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ENHANCING TRAFFIC SAFETY THROUGH INTERNET OF VEHICLES (IOV): A COMPARATIVE ANALYSIS OF EMERGENCY NOTIFICATION TECHNIQUES AND FUTURE DIRECTIONS

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ABSTRACT

The surge in population growth contributes to an increased number of vehicles on the roads, posing challenges to effective traffic management. Despite traffic regulations and governing bodies, controlling drivers' behavior—such as speeding, driving under the influence, and committing traffic violations—remains a complex task. These challenges exacerbate traffic congestion and fatalities, leading to significant time delays. The Internet of Vehicles (IoV) presents a promising solution by enabling a connected and controlled vehicular environment. However, the application of IoV introduces many options, encompassing both safety and non-safety-related features. This article presents a comprehensive study, offering a valuable model for distributing emergency messages within a network. This aligns with existing research efforts and reflects current trends in research to address challenges. In addition to studies and obstacles in the ongoing evolution of this research, the paper delves into the selection of optimal study domains by focusing on performance metrics and scenarios with different vehicle sizes.

KEYWORDS: Emergency Message Dissemination, IoV, Analysis, Sustainable Transportation.

1. INTRODUCTION

Advancements in transportation have significantly transformed human mobility, leading to increased vehicle density and related challenges. With the increase in the number of vehicles and speed, there is a drastic increase in the number of road accidents John and Shaiba (2022). According to the WHO (World Health Organisation) fact sheet, approximately 1.3 million people die every year due to road accidents across the world. The primary victims of deaths and disabilities are those aged 5-29 years. It significantly impacts the gross domestic product of many countries, resulting in a reduction of approximately 3% https://www.who.int/news-room/fact-sheets/ detail/road-traffic-injuries. The leading causes of road fatalities encompass poor road conditions, distracted driving, speeding, driver fatigue, multitasking while using a phone, pedestrian negligence, as well as the influence of alcohol and drugs. However, the other miscellaneous contributors include vehicular design defects, accidents due to weather conditions, technical defects, and poor bag quality John and Shaiba (2022); Kaur et al.; Gupta et al. (2024).

The rapid development in the automobile industry is a preventive measure to fix these issues. The collaboration of communication systems and automobiles develops different safety applications for prior road safety information. This helps the drivers to react accordingly, and supports a reduction in fuel consumption Manasa et al. (2024).

The other crucial factor is the mobility pattern of nodes. The frequent topology change and dispersion impose challenges in IoV. Mobility depends on the speed, direction, neighboring vehicles, and zone of relevance while communicating the emergency message. In earlier studies, Vehicle-to-vehicle (V2V) communication has been used, which leads to hidden terminal problems, network overhead, and broadcast storm problems Manasa et al. (2024). Using V2V communication for safety message dissemination will alert the nearby vehicle, but the link breakage leads to security, reliability, and scalability issues. In addition, it is unable to provide maximum coverage. Flooding is the solution that provides maximum coverage, but with high network overhead and bandwidth wastage.

Public road safety is a pressing concern with active research in this domain. This paper aims to provide a comprehensive framework for emergency message dissemination in IoVs, addressing the following research questions.Harnal et al. (2022) to **answer the following research questions**

1. What are the effective strategies for regulating drivers' behaviors, such as speeding, drunk driving, and disobeying traffic regulations, to mitigate road accidents?
2. How does the IoV contribute to improving traffic management and reducing road fatalities?
3. What challenges and limitations exist in the dissemination of emergency messages within the IoV, and what potential solutions can be implemented?
4. What are the emerging research topics and directions in IoVs for enhancing road safety and traffic management?

1.1. Organization

This research study consists of five sections. The related work for quality publications is in Section 2. In addition, the insights from literature, mobility analysis, and simulator comparisons are discussed in Section 3, wherein the key considerations for designing algorithms are provided in Section 4. Finally, Section 6 envisioned the conclusion and the future directions, respectively.

2. RELATED WORK

In 1999, Klaus Eitzenberger proposed the vehicle communications system and methods to attain safety, traffic control, dynamic navigation aids, and the mobile office. According to Scopus, since 2004, the research community has been working on emergency message dissemination in IoVs. Emergency message dissemination involves consideration of security threats, routing protocols, and both infrastructure-based and infrastructure-less communication architectures.

In Shankar et al. (2022), the authors proposed a modified spider algorithm for efficient message dissemination. The researchers proposed a social probabilistic scheme based on efficient sampling and thus provided a routing framework for probabilistic contacts. However, Kaur et al. (2021) stated that for the timely dissemination of emergency messages, clustering techniques play a key role in IoVs. Soni et al. (2021) investigated that V2I communication is more secure and proposed a lightweight protocol to achieve high-performance results. They concluded that this clustering method is cost-effective and less time-consuming. Moreover, Quy et al. (2021) suggested three main approaches that include the usage of internet services, cloud or intelligent, and multi-metric design for communication. They concluded that the multi-metric approach consumed high energy, whereas the issue of frequent disconnections is more prominent on internet/UAV/cloud services than on IoVs. They finally provided research directions in IoVs with blockchain, and edge computing is the future of IoVs for emergency message dissemination. Another article Kaur et al. (2024a) claimed that infrastructure is necessary for information coverage and provides the best route for fast delivery of messages in highway scenarios.

While numerous studies have explored various approaches to emergency message dissemination, there is a notable lack of direct comparison among these methods. For instance, while clustering techniques, as discussed in Azam et al. (2021), have shown promise in enhancing message delivery efficiency by reducing congestion during high vehicle density scenarios, their performance does not universally surpass traditional flooding methods. Flooding can achieve greater reach in less dense environments but may suffer from significant overhead and latency, particularly with increased traffic. Similarly, V2I communication presents its advantages in terms of security and infrastructure reliance, as outlined in Kaur et al. (2024b). However, it can be hampered by latency issues associated with the infrastructure setup and maintenance. Therefore, it is essential to critically evaluate these methods not only in isolation but also in comparative scenarios to determine the most effective strategies for specific use cases in emergency messaging. Such an analysis will provide a clearer understanding of the trade-offs involved and guide future research directions.

In Table 1 one-line summary of 8 articles studied that worked on the broadcast schemes, routing protocols, warning messages, hybrid beaconing technique, and clustering approach for emergency message dissemination.

Table 1: One-Line Summary of 8 Articles for Emergency Message Dissemination.

Ref	Summary	Publication Venue	Citations
Sheikh et al. (2019)	Summarization of security attacks with comprehensive applications.	Sensors	217
Azam et al. (2021)	Taxonomy for authentication schemes in IoVs	IEEE Access	127
Ghazi et al. (2020)	Scenario-based discussion is provided	IEEE Access	93
Khan et al. (2021)	Critical analyses of location privacy	Future Internet	65
Farooq et al. (2015)	Review of multi-cast geo cast & cluster-based routing protocols	International Journal of Distributed Sensor Networks	62

2.1. Paper Contribution and Scope of the Survey

Public safety is an alarming issue; therefore, the research community majorly produced major solutions for emergency message dissemination, including techniques like flooding, route definition, clustering Li et al. (2022), predictions Kaur et al. (2022), link connectivity based, game theory Manasa et al. (2024), and recommendation systems Awan et al. (2020). However, despite various approaches, no single algorithm provides optimal performance across all scenarios. Consequently, this paper aims to fill the gaps by providing a detailed analysis of the emergency message dissemination landscape within IoVs, emphasizing the following contributions:

1. This research specifically identifies and addresses the shortcomings i current literature regarding emergency message dissemination. For instance, the issues related to routing inefficiencies in dynamic environments, particularly those caused by high vehicle mobility and network topology changes. By analyzing existing methods and their limitations, a new framework that enhances the efficiency of message dissemination is presented, particularly in high-density scenarios Li et al. (2022); Zhang et al. (2022).
2. Guidelines to build a novel hybrid algorithm that combines clustering techniques with real-time data analysis to adapt to rapidly changing traffic patterns. This leads to a reduction in EED and increased communication reliability John and Shaiba (2022); Kaur et al. (2021).

2.2. Literature Review Methodology

This section involves a systematic literature review on emergency message dissemination in IoV.

- **Databases Identified:** The prominent academic databases are selected for a comprehensive search, such as Scopus, Google Scholar, and IEEE Xplore, to consider a wide array of literature.
- **Selection Criteria:** The following are the key

points that are relevant to structuring the review article.

a) Emergency message dissemination in IoV articles is considered.
b) Survey, empirical studies, and reviews are published in peer-reviewed journals.
c) Articles published in English.

- **Exclusion Criteria:** The following are the criteria for the survey were applied to exclude articles:

a) Studies not directly related to emergency message dissemination or IoV.
b) Articles lacking empirical data or those that were opinion pieces or editorials.

- **Search Query and Time Frame**: We employed the following search query on November 20, 2024, to identify relevant articles within the time frame of 2004 to 2024:

a) (TITLE-ABS-KEY (emergency AND message AND dissemination AND in AND Internet of Vehicles) OR TITLE-ABS-KEY (safety AND message AND in AND IOV) OR TITLE-ABS-KEY (emergency AND message AND dissemination AND in AND IOV AND ad-hoc AND networks) OR TITLE-ABS-KEY (safety AND message AND in AND IOV) OR TITLE-ABS-KEY (emergency AND message AND dissemination AND in AND IOV) OR TITLE-ABS-KEY (safety AND message AND in AND IOV) OR TITLE-ABS-KEY (safety AND message AND in AND IOVs) OR TITLE-ABS-KEY (emergency AND message AND dissemination AND in AND IOVs)).

This comprehensive search yielded 2,246 documents, which were subsequently cleansed to ensure relevance.

- **Final Article Selection:** After thorough screening and applying the above criteria, a total of 46 articles were retained for review. These articles provided significant insights into topics such as routing protocols, security issues, and clustering approaches in the context of emergency message dissemination.

3. KEY FACTORS IN EMERGENCY MESSAGE ROUTING FOR IOVS: INSIGHTS FROM LITERATURE, MOBILITY ANALYSIS, AND SIMULATOR COMPARISONS

The safety message-based articles help to identify the key parameters to propose the algorithm for routing emergency messages. Therefore, this section is divided into three parts, namely, (1) Representative Keyword Oriented Articles on Emergency Message Dissemination in IoVs, (2) Analysis of Mobility Models and Traffic scenarios w.r.t. Vehicle Density, and (3) Comparative Analysis of Simulators Selected by Research Community.

3.1. Representative Keyword Oriented Articles on Emergency Message Dissemination in IoVs

From Fig. 1, the most used search keywords in the research domain can be divided into 4 parts Kaur et al. (2022) namely Internet of Vehicles, Issues and Comparisons, Securing and Emergency messages. This division has been made according to highly used keywords in the research articles. These keywords will be useful for the upcoming researchers who are selecting relevant articles.

In table 2, the summary of articles with specified keywords is discussed. Likewise, in Ma et al. (2011), the distributive cross-layer technique was designed. They claimed reliability by providing the mini slots, a busy tone for multi-frequency, and dynamic receiver-oriented packet repetitions. Furthermore, Rayeni et al. (2015) gave multi-hop broadcasting with high-reliability support to the density-based emergency messages.

However, using advanced ML in Li et al. (2022), the research group predicts the trajectory for vehicle density. Wherein Li et al. (2022) proposed a multi-hop warning message protocol through end-edge cloud architecture using machine learning, to predict future trajectories that decrease network overhead, and unnecessary interference.Abbas et al. (2022) selected mobility metrics to predict the route to deliver the emergency message using greedy forwarding. However, Sharma et al. (2022) published the importance of connectivity by defining a threshold mechanism to achieve maximum PDR and throughput with less delay. Moreover, in de Almeida et al. (2020), a comparison of two simulators, namely VEINS and NS3, with the IEEE 802.11p protocol in the IoV scenario is provided. The investigators depicted that both simulators were generating similar results and could reproduce the same behavior of IEEE 802.11p.

On the other hand, security is useful for protecting transmitted information in different applications to avoid attacks, interference, false information, induced traffic jams, and road congestion. In Yang et al. (2022), a novel scheme to achieve efficient conditional privacy. They guaranteed the privacypreserving aggregation authentication scheme best suited for a safety warning system. In Chen et al. (2022), a multi-signature scheme was developed that aggregates signatures sent to roadside units (RSUs), enabling onboard unit

(OBU) signatures to be derived through a minimal number of operations. Similarly, Zhang et al. (2022) introduced a fast verification scheme utilizing a common string for secure, privacy-preserving aggregated signatures. Additionally, Han et al. (2021) proposed a pair-free certificate-less aggregate signature for secure communication, though this method faces limitations from pseudo-individual signatures, which can disrupt the system. While aggregate signature schemes show promise in reducing data size and verification time in IoV environments, they suffer from significant computational overhead, posing challenges for resource-constrained devices like vehicles, especially in dense traffic where delays in message delivery can be critical.

Table 2: Summary of Research Articles with Keywords.

Ref	Summary	Keyword Count	Keywords
[19]	Predict vehicles' trajectories using advanced algorithms to enhance emergency messaging.	3	Vehicle trajectory, prediction, emergency messaging
[31]	Utilizes quotient filter and elliptical curve cryptography to address both security and efficiency in vehicular communications.	5	Security, authentication, cryptography, vehicular networks, emergency communication
[32]	Proposes a location privacy preserving scheme tailored for vehicular ad-hoc networks.	4	Privacy, vehicular networks, ad-hoc communications, security
[33]	Explores group communication techniques utilizing pseudonyms to ensure user privacy in IoV settings.	5	Security, privacy, IoV, group communication, authentication
[34]	Introduces a ring signature encryption technique focused on conditional privacy preservation in IoV.	4	Conditional privacy, encryption, IoV, security
[25]	Develop an optimized routing scheme incorporating reliability metrics and mobility-based strategies for effective emergency message dissemination.	4	Reliability, routing, optimization, emergency messaging
[26]	Analyze link stability and throughput to enhance emergency communications in vehicular networks.	5	Link stability, throughput, vehicular networks, emergency communication, reliability
[36]	Implements an LSTM-based intrusion detection system to enhance security measures in IoV.	4	Intrusion detection, deep learning, IoV, security

Figure 1: Mostly Used Keywords as per Domains.

In contrast, blockchain technology offers inherent security, transparency, and lower latency for message verification, making it a strong alternative as it ensures tamper-proof message recording and accountability. Compara-tive evaluations highlight that although aggregate signatures are bandwidth efficient, blockchain systems are better suited for the dynamic conditions of IoVs. Future research should focus on balancing computational efficiency with real-time performance for optimal security solutions in these environments. Additionally, Goudarzi et al. (2022) demonstrated the use of fog nodes and RSU fog nodes to enhance security while decreasing latency, employing a quotient filter for legitimate vehicle authentication and elliptical curve cryptography for message integrity.

3.2. Analysis of Mobility Models and Traffic Scenarios w.r.t Vehicle Density

Mobility is defined as the pattern of moving nodes possessing speed, direction, headway, location, and acceleration. The summary of mobility models to derive the traffic pattern is described in Table 3. In subsection 3.2.1, the relevance and limitations of the mobility model are discussed.

Table 3: Summary of Selected Mobility Models According to Traffic Scenarios and Vehicle Density.

Ref	Mobility Model	Traffic Scenario	Vehicle Density
Li et al. (2022)	Hybrid Markov Chain	City Scenario	600+net worked OBUs, 120+RSUs
Goudarzi et al. (2022)	Random Model	5kmx5km area	500 Vehicles
Guo et al. (2022)	Random Model	2500x2500 m^2	80
Abbas et al. (2022)	Krauss Car following Model	Highway Scenario (2-Lanes)	30-240
Sharma et al. (2022)	500 m Highway		Less, Moderate, More
Zhang et al. (2022)	Random model	1x1 km^2 road	50-300 vehicles
Yu et al. (2022)	Random model	3-Lane High	80000 Samples
Yang et al. (2022)	Random model	Road Scenario	20-200
Sharma and Jaekel (2021)	Random model	Urban Area	35-39 (low), 108(medium), 519(high)

3.2.1. Relevance and Limitations of Mobility Models for Emergency Message Dissemination

In this subsection, the relevance of the listed mobility models to emergency message dissemination is elaborated, with limitations to provide a comprehensive understanding of their applicability in IoV.

1. Hybrid Markov Chain Model: This model is effective in simulating urban scenarios where vehicle movements are influenced by various factors such as traffic signals and intersections. The unpredictable behavior of vehicles can be captured because of their probabilistic nature for emergency message dissemination. It also assesses the reliability and fast delivery of emergency messages in different traffic scenarios. Though, due to its rapid topology change, it cannot depict high-speed highway scenarios accurately.
2. Krauss Car-Following Model: For high-density scenarios, to provide real-time vehicle acceleration, this model plays a key role in emergency message dissemination. This includes lane changes or sudden stops; however, scalability in dense traffic scenarios is a concern. In addition, the increase in the number of vehicles leads to an increase in computational complexity and performance issues. Therefore, its applicability is restricted in emergency road scenarios due to high mobile nodes on the road and have complex road pattern.
3. Random Mobility Model: In this mobility model, vehicles move randomly in the zone of relevance. The random topology change of the mobile node has a limited baseline structure movement and evaluate effective emergency message communication.

3.3. Comparative Analysis of Simulators Selected by Research Community

Table 4: Network and Traffic Simulators for Emergency Message Dissemination.

Ref	Network Simulator	Traffic Simulator
Sharma and Jaekel (2021)	Veins	LuST
Han et al. (2021)	C/C++	NA
Li et al. (2022); Yu et al. (2022); Guo et al. (2022)	OMNET++	SUMO
Goudarzi et al. (2022)	OMNET++	NA
Abbas et al. (2022)	NS2.34	MOVE, SUMO
Sharma et al. (2022)	NetSim, MATLAB	SUMO
de Almeida et al. (2020)	NS-3, VEINS	SUMO
Zhang et al. (2022)	NS2	IoVMobiSim
Yang et al. (2022)	NS3	IoVMobiSim

Mobility-generated simulators are used to trace vehicles on the road. The mobile nodes on the road can be captured using different hardware, such as cameras, magnetic card readers, and RSUs. However, it is expensive to have all the hardware, thus various application softwareś available to calculate the vehicle density. Different network and traffic simulators are showcased in table 4. Google Earth Kaur and Khurana (2015) or Open Street Map (OSM) Kaur et al. (2016) are used in the simulator to provide a realistic environment. These maps are used to generate the traffic scenario through the roads of the city, highways, freeways, and intersection points Kaur et al. (2022). In contrast with Google Earth, an OSM is another way of generating interactive online maps with zooming ability. OSM is used for extracting roads in the .osm file format, which can be used to generate node and edge files using the net convert command, i.e.

netconvert − osm − files < filename.osm > − − o < filename.net.xml >

Furthermore, the configuration file is used to define the mobility metrics of the selected road scenario. polyconvert –net-file <filename.net.xml> –osm-files –type-file typemap.xml –o <filename.poly.xml>

Table 4 presents a comparison of various network and traffic simulators widely used in research for emergency message dissemination, including NS3, OMNET++, SUMO, and LuST. While these tools share core functionalities, significant differences exist in their capabilities that warrant a more critical evaluation.

Traffic Simulation Preferences: SUMO vs. LuST: SUMO (Simulation of Urban MObility) is often preferred over LuST (Lattice-based Urban Traffic Simulator) for several reasons associated with its comprehensive features and adaptability. SUMO provides a highly detailed and versatile environment for the simulation of urban traffic conditions, with ease of integration of various automobile classes, road configurations, and traffic flow patterns. Furthermore, with its strong integration capabilities with other simulation environments, such as OMNET++, it enhances its performance in simulations that require network communication and vehicle dynamics.

On the other hand, while LuST is great at simulating large traffic networks using its lattice-based approach, it perhaps won't be able to simulate the same level of complexity and realism in urban environments as is being provided by SUMO. Moreover, SUMO's ability to model real-time traffic realistically coupled with its popularity among researchers makes it extremely fit for use on emergency-related applications, where careful traffic behavior modeling is a must.

Handling Real-Time Emergency Scenarios: Both SUMO and OMNET++ are specifically designed to handle real-time emergency simulation efficiently. SUMO's real-time capability allows researchers to simulate dynamic changes in traffic flow and to automatically adjust vehicle behavior, which is crucial in handling emergency cases such as accidents or road obstruction. SUMO also facilitates functionalities in creating traffic light control, managing multi-modal transport interactions, and simulating emergency response methods.

OMNET++, however, has strengths in network simulations with complete protocols and frameworks for vehicle-to-vehicle and vehicle-toinfrastructure communication. OMNET++ is also extensible, which enables researchers to model complex emergency message dissemination algorithms for different scenarios and hence suitable for emergency communication research on IoV scenarios.

In conclusion, the choice between the use of SUMO and LuST depends on the requirements of the simulation environment. SUMO is widely used because of its detailed and versatile model of traffic within urban environments. OMNET++, on the other hand, is invaluable because of its robust communication system, both of which are required in the evaluation of the efficiency of plans for the transmission of emergency messages.

4. INDUSTRY EXPECTATIONS AND KEY CONSIDERATIONS FOR DESIGNING EMERGENCY MESSAGE DISSEMINATION ALGORITHMS

Effective and timely dissemination of emergency messages is a crucial factor. Adoption of time-efficient algorithms in light of real-time operation under industry standards is crucial. It is therefore crucial to keep the following factors in mind while designing the emergency message release algorithm.

- **Mobility Models** Mobility model includes a set of features Ren et al. (2017). The models are used to generate realistic traffic data and help decide the traffic context. It is essential to know the traffic context to design an algorithm for emergency message spreading.
- **Mobile Node** A mobile node refers to any vehicle that possesses communication capabilities and can interact with other vehicles and RSUs Gill et al. (2024).
- **RSU** An RSU is a stationary communication point that enables V2I connectivity, supporting information dissemination in the IoV.Gupta et al. (2024).

- **Communication** For message passing, communication is necessary. This communication happens in the form of message packets or beacons that help to identify the active network Gupta et al. (2024).
- **Transmission Range (TR)** The TR is the range that defines the limit to the mobile node for their communication Gill et al. (2024).
- **Clustering** Clustering is the method of grouping nodes for efficient communication. In IoV applications, clustering techniques such as KMeans or hierarchical clustering facilitate localized communication, reducing network congestion and enhancing the reliability of emergency message dissemination. The use of clustering also aligns with industry efforts to implement V2V communication systems, which can dynamically form clusters based on vehicle proximity and traffic conditions to optimize message delivery Li et al. (2024).
- **Cluster Head (CH)** It is the leader of the group of nodes Manasa et al. (2024).
- **Cluster Members (CM**) The nodes associated or directly linked with the CH are termed as CM Yu et al. (2022).
- **Routing** Routing is the essential step to forward the emergency message. In the context of the IoV, effective routing protocols such as Dedicated Short-Range Communications (DSRC) and Cellular Vehicle-toEverything (C-V2X) are industry standards. These protocols enable vehicles to share critical information in real-time, thereby ensuring timely communication during emergencies. For example, the DSRC standard facilitates fast and reliable message passing between vehicles and infrastructure, which is paramount for emergencies. Kaur et al. (2022).
- **Length of vehicle** The length of the vehicle plays a key role in predicting the traffic density ρ. If L is the length of the vehicle, to calculate the traffic flow F , it has been concluded that L 1 ρ Rao (2007). To compute the traffic flow F , the lengths of different vehicles are provided in Table 5.
- **Vehicle Density** It is defined as the count of vehicles on the road. This is used to generate the mobile nodes of the scenario Simoncini et al. (2018).
- **Safety Distance** The minimum distance between the two vehicles to avoid a crash. Safety distance depends on the traffic scenario, such as (i) traffic jam, (ii) freeway, (iii) highway, (iv) city scenario Brito and Others (2018).

Table 5: Type of Road Transports and their Length https://www.way.com/blog/ average-car-length/

Name of Vehicle	Length of Vehicle
Mini cars	3.2004 m
Small car	4.20624 m
Small SUV	4.38912 m
Mid-sized car	4.51104 m
Full-sized car	4.78536 m
Small pickup	4.96824 m
Large SUV	5.09016 m
Large pickup	5.60832 m

- **Traffic Flow Rate** It is the count of vehicles within a specified length of roadsRen and Yao (2020).
- **Communication Link** The communication link is established between mobile and fixed nodes. The stable link establishes a reliable connection and data transfer. It also leads to a reduction in security breaches Awan et al. (2020).
- **Integration with Intelligent Transportation Systems (ITS)** Incorporating IoV with ITS represents a significant step towards optimizing emergency response. ITS integrates advanced technologies, including traffic management systems, real-time data analytics, and predictive modeling, to enhance the overall effectiveness of traffic management and emergency services. For example, coupling IoV data with traffic signal control systems can dynamically adapt traffic signals in response to emergencies, facilitating faster routes for emergency vehicles. This alignment with industry standards such as the IEEE 802.11p, which focuses on wireless access in vehicular environments, underscores the transformative potential of these technologies in improving road safety.

5. PREDICTION OF VEHICLE DENSITY IN DIFFERENT ROAD SEGMENTS

To strengthen the analysis in Section 5 regarding vehicle density and traffic flow, Figures 2, 3, 4, 5, 6, 7, 8, and 9 have been included to depict various scenarios of vehicle density across different vehicle types and road segments.

These figures illustrate the critical relationship between vehicle density and traffic flow, which is essential for understanding real-time traffic dynamics, particularly during emergencies. The visual data provides a substantiated analysis of how different vehicle types influence traffic density and flow rates.

The inclusion of these figures serves two key purposes

1. **Empirical Support for Communication Challenges** Figures 2, 3, 4, 5, 6, 7, 8, and 9 provide empirical evidence supporting the challenges in sparse network topologies highlighted in Section 5. In low-density scenarios, such as night-time conditions, the potential for reliable communication links decreases due to greater distances between vehicles and fewer transmission opportunities. This underscores the necessity of deploying RSUs as communication backbones in such environments.
2. **Illustration of Traffic Dynamics** These figures demonstrate predicted flow rates and densities, highlighting how maximum and minimum safety distances vary with traffic conditions. They visually represent how increasing vehicle density during emergencies can lead to congestion, which adversely impacts the timely dissemination of emergency messages.

5.1. Methodology for Vehicle Density Calculation

The calculation of vehicle density incorporates parameters such as lane length, direction, vehicle length, and safety distance. Sparse scenarios (e.g., nighttime with fewer vehicles) contrast with dense scenarios where increased vehicle numbers result in congestion. A maximum safety distance of 75 cm Kaur et al. (2021) is used to estimate vehicle density across lane segments of 1 km, 5 km, and 10 km. Eight types of vehicles—small SUVs, mid-sized cars, mini cars, small pick-up cars, full-sized cars, large pick-up cars, and large SUVs—are analyzed to calculate vehicle density and traffic flow rates. The results are depicted in Figures 2, 3, 4, 5, 6, 7, 8, and 9. By detailing the methodology for calculating vehicle density using the formula, L 1 ρ Rao (2007). This study provides a clear visual representation and quantitative analysis that substantiates claims regarding the impact of vehicle density on communication link stability and emergency response effectiveness.

Figure 2: Comparison of Vehicle Density and Traffic Flow for Small Cars on 1 km, 5 km, and 10 km of Lane.

Figure 3: Comparison of Vehicle Density and Traffic Flow for Mid-Sized Cars on 1 km, 5 km, and 10 km of Lane.

Figure 4: Comparison of Vehicle Density and Traffic Flow for Full-Sized Cars on 1 km, 5 km, and 10 km of Lane.

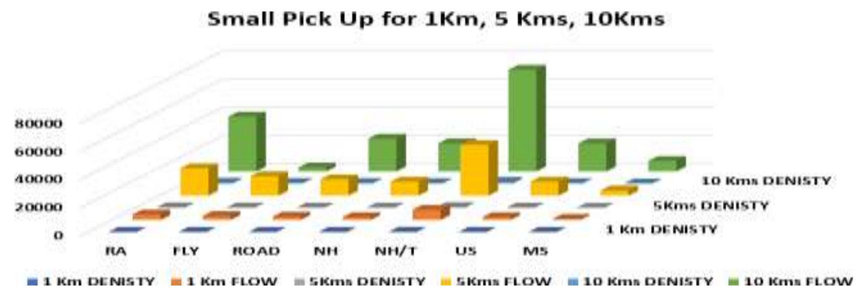

Figure 5: Comparison of Vehicle Density and Traffic Flow for Small Pick-Up Car on 1 km, 5 km, and 10 km of Lane.

Figure 6: Comparison of Vehicle Density and Traffic Flow for Small SUV Cars on 1 km, 5 km, and 10 km of Lane.

Figure 7: Comparison of Vehicle Density and Traffic Flow for Mini Cars on 1 km, 5 km, and 10 km of Lane.

Figure 8: Comparison of Vehicle Density and Traffic Flow for Large Pick-Up Cars on 1 km, 5 km, and 10 km of Lane.

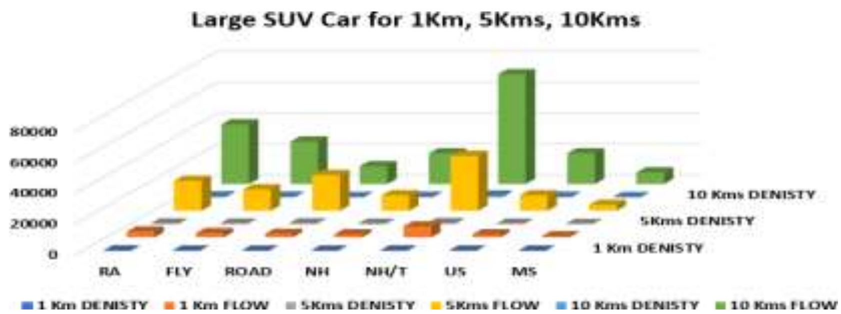

Figure 9: Comparison of Vehicle Density and Traffic Flow for Large SUV Cars on 1 km, 5 km, and 10 km of Lane.

Additionally, it has been concluded that the maximum speed scenario contains fewer vehicles, whereas the national highways having tolls create traffic jams. The following are the key points analyzed while performing the defined calculations.

- For traffic scenario generation, traffic density is a very important parameter. The count of vehicles can be predicted using the safety distance with different vehicle lengths.
- Traffic flow rate helps predict traffic accidents and congested roads.
- It is difficult to maintain communication links in the sparse network topology. This inculcates the embedding of RSUs on the roads that will serve as the backbone of future communication.
- Transmission range is another parameter to use for communication in different hops and therefore provides maximum information coverage.

5.1. Key Considerations for Designing Emergency Message Dissemination Algorithm

The following are the key points to remember while designing the algorithm.

1. To enhance and optimize the fast communication in safety applications, the clustering approach can significantly provide a better solution Kaur et al. (2021, 2024b).
2. For secure group communication, communication between RSUs, and OBUś opens new avenues in research Nath and Choudhury (2022).
3. Mini-slots, road segmentation, or small partitions are needed to have the reliable delivery of messages in one-hop or multi-hop architecture design Ma et al. (2011); Li et al. (2022); Heile and Allen (2015); Kaur et al. (2024a).
4. For achieving conditional privacy to avoid pseudonym cost management in safety warning messages, fog cloud is useful Yang et al. (2022).
5. For security and privacy preservation, the aggregate signature scheme is mostly used for safety message notifications Zhang et al. (2022); Goudarzi et al. (2022)
6. To implement the emergency message notifications or safety messages three ways of tools can be used namely; the use of simulators, the use of simulators with fog computing, and the use of simulators with ML and DL.

6. CONCLUSION AND FUTURE RESEARCH PERSPECTIVES

This research paper delves into the importance of emergency message spreading in IoVs and its possible influence on road safety. Through analysis, various important findings have been revealed that highlight the significance of this area in traffic management and road safety. As a conclusion to this study, the research prospects of the future and a detailed conclusion to the research have been presented.

6.1. Conclusion

Finally, this research paper has highlighted the central role played by emergency message dissemination in IoVs. The growing population and au- tomobile traffic have increased the stakes for proper traffic management and road safety. IoVs provide a suitable solution by supporting real-time vehicle- infrastructure communication, offering critical road safety information, and allowing quick accident prevention. The study highlights the necessity of fur- ther specialized studies in emergency message spreading in IoVs to mitigate traffic management problems and improve road safety efficiently.

In conclusion, this paper has not only recognized the significance of emer- gency message dissemination in IoVs but has also defined major directions for future research to make these systems more efficient, secure, and user- friendly. This research will motivate scholars and practitioners to join the effort to develop emergency message dissemination in IoVs and, consequently, contribute to safer and more efficient road transport systems.

6.2. Future Research Perspectives

1. Federated Learning Integration for Adaptive Algorithms: Adaptive emergency message broadcast algorithms can be developed using fed- erated learning techniques in future research. That way, vehicles can make inferences on user behavior and traffic conditions at the local level without compromising data privacy. Vehicles can work together to improve message delivery processes in real-time without centralizing sensitive data, addressing algorithmic efficiency and privacy concerns.
2. Resource-Aware 6G Network Utilization: Explain how the distinct fea- tures of 6G networks, such as ultra-reliable low latency communication (URLLC) and massive machine-type communications (mMTC), can be utilized to improve emergency message delivery in IoVs. Research can explain protocol design to utilize the features of 6G to improve the de- livery speed and reliability of messages

in high-density urban driving conditions.

3. AI-Powered Context-Aware Message Delivery Systems: Begin research to create AI-driven context-aware systems that utilize real-time data analysis and machine learning to adjust message delivery strategies dy- namically. These systems can consider a list of variables, from vehicular traffic volume and road conditions to driver behavior, to optimize the time and mode of message delivery.
4. Blockchain for Decentralized Message Authentication: Suggest the de- velopment of blockchain-based protocols to enable decentralized ver- ification of emergency messages. This can include the development of smart contracts that automatically function to verify the message, guarantee tamper-proof delivery, and hold the communicating entities accountable. This research area would address current issues regarding the trust and reliability of messages in IoVs.
5. Intelligent Integration of Infrastructure to Facilitate Enhanced Coor- dination: Research may investigate integrating IoVs with intelligent transportation infrastructure,e like networked traffic signals and adap- tive road signs to enhance emergency response coordination. This would entail creating communication protocols that enable vehicles to talk to infrastructure seamlessly so that they're able to get timely alerts and respond accordingly in case of emergencies.
6. Simulated Real-World Testing: Promote extensive real-world field tests with simulation enhancements that mimic various traffic conditions, emergencies, and vehicle-to-vehicle interactions to test the suggested dissemination protocols. This area of research should involve the use of advanced simulation software to simulate real-world environments so that the algorithms created can be tested under multiple conditions and lessons learned for subsequent versions.
7. Resilience in Hostile Environments: Examine the robustness of emer- gency message dissemination algorithms in hostile weather conditions or heavy traffic environments. Research may involve the design of re- dundancy protocols or alternate channels of communication to maintain the reliability of messages in hostile environments.

REFERENCES

Abbas, G., Ullah, S., Waqas, M., Abbas, Z. H., & Bilal, M. (2022). A position-based reliable emergency message routing scheme for road safety in VANETs. *Computer Networks, 213*, 109097.

Awan, K. A., Ud Din, I., Almogren, A., Guizani, M., & Khan, S. (2020). STABTRUST—A stable and centralized trust-based clustering mechanism for IoT-enabled vehicular ad-hoc networks. *IEEE Access, 8*, 21159–21177.

Azam, F., Yadav, S. K., Priyadarshi, N., Padmanaban, S., & Bansal, R. (2021). A comprehensive review of authentication schemes in vehicular ad-hoc network. *IEEE Access, 9*, 31309–31321.

Brito, T. H. O. N., et al. (2018). Analysis of vehicle length distribution for traffic simulation. *Journal of Traffic and Transportation Engineering, 5*, 113–126.

Chen, X., Yang, A., Tong, Y., Weng, J., & Li, T. (2022). A multi-signature-based secure and OBU-friendly emergency reporting scheme in VANET. *IEEE Internet of Things Journal, 9*, 23130–23141.

de Almeida, T. T., de Carvalho Gomes, L., Ortiz, F. M., Júnior, J. G. R., & Costa, L. H. M. (2020). Comparative analysis of a vehicular safety application in NS-3 and Veins. *IEEE Transactions on Intelligent Transportation Systems, 23*, 620–629.

Farooq, W., Khan, M. A., Rehman, S., & Saqib, N. A. (2015). A survey of multicast routing protocols for vehicular ad hoc networks. *International Journal of Distributed Sensor Networks, 11*, 923086.

Ghazi, M. U., Khattak, M. A. K., Shabir, B., Malik, A. W., & Ramzan, M. S. (2020). Emergency message dissemination in vehicular networks: A review. *IEEE Access, 8*, 38606–38621.

Gill, S. S., Wu, H., Patros, P., Ottaviani, C., Arora, P., Pujol, V. C., Haunschild, D., Parlikad, A. K., Cetinkaya, O., Lutfiyya, H., et al. (2024). Modern computing: Vision and challenges. *Telematics and Informatics Reports*, 100116.

Goudarzi, S., Soleymani, S. A., Anisi, M. H., Azgomi, M. A., Movahedi, Z., Kama, N., Rusli, H. M., & Khan, M. K. (2022). A privacy-preserving authentication scheme based on elliptic curve cryptography and using quotient filter in fog-enabled VANET. *Ad Hoc Networks, 128*, 102782.

Guo, R., Xu, L., Li, X., Zhang, Y., & Li, X. (2022). An efficient certificateless ring signcryption scheme with conditional privacy-preserving in VANETs. *Journal of Systems Architecture, 129*, 102633.

Gupta, N., Juneja, P. K., Sharma, S., & Garg, U. (2024). An intelligent technique for network resource management and analysis of 5G-IoT smart healthcare application. *Journal of Autonomous Intelligence, 7*.

Han, Y., Song, W., Zhou, Z., Wang, H., & Yuan, B. (2021). ECLAS: An efficient pairing-free certificateless aggregate signature for secure VANET communication. *IEEE Systems Journal, 16*, 1637–1648.

Harnal, S., Sharma, G., Malik, S., Kaur, G., Khurana, S., Kaur, P., Simaiya, S., & Bagga, D. (2022). Bibliometric mapping of trends, applications and challenges of artificial intelligence in smart cities. *EAI Endorsed Transactions on Scalable Information Systems, 9*, e8–e8.

Heile, R. F., & Allen, J. D. (2015). IEEE 802.15.4-2015 standard. *IEEE Std 802.15.4-2015 (Revision of IEEE Std 802.15.4-2011)*, 708.

John, M., & Shaiba, H. (2022). Analysis of road accidents using data mining paradigm. In *Mobile Computing and Sustainable Informatics: Proceedings of ICMCSI 2021* (pp. 215–223). Springer.

Kaur, R., Doss, R., & Pan, L. (2024a). The route-based emergency message dissemination scheme using multihop wireless network for VANETs. Telecommunication Systems, 87, 1183–1199.

Kaur, R., Ramachandran, R. K., Doss, R., & Pan, L. (2021). The importance of selecting clustering parameters in VANETs: A survey. Computer Science Review, 40, 100392.

Khan, S., Sharma, I., Aslam, M., Khan, M. Z., & Khan, S. (2021). Security challenges of location privacy in VANETs and state-of-the-art solutions: A survey. *Future Internet, 13*, 96.

Li, H., Liu, F., Zhao, Z., & Karimzadeh, M. (2022). Effective safety message dissemination with vehicle trajectory predictions in V2X networks. *Sensors, 22*, 2686.

Li, J., Ma, R., Deng, M., Cao, X., Wang, X., & Wang, X. (2024). A comparative study of clustering algorithms for intermittent heating demand considering time series. *Applied Energy, 353*, 122046.

Ma, M., Liu, K., Luo, X., Zhang, T., & Liu, F. (2020). Review of MAC protocols for vehicular ad hoc networks. *Sensors, 20*, 6709.

Ma, X., Zhang, J., Yin, X., & Trivedi, K. S. (2011). Design and analysis of a robust broadcast scheme for VANET safety-related services. *IEEE Transactions on Vehicular Technology, 61*, 46–61.

Manasa, P., Ananth, P., Natarajan, P., Somasundaram, K., Rajkumar, E., Ravichandran, K. S., Balasubramanian, V., & Gandomi, A. H. (2024). An analysis of causative factors for road accidents using partition around medoids and hierarchical clustering techniques. *Engineering Reports*, e12793.

Nath, H. J., & Choudhury, H. (2022). A privacy-preserving mutual authentication scheme for group communication in VANET. *Computer Communications, 192*, 357–372.

Quy, V. K., Nam, V. H., Linh, D. M., Ban, N. T., & Han, N. D. (2021). Communication solutions for vehicle ad-hoc network in smart cities environment: A comprehensive survey. *Wireless Personal Communications*, 1–25.

Rao, K. V. K. (2007). Fundamental parameters of traffic flow. *Transportation Engineering*, 1–8.

Rashid, S. A., Audah, L., Hamdi, M. M., Abood, M. S., & Alani, S. (2020). Reliable and efficient data dissemination scheme in VANET: A review. *International Journal of Electrical and Computer Engineering (IJECE), 10*, 6423–6434.

Rayeni, M. S., Hafid, A., & Sahu, P. K. (2015). Dynamic spatial partition density-based emergency message dissemination in VANETs. *Vehicular Communications, 2*, 208–222.

Ren, J., Zhang, G., & Li, D. (2017). Multicast capacity for VANETs with directional antenna and delay constraint under random walk mobility model. *IEEE Access, 5*.

Ren, Q., & Yao, G. (2020). An energy-efficient cluster head selection scheme for energy-harvesting wireless sensor networks. *Sensors (Switzerland), 20*, 1–17.

Shankar, A., Dayalan, R., Chakraborty, C., Dhasarathan, C., & Kumar, M. (2022). A modified social spider algorithm for an efficient data dissemination in VANET. *Environment, Development and Sustainability*, 1–44.

Sharma, A., & Jaekel, A. (2021). Machine learning based misbehaviour detection in VANET using consecutive BSM approach. *IEEE Open Journal of Vehicular Technology, 3*, 1–14.

Sharma, M., Kumar, P., & Tomar, R. S. (2022). Vehicular connectivity algorithm for cooperative transportation systems. *Computers and Electrical Engineering, 102*, 108199.

Sheikh, M. S., Liang, J., & Wang, W. (2019). A survey of security services, attacks, and applications for vehicular ad hoc networks (VANETs). *Sensors, 19*, 3589.

Simoncini, M., Taccari, L., Sambo, F., Bravi, L., Salti, S., & Lori, A. (2018). Vehicle classification from low-frequency GPS data with recurrent neural networks. *Transportation Research Part C: Emerging Technologies, 91*, 176–191.

Soni, M., Rajput, B. S., Patel, T., & Parmar, N. (2021). Lightweight vehicle-to-infrastructure message verification method for VANET. In *Data Science and Intelligent Applications: Proceedings of ICDSIA 2020* (pp. 451–456). Springer.

Talib, M., Hassan, A., Hussin, B., Talib, Z., Rasoul, Z., & Sammour, M. (2018). Data dissemination based clustering techniques for VANETs: A review. *J. Adv. Res. Dyn. Control Syst, 10*, 596–604.

Yang, Y., Zhang, L., Zhao, Y., Choo, K. K. R., & Zhang, Y. (2022). Privacy-preserving aggregation-authentication scheme for safety warning system in fog-cloud based VANET. *IEEE Transactions on Information Forensics and Security, 17*, 317–331.

Yu, Y., Zeng, X., Xue, X., & Ma, J. (2022). LSTM-based intrusion detection system for VANETs: A time series classification approach to false message detection. *IEEE Transactions on Intelligent Transportation Systems*.

Zhang, L., Kang, B., Dai, F., Zhang, Y., & Liu, H. (2022). Hybrid and hierarchical aggregation-verification scheme for VANET. *IEEE Transactions on Vehicular Technology, 71*, 11189–11200.