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REAL-TIME V2V COMMUNICATION: REVOLUTIONIZING TRAFFIC SAFETY AND EFFICIENCY

Kushagra Duggar[*1], Sahil Mahajan[*2], Ridham Joshi[*3], Sakshi Shisodiya[*4], Prof. Arti Bhise[*5]

[*1,2,3,4,5]Department Of Computer Engineering, Smt. Kashibai Navale College Of Engineering, Pune, India.

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ABSTRACT

This project relates to the development of a Vehicle-to-Vehicle (V2V) communication system which relies on simulation tools such as SUMO and NS-3 in realizing the realistic modeling of the traffic and the communication system. Adaptive protocols adjust the communication according to real-time traffic conditions, optimizing bandwidth and minimizing latency. The system, therefore, offers a real-time data processing capacity that allows fast analysis and decision-making support emphasizing safety, alerts like collision warnings, and hazard warnings. Along with this, machine learning algorithms predict traffic congestion to enhance situational awareness and improve the ability to counter the challenges of V2V by making roads safer, reducing traffic congestion, and fueling sustainable efficient traffic flows toward the future of connected vehicle technology. The basic design of the study, results of your analysis and brief summary of your interpretations and conclusion

Keywords: Vehicle-to-Vehicle (V2V) Communication, Intelligent Transport System (ITS), Real-Time Data Processing, Traffic Safety, Collaborative Data Sharing, Safety Alerts.

I. INTRODUCTION

The rapid advancement in vehicular technology as well as the mushrooming population in urban centers increase the problem of traffic management, road safety, and driving efficiency of the roads. Vehicle-to-Vehicle Communication appears to be a key to allowing vehicles to share real-time data about its location, speed, and movement. This eventually represents Intelligent Transportation Systems (ITS) where interconnected vehicles would enhance road safety and optimize traffic flows. The project looks towards a Vehicular Ad-hoc Network architecture in which all vehicles are separate, independent nodes that can both share and process information with each other in direct and indirect ways through Roadside Units. The structure of VANET enables the key information to be communicated from time to time among the vehicles so that potential collisions can be avoided, warning signals can be prompted on time, and changes can be made according to real-time traffic conditions so as to avoid the mishap possibilities while making road transportation more efficient.

The project uses advanced simulation tools in the following: SUMO simulates the movement of vehicles in a realistic way, while NS-3 is what simulates wireless communication channels. TraCI represents a common platform between SUMO and NS-3 connecting all the data that can be exchanged by both systems in a real-life representation of interactions between vehicles. Furthermore, adaptive Communication Protocols help make communication with reduced latency optimize message delivery depending on current traffic dynamics.

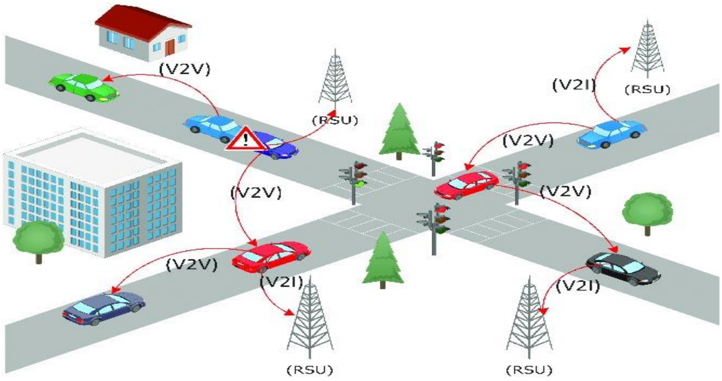

Fig.1 V2V Communication

This V2V system, over the long term, would find an integration with the edge computing system to process real-time data and take decisions in real time, thereby responding to safety alerts quickly. A machine learning algorithm for predictive analysis would identify numerous patterns and associated hazards in traffic, thus making problems fairly easy to foresee, which, in turn, would push vehicle connectivity toward truly intelligent and autonomous road networks. The project contributes to building a safer, efficient, and resilient transportation ecosystem through alleviation of urban mobility challenges.

II. METHODOLOGY

1. Problem Statement:

- Objective: Design and test a V2V networking system where automobiles can, in real time, share information ranging from each other's speed and position to emergency messages that will improve road safety, reduce traffic congestion, and make driving safer.
- Key challenges:
  - Reliable datagram transmission under heavy dynamic conditions of the vehicular world.
  - Packets must reach destinations in near real-time so that time-sensitive information is conveyed.
  - Routing algorithms must adapt to constantly changing topologies due to the movement of the nodes or automobiles.

2. Selection of Technology and Tools:

- Simulation Software:
  - SUMO (Simulation of Urban Mobility): To model the mobility of vehicles and real-world traffic scenarios.
  - NS-3 (Network Simulator 3): This utility can be utilized for simulating the V2V communication between vehicles.
- Protocols:
  - IEEE 802.11p (WAVE): This is a standard protocol for vehicular communication.
  - Routing Protocols: Choose a routing protocol according to choice, such as AODV or GPSR, to send the message between the vehicles.

3. System Design and Architecture:

- Vehicle Node Creation:

Configure several nodes in NS-3. Each node will consist of a wireless communication device, 802.11p for the protocol. On NS-3, integrate SUMO. This enables real time mobility data regarding the vehicles to be generated and fed into the network simulation.

- Configuring the Communication:

Define the structure of the message including the vehicle ID, speed, position, and emergency alerts. The transmission and reception of the message will be based on UDP or TCP.

- Choose the Routing Protocol:

Implement a routing protocol such as AODV or GPSR dynamically that discovers routes to transmit data packets among the vehicles by considering the location and mobility of vehicles

4. Data Exchange and Simulation Setup:

- Message Transfer:

The cars will broadcast and request status info location, speed, warnings, etc to neighboring vehicles at regular intervals Simulation the wireless exchange of data over the 802.11p protocol using the NS-3 network stack

- Emergency Response:

Implement a priority-based strategy where a high-priority message, such as collision warnings, is sent with a minimal amount of delay using priority queues or TCP PSH flag.

- Mobility Scenarios:

Study various traffic scenarios with SUMO, such as cities, highways, and intersections, where vehicles move at a distance and with different speeds.

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- Logging and Tracing:

Use PCAP in NS-3 to record the communication data that will be analysed post-simulation.

5. Performance Evaluation:

- Metrics:

Packet Delivery Ratio: Number of messages delivered successfully

Latency: The time taken between the transmission and reception.

Throughput: Amount of data the protocol can successfully send in a particular interval of time.

Congestion and Collision Control: The extent to which the protocol handles network congestion and avoids data collisions.

- Test Scenarios:

Test under low-traffic vs. high-traffic areas and various speeds of moving vehicles. Test the system's support for high-priority emergency messages, to determine how fast those messages are being delivered.

6. Results and Analysis:

Analyze the obtained metrics like PDR, latency, etc.

Compare the routing protocols and message-handling techniques against different traffic conditions.

Additional help in showing where the message is actually being transmitted well or where packet loss happens would be furnished by tools for displaying protocol traces, such as Wireshark to understand the flow with PCAP or trace files in NS-3. This would allow the identification of transmission time intervals, delays and communication flow disruptions which are bound to fine-tune the performance of VANET.

- **Algorithm**

1. Initialize: Set up vehicle nodes with On-Board Units (OBUs) and Roadside Units (RSUs) along the route.
2. Start Simulation: Use SUMO to simulate vehicle movement (speed, position, direction). Data Exchange:
3. V2V Communication: Vehicles exchange real-time data (speed, location) using the 802.11p protocol.
4. V2I Communication: Vehicles interact with RSUs for extended range and additional information.
5. Sync Mobility with Network: TraCI transfers simulated vehicle data to NS-3 for network simulation.
6. Simulate Communication: NS-3 handles message exchange, logs data, and tracks metrics.
7. Analyze Results: Evaluate packet delivery, latency, and resource efficiency.

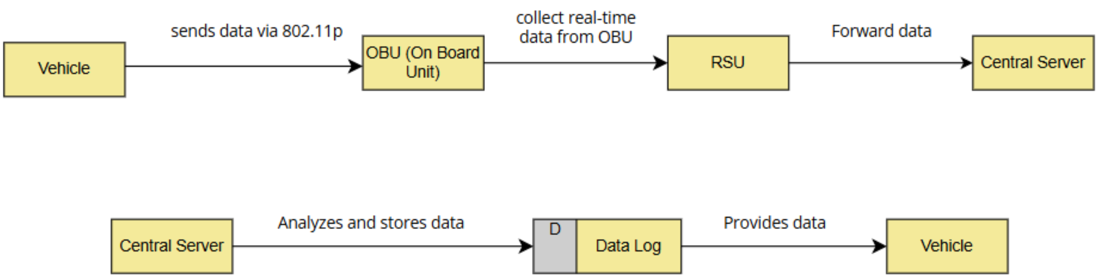

Fig 4: Data Flow Diagram

III. VANET ARCHITECTURE

In VANET, moving vehicles are considered to act as separate nodes having **On-Board Units**. These **OBUs** are installed in every moving vehicle for real-time communication. So, they can communicate with each other by exchanging messages relating to speed and location. Some roadside units called Fixed Roadside Units are installed along the roads for an extended communication range and for involving **Vehicle-to-Infrastructure (V2I)** interfaces that are used for critical traffic information.

The **802.11p protocol**, named Wireless Access in Vehicular Environments (WAVE), enables short-range communication between vehicles (V2V) and between vehicles and infrastructure (V2I). It is reliable for data transfer to ensure safety and management of traffic. We utilize the **Simulation of Urban Mobility** to create a realistic simulation of vehicle mobility, which produces very significant movement data including velocity and direction.

TraCI: It interfaces SUMO to the NS-3 network simulator. Synchronize vehicle position data by real-time communication simulation. NS-3: This simulates wireless communication based on the 802.11p protocol and it logs all the communication data after the simulation, which is necessary for such evaluation as checking the efficiency of communication, a distinction in traffic patterns, and enhancement of the total system in operation.

- **Vehicles as Nodes**: Cars act as independent network nodes with On-Board Units (OBUs), allowing them to send/receive data.
- **Roadside Units (RSUs)**: Fixed devices help extend communication beyond cars, enabling V2V and V2I communication.
- **802.11p Wireless Protocol**: Enables fast, wireless communication between vehicles and infrastructure.
- **SUMO**: Simulates vehicle movement.
- **TraCI**: Synchronizes vehicle positions in real-time.
- **NS-3**: Simulates wireless data exchange between vehicles.
- **Data Logging**: Tracks communication for analysis and improvement.

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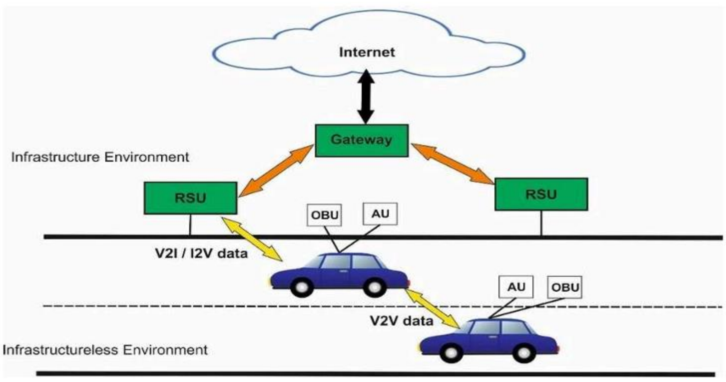

Fig.2 Vanet Architecture

V. CONCLUSION

A key step forward in developing the robust Vehicle-to-Vehicle communication system is advancement of development towards enhancing road safety and maximizing efficiency in traffic movement in modern cities. The modeling of vehicle mobility and communication dynamics using advanced tools such as SUMO and NS-3 efficiently leads to real assessments of various V2V interactions. By combining adaptive communication protocols with the core strength of edge computing - real-time data processing, it ensures timely exchange and decision-making concerning information. Beyond this, the use of machine learning in predictive analytics along with prioritized sending of alerts of dangers ensures proactive responding of vehicles to potential threats and, hence, hugely reduces risks of accidents. Overall, this project shapes the future of Intelligent Transportation Systems and paves the way for the connected vehicle. It addresses several challenging issues in traffic management and safety to create a foundation for smarter, sustainable solutions that impact urban commuting. More research and developments on V2V communication must be made and expanded to realize the maximum benefits of connected vehicle technology toward safer roads and more efficient routes.

In the given project, we analyzed architecture and communication protocols present in VANETs with regards to how V2V communications and V2I communications might be exploited for safety in roads, efficient traffic management, and resource use. In order to demonstrate the same in action, we connected vehicle mobility simulations with SUMO and linked it to the NS-3 network simulator using the TraCI interface. The output was an illustration of real-time data exchange, possibly critically necessary for effective measures of traffic control as well as related accident risks.

The 802.11p protocol provided short-range communication, thus allowing the vehicles to exchange safety-critical information within some milliseconds. The results show the implications of roadside unit placement on extending the range of communications, meaning much more reliable delivery of messages and packet delivery ratio. This project also showed the benefits of more advanced methods, such as the estimation of congestion using machine learning models and blockchain integration with trust management. It helped to further enhance data security.

The test disclosed promising outcomes and areas where VANET technology can be optimized. The limitations found were problems of scalability and high demands in processing. Future enhancement may include the imposition of more robust AI-driven solutions, the more integration of blockchain to strengthen security, and lead to the achievement of highly efficient and safe communication over the internet of things by setting it up with intelligent transportation systems.

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