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Research Article

Quality Of Service (QoS) Framework for Vehicular Communications In VANETS Focused On Message Characteristic Detections

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ARTICLE INFO	ABSTRACT

Vehicular Ad-Hoc Networks (VANETs) are well recognized as a potential technology to improve road safety and promote efficiency in the transportation system. Delivering Quality of Service (QoS) for VANET is a serious challenge, due to mobility features of vehicles. This paper also investigates state of a art QoS-based framework for VANETs that applies message properties to recognize and assign priority means to the messages. Through this proposed method, the adjustment of network configurations is performed, allowing the critical messages to be prioritized and transmitted as per the guarantee. The proposed model obtained a 95.14% packet delivery ratio, 4.86 msend-to-end delay, 93.62% network throughput, 89.98% Transmission Data rate, and 93.87% Bandwidth Utilization. Simulation results prove the effectiveness of the proposed method in improving QoS parameters. With QoS support, VANETs can be used for practical applications, which can significantly improve VANETs by ensuring reliability and efficiency.

Keywords: Vehicle, Ad-Hoc Networks, Quality of Services, Infrastructure, Delay, Throughput

1. Introduction

A vehicular ad-hoc network is a type of wireless communication network that extends connectivity beyond automobiles through communication with roadside infrastructure. Such communication is an important aspect of modern transport and could significantly improve road safety, the effectiveness of the road network, and the driving experience in general. The fundamental purpose of vehicle communication in the context of VANET is to convey real-time data between infrastructure and vehicles. These could be road conditions, neighbouring traffic conditions, accidents, or any other information of interest. By sharing these facts, vehicles are able to make more educated decisions and improve their performance in preventing accidents on the road. Dedicated short-range communication (DSRC) is a critical component in vehicular networks. Like Wi-Fi, it uses the same standard, IEEE 802.11p, but it is designed explicitly for automobile communications. Its operating frequency range is 5.9 GHz, enabling high-speed communications and rapid, efficient message passing with surrounding vehicles. This allows vehicles to communicate with each other through different means using devices called DSRC. These technologies allow vehicles to communicate with other cars and elements of infrastructure. The MAC protocol allocates time slots to vehicles for communication which are free of collision or interference from other vehicles with similar messages.

They might do this by communicating their state and velocity, individually and as a group. This will help avoid accidents and allow for route optimization, cutting down on time spent on the road, and reducing fuel consumption and emissions. This function could be supportive of users located in crowded urban areas with high transportation difficulties. However, with the widespread deployment of vehicular communication in VANET, new services and applications have emerged in transportation systems. It might send real-time alerts regarding nearby parking areas, gas stations and restaurants to cars, leading to a hassle-free driving experience for the users.

QoS in VANETs is aimed at ensuring reliable and fast data packet delivery between vehicles in the network. VANETs, as a class of networks, are continuously evolving mainly because of vehicles which are in constant motion, changing their geographical position. As a result, achieving a stable and reliable communication link between vehicles remains challenging. Percentages of critical messages delivered in time despite adversities are significantly improved with the use of traffic prioritization and adaptive routing algorithms. This will act as a responsible use of network resources for property communication quality. Without proper QoS management, these networks can quickly become congested and experience delays and packet loss. QoS handling mechanisms, including admission control, rate limiting, and bandwidth management, are highly needed to control flow and avoid congestion. It also allows us to prioritize different types of data and use bandwidth packets wisely so that important communication between vehicles is never interrupted. QoS is a requirement to enable security and privacy in VANETs. QoS mechanisms ensure the security of communication between vehicles and protect against cyber-attacks. They also help ensure the owner's privacy by hindering correlative tracking of their movement through traffic, as each vehicle appears as simply a point of motion rather than a distinct vehicle [29]. VANETs are anticipated to enable a variety of applications. Different QoS requirements for each of these applications The QoS mechanisms enable the differentiation of traffic and the allocation of network resources according to these requirements. Requirements for many applications may take precedence over others for timely and accurate delivery. QoS ensures that the network remains resilient and stable. The vehicular mobility in VANETs leads to varied network topologies. Such route failures are able to break communication [30]. The communication between vehicles can be ensured without being interrupted by disruptive nodes using various QoS protocols. The prime contribution of the proposed research has the following,

- The proposed model can help with traffic management in VANETs by prioritizing traffic types. Emergency vehicles and public transportation can be assigned higher priority, allowing for better traffic flow and less congestion across the network.
- The designed QoS-supported mechanisms are adaptive to the substantially changing network conditions of the vehicular ad hoc network. They constantly update the QoS parameters of their devices according to the current network condition and adapt to give the best performance.
- The proposed QoS mechanism can provide smooth handoff processes by prioritizing and managing traffic for packet transfer, thus decreasing packet loss probability, and sustaining continuous communication.
- The proposed QoS model can contribute to enhanced quality of service across VANETs. Applications that require better quality communication are getting that by the network.

2. Related Works

Fatemidokht H. et al. [14] have explored clustering in the context of vehicular ad hoc networks under QoS measures and hostile car monitoring. Clustering's purpose is to improve network QoS performance and security by grouping reliable vehicles to form trust and to detect and quarantine malicious vehicles. Jubair, M. A. et al. [15] for improving the energy efficiency and security of VANETs. Incorporating a combination of cluster routing and encryption techniques improves service and provides safety from menacing sources, thus providing more efficient and secure communication in the network. Zhao J. et al. [16] focused on a research study providing interference-based Quality of Service and capacity assessment of Vehicular Ad Hoc Networks for safety applications. A vehicle gets authenticated, which might make it possible for attackers to break the system and obtain sensitive information or replay the message of the sender. Sarlak A. et al. [17] explores the measures designed to enhance service quality both for Delay-Tolerant Networks (DTNs) and for non-DTN networks. This approach uses a combination of caching, routing and congestion control techniques to improve message delivery, reduce delay and increase network reliability in highly dynamic, uncertain and intermittent scenarios. Mchergui A. et al. [18] have studied a system that aims to test the performance and dependability of automotive ad hoc networks. It uses fuzzy logic to handle uncertainty in network environments and effectively evaluates QoS metrics such as latency, throughput, and packet loss. This improves the efficiency and dependability of network in-vehicle communications. Ahmed, A. et al. [19] proposes a sophisticated approach: blockchain-based secure communication accompanied by QoS assurance for connected cars over the IoT domain. This system uses edge cloud computing to shorten processing and response times for time-sensitive applications. Oche M. et al. [20] have researched wireless networks enabling communication between automobiles and infrastructure, which is, therefore, vital to providing entertainment services for Intelligent Transportation Systems. QoS-based routing approaches consider various constraints.
McCarthy J. et al. [21] have explored an information-centric approach to QoS in vehicular environments. The service model is centred on QoS with a focus on the desired content and not the specific network architecture or geographic location It facilitates better QoS provisioning and resource distribution systems in order to meet the varying and dynamic needs of vehicle communications. A game-theoretical model which is used to evaluate the QoS-security tradeoff in VANETs is studied in Sun, Z. et al. [22]. have studied a game-theoretical framework to assess the QoS/security trade-off in VANETs. This approach assesses the impact of the automobile security of QoS parameters, security costs, and incentive strategies. This suggests that Quality of Service and security trade off could be improved. Belamri F. et al. [23] [23] focused routing algorithms for vehicle ad hoc networks

in highways. It utilizes a Barris scheme to manage network performance and provide services quality for the internet applications. It also assesses the vehicle density and network stability to determine the most reliable path for data communication.
Vafaei M. et al. [24] proposed an Ant Colony Optimization (ACO) technique for the selection of multiple paths for video streaming in urban VANETs to ensure QoS. So, this method considers the dynamics characteristics of urban environment and the varying network conditions to find the optimal and reliable paths for video streaming. Debnath A. et al. [25] proposed a routing protocol based on dynamic mechanism which improved QoS in vehicle ad hoc networks. By incorporating several factors, the system can offer adaptive intelligence for routing decisions that respond to changing network conditions. Nadarajan J. et al. [26] have proposed a routing algorithm that utilizes machine intelligence to enhance QoS and security in routing decisions for future vehicle ad hoc networks. It calculates the real-time data and employed machine learning approaches for real-time route modification with the aim of optimizing communication efficiency and safety. Evangeline, C. S. et al. [27] Proposed and implemented a segmented approach to selecting an optimal access-network. Then, we evaluate the methods used, the second phase uses fuzzy logic to decide the best network from a set of parameters evaluated. Thanks for this make autonomous cars on-the-fly issue the selection of the network. Rajesh, I. S. et al. [28] Proposed a hybrid-based model that combines the best features of both Fuzzy Logic and machine learning to improve QoS-aware routing in the scope of VANETs. Includes both Fuzzy Logic to handle uncertainty and machine learning to adapt to changes in the network, thereby improving the dependability of the routing decisions.

Table.1: Comprehensive analysis

Authors	Year	Model Used	Advantage	Limitation
Fatemidokht, H., et al. [14]	2020	Clustering Algorithm	This proposed algorithm improves network performance by detecting and isolating malicious vehicles.	Limited to vehicular ad hoc networks and may not be applicable to other types of networks.
Jubair, M. A., et al. [15]	2022	QoS aware cluster head selection	Efficient use of network resources.	This model may not adequately address all security threats.
Zhao, J., et al. [16]	2021	Interference-based QoS	It provides an accurate model for analyzing QoS and capacity in VANETs for safety applications.	It may not account for real-world interference and environmental factors for ideal network conditions.
Sarlak, A., et al. [17]	2021	DTN Based VANET	It can improve the quality of service in both DTN and non-DTN based VANETs.	It may require significant resources and infrastructure updates to be fully implemented.
Mchergui, A., et al. [18]	2020	Fuzzy System	It provides more accurate assessment of QoS in highly dynamic vehicular environments.	It may require a large number of computational resources for complex scenarios.
Ahmed, A., et al. [19]	2022	Blockchain based QoS	Improved security and quality of service in vehicular networks through blockchain and edge cloud computing integration.	It may be limited in scalability and high resource requirements for implementation.
Oche, M., et al. [20]	2020	QoS-based routing	Efficiently supports different types of infotainment services for vehicles.	It may be complex to implement and maintain due to multi-constrained routing requirements.
McCarthy, J., et al. [21]	2021	Information-centric approach	It allows for efficient information retrieval and sharing in vehicular networks.	It may require significant infrastructure and network support to fully implement and maintain.
Sun, Z., et al. [22]	2021	Game theoretical approach	It provides a comprehensive analysis of QoS and security trade-offs in Vehicular ad hoc Networks.	It may not consider real-time changes in network conditions and may not be applicable to all scenarios.
Belamri, F., et al. [23]	2024	Cluster Based QOS-Routing	Efficient utilization of cluster-based communication in highway environments.	Limited applicability in other types of environments (e.g. urban or rural).
Vafaei, M., et al. [24]	2020	ACO Algorithm	It can improve video delivery quality in urban VANETs.	It may not perform as well in high traffic scenarios.
Debnath, A., et al. [25]	2021	Fuzzy logic-based VANET routing	It takes into account dynamic vehicles for more efficient routing	Relies on complex fuzzy logic algorithms, which may be difficult to implement and interpret.
Nadarajan, J., et al. [26]	2021	Secured routing algorithm	Improved performance and increased security in routing decisions.	Dependence on accurate, timely and reliable data inputs for efficient decision making.

Evangeline, C. S., et al. [27]	2022	Fuzzy based access selection	The proposed model can improve network selection accuracy.	It may require significant computing resources and delay in decision-making for real-time applications.
Rajesh, I. S., et al. [28]	2024	Q-learning Scheme	Improved routing decision making in VANET by combining the strengths of fuzzy logic and Q-learning algorithm.	Complexity of implementation and integration of both methods may pose challenges in real-world implementation.

Research Gaps

- VANETs have dynamic and irregular movement trends, which may lead to the poor performance of message identification. Further research is needed to understand which mobility environments work.
- VANETs operate in a dynamic and uncertain environment affected by various factors. Additional research is needed to explore how these contextual factors may affect the recognition of different message features.
- VANETs generate a large volume of data, compressing these data is rather complicated. An appropriate way of data encoding is critical for quickly retrieving the relevant data. Some works studied different encoding/compression methods, verification of features of messages on vehicular channels.
- Due to the increased mobility and dynamic nature of the network in VANETs, they are more prone to loss of packets and issues in transmissions. More research is needed to identify how these barriers affect the maximum perception of different message attributes and how they can be minimized.

Novelty of the research

- The proposed QoS mechanism is aimed towards achieving efficient usage of the existing network resources in VANET infrastructure. This will allow the network to optimize resource allocation and avoid congestion, creating a more resilient, stable, and robust network by distributing use and traffic management depending on importance.
- This proposed QoS system can increase the quality of communication and hence even fortify the network security. Simply put, this ensures that critical safety and emergency messages will be sent quickly (increased efficiency); reducing accidents and providing increased security to the entire network.
- It will provide a better QoS allowing mitigating a bigger number of connected vehicles. It's ensuring that the network effortlessly allocates resources and handles traffic based on priority, enabling consistent and reliable communication between multiple connected devices.

3. Proposed Model

The proposed QoS methodology aims to increase communication by listing messages sent from vehicle to vehicle. To achieve this a combination of methods are used such as priority-based routing, dynamic congestion control and adaptive modulation and coding. Each message has assigned a priority level according to its significance and immediacy, and is routed through the network accordingly. To ensure maximum effectiveness, the technique continuously alters transmission power and data rate based on network conditions. Thus, by recognizing message features, this QoS method can effectively regulate network traffic and ensure timely delivery of critical messages, thereby enhancing the overall communication quality in VANETs.

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3.1. Construction

The CH Vehicle Node The Real-time Event system collects real-time data from multiple sources, such as In-Vehicle Sensors and External Devices. Figure 1 shows the construction of the proposed model

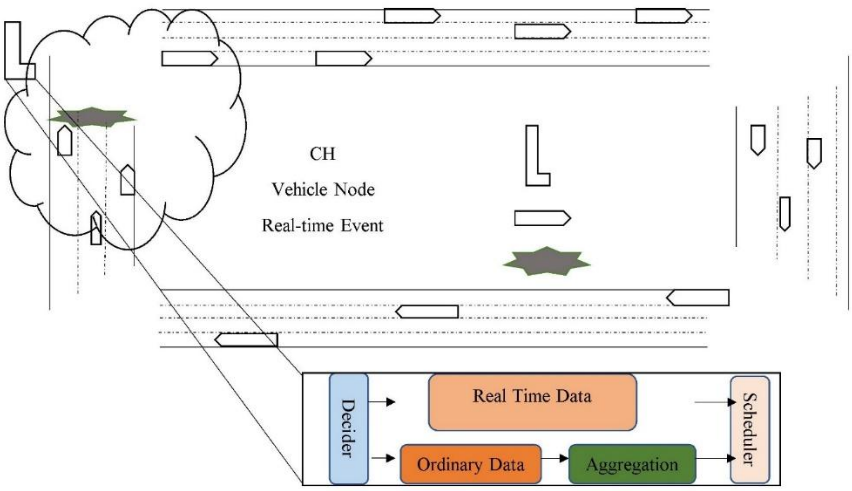

Fig.1: Construction of proposed model

This data is processed, and decisions are made according to predefined rules. The DR takes all this real-time information and sends it to the scheduler, which, based on the decisions of the decider, organizes and prioritizes tasks for the vehicle. It also collects and sends the Ordinary Data, vehicle status and performance to the Scheduler so it can make adjustments to the vehicle's agenda. The Scheduler sends the instructions to the systems in the vehicle, and Ordinary Data is continuously monitored. This process operates in sequence to facilitate real-time decision-making and adjustments to achieve the best performance and safety in driving.

3.2. Proposed Algorithm

The Start command is the first step in the procedure that initiates the process. Then, it collects information about nearby nodes such as their parameters and communication facilities. This information is collected, and the device is now ready to send a data packet. Before moving forward, it checks if peripheral nodes have information that could contain additional info regarding the finalized destination. In this case, the device determines the location of the peripheral node and validates if it is indeed the required end point. Otherwise, it forwards the data packet to the closest peripheral node to the destination. Figure 2 shows the architecture of the proposed approach.

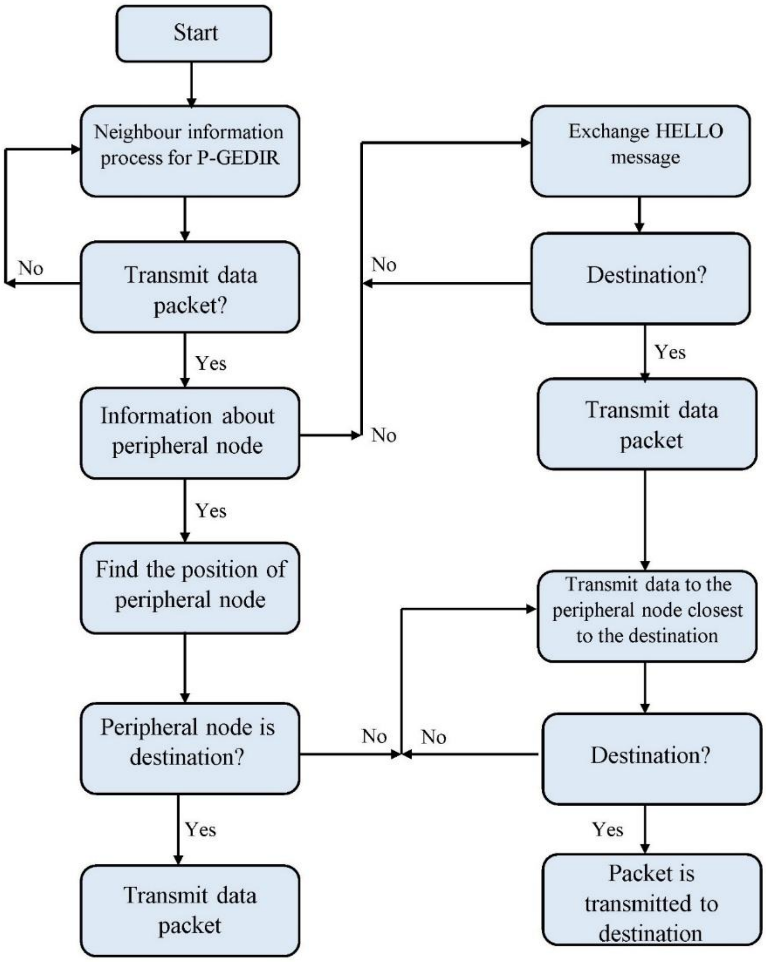

Fig.2: Proposed flow chart

Before communicating with the destination, it sends HELLO signals to determine whether the destination is reachable or not. Once the confirmation arrives, it passes the data packet to the target. If not accepted by destination device, the device continues transmitting to the nearest peripheral node until it reaches the desired destination. Sequential steps have been performed except the final, to transmit the data packet to the destination successfully. An efficient routing of the nodes from within the network is ensured by constructing the OptA2PV protocol. The protocol relies on a database, which holds information on the network, such as the locations and paths available to nodes within the network. V0 is used to discover alternative paths in case the primary path is blocked or facing issues. The Check_ Alter_ Route() method determines if there is any problem in the current route. Once it identifies some issues, The method Resp-Find_ Alter_ Route() is triggered. It tries to find another path and if it does so it calls the method Forward Data() to forward the data on the new path.
When no alternate route is found, the Chock Neighbors() function is used to hinder communication with the affected neighbours. The Resp-Find Neighbors() method is used to discover new potential nodes to connect, and Select Neighbors_ Dest () chooses the most appropriate node to reach the destination. If another path can be discovered, the Send Paquet(RERR) function is employed to inform the affected nodes to update their

installation. If no such alternative route exists, Send Paquet(RREQ) is executed to initiate a route discovery process in order to find a new path to the target. The Neighbors_ VO function keeps a list of reliable and active neighbours, while the Forward Data() method sends the data to proper neighbours on the best route to a destination. This process continues until the data reaches its final destination. Combined, these sequential procedures collectively provide effective and reliable communication between nodes within the network. Figure 3 illustrates the operational efficacy of the proposed approach in real-world scenarios.

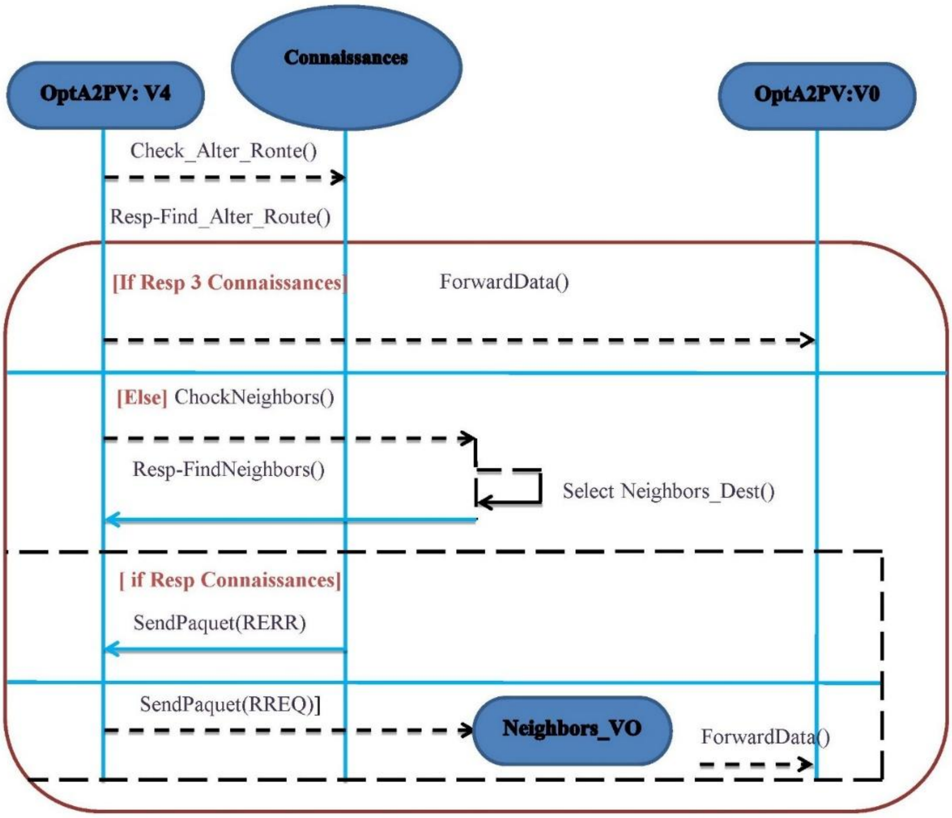

Fig.3: Functional working of proposed model

Assume the traffic predominantly encompasses urban and highway regions.

$$T_{speed} \alpha \frac{1}{C} \tag{1}$$

This model is selected due to its simplicity and its ability to boost accuracy in real-time situations. The variables utilized in the computation are density (C) and vehicle speed.

$$T_{speed} = D_{window} \frac{1}{C} \tag{2}$$

The formula illustrates the relationship between velocity and density. Determine the quantity of neighbours for the cars utilizing their neighbour table.

$$SuR_{value} = (I_g \times R_{avg} \times \frac{C_{value}}{T_{value}}) / V_t \tag{3}$$

The neighbour table comprises node location, speed, and density. Calculating connection stability is crucial for selecting the next hop in the DX.

$$LinkStability = \{F_{initial.a} + I_{buffer.a} + RF_{ba}\} \tag{4}$$

The collection of neighbours of the current cluster leader is referred to as MB. It signifies the signal-to-noise ratio of the connection between the current and the adjacent neighbour.

$$RF_{ba} = \frac{QBML}{C_a todestination} \tag{5}$$

DJ to destination signifies the travel distance from the current CH neighbour to the destination. The stable connection is identified by these calculations and the source.

$$Xuf_{next} = Max \tag{6}$$

DX disseminates the route request packet (RREQ) to the subsequent neighbour. This option facilitates the straightforward calculation of the end-to-end latency for each packet.

$$C_{trust}(H,K) = \frac{\sum_{b=1}^{time} J^{v-b} S_{HK}^{b}}{S} \tag{7}$$

The reduction of control packets automatically lowers network overhead, resulting in power savings. The computation of the indirect trust factor is also crucial in the trust evaluation process of the node.

$$BC_{trust}(H,K) = \frac{1}{f}\sum_{b=1}^{p} CV_{b}^{c}(c) \tag{8}$$

The indirect trust factor and nodes X and Y are contingent upon historical data, including anomalous departures, abnormal arrivals, normal departures, and normal arrivals. Amax denotes the vehicle speed when the density is zero.

$$Q = Q_{\max} - \frac{C}{C_{\max}} Q_{\max} \tag{9}$$

Coax denotes the vehicle density when the speed is zero. Hypothesis testing is conducted to assess the harmful behaviours of automobiles.

$$C_{avg} = \frac{1}{M}\sum_{b=1}^{M} C_{initial} v_{slot} \tag{10}$$

During hypothesis testing, the mean speed and the individual speed of the vehicle are compared with the data transmission. The hypothesis testing Hottest is conducted with the null hypothesis.

$$\sigma = \sqrt{\frac{1}{M}\sum_{b=1}^{M} (Q_{avg} - Q_{initial}) D_{window}} \tag{11}$$

Assume Hottest denotes the velocity recognized from the vehicle that sustains peak speed and Window. Communication occurs between the CH and the automobiles via traffic flow.

$$C = J_{data} \times M \times D_{window} \tag{12}$$

The CH assessed the densities of individual cars by utilizing the acknowledgment messages received from them. The MCP problem involves ascertaining if a path P exists from a source s to a destination d that satisfies all QoS conditions.

$$z_b(F) \le R_b b = 1, 2, \ldots n \tag{13}$$

If many routes fulfil the criterion in 1, then 0 < Oi ≤ 1 represents the weighting factors linked to each QoS constraint, which are contingent upon the kind of transmitted traffic.

$$P(F) = \sum_{b=1}^{n} U_b \left(\frac{R_b}{z_b(F)} \right) \tag{14}$$

Consider that audio data necessitate two QoS constraints: L1 = 100 ms for end-to-end latency and L2 = 10 hops for cost. We offer a technique enabling apps to establish tolerance factors that relax QoS demand constraints.

$$z_b(F) \le (1+\psi_b) R_b, b = 1, 2, \ldots, n \tag{15}$$

Tolerance factors are used just when the identified route contravenes one or more QoS standards. The concentration of pheromone on a communication connection between two cars, Ci and Cu.

$$\tau_{ba} = jl(r_{ja}) + i\sum_{h=1}^{n} \frac{R_h}{z_h(r_{ba})} \tag{16}$$

To evaluate the quality of the link/route about the specified QoS restrictions. It should be noted that when the established link becomes invalid for usage, i.e., it no longer meets the requisite QoS criteria.

$$\rho_{ba}(v)1 = 1 - \sqrt{\frac{\tau_0}{\tau_{ba}(t)}} \tag{17}$$

The pheromone value is designated as τ0, and no further evaporations are implemented. Dt cannot be included in any viable route between s and d at this moment.

$$z_i(F(q, D_t) + F(D_t, c)) > R_b \tag{18}$$

Given the very dynamic nature of vehicle movements, Dt may qualify as part of a viable route determined thereafter.

4. Results and Discussion

The performance of proposed QoS Scheme (QoSS) has compared with the existing efficient clustering algorithm (ECA) [14], information-centric approach (ICA) [21], game theoretical approach (GTA) [22], ACO algorithm (ACOA) [24] and Hybrid Fuzzy Logic approach (HFLA) [28]. Here, VANET dataset [29] used and the python simulator is the tool used to execute the results.

4.1. Estimation of Packet delivery ratio

The packet delivery ratio (PDR) is a vital measure for evaluating the effectiveness of a QoS scheme in vehicular communication over the VANETs. It measures the number of packets delivered successfully compared to total packets sent. The proposed QoS solution aims to improve the Packet Delivery Ratio by analyzing the characteristics of messages exchanged between vehicles. The technique uses a priority-based scheduling algorithm that assigns different priorities to classes of data. This allows the system to ensure all essential communications are delivered with very little delay and very high reliability. Table.2 shows the estimation of packet delivery ratio between existing and proposed models.

Table.2: Comparison of packet delivery ratio (in %)

Author	Year	Model	No. of inputs				
			100	200	300	400	500
Fatemidokht, H., et al. [14]	2020	ECA	70.89	70.77	70.62	70.54	70.27
McCarthy, J., et al. [21]	2021	ICA	78.71	78.65	78.6	78.37	78.33
Sun, Z., et al. [22]	2021	GTA	65.46	65.38	65.27	65.13	65.02
Vafaei, M., et al. [24]	2020	ACOA	71.86	71.74	71.71	71.52	71.41
Rajesh, I. S., et al. [28]	2024	HFLA	87.41	87.28	87.25	87.07	87.03
Proposed	2024	QoSS	95.47	95.33	95.32	95.13	95.14

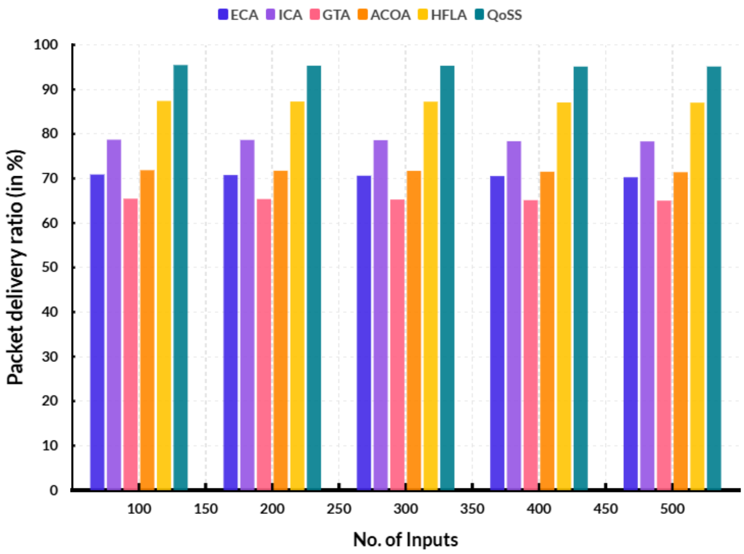

Fig.4: Comparison of packet delivery ratio

The packet delivery ratio comparison is displayed in Figure 4. The proposed QoSS realized a packet delivery ratio of 95.14% in the computational approach. The achieved power packet delivery ratio for the ECA is 70.27%, ICA 78.33%, GTA 65.02%, ACOA 71.41%, and HFLA 87.03%. Recognizing the message attributes and adjusting transmission properties according to the identified attributes helps identify impending network congestion. This improves PDR in terms of vehicular communication in VANETs, thus enabling better connection and optimized data relay for various applications.

4.2. Estimation of End-to-end delay

The latency from end to end is evaluated based on the characteristics of the communications. The operational data is used to schedule and manage message queues at midpoint nodes to reduce queuing delays, thus allowing us to optimize overall end-to-end latency. The efficient routing and scheduling methods are used to minimize the processing time and total delay. A QoS solution is proposed in this approach to achieve minimum end-to-end latency and ensure timely and reliable vehicle-to-vehicle communication in its VANETs by taking into account different message characteristics and adopting adequate strategies. Table.3 shows the estimation of end-to-end delay between existing and proposed models.

Table.3: Comparison of end-to-end latency (in ms)

Author	Year	Model	No. of inputs				
			100	**200**	**300**	**400**	**500**
Fatemidokht, H., et al. [14]	2020	ECA	29.11	29.23	29.38	29.46	29.73
McCarthy, J., et al. [21]	2021	ICA	21.29	21.35	21.4	21.63	21.67
Sun, Z., et al. [22]	2021	GTA	34.54	34.62	34.73	34.87	34.98
Vafaei, M., et al. [24]	2020	ACOA	28.14	28.26	28.29	28.48	28.59
Rajesh, I. S., et al. [28]	2024	HFLA	12.59	12.72	12.75	12.93	12.97
Proposed	2024	QoSS	4.53	4.67	4.68	4.87	4.86

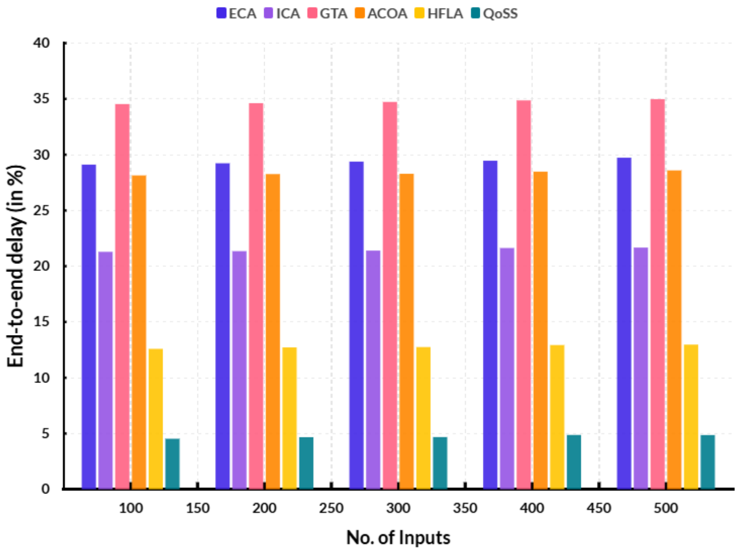

Fig.5: Comparison of end-to-end delay

Figure 5 shows the comparison of end-to-end delay. In a computational point, the proposed QoSS obtained 4.86 msend-to-end delay. The existing ECA obtained 29.73%, ICA obtained 21.67%, GTA obtained 34.98%, ACOA obtained 28.59% and HFLA reached 12.97% end-to-end delay.

4.3. Estimation of Network Throughput

Network throughput refers to the analysis of message types and traffic patterns on a network to determine how much data has been successfully transmitted. This can be done by assessing respective features. The Quality-of-Service message prioritization approach establishes prioritization between essential safety-critical messages and other messages and allocates just the right amount of network resources for the messages. By correlating and grouping different types/varieties of messages, the QoS system can estimate the acceptable bandwidth and communication speed necessary for consistent and on-time delivery of vital messages. Table.4 shows the estimation of network throughput between existing and proposed models.

Table.4: Comparison of network throughput (in %)

Author	Year	Model	No. of inputs				
			100	**200**	**300**	**400**	**500**
Fatemidokht, H., et al. [14]	2020	ECA	87.29	87.16	87.02	86.88	86.74
McCarthy, J., et al. [21]	2021	ICA	72.24	72.09	71.94	71.81	71.65
Sun, Z., et al. [22]	2021	GTA	77.24	77.14	77.03	76.93	76.82
Vafaei, M., et al. [24]	2020	ACOA	69.89	69.78	69.67	69.55	69.44
Rajesh, I. S., et al. [28]	2024	HFLA	83.24	83.13	83.02	82.91	82.79
Proposed	2024	QoSS	93.99	93.89	93.8	93.71	93.62

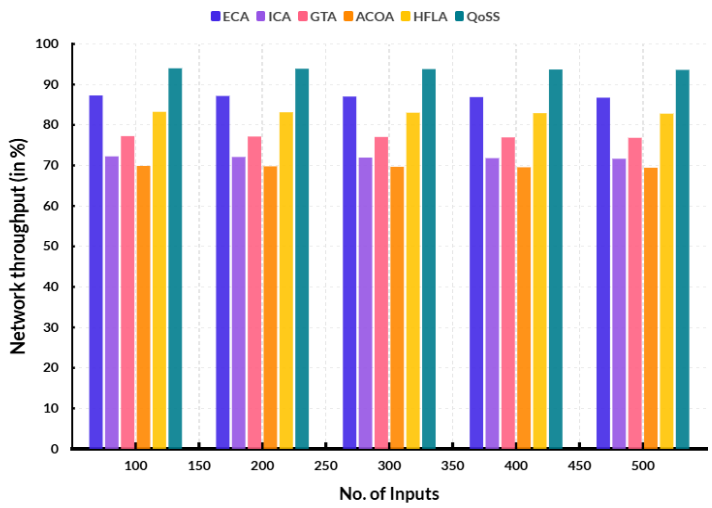

Fig.6: Comparison of network throughput

Figure 6 shows the comparison of network throughput. In a computational point, the proposed QoSS obtained 93.62% network throughput. The existing ECA obtained 86.74%, ICA obtained 71.65%, GTA obtained 76.82%, ACOA obtained 69.44% and HFLA reached 82.79% network throughput. The scheme may also implement congestion control and adaptive routing techniques to optimize network throughput and minimize delays. Estimating network throughput is crucial in determining the feasibility and effectiveness of the proposed QoS scheme in improving communication performance in VANETs.

4.4. Estimation of Transmission Data rate

Transmission data analysis involves analyzing the characteristics of the communication being transmitted. This proposed system evaluates these characteristics and figures out an adequate transmission rate to ensure higher priority and faster delivery of the most important messages. Mainly for safety protocols, the transmission of timely and accurate information is presented as an important communication functionality in VANETs. Table.5 shows the estimation of Transmission Data rate between existing and proposed models.

Table.5: Comparison of Transmission Data rate (in %)

Author	Year	Model	No. of inputs				
			100	**200**	**300**	**400**	**500**
Fatemidokht, H., et al. [14]	2020	ECA	80.66	81.41	81.38	80.56	80.47
McCarthy, J., et al. [21]	2021	ICA	76.36	80.98	80.98	80.51	80.31
Sun, Z., et al. [22]	2021	GTA	61.63	65.22	64.64	63.45	63.58
Vafaei, M., et al. [24]	2020	ACOA	78.94	79.04	79.11	79.15	79.19
Rajesh, I. S., et al. [28]	2024	HFLA	84.69	86.83	86.78	86.26	86.29
Proposed	2024	QoSS	88.31	90.45	90.46	89.93	89.98

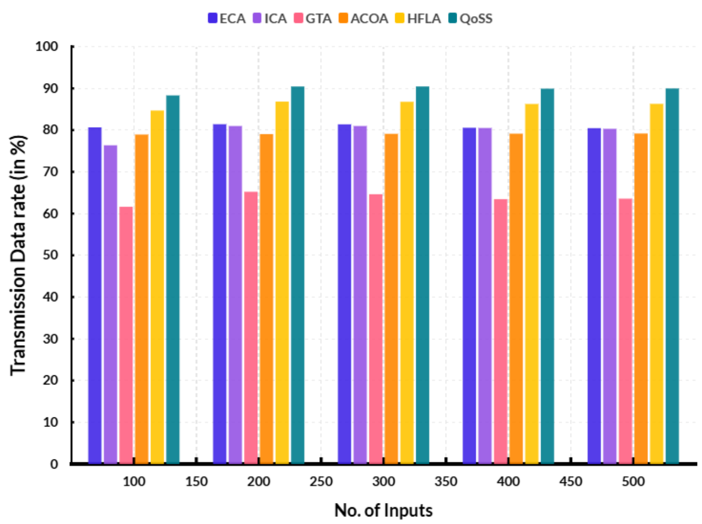

Fig.7: Comparison of Transmission Data rate

Figure 7 shows the comparison of Transmission Data rate. In a computational point, the proposed QoSS obtained 89.98% Transmission Data rate. The existing ECA obtained 80.47%, ICA obtained 80.31%, GTA obtained 63.58%, ACOA obtained 79.19% and HFLA reached 86.29% Transmission Data rate. The estimation of the transmission data rate for the proposed QoS scheme also considers the network conditions to optimize the transmission rate further. By accurately estimating the transmission data rate, the proposed QoS scheme can effectively detect and prioritize messages, leading to efficient and reliable communication in VANETs.

4.5. Estimation of Bandwidth Utilization

A QoS scheme should avoid high bandwidth consumption. The proposed model needs to specify the properties of messages going out through the VANET. This covers the type of information communicated, the size of the messages, and the recurrence with which they are conveyed. The above criteria will determine the bandwidth required for communication. The VANET network structure and traffic patterns must be analyzed, as they can significantly change the bandwidth consumption. Table.6 shows the estimation of Bandwidth Utilization between existing and proposed models.

Table.6: Comparison of Bandwidth Utilization (in %)

Author	Year	Model	No. of inputs				
			100	**200**	**300**	**400**	**500**
Fatemidokht, H., et al. [14]	2020	ECA	61.41	61.06	61.44	61.48	61.53
McCarthy, J., et al. [21]	2021	ICA	82.43	81.98	81.98	81.83	81.61
Sun, Z., et al. [22]	2021	GTA	79.07	78.44	79.77	80.01	80.25
Vafaei, M., et al. [24]	2020	ACOA	68.58	68.15	68.68	68.71	68.74
Rajesh, I. S., et al. [28]	2024	HFLA	71.15	71.17	71.25	71.32	71.34
Proposed	2024	QoSS	93.36	93.22	93.66	93.76	93.87

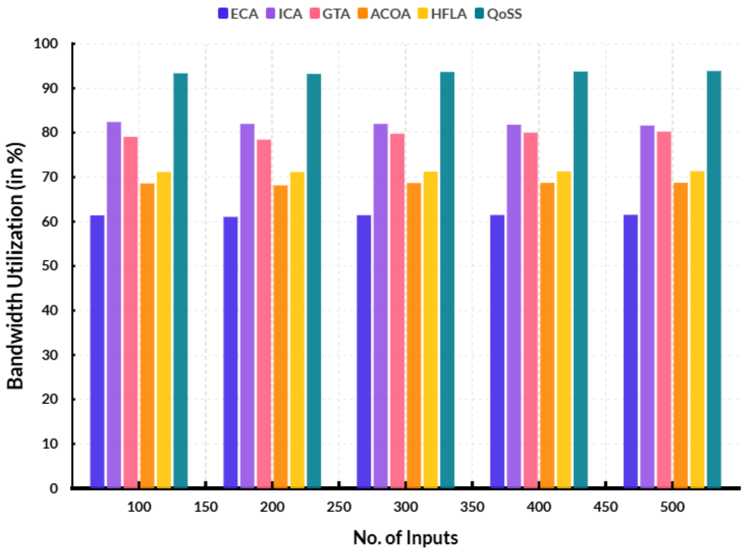

Fig.8: Comparison of Bandwidth Utilization

Fig.8 shows the comparison of Bandwidth Utilization. In a computational point, the proposed QoSS obtained 93.87% Bandwidth Utilization. The existing ECA obtained 61.53%, ICA obtained 81.61%, GTA obtained 80.25%, ACOA obtained 68.74% and HFLA reached 71.34% Bandwidth Utilization. By taking all these factors into account, an estimation of the bandwidth utilization for the proposed QoS scheme can be made, which will help ensure that the network has enough capacity to support the desired level of QoS for vehicular communication.

5. Conclusion

A proposed QoS approach aims to increase the effectiveness and reliability of message delivery by recognizing message parameters. This includes identifying important communications, giving them priority for timely transport, and deciding the type and quantity of messages to allocate appropriate network resources. Once executed, this plan would enhance the quality of service for vehicle communications, ensuring timely delivery of critical messages and gradual management of congestions. This will significantly improve the safety and efficiency of vehicular networks, making them more reliable for real-time applications, including emergency services and traffic management. The proposed method has great potential to enhance the communication performance of VANETs, but more studies and tests are necessary for a thorough evaluation. The proposed model obtained 95.14% packet delivery ratio, 4.86 msend-to-end delay, 93.62% network throughput, 89.98% Transmission Data rate, and 93.87% Bandwidth Utilization. This proposed model furtherly enhance the following,

- The proposed QoS scheme should be able to dynamically allocate resources based on traffic conditions and message priority. This will ensure that critical messages are given more resources and delivered in a timely manner.
- The proposed QoS scheme should be able to identify and manage network congestion. It should also prioritize critical messages over non-critical ones during peak traffic conditions to ensure timely delivery.
- The proposed QoS scheme should have mechanisms in place to ensure reliable message delivery, even in the presence of network failures or faults. This can be achieved through redundancy and error correction techniques.
- The proposed QoS scheme should prioritize safety-critical messages over other types of messages to ensure that they are delivered in a timely and reliable manner. This will help improve road safety and reduce accidents.
- The proposed QoS scheme should optimize the QoS parameters by considering parameters from multiple layers of the communication protocol stack. This will help achieve a more efficient and effective QoS for vehicular communication on VANETs.

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