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Secure Data Dissemination Scheme for Vehicular Relay Network based on Predictive Clustering

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Abstract

Background/Objectives: In the current work, a new approach named as Secure Data dissemination scheme for Vehicular Relay Network based Predictive Clustering has been accomplished by incorporating fuzzy decision system and secure vehicle authentication mechanism to improve our existing solution Energy Efficient Predictive Clustering approach. **Methods/Statistical Analysis:** In past several years, tremendous growth has been observed in vehicular network capabilities for information processing, which makes it an enthralling research area. Integration of vehicular network with next generation of wireless communication technologies provides increased comfort and safety for passengers in the vehicle. The network topology of vehicular networks is highly dynamic in nature that results in high overhead because of the missing central control and increased network traffic. However, to maintain quality of service without compromising any critical parameters is a challenging task in the vehicular networks. Hence, there is a requirement of an intelligent data dissemination technique that minimizes the complexity of the network by providing a backbone architecture that collects the node into multiple clusters. **Findings:** The performance evaluation of the introduced scheme is estimated using pervasive simulations confirm the effectiveness of the proposed scheme in terms of improved cluster stability and longer cluster head lifetime that decrease the overhead while also demonstrating improved reliability. **Application/ Improvements:** This scheme helps in improving the data deamination and security in the vehicular relay network that can be beneficial for those real time applications where data delivered on time is essential like emergency alerts, critical passenger information and traffic information.

Keywords: Clustering, Curve Cryptography, Elliptic, Fuzzy Decision System, Predictive Clustering, VANETs

1. Introduction

Vehicular Ad-Hoc Networks (VANETs)[1-6] are becoming one of the game changer technologies in the future time with a goal to deliver uncompromising services for passenger's comfort and safety. Communicate between vehicles in VANETs is achieved through Inter-Vehicle-Communication (IVC) or Vehicle-To-Infrastructure (V2I). IVC is a fascinating research field to enhance traffic safety and to create comfortable driving environment for passengers in VANETs and considered as the most convincing attribute of next generation Intelligent Transportation Systems (ITS)[7-9]. There would be more chances of topology changes in VANETs scenario due to its high mobility nature, unsteady traffic density, and frequent link break which results in unreliable network connectivity and network disconnection in some portion. In appreciation of these issues, the IEEE society is acting on the standardization of IEEE 802.11p to improve reliability and low latency in VANET's that are very crucial for safety applications[10]. What this protocol also suffered from difficulties like low throughput, integrity, predictability, and high packet collision primarily in high traffic density[11-13]. So, to resolve the current problems and retain the high rate of connectivity between the vehicles, based on some predefined set of rules these are grouped collectively, which identified as clustering. Clustering is an important part of VANETs for overcoming the scalability and stability problems also. During vehicular communication, the performance of each clustering protocol depends

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on upon the number of available vehicles in the respective region[14-15]. Clustering is mainly a systematic grouping scheme which comprised with vehicles that are arranged together in an organized manner, and among all of them, one Cluster Head (CH) is elected. CH is responsible for taking judgments on behalf of all the remaining nodes in the cluster also designated as the Cluster Member (CM) to minimize the communication overhead. However due to the high vehicular velocity in VANETs, CHs election among the nodes which are participating in communication is the major challenging issue to be accomplished.

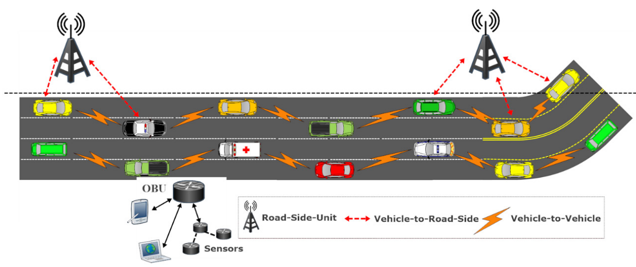

Figure 1. VANET Architecture.

In VANET, vehicles are loaded with the various components such as GPS, actuators, sensors and all these are mounted on the On-Board Units (OBU) that make it an intelligent machine. Vehicular network entirely relies on two type of communication IVC and V2I[16]. IVC is a short range communication in which one vehicle interacts with another in its range, in IVC one vehicle relay on another to transmit their message from one place to other, so it is also named as Vehicular Relay Network (VRN). In V2I, vehicles interact with Roadside Units (RSUs) stationed near the road provide access to the central network as shown in Figure 1. RSU offers the additional data storage and processing capability to OBU. OBU depends on upon Application Unite (AU) for accessing the services provider by the service provider through RSU. However, efficient handoff mechanisms are required to manage vehicles mobility between multiple RSUs increase overheads. Because the introduced clustering scheme relies on IVC/VRN communication, effects caused by V21 transmission not included.

The requirement of improving available resource utilization and level of user satisfaction, safety applications, and traffic management demand an efficient clustering mechanism for VANET. So an efficient clustering algorithm for VANET is designed that able to react according to topological variations and handle topological varia tions with minimized influence on cluster topology. Cluster formation in VANETs depends on upon multiple parameters such as position, relative mobility, distance, and a lane of the vehicle[17]. Moreover, Time Division Multiple Access (TDMA), Space-Division Multiple Access (SDMA), Wavelength Division Multiple Access (WDMA) is needed to be considered as addition network properties that affect the reliability of communication in VANETs[18].

While, various clustering schemes have been introduced for VANETs. But, future position prediction based clustering is still challenging area need to be explored. This clustering scheme depends on the accurate prediction of the vehicles regarding its future location at the network by estimating its past and present position as well as speed. The predicted positions of the vehicles are beneficial for cluster formation. If predictive clustering is done in an efficient manner, enhance the overall efficiency and stability of the vehicular network. To improve the predictive clustering mechanism, it combines with the fuzzy decision system for electing some vehicles as CHs and Backup Cluster Heads (BCHs) based on their accuracy of relative prediction. The vehicles with least and second least variation in relative prediction are elected as CHs and BCHs respectively, and remaining nodes act as Cluster Members (CMs). CMs that are associated with multiple clusters are nominated as Gateway Nodes (GNs).

Zhang, et al.[19] introduced a VANET scenario in which vehicular nodes (mobile) are selected as CH. Mobility among the nodes can affect the clustering of a network, so the focus of multi-hop clustering scheme is to select only those nodes as CH, which are having the little-aggregated mobility. Maglaras, et al.[20] discussed the cluster formation among the network which depends on force-directed algorithms. In this clustering scheme, directed algorithm assigns the force to all nodes participating in the communication and the different forces are introduced. The positioning force is assigned when all vehicles move in the same direction otherwise negative force can be applied. Among all the Cluster Members (CM) the node having highest force declares itself as CH and in cluster merging process, CH having the lowest force declares itself as CM. Caballero-Gil, et al.[21] introduced a solution for the problem of same packet travel throw multiple paths and increase the network overhead. So the author proposed a new algorithm in VANET's by grouping the nodes to avoid this problem and to reduce the communication overhead as well.

Bali, et al.[22] proposed a new clustering mechanism for VANET's in which cluster formation is done by current geographic location as well as the future behavior of vehicles which are participating in transmission purpose. The two predictive algorithm are introduced that will make the network more stable. In clusters, predictive clustering approach defines the CM, and future mobility approach determines the vehicle's mobility in future. Every node has the equal chance to become a CH but in case if prediction accuracy of the node is below that level threshold setup, that node will be elected as CH of respective cluster otherwise, it declares itself as a member of the nearby cluster. Wang, et al.[23] presented a clustering approach for VANET's scenario by considering the vehicle's location. CH is being elected by using minimum dominating technique and the nodes having maximum priority among all of them is elected as CH. Dror, et al.[24] presented the hierarchical clustering technique for the purpose of enhancing a reliability of the network. This approach is mainly designed for the multichannel network where the shared channels are used very effectively.

H. Su and X. Zhang[25] presented an intelligent clustering approach for VANET's based on the MAC protocol. Each node consists with two transceivers, and both of them can operate simultaneously but on the different channels. On the basis of time and size, nodes having the maximum CM and sends an invitation message to join earlier that node will be elected as CH. This approach gains the remarkable improvement infrequent network topology change. Raw shdey, et al.[26] proposed a scheme by grouping the vehicles in different clusters with the help of similarity index. Based on the predefined threshold velocity, vehicles are assigned to clusters and vehicle with less speed among all of them is elected as CH. Lin et al.[27] proposed an approach where the nodes in a cluster broadcasting its ID's to other ones. This scheme named as Lowest ID Clustering Algorithm' in which the nodes have lowest ID is elected as CH, and remaining nodes are declared as the CM of respective clusters. Almalag, et al.[28] proposed the hybrid clustering scheme by combining artificial intelligence and fuzzy logic. This scheme is entirely based on the estimation of mobility among vehicles and for the election of an appropriate CH.

The remaining formation of this paper is as follows. Basic system model and assumptions are summarized in Section 2. The proposed scheme for VANETs scenario is revealed in Section 3. Section 4 depicts the simulations, performance evaluation, and results. In the end, a conclusion with reasonable future improvements is discussed in Section 5. System Model in this section, all assumptions and network model adopted in proposed scheme is described.

2. System Model

In this section, all assumptions and network model adopted in proposed scheme is described.

2.1 Network Model

In this section, the assumptions and network model adopted in proposed scheme is described. New generation vehicles are equipped with technologies such as Global Positioning System (GPS) and multiple types of sensing devices, which are responsible for the movement, speed and directional estimation of vehicles. The proposed work assumes that lanes for vehicle movements are is straight and have the orthogonal intersections. The total Width of the road (W) is divided into two equal bi-directional roadways. Each roadway is further partition into multiple lanes for traffic flow. The vehicles participating in the network use an Omni-directional antenna which provides the radio range between 200 to 500 meters that is sufficient to cover large portion of the road. If the vehicles are within the radio range of each other, then we assume that the vehicles are connected among themselves. Vehicles moving in the same direction on adjacent lanes have little relative velocity and long interaction time with each other whereas vehicles moving in opposing direction have high relative velocity and small interaction time. The estimation of vehicle direction is performed automatically because vehicles with low relative velocity will be out of range of neighboring vehicles with after a short time interval. A small prediction interval (t_1) is also assumed that is then used in the proposed scheme for directional prediction of vehicles.

2.2 Security Model

Security model for the proposed scheme ensures authentication of the participating vehicles during communication. The CH verifies the identity of each member vehicle and assigns a time slot and pseudo-random ID code to every vehicle when it joins any cluster. This id is used by member vehicles for further communication. This critical information is transmitted to member vehicles in encrypted format. This ensures that only authorized vehicles can participate in the intra-cluster communication process.

The proposed data dissemination approach also ensures the privacy of all the member vehicles by hiding their primary Identification information from the other vehicles. All the member vehicles are assigning pseudo-random ID for communication in place of vehicle ID that is used in conventional data dissemination protocol. This procedure helps to ensure that privacy of member vehicles is not compromised during communication.

The integrity of critical information is also ensured in the propose scheme. Information such as allocated time slot and a unique pseudo-random ID for data dissemination. Is uniquely generated for each vehicle. This is achieved by implementing Elliptic Curve Cryptography (ECC) based encryption technology to encrypt information before a node transmits it.

3. Propose Work

Due to high frequency of changes in vehicle speed and position cluster formation, maintainability and security is a challenging task, in proposed presents a scheme secure and stable future position predictions and FDS based clustering scheme, named as SDPC is designed. The propose scheme is applicable for wide variety of applications and also provides efficient utilization of network bandwidth with minimum computation and network overhead. Figure 2 depicts the basic cluster formation and CH election cycle of propose scheme.

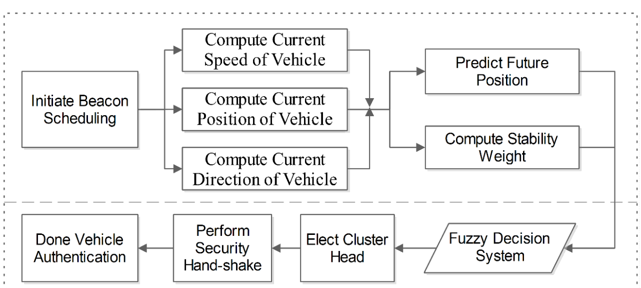

Figure 2. Key Modules for Proposed mechanism.

The security of communication model is based on ECC cryptography technique and initialization of security parameters is performed using Time division multiplexing that helps in sharing channel bandwidth while also providing security. The full scheme is described as follows:

3.1 Beacon Scheduling

For an effective vehicular mobility prediction and CH selection, beacon scheduling is used. In proposed scheme three stage beacons scheduling is used for short term prediction, actual prediction and CH selection respectively. The total time interval is assumed to be time T that is further divided into t_1 and t_2 time intervals. The time t_1 is further split into (τ) discrete periods that are used for determining both short-term and actual predicted future positions as show below: -

$$T = t_1 + t_2 \tag{1}$$

$$t = k \cdot \tau \tag{2}$$

To estimate the distances between neighboring vehicles and predicted position computation the proposed data dissemination scheme uses the algorithm and equation described in our existing predictive clustering approach[20].

Algorithm 1. Future position and stability weight computation

Input: Vehicles previous and current position, acceleration of vehicle, velocity of vehicle at time t-1and actual previous position of vehicle i

Output: ($Final\ Pos_{pred}$, S_w) of vehicle i

function PREDICTION
  for *vehicle* → i **do**
    Set time-stamp = T
    Initiate = beacon message transmission
    Pos$_{actual(t)}$ = Previous position of vehicle i
    v$_{t-1}$ = previous speed of vehicle i
    v$_t$ = current speed of vehicle i
  end for
  for Time interval → t^1 **do**
    $\mathbf{Pos}_{pred(t+1)} = \mathbf{Pos}_{actual(t)} + (v_{t-1} + (v_t - v_{t-1})/2)^* t$
    if ($t \neq 0$) **then**
      $\Omega_{(t+1)} = (\Sigma^t_{(i=1)}\ \Omega_{(i)} + (Pos_{pred(t+1)} - Pos_{actual(t+1)}))/2,$
    end if
  end for
  for Time interval → t^2 **do**
    FinalPos$_{pred(t+1)} = Pos_{pred(t+1)} + (Pos_{pred} - Pos_{actual})\ ^*\ \Omega_t$
  end for
  Construct = $G(V,E)$ using $FinalPos_{pred(t+1)}$
end function

function S_w COMPUTATION
  Assign S_w High vehicle with $High_{Sw} = Minimum_{\Omega(t+1)}$
  Assign S_w Low vehicle with $Low_{Sw} = Maximum_{\Omega(t+1)}$
    return (**FinalPos**$_{pred}$, S_w)
end function

3.2 Stability Weight Computation

After determining these parameters, the actual predictive position for vehicles is computed used in stability weight computation technique as shown in Algorithm 1. After a fix, time interval t_1 each vehicle will predict the future position for subsequent time interval by considering actual position at time t, current and previous velocities (υ) of vehicle as per Equation:

$$Pos_{actual(t+1)} = Pos_{actual(t)} + \left(\upsilon_{t-1} + \frac{\upsilon_t - \upsilon_{t-1}}{2}\right) \cdot t \quad (3)$$

The effectiveness of predictive clustering approach is the key objective for cluster formation. The accuracy of future prediction is achieved by minimizing the deviation between the actual (Pos_{actual}) and predicted (Pos_{pred}) position at $t + 1$ time. Prediction deviation is computed as per equation:

$$Min(Pos_{Pred} - Pos_{actual}) \quad (4)$$

Above equation is repeated multiple times and the calculated deviation of each interval is averaged with the previous one to generate the average mean variation (Ω) as per Equation:

$$\Omega_{(t+1)} = \frac{\left(\sum_{(i=1)}^{t} \Omega_{(i)} + (Pos_{pred(t+1)} - Pos_{actual(t+1)})\right)}{2} \quad (5)$$

Where (Ω) indicates average mean variation that is calculated using Equation 11. The value of (Ω) is primitive variable for Stability weight computation that becomes the primary input for FDS. The computed values of (Ω) at a particular time interval are further analyzed to determine the minimum and maximum values. The minimum value of (Ω), defined as (Ω_{min}) denotes the higher threshold value of stability weight ($High_{Sw}$) and maximum value (Ω_{max}) denotes the lower threshold value of stability weight (Low_{Sw}).

$$High_{S_w} = Minimum_{\Omega(t+1)} \quad (6)$$

$$Low_{S_w} = Maximum_{\Omega(t+1)} \quad (7)$$

On the basis of the past prediction accuracy of the vehicle and determined (Ω) value the final predicted position ($FinalPos_{pred}$) of the vehicle is calculated as per following Equation:

$$Pos_{pred(t+1)} + (Pos_{pred} - Pos_{actual}) \cdot \Omega_t = FinalPos_{pred(t+1)} \quad (8)$$

Based upon this ($FinalPos_{pred}$) cluster formation is performing and then CH election is done.

3.3 Fuzzy Decision System

The FDS is a rule base reasoning mechanism consists of fuzzifier and defuzzifire for determining the essential elements of every Fuzzy Inference System (FIS)[29,30]. In proposed scheme, triangular reasoning system is implemented as shown in Figure 3 to form FDS. The decision parameter μ_s in FDS depends upon the stability weight (S_w) of each vehicle. The value of (S_w) is determined in term of (Ω) and predicted position of all vehicles.

Algorithm 2 CH election using FDS

Input: S_w and list of neighboring vehicles
Output: Cluster Head and Backup Cluster Head

Begin
function CH ELECTION
  for each vehicle $\longrightarrow i$ **do**
    Search all vehicles V_i in transmission range
    Receive beacon message from each other with S_w
    if Vehicle V_i has $S_w = High_{Sw}$ **then**
      Elect It as a CH
    else if Vehicle V_i has $S_w = High_{Sw} - 1$ **then**
      Elect It as a BCH
    else
      Appoint it as CM
    end if
  end for
end function
End

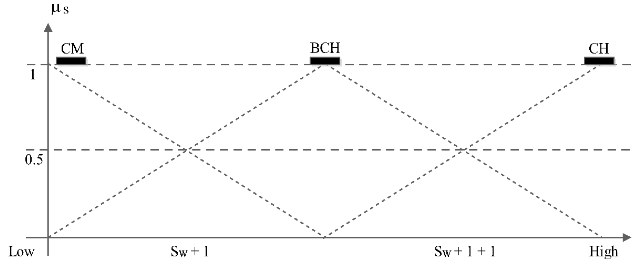

Figure 3. Decision Function of the CH selection.

A vehicle with higher (S_w), within a cluster is appointed as CH and the vehicle or vehicles with second higher weight become BCH. Algorithm 2 describes the operational steps of FDS and the process of electing CH and BCH's.

This stage also called as member joining phase, is implemented after the completion of CH election process. The designated CH, broadcasts its CH elect message and the public key (CH_{PU}) generated using standard ECIES algorithm to all the vehicles within in its transmission range. The structure of a cluster is determined using a graph G (V, E) as discussed in Algorithm 3. All vehicles in the transmission range of CH receive this CG elect message + public key of CH (CH_{PU}) and then initiate the joining phase. In join Phase Vehicle V_i broadcasts join message and CM Public key (CH_{PU}) that received by CH and it then initializes authentication and the secure handshake procedure. The CH generates a pseud random ID PS_{ID} and allocates a specific time slot Γ_{slot} to V_i. These values are combined to generate a parameter called S_{ID}. Before transmitting, encryption of S_{ID} is then performing with CM_{PU} to generate encrypted message ES_{ID} and sign it with digital signature (D_{sign}) using ECDSA to ensure message authenticity.

After receiving message, the CM performs authentication check by verifying (D_{sign}), if (D_{sign}) = True then CM synchronizes its clock with CH and decrypt the message (ES_{ID}) with CM's private key CM_{PV} as discussed in Algorithm 3. CM only broadcast its message during designated time-slot. To ensure vehicle authentication and privacy, CH monitors all the Γ_{slot} to check that only authenticated vehicle are using the allocated time slot. All the encryption and digital signature schemes use in this phase are based on ECC[31,32], so as to achieve high provides the high level of security with smaller key length and have less computation time[33,34].

Algorithm 3 Three Way hand Shake to ensure vehicle authentication

Input: STATUS ID of CH an CM nodes
Output: $(SU_{ID} + \Gamma_{slot})$ + Authenticated Connection between CH and CM

1: **Begin**
2: **function** SECURE HANDSHAKE
3: **for** $vehicle \longrightarrow i$ **do**
4: **if** (Vehicle $V_i = CH \parallel V_i = CM$) **then**
5: Broadcast CH elect message $+ CH_{PU}$ Key
6: **else**
7: Broadcast Join Message $+ CM_{PU}$ Key
8: **end if**
9: **if** CH receive join message From CM **then**
10: Allocate S_{ID}=$(PS_{ID} + \Gamma_{slot})$ to CM
11: Encrypt S_{ID} Using CM_{PU} Key = ES_{ID}
12: Compute D_{sign} For ES_{ID}
13: Transmit D_{sign} + ES_{ID} to CM
14: **end if**
15: **if** CM receive D_{sign} + ES_{ID} From CH **then**
16: Verify D_{sign}
17: **if** D_{sign} = True **then**
18: Synchronize Clock With CH
19: Decrypt ES_{ID} Using CM_{PV} Key = S_{ID}
20: Set acknowledgment to the CH
21: **else**
22: Return to Step 7
23: **end if**
24: **end if**
25: **end for**
26: **return** $(SU_{ID}+\Gamma_{slot})$ + Authenticated Connection between CH and CM
27: **end function**

4. Performance Evaluation

The Proposed scheme performance was evaluated by creating a simulation environment using parameters discussed in Table 1 in which vehicles behavior was identically similar to reality. To generate the mobility patron of traffic use Simulation of Urban Mobility (SUMO) and integrate with Network Simulator 2 (NS-2) to produce network data traffic. Performance evaluation is done by parameters discussed as follows:

Table 1. Parameter required for propose scheme

Parameter	Value
Number of vehicles	100-300
Transmission Range	300 m
Possible Lane speed	40-60 Km/h

Number of bi-direction lanes	2,4
Routing Protocol	AODV
Mac Protocol	IEEE 802.11p
Simulation time	200 sec

- **Throughput:** The total quantity of packets delivers successfully from one node to another in the network on a per unit time. The measurement of throughput regularly performed in bits per second or packet per second. In Figure 4 the average variation in the throughput is observed on the simulation time and compares the result observed in different traffic density levels "Low-to-Dense". Initially, throughput increase with simulation time till reaching its content value the show stability in it, from the figure observed that proposed scheme perform better in dense traffic condition.
- **Jitter:** The average inequality within the original packet arriving time or demanded packet arriving time is acknowledged as jitter, and it measures in milliseconds (msec). In Figure 5 the average inequality in the jitter is observed on the simulation time and compares the result observed in different traffic density levels "Low-to-Dense". Initially, it displays some height but with simulation time, it starts decreasing till reaching its content vale the show stability in it, from the figure observed that proposed scheme delivers reliable results in all traffic condition.
- **End to end message latency:** The packet total traveling time of source to destination is determined as the end to end latency. The measurement of the end to end latency usually performed in seconds. In Figure 6 the end to end latency is observed on the simulation time and compares the result observed in different traffic density levels "Low-to-Dense". Initially, it displays some height but with simulation time, it starts decreasing till reaching its content vale the show stability in it, from the figure observed that proposed scheme delivers reliable results in all traffic condition.

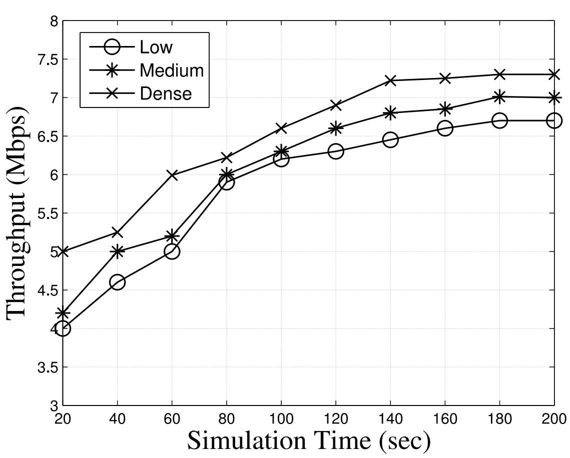

Figure 4. Average throughput in Mbps.

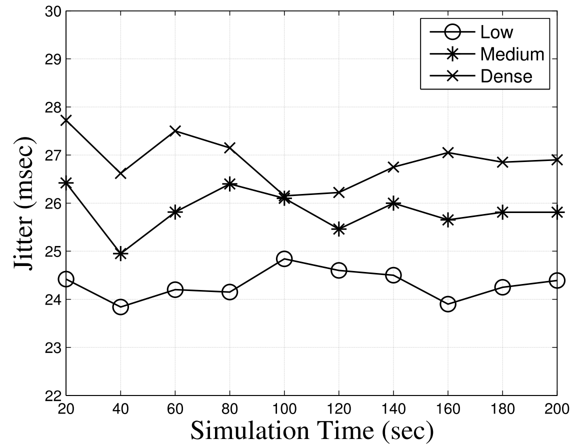

Figure 5. Average jitter in (msec).

- **Packet delivery ration:** The ratio of a total number of packets successfully delivers, and a total number of packets transmitted are determined as Packet Delivery ratio (PDR). The measurement is usually performed percentage (%). In Figure 7 the PDR is observed on the Vehicular density and comparison of the result is observed in different traffic density levels "Low-to-Dense". It observed from the figure that the proposed scheme delivers reliable results in dense traffic condition.
- **Average cluster head count:** The average of the number of CH elected in the entire simulation time in identified as an average number of CH. In Figure 8 the average number of CH count is observed on the Vehicular density and comparison of the result is examined in different traffic density levels "Low-to-Dense". It perceived from the Figure 8 that average count of CH increases with increase in the traffic density.
- **Average cluster head stability time:** The average time elected nodes to stay in the stage of CH is known as average cluster head time. In Figure 9

the average cluster head time is observed on the Vehicular density and comparison of the result is examined in different traffic density levels "Low-to-Dense". It perceived from the figure that average cluster head time is higher in the dense traffic environment.

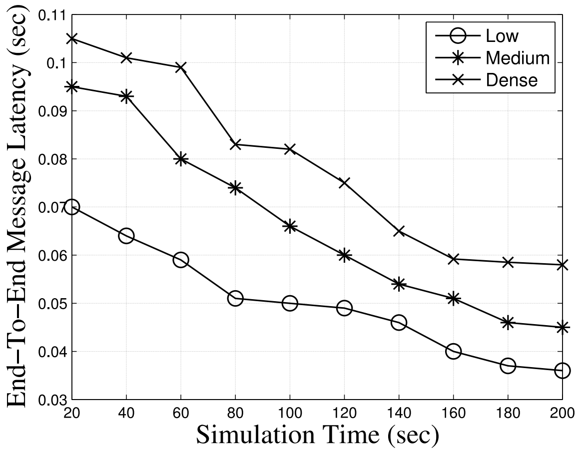

Figure 6. Average End-to-end message latency in sec.

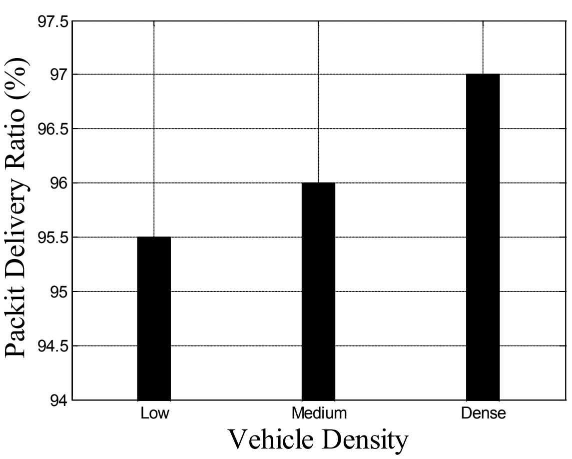

Figure 7. Average packet delivery ration in % with Vehicular density low to dense.

- **Comparative analysis:** To estimates, the performance of proposed scheme comparative analysis with some of the relevant parameters of existing scheme like throughput and packet delivery ratio is performed, by considering similar simulation parameters for both. Result oblation from the comparative analysis display that the proposed scheme performs better in all type of traffic condition as shown in the Figures 10 and 11.

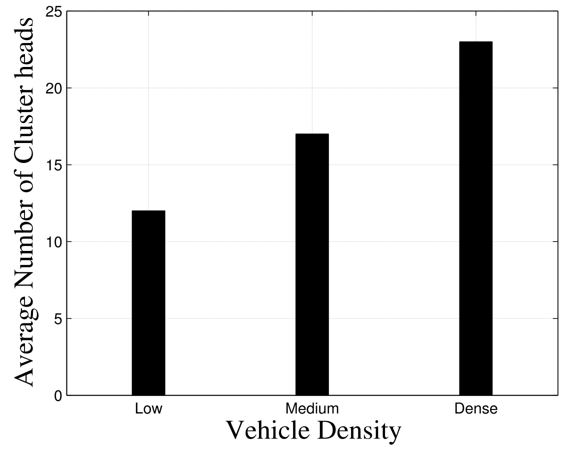

Figure 8. Average number of cluster heads with Vehicular density low to dense.

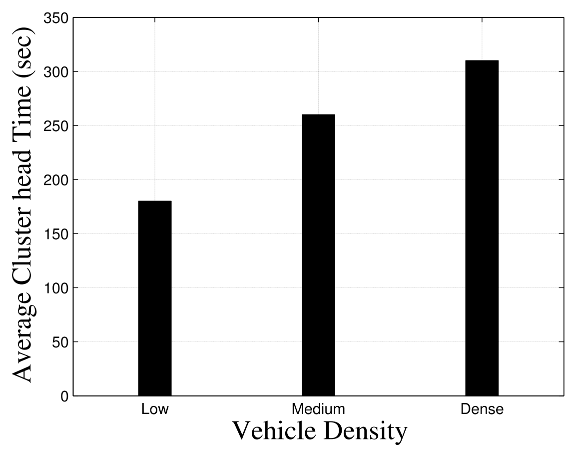

Figure 9. Average number cluster head time in sec with Vehicular density low to dense.

5. Conclusion

In this paper, a fuzzy-logic based clustering algorithm has been used to generate hierarchical groups of the vehicle that modify the existing[20] predictive clustering scheme to provide an efficient data dissemination. Further, the proposed scheme has been enhanced by incorporating ECC-based security so as to prevent generic attacks against vehicular relay networks. Evaluation performs by extensive simulations determines an effectiveness of the proposed scheme. In the future required some more attention on security techniques to make it more secure and computation efficient.

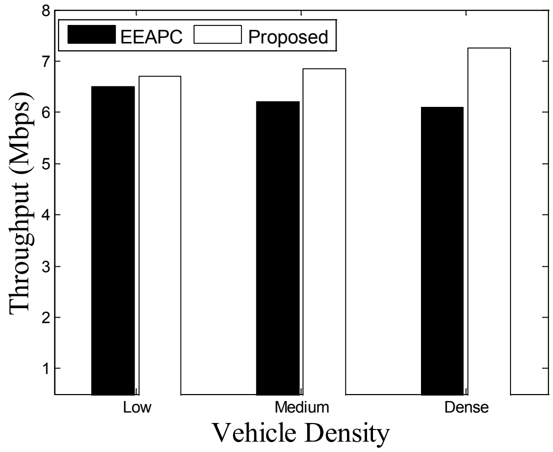

Figure 10. Proposed scheme throughput (Mbps) comparison with existing one20.

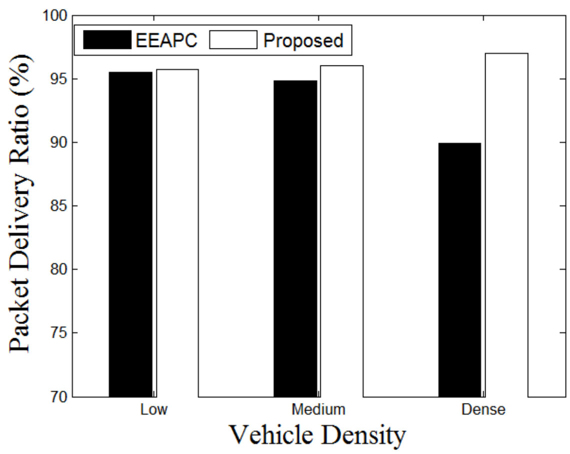

Figure 11. Proposed scheme packet delivery ratio (%) comparison with existing one[20].

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