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Scalable and Robust Mobility Prediction with Traffic Management Strategy for Connected and Autonomous Vehicles

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Abstract - Vehicular Ad-hoc Network (VANET) is a highly trending communication technology and it is developed mainly to handle complicated futuristic environment in the intelligent transportation system (ITS) based applications. In the vehicular network the communication is performed by transmitting the control messages through the roadside units (RSUs) and that leads to increase the communication capacities of the vehicles. In an urban environment recent times the development of vehicles are huge and that leads to the increase of lack of connectivity and other traffic issues among the vehicles which directly affects the communication quality. For that purpose in this article Scalable and robust Mobility Prediction with Traffic Management Strategy in VANETs (SRMPT-VANETs) are developed. This method perform two operation namely effective predictive information gathering and traffic management strategy that helps to control the traffic and to predict the high speed mobility in an effective manner. As the results the communication quality of the urban environment can be improvised. The implementation of this method is done in OMNET++ and as well the matrices which are in use for the performance analysis are The essential metrics to consider are energy efficiency, delay, routing overhead, and packet delivery ratio. In the final step of the study, results are compared to those obtained using reference methods such as the ICFDB-VANET and the RSUCI-VANETs. The results show that the proposed method improves upon the state-of-the-art by 17% in terms of packet delivery ratio and 20% in terms of energy efficiency.

Index Terms: Vehicular Ad-hoc Network (VANET), Effective Predictive Information Gathering, Traffic Management Strategy, Scalable and robust Mobility Prediction

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1. Introduction

Vehicular Adhoc Network (VANETs) is the current trending technology which is the main way to create the future automation based communication. This technology is used to exchange the data among the real time conditions and acts intelligently to achieve road safety [1]. Here communication carried out between any two vehicles and with the infrastructure. At the initial condition the vehicles are moving in the urban area with high speed and mobility so that the timely data transmission becomes a complicated process among the vehicles. Some of the issues which are present in these vehicles are data collision in the wireless medium, congestion and delay [2]. The communication system of VANETs is illustrated in figure 1.

In VANETs sue to the high speed mobility the link establishment among the vehicles are difficult to employ and the data reversal is a failure process and it is highly effective and delayed [3]. The essential parts to handle proper vehicles based communication systems are MAC model with IEEE 802.11 wireless communication. Before initiating the data transmission to find its destination the source node finds its positive neighbors which are present in the line of sight to the destination.

Then the path between the current node and the destination is identified to transmit the data. The distance among the vehicles is periodically analyzed and then the destination location information is found by the source [4]. But still this method is inaccurate and it still needs an improvement. For that purpose in this paper effective prediction of mobility and traffic management is concentrated. And the contribution of the research is described.

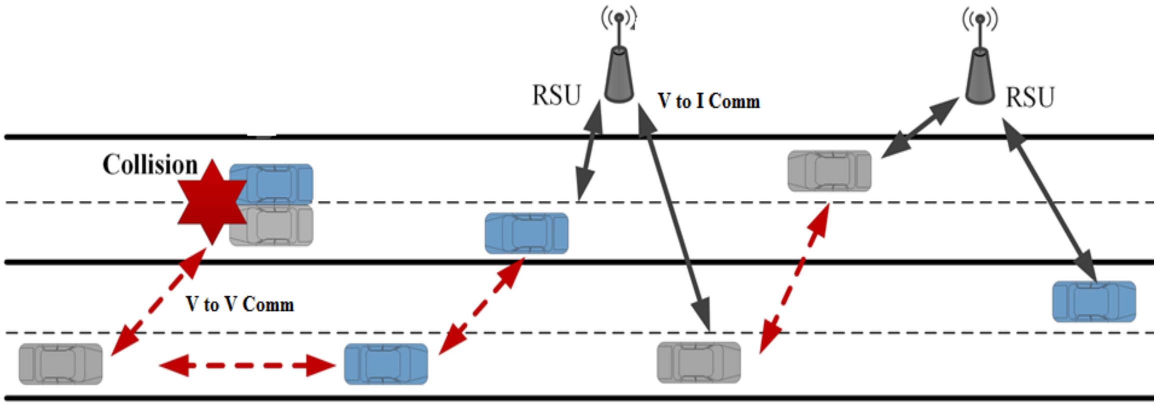

Figure 1. Communication System of VANETs

1.1 Research Contribution

To overcome the current drawbacks like mobility management and traffic control an effective model gets introduced in VANETs called SRMPT-VANETs. The main concentration of this method is effective predictive information gathering and traffic management strategy. Using data gathering process, at the time data transmission among the source and the destination the neighbor selection of the source which is present in the line of sight to the destination is effectively identified and that leads to reduce the network delay and overhead occurrences. Through traffic management strategy the system can able to handle huge density of vehicle with maximum performance. As the results it can be able to achieve high energy efficiency and packet delivery ratio. The organization of the paper is listed. Section 2 discusses previous literature on traffic prediction-based models and identifies the limitations of these models. Section 3 provides a more in-depth explanation of the SRMPT-VANETs methodology and its fundamental ideas. The simulation results and a comparison to the reference methods are presented in sections 4 and 5. Conclusion for the futures are presented in part 6.

2. Related Works

Noura Aljeri, the author of [5], proposed a novel online ML-based Roadside Unit (RSU) prediction Scheme to provide mobile connectivity to the vehicles and to boost the performance of the prediction method by using it in various traffic and mobility areas. This results in high accuracy but has a high delay. The intelligent transportation system was described by Caitlin Facchina in [6]. He used sensor data and information, and he also built a novel distributed congestion management algorithm that helps to distinguish the transmission power depending on the computation of the vehicle speed. Less packet loss is a benefit of this structure, but the negative is the large routing overhead. Route planning and real-time data transmission over the Internet of Things in VANET were suggested by author Awais Ahmad in [7] as a way to manage traffic road monitoring and vehicle safety. The load balancing approach is also utilized to prevent future congestion. In order to improve road safety by lowering traffic accidents, O.Jaiyeoba built connected and autonomous vehicles in VANET. A delay of 4 seconds is recommended to continue with correct avoidance time between leading and oncoming for CAVs.

Nadeem Javaid, the author of [9], suggested an incentive program in VANET to increase traffic efficiency and dependability. This program uses block chain-based data storage as a means of security, trust, and transparency. The program's output is a reduction in transaction costs and storage requirements, but it has a high delay drawback. Kartik Pandit described the adaptive traffic light controller in [10], which organizes and controls traffic with the flow and also provides information about vehicle speed, traffic density, and flow. However, the drawback of this is high energy consumption. The QoS safety messages dissemination protocol was introduced in [11] by author Soumia Bellaouar to guarantee the security of the warning message during broadcast and to prevent problems that may occur during network agglomeration. The quick and effective transmitter provided by this design is a plus, but the high energy consumption is a drawback. In [12], author Miao Zhang provided models and algorithms for creating avoidance schemes to prevent rear-end collisions and junction collisions. This aids in giving drivers information about safe and secure routes, but the drawback is significant routing overhead. The hybrid model in VANET presented by author Pouran Soleimani in [13] has been assessed using NS2 and SUMO, with the advantages being end-to-end latency and the disadvantage being high routing overhead. It is intended to provide comfort and security to passengers while also avoiding communication problems.

Improved Contention Based Forwarding, also known as ICFDB-VANETs, was proposed by author Hajjej in [14] for data broadcasting in VANETs with the goal of reducing network delay, enhancing message coverage, and managing the ongoing re-transmissions process that occurs during data transmission. However, this approach is not appropriate for highly populated areas where there is high vehicle movement. The Roadside Unit Deployment for Coverage Improvement in Vehicular Communication (RSUCI-VANETs) method was introduced by author Navdeti in [15] to improve the communication capabilities of the cars, which are mostly utilized for safety-related applications. This strategy helps to boost the dependability of communication, but it is not appropriate for high-speed vehicles since this model's mobility prediction is subpar. After examination, the shortcomings of the preceding studies and baseline techniques are emphasized in this suggested approach's Mobility Prediction and vehicle traffic management, which improves the vehicular network's overall network performance.

3. Proposed SRMPT-VANETS Approach

Predicting mobility and managing traffic are the key goals of the suggested strategy. The system model, efficient predictive information collection, and traffic management technique are the main categories of the proposed SRMPT-VANETs. Figure 2 details the planned SRMPT-VANETs' procedure.

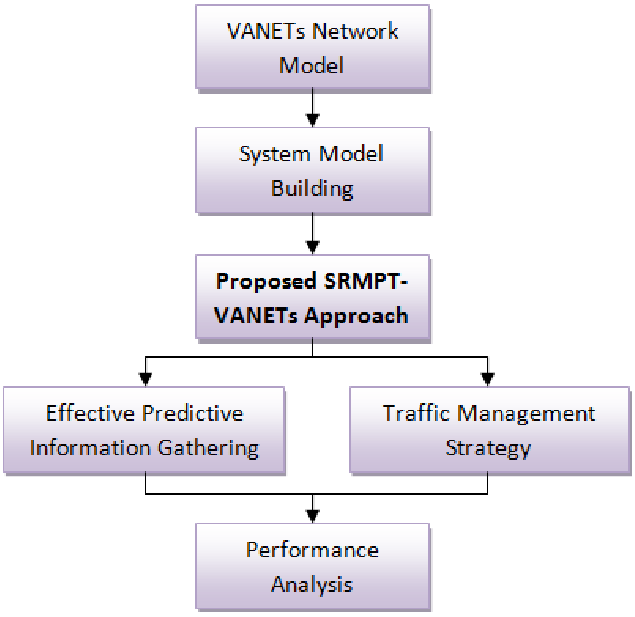

Figure 2. Workflow of the SRMPT-VANETs

The SRMPT-VANETs model is created to manage the vehicles mobility in an effective manner. Achieving to better quality in communication using the high speed vehicles are the complicated task and that is achieved by the proposed SRMPT. The detailed elaboration about the system model and the traffic prediction process of the vehicles are elaborated in the upcoming sub-sections.

3.1 System Model

In order to spread the numerous messages sent by vehicles swiftly, consistently, and efficiently throughout the Smart City network, we presumptively employ two disseminations. The first one uses sensors that have previously been put along highways to provide warning signals to vehicles that are in a Risk Zone (RZ). The second is to use V2V communication to inform the other vehicles as they arrive in order to ensure that alarms are spread. Our recommended SRMPT-VANET approach consists of line architecture and several lanes. employing a Poisson point process, a set of vehicles employing IEEE 802.11p-based radio communication interfaces for DSRC are running on each lane. The communication range of a vehicle is far greater than the width of the road. The ZigBee interface (802.15.4) is used by the sensor nodes to communicate with one another. The nodes are positioned at the edges and in the middle of the highways, closer together than the distance between them and their communication ports. They communicate via a variety of event messages (heterogeneous data collecting, including temperature, speed, etc.). The VANET nodes may communicate with one another through the 802.15.4 interface to exchange routing suggestions as well as warning messages. We anticipate that the sensors will only be put in place in specific areas known as the "Risk Zone" (RZ) or "Risk Area," where accidents are often reported. According to the probability and facts produced by the government on urban roads or highways since doing so would be too expensive, roads are often crowded, or they are at risk of landslides, ice storms, or other catastrophes. Moving vehicles are more worried about an alert in Predictive Zones (PZ), which come before RZs (after those in the RZ). When an accident happens or whenever there is a risk on the road, people should be informed so that they can take precautions and, if required, change their course.

3.2 Effective Predictive Information Gathering

In order to choose the best next-hop forwarder, mobility information is obtained. Assume that at time t_i, current position and vehicle's velocity are presented as $(P_{x_i}, P_{y_i}), (v_{x_i}, v_{y_i})$ and n_i respectively. In a same manner, assume that at time t_r, the current position and vehicle's velocity are givens as $(P_{x_r}, P_{y_r}), (v_{x_r}, v_{y_r})$ and n_r respectively. At time t_i, the mobility information of n_i and vehicle's NeighBor Table (NBT) is given as $NBT_r(i, t_i) = (P_{x_i}, P_{y_i}), (v_{x_i}, v_{y_i})$. Moreover, $NBT_r(r, t_r) = (P_{x_r}, P_{y_r}), (v_{x_r}, v_{y_r})$. Also, assume that $(P_{x_r}, P_{y_r}), (v_{x_r}, v_{y_r})$ are the current location and speed of the vehicle n_r at time$t_r$and so forth. near neighbor Table (NBT) of vehiclen_r, the details of their mobility n_i at time t_i is represented as an entry$NBT_r(i, t_i) = (P_{x_i}, P_{y_i}), (v_{x_i}, v_{y_i})$. Moreover, $NBT_r(r, t_r) = (P_{x_r}, P_{y_r}), (v_{x_r}, v_{y_r})$. The projected locations of vehicle n_i at time t are as follows, assuming that t is only a little bit bigger than t_i.

$$\begin{cases} p'_{x_i} = P_{x_i} + v_{x_i}(t - t_i) \\ p'_{y_i} = P_{y_i} + v_{y_i}(t - t_i) \end{cases} \tag{1}$$

Likewise, we develop $NBT_r(r, t_r) = (p'_{x_r}, p'_{y_r}, v_{x_r}, v_{y_r}, t)$. Instead of using out-of-date information from the NBT, The predicted present positions of the vehicles in the NBT are used to select the optimal next-hop forwarder. Because there are so many high-mobility vehicles, it is difficult to forwarder interest to reach producers rapidly and send Data back to consumers based on the opposite manner in vehicular networks. In NBT, the vehicle that is farthest from the current forwarder and has the longest stable link is picked. The Link Expired Time (LET) and Distance along the Road (DR) of each pair of neighboring nodes may also be calculated based on their current positions. For instance, the LET between nodes n_i and n_r at time t is calculated as follows:

$$L\,(n_i, n_r) = \frac{-\,(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \tag{2}$$

Where$a = v_{x_i} - v_{x_r}, b = p'_{x_i} - p'_{x_r}, c = v_{y_i} - v_{y_r}, d = p'_{y_i} - p'_{y_r}$. The DR between node n_i and n_r is measured as follows

$$D(n_i, n_r) = d(n_i, n_r)\cos\left(\alpha - arctan\left|\frac{p'_{x_r}-p'_{x_i}}{p'_{y_r}-p'_{y_i}}\right|\right) = \sqrt{(p'_{x_i} - p'_{x_r})^2 + (p'_{y_i} - p'_{y_r})^2}\cos\left(\alpha - arctan\left|\frac{p'_{x_r}-p'_{x_i}}{p'_{y_r}-p'_{y_i}}\right|\right) \tag{3}$$

This is the formula for the Euclidean distance between two vehicles: d(n_i,n_r). You can get driving directions from the digital map. (α). The DR is utilized to contact the service provider quickly rather than relying on the Euclidean distance between vehicles to distribute interest. Using (2) and (3), we can calculate the LET and DR for every pair of cars in NBT. There is provided the pseudo-code for this helpful predictive information procedure.

With the help of this information gathering process the communication among the vehicles are performed without any loss of packets which results in the enhancement in data transmission quality.

Pseudo code:

Inputs: projected locations of vehicle n_i, the LET between nodes n_i and n_r ($L\ (n_i, n_r)$), DR between node n_i and n_r ($D(n_i, n_r)$)

Output: Effective prediction

1: State vehicle data transmission

2: for each N do;

$$\begin{cases} p'_{x_i} = P_{x_i} + v_{x_i}(t - t_i) \\ p'_{y_i} = P_{y_i} + v_{y_i}(t - t_i) \end{cases}$$

3: end for

4: for each N do;

$$L\ (n_i, n_r) = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$

5: end for

6: for each N do;

$$D(n_i, n_r) = d(n_i, n_r)\cos\left(\alpha - arctan\left|\frac{p'_{x_r} - p'_{x_i}}{p'_{y_r} - p'_{y_i}}\right|\right)$$

$$= \sqrt{(p'_{x_i} - p'_{x_r})^2 + (p'_{y_i} - p'_{y_r})^2}\cos\left(\alpha - arctan\left|\frac{p'_{x_r} - p'_{x_i}}{p'_{y_r} - p'_{y_i}}\right|\right)$$

7: end for

8: Finish

9: Effective prediction

3.3 Traffic Management Strategy

VANET networks are currently limited in that they can only be controlled inside a specific zone and cannot be controlled outside of that region. The use of the Internet is another need for IOV technology, which is a challenge. The recommended framework combines IoV and VANET to support a broader environment. By doing so, the aforementioned problems are addressed, IoV's communication capacities are enhanced, and network stability is maintained. There will always be a need for the ambulance and fire trucks to get on the scene quickly in an emergency. It is necessary to have an effective method of communication between emergency vehicles, traffic lights, and other vehicles because communication between mobile nodes, road units, and traffic lights must go on until the emergency vehicle successfully reaches its objective. The initial strategy was to select a green channel and pick the route with the maximum capacity to allow the emergency vehicle to reach its destination as quickly as feasible. The objective of this operation is to control traffic and traffic lights simultaneously in order to limit the amount of traffic on the road and to give emergency vehicles the greatest priority. While VANET networks are used inside the area to connect automobiles together, IOV technology is employed outside the area to control traffic and traffic lights. This hybrid paradigm allows for the control and dominance of all necessary pathways. Furthermore, the emergency vehicle may be led properly at the same time. The SRMPT-VANETs' excellent mix of predictive information gathering and traffic management has significantly improved the communication standard that lessens data collision during data transfer between vehicles.

4. Research Experimentations

The section presents the proffered SRMPT-VANETs simulation result calculation and contrasts it with prior methods like ICFDB-VANET [14] and RSUCI-VANETs [15]. Considerations such as packet delivery success rate, latency, and routing overhead [15], and energy efficiency are taken into consideration while computing the results. The OMNET++ simulation application, which runs on the Ubuntu operating system, is used to carry out the simulation. The input parameters which are considered for this research are described in table 1.

Table 1. Simulation Settings

Input Parameters	Values
Implementation Time	100 ms
Propagation Model	802.11
Network Density	750m*750m
Vehicles Numbers	250 Vehicles
Initial Energy	100 Joules
Vehicles Speed	30 km/hr
Network Layer	AODV
Transport Layer	RTP/UDP

4.1 Estimating Energy Savings

The leftover energy is measured after a simulation with a user-specified number of nodes has terminated. Maximizing energy efficiency is critical for enhancing connectivity in networks. Figure 3 provides a visual representation of energy efficiency estimates, showing that the proposed SRMPT-VANETs are more efficient than the ICFDB-VANET and the RSUCI-VANET. The improved energy efficiency of the proposed SRMPT-VANETs is due to its dual focus on prediction-based data collecting and traffic management. As a result of these measures, the energy efficiency of the network improves, and vehicle power consumption decreases.

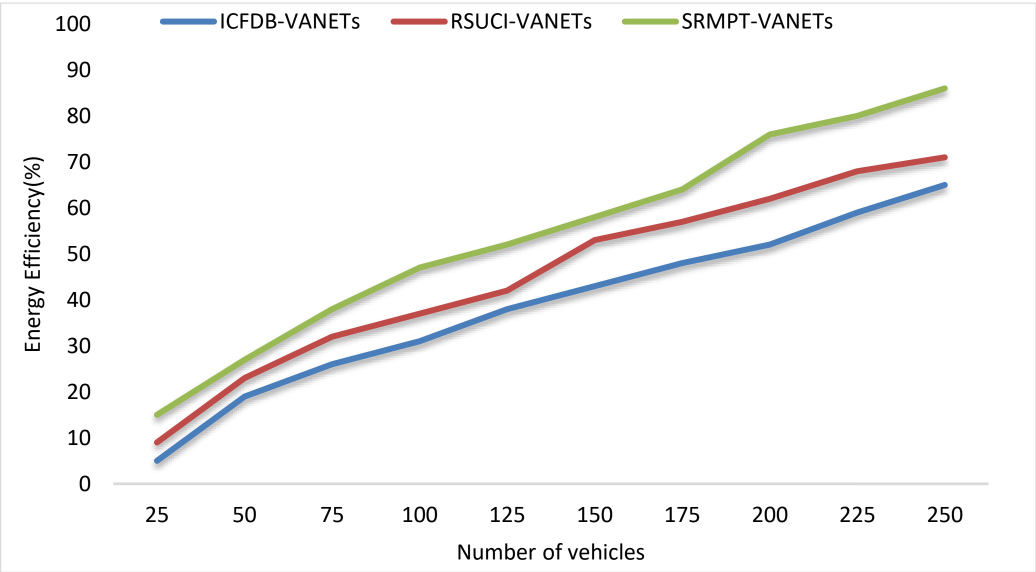

Figure 3. Estimating Energy Savings

4.2 The data packet delivery ratio

It is the number of packets sent from the source divided by the total number of packets sent. Figure 4 is a graphical representation of the packet delivery ratio computation, which makes it easy to see why the proposed. SRMPT-VANETs perform better than other approaches like ICFDB-VANET and RSUCI-VANETs. Because, in the proposed work the congestion reduction and effective traffic allocation is highly concerned and that reduces the delay which allows more packets in the queue that is the reason to attain maximum delivery ratio among the vehicles at each instant of data transmission.

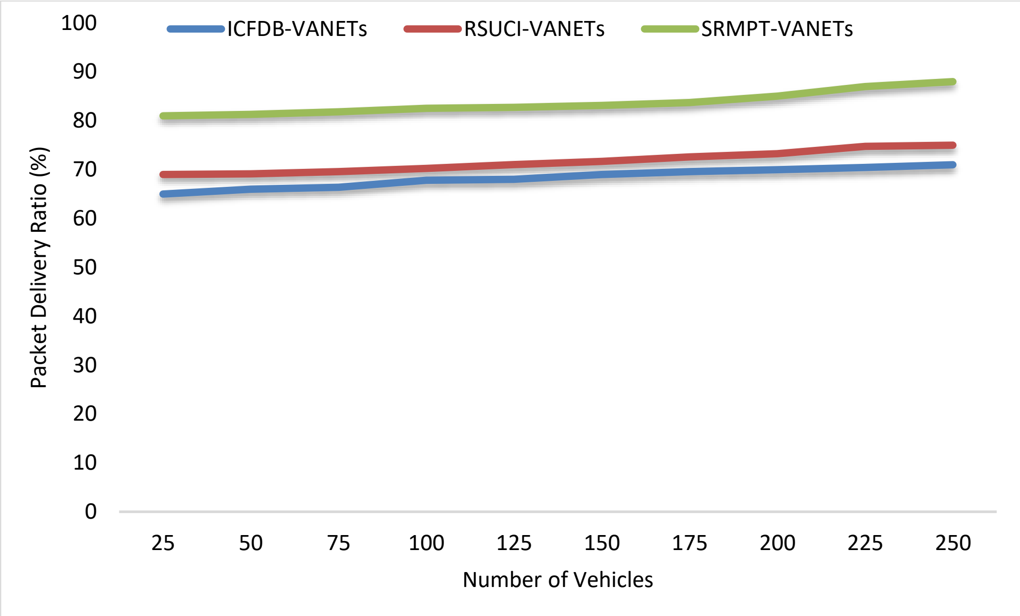

Figure 4. Calculating the Packet Delivery Success Rate

4.3 Transportation Cost Estimation

It involves computing the sum of all data packets created by the source and all data packets delivered to all nodes. The proffered SRMPT-VANETs offered less routing overhead when compared to existing techniques like ICFDB-VANET and RSUCI-VANETs, as shown by the graphical explanation of routing overhead computation in figure 5. Hence in the proposed SRMPT-VANETs many packets are transmitted in the queue with effective traffic management, the data forwarding ratio from the destination to the source is highly reduced and that results in the decrease of routing overhead.

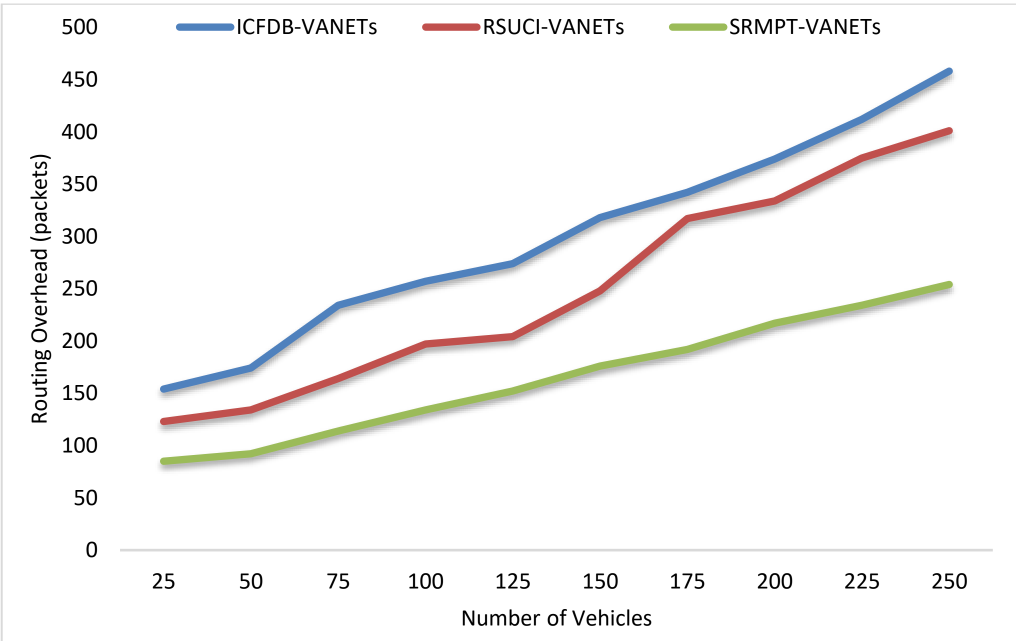

Figure 5. Transportation Cost Estimation

4.4 Total Time Delay Estimation

Delay from sending a data packet from one node to another, including transmission and reception times. Figure 6 displays the end-to-end delay calculations for the approaches utilized in this study for various values of n, and it is clear that the suggested SRMPT-VANETs resulted in the least amount of end-to-end delay when compared to the earlier approaches.. ICFDB-VANET and RSUCI-VANETs. The proposed work is mainly designed to perform effective traffic control as the results delivery ratio can be increase and the delay production among the vehicles are also reduced.

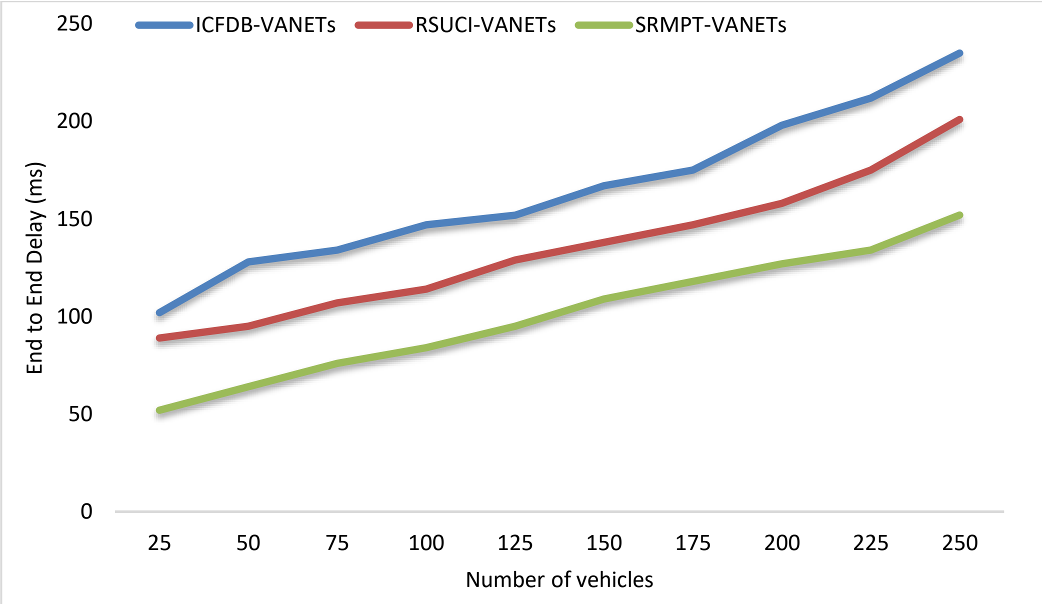

Figure 6. Total Time Delay Estimation

5. Results and Discussion

This section compares and contrasts measurements of packet delivery rate, latency, routing overhead, and power efficiency the ICFDB-VANET, the RSUCI-VANET, and the proposed SRMPT-VANET. The relevant metrics for these methods are shown in Table 2.

Table 2. Analyzing and Measuring Outcomes

Parameters / Methods	ICFDB-VANET	RSUCI-VANET	SRMPT-VANETs
Delivery Ratio	71%	75%	88%
End to End Delay	235 ms	201 ms	152 ms
Energy Efficiency	65%	71%	86%
Routing Overhead	458	401	254

This simulation evaluates the proposed system's SRMPT-VANETs compared to the ICFDB-VANET and the RSUCI-VANET regarding packet delivery rate, end-to-end delay, energy efficiency, and routing overhead in network transmission. The suggested SRMPT-VANETs system obtains a packet delivery rate of 88%, while older approaches like ICFDB-VANET and RSUCI-VANET achieve a rate of 71% and 75%, respectively. Therefore, the proposed SRMPT-VANETs system outperforms the ICFDB-VANET and the RSUCI-VANET in terms of packet delivery rate by 17% and 13%, respectively. The end-to-end latency proposed by SRMPT-VANETs is 152 ms, whereas previous estimates by ICFDB-VANET and RSUCI-VANET were 235 ms and 201 ms, respectively. Therefore, the proposed SRMPT-VANETs system has a lower end-to-end delay than the ICFDB-VANET and the RSUCI-VANET by a margin of 83 ms and 49 ms, respectively. The expected routing overhead of SRMPT-VANETs is 254 packets, compared to over 458 and 401 for ICFDB-VANET and RSUCI-VANET, respectively. This results in a routing overhead for the proposed SRMPT-VANETs technique, 147 packets lower than RSUCI-VANETs and 204 packets lower than that of ICFDB-VANETs. The proposed SRMPT-VANETs strategy has a higher energy efficiency (86%) than the ICFDB-VANET and the RSUCI-VANET (75%) schemes. The suggested SRMPT-VANETs technique reached its best overall performance, as determined by the above computations because it is based on a traffic prediction and management procedure.

6. Conclusion

Vehicular Ad-hoc Networks (VANETs) are used for maximum of the intelligent communication so that it needs continuous improvement. Currently the usage of vehicles is highly increased so that controlling the network traffic becomes the huge challenge. For that reason in the proposed SRMPT-VANETs, effective predictive information gathering and traffic management strategy are concentrated for that the traffic oriented issues are highly managed and as well the mobility of the vehicles are intelligently predicted. The experimental demonstration of the proposed SRMPT-VANETs is performed in OMNET++ here the performance are measured in an effective way by calculating the parameters The findings are compared to the baseline approaches in a number of areas, including Considerations such as packet delivery rate, latency, and routing overhead, and energy efficiency. ICFDB-VANET and RSUCI-VANETs. From the results it is proven that the proposed SRMPT-VANETs achieved 13% to 17% high packet delivery ratio, 49ms to 83ms lower end to end delay, 147 packets to 204 packets lesser overhead and 15% to 21% higher energy efficiency when compared with the earlier methods. In the future direction to future improve the network coverage drone are planned to get introduced.

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