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Adaptive Mobility and Reliability-based Routing Protocol for Smart Healthcare Management Systems in Vehicular Ad-hoc Networks

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Abstract

Ambulances enable digital and widespread remote care for older people in the healthcare sector. The Vehicular Ad Hoc Network (VANET) is critical for allowing the digital and Intelligent Transportation System (ITS) for the smart healthcare world. Enhancing the dependability and flexibility of an adaptive routing algorithm improves vehicular communications' Quality of Service (QoS) effectiveness. An essential concern in vehicular technology is enabling drivers to make reliable judgments. Developing an effective routing system that ensures a suitable QoS takes time and effort. The vehicular network ecosystem is characterized by limited mobility, fast vehicle speeds, and constantly changing configurations. This study makes four distinct contributions. Initially, it presents adaptive routing protocols, capable of recognizing changes in the network environment, aware of the mobility of nodes, and dependable in delivering data packets. The experimental configuration is implemented inside a discrete Network Simulator (NS-3) scenario to enhance the QoS. Mobility-aware routing algorithms can provide ITS with satisfactory mobility, vital dependability, high Packet Delivery Ratio (PDR), high throughput, and low End-to-End (E2E) Delay. The proposed method has an average throughput of 664.3 kbps, a delay of 151.3 ms, and a packet delivery ratio (PDR) of 94.23%.

Keywords: Vehicular Ad-Hoc Networks, Healthcare Management, Mobility, Inclusive Innovation, Reliability.

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1 Vehicular Ad-Hoc Networks and Healthcare Management

Efficient and effective monitoring of mobility and dependability is crucial for transferring route data among paramedics and between ambulances and healthcare facilities due to the high speeds of 60-120 Km/hr in healthcare trucks like ambulances. Government officials and other security experts, including various automobile companies, have shown a keen interest in developing security applications for Intelligent Transportation Systems (ITS) (Njoku et al., 2023). They suggested reducing the impact of accidents on the side of the road and developing strategies to decrease the number of injuries and deaths resulting from these accidents. Vehicle crashes are often considered among the most significant and dangerous threats to public safety worldwide. Ensuring the protection of individuals has become a paramount concern for stakeholders in the transportation industry.

Implementing a platoon-based architecture in the ITS, as opposed to individualized driving patterns for autos, resolves the issue of highway capacity and allows for optimal fuel economy. The development of Vehicular Ad Hoc Networks (VANETs) has received significant attention in research due to their dynamic topology and excellent mobility (Azam et al., 2021). VANETs facilitate the exchange of vehicle data and traffic data via three types of interactions: vehicles-to-vehicles (V2V), vehicles-to-infrastructures (V2I), and infrastructures-to-infrastructures (I2I) (Arif et al., 2020). Implementing information-sharing protocols has facilitated the development of apps to improve transportation effectiveness, mitigate traffic congestion, and enhance roadway security (Trivedi et al., 2023). It facilitates communication and coordination between cars and infrastructure, guaranteeing a pleasant and effortless ride.

In disaster-prone areas and smart cities, the VANET smart traffic infrastructure is crucial for immediately sending safety and emergency alerts and monitoring health-related concerns (Ariyachandra & Wedawatta, 2023; Harang & Hyun, 2024). The need for an effective routing method for healthcare monitoring in smart city traffic management systems is evident (Punriboon et al., 2019). This protocol should use the best route to transmit time-sensitive signals from individuals to healthcare providers or hospitals via VANET (Singh et al., 2021). A routing system that is efficient and adaptable will have the capability to establish an ad-hoc network under urgent and crucial circumstances rapidly. Many routing methods have been examined to address the high speed of vehicles (Manipriya et al., 2020). Three such methods, Adhoc On-demand Distance Vector (AODV) routing (Taterh et al., 2020), Destination-Sequenced Distance-Vector Routing (DSDV) (Sarao, 2020), and Optimized Link State Routing (OLSR) (Tuli et al., 2022), have been explored, and their efficiency has been enhanced.

2 Background and Related Works

This section provides a comprehensive analysis of the previous research on the problems encountered in the routing techniques used in V2V Communications. Singh et al., introduced a model for VANET that aims to collect pre-recorded Personal Health Information (PHI) from individuals (Singh et al., 2021). The model involves modifying patients' medical Wearable Sensor Networks (WSN) to gather the PHI according to the specific needs of physicians using electric vehicles (Raman & Ramachandaran, 2023; Ram & Chakraborty, 2024). The assumption is that the patient will have a lightweight jacket equipped with many sensors for measuring different PHI parameters to satisfy customer experience (Raman et al., 2023; Priyanka et al., 2023).

The study presents a framework for a Smart VANET (SVANET) (Othman et al., 2021). SVANET employs WSN to monitor occurrences, and vehicles are used to distribute both safety and non-safety information. Various sensors were fitted in automobiles to record health data in the logistics industry (Prashanth et al., 2024). The efficacy of three routing methods has been evaluated, and the findings indicate that the Dynamic Source Routing (DSR) method offers improved performance in terms of Packet Delivery Ratio (PDR) for systems of various sizes and with varying speeds (Sehrawat & Chawla, 2023). The researchers have analyzed the influence of routing algorithms on various propagation scenarios for VANET with effective supply chain management (Subrahmanyam et al., 2024). Their findings indicate that radio propagation has no significant effect on VANET.

The paper has focused on OLSR and AODV (Kim et al., 2020). AODV demonstrates superior performance in situations with a low density of vehicles, whereas OLSR is more effective in high-density traffic scenarios (Jazem, 2023). The system employs ten fundamental security alerts to convey information between vehicles. An analysis has been conducted to review multiple categories of routing algorithms, such as AODV, DSDV, and OLSR, in V2V communication situations to distribute the mobile centers (Mansyur et al., 2022). The level of service has been assessed using metrics such as PDR, packet overhead, and throughput. The evaluation has shown that AODV outperforms all other methods in several aspects.

The proposed study investigates the relationship between vehicle density and the surroundings in urban, suburban, and rural areas. The message payload size is 256 bytes, with a data rate of 8 kilobits per second. The vehicle's velocity remains constant at 20 meters per second, and the car separation is assumed to stay the same during the journey. Every vehicle in the fleet transmits non-safety messages at regular intervals, following a predetermined rate and payload capacity. The proposed study includes simulations that assess proactive and reactive routing techniques for non-safety programs.

3 Adaptive Mobility and Reliability-based Routing Protocol

The proposed method is designed to provide convenient and expeditious medical care access for older people and infants, regardless of the time. The suggested framework involves equipping healthcare vehicles with a video camera to record photos of unwell patients. These images are promptly sent to a skilled physician for a thorough diagnosis. A medical professional can assess the severity and worrisome condition of newborns and diabetic patients by examining their wounds, mostly on the fingertips of their hands and the bottoms of their feet (particularly in elderly individuals with diabetes). The physician can evaluate the facial color of newborn children and the responses of both elderly patients and young children.

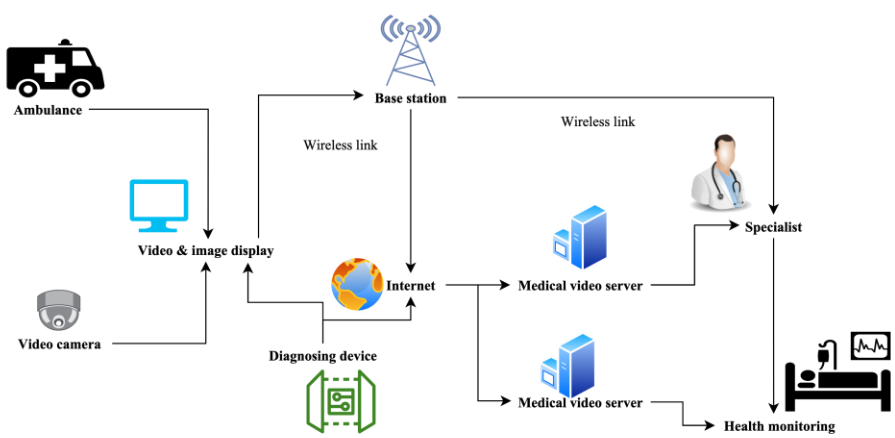

Figure 1: Architecture of the Proposed Method

With this information, the doctor promptly sets up and administers appropriate and efficient treatment for the individuals upon their arrival at the medical facility. At the same time, the doctor sends the report to the nurses at the patient's house in a distant location using recorded photos. The doctor offers clear instructions to the paramedics on the recommended treatment dosage and dietary requirements. Figure 1 illustrates the situation in which video pictures are used to provide emergency medical treatment to elderly individuals and young children in remote places where specialized medical resources are not accessible.

1) Reliability Zone

The proposed method employs a greedy forwarding approach for packet transmission. In some cases, the chosen next relay vehicle is located at the furthest boundary of the communication range. Because the cars are rushing, the transmission connection is unstable, and the next-hop node selected is out of range for communications by the time the data packet reaches it. It commonly leads to damaged communication connections and failures in data packet transfer. This research demonstrates that the data flow rate approaches 100% when the communication radius is less than or equal to 90% of the Communication Range (Cr). The suggested study employs a Cr equal to or less than 90% (0.9Cr), the safe zone. If the separation between nearby nodes gradually grows from 0.9 Cr to Cr, the packet loss rate rises rapidly, leading to a significant decline in communication link efficiency.

To prevent communication problems from selecting a neighboring node on the boundary, the proposed algorithm utilizes the Link Risk Degree (LRD) to calculate the weighting function during construction. Equation (1) is used to estimate the LRD.

$$LRD_x = \frac{1}{0.9*C_r - D_{CFV,D}} \quad (1)$$

$D_{CFV,D}$ represents the distance from the Current Forwarded Vehicles (CFV) to the target vehicle, D. If, at time T_0, the positions of CFV and D are (I_{CFV}, J_{CFV}) and (I_D, J_D) accordingly, then the $D_{CFV,D}$ is computed as Equation (2):

$$D_{N,D} = \sqrt{(I_D - I_{CFV})^2 + (J_D - J_{CFV})^2} \quad (2)$$

The suggested work utilizes the LRD_x as the routing parameters increase the weighting factor—neighbours located inside a hazardous area will have a negative S_D value, which reduces the weighting factor for selecting the next-hop nodes.

2) Normalized Speed Variable

Speed is critical for efficient and dependable data transmission in multi-hop wireless communications. In VANET, the movement of vehicles is constrained by the layout of the roads, and their speed ranges from 10 to 80 km/h. Rapid velocity leads to frequent alterations in topology and disruptions in network connectivity. In healthcare and security monitoring, transmitting information within a specific timeframe is essential. Fast automobiles can communicate PHI data more quickly than slower ones. PHI data should not be sent to a high-speed vehicle since it soon gets out of communication distance before the sending node receives an acknowledgment.

This might result in packet retransmission. Normalized Speed Factor (NSF) is used in this research. The NSF of a vehicle is mathematically expressed using Equation (3).

$$NSF_y = \frac{S_{CFV}}{NN\{\max(S_{N_x})\}} \quad (3)$$

S_{CFV} refers to the velocity of the neighboring node N_x of the CFV, whereas $\max(S_{N_x})$ denotes the neighboring node that is currently traveling at the maximum velocity. The speed of $N_x(S_{N_x})$ is determined using Equation (4), where (i_x, j_x) represents the coordinates of the velocity vector of N_x:

$$S_{N_x} = \sqrt{(i_x)^2 + (j_x)^2} \tag{4}$$

When neighbours have a more significant normalized speed variable, it helps to enhance the weighting function. The proposed method prioritizes PHI distribution over slow-moving vehicles.

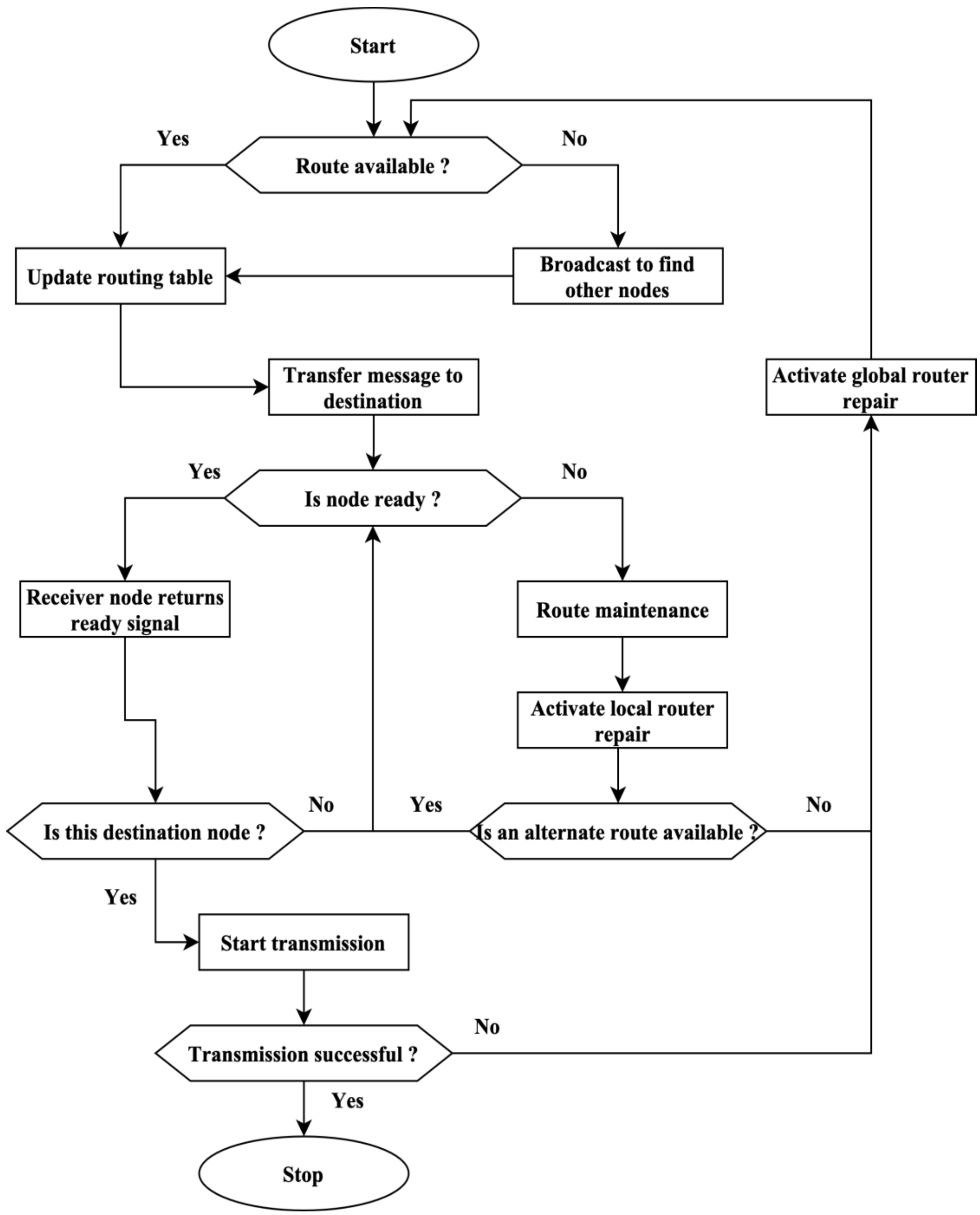

Figure 2: Workflow of the Routing Algorithm

The proposed routing method is classified as a reactive mechanism that operates in a distributed way, as seen in Figure 2. It does not pre-store data about endpoints in its routing table. It just retains data on a limited number of recently traveled itineraries. Proximity nodes are identified by regularly sending out beacon signals, and the formation of loops is prevented by using hop-by-hop routing.

A node initiates a route discovery process by sending a route request signal anytime, which requires distributing messages in a system. The proposed method uses the HELLO signal to eliminate a path from the routing table when there is no activity for a particular duration, as indicated by a time-out signal. In the case of a link collapse, a Route Error (RERR) is produced to broadcast an error message. It needs to save data regarding endpoints in its routing table beforehand. It just monitors and records one or two recent paths. To prevent the occurrence of routing loops, the method employs regular beacon signals to ascertain the identification of neighboring nodes, and the path is computed step by step using sequence identifiers.

4 Simulation Analysis and Findings

The study uses simulations executed on the Network Simulator -3 (NS-3) discrete network simulator structure, which runs on a Linux operating system (ns-3 Network Simulator). The efficiency of cutting-edge technologies has been evaluated using the NS-3.23 network simulation. The needed tool of the SUMO editor is used to design a road network to simulate vehicular traffic.

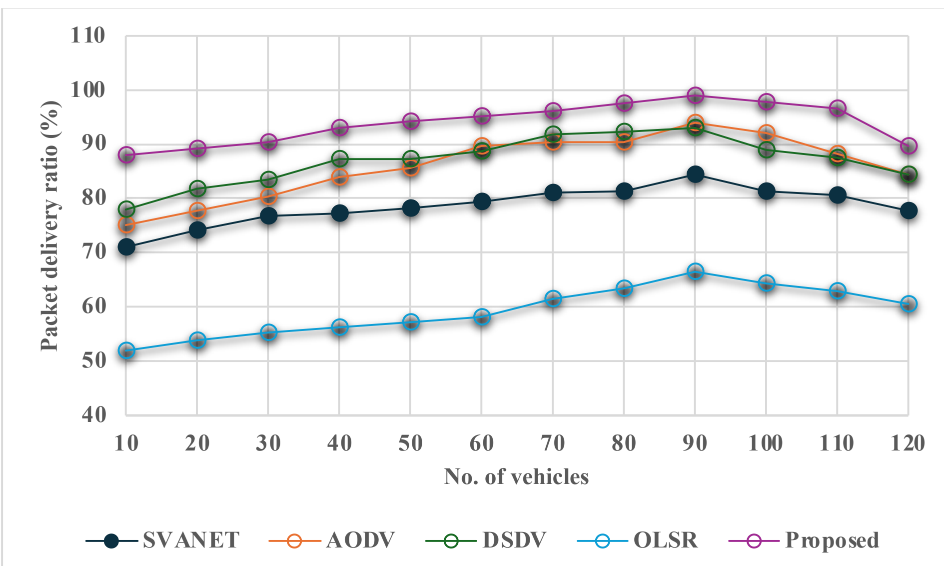

Figure 3: PDR Analysis

According to Figure 3, the first rise in PDR is seen as the number of vehicles increases. However, as the number of vehicles approaches 100, the PDR decreases. A lower node density might result in an unstable PDR, while in high-density surroundings, cars are in closer proximity to each other, leading to improved connections. The average PDR for SVANET, AODV, DSDV, OLSR, and the proposed method are 78.71%, 86.12%, 87.29%, 59.26%, and 94.23%, respectively. The suggested method achieves a higher PDR than other protocols by actively avoiding nodes inside dangerous zones. This reduces the likelihood of connection breakdown, resulting in a rise in PDR as the node density increases.

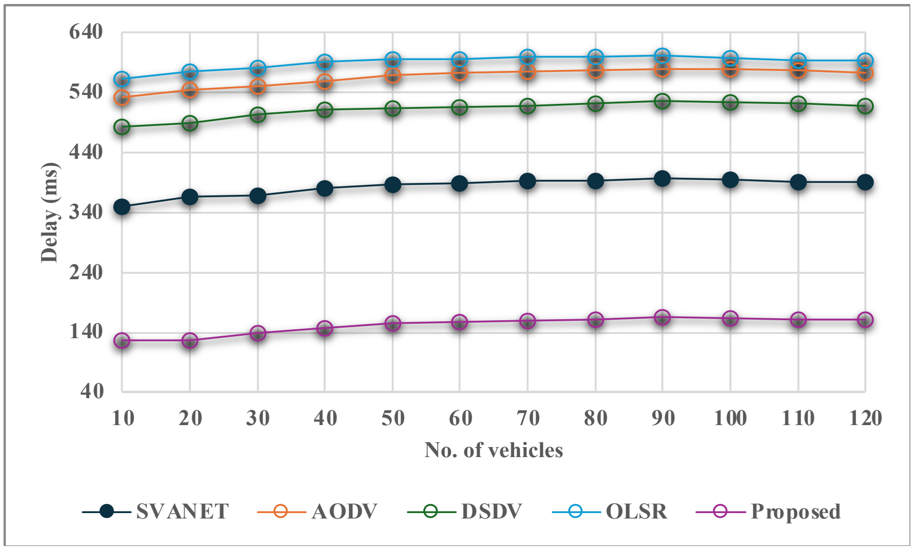

Figure 4: Delay Analysis

Figure 4 demonstrates that when the density of nodes is low, all methods exhibit a significant increase in end-to-end latency. When a packet is sent, the perimeter relaying is continuously activated, increasing route redundancy and a higher latency. As the number of cars rises, the stability of the link between neighboring vehicles improves, resulting in a more reliable and robust connection. The average delay times for SVANET, AODV, DSDV, OLSR, and the proposed method are 382.55 ms, 564.49 ms, 511.69 ms, 589.92 ms, and 151.3 ms, respectively. The proposed method exhibits the lowest delay after SVANET, DSDV, AODV, and OLSR at larger node densities due to the proposed method's preference for selecting a more stable route.

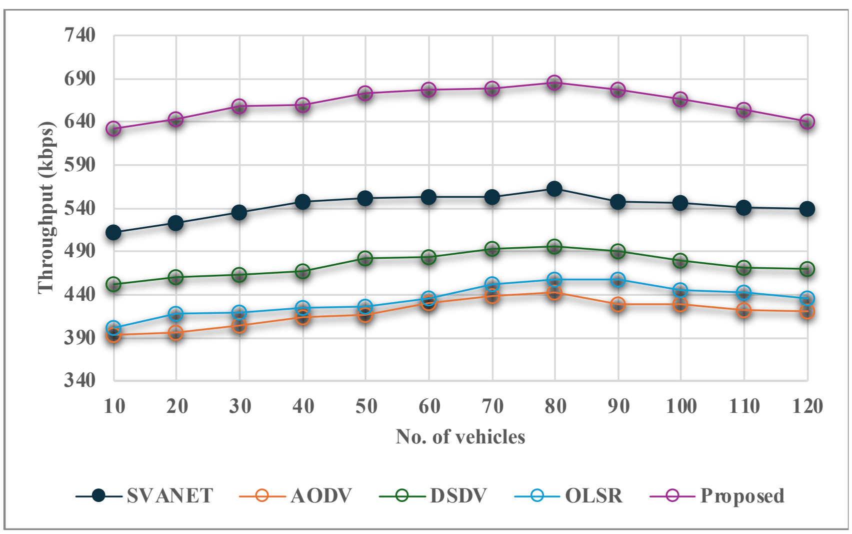

Figure 5: Throughput Analysis

According to Figure 5, there is a positive correlation between the number of vehicles and throughput, indicating that as the number of vehicles grows, the throughput improves. The proposed algorithm has a minimal performance at a node density of 10. However, as the node density increases, it achieves the maximum throughput. The node density of 120 achieves the maximum throughput for all methods. The average throughput for SVANET, AODV, DSDV, OLSR, and the proposed method are 543.06 kbps, 419.7 kbps, 476.51 kbps, 434.84 kbps, and 664.3 kbps, respectively. The proposed algorithm has the best throughput among the SVANET, DSDV, AODV, and OLSR methods. This is because an elevated node density enhances the likelihood of finding a CFV to create a stable connection between the sender and the recipient. This vehicle is capable of carrying a large number of packets containing PHI messages.

5 Conclusion and Discussions

Monitoring the mobility and dependability of medical vehicles, such as ambulances, is vital due to their faster speed (60-120 km/h). It is essential to develop adaptive and intelligent routing algorithms to provide efficient and accurate communication and content dissemination between vehicles and from vehicles to hospitals. This study thoroughly examines the VANET routing techniques employed for V2V communications. The study focuses on non-safety aspects within the context of cars. NS-3 is used to conduct simulations for proactive OLSR and reactive AODV. PDR, throughput, and delay are the primary characteristics used to evaluate the behavior and efficiency of routing algorithms across different network sizes. The proposed method has an average throughput of 664.3 kbps, a delay of 151.3 ms, and a packet delivery ratio (PDR) of 94.23%. The mean delay is determined to assess the system's latencies for an aggregate distance of 1200 m. A proposal will be made for an effective and adaptable channel modeling technique to ensure the accurate delivery of multimedia in 5G healthcare systems in the future. An upgraded power management method will be proposed to increase the energy economy in vehicular and medical applications for safety purposes.

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