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Original scientific paper

QoS based Adaptive Multi-Constrained Energy Efficient Routing for Vehicular Ad hoc Networks

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Abstract: A QoS-based Adaptive Multi-Constrained Energy-Efficient (AMQoS) routing approach addresses the limitations of the current single-constrained and multi-constrained Quality of Service (QoS) routing algorithms for Vehicular Ad-hoc Networks (VANETs). The proposed method aims to enhance packet delivery effectiveness by effectively managing the utilization of QoS resources. Unlike the current reactive Dynamic Source Routing (DSR) algorithm, the suggested routing algorithm incorporates QoS parameters and network stack parameters into the route discovery process. This cross-layer model is established by aggregating QoS and network stack parameters from various layers of the TCP/IP protocol stack. Additionally, the proposed routing method integrates a Rough Set Theory-based analysis of multi-layer stack parameters pertaining to VANET QoS to determine the relevant stack parameters for routing packets. In terms of network scalability, the proposed routing algorithm demonstrates superior performance over Priority-Aware Dynamic Source Routing (PA-DSR) for various metrics, including energy efficiency, goodput, Packet Error Rate (PER), delay, and more. PA-DSR, while effective in small networks with low mobility, establishes QoS routes with reserved bandwidth from source to destination. The performance evaluation of AMQoS, DSR, and PA-DSR encompasses several QoS measures, considering factors such as the number of mobile nodes and mobility speed. The proposed routing stands out due to its strategies for load distribution across the network and efficient routing cost management, outperforming DSR and PA-DSR across various metrics, including goodput, delay, and energy efficiency.

Keywords: DSR; multi-constrained; PA-DSR; quality of service; rough set theory; routing protocol QoS metrics; VANET

1 INTRODUCTION

Vehicular Ad-hoc Networks (VANETs) present a distinctive wireless network paradigm in which mobile devices equipped with the necessary radio hardware can autonomously engage with the network protocol stack. These mobile devices establish direct communication with each other, obviating the need for a central base station, cellular tower, or satellite infrastructure. This wireless architecture facilitates the spontaneous formation and participation of networks in real-time, a phenomenon often described as "on-the-fly" networking [1].

Furthermore, in applications like group communication during conference calls among nodes within a lightweight network, minimizing energy consumption becomes paramount. This necessity places a strong emphasis on battery life and energy conservation as the primary Quality of Service (QoS) criteria in such cases [2].The widespread deployment of IoT devices connected to the network for a multitude of applications has led to a substantial increase in both the quantity and diversity of network traffic. This growth poses challenges not only in terms of volume but also in the quality of data transmission. This is primarily due to the inherent mobility of IoT devices, causing fluctuations in the wireless channel quality among connected nodes over time, attributed to factors like path loss, the Doppler Effect, and signal fading [3].

In addition to dealing with the dynamic nature of traffic and VANET-specific characteristics, network survivability becomes a critical concern in scenarios where nodes may fail, links may be severed, or disruptions in network connectivity occur [4]. This is particularly important in VANETs, given the safety-critical nature of many applications. Consequently, the focus in VANET applications extends beyond merely ensuring the secure delivery of information; it also places a strong emphasis on achieving a higher level of Quality of Service (QoS).

2 RELATED WORKS

In the context of distributed networks like VANET, adjustments to MAC strategies become necessary to mitigate packet collisions and efficiently manage channel access. Consequently, it is important to acknowledge that the physical and MAC layers wield a significant influence on the successful delivery of packets, regardless of the specific routing protocol in use. The nodes involved in VANET routing have a variety of responsibilities, including buffer management and traffic conditioning. Before being forwarded to the channel, packets carrying traffic are prioritized as high or low. Ultimately, the servicing of packets can be prioritized by using a buffer management technique in each node's buffer. The applications that create the packets and their QoS requirements will have an impact on how the packet service is prioritized [5-9]. The QoS requirements differ amongst apps. While security and dependability are supplementary requirements for military applications, bandwidth and delay are the essential characteristics for multimedia applications. The most important QoS criterion for applications like emergency search and rescue operations is availability.

The proposed single restricted QoS routing protocols for VANET are shown to have inherent problems in achieving high standards for delay, energy, Packet Delivery Fraction (PDF - packets receiving performance metric with various nodes), jitter, and other QoS parameters. To adhere to several QoS criteria, it is suggested to use an Ad Hoc On-Demand Distance Vector (AODV)-based multicast routing strategy that is multi-Constrained QoS aware [10-12]. Here, mobile nodes are utilized for multicast route discovery, building the foundation for trustworthy multicast routing and topology adaptation. In instances where link failures occur due to node mobility, a multi-path approach is employed to expedite the rerouting process. Additionally, to meet diverse Quality of Service (QoS) requirements, the source node may opt for the most efficient path for data transmission.

When connecting to the internet for connections to the rest of the world, VANET has significant interdependency difficulties. VANET adopted a layered strategy as a result of the internet's overwhelming popularity, particularly with layered design. In order to ensure compatibility for applications using VANET and its features, it is crucial to adapt to a cross-layer paradigm [13-15]. Data encapsulation is carried out through the conventional TCP/IP protocol using a standardized network connection. The OSI paradigm is also used for data encapsulation in addition to TCP/IP. Both of these models were impacted by service quality and response time due to strictly tiered techniques. Numerous cross-layer frameworks have been established to enhance the quality of service, with a focus on both performance and security improvements as a means of addressing these challenges.

This work analyzes QoS-aware routing protocols in the existing literature for VANETs. It analyzes the protocols' support for ITS infotainment services, their multi-constraint path problem (MCP), their functionality and weaknesses, goals, and design issues. In this way, potential future paths for the study of VANETs QoS-aware protocols are proposed [16-18]. Through the establishment of cooperation between the network, adaptive multi-QoS cross-layer cooperative routing improves QoS performance, including delay, jitter, packet loss rate, and next hop selection. The initial stage of channel state variation has been carried out for efficient communication. In order to implement the cooperative MAC system, the transmission mode is dynamically chosen. Finally, a decision has been made at the network layer to select the optimized route using the most qualified relay candidate while taking various QoS metrics into account [19, 20]. Results of Adaptive Multi QoS Cross-layer Cooperative Routing (AMCCR) show a significant improvement in the network's delay, throughput, and lifespan as a whole. In order to enhance QoS, a new priority-aware DSR protocol is proposed.

3 PROPOSED SYSTEM

Adaptive routing algorithms construct routing decisions dynamically depending on the network environment. Decision-making algorithm is based on the QoS constraints thereforeAMQoS is a multi-path source routing method that takes several QoS factors into account. The suggested routing method finds the path when it is needed, taking into account a multi-layer framework for various network stack parameters. Based on the network parameters, the route selection procedure is adaptive and takes VANET properties into account. Variations in VANET stack parameters result with change in route selection approach. Other routing algorithms, such as the Dynamic Source Routing (DSR) protocol, have shortcomings including poor scalability, long delays in obtaining routing information, route decay, and the issue of each route reply being sent to each sender, which affects intermediate nodes. Adaptive multi constrained QoSlaunch the RREQ (Route Request) packet for the chosen routes, limiting the transmission of control packets to those routes in the destination. Fig. 1 depicts the node state transition during route development.

3.1 RREQ Packet Construction

When a path is absent in the source cache, the routing path must be created dynamically during the initial phase of route discovery. As depicted in Fig. 1, to find a path to a destination, the source node constructs the Route Request (RREQ) packet and broadcasts it to nearby nodes. This packet typically includes Source ID, Destination ID, and Request ID to distinguish an RREQ message from duplicates. In the packet header, the general Dynamic Source Routing (DSR) algorithm retains information about intermediary nodes (i1, i2, i3) for traversal. Consequently, an Intermediate ID is maintained to keep a record of all the intermediate nodes through which an RREQ packet traverses. The process of route selection should be dynamic and contingent on the network's current state. The attainment of good Quality of Service (QoS) is facilitated by network stack parameters, which exert a significant influence on network resources. In Fig. 2, the RREQ message incorporates supporting parameters like Signal-to-Noise Ratio (SNR), Transmission Power (TX), and Link Distance (LD) to assist in making dynamically changing decision criteria.

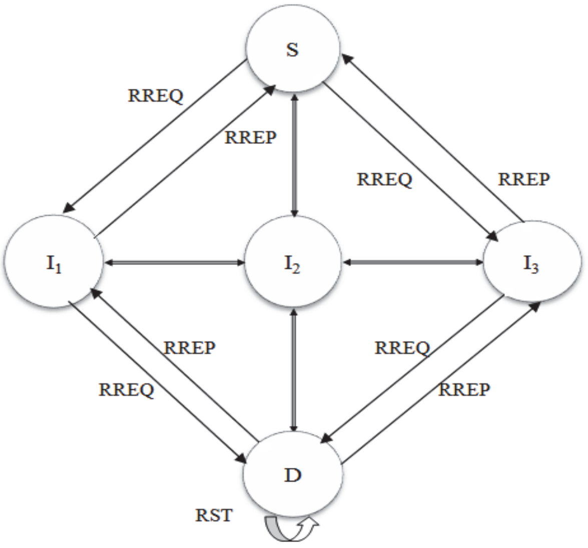
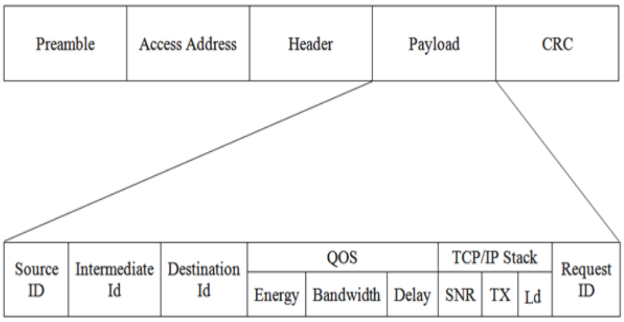


Figure 1 Node state transition diagram

The QoS metrics that will be used to make decisions are also presented.According to the choice made for path filtering, the energy, latency, and bandwidth, the RREQ message incorporates these elementsshown in Fig. 2.



Preamble	Access Address	Header	Payload	CRC

Source ID	Intermediate Id	Destination Id	QOS			TCP/IP Stack			Request ID
			Energy	Bandwidth	Delay	SNR	TX	Ld	

Figure 2 RREQ packet format

3.2 RREQ Packet Propagation

Upon receiving an RREQ message from a neighboring node, the first step is for the recipient node to inspect its route cache to identify any existing routes leading to the destination. If a route is found, it is appended to the route header, and the node proceeds along that path to reach the intended destination. In cases where routes are not available, the current node's ID is added to the intermediate ID list. Additionally, a comparison is made between the Quality of Service (QoS) parameters and network stack parameters with the most up-to-date data at the node.

3.3 Filtration of RREQ Packets

The destination node will store the received RREQ message and their route request ID in their cache. The destination node is now aware of every route that is open as well as its status with regard to QoS resources and network stack settings. There will be two problems with the network when all RREQ messages are converted to RREP messages. The first is the potential for transmitting messages across a path where the necessary QoS resources have not been maintained. This will result in packet loss and retransmission requests. Flooding RREP messages results in QoS resource consumption, which is another problem. Fig. 3 shows the AMQoS route discovery and Packet forwarding.

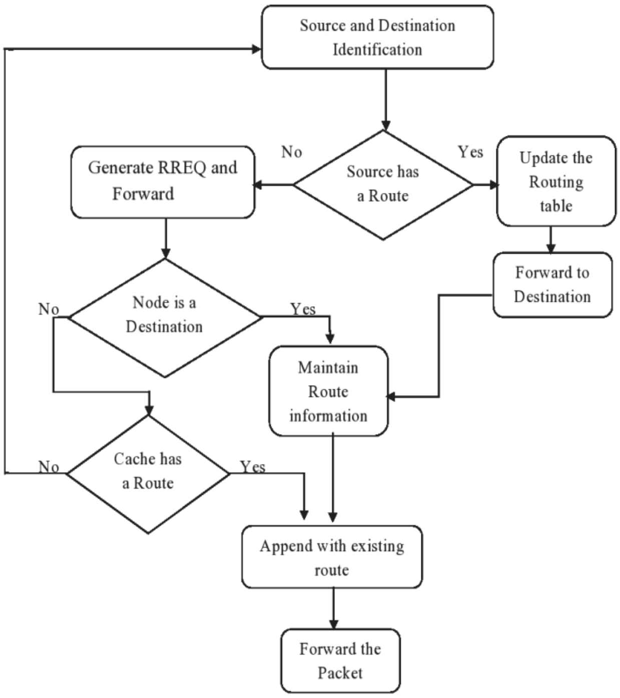


Figure 3 AMQoS route discovery and packet forwarding

3.4 RREP Packet Construction

The packet construction is shown in Fig. 4.

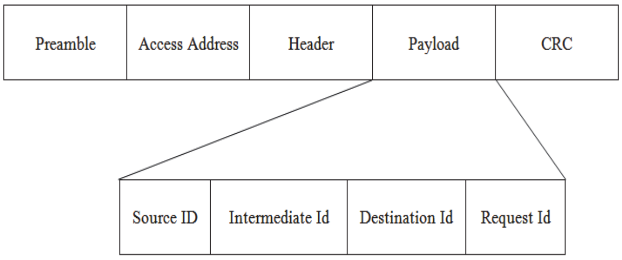


Figure 4 RREP packet format

3.5 RREP Packet Propagation

For the destination node or any intermediate node to forward the Route Reply (RREP) to the source node, there must be an established route from the destination to the source. The Route Request (RREQ) message serves as a means for the destination node to establish a route back to the source node, and similarly, the RREP message facilitates this, as illustrated in Fig. 5. However, it is important to note that there can be disparities in the functionality of the communication interface between two nodes in both directions. This asymmetry arises due to different sources of interference and varying radio propagation patterns, rendering wireless communication unidirectional and non-symmetric. Consequently, if an intermediate node encounters such a situation, it initiates a new RREQ and transitions to generating an RREP for the newly discovered path. Fig. 5 provides a comprehensive representation of the propagation of RREP packets in this context.

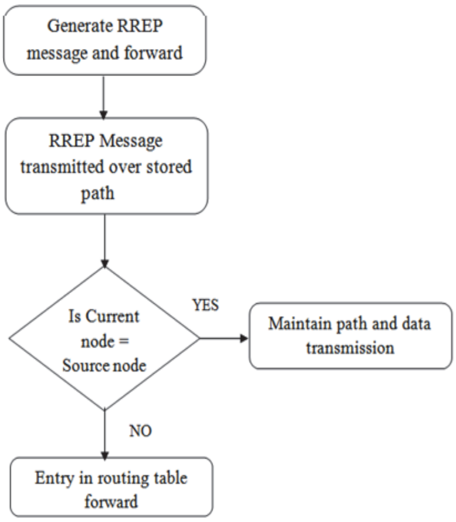


Figure 5 Overview of RREP packet propagation

3.6 RREP Route Maintenance

Fig. 6 displays a comprehensive overview of route maintenance.

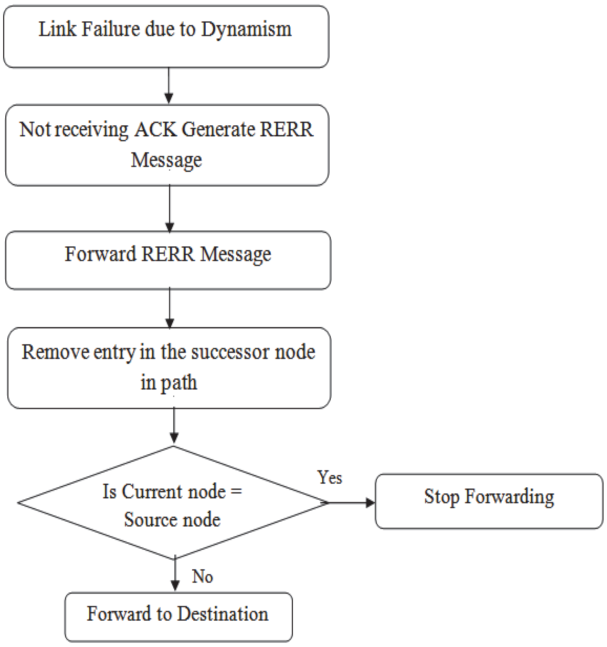


Figure 6 Overview of route maintenance

4 RESULTS AND DISCUSSION

In NS - 2.36, the AMQoS has been simulated. From 25 to 70 nodes are used in the experiment, and they are distributed at random over the 1000 × 1000 metre space (area). Rough Set Theory (RST) serves as a mathematical decision-support technique for managing information systems that are inherently unreliable. When it comes to dynamic decision-making in route selection, considering various factors, a robust decision support system is essential. RST emerges as the ideal choice for deriving multi-constrained Quality of Service (QoS) decision rules for route selection. To put RST concepts into practical use and explore different QoS values across various routes, the Rough Set Exploration System serves as a valuable tool. The RSES uses a variety of methods, including discretization, reduction, decision rules, and RST prediction. The performance analysis of proposed system are plotted in Fig. 7, Fig. 8, and Fig. 9 and Tab. 2, Tab. 3 and Tab. 4. VANET Simulation parameters with traffic simulators is given below in Tab. 1.

Table 1 VANET simulation parameters

NetworkSimulator	NS 2.34
Number of Nodes	10 - 70
Minimum Speed	8 m/s
MaximumSpeed	24 m/s
Simulation time	1000, 2000 s
Data Packet	512 k byte
Control Packet	64k byte
Type of data traffic model	CBR

Table 2 The results values of AMQoS, PA-DSR and DSR in delay

Number of Nodes	AMQoS	PA-DSR	DSR
25	0.85	0.858	0.86
30	0.855	0.865	0.869
35	0.861	0.875	0.889
40	0.911	0.925	0.930
45	0.93	0.958	0.965

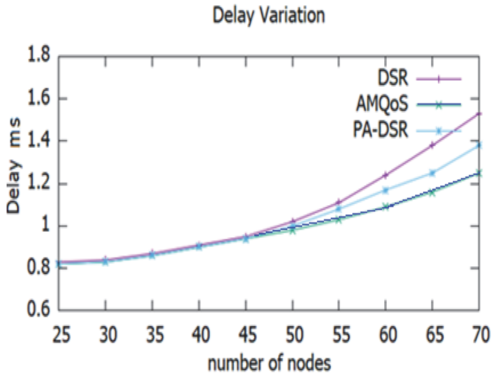


Figure 7 Delay variation against varying nodes

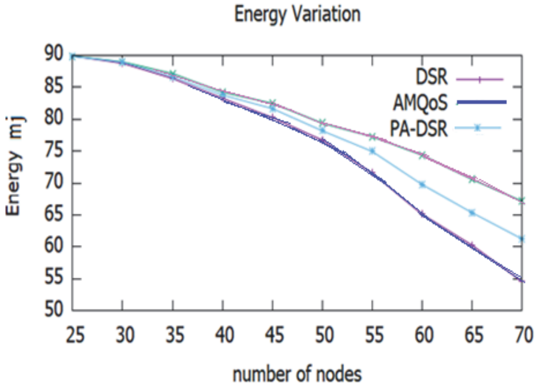


Figure 8 Energy variations against varying nodes

Table 3 The results values of AMQoS, PA-DSR and DSR in energy

Number of Nodes	AMQoS	PA-DSR	DSR
25	90	90	90
30	87	87	88
35	86	85	86
40	82	83	84
45	80	81	84

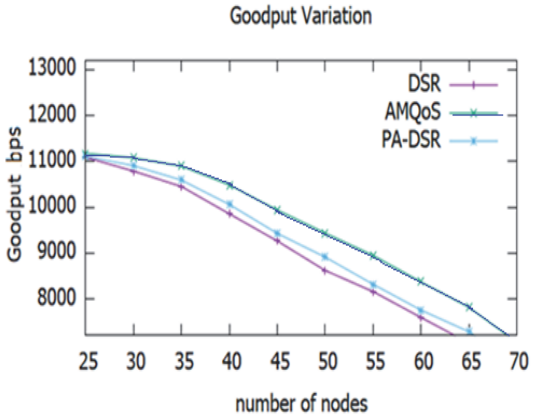


Figure 9 Goodput variations against varying nodes

Table 4 The results values of AMQoS, PA-DSR and DSR in good put

Number of Nodes	AMQoS	PA-DSR	DSR
25	11110	11100	11000
30	11100	11125	11150
35	11050	10500	11000
40	10900	10100	10000
45	10500	9500	9400

5 CONCLUSIONS

The proposed routing algorithm undergoes adaptations that consider the unique attributes of VANET and the specific types of applications utilized within the network. Applications operating within VANET have distinct Quality of Service (QoS) requirements. To comprehend the VANET features, the TCP/IP protocol stack parameter has been taken into consideration. RST is used to examine the trade-off between the stack parameter and the QoS metric. In the proposed system's decision-making, an empirical model resulting from the analysis of ID and PTX is employed. By utilizing the NS 2 and SUMO simulators as tools to build the decision model from the large set of inconsistent data with multiple attributes, the dynamic threshold identification for the QoS measure is accomplished.By filtering RREQ messages that have been received at the destination and reducing routing costs, the proposed routing will improve compared to DSR. RST-derived decision criteria are implemented on RREQ messages, and RREPs are generated and sent to the source only for selected RREQ messages. The source node, which accumulates multiple routes to the destination obtained from RREP messages, keeps track of all these routes. This approach simplifies route maintenance since there is always a backup route available in case the primary route fails. However, the proposed method surpasses DSR and PA-DSR by effectively distributing the network load and efficiently managing routing costs.

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