycle of the solution. During the instantiation stage, it leverages the instantiation parameters to set the proper network configurations required by Multus and compute node selection (Kubernetes node name) according the network topology.
- The PoC presents the implementation of a real use case deployed and tested in Barcelon (Spain). It consists of radio units, edge nodes, and an end-user application that receives the V2X messages and provides alerts to the end-users in real time.

V2X Technology

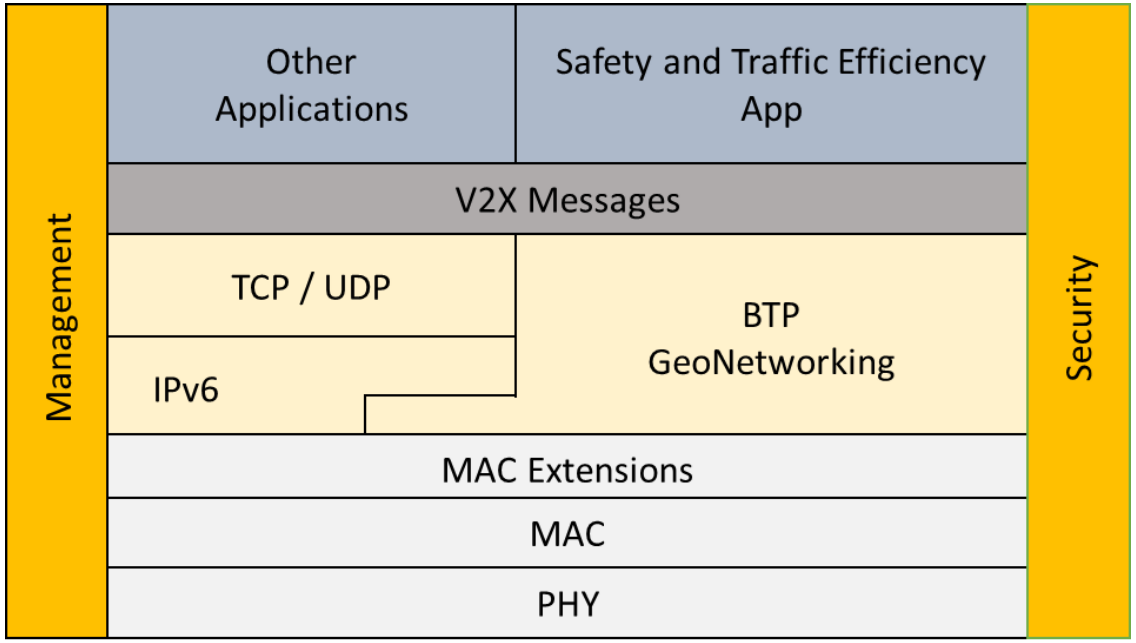
Vehicle-to-Everything (V2X), is a communication technology that **enables vehicles to exchange data with vehicles, infrastructure, pedestrians, and networks:**

- It enables **real-time sharing of information** such as traffic conditions, road hazards, and potential accidents, making driving safer and more efficient
- It is expected to play a significant role in the development of **autonomous driving** and smart transportation systems.

Source: elenabs/iStock

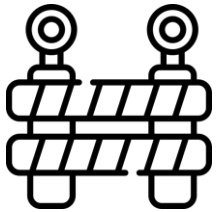
Standardization Efforts

- Different standards have been proposed from different regions (USA, Europe, China), being the ETSI C-ITS standard the one adopted in Europe.
- The ETSI C-ITS (Cooperative Intelligent Transport Systems) defines the standard for V2X technology that enables interoperability between vehicles and infrastructure.
- It consists of several layers, with specifics functions, such as message encryption and data transmission

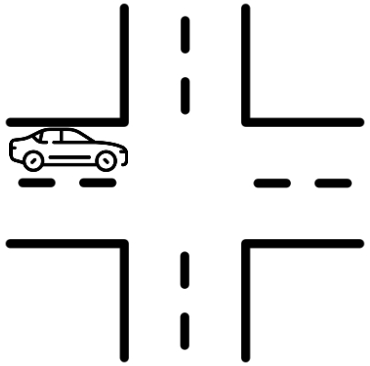


Mobility Problems

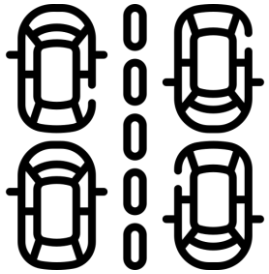
Collision Avoidance



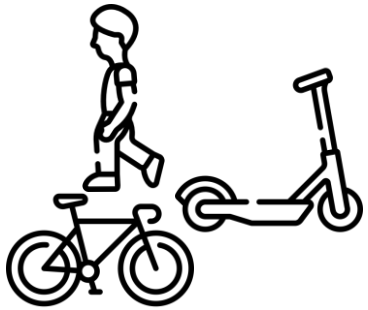
Road Works



Intersection Collision Warning



Traffic Jams



Vulnerable Road Users (VRUs)

Emergency / stationary vehicle warning

V2X Requirements

V2X relies on:

- **Wireless communication:** 802.11p, 4G/5G, DSRC (Dedicated Short-Range Communications) and C-V2X (Cellular V2X)
- **Latency:** a critical requirement in V2X applications is the low latency between parties (latency < 100ms)
- **Security:** security measures to protect the privacy and integrity of transmitted data.
- **Accuracy and reliability:** Enable effective communication between vehicles and other devices
- **Scalability:** Support a large number of connected vehicles and devices in a wide variety of traffic scenarios
- **Interoperability:** Enabling effective and seamless communication between actors

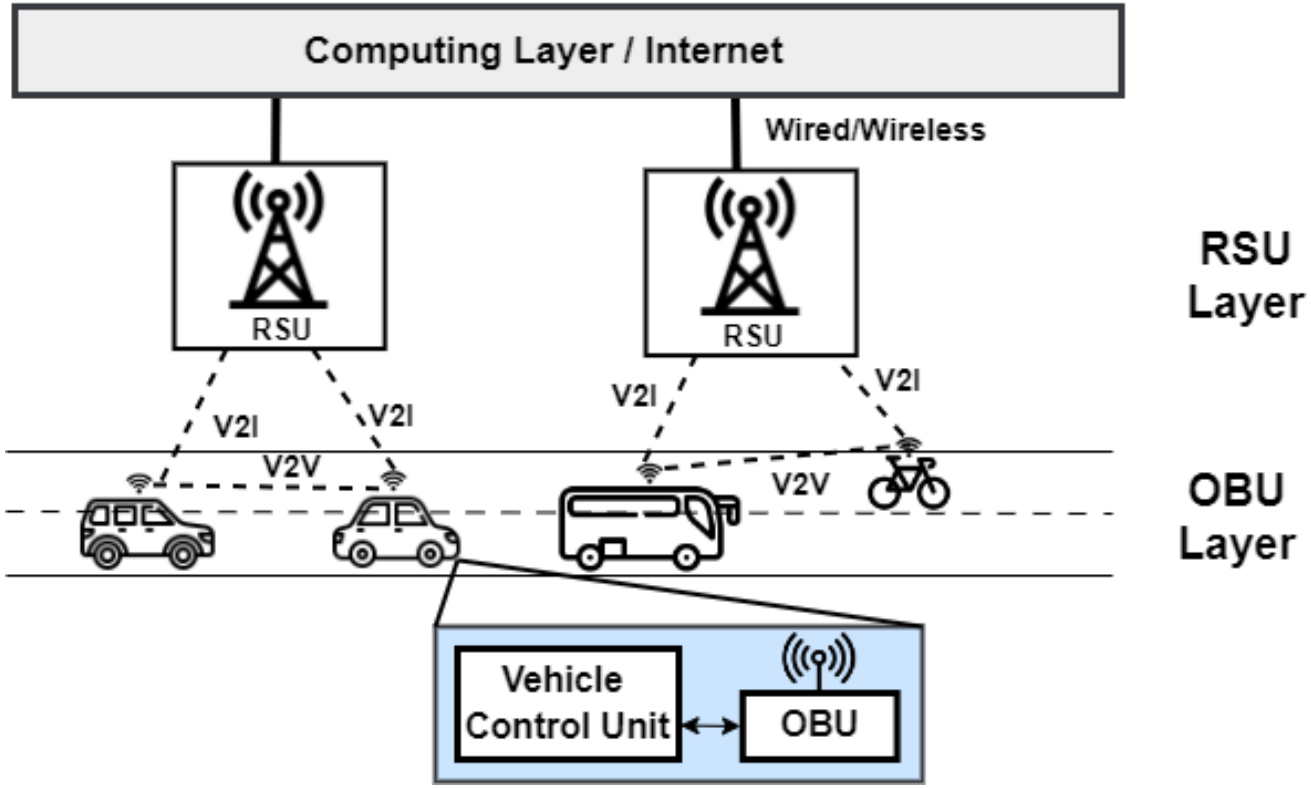
C-ITS Infrastructure

C-ITS systems are based on the fact that both vehicles and infrastructure are equipped with radio capabilities:

- **RSU:** Road-Side Unit
- **OBU:** On-Board Unit

Vehicular communication types:

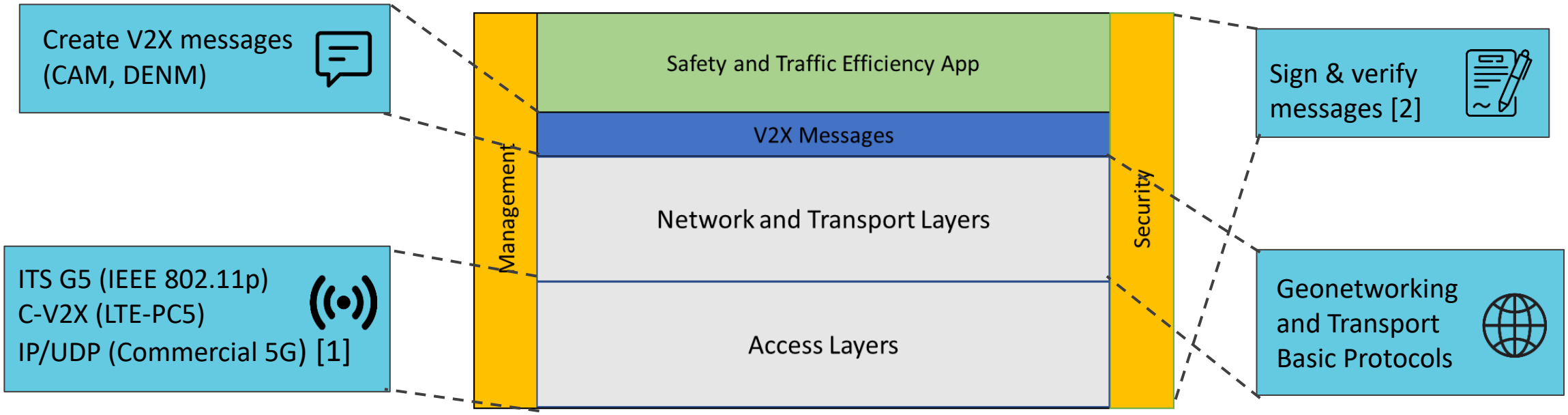
- **V2I:** Vehicle-to-Infrastructure
- **V2V:** Vehicle-to-Vehicle
- …
- **V2X:** Vehicle-to-Everything



i2CAT V2X Solution

i2CAT V2X Software Solution

Functionalities: Implements the transport, network, security, management and access layers of the ETSI C-ITS protocol stack

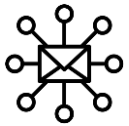


i2CAT V2X Software Solution

Characteristics:

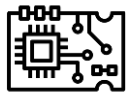
ETSI C-ITS compliant

Available for container-based scenarios



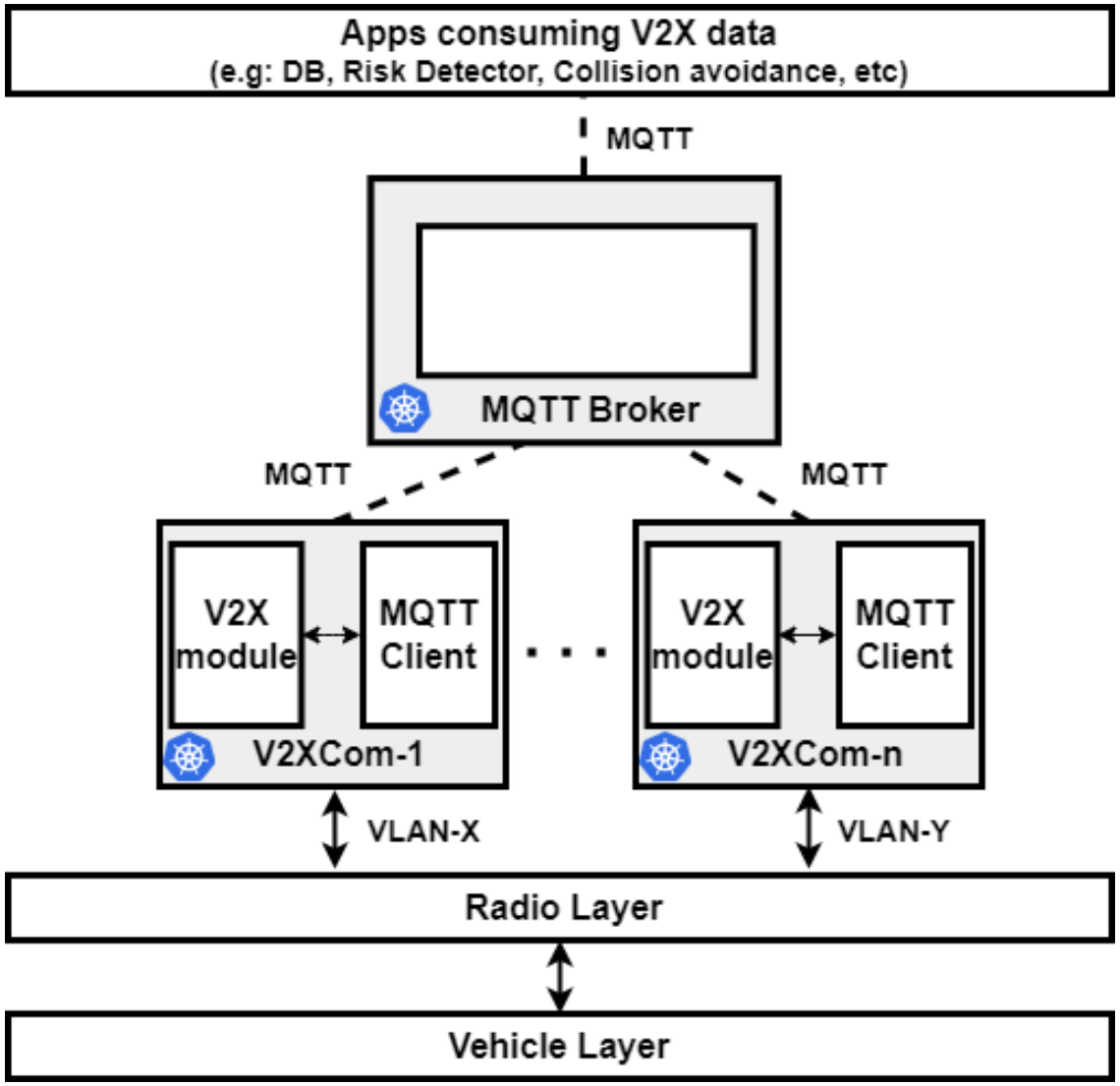
Easy-to-use interface between the ETSI C-ITS protocol stack and the external software applications via MQTT

The access layer supports ITS G5 (802.11p), C-V2X (LTE-PC5), and IP/UDP (Commercial 4G/5G) and the intercommunication among them [1].



Lightweight solution: ported and integrated into embedded systems (e.g., Raspberry Pi, Odroids)

V2X Software Architecture

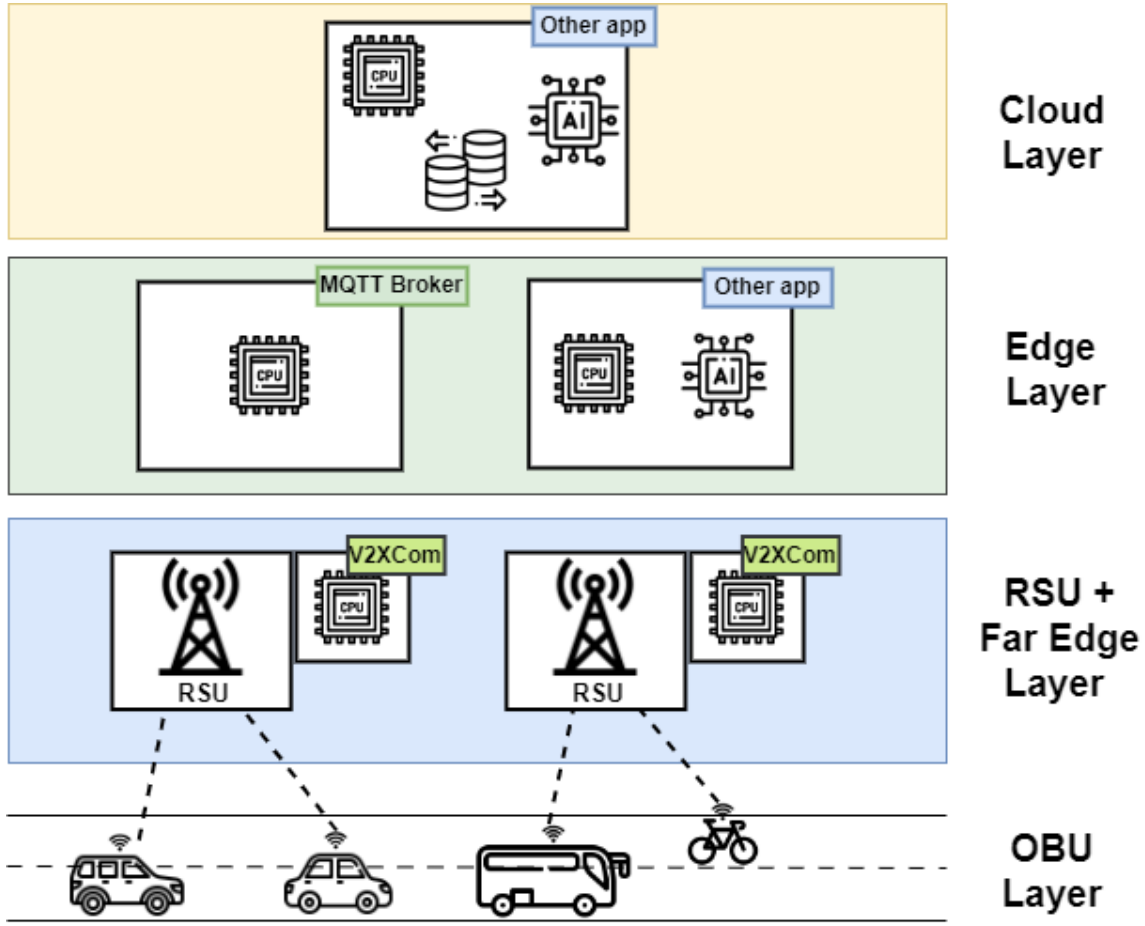


V2X Edge Infrastructure

In order to meet the latency requirements, different computing layers are implemented:

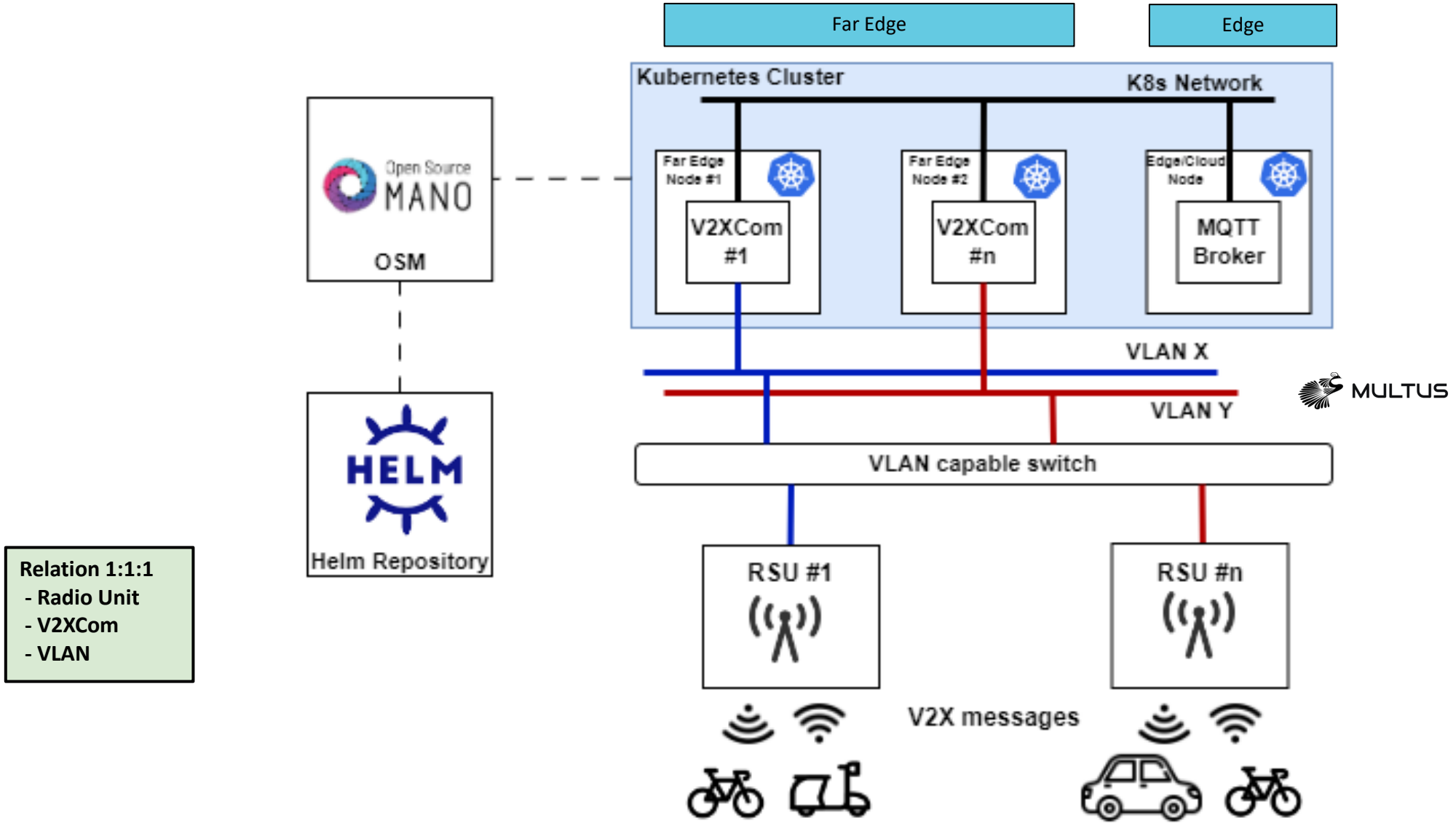
- **Far Edge:** Located next to the radio devices. Applications with extreme latency requirements (e. g: V2X Com) are placed here.
- **Edge:** Applications with low latency and computing requirements (e.g: MQTT Broker) can be located here.
- **Cloud:** Computing-intense applications (e.g: Training of ML models), or applications without latency requirements can be placed here.

The C-ITS Infrastructure is implemented through the Road-Side Unit (RSU) and On-board Unit (OBU) layers.

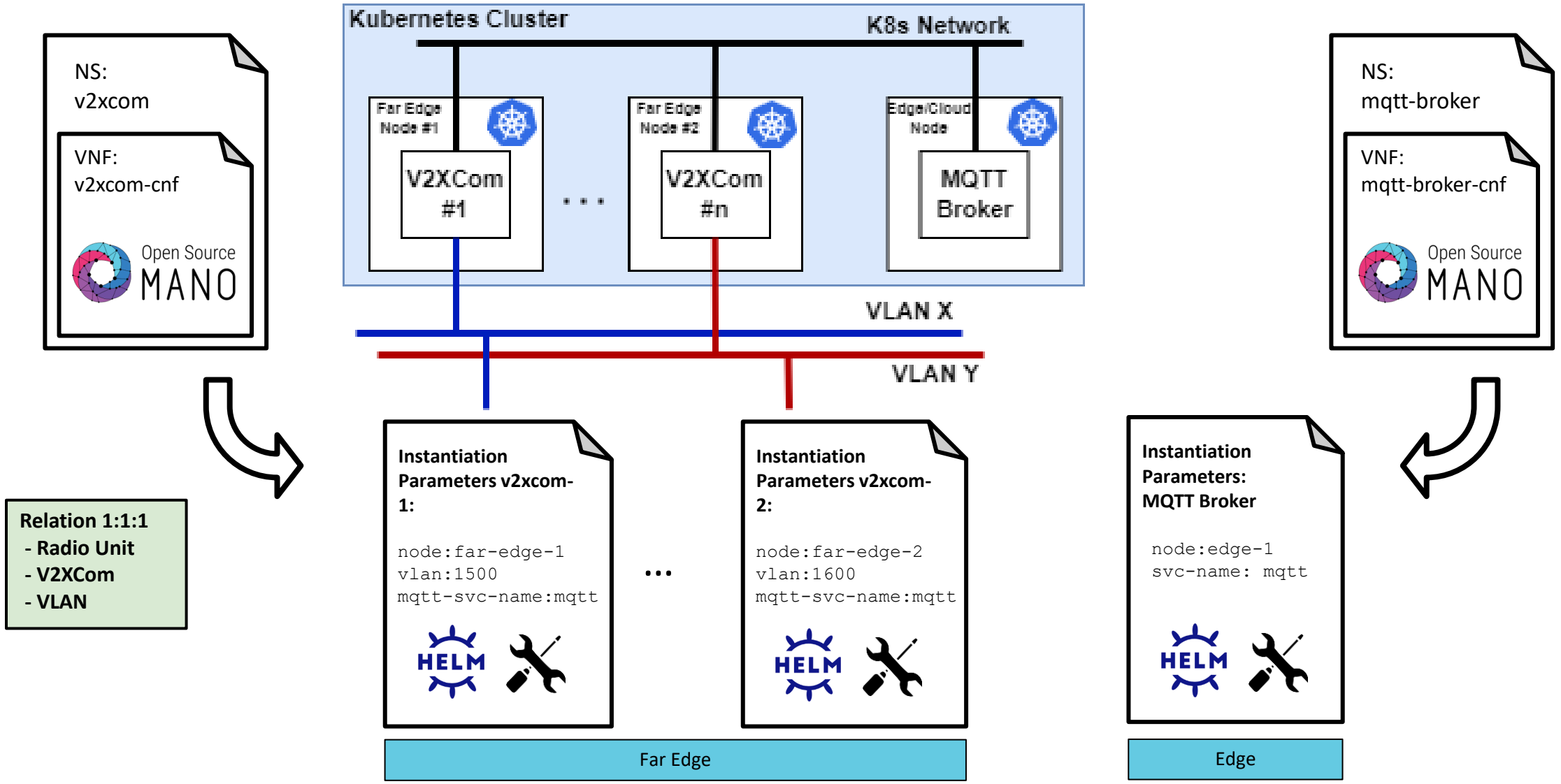


Demo 1: Deployment of V2X Stack via OSM

V2X Software Architecture



Instantiation of the V2X Stack according to the Network Topology via OSM



Demo video

The demo video for the deployment of the V2X stack via OSM can be found in the following **QR-code**. Here a YouTube video is linked (8’10” – 14’20”). The video contains the whole V2X presentation presented in the **OSM MR14 Ecosystem Day.**

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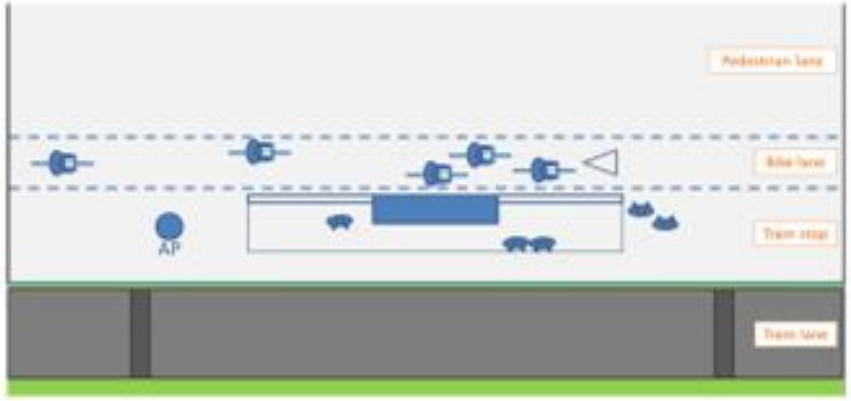
Demo 2: Validation in a Real Environment

Validation in a real scenario: UC2 PLEDGER Project

PLEDGER

Edge infrastructure for enhancing the safety of vulnerable road users

- We aim to enhance the safety of vulnerable road users (VRUs), by providing a timely detection of risky situations and warning the VRUs about said situations. Across the city one can find several instances, where the layout of bicycle lanes, pedestrian lanes and public transport lanes can be confusing and may lead to accidents:



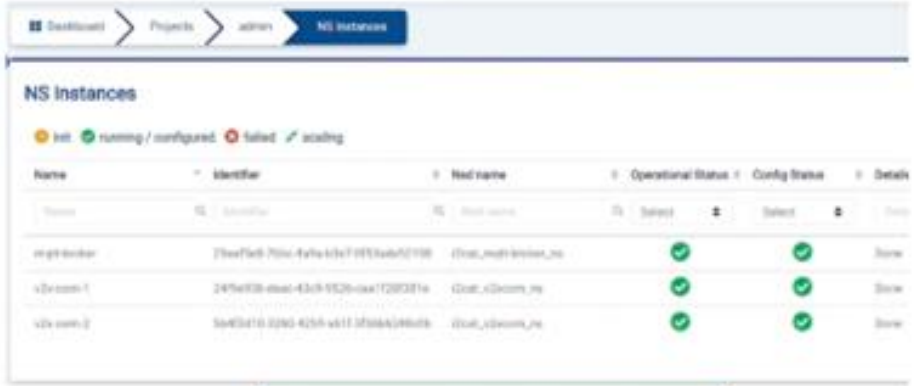
- The UC leverages the Pledger platform to host and orchestrate a safety application (RDNS) that detects risky situation and is capable of warning VRUs to prevent possible accidents.

Validation in a real scenario: UC2 PLEDGER Project

PLEDGER

Pilot preparations (on-site + remote)

Testing of VRU gadget, tuning LEDs and buzzer



Instantiation of Network Services (NS) via OSM

Demo 2: Validation in a Real Environment

The demo video for the deployment of the V2X stack via OSM can be found in the following **QR-code**. Here a YouTube video is linked (14’20” – 16’40”). The video contains the whole V2X presentation presented in the **OSM MR14 Ecosystem Day.**

Acknowledgements

This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreements No 833611- CARAMEL and No 871536-PLEDGER.

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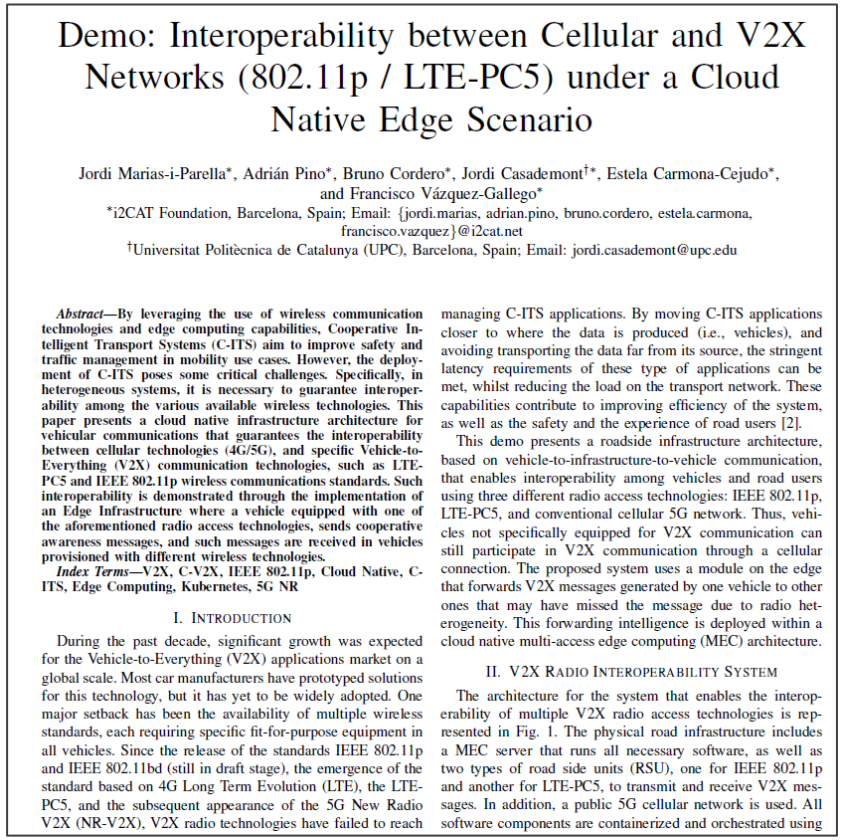
CARAMEL

CARAMEL Project
https://www.h2020caramel.eu/

PLEDGER

PLEDGER Project
http://www.pledger-project.eu/

References



Demo: Interoperability between Cellular and V2X Networks (802.11p / LTE-PC5) under a Cloud Native Edge Scenario

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***Abstract*—By leveraging the use of wireless communication technologies and edge computing capabilities, Cooperative Intelligent Transport Systems (C-ITS) aim to improve safety and traffic management in mobility use cases. However, the deployment of C-ITS poses some critical challenges. Specifically, in heterogeneous systems, it is necessary to guarantee interoperability among the various available wireless technologies. This paper presents a cloud native infrastructure architecture for vehicular communications that guarantees the interoperability between cellular technologies (4G/5G), and specific Vehicle-to-Everything (V2X) communication technologies, such as LTE-PC5 and IEEE 802.11p wireless communications standards. Such interoperability is demonstrated through the implementation of an Edge Infrastructure where a vehicle equipped with one of the aforementioned radio access technologies, sends cooperative awareness messages, and such messages are received in vehicles provisioned with different wireless technologies.**

***Index Terms*—V2X, C-V2X, IEEE 802.11p, Cloud Native, C-ITS, Edge Computing, Kubernetes, 5G NR**

I. Introduction

During the past decade, significant growth was expected for the Vehicle-to-Everything (V2X) applications market on a global scale. Most car manufacturers have prototyped solutions for this technology, but it has yet to be widely adopted. One major setback has been the availability of multiple wireless standards, each requiring specific fit-for-purpose equipment in all vehicles. Since the release of the standards IEEE 802.11p and IEEE 802.11bd (still in draft stage), the emergence of the standard based on 4G Long Term Evolution (LTE), the LTE-PC5, and the subsequent appearance of the 5G New Radio V2X (NR-V2X), V2X radio technologies have failed to reach

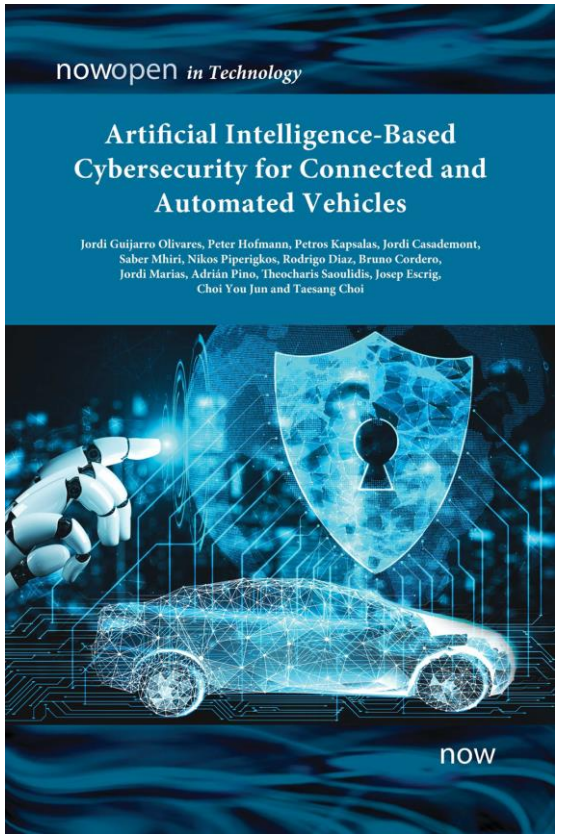
managing C-ITS applications. By moving C-ITS applications closer to where the data is produced (i.e., vehicles), and avoiding transporting the data far from its source, the stringent latency requirements of these type of applications can be met, whilst reducing the load on the transport network. These capabilities contribute to improving efficiency of the system, as well as the safety and the experience of road users [2].

This demo presents a roadside infrastructure architecture, based on vehicle-to-infrastructure-to-vehicle communication, that enables interoperability among vehicles and road users using three different radio access technologies: IEEE 802.11p, LTE-PC5, and conventional cellular 5G network. Thus, vehicles not specifically equipped for V2X communication can still participate in V2X communication through a cellular connection. The proposed system uses a module on the edge that forwards V2X messages generated by one vehicle to other ones that may have missed the message due to radio heterogeneity. This forwarding intelligence is deployed within a cloud native multi-access edge computing (MEC) architecture.

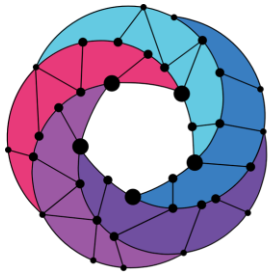
II. V2X Radio Interoperability System

The architecture for the system that enables the interoperability of multiple V2X radio access technologies is represented in Fig. 1. The physical road infrastructure includes a MEC server that runs all necessary software, as well as two types of road side units (RSU), one for IEEE 802.11p and another for LTE-PC5, to transmit and receive V2X messages. In addition, a public 5G cellular network is used. All software components are containerized and orchestrated using

[1] Jordi Marias i Parella, et all "Demo: Interoperability between Cellular and V2X Networks (802.11p / LTE-PC5) under a Cloud Native Edge Scenario, 9th CNERT, INFOCOM 2023.



[2] Jordi Guijarro Olivares, et all,, "Artificial Intelligence-based Cybersecurity for Connected and Automated Vehicles", Boston-Delft: now publishers,



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Thank You!