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# Simulation of Vehicle-to-Pedestrian Communication for Development of Novel C-ITS Services for Vulnerable Road Users

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## INTRODUCTION

**The development of Connected, Cooperative and Automated Mobility (CCAM) technologies, including its key enabling technologies, such as Vehicle-to-Pedestrian (V2P) communication, aims to respond to the following socioeconomic and market drivers:**

- increasing urbanization;
- the push for increased road safety;
- necessity to decrease the negative environmental and health impacts of transport.

**Despite its potential, V2P communication remains underdeveloped due to:**

- the unpredictable nature of pedestrian movement
- the variability in pedestrian devices (e.g., smartphones, wearables)
- high costs and logistical challenges of real-world testing

**Research Objectives:**

- Extend existing simulation tools to support dynamic pedestrian interactions.
- Enable modeling of V2P communication using DSRC and 5G networks.
- Enable rapid prototyping and evaluation of C-ITS services for VRUs.

**Expected Impact:**

- Accelerate the design of safer mobility solutions for pedestrians.
- Reduce the scale of costly real-world testing in early development stages
- Support cities in achieving road safety and smart mobility goals

## MATERIALS, METHODS & IMPLEMENTATION

**Simulation Tools:**

- OMNeT++: Network simulation for V2X communication
- SUMO: Microscopic traffic simulation including pedestrian behavior
- Veins: Integrates OMNeT++ and SUMO and provides models for DSRC communication modelling but originally lacks pedestrian support
- Simu5G & INET: Enable 4G/5G communication modeling

**Framework Architecture:**

- Bi-directional coupling of OMNeT++ and SUMO via TraCI
- Extension of Veins framework to support SUMO “Person” objects
- TraCIScenarioManager modified to handle pedestrian data
- Integration of cellular-based (4G and 5G) V2P via Simu5G

## RESULTS

The extended simulation framework successfully integrates pedestrian dynamics into V2X simulations by enhancing existing tools (OMNeT++, SUMO, Veins) and introducing support for V2P communication via both DSRC and cellular (4G/5G) technologies.

**Key Outcomes:**

- **Pedestrian Integration:** Extended the Veins framework to support SUMO’s "Person" objects, enabling realistic modeling of pedestrian movement and behavior.
- **Bi-Directional Communication:** Enables pedestrians to act as communication nodes using mobile devices, exchanging messages with vehicles and infrastructure.
- **Customizable Framework:** Flexible simulation scenarios can be developed where user-defined variables (e.g., movement patterns, message types, connectivity parameters) can be configured.
- **Modularity and Expandability:** The framework is modular, open-source, and compatible with existing ITS research tools, supporting reproducibility and community-driven development.
- **Runtime Visualization:** Simulations demonstrate live interactions between vehicles and pedestrians, in the traffic and communication domains.

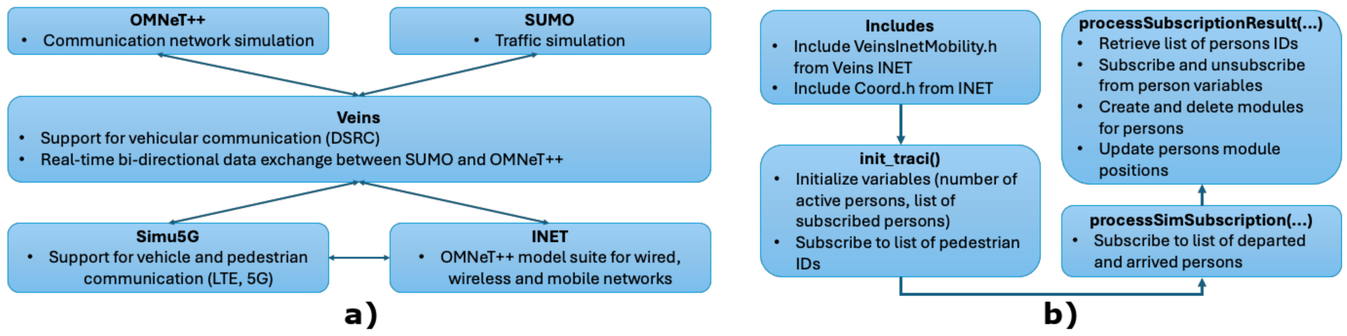


*Fig. 1. Simulation framework capable of simulating V2V, V2I and V2P communication: a) modules of the framework; b) indicative list of changes in the TraCIScenarioManager module.*

- This platform lays a foundation for testing innovative V2P use cases, benchmarking V2P applications, and informing standardization activities and future mobility policies.
- The extended Veins simulation files supporting the SUMO Person object integration are available in the project’s GitHub repository (scan the QR code)

## CONCLUSION & IMPLEMENTATION PATH

- The framework enables the simulation of realistic V2P scenarios crucial for Cooperative Intelligent Transport Systems (C-ITS).
- It addresses limitations of existing tools by modeling:
  - unpredictable pedestrian behavior;
  - mobile device constraints (e.g., power, connectivity).

The framework supports benchmarking and prototyping of C-ITS services with reduced need for complicated real-world trials during early stages of development.

**Contribution:**

- A flexible, scalable, and open-source simulation environment for V2P.
- Bridging the gap in existing simulators by adding pedestrian communication features.

**Future Work:**

- integrate advanced pedestrian mobility models
- include VRU-specific messages and next-gen communication protocols

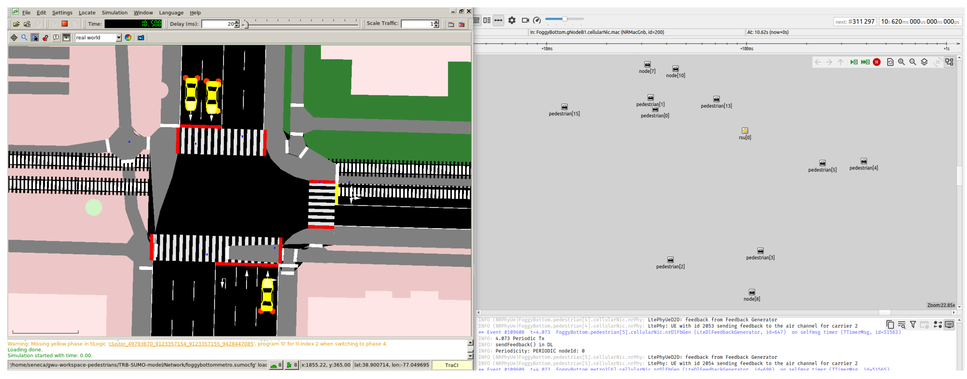

*Fig. 2. Screenshot of a bi-directionally coupled V2X simulation including Persons (blue dots in the left part of the figure).*

## ACKNOWLEDGEMENTS

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