# Evaluation of Traffic Accident Detection by Simulating and Modeling the Vehicle Network Using SUMO and OMNeT++ Simulators

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***Abstract*—This paper presents a solution to the problem of increasing the total number of vehicles that lead to accidents on roads. Vehicular Ad-hoc Networks (VANET) have been developed in the infrastructure. This study suggests using VANET networks to communicate with vehicles, Roadside Units (RSU), and network servers. The proposed method properly simulates VANET by executing the fundamental parameters of IEEE 802.11p based on maps of the framework (Veins) inside OMNET++ and SUMO simulators to implement and simulate the strategy of planning traffic of vehicle routes. The suggested technique's primary advantage is enabling vehicles to communicate with each other or communicate across the infrastructure to send and receive various types of warning and information messages. Two significant contributions are made in this paper: an environmental contribution by lowering pollution levels in the air by decreasing $CO_2$ emissions from vehicles and reducing road congestion, as well as a technological contribution to simulate the planning traffic of vehicle routes. Our technology is capable of monitoring air pollution and architecture simulation tested on highways and in a scenario of emergency braking. Each vehicle may request the shortest route by sending a packet request to the network server and awaiting a response that includes a new path. The primary performance parameter indicator refers to the exchange of data in wireless communication for vehicles such as speed and acceleration at different times of simulation. The vehicles' speed, acceleration, $CO_2$ emission, and total lost packets at RSU were analyzed when changing the length of the path in each scenario. In the simulation, 100 vehicles were used to travel on a lane with a speed of 14 km/h on a 3,400-meter-long highway in a network size of (3000 × 3000) m. Simulation results were obtained with a travel time of 300 seconds for 100 vehicles, the total lost packets at RSU were 61, and the total $CO_2$ emissions were 3,1548 gm/miles. The advantages of simulation results are providing safer roads for vehicles to prevent accidents, enhancing wireless infrastructure, and lowering pollution levels.**

***Keywords*—vehicular communication, Roadside Units (RSU), veins, OMNeT++ Simulators, Vehicular Ad-hoc Networks (VANET), SUMO, $CO_2$ emissions, prevent accidents, congestion control**

## I. INTRODUCTION

VANETs, short for Vehicle Ad-hoc Networks, are primarily used to facilitate dynamic wireless vehicle communications [1]. VANETs involve Vehicle-to-Roadside (V2R) or Vehicle-to-Vehicle (V2V) short-range wireless communication, and are considered a branch of Mobile Ad-Hoc Networks (MANET). Vehicles equipped with the necessary hardware and software, positioned between 100 and 900 meters apart from each other, use wireless technologies like IEEE802.11p to create a VANET network. In this network, vehicles can self-organize, function as network routers, and communicate wirelessly [2].

VANET properties have distinct qualities such as the placement and movement of vehicles, the type of communication technology used, the distributed architecture, and broadcasting in all directions [3–5]. Important cases have been simulated to develop traffic as a simulation of larger cities to monitor traffic signals, vehicle paths, and road information, in addition to simulating safe speeds for vehicles, the gap between leading vehicles, drivers' reactions, and estimating safe velocities [6]. Factors such as position, speed, road slopes, and the weight of the vehicle during driving impact the amount of energy consumed. It is necessary to utilize technology for wireless communication, such as VANET, to ensure safety for short distances between two vehicles (V2V) using the standard IEEE 802.11p. Additionally, exchanging messages and sharing data with autonomous vehicles (V2V) and infrastructure (RSU) is important [7, 8]. VANETs are considered a promising technology to enhance road safety, reduce traffic congestion, and address issues with driving errors, especially at roundabouts and highway intersections [9]. Multi-layer protocols IEEE 802.11p and IEEE 1609.x have been utilized as traffic simulators for the metro transportation network. Intelligent transportation systems have shown the ability to reduce traffic collisions and provide passengers with valuable road information. The IEEE 802.11P protocol includes a

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Physical and MAC layer to establish a WAVE standard used as a wireless vehicle standard [10–12]. The system presents multiple challenges in exchanging information about vehicles, such as speed, position, and acceleration in potential collision paths. However, driving at close distances reduces air resistance and fuel consumption. Sharing data with other vehicles using Inter-Vehicle Communication (IVC) improves the efficient use of road infrastructure and enhances safety [13–15]. Both industry and academia have shown a strong interest in Vehicular Ad Hoc Networks (VANETs) to manage traffic and enhance roadway safety. VANETs consist of two types of nodes: On-Board Units (OBUs) and Road Side Units (RSUs) for vehicles [16]. According to the National Highway Traffic Safety Administration (NHTSA), nearly 30,000 individuals die in vehicle accidents in the United States each year. Utilizing communicated vehicles helps alleviate driving issues [17]. Numerous studies have shown that 60 percent of highway accidents could be prevented if drivers receive warning messages just seconds before a collision, thanks to the benefits of VANET networks: low latency due to wireless direct communication, low power consumption, wide area coverage, and no service fees. Veins is a toolbox and model library in the OMNET++ program used to simulate communication between vehicles on the road for the VANET Network. A summary of the vein stack for PHY and MAC layers in the IEEE 802.11p standard is presented in Fig. 1 [18].

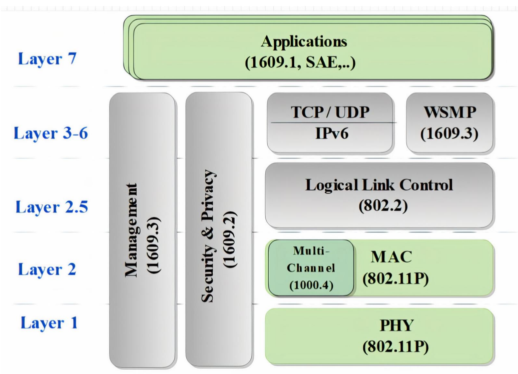



Fig. 1. The stack used by IEEE and veins is represented by [16].

VANET utilizes vehicles as sensors and routers to collect and relay data, creating a network that distributes and disseminates data [19]. The 75 MHz frequency from the 5.9 GHz spectrum will be available for Vehicle-To-Vehicle (V2V) communication in the VANET through wireless access and specialized short-range communications for the vehicular environment [20]. Technologies have been developed to transfer data between automobiles and infrastructure using WiFi, WiMAX, and 3G cellular telephony networks [21]. VANET is unique compared to other networks such as Mobile Ad Hoc Networks (MANET) and Wireless Sensor Networks (WSN) due to vehicle mobility being crucial for data transfer, requiring a specific mobility model to determine vehicle movement. In this case, V2I refers to a hybrid architecture/network, consisting of roadside sensors and high-density cars [22]. The researchers working on VANET used a road simulator called SUMO and a network simulator called OMNET++. Veins, which is a free and open-source network, is one of the VANET applications used to simulate vehicular networks [23].

The application of SUMO (Simulation of Urban Mobility) provides tools for urban mobility simulation. It includes a simulator for multimodal road traffic and various applications for setting simulation of input data (such as importing and modifying networks, importing traffic, and routing) to analyze the simulation outputs [24].

The rest of the paper is structured as follows: Section II presents the literature that was reviewed. Section III provides details on the simulation methodology of the network and explains the simulation experiments. Section IV presents the findings of the experiments, along with the debates that followed and an analysis of the simulation results. Finally, Section V contains a discussion of the conclusions.

## II. Literature Review

In 2013, Akhtar *et al.* [25] created applications for safety in Vehicular Ad-Hoc Networks (VANETs), which requires an understanding of network topology dynamics to optimize routing protocol performance. They utilized the Performance Measurement System (PeMS) database to generate realistic highway traffic flows using data from four different Californian freeways. Data from 419 sensors on the highways was collected during high traffic density at 18:00 and low traffic density at 01:00. Their findings showed that in low traffic density situations, the error rate was less than 5%, while in high traffic density situations, the error rate was less than 12% for 80% of the speed and flow values.

In 2016, Ronan Doolan and Gabriel-Miro Muntean [26] introduced the EcoTrec algorithm to reduce $CO_2$ emissions per vehicle-mile-traveled and improve environmental impact during travel. They developed a model to calculate fuel efficiency based on road conditions, traffic information, and congestion times. By implementing a VANET-based routing system that considers traffic and road conditions, they were able to achieve a 21% reduction in fuel consumption.

In 2016, Pacheco *et al.* [27] presented a framework for developing services for smart cars applications. They successfully conducted experimental results using ABA methodology to protect and secure the operations and data of the VIMP sensor.

In 2017, Chaczko *et al.* [28] emphasized the importance of detecting motorcycles at a distance of 20 meters around vehicle drivers. They utilized the Internet of Things infrastructure at the roadside, adopting the OMNET++ simulator and Internet Network Environment Toolkit (INET) framework to distinguish between users, register them upon entering the network, warn vehicle drivers of nearby motorbikes, and eliminate them from the database when they move to new clusters.

In 2018, Ibrahim *et al.* [29] focused on designing a system for wireless communication between vehicles using the features of the 802.11p standard, traffic characteristics, and control algorithms. They conducted simulations using Matlab, NS-3, and SUMO frameworks. The SUMO simulation revealed lost packets of up to 50% and an average delay of 20.15 ms in receiving packets. Results also showed that the acceleration ratio fluctuated between 1 and −1m/s2 over a 40 second simulation period, while vehicle speeds increased from zero to 80 km/h during the same time frame.

In 2018, Vahidia and Sciarrettab [30] highlighted the potential for connected cars to save energy through advanced sensors and V2X connectivity. This could improve the flow of mixed traffic, resulting in energy savings for nearby cars, increased comfort, time savings, and enhanced safety while driving.

In 2019, Silgu *et al.* [31] conducted a hypothetical test of two networks with varying degrees of complexity using Eclipse SUMO simulation to determine the optimal CACC penetration rate in urban roads.

In 2019, Upadhyaya and Shah [32] demonstrated the use of communicated mobility nodes with a network structure in VANET. They collected data from RSU via communicated vehicles such as V2V and V2I using AODV routing to select the best path. They analyzed results using simulators like NS2, MOVE, and SUMO, considering parameters such as Throughput, Average End-to-End Delay, Jitter, Packet Drop Rate, and Routing Load.

In 2019, Haidari and Yetgin [33] showed how vehicles exchanged information with nearby infrastructure or other vehicles using standard protocols. They utilized the Veins simulation urban technology in the OMNET++ simulator to offer new classifications in areas such as security, safety, traffic management, routing, and comfort.

In 2020, Ramli and Rawi [34] proposed several methods to reduce traffic congestion using RSU with SUMO simulation in VANET. They highlighted the potential of VANET dynamics to implement various solutions in its architecture for traffic congestion detection.

In 2020, Um [35] created a roadway environment by combining the SUMO traffic simulator and Veins framework in experiments with wireless communication in VANET. They successfully analyzed the effectiveness of categorizing Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication in a Roadside Unit (RSU) within a simulation network.

In 2020, Bhatia *et al.* [36] used OSM, SUMO, and MOVE as primary tools to create road layouts and traffic flow. They displayed vehicle movement through an experiment procedure consisting of two steps: manual generation using node, edge, and route with OSM assistance, and road mapping and traffic flow creation for Delhi area using the SUMO tool.

In 2021, Seraj *et al.* [37] utilized communicated vehicles technology to achieve broadcast coverage with a 360-degree reach of 300 meters. Messages were transmitted and received via the VANET network using OMNET++ simulation. They observed that the SNIR decreases with increasing traffic due to interference, impacting delay.

In 2021, Aljabry and Al-Suhail [38] conducted a study comparing the performance of GPSR and AODV protocols in VANET using OMNET++ and SUMO simulation programs. They analyzed Packet Drop Ratio, Throughput, Packet Delivery Ratio, and End-to-End Delay to assess QoS while varying communication range, speed, and the number of vehicles.

In 2022, Khaoula and Balkis [39] combined OMNET++ network simulation with SUMO 0.25.0 traffic simulation in the VEINS 4.4 open framework to achieve realistic simulation outcomes. They also utilized the PREXT open project to create and develop novel schemas with current security diagrams.

In 2023, AL-Shareeda and Manickam [40] conducted a study on Vehicles in Network Simulation (VEINS) focusing on security concerns in modern technology such as SDN, blockchain, and machine learning in Vehicular Ad-hoc Network (VANET). They emphasized achieving authentication, privacy, reliability, and trust management to address technology solutions, vulnerabilities, security requirements, and threats.

## III. Simulation Methodology of Network

### *A. Environment for Simulation*

A variety of environmental simulations were used to assess the performance of strategy planning. The VANET (Vehicle Ad Hoc Network) simulation environment was presented using a combination of OMNET++ (5.6.2), SUMO (1.8.0), and Veins (5.1) versions.

**OMNET++:** OMNET++ is a simulation program that offers a robust GUI, used for network simulators to carry out VANET protocols. Different simulation models can be integrated into OMNET++ for unique tasks, creating a trace file that includes all relevant data about the scenario situation.

**SUMO (Simulation of Urban Mobility):** SUMO is an open-source simulator used to accurately simulate traffic. SUMO is used to select various tasks in VANET such as vehicle types, the road network, and creating paths for vehicles. SUMO has the advantage of permitting bidirectional communication with any simulator in the network, enabling the traffic simulator's results to influence the network simulator and vice versa.

**Veins (Vehicles in Network Simulation):** The veins simulation framework's main advantage is supporting bidirectional coupling between road traffic simulations and network simulations.

### *B. Simulation Environment Analysis*

The simulation was executed by the OMNET++ network simulator interacting with a traffic simulator for the roads by SUMO and implementing an open-source simulation of the vehicular network by Veins. The OMNET++ simulator executes VANET protocols such as the IEEE 802.11p protocol to assess and analyze the generated information in the OMNET++ file regarding the scenario.

SUMO uses vehicle models to accurately simulate each vehicle's rate of acceleration and deceleration. The amount of traffic can be managed by creating routes within a specific time. Running the network after setting up the

SUMO configuration file creates a road map and flow of traffic movement.

The majority of network traffic in a VANET consists of broadcast transmissions. The performance of the IEEE 802.11p protocol can be gauged depending on how well its broadcast messages are received.

VANET uses the IEEE 802.11p standard that enables V2V communications in the line of sight over short distances of up to 150 meters. Veins employed two kinds of communications: vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) across RSU (Road-Side Unit) as shown in Fig. 2.

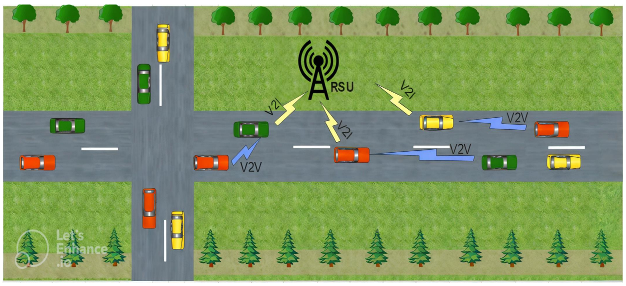



Fig. 2. Show communications between vehicles (V2V) and vehicles to infrastructure (V2I) via RSU.

### C. Simulation Scenario

The simulator used transmitted power 18 mW for vehicles to enable communication with a range of up to 3,400 m. The network performance is affected by the number and location of RSUs, the number of vehicles as well as the bitrate and size of broadcast messages. Table I display the parameters of the simulation used in the network.

TABLE I. PARAMETERS OF THE SIMULATION NETWORK

| Parameter | Value |
|---|---|
| Simulation time | 300 sec |
| Payload length | 100 byte |
| Time of Traffic jam start | 112 sec |
| Time of Traffic jam duration | 6 sec |
| Rsu site in the network | (2500 × 2500) m |
| Network size | (3000 × 3000) m |
| Power transmitted of msg | 18 mw |
| Bit rate of msg | 6 Mbps |

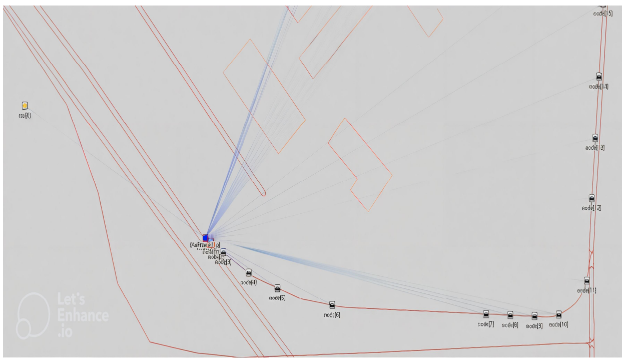


Fig. 3. SUMO simulation depicting 100 vehicles and one RSU placed along a 3400m path.

The scenario consists of a 3,400-meter-long highway with multiple secondary lanes designated for one-way traffic, and 100 vehicles are utilized to travel on these lanes. The speed limit for the vehicles in these lanes is 14 km/h. Six scenarios were conducted at various time intervals (50, 100, 150, 200, 250, 300 seconds) to ensure the accuracy of the results obtained. Figs. 3 and 4 illustrates a SUMO simulation where 100 vehicles are simulated to flow through the traffic, with randomly generated journey paths. An RSU is positioned at a fixed location in a (2500×2500) m area to facilitate communication between the vehicles and the infrastructure.

Fig. 4. More vehicles flowed and spread on the 3400-metre path.

The Veins Framework created a model that simulated real vehicles. Each vehicle broadcasts messages with a payload of 100 bytes.

Thirteen vehicles join the simulation at 2-second intervals and accelerate until they reach the required speed of 14 km/h at 8 seconds. The speed of the vehicles then stabilizes at 14 km/h after another ten seconds.

At 40 seconds into the simulation, the first vehicle begins sending broadcast information messages to the RSU and then to the 5 vehicles close to it within a 2-second time period. We tested the vehicles' behavior, and they respond to the controller's commands promptly, with slight delays during acceleration and deceleration. At 44 seconds, vehicle number 5 began rebroadcasting messages to far vehicles on the RSU, causing a 35-second delay. Another group of vehicles gradually entered at 70 seconds, bringing the total to 33 vehicles by 102 seconds into the simulation. This led to a traffic jam and a slowdown in vehicle movement at time 112 seconds of the simulation time.

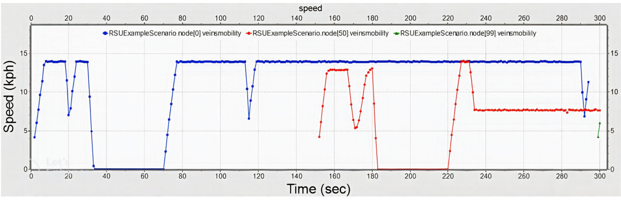
After exchanging data between vehicles and between vehicles and the RSU, the RSU requested some vehicles withdraw to take less crowded paths, allowing other vehicles to pass. Another group of vehicles entered until the total reached 100 vehicles, taking various paths up to 300 seconds, ending the simulation after the first vehicle traveled 3,400 meters.

## IV. SIMULATION RESULTS ANALYSIS

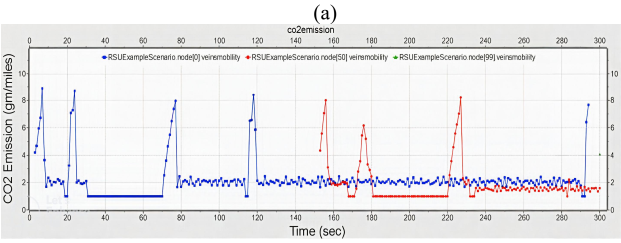
Simulation results are presented in this section to analyze essential metrics such as speed, $CO_2$ emissions, and acceleration of vehicles in relation to travel time when changing the length of the path in each scenario. An increase in travel time results in an increase in the number of vehicles. The outcomes of our proposed approach are compared with varying numbers of vehicles.

The findings show that an increase in the number of vehicles to 100 has a significant impact on network performance, causing delays in data transfer between vehicles and RSU. However, the condition of road segments does not affect travel time significantly, as each road segment's travel time remains relatively constant even with more vehicles.

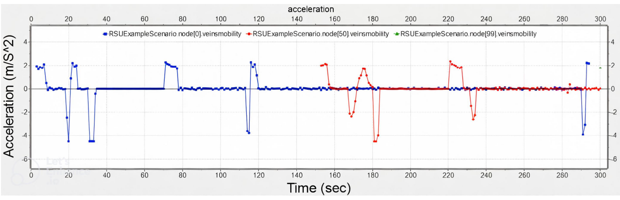
Fig. 5 illustrates the test results of the scenario, showing acceleration, vehicle speed, and $CO_2$ emissions as functions of time. Fig. 5a displays the speed profiles of vehicles at different times. Thanks to the design of the RSU controller, each vehicle can accurately follow RSU instructions by adjusting its speed and acceleration.




(a)




(b)




(c)

Fig. 5. Different parameters profiles of vehicles at travel time. (a) Speed profiles of vehicles, (b) Total $CO_2$ emissions of vehicles, and (c) acceleration profiles of vehicles.

TABLE II. RESULTS OF SIMULATION FOR DIFFERENT SIMULATION TIMES

| Simulation time (sec) | 50 | 100 | 150 | 200 | 250 | 300 |
|---|---|---|---|---|---|---|
| Number of vehicles | 17 | 34 | 50 | 67 | 84 | 100 |
| Longest path (m) | 365 | 830 | 1,413 | 2,110 | 2,807 | 3,400 |
| Total lost packet at RSU | 13 | 15 | 25 | 36 | 48 | 61 |
| Total $CO_2$ emission | 1115 | 3,760 | 8,184 | 14,298 | 22,070 | 31,548 |

Figs. 5a and 5b illustrate the dynamics of the simulation in terms of path length, speed, and acceleration. It is worth noting that as the simulation progresses, vehicles exhibit varying dynamics. For example, Vehicle (0) follows a longer path, while Vehicle (50) reaches its destination more quickly due to the simulation ending sooner.

In Fig. 5b, accelerations and decelerations occur abruptly and with oscillation. Fig. 5c shows the total $CO_2$ emissions of the vehicles. This simulation demonstrates the effectiveness of implementing simulations for driving and controlling vehicles on roads, which can assist researchers in conducting realistic and reliable analyses of such systems.

Table II shows the control at different simulation times and path lengths for various numbers of vehicles.

## V. CONCLUSION

In this article, a simulation environment has been utilized for traffic simulations on roads. The network integrates SUMO to simulate traffic flow and OMNET++ as the network simulator, along with the Veins framework. Wireless technologies for communication have been implemented in mobile vehicles in the VANET field to achieve successful communication between V2V (vehicle to vehicle) and V2I (vehicle to infrastructure).

VANET has achieved numerous benefits, including spreading traffic information, reducing vehicle accidents, alleviating traffic congestion, and decreasing fuel usage and $CO_2$ emissions. Based on the results, the IEEE 802.11p protocol allows for V2V communications in the network. According to our findings, performance measures are influenced by the distance between vehicles and RSU, as well as the size of broadcast messages. The broadcast messages transmitted from RSU provide information on alerts for collision risks, awareness notifications to prevent accidents, speed limits for vehicles on the road, and the average time it takes for messages to reach vehicles. In the near future, it is expected that advancements in wireless communication will enhance efficiency and road traffic safety, facilitate high-speed data transfer, expand geographical coverage, and support QoS.

## CONFLICT OF INTEREST

The authors declare no conflict of interest

## AUTHOR CONTRIBUTIONS

Authors contributed to enhancing this work as follows: Dr. Mohammad oversaw the entire study project, wrote the first draft of the manuscript, formatted and proofread the completed manuscript, and oversaw the journal's contact and submission procedure. Amina carried out the main research and experiments, gathered and analyzed information, helped with interpreting the results, and assisted with editing and drafting the manuscript. Fawaz provided knowledge and direction, conducted statistical analysis, checked for significant content in the manuscript, made revisions, and communication among team members. All authors had approved the final version.

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