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A Review on Different Types of Data Dissemination and Traffic information in Vehicular Ad-hoc Networks

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Abstract:

Vehicular Ad-Hoc network is a form of mobile Ad-Hoc networks. VANETs provides the communication amoung vehicle to vehicle and vehicle to road side units. Data Dissemination is used to transfer the data from source to destination and it is used to improve the quality of driving in term of time, distance, and safety. In this paper we discuss different types of data dissemination technique and propose a new 3-steps approach for calculating of traffic level in a road section based on actual level of wireless-equipped vehicles. For calculating the traffic data we collect the data of different vehicles using clustering approach. The Performance of the future approach is calculated using wide simulation and the proposed approach is shown in comparison with state-of-the-art existing schemes.

General Terms – Data Dissemination, Traffic information systems (TIS), CTIS, VANET, Clustering.

I. INTRODUCTION

Vehicular Ad Hoc networks are rising new technologies to combine the ability of new generation wireless networks to vehicles [1]. Data dissemination in VANETs can be used to inform drivers or vehicles for traffic jams and to propagate emergency warning among the vehicles (incident or accidents) to avoid the collision. VANET improves the efficiency of traffic system. Node mobility, extreme network density and changing topology from urban gridlock to rural traffic [2]. In vehicular ad hoc network the delivery is not single hop but multichip, in these situations vehicles can forward their request to other vehicles and get respond in back in fraction of second. Data disseminations have been investigated in the area of wireless sensor technique. Aim of data dissemination is to maximum utilize network resource to serve the data needs of all users. In data dissemination, a single source node streams data to one or more sink nodes. [3] Many data dissemination protocols are proposed to disseminate information about obstacle information, traffic conditions and mishap on the roads. Besides these there are some problems in data dissemination like the vehicular network consists of a multitude of data sources and the data users; each vehicle is potentially a data source and the user at the same time. Diverse type of the application, such as traffic management, situational awareness, and commercial services share the same networking infrastructure (RSUs) [4]. Data broadcast from a vehicle with in the transmission range, which is done by flooding, in which each node receiving the message would simple rebroadcast the message without any regard to its current position or any other factors.

The proper management of traffic is becoming a great attention today as traffic jamming becomes more and more brutal problem. In the large part of the world millions of hours and gallons of fuel wasted daily by vehicles due to traffic jamming. Therefore, overcrowded flow circumstances have a negative impact on the economy, health, and environment. The improvement of traffic flow and congestion reduction can be achieved by means of Traffic Information Systems (TISs) [5]. In general, the aim of TIS is to confine, calculate and distribute traffic regarding information. Conventional technologies (e.g. Traffic Management Center (TMC) and Road Data Services (RDS)) in TIS offer very limited bandwidth; therefore, traffic information details available less in number. These drawbacks can be overcome by Cooperative Traffic Information Systems (CTISs), where traffic regarding information is gathered individually by vehicles and exchanged between themselves using wireless networks [5,6].

Clustering as a technique to form group of nodes or vehicles which can definitely improves the vehicular network performance. The cluster thus formed moves on the road and the vehicles can easily join the cluster or can leave the cluster according to their variable speeds and closeness to recognized Cluster Head (CH) also the vehicles can communicate with other vehicles or Cluster Members (CMs) based on V2V communication.

In this paper we discuss different types of data dissemination and clustering approach to calculate the traffic data. The rest of this paper is organized as follows: In Section 2, we describe different types of data dissemination. Section 3, we describe different applications and challenges in VANETs. Section 4, introduces the system design and different steps of the proposed approach. Finally, Section 5 concludes the work.

II. TYPES OF DATA DISSEMINATION

Data Dissemination is a technique which helps in transferring the data from sender to receiver using different types of data dissemination techniques. Data Dissemination helps in delivering the data at receiver end and helps in end to end connection of sender and receiver. There are different types of data dissemination techniques which are classified below.
i) V2I/I2V Dissemination (vehicle to infrastructural, RSU)

ii) V2V Dissemination
iii) Opportunistic dissemination
iv) Geographical dissemination
v) Peer-to-peer dissemination
vi) Cluster based dissemination

i) V2I/I2V Dissemination: In this type of data dissemination the data is transmitted by the sender to the RSU and the other way the data is transmitted by RSU to the vehicles and vice versa.
ii) V2V Dissemination: In vehicle to vehicle data dissemination the data is transferred from one vehicle to the other vehicle and vice versa.
iii) Opportunistic Dissemination: Due to clustering in VANET, some work such as, recommend the use of opportunistic diffusion of data in which message are stored in each intermediate node and forwarded to every encountered node till the destination is reached.
iv) Geographical Dissemination: When continuously topology change the end to end paths are not constantly present in VANET a geographic dissemination is used in by sending the message to the closest node toward the destination till it reaches. Sometimes geo-casting is also used to deliver message to several nodes in geographical area.
v) Peer-to peer Dissemination: In P2P solution, the source node stores the data in its storage device and do not send them in the network till another node asks for them. This is proposed for delay tolerant application.
vi) Cluster based Dissemination: For a better delivery ratio and to reduce broadcast storms, a message has to be relayed by a minimum of intermediate nodes to the destination .To do so, nodes are organized on a set of cluster in which one node or more gathers data in his cluster and send them after to the next cluster .cluster based solution provide less propagation delay and high delivery ratio with bandwidth fairness.

III. DIFFERENT APPLICATIONS AND CHALLENGES IN VANETS

Extensive list of potential applications were compiled by the various projects and consortia. Typically, applications are categorized as safety applications and non safety applications, transport efficiency and information/entertainment applications. Examples for each category are:

- Cooperative forward collision warning to avoid rear end collisions.
- Traffic light optimal speed advisory for assisting the driver to drive during a green phase.
- Road navigation and mobile infotainment.
- Traffic information.

Application were analyzed as to whether their requirements can be satisfied and whether they will provide the beneficial impact on the requirement side a prominent factor is the required penetration rate i.e. the percentage of vehicles having VANETs technology compared to the vehicle population. Applications are also assessed with respect to the levels they increased safety or transport efficiency or serve desired information.
For safety related applications, the vehicle safety communications (VSC) consortium identified eight high potential applications [7]:

- Traffic signal violation warning.
- Curve speed warning.
- Emergency electronic brake light.
- Pre crash sensing.
- Cooperative forward collision warning.
- Left turn assistant.
- Lane change warning.
- Stop sign movement assistant.

The technical requirements show the importance of one hop broadcast communication which means a vehicle simply transmit the package and every vehicle that is able to get the data is directly considered a one hop neighbor. One hop broadcast communication is further of two types: Event driven and periodic. Event driven messages are sent when a hazardous situation is detected. Periodic messages inform neighboring vehicles about the status, for example the position of sending vehicle. The VSC suggests that periodic one-hop broadcasts that are required, for example, with forward collision warning, require a frequency of 10 messages per second, with a maximum latency of 100 ms and a minimum range of 150 meters. In the meantime, studies show that in dense vehicular traffic scenarios, these periodic messages can overload the available radio channel. Thus, adaptive transmit power and rate control mechanisms are required as discussed below. For transportation efficiency applications, the Car-to-Car Communication Consortium [8] analyzed exemplarily enhanced route guidance and navigation, green light optimal speed advisory, and lane merging assistants. Whereas for the first two applications, roadside infrastructure is considered a prerequisite, the lane merging assistant is assumed to be based on vehicle-to-vehicle communication.

ITS is the major application of VANETs. ITS includes a variety of applications such as co-operative traffic monitoring, control of traffic flows, blind crossing, prevention of collisions, nearby information services, and real-time detour routes computation. Another important application for VANETs is providing Internet connectivity to vehicular nodes while on the move, so the users can download music, send emails, or play back-seat passenger games.

The different challenges which are faced in VANETs are given as below:

- **Distributed control:**

A central challenge of VANETs is that no communication coordinator can be assumed. Although some applications likely will involve infrastructure (e.g., traffic signal violation warning, toll collection), several applications will be expected to function reliably using decentralized communications. Because no central coordination or handshaking protocol can be assumed, and given that many applications will be broadcasting information of interest to many surrounding cars, the necessity of a single, shared control channel can be derived (even when multiple channels are available using one or more transceivers, at least one shared control channel is required). This one-channel paradigm, together with the requirement for distributed control, leads to some of the key challenges of VANET design.

- **Cost consideration and availability of network:**

Cost needs to be considered while designing of the VANETs and it requires to be minimal. The availability of network is an important issue that needs to be present at each and every norm of the communication.

- **Bandwidth requirement:**

The bandwidth of the frequency channels currently assigned or foreseen for VANET applications ranges from 10 to 20 MHz with a high vehicular traffic density, those channels easily could suffer from channel congestion.

- **Dynamic network topology:**

It is based on the mobility of the vehicles as communication is between the mobile vehicles that are interrelated with the network communication.

- **Message confidentiality:**

The confidentiality of the transmitted messages in VANETs depends on the message encryption mechanism. This is related to the PKC-based pseudonym generation for vehicle anonymity, as well as the encryption/decryption.

- **Time constraint:**

Because of the high mobility of a vehicular movement, strict time constraint is required for VANETs, which means that the lower the delay overhead, the more efficient and timely the communication.

IV. PROPOSED APPROACH

A. System Design

In our proposed scheme we assume a highway environment with predefined segments. According to [9] we consider two types of vehicles: equipped vehicles and normal vehicles. We assume that equipped 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 or RSUs.

Based on the inspiration that vehicles in geographical closeness often share same type of traffic information, we introduce a clustering algorithm, in which vehicles that have similar features and are close to each other are grouped into clusters and only a cluster head is responsible for information transmission. The vehicles selected as cluster heads are called CH, while the remaining system users are referred as cluster members CM.

Members of a cluster exchange traffic information using V2V communication. The CH combines the report into the single format and on the basis of driving speed in the cluster, and builds a special aggregated message containing average speed of the cluster members, number of the cluster members and also the position of the cluster. Note that, we can use more complicated approaches for aggregation recently proposed in the literature. Then, the CH communicates this information with the stationary RSU when it is in the RSU's communicating range. If the CH node is not in the RSU's range, it either buffers the information till it is in the range of the RSU or as shown in Fig.1, transmits the information to the other CH nodes that is in the range of the RSU using the chain of clusters. Also, a CM node requests traffic information by contacting the CH of its cluster.

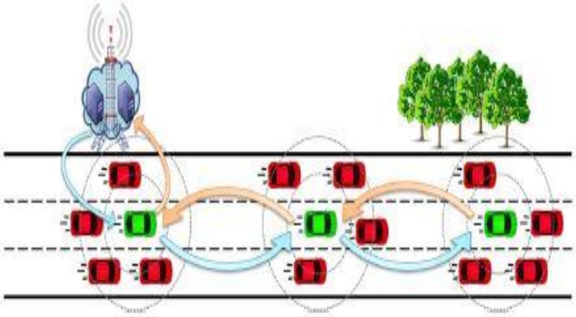

Fig.1 Overview of proposed approach. [17]

In the RSU side, we provide Roadside Cloud in our approach. A roadside cloud is composed of two main parts: dedicated lo-cal servers and RSUs [10]. The dedicated local servers virtualizes physical resources and act as a potential cloud site. RSUs give radio interfaces for vehicles to access the cloud. All RSUs are attached to a traffic management center to transmit traffic information and provide some traffic services for vehicles. A roadside cloud is accessible only to nearby vehicles. This fact helps us remind the concept of a Cloudlet. A Cloudlet is a trusted resource rich computer or cluster of computers connected to the Internet and available for use by nearby mobile devices [11]. We employ road side clouds to estimate the traffic volume of all vehicles on the road segment (i.e. both equipped and normal vehicles) by generalization of traffic information received from the clusters of equipped vehicles.

B. Clustering Of Vehicles

Equipped vehicles which have the GPS system inbuilt form the dynamic clusters and the one vehicle which is more perfect becomes the cluster head. CH is responsible for checking the data dissemination inside and in between the clusters. The dynamic clusters are themselves mobile, moving along with the high speed nodes; this enables that even with high speed nodes, the moving cluster architecture result in relatively stable topology, as long as velocity of the vehicles remains more or less the same. [17]

C. Cluster Formation Procedure

A leading vehicle or the vehicle which is ahead of all the vehicles when enters the new segment of the road would first search for the available cluster by sending the cluster join request message (*MCJR*), or by communicating with the RSU when it would be available in communication range. According to **Algorithm1**, when the vehicle which is called *Vinit*, wait for a while (*Tw*) and is not received any revert, it initiate the cluster formation process to identify cluster members by transmitting *Minit* message. Generally, vehicles to build their neighborhood relationship transmit their current speed and position data embedded in *HELLO* messages (*MHELLO*) to other vehicles within their communication range. The nodes moving in the similar direction and in the neighborhood of each other come under a primitive group, as illustrated in Fig.2.

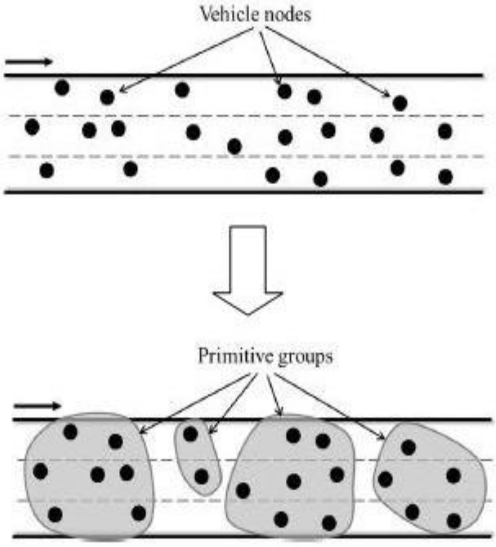

Fig.2 Cluster formation procedure. [17]

However, the speed levels in some area are different and this variation might be very high; thus, all neighboring vehicles are not appropriate ones to be included in one cluster. Besides, we define a member's threshold (*MEMthr*) to prevent the formation of small clusters with some members.

For selecting cluster members with the same speed level, first, *Vinit* compares the speed difference of all its neighbors with a threshold (*_Sthr*). In case of speed threshold if the speed difference value is less than the threshold value than it forms the cluster and if the value is greater than the threshold value than it will not forms the cluster. Similarly in case of members threshold if the number of members are greater than the members threshold than the cluster will be formed and vice versa. [12]

Algorithm 1 Cluster formation procedure. [17]
– *Tw*: time to waiting for a cluster head response
– *v*: leading vehicle entering a new segment of the road
– *Vneighbor*: the vehicle in the transmission range of *v*
– *Sneighbor*: speed of *Vneighbor*
– *Sinit*: speed of *Vinit*

(In the vehicle *v* side):
If there is no RSU in the vicinity of *v* **then**
Broadcast *MCJR*
If time of the *MCJR* > *Tw* **then**

set current state of vehicle *v* to *Vinit*
Vinit broadcasts *Minit*
End if
(In the vehicle *Vneighbor*):
If *Vneighbor* receives a *Minit* from *Vinit* **then**
Vneighbor broadcasts *MHELLO*
End if
(In the vehicle *v* side):
For all *Vneighbor* **do**
if| *Sneighbor*−*Sinit*| <_*Sthr* **then**
Add *Vneighbor* ID to primitive group list
End if
End for
if number of group members >*MEMthr* **then**
Vinit broadcasts *Mcluster*
else
Vinit discards the cluster formation process
End if
(In the vehicle *Vneighbor* side):
If *Vneighbor* receives a *Mcluster* from *Vinit* **then**
Vneighbor set its *IDCH* to the *IDinit*
End if
End if

D. Cluster Head Selection Procedure

Cluster Head selection is done on the basis of **Algorithm 2** which depicts the formation of the Cluster Head. Cluster head selection information for any node is limited to the nodes that are within *r* distance (i.e. service channel transmission range) from the node itself. The priority of a node to become a CH is determined by the value of its Befit Factor (*BFv*). So, first the nodes start calculating their Befit Factor to become a CH and broadcast *MBF* messages containing their *BFv*.

Then, as shown in **Algorithm2**, each node votes for its neighbor having the local maximum *BFv*. A node can as well vote for itself, if it has the maximum *BFv*. The nodes use their special voting messages (*Mvote*) to locally broadcast their votes. Once the election procedure is done, the elected node acknowledges selecting as a cluster head by changing its state to a CH and sending an Acknowledgement message (*MAck*). Subsequently, neighboring vehicles change their cluster ID to the ID of the new CH and dynamic cluster head is formed in this way. **Table1** shows all message types used in the proposed clustering algorithm. [17]

Table 1 [17] 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_{BF}	Vehicles Befit factor values
M_{vote}	Vehicles votes
Mack	Acknowledgement of electing as a cluster

E. Cluster Maintenance Procedure

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 [13], we use a maintenance algorithm contains three different scenarios as following:

Cluster joining - When a non-clustered vehicle sends membership request message to a cluster head, the cluster head checks whether its relative speed is within the threshold of cluster (*_Sthr*); If so, then the cluster head will accept the vehicle by adding its ID to the cluster members list.

Algorithm 2 Cluster head selection procedure. [17]
– *Vi*: vehicles in the cluster members list
– *Vneighbor*: the vehicle in the transmission range of *Vi*
– *BFmax*: maximum value of Befit Factor

– *BFi*: the value of Befit Factor of vehicle *i*
– BEFIT_VAL (*Vi*): a procedure to calculate Befit Factor

For all *Vi* **do**
Call BEFIT_VAL (*Vi*)
Broadcast *MBF*
End for
For each *Vi* **do**
IDCH←IDi
BFmax←BFi
For all *Vneighbor* **do**
If *BFmax<BFneighbor* **then**
IDCH←IDneighbor
End if
End for
Broadcast *Mvote*
End for

Cluster leaving When a vehicle moves out of the cluster, the cluster head loses the contact with it. Therefore, the cluster head re-moves 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 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.

F. Calculating Befit Factor

The Befit Factor is defined to maximize the stability of the cluster structure. As a result, an elected CH is expected to stay connected with the cluster members for the longest period of time. Thus, we define Befit Factor and the vehicles having higher *BFv* value are more qualified for winning the dynamic cluster head status. Befit Factor (*BFv*) derived from three metrics as follows:

$$BFv = c1 \times Tleave + c2 \times \psi v + c3 \times Dn \quad (1)$$

Where *c*1, *c*2and *c*3are the corresponding weights varying in the range of 0 to 1 (i.e. *c*1+*c*2+*c*3=1) and decided by local authority based on road conditions and members behavior.

Time to leave - First, based on the vehicle current location that is measured by using the position information provided by GPS, each vehicle periodically computes the time to leave that means remaining time to cross the road segment [6]. Considering the time to leave we ensure to select CHs with considerable distance to the end of current segment of the road. This metric contributes in prolonging the lifetime of the clusters and calculated as:

$$Tleave = ((L - d) / d) * t \quad (2)$$

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. **Table2** shows the main notations used in our paper.

Table 2 [17] Table of Symbols

Symbol	Description
BF*v*	Befit factor
T_{leave}	Time to leave the segment
ψ*v*	Relative average speed
CS*v*	Current speed of the vehicle v
S_{avg}	Average speed of all vehicles in the current time interval
D_n	Neighborhood degree
T (i,j)	Aggregated similarity measure
$W_i(j)$	Assigned weight to cluster j
Θ(*i*)	Estimation of traffic volume for cluster i

Relative average speed (ψv) - Then, in order to selection 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 pro-vided 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 (δ), and value of their relative average speed (ψ*v*) is incremented or decremented, consequently. We ensure to select CHs with reasonable velocity through adding this metric. The vehicles compute their relative average speed for each time interval where, *_Sthr* is a threshold ensuring that vehicle *v* is moving with the almost same speed with its neighbors, *CSv* is the current speed of vehicle *v* and *Savg* is the average speed of all vehicles in the current time interval. Note that, the initial value of ψ*v* and δ could be dynamically set depending on environment terms. (We initial ψ*v* as 1, and also consider δ=0.01in our simulations.)

Neighborhood degree (Dn) - Moreover, in order to build relatively stable cluster structure, vehicles with better neighborhood degree should 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 (*Dn*) is defined as the number of corresponding real neighbors of *v* that their speed differences are lower than *_Sthr*. [12]

According to [14], the speed of a vehicle (s) is computed as a random variable following the normal distribution with mean (μ) and variance (σ2), and its Probability Density Function (PDF) is given by:

$$f_S(s) = (1/\sigma\sqrt{2\pi})^{*} e^{-(s-\mu)2}/2\sigma^2 \quad (3)$$

According to [16], the speed difference (*_S*), between two neighboring vehicles, also follows normal distribution with PDFgiven as:

$$f_S(\_S) = (1/\sigma\_S\sqrt{2\pi})\, e^{-(\_S-\mu\_s)2}/2\sigma\_S^{2} \quad (4)$$

G. Chaining Of Clusters

As described earlier, the roadside cloud estimate traffic volume mainly based on information received from clusters. In case of collecting the traffic information from clusters we need to create a virtual chain between clusters. The main objective is to cope limited transmission range of RSUs which is affected the connectivity of clusters with RSUs. For this propose we use the properties of DSRC standard. [17]

The DSRC uses 75 MHz bandwidth (5.850–5.925 GHz) which is divided into seven channels. One of the channels is called the control channel and has higher TX power (i.e. 44.8dBm); and the remaining six are called service channels which have lower TX power (i.e. 24–33dBm) [15]. Vehicles are assumed to utilize the control channel to exchange periodic control messages and gather information about their neighborhood, and use one service channel to define the cluster radius and perform all intra-cluster communication tasks. According to the DSRC specifications [15], it can provide a transmission range of up to 1000m for a channel. As depicted in Fig.3, VANET applications can use a longer range, *R*, as the control channel transmission range. Hence, a cluster head can communicate with neighboring cluster heads for chaining pro-poses, and a shorter range, *r*, as the service channels range that is used for intra-cluster managements.

In this way, the cluster members in a cluster communicate with their CH. This CH node can communicate beyond the cluster boundaries using the control channel and sends the status information to the next CH node which in-turn transmits it again to next CH node. This process is repeated till one of the CH nodes that have received the packets is in the communication range of RSU and hence, could transmit these packets directly to the RSU. [17]

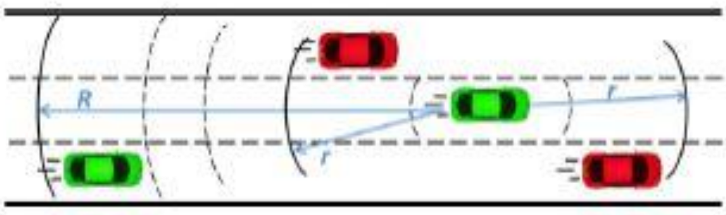

Fig.3 DSRC transmission range. [17]

V. SIMULATION RESULTS

a. Simulation model

A comprehensive simulation was conducted to evaluate the performance of our algorithm. We have used a simulation platform composed by the OMNet++ [21] and the SUMO [22] tools. In order to connect these two tools, we resorted to the use of Veins [23]. OMNet++ is a network simulator representing the network features such as number of nodes, topography, velocity, duration, and time steps. We have implemented the functionalities of our scheme and modeled the wireless communication among the vehicles by using OMNet++. SUMO supports both micro-mobility and macro-mobility features.

We use several traffic characteristics in our simulation: inter-vehicle spacing, density and flow rate. Inter-vehicle spacing is the distance between vehicles [24]. 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 [26]. According to [25], inter-vehicle spacing can be reasonably approximated by exponential distributions when the network is divided into different segments. The flow rate in different traffic densities can have three different types of distributions: Poisson, exponential, or uniform [27]. We consider 1800, 3600 and 5400 vehicles/h for low, medium and high flow rates, respectively.

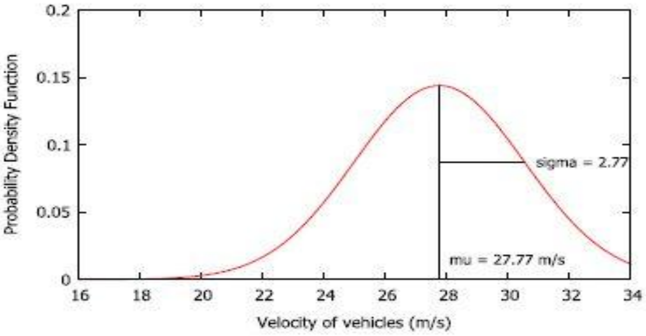

Fig.4 Normal distribution of speed. [17]

The speed assigned to the vehicles follows the normal distribution. The velocity bounds on this highway range from 60 km/h to 120 km/h. For all simulation scenarios, the *_Sthr*=σ. 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. Fig.4 shows an example of the normal distribution of the speed with mean 100 km/h (i.e. μ =27.77m/s) and σ=2.77and the relative PDF values which is used in our simulation. The performance of different *_Sthr* values can be found in [20].
Furthermore, according to DSRC standard supporting bit rate in the range 6–27 Mbps [19], the data rate is set to 6Mbpsas default and the size of the messages are 100 bytes. To provide more ac-curate simulations, we took a confidence level of 95% and for each case we repeated the simulation with different random seeds (i.e. independent simulations). **Table3** shows the values of the parameters used in our simulation. We discuss simulation results of our approach in two separate sections as the following. [17]

b. Performance of clustering method

We first focus on stability evaluation of our clustering method, and study the effects of the metric's values in different flow rates. We present a comparison between proposed clustering scheme and two existing algorithms, Lowest-ID and MCMF techniques, presented in [42] and [23], respectively. In Lowest-ID algorithm, each node in the network has an identifier which it distributes to all its neighbors in a broadcast transmission and the node with lowest ID in its *k*-hop neighborhood becomes the cluster head. We choose Lowest-ID algorithm because it is a well known and widely accepted clustering scheme in the area of ad-hoc networks. The MCMF scheme is a state-of-the-art clustering algorithm which selects cluster heads based on mobility metrics and its simulation results show the best stability among existing clustering algorithms. We compare the three schemes under the same environment variables in two different performance metrics: cluster head duration and number of clusters.

Table 3 [17]Simulation Parameters

Simulation parameters.

Parameter	Value
Simulation time	180 s
Highway length	3000 m
Speed of vehicles	60–120 km/h
Transmission rate	6 Mbps
Size of a messages	100 bytes

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. Fig.5 illustrates the variation of the average cluster head duration of three clustering schemes in three different flow rates with respect to the velocity of vehicles. Due to the fact that when the vehicles move faster, the topology of the vehicle network is more dynamic, the average cluster head duration will decrease when the velocity of vehicles increases. [17]

Simulation results show that when the maximum speed changes from 60 km/h to 120 km/h, the cluster head duration is reduced around 15% for the proposed clustering algorithm, while this value is reduced much more for two other methods. Moreover, by in-creasing the density of vehicles, the probability of clusters merging goes up and average CH duration decreases, consequently.

In this case, MCMF algorithm has better performance than Lowest-ID algorithm; considering the transmission range and vehicles movement direction is the reason of its better results. How-ever, the mobility of vehicles and the time of existence of cluster head in direction with its members are not considered in this scheme. As a result, it has lower performance in comparison with proposed scheme, which both time to leave and mobility metrics are participated in cluster head selection process. On the other hand, proposed scheme decreases re clustering times by defer clusters merging and increases average CH duration in this way. [17]

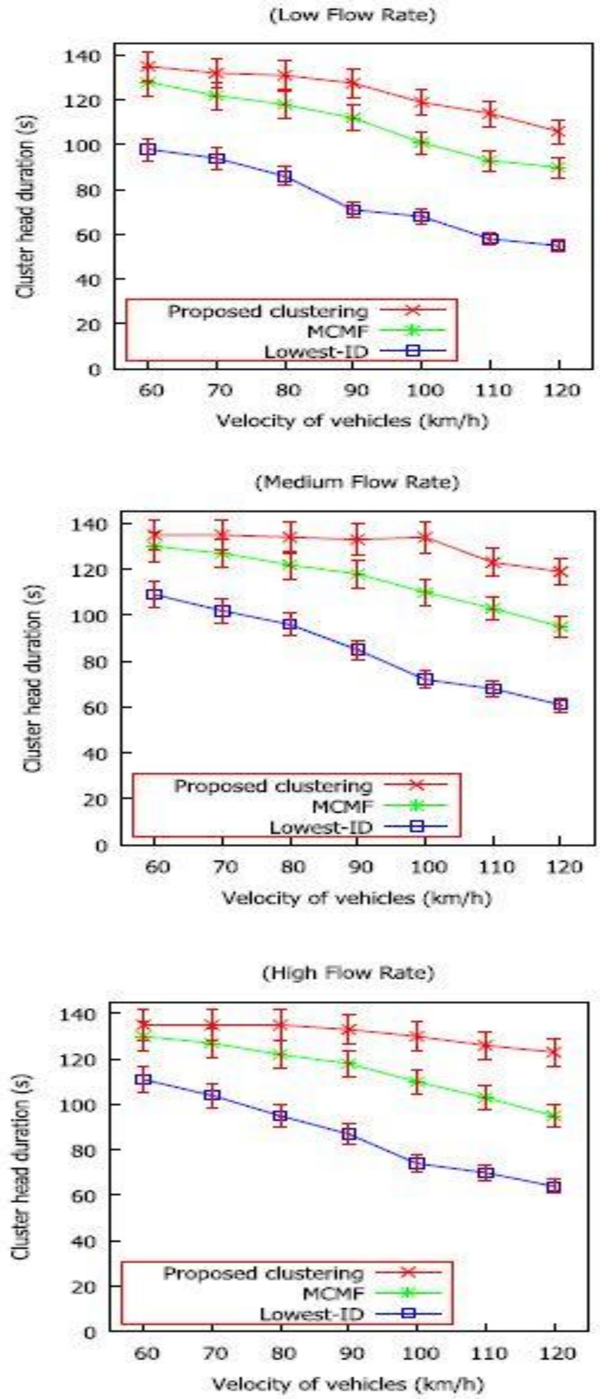

Fig.5 Cluster Head duration [17]

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 smaller the number of clusters, the more the mobility of the vehicles can trigger connection failures and cluster divisions. Moreover, more cluster merges and cluster formation overheads produced 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. We attempt to decrease the number of dynamic cluster formations using two techniques: 1) Checking existence of clusters in the vicinity of the initializer vehicle and 2) Discarding small groups of members before converting to a cluster. The number of cluster heads produced by our proposed clustering algorithm is smaller than by two other methods. [17]

c. Traffic volume estimation accuracy

Since increasing the accuracy of volume estimation is the main objective of our scheme, as the second part of our simulation, we focus on the evaluation of the performance of our generalization scenario. We first selected 1000 real clusters as the test set Ψ. We use each virtual cluster *i* upon a real cluster of Ψ as a test case. Moreover, we use exponential distribution for arrival rate of vehicles to our simulation environment as ground truth to quantify our estimates. Then, according to generalization scenario we estimated the traffic volume of each virtual cluster.

The 'Gradient' is the slope of minimum mean square error (MMSE) fit between real traffic volume and the estimated volume. MMSE is an estimation method which minimizes the mean square error (MSE) of the fitted values of a dependent variable, which is a common measure of estimator quality. As depicted in this figure, most of the virtual clusters lie in the range of 0.8–1.2. Thus, the gradient error is mostly in the 20% range. As such, the estimated volume approximates well the real volume.

As the second metric for the evaluation of the traffic volume estimation accuracy of our approach, we focus on the estimation accuracy depend on the real traffic volume in the current road segment and over the simulation time (180s). We compare the simulation results of the proposed scheme with the state-of-the-art prediction model, called online learning weighted support-vector regression (OLWSVR) which is proposed in [18] as one of the newest traffic estimation approaches.

Fig. 6 illustrates the actual volume and estimated values of the proposed scheme and OLWSVR method and also shows the behavior of the flow rate changing within current segment in three different charts. The results have been obtained on the 3000mroad segment and the flow of vehicles is set to 90, 180 and 270 respectively for Low, Medium and High flow rates in 180s. Also, the relative errors for the low, medium and high flow rates could be observed in these three charts.

As shown in Fig. 6, values of the proposed scheme are much closer to the actual values compared with OLWSVR in all three flow rates. In fact, the main reason of this superiority is considering to the penetration rate of the equipped vehicles in the proposed scheme. Furthermore, the results shown that OLWSVR experiences less accuracy by decreasing the flow rate which is caused by lower number of vehicles participated in online learning procedure of this method. However, proposed approach can handle low density of vehicles using cluster-based structure. [17]

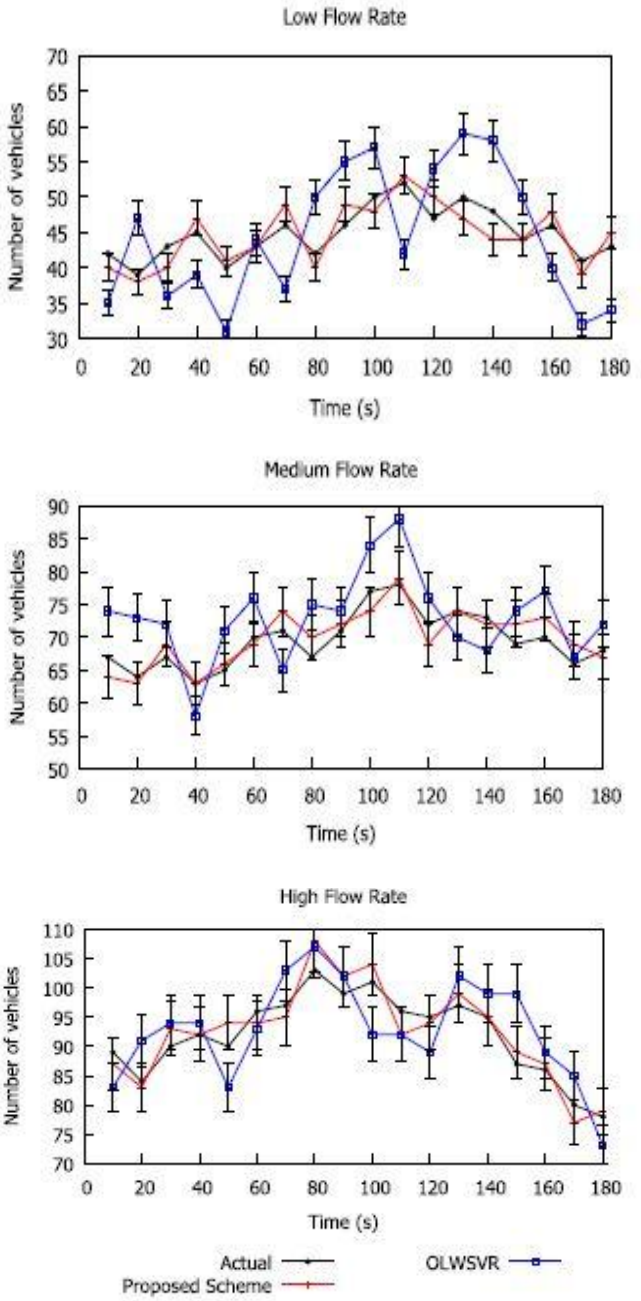

Fig.6 Comparing actual and estimated traffic volumes [17]

VI. CONCLUSION

In this paper, we presented a hybrid cooperative traffic information system to provide traffic data to drivers and other suppliants. The hybrid approach is a scalable mechanism that makes efficient use of the number of equipped vehicles moving in a road segment to optimally estimate the total traffic density. For this reason, we provided a new clustering method, a cluster chaining technique, and also a traffic generalization method. Also, a comprehensive simulation was conducted which its illustrative results demonstrate the superiority of the proposed clustering algorithm in the case of forming more stable dynamic clusters comparing with two existing algorithms.

Some of the additional research issues that can be investigated for future extension of the work are as follows: (1) cluster-based detecting congestion and monitoring end-of-queue situations, (2)ability of the approach to deliver data in transient sparse traffic, (3)evaluation of the approach overheads including memory, computational and communication overhead, (4)consideration of urban scenarios as noisy environments with traffic lights and signs at the intersections, (5)extending the approach to a spatiotemporal method to further improve the prediction accuracy of traffic flows. [17]

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