2023 IEEE ITSS R8 CHAPTERS MEETING

"An Eclipse MOSAIC-based Hardware-in-Loop V2X Co-Simulation Framework for CCAM services"

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Spoke 7 – CCAM & Smart Infrastructures

FRAMEWORK

The mobility sector is going through a phase of significant transformation, driven by technological advances and the evolution of social needs

- The CCAM paradigm is poised to transform transportation and revolutionize the way we move
  - The aim is to improve the safety, efficiency and sustainability of mobility by using and integrating innovative technologies
  - It's about making road users (drivers, pedestrians, cyclists, etc.) connected and aware of the conditions of the surrounding environment

McKinsey Quarterly: the future of mobility

EMERGING CHALLENGES

New paradigm, new challenges

- Ensuring seamless cooperation between different entities
- Upgrade of infrastructures to support CCAM to handle the data exchange between vehicles and infrastructure
- Lack of analysis approaches and methodologies to systematically and comprehensively evaluate the pros and cons of the integration and market deployment of CCAM solutions in mobility systems
- To speed up the development, implementation and market deployment of CCAM systems, significant improvements in the testing of such solutions are needed

CN-MOST SPOKE 7

The **Spoke 7** "***CCAM and Smart Infrastructure***" face some challenges of the new mobility environment. Indeed, it aims to facilitate the development of an integrated environment of technologies and services, so to address the requirements of digital transformation and sustainability.

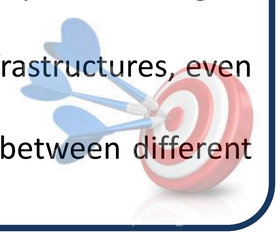
Some Macro-Objectives:

- Development of C-ITS services and Digital Twins of Smart Highways
- After-market solutions for automated vehicle and safety-oriented services
- Innovative solutions for traffic management and control in multi-operator contexts
- Services for the assessment of automated driving systems on public roads

THE AIM

Our aim is to design of an **innovative** testing and validation **ecosystem** for the realistic modeling of Smart Highways, able to integrate the Digital Twins of transport infrastructures.

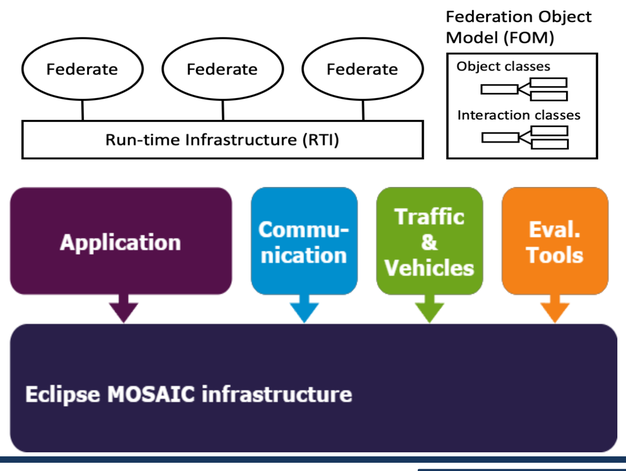
- Support the development, upgrade, adaptation and testing of physical and digital components of the traffic environment (e.g., C-ITS services)
- Identify inadequacies in established physical and digital road infrastructures, even in mixed traffic situations
- Model processes, information exchange and interrelationships between different entities in a uniform and integrated way



Eclipse MOSAIC

Eclipse MOSAIC Co-Simulation framework starting point

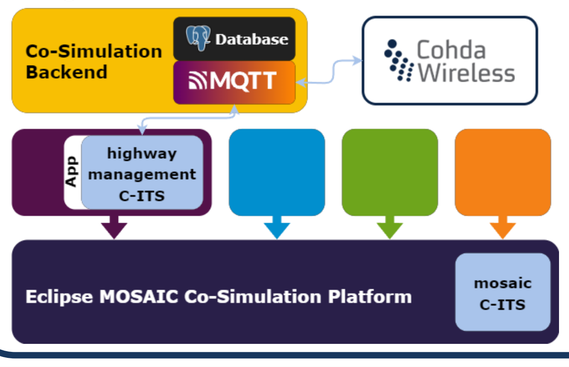
- ✓ Multi-Domain and Multi-Scale Simulation Framework for Connected and Automated Mobility.
  - Provides a collection of simulation models for different scales, and already integrate and coupled with some well-established simulators such as SUMO or Omnet++/NS3
- ✓ Modular framework based on High-Level Architecture with Federates
  - Simulators could be exchanged according to the scenario
- ✓ Suitable for the the development and virtual testing of new mobility solutions and application
- ✓ Open Source
- ✓ Open to pairing with new simulators and external hardware

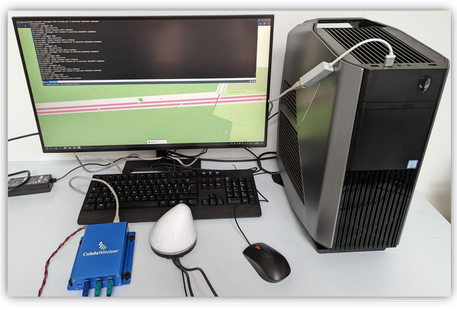


ECLIPSE MOSAIC

We **extended** the Eclipse MOSAIC by coupling with external Hardware

- ✓ Enables hardware-in-loop testing, implementing specific algorithms on the hardware board instead of in a simulated environment, thus increasing the realism of the tests and their results
- ✓ Development and implementation of CCAM services according to CE regulations

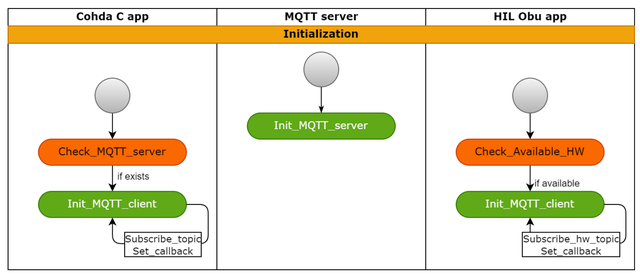




EXTENDED PLATFORM

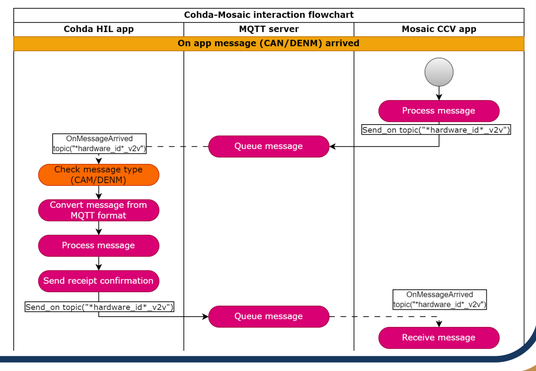
MQTT queue enables the connection between the Hardware device and the Java OBU app

Thus, both need to connect to the queue and subscribe to their given topics



The message received by the OBU app is sent on the MQTT queue to a topic the Hardware app is subscribed for

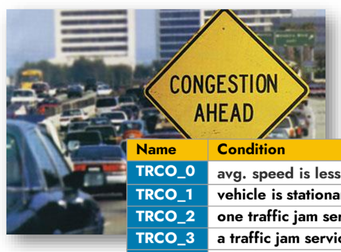
Elaboration is then processed by the Cohda app



CASE STUDY

Validation of the developed co-simulation platform in a realistic traffic scenario

- A56 Urban Highway (Italy) (Tangenziale di Napoli)
  - Three-lane, a total length of 20 km, a maximum legal speed of 80 km/h.
- Traffic demand: 5000 veh/h along the mainline and 1500 veh/h entering at Camaldoli entry
  - Stop&Go phenomena and queue formation
- Mixed traffic conditions
  - Conventional Vehicles (CVs) and Connected Conventional Vehicles (CCVs)
- Implementation of the C-ITS service "Traffic jam ahead" in accordance with CE regulations.



Name	Condition
TRCO_0	avg. speed is less than 30km/h but nonzero
TRCO_1	vehicle is stationary, speed 0
TRCO_2	one traffic jam service DENM message has been received
TRCO_3	a traffic jam service radio message has been received
TRCO_4	vehicle indicating a speed of 30 km/h or less of at least five other vehicles within 100 m and with the same driving direction
TRCO_5	on board sensors detect traffic jam conditions

RESULTS

- ✓ Eclipse MOSAIC is a suitable environment to model Smart Highways
- ✓ The proposed extended platform correctly supports HiL testing, allowing a detailed representation of operating conditions of the technology
- ✓ Possibility of implementing C-ITS services in accordance with CE specifications
- ✓ C-ITS service «Traffic jam ahead»
  - Under low penetration rated of connected vehicles, not all activation conditions are satisfied
  - The service activation time increases as the penetration rate decreases

CCV% Rate	Activating Condition	Activation Time (s)	Stressed Conditions
30%	TRCO_0	729	TRCO_0,1,2,4
20%	TRCO_0	745	TRCO_0,1,2,4
10%	TRCO_0	758	TRCO_0,1,2,4
5%	TRCO_0	762	TRCO_0,1,2

- ✓ Test before Invest
  - Analysis of technological solutions and services before implementation
  - Optimization of the design, development, testing and validation phases of technological solutions (e.g. C-ITS services)

…WORKS

- more sophisticated case studies, including field-based traffic demand data
- integration of physic-based simulators (such as CARLA or PHABMACS) or other hardware
- using a more realistic wireless network
- enhancing the real-time capabilities of the framework (e.g., making sure the simulation computes at least 1on1 with real-time

Andrea Marchetta, **Angelo Coppola**, Marcello Cinque, Mario Fiorentino, Gennaro Nicola Bifulco. 2023. *An Eclipse MOSAIC-based Hardware-in-Loop V2X Co-Simulation Framework for CCAM services*. 26th IEEE International Conference on Intelligent Transportation Systems ITSC.

Partially financed by Ministero Università e Ricerca (MUR), Italy, through the PNRR project Centro Nazionale per la Mobilita Sostenibile CUP E63C22000930007

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