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Expansion of Cluster Head Stability Using Fuzzy in Cognitive Radio CR-VANET

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ABSTRACT The Vehicular Ad Hoc Network (VANET) plays a vital role in the development of smart cities, especially in ensuring vehicles' safety on roads. However, VANET wireless-based networks face some challenges such as security, stability, communication, and reliability. To resolve these issues, we propose a fuzzy cluster head selection scheme in Cognitive Radio (CR) VANET, which uses the CR technology for the spectrum sensing algorithm. In this technology, the free spectrums of the primary user are utilized by secondary users without any correlation. Moreover, we have considered some input parameters such as vehicles' average velocity, distance, network connectivity level, lane weight and trustworthiness for the fuzzy system based CR VANET in this research. The selected cluster head provides stability and reliability to the cluster compared to the state of art techniques. Extensive experiments were conducted in order to evaluate the effectiveness of the proposed approach. However, simulation results authenticate more stable and secure cluster formation using the proposed fuzzy logic based CR VANET.

INDEX TERMS Cluster formation, cluster selection, cognitive radio, fuzzy logic rules, VANET.

I. INTRODUCTION

Currently, road safety has become a key concern of the people living in big cities. This concern is evident due to the increased traffic on small congested roads in big cities [1]. To overcome the safety concern, a new invention of an internet branch called Vehicular Ad Hoc Network (VANET) has been proposed by many researchers [1]–[4]. The main focus of VANET is road safety and vehicle entertainment. The VANET is refered to the ad hoc manner network in which moving vehicles and other devices come into contact with the wireless medium. The moving vehicle share useful information with the other devices. In the network, other devices behave like a node which transfers useful information to the other nodes. After received the useful information or data from the moving vehicles, the nodes generate useful information from them and transferred to other nodes. The nodes are free to join or leave the network in an open network [1]–[7].Due to the high vehicle mobility condition, the VANET is suffering from rapid network topology change and variable network connectivity. Above said issues are resolved with the clustering topology built in the VANET. All the nodes combined in a group during clustering process. A cluster has three main parameters cluster head (CH), cluster member (CM) and cluster gateway (CG). The cluster head coordinates with all members of the cluster while the cluster gateway deals with the different cluster member. The cluster head selection is the main challenge in the clustering scheme. The cluster head (CH) is that vehicle which receives data from all vehicles moving in a VANET. CH vehicle of VANET should be trustworthy, dynamic and with normal speed. Various methods are used in the selection of the cluster head. In this work, we propose fuzzy logic based cluster head selection in VANET. The VANET faces some issues due to the scarce spectrum while transmitting data to the receiver. This scarce spectrum problem resolves with the help of cognitive radio VANET [11].

Cognitive Radio in VANET allows the secondary user to share the spectral resources of the primary user without affecting them harmfully. The vehicle communication

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efficiency is improved by the CR devices. VANET has many applications in the big cities area; but in the rural areas, where the roads have open spaces, there is a high probability of finding the spectrum hole. So, CR VANET network can be adopted in these conditions. But in both urban and semi-urban areas, the chance of spectrum hole is less due to the congestion of vehicles. The combination of CR and VANET technology resolve the issues of scarcity, less bandwidth spectrum and the use of the present spectral resources in a vehicle communication system [15].

We have extended the work of the cluster head's stability and improvement in CR VANET, whereby the primary objective of the improvement is selecting the vehicle with the most trust value. We have suggested two different fuzzy logic for efficient spectrum sensing in CR VANET and cluster head selection. The fuzzy inputs for CR VANET are signal energy and signal to noise ratio (SNR); however, previous work on cognitive radio considered only the signal energy to detect the primary user in the network. Four different fuzzy inputs such as average speed, distance, lane weight and trustworthiness of vehicles are considered in the cluster head selection. To match the real vehicle environment at the road junction of a city, we chose the variable speed of each node which poses a challenge to handle the dynamic nature of VANET. In the subsequent sections of this paper, we have discussed the present issues which motivated us to conduct this research. Moreover, the solution, simulation work, and outcomes of this study are also discussed.

Further in this paper, we discussed the related work on cluster head stability in section II. Based on findings of work in section II, we extract the problem and discuss in section III. The proposed solution is given in section IV and section V discusses the results and compare the solution with state of art work. We conclude the proposed work's findings in section VI.

II. RELATED WORK AND BACKGROUND

The one road weight evaluation method for VANET application was proposed in [1], where each road assigned the weight based on historical and real-time information. Based on this weight information's, the road segment is selected one by one to create an optimal route path and avoid data congestion. In [2] a naïve Bayesian probabilistic estimation method was presented and applied to the traffic flow for creating a stable cluster in VANET. For improving the routing, this method uses some traffic flow factors such as the speed difference, direction, and distance of vehicles. a naïve Bayesian probabilistic estimation method was presented and applied to the traffic flow for creating a stable cluster in VANET. To improve the routing, this method uses some traffic flow factors such as the speed difference, direction, and distance of vehicles. Moreover, the highest packet delivery ratio and low end to end delay were obtained by the proposed method.

A fuzzy-based cluster head selection method based on three security parameters GS (the group speed), DC (degree of connectivity), and RA (relative acceleration) was proposed in [3]. The effect of these parameters on the CH value is also given. A rough set-based fuzzy clustering scheme was implemented for the creation of a stable cluster in VANET in [4]. This scheme provided a stable and long lifetime cluster. A novel cluster head selection by fuzzy logic rules is presented in [6] which considered the speed of vehicles and their respective distances from the neighborhood vehicles.

The authors in [8] proposed a mobility based double head cluster (DHC) algorithm which was implemented for the cluster head selection in VANET application. In this scheme, the second cluster head added to the system, which improved the stability and efficiency of the cluster. A link reliability-based clustering algorithm (LRCA) was used to obtain efficient and reliable data transmission in VANET. Due to several vehicles in the group, the routing reliability and scalability affected the LRCA and can improve it. The LRCA process contains cluster head selection, cluster formation, and cluster maintenance [9].For the purpose of the improvement in a cluster routing protocol and VANET network instability issue, several algorithms were proposed in [10]. In this scheme, the cluster divided into multiple stationary clusters by the CBLTR approach and then multi metric based algorithm was introduced for the election of cluster head. The authors in [11], [13], presented a survey of a new technology Cognitive Radio (CR) applicable in the VANET application. Some challenges and requirement of effective design and implementation of CR have been discussed in this study. The basic requirement of the CR network design is spectrum sensing. An FL-CSS (Fuzzy Logic Cooperate Spectrum Sensing) approach was proposed in where each CR user used an energy detector for sensing the spectrum. The CR network dynamically accesses the present spectrum when a primary user is not utilizing it. The FL-CSS scheme shows better spectrum sensing results [5]. Due to the highly dynamic nature of VANET, CR faces some instability issues. In [12], a low delay and high throughput radio environment were proposed for CR VANET. The time of radio environment adaptation was reduced and increased the throughput of CR VANET. A study was proposed for non-continuous spectrum allocation in the CR network, with non-deterministic bandwidth of spectrum holes. A PDF (Probability Distributed Function) model has described the non-deterministic bandwidth of spectrum holes. Then a stochastic MKP model was developed for spectrum allocation with PDF model. The time-varying bandwidth of spectrum holes provided better performance of the system [14].

A spectrum handoff selection scheme proposed for the CR VANET [15] used the game theoretic auction theory scheme to select the optimal network of spectrum handoff. An effective spectrum handoff was selected from multiple available networks in the proposed method. A trust management system is presented, with Markov chain to main, with a safety message transmission delay below its limit value in [16]. This trust management scheme applied to the CR VANET, which improved the reliability of the system. The trust management scheme also enhanced the security of transmission of data in CR VANET [17]. The security of data transmission in CR VANET also improved by hybrid Genetic Artificial Bee Colony (GABC) algorithm [18]. The algorithm optimized the spectrum utilization by detecting primary user attack and improving the probability of detection. An innovative method Cognitive Internet of Vehicles (CIoV) was proposed for the improvement of network safety. It enhanced the network security and transportation safety based on specific information of both physical and network data space. In the CIoV, three network issues: inter-vehicle network, intra-vehicle network and beyond vehicle network were also presented [20]. Kasem et al. presented a MATLAB based simulator of cooperative spectrum sensing with different channel atmosphere. The created model performance was tested in Vehicular and Pedestrian channel with different communication signal and four cooperative users [21].

In [22], a periodic spectrum sensing problem was design with the MAC frame structure. The sensing throughput trade-off problem was formulated by taking both users' interests. The cooperative based sensing was also studied in this study. Author proposed a hybrid approach using mobility and trust-based clustering scheme for the VANETS. It focuses only on the cluster head selection using trust metric and trust management based on data and communication trust [24]. A stable clustering head selection algorithm was proposed for the VANETS. The malicious attacks were identified which improves the security of Vanet. The proposed algorithm utilized the direction vectors, center of the vehicle densed area and selected stable cluster. The relative mobility metrics were utilized by the stable clustering algorithm [25]. A double head clustering (DHC) algorithm was proposed for VANET in [26]. It was a mobility-based scheme and produced mobility metrics like vehicles speed, direction, and position. The communication link mobilities metrics also added to the stable cluster head selection process. The DHC algorithm proves own stability and efficiency under various mobility scenarios.

A Rough set theory scheme was proposed for the cluster head selection, which minimizes the CH selection time. The Rough set schemes reduce the number of nodes who participated in the cluster head selection, so the CH selection time is reduced, and network reliability improved [27]. Cheng et al. proposed the center-based clustering algorithm to improve the performance of self-organizing VANET's. It provided stability to the cluster head selection process and reduced the variable frequency status in vehicles on the highways. The basic parameters use by proposed methods were direction vector, a median of vehicle denser area and intersection to group minimum quantity of more stable cluster [28]. An EGT (Evolutionary Game Theoretic) approach was proposed for the automatic clustering of nodes and attained cluster stability in VANET's. The stability of cluster head was tested by Lyapunov function [29]. A novel method CCBR (Cross-Layer Cluster-Based Routing) was proposed for the stable cluster formation. The CCBR method improved the routing path lifetime by reducing the link break for better multimedia data dissemination. The basic principle of CCBR approach is cross-layer autonomous route recovery (CLARR) scheme. The clustering concept introduces into the CLARR approach using mobility metric and measures the distance among vehicles [30].

A multi-cluster head Dolphin swarm IDS algorithm was proposed for detection the various Malevolent attacks like warm hole, selective forwarding, and packet dropping in VANET. The proposed method improved the performance and working of the network. Further, a hybrid fuzzy-based multi-criteria decision-making method was proposed for the selection of cluster head from available nodes [31]. A dynamic mobility and stability based clustering method were proposed for the VANET. It applies the vehicle moving direction, link lifetime and vehicle position estimations. The proposed method compares with the lowest-ID scheme and VMaSC algorithm [32]. The K-mean and Floyd-Warshall algorithms were proposed for the cluster head selection. The centralized vehicle was selected as the cluster head in case of Floyd-Warshall algorithm. The stability time was improved during the selection of cluster head through proposed method [33]. A combination of bulley and Lamport timestamp algorithm was presented for the cluster head selection in [34]. It also provided the efficient switching of cluster head which improved the stability of VANET nodes. The aforementioned works have proposed some techniques while others have proposed some algorithms but none of them consider this key challenge pointed out in our study.

III. PROBLEM STATEMENT

VANET is dynamic as vehicles keep on moving with variable speed and it is cumbersome to manage the link between them without interruptions. The density of vehicles in any area may also vary; so, the scarcity of bandwidth may also arise. Recently, many researchers worked on cluster formation in VANET; therefore, a flawless connection between vehicles can be managed. The CH among them has to be elected which maintains the relationship $V_i \forall_i = 1, 2, 3.....N$ in that cluster.

State of the art lowest ID clustering algorithm is proposed for the CH selection [1], highest degree clustering schemes [2], weighted clustering schemes [3], [4], Affinity propagation algorithm [5], and fuzzy logic-based algorithms [6], [7]. The earlier work has an issue with CH stability. The continuous change of CH index in a cluster increases the overhead. The stable CH improves the continuous linkage and consumes less bandwidth. The work in [6], [7] identified this issue and proposed fuzzy logic scheme to select the CH. They considered the constant vehicle speed in every cluster to improve the CH stability but vehicle moves with unpredicted velocity in the real environment. So, their model lacks in presenting the realistic vehicle movement model. The latest work in this field has major setbacks such as:

- It considered the four parameters purposed to include the CH in a cluster [19], therefore, it lacks the definition of vehicle security and vehicle trustworthiness.

- Those papers did not consider lanes on the road as the vehicle, while the lanes affect the CH stability. The vehicle moving in a lane constantly will have a high probability of being selected as CH due to the uniform linkage between RSU and another cluster node. Vehicle speed is considered constant for every vehicle which is not possible in a real environment.

IV. PROPOSED WORK

We extended the work of Kevin [7] while considering the network security and vehicle trustworthiness using co-operative spectrum sensing. The co-operative spectrum sensing introduces the spectrum sharing concept in VANET and avoids congestion in bandwidth. Since the CSS is based on the fact that SU has to release the acquired bandwidth once PU is detected in the network and if it does not free the bandwidth, SU is compromised and detected. So it also adds security in the network by easily recognizing the compromised node. The CH selection is based on fuzzy logic schema in our work however, the input to FL to decide the CH are more near to real environmental condition and make the CH more stable for long. Figure 1 shows the overall framework of the proposed algorithm. Some notations are listed in Table 1, which will be used for further gradation.

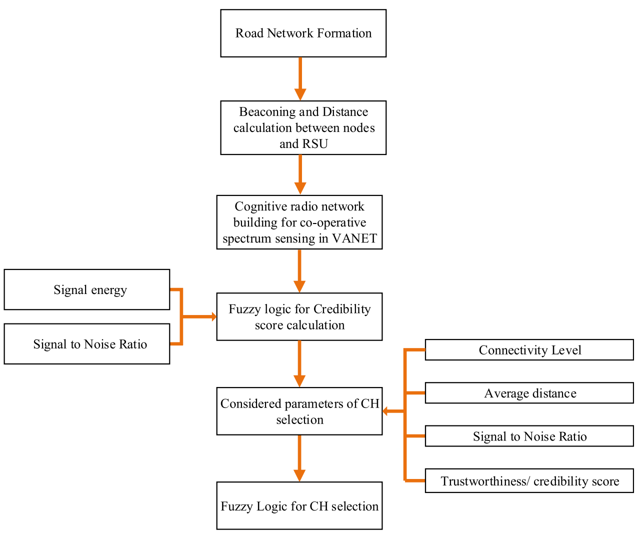

FIGURE 1. Complete flow chart of a proposed solution.

To improve the stability of CH in a more realistic VANET environment in the proposed work, this study has flowing contributions:

1) A four road junction with two lanes of each side considered to test the approach into a more realistic environment cluster at junction faces abrupt change in cluster nodes due to new joiner and release of vehicles.
2) The vehicle with random varying velocity is considered in the network to match the real traffic conditions.
3) The CH selection is based on a few more parameters such as:

TABLE 1. Notations used in this cluster head selection.

Symbols	Definitions	Symbols	Definitions
V_i	Vehicles	OBU_{range}	Onboard unit transmission range
N	Number of vehicles	$d_{node_{i,j}}$	Euclidean Distance between two nodes
T_{sim}	Simulation time	CH	Cluster head
$L_{to}R$	Traffic direction from left to right	P_d	probability of detection
$R_{to}L$	Traffic direction from right to left	P_f	probability of false detection
$L_{to}U$	Traffic direction from low to up	CSS	cooperative spectrum sensing
$U_{to}L$	Traffic direction from up to low	PU	Primary used in CSS
$V_{i,x'}V_{i,y}$	i^{th} vehicles' x,y coordinates	SU	Secondary User in CSS

Lane Weight: we have considered that traffic which merges at a road intersection. There are three main traffic flows at an intersection:

- Left Turn (LT) -it applies to the left lane while the traffic splits to the left side.
- Right Turn (RT) -it applies to the right lane while the traffic splits to the right side.
- No Turn (NT) -it is applied to the Centre lane while traffic goes straight.

The lane weight is estimated depending on the overall number of lanes (TNL) present on the road and the lane present in each traffic flow (NLTF). The lane weight formulation is described in Equation 1.

$$LW_K = \frac{1}{TNL} \times NLTF_k \tag{1}$$

where k is the lane number. Equation 1 is a general lane weighing formula. In this work, CH should be a node that is in the middle lane as much as possible thus the middle lane is given more weight.

$$LW_k = \begin{cases} \frac{1}{TNL} \times NLTF_k & for \quad TNL \leq 2 \\ \frac{2}{TNL} \times NLTF_k & TF = NTforTNL > 2 \\ \frac{1}{2TNL} \times NLTF_k & TF = RT = LTforTNL > 2 \end{cases} \tag{2}$$

Network Connectivity level(NCL): The network connectivity level (NCL) depends on the overall network connectivity and traffic in each network. The NCL, for the entire network, is denoted by α while the traffic lane is β. Both formulations are shown in Equation (3) and (4).

$$\alpha_i(t) = \Sigma_j A(i, j, t) \tag{3}$$

Here the j reflects the nearby potential vehicle and the value of $A(i, j, t)$ is considered as 1 in case of connection finishes at time t. In another case it will be zero.

$$\beta_i(t) = \Sigma_{jTF} A(i, j_{TF}, t) \tag{4}$$

Here j_{TF} is the same traffic flow lane vehicle. So net connectivity of the vehicle i in a lane TF is estimated as:

$$NCL_i(t) = B_i(t) + (a_i(t) \times LW_{TF}) \tag{5}$$

where LW_{TF} represents lane weight of the vehicle i position in the lane.

$$P_{Nnorm} = \frac{NCL_i - min(NCL_x)}{max(NCL_x) - min(NCL_x)} \tag{6}$$

Average distance: The average distance level is obtained with the help of complete absolute distance between the vehicles present in the lane. It is represented by the δi and formula to estimate:

$$\delta_i = \frac{\sum_j \sqrt{(x_j - x_i)^2 - (y_j - y_i)^2}}{NV} \tag{7}$$

where j represents the random vehicle from the subset of i. At that time we estimate the average distance between the vehicle in the same traffic flow lane and vehicle i. It is represented by X_i which formulates below:

$$X_i = \frac{\sum_{jTF} \sqrt{(x_j - x_i)^2 - (y_j - y_i)^2}}{NV_{TF}} \tag{8}$$

where j represents random vehicle related to i and NV_{TF} represents the entire number of vehicle on the same traffic lane flow and connected to the vehicle i. The average distance level (ADL) estimated as per Equation (9).

$$ADL_i = X_i + (\delta_i \times LW_{TF}) \tag{9}$$

The normalized average distance is calculated in Equation (10).

$$P_{Dnorm} = \frac{ADI_i - min(ADL_x)}{max(ADL_x) - min(ADL_x)} \tag{10}$$

Average velocity: The term average velocity level (AVL) defined as the cluster head velocity and all vehicle's average velocity in the communication range. The complete average velocity level represented by σ_i and estimated as per Equation (11).

$$\sigma_i = \frac{\sum_{NV} \left|Vel_i - Vel_j\right|}{NV} \tag{11}$$

Now, the AVL, ρ_i for a vehicle, i is defined as:

$$\rho_i = \frac{\sum_{jTF} \left|Vel_i - Vel_{jFT}\right|}{NV_{jTF}} \tag{12}$$

The AVL for the vehicle i in a traffic flow TF is

$$AVL_i = \rho_i + (\sigma_i \times LW_{TF}) \tag{13}$$

$$P_{Vnorm} = \frac{AVL_i - min(AVL_x)}{max(AVL_x) - min(AVL_x)} \tag{14}$$

Trustworthiness: This is the most important factor to consider the CH to make the VANET nodes' communication more secure. The high credibility of node leads its selection as CH and less probability of joining any adversary vehicle in the cluster.

We will calculate this trustworthiness using spectrum sensing approach. The more any vehicle takes part in spectrum sharing; more will be its rewards to be elected as CH. The overall Average Reward Credit (ARC), W_i for the vehicle i is defined as:

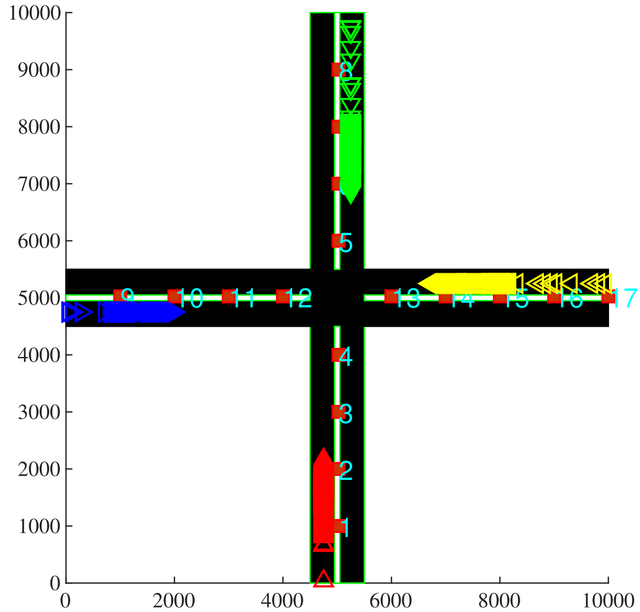

FIGURE 2. Four road junction design.

$$W_i = \frac{\sum_{jNV}(crd_i - crd_j)}{NV} \tag{15}$$

where j is a nearby vehicle and crd_i is the credit of vehicle i. Now the ARC and Wi' is calculated for i^{th} vehicle and for corresponding traffic flow. This is defined as

$$W_i{}' = \frac{\sum_{jTF}(crd_i - crd_j)}{NV_{TF}} \tag{16}$$

where jTF shown the same vehicle present in traffic flows like vehicle i. So the ARC calculates or defined for same vehicle i.

$$ARC_i = W_i{}' + (W_i \times LW_{TF}) \tag{17}$$

$$P_{Cnorm} = \frac{ARC_i - min(ARC_x)}{max(ARC_x) - min(ARC_x)} \tag{18}$$

A. ROAD NETWORK AND CLUSTER FORMATION:

We have considered the highway scenario of four roads junction with fixed width and length. Each side of the traffic flows towards the junction and cross the junction too as shown in the Figure 2. We have started initially with $V_N \forall N = 5$ for each side traffic flow making $\sum N = 20$. Every vehicle has different random velocity profile which gets updated for each T_{sim}. It has been assumed that since every V_N is initialised randomly and highway road network is considered, the speed of vehicle will remain constant throughout the simulation. The position update of V_i for each traffic flow is different and is calculated as:

$$V_{i,position_{LtoR|Tsim+1}} = [(V_{i,x_{LtoR|Tsim}} + V_{i,LtoR}, , V_{i,y_{LtoR|Tsim}}] \tag{19}$$

$$V_i, position_{RtoL|Tsim+1} = [(V_{i,x_{RtoL|Tsim}} + V_{i,RtoL}, , V_{i,y_{RtoL|Tsim}}] \quad (20)$$

$$V_i, position_{LtoU|Tsim+1} = [(V_{i,x_{LtoU|Tsim}} + V_{i,LtoU}, , V_{i,y_{LtoU|Tsim}}] \quad (21)$$

$$V_i, position_{UtoL|Tsim+1} = [(V_{i,x_{UtoL|Tsim}} + V_{i,UtoL}, , V_{i,y_{UtoL|Tsim}}] \quad (22)$$

Every node has the probability of taking a turn at the junction or going straight. The turned V_i probability is defined as $\rho_i = 1 \mid (i+1)\%2 \cong 0$. By this way every third vehicle changes flow direction at the junction. For the cluster formation of vehicles, we initially started with the number of clusters as the number of RSU_s. The nodes in transmission range of the RSU are assumed in a cluster. The Euclidean distance between RSU_i and V_i is calculated to check if within range to RSU. The cluster formation is explained as graph theory. Two different node graphs are generated defined as:

Defination 1 (RSU Node Link): A VANET cluster graph can be represented by $G = (T, E)$, where T is the vertex set and each vertex is related to RSU_i. E is the edge set (i, j) which is related to the link between RSU_i and $V_{j\epsilon 1,2....N}$. For $E(i, j)$, the distance $d(i, j)$ is known and compared with RSU_{range}. If $d(i, j) < RSU_{range}$ then that node is considered in the cluster linked to RSU_i.

Defination 2 (Node to Node Link): Every node to node linkage is mapped to the graph $G = (T, E)$ for cluster formation as nodes' distance must also be within OBU_{range}. The mapping is done for every node linkage to G is $\rho : d_{node_{i,j}} \rightarrow G$. A distance set D for G is set of all edge pairs' distance $d_{node_{i,j}}$. Given a distance OBU_{range}, the node V_i will be in a cluster C if $d_{node_{i,j}} < OBU_{range}$. Here $d_{node_{i,j}}$ is the Euclidean distance between $V_{i\rightarrow j|i,j\epsilon 1,...N}$. In this case a matrix $link_{i,j}$ will be generated to check the mapping of edge E. The E is connected to T only if $link_{i,j} = 1 \forall d_{node_{i,j}} < OBU_{range}$ else $link_{i,j} = 0$. Using the above two definitions, a cluster C is formed out of which CH is elected by the proposed approach. The pseudo code for the cluster formation is proposed as:

Algorithm 1 Proposed Algorithm

```
Input: V_{i|x,y}, RSU_{x,y}, OBU_{range}, RSU_{range}
Output: Cluster C
Calculate the distance d(i,j) between RSU_i and V_j
if : d(i,j) < RSU_{range}
RSU_{inrange(i,j)} = 1
else :
RSU_{inrange(i,j)} = 0
Calculate the distance d_{node_{i,j}} betweenV_i and V_j
if : d_{node_{i,j}} < OBU_{range}
link_{i,j} = 1
RSU_{inrange(i,j)} ⋃ link_{i,j} = 1
Node is in cluster
```

B. SPECTRUM SENSING FOR BANDWIDTH OVERHEAD REDUCTION

In proposed work, we introduced a new spectrum sensing concept in VANET. Each vehicle node takes part in cognitive radio networking to transfer the message to each other. It uses the limited spectrum and due to limited bandwidth allotted to network, the overhead is imposed due to fast switching of CH index. Spectrum sensing reduces this overhead by utilizing and making free the spectrum of primary nodes. We have assumed all VANET nodes as secondary nodes and they have initially occupied the whole spectrum. The node is selected as CH if it takes part in CSS. In the co-operative spectrum sensing, if V_i finds the energy of received signal is greater than threshold signal energy, the presence of the primary user is sensed and the captured spectrum should be released. If SU is legitimate then it won't free the allocated spectrum and thus the credibility of this vehicle node will be reduced. Thus, a genuine vehicle node will free the spectrum for PU and every time it will act as non-compromised node, the credibility counter increases. Equation (34) mathematically represents this condition. The threshold energy is the received signal energy which is calculated by inverse of Q function with received signal packet size and false alarm probability as input arguments [23]. As much as it follows the protocols of CSS, more will be its credibility and higher the chances of selection as CH. The release of bandwidth for the primary user by nodes is sensed by threshold signal energy detection.

Here, we have proposed a new double threshold method to incorporate the credits to each secondary node in the network. The probability of detection of the primary node in the network improves the credibility of secondary nodes and double threshold method is used to calculate the P_d. The SS process follows the orthogonal frequency demodulation multiplexing (OFDM) communication scheme to transfer the messages. Each channel between the primary user and the secondary user is modeled as OFDM communication channel. The signal gathered from primary user is transmitted to a common fusion centre which takes the decision of spectrum sensing and attacks. The bandwidth of transmitted signal is divided into N_s subcarriers and transmitted in chunks. These subcarriers are frequency spaced by $\Delta f = 1/T_d$. Where, T_d is time to transmit a signal. The signals are multiplexed using inverse discrete Fourier transform (IDFT) as;

$$Y_b(t) = \sum_{k=1}^{N_s} Y_k e^{f 2\Pi k \Delta f t} \quad (23)$$

This signal is then converted into a carrier band and transmitted through a fading channel to match more realistic Rayleigh transmission channel:

$$h(t) = \sum_{p=1}^{N_p} A_p \delta(t - t_p) \quad (24)$$

where, N_p is a number of paths. A_p is the channel gain and t_p is the delay in p^{th} path. This way every secondary node is transmitting the signal. A free space path loss propagation model is modelled which considers the signal moves in line of sight (LOS) [22]. Based on this propagation model, the received power at secondary can be calculated as:

$$P_r = \frac{G_l \times \lambda^2}{(4\Pi d)^2} \times P_t \tag{25}$$

where P_r and P_t are received and transmitted power respectively, λ is the wavelength d is the LOS distance and G_l is the factor dependent upon antenna field radiation of PU and SU antenna. The received power is inversely proportional to square of distance between PU and each SU channel. The actual received power may differ from the above equation due to noise variance σ^2 inserted in the channel. The noisy channel is modeled as convolution of Rayleigh channel response and noise variance as:

$$g(t) = h(t) * n(t) \tag{26}$$

whereby, $n(t)$ is noise variance. Every secondary node senses the energy of the transmitted signal by PU and based on the comparison with threshold ϵ, it decides whether it is from the primary user and to vacate the channel. The Energy of received signal is square of magnitude of complex signal. The energy calculates test statistics $T(y)$ in time domain to compare with, which follows the Neyman-Pearson criteria.

$$T(y) = \frac{1}{2N} \sum_{i=1}^{N} \left| Y_i^{re} + y_i^{im} \right|^2 \tag{27}$$

The test statistic $T(y)$ is the random variable with chi square probability distribution function (χ^2) with k degrees of freedom. It can also be represented as $Q = \sum_i^k = 1|z_i|^2$. Here $k = 2N$ for complex valued case and $k = N$ for absolute values. The threshold ϵ can be defined using the central limit theorem. Based on ϵ, the probability of false alarm is $P_f(\epsilon, t) = Pr(T(y) > \epsilon)$. Our channel model is with complex QPSK and Gaussian noise, so the detection probability can be defined as:

$$P_d(\epsilon, t) = Q((\frac{\epsilon}{\sigma_u^2} - \gamma - 1)\sqrt{\frac{tf_s}{2\gamma + 1}}) \tag{28}$$

where $Q(.)$ is the complementary distribution function and is Gaussian in nature i.e.

$$Q(x) = \frac{1}{\sqrt{2\Pi}} \int_x^{\infty} exp(-\frac{t^2}{2})dt \tag{29}$$

If we take the inverse of equation (29) then the threshold for probability detection can be calculated as:

$$Q^{-1}(P_d) = (\frac{\epsilon}{\sigma_u^2} - \gamma - 1)\sqrt{\frac{tf_s}{2\gamma + 1}} \tag{30}$$

In terms of the probability of false detection P_f, it can be calculated as:

$$Q^{-1}(P_f) = (\frac{\epsilon}{\sigma_u^2} - 1)\sqrt{tf_s} \tag{31}$$

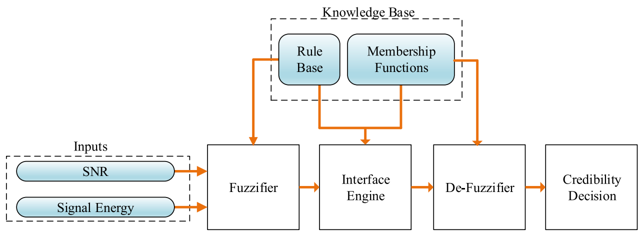

FIGURE 3. Fuzzy logic pipe line for credibility score calculation.

in above equations, γ is used to represent the SNR and t is for spectrum sensing time. In our work, we used the MATLAB's inverse Q model function to calculate the threshold detector value for particular $P_f|_{i=0.01,....,1}$. Compared with ϵ, the probability of detection will be as:

$$P_d = \{1; T(y)\} > \epsilon \ 0; otherwise \tag{32}$$

The equation (32) is updated in our work using fuzzy logic. The responsibility to decide whether the channel should be freed from the PU or not is passed to the fuzzy logic. We propose here a fuzzy logic decision scheme based on $T(y)$ and SNR as inputs. It can be seen as:

$$fuzzyDecision = f(T(y), SNR) \tag{33}$$

The trustworthiness of a V_i is also defined by Equation (33). Higher the P_d, more will be its trustworthy score $crd = \sum P_d$. The complete block diagram of proposed fuzzy logic based crd calculation is shown in Figure 3. With this fuzzy logic decision for the probability of detection of the primary user, the Equation (32) changes to

$$P_d^* = \{1; fuzzyDecision(y) > \epsilon \ 0; \quad otherwise\} \tag{34}$$

The credit score is now the sum of P_d^*. We designed the fuzzy logic function in MATLAB for this. Three membership functions for 2 inputs and outputs are defined with trapezoidal and triangular shapes. These shapes are more in common and have the advantage of simplicity. The membership functions have the weight between 0 and 1. So, we normalized each input to the fuzzy schema. These membership functions are shown in Figure 4. A rule set Table is also shown in Table 2.

TABLE 2. Fuzzy logic rules to decide the credibility score.

SNR ↓ Energy→	Low	Medium	High
Low	Low	Quite-low	Medium
Medium	Quite-low	Medium	Quite-high
High	Medium	Quite-high	High

Due to the 2 inputs and 1 output, a total of 9 rules will decide the credibility score. These rules are set after various tests. Output has five membership functions low, quite-low, medium, quite-high and high. A three-dimensional surface view of Table 2 is shown in Figure 5. We analyzed the fuzzy logic decision for the true detection probability of primary users in spectrum sensing of vehicles. A curve between P_d^* and P_f is plotted for SNR = 7.5dB, though we have used

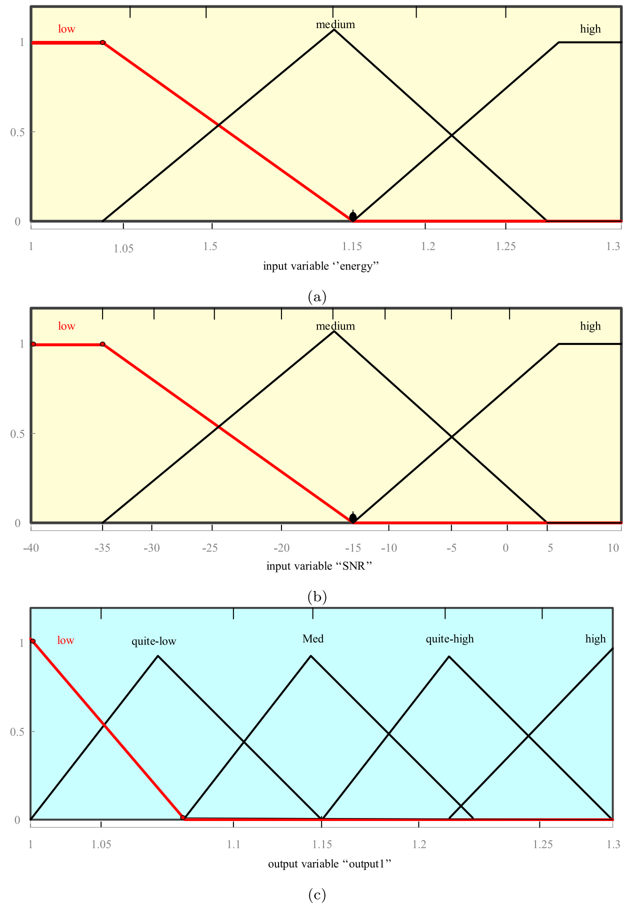

FIGURE 4. Fuzzy logic membership functions for inputs (a) Energy (b) SNR and output (c) fuzzy decision to vacate the channel.

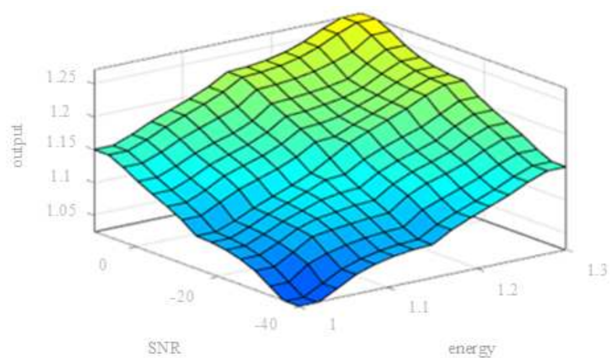

FIGURE 5. Surface view of rules for credibility score calculation.

different SNR values in SS of VANET. P_d^* Is calculated for each vehicle node during every T_{sim}. A comparison between the P_d^* vs P_f for the proposed solution and P_d and P_f for the existing solution is plotted in Figure 6. The current solution executed for $T_{sim} = 50$ and comparison curve is shown for the last simulation time.

Since the $P_{d,max} = 1$, so higher the probability of detection, better is the credit score and accordingly the trustworthiness of that node is considered. In the Figure 6, y-axis label denotes the probability of detection only (not to confuse

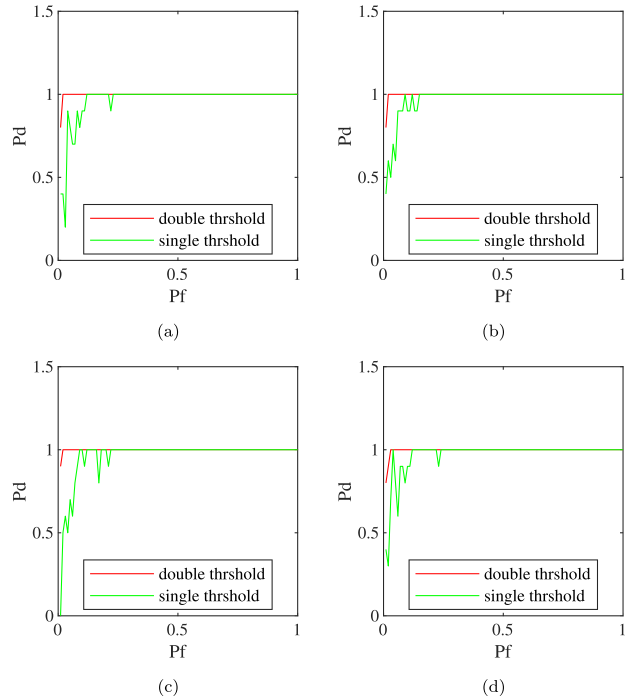

FIGURE 6. Comparison of the probability of detection of PU by proposed double threshold method and by existing single threshold method with P_d Vs P_f curve at SNR = 7.4db for a) LtoR road segment b) RtoL road segment c) LtoU road segment d) UtoL road segment.

with the notation used in Equation (32). The threshold value to decide the absence or presence of PU is calculated from Equation (31). $P_f \epsilon (0, 1)$ is used to check various P_d and P_d^*. It can be analyzed from the above graph that while P_d gives less true detection of PU for every node, the proposed SS scheme has always higher probability $\left(P_d^* > P_d\right)$ for the same P_f. The pseudo code for credibility calculation using spectrum sensing approach is written as;

Algorithm 2 Pseudo Code for Credibility Calculation Using Spectrum Sensing

Input: nodes, fuzzy rules, OFDM parameters, P_f, SNR
Output: credibility score (crd)
For $V_i \epsilon$ $(0, N)$
$P_f \epsilon$ $(0, 1)$
Generate the random signal to be transmitted to CH
QPSK modulate it and transmit through noisy Rayleigh channel
Extract the signal energy $T(y)$
$fuzzyDecision = f(T(y), SNR)$
if : $fuzzyDecision(y) > \epsilon$
$P_d^* = 1$
else :
$P_d^* = 0$
End if
End P_f
$crd = \sum P_d^*$
End V_i

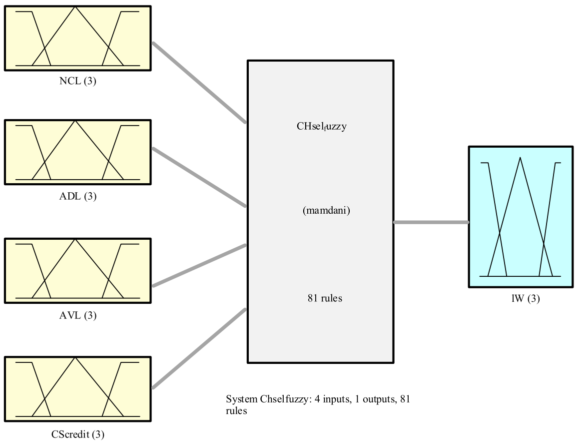

FIGURE 7. Fuzzy logic structure for cluster head selection.

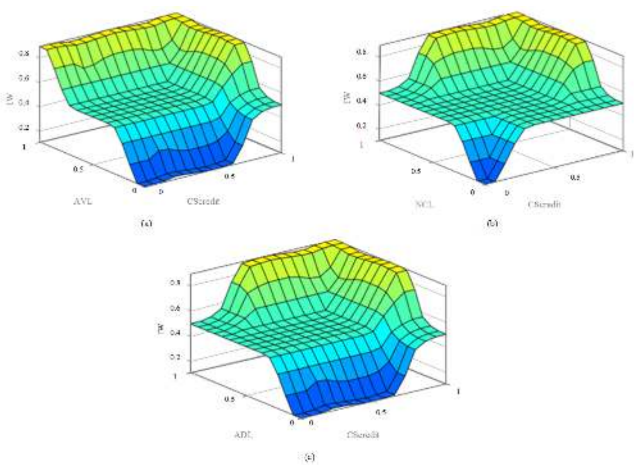

FIGURE 8. Surface view plot of fuzzy rules for cluster head selection.

C. CLUSTER HEAD SELECTION

As we have proposed in the section above, the five vehicle parameters can help in selecting CH in a cluster. From definition 1 and definition 2 in section A., we get to know that vehicle node is in the cluster if $RSU_{inrange(i,j)} \bigcup link_{i,j} = 1$. We propose here fuzzy logic to select the cluster head with different inputs to it than in section B. Inputs to fuzzy logic are briefed from Equation 1 to 18. LW is not directly input to the fuzzy scheme rather it helps to calculate the other inputs. For every node, the spectrum sensing module is called; $P_N norm$, $P_D norm$, $P_V norm$, and $P_C norm$ are calculated. These are stored in the database for every T_{sim}. We have given equal weightage to each input and drove the rules accordingly. The proposed fuzzy schema has four inputs and a single output with 81 rules as shown in Figure 7. The surface view of fuzzy rules is shown in Figure 8. The z-axis has the IW_i, the x-axis has $P_c norm$ and y-axis displayed the rest inputs. Every surface view has the falling water shape which is an indication of optimal rules selection. The different set of rules will give different CH stability. We set these rules after various experiments. The MATLAB code is executed for a definite simulation time (simulation system parameters are tabulated in Table 3) and each time the input weights from the fuzzy logic output are achieved and stored. The nodes in a cluster are compared for their IW_i and vehicle with a maximum of IW_i is declared at CH. In our implementation, we have made a structure for nodes and RSU's which saves the information about each node for current T_{sim}. The pseudo code for CH selection is shown in the Algorithm 3.

TABLE 3. System parameters for VANET simulation in MATLAB.

VANET network parameters		Co-operative spectrum sensing parameters	
Traffic Flow directions	4	Signal multiplexing method	OFDM
Lanes for each traffic flow	2	FFT length	128
Initial vehicles in each lane	5	Modulation	QPSK
Road length	10Km	Cyclic prefix Length	32
RSU Range	1000 m	PU's False detection probability	0.01-1
OBU range	300 m		
Simulation time	50 m		

Algorithm 3 Pseudo Code for CH Selection

Input: nodes table, RSUs table, $link_{i,j}$, $d_{node_{i,j}}$
Output: Cluster head
For $kk = T_{sim}$
for $jj = 1$:traffic flow direction
update the position of vehicle $V_{i,position_{jj|Tsim+1}} = [(V_{i,xjj|Tsim \pm v_{i,jj}}), (V_{i,yjj|Tsim \pm vi,jj})]$
if :$node_{pos} = jnctnpt_{pos}$
change the vehicle direction randomly
else :
go straight
$P_{Nnorm} = nwconnection(nodes, IW, RSU)$
$P_{Dnorm} = avgDistance(nodes, IW, RSU)$
$P_{Vnorm} = avgVelocity(nodes, IW, RSU)$
$P_{Cnorm} = SSCredits(nodes, IW, RSU)$
$IW_i = fuzzy(P_{Nnorm}, P_{Dnorm}, P_{Vnorm}, P_{Cnorm})$
$CH_{index} = max(IW_i)$
End For
End For
Calcualte CH_{index} time in an cluster for results evaluation

V. DISCUSSION

In this study, we have used a four road junction network of 5000 m segment length of one side as shown in Figure 2. The OBU range is considered as 300 m and we started with 5 vehicles at each traffic flow, making a total of 20 vehicles at an instant of time. Since the simulation is executed for 50-time samples, no new vehicle enters the network. The VANET is very dynamic and to reduce the overhead the CH must be stable for the longest time. We have assumed the

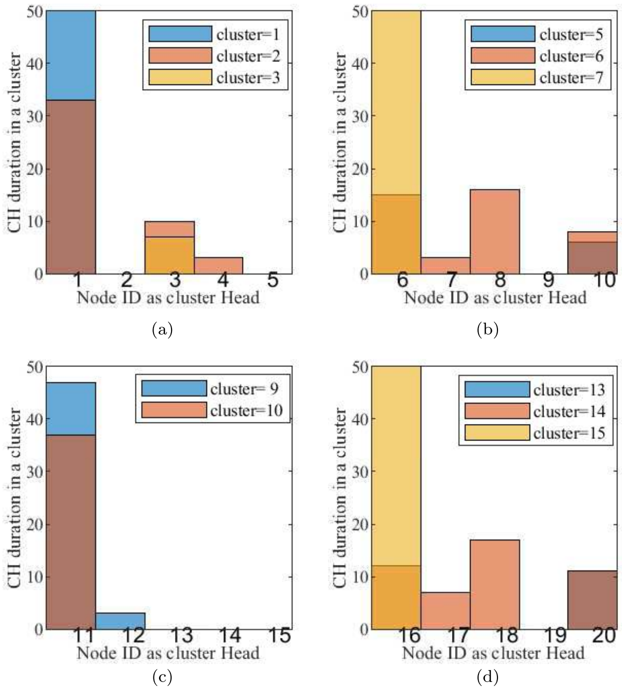

FIGURE 9. cluster head stable time for nodes elected as cluster head a) during LtoU road b) during UtoL road c) during LtoR road d) during RtoL road.

number of clusters as RSUs. A graph for the comparison of CH time interval in each cluster is shown in Figure 9. The CH time interval is the total time duration for which a node remains as a cluster head. Higher is this time interval, stable is the CH and less overhead is in selecting it. The traffic is indicated in the direction low to up and left to right has shown very less overhead as CH is assigned to a single node for a maximum of T_{sim}. For example, in cluster the node ID 1 stays as a cluster head for 37-time samples out of 50, which is approximately 74% of the stable time.

Similarly, in cluster 10 the node with ID 11 stays as CH for 90% of the total simulation time. It has also been observed that the node selected as cluster head at the beginning, remains as the cluster head for maximum sample times. This also matches the condition to reduce the overhead over RSUs for CH selection.

During the whole simulation time, the nodes in range with every cluster keep on changing. Nodes may join or leave any cluster depending upon the OBU range. Figure 10 shows the average number of nodes in a cluster during the simulation. As in Figure 2, the nodes enter into the network and join the cluster immediately they are connected with RSU 1,9,8,16 for different traffic flow. These road segments of four traffic flows are considered as 5000 meters long. Since, we have tested the simulation for 50 secs, nodes could not cover the distance to join the 3^{rd} and 4^{th} Road Side Unit. Due to this, the number of average nodes in these is zero where some joined the 2^{nd} cluster after passing the 1^{st} cluster. Most of the nodes remain connected with the 1^{st} cluster during the simulation. Thus, it has the maximum number of

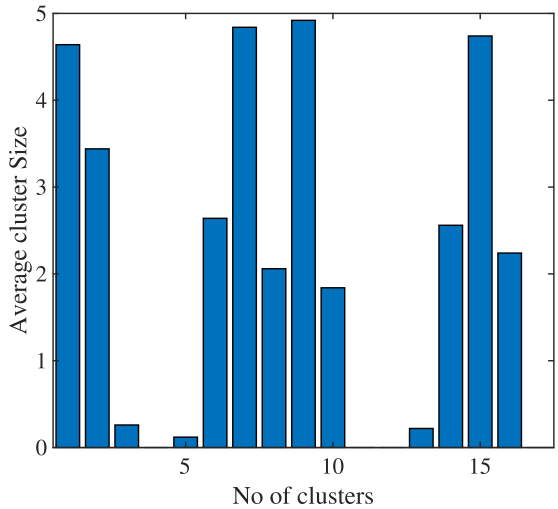

FIGURE 10. Average cluster size in each cluster.

average nodes. The vehicle speed in each traffic flow side is different and also varies for each vehicle during every simulation time with some random speed between 5-10 m/s. Due to this, the connected nodes with clusters differ and so is the average nodes in each cluster. Few other researchers also considered the similar VANET simulation environment. In rest of this paper, we analytically compare our approach with them.

The trust based selection of cluster head is used previously eliminate too [7], [24] but they have calculated the trust based on message received. We have included the novel mechanism of trust calculation in our work. We proposed the spectrum sensing approach and double threshold scheme to remove the malicious node in the VANET to calculate the trust. This scheme is independent of received messages, instead energy of the received signal. The advantage of using this scheme is that the thresholding approach is independent of the noisy signal unlike in the trust calculation based on received message. The proposed scheme has 0 probability of electing the dishonest vehicle whereas Oubabas et al. [24] has this value 0.05, 0.23 by VWCA [35] and 45 by MOBIC [32]. The [24] considered the highway scenario with variable vehicle speeds but it did not consider the highway junction. The more dynamic nature of VANET and vehicle density affects the trust factor based on message.

The cluster head stability in our scheme is upto 90% of its simulation time. The vechicle in any cluster can be a cluster head for a longer time due to more weightage given to trust factor in fuzzy logic rules. This CH stability is upto 50% of total simulation time of 100 sec in [26] whereas, in [24] it is 86% of 500sec simulation time. Compared to [32] and [35] the cluster head stability is more than 14 % and 34% respectively by our scheme.

VI. CONCLUSION

In this work, a fuzzy-based management system for the cluster head selection in CR VANET is successfully implemented. It is clear from the above results section that the stability, trustworthiness, and security is achieved in cluster head selection. Two fuzzy logic systems are used in this work: one for improvement of the probability of true detection of PU in CR with signal energy, SNR as fuzzy input and the other for stable cluster head selection considering the speed, probability of true detection, distance and lane weight as input.

The proposed solution to improve the probability of true detection of PU has shown 1.66 times higher detection at 0.01 probability of false detection than spectrum sensing based on signal energy threshold. This improvement decreases with an increase in false detection probability, and least improvement is 0.11 times for 0.07 false probability detections. So, the proposed solution achieved higher improvement even at lower probability. This improvement in CR VANET performance improves the trustworthiness of the vehicle node making the stability to be improved to 90 % of the overall cluster time.

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