MOSIC: Mobility-Aware Single-Hop Clustering Scheme for Vehicular Ad hoc Networks on Highways

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Abstract—As a new branch of Mobile ad hoc networks, Vehicular ad hoc networks (VANETs) have significant attention in academic and industry researches. Because of high dynamic nature of VANET, the topology will be changed frequently and quickly, and this condition is causing some difficulties in maintaining topology of these kinds of networks. Clustering is one of the controlling mechanism that able to grouping vehicles in same categories based upon some predefined metrics such as density, geographical locations, direction and velocity of vehicles. Using of clustering can make network's global topology less dynamic and improve the scalability of it. Many of the VANET clustering algorithms are taken from MANET that has been shown that these algorithms are not suitable for VANET. Hence, in this paper we proposed a new clustering scheme that use Gauss Markov mobility (GMM) model for mobility predication that make vehicle able to prognosticate its mobility relative to its neighbors. The proposed clustering scheme's goal is forming stable clusters by increasing the cluster head lifetime and less cluster head changes number. Simulation results show that the proposed scheme has better performance than existing clustering approach, in terms of cluster head duration, cluster member duration, cluster head changes rate and control overhead.

Keywords—*Vehicular Ad hoc Networks; Mobile ad hoc Networks; Network Topology Control; Clustering Scheme*

I. Introduction

Vehicular ad hoc networks (VANETs) makes a new vision in the field of Intelligent Transportation Systems (ITS). Recently, VANET becomes a most important area of research both in academic and industry field, because it has the potential to create numerous applications such as dissemination of safety, routing plans, traffic condition message, entertainment (e.g. information sharing, gaming), e-commerce and control of vehicle flow formations [1], [21], [22]. In principle, VANET is a special form of MANETs, with the difference that there are mobile nodes (Vehicles) have high dynamic mobility. In VANET vehicles equipped with an on-board unit (OBU) which make theme able to communicate with each other (vehicle-to-vehicle, V2V) and via roadside units (vehicle-to-roadside, V2R) also called as RSUs. The communication standard that vehicles used to communicate with each other is Wireless Access for Vehicular Environments (WAVE), which it is an approved amendment to the IEEE 802.11 standard. WAVE is also known as IEEE 802.11p [13].

Due to high mobility, VANET topology changes rapidly, so establishing new control topology cause to introducing high communication overhead for exchanging information. There are several control schemes for media access and topology management have been proposed. One of these schemes is clustering structure. In clustering structure, the mobile nodes are divided into a number of virtual groups based on certain metrics. These virtual groups are called clusters [2].

Some cluster-based approaches have been proposed and applied in Ad-hoc Networks, because the clustering have more advantages such as reduce the delay, overhead and solving the scalability problem in large scale networks. However, in dynamic environments the clusters usually are unstable and frequently disjointed. Hence the clustering schemes which are proposed for Mobile ad hoc networks (MANET) and Wireless Sensor networks (WSN) are not suitable for VANET. On the other word, in VANET, vehicle move with high and variable speeds which causing to frequent changes in the network topology, and it can significantly reduce the cluster stability and efficiency. CH duration is one of the reasons that can be caused to this reduction. It means that whatever CH duration increased respectably cluster stability will be increased. On the other hand, an efficient cluster maintenance has directly impact on CH lifetime. Hence, this parameters should be considered in the design of new cluster scheme. The aim of this work is proposed a scheme to construct a stable single-hop clusters with more CH lifetime, more CM duration and less cluster change rate. In this scheme CH selection conducted base on relative mobility, which calculated as the average relative distance and relative velocity.

The rest of this paper is organized as follows. In Section II previous work related to cluster formation and maintenance will be described. Section III explain preliminaries of proposed scheme. Section IV present our proposed algorithm processing. Section V includes simulation description with comparative results. The paper is concluded in Section VI.

II. Related Works

As a well-known organizing and controlling networks, node clustering is widely used in MANET and Wireless Sensore Networks (WSN). Clustering technique can be used for diverse purpose such as broadcasting, routing and QoS.

There are many clustering solution based on topology, energy, neighbor have been proposed [16], [7], [8], [9], [10], [11], [12]. However, these clustering algorithms significantly are not suitable for dynamic environments such as VANET. One of the well-known clustering scheme which frequently used for comparison with other VANET clustering algorithms, is MOBIC [4]. Indeed, this algorithm is based on the lowest-ID algorithm [16]. In MOBIC, cluster head selection is based on the signal power which received at any node from its neighbors derived from successive receptions. The performance of MOBIC is medium and not effective for dynamic scenarios.

The aggregate local mobility (ALM) algorithm is proposed in [5]. This algorithm used a relative mobility which calculate based on distance between a node and its neighbors. ALM algorithm aims to extend cluster lifetime using ALM.

Another known clustering algorithm which was proposed is affinity propagation (AP) algorithm [14]. AP algorithm is a distance-based clustering scheme which vehicles exchange the availability and responsibility information with their neighbors and based on this information, CH is selected. The drawback of AP is that frequent changing of CH increased when vehicle's speed increased. it is because of that the AP does not take the speed difference of vehicles into consideration.

Adaptable mobility-aware clustering algorithm based on destination positions (AMACAD) [17] is clustering scheme which is proposed for VANETs. This algorithm used set of parameters, including position, speed and distance as a metric for CH selection. DMMAC is a novel clustering algorithm which proposed by Hafeez et al [15]. DMMAC used velocity as main factor to form clusters, meanwhile it utilized fuzzy system to processing vehicle's velocity to enhance stability of cluster. Beside aforementioned aspects, DMMAC algorithm used a temporary cluster head concept which will be used when the main CH are unavailable. But this algorithm suffers from CHs frequently change when the vehicle's speed increased.

At the end of review the previous works, we will refer to laned-based clustering (LBC) scheme [19]. This scheme is designed specifically for the urban environments, which the number of lanes in its traffic flow considered as metric for CH selection process. However, this scheme does not consider the exact number of vehicles for each flow.

III. PRELIMINARIES

The proposed clustering scheme uses Gauss-Markov Mobility (GMM) model [3] to calculate the future vehicles position and based on that predicted position and other metrics (e.g. Relative velocity, relative distance), the proposed scheme try to form a stable single-hop cluster. We call this, MObility-aware and SIngle-hop Clustering scheme (MOSIC). The term of single-hop cluster refer to a cluster architecture which cluster-member can communicate with cluster-head directly. The MOSIC focuses only on V2V (Vehicle-to-Vehicle) communication and the main objective of proposed scheme is to make a large network with highly dynamic nodes appear smaller and able to sustaining clusters for long period by increasing the cluster-head and cluster-member duration. So in following some essential assumptions and definitions which MOSIC used will be described.

A. Assumptions and Definitions

The proposed clustering scheme assumes that all vehicles traveling in the same direction (one way) on highway and all of them are equipped with Global Position System (GPS) receivers an On Board Units (OBU). Location information of all vehicles needed for clustering scheme is collected with the help of GPS receivers. Also The roads in highway has a maximum allowed velocity (V_{max}). Each vehicle have the same transmitting capability since they have equal chance to be elected as CHs. In this paper we use some definitions that we'll explain them in the following.
In addition, Table II provides the notations that utilize in this paper.

Definition 1: (Vehicle State): In proposed scheme, vehicles have four kinds of state which listed in Table I. Where

TABLE I: Vehicle States

State	Description
NC	Non-Clustered
CM	Cluster-Member
CH	Cluster-Head
TCM	Temporary Cluster-Member

NC indicate as a vehicle is standalone and doesn't belong to any cluster, CM as a vehicle which belong to a cluster, CH as a vehicle that has task of coordination among cluster members and responsible for management of cluster structure [20] and TCM represent as a vehicle which doesn't receive the information broadcasted by the CH for ΔT interval.

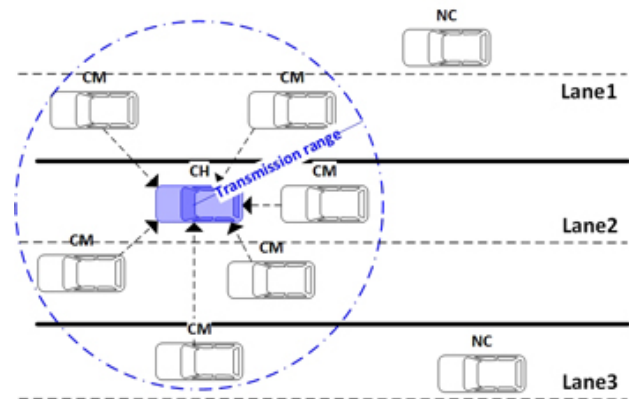Figure 1 show the vehicle's state in a highway environment.

Fig. 1: Vehicle's States

Definition 2: (r-neighbors): We considered two vehicles are r-neighbors if the distance between them is less than r. Consequently, the neighborhood N_i of a vehicle i is defined as follows:

$$N_i = \{j, D_{i,j} < r\} \qquad (1)$$

Where $D_{i,j}$ is the average distance between vehicles i and j.

TABLE II: Notations and Description

Notation	Description
ID_i	Unique ID of vehicle i
r	Communication Range of vehicle i
N_i	Neighborhoods of vehicle i
Deg_i	The nodal degree of vehicle i
$d_{i,j}$	Relative distance between vehicle i and j
$d'_{i,j}$	Predicted relative distance between vehicle i and j
x_i	Position of vehicle in axe x
y_i	Position of vehicle in axe y
x'_i	Predicted position of vehicle in axe x
y'_i	Predicted position of vehicle in axe y
$\bar{R}$	Relative Distance
V_i	Velocity of vehicle i
$\bar{V}_{m_i}$	Mean relative velocity of vehicle i among their neighbors
$\bar{V}_{rel_i}$	Relative Velocity of vehicle i
V_{max}	Maximum speed of road
$\bar{M}_i$	Relative Mobility metric of vehicle i
M_i	Mobility metric of vehicle i
ΔV_{th}	The threshold used to classify neighboring nodes as stable or non stable neighbors
CFV	Cluster forming vehicle

Definition 3: (Nodal degree): The total number of r-neighbors of a vehicle is called the nodal degree of the vehicle i which calculated as follow:

$$Deg_i = |N_i| \tag{2}$$

The nodal degree of a node i can be concluded as the cardinality of the set N_i.

Definition 4: (Stable r-neighbors): Two vehicles are considered as a stable r-neighbors if the difference speed between them is less than $\pm\Delta V_{th}$. Where ΔV_{th} is a predefined threshold.

B. Gauss-Markov Mobility (GMM) Model

The Gauss-Markov Mobility (GMM) Model [3] is a memory-based mobility model which able to calculate next position of mobile node based on its current mobility metric. In this model, each mobile node is assigned to the initial speed and direction. The GMM model used alpha α, $0 \le \alpha \le 1$, parameter which determines variability in mobile node movement. In this model, at each fixed interval of time, n, the mobile node update it current speed and direction which the new speed and direction are calculated as follows:

$$s_n = \alpha s_{n-1} + (1-\alpha)\bar{s} + \sqrt{(1-\alpha)^2}s_{x_{n-1}} \tag{3}$$

$$d_n = \alpha d_{n-1} + (1-\alpha)\bar{d} + \sqrt{(1-\alpha)^2}d_{x_{n-1}} \tag{4}$$

where s_n and d_n are the new speed and direction of the mobile node at time interval n; $\bar{s}$ and $\bar{d}$ are representing the mean value of speed and direction and $s_{x_{n-1}}$ and $d_{x_{n-1}}$ are random variables from a Gaussian (normal) distribution. At each time interval the next location is calculated based on the current location, speed, and direction of movement.

Specifically, at time interval n, an Mobile node's position is given by the equations 5 and 6:

$$x_n = x_{n-1} + s_n \cos(d_{n-1}) \tag{5}$$

$$y_n = y_{n-1} + s_n \sin(d_{n-1}) \tag{6}$$

where (x_n,y_n) and (x_{n-1},y_{n-1}) are the x and y coordinates of the mobile node's position at the (n^{th}) and $(n-1)^{st}$ time intervals, respectively, and s_n and d_n are the speed and direction of the mobile node, at the $(n)^{st}$ time interval which achieved based on equations 3, 4.

C. Message passing format

As previously mentioned, the VANET is running under WAVE (Wireless Access for Vehicular Environments) architecture (IEEE 802.11p) and messages are encapsulated in UDP packets in the network layer. Each vehicles exchange their status message with their neighbors in its communication range, r, periodically. The status message contains information about the vehicle's ID, vehicle state, current speed V, communication range r, CH's ID (CHID) and position POS, as shown in Fig. 2.

ID	$State$	V	r	$CHID$	POS

Fig. 2: Status message packet format

In addition, POS consist two parts, Geographical and Predicted position, which both of them are based on Cartesian coordinates. The geographical location include (x,y) and predicted location consist (x',y').

D. Cluster Metrics

In this section the cluster metrics, which plays an important role in cluster formation and cluster maintenance, will be described.

1) Average relative velocity: In every time interval, each vehicle will be aware about all r-neighbor vehicles, using exchange status message, and based on that information, average relative velocity $\bar{V}_{rel_i}$ will calculated as follow:

$$\bar{V}_{rel_i} = max\left\{\frac{\bar{V}_{m_i}}{V_{max}}, 0\right\} \tag{7}$$

where V_{max} is the maximum allowed velocity on the road, and $\bar{V}_{m_i}$ is the average velocity of vehicle i against their r-neighbors which defined as follow:

$$\bar{V}_{m_i} = \frac{1}{|Deg_i|} \sum_{j=1}^{Deg_i} (V_i - V_j) \tag{8}$$

where j is a potential neighboring vehicle, and V_i, V_j are the velocity of vehicle i and j respectively in m/s and Deg_i is nodal degree of vehicle i.

2) Average relative distance: Each vehicle will collect its mobility information such as its location at every time interval ΔT and send this information to all its r-neighbors via Control Channel. So each vehicle able to calculate its average relative distance among its r-neighbors. Relative distance is one of the measure that play a key role to elect CH.

Consequently relative distance defined and calculated as follow:

$$\bar{R}_i = \frac{1}{|Deg_i|} \sum_{j=1}^{Deg_i} R_{i,j} \qquad (9)$$

where $R_{i,j}$ is obtained from the below equation:

$$R_{i,j} = 10 \times log_{10}\left(\frac{d_{i,j}}{d'_{i,j}}\right) \qquad (10)$$

We use the metric proposed by Basu [4] to calculate average relative distance (Equation 10), but whit difference that we used distance and predicted distance between two nodes instead of Packet Delay, which is used in [4]. In formula 10, $d_{i,j}$ is distance between vehicle i and j which can achieved and calculate via Euclidean distance.

$$d_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (11)$$

also $d'_{i,j}$ represents the distance between vehicle i and j which is predicted with mobility model, and similar to $d_{i,j}$ calculated as follow:

$$d'_{i,j} = \sqrt{(x'_i - x'_j)^2 + (y'_i - y'_j)^2} \qquad (12)$$

where x'_i and y'_i is future position of vehicle i that calculated and obtained using Gauss-Markov Mobility model (see Sect. III-B).

3) Average relative mobility: Average relative mobility is an important measurement that vehicles can be informed about their r-neighbors and based on this parameter, vehicles decides which vehicle is more suitable to selected as CH. $\bar{M}_i$ is defined as follow:

$$\bar{M}_i = \bar{R}_i + \bar{V}_{rel_i} \qquad (13)$$

where $\bar{R}_i$ is average relative distance and $\bar{V}_{rel_i}$ is average relative velocity which described in previous subsections.
As you can see, whatever the nodal degree of a vehicle is increased, then correspondingly, the value of $\bar{R}_i$ and $\bar{V}_{rel_i}$, will be decreased. Because according to Formula 8 and 9, the relative distance and relative velocity are inversely proportional with nodal degree (Deg_i). So a vehicle with lower value of $\bar{M}_i$ is more considerable.

IV. MOSIC PROCESSING

This section contains the description of the procedures that form part of the proposed clustering scheme. In brief, the proposed clustering scheme is formed by the four phase (Initialization, CH Selection, Cluster Formation and Cluster maintenance), described in the following subsections.
When a node is not belong to any cluster (in Non-Clustered state), it executes the initialization phase. after that, depending

on whether the cluster head can be found in nearby or not, the node can launches the join procedure or the cluster formation phase. Hence, after the cluster formation phase or after joining a cluster, the maintenance procedure will be executed and it checks the validity of the cluster periodically.

A. Initialization phase

This phase is executed by any vehicle which its state is NC (Non_Clustered) and also receives a status message from its r-neighbors. In any interval time, ΔT, a vehicle which its state is NC broadcast its status message to discover weather a Cluster Head exist in vicinity or not. If there is at least one Cluster Head can be found, then the vehicle launches the join procedure. Otherwise, it execute the cluster formation phase. The pseudo code of the Initialization phase shown in Algorithm 1.

Algorithm 1 Node Initialization

1: $State_i$: state of vehicle i;
2: N_i: r-neighbors set of vehicle i;
3: **if** ($State_i$ == NC) **then**
4:     Broadcast its status message;
5: **end if**
6: **if** (Receive messages after ΔT interval) **then**
7:     Update its N_i sets;
8:     **if** ($State_i$ == NC) **then**
9:         **if** (r-neighbors indicate CH exist) **then**
10:             Call $JoinCluster()$;
11:         **else**
12:             Call $ClusterFormation()$;
13:         **end if**
14:     **end if**
15: **else**
16:     After ΔT interval, broadcast its status message again;
17: **end if**

B. Cluster Head selection phase

In principle, CH is a coordinator with the task of coordination among cluster members and also responsible for management of cluster structure [20]. One of the most frequently used technique to increase cluster stability is CH duration. CH duration has impact direct relative with cluster stability. It means that select a more stable CH can be beneficial to keep cluster structure for long periods and stable cluster can reduce packet loss probability. Consequently, select a CH that can be stable for long period, is an important factor in the design of MOSIC. In proposed scheme, we defined a mobility measure, M_i, that each vehicle calculated it based on status messages which received in interval time ΔT from r-neighbors and each vehicle has greatest value of M_i, will be selected as CH. Mobility measure calculated as follow:

$$M_i = \begin{cases} |\frac{1}{\bar{M}_i}| & , \bar{M}_i \neq 0 \\ 0 & , \bar{M}_i = 0 \end{cases} \qquad (14)$$

where $\bar{M}_i$ is average relative mobility. As mentioned in sec: III-D3, a vehicle with lowest value of $\bar{M}_i$ is more considered to be CH, So, for simplicity calculations, the value

of $\bar{M}_i$ will be reversed, because the lowest value becomes to the greatest value, And it's exactly what Formula 14 shows.

Once status message are received, the vehicle with highest M_i among its r-neighbors will elect itself as CH. Vehicle with highest M_i will set its $CHID$ field to its own ID and send the status message to r-neighbors and subsequently all r-neighbors will join cluster (All r-neighbors sets their $CHID$ field to vehicle's ID which selected as CH). It should be noted that nodes with Non-Clustered state, can't participate in the election process and they must commence the initialization phase.

The pseudo code of the CH selection shown in Algorithm 2.

Algorithm 2 Cluster-Head Selection

1: $State_i$: state of vehicle i;
2: N_i: r-neighbors set of vehicle i;
3: M_i: mobility measure of vehicle i;
4: $CHID$: cluster head;
5: ID_i: ID of vehicle i;
6: Receive status message from r-neighbors in ΔT;
7: Update its N_i sets;
8: Calculate the M_i based on received status messages;
9: **if** ($N_i > 0$ and $State_i$!= NC) **then**
10:    **if** (M_i = max ($M_j | j \in N_i$)) **then**
11:       **if** $State_i$ == CH **then**
12:          DoNothing();
13:       **else**
14:          $CHID = ID_i$; //select itself as a CH
15:          $State_i = CH$;
16:          Broadcast head message and r-neighbors will join cluster;
17:       **end if**
18:    **end if**
19: **else**
20:    Call $Initialization()$;
21: **end if**

C. Cluster formation phase

The cluster formation phase is executed every time interval, ΔT, with nodes in NC state that already before run the initialization phase and discover that there is no CH in vicinity. However, after initialization phase (which all NC state nodes broadcast its status message and receive reply messages), a vehicle whose speed is the slowest among all its NC r-neighbors, start the cluster formation process. This vehicle is called cluster forming vehicle (CFV). At the beginning of the process, CFV select itself as a CH and broadcast status message to r-neighbors. Thus vehicles upon receipt the status message, set its $CHID$ field to CFV's ID and also update its state to CM.

The pseudo code of the Cluster formation shown in Algorithm 3.

D. Cluster maintenances phase

The main aims of clusters maintenance phase is to maintain the cluster structure as stable as possible. Because of the dynamic nature of the VANET, joining and leaving the

cluster happen frequently. However, there are three events that can affect on stability of a cluster include: Joining Cluster, Leaving Cluster and Cluster merging. In the following cluster maintenance procedure will be described.

1) Joining Cluster: When a NC (Non-Clustered) state vehicle approach a CH (comes within CH transmission range), then the vehicle and CH compare and check their relative velocity, $\bar{V}_{rel_i}$, and if the velocity difference is within $\pm\Delta V_{th}$, then the vehicle will join to the cluster and subsequently, CH add it to its members list. In some cases, a NC state's vehicle maybe comes in multiple CHs transmission range, r, then in this condition, vehicle join to cluster which has more nodal degree.

2) Leave Cluster: When a cluster-member moves out of the CH's transmission range, r, it is not removed from the cluster members list maintained by the cluster-head immediately. In the other hand, if a CM does not receive the information broadcasted by the CH every ΔT interval, the state of this node changes from CM to TCM (Temporary Cluster Member). It does not leave the cluster immediately, because this disconnection maybe due to the weak quality of the wireless signals. If the temporary member receives the information broadcasted by the CH again in the coming m interval, the state of this node changes to CM again. But when a temporary member does not receive the CH information consecutively for m times, it means that the node moves out of the cluster range. Thus the state of that node changes to the NC. Meanwhile, the CH will delete this member from the members list. Then, the node can either join another cluster or form a new cluster.

3) Cluster Merging: Whenever two CH approach and come in each other transmission ranges, and they stay connected over a time period and also their relatively velocity is within the $\pm\Delta V_{th}$, then the cluster merging process will commence. In this process, the CH with less nodal degree abandon their CH's role and joins to the cluster with more nodal degree. The other members of the merged CH according to its condition can join another cluster or become a standalone member (NC).

Algorithm 3 Cluster Formation

1: $State_i$: state of vehicle i;
2: N_i: r-neighbors set of vehicle i;
3: M_i: mobility measure of vehicle i;
4: $CHID$: cluster head;
5: CFV: cluster forming vehicle;
6: ID_i: ID of vehicle i;
7: **if** (V_i = min ($V_j | j \in N_i$)) **then**
8:    $CFV = i$;
9:    $State_{\{cfv\}} = CH$;
10:    $CHID_{\{cfv\}} = ID_i$;
11:    Broadcast(ClusterFormation(CFV_i));
12: **end if**
13: **if** (Receive temporary cluster formation message from CFV;) **then**
14:    $CHID_j = ID_{\{cfv\}}$;
15:    $State_j = CM \mid \{j \in N_i\}$;
16: **end if**

TABLE III: Simulation Parameters

Parameter	Value
Simulation Time	300 s
Area Size	1000 m × 1000 m
Number of lans for each direction	3
Maximum Vehicle Velocity	10 - 35 m/s
Maximum Allowed Velocity	55 m/s
The threshold for stable r-neighbors	10
Number of vehicles	100
Interval Time	1 s
Packet Type	UDP
Packet Sze	100 Bytes
Transmission Range	200 m
Chanel	IEEE-802.11
Tuning parameter (α)	0.85

V. Simulation and Performance Evaluation

The aim of the simulation is to compare the performance of the our proposed mobility-aware single hop clustering scheme (MOSIC) to the previously proposed VANET clustering schemes. However, the performance of the clustering scheme is evaluated by using the metrics of cluster head duration, cluster member duration, cluster head change rate, the number of cluster and control overhead, which these performance metrics can demonstrate the stability of our clustering scheme [14], [1].

The MOSIC is implemented in NS-3 simulator at version 3.24.1 [18]. The simulation scenario is based on one directional highway segment of 1000 m in length and three lanes. The vehicles are injected into the road randomly. Maximum Velocity varies from 10 to 35 m/s and the transmission range is 200 m. The total simulation time is 600 s. The clustering process start at the 300th second where all the vehicle are on the road. All of the performance metrics are evaluated for the remaining 300 s. Also we consider that the maximum allowed velocity in the road is 55 m/s. The general and important simulation parameters are listed in Table III. Also we used Gauss-Markov mobility model, as temporary hybrid model beside vehicles mobility. In other words, we used Gauss-Markov mobility (GMM) model as a prediction model for calculated next position of vehicles, which used in equation 10. We set α, Tuning parameter, to 0.85, as shown in Table III.

A. Cluster-Head Duration

Cluster-Head duration refers to the interval during which the vehicle' state is in CH and remain in this state until its state changed into CM or NC. The average CH duration is calculated by dividing the total CH duration with the total number of state changes from CH to CM or NC. Figure 3 illustrate the average CH duration of MOSIC and other clustering schemes for different maximum vehicle velocities. In Figure 3, the average CH duration decreases when the vehicle velocity increases. The reason for this is that when the vehicle velocity increase, the topology of network becomes more dynamic and eventually this makes it difficult for CHs to maintain a relatively stable condition with their neighbor vehicles for a long period. As

shown in Figure 3, the MOSIC has better performance in term of CH duration against N-Hop [1], AMACAD [7], ASPIRE [23] and Lowest-ID [16] respectively.
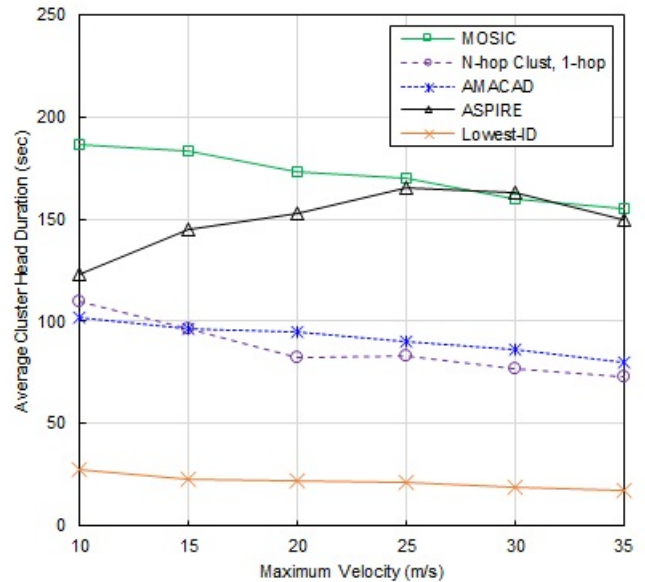

Fig. 3: Average CH Duration

B. Cluster-Member Duration

Cluster-Member duration is the interval from the time during which a vehicle joins a specified cluster to the time when it leaves the cluster. By dividing the total cluster member duration into total cluster member changes, average cluster member duration is calculated. Figure 4, shows the CM duration of MOSIC and other approaches for different maximum vehicle velocities. As shown in Figure 4, CM duration increases when vehicle velocity increases and it's because of the efficient cluster maintenance mechanism. The result which shown in Figure 4 indicate that the MOSIC CM duration is higher than N-Hop, AMACAD, ASPIRE and Lowest-ID respectively in most cases.

C. Cluster-Head Change Rate

Cluster-Head change number is the number of vehicles whose state changes from CH to CM or NC during a simulation process, and the rate of CH Change is defined as the changing per unit time. Figure 5, shows the CH change rate of MOSIC and other clustering schemes for different maximum vehicle velocities. A low CH change rate leads to a stable cluster structure. As shown in Figure 5, CH change rate increases when vehicle velocity increases. This is because of the dynamic nature of network. It means that with increasing velocity, it will be difficult for CH to keep efficient relatively stable with their CMs for a long period and maybe CH exited from cluster or in another condition, maybe CH into range of other CHs and merged with it and this situation effect of CH changes rate.

D. Number of Clusters

In VANET, because of highly dynamic movement of vehicles, clusters are created and vanished frequently over time and it cause to increase clusters number and consequently, increase maintenance cost. A Few clusters can enhance efficiency and performance of VANETs. A clustering algorithm is suitable, if it could reduces the number of clusters in system. This suitability achieved by create a relatively metric which sustain the current cluster scheme stable as much as possible. Figure 6 demonstrate the number of clusters under different transmission ranges and velocity scenarios. As shown in Figure 6, With increasing velocity the changes in the number of clusters is minimally and it because of good relative mobility metric which utilized in our scheme.

E. Average Control Message Overhead

All clustering schemes incur some additional control overhead to form and maintain their cluster structures and most of this overhead related to cluster formation and CH selection. So, in this paper we consider the overhead of the cluster formation and cluster head selection as the control message overhead. However, the average control message overhead is the count of total control message received by each vehicle in the network at cluster formation and CH selection procedures. Figure 7 shows the average control message overhead of MOSIC, N-Hop, AMACAD and ASPIRE at different velocities. Compared with above-mentioned clustering algorithm, MOSIC performs better in terms of control overhead. In MOSIC, each vehicle creates a control message during every channel interval and broadcast it to its single-hop neighbors to calculate the relative mobility between vehicle and its neighbors. This condition is equal to all above-mentioned clustering algorithms. But because of hight stability of cluster structure in MOSIC, with more CH duration and low CH change rate, the control message to reestablish the clusters structure and CH selection will be reduced and consequently the control overhead will be decreased.
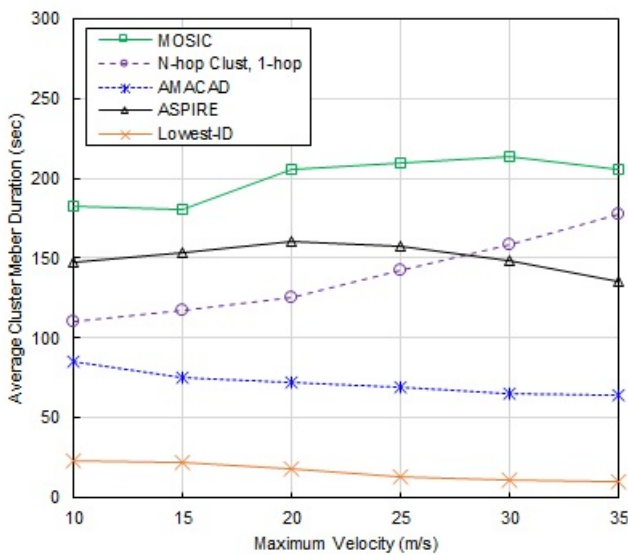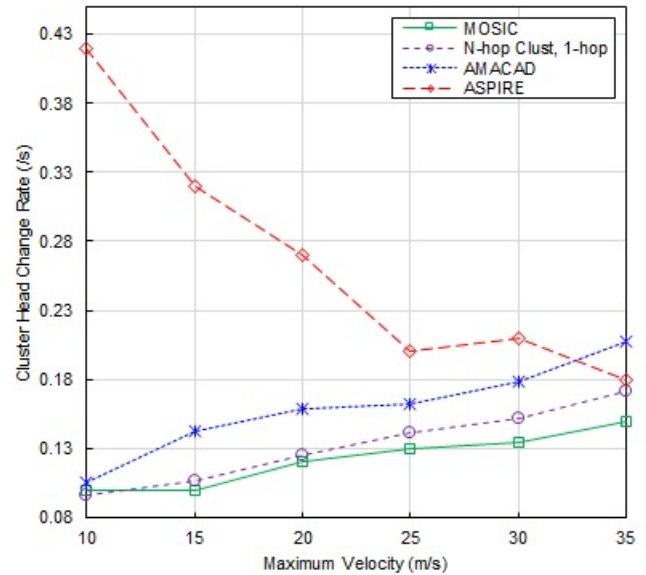

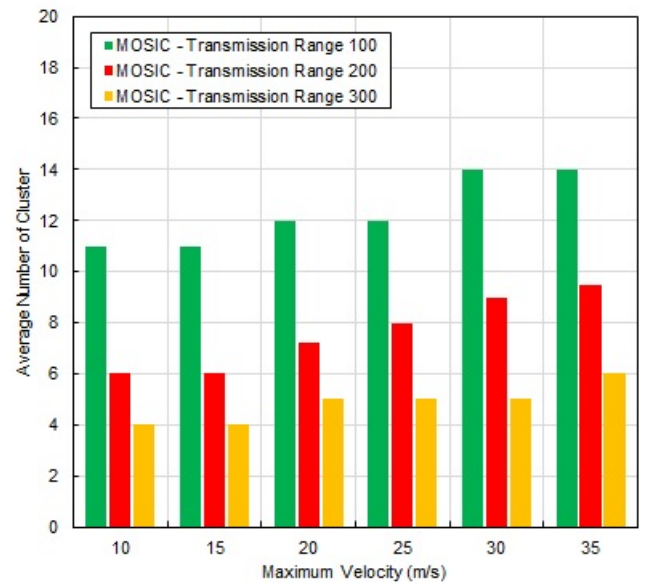Fig. 4: Average CM Duration

Fig. 5: Average CH Changes Rate

Fig. 6: Average Number of clusters

VI. CONCLUSION

Clustering mechanism is one of existence organizing mechanism which designed to adapt to the VANET environment. In this study, a mobility-aware and single-hop clustering scheme (MOSIC) was proposed. The MOSIC is based on the changes in the relative mobility of the vehicles, which is calculated by finding the average of the relative velocity, the nodal degree and relative distance of all the same direction neighbors. It used Gauss-Markov mobility model to predict the vehicle next location and based on the vehicle's location and its predicted location, relative distance will be calculated and consequently

relative mobility can be obtained. The MOSIC simulated on NS-3 and its performance compare to some clustering approach. Simulation indicate that the clustering of MOSIC outperforms than N-Hop, AMACAD, ASPIRE and Lowest-ID clustering in terms of CH duration, CM duration, CH change rate metrics and Control Message Overhead at various vehicle velocity scenarios. As future work, we aim to investigate the use of MOSIC in urban traffic scenarios and design the efficient routing protocol based on this scheme.

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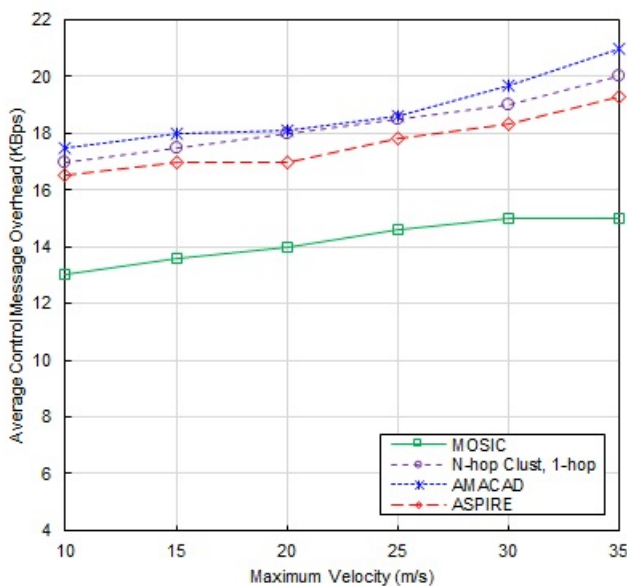
Fig. 7: Average Control Message Overhead