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Senior Design Project

on

V2X Communication for Enhanced Vehicular Safety

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CERTIFICATE

This is to certify that project entitled **"V2X Communication for Enhanced Vehicular Safety"** is a bonafide work carried out by the student team of **"Samit Patil - 01FE22BEC410 , Pavan Shivalli - 01FE22BEC411 , Sarvesh K - 01FE22BEC412 , Nitin Savvase - 01FE22BEC413 , Mahamadshiraj B - 01FE22BEC432"**. The project report has been approved as it satisfies the requirements with respect to the senior design project prescribed by the university curriculum for BE (VII Semester) in School of Electronics and Communication Engineering of KLE Technological University for the academic year 2024-2025.

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-The project team

ABSTRACT

A simulation model for inter-vehicle communication is presented in this research with the goal of improving traffic control and road safety during collisions. The model mimics data transfers between vehicles using OMNET++ and SUMO, allowing for the real-time identification and notification of traffic accidents. The framework makes use of "VEINS" to seamlessly integrate traffic and network modeling, enabling efficient data packet transfers for both routine and urgent messages. Dedicated Short-Range Communication (DSRC) with a 300-meter range and optimized power transfer at 9mW, which increases energy efficiency, are two important aspects. The framework achieves high-speed data transfer by using the UDP protocol, which is necessary for prompt response in accident situations. The findings show that vehicles can communicate reliably with one another, which could speed up emergency responses and lessen traffic interruptions caused by accidents.The model can be modified to accommodate different traffic situations and allows for the addition of more safety beacons. This model may be expanded in the future to support practical Intelligent Transportation Systems (ITS) applications.

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Chapter 1

Introduction

Road safety and effective traffic management are becoming more and more important issues in the quickly expanding transportation environment of today. Particularly on national and state highways, the growth in vehicles worldwide has resulted in higher tra ffic densities and a higher danger of accidents. According to statistics, these highways account for a sizable percentage of traffic accidents, which result in significant numbers of fatalities and injuries. Control rooms and manual emergency warnings are examples of traditional accident management techniques that are frequently ineffective for managing large-scale occurrences or guaranteeing prompt response times in emergency scenarios.

Intelligent Transportation Systems (ITS) are being made possible by inter-vehicle communication (IVC), which is a game-changing technology for real-time data transmission between cars in order to address these problems. Vehicles can exchange information about events, position, and speed thanks to vehicle-to-vehicle (V2V) communication, which enables prompt notifications and reaction in the event of a collision. This feature is especially crucial as transportation transitions to autonomous and semi-autonomous systems, where quick information exchange can greatly lower collision rates and enhance traffic flow.

In this research, we offer a framework for inter-vehicle communication that uses OMNET++ and SUMO simulators to detect accidents in real time. To provide realistic traffic and communication scenarios, this model uses the VEINS framework to link the network simulation tool OMNET++ with the traffic simulation tool SUMO. Our solution guarantees dependable, low-power communication for effective accident detection and response by utilizing dedicated short-range communication (DSRC) within a 300-meter radius. Furthermore, the UDP protocol maximizes data transfer speed, guaranteeing prompt accident notifications and inter-vehicle communication.

In addition to aiding in the creation of dependable V2V communication systems, this research offers suggestions for improving them for efficient traffic control and accident response. The literature study, simulation approach, results analysis, and possible future developments of the suggested framework will all be covered in detail in the parts that follow.

1.1 Motivation

The inter-vehicle communication framework, which uses real-time data sharing to improve traffic management and road safety, is motivated by the following:

1. Increasing Traffic Accidents: Due to heavy traffic and a lack of real-time accident response systems, a considerable number of fatalities and injuries happen on highways.

2. Limitations of Conventional Systems: For large-scale occurrences, traditional accident management techniques like centralized control rooms and manual emergency warnings are frequently inefficient and slow.

3. Real-time communication between vehicles is essential for improving situational awareness and speeding up reaction times in emergency situations.

4. Development of Autonomous Vehicles: To maintain safety and maximize traffic flow, the shift to autonomous and semi-autonomous transportation necessitates dependable inter-vehicle communication.

5. Potential of Vehicle-to-Vehicle (V2V) Communication: By allowing cars to instantly exchange vital information like position, speed, and incident warnings, V2V communication has the potential to completely transform road safety.

1.2 Objectives

The following are the goals of this study, which aims to create an efficient system of inter-vehicle communication for better traffic management and real-time accident detection:

1. Design and Implement a Real-Time Accident Detection System: Create a framework that uses OMNET++, SUMO, and the VEINS framework to model real-time accident detection and response via inter-vehicle communication in order to design and implement a real-time accident detection system.

2. Incorporate Dedicated Short-Range Communication (DSRC): Provide dependable, low-latency communication within a 300-meter radius to enable timely alerts and emergency vehicle coordination.

3. Utilize UDP Protocol for Efficient Data Transfer: Use UDP Protocol for Efficient Data Transfer: Make use of the UDP protocol to maximize data transfer speeds and guarantee that vital information, such vehicle status updates and accident alarms, is sent on time.

4. Assess System Performance: Examine how well the system detects collisions, reduces communication lag, and maintains reliable traffic control in a range of simulation scenarios.

5. Suggest Improvements for Traffic Safety and Management: Offer analysis and suggestions for upcoming advancements to raise the dependability, scalability, and effectiveness of V2V communication systems for traffic control and accident detection.

1.3 Literature survey

The following are the main conclusions of the literature review, which provide a summary of the body of knowledge about intelligent transportation systems (ITS) and inter-vehicle communication (IVC) for traffic control and accident detection:

Despite DSRC's usefulness, security remains a top worry because errors could allow for unauthorized access and data manipulation, putting traffic safety at risk. Although Wolf et al. recommended employing cryptographic approaches to enhance vehicle-to-vehicle communication security, researchers like Vershinin et al. pointed out that DSRC was susceptible to hacking. Yuan et al. stressed the need of reducing delivery delays for safety messages in their analysis of IEEE 802.11p, especially in high-speed settings. While Gaurav and John developed the LIMERIC algorithm to optimize data flow and prevent delays in threat warnings in response to network congestion, Bittl et al. and Lyamin et al. provided solutions for GPS spoofing and jamming attack detection, respectively, to ensure the reliability of V2V communications.[6] This corpus of work highlights the importance of secure, real-time communication in V2V systems. In order to provide a simulation framework that supports safer and more reliable intelligent transportation systems by enhancing traffic efficiency and enabling real-time accident detection, our research expands on previous studies by merging OMNET++ with SUMO.[6]

The study [5] looks at the challenges and advancements in modeling Vehicle-to-Everything (V2X) communication in a 5G environment, with a focus on New Radio V2X (NR-V2X). There are numerous categories within the literature on V2X simulation. OMNeT++ has gained popularity as a platform for creating V2X scenarios due to its extensible features, such as INET, Simu5G, and Veins. Simulating complex network scenarios, such as smart parking, vehicle platooning, and emergency message distribution, is made simpler by these technologies. In previous studies, OMNeT++ has been used to simulate 4G and 5G V2X use cases, often in contrast to other simulators like ns-3. Moreover, recent advancements in 5G NR subcarrier configurations and their impact on delay, as well as attempts to include Multi-Access Edge Computing (MEC) and other state-of-the-art technologies into V2X modeling frameworks, are notable. This study presents a comprehensive NR-V2X modeling framework using OMNeT++, which contributes to the field by assessing a VoIP uplink application in two scenarios, Lumsden and NRCar, each with different network and environmental parameters. This approach can be expanded upon in future studies on 5G-V2X communication and the application of AI/ML models to increase network efficiency and reliability.[5]

The paper [3] talks about the limitations of the current AV simulation settings, particularly in relation to naturalistic driving behavior and modular testing of AV subsystems. A framework called CARLA-SUMO-Gym makes advantage of already-existing simulators like SUMO and CARLA to replicate complicated environments in a realistic manner. It creates traffic using SUMO and produces high-fidelity sensor output using CARLA. A comprehensive evaluation of AV performance is made possible by this connection, which allows the planning, control, and AV perception modules to be tested independently. The CARLA-SUMO-Gym framework covers a number of scenarios, including urban and highway environments, and allows AV developers to test object detection in a range of circumstances, including different illumination conditions. Benchmark experiments that employ deep neural network-based object detectors demonstrate the importance of sensor fusion for dependable AV perception and demonstrate how detection performance changes significantly with visibility. The authors conclude that CARLA-SUMO-Gym offers comprehensive AV testing in a realistic, adaptable, and easily accessible simulation environment, with the possibility of future revisions to include more sensors and situations.[3]

A decentralized Frequency Division Multiple Access (dFDMA) architecture tailored for Dedicated Short Range Communications (DSRC) is proposed in the IEEE 802.11p standard. This approach tackles the challenge of operating simultaneously on many frequency channels in a decentralized, self-organizing vehicular ad hoc network (VANET). The authors outline a number of significant challenges, including the need for reliable safety message reception and efficient use of scarce spectrum without a lot of equipment. The dFDMA technique uses a control channel for critical safety messages, while other channels provide a range of vehicle applications. Flexible channel selection and periodic synchronization are made possible by the "exchange" and "arbitrary transmission" phases of frequency usage. This phased approach allows a single transceiver to periodically monitor the control channel, resulting in efficient frequency usage. The method is a promising choice for DSRC deployments in the future since it can boost throughput while ensuring reliable safety message transmission, according to simulation data.[4]

The shortcomings of conventional techniques like rule-based and signature-based detection, which frequently suffer with high false alarm rates and adaptability to developing threats, have been addressed by intrusion detection systems (IDS), which have been the subject of much study in an effort to improve network security. Machine learning methods, such as supervised, unsupervised, and hybrid approaches, have been widely used to improve performance. Significant gains in accuracy and flexibility have been shown by algorithms like Decision Trees, Random Forests, Support Vector Machines (SVM), K-Means clustering, and Neural Networks. Decision trees are renowned for their ease of use and effectiveness, whereas neural networks are more accurate but require more processing power. IDS models have often been evaluated using benchmark datasets such as KDD Cup 99, NSL-KDD, and UNSW-NB15, which provide a variety of attack scenarios for thorough testing. But issues like managing data imbalance, reducing false positives, and guaranteeing real-time detection still call for more research and development.[7]

1.4 Problem statement

Highway traffic density growth has resulted in more collisions and fatalities, and conventional management methods are not able to respond quickly enough. Traffic control and accident prevention are further hampered by ineffective real-time vehicle communication. In order to improve road safety and traffic management, this project attempts to create a strong foundation for inter-vehicle communication for real-time accident detection and response.

1.5 Application in Societal Context

The following are the societal uses of the suggested inter-vehicle communication system, which seeks to enhance traffic control and road safety by detecting and responding to accidents in real time:

1. Road Safety: By drastically cutting down on reaction times, real-time accident detection and communication can lower the number of fatalities and injuries that occur on highways.
2. Better Emergency Services: Emergency responders can arrive at incident locations faster thanks to quicker accident alerts, increasing survival rates and lowering the number of subsequent accidents.
3. Traffic Congestion Management: Vehicles can be rerouted to ease traffic flow and reduce congestion with the use of timely reports on road events.
4. Support for Autonomous cars: By guaranteeing dependable vehicle-to-vehicle communication, the framework lays the groundwork for a safer integration of autonomous and semi-autonomous cars.
5. Reduction of Economic Losses: The system helps to reduce the financial consequences of accidents, including as lost productivity and medical bills, by preventing collisions and reducing traffic delays.
6. Environmental Benefits: Sustainable practices are promoted by smoother traffic flow, which lowers emissions and fuel consumption.

Chapter 2

Simulator Design and Execution

This section explains how different simulators operate and perform, as well as how they combine to create a simulation model for vehicle communication.

2.1 Functional Block Diagram

A block diagram of the general approach used to create a simulation model using all the different simulators is displayed in Fig. 2.1.

1) Input: The output is a simulation model that enables communication between vehicles, while the input is a network scenario including roads, cars, and other relevant components.

2) SUMO (Traffic Simulator): The files for the nodes, edges, and types that make up a traffic network's structure are created using SUMO. Realistic traffic simulations are produced by combining the network file with route files. To control traffic behavior on the chosen map, an SUMO configuration file is made. Maps made by hand or downloaded from OpenStreetMap (OSM) can serve as the basis for traffic production. Following SUMO's integration with OMNeT++, automobiles (nodes) in the network start interacting with one another as they travel across several lanes at different speeds.

Figure 2.1: Traffic running on a manually generated map in SUMO.

3) OMNET++ (Network Simulator): Network simulations can be created and executed using the C++-based simulation library OMNeT++. OMNeT++ loads the VEINS and INET frameworks for vehicular communication. Protocol, channel, and network environment models that are necessary for simulation are provided by the INET framework. The NED language is used in OMNeT++ projects to specify the network topology. Vehicles can communicate with each other more easily thanks to the simulation environment's capability for event-driven message handling.

4) VEINS (VANET Simulator): VEINS simulates vehicle networks by combining OMNeT++ and SUMO. Because SUMO-created maps are synchronized with OMNeT++, cars may follow realistic traffic patterns. Vehicles can communicate vital information like position and speed thanks to VEINS. The technology also facilitates event-driven communication for accident prevention notifications, which notify cars to take the necessary precautions to stay clear of possible dangers.

5) Output: Relay signals are successfully sent between cars in the simulation, allowing position and speed information to be shared. Alerts for accident prevention are produced to make sure cars react appropriately to possible road dangers. Road safety and traffic management are improved by this real-time communication paradigm.

2.2 Algorithm

Algorithm presents the design methodology's step-by-step process.

Algorithm for V2X Communication
Input: Network Scenario (Including Roads and vehicles as nodes)
Output: Signal transfer between nodes for related communication

- Start the simulation
- Check the vehicle start moving on their paths
If Vehicles in set range **then**
- Check
If Accident detected **then**
- Send accident signals
- Alerting the vehicles and send relay signals
- Indicating positioning and speed of each vehicle
Else If Signaled vehicles very near (preset range) then
- Stop the vehicles behind the scene
Else
- Instruct vehicles to change the lane or take U-turn
End
Else
- Send relay signals
End
Else
- Send no signals (No communication)
End

2.3 Parameters

Table I displays the parameters that were utilized to create the network simulation model for V2X communication.

Parameters used	**Value**
Network Simulator	OMNET++ 6.0.2
Mobility/Traffic Simulator	SUMO 1.14.1
Veins Vanet Simulator	VEIN 5.2
Transmission protocol	UDP
Radio bandwidth	10MHz
Operating Mode	802.11p
Mapping	Manual
Transmitter power	20mW
Frequency	5.9GHz
Bandwidth	20MHz
Data Rate	6-27 Mbps

Table 2.1: Parameters for V2X communication simulation

2.4 Types of Data Transmission

The pace at which the cars travel on the track affects the data that is sent back and forth between them. Firstly, these consist of:

1) Inter Vehicle Communication (IVC) : Data transmission between vehicles is established using Inter Vehicle Communication (IVC). Data can be transmitted in two ways.

- Single Hop IVC (SIVC) : In this scenario, data is executed by merely moving it from one location to another. For any other point transmission, there is no more transmission feasible. SIVC, where data is sent from a specific node to just one node, as seen in Fig. 1.
- Multi-hop IVC (MIVC) : Data is sent to the final node via a number of intermediate nodes in a multi-hop IVC (MIVC) scenario. In MIVC, as depicted in Fig. 2, data is sent to the end node via a number of intermediate nodes, with Veh4 sending data to Veh1 via Veh2 and Veh3.

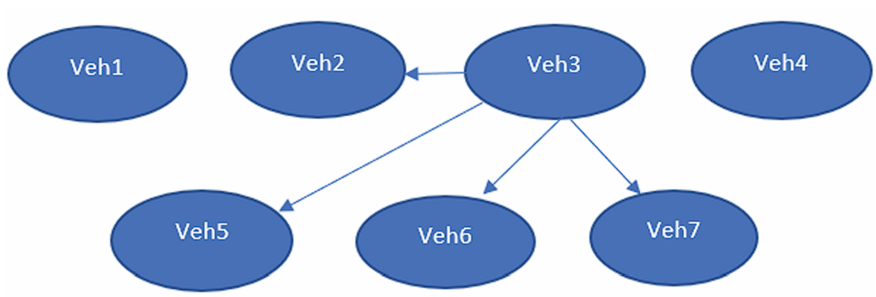

Figure 2.2: Single-hop transmission.

2) Roadside Vehicle Communication (RVC) : Refers to the communication system set up with roadside units (RSUs) in conjunction with roadside infrastructure. Here is a discussion of the several RVC approaches.

- Communication at busy locations, such as parking lots and traffic light control, is part of the sparse RVC.
- All communications pertaining to roadside data are included in the omnipresent RVC. This makes the algorithm extremely sluggish.
- Hybrid vehicle communication broadens the communication range and incorporates elements of both IVC and RVC.

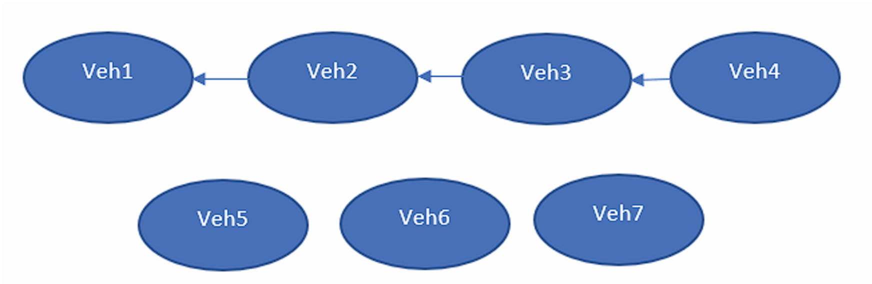

Figure 2.3: Multi-hop transmission.

Chapter 3

Simulation Results and Analysis

Following the simulation, we can calculate the number of successfully transmitted and received packets using the packet data provided by the OMNET++ simulator. Additionally, we can forecast if signals are transferred correctly and whether the algorithm has been executed correctly based on data and graphical depictions. Figure 3.1 illustrates how packet data is sent to various nodes following the detection of the accident. Until every range node is covered, various events signify transmission to various nodes. As can be seen from the simulation's visualization and packet data, the nodes initially sent the relay signal to the cars, telling them of their position, speed, and other details.However, if a node was involved in a collision, the car alerted the other nodes with a crash signal before taking further action.

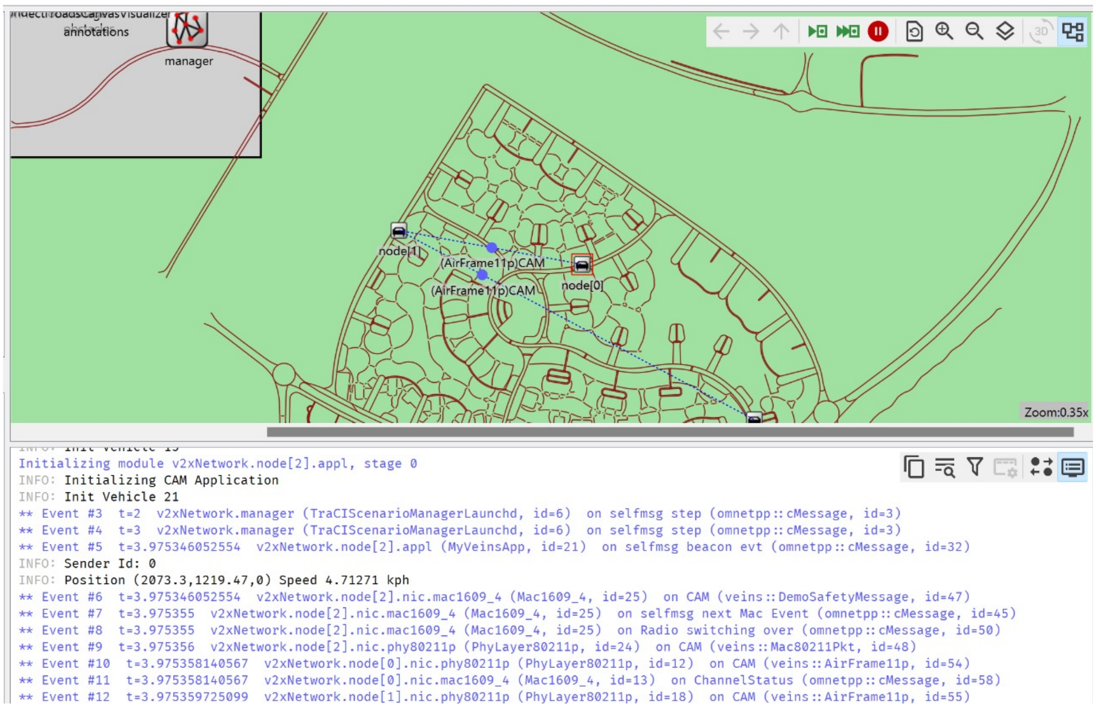

Figure 3.1: Simulation model created in OMNET++ with a merged manual map generated in SUMO.

This picture shows a simulation of V2X communication utilizing the OMNeT++, SUMO, and VEINS frameworks. Vehicles (node[0], node[1], and node[2]) are moving over a predetermined road network in the network map displayed on the top panel. Cooperative Awareness Messages (CAM), which include vital information such vehicle position and speed, are represented by the blue dotted lines.

The simulation log displays several system events in the bottom panel. After initializing the CAM program for node[2], other vehicles begin receiving safety messages. The record contains information about event triggers, vehicle position (e.g., 2073.3, 1219.47, 0)), and speed (4.71271 kph). The constant exchange of information between nodes is shown by events such as message transmissions, MAC layer operations, and physical layer activities.

In order to effectively control traffic flow and prevent accidents, this configuration emphasizes real-time communication between cars, enabling situational awareness.

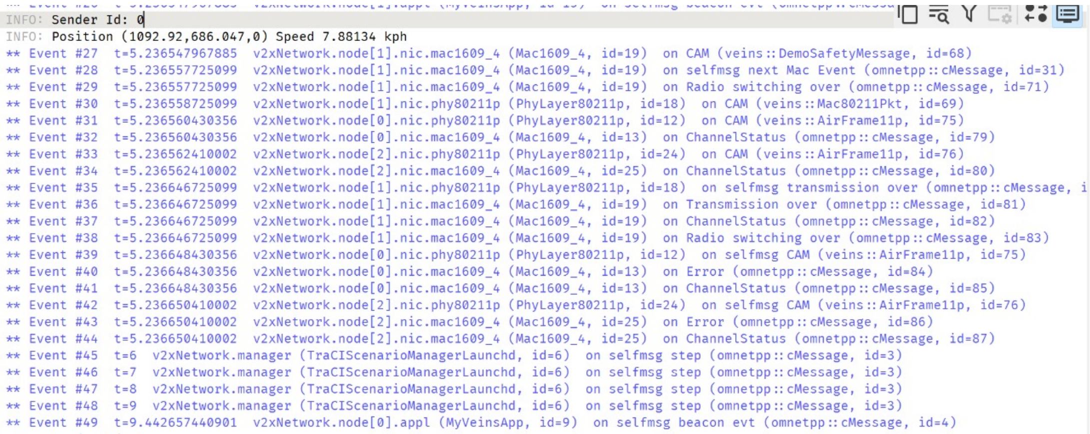

Figure 3.2: Packet results obtained from network simulator for different events.

The outcome of a V2X communication simulation using OMNeT++ combined with VEINS and SUMO is shown in this log. The vehicle's unique identification, with a position of (1092.92, 686.047, 0) and a speed of 7.88134 kph, is indicated by the Sender Id: 0. The log then shows a series of events that describe the activities of nodes (vehicles) in the network and are arranged by timestamp.

Cooperative Awareness Messages (CAM) are processed by each node, including v2xNetwork.node[0], v2xNetwork.node[1], and v2xNetwork.node[2], via their network interface cards (mac16094 for MAC layer and phy80211p for physical layer communication). Vehicles can exchange real-time position and speed information thanks to these communications. At certain periods, things like channel status updates, radio switching, and message broadcasts are recorded. Errors during communication, such as those at nodes 0 and 2, suggest possible interference or transmission collisions.

By carrying out recurring simulation steps (selfmsg step), the TraCIScenarioManager makes sure that the OMNeT++ network simulator and the SUMO traffic simulator are in sync. Lastly, beacon processing on node[0] and other application-level events verify that vehicles are correctly exchanging messages for V2X communication. In order to help traffic management and accident prevention, this procedure guarantees data sharing for vehicle positions and speeds.

Chapter 4

Conclusions and future scope

The proposed project will result in communications advancements that will open up significant prospects in the global transportation industry. The simulation model that was created explains how wireless communication standards are used to transfer data between cars. In automobile communications, the IEEE 802.11p vehicle standard is effectively utilized for wireless connectivity. OMNET++, SUMO, and Veins are a few of the simulators that are useful for creating simulation models for wireless vehicle communication. According to the simulation results, there is appropriate data exchange between the accident cars' nodes in traffic accidents. With prompt rescue efforts, it can help with appropriate traffic management to lower accident rates. The established model can be modified in the future to meet the needs of the activities that need to be conducted in response to various situations. It is possible to add different beacons to work with different models. Additionally, messages can be issued to emergency vehicles and RSUs to inform the vehicles and clear the lanes so that the victim can receive prompt assistance and traffic can be appropriately managed.This model may be expanded in the future to support practical Intelligent Transportation Systems (ITS) applications.

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