Deploying a V2X Stack in Edge environments for improving Mobility Safety

OSM #14 Ecosystem day

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Agenda

1. V2X Background & Challenges
2. i2CAT V2X solution
3. Demo 1: Deployment of V2X Stack via OSM
4. Demo 2: Validation in a Real Environment
5. Q&A
V2X Background & Challenges
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.

![Diagram of V2X Messages and Security layers]

**Other Applications**
- V2X Messages
- TCP / UDP
- IPv6

**Safety and Traffic Efficiency App**
- BTP GeoNetworking

**Management**
- MAC Extensions
- MAC
- PHY
V2X Challenges
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 [1]).
- **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.

[1] ETSI TS 122 185 V14.3.0 (2017-03)
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

- Create V2X messages (CAM, DENM)
- Sign & verify messages
- ITS G5 (IEEE 802.11p)
- C-V2X (LTE-PC5)
- IP/UDP (Commercial 5G)
- Geonetworking and Transport Basic Protocols
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)
- Lightweight solution: ported and integrated into embedded systems (e.g.: Raspberry Pi)

[Source: icons from Flaticon.com]
V2X Software Architecture

Apps consuming V2X data
(e.g: DB, Risk Detector, Collision avoidance, etc)

MQTT Broker

MQTT

V2X module
MQTT Client
V2X module
MQTT Client

VLAN-X
VLAN-Y

Radio Layer

Vehicle Layer
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 RSU and OBU layers.

[Source: icons from Flaticon.com]
Demo 1: Deployment of V2X Stack via OSM
V2X Stack Networking Architecture

Relation 1:1:1
- Radio Unit
- V2XCom
- VLAN

[Source: icons from Flaticon.com]
Instantiation of the V2X Stack according to the Network Topology via OSM

Relation 1:1:1
- Radio Unit
- V2XCom
- VLAN

Instantiation Parameters
v2xcom-1:
node: far-edge-1
vlan: 1500
mqtt-svc-name: mqtt

Instantiation Parameters
v2xcom-2:
node: far-edge-2
vlan: 1600
mqtt-svc-name: mqtt

Instantiation Parameters:
MQTT Broker
node: edge-1
svc-name: mqtt

NS: v2xcom
VNF: v2xcom-cnf

NS: mqtt-broker
VNF: mqtt-broker-cnf
Instantiation of the V2X Stack according to the Infrastructure

Video (Duration: 4’)

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Demo 2: Validation in a Real Environment
Validation in a real scenario: UC2 PLEDGER Project

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:

![Diagram of a road layout showing bicycle, pedestrian, and bus lanes.]

- 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

Pilot preparations (on-site + remote)

Testing of VRU gadget, tuning LEDs and buzzer

Instantiation of Network Services (NS) via OSM
Validation in a real scenario: UC2 PLEDGER Project

Video (Duration: 1’

i2cat
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CARAMEL Project
https://www.h2020caramel.eu/

PLEDGER Project
http://www.pledger-project.eu/
Literature supporting the work

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nowopen in Technology

Artificial Intelligence-Based Cybersecurity for Connected and Automated Vehicles

Jordi Guijarro Olivares, Peter Hofmann, Peter Kapodistria, Jordi Casademont, Joaquin Mato, Aitor Fiszman, Rodrigo Dias, Simona Craciun, Jordi Mira, Ahto Ronkko, Thomas Bauder, Tony Borissov, Chet Yoan Jat and Tanmoy Choudhury

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 efficiency on public roads. Although the implementation of C-ITS poses some critical challenges, specifically in heterogenous vehicles, it is necessary to enable 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 (3G/4G), and specific Vehicle-to-Everything (V2X) communication technologies, such as LTE-PC5 and IEEE 802.11p wireless communication standards, such that information in the edge is processed in real-time by means of a novel Cloud Native 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 provided with different wireless technologies.

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 off-the-shelf equipment in all vehicles. Since the release of the standards IEEE 802.11p and IEEE 802.11ad (millimeter wave), the emergence of the standard for 4G Low Term Evolution (LTE), the LTE-PC5, and the subsequent appearance of the 5G New Radio (NR) V2X (C-ITS), 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, while 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 II.

This demo presents a scalable infrastructure architecture, based on vehicle-to-infrastructure-to-vehicle communications, 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 necessary software, as well as two types of roadside units (RSUs), 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.

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."
Q&A
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