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VANET Data Collection through Cluster Based Technique

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ABSTRACT: As a prominent application of intelligent transportation system, Vehicular Ad-hoc Network is designed to enhance the road traffic safety by deploying effective wireless communication technologies. The paradigm of connected vehicles enables to connect vehicles to each other, and vehicles to infrastructure. Because of the significance of safety-related driving data that are exchanged in vehicular networks, it is mandatory to provide a suitable collection solution. In this paper, we propose an efficient data collection based on vehicle to vehicle and vehicle to infrastructure communications. The proposed solution is endowed with a clustering approach for reducing the effects of mobility and density on the data collection stations. In order to demonstrate the effectiveness of the proposed solution, we have conducted a simulation using MATLAB 2016a. The obtained results show that proposed solution achieves a better organized collection of the road traffic data while reducing the over head and the topology changes.

Keywords: Intelligent Vehicles (IV), VANET, Data collection, Clustering, Traffic information

I. INTRODUCTION

ITS means intelligent transportation systems this system is a combination of foremost information and communication technologies employed in traffic management and forecasting systems to improve an extensive variety of transportation services [1]. As emerging paradigm of ITS, VANET Vehicular Ad - hoc networks (VANETs) have accessible an important field for researchers. Researchers can create many new applications such as dissemination of safety and traffic condition messages and control of vehicle flow formations. Day by day development and improvement of vehicular safety technologies can significantly decrease the accident rate and improve road safety. Modern advances in wireless communications technologies opens the way toward sharing information between vehicles and vehicles and roadside infrastructure. Thus, vehicular network comprise vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. V2V communications are dedicated to ameliorate road traffic safety and provide information and comfort services to the drivers, whereas V2I communications are used to share real-time traffic safety-related information between vehicles and fixed roadside unit (RSU) [2].

To harmonize the use of vehicular communications. The US FCC (Federal Communication Commission) decided in October 21, 1999 to assign 75 MHz of spectrum in 5850-5925 MHz frequency band for many dedicated short- range communication (DSRC) applications [3]. DSRC is expected to provide a protocol stack improved for vehicular network, plus reliable transfer information between vehicles, and vehicles and surroundings infrastructure. As well, in August 5, 2008 the ETSI (European Telecommunications Standards Institute) assigned 30 MHz of spectrum in 5875- 5905 MHz frequency band to coordinate the use of radio spectrum and allow the automotive industry to establish radio communication in vehicular network [4].

Enabled by V2V and V2I communications, vehicles can collaborate with each other or interact with the infrastructure to exchange information ranging from safety-related to comfort data, including traffic safety information and environment-related conditions [5], traffic state and mobility [6] or assist navigation [7]. The traffic information obtained from vehicles depends on different attributes and their interrelation that is pertinence, accuracy and the level of novelty of the data [8]. This information allows in assisting road network decision-making, monitoring the evolution of traffic, improving the performance of existing infrastructure and controlling the results of applied plans to enhance road safety [9].

Due to the importance of these goals, we have focused our attention in this paper on developing a clustering-based data collection scheme that collects road traffic experienced information in real-time. The designed scheme is expected to use vehicles as mobile sensors and then send the gathered information to the infrastructure. However, developing data collection system based on VANET communications is a challenging problem as vehicular networks are often large with high mobility. Thus, to overcome the impact of these issues, we use the clustering approach to organize vehicles into small disjoint clusters, where each cluster coordinator referred as a cluster head [10].

II. PROBLEM STATEMENT

Even though the capabilities of VANET communications have been improved in recent years, most improvements have been achieved by minimizing the amount of information lost as the result of congested flow traffic and high velocity. Nonetheless, it is possible to further improve the efficiency by introducing the clustering approach. With this goal, this paper seeks to mitigate the additional overhead of delivering data, to collect more information from the vehicles, to minimize the consumption of network resources by overcoming the volume of application and management messages and building stable topology with a long lifetime.

Based on the approach depicted in the figure 1, a clustering-based management strategy aims to divide the vehicular network into small disjoint clusters, and one vehicle in each cluster is selected as a cluster head (CH). A CH is responsible for forwarding the information messages collected via inter-vehicular communications to the infrastructure through RSUs. Typically, a CH serves as a gateway between cluster member (CM) and infrastructure. Then, for improving the capacity and efficiency of data collection process, only CHs around the RSU can directly send the data messages.

The selection phase is aimed at finding the appropriate cluster heads depending on the density, velocity and driving direction constraints. More specifically, each vehicle calculates its weight metric, based on these constraints. Eventually, CM assignment relies upon the cluster head which is closest and who has a maximum weight metric.

III. PROPOSED ALGORITHM AND ARCHITECTURE

As discussed in above Section, the reliability of the data collection scheme depends on the number of vehicles connected to the RSU, which varies with the volume or density of traffic demands. In practice, the traffic state is often unpredictable in advance or dynamically changing. Hence, in this section, we first describe the neighbor discovery algorithm that we have implemented to create neighbor tables, which are further used respectively in the cluster heads selection phase and Cluster member assignment.

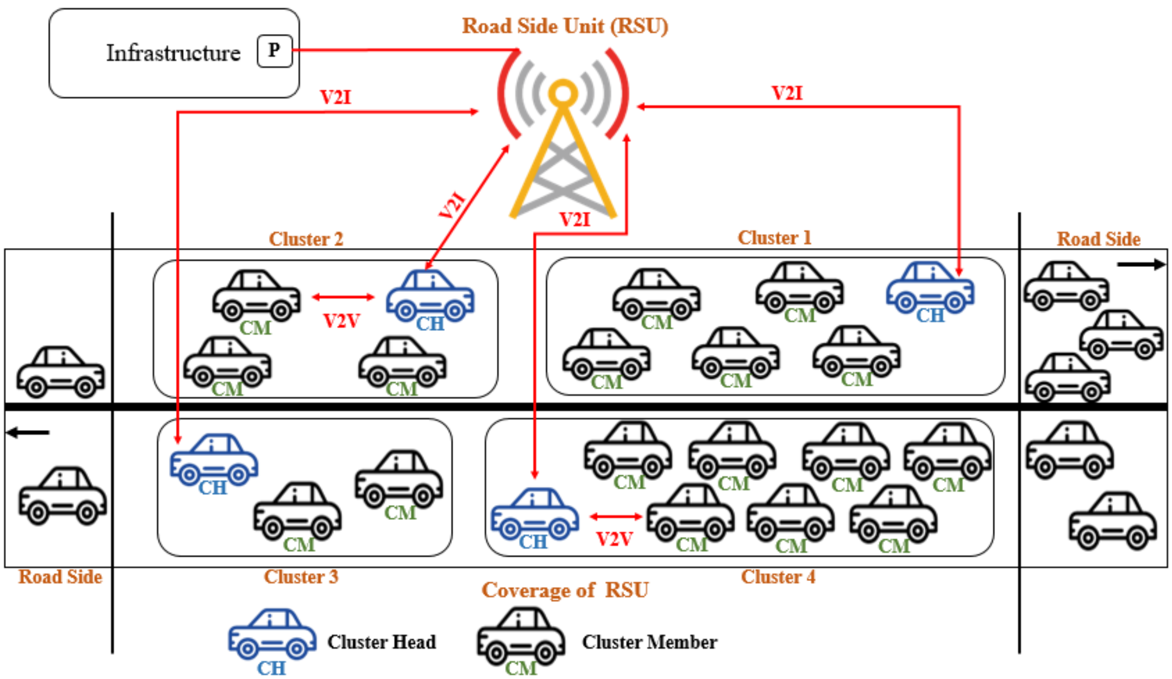

Fig. 1. Data collection through cluster - based technique in VANET architecture.

A. Neighbor's discovery algorithm (NDA)

To construct a list of adjacent neighbors, each vehicle periodically exchanges its identity through beacons messages sent to all vehicles within its communication range. A beacon message contains the identifier of the sender, relative velocity and location obtained over satellite-based radio navigation system. Upon receiving beacon from neighbor υ, the destination vehicle µ tries to keep the information in the neighbor table N (µ) as entry that can be expressed as follow:

$e(\upsilon) = \{I, y^{(x,y)}, v, \tau^{hold}\}$

I is the unique identifier of sender υ

$y^{(x,y)}$ is the current location

v is the relative velocity

τ^{hold} is the hold timer

Based on VN constraints, we set the value of the timeout to 5 seconds.

As presented in the algorithm I (NDA), the neighbor table must be updated each time the vehicle receives beacons messages. Therefore, if the destination determines that the identifier of the sender is on the neighbor table, it updates the entry by the information supplied in the beacon message. Otherwise, if a hold timer has expired, the adjacency entry corresponding to that neighbor will be removed from the neighbor table.

Algorithm: I Neighbors discovery algorithm (NDA)

Require: $I(\upsilon)$: identifier;
$y(\upsilon)^{(x,y)}$: current position;
$v(\upsilon)$: relative velocity
On receiving beacon message from neighbor υ.

Initialize $e(\upsilon) \leftarrow \{I, y^{(x,y)}, v, \tau^{hold}\}$
if there exists $\omega \in N(\mu)$ AND $I(\omega) = I(\upsilon)$ **then**
Update e(υ) information in the neighbor table.
$N(\mu)[e(\upsilon)] \rightarrow e(\upsilon)$
else
Create a new entry for υ in neighbor table.
$N(\mu) \leftarrow N(\mu) \cup \{e(\upsilon)\}$
end if
if there x is t s $\omega \in N(\mu)$ AND $\tau(\omega)^{hold} > 5s$ **then**
Delete the neighbor with expired hold time.
$N(\mu) \leftarrow N(\mu) \setminus \{e(\omega)\}$
end if

B. Cluster heads selection process (CHSP)

Based on the approach presented in [11], we developed a novel adapted weight metric using three different criteria:
-The identifier
-Relative velocity
-Beacon delay

The identifier is a unique unsigned integer value that identifies each vehicle. It allows the value of weight metric to be different from zero when the relative velocity equals to zero in congested areas. Then, to increase the lifetime of clusters and mitigate the frequency of cluster member's assignments, the velocity-difference allow determining the vehicles with optimal speeds. Finally, beacon delay defines the closest vehicle to its neighbors. Thus the following formulas are obtained:

$$v = \frac{1}{\delta} \sum_{\omega \in N(\mu)} v(\omega) \quad \text{(I)}$$

$$p(\mu) = I(\mu)\alpha + |v(\mu) - v|\beta \frac{1}{\delta} \sum_{\omega \in N(\mu)} D(\mu, \omega) \quad \text{(II)}$$

where δ is the degree of μ and δ = | N(μ) | , I(μ) is the identifier of vehicle, v(μ) the relative velocity, v average velocity of neighbors and D(μ, ω) is the relative beacon delays between vehicle and its neighbors. The constants α, β are the pond ration factors, which select the dominant criterion to be considered according to the mobility state, where α + β = 1.

Algorithm: II Cluster head selection algorithm (CHSA)

Require: $y(\mu)^{(x,y)}$: current position;
$v(\mu)$: relative velocity
Each vehicle gets the position information and relative velocity. Therefore, calculate the weight value ρ(μ).

$\rho(\mu) = I(\mu)\alpha + |v(\mu) - v|\beta \frac{1}{|N(\mu)|} \sum_{\omega \in N(\mu)} D(\mu,\omega)$
Initialize *role*(μ)= CH, ch(μ)= μ
for each $\upsilon \in N(\mu)$ **do**
if ρ (υ) < ρ (ch(μ)) **then**
ch(μ) ← υ
end if
end for
if ch(μ) ≠ μ **then**
role(μ) ← CM
Send Join(μ, ch(μ)) message to ch(μ)
else
Send CH(μ) message to neighbors in N(μ)
end if

As presented in the algorithm II CHSP, to form clusters, each selected vehicle as a predominant in its vicinity having the lowest weight value.

For example, if μ has the lowest weight value in its neighborhood, then it becomes a cluster head. The equal weight values are managed by selecting the vehicle whose identifier is higher. In addition, if a vehicle is neighbor of two cluster heads, it sends a join message to the cluster head with the lowest value. In this way, all cluster heads are at a distance of 3 hops.

C. Cluster member assignment process (CMAP)

As described in the algorithm III CMAA. Once a vehicle µ is selected as a cluster head, it starts the Cluster member assignment process by broadcasting CH message to its neighbors. The sent message includes a CH flag set to on, source identifier, weight value, current location and relative velocity. Upon receiving the message, the neighbor vehicle υ updates the location and relative velocity of µ entry in its neighbor table. If the cluster head of υ has a highest weight, it sends a join message to µ then changes its role to a cluster member. Otherwise, if υ has already joined a cluster, it compares the weight value ρ (µ) with the weight value of its cluster head ch(υ). Then, send the join message to µ if its weight value is lower.

The join message includes CM flag set too, source identifier, destination identifier which is the id of cluster head, current location, and relative velocity. Upon receiving the message, the cluster head compares its identifier against the destination identifier. In case, the identifiers are equal, µ updates the location and relative velocity in its neighbor table and add the source id to its cluster table C(µ).

Algorithm: III Cluster member assignment algorithm

On receiving a cluster head message CH(µ) from neighbor µ.

if $\rho(\mu) < \rho(ch(\upsilon))$ **then**
    $role(\upsilon) \leftarrow CM$
    $ch(\upsilon) \leftarrow \mu$
    Send $join(\upsilon,\mu)$ message to μ
end if
On receiving a join message from neighbor υ
if $I_{dest} = I(\mu)$ **then**
    $C(\mu) \leftarrow C(\mu) \setminus \{\upsilon\}$
endif

D. Cluster update process (CUP)

In the case of inter-vehicular communication failure, vehicles check their neighbor table to identify the neighbor moving out of range of each other. The update mechanism depends on the hold timer value, which determines when a neighbor sent the last beacon message. If a vehicle µ did not receive any beacon message from unreachable vehicle υ after 5 seconds, then it removes υ from its neighbor table and cluster table if it has CH role. If the vehicle υ has CH role and µ is a cluster member. Then, µ attempts to find new CH in its neighbor table that has a weight value lower than its weight value. If µ finds a new cluster head ω, it transmits a join message to join ω in its cluster. Otherwise, it becomes a cluster head.

Algorithm: IV Cluster update algorithm (CUP)

If µ detects that a cluster member vehicle υ is unreachable
If µ is cluster head
if $role(\mu) = CH$ AND $\upsilon \in C(\mu)$ **then**
Delete the unreachable neighbor from cluster table.
    $C(\mu) \leftarrow C(\mu) \setminus \{e(\upsilon)\}$
end if
if $role(\mu) = CM$ AND $ch(\mu) = \upsilon$ **then**
µ attempts to find new CH in neighbor table.
    if $\omega \in N(\mu)$ AND $role(\omega) = CH$ AND $\rho(\omega) < \rho(\mu)$ **then**
        $role(\mu) \leftarrow CM$
        $ch(\mu) \leftarrow \omega$
        Send $join(\mu,\omega)$ message to ω
    else
Send CH(µ) message to neighbors in N(µ)
    endif
endif

E. Data collection process (DCP)

The traffic data gathered by infrastructure is used to perform a variety of purposes, ranging from reliability of safety-related applications to enhancement of roads performances. Further, roadside units provide vehicles with ex- tended communication capabilities, such as Internet services. Nevertheless, the data collection method in this scheme is not adequate for networks with high mobility and high node density such as vehicular network.

The proposed technique for data collection includes RSU as a data collection station, cluster members and cluster heads that are determined by a selection process. Thereby, cluster heads get data from their cluster members and forward the data to the infrastructure through the nearest RSU.

IV. RESULT AND ANALYSIS

In this section we defines the obtained results after the simulation of the proposed work. MATLAB 2016a software has been used with communication toolbox for the simulation. We are interested in the approach performance concerning the average cluster head change rate and the average packet delivery ratio (PDR). To properly evaluate the data collection, RSU is located at the middle of the road. The evaluation has been done on the basis of below mentions parameter as shown in Table 1.

Table 1. Simulation Parameters.

Parameter	Value
Simulation Period	1000s
Highway Length	20KM
Number of Lanes	4 Lanes
MAC/PHY Standard	IEEE 802.11p SCH
Size of Messages	100 Bytes
Transmission Range	300 M
Transmission Rate	6 - 10 Mbps
Density (No. of Vehicles) 10, 30, 50, 70, 100 Velocity	60KM - 120KM
Beacon Interval	1s

As you can be seen from Fig. 2, we compare the proposed approach with the lowest identifier clustering algorithm [12] and the presented clustering algorithm [10]. As illustrated in the figure, the lowest value of cluster changes is achieved by the proposed approach. The reason for this decreasing rate is given by the use of both velocity and beacon delay in the weight metric calculation. Furthermore, the results explain that we have clusters lifetime longer in spite of the raising of the number of vehicles.

Fig. 3 shows that the proposed approach has better achievement than regular data collection; considering the clustering mechanism is the main raison of its better results. The clustering led to reducing the load on the RSU by decreasing the number of connected vehicles to this one, each CH is considered as a gateway that forwards data from the cluster members to RSUs.

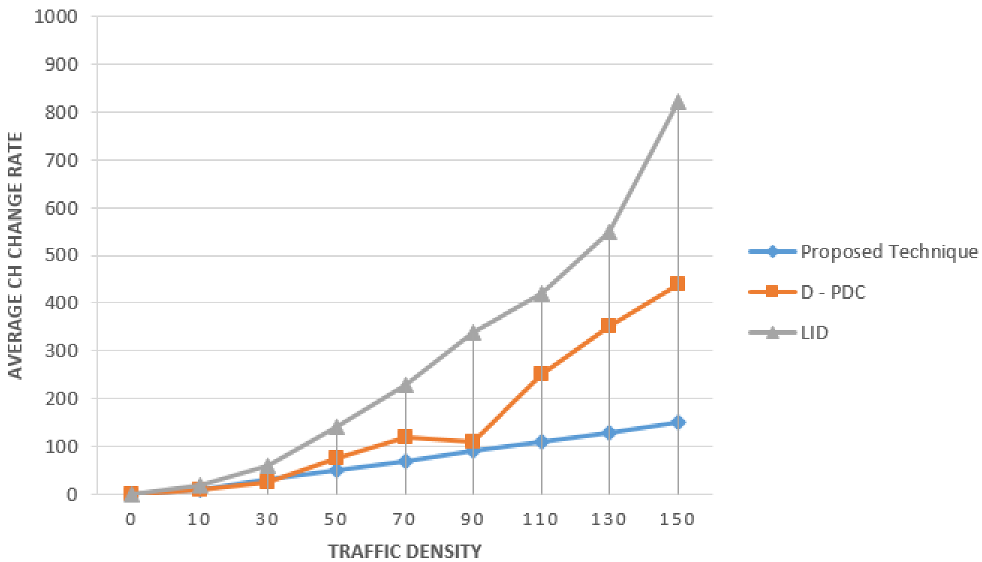

Fig. 2. Average CH Change Rate per number of vehicles.

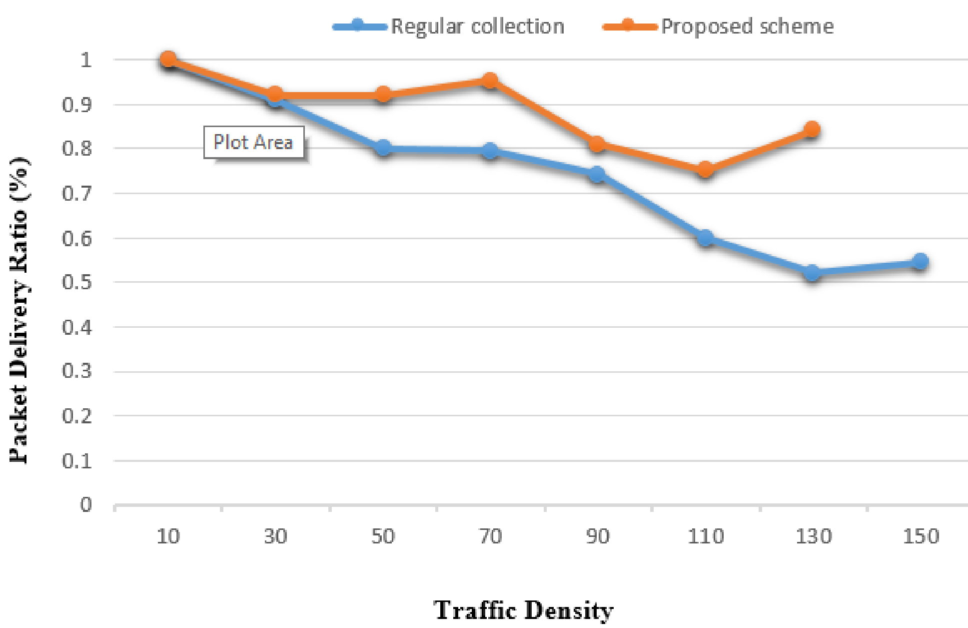

Fig. 3. Packet Delivery Ratio (PDR) per number of vehicles.

V. CONCLUSION AND FUTURE

The main challenges to successful data collection in the vehicular network are the mobility and density. Thus, to overcome the effects generated, we use clustering approach as an access management approach for RSUs. Consequently, the clustering splits the vehicular network into sets of clusters. Each cluster is maintained by a particular vehicle so-called cluster head. Cluster heads provide the coordination, gathering and routing data capabilities. While cluster members send data to the cluster head of their cluster. Only the cluster head forward the data to adjacent RSU, which improve the performance of data collection. Future research will compare the proposed approach in this paper with other data collection schemes designed for vehicular networking.

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