**JOURNAL OF SOFT COMPUTING AND DATA MINING**
e-ISSN: 2716-621X

**JSCDM**

Vol. 6 No. 1 (2025) 127-137
https://publisher.uthm.edu.my/ojs/index.php/jscdm

# A Fuzzy-based Cluster Head Selection Technique for Optimizing Communication of VANETs

**Yousif Khalid Yousif[1]*, Ali Kadhim Bermani[2,3], Mohammed Hasan Aldulaimi[3], Mohammed Khalaf[4], Rasha Bashar Mohammed[1], Ahmed J.M. Almihi[5]**

[1] *Technical Engineering College for Computer and AI, Northern Technical University, Mosul, 41000, Nineveh, IRAQ*
[2] *College of Information Technology, University of Babylon, Babylon, IRAQ*
[3] *Department of Computer Techniques Engineering, College of Engineering, Al-Mustaqbal University, Hillah, 51001, Babylon, IRAQ*
[4] *Department of Computer Sciences, College of Science, University of Al Maarif, 31001, Anbar, IRAQ*
[5] *Department of Artificial Intelligence Technology, Engineering College of Technical Engineering, Alnoor University Mosul 41012, Nineveh, IRAQ*

*Corresponding Author: yousif.k.yousif@ntu.edu.iq
DOI: https://doi.org/10.30880/jscdm.2025.06.01.009

**Article Info**

Received: 14 April 2025
Accepted: 28 May 2025
Available online: 30 June 2025

**Keywords**

Fuzzy logic, decision-making, VANET, cluster head selection, effective communication

**Abstract**

The continuous developments in vehicular communication technology have brought a significant interest in Vehicular Ad-Hoc Networks (VANETs). VANETs aim to enhance road safety, improve traffic management, and provide a suite of infotainment services to passengers. This type of network is characterized by high-speed, dynamically varying mobility, leading to increased Energy Consumption (EC), End-to-End (E2E) delay, and Routing Overhead (RO) during network communication. Various researchers have developed ways to overcome this drawback through the employment of clustering techniques in VANETs. However, utilizing clustering techniques in VANETs is critical as it requires maintaining robust communication links, optimizing resource allocation, and minimizing E2E delay. Subsequently, this paper proposes an improved Fuzzy-based Cluster Head Selection (FCHS) technique to enhance the overall performance of VANET. In VANET, the clustering is formed from Cluster Head (CH), Cluster Child (CC), and Backup-Cluster Head (BCH) along with the other network nodes. The FCHS optimizes the CH selection using a fuzzy logic algorithm based on various VANET parameters, including average distance, satisfaction degree, EC, Packet Delivery Ratio (PDR), and vehicle connectivity level. The performance of the proposed FCHS technique is simulated utilizing Network Simulator (NS) 2.35 with the Simulation of Urban MObility (SUMO) platform. The performance metrics that are considered for the result evaluation are PDR, EC, E2E delay, and RO. The overall results of the VANET is compared with two recent methods. The results show that the VANET performance with the aid of the proposed FCHS technique achieves the highest PDR, low EC, E2E delay, and RO.

## 1. Introduction

In recent years, Vehicular Ad-Hoc Networks (VANETs) technology has grown massively through its communication intelligence. VANETs commonly maintain vehicle-to-vehicle and infrastructure-based communication [1-2]. It is essential to recognize that VANETs exhibit unique characteristics VANETs, including high speed, random mobility in unpredictable ways. Nevertheless, these characteristics may affect the network stability and reliability. Subsequently, it directly affects communication effectiveness by increasing Energy Consumption (EC), End-to-End (E2E) delay, and Routing Overhead (RO). Fortunately, these drawbacks can be mitigated through the implementation of an innovative clustering technique within the VANETs.

Cluster Head (CH)-based architectures are used to improve the lifetime of VANETs [3-6]. Additionally, CH-based communication reduces network RO in VANETs, as well as energy consumption and delay time [7-9]. The vehicles present in a particular place are grouped together to form clusters, consisting of CH and others referred to as Cluster Children (CC). CH plays an important role in controlling and monitoring the entire cluster through collecting the information from all CC and neglecting any unnecessary information.

The literature has confirmed that clustering and CH selection are the most efficient and reliable techniques in VANET communications. [7-9]. However, selecting effective CH is the biggest challenge with time-critical and constrained resources [10]. The technique should ensure that the vehicle which selected as CH is effective, worthwhile, and efficient compared to other vehicles in the network.

This paper improves CH selection using a fuzzy-based decision-making process by proposing an improved Fuzzy-based Cluster Head Selection (FCHS) technique. In VANET architecture, the clustering is formed from CH, CC, and Backup-Cluster Head (BCH) along with the other network nodes. The FCHS optimizes the CH selection and the overall performance of VANET by applying a fuzzy logic algorithm on various VANET parameters, including average distance, satisfaction degree, threshold energy, Packet Delivery Ratio(PDR), and vehicle connectivity level. The main contributions of this paper are outlined as follows:

- Propose FCHS technique to improve the efficiency of VANET communication.
- Construct VANET architecture from CH, CC, backup BCH, and other network nodes.
- Construct a Fuzzy-based decision-making process that aimed to select the best CH and BCH vehicles within the cluster. The fuzzy logic considers the multi parameters of the CH selection process, such as average distance, satisfaction degree, threshold energy, PDR, and vehicle connectivity level.
- Evaluate the performance of the VANET and FCHS technique, considering different performance metrics such as PDR, EC, E2E delay, and RO.

The reminder of the paper is structured as follows: In section 2 the earlier works on CH selection approaches in VANETs are presented. Section 3 illustrates the proposed FCHS technique. Section 4 shows the results and discussion. Section 5 presents the conclusion and future directions.

## 2. Related Work

Cluster-based routing optimization is becoming popular for making VANET networks more scalable, stable and efficient where vehicles are moving around constantly [1]. Vehicles are grouped into clusters and assigned with cluster heads to lower the cost of routing, handle changes in the network and help data be transmitted more securely [2]. A number of studies have introduced intelligent approaches for selecting CH based on residual energy, how mobile the device is, the strength of its connection and how well it communicates data. Among the techniques developed, fuzzy logic-based methods stand out because they allow networks to adjust their operations under uncertain or vague conditions [3]. Despite the challenges of using up more energy when the network is spread over a larger area, these new methods usually perform better than traditional ones.

The authors Alsarhan [11] suggested a fuzzy logic and game theory-based clustering solution to enhance the constancy of network topology and effectively utilize the spectrum to improve network efficiency lifetime and demonstrate better recovery in response to topology changes. However, under this framework, energy usage did not decreased significantly as the communication range increases. while in [12], a clustering technique was proposed to raise the stability of the entire cluster rather than only the stability of the CH, thereby providing better QoS. This approach is particularly suitable for short-range communication only which results in processing RO when applied to. long-distance communication. In [13], a Geographic Routing method was developed by considering parameters such as Velocity, Angle, and Density. It offers a better PDR but fails to maintain minimum E2E delay. In [14], a fuzzy-based self-adaptive learning technique was offered for CH selection. The main advantage of this approach is its ability to lowers traffic congestion but it consumes more energy as distance increases.

In [15], a fuzzy interface system was introduced for CH selection. This approach greatly increased the network's lifetime. At the same time, the PDR was low, results in increasing the packet delay. To mitigate this issues authors in [16] presented an approach combining fuzzy logic and a greedy routing protocol. This approach achieves the highest PDR and minimizes the number of hops. This approach involves high complexity, t thus connectivity duration is increased.

In [17] researchers proposed framework that reduces communication and computational costs but fails to reduce EC during congested scenarios of VANETs. The work of [18] presented a fuzzy-based routing protocol that considered two parameters, quality factor of the channel and communication expiration time for selecting a reliable CH. This framework gives better performance in terms of PDR and control messages. However, it is vital to note that this approach requires more energy for the handover operation under real-time scenarios.

In [19], a fuzzy logic-based CH selection scheme was developed to save the cluster and prevent collisions. The proposed approach offered an increased network lifetime and significantly reduced the re-clustering RO. Despite its advantages, it requires additional resources for long-range communication to maintain the same performance. In [20] an approach was introduced for improving the density of the cluster based on various VANET parameters such as latency, PDR, throughput, RO, and packet loss, but it fails to improve the cluster efficiency.

Lavanya et al. [21] proposed an ant colony optimization algorithm-based CH selection in VAENTs for a better network lifetime. The performance is moderate and unsuitable for high-speed and random mobility networks. In [22], A clustering scheme was designed that aims to improve the efficiency and flexibility of the VANETs. c. Through this approach, effective CH election and re-clustering are performed with the help of vehicle comparative displacement which can increases the efficiency of the network but fails to reduce the RO, and the throughput remains at moderate performance level.

From aforementioned related works above, it is clearly revels in that there is no scheme that offers an energy efficiency and scalable CH selection for VANETs while maintaining stable communication over short and long distance. Moreover, the lack of optimizing QoS in comprehensive manner, besides the ability to adapt to the conditions of high speed and dynamic mobility without introducing complexity or energy expenditure are also shown in discussed related works

## 3. Proposed FCHS Technique

### 3.1 VANET Architecture

VANETs are connected vehicles that perform communication both among vehicles and between vehicles and infrastructure. This kind of communication is a complex when applied large scale network as unwanted communication occurs, thus producing interference and collision in the network, leading to heightened EC, E2E delay, and RO during VANET communication. To enhance the operational efficiency of VANETs, the vehicles that share a similar destination form a cluster along the roadway to perform both inter-cluster and intra-cluster communication. Within the cluster, any vehicle that meets the specified criteria may be selected as CH based on fuzzy-based CH selection illustrated in (Section 3.2).

### 3.2 Fuzzy-based CH selection

The FCHS technique helps VANETs as vehicles often move and change positions, so routes and communications may be shaky and inconsistent. As the network changes rapidly, traditional routing algorithms are slow to respond, causing increased loss of packets, depletion of energy, and poor Quality of Service (QoS). The FCHS technique uses fuzzy logic to ensure the clusters are dynamically setup thanks to information on energy levels, radio connectivity, movements, and previous deliveries. As a result, routing becomes more reliable and more efficient, which also reduces the lack of data in VANETs. The CH selection process considers average distance, satisfaction degree, threshold EC, PDR, and vehicle connectivity level. Figure 1 describes FCHS's workflow.

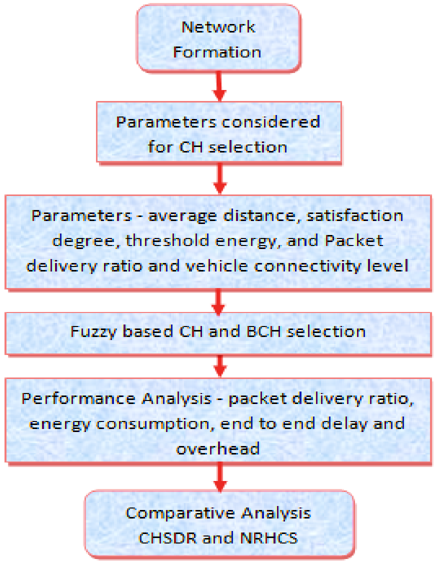


**Fig. 1** *Workflow of FCHS technique*

The mathematical expression to calculate these parameters is defined. Average distance is the sum of the neighbor vehicle distance which is expressed as flow,

$$D_{AV} = \frac{(d_1(X))^2 + (d_2(Y))^2}{2} \tag{1}$$

In equation (1), the variables $d_1$ and $d_2$ represent the shortest and longest distances of the vehicles. Respectively $X$ indicates the coordinates of the source, while $Y$ signifies the coordinates of the destination. The degree of satisfaction is characterized by the capability of the CH to establish communication with its cluster children and other **CH**s. The formula used to calculate the satisfaction degree of the vehicle is presented as follows:

$$SD_{vehicle} = \alpha * D_{AV} \tag{2}$$

In equation (2), α is the experimental constant, which lies between 0 and 1. The threshold energy of the vehicle is defined as the energy present in the vehicle at various stages of communication according to time variation. The expression for the calculation of threshold energy is given as,

$$Th_{energy}(V) = \frac{\sum_{i=i}^{V}(EC_{TX}(t) + EC_{AG}(t))}{t+1} \tag{3}$$

In equation (3), the variables $EC_{TX}(t)$ and $EC_{AG}(t)$ represent the energy expenditure associated with data transmission and data aggregation at every given moment. The PDR is defined as the proportion of the total packets number that are successfully received in relation to the total packets number that have been transmitted to the vehicle. The formula for determining the PDR is presented as follows:

$$PD_{ratio}(V) = \frac{\sum_{t=0}^{n} SR_{pac}}{\sum_{t=0}^{n} TX_{pac}} \tag{4}$$

Vehicle connectivity level ($VC$) calculation is related to the vehicle's threshold energy and its successful PDR according to the time in which a vehicle $V$ in VANETs can be found by adding the remaining energy ($Th_{energy}$) and the packet delivery ratio ($PD_{ratio}$). By using $\alpha 1$ and $\beta 1$, each factor's importance can adjust to the chosen routing goal. Unfolding the score by $t$+1 helps the assessment keep up with changes happening in the network. The formula aids in choosing suitable vehicles to act as cluster heads, as it calculates how efficient and reliable they are in terms of energy use and communication. The expression for the calculation of vehicle connectivity level is given as,

$$VC_{level} = \frac{\left(\alpha_1 * Th_{energy}(V)\right) + (\beta_1 * PD_{ratio}(V))}{t+1} \tag{5}$$

J. of Soft Computing and Data Mining Vol. 6 No. 1 (2025) p. 127-137

In equation (5), the parameters $\alpha_1$ and $\beta_1$ represent the experimental constants that fulfill the condition ($\alpha_1 + \beta_1 = 1$). The pseudo-code for the calculation of parameters in the FCHS process is presented in Algorithm 1 below

In the network, CH selection is performed using the calculation of the above equation. In certain conditions, many vehicles can able to have maximum probability according to those parameters. In order to select the best CH from those vehicles, a fuzzy-based decision-making process is initiated. The expression for the calculation of fuzzy-based decision-making is given as,

$$FUZZY_{CH} = \sum_{i=1}^{k} ED_{(CH,i)} * VC_{level}(CH, i) \qquad (6)$$

The fuzzy value for CH and BCH is calculated in equations (6) and (7). ED (CH,i) and ED(BCH,j) are the Euclidean distances between the vehicles. The terms k and l denote the probability of the total count of CHs and BCHs. The vehicle with the shortest Euclidean distance, which vehicle can cover a maximum number of other vehicles, is considered CH; likewise, the second-best value is considered BCH. This process performs an effective CH selection using the proposed fuzzy-based CH selection approach.

$$\mathrm{FUZZY_{BCH}} = \sum_{j=1}^{l} \mathrm{ED_{(BCH,j)}} * \mathrm{VC_{level}}(\mathrm{BCH}, \mathrm{j}) \qquad (7)$$

To choose the best cluster heads in VANET routing, the FCHS technique collects the average distance of each vehicle to its neighbors, satisfaction level, EC level, PDR, and the connectivity it currently has, as shown in Algorithm 1. This information reflects how well a vehicle can act as a communication center or cluster head in various dynamic situations. All the parameters are next changed into fuzzy terms such as Low, Medium or High so that uncertain and imprecise information present in car data is represented.

After that, fuzzy sets are used to assign levels of membership to each numerical value in the input parameters. Next, a set of fuzzy rules (for instance, Rule R1) is applied to assess the fuzzy inputs. In this case, R1 explains that if the vehicle is neither close nor far from others and has extremely good results for satisfaction, energy, PDR and connectivity, then it could become a CH. Each fuzzy rule is followed and the CH potentials from each rule are combined to provide a fuzzy score for every vehicle. It is important for this process to turn several criteria into a single calculation of the area's suitability.

**Algorithm 1** *The proposed FCHS technique*

Input : Average distance, satisfaction degree, threshold energy, PDR, connectivity level;
Output: CH, BCH;

Collect the above parameters for every vehicle in the network;
Convert each input parameter into fuzzy linguistic terms (e.g., Low, Medium, High)
Apply suitable membership functions;
Select a set of fuzzy rules {R1, R2,} to combine the fuzzified inputs;

R1: *IF Average Distance is Near AND Satisfaction Degree, AND EC, PDR, is and Connectivity Level are High THEN CH Potential is Very High*.

Execute the selected fuzzy rules;
Combine the fuzzy outputs from all applied rules;
Obtain an overall fuzzy score for each vehicle;
For each vehicle, Do:
    Apply a defuzzification method (e.g., centroid method);
    Convert the aggregated fuzzy score into a crisp (numerical) value;
    Compare the crisp scores of this vehicle with other vehicles;
End For
Select the vehicle with the highest score as the CH;
Select the vehicle with the second highest score as the BCH;

After combining all the inputs, the centroid method transforms the fuzzy results into real scores for each CH. The score from the crisp function is used to pick the group's leader and backup leader. Thanks to this approach, routing in VANETs is stable and economical since leaders are elected regularly based on a number of factors that work against each other, ensuring the VANET system can grow, balance its energy, and maintain reliable communication.

## 4. Simulation and Results

For the process of experimentation and result analysis of the proposed FCHS technique, an NS2.35 network simulator under Ubuntu 14.06 OS is used. The construction of network mobility is facilitated by the mobility model generator for vehicular networks (MOVE) and SUMO. A comparative analysis of the performance of the proposed FCHS technique has been conducted in relation to previously developed models, including CHSDR. [15] and NRHCS [16]. Furthermore, PDR, EC, E2E delay, and RO are considered to be the parameters for result calculation.

In general, the PDR is the ratio between the number of packets received and the number of packets transmitted. Energy consumption is referred to as that it is the amount of energy spent during the time of transmission in the network. E2E delay is referred to as the time taken to complete the transmission of the entire network. RO is referred to as the retransmission of packets to the source when the bandwidth of the link is increased in the current link. The simulation parameters considered for implementing the proposed FCHS technique are given in Table 1.

**Table 1** *Simulation parameters*

| Input Parameters | Values |
|---|---|
| Operating System | Ubuntu 16.04 |
| Software | NS-2.35 |
| Mobility Generator | MOVE and SUMO |
| Dimension | 1000m*1000m |
| Vehicle Density | 200 vehicles |
| Antenna Type | Omni-directional Antenna |
| Propagation Model | Two-Ray Ground Model |
| Queue Type | DropTail |
| Topology | Urban |
| Road Direction | Two way |
| Speed | 50 km/hr |
| Connection | Multiple |
| Packet Size | 1024 Bytes |

### 4.1 Packet Delivery Ratio

In Figure 2, the PDR of the proposed FCHS scheme presented and compared with the CHSDR and NRHCS. The PDR is calculated using varying numbers of vehicles, and it shows that the ratio increases due to the increase in vehicle density. The ratio achieved by the proposed FCHS technique is higher than the ratio achieved by, CHSDR and NRHCS. This is facilitated as different vital parameter are taking into consideration in CH selection process which ensuring better CH selection compared to CHSDR and NRHCS. Additionally, introducing BCH results in reduction of route failure thereby improving the packer delivery.

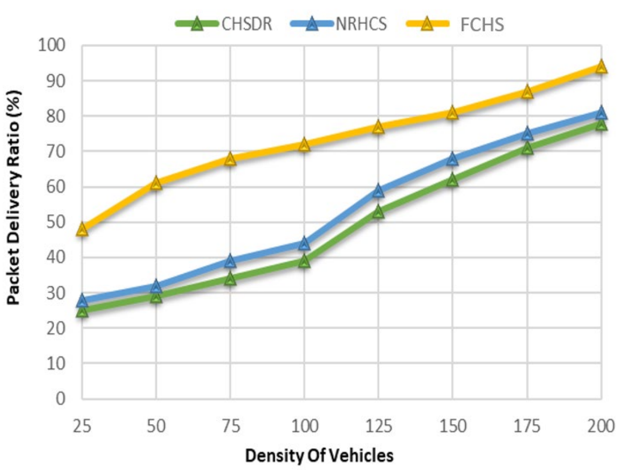


**Fig. 2** *Packet deliver ratio vs. density of vehicles*

Table 2 gives the PDR values according to the varying density of vehicles of the processed methods like CHSDR, NRHCS, and the proposed FCHS technique. The ratio achieved by these methods is CHSDR 78%, NRHCS 81%, and the proposed FCHS technique 94%, respectively. The proposed FCHS technique achieved a 13% to 16% higher PDR when compared with the earlier works.

**Table 2** *PDR performance value*

| Density of vehicles | CHSDR | NRHCS | FCHS |
|---|---|---|---|
| 25 | 25 | 28 | 48 |
| 50 | 29 | 32 | 61 |
| 75 | 34 | 39 | 68 |
| 100 | 39 | 44 | 72 |
| 125 | 53 | 59 | 77 |
| 150 | 62 | 68 | 81 |
| 175 | 71 | 75 | 87 |
| 200 | 78 | 81 | 94 |

## 4.2 Energy Consumption

In Figure 3, the Energy Consumption (EC) of the proposed FCHS technique is presented and compared with the CHSDR and NRHCS. The EC is calculated in terms of varying numbers of vehicles, and it shows that EC increases due to the increase in vehicle density. It is clearly shown that FCHS outperforms when compared with CHSDR and NRHCS. This is because FCHS selects the CH with the highest residual energy as well BCH which in turn reduces the unnecessary re-clustering and hence reduce the overall EC.

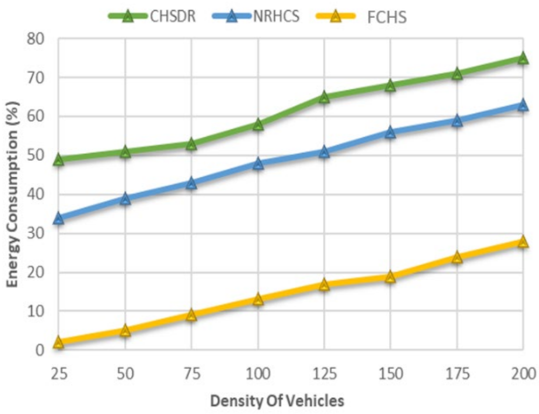


**Fig. 3** *EC vs density of vehicles*

Table 3 gives the EC values according to the varying density of vehicles of the processed methods like CHSDR, NRHCS, and the proposed FCHS technique. The EC produced by these methods is CHSDR 75%, NRHCS 63%, and the proposed FCHS technique 28%, respectively. The proposed FCHS technique produced around 35% to 50% lower EC when compared with the earlier works.

**Table 3** *PDR performance value*

| Density of vehicles | CHSDR | NRHCS | FCHS |
|---|---|---|---|
| 25 | 49 | 34 | 2 |
| 50 | 51 | 39 | 5 |
| 75 | 53 | 43 | 9 |
| 100 | 58 | 48 | 13 |
| 125 | 65 | 51 | 17 |
| 150 | 68 | 56 | 19 |
| 175 | 71 | 59 | 24 |
| 200 | 75 | 63 | 28 |

## 4.3 End-to-end Delay

In Figure 4, the E2E delay of the proposed FCHS technique is presented and compared with CHSDR and NRHCS. The E2E delay is calculated in terms of varying numbers of vehicles, and it shows that it increases due to the increase in vehicle density. Effective CH selection in VANETs is mainly aimed to reduce the network delay. The result shows that the delay produced by the proposed FCHS technique is lower compared to other works. This is due to the CHs selection in FCHS relies on various real-time parameters, allowing the data to be routed through the most suitable path, resulting in reduced packet retransmission. Also, FCHS reduces the topology change and provides fault tolerance through introducing the BCH, which results in a reduction of E2E delay.

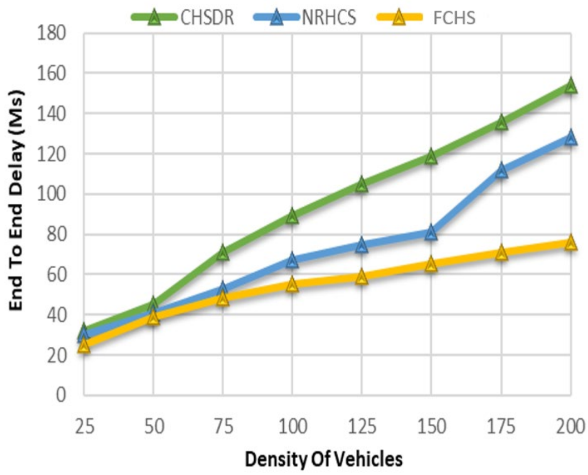


**Fig. 4** *E2E delay vs. density of vehicles*

Table 4 presents the E2E delay values corresponding to the differing vehicle densities for the analyzed methods, namely CHSDR, NRHCS, and the proposed FCHS technique. The E2E delays yielded by these methods are 154 milliseconds for CHSDR, 128 milliseconds for NRHCS, and 76 milliseconds for the proposed FCHS technique. Notably, the FCHS technique demonstrates a reduction in E2E delay of approximately 50 to 70 milliseconds when compared to the previous methods.

**Table 4** *E2E delay performance value*

| Density of vehicles | CHSDR | NRHCS | FCHS |
|---|---|---|---|
| 25 | 32 | 30 | 25 |
| 50 | 45 | 41 | 39 |
| 75 | 71 | 53 | 48 |
| 100 | 89 | 67 | 55 |
| 125 | 105 | 75 | 59 |
| 150 | 119 | 81 | 65 |
| 175 | 136 | 112 | 71 |
| 200 | 154 | 128 | 76 |

## 4.4 Routing Overhead

In Figure 5, the Routing Overhead (RO) of the proposed FCHS technique is presented and compared with the other works, CHSDR and NRHCS. The RO is calculated in terms of varying numbers of vehicles, and it shows that RO increases due to the increase in vehicle density. The proposed approach provides effective CH selection so that the EC and delay of the network are reduced, reflected in the RO reduction in the network.

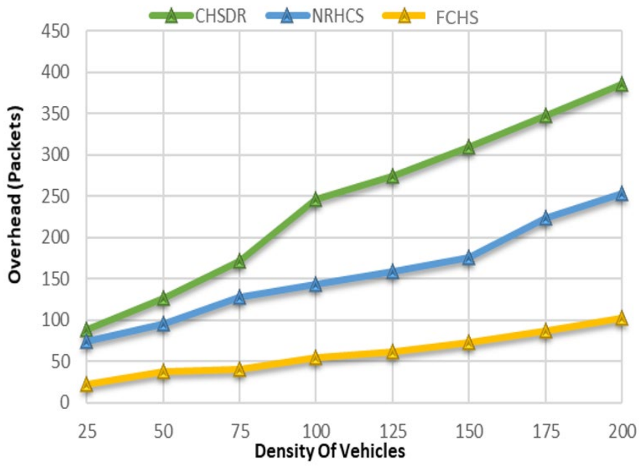


**Fig. 5** *RO vs. density of vehicles*

Table 5 gives the RO values according to the varying density of vehicles of the processed methods like CHSDR, NRHCS, and the proposed FCHS technique. The RO produced by these methods is CHSDR 386 packets, NRHCS 253 packets, and the proposed FCHS technique 102 packets, respectively. The proposed FCHS technique produced around 150 packets to 30 packets lower RO when compared with the earlier works. The reason behind this is that NRHCS reduces the message broadcast and redundant control message by avoiding frequent re-clustering, which is achieved by the process of CH selection and BCH.

**Table 5** *RO performance value*

| Density of vehicles | CHSDR | NRHCS | FCHS |
|---|---|---|---|
| 25 | 89 | 75 | 22 |
| 50 | 127 | 96 | 38 |
| 75 | 172 | 128 | 41 |
| 100 | 246 | 143 | 55 |
| 125 | 274 | 159 | 62 |
| 150 | 309 | 176 | 73 |
| 175 | 348 | 224 | 87 |
| 200 | 386 | 253 | 102 |

## 4.5 Results Analysis

The above results show that when it comes to major factors of performance, FCHS performs better than CHSDR and NRHCS. The stable and smart election of cluster heads by FCHS helps it achieve a higher PDR, improving the consistency of messages transferred. Decreased energy use is anticipated because FCHS looks at residual resources and equally assigns load to nodes to prevent untimely shutdowns. The scheme also cuts down on task completion time by ensuring the paths stay unchanged and are not altered too often. Efficient use of fuzzy logic made it possible to limit the overhead from routing and control messages which improves the ability of the system to handle more vehicles.

## 5. Conclusion

The clustering approach was introduced in earlier research to improve data transmission performance in VANETs. Still, this approach is not effective for high-speed VANETs. Hence, this paper proposed a clustering approach enhanced with a Fuzzy-based Cluster Head Selection (FCHS) technique. Consequently, the FCHS technique uses the parameters of average distance, satisfaction degree, threshold energy, PDR, and vehicle connectivity level in the CH selection process. Sometimes, one or more vehicles can have the highest score and confuse the CH selection process. In this case, fuzzy-based decision-making helps find the best available candidates. The first-best vehicle is declared CH, and the second-best vehicle is declared BCH. Four parameters are considered to analyze the performance of the proposed FCHS technique: PDR, EC, E2E delay, and RO. Subsequently, a simulation of the VANET with the FCHS technique is developed, and the simulation outputs are compared with recently developed methods of CHSDR and NRHCS. From the result analysis, it is understood that the proposed FCHS technique achieved a 13% to 16% higher PDR, produced around 35% to 50% lower EC, produced around 50ms to 70ms lower E2E delay, and produced around 150 packets to 30 packets lower RO. Through this technique, communication in VANETs has become more efficient and reliable. The proposed FCHS technique will be applied to a highly dense network of VANETS and FANETS, and the performance will be evaluated.

## Acknowledgement

The authors thank Alnoor University for supporting this project through the Research Supporting Fund (ANUI2025M111). The authors also extend their sincere gratitude to Northern Technical University for providing access to its advanced computer laboratories, which were instrumental in the successful completion of this research. The university's resources and support greatly facilitated the computational analyses and data processing required for this study.

## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm contribution to the paper as follows:* ***study conception and design:*** *Yousif Khalid Khalid, Ali Kadhim Bermani;* ***data collection****, Mohammed Hasan Aldulaimi, Mohammed Khalaf ;* ***analysis and interpretation of results:*** *Yousif Khalid Khalid, Ali Kadhim Bermani, Rasha Bashar Mohammed;* ***draft manuscript preparation:*** *Yousif Khalid Khalid, Ali Kadhim Bermani, Rasha Bashar Mohammed.*

## References

[1] Zhang, D. G., Ni, C. H., Zhang, J., Zhang, T., & Zhang, Z. H. (2023). New method of vehicle cooperative communication based on fuzzy logic and signaling game strategy. Future Generation Computer Systems, 142, 131-149.

[2] A, M. C. B., & S, B. (2023). Maximizing VANET performance in cluster head selection using Intelligent Fuzzy Bald Eagle optimization. Vehicular Communications, 45, 100660. https://doi.org/10.1016/j.vehcom.2023.100660

[3] Ayyub, M., Oracevic, A., Hussain, R., Khan, A. A., & Zhang, Z. (2021). A comprehensive survey on clustering in vehicular networks: Current solutions and future challenges. Ad Hoc Networks, 124, 102729. https://doi.org/10.1016/j.adhoc.2021.102729

[4] Aissa, M., Bouhdid, B., Mnaouer, A. B., Belghith, A., & AlAhmadi, S. (2022). SOFCluster: Safety-oriented, fuzzy logic-based clustering scheme for vehicular ad hoc networks. Transactions on Emerging Telecommunications Technologies, 33(3). https://doi.org/10.1002/ett.3951

[5] Abdulsattar, N. F., Mohammed, D. A., Alkhayyat, A., Hamed, S. Z., Hariz, H. M., Abosinnee, A. S., Abbas, A. H., Hassan, M. H., Jubair, M. A., Abbas, F. H., Algarni, A. D., Soliman, N. F., & El-Shafai, W. (2022). Privacy-Preserving mobility Model and Optimization-Based Advanced Cluster Head Selection (P2O-ACH) for vehicular ad hoc networks. Electronics, 11(24), 4163. https://doi.org/10.3390/electronics11244163

[6] Najem, I., Abdulhussein, T. A., Ali, M. H., Hameed, A. S., Ali, I. R., & Altaee, M. (2023). Fuzzy-Based Clustering for Larger-Scale Deep Learning in autonomous systems based on fusion data. Journal of Intelligent Systems and Internet of Things, 12(1), 71–87. https://doi.org/10.54216/jisiot.090105

[7] Ren, M., Zhang, J., Khoukhi, L., Labiod, H., & Vèque, V. (2021). A review of clustering algorithms in VANETs. Annals of Telecommunications, 76(9–10), 581–603. https://doi.org/10.1007/s12243-020-00831-x

[8] Saleem, M. A., et al. (2019). Expansion of cluster head stability using fuzzy in cognitive radio CR-VANET. IEEE Access, 7, 173185-173195. https://doi.org/10.1109/ACCESS.2019.2956478

[9] Sharma, S., & Kaul, A. (2018). Hybrid fuzzy multi-criteria decision making-based multi-cluster head dolphin swarm optimized IDS for VANET. Vehicular Communications, 12, 23-38. https://doi.org/10.1016/j.vehcom.2017.12.003

[10] Behura, A., Kumar, A., & Jain, P. K. (2025). A multi-objective approach for secure cluster based routing & attack classification in VANETs. Peer-to-Peer Networking and Applications, 18(3). https://doi.org/10.1007/s12083-024-01895-5

[11] Alsarhan, A., Kilani, Y., Al-Dubai, A., Zomaya, A. Y., & Hussain, A. (2019). Novel fuzzy and game theory based clustering and decision making for VANETs. IEEE Transactions on Vehicular Technology, 69(2), 1568-1581.

[12] Liu, G., Qi, N., Chen, J., Dong, C., & Huang, Z. (2020). Enhancing clustering stability in VANET: A spectral clustering-based approach. China Communications, 17(4), 140-151. https://doi.org/10.23919/JCC.2020.04.013

[13] Zhang, D. G., Wang, J. X., Zhang, J., Zhang, T., Yang, C., & Jiang, K. W. (2022). A new method of fuzzy multicriteria routing in VANETs. IEEE Transactions on Computational Social Systems. https://doi.org/10.1109/TCSS.2022.3193739

[14] Karthikeyan, H., & Usha, G. (2021). Adaptive clustering algorithm for stable communication in VANET. Turkish Journal of Computer and Mathematics Education, 12(9), 1778-1785.

[15] Shafi, S., & Thakur, T. (2020). Stable clustering approach for VANETs in highways communication with fuzzy decision model. International Journal for Research in Applied Science & Engineering Technology, 8(7), 809-814.

[16] Stephen, T., et al. (2020). Modified fuzzy-based greedy routing protocol for VANETs. Journal of Intelligent and Fuzzy Systems, 36(6), 8357-8364. https://doi.org/10.3233/JIFS-200960

[17] Jyothi, N., & Patil, R. (2021). A fuzzy-based trust evaluation framework for secure authentication in VANET. Journal of Information and Communication, 6(3), 270-288. https://doi.org/10.1080/24751839.2022.2040898

[18] Debnath, A., Basumatary, H., Dhar, M., Debbarma, M., & Bhattacharyya, B. (2021). Fuzzy logic-based VANET routing method to increase QoS. Computing, 103, 1391-1415. https://doi.org/10.1007/s00607-020-00890-x

[19] Aissa, M., Bouhdid, B., Mnaouer, A. B., Belghith, A., & AlAhmadi, S. (2020). SOFCluster: Safety-oriented fuzzy logic-based clustering scheme for VANETs. Transactions on Emerging Telecommunications Technologies, 1-20. https://doi.org/10.1002/ett.3951

[20] Rashid, S. A., Audah, L., Hamdi, M. M., & Alani, S. (2020). Prediction-based multi-hop clustering for VANET. Journal of Communications, 15(4), 332-344. https://doi.org/10.12720/jcm.15.4.332-344

[21] Lavanya, M., Preethi, S., & Nivetha, G. S. (2019). Cluster head selection using distance and residual energy for VANET. In IEEE International Conference on System, Computation, Automation and Networking (ICSCAN).

[22] Folsom, R. D., Aravindhan, K., & Sikamani, K. T. (2021). A novel routing and hybrid clustering scheme in VANETs. International Journal of Intelligent Networks, 2, 103–114. https://doi.org/10.1016/j.ijin.2021.10.002