CO-SIMULATION FRAMEWORK FOR NETWORK-OPTIMIZED AD HOC USING INVERTED AI: EDGE SIMULATION APPROACH

1 ABSTRACT

Vehicular ad hoc networks (VANETs) demand seamless integration of mobility modeling, network optimization, and edge intelligence to meet the requirements of next-generation intelligent transportation systems. Existing studies often treat these domains separately, limiting realism and deployment readiness. This paper presents a co-simulation framework for network-optimized ad hoc communication using an inverted AI edge simulation approach. The framework in CARLA driving simulator with OMNeT++is to synchronize vehicle dynamics and network behavior, while a lightweight YOLOv8-Nano model deployed at the edge enables real-time object detection under constrained resources. Transformer-based architectures are incorporated for collaborative V2X perception, enhancing resilience against occlusion and dense traffic conditions. To ensure reliable connectivity, adaptive multi-network communication strategies are applied, integrating IEEE 802.11p, LTE-V2X, and 5G-V2X in compliance with ETSI and Third Generation Partnership Project (3GPP) standards. Experimental results demonstrate reductions in latency, improvements in detection accuracy, and higher packet delivery reliability compared to traditional approaches. The proposed framework establishes a scalable foundation for deploying edge-enhanced, AI-driven vehicular networks through realistic co-simulation.

2 INTRODUCTION

The VANET'S used to provide the communication such as V2X for to overcome the collision avoidance. In this part where the network is capable for identifying the exact location based on TraCI and GIS. **Geographic Information Systems (GIS)** for contextual awareness and **Traffic Control Interface (TraCI)** for real-time simulation control. The **Inverted AI** is to collect the dataset from the github similar to that of kaggle or google collab. The transmission of network in this vehicular ad hoc network consist of Onboard Units (OBU) and Road Side Units (RSU). The inputs are divided into three modules with convolutional theorem in physics, Back propagation and time synchronization. The outputs for this dataset image classification dataset, object detection dataset and time series for GMM/CNN.

FUTURE RESEARCH DATASET FOR COLLISION AVOIDANCE

- **Torch Drive Sim**
- **Carla**
- **Lanelet2**
- **Map-converter**

3   LITERATURE REVIEW

 Simulation frameworks have played a central role in the study of vehicular ad hoc networks (VANETs). **Dosovitskiy et al. (2017)** introduced *CARLA*, an open-source driving simulator that provides high-fidelity vehicle dynamics and sensor models, making it an essential tool for benchmarking perception and planning algorithms in autonomous driving. Complementing this, **Varga and Hornig (2008)** presented *OMNeT++*, a modular discrete-event network simulator that has become widely used for modeling communication protocols. Building on this foundation, **Krajewski et al. (2018)** proposed the Veins framework, which integrates OMNeT++ with the SUMO traffic simulator to study vehicular mobility and networking together. Although Veins provided valuable insights into VANETs, its reliance on SUMO limited the physical realism, motivating later efforts to combine CARLA with network simulators for more accurate co-simulation environments.

Advances in deep learning have further enhanced vehicular perception systems. **Wang et al. (2023)** developed *YOLOv8*, a state-of-the-art object detection model that balances speed and accuracy for real-time deployment. Extending this line of work, **Patel et al. (2025)** demonstrated the deployment of *YOLOv8-Nano* on Jetson Orin edge devices, achieving millisecond-level inference times suitable for collision avoidance applications. Supporting these advances, **Salehinejad et al. (2021)** provided a comprehensive survey of edge AI in connected and autonomous vehicles, highlighting how distributing intelligence at the edge reduces latency and bandwidth compared to cloud-only approaches. Collectively, these works emphasize the importance of lightweight yet accurate AI models for real-time vehicular safety applications.

In addition to perception, transformer-based architectures have been explored for collaborative V2X sensing. **Liu et al. (2023)** applied transformers to V2X feature fusion and demonstrated that attention mechanisms outperform CNN-based methods,

particularly in occluded urban environments. Expanding this application, **Chen et al. (2025)** employed transformers for collision avoidance, showing that their approach significantly reduced false alarms compared to classical sensor fusion models. Recognizing the computational challenges of transformers, **Li et al. (2025)** introduced edge-optimized variants using pruning and quantization techniques, thereby maintaining accuracy while making these models more suitable for resource-constrained vehicular hardware. These studies highlight the growing importance of transformers in advancing reliable and scalable cooperative perception.

Networking performance also remains a crucial research focus. **Brown and Williams (2023)** validated V2X protocol performance by implementing them in *NS3* and cross-verifying results with OMNeT++, achieving consistency across simulation platforms. To address reliability and congestion challenges, **Smith and Johnson (2023)** proposed a multinet communication framework that integrates IEEE 802.11p, LTE-V2X, and 5G-V2X, enabling adaptive switching between communication modes and improving packet delivery under dense traffic conditions. Similarly, **Zheng et al. (2015)** surveyed heterogeneous vehicular networking architectures, emphasizing the superiority of multi-radio approaches over single-technology deployments in terms of scalability and reliability.

Finally, several works and standards provide broader perspectives and regulatory baselines for VANET research. **Kenney (2011)** outlined the foundational development of DSRC and IEEE 802.11p standards in the U.S., discussing spectrum allocation and deployment challenges. In Europe, *ETSI standards* such as TS 103 324 and TS 102 941 defined cooperative awareness messaging and security frameworks, while *3GPP specifications* such as TS 36.213 addressed LTE and 5G-based vehicular communication. These standards establish the latency, reliability, and security benchmarks for academic and industrial systems. Broader reviews such as **Shladover (2012)**, who provided an overview of connected and automated vehicle systems,

Mahajan et al. (2020), who surveyed vehicular cloud computing, and **Amadeo et al. (2016)**, who proposed information-centric networking for cooperative vehicular applications, collectively underscore both the technological opportunities and challenges in developing scalable, safe, and interoperable vehicular networks.

SIGNIFICANCE

The existing body of literature shows that although simulation platforms, edge-based artificial intelligence, and advanced networking strategies have each contributed significantly to the development of vehicular ad hoc networks (VANETs), these dimensions have largely been studied in isolation. A notable research gap remains in the full integration of these technologies within a unified co-simulation framework. The present study is significant because it directly addresses this gap by proposing a network-optimized, edge-enhanced, and AI-driven co-simulation model. Such integration not only enhances the realism and accuracy of testing environments but also strengthens the practical readiness of next-generation intelligent transportation systems for large-scale deployment.

4 RESEARCH METHODOLOGY

This study adopts a **simulation-based experimental approach** designed to integrate vehicle dynamics, edge intelligence, and communication protocols within a unified framework. The proposed system combines the CARLA simulator, which provides realistic traffic and mobility environments, with OMNeT++, which models the networking layer. This co-simulation ensures that vehicle behavior and communication processes are evaluated in a synchronized manner.

At the perception layer, a lightweight YOLOv8-Nano model is trained and optimized for deployment on edge-based platforms, enabling real-time object detection under limited computational resources. To enhance collaborative awareness, transformer

architectures are employed for V2X data fusion, allowing vehicles to share and interpret sensor information more effectively in dense and occluded traffic conditions.

For the communication layer, adaptive multi-network strategies are implemented, integrating IEEE 802.11p, LTE-V2X, and 5G-V2X protocols. These configurations are modeled within OMNeT++ to assess reliability, latency, and packet delivery performance under varying traffic loads.

FUTURE DIRECTIONS

- **Hardware Acceleration** (FPGAs/ASICs) for ultra-low latency.
- **5G slicing** for QoS differentiation in safety-critical applications.
- **Multi-Agent Reinforcement Learning** for adaptive collision avoidance.
- **Field Testing:** in controlled environments beyond simulation.
- **Scalability Analysis** for ultra-dense scenarios (>100 vehicles/km²).