

# A stable clustering scheme based on adaptive multiple metric in vehicular ad-hoc networks

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## ABSTRACT

Vehicular Ad-hoc Networks (VANETs) are the special class of Mobile Ad-hoc Networks (MANETs) with high mobility and frequent changes of topology. Clustering is applied in VANETs to divide the network into smaller groups of mobile vehicles and improve routing, information dissemination and data gathering. In this paper, we propose a 2-layer stable clustering scheme based on adaptive multiple metric combining both the features of static and dynamic clustering methods. The cluster head is selected among the cluster members based on a new multiple metric called suitability value. It is derived from both mobility metrics such as relative speed, position and time to leave the road segment and Quality of Service metrics including available bandwidth, neighborhood degree and RSU link quality. Due to the proposed adaptive metric, the higher cluster stability as well as QoS are achieved. The simulation results clarify effectiveness of our proposed method in a highway scenario and show that our technique has better results and provides more stable cluster structure compared with the other related methods.

KEY WORDS: Vehicular Ad hoc Network; VANET; Dynamic Clustering; Quality of Service; Stability;

## 1. INTRODUCTION

Vehicular ad-hoc network (VANET) is the new emerging technology which provides many applications on roads. However, the mobility of vehicles as wireless devices in VANETs causes frequent disconnection of the communication links and changing topology of the network [1]. Clustering is a technique to form grouping of nodes and can greatly improve network performance. It allows the formation of a virtual communication backbone that supports efficient data delivery in VANETs and also improves the consumption of scarce resources such as bandwidth [2]. The clustering technique has been well studied in Mobile Ad-hoc Networks (MANETs) in recent years. According to the characteristics of VANETs, such as high speed, frequently changes of topology, scale of the network, etc., the traditional clustering schemes are not suitable for VANETs [3]. Therefore, new clustering schemes should be designed specifically based on VANET characteristics.

Generally, two different approaches for the clustering of vehicles are defined in VANET: First, static clustering based on Vehicle-to-Infrastructure (V2I) communication that Road Side Units (RSUs) play the role of static cluster heads. In order to have real-time communication and connectivity with the Internet, the vehicles are essentially connected with RSUs [4]. However, according to the large distance between the RSUs, the vehicles with high mobility are not always connected to the RSUs. Second, dynamic clustering based on Vehicle-to-Vehicle (V2V) communication that cluster heads are chosen from cluster members [2]. In fact, dynamic clustering method removes the concept of static cluster heads. The dynamic clusters are in motion on the road and vehicles either join or leave the clusters according to their speed and proximity to identified cluster heads [5]. In this case, since the V2V communications are more flexible and independent of

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the roadside conditions, they are particularly attractive for the most developing countries or remote rural areas where the roadside infrastructures are not necessarily available [6].

### *1.1. Motivation and challenges*

As mentioned above, since VANETs have been used in various applications such as safety and infotainment which need high stable topology, optimized solutions for clustering in VANETs are required. Efficient communication among the vehicles on the road without scalability and hidden terminal problems, is another motivation to proposing clustering solutions in VANETs. But on the other hand, there are number of challenges that need well designed solutions for clustering of vehicles.

In the usage of cluster structures, the stability of clusters is a critical point [2]. In dynamic environments such as VANETs, the unavoidable cluster reconfigurations and the changing of cluster heads affect the stability. Hence, not only the vehicular movement, vehicle density and vehicle speed should be considered for stable and dynamic clustering in VANETs, but also cluster formation in minimum time, maintenance of moving cluster with reduced overheads and cluster reconfiguration, should be addressed during designing dynamic clustering algorithms [3]. Furthermore, the term Quality of Service (QoS) is another issue using to express the level of performance provided to users [7]. The QoS relies primarily on connectivity, reliability, and end-to-end delay. Therefore, since QoS is important to safety, emergency, Internet and multimedia services in VANET, its parameters such transmission efficiency and transmission overhead also should be considered in designing a clustering algorithm.

### *1.2. Our contribution*

In this paper we introduce a new clustering approach which is motivated by observing inherent drawbacks of existing clustering algorithms such as less robust to link failures, vehicle mobility, dynamic topology, and lack of RSU link consideration. Furthermore, previous researches on clustering in VANET have been focused on clusters stability and decreasing the overheads and the Quality of Service have been ignored. The contributions of this paper are as follows:

- (i) We introduce a 2-layer clustering method which possesses the advantages of both static and dynamic clustering techniques.
- (ii) In order to maintain the stability of VANET and good connection to the RSU, a new combined metric for cluster head selection is proposed which is also able to achieve a tradeoff between QoS requirements and mobility.
- (iii) We propose a new adaptive technique for computing weighing factors in cluster head selection process improving accuracy of factors based on realistic vehicular environment.
- (iv) A new technique to control number of formed clusters in the road segment is introduced.
- (v) The evaluation of three different values of weighing factors for cluster head selection is provided, which reflect the requirements of three different classes of vehicular applications.

### *1.3. Organization*

The organization of the paper is as follows: In section 2, we review the existing clustering algorithms for VANETs. Section 3 introduces the system model and different steps of the scheme, while in section 4 we provide a detailed description of the components of cluster head selection metric. In Section 5, we analyze the performance of the proposed algorithm; and in section 6, we evaluate the performance of our scheme in comparison with two existing algorithm through simulation. Finally, Section 7 concludes the work and simulation results.

## 2. RELATED WORKS

Several techniques have been proposed in the literature, dealing with clustering solution. In [3] and [2] different clustering algorithms for vehicular networks have been surveyed and their objectives,

features, specialties and possible limitations have been highlighted. We briefly review the main representatives of the proposed algorithms and their characteristics.

In order to select a cluster head in MANETs, several heuristic techniques are proposed such as lowest-ID algorithm [8], highest-degree algorithm [9], and weighted clustering algorithm (WCA) [10]. High dynamic mobility of vehicles and high change of network topology in VANET cause that the traditional approaches proposed for MANET cannot be appropriate for clustering of VANET. In [11], two D-HD and D-LID methods have been suggested to improve the stability of the highest degree and lowest-ID algorithms for VANET. This approach is simple but does not guarantee connectivity.

To maintain connectivity, some new algorithms were introduced. A clustering algorithm is proposed in [12] working with a hierarchical routing protocol to achieve the network stability. ASPIRE as a distributed clustering algorithm based on local network criticality is presented in [6]. This scheme has two main objectives: creating large clusters and providing high network connectivity. It uses criticality metric to increase robustness of the network. Moreover, ASPIRE captures more cluster stability with postponing the re-clustering process for some times when the two cluster heads meet each other.

Another significant parameter which is considered in clustering algorithms is direction of vehicles. In this case, proposed algorithms are constructed either one-hop or multi-hop structure. The direction-based clustering [13] is suggested for VANETs and takes into consideration the moving direction of vehicles and leadership of cluster heads. Also, a vehicular clustering based on the weighted clustering algorithm (VWCA) is presented in [14]. VWCA is a scheme using multiple metric derived from distrust value, number of neighbors based on dynamic transmission range and vehicle movement direction to increase cluster stability and connectivity. According to distance between a potential cluster head and its neighbor cluster associate node as a metric to select a cluster head, a new cluster construction technique is presented in [15]. A Moving Cluster Multiple Forward (MCMF) architecture based on clustering of vehicles, cluster movement and continuous transmission of messages in a multi-hop manner was proposed in [16]. MCMF introduces a hierarchical multiple forwarding mechanism enabling communication between every vehicle and RSU via other vehicles. In [17] a stable clustering algorithm for N-hop clustering is proposed. A game theoretical approach is proposed to stimulate vehicles to disseminate the ad packets cooperatively in a stable cluster-based VANET. Thus, the network is modeled as a two level graph game: a cluster level and an inner level.

The disadvantage of these approaches is the lack of consideration for the mobility of vehicles. Several other works are reported in VANETs dealing with mobility pattern of vehicles and formation of clusters. The study of VANET characteristics and different mobility patterns of vehicles are presented in [18]. A mobility-based stable clustering scheme for VANETs which utilizes the affinity propagation algorithm in a distributed manner is presented in [19]. The idea of affinity propagation is used to cluster vehicle nodes in a distributed manner. Every node transmits the responsibility and availability messages to its neighbors and then makes an independent decision on clustering. A clustering approach is discussed in [20] that groups vehicles of similar mobility patterns in one cluster. The ultimate aim of this scheme is to achieve the stability and increase the cluster lifetime. Moreover, a new model for traffic regulation containing a hierarchical clustering algorithm (CCA), a hybrid mobility model and a new data forwarding technique (L2MF) is presented in [21]. In order to form a stable cluster structure, the authors considered some of the mobility metrics in cluster construction procedure. In [22], the authors propose a multi-hop clustering algorithm and introduce a new mobility metric according to relative mobility among vehicles in multi-hop distance and chooses the vehicle with smallest aggregate mobility value as cluster head. Likewise, a stable multi-hop clustering technique (VMaSC) is introduced in [23]. VMaSC is based on the changes in the relative mobility of the vehicles which is calculated by finding the average of the relative speed of all the same direction neighbors.

Some of the above mentioned clustering algorithms mainly used mobility, direction or neighbors connectivity as clustering metrics. However, none of them addressed the dynamic clustering concept by considering mobility, direction and connectivity of vehicles jointly; hence, the new algorithms

are proposed. A new speed difference based clustering technique is presented in [24]. It enhances the stability of the network topology by defining stable and unstable clustering neighbors depending on their speed and relative movement direction. Moreover, a multiagent driven dynamic clustering scheme is discussed in [5]. This paper proposes a dynamic cluster formation scheme that consist heavy weight static and light weight mobile agents and groups the vehicles showing similar mobility pattern, direction and velocity. The authors in addition propose an approach to prediction of similar cluster members based on mobility pattern for future associations.

Although, presented clustering algorithms are proposed for different purposes such as clusters stability and overhead minimization; however, these algorithms ignore the Quality of Service. In the case of achieving QoS few approaches was presented in the literature. A Dynamic Backbone Assisted (DBA) MAC protocol is presented in [25] to support Geocast communication on highway scenarios. The architecture of proposed protocol contains a distributed clustering algorithm that provides stability and channel quality of each link. A new cluster-based protocol proposed in [26] aiming to prolong the network lifetime. It uses some metrics such as the residual energy with the bandwidth to increase network lifetime. However, it ignores the mobility of nodes while computing the QoS that make it unsuitable to achieve the VANET requirements. In [7] a new QoS-based clustering algorithm is discussed. This algorithm forms the stable clusters by considering the mobility of vehicles and maintain the stability during communications and link failures while satisfying the Quality of Service requirements.

Most of these works attempt to increase the stability of the cluster structure, by using different metrics in cluster formation such as direction, speed and connectivity while select the cluster head based on other metrics such as mobility pattern and number of neighbors. To ensure the stability of the network, in the clusters formation a tradeoff between the Quality of Service and the mobility metrics should take into consideration. None of the mentioned works address the consideration (except for [7], which however have much focus on QoS and might still suffer of weak mobility metrics). Furthermore, none of these works address RSU connectivity as a cluster head selection metric and also adaptation of metrics for different applications is ignored, which will affect lots of VANET applications in real world.

To achieve these goals, we propose a new clustering approach that uses an adaptive multiple metric for selection of a stable cluster head and provide stability, scalability and QoS jointly for the cluster. Compared to previous schemes, it takes into account the requirements of the vehicular applications and the quality of link to the RSU during the cluster creation process. As a result, the proposed approach is more stable and can better support RSU-based applications (e.g. Internet), as demonstrated by the simulation results in Section 6.

### 3. PROPOSED APPROACH

#### 3.1. System model

In this paper, we consider the case of Vehicular Ad-hoc Network where a set of vehicles needs to form stable clusters and maintain the stability during the communications and should have connectivity with RSU in respect of getting traffic information and internet services. We consider a highway scenario with two types of communications in the proposed scheme:

- (i) V2I, that one RSU is deployed in different regions of the area. The RSU sends/receives the information from the central base station to vehicles moving in different predefined road segments.
- (ii) V2V, that each vehicle communicates and shares the information with the other vehicles in peer-to-peer (P2P) manner.

Our proposed scheme combines the features of static and dynamic clustering together with a 2-layer clustering algorithm as shown in Figure 1. In the first layer, every fixed RSU acts as static cluster head which is located at the certain predefined places like junctions, traffic signals, congested places, city exit points and toll gates. All static cluster heads are attached to a traffic management

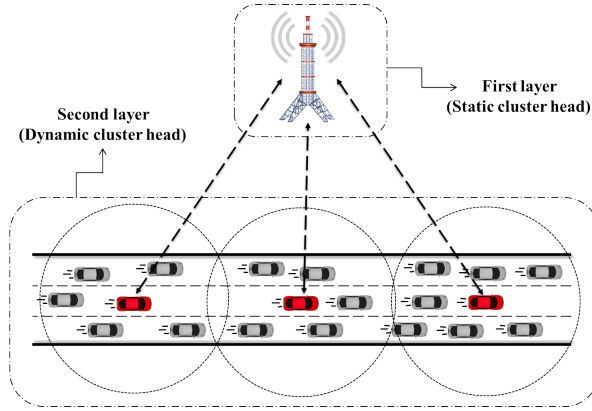


Figure 1. Proposed 2-layer clustering scheme.

centre to transmit traffic information and provide some services for vehicles (e.g. Internet). In the second layer, vehicles form dynamic clusters and the ones that are more suitable become cluster head (CH). CH is responsible for controlling the data propagation inside the cluster. Dynamic cluster heads within the range of static cluster head (i.e. RSU) become its members. As a result, the dynamic clusters are themselves mobile, moving along with the high-speed vehicles and the vehicles communicate with the RSU through CH node. This ensures that even with high-speed vehicles, the moving cluster architecture remain with a stable topology, as long as velocity of the vehicles remains more or less the same.

Moreover, we assume that all vehicles are equipped with a positioning system (e.g. a GPS), through which it can acquire information about its current location, and an IEEE 802.11p-compliant radio transceiver, through which it can communicate with the other vehicles. Also, every vehicle has a location digital map and is aware about road information and its moving road segment length and communicates with the other vehicles into its communication range. According to the DSRC specifications [27], it can provide a transmission range of up to 1000m for a channel. However, this assumption might not be guaranteed in a realistic network scenario, where the transmission range can dynamically change due to the shadowing effects, attenuation from buildings, etc. For this reason, we assume the transmission range  $R$  is approximately 300m for all vehicles. For more accurate results an on-line algorithm for the computation of  $R$  can be used, like the one described in [28].

### 3.2. Proposed clustering algorithm

**3.2.1. Dynamic cluster formation.** A leading vehicle entering a new segment of road would first search for any available cluster by broadcasting a cluster join request message ( $M_{cjr}$ ), or by communicating with a RSU when it is in its communicating range. According to Algorithm 1, when the leading vehicle (i.e. called  $V_{init}$ ), waits for a while ( $T_w$ ) and did not receive any response, it initiates the cluster formation process to identify cluster members by broadcasting  $M_{init}$  message.

In general, vehicles to build their neighborhood relationship broadcast their current speed and position data embedded in *HELLO* messages ( $M_{HELLO}$ ) to other vehicles within their communication range and  $V_{init}$ , consequently. The vehicles moving in the same direction and in the vicinity of each other come under a primitive group, as illustrated in Figure 2. However, the speed levels in certain area are different and this variation might be very high; thus, all neighboring vehicles are not suitable ones to be included in one cluster. Besides, we define a members threshold ( $MEM_{thr}$ ) to prevent the formation of small clusters with few members.

For selecting cluster members with the same speed level, first,  $V_{init}$  compares the speed difference of all its neighbors with a threshold ( $\Delta S_{thr}$ ). If the speed difference of corresponding neighbor of  $V_{init}$  is less than the threshold, the neighboring vehicle will be considered as a primitive group member. This comparison assists in assumption that members of the cluster, moving with almost

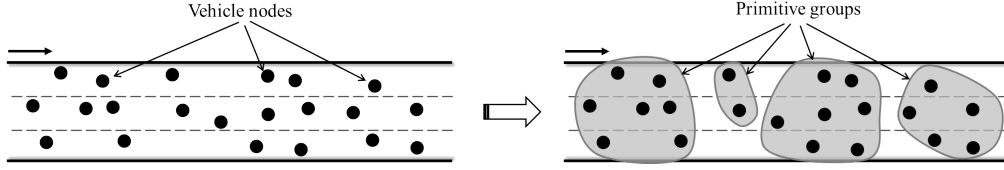


Figure 2. Dynamic cluster formation. The circles in the left figure represent non-clustered vehicles in a road segment, and the shapes in the right figure illustrate primitive groups formed by vehicles.

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**Algorithm 1** Dynamic cluster formation

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- $T_w$ : time to waiting for a cluster head response
- $v$ : leading vehicle entering a new segment of the road
- $V_{neighbor}$ : the vehicle in the transmission range of  $v$
- $S_{neighbor}$ : speed of  $V_{neighbor}$
- $S_{init}$ : speed of  $V_{init}$

(In the vehicle  $v$  side):

**if** there is no RSU in the vicinity of  $v$  **then**

Broadcast  $M_{cjr}$

**if** time of the  $M_{CJR} > T_w$  **then**

set current state of vehicle  $v$  to  $V_{init}$

$V_{init}$  broadcasts  $M_{init}$

**end if**

(In the vehicle  $V_{neighbor}$  side):

**if**  $V_{neighbor}$  receives a  $M_{init}$  from  $V_{init}$  **then**

$V_{neighbor}$  broadcasts  $M_{HELLO}$

**end if**

(In the vehicle  $v$  side):

**for all**  $V_{neighbor}$  **do**

**if**  $|S_{neighbor} - S_{init}| < \Delta S_{thr}$  **then**

Add  $V_{neighbor}$  ID to primitive group list

**end if**

**end for**

**if** number of group members  $> MEM_{thr}$  **then**

$V_{init}$  broadcasts  $M_{cluster}$

**else**

$V_{init}$  discards the cluster formation process

**end if**

(In the vehicle  $V_{neighbor}$  side):

**if**  $V_{neighbor}$  receives a  $M_{cluster}$  from  $V_{init}$  **then**

$V_{neighbor}$  set its  $ID_{CH}$  to the  $ID_{init}$

**end if**

**end if**

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same speed. Then,  $V_{init}$  computes the number of primitive group members. If the number of members is more than  $MEM_{thr}$ ,  $V_{init}$  broadcasts  $M_{cluster}$  message, to notify its ID to the cluster members. Otherwise, as shows in Figure 3,  $V_{init}$  discards the cluster formation process and waits for  $T_w$  again. In the next step, non-clustered members react upon receiving the  $M_{cluster}$  by setting their cluster head ID temporarily to the ID of  $V_{init}$ .

3.2.2. *Cluster head selection.* We model a cluster head selection algorithm that allows to electing a set of optimal cluster heads. Cluster head election information for any node is limited to the

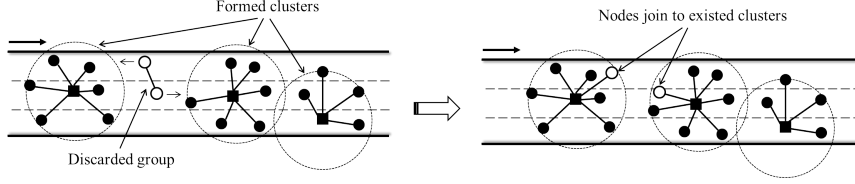


Figure 3. Cluster head election. Each square represents a cluster head. The link between cluster members and cluster heads is marked by a solid line. Hollow circles indicate members of a primitive group which have not enough members and is not formed, consequently.

Table I. Message Types

Message	Description
$M_{cjr}$	Cluster joining request
$M_{init}$	Initialization of the cluster formation process
$M_{HELLO}$	Current speed and position data of vehicles
$M_{cluster}$	Notification the $V_{init}$ ID as temporary CH
$M_{suit}$	Vehicles suitability values
$M_{vote}$	Vehicles votes
$M_{Ack}$	Acknowledgement of electing as a cluster
$M_{mrg}$	clusters merging request

nodes that are within  $R$  distance from the node itself. The priority of a node to become a CH is determined by its suitability value ( $\Pi$ ). So, first the nodes start calculating their suitability value to become a CH and broadcast  $M_{suit}$  messages containing their suitability values. Then, as shown in Algorithm 2, each node votes for its neighbor having the local maximum suitability value. A node can as well vote for itself, if it has the maximum suitability value. The nodes use their special voting messages ( $M_{vote}$ ) to locally broadcast their votes. Once the election procedure is done, the elected node acknowledges electing as a cluster head by changing its state to a CH and sending an Ack message ( $M_{Ack}$ ). Subsequently, neighboring vehicles change their cluster ID to the ID of the new CH and dynamic cluster head is formed in this way. Table I shows all message types used in proposed clustering algorithm.

**3.2.3. Cluster maintenance.** Beside the cluster formation algorithm, we also need a cluster maintenance algorithm to cope with the topology changes caused by the frequently joining and leaving cluster by vehicles. According to [24], we define a maintenance algorithm (i.e. Algorithm 3) contains three different scenarios as following:

**Cluster joining.** when a cluster head receives a cluster joining request ( $M_{cjr}$ ) from a non-clustered vehicle, the cluster head checks whether its relative speed is within the threshold of cluster ( $\Delta S_{thr}$ ); If so, then the cluster head will accept the vehicle by adding its ID to the cluster members list.

**Cluster leaving.** when a vehicle moves out of the cluster, the cluster head loses the contact with it. Therefore, the cluster head removes this vehicle from the cluster members list.

**Cluster merging.** when two cluster heads come into the transmission ranges of each other and their properties are the same (e.g. relative speed), the cluster head with lower suitability value gives up its cluster head role and becomes a cluster member of other one. Note that, to reduce the number of re-clustering, instead of starting the re-clustering process immediately, we start the process when the two cluster head nodes are in the contact range for several broadcast intervals. Therefore, the number of re-clustering is decreased and the cluster head duration time is increased.

**Algorithm 2** Cluster head selection

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- $V_i$ : vehicles in the cluster members list  
 - $V_{neighbor}$ : the vehicle in the transmission range of  $V_i$   
 - $\Pi_{max}$ : maximum value of suitability  
 - $\Pi_i$ : Suitability value of vehicle  $i$   
 -SUIT\_VAL ( $V_i$ ): A procedure to calculate suitability value of  $V_i$

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```

for all  $V_i$  do
  call SUIT_VAL ( $V_i$ )
  Broadcast  $M_{suit}$ 
end for
for each  $V_i$  do
   $ID_{CH} \leftarrow ID_i$ 
   $\Pi_{max} \leftarrow \Pi_i$ 
  for all  $V_{neighbor}$  do
    if  $\Pi_{max} < \Pi_{neighbor}$  then
       $ID_{CH} \leftarrow ID_{neighbor}$ 
    end if
  end for
  Broadcast  $M_{vote}$ 
end for
 $V_i$  broadcasts  $M_{Ack}$  as the elected node
  
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## 4. CLUSTER HEAD SUITABILITY VALUE

As described in our model, each node uses the suitability value to determine the eligibility as a cluster head. The metric of vehicle's suitability is defined to increase the stability of the cluster structure and Quality of Service, while maximizing lifetime and quality of connection to the static cluster head (i.e. RSU). As a result, an elected CH is expected to stay connected with its members and RSU for the longest period of time. Therefore, we define suitability value ( $\Pi$ ). Vehicles having higher suitability value are more qualified for winning the dynamic cluster head status. Suitability value is a multiple metric derived from mobility and QoS criteria described as the following equation:

$$\Pi = \alpha \times \Phi_v + \beta \times \Lambda_v \quad (1)$$

where  $\Lambda_v$  is aggregated mobility metric and  $\Phi_v$  is Quality of Service (QoS) metric. Furthermore,  $\alpha$  and  $\beta$  are the corresponding weighing factors varying in the range of 0 to 1 and  $\alpha + \beta = 1$ . These factors facilitate the weighting to the metrics and indicate the sensitivity of  $\Pi$  to initial values of the mobility and QoS metrics. The parameters used in the development of the our algorithm are described in Table II.

4.1. Aggregated mobility metric ( $\Lambda_v$ )

The relative mobility parameters are applied to calculate the aggregated mobility metric. In order to form a stable cluster structure, aggregated mobility is used representing the suitability level of vehicles to become a CH. To calculate relative mobility between two vehicle nodes, a lot of solutions are proposed in the literature, such as aggregated relative speed, relative position, relative remaining time, etc [29]. we compute mobility metric based on three parameters as shown in the following equation:

$$\Lambda_v = c_1 \times |T_{leave}| + c_2 \times |Pos_v| + c_3 \times \psi_v \quad (2)$$

Considering the time to leave ( $T_{leave}$ ), we ensure to select CHs with considerable distance to the end of current segment of the road. Similarly, with relative position metric ( $Pos_v$ ) we ensure that maximum nodes have direct connection with CH and also we ensure to select CHs with



**Algorithm 3** Cluster maintenance

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- $V_{CH}$ : the cluster head vehicle  
 - $V_n$ : the non-clustered vehicle  
 - $V_{CM}$ : the cluster member vehicle  
 - $S_{CH}$ : speed of  $V_{CH}$   
 - $S_n$ : speed of  $V_n$   
 - $N_{cfc}$  = contact fails counter  
 - $thr_{cfc}$  = the threshold of  $N_{cfc}$   
 $N_{pm}$  = received periodic message counter  
 $thr_{pm}$  = the threshold of  $N_{pm}$

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(Cluster joining scenario):

(In the  $V_{CH}$  side):

**if** a  $M_{cjr}$  received from  $V_n$  **then**  
   **if**  $|S_n - S_{CH}| < \Delta S_{thr}$  **then**  
     add  $V_n$  ID to the cluster members list  
     send  $M_{cluster}$  to the  $V_n$   
   **else**  
     ignore  $M_{cjr}$   
   **end if**  
**end if**

(In the  $V_n$  side):

**if** a  $M_{cluster}$  received from  $V_{CH}$  **then**  
    $ID_{CH} \leftarrow$  ID of  $V_{CH}$   
**end if**

---

(Cluster leaving scenario):

(In the  $V_{CH}$  side):

**if** did not get any response from  $V_{CM}$  **then**  
   **if**  $N_{cfc} > thr_{cfc}$  **then**  
     remove  $V_{CM}$  ID from cluster members list  
   **else**  
      $N_{cfc} \leftarrow N_{cfc} + 1$   
   **end if**  
**else**  
   reset  $N_{cfc}$   
**end if**

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(Cluster merging scenario):

(In both side):

**if** a periodic message received from  $V_{CH2}$  **then**  
   **if**  $N_{pm} > thr_{pm}$  **then**  
     send  $M_{mrg}$  to the  $V_{CH2}$   
   **end if**  
**end if**  
**if** a  $M_{mrg}$  received from  $V_{CH2}$  **then**  
   send  $M_{suit}$  to the  $V_{CH2}$   
**end if**  
**if** a  $M_{suit}$  received from  $V_{CH2}$  **then**  
   **if**  $\Pi < \Pi_{CH2}$  **then**  
      $ID_{CH} \leftarrow ID_{CH2}$   
     send  $ID_{CH2}$  to the members as the new CH  
   **end if**  
**end if**

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Table II. Notations used in the scheme.

Symbol	Description
$\Pi$	Suitability value
$\Phi_v$	Quality of Service metric
$\Lambda_v$	Aggregated mobility metric
$\alpha$	Weighing factor of $\Phi_v$
$\beta$	Weighing factor of $\Lambda_v$
$T_{norm}^{leave}$	Normalized time to leave current section
$Pos_{norm}^v$	Normalized relative position of the vehicle $v$
$\psi_v$	Relative average speed of the vehicle $v$
$D_n$	Neighborhood degree
$RLQ$	RSU link quality
$\lambda$	Weighing factor of the link quality metric
$\rho(RSU, v)$	Link power of the connection of the vehicle and RSU
$\Delta S_{thr}$	Threshold of speed difference

reasonable velocity through adding the relative average speed parameter ( $\psi_v$ ). The first objective contributes in prolonging the lifetime of the clusters; while the second reduces the link failures and the third one bring both improvements to clusters. Adding these parameters in cluster head election process ensures to have a stable cluster based vehicular ad-hoc network. Furthermore,  $c_1, c_2$  and  $c_3$  are constants decided by local authority based on road conditions and members behavior (i.e.  $c_1 + c_2 + c_3 = \beta$ ).

**Time to leave ( $T_{leave}$ ):** Based on the vehicle current location measured by using the position information provided by GPS, the vehicle periodically computes the time to leave ( $T_{leave}$ ) that means remaining time to cross the road segment. This metric contributes in prolonging the lifetime of the clusters [5] and calculated as:

$$T_{leave} = \frac{(L - d)}{d} t \quad (3)$$

where ‘L’ is length of the road segment and ‘d’ is the distance covered by a vehicle on the road segment, and ‘t’ is driving time of the vehicle to cover distance ‘d’. Note that, it is necessary to use the normalization technique to avoid having a parameter dominate the results of the other parameters.

**Relative position ( $Pos_v$ ):** We define  $Pos_v$  as the position of each vehicle toward the mean position of all its neighbors. Since the position of the vehicle can have large values, we normalize relative position of a node to its neighbors by calculating the mean position ( $\mu_{pos}$ ) and the standard deviation ( $\sigma_{pos}$ ) of its all neighbors. Thus, the smaller the  $Pos_v$  value, the closer the position of the vehicle to the mean position of its neighbors.

**Relative average speed ( $\psi_v$ ):** In order to select more stable cluster head, each vehicle also determines how close its velocity is to the mean velocity of all its neighbors. A reward function is provided and defined to take into account the velocity of vehicles in a long-term history. In fact, the speed of vehicles is evaluated, and accordingly, their speed is rewarded or penalized with a certain value ( $\delta$ ), and value of their relative average speed ( $\psi_v$ ) is incremented or decremented, consequently. The vehicles compute their relative average speed for each time interval as follows:

$$\begin{cases} \psi_v(t+1) = \psi_v(t) + \delta, & |CS_v - S_{avg}| \leq \Delta S_{thr} \\ \psi_v(t+1) = \psi_v(t) - \delta, & |CS_v - S_{avg}| > \Delta S_{thr} \end{cases} \quad (4)$$

where,  $\Delta S_{thr}$  is a threshold ensuring that vehicle  $v$  is moving with the almost same speed with its neighbors,  $CS_v$  is the current speed of vehicle  $v$  and  $S_{avg}$  is the average speed of all vehicles in the current time interval. Note that, the initial value of  $\psi_v$  and  $\delta$  could be dynamically set depends on environment terms. (We initial  $\psi_v$  as 1, and also consider  $\delta = 0.01$  in our simulations).

#### 4.2. Quality of Service metric ( $\Phi_v$ )

The clusters formation should take into consideration a tradeoff between the Quality of Service (bandwidth, connection degree and link quality) and the mobility metrics (speed, position and residual distance). The Quality of Service's metrics are considered to ensure the reliability and to increase the coverage of cluster heads, while the mobility parameters are considered to maintain the stability of the network. Therefore, we define Quality of Service metric of node  $v$  ( $\Phi_v$ ) as follows:

$$\Phi_v = \zeta \times (WB + D_n) + \lambda \times RLQ \quad (5)$$

where  $WB$  and  $D_n$  are normalized available bandwidth and normalized neighborhood degree for vehicle  $v$ , respectively; and also  $RLQ$  is RSU link quality. Furthermore, we assume  $\zeta = \alpha - \lambda$  that  $\alpha$  is weighing factor of Quality of Service as shown in Eq. 1, where  $\zeta$  and  $\lambda$  are dynamic factors varying based on density of vehicles in the current segment of the road. This means that, if the density of vehicles is low,  $\lambda$  should set dynamically higher to increase the impact of  $RLQ$  on suitability value; and set lower by increasing the density of vehicles. Therefore, In order to compute  $\lambda$ , we first should determine average density of vehicles through the road segment by computing average neighborhood degree of vehicles.

In this case, all nodes broadcast a message containing their neighborhood degree ( $D_n$ ). Then, each node computes the average of all  $D_n$  values that received from its neighbors including its own which is called  $\omega$ . Weighing factor of link quality metric ( $\lambda$ ) is computed as shown in the following equation:

$$\lambda = \max \left\{ \lambda_{max} - \frac{\omega}{100}, 0 \right\} \quad (6)$$

where  $\lambda_{max}$  is the maximum impact of link quality metric defined by local authority (e.g.  $\lambda_{max} = 0.3$ ).

**Neighborhood degree ( $D_n$ ):** In order to build relatively stable cluster structure, vehicles with better neighborhood degree could be considered as the cluster head. We use the relative average speed to identify real neighbors of vehicle  $v$ . As a result, the neighborhood degree ( $D_n$ ) is defined as the number of corresponding real neighbors of  $v$  that their speed differences is lower than  $\Delta S_{thr}$ .

According to [30], the speed of a vehicle ( $s$ ) is computed as a random variable following the normal distribution with mean ( $\mu$ ) and variance ( $\sigma^2$ ), and its Probability Density Function (PDF) is given by:

$$f_s(s) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(s-\mu)^2}{2\sigma^2}} \quad (7)$$

According to [5], the speed difference ( $\Delta S$ ), between two neighboring vehicles, also follows normal distribution with pdf given as:

$$f_{\Delta S}(\Delta S) = \frac{1}{\sigma_{\Delta S}\sqrt{2\pi}} e^{-\frac{(\Delta S - \mu_{\Delta S})^2}{2\sigma_{\Delta S}^2}} \quad (8)$$

where

$$\Delta S = S_1 - S_2$$

$$\mu_{\Delta S} = \mu_1 - \mu_2$$

$$\sigma_{\Delta S}^2 = \sigma_1^2 + \sigma_2^2$$

Note that, as discussed in [24], through increasing  $\sigma_{\Delta S}$ , the  $f_{\Delta S}$  value will decreases. Therefore, in order to avoid having high variation of the number of neighbors, the threshold can be set as a function of the standard deviation (e.g.  $\Delta S_{thr} = b\sigma$ ) and the threshold will be considered as a dynamic parameter which depends on the speed characteristics of the vehicles within the vicinity.

**RSU link quality (RLQ):** Through this metric, we attempt to choose vehicles that have maximum robustness of the communication with RSU, as the dynamic cluster heads. For this reason, we prefer as a dynamic CH which is connected to the RSU, the vehicle  $v$  providing the highest value of  $\rho$ .  $\rho$  represents the quality of connection between vehicle  $v$  and RSU and is computed by vehicle  $v$  as follows:

$$\rho = P_{rx}^v - S_v \quad (9)$$

where  $P_{rx}^v$  is the power (in dB) of the membership message received from RSU and is computed based on Link Budget;  $S_v$  also is the sensitivity of the vehicle wireless interface (in dBm). According to [31], the Link Budget is simply a balance sheet of all the gains and losses on a transmission path, and usually includes a number of product gains and losses. It relates TX power, RX power, path loss, RX noise and additional losses, and merges them into a single equation. A link budget equation can be written as:

$$P_{rx} = P_{tx} + G - L \quad (10)$$

where  $P_{tx}$ = transmitter output power,  $G$ = total transmitter and receiver antenna gain and  $L$ = total transmitter, receiver and other losses (i.e. large and small scale fading, shadowing, interference, etc.).

Furthermore,  $\rho_{thr}$  is defined as the difference between the threshold values of the power of received message ( $P_{rxMin}^v$  and  $P_{rxMax}^v$ , respectively) corresponding to the minimum and maximum data rates (e.g. respectively  $Rate_{Min}=6\text{Mbps}$  and  $Rate_{Max}=27\text{Mbps}$  in DSRC) supported by the wireless interface of vehicle  $v$ . Therefore, we define  $RLQ$  as follows:

$$RLQ = \min \left\{ \frac{\rho}{\rho_{thr}}, 1 \right\} \quad (11)$$

If  $RLQ \sim 1$ , then vehicle  $v$  and RSU will communicate at the maximum rate; and vehicle  $v$  can preserve the link connectivity with RSU and handle the impact of vehicular mobility.

## 5. ANALYTICAL MODEL

### 5.1. Communication overhead analysis

All clustering schemes incur some additional communication overhead to form and maintain their cluster structures. Since the simulation results have become recently not sufficient for evaluating the overhead of proposed scheme, we first analyze the communication overheads of our scheme, and then verify it with simulation results.

According to the Figure 4, the  $V_{init}$  node sends one message to initiate the process and then  $M_{HELLO}$  messages are broadcasted by the other vehicles. These messages carry mobility information (e.g. velocity) which will be used in the cluster formation and the cluster head selection procedures. After computing speed difference and number of members, if the conditions is satisfied,  $V_{init}$  broadcast  $M_{cluster}$  message containing members list and its ID as the temporary CH; Otherwise,  $V_{init}$  discard the procedure. In next step, special messages ( $M_{suite}$ ) used to disseminate the suitability values, during cluster head selection procedure. Also, all the cluster members use  $M_{vote}$  messages to locally broadcast their votes. Once the election procedure is done, the elected node acknowledges serving as a cluster head by sending an Ack message ( $M_{Ack}$ ) to its neighbors with its ID embedded in the message. Hence, according to the total number of the nodes ( $N$ ) the communication overhead of our algorithm is computed as follows:

$$\begin{aligned} 1 \times M_{init} + (N - 1) \times M_{HELLO} + 1 \times M_{cluster} + N \times (M_{suite} + M_{vote}) + 1 \times M_{Ack} \\ \leq (2 + 3N)M_{HELLO} \quad (12) \end{aligned}$$

We assume all communicated messages are the same size; as a result, we replaced them with a special HELLO message. Note that, we have an additional overhead for those situations that  $V_{init}$

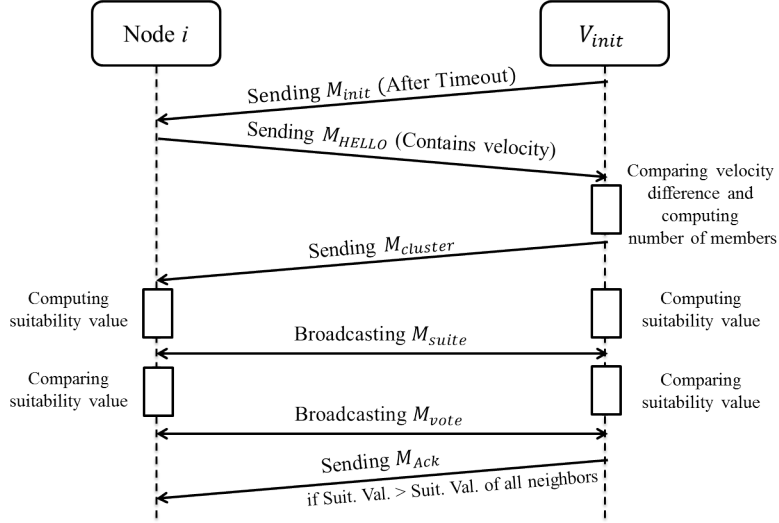


Figure 4. The procedure of cluster formation and cluster head selection.

discard the procedure and its given by:

$$1 \times M_{init} + (N - 1) \times M_{HELLO} \leq N \times M_{HELLO} \quad (13)$$

Furthermore, as described in this paper, cluster maintenance is done periodically. Three different scenarios have been defined in our scheme: cluster joining, cluster leaving and cluster merging. In the cluster joining scenario, the new node deciding to join an existing cluster, sends a  $M_{cjr}$  message to the related CH and the CH will add its ID to the cluster members list and informs it by sending a  $M_{cluster}$  message. Hence, the number of messages required for the cluster joining scenario is as follows:

$$1 \times M_{cjr} + 1 \times M_{cluster} \leq 2 \times M_{HELLO} \quad (14)$$

In the cluster merging scenario, when two neighboring cluster heads decide to merge, CH1 sends a  $M_{mrg}$  message to CH2, and CH2 responds with a  $M_{suit}$  message. Then, the cluster head with lower suitability value will lose its role and becomes a cluster member of the other cluster. The losing node broadcasts a  $M_{cluster}$  message to inform its members about its decision.

$$1 \times M_{mrg} + 1 \times M_{suit} + 1 \times M_{cluster} \leq 3 \times M_{HELLO} \quad (15)$$

Then, the cluster members either join to the nearby cluster or form a new cluster. Overheads for forming new cluster and joining to a cluster were explained earlier by Eq. 12 and Eq. 14, respectively.

## 6. PERFORMANCE EVALUATION

### 6.1. Simulation model

A comprehensive simulation is conducted to evaluate the performance of our algorithm. We apply the simulation platform composed by the OMNet++ [32] and the SUMO [33] tools. In order to connect these two tools, we resorted to the use of Veins [34]. OMNet++ is a network simulator representing the network features such as number of nodes, topography, velocity, duration, and time steps. We implement the functionalities of our clustering scheme and modeled the wireless communication among the vehicles by using OMNet++. SUMO supports both micro-mobility and macro-mobility features and through it, the mobility patterns for different vehicle densities are generated as well.



Figure 5. Simulation a part of Rasht city with SUMO.

As shown in Figure 5, we simulate a part of Rasht city and consider 5km length of its main highway with two lanes and two traffic direction. At the beginning of a simulation, vehicles are uniformly distributed in lanes and when reaching directional and non-directional ramps (as in exit ramp and entrance ramp), each vehicle randomly have decision to continue.

We use several traffic characteristics in our simulation: inter-vehicle spacing, density and flow rate. Inter-vehicle spacing is the distance between vehicles [35]. The density is the number of vehicles occupying a certain area, usually represented in vehicles/km. Also, flow rate is the number of vehicles passing a certain point over a certain amount of time, usually represented in vehicles/h [36]. According to [37], inter-vehicle spacing is reasonably approximated by exponential distributions when the network is divided to different segments. The flow rate in different traffic densities can have three different types of distributions: Poisson, exponential, or uniform [30]. We consider 1800, 3600 and 5400 vehicles/h for low, medium and high flow rates, respectively.

The speed assigned to the vehicles typically follows the normal distribution [30], and the velocity bounds on this highway range from 60 km/h to 120 km/h. For all simulation scenarios, the  $\Delta S_{thr} = \sigma$ . As discussed in section 4.2, in order to avoid having high variation of the number of neighbors, the threshold can be set as a function of the standard deviation. As result, the threshold will be considered as a dynamic parameter which depends on the speed characteristics of the vehicles within the vicinity. Figure 6 shows an example of the normal distribution of the speed with mean 100 km/h (i.e.  $\mu=27.77$  m/s) and  $\sigma=2.77$  and the relative PDF values which is used in our simulation. The performance of different  $\Delta S_{thr}$  values can be found in [20]. The relationship between inter-vehicle spacing, flow rate, and mean speed is expressed in Eq. 16:

$$\beta \approx \frac{S}{v} \quad (16)$$

where  $\beta$  is the inter-vehicle spacing,  $S$  is the mean speed of vehicles, and  $v$  is the flow rate.

Furthermore, according to DSRC standard supporting bit rate in the range 6-27 Mbps [27], the data rate is set to 6Mbps as default and the 5.9 GHz frequency band is considered in the simulation design. The transmission ranges for the simulations fixed on 300 meters and the size of the messages is 100 bytes. To provide more accurate simulations, we took a confidence level of 95% and for each case we repeated the simulation with different random seeds (i.e. independent simulations). Table III shows the values of the parameters used in our simulation.

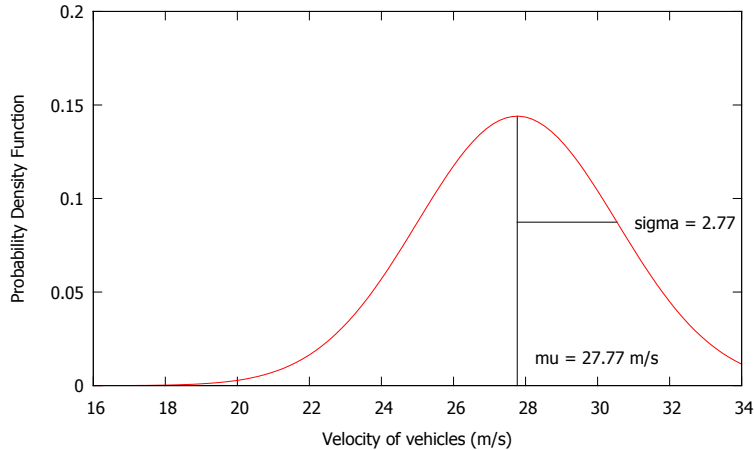


Figure 6. Normal distribution of the speed with  $\mu=27.77$  m/s and  $\sigma=2.77$ , where the velocity bounds range from 60 to 120 km/h ( $\approx 16$  to 34 m/s).

Table III. Simulation parameters.

Parameter	Value
Simulation time	180s
Highway length	5km
Speed of vehicles	60-120km/h
Transmission range	300m
Transmission rate	6Mbps
Size of messages	100 Bytes
Weighing factor $\alpha$	0.25, 0.5, 0.75
Weighing factor $\beta$	0.25, 0.5, 0.75
$\lambda_{max}$	0.2-0.6
Constant factor $c_1$	0.05- 0.4
Constant factor $c_2$	0.05- 0.4
Constant factor $c_3$	0.05- 0.4

Since multiple metrics are used in our scheme, we first focus on stability evaluation of our scheme, and study the effects of metrics values in different classes of vehicular applications. Then, we present a comparison between proposed scheme and two existing algorithms, dynamic clustering and VANET QoS-OLSR techniques, presented in [5] and [7], respectively. The VANET QoS-OLSR scheme is the best clustering algorithm proposed with focus on QoS. VANET QoS-OLSR uses the proportional bandwidth combined with the residual energy of each node to build the Quality of Service function as the cluster head selection metric, while in the dynamic clustering algorithm, cluster heads are selected based on mobility metrics and its simulation results shows the best stability among existing clustering algorithms. We compare the three schemes under the same environment variables in four different performance metrics: cluster head duration, number of clusters, packet delivery ratio and communication overhead.

## 6.2. Cluster stability value

In the proposed cluster head selection scenario, each vehicle self-determines its Suitability value using Eq. 1. This priority is a weighted combination of mobility and QoS metrics. This section explores the effect of these weighted factors and their parameters. The three different case studies are considered to compare different adaptations of the metrics:

Table IV. Adapted factors for three different case studies

Factors	$\alpha$	$\beta$	$c_1$	$c_2$	$c_3$	$\lambda_{max}$	$\zeta$
Case 1	0.25	0.75	0.25	0.1	0.4	0.2	0.05
Case 2	0.75	0.25	0.1	0.05	0.1	0.6	0.15
Case 3	0.5	0.5	0.15	0.1	0.25	0.4	0.1

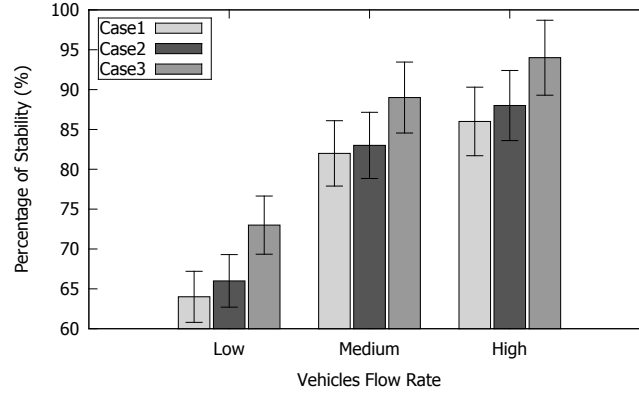


Figure 7. Cluster stability value

- Case1 *Safety application*; In this case, we model the characteristics of a safety-related application which produces short-size messages, once an alert condition is detected by a vehicle. In order to time constraints for safety messages, we attempt to minimize the delivery delay while providing high stability which is depend mainly on the time to leave and velocity factors.
- Case2 *Internet application*; Concerning the Internet application, high quality of link to the RSU and bandwidth are most important while also providing cluster connectivity and robustness of the communications should be considered.
- Case3 *Traffic regulation application*; The performance of traffic regulating application is between two applications above, and thus need to provide a good compromise between delivery delay and robustness.

For ease of explanation, we denote the values of weighted factors in Table IV. Note that, Table IV shows the final values of factors and weights which are obtained through several trial and error determination in our simulations. It is represented as an example of weights setting in our scheme. In order to setting the weights, we first determine the values of  $\alpha$  (weight of Quality of Service metric) and  $\beta$  (weight of aggregated mobility metric) as fixed values depending on the applications (i.e.  $\alpha=0.25$ ,  $\beta=0.75$  for Safety applications,  $\alpha=0.75$ ,  $\beta=0.25$  for Internet applications and  $\alpha=0.5$ ,  $\beta=0.5$  for Traffic regulation applications). Then, based on the importance of other metrics in each application, we allocate appropriate weight to them. Note that,  $c_1 + c_2 + c_3 = \beta$ , while  $\zeta + \lambda = \alpha$ .

As mentioned earlier, we consider the percentage of cluster stability to evaluate efficiency of our algorithm in the three case studies. *Cluster Stability*, is the changes value of cluster configuration according to the topology changes. Stability of a clustering algorithm will vary depending on the number of cluster changes of vehicles and the number of cluster breaks. Generally, a good clustering algorithm should be designed to minimize the number of cluster changes by maximizing the proportion of mobility pattern of the cluster head with the cluster members. Also, the percentage of stability increases when the quality of links reaches larger quantities.

Figure 7 shows the comparison of cluster stability percentage between defined cases. As depicted in this figure, Case 3 experiences the highest value of cluster stability among the case studies in all flow rates. The reason of this superiority is participation of both QoS and aggregated mobility metrics in this case. Furthermore, as expected, the results shown in Figure 7 describe that we have more stable clusters by increasing the flow rate. However, the figure shows that in medium flow



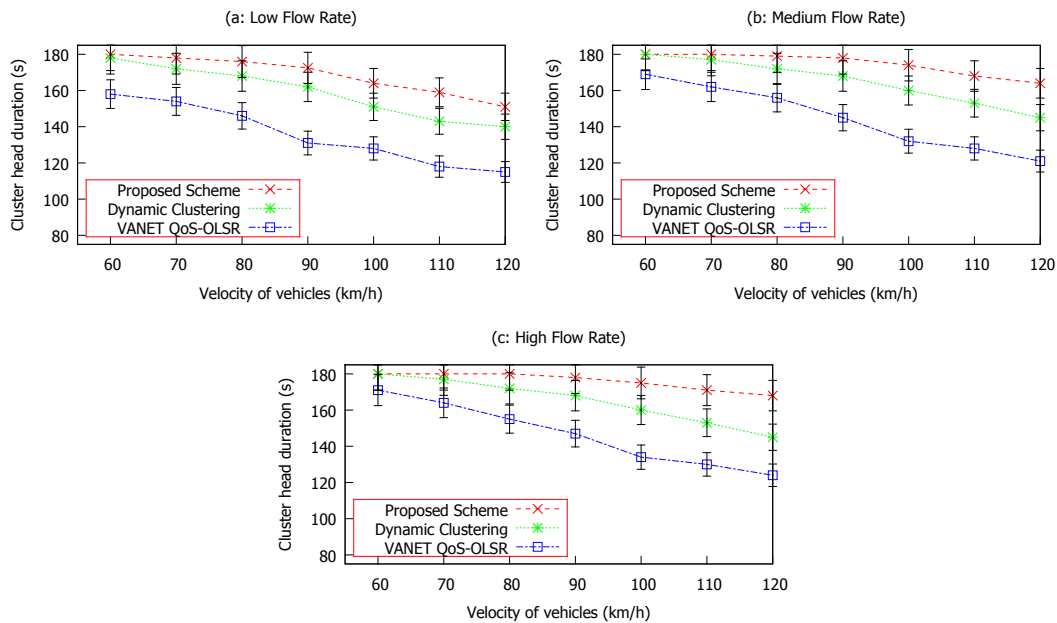


Figure 8. Cluster head duration

rate we have an improved percentage of stability compared to the low flow; but, this improvement decrease in case of high flow rate. We conclude that despite having less cluster breaking in higher flow rates, the higher density of vehicles, the more changing in cluster configuration.

### 6.3. Cluster head duration

The time of dynamic cluster existence on the road is directly related to the duration of its cluster head. Therefore, we define the cluster head duration as the time interval from when a vehicle node becomes the cluster head node to when it gives up the cluster head role. The cluster head duration allows us to evaluate the global stability of the clustering algorithms. Figure 8 illustrate the variation of the average cluster head duration of three schemes in three different flow rates with respect to the velocity of vehicles. When the vehicles move faster, the topology of the vehicle network is more dynamic. Hence, the average cluster head duration will decrease. Simulation results shows that when the maximum speed changes from 60 km/h to 120 km/h, the cluster head duration is reduced more than 15%. Moreover, by increasing the density of vehicles, the probability of clusters merging goes up; and average CH duration decrease, consequently.

As shown in Figure 8, Dynamic clustering has better performance than VANET QoS-OLSR; considering the behaviors of vehicles is the reason of its better results. However, QoS parameters are not considered in this scheme. As a result, it has lower performance in comparison with proposed scheme, which both QoS and mobility metrics are participated in cluster head selection process. On the other hand, proposed scheme decrease re-clustering times by defer clusters merging and increases average CH duration in this way.

### 6.4. Number of clusters

The total number of dynamic clusters, formed on the road segment, is another significant performance metric. Knowing the number of clusters allows us to evaluate the quality of their formation. The less clusters along with more mobility of the vehicles trigger connection failures and cluster divisions. Moreover, more clusters merges and cluster formation overheads produce by increasing the number of clusters. Therefore, a good clustering algorithm should reduce the formation rate of the clusters by producing stable clusters and maintain them as much as possible.

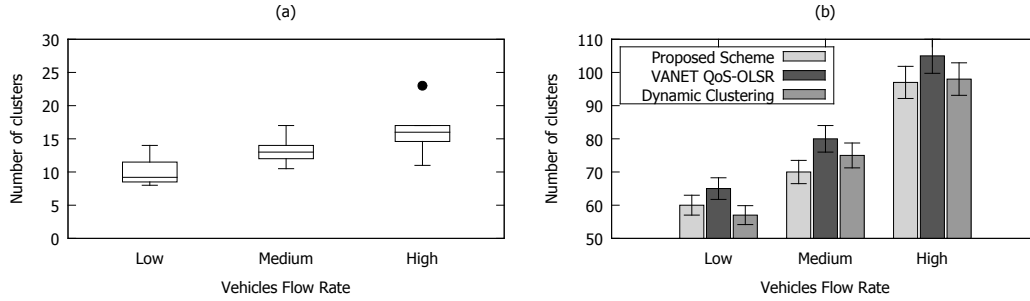


Figure 9. Number of clusters

Table V. Definition of packet delivery ratio metric.

ID	Metric	Definition	Formula
PS	Packet Sent	Total number of packets sent by the source node	Computed from trace file
PR	Packet Received	Total number of packets received by the destination node	Computed from trace file
PDR	Packet Delivery Ratio	Percentage of throughput	$PDR = (PR/PS) * 100\%$

We attempt to decrease the number of dynamic cluster formations using two techniques: 1) Employing static cluster heads (RSUs) and checking existence of clusters in the vicinity of the initializer vehicle and 2) Discarding small groups of members before converting to a cluster. As a result, as depicted in Figure 9(b), the number of cluster heads produced by our proposed algorithm is smaller than two other methods.

Moreover, for studying the average number of clusters, we repeat the simulation 50 times for each flow rate, with different initialization seeds. This number is set to 50 because the variance of the simulation results was reasonable. The box plots in Figure 9(a) show the results returned from all 50 replications for the three flow rates.

### 6.5. Packet delivery ratio

As another performance evaluation metric in our simulation, we consider the packet delivery ratio (PDR) of the network. Table V shows calculation details of PDR we used in our evaluation. General definition of PDR is the successful arrival rate of packets in Network Layer. Thus, as the number of received packets increases, this ratio will also increase. The number of received packets relies on several factors including: connectivity and percentage of stability [7]. The connectivity and the percentage of stability ensure that the packets are transmitted along a continuous connected path with minimum packet losses. This increases the probability of the packets to be received.

Figure 10 shows that the proposed scheme outperforms both VANET QoS-OLSR and Dynamic Clustering in packet delivery ratio at different vehicle velocities. This is because the proposed scheme considers the available bandwidth, neighborhood degree, and RSU link quality in the cluster head selection. VANET QoS-OLSR is better than Dynamic Clustering due to the consideration of QoS. However, the performance of VANET QoS-OLSR drops with an increase in the node velocity. The main reason is lack of effective consideration to the mobility of the vehicles. Also, the Dynamic Clustering does not consider link quality and available bandwidth in the cluster head selection. This is why Dynamic Clustering cannot provide a high packet delivery ratio.

Besides, as depicted in Figure 10, there is a little difference among the percentage of packet loss in different flow rates. In the low flow rates based on the Eq. 16 the distance between vehicles is increased causing packet loss to increase. On the other hand, in high flow rates, high density of vehicles consequently makes more interference and more packets lost. VANET QoS-OLSR experience good results only in medium flow rate, while our proposed scheme can appropriately

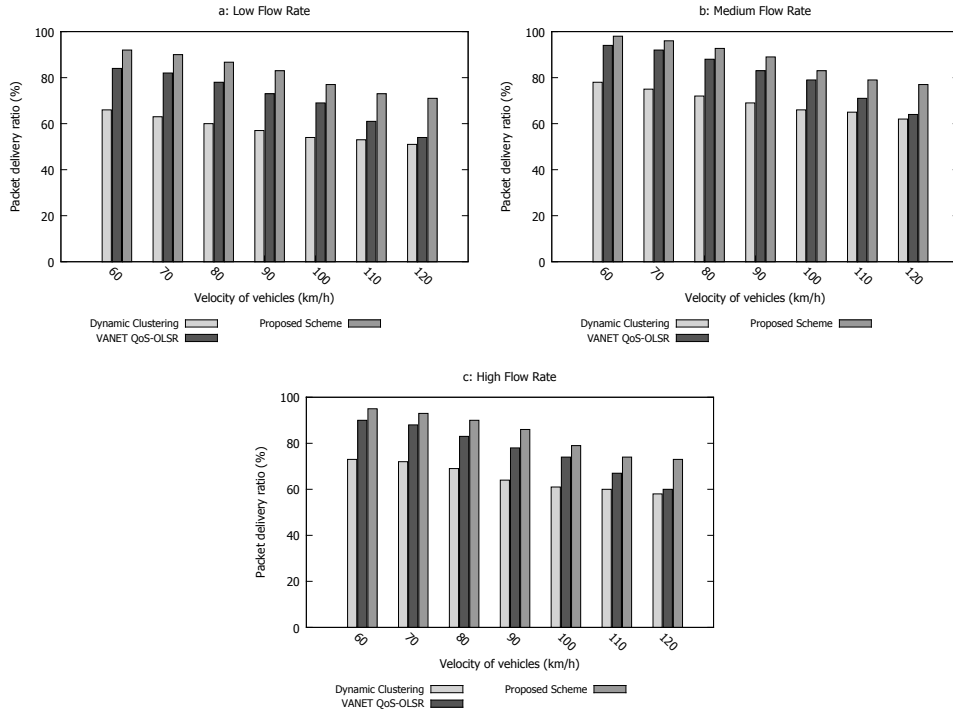


Figure 10. Packet delivery ratios of the three schemes under different vehicle velocities and in different flow rates.

handle low and high flow rates. Apparently, knowledge of mobility correlations among nodes is helpful for establishing stable network topology. Hence, considering velocity difference and Quality of Service jointly in cluster head selection process is the main reason of this superiority of our approach.

### 6.6. Communication overhead

As mentioned in section 5.1, each clustering algorithm incur some communication overhead that mainly affects the efficiency of algorithm. We consider the communicating overhead of the cluster formation and cluster head selection as the *communication overhead*; and compare the total overhead inferred from our analysis and resulted from our simulation with the overhead of other two algorithms. As resulted from section 5.1 and depicted in Figure 11, the overhead of proposed scheme theoretically increases linear, based on Eq. 12. However, simulation result shows a little more overhead which is increased when the number of vehicles goes up. The main reason is unsuccessful cluster formations caused by discarding small groups. Note that, we define a threshold for the number of members in each cluster (i.e. its value is 5 for our experiment); Hence, we have lower overhead when the number of vehicles is smaller than 5.

Furthermore, Figure 11 represents lower values of overhead for VANET QoS-OLSR compared to proposed scheme, while dynamic clustering scheme has higher overhead. The reason of worse results for dynamic clustering is Multi-agent system using in cluster formation process while better results produced for VANET QoS-OLSR because of its simple cluster formation procedure.

## 7. CONCLUSION

In this paper, we proposed a new 2-layer clustering scheme in a highway scenario that aims at maintaining the stability of the vehicular network while achieving the Quality of Service

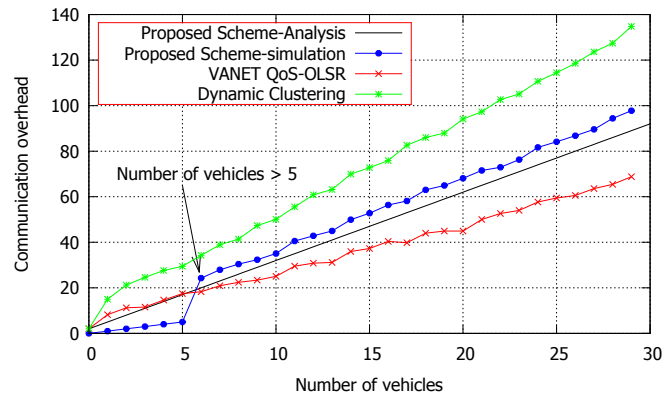


Figure 11. Communication Overhead

requirements. The algorithm selects the dynamic cluster heads according to the aggregated mobility and local QoS metrics. To ensure the stability of clusters, we added the velocity, position and time to leave the road segment representing the aggregated mobility metric. Furthermore, we append quality of link to the RSU, bandwidth and neighborhood degree as the Quality of Service metric. We analysed the communication overhead of our proposed algorithm and evaluated the performance of our scheme through simulation study. We compared simulation results of our scheme with two recently proposed algorithms and demonstrate the superiority of proposed scheme in forming more stable dynamic clusters while providing more Quality of Services.

Some of the additional research issues that can be investigated for future extension of the work are as follows: (1) adding security parameters to the cluster head selection process and analysing the overheads and network delay when security parameters is also incorporated, (2) extending the analytical model by considering types and sizes of messages and also adding network delay analysis, (3) making analytical model more precise and realistic by including channel parameters such as bit error rate, etc., (4) consideration of urban scenarios as noisy environments with traffic lights and signs at the intersections, (5) extending the approach by setting the weight factors smarter (i.e. adaptive and dynamically), and (6) including memory and computational overheads to the evaluation of the approach overheads.

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