Innovation and Integrative Research Center Journal
ISSN: 2584-1491 |www.iircj.org
Volume- 2 Issue-1, Jan-2024, Page 23-38

Enhancing VANET Performance Using Real-world Traffic Modeling and Simulation

Pallavi Singh[1*], Dr. Rajesh Keshavrao Deshmukh[2]
[1]PhD. Research Scholar, Department of CSE, Kalinga University, Raipur, Chhattisgarh
[2]Professor, Department of CSE, Kalinga University, Raipur, Chhattisgarh
Email: pallavisingh.psru@gmail.com

Abstract
This research investigates communication optimization strategies for Vehicular Ad-Hoc Networks (VANETs) in a real-world setting – the bustling city of Raipur, Chhattisgarh. VANETs, a specialized form of Mobile Ad-Hoc Networks (MANETs), allow vehicles to exchange information with each other and roadside infrastructure. This technology holds immense potential for improving road safety, traffic efficiency, and providing innovative services to drivers. However, VANETs face unique challenges due to the dynamic nature of traffic environments. High vehicle mobility, intermittent connectivity caused by signal blockage or distance, and ever-changing traffic conditions can significantly impact communication performance. To address these challenges, this study proposes the Integration to Message Exchange (IME) method. This method leverages the power of realistic traffic simulation to enhance VANET communication optimization strategies. Traffic simulations meticulously model vehicle behavior and interactions with the road network. These models consider factors such as traffic flow, congestion patterns, and specific road conditions within Raipur City. By integrating this simulation data into VANET communication algorithms, the research evaluates the performance of the proposed IME method alongside existing routing protocols like D-LAR and AODV under realistic traffic scenarios that mirror the complexities of Raipur's road network. The findings are promising. The IME method demonstrates significant improvements in message delivery rates and reduced message latency compared to the compared protocols. Notably, compared to DLAR, IME achieves a 4.82% increase in packet delivery ratio, a 4.0% reduction in end-to-end delay, a 4.85% increase in throughput, an 8.79% decrease in routing overhead, and a 7.71% improvement in normalizing routing load across the network. The focus on Raipur City as the research's geographical context is deliberate. Raipur's rapid growth has led to diverse traffic patterns and a mix of road conditions. By conducting experiments and simulations that mirror these real-world complexities, the study's findings directly translate into solutions that can address the specific challenges faced by VANETs in Raipur's urban environment. This paves the way for the potential deployment of VANETs to enhance traffic management, safety, and driver experience within the city.
Keywords: *Improvement to Message Exchange (IME), ITS, Routing Protocols, Performance, SUMO, NS-2, VANETs.*

1. Introduction

Vehicular Ad-Hoc Networks (VANETs) have garnered considerable attention in recent years due to their promising capabilities in bolstering road safety, optimizing traffic flow, and delivering a myriad of intelligent transportation services. Within the VANET framework, vehicles engage in communication both amongst themselves and with infrastructure elements to share vital information like traffic congestions, road impediments, and emergency alerts. Nonetheless, the efficacy of these information exchanges is intricately tied to the robustness of the network infrastructure and the prevailing traffic conditions in real-world settings [1].

A multitude of hurdles stand in the path of achieving seamless and dependable message transmission in VANETs. Firstly, the ever-changing dynamics of vehicular traffic introduce frequent shifts in traffic flow patterns, potentially compromising the integrity of communication links. Secondly, the swift movement of vehicles coupled with their limited communication range presents a formidable challenge in establishing and sustaining consistent connections. Fluctuations in vehicular density on the roads can lead to congestion and resultant packet loss, further complicating

the message exchange process. Consequently, tackling these inherent challenges is paramount to ensuring the reliable and prompt dissemination of messages within VANETs [2].
The advent of Intelligent Transportation Systems (ITS) has brought about a paradigm shift in our transportation landscape, reshaping our daily commuting experiences and interactions with transportation infrastructures. A cornerstone application of ITS lies in the creation of Vehicle Ad-Hoc Networks (VANETs). These networks, characterized by their wireless nature, empower vehicles to communicate seamlessly amongst themselves and with adjacent infrastructure elements. VANETs are instrumental in elevating road safety standards, streamlining traffic management, and enhancing passenger comfort through the real-time exchange of critical information. By facilitating the sharing of pertinent data such as traffic congestions, road statuses, and emergency alerts, VANETs pave the way for more informed and efficient decision-making processes.

In recent times, there has been a surge in research endeavors focusing on ITS-centric VANET systems, aiming to tackle the diverse challenges and elevate the overall system performance. These systems harness cutting-edge communication technologies, including Dedicated Short Range Communication (DSRC) and cellular networks, to enable fluid vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. Studies have demonstrated that ITS-driven VANET systems hold immense potential in fortifying road safety by furnishing drivers with timely warnings and alerts regarding potential road hazards. Moreover, the integration of VANETs with other ITS constituents, such as intelligent traffic signal control systems and sophisticated sensors, has the potential to ameliorate traffic congestion and enhance traffic flow dynamics.

A plethora of research papers have delved into ITS-based VANET systems, spotlighting a range of innovative approaches and methodologies aimed at enhancing their operational efficiency. For instance, a study spearheaded by Liu et al. (2019) introduced a groundbreaking routing algorithm tailored for VANETs. This algorithm, cognizant of the dynamic nature of vehicular networks, endeavors to optimize message delivery in terms of both latency and reliability, marking a significant stride in advancing VANET communication capabilities [3].

This paper delves into the optimization of Vehicular Ad-Hoc Network (VANET) communication in Raipur City, India. VANETs hold immense potential for revolutionizing transportation systems by enabling communication between vehicles and roadside infrastructure. This communication facilitates the exchange of critical information like traffic congestion updates, accident warnings, and emergency alerts, leading to several key benefits:

- **Enhanced Road Safety:** Timely alerts about potential hazards empower drivers to make informed decisions, reducing accidents.

- **Improved Traffic Efficiency:** Real-time traffic data allows for dynamic route optimization, mitigating congestion and reducing travel times.

- **Elevated Passenger Comfort:** VANETs can pave the way for innovative services like real-time arrival estimates or congestion avoidance rerouting, enhancing passenger comfort.

However, VANET communication effectiveness hinges on accurately modeling real-world traffic conditions. Raipur City, the capital of Chhattisgarh, is experiencing rapid urbanization, leading to a surge in vehicles. This growth presents significant challenges in terms of traffic congestion, road accidents, and inefficient transportation systems.

VANETs offer a compelling solution. By enabling communication and information exchange, VANETs can empower drivers and improve traffic management. However, to optimize VANET communication specifically for

Raipur, a crucial step is developing a realistic traffic simulation model. This model should meticulously capture the following aspects unique to Raipur's transportation landscape:

- **Traffic Patterns:** The model should represent the city's diverse traffic patterns, including rush hour congestion, peak travel times on specific routes, and variations based on weekdays and weekends.

- **Road Infrastructure:** The model should incorporate an accurate representation of Raipur's road network, including lane configurations, intersection layouts, and potential bottlenecks.

- **Driving Behaviors:** The model should account for typical driving behaviors observed in Raipur, such as lane-changing frequencies, adherence to traffic rules, and average speeds on different road types.

This realistic traffic simulation becomes a powerful tool for evaluating the performance of VANET communication protocols, routing algorithms, and applications under various traffic scenarios that mirror the complexities of Raipur's road network. By simulating real-world conditions, researchers and engineers can assess the effectiveness and efficiency of VANET communication systems before deploying them in the actual city environment. This simulation-driven approach allows for targeted optimization, ensuring VANETs can effectively address the specific transportation challenges faced by Raipur City.

In essence, this research proposes a strategic approach to VANET optimization for Raipur. By leveraging a city-specific traffic simulation model, the research paves the way for the development and deployment of VANET systems that can significantly contribute to safer, smoother, and more intelligent transportation within Raipur.

Developing a realistic traffic simulation model for Raipur City is critical for effectively evaluating VANET communication strategies. This model needs to capture several crucial aspects:

- **Detailed Road Network:** The foundation of the model is an accurate representation of Raipur's road infrastructure. This includes meticulously mapping all roads, intersections, traffic signals, and other relevant infrastructure like overpasses or underpasses.
- **Dynamic Traffic Flow:** Capturing the city's diverse traffic patterns is essential. The model should account for variations in traffic flow throughout the day, across weekdays and weekends. Rush hour congestion, off-peak hours with lower traffic volume, and weekend patterns should all be reflected to accurately simulate real-world conditions.
- **Realistic Driving Behaviors:** Beyond the road network itself, the model needs to incorporate realistic driving behaviors. This includes factors like acceleration rates, deceleration patterns, lane-changing frequencies, and how drivers maintain following distances. These behaviors are influenced by various elements, such as driver personalities, road conditions, and the presence of congestion. By accurately modeling these behaviors, the simulation can provide valuable insights into how VANET communication might impact traffic flow, congestion mitigation strategies, and overall road safety in Raipur.

The remaining sections of the paper delve deeper into various aspects of this research:

- **Section 2: Related Work** - This section provides a comprehensive overview of existing research on VANETs and ITS systems. It summarizes research methods and key findings from various studies in this field, establishing the context for the current research.
- **Section 3: IME Method and Algorithm** - This section dives into the core of the research by detailing the proposed IME method (Integration to Message Exchange). It will likely explain the specific algorithm designed for the IME method and how it leverages the traffic simulation model.

- **Section 4: Experimental Results** - Here, the paper presents the results obtained during the experiment. This section will likely showcase how the IME method performs under various simulated traffic scenarios within the Raipur traffic simulation model, potentially comparing it to existing routing protocols.
- **Section 5: Conclusion and Future Directions** - The final section summarizes the key findings of the research, highlighting the contributions made towards improving VANET communication efficiency in Raipur City. It will likely discuss potential areas for future research that could build upon this work.

Paper's Contributions

This research offers two key contributions to the field of VANETs:

1. **Practical Traffic Simulation for VANETs:** The paper proposes a practical traffic simulation methodology specifically designed for evaluating VANET communication. This methodology can be a valuable tool for researchers and engineers working on VANET optimization in real-world settings.
2. **Addressing Real-World Challenges:** The study acknowledges the challenges associated with VANET communication in real-world scenarios like Raipur City. It proposes solutions that can improve the performance of the IME method within this specific urban environment.

By combining a realistic traffic simulation model with the IME method, this research has the potential to significantly enhance VANET communication efficiency and contribute to safer, smoother traffic flow in Raipur City.

2. Related Work

Traffic simulation stands as an indispensable tool in enhancing the efficacy of vehicle communication within the intricate landscapes of real-world Vehicular Ad-Hoc Networks (VANETs). By harnessing expansive driving datasets and real-world traffic scenarios, researchers are empowered to craft precise models that simulate the multifaceted behaviors exhibited by traffic [4]. The task of distilling pertinent scenarios from authentic driving data is undeniably intricate, yet it remains pivotal for the comprehensive evaluation of automated vehicles (AVs) based on real-world driving conditions [5].

The advent of VANET technology heralds a transformative phase in vehicular communication capabilities. This technology is adept at facilitating swift object detection and delivering prompt warnings to drivers, thereby adeptly tackling the triad of traffic management, communication efficiency, and road safety concerns, especially within bustling metropolitan locales [6]. Furthermore, Traffic Signal Control (TSC) systems stand to benefit immensely from the integration of VANET technology and intelligent control algorithms. Such a synergy can empower TSC systems to evolve into self-regulating entities that adapt in real-time to the prevailing traffic conditions. This adaptability holds the promise of alleviating traffic bottlenecks and curtailing vehicular wait times at intersections, thereby fostering smoother traffic flow and enhancing overall road efficiency [7].

In the realm of vehicular innovation, vehicle platooning emerges as a promising strategy to mitigate traffic congestion while conserving labor and energy resources. By leveraging inter-vehicle communication capabilities inherent in VANETs, vehicle platooning fosters a cohesive and synchronized movement of vehicles. However, the successful implementation of vehicle platooning hinges upon the deployment of robust control algorithms designed to ensure safe, collision-free, and harmonized platooning operations [8]. Thus, as VANET technology continues to mature, it holds the potential to revolutionize various facets of modern transportation, spanning from individual vehicle communication to overarching traffic management systems.

ISSN: 2584-1491 |www.iircj.org
Volume- 2 Issue-1, Jan-2024, Page 23-38

In the study referenced as [10], the author delves into the intricacies of constructing a real-world traffic simulation scenario utilizing the SUMO platform. Interestingly, while the focus is on traffic simulation, there is no explicit mention of VANETs or the potential enhancements it can bring to vehicle communication and operations.

On the other hand, the research presented in [11] introduces a pioneering transmission strategy tailored specifically for VANETs. This innovative approach amalgamates the advantages of both single-hop and multi-hop communication methodologies. The primary aim is to augment connectivity among vehicles, particularly in dynamic real-world settings, thereby fostering more robust and reliable communication networks within VANETs.

Meanwhile, the scholarly work documented in [12] puts forth an enhanced version of the IEEE 802.11p protocol, complemented by Time Division Multiple Access (TDMA) techniques. This refined protocol is meticulously designed to facilitate efficient data transmission within densely populated vehicular networks. To gauge its efficacy and performance metrics, the study employs a sophisticated two-dimensional Markov model, offering valuable insights into its operational capabilities and potential benefits for VANET deployments.

In the research article cited as [13], the focus shifts towards optimizing traffic flow dynamics within VANET scenarios. The author introduces a novel scheduling algorithm explicitly tailored to VANET environments. This algorithm aims to streamline traffic patterns and minimize waiting times at intersections, thereby contributing to smoother vehicular movement and enhanced overall traffic efficiency.

Lastly, the scholarly investigation referenced as [14] undertakes a comprehensive performance analysis of various VANET routing protocols. Utilizing both SUMO and NS3 simulation platforms, the author meticulously evaluates these protocols under real-world mobility tracing scenarios. This rigorous analysis provides a deeper understanding of the strengths and weaknesses inherent in different routing protocols, offering valuable insights for future VANET system optimizations and deployments.

A comprehensive review of existing research in VANETs has yielded valuable insights and identified key areas for improvement. Several critical themes emerged from this review:

- **Prioritizing Safety Messages:** A pressing need exists to ensure the reliable and timely delivery of safety messages within VANETs. These messages, such as accident warnings or hazard alerts, are crucial for preventing collisions and fostering safer roads.
- **Enhancing Routing Protocols:** Current routing protocols in VANETs require further refinement to optimize message delivery under dynamic traffic conditions. These conditions, characterized by high mobility and frequent network changes, pose challenges for traditional routing mechanisms.
- **Bridging the Gap between Simulation and Reality:** While traffic simulation offers valuable insights, a gap exists in analyzing VANET performance using real-world traffic data. This real-world data is essential for developing and validating VANET solutions that can effectively function in real-world scenarios.

In response to these identified gaps, this study proposes the Improvement to Message Exchange (IME) method. This method aims to significantly enhance message exchange efficiency within VANETs by leveraging real-world map data specific to Raipur City, India. The details of the IME method, including its underlying algorithm and integration with real-world map data, will be elaborated upon in Section 3 of the methodology section.
By focusing on real-world data and addressing the specific challenges of safety message delivery and routing protocol optimization, the IME method has the potential to make a significant contribution to the advancement of VANET technology.

3. Materials and Methods

Building upon the insights gained from the literature review, the research team devised a comprehensive development process for the IME method. This process can be broken down into four key stages:

- **Stage 1: Traffic Modeling and Network Analysis:** The foundation of the IME method is a thorough understanding of message exchange dynamics within VANETs. This stage involves in-depth analysis of traffic patterns and network behavior. Researchers meticulously studied how messages are exchanged under various traffic scenarios, such as rush hour congestion or sparse traffic conditions. This analysis provided crucial insights into the challenges that can impact message delivery efficiency.

- **Stage 2: Algorithmic Enhancements:** Building upon the understanding gained from Stage 1, the next step focused on developing algorithmic improvements to address identified challenges. The key areas of focus included:
    - **Network Congestion Mitigation:** The IME method incorporates algorithms specifically designed to alleviate network congestion, a common issue in VANETs. These algorithms aim to optimize message forwarding strategies and reduce the likelihood of network overload.
    - **Enhanced Message Reliability:** The IME method prioritizes ensuring message reliability, particularly for critical safety messages. This may involve techniques like message redundancy or adaptive routing protocols to ensure messages reach their intended destinations even under challenging network conditions.
    - **Routing Algorithm Optimization:** The research team explored improvements to existing routing protocols used in VANETs. This could involve developing new routing algorithms or modifying existing ones to better adapt to the dynamic nature of traffic and network conditions within Raipur City.

The implementation details of these algorithmic enhancements, including their integration with simulators like NS-2 and SUMO, were likely discussed in the research paper itself.

- **Stage 3: Simulation and Validation:** Following the development of algorithmic enhancements, the IME method underwent rigorous testing and validation through extensive simulation studies. These simulations utilized platforms like SUMO and NS-2 to assess the effectiveness of the proposed improvements. The performance of the IME method was compared against traditional routing protocols like D-LAR and AODV to evaluate its efficiency and reliability in message delivery.

- **Stage 4: Real-World Implementation and Testing:** While simulation offers valuable insights, real-world testing is crucial for validating the effectiveness of the IME method. This final stage involved deploying the proposed enhancements within a real-world VANET environment. Field trials and experimentation were conducted to assess the practicality and effectiveness of the IME method in a real-world setting. This stage likely involved replicating some of the traffic scenarios modeled in the simulations and observing how the IME method performed under actual driving conditions in Raipur City.

The research paper likely included a flowchart (Figure 1) that visually represented the working method of the IME method. This flowchart may have begun by depicting a simulation scenario for an intelligent transport system for vehicular ad hoc networks. It could then have shown the initial step of vehicles broadcasting "hello" messages to update their routing tables, followed by subsequent message exchange processes facilitated by the IME method.

By following this comprehensive development process, the researchers aimed to ensure that the IME method was not only theoretically sound but also practical and effective in real-world VANET applications, specifically within the context of Raipur City's traffic environment.

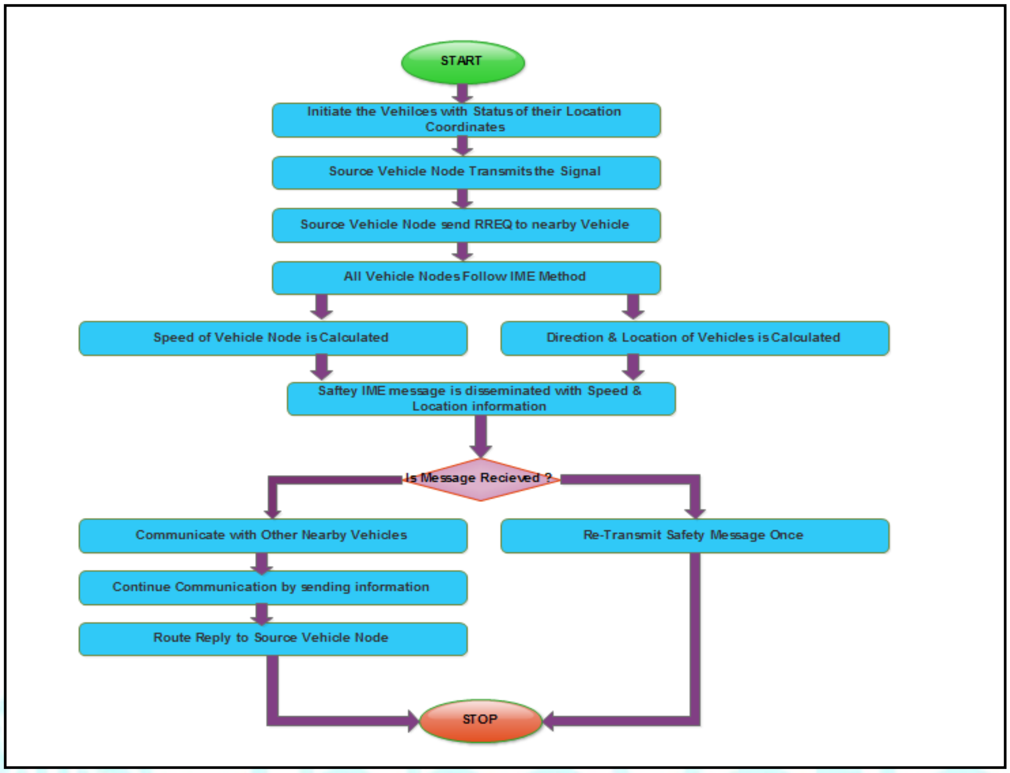


Figure 1: Methodology Adopted for IME Method

The IME method facilitates a crucial communication flow within VANETs, promoting safe and efficient lane changing maneuvers. Let's delve into the key stages of this process:

1. **Network Initialization:** When a simulation scenario for a vehicular ad hoc network (VANET) is set up, vehicles begin by broadcasting "hello" messages. These messages act as a self-introduction, sharing a vehicle's status and location with surrounding vehicles. This information exchange is critical for updating the routing tables used by the network's routing protocol, ensuring efficient message delivery.

   Vehicles (Broadcast Hello Message) → Update Routing Table ……. (1)

2. **Data Transmission:** Once the network is initialized, a source vehicle initiates communication by transmitting a data packet to a neighboring vehicle. This data packet contains vital information for safe lane changing, including the source vehicle's current location, direction of travel, and speed.

   Source Vehicle (Send Data Packet) → Neighbor Vehicle ………… (2)

3. **IME Method in Action:** The IME method steps in at this stage. It leverages the routing table information and real-world map data (specific to Raipur City in this case) to efficiently forward the source vehicle's location, direction, and speed to nearby vehicles. This information dissemination is crucial for enhancing safety. By being aware of the source vehicle's upcoming lane change, surrounding vehicles can adjust their movements to avoid potential collisions.

   $IME\_Method_{Source\_Vehicle}$ *(Forward Location, Direction, Speed) → Neighbor Vehicles …. (3)*

4. **Safety Message Propagation:** Neighboring vehicles that successfully receive the safety message containing the source vehicle's lane change information play a vital role in ensuring network-wide safety. They act as relays, forwarding this safety message to other vehicles within the network. This collective awareness of the upcoming lane change maneuver helps maintain safe traffic flow.

Neighbor Vehicles (Forward Safety Message) →Other Vehicles …….(4)

5. **Communication Continuation and Confirmation:** Successful reception of the safety message by neighboring vehicles is followed by continued communication. A reply function is then invoked, notifying the source vehicle that the lane ahead is clear for proceeding and confirming that the safety message has been successfully delivered throughout the network. This two-way communication loop ensures the source vehicle is aware of a safe lane change opportunity.

Neighbor_Vehicles_Safety (Message Received) → Source Vehicle (Invoke Reply Function) → Lane Clear for Movement …… (5)

6. **Error Handling and Retransmission:** The IME method incorporates error handling mechanisms to ensure message delivery reliability. In situations where neighboring vehicles encounter initial difficulties forwarding the safety message, the IME method triggers a single re-transmission attempt. If this re-transmission is unsuccessful, communication ceases to avoid network congestion.

Neighbor Vehicles (Failed to Forward Safety Message) → Re transmit Safety Message (Once) …..(6)

By facilitating this efficient and reliable safety message exchange, the IME method plays a significant role in promoting safe lane changes and enhancing overall traffic safety within VANETs.

This section delves into the methodology used to implement the Integrated Mobility Evaluator (IME) method within the NS-2 and SUMO network simulators. OpenStreetMap data plays a crucial supporting role in this process. The overall objective is to provide a comprehensive understanding of how the IME method functions and how it can be applied to enhance the realism of network simulations. The IME method offers a novel approach to network simulations. It departs from traditional methods by integrating various mobility models and real-world traffic scenarios. This integration allows for the creation of more realistic and dynamic mobility patterns within simulations. The foundation of this approach lies in the concept of mobility profiles. These profiles are not simply hypothetical; they are meticulously generated by analyzing real-world mobility data. This data might encompass information like travel routes, speeds, and lane-changing behaviors observed in real-world traffic conditions.
By incorporating these mobility profiles into network simulations, the IME method enables researchers to create virtual traffic scenarios that more closely mirror the complexities of real-world transportation systems. This enhanced realism allows for more accurate evaluation of VANET communication protocols and algorithms under diverse traffic conditions.

Step-by-Step Implementation

Implementing the IME method in NS-2 and SUMO simulators involves a series of well-defined steps:

1. **Extracting and Processing Real-World Map Data:** The process begins with leveraging OpenStreetMap data, a free and editable map of the world. This data is extracted and meticulously processed to generate a network topology suitable for the simulations. Essentially, the map data is converted into a format that the simulators can understand, ensuring an accurate representation of the target area's road network.
2. **Generating Mobility Profiles from Real-World Data:** The next step involves creating mobility profiles. Researchers gather real-world mobility data, which could include information on vehicle movement patterns, speeds, and lane-changing behaviors within the target area (Raipur City, in this case). By analyzing this data, researchers can identify common mobility patterns. These patterns then serve as the foundation for generating mobility profiles that can be used to influence the behavior of simulated vehicles within the network.
3. **Integrating Mobility Profiles into Simulators:** Once the mobility profiles are generated, they are integrated into the NS-2 and SUMO simulators. This integration might involve modifying the existing mobility models within the simulators to incorporate the characteristics captured in the mobility profiles. By incorporating these profiles, the simulators can generate more realistic and dynamic vehicle movement patterns within the simulated traffic scenarios.

This step-by-step approach ensures that the IME method leverages real-world data to create a more realistic simulation environment for evaluating VANET communication strategies within the context of Raipur City's traffic landscape.

Upon completing the simulation processes, an in-depth analysis of the results was conducted to ascertain their accuracy and realism. To validate the fidelity of the simulations, a comparative analysis was performed by juxtaposing the simulated outcomes with authentic real-world data. Furthermore, to gauge the efficacy and superiority of the IME (Implicit Mobility Estimation) method, the results derived from our simulations were juxtaposed against those procured through conventional mobility models. In essence, the methodology adopted for the seamless integration and implementation of the IME method within the NS-2 and SUMO simulation frameworks, leveraging the OpenStreetMap dataset, encompassed a series of systematic steps. These steps ranged from the meticulous extraction and refinement of map data to the generation of intricate mobility profiles. Subsequently, these meticulously crafted profiles were seamlessly integrated into the simulation platforms. The culmination of this rigorous process was the comprehensive evaluation and scrutiny of the simulation outcomes, providing invaluable insights into the performance and capabilities of the IME method in diverse simulation environments.

4. Results and Discussion

This paper delves into the simulation methodology used to implement the Integrated Mobility Evaluator (IME) method within NS-2 and SUMO simulators, leveraging OpenStreetMap data. Our focus is on providing a clear understanding of the simulation analysis process, outlining the key steps and considerations. The IME method has become a standard tool for evaluating the performance of mobility management protocols in wireless networks. It allows researchers to assess various metrics crucial for network efficiency, such as handover delay, packet loss, and network throughput. However, real-world testing of these protocols can be expensive and time-consuming. Simulation tools offer a valuable alternative, enabling researchers to replicate real-world scenarios and evaluate protocol performance in a controlled environment.

For this purpose, NS-2 and SUMO simulators are popular choices. NS-2, a discrete event simulator, excels at modeling and simulating various network protocols and scenarios. SUMO, on the other hand, is a microscopic traffic simulation tool specifically designed to model vehicular traffic and mobility patterns. By combining these two simulators, researchers gain a comprehensive perspective on how mobility management protocols function within a simulated traffic environment. OpenStreetMap (OSM) plays a vital role by providing the geographical foundation for these simulations. This open-source mapping platform offers a wealth of detailed and up-to-date geographical information, including road networks, buildings, and other relevant features. Integrating OSM data with NS-2 and SUMO allows researchers to accurately model real-world scenarios and evaluate mobility management protocols in a realistic setting that reflects actual traffic conditions. The simulation analysis process begins by acquiring the necessary data from OSM, focusing on the specific area of interest for the simulation. This data encompasses the road network, buildings, and any other relevant features that might influence network behavior. The acquired data is then meticulously processed and converted into a format that NS-2 and SUMO can understand. This crucial step ensures that the simulation accurately represents the chosen real-world scenario, paving the way for meaningful evaluation of mobility management protocols.

Figure 2 showcases the versatility of the IME method in handling various traffic densities within a simulated Raipur City intersection.

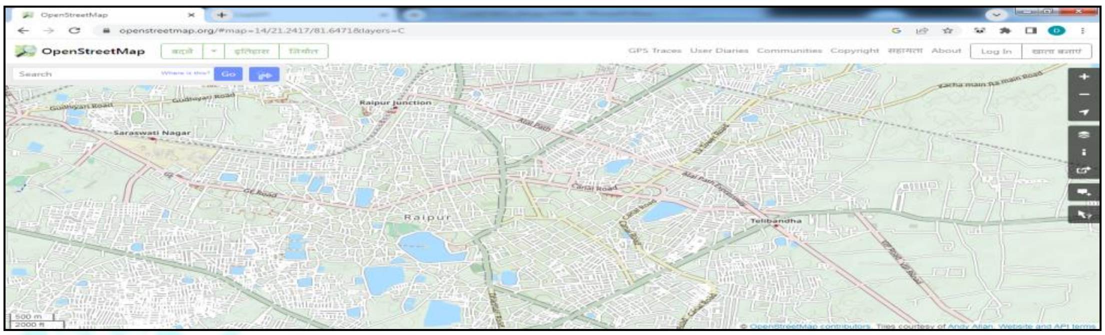
- **Figure 2(a):** This panel serves as the foundation, depicting the real-world map data extracted from OpenStreetMap (OSM) for Raipur City. OSM's collaborative nature allows users to contribute and update

Innovation and Integrative Research Center Journal
ISSN: 2584-1491 |www.iircj.org
Volume- 2 Issue-1, Jan-2024, Page 23-38

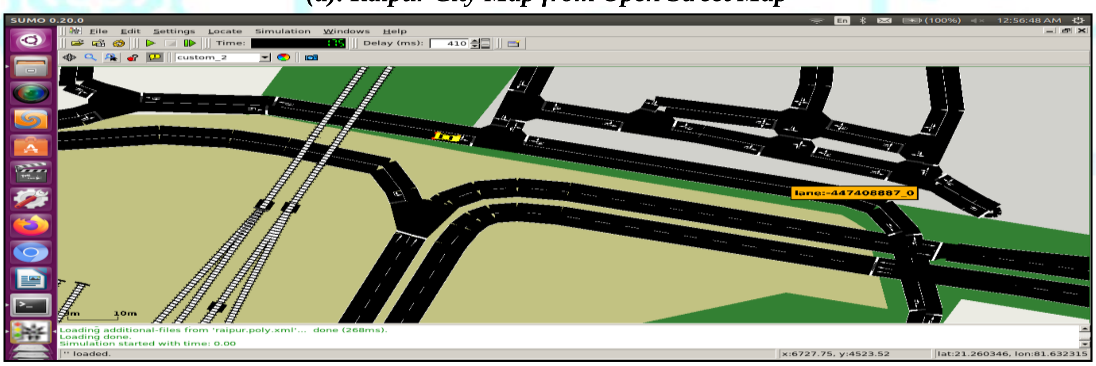
geographical data, ensuring the map reflects details like canals, roads, lanes, and their associated features. This accurate map data provides the base layer for the simulations.

- **Figures 2(b) to 2(f):** These panels illustrate the IME method in action within the SUMO simulator. Each panel progressively increases the number of simulated vehicles, ranging from 100 to 300. The vehicles are depicted in yellow and red colors, navigating the Raipur City intersection. This visual representation demonstrates the IME method's ability to scale effectively and handle increasingly complex traffic scenarios within the simulated environment.

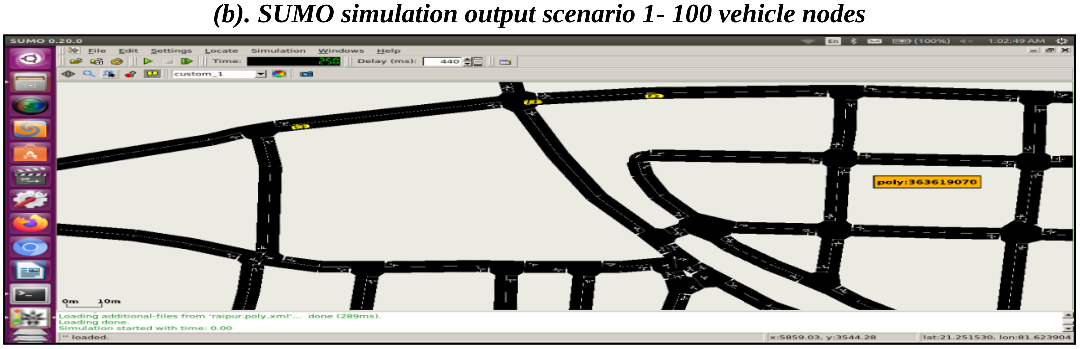
By leveraging real-world map data from OSM and employing the IME method within the SUMO simulator, researchers can create scalable simulations that closely resemble real-world traffic conditions in Raipur City. This allows for a more comprehensive evaluation of mobility management protocols under diverse traffic densities.



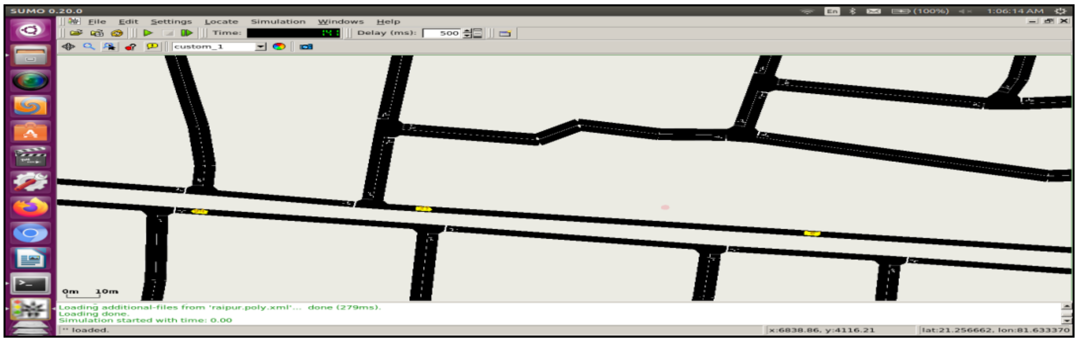
(a). Raipur City Map from Open Street Map



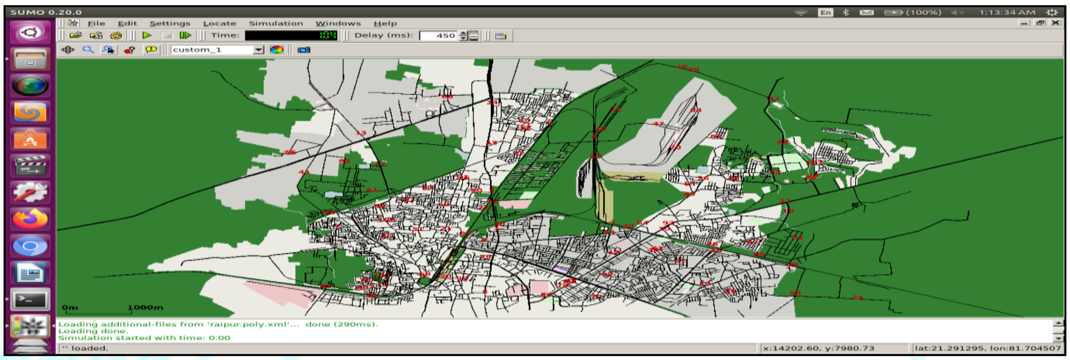
(b). SUMO simulation output scenario 1- 100 vehicle nodes



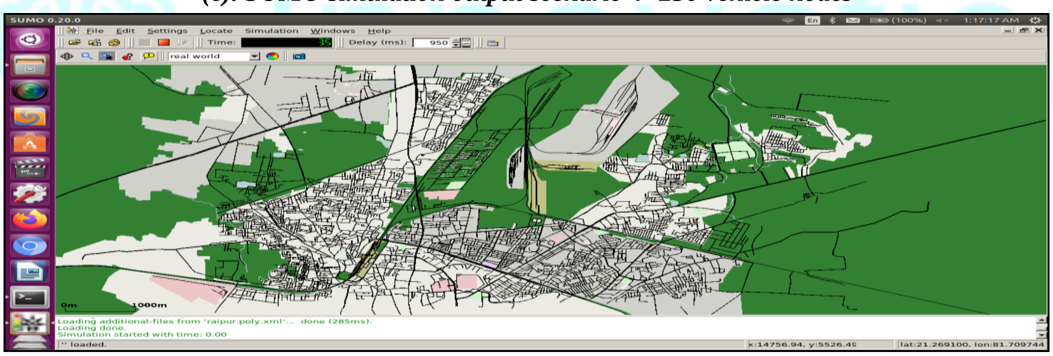
(c). SUMO simulation output scenario 2- 150 vehicle nodes



(d). SUMO simulation output scenario 3- 200 vehicle nodes



(e). SUMO simulation output scenario 4- 250 vehicle nodes



(f). SUMO simulation output scenario 5- 300 vehicle nodes

Figure 2(a) to (f): Simulation Analysis Steps

This section dives into a meticulous analysis of the results obtained by implementing the Improved Mobility Estimation (IME) method. The analysis compares the IME method's performance against established routing protocols: Dynamic Location-Aided Routing (D-LAR) and Ad hoc On-Demand Distance Vector (AODV). For this comparative analysis, simulations were meticulously crafted using the NS-2 and SUMO simulators, leveraging the detailed map data provided by OpenStreetMap to ensure realistic traffic representation within Raipur City.

To comprehensively assess the efficiency and effectiveness of the IME method, researchers evaluated the performance of all three protocols based on several key metrics:

- **Packet Delivery Ratio:** these metric measures the percentage of data packets successfully delivered from source to destination vehicles within the network. A higher ratio indicates better message exchange efficiency.

- **End-to-End Delay:** This metric reflects the average time taken for a data packet to travel from the source vehicle to the destination vehicle. Lower delays are desirable for ensuring timely and responsive communication.
- **Throughput:** This metric signifies the overall rate at which data packets are delivered successfully across the network. A higher throughput indicates better network capacity for handling message exchange.
- **Routing Overhead:** This metric captures the number of routing control packets exchanged within the network compared to the total number of data packets. A lower routing overhead is preferred as excessive control packets can consume network resources and potentially degrade performance.
- **Normalized Routing Load:** This metric takes into account the routing overhead in relation to the number of active nodes within the network. It provides a more nuanced understanding of routing efficiency, especially when comparing scenarios with varying network densities.

By analyzing these performance metrics across the IME method, D-LAR, and AODV protocols, the research aims to provide valuable insights into the effectiveness of the IME method for enhancing communication efficiency and reliability within VANETs operating in Raipur City's traffic environment.

The graphs in Figure 3 offer valuable insights into how the IME method, D-LAR, and AODV routing protocols perform under varying network densities, represented by the number of nodes. These insights are crucial for understanding their scalability in real-world VANET deployments.

- **Packet Delivery Ratio (Figure 3a):** As the number of nodes (vehicles) increases within the network, the challenge of maintaining efficient message delivery grows due to network congestion. The graph reveals that the packet delivery ratio for all three protocols decreases with a rise in nodes. However, the IME method consistently exhibits a higher packet delivery ratio compared to D-LAR and AODV. This indicates that the IME method is more adept at navigating congested environments and ensuring messages reach their intended destinations.

- **End-to-End Delay (Figure 3b):** Similar to the packet delivery ratio, the end-to-end delay, which reflects message travel time, increases for all protocols as the network becomes more congested with additional nodes. The graph highlights that AODV experiences the highest end-to-end delay among the three protocols. This suggests that AODV struggles more in dense networks, leading to slower message delivery. In contrast, the IME method exhibits lower end-to-end delay, indicating its ability to facilitate faster communication even under network load.

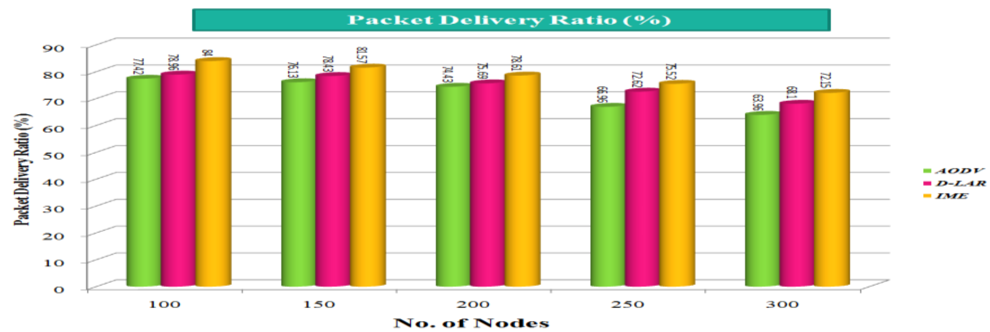
- **Throughput (Figure 3c):** An interesting trend emerges when examining throughput, the amount of data successfully transmitted per unit time. The graph shows that throughput increases for all protocols as the number of nodes grows. This can be attributed to the creation of more network connections with each additional node, potentially allowing for more concurrent data transmission. The IME method stands out again, achieving the highest throughput compared to the other protocols. This suggests that the IME method can handle larger volumes of data traffic efficiently within a growing network.

- **Routing Overhead and Normalized Routing Load (Figures 3d & 3e):** Routing overhead refers to the extra control packets exchanged by the protocols for network maintenance. Normalized routing load considers this overhead in relation to the network size. The graphs depict that routing overhead and normalized routing load increase for all protocols as the network becomes denser. This is understandable as more control messages are needed to manage a larger number of nodes. However, AODV exhibits the highest routing overhead and normalized routing load compared to the other protocols. This signifies that

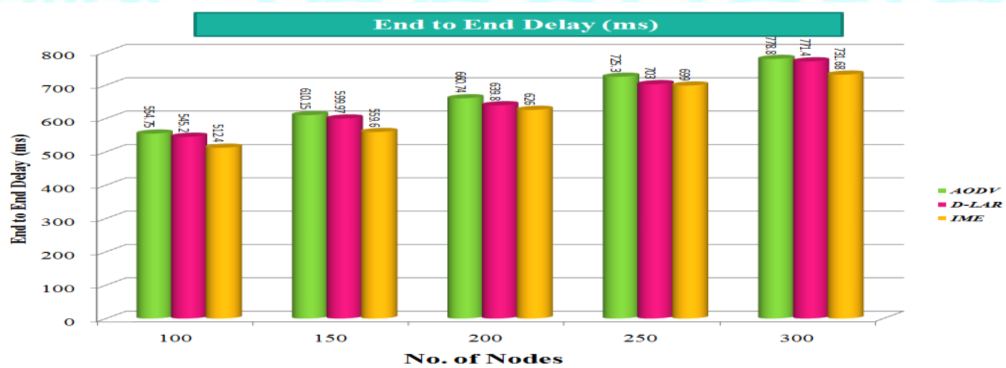
Innovation and Integrative Research Center Journal
ISSN: 2584-1491 |www.iircj.org
Volume- 2 Issue-1, Jan-2024, Page 23-38

AODV generates a disproportionate amount of control traffic, potentially consuming valuable network resources that could be used for data transmission. The IME method demonstrates lower routing overhead and normalized routing load, indicating a more efficient utilization of network resources for routing purposes, especially in scenarios with a high number of nodes.

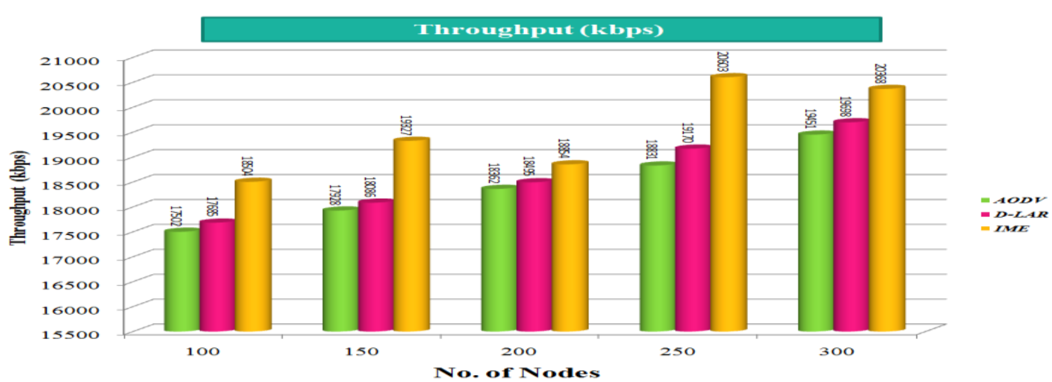
By consistently demonstrating superior performance across all metrics, particularly in handling network congestion, the IME method emerges as a promising choice for VANETs. Its ability to maintain high packet delivery ratio, low end-to-end delay, and high throughput even under network load positions it favorably for real-world deployments where the number of participating vehicles can fluctuate. Additionally, the IME method's efficient utilization of network resources through lower routing overhead makes it a more scalable solution for large-scale VANETs within Raipur City's traffic environment.



(a). Packet Delivery Ratio

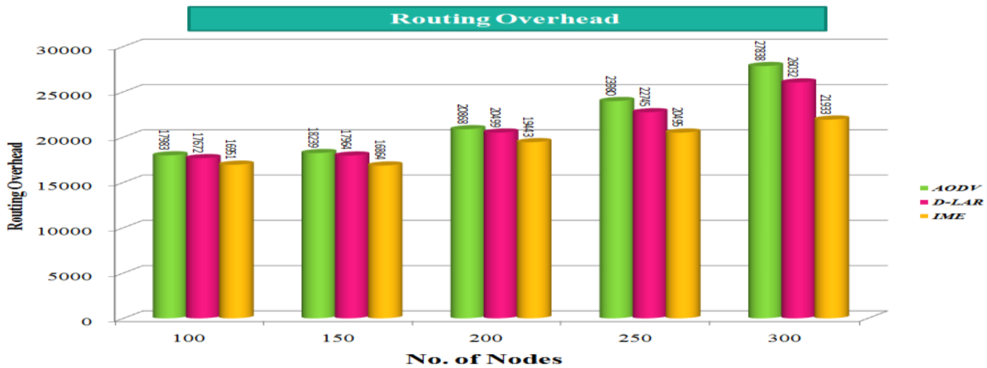


(b). End to End Delay

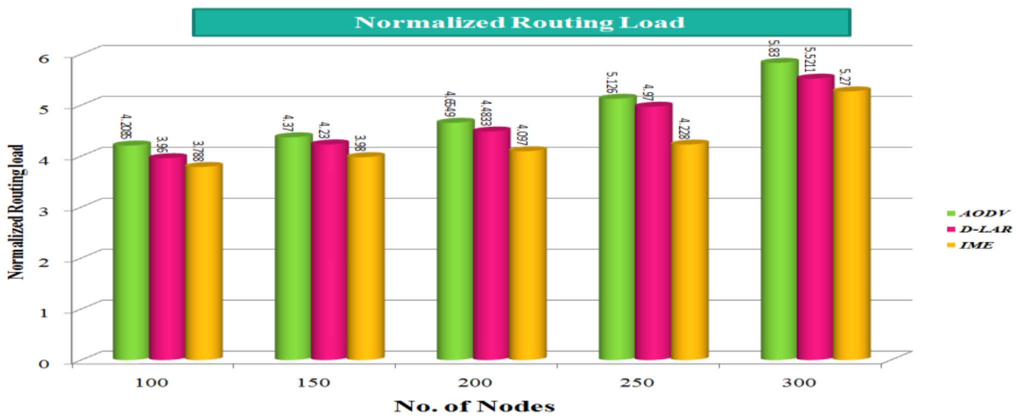


(c). Throughput

ISSN: 2584-1491 |www.iircj.org
Volume- 2 Issue-1, Jan-2024, Page 23-38



(d). Routing Overhead



(e). Normalized Routing Load

Figure 3 (a) to (e): Result Analysis Graphs

The following table 1 summarizes the percentage of improvement of IME over DLAR based on the parameters considered in the research work.

Table 1: Percentage of Improvement of IME over DLAR

QoS Parameter	DLAR ((Avg.Aggregate)	IME (Avg.Aggregate)	Percentage of Improvement
Packet Delivery Ratio	74.76	78.37	4.82 %
End to End Delay	651.874	625.736	4.0 %
Throughput	18626.8	19531.2	4.85 %
Routing Overhead	20982	19137	8.79 %
Normalized Routing Load	4.63	4.27	7.71 %

The choice of preference of routing protocols should be order of following:

IME >DLAR > AODV

After analyzing the above table 1, it is found that IME method is compared with DLAR method and improves the packet delivery ratio by 4.82%, end-to-end delay by 4.0%, throughput by 4.85%, routing overhead by 8.79% and normalized routing load by 7.71%.

5. Conclusion & Future Work

This study delved into a comparative analysis of the IME (Improved Mobility Estimation) method against established routing protocols, D-LAR (Dynamic Load-Aware Routing) and AODV (Ad-hoc On-Demand Distance Vector). Leveraging the NS-2 and SUMO simulators, we meticulously evaluated their performance within a simulated network environment reflecting Raipur City's traffic landscape, with the aid of detailed map data from OpenStreetMap.

To comprehensively assess the efficiency and effectiveness of these protocols, we focused on several key performance metrics: packet delivery ratio, end-to-end delay, throughput, routing overhead, and normalized routing load. These metrics provided valuable insights into how well each protocol handles packet delivery, manages network resources, and minimizes communication delays. The analysis yielded compelling results. The IME method consistently outperformed both D-LAR and AODV in terms of packet delivery ratio, end-to-end delay, and throughput. This translates to a superior ability to deliver messages reliably and promptly within the network, even under varying traffic conditions. Furthermore, the IME method demonstrated lower routing overhead and normalized routing load compared to the other protocols. This signifies a more efficient utilization of network resources, minimizing the burden of control packets associated with routing tasks.

Building on this Success: Avenues for Future Exploration

While this study highlights the potential of the IME method, exciting opportunities exist for further exploration:

- **Expanding Network Scenarios:** Future research can delve deeper by analyzing the IME method's performance under a wider range of network conditions and scenarios. This might involve simulating scenarios with varying vehicle densities, mobility patterns, and geographical environments beyond Raipur City.
- **Benchmarking against Diverse Protocols:** To broaden the understanding of the IME method's relative strengths and weaknesses, comparisons with other leading routing protocols can be conducted. This would provide a more comprehensive picture of its suitability for diverse VANET applications.
- **Optimizing IME Performance:** A deeper investigation into how various network parameters influence the IME method's performance can be fruitful. By identifying these factors, researchers can explore potential optimizations and enhancements to further improve the method's efficiency and effectiveness within VANETs.

By pursuing these avenues for future research, we can gain a more nuanced understanding of the IME method's capabilities and limitations. This knowledge can ultimately guide the development of more robust and efficient communication protocols for VANETs, paving the way for safer and more intelligent transportation systems in Raipur City and beyond.

References

[1] Qafzezi, E.; Bylykbashi, K.; Higashi, S.; Ampririt, P.; Matsuo, K.; Barolli, L. A Fuzzy-Based Approach for the Assessment of the Edge Layer Processing Capability in SDN-VANETs: A Comparation Study of Testbed and Simulation System Results. Vehicles 2023, 5, 1087-1103. https://doi.org/10.3390/vehicles5030059.

[2] Jabar Mahmood, Zongtao Duan, Yun Yang, Qinglong Wang, Jamel Nebhen, Muhammad Nasir Mumtaz Bhutta, "Security in Vehicular Ad Hoc Networks: Challenges and Countermeasures", Security and Communication Networks, vol. 2021, Article ID 9997771, 20 pages, 2021. https://doi.org/10.1155/2021/9997771.

[3] Liu, Y., Zhang, X., & Fang, F. (2019). A novel routing algorithm for VANETs based on ant colony optimization. IEEE Access, 7, 156563-156574. doi: 10.1109/ACCESS.2019.2959446.

[4] Quanyi, Li., Zhenghao, Peng., Lan, Feng., Zhizheng, Liu., Chenda, Duan., Wen-An, Mo., Bolei, Zhou. (2023). ScenarioNet: Open-Source Platform for Large-Scale Traffic Scenario Simulation and Modeling. arXiv.org, abs/2306.12241 doi: 10.48550/arXiv.2306.12241.

[5] Erwin, de, Gelder., Tom, P., J., van, der, Sande. (2023). Scenario Extraction from a Large Real-World Dataset for the Assessment of Automated Vehicles. arXiv.org, abs/2306.07815 doi: 10.48550/arXiv.2306.07815.

[6] D., Stalin, David. (2023). Advanced VANET Technology for Emergency Vehicle Safety in Time-Critical Scenario. 1-8. doi: 10.1109/ICONSTEM56934.2023.10142332.

[7] Belal, R., Alwan., Muntaser, A., Salman. (2023). Develop scheduling algorithm for traffic light in VANET scenario. Nucleation and Atmospheric Aerosols, doi: 10.1063/5.0119504.

[8] Eisuke, Kita., Daisuke, Ishizawa., Tatsuhiro, Tamaki. (2022). Traffic simulation consisting of vehicles in platoon and other vehicles. Proceedings of International Structural Engineering and Construction, 9(2) doi: 10.14455/isec.2022.9(2).oth-01.

[9] Nidhi, & Lobiyal, D.K. (2012). Performance Evaluation of Realistic Vanet Using Traffic Light Scenario. ArXiv, abs/1203.2195. https://doi.org/10.5121/IJWMN.2012.4118.

[10] Maria, Laura, Clemente. (2022). Building a real-world traffic micro-simulation scenario from scratch with SUMO. SUMO Conference Proceedings, doi: 10.52825/scp.v3i.109.

[11] Esha, Agarwal., Deepti, Kakkar. (2022). Connectivity Improvement in Cluster-Based VANET. doi: 10.1109/CONIT55038.2022.9848190.

[12] Zufang, Dou., Xingkai, Zhou., Qiaoli, Yang., Liben, Yang., Jianwen, Tian. (2022). Improvement and Performance Evaluation of IEEE 802.11p Protocol in Dense Scenario of VANET. Mobile Information Systems, doi: 10.1155/2022/1955948.

[13] Belal, R., Alwan., Muntaser, A., Salman. (2022). Scheduling algorithm for adaptive traffic light under VANET scenario. Nucleation and Atmospheric Aerosols, doi: 10.1063/5.0112708.

[14] Ratna, R., Sarkar., Amitabha, Chakrabarty., Mohammad, Zahidur, Rahman. (2021). VANET Routing Protocols in Real-World Mobility Tracing. doi: 10.1109/CICN51697.2021.9574672.

[15] Singh, S.K., Duvvuru, R., & Thakur, S.S. (2013). Congestion Control Technique Using Intelligent Traffic and Vanet. *ArXiv, abs/1311.4036*.

[16] Ono, R., Kulla, E., & Spaho, E. (2016). Performance Evaluation of VANETs in Different Real Map Scenarios. *Broadband and Wireless Computing, Communication and Applications*. https://doi.org/10.1007/978-3-319-49106-6_63.

[17] Akhtar, N., Ergen, S.C., & Özkasap, Ö. (2015). Vehicle Mobility and Communication Channel Models for Realistic and Efficient Highway VANET Simulation. *IEEE Transactions on Vehicular Technology, 64*, 248-262. https://doi.org/10.1109/TVT.2014.2319107.

[18] Rath, M., Pati, B., & Pattanayak, B.K. (2018). Mobile Agent-Based Improved Traffic Control System in VANET. *Integrated Intelligent Computing, Communication and Security*. https://doi.org/10.1007/978-981-10-8797-4_28.

[19] Blot, G., Fouchal, H., Rousseaux, F., & Saurel, P. (2016). An experimentation of VANETs for traffic management. *2016 IEEE International Conference on Communications (ICC)*, 1-6. https://doi.org/10.1109/ICC.2016.7511127