



DEPARTMENT OF
NETWORKED SYSTEMS
AND SERVICES

MEC-Assisted Collective Perception

Introduction, modelling and initial simulation results

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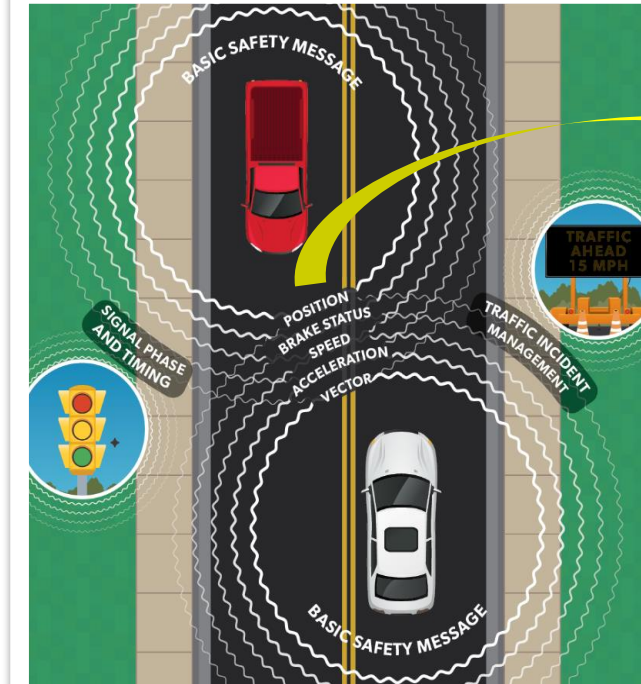




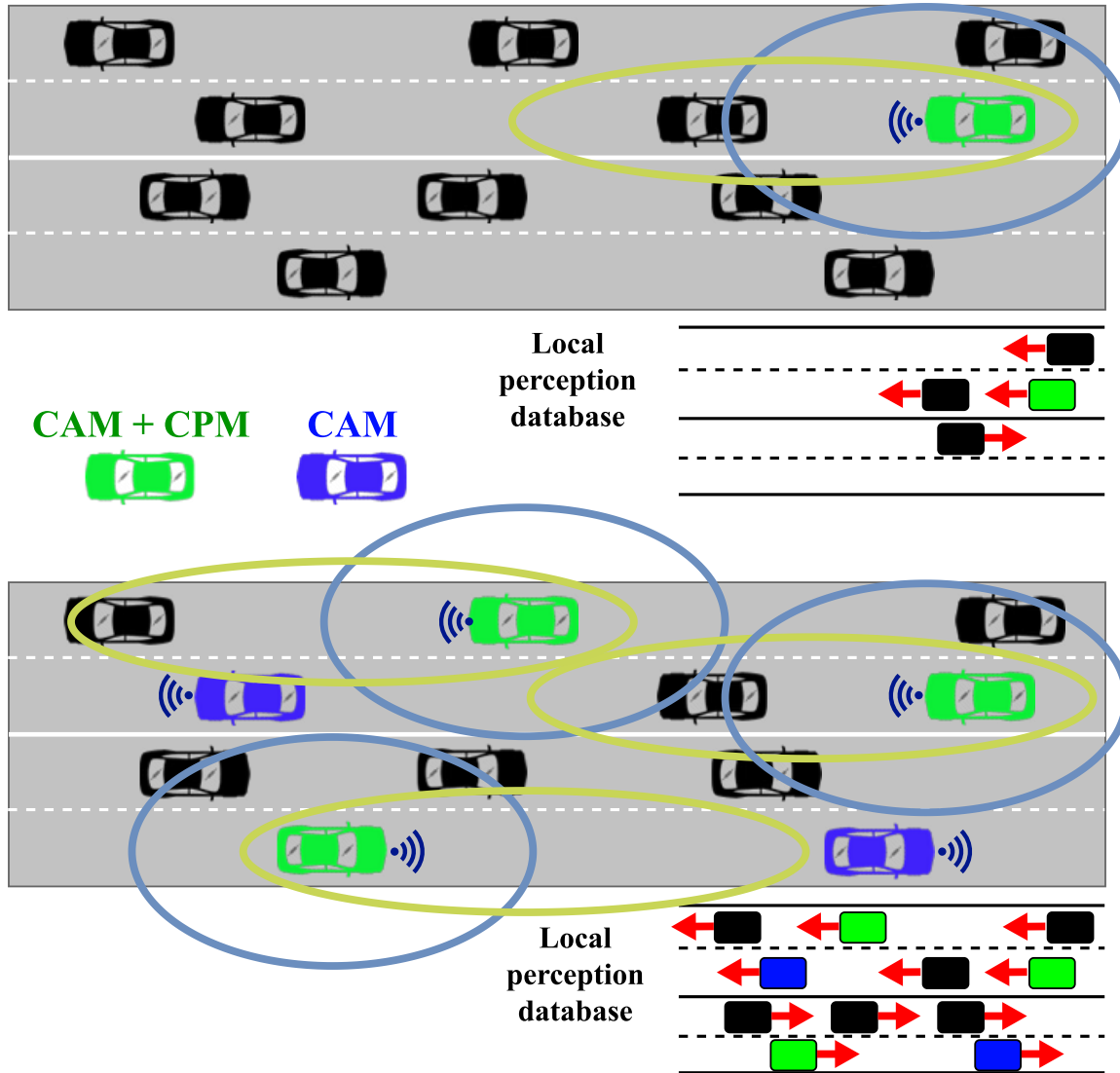
Introduction

THE VISION OF V2X/C-V2X: CRASH PREVENTION AND ADVANCED INFORMATION PROVISION

- Vehicle-to-Everything (V2X) communications are transformative for vehicle crashes/fatalities/injuries and improve overall mobility
- Cellular Vehicle-to-Everything (C-V2X) for 4G/5G and beyond cellular infrastructures
- Wide scale of applications
 - safer, more efficient, and green transportation for connected, cooperative, and automated vehicle environments.



Source: U.S. Department of Transportation



The number of perceivable objects grows using V2X:

Case 1: no V2X used, ego vehicle relies only on proprietary sensors

~1/2 of the vehicles detected

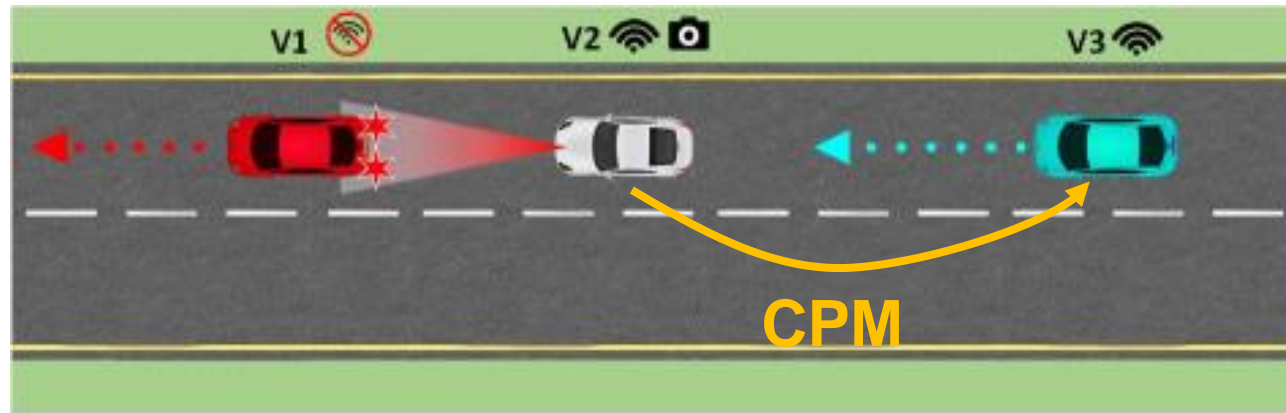
Case 2: state information and perceived object data shared via V2X

All vehicles detected in the scenario



Use cases

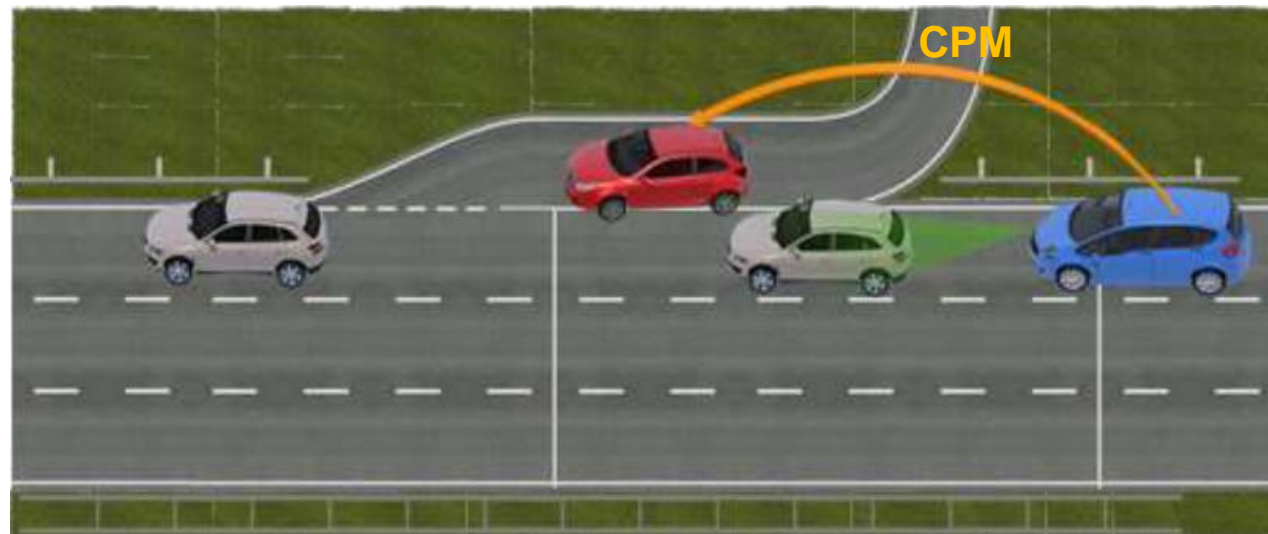
- Emergency Electronic Brake Light (EEBL)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Blind Spot Warning (BSW)



https://www.etsi.org/deliver/etsi_tr/103300_103399/10330001/02.02.01_60/tr_10330001v020201p.pdf

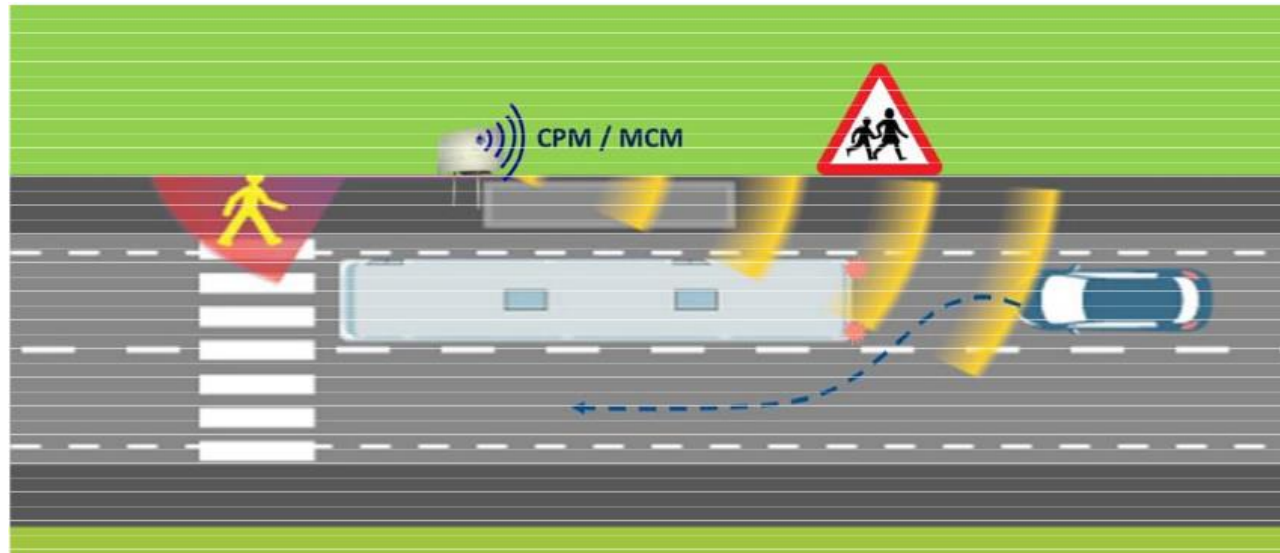
ADVANCED USE CASES: COOPERATIVE MERGING

- Highway scenario, the environmental model of a connected car can be completed with information propagated through CPMs



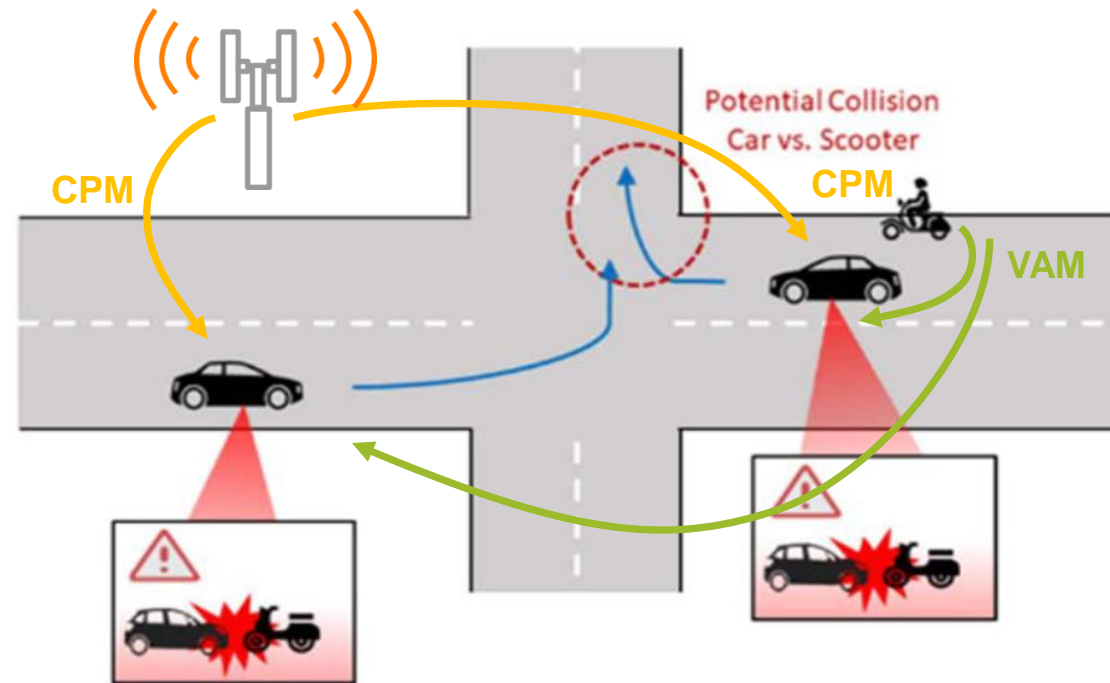
https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_WP_2072_RoadmapDay2AndBeyond.pdf

The pedestrian is detected by fixed cameras/sensors and perception data is broadcasted by an RSU to nearby vehicles.



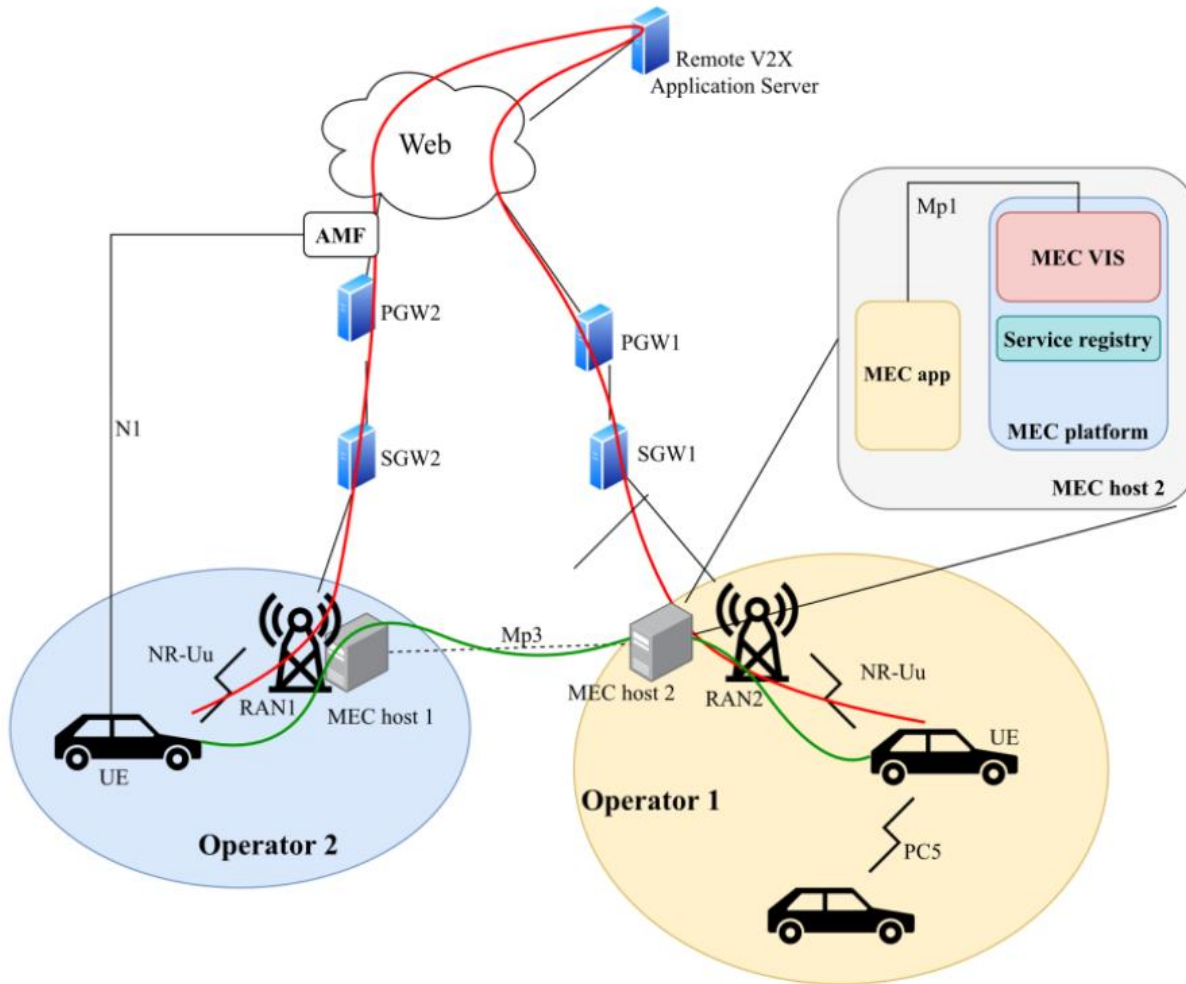
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The scooter (or the rider's mobile device) actively sends CPMs to nearby vehicles, warning them about a potential collision.



https://www.etsi.org/deliver/etsi_tr/103300_103399/10330001/02.02.01_60/tr_10330001v020201p.pdf

MEC-ASSISTED V2X: ETSI V2X INFORMATION SERVICE



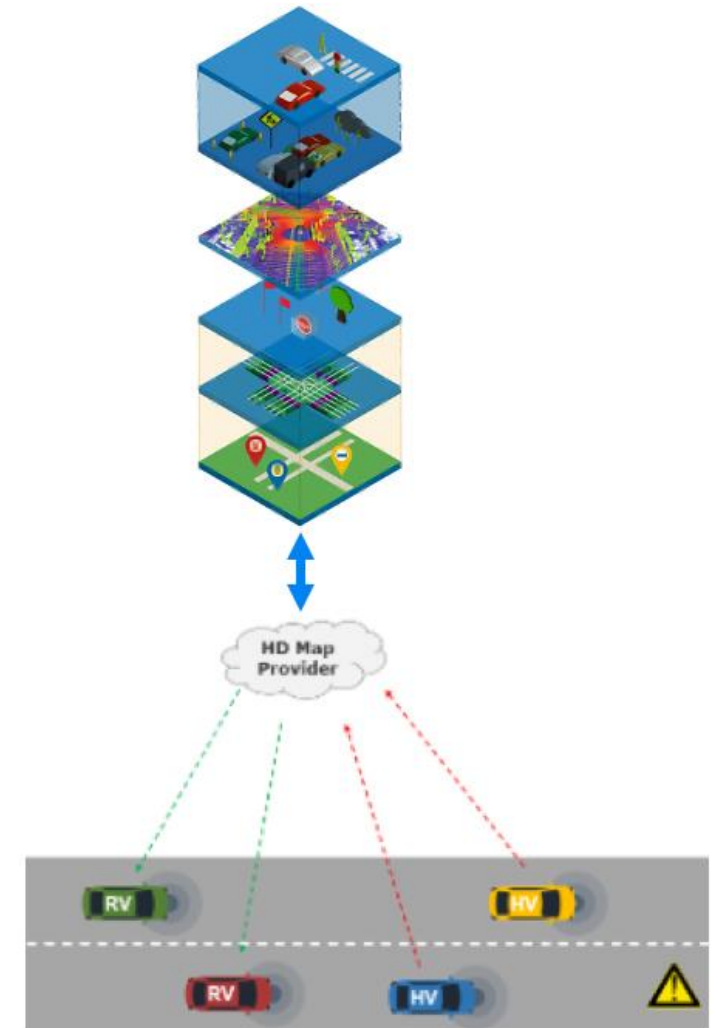
ETSI GS MEC 030 V3.1.1 (2023-03)

- Gathering of PC5 V2X-related information from the 3GPP network
 - authorized UEs, subscription info, configuration parameters
- Exposure of this information to MEC apps
- Enablement of secure communication between MEC apps and the logical functions in the core network
- Enablement of secure communication between MEC apps in different MEC systems
- Gather and process information available in other MEC APIs to predict RAN congestion and notify UEs
 - e.g., journey-specific QoS prediction

Collects higher-level applications enabling more optimized traffic and a safer driver experience. Not only sensory data is transmitted, but also intentions for various maneuvers and pre-calculated trajectories

- Cooperative Collision Avoidance (CoCA)
 - Collision avoidance system based on CAM, CPM, and MEC-based sensors fusion in case of fully autonomous vehicles
- 3D video composition for V2X scenario
 - Based on a video feed and processed object data (via CPM) from traffic participants a 3D model can be established
 - Could help law enforcement personnel in the assessment of traffic accidents in an urban area

- HAD MAP rendering
 - V2X information feed instances of a HD map rendering application deployed on MEC servers
 - ensures lower latency and offers more computational resources
- Multiple data sources data fusion
 - continuous maintenance of a much broader view/model of the environment
 - tracking the detected objects as they move around





The simulation framework

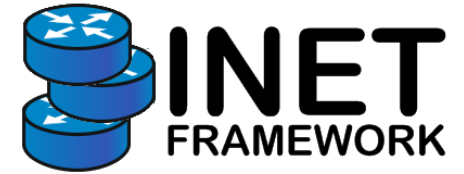
- OMNeT++

- extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators
- <https://omnetpp.org/>



- INET

- an open-source model library for the Internet stack, wired and wireless protocols, applications, etc.
- <https://inet.omnetpp.org/>



- SUMO

- microscopic multi-modal traffic simulation package - including road vehicles, public transport, and pedestrians
- <https://www.eclipse.org/sumo/>



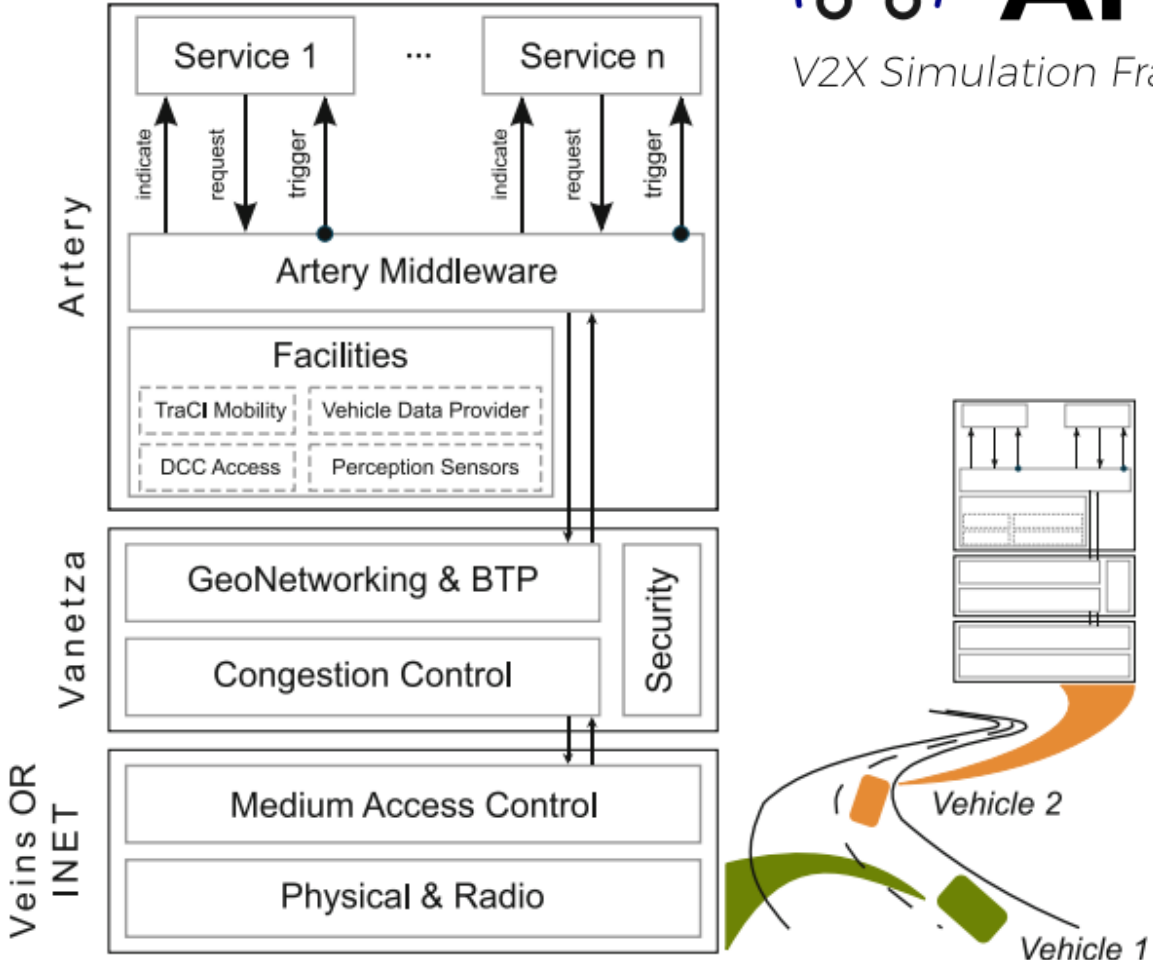
SUMO
SIMULATION OF URBAN MOBILITY

- Vanetza

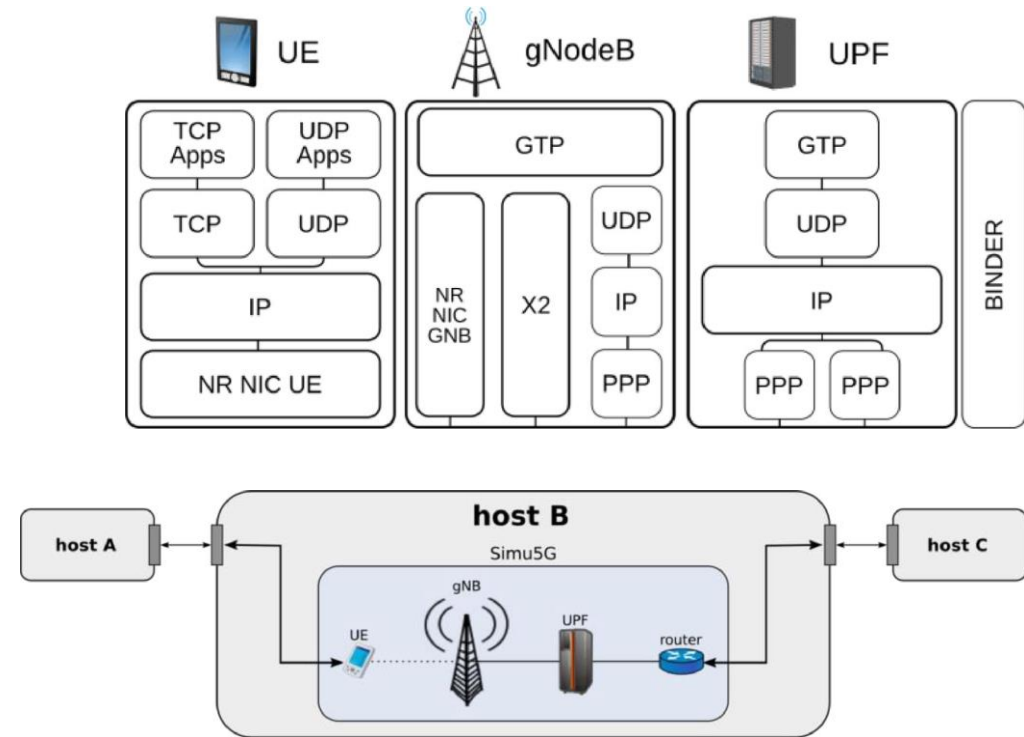
- open-source implementation of the ETSI C-ITS protocol suite
- <https://www.vanetza.org/>



THE INTEGRATED SIMULATION COMPONENTS 2/2



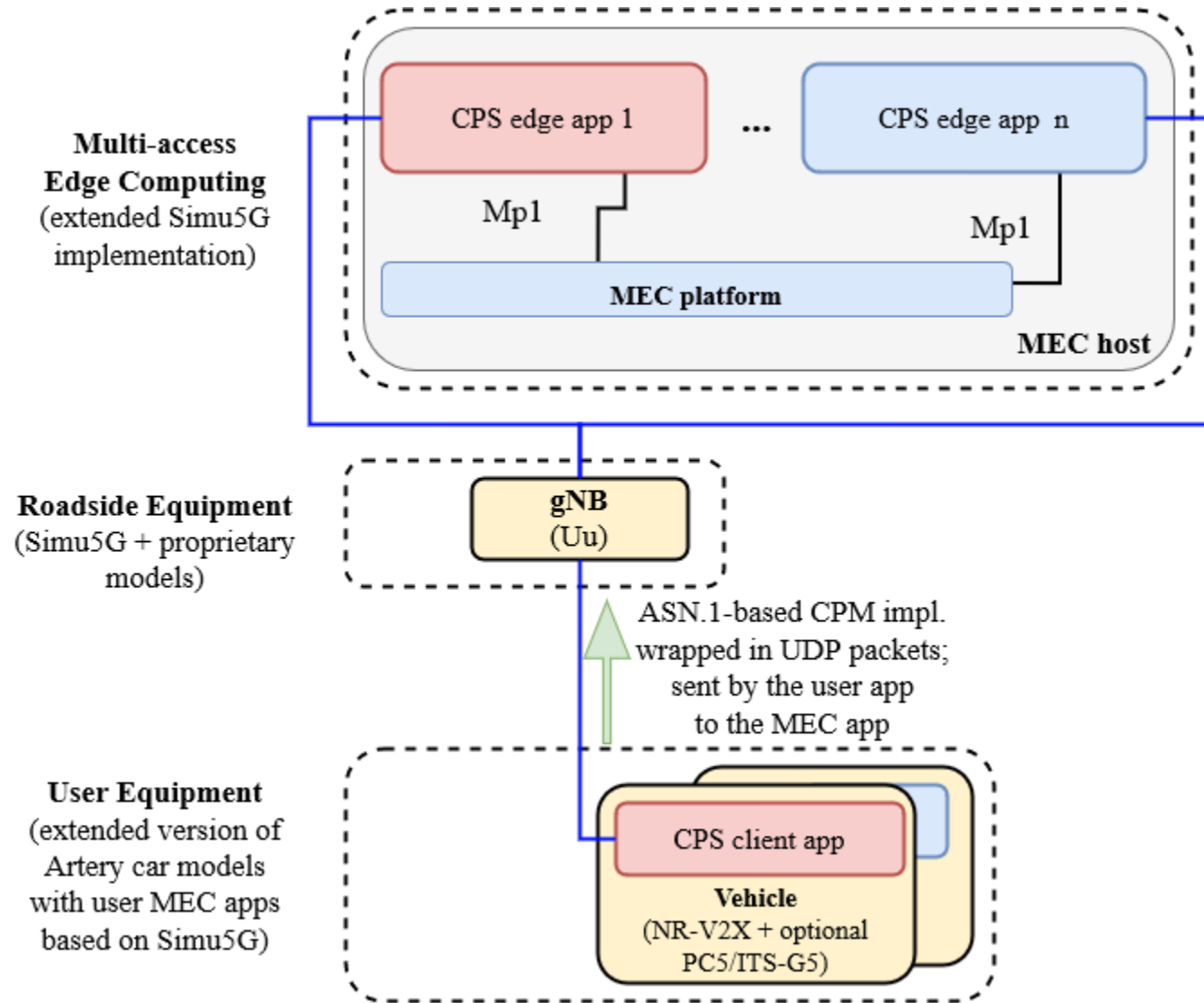
https://link.springer.com/chapter/10.1007/978-3-030-12842-5_12

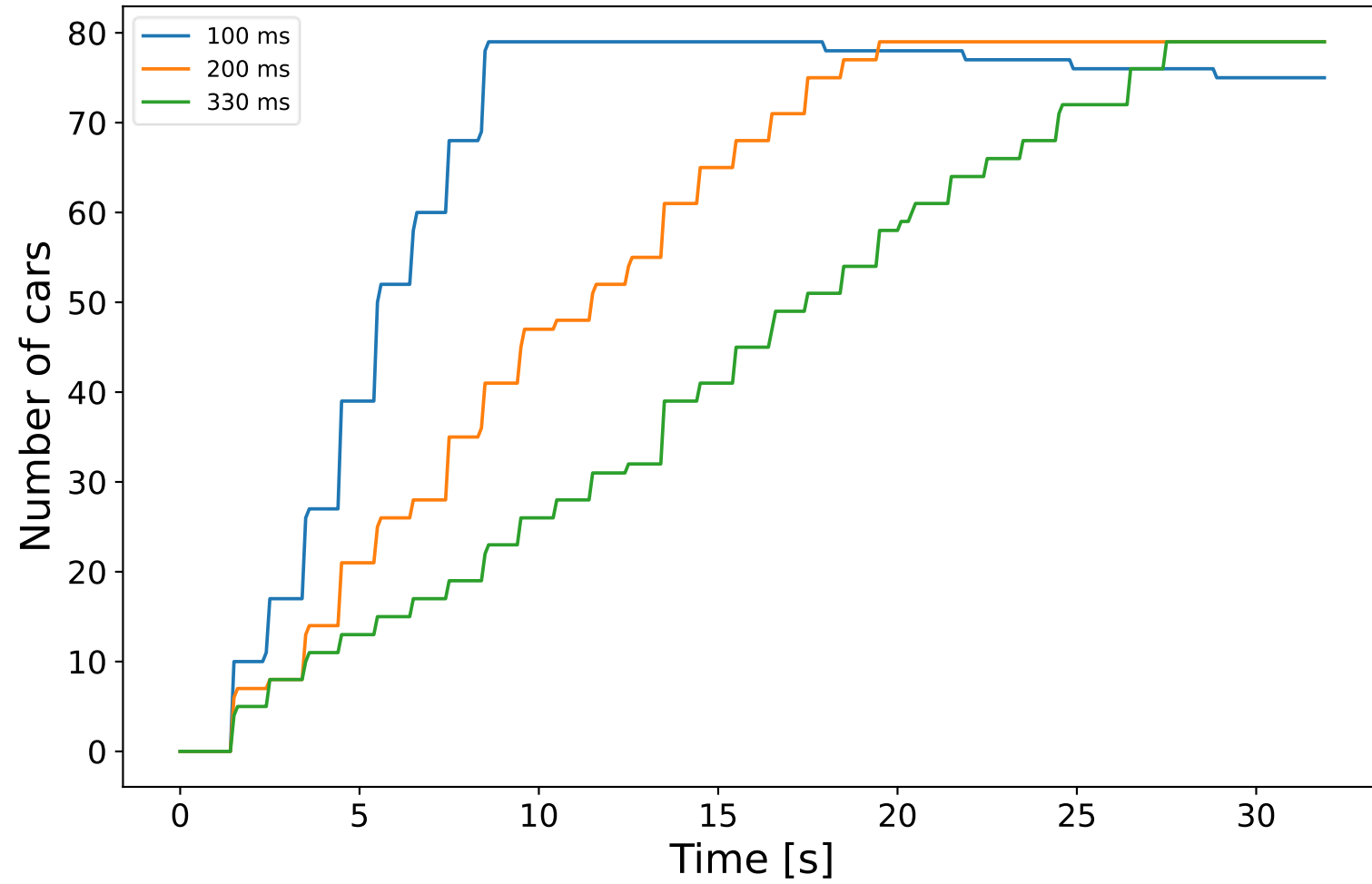
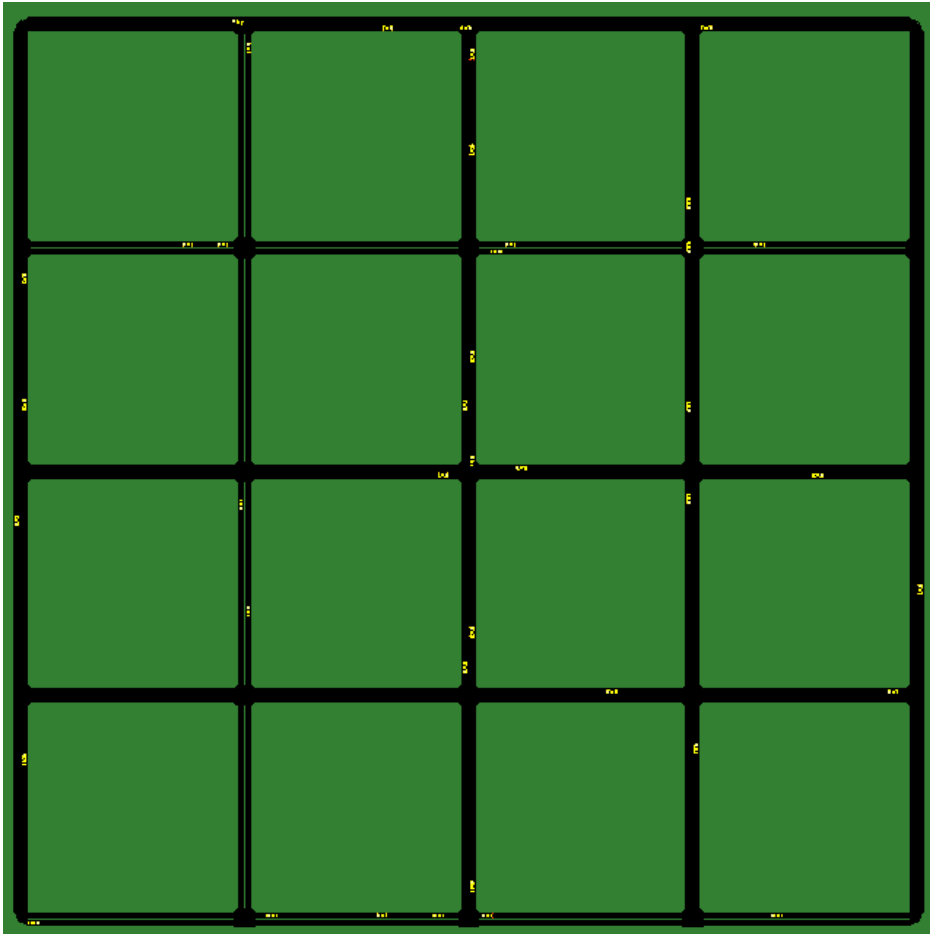


<https://doi.org/10.1016/j.simpat.2022.102700>

- Extending the build system with the Simu5G library
- Integrating model components into an existing Artery scenario
 - Replacing network components, setting up the 5G network
 - Integrating the model of the MEC infrastructure
- Implementing a new MEC application
 - Client side (car) app
 - collects Collective Perception Messages (CPM) from the V2X stack running on the car
 - Sends them to the app instance running in the MEC
 - MEC app
 - Digests incoming CPM messages

- Newest CPM message format (July 2023)
- CPMs are encapsulated in UDP packets
- Vehicles use 5G Uu interface
- Edge applications receive and digest incoming CPMs



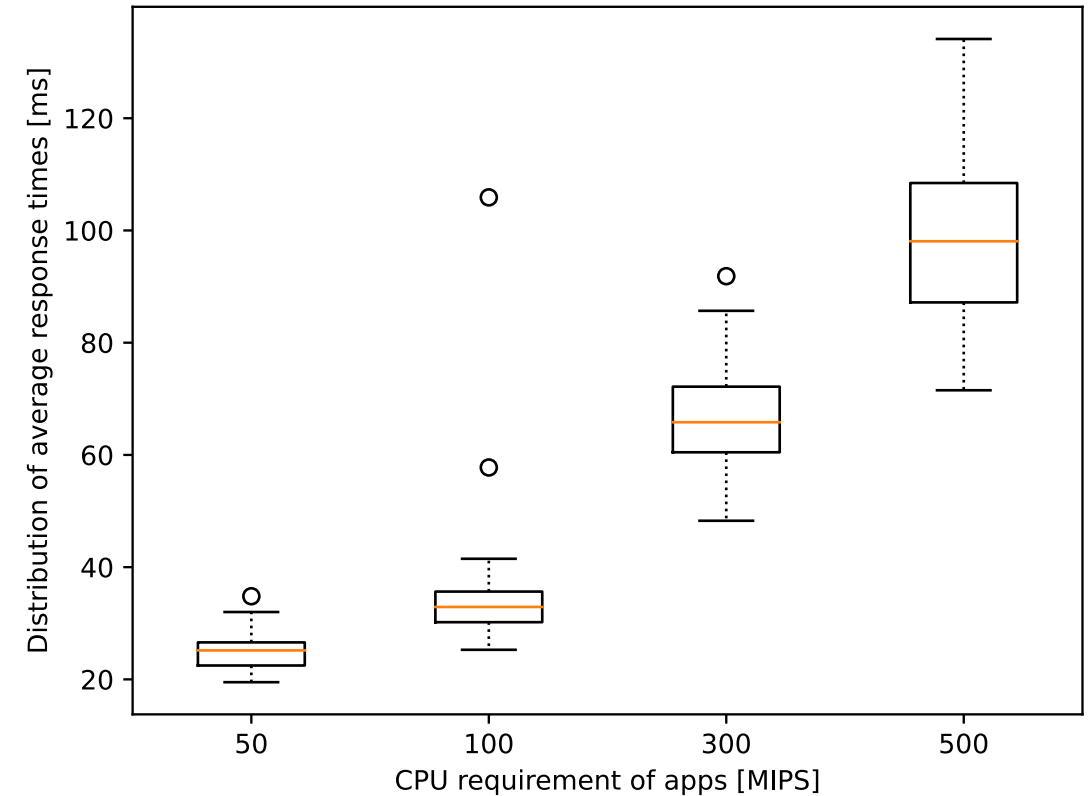


Grid map with different traffic flows

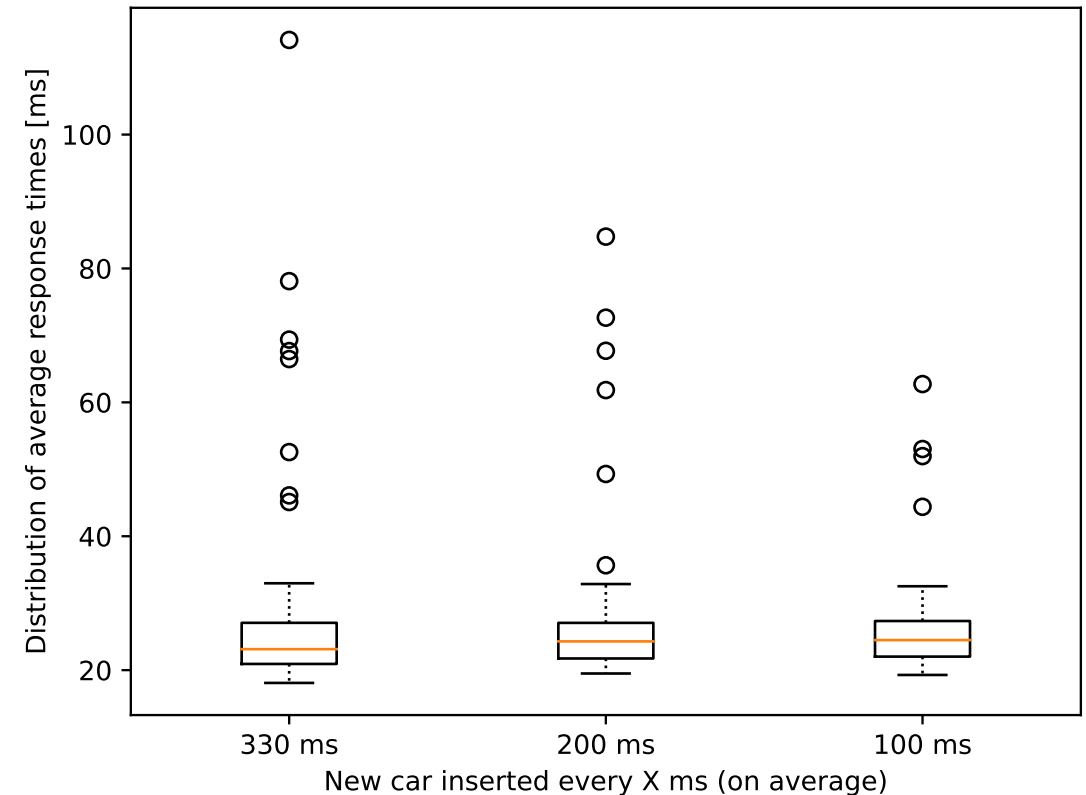
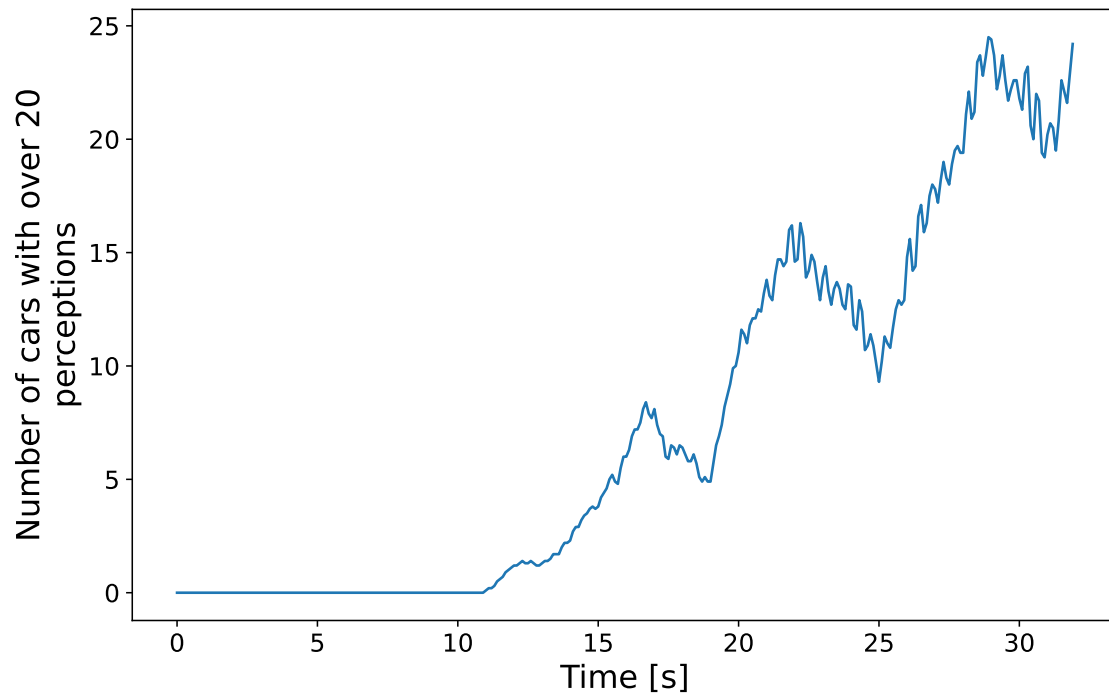
MEC Host Capability [MIPS]	MEC App CPU Requirement [MIPS]	Average End-to-End Latency [ms]	Average Response Time [ms]
400,000	50	11.4	25.0
400,000	100	12.5	34.1
400,000	300	12.0	66.0
400,000	500	11.8	97.5

Response time model: $resp = d_{UL} + t_{process} + d_{DL}$

- Scenarios with fixed CPU requirements per MEC app
 - To simulate the processing time of each CPM
- End-to-end latency was measured to test the network load
- Processing time had a greater role in the overall response time



- Different traffic densities as before
- Sensors configured to capture most of the nearby vehicles
- Dynamic required processing time based on the number of detected objects

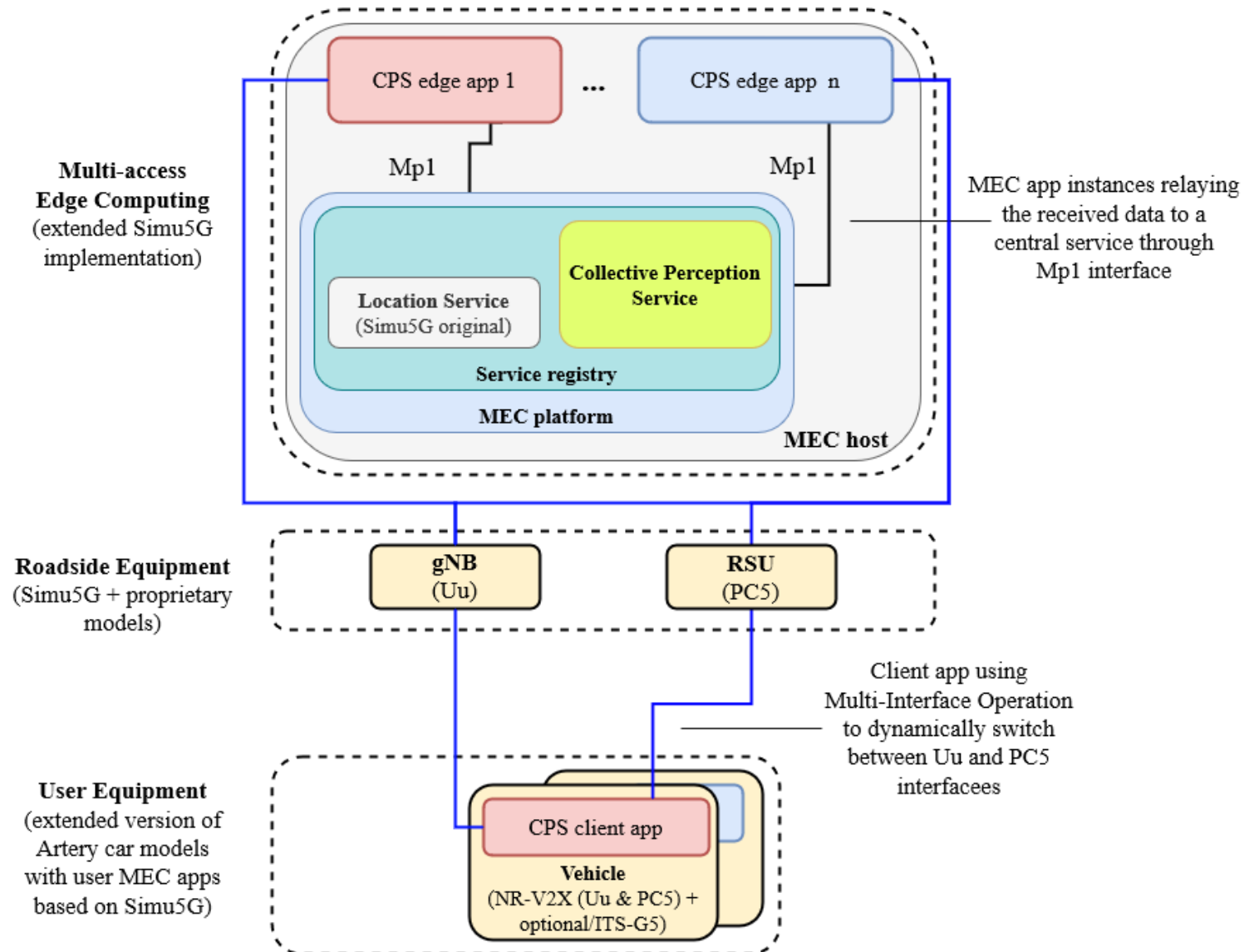




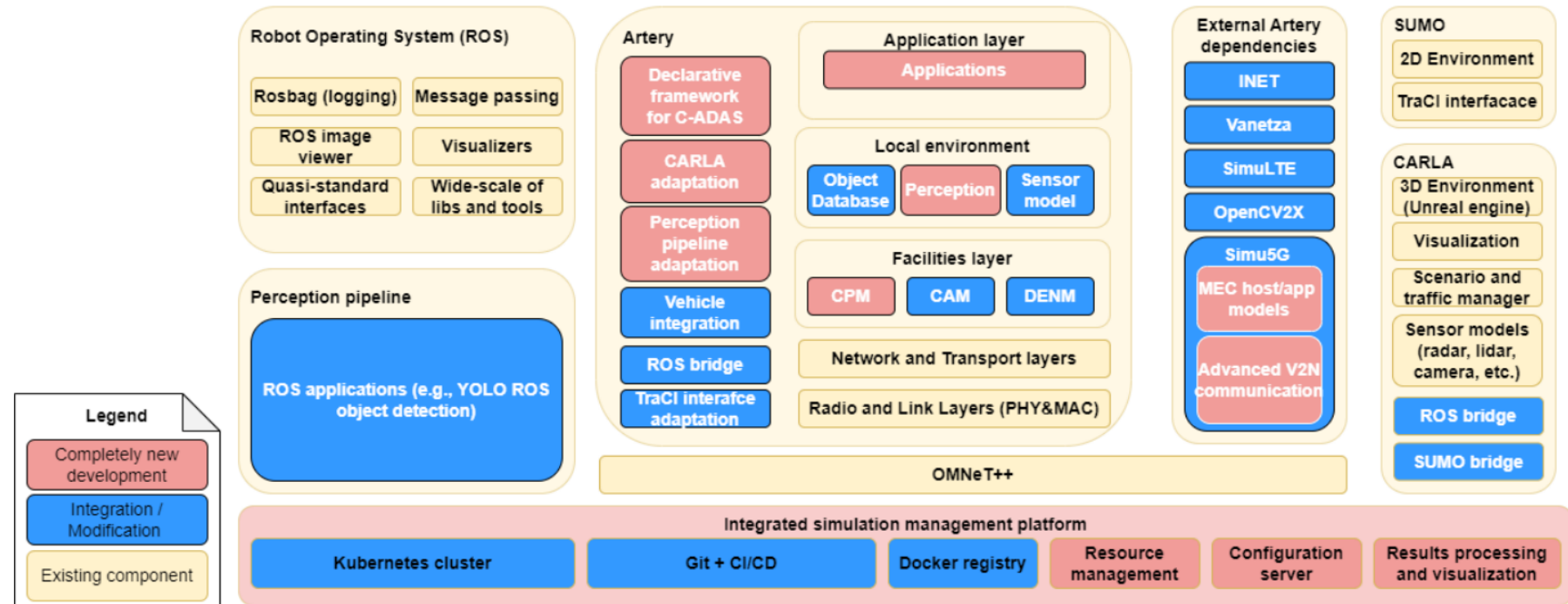
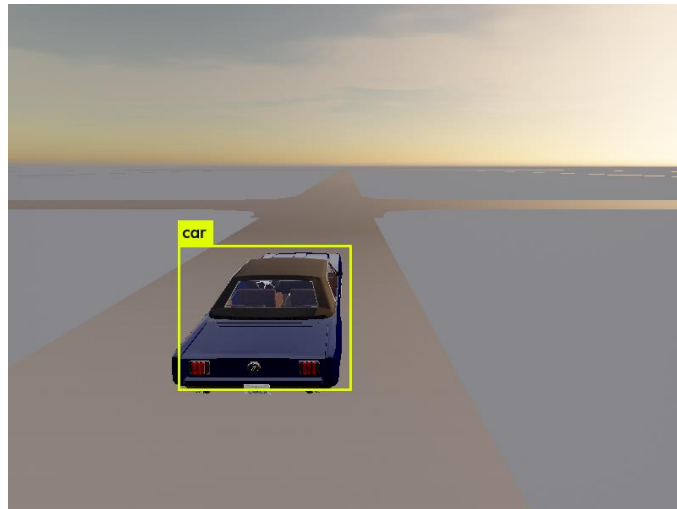
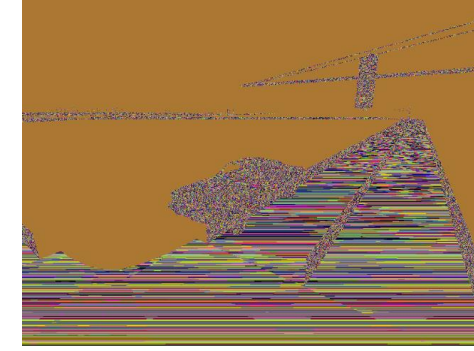
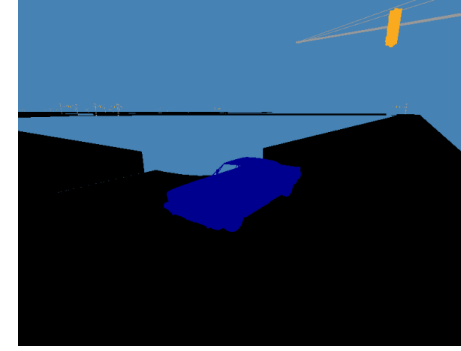
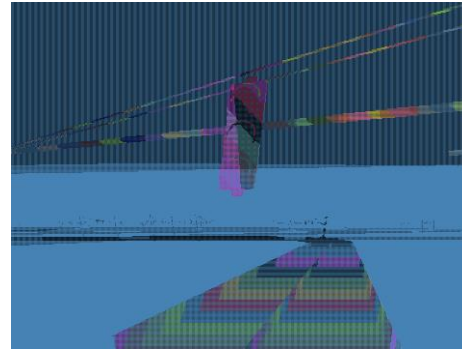
Conclusions and future work

- The integrated simulation framework can model 5G + MEC-assisted V2X applications
 - 5G radio/ aspects and MEC performance can also be studied
- The out-of-the-box MEC implementation responds adequately to data in the CPMs
 - Fixed requirement scenarios show the limitations of the MEC model
 - Dynamic scenarios show how the environment model can affect MEC performance
- The overall QoS is within acceptable boundaries

- Central CPS MEC service to consume and aggregate all incoming CPMs
 - E.g., sensor fusion
- NR V2X PC5 Mode 2
- Multi-interface hybrid V2X (Uu + PC5)
- Realistic sensor suites



THE HOLY GRAIL: ARTERY + CARLA + ROS INTEGRATION





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Thank you for your attention!