International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 • Website: www.ijfmr.com • Email: editor@ijfmr.com

Data Rate Control and Channel Aware Congestion Managing Approach to Improve QoS in VANETs

Sadhana Parashar[1], Ravindra Tiwari[2]

[1,2]Department of Computer Science & Engineering, Lakshmi Narain College of Technology University (LNCTU), Bhopal, Madhya Pradesh, India.

Abstract

Vehicle ad hoc networks (VANET) require enhanced traffic systems, leading to the development or implementation of the Intelligent Transport System. However, although the situation differs between urban and rural locations, the problem of traffic congestion and the effect it has on the delivery of traffic messages continue to be a serious concern in certain regions. Despite the fact that a significant number of cars send requests for traffic status, they are unable to get accurate traffic-related information because of heavy traffic, insufficient channel capacity, or bandwidth constraints. The purpose of this research is to offer a data rate and channel-aware congestion management technique (DRCA) in order to control congestion and improve Quality of Service (QoS). It is the responsibility of the Roadside Unit (RSU) to gather information regarding the available channel, the interference level, and the signal-to-noise ratio of the nodes in this situation. The performance of all techniques is evaluated using performance measures like as PDR, Delay, Overhead, and data packet drop. The least improvement in DSRC performance is 5% in all of the performance metrics, while the maximum is more than or equal to 10%. The congestion is managed using the DRCS method that has been proposed, and the routing is improved without any additional overhead associated with the transmission of traffic status in the network.

Keywords: Congestion, Channel, Routing, Vehicles, VANET.

1. Introduction

The Vehicular Ad hoc Network, often known as VANET, is a network that facilitates the transmission of communications between vehicles that are located in vehicular regions and are equipped with Road Side Units (RSUs) [1]. The MANET routing standard is followed while establishing the connection for the purpose of obtaining traffic information [2][3]. It is possible to present the driver with information in this way, allowing them to make a decision regarding whether to follow the typical route or an alternative path. A further benefit is that it ensures the driver's safety. Intelligent Transport Systems (ITS) are the most recent advancements in wireless communication technology for vehicle communication. They have considerably decreased the risks associated with transportation by concentrating on the avoidance of accidents, the reduction of collision damage, the management of emergency situations, and the safety of drivers during transportation. It is possible for vehicles and roadside units (RSUs) to be examples of VANET components that are capable of sending packets in multi-hop mode [3][4][5]. As a result of the limited transmission range, communication is carried out by means of a number of hops between intermediary nodes. Vehicles are outfitted with On-Board Units (OBUs), which enable wireless communication between vehicles or between vehicles and remote sensing units (V-to-V or V-to-RSU) across short distances and provide area-specific location information [4]. On the road, the device that supplies the communication infrastructure is called an RSU. OBUs and RSUs of varying types connect with one another in order to share information regarding traffic. Through the use of the Vehicle to Vehicle (V-to-V) and Vehicle to RSU (V-to-RSU) communication protocols, the operation of VANET is illustrated in Figure 1. In this location, only automobiles are able to connect with one another in order to share information about traffic.

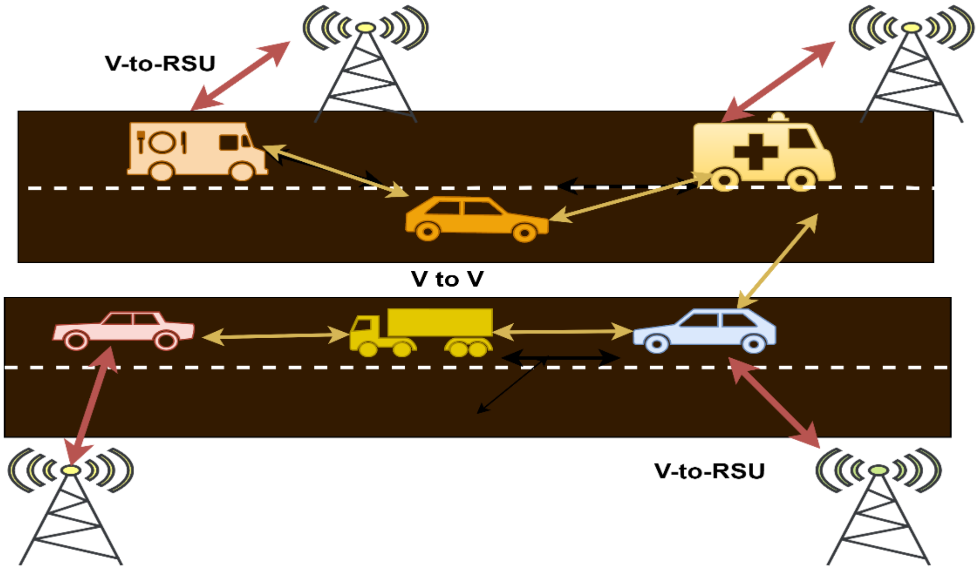

Figure 1 Vehicle to Vehicle and Vehicle to RSU Network

As a result, a VANET is a dynamic automotive network that does not have any fixed infrastructure, such as a base station. The velocity and acceleration of vehicles allow them to drive in a manner that is within conscious control. Controlling the flow of traffic within a certain region is the duty of the RSU, which is also responsible for transmitting the data to the server or to other RSUs, depending on the circumstances. An increase in the number of vehicles connected to a remote service unit (RSU) also results in an increase in the amount of channel contention to the RSU [6][7][8]. This can lead to problems like as increased latency and probable packet loss, which ultimately leads to a decline in the overall performance of the network. In comparison to the costs of deploying MANETs, the costs of deploying VANETs are significantly higher. When opposed to the VANET, which has vehicles that are faster, the MANET has a lesser degree of mobility [9][10]. There is an absolute necessity for communication between high-speed vehicular nodes. Over the course of its existence, the VANET has considered two different ways of communication. The first is called communication between vehicles, and the second is called connectivity between vehicles and the infrastructure that is located along the roadside. Both multi-hop and hop-by-hop are methods of communication that are utilised in VANETs.

2. Congestion issue in VANET

VANETs are a type of ad hoc network in which cars connect with one another and with infrastructure elements to exchange safety-related information, such as traffic conditions and road dangers. Congestion control and channel aware routing is critical in VANETs to support time-sensitive applications and improve overall network efficiency [11][12][13]. Here are some critical considerations to consider while maintain Quality of Service (QoS) in VANETs. VANETs should provide for reliable communication between cars and infrastructure elements. For applications like as collision avoidance, emergency messaging, and traffic management, dependable data transfer is critical [14][15][16]. Techniques for improving dependability include error control coding, retransmission systems, and channel diversity.

- **Energy Efficiency**

Due to the limited electrical resources of VANET vehicles, energy efficiency is critical. While maintaining QoS, energy-aware protocols, power management methods, and sleep/wake algorithms can all help to save energy. VANETs are prone to congestion, especially in busy traffic environments. Congestion management strategies, including as traffic-aware routing algorithms, adaptive data rate regulation, and traffic prediction approaches, help to reduce congestion while maintaining quality of service. To achieve the desired QoS in VANETs, a mix of effective network protocols, intelligent resource management, and tight security measures is required. Future vehicular applications will require communication systems that are dependable, efficient, and secure.

- **Communication Latency**

Real-time applications on VANETs demand low connection latency. For safety-critical applications like cooperative collision alerts, the delay between data transmission and reception must be kept to a minimum. Prioritising, using efficient routing protocols, and optimising network architecture can all help to reduce latency.

- **Scalability**

VANETs should be capable of supporting huge numbers of vehicles as well as scalable services. The network should be able to react to changes in vehicle density and traffic circumstances while maintaining high service quality. Scalability can be improved through hierarchical routing, aggregation, and dynamic resource allocation algorithms. VANETs must guarantee the security and secrecy of all transmitted data. Authentication, access control, encryption, and intrusion detection technologies help to prevent unauthorised access, tampering, and privacy violations.

- **Limited Bandwidth**

VANETs require appropriate bandwidth to support a diverse set of applications and services. Streaming video, creating high-resolution maps, and exchanging real-time sensor data all require a lot of bandwidth. Bandwidth utilisation can be improved through good resource management, channel allocation, and quality-conscious routing techniques. High-speed networks can improve bandwidth utilisation [17].

3. Literature Survey

In this section, we covered prior work on VANET congestion control. The previous study gives knowledge of existing work in the congestion field, allowing for more efficient bandwidth utilisation and vehicle communication.

Wenfeng Li et al. [12] proposed an adaptive beacon generating rate (ABGR) to control traffic based on the number of cars on the road. This was done to address the issues with channel congestion stated earlier. The primary principle underlying the ABGR system is that the pace at which the vehicle sends out beacons varies according to the number of vehicles and the congestion threshold. This decreases the possibility of packet collisions and prevents the channel from becoming overcrowded. The congestion threshold is calculated by considering the impact of vehicle density on the QoS requirements for the safety application. The QoS requirements for three common safety applications with the most stringent QoS requirements are then outlined and assessed. A dynamic application-level reliability evaluation scheme (T-Pro) is proposed based on traffic theory's relationship between vehicle density and speed. Metrics for QoS needs in safety applications must alter when the density changes, not just for different safety applications but even for the same application. One limitation of the research is that it evaluates bacon reception time with varying node density, but in real-world VANET scenarios, vehicle speeds may vary. Beacon messages require unneeded bandwidth for collision detection. More beacon messages indicate poor bandwidth utilisation.

Xiaofeng Liu [13] proposed a new algorithm for controlling traffic jams that considers both the requirement for vehicles to be aware of their surroundings and the necessity to maintain traffic jams at a minimum. In this method, each vehicle has a changeable gearbox power for each BSM. This means that cars near a vehicle receive more BSMs from it, whilst cars farther away receive fewer BSMs. Vehicles that are closest to the EV in terms of safety have a stronger influence on its safety. This is because the time it takes to reach a nearby vehicle is far less than it takes to reach a distant vehicle, resulting in a smaller margin for error. As a result, communicating safety alerts to neighbouring vehicles in a timely manner is critical. The focus is on safety messages and transmission power, yet there is no discussion of the necessity for safety messages in the network or transmission power analysis. The proportion of traffic control and performance improvement is not specified.

Marwan Aziz Mohammed et al. [14] describe a strategy for maximising control channel (CCH) utilisation and adapting control channel interval (CCHI) to emergency scenarios in vehicle settings. More specifically, in an emergency, a portion of the service channel interval (SCHI) is used to ensure that emergency messages are delivered. The laying chicken algorithm was then utilised to determine the optimal CCH utilisation. Finally, comprehensive simulations were run to validate the proposed improved CCH utilisation. Furthermore, the proposed method can be used to satisfy tight emergency message deadlines, allowing vehicles to successfully convey safety-related information Our primary goal is to manage high traffic through the Control Channel (CCH), but we also have other pathways to minimise congestion. This is not covered in the paper. The number of entering and exiting cars at any terminal is missing.

Sofiane Zemouri and her colleagues [15] developed a Prediction and Adaptation Algorithm (P&AA) to improve traffic flow in areas with rigorous beaconing conditions. This method for customising Tx parameters is based on real-time density data that each vehicle can access. However, accurate density forecasts are also essential to enable proactive intervention. A quick TR and TP adjustment technique that assures a low collision rate while maintaining the level of awareness required to operate most VANET applications. A new short-term local density prediction technique forecasts near-future channel demand, allowing for the avoidance of utilisation peaks and control over channel congestion. The research has disadvantages, including the lack of evaluation of power-related metrics due to the availability of a large battery backup. Additionally, packet loss due to congestion and collision analysis is not included in the results.

Mahendra Kumar Subramaniam et al. [16] suggested a TTDCA method to manage congestion in VANET. The channel condition identifies congestion in the vehicular environment. The channel's load is evaluated, and congestion is detected. Following then, the condition is broadcast to nearby users to alert them about the congestion. If traffic is detected using the vehicle congestion index (VCI), data can be broadcast to other cars and the remote service unit. depending on this constraint, a rerouting algorithm considers other routes depending on the remaining number of accessible roadways. The information is subsequently transmitted to the other vehicles, which must reroute themselves depending on the ideal route. Vehicles capture traffic data, and the VCD is used to locate traffic. (A high concentration of automobiles). Path weight computation (PWC) is a method of assessing road levels in order to obtain current data for determining the best route for automobiles. The research has shortcomings such as measuring performance in varied vehicle densities and speeds and not comparing it to other approaches.

G. Soni et al. [17] developed a security strategy for black hole attackers on VANET. Without security guarantees, certain disobedient or malicious cars expose the system to low-quality services or potentially endanger user vehicles in 6G-VANET. As a result, detecting misbehaving or malicious automobiles has emerged as a critical challenge in VANET security. The security approach for locating an attacker's car is based on network traffic data. The method detects the presence of the attacker and calculates the total number of packets dropped in the network by the black hole attacker. The author focusses on attacker detection and prevention without comparing 6G technology to prior generations. There is no mention of attacker infection analysis.

Kashif Nisara et al. [18] proposed a strategy for determining the stability of a routing path using the k-hop method and the projected linking duration. Transceivers are assumed to be built within the cluster's head. The proposed solution leverages packet-level quality routing to address the issue caused by putting packets with various priorities in the same queue. In a real-time application, the message must also be forwarded to the destination within the time frame; otherwise, packets will be lost after exceeding the time limit, resulting in packet loss. The research has disadvantages, including the lack of information on CHs and CMs in each cluster head.

The algorithm discusses location information, but does not provide a technique or standard for maintaining location records.

Sreya Ghosh et al. [19] offered an approach to increase VANET performance. ACO is used in VANET to route data packets along the most efficient path. The primary contribution of the proposed research is an ACO optimization-based technique that is recommended to avoid such a situation where a link fails due to an unanticipated event, such as an accident, and data packets cannot be transferred as a result. The recommended routing technique is intended to find the optimal QoS path between source and destination while minimising hop count and time. Sending packets uses more energy than getting them. As a result, this strategy reduces packet transmission and routing expenses. Ant colony optimisation does not consider or assess pheromone values for multiple pathways. The GPS position information fields are not mentioned. Also not discussed is the scenario when the load is high on the shortest way and low on the long path (not the longest path).

Ankita Srivastava et al. [20] proposed a strategy to maintain optimal results. This paper describes RDACO, a quality-of-service-based, reliable route finding algorithm for VANET that employs ant colony optimisation. Bio-inspired techniques have recently gained a lot of attention because to their potential benefits, which include scalability, self-organization, robustness, adaptability, and failure resistance. Ant-Colony Optimisation (ACO) has gotten a lot of attention among the bio-inspired algorithms proposed so far for VANET data packet routing. The disadvantages of research include only transmitting one packet per second. It takes time to communicate 100 or 1000 packets in a network. Vehicles can only move at 10 to 20 meters per second. At this speed, the probability of congestion and network failure is reduced.

Boubakeur Achichi et al. [21] described a technique for preventing traffic bottlenecks that employs both event-based and measurement-based methodologies. This combination makes it easier to avoid traffic congestion and ensures that security alerts regarding problems are sent out immediately. This strategy is a dependable and effective solution to reduce congestion and ensure that event security messages are sent swiftly. (A critical communication, such as the presence of an accident or snow). One problem of the research is that it only proposes an idea for congestion control without evaluating its results. The limitations of other approaches are not acknowledged.

4. Proposed Congestion Control Technique

The quality-of-service requirements for safety applications dictates the reliable and timely transmission and reception of data across the network. There is a chance that channel contention and congestion will get worse if multiple vehicles try to send a route or safety message at the same time in a small region. Because of this, congestion control mechanisms are very important for ensuring that safety applications work reliably and effectively.

4.1. Proposed Algorithm

In this section, we describe the proposed DRCA algorithm, which is able to control the congestion of vehicular communication. We split the algorithm into three sections: the input initial setup phase, the output phase, and the algorithm execution phase. In this section, we describe the implementation of algorithms in a step-by-step manner.

4.1.1. Steps for Implementation:

1. **Initial Setup:** Each vehicle is equipped with the ability to sense network conditions and gather CSI.
2. **Continuous Monitoring:** Vehicles continuously monitor the network for ADR and CSI parameters.
3. **Data Rate:** Based on the monitored data, the rate adaptation algorithm adjusts the transmission rate to optimize communication.
4. **Congestion Control:** The congestion control algorithm uses CSI to manage channel access and prioritize safety messages.
5. **Feedback and Learning:** Vehicles exchange feedback about their network experience, which helps in refining the rate adaptation and congestion control algorithms.

Input:

Ψ: Vehicle Radio Zone 550^2 Meter
V_n: Vehicle in network
T_n: Transmitter vehicle $\in V_n$
R_n: Receiver vehicle $\in V_n$
M_n: vehicles in path $\in V_n$
RSU_k: centralized road side unit
DRCA: Data Rate Congestion Aware module
AODV: Routing strategy
S_{nc}: sense network condition
d_{rate}: data rate
Ch_a: available channel
th_r: threshold (60% channel capacity)
d_{rc}: ± change data rate
Ch_{ld}: channel load
Int_l: interference level
R_{req}: Route request message

SnR: Signal to Noise ratio
D_t: Data Type (tcp/udp/safety)
P_{rt}: data priority (safety message → High, normal message→ Low)
F_b: feedback by vehicles
Output: Rear-end chain collision warning (RCW), Cooperative collision warning (CCW), Packet Reception ratio (PRR), delay (ms), Percentage of data receives (PDR), Normal routing load (NRL).
Execution Steps:
D_{rca} Route Discovery Process
Step1: Deploy RSU_k and form V_n
Step2: configure all initial parameter by V_n
Step3: T_n start search route to take service from V_n
Step4: T_n call AODV(T_n, R_n/RSU_k, AODV)
Step5: **While** M_n!= R_n || ∀M_n!= visited **do**
Step6: **If** M_n in Ψ of RSU_k&M_n!= R_n **Then**
M_n receives R_{req}(T_n, R_n/RSU_k, AODV)
RSU_k get detail of M_n(S_{nc}, Cha_a, Int_l, SnR)
Step7: **If** S_{nc} is True & Ch_a ok & Int_l is low & SnR is High **Then**
M_n select in route
M_n forward R_{req}(T_n, R_n/RSU_k, AODV)to next hop
M_{n+1}
Else
$M_n$not full fill criteria
Discard R_{req}(T_n, R_n/RSU_k, AODV)
Stop route broadcasting
RSU_k inform to T_n for new R_{req}packet generation
End if
Else if M_n== R_n**Than**
$R_n$develop routing table(No of M_n,$M_n$id, $T_n$id)
Create reverse path & send ack to T_n
T_n receives ack
T_n call Data_Module(T_n, R_n, D_t)
RSU_k monitor complete path of T_n to R_n
Else
M_n not in Ψ
Re-search route by T_n
End if
End do
Data_Module using DRCA Technique
Step8: Data_Module (T_n, R_n, D_t)
Step9: $T_n$call data generator (tcp/udp)
Step10: T_n start sending data to $R_n$using established route
Step11:
If M_n active in route & forward data to R_n**Then**

$R_n$receives data & send ack to T_n
RSU_kgather of $\forall M_n(Ch_{ld}, Int_l, SnR)$
Else
RSU_k gather of $\forall M_n(Ch_{ld}, Int_l, SnR)$
End if
Step12:
While$Ch_{ld} > th_r$ || $Int_l$is High || SnR is Low
Do
d_{rate}: = d_{rate}: - 10%d_{rc}
M_n check number of used channel & P_{rt}
Step13:
If Ch_a is 0 **Than**
RSU_k make decision to freeze Low P_{rt}channel
Step14:
If (Ch_{ld} || Int_l|| SnR) is not required form than
Go to Step12
Else
RSU_kCheck M_n (Ch_{ld} || Int_l|| SnR) is required form
End if
Else
Ch_ano need to update information
End if
RSU_k monitor continue to control congestion
End do

5. Result Analysis

In this section mention the result analysis of ABGR, DSRC and proposed DRCA approaches in vehicular network. The performance of all approaches measured through performance metrics. The results comparison shows that the performance of proposed DRCA scheme is better as compared to rest of two schemes in VANET.

5.1 Analysis of Cooperative Collision Warning

The continue movement of vehicles are significant on roads because of avoids congestion on roads and in network. Traffic status information plays an important role because it aware the other vehicles to not follow the current path. In this graph measure the performance of Cooperative Congestion Warning (CCW) Vs vehicles density in proposed DRCA and other two approaches. The awareness probability (CCW) in previous ABGR and DSRC is 0.96 and 0. 86 in all vehicles density modules but in proposed DRCA showing better CCW i.e. 0.97b (minimum) in network. The performance of proposed DRCA approach is 0.99 in 200 and 250 vehicles scenarios. The proper channel handling is able to balance to control the congestion in network.

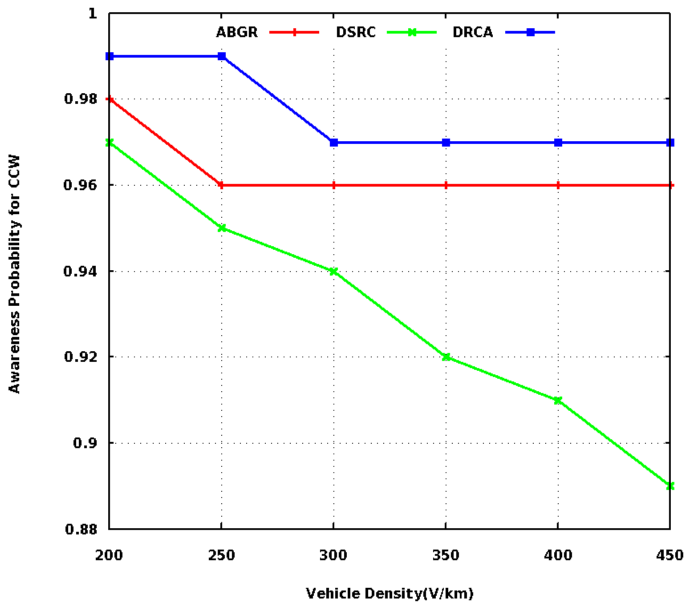

Figure 2 CCW Vs Vehicle Density (V/Km)

5.2 Analysis of Rear-end Chain Collision Warning (RCW)

Congestion in network occurs due to weak connectivity between the nodes or certainly heavy load of packets starts flowing in network. There are different reasons too for congestion but that are based on resources or improper handling of data. In this graph, compare the RCW performance of ABGR, DSRC and DRCA and observed that the performance of proposed scheme is better because of properly detect the congestion and control data rate in network. RCW warning is possible to avoid by ignore other nearby vehicles requests or responses. The performance of proposed DRCA scheme is showing 0.98(minimum) and 0.99 (maximum) awareness probability for RCW.

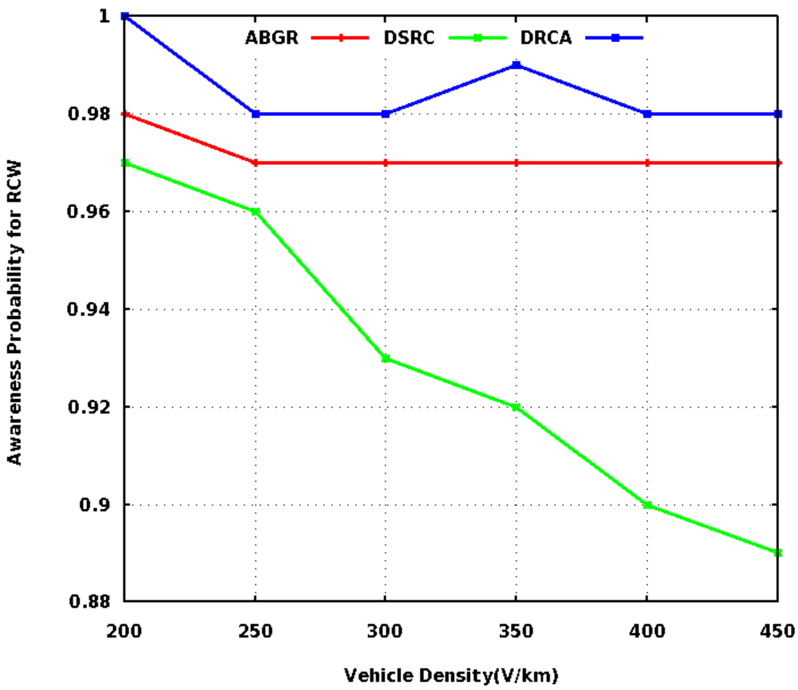

Figure 3 RCW Vs Vehicle Density (V/Km)

5.3 Analysis of Packet Reception Ratios (PRR)

All nearby vehicles, senders or receivers playing an important role in traffic messages forwarding in network. The vehicles in network are continuously need the status of busy areas. The neighbor vehicles forward the actual information to neighbor till destination not found. In this graph, PRR performance is measured of all three protocols but performance of proposed DRCA is better than ABGR and DSRC. Congestion presence is the main hindrance in proper communication between the vehicles but in proposed DRCA scheme congestion is negligible and due to that performance of proposed scheme is showing improvement. Graphs shows minimum 5 % improvement in performance in few vehicles scenario and 10 % (maximum) in rest of them.

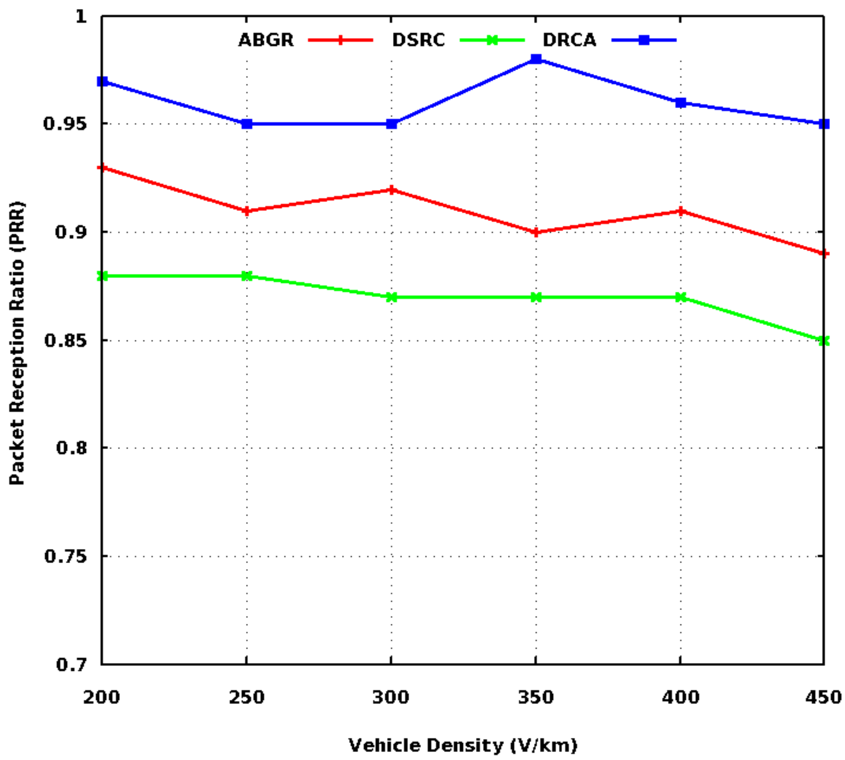

Figure 4 PRR Vs Vehicle Density (V/Km)

5.4 Analysis of Delay [ms]

Numbers of vehicles are moving on the roads and continuously transferring the traffic status information to other vehicles in network. As we know that the connection between the vehicles is dynamic and continuously changing and the role of RSU unit is also specific. Congestion in network is directly affect the normal message exchange and it is a main reason of delay in vehicles-to-vehicles communication. In this graph compare the delay performance of ABGR, DSRC and DRCA in different vehicles scenario. DRCA scheme is able to handle the congestion properly by that delay is minimum. The number of vehicles is 450 but delay is less than 1milliseconds. It shows the proper response of the vehicles that shows improvement in performance.

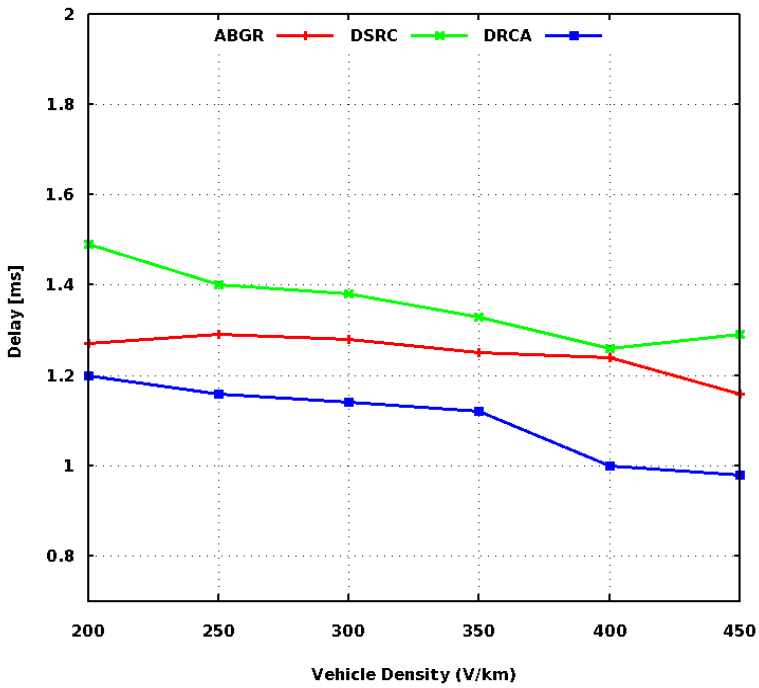

Figure 5 Delay Vs Vehicle Density (V/Km)

6. Conclusion and Future Work

Traffic signals can automatically adjust their timing intervals, eliminating the need for human intervention. Because it makes use of modern technology and automation, the subject of research known as VANET is one that holds enormous potential. In the context of this strategy, the available bandwidth constraint serves as the focal point for all of the actions that regulate congestion. In order to maintain control over the congestion, it is essential to check the channel availability, interference level, and SNR ratio. The obligation will be assumed by RSU in the event that vehicles are unable to transmit the information regarding the current traffic status on the route. If there is a congestion of vehicles in any location, this indicates that the exchange of information regarding the current traffic status has been halted, and drivers of vehicles are waiting for the RSU to resolve the issue and provide a response. The DRCA method examines the available channel load as well as the signal-to-noise ratio (SNR) in order to lower the data rate and manage the congestion. Comparative analysis is performed between the performance of the suggested approach and that of the ABGR and DSRC approaches. The performance measurements demonstrate that the unique DRCA technique generates superior results in terms of performance. The performance takes into account the smallest possible gain in performance and takes into account all of the techniques that were measured in various vehicle densities. To begin, let's begin the comparison with CCW and RCW, and both probabilities are higher than the approaches that came before them. The minimal number of data packets that are dropped is 5%, and the packet delivery ratio (PDR) of the proposed scheme is 10% higher than that of ABGR and DSRC in the network. The DRCA technique also results in a reduction in delay and overhead, with a minimum reduction of 10%. The findings conclude that the DRCA technique performs outstandingly across all aspects. The proposed technique effectively manages congestion and enhances the network's performance in VANET.

There are no congestion criteria given in this article, although the DRCA technique is a congestion control approach. The solution may vary with congestion level; if congestion is high, the solution will also differ.

This means that in the future, you should first determine the status of the congestion, then estimate the load, and finally, apply the proper strategy to it to find a solution.

References

1. Hameed AG, Mahmoud MS. Vehicular Ad-hoc Network (VANET) – A Review. Iraqi International Conference on Communication and Information Technologies (IICCIT). 2022: 367-372.
2. Chandravanshi K, Soni G, Mishra DK. Design and Analysis of an Energy-Efficient Load Balancing and Bandwidth Aware Adaptive Multipath N-Channel Routing Approach in MANET," IEEE Access. 2022; (10):110003 – 110025.
3. Kaurav AS, Dutta SR. Detection and prevention from different attacks in VANET: A Survey. International Conference on Physics and Energy(ICPAE 2021). 2021: (2040).
4. Soni G, Jhariya MK, Chandravanshi K, Tomar D. A Multipath Location based Hybrid DMR Protocol in MANET. 3rd International Conference on Emerging Technologies in Computer Engineering: Machine Learning and Internet of Things (ICETCE). 2020;191-196.
5. Sepulcre M, Gozalvez J, Altintas O, Kremo H. Integration of Congestion and Awareness Control in Vehicular Networks. Ad Hoc Networks. 2016;(37): 29-43.
6. Ishaq M, Malik M H, Aydin M.E. Managing Congestion in Vehicular Networks Using Tabu Search. Engineering Applications of Neural Networks (EANN), Communications in Computer and Information Science.2018;(893).
7. Lee M, Atkison T. ANET Applications: Past, Present, and Future. Vehicular Communications. 2021; (28).
8. Karne RK, Sreeja TK. Review on VANET Architecture and Applications. Turkish Journal of Computer and Mathematics Education. 2021; 12(4).
9. Soni, G., Chandravanshi, K., Jhariya, M.K., Rajput, A. An IPS Approach to Secure V-RSU Communication from Blackhole and Wormhole Attacks in VANET. Contemporary Issues in Communication, Cloud and Big Data Analytics. Lecture Notes in Networks and Systems. 2022 ; (281).
10. Xiao L, Zhuang W, Zhou S, Chen C. Learning-based VANET Communication and Security Techniques. Wireless Networks. Springer: 2019.
11. Valocky F, Mokry D, Orgon M, Bohacik, A. Road Traffic Control Management and Creation of VANET Networks by Vanet Sim Simulator. Springer Conference on Data Science and Algorithms in Systems (CoMeSySo). 2023; (597).
12. Sharma S, Kumar S, Awasthi SK, VANETs: Introduction, Communication Protocols, and Challenges," Chapter 7, Distributed Intelligent Circuits and Systems; 2024.
13. Rashid SA, Audah L, Hamdi MM, Abood MS, Alani S. Reliable and Efficient Data Dissemination Scheme in VANET: A Review. International Journal of Electrical and Computer Engineering (IJECE). 2020 ; 10 (6): 6423-6434.
14. Giripunje LM, Vidyarthi A, Shandilya SK. Routing and Congestion in Vehicular Ad-Hoc Networks (VANET's): Characteristics, Challenges and Solutions. Advances in VLSI, Communication, and Signal Processing. Lecture Notes in Electrical Engineering. 2022; (911)
15. Giripunje LM, Masand D, Shandilya SK. Congestion Control in Vehicular Ad-Hoc Networks (VANET's): A Review. Hybrid Intelligent Systems. HIS 2019, Advances in Intelligent Systems and Computing. 2021; (1179).

16. Liu X, Jaekel A. Congestion Control in V2V Safety Communication: Problem, Analysis, Approaches. Electronics. 2019 :1-24.
17. Liang W, Li Z, Zhang H, Wang S, Bie R. Vehicular Ad Hoc Networks: Architectures, Research Issues, Methodologies, Challenges, and Trends. International Journal of Distributed Sensor Networks. 2015: 1-15.
18. Wenfeng Li, Wuli Song, Qiang Lu, Chao Yue, "Reliable congestion control mechanism for safety applications in urban VANETs," Ad-Hoc Network, pp.1-12, 2020.
19. Xiaofeng Liu, Ben St. Amour and Arunita Jaekel, "Balancing Awareness and Congestion in Vehicular Networks Using Variable Transmission Power," electronics, pp.2-16, 2021.
20. Marwan Aziz Mohammed, Shareef M. Shareef, and Kayhan Zrar Ghafoor, "Adaptive and Optimized Control Channel Utilization in Vehicular Ad Hoc Networks Marwan Aziz," Wireless Communications and Mobile Computing, Willey, 2022.
21. Sofiane Zemouri, Soufiene Djahel, John Murphy, "An Altruistic Prediction-Based Congestion Control for Strict Beaconing Requirements in Urban VANETs," IEEE Transactions on Systems, Man, And Cybernetics: Systems 1, pp.1-16, 2019.
22. Mahendrakumar Subramaniam, Chunchu Rambabu, Gokul Chandrasekaran, Neelam Sanjeev Kumar, "A Traffic Density-Based Congestion Control Method for VANETs," Wireless Communications and Mobile Computing, pp.1-12, 2022.
23. Gaurav Soni, Kamlesh Chandravanshi, "A Novel Privacy-Preserving and Denser Traffic Management System in 6G-VANET Routing Against Blackhole Attack," Sustainable Communication Networks and Application, 2022.
24. Kashif Nisara,d, Abubakar Aminu Mu'azub Ibrahim A. Lawalc, Sohrab Khand, Shuaib Memon, "Reliable Priority Based QoS Real-Time Traffic Routing in VANET: Open Issues & Parameter," IEEE 14th International Conference on Application of Information and Communication Technologies (AICT), 2020.
25. Sreya Ghosh Saha Misra, "Enhanced QoS Performance with Reduced Route Overhead by Ant Colony Optimization Algorithm for VANET," IEEE Proceedings of IEEE Applied Signal Processing Conference (ASPCON), pp. 237-241, 2020.
26. Ankita Srivastava, Arun Prakash Rajeev Tripathi, "Quality-of-Service based Reliable Route Discovery using Ant Colony Optimization for VANET," IEEE Conference on Information and Communication Technology (CICT), 2019.
27. Boubakeur Achichi, Fouzi Semchedine, Lakhdar Derdouri, "Hybrid Approach for Congestion Control in VANETs," IEEE Proceedings of the 7th International Conference on Software Engineering and New Technologies (ICSENT-2018), pp.1-4, 2018.