Fuzzy Logic Based Geographical Routing for Urban Vehicle Ad-Hoc Networks Based on Intersection Detection

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ABSTRACT:
Vehicular ad-hoc networks are a type of ad-hoc network that lacks a fixed infrastructure. The network's nodes are vehicles that self-organize and perform various network operations, including packet routing and network management. These networks enable intelligent autonomous behavior in vehicles, particularly in situations such as accidents. Each vehicle in a vehicular ad-hoc network acts as a network node, and these nodes can collaborate to enhance network efficiency. Nowadays, technologies like vehicular ad-hoc networks are widely employed to enhance traffic flow and transportation in urban areas. Routing in vehicular ad-hoc networks remains a fundamental challenge in these networks. This article presents a routing method specifically designed for vehicular ad-hoc networks operating in urban environments. Given that urban environments consist of numerous roads and intersections, the proposed approach is divided into three phases. The first phase introduces an intersection detection method that does not require a city map. It classifies the network nodes into two categories: those located at intersections and those outside intersections. The second phase presents a routing method for nodes outside intersections, while the third phase outlines a method for determining routes for nodes within intersections. To evaluate the performance of the proposed method, key parameters such as packet delivery ratio, routing overhead, throughput, and end-to-end delay have been analyzed. The results indicate that the proposed method outperforms other existing methods.

KEYWORDS: Vehicular ad-hoc networks, Fuzzy logic, Routing, Intersection.

1- INTRODUCTION

Vehicular ad-hoc networks (VANETs) are a type of mobile ad hoc networks that enable communication between vehicles in close proximity and between vehicles and fixed equipment typically installed on the roadside [1]. The primary purpose of VANETs is to facilitate the establishment and maintenance of a communication network among vehicles in emergency situations, without relying on a central base station or controller [2]. The absence of infrastructure in VANETs places additional responsibilities on the network nodes, which are the vehicles themselves [3]. Each vehicle becomes an integral part of the network and assumes the responsibility of managing and controlling its communications within the network. Automotive ad hoc networks are responsible for facilitating communication between vehicles operating within a specific environment [4].

VANETs serve three main distinct purposes: safety, convenience, and commercial use. Vehicles can swiftly receive notifications about accidents within a few hundred meters and proactively adjust their routes [5]. They can also communicate with other vehicles to inquire about traffic conditions, obtain information about upcoming intersections or side streets, and share insights about the traffic situation [6]. By leveraging the information obtained from surrounding vehicles, drivers can make more informed decisions, resulting in safer, more comfortable, and enjoyable driving experiences [7].

Routing plays a crucial role in VANETs. Due to the high mobility nature of these networks, designing efficient routing protocols poses significant challenges [8]. The dynamic nature of VANETs creates obstacles in devising effective routing mechanisms [9]. Numerous routing protocols have been introduced in recent years to address these

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challenges. These protocols enable data exchange between separate nodes through intermediate network nodes [10]. Sending real-time and timely messages in VANETs is particularly challenging, as prompt message delivery is crucial in critical scenarios such as accidents. Delays in delivering warning messages can lead to irreversible consequences [11]. The unique characteristics of these networks, including drivers' decision-making processes, high speeds, and continuous vehicle movements, necessitate robust routing mechanisms for efficient data dissemination [12]. Due to the high mobility nature of VANETs, designing efficient routing protocols is an arduous task [13].

The research motive of the proposed method presented in this article is:

- Geographical routing in VANETs has significant potential for optimizing network resource utilization and reducing communication overhead. By taking into account the geographical location and movement patterns of vehicles, intelligent routing decisions can be made to establish efficient and direct communication paths. This approach reduces latency, mitigates packet loss, and improves overall network throughput, enabling real-time data exchange such as traffic updates, emergency notifications, and route recommendations among vehicles.
- Geographical routing offers resilience against network disruptions, including node failures, limited connectivity, and high congestion. By utilizing spatial information, routing protocols can dynamically select alternate routes based on real-time traffic conditions, ensuring reliable end-to-end communication. This resilience is crucial for critical applications such as collision avoidance systems, emergency services coordination, and cooperative driving, where even a momentary communication breakdown can have severe consequences.
- Geographical routing algorithms are specifically designed to handle the challenges posed by high vehicle density, complex road networks, and heterogeneous mobility patterns in urban areas. They take into account the unique characteristics of urban environments, adapting to dynamic vehicular traffic, accommodating frequent changes in network topology, and addressing obstacles such as buildings and urban infrastructure. By incorporating contextual information such as road conditions, traffic congestion, and vehicle density, geographical routing enables efficient and context-aware data dissemination, facilitating intelligent traffic management and urban planning.

To achieve these goals, we propose a routing method for vehicular ad-hoc networks in urban environments. Given the complex nature of urban areas with multiple roads and intersections, our approach consists of three steps. In the first step, we introduce an intersection detection method that operates without relying on a city map. This method categorizes the vehicles in the network into two groups: those located within intersections and those outside of intersections. In the second step, we present a routing method specifically designed for vehicles outside of intersections. This routing method aims to efficiently direct the traffic flow and optimize communication paths between these vehicles. In the third step, we propose a method for determining the routes of vehicles within intersections. This method takes into account various factors, such as traffic conditions and priority rules, to ensure safe and efficient movement of vehicles within these complex road junctions. The main contributions and innovations of our proposed method include:

- Intersection detection method without the need for an urban map: One of the key innovations of this paper is the introduction of an intersection detection method for VANET networks in urban environments that does not rely on an urban map. This method accurately detects intersections without requiring detailed or up-to-date city maps. This capability is particularly valuable in situations where precise city maps are unavailable or outdated.
- State-based intersection routing method: The paper presents a routing method for vehicles both inside and outside intersections in VANET networks. This method performs routing separately based on the status of vehicles at intersections and those outside of them. This innovation improves routing performance in VANET networks in urban environments.
- Comprehensive evaluation of the proposed method's performance: The paper conducts a thorough evaluation of the proposed routing method, considering metrics such as packet delivery ratio, routing overhead, throughput, and end-to-end latency. The results demonstrate that the proposed method outperforms other methods, affirming its effectiveness and efficiency in VANET routing in urban environments.

The remaining sections of the paper are organized as follows: Section 2 provides an overview of the related work. Section 3 presents the details of the proposed method. The simulation and analysis of the proposed method are presented in Section 4. Finally, Section 5 concludes the paper.

2- RELATED WORKS

In [14], a routing protocol called Rectangle-Aided LAR (RALAR) is proposed for Vehicular Ad-Hoc Networks (VANETs). The protocol incorporates a heuristic approach to differentiate accurate GPS location data from weaker ones, thereby improving data reliability. RALAR utilizes a moving rectangular zone based on node mobility models to optimize routing decisions. Furthermore, a Genetic Algorithm (GA) is employed to optimize the selection of a time-out variable, further enhancing the protocol's performance. The performance of RALAR is compared to that of LAR and KALAR protocols, using metrics such as Packet Delivery Ratio (PDR), average End-to-End Delay (E2E Delay), routing overhead, and energy consumption.

In [15], a routing protocol called TAD-HOC (TROPHY-based Ad Hoc) is proposed for VANET networks with the aim of enhancing efficiency and resource utilization. The TAD-HOC protocol combines the ad hoc network with the TROPHY protocol to enable data transmission based on time demand while ensuring desired authentication. Experimental results demonstrate improved performance in terms of packet delay, transmission range, and end-to-end delay when compared to I-AODV, AODV-R, and AODV-L protocols. The integration of ad hoc principles with secure routing capabilities in the TAD-HOC protocol provides an effective solution for VANET networks, surpassing other protocols in terms of network performance measures.

In [16], a hybrid routing algorithm called GAACO (Genetic Algorithm and Ant Colony Optimization) is proposed for optimizing VANET routing in realistic traffic scenarios. GAACO combines genetic algorithm (GA) and ant colony optimization (ACO) techniques to enhance routing efficiency. The algorithm is compared to traditional VANET routing approaches and metaheuristic methods using traffic scenarios from Dehradun City. The implementation is tested using SUMO and NS3.2 simulation tools. Performance evaluation encompasses metrics such as average throughput, packet delivery ratio, end-to-end delay, and packet loss. Experimental results demonstrate that GAACO outperforms other protocols, including PSO, ACO, and AODV across all scenarios.

In [17], the authors introduce DyTE, a novel routing protocol for VANETs that dynamically selects a trilateral zone based on node coordinates to enhance Packet Delivery Ratio (PDR) and throughput. DyTE restricts participation to only relevant nodes, thereby reducing the network routing load. Comparative analysis with existing protocols demonstrates that DyTE significantly improves PDR and throughput while maintaining reliability. By dynamically adjusting the communication zone, DyTE optimizes routing and promotes efficient data transmission in VANETs. The protocol's ability to selectively involve relevant nodes contributes to improved network performance, making it a promising solution for enhancing routing efficiency in VANETs.

In [18], the authors propose ECRDP, an Efficient Clustering Routing approach for vehicular networks. ECRDP utilizes a clustering algorithm that combines Density Peaks Clustering (DPC) and Particle Swarm Optimization (PSO). The approach involves using PSO or a new fitness function based on DPC to determine cluster heads. Clustering is performed based on the link reliability between vehicles. Additionally, a maintenance phase is introduced to update cluster heads and redistribute vehicles as needed. The ECRDP approach aims to optimize cluster formation and routing efficiency in vehicular networks by selecting appropriate cluster heads and adapting to network changes. By combining DPC and PSO, the method improves network performance and adaptability, leading to enhanced efficiency in vehicular network routing.

In [19], a Hybrid Genetic Firefly Algorithm-based Routing Protocol (HGFA) is proposed for Vehicular Ad-Hoc Networks (VANETs) with the objective of enhancing communication speed. The protocol integrates the Genetic Algorithm (GA) with the Firefly algorithm to achieve faster and more reliable routing in both sparse and dense network scenarios. By combining the adaptive mutation capability of GA with the efficient routing properties of the Firefly algorithm, the HGFA protocol enables dynamic adjustment and optimization of routing strategies based on VANET requirements. This hybrid approach significantly improves VANET routing performance, enhancing communication speed and reliability.

In [20], the authors present TGRV, a trust-based geographic routing protocol designed for VANETs (Vehicular Ad-Hoc Networks). TGRV aims to mitigate the involvement of malicious vehicles by considering both direct and recommendation trust when selecting the next-hop for packet forwarding. A monitoring system is employed to enable vehicles to assess the packet forwarding rate of their next-hop and update trust values accordingly. Push-based notifications facilitate the sharing of observations among vehicles and the update of recommendation trust with neighboring vehicles. The monitoring system utilizes distance prediction and a modified promiscuous mode to accurately estimate the packet forwarding capability of vehicles. Trust values decay over time, enhancing the accuracy of trust management. Additionally, TGRV incorporates the number and trust levels of two-hop neighbors to select a more trusted next-hop for routing.

In [21], the authors propose DARVAN, a fully decentralized infrastructure aimed at addressing location privacy and reliability issues in VANET routing protocols. DARVAN utilizes a distributed database and collective consensus mechanisms to minimize the exposure of data typically stored in centralized units. The I2P (Invisible Internet Project) protocol is modified to enhance routing reliability and resilience against various adversary activities in VANets. Notably, DARVAN provides an effective and efficient network-level mitigation for Sybil attacks in VANets. By adopting a decentralized approach, DARVAN offers anonymous and reliable routing while ensuring location privacy. The protocol's emphasis on decentralization and security makes it a promising solution for improving the performance and security of VANet routing protocols.

In [22], the authors propose RTRV, an RSU-assisted trust-based routing protocol for VANETs (Vehicular Ad-Hoc Networks). RTRV incorporates trust criteria to ensure secure routing in the network. The protocol includes a reliable monitoring process where two vehicles observe the behavior of the next-hop in forwarding packets, updating the direct trust value. These observations are reported to RSUs (Roadside Units), which update the indirect trust and provide recommendations to nearby vehicles. RSUs also actively participate in data packet routing, contributing to improved performance. RTRV aims to identify and limit the influence of malicious nodes, thereby increasing resistance to trust-based attacks. By integrating trust management and leveraging the capabilities of RSUs, RTRV enhances routing security and efficiency in VANETs.

In [23], the authors propose TT-SHO, a novel secured protocol for VANETs. TT-SHO combines Tent Tuned Spotted Hyena Optimization (TT-SHO) for routing and Hybrid Chaotic Encryption for data transmission security. The TT-SHO algorithm optimizes the shortest path for routing while ensuring the transmission of chaotic encrypted data with a focus on maintaining Quality of Service (QoS). Experimental results demonstrate low latency, high Packet Delivery Ratio (PDR), and reliable throughput when compared to existing frameworks. The proposed protocol outperforms other approaches, providing safe, reliable, and robust data transmission in VANETs. The integration of TT-SHO and Hybrid Chaotic Encryption enhances security and maintains QoS, making it a promising solution for secure and efficient communication in VANET environments.

3- PROPOSED METHOD

The proposed approach is divided into three phases. In the first phase, an intersection detection method is presented that does not require a city map. The status of the Duran network vehicles is categorized into two groups: those located within the intersection and those outside the intersection. In the second phase, a routing method is introduced for the nodes outside the intersection. In the third phase, a method is provided for determining the route for the nodes within the intersection. In the proposed method, each node periodically sends a packet containing its ID, location, direction, speed, and sending time at specific intervals. This packet is broadcasted to all neighboring nodes. The structure of this message is illustrated in Figure (1).

ID	Location	Direction	Speed	Time

Fig. 1. INF packet structure

Each node maintains a neighbors table to store information about its neighboring vehicles. The structure of this table is depicted in Table (1).

Table 1. Neighbor’s information table

ID	Location	Direction	Speed	Time

After receiving the INF packet from its neighbors, the vehicle performs the following actions based on the neighbor vehicle ID:

- If the vehicle ID exists in the table and the packet time is older than the recorded time in the neighbor table, the packet is discarded.
- If the vehicle ID exists in the table and the received packet time is newer than the recorded time in the neighbor table, the corresponding row in the table is updated.
- If the vehicle ID of the received packet is not found in the table, a new row is created to register the new vehicle in the table.

Considering the dynamic nature of the network topology in vehicular environments, if a packet from a vehicle is not received and the corresponding row in the neighbor table is not updated for a period exceeding 2t, it is assumed that the vehicle has left the neighborhood. Consequently, the corresponding row is removed from the table. Here, t represents the time interval for sending the INF packet to the neighbors. The steps of the proposed method are described below.

3-1- First phase: Intersection detection

The intersection detection method is performed individually by each node in the proposed approach. In this method, an intersection is defined as a location where a moving vehicle can establish communication not only in the direct direction (front and rear) but also with vehicles in other directions. The different types of intersections that are possible are illustrated in Figure (2).

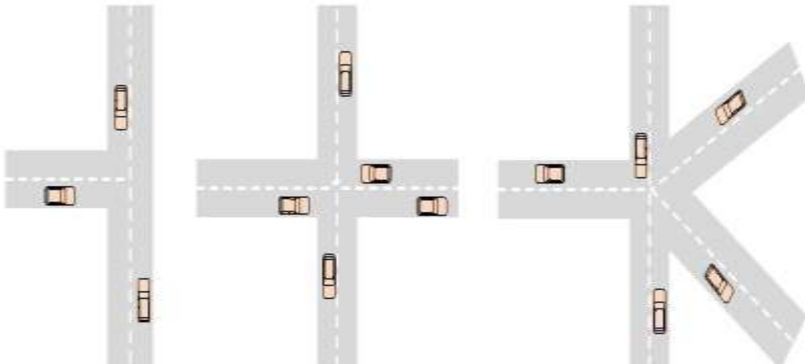

Fig. 2. Types of intersections

Considering that routing in the proposed method is based on the positioning of nodes within the intersection, the status of each node in the network is categorized into two states: being in the intersection and being outside the intersection. Consequently, each node in the network determines its status by examining the packets received and stored in the neighbor table. The following steps outline the process of determining the node's status.

Step 1: Each node defines a circular wireless communication space around itself with a radius of r (communication range). This communication space is divided into eight equal and non-overlapping slices using four diameters, as depicted in Figure (3).

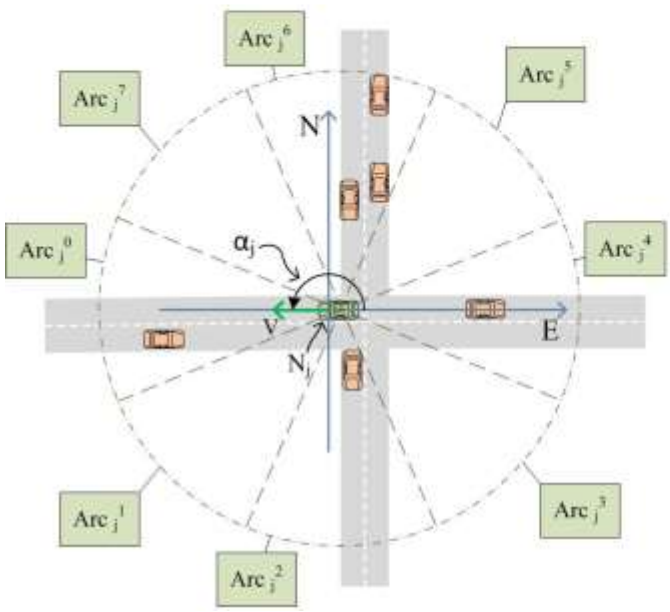

Fig. 3. Intersection division

Step 2: The starting and ending angles of each arc are calculated using Equation (1).

$$Arc_i^j = \begin{cases} start: \alpha_j + \frac{i\pi}{4} - \frac{\pi}{8} \\ End: \alpha_j + \frac{i\pi}{4} + \frac{\pi}{8} \end{cases} \quad (1)$$

Where i=0,1, 2...,7 and αj is the angle of the speed vector of node j with respect to the horizontal coordinate axis.

Step 3: Each vehicle sends an ARCINFO packet to its neighbors. Based on the information in the neighbor table, the vehicle calculates the difference in direction with the neighboring node using Equation (2).

$$Direction_{ij} = |Direction_i - Direction_j| \quad (2)$$

Where $Direction_{ij}$ indicates the difference in the direction of the source vehicle i and the source vehicle j. $Direction_i$ is the direction of the source node and $Direction_j$ is the direction of the neighboring node j.

Step 4: Based on the calculated direction difference, the arc representing the location of each neighboring node is determined and recorded in the neighbor table.

Step 5: If all the neighboring nodes in the neighbor table are positioned within the arcs in front of and behind the node, it indicates that the node is not within the intersection.

Step 6: If half of the neighboring nodes of the current node are located within arcs other than the arc in front of and behind the node, it indicates that the node is within the intersection.

3-2- Second phase: Routing outside the intersection

Routing is conducted outside the intersection among vehicles traveling in the same direction on a road. In this phase of the proposed method, each node follows the following steps to determine its next move, utilizing the information stored in the neighbor table.

Step 1: Initially, the source vehicle compares the direction of the destination with the direction of its neighboring vehicles (as indicated by the Direction field in the neighbor table). Vehicles that are moving in the opposite direction of the destination are excluded from the routing process. Nodes that are traveling in the same direction as the destination vehicle are added to set D, utilizing Equation (3).

$$\}\mathbf{D} = \{\mathbf{N_i}|\mathbf{N} \in \mathbf{Neighbors\ Table.\ Direction_i} - \mathbf{Direction_d} < \mathbf{90} \quad (3)$$

Where $Direction_d$ is the direction of the destination node and $Direction_i$ is the direction of the neighboring node.

Step 2: The source vehicle calculates the distance to the destination for the nodes in set D using Equation (4) and determines the speed difference between itself and each node using Equation (5).

$$Distance_{id} = \sqrt{(x_i - x_d)^2 + (y_i - y_d)^2} \quad (4)$$

Where (x_i . y_i) are the coordinates of the neighboring node and (x_d.y_d) are the coordinates of the destination node.

$$DiffSpeed_{si} = Speed_s - Speed_i \quad (5)$$

Where $Speed_s$ is the speed of the origin node and $Speed_i$ is the speed of the neighboring node.

Step 3: the source vehicle evaluates the member nodes of set D using equation (6).

$$Fit_i = \left(1 - \frac{Distance_{id}}{Distance_{sd}}\right) + (1 - \frac{DiffSpeed_{si}}{\max(diffspeed)}) \quad (6)$$

Where $Distance_{id}$ is the distance of the neighboring node to the destination node and is calculated based on equation (4), $Distance_{sd}$ is the distance of the origin node to the destination node and is calculated based on equation (7). $DiffSpeed_{si}$ is the speed difference of the neighboring node with the original node, which is calculated based on the equation (3-5), and $\max(diffspeed)$is the maximum speed difference calculated with the neighbors in set D.

$$\mathbf{Distance_{sd}} = \sqrt{(\mathbf{x_s} - \mathbf{x_d})^2 + (\mathbf{y_s} - \mathbf{y_d})^2} \quad (7)$$

Where (x_s.y_s) are the coordinates of the origin node and (x_d.y_d) are the coordinates of the destination node.

Step 4: The source vehicle evaluates the scores of the nodes in set D, and selects the nodes whose score is greater than or equal to half of the highest score. These selected nodes are then included in set C, determined using Equation (8).

$$C = \{N_i|N \in D.\ Fit_i \geq \frac{\max(Fit_i)}{2}\} \quad (8)$$

Step 5: The source vehicle sends the data packet to the neighboring vehicle in set C that has the shortest distance to the destination.

3-3- Third phase: Routing at the intersection

If the node detects that it is in an intersection, the next step is chosen by taking into account the relevant factors and employing fuzzy logic. The following steps outline this phase of the proposed method.

Step 1: Fuzzy inputs

The inputs of the fuzzy system at this stage are density and distance to the destination.

- Density or the number of neighbors: This parameter is significant and influential in selecting the next step, as it affects the network's connectivity and potential delays. A high density of nodes can lead to increased connections and network congestion, while a low number of neighbors can result in a higher likelihood of failure and weaker links between nodes. To determine the density of neighboring nodes, the source node sends a REQ packet to its neighbors. In response, the neighboring nodes send the count of their neighbors, based on the neighbor table, to the source node in the form of a REP message. The structure of the REP message is illustrated in Figure (4).

ID	Density

Fig. 4. REP packet structure

The membership diagram for neighbor density is depicted in Figure (5).

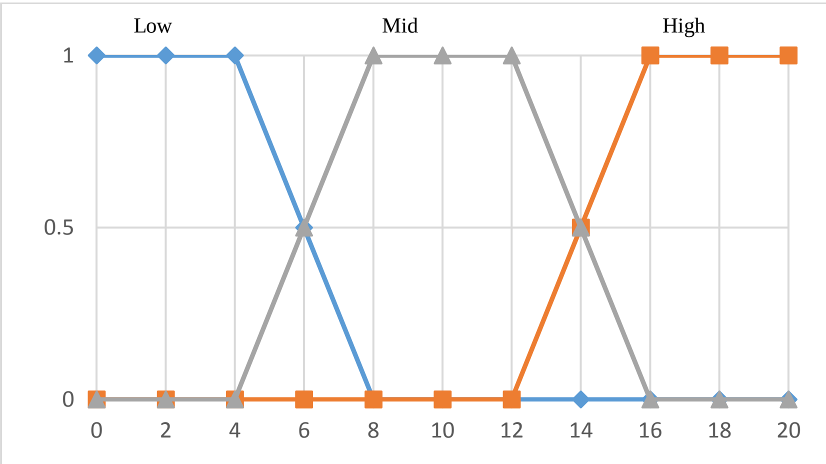

Fig. 5. Density membership chart

- Distance to the destination: Each node computes the distance of its neighboring nodes to the destination using Equation (9) based on the information available in the neighbor table.
-

$$Distance_{id} = \sqrt{(x_i - x_d)^2 + (y_i - y_d)^2} \quad (9)$$

Where (x_i, y_i) is the coordinates of the neighboring node and (x_d, y_d) is the coordinates of the destination node. The membership chart of the distance to the destination is shown in Figure (6).

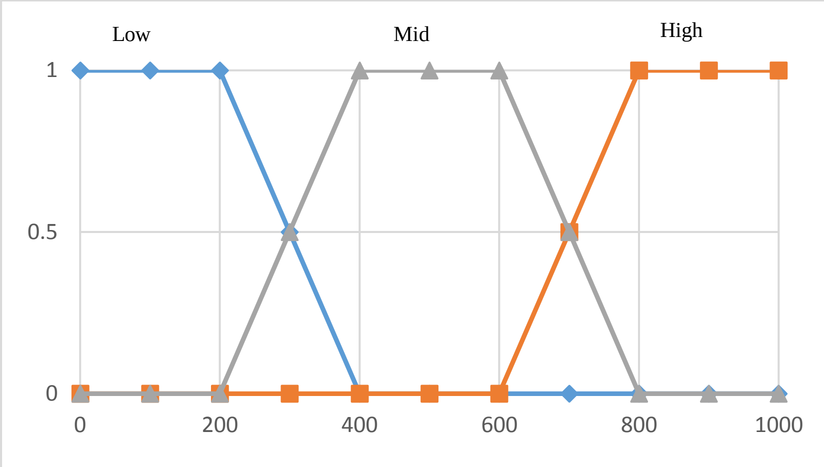

Fig. 6. Distance density membership chart

Step 2: Fuzzy rule

A fuzzy if-then rule follows the structure "if fuzzy statement, then fuzzy statement." By employing fuzzy if-then rules, the necessary rules for decision-making can be formulated. The interpretation of these rules is a crucial aspect. In two-valued logic, when considering the rule P⟹Q, its value can be easily determined since the final interpretation is based on the true and false states. The truth table of a regular conditional statement illustrates the relationship between the antecedent and the consequent. In essence, the conditional statement is false when the antecedent is true and the consequent is false. In the proposed method, each input possesses three states: low, medium, and high. The fuzzy system consists of two inputs. The number of fuzzy rules in the proposed method amounts to 9, as exhibited in Table (2).

Table 2. Fuzzy rules

No	IF		Then
	Distance	Density	Cost
1	Low	Low	Medium
2	Low	Mid	Very High
3	Low	High	High
4	Mid	Low	Low
5	Mid	Mid	High
6	Mid	High	Medium
7	High	Low	Very Low
8	High	Mid	Medium
9	High	High	Low

Step 3: Fuzzy output

The output function in the proposed method is responsible for determining the probability of selecting a node as the next step in the routing process. The value of the output membership function is obtained using the output weighted average method. In the proposed method, five outputs are considered for the fuzzy system, as illustrated in Figure (7).

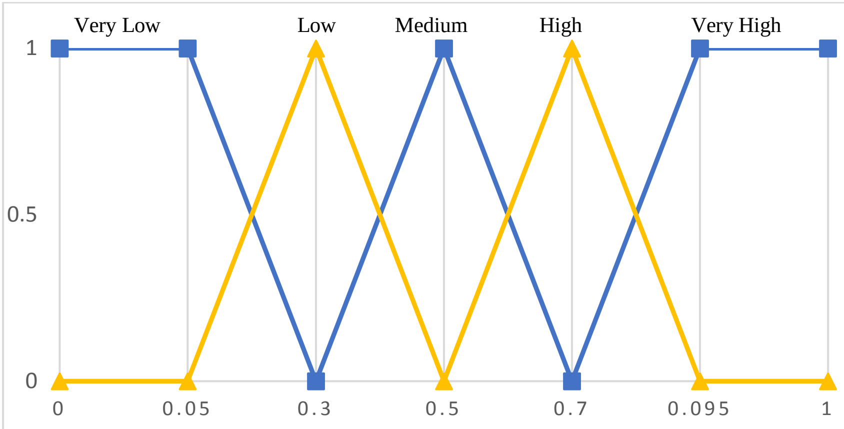

Fig. 7. Fuzzy output.

4- SIMULATION AND RESULTS

The effectiveness of the proposed approach is demonstrated using MATLAB simulation software. The proposed method is compared with DBAFS [24] and EGSR [25] methods. The simulation parameters are provided in Table (3).

Table 3. Simulation parameters.

Parameter	Value
Network size	5000 m^2
Number of nodes	0-500
Velocity	0-42 $\frac{m}{s}$
Communication range	150 m
Source/destination	Random
Simulation time	300 s
Channel type	Wireless channel
MAC type	IEEE 802.11

To assess the performance of the proposed method, various parameters including packet delivery ratio, routing overhead, throughput, and end-to-end delay have been analyzed.

The packet delivery ratio represents the ratio of successfully delivered data packets to the destination compared to the total number of packets sent in the network. The comparison of the packet delivery ratio between the proposed method, DBAFS, and EGSR methods is illustrated in Figure (8), while Figure (9) displays the variation of the packet delivery ratio with respect to different vehicle speeds.

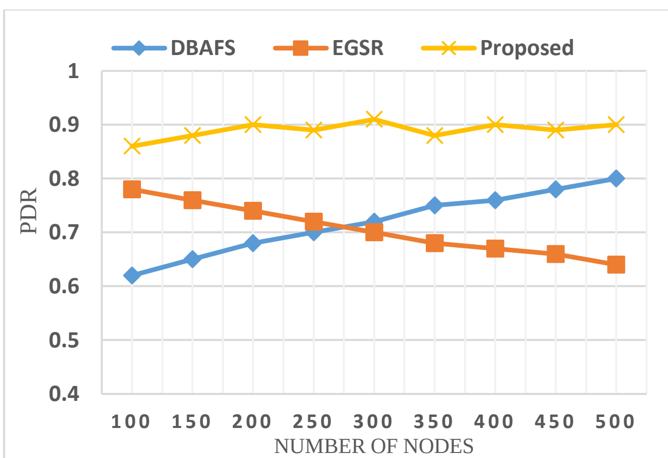

Fig. 8. Packet delivery rate in different number of nodes.

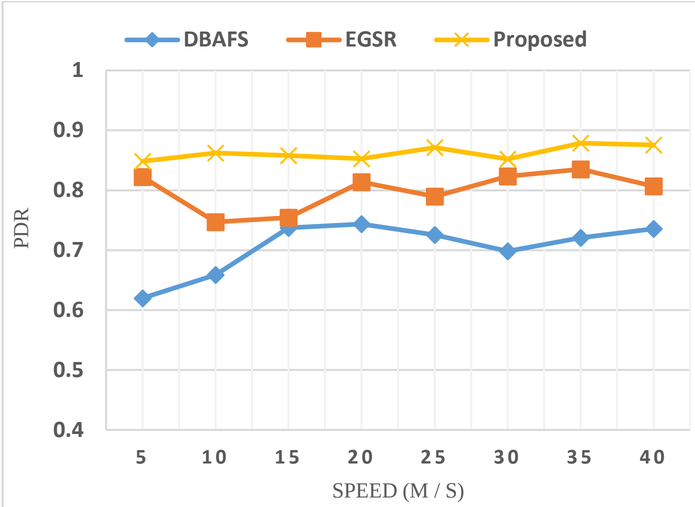

Fig. 9. Packet delivery rate at different speeds of nodes.

In the proposed method, vehicles exchange their information with neighboring nodes at predefined time intervals. If a neighboring node fails to provide its location information within the designated time interval, it is removed from the routing table. This prevents the transmission of packets to neighboring vehicles that are outside the communication range of the source, thus reducing packet loss. Additionally, the proposed method employs two different routing approaches: inside and outside the intersection. In routing outside the intersection, the parameters considered for selecting the next step are the distance to the destination and the speed difference with the neighboring vehicle. In routing within the intersection, the parameters of distance to the destination and density are taken into account, and the best next step is determined using fuzzy logic. Considering these parameters helps establish more stable routes for packet transmission. Consequently, the strategies employed in the proposed method enhance the packet delivery ratio compared to other methods.

The time required for a data packet to travel from the source to the destination is referred to as the end-to-end delay. It encompasses delays stemming from packet buffering, route discovery process, retransmission process, and propagation time. Communication link losses often contribute to delays in many instances. In a vehicular ad-hoc networks, increasing the speed and density of the network raises the likelihood of communication link losses and subsequently increases the end-to-end delay. In the proposed method, selecting more stable routes and considering the parameters of speed and density in both the routing process outside and inside intersections minimize the occurrence of broken links during data transmission, thereby reducing the average end-to-end delay. Hence, as demonstrated in Figure (10) and Figure (11), the proposed method outperforms other methods in various density and speed scenarios within the vehicle network.

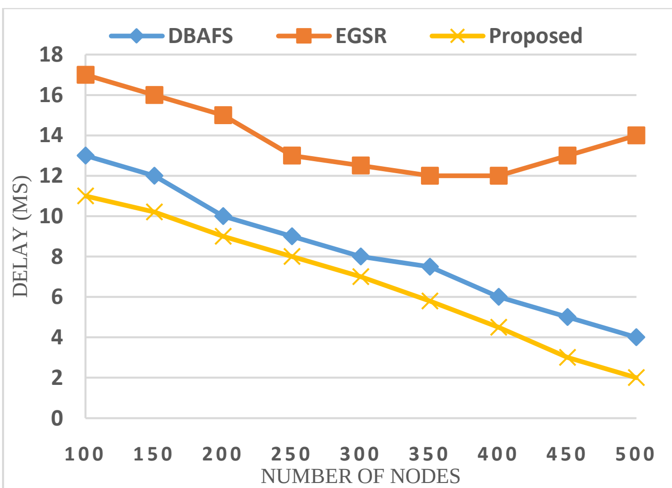

Fig. 10. Average end-to-end delay in different number of nodes.

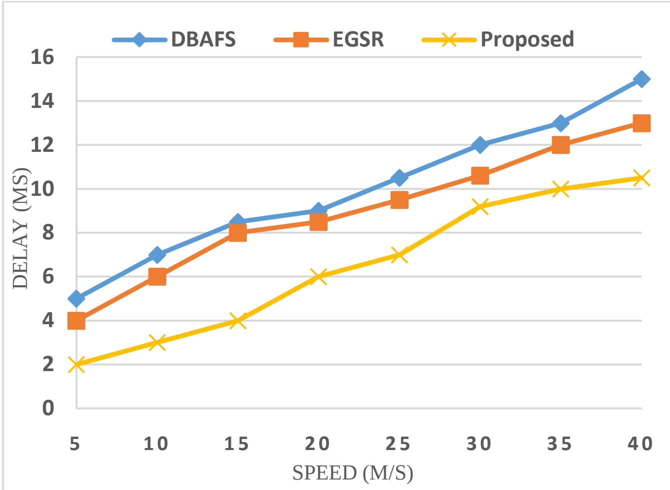

Fig. 11. Average end-to-end delay at different vehicle speeds.

Control messages, such as INFO messages and route discovery messages, serve as control signals and contribute to network overhead, known as control overhead. In the proposed method, control messages are utilized for neighbor table registration and route discovery between vehicles. Additionally, at intersections, control messages are employed for route discovery purposes. As the proposed method is a reactive protocol, it incurs higher control overhead compared to DBAFS methods. Figure (12) illustrates the comparison of control overhead between the proposed method and other methods. It is evident that control overhead increases with a higher number of nodes in the network.

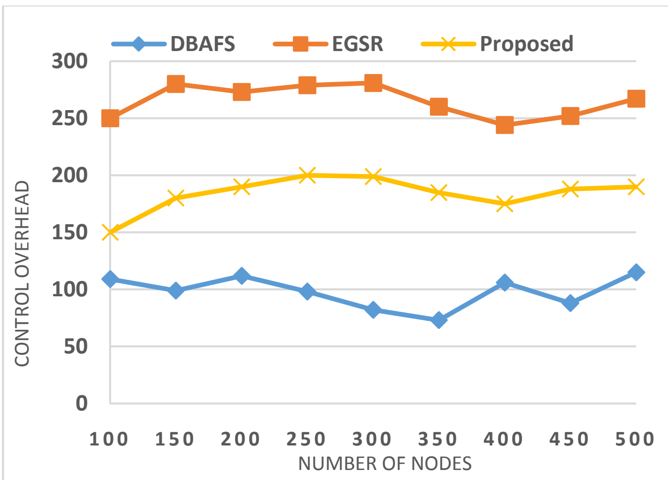

Fig. 12. Control overhead in different number of nodes.

5- CONCLUSION

The primary objective of vehicular ad-hoc networks is to establish communication between vehicles, both within and between road units. Several routing protocols have been proposed for these networks, but they often fail to address all the challenges specific to such environments. This paper presents a routing method for vehicular ad-hoc networks in urban environments. Given the complex nature of urban settings, the proposed approach is divided into three phases. In the first phase, an intersection detection method is introduced eliminating the need for a city map. The vehicles in the network are categorized into two groups: those located within intersections and those outside intersections. The intersection detection mechanism is performed independently by each node. Since the routing method in the proposed approach is chosen based on the vehicle's location in the intersection, each node in the network is assigned one of two states: within the intersection or outside the intersection. In the second phase, a routing method is devised for nodes outside the intersection, while in the third phase, a method is presented for determining the route for nodes within the intersection. In the third phase, the selection of the next step is made by considering relevant parameters and employing fuzzy logic. MATLAB simulation software is employed to validate the effectiveness of the proposed approach. A comparison is made between the proposed method and the DBAFS and EGSR methods. The simulation results demonstrate that the proposed method achieves satisfactory outcomes in terms of packet delivery ratio, routing overhead, throughput, and end-to-end delay.

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