

Original Article

Intelligent VANETS: Neuro-Fuzzy Optimization for Traffic Management and Accident Prevention using Vehicle Cluster Routing-based Neuro-Fuzzy Logic

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Abstract - In wireless communication between vehicles, the The Vehicular Ad Hoc Network (VANET) is a key component of optimizing efficient and secured traffic management. But it gives more complications due to its dynamic changing architecture associated with rapid vehicle mobility, inconsistent communication network, and restricted framework region. In this research, an innovative approach is introduced Vehicle Cluster Routing based Neuro-Fuzzy Logic (VCR-NFL) to achieve stable connectivity in VANET. The main goal of this proposed VCR-NFL approach is to address the problem of over speed vehicles. The Cluster Head (CH) is elected with vehicles having slow speed, minimal distance, and high energy levels. This cluster concept is applied to monitor and control the vehicles effectively. The stability of the cluster is achieved by FUZZY logic which enables the automated succeeding CH selection process. Simulation results demonstrate that the proposed VCR-NFL approach outperforms the other methods currently in use. by providing reliable communication in VANET.

Keywords - VANET, CH, Fuzzy logic, Traffic, and Safety.

1. Introduction

There are many links between vehicles and other electronics in today's transportation system. Vehicular Ad hoc Networks (VANETs) are an extension of Mobile Ad Hoc Networks (MANETs) where a moving vehicle acts as a substitute for the normal nodes. VANET uses the On-board Units (OBUs) which are installed in the vehicles to enable the Vehicle to Vehicle (V2V) communication and Vehicle to Infrastructure communication (V2I) [1] in which the vehicle communicates with the static Roadside Units (RSUs). In modern transport systems, the most significant technology in terms of efficiency and security is VANET. It manages challenging cases like reducing traffic jams in congested regions which prevents accidents and enables the sharing of traffic status among neighbouring vehicles. Using network connectivity, VANET enables the vehicle to receive live updates on the news, congestion information, and weather status. In addition to it, users can share files and play games via internet access or local ad hoc networks. A distinctive feature of VANET that differs from MANET is easily identified, highly portable, dynamic architecture, constrained mobility pattern, and uninterrupted charging of batteries. As seen from the above-mentioned characteristics, energy utilization is not a major issue in VANET [2]. The vehicular system poses a major challenge in implementing and

commercializing VANET in real time due to its dynamic framework [3]. An efficient routing mechanism is required for V2V and V2I communication to overcome the above issues. It is not possible to utilize all of VANET's features in real life without a persistent and secured routing method [4]. Research shows that there are numerous routing strategies available for Vehicle to Everything (V2X) communication [2, 5, 6]. Based on the infrastructure and route identification mechanism, the current routing method is categorized into two different types [3, 6]. But each type has unique restrictions in different circumstances [7]. In particular, in highly congested networks, the computational and communication expenses of hierarchy-free or nonlinear routing methods get worse [3, 8, 9]. Hence, we established a routing protocol that works based on a cluster mechanism. In this cluster-based routing method, cluster formation occurs based on similar type of vehicles to identify the perfect number of clusters with less computational cost [4, 6-8]. In the research, the different method is determining the members of the cluster and Cluster Head (CH) based on various factors such as Identification (ID), neighbors' connectivity range, velocity, travel duration, transmission delay, typical relative velocity, route security level, standard link lifespan, vehicle's quantity to follow and link credibility [3, 6, 10]. But also, the researchers are still facing some difficulties in terms of cluster members durability and stability [1, 3]. By considering the above issue, the main objective of



this research is to solve the VANET's dynamic nature by identifying the ideal cluster members.

Research gap: From the above studies it can be seen that an important challenge still remains in developing an adaptive cluster-management mechanism that jointly considers the dynamic vehicle characteristics affecting cluster stability. In particular, vehicle speed, inter-vehicle distance, and node energy can influence the suitability of a vehicle to act as a CH at the same time. However, these parameters are not adequately incorporated into a unified fuzzy decision-making mechanism for adaptive CH selection and cluster maintenance in the existing approaches. Therefore, frequent CH changes and unstable communication links may increase routing overhead and delay and may have a negative impact on packet delivery in dynamic VANET environments.

To solve this problem, this paper proposed a Vehicle Cluster Routing-based Fuzzy Logic (VCR-FL) approach to improve the communication stability in VANETs. The proposed approach forms vehicle clusters according to the relevant vehicle and network characteristics and chooses a CH based on low vehicle speed, small inter-vehicle distance and high energy level. These parameters are included in a fuzzy logic framework to provide adaptive decision making for cluster stability. The fuzzy mechanism fuzzification the linguistic representations of the input parameters, and defuzzification. them to produce a stability-oriented output by centroid-based defuzzification. In this way the CH selection process can react to changing vehicular conditions and not rely on a fixed selection criterion.

2. Related Work

Zahid Khan et al. [1], presented the Proposed Connectivity Based Clustering (PC-BC) method for VANET. An efficient way of routing based on cluster is to solve the VANET's constantly changing and heterogeneous framework.

In this method, the cluster formation and CH selection is done through link connectivity. When the quantity of cluster formation is increased, then employ the heuristic method for spectral clustering. A Strong (STC) Route Selection and Route Request Messages (RRMs) are used to locate the target route.

According to Liu et al. [11] they developed a Q-learning adaptive congestion-control technique that works for V2V communications and dynamically adjusts the transmission speed as per the CBR and the density of vehicles. But it does not utilize ensemble learnings and decision-making based on TARP techniques which leaves some space for intelligent real-time congestion control. Deshmukh, Dhawale, and Dorle [12] examined VANET's cluster-based routing mechanism in real-time geographical settings. They performed SUMO which simulates for different numbers of vehicles.

Yogarayan et al. [13] studied the VANET routing method through a cluster-based routing protocol. Srivastava, Prakash, and Tripathi [14] solved the issues regarding channel allocation in the VANET routing method. They have also intimated the problems and challenges in the cluster-based routing protocol. Khatri et al. explained that the VANET security, communication, and congestion issues may be addressed by machine intelligence. And proposed a case study on VANET [15] dealt with the potential approaches and possible concerns.

Alaya et al. proposed a method known as the Efficient Key Management Scheme (KMSUNET) to enhance the worldwide standard while optimizing the data transmission, categories lifetime, and reducing the inter-class traffic [16]. Mirsadeghi et al. suggested a reliable authentication method to develop a consistent and robust cluster in VANET. A Reliable authority provides an encoded signal by pairing with a public or private key and cluster heads are selected within the reliable and determined range of every vehicle [17].

According to Alkhalidy et al, in Intelligent Transportation System, VANET plays a vital role in road monitoring and protection. And also proposed an innovative method using a fuzzy logic model to predict the harmful nodes [18]. Bijalwan et al. proposed a Self-Adaptable Angular-based k-medoid Clustering Scheme (SAACS). Having an accurate prediction about the length of the route and signal limits minimizes the network transmission delay. It brings down the dropped packets to total packets ratio by 45% and is 50% more efficient than RTVC with ECHS [19].

The techniques for lessening traffic congestion were investigated by Ouallane et al. To develop a feasible and effective system, it evaluates the three key components of the traffic management system and also suggests other factors to be analyzed and areas to be investigated [20] Rajeswari et al examined the SUMO model similar to the road traffic, to ensure security and information reliability protection in VANET based health care networks by the one-way hash chain model [21]. The author approaches a method to identify the health outcome is mostly affected by either bicycle or pedestrian routes. Although walking is the most convenient and popular traveling mode, the quality of life of pedestrians is reduced by transport system development. This article comprises the questions of conducting a survey and accessing pedestrian safety to identify the public thoughts about walking.

To overcome the disruption, several existing VANET method make use of Time Division Multiple Access (TDMA). The researcher [22] proposed a strategy for TDMA slot reserving based on grouping vehicles for making communication within the clusters in VANET. This is known as TDMA Cluster based Medium Access Control (TC-MAC). The significant streamlined cluster technique is utilized to

combine the TC-MAC with the TDMA slot reservation. In this method, the node is provided with time slots for transmitting the data without colliding. In highly congested region, the task allows the vehicle to transmit the risky data without disturbing the transmission and reception reliability.

The effort made by researcher [23] is to optimize the cluster stability by introducing the mobility-based cluster method which works on the basis of the CH's and cluster members times slot. The above-mentioned methods are employed for CH selection and cluster member formation in V2V transmission.

A Priority-based Hybrid MAC protocol (PHB-MAC) was proposed for VANET by Xin Yang et al. [24]. The RSUs is very important for connecting the vehicle to the transport terminals in VANET. The UAV enabled RSU (U-RSU) is a powerful mechanism to improve the effectiveness of the VANET for the enhancement of UAV fastly. The PHB-MAC protocol is doing data transfer based on prioritization. The proposed PHB-MAC protocol and U-RSU is to make sure the effective secured message transmission.

Rajeshwari Chiluveru et al. [25] suggested a method in terms of VANET's security, Mobility Aware Multi-Hop Clustering (MAMC). This method's main goal is to effectively communicate the secured information.

To achieve this, opted the MAMC based on MAC method (MAMC-MAC). The clusters are generated by applying TDMA methodology. This mechanism is intended especially for creating the borders in the roadways to provide the efficient communication and reliability.

The complexities faced in VANET are unstable and inconsistent communication network due to its dynamic changing framework, with extreme vehicle speed, constrained infrastructure range and fluctuating transmission lines.

2.1. Research Contribution

- A customized stable connection protocol is intended with adaptive algorithm and automated model employ as per speed is introduced specially for VANET.
- Introducing Context aware clustering method to ensure efficient communication by considering variables like vehicle speed and congestion level.
- An adaptive channel allocation method is presented to acquire minimal disruption and enhanced data communication by selecting channel automatically based on the status of current network.

2.2. Motivation

- It is very essential to optimize the VANET's efficiency and reliability to enable the implementation of security applications and live communication circumstances.

- The main target on introducing adaptive architecture which enhances communication network for the dynamic nature of VANET to overcome the current issues and satisfy the demands of modern transport system.

3. Proposed Methodology

Figure 1 clearly explains the proposed framework of Vehicle Cluster Routing -based Neuro-Fuzzy Logic (VCR-NFL). The first step of this method is to establish a network between the vehicles. One node (vehicle) is selected randomly and sends a "hello" message to all its neighbouring nodes. This method helps to find out the activity and status of the node whether it is in active or idle state.

The responding nodes to that broadcast message are recorded as active nodes and they are included in the cooperative node list whereas the non-responded nodes are considered as idle nodes. But the idle node could be at any given time active. The routing path is determined only by the active nodes in the cooperative list. Algorithm 1 describes the CM Cooperative Node List creation process. Then, the Algorithm 2 is described for the first process of CH selection. The next section describes the whole CH selection process in a lucid manner.

Algorithm 1: Cluster Formation

1. Vehicles are randomly deployed (x,y) coordinates
2. Vehicles parameters $V(p) = V(s), V(d), V(e), V(l), V(p);$
3. $V(s) = \frac{d}{\Delta t}$ // d is the distance between the position t_0 and t_1 ; Δt time difference between the t_0 and t_1 ;
4. $V(d) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$ // (x1, y1) and (x2, y2) (x2, y2) for two points, the Euclidean distance (d)
5. $V(l) = f(x, y)(x_0, y_0), (x_1, y_1) \dots$
6. $V(e) = \frac{I_{at}}{T_t}$ // I_{at} initial access time and total communication time to other vehicle;
7. $V(p) \rightarrow$ updated $V(s), V(d), V(e), V(l), V(p);$
8. For ($i = 0; i < n; i++$)
9. {Send "request" messages to all nearby vehicles;
10. If (receives the message and sends the "Acknowledgment") that node
11. {"Active state;
12. Else if
13. If not received the messages and no "response" the nodes are in an idle state;
14. The active list is collected and mapped this node is a cooperative node list;
15. The cooperative node list is ready to choose the cluster head;
16. }}
17. End if;
18. End process;

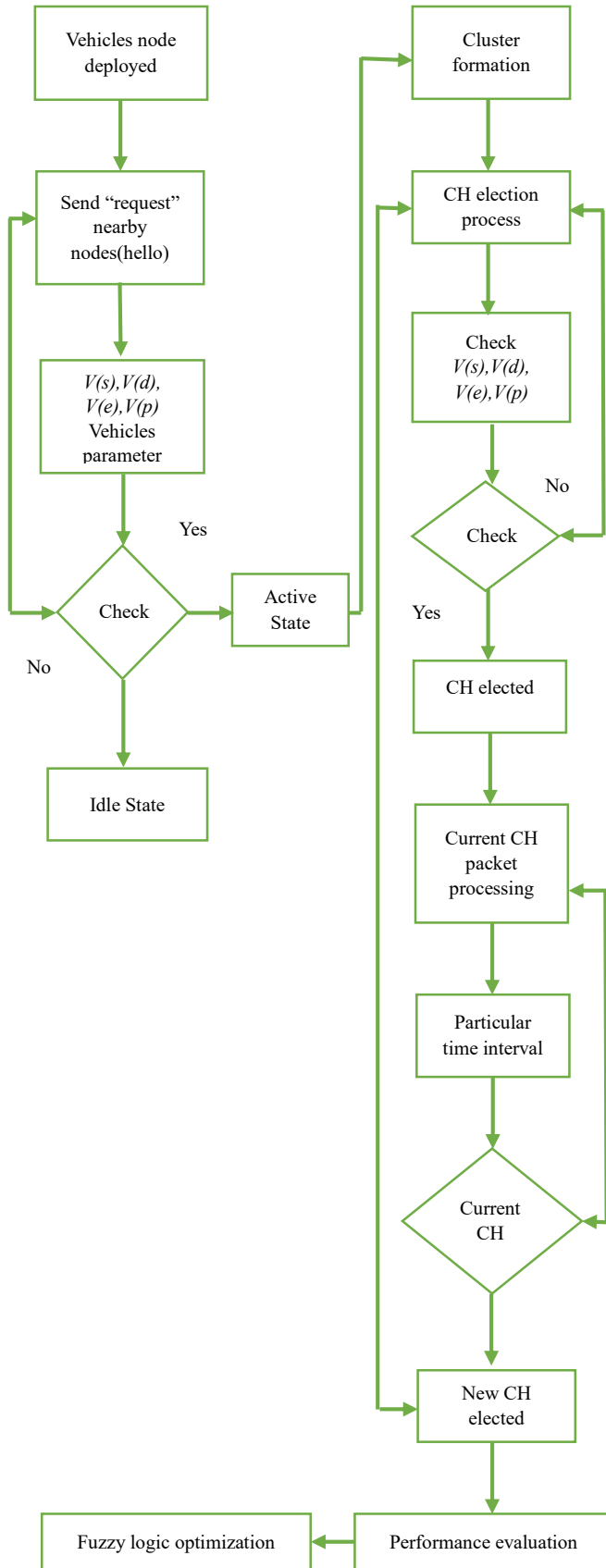


Fig. 1 Proposed workflow (VCR-NFL)

3.1. Cluster Formation

In the network area, the nodes are set up randomly. The cluster creation in the proposed method is clearly shown in Figure 2. The essential parameters required to verify before starting cluster formation are vehicle distance, velocity, speed, and location $V(s), V(d), V(e), V(l), V(p)$; A group of the neighbouring nodes establishes the Cluster formation. Then sends the "request" message to all nearby nodes to gather the active and idle node list. Whichever nodes received the message and acknowledged it is said to be an active node. The remaining unresponsive nodes are noted as idle nodes but it will turn into active state at any moment. All the active nodes are collected in the cooperative node list which helps to select the CH. This list creation is clearly explained in Algorithm 1.



Fig. 2 Proposed architecture cluster formation

The proposed method of cluster formation is shown in Figure 2. Depend upon the various vehicle speeds, data levels, location, and velocity generate the clusters. The regions are grouped into four clusters are V1, V2, V3, V4, V5 in the first region, the second region contains V6, V7, V8, V9, V10, the third region consists of V11, V12, V13, V14, V15 and V16, V17, V18, V19, V20 in the fourth region. This proposed cluster formation is clearly explained in Figure 2.

Algorithm 2: Cluster Head Election

1. Vehicles parameters are updated;
2. $[V_p \rightarrow V_l; V_s, V_d, V_p, v_e]$; // vehicles details are updated
3. Update to V_d (details);//
4. Choose CH election // cluster head selection process;
5. For $(i = 0; i < n; i++)$;
6. { If $V_s(\text{low}), V_d(\text{low}), V_e(\text{high})$; // vehicles speed (low), distance (low), energy (high);

7. { Else if
8. $V_s(\text{medium}), V_d(\text{medium}), V_e(\text{medium}); //$
vehicles speed (medium), distance (medium), energy (medium)
9. The node act as member node;
10. Else if
11. $\{V_s(\text{high}), V_d(\text{high}), V_e(\text{low}); //$ vehicles speed (medium), distance (medium), energy (medium)
12. Remove from the network;
13. }}}
14. End if
15. End process;

3.2. Cluster Head Election

Once the cluster formation is done, proceed with an essential CH selection process. The establishment of CH is based on specific node attributes. Initially, the node with a slow-speed vehicle, short distance, and high energy level is assigned as CH. This type of selection CH is essential for effective cluster management.



Fig. 3 Cluster head election process

Based on certain scenarios, CH selection occurs after cluster formation. As in Figure.3, the first case involves the node (vehicle) which has slow speed, short distance, and high energy level assigned as CH. In the next scenario, the vehicle with medium speed, medium distance, and medium energy level will act as a normal member.

On the contrary in the third case, remove the vehicle with medium speed, medium distance, and medium energy level from the network. The networks are grouped into four clusters. The first cluster consists of vehicles V1, V2, V3, V4, and V5,

with V2 assigned as CH1 which connects the RSU1 and RSU2. The second cluster comprises of V6, V7, V8, V9, and V10 where V10 serve as CH2 connects the RSU3 and RSU4. In the third cluster, V11, V12, V13, V14, and V15 are present, and V14 act as CH3 which connects the RSU5 and RSU6. The fourth cluster includes V16, V17, V18, V19, and V20 with V18 assign as CH4 connects the RSU6 and RSU1. The suggested cluster formation with the automatically changing CH over a while is shown in Figure 3.

4. Fuzzy Logic Optimization

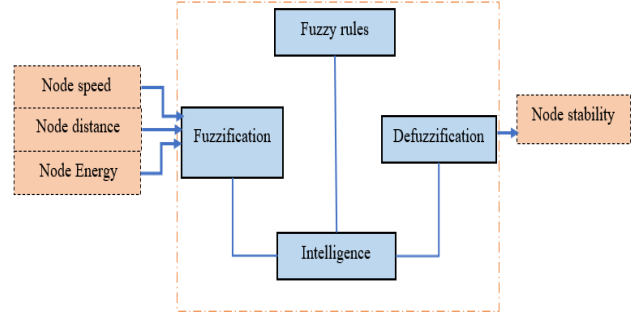


Fig. 4 Fuzzy logic methodology using SCR-NFL

The Secure Cluster Routing based Neuro-Fuzzy Logic (SCR-NFL) fuzzy logic system with its input attributes is shown in Figure 4 [21, 22].

Node Speed (NS): The node travel with high speed has a chance to lost their connection hence the node mobility needs to be monitored.

Node Energy (NE): The energy level of node should be monitored effectively for having the uninterrupted network connectivity and longevity. Since the low energy nodes might break down or become unstable.

Node Distance (ND): The node distance affects the message delivery success ratio, signal quality, network strength and also affects the entire architecture. It is very essential to select the proper routing path.

4.1. Fuzzification

In fuzzification, the input attributes are fuzzified and located with appropriate fuzzy set. As per trapezoidal membership operation, the precise input variables are mentioned in three linguistic values such as small, medium, and large for the NS, OHND, and LR. If the membership range is asymmetrical or irregular, the trapezoidal function provides more flexible model. The membership value remains same between the left and right bounds, indicating the complete level of membership Table 1 shows the node parameters and the membership range. Here, every node is noted as cluster ID with attributes like speed, distance, energy level and TValue with level as Low, Medium and High.

Table 1. Fuzzy logic based vehicle parameters

Node id	Speed	Distance	Energy	Node status
V1	Low	Low	High	CM
V2	Medium	Low	Medium	CH
V3	High	High	Low	CM
V4	Low	Medium	High	CM
V5	Medium	Medium	Low	CM
V6	High	High	Low	CM
V7	Low	Medium	High	CM
V8	High	High	Low	CM
V9	Low	Medium	High	CM
V10	Medium	Medium	Low	CM
V11	High	High	Low	CM
V12	Low	Medium	High	CM
V13	Medium	Medium	Low	CM
V14	Medium	Low	Medium	CM
V15	High	High	Low	CH
V16	Medium	Low	Medium	CH
V17	High	High	Low	CM
V18	Medium	Low	Medium	CM
V19	High	High	Low	CM
V20	Medium	Low	Medium	CM

4.2. Defuzzification

In defuzzification process, the fuzzy sets are converted into accurate output values. The output value comprises of six membership function are Short, Medium Short, Medium, Medium Long, Long and Very Long. The transmitter's time interval is specified in seconds in the output. The input and output membership function is shown in Figure 5. In the proposed system, defuzzification is done using the Centre of Gravity (COG) known as centroid. Locating the centre of mass of the output component is equivalent to applying the centroid technique [21].

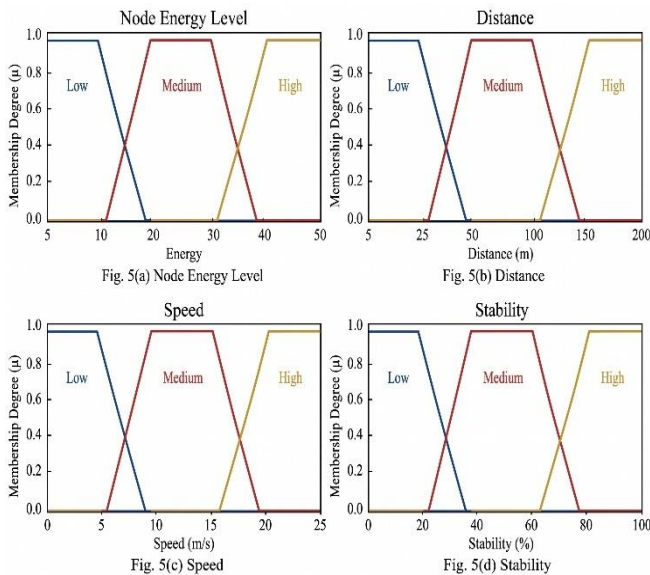


Fig. 5 Shows inputs and output membership function, (a) Energy level, (b) Distance, (c) Speed, and (d) Stability.

5. Experimental Results

In this section, the performance of Multi Threshold Fuzzy logic with different variables and the experimental analysis is explained clearly. The NS-2 network simulator is utilized for the experimental configuration. Random Mobility model is applied to employ the nodes randomly in the 2500 x 2500 m range. There are 2 to 100 vehicles are used for this operation with a velocity 0 to 120 km/h covered with a distance of 500 and 1000 m. Table 2 clearly explains about the attributes and their values utilized for simulation execution. The proposed Multi-Threshold Fuzzy logic's performance is compared with MAMC-MAC method, PC-BC, and PHB-MAC algorithm.

Table 2. Simulation parameter

Parameter	Value
Network area	2500 x 2500 m
Data rate b/s	512 kb/s
Vehicle coverage distance (L)	500,1000 m
Velocity range	0 to 120 km/h
Total number of vehicles (N)	20 to 100
Simulation time	400 sec

Let us discuss in detail of every algorithm's obtained outcome under various attributes such as Packet Delivery Ratio (PDR), routing overhead, power consumption, dynamic cluster head changes and end to end delay. Figure 6 describes the Packet Delivery Ratio (PDR) efficiency obtained by the proposed VCR-FL algorithm with the existing algorithms as MT-FUZZY logic and ACP. The X-axis denotes the number of vehicles taken for simulation execution and the packet delivery ratio of each algorithm shown in Y-axis. The PDR output simplifies the system reliability. The obtained PDR is measured in terms of percentage. The number of vehicles taken for execution is from 20-100 increases by 20 counts. The PDR mentioned in the graph in percentage (%). The total PDR obtained by VCR-FL > ACP > MT-FUZZY is 96% > 73% > 68% for 100 vehicles. From the above graph, total PDR received by proposed VCR-FL is higher than the other existing algorithm.

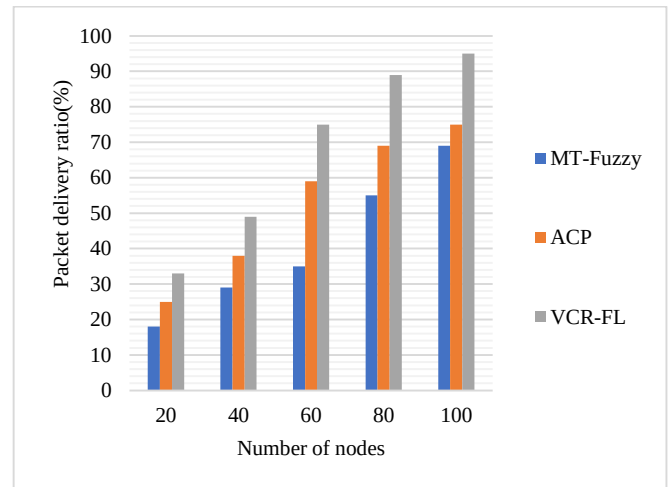


Fig. 6 No. of nodes vs packet delivery

Figure 7 shows the graphical representation of comparing the cluster head changes in the proposed VCR-FL algorithm with the other existing MT-FUZZY logic and ACP algorithm. The number of node (vehicle) taken for simulation is 20-100 vehicle raised by 20 count is noted in X-axis. Y-axis denotes the cluster head changes which is indicated in percentage (%). A cluster head is selected by the vehicle (node) with slow speed, short distance and high energy level from the clusters. It can automatically change over period of time. In our proposed VCR-FL algorithm, the cluster changes by 4% for 20 nodes, 8% for 40 nodes, 12% for 60 nodes, 15% for 80 nodes and 22% for 100 nodes. The cluster head changes for another algorithm are mentioned in the graph. It clearly shows that proposed algorithm undergoes minimum cluster head changes than the existing algorithm.

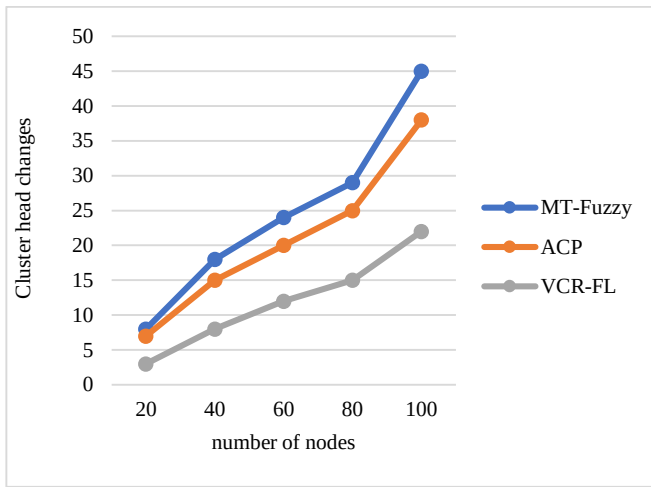


Fig. 7 No. of cluster vs cluster head

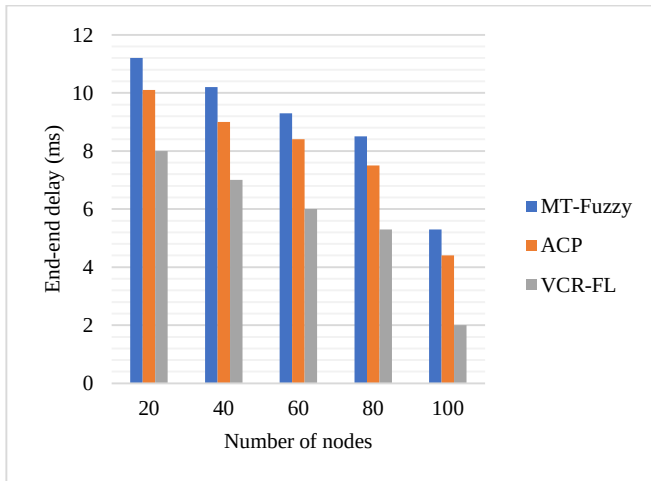


Fig. 8 No. of nodes vs end-end delay

A graphical representation of the end-end delay time taken by the proposed VCR-FL algorithm with other existing algorithms as MT-FUZZY and ACP methods is shown in Figure 8. The number of nodes taken for execution from 20 nodes raised by 20 counts up to 100 nodes and is denoted in

X-axis. The end-end delay period is noted in Y-axis and is measured in ms. A better algorithm should have a less packet transmission time from source to destination. From the comparison result, the end-to-end delay for 60 vehicles by proposed algorithm is 6ms whereas the existing algorithm MT-FUZZY and ACP in 8.6 ms and 8.2 ms. It is clearly proven that from the comparison result, the proposed algorithm requires minimum end-end delay than the other existing algorithm.

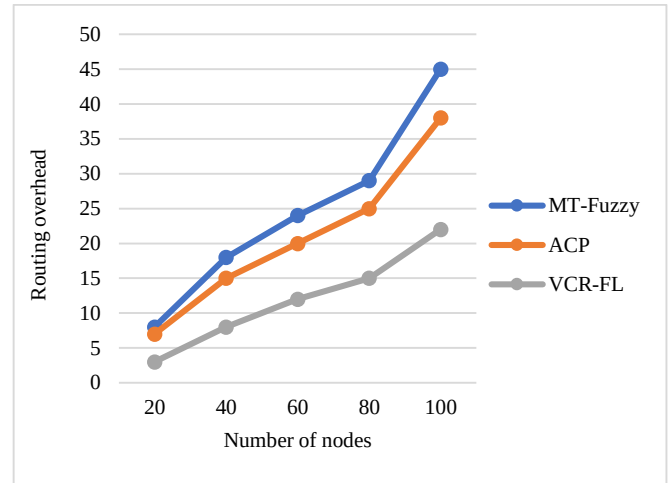


Fig. 9 No. of nodes vs routing overhead

Figure 9 represents the routing overhead obtained by the proposed VCR-FL algorithm with other existing algorithms as MT-FUZZY and ACP methods. The number of nodes taken for execution from 20 nodes raised by 20 counts up to 100 nodes and is denoted in X-axis, the routing overhead obtained is marked in Y-axis and is denoted in sec. More routing overhead will affect the PDR and end-end delay. In our proposed VCR-FL algorithm, the routing overhead in 4sec for 20 nodes, 8 sec for 40 nodes, 11sec for 60 nodes, 15sec for 80 nodes and 22 sec for 100 nodes. The routing overhead for another algorithm is mentioned in the graph. It clearly shows that proposed algorithm undergoes minimum routing overhead than the existing algorithm.

6. Conclusion

Our research concludes that the proposed VCR-FL poses a potential method for overcoming the issues that occurred in VANET. Simulation results emphasize its efficiency after comparing with existing methods such as ACP and MT-FUZZY logic. In particular, dynamic cluster head changes reduced significantly by 95% and enhanced the outstanding PDR value by 98%. Moreover, the routing overhead and end-end delay were reduced by 91% and 96% respectively. As a result of this evaluation, VCR-FL's stability and efficiency is validated and is suited perfectly for an uninterrupted communication network in VANET. The combination of Vehicle clustering and Neuro-fuzzy logic performs better than the existing typical technique by incorporating flexible and dynamic features.

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