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# Clustering-based Algorithm for Connectivity Maintenance in Vehicular Ad-Hoc Networks

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**Abstract**—Among recent advances in wireless communication technologies' field, Vehicular Ad-hoc Networks (VANETs) have drawn the attention of both academic and industry researchers due to their potential applications including driving safety, entertainment, emergency applications, and content sharing. VANET networks are characterized by their high mobile topology changes. Clustering is one of the control schemes used to make this global topology less dynamic. It allows the formation of dynamic virtual backbone used to organize the medium access, to support quality of service and to simplify routing. Mainly, nodes are organized into clusters with at least one cluster head (CH) node that is responsible for the coordination tasks of its cluster. In this sight, our paper introduces a clustering mechanism based for connectivity maintenance in VANET. The proposed solution is experimentally evaluated using NS2 simulator.

**Keywords**—Vehicular ad-hoc networks, clustering, connectivity maintenance, NS2, cluster stability.

## 1. INTRODUCTION

Vehicular ad-hoc networks (VANETs) are designed to enable communication between vehicles, with or without fixed infrastructures [1]. It's addressed for special purposes such as traffic conditions, road warnings, data sharing, and safety purposes. VANETs are a particular case of MANETs where vehicles are equipped with wireless transceivers, which along driving allow spontaneously the network establishment. Intelligent Transportation Systems (ITS) are also based on VANET communications, with the purpose of assisting drivers to obtain necessary information for safety and entertainment purposes, traffic management, and to provide convenience applications to passengers. Compared to MANETs, vehicular networks have some special characteristics and networking properties including: predictable mobility model, variable network density, large-scale networks, and rapid topology changes. Also, the ability to use GPS and digital maps to acquire location is one of the beneficial features of VANETs. Because of the special VANET characteristics, many protocols designed for MANETs cannot work efficiently for VANETs [2]. In all VANET's applications, connectivity maintenance during a journey is a primordial goal to achieve. Connectivity interruption occurs when a node is in the radio range of no other node. Due to the high mobility model of VANET, a node enters and leaves radio range of other nodes in a lapse time (at time  $t$ , node establishes connection between other nodes, and just after a while,  $t+\Delta t$ , it leaves). Clustering is one of the control schemes used to make this global topology less dynamic. It allows the formation of dynamic virtual backbone used to organize the medium access, to support quality of

service and to simplify routing. Mainly, nodes are organized into clusters with at least one cluster head (CH) node that is responsible for the coordination tasks of its cluster. Our algorithm is designed to continuously keep connectivity based on virtual mobile formed clustering.

VANETs are large-scale networks and dividing the network into smaller clusters in such dynamic environment is an advantageous technic. Each cluster seems to be smaller and more stable in the view of the cluster member nodes because nodes have been chosen due to similarity of special characteristics in each cluster [3]. Thus, vehicles in a cluster have more similar movement patterns and face less topology changes compared to the whole network. Also, managing the clusters separately is easier than managing the whole network.

Cluster forming exists under two manners: 1) *Physical* one where road is preliminary divided to equal segments, and nodes within the same fragment belong to the same cluster. Cluster head (CH) is the nearest node to the middle of the road segment as in [4], [5]. The CH election algorithm can easily be done, and, 2) *Mobile* one where clusters are formed by nodes moving in the same direction and have nearly the same velocity [3][6],[7]. In a pre-segmented road with landmarks along and/or vehicles move with moderate speed, the physical clustering fashion seems suitable for such applications. Vehicle move suffusion time in the same road's segment, so cluster head re-election is less frequent and the network is more stable. Overhead will be reduced. Otherwise, when vehicles move with high speed, nodes frequently joining or leaving clusters jeopardize the stability of the network. The impact of these perturbations becomes worse on network performance. CH re-election algorithm becomes frequent that mislead to network overhead. In such scenarios, VNETs' protocol designers opt for mobile clustering solutions.

In this paper, we present a virtual mobile clustering based solution to improve connectivity in a highway. We introduce the average speed election factor and vector velocity variable to differ between vehicles driving in opposite directions in order to reduce the fast connection and disconnection event, which overload the network control traffic.

The rest of the paper is organized as follow: Section 2 presents the related work on clustering algorithms proposed for VANETs. Section 3 gives a brief overview of our proposed algorithm and defines the terms used in algorithm description. Section 4 is dedicated to experimental results' analysis and we conclude the paper by section 5.

## 2. RELATED WORK

There have sufficient number of clustering methods proposed for MANETs and WSNs such as [6], [8], and [9]. However, all these algorithms do not fit VANETs' behavior. Vehicular networks differ from MANETs and WSNs in several parameters such as high topology changes, restrictions on vehicles movement due to roads structures, and availability of ample energy source and processing power in VANETs compared to other kinds of mobile ad hoc networks. Some of these characteristics are helpful for designing protocols for VANETs. As a case in point, vehicle's movement pattern is predictable and can be retrieved from driver's behavior and roads' map. Furthermore, we can use GPS to retrieve vehicle's location and digital maps are beneficial for VANET tracking purposes. Also, in MANETs and WSNs, energy consumption is a very important issue and is considered as a vital mechanism in most of the protocols. Unlike MANETs, VANETs have abundant energy source. As the result, power management mechanisms used in MANETs to save energy consumption is not required in these networks.

Clustering algorithms are classified according to their metric as cited in [10], where vehicle position is refined with the accurate way's knowledge on which its travels. The vehicle's way is obtained by matching vehicle position with a precise road map. Dedicated for urgent break assistance application, Bononi L and Di Felice M. in [11], for each direction there is a cluster in function of the vehicle future direction after a cross-road "turn left, turn right". A further parameter was introduced, the Euclidian distance between vehicles and their membership to geographical area. The goal was to reduce locale rang message diffusion in limited space either for routing or ITS applications

In [12], the protocol VHRP (Vehicle-Heading Based Routing Protocol) where clusters are formed according to vehicles travel direction is introduced. The cluster head is the first vehicle in the group. Inner the cluster, path is established based on radio signal quality to link all cluster members. Direction change and radio link interruption leads to cluster reorganizing. In [13], authors defined a cluster head election algorithm based on positions and velocity of neighborhood vehicles. The goal was to increase the cluster stability. On high-way, vehicles moving on the same line are followed and tend to be grouped in convoys at closer speeds. Cluster or convoy is naturally formed in highway context [14].

Based on the above mentioned points, designing specific protocols for VANETs are more recommended than to use other ad hoc protocol for VANET applications. The other problem in VANET environment which should be taken into consideration is cluster management in such a dynamic environment. In order to decrease re-clustering which causes huge overhead in changing topologies, we should consider dedicated VANET technics to increase cluster lifetime and prevent cluster changes as much as possible.

A number of researches such as Modified DMAC (MDMAC) [15], SBCA [3], have focused on strengthening cluster stability by avoiding frequent re-clustering. In MDMAC algorithm, Polska et al. proposed to only add long-living nodes to cluster and avoid adding nodes that are moving in different

directions, as nodes moving in different direction are going to stay in the cluster for a short period of time. The overhead caused by adding them to the cluster is high and decreases cluster stability.

In [16] a force-based algorithm is proposed to improve cluster stability. The algorithm is based on the idea that nodes apply a force to other nodes based on their velocity vectors and distance, and nodes that apply positive forces to each other can join the same cluster. If two vehicles are moving towards each other or in the same direction the total forces applied to any of them from the other vehicle is positive; whereas the total forces is negative when they are moving in the opposite direction. The idea is to improve cluster stability by adding vehicles moving in the same direction. Nodes are supposed to move together for a longer period of time unlike those moving in the opposite direction.

MOBIC [17] uses the signal strength of received beacon messages to find mobility metric between two nodes. The same idea is proposed by Zhenxia et al. in [18]. In his multi-hop clustering algorithm, the nodes send beacon messages and calculate their mobility metric with their N-hop neighbors. Relative mobility is calculated based on distance, speed, or signal strength (such as in MOBIC). However, in multihop clusters as mentioned in [18] these metrics are not supposed to work properly because of fading effects. In order to calculate relative mobility in [18], a vehicle finds packet delay of first and second beacon message and computes the delay ratio in delivery of these two messages. A value called "Aggregate mobility metric" is computed to choose the node with lowest value as cluster head.

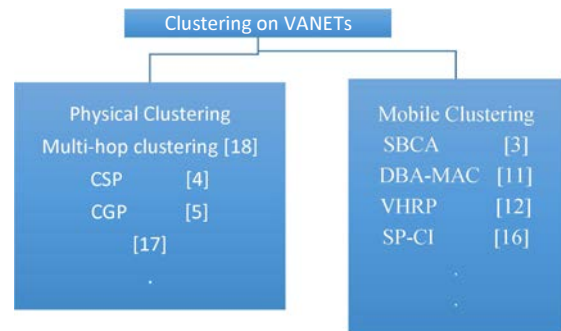


Fig 1. VANETs clustering classification.

## 3. PROPOSED SOLUTION

In our proposed solution, we used some special control packets which we describe below before we used them:

- *Hello packet*: The hello packet is composed of four fields: Node id, its velocity vector, its status, and a list of its neighbors (NL). The status field is one of three possible values: cluster head (CH), gateway (GW), or cluster member (CM)

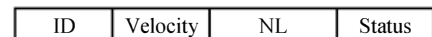


Fig 2. Hello packet structure

- *Cluster Head packet (CH Packet)*: Four fields form this packet: Packet identifier (Msg-ID), source ID, destination ID, and the ID of the elected cluster head (ID-CH)

Msg-ID	ID-source	ID-destination	ID-CH
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Fig 3. CH\_Packet structure

- *Gateway packet*: The gateway packet has three fields: Packet identifier (Msg-ID), source ID, list of cluster head identifiers (CHs-IDs- destination) which refer to a list of cluster-head identifier that are in the Gateway vehicle radio range.

Msg-ID	ID-source	CHs -IDs - destination
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Fig 4. GW\_packet structure

We propose a new clustering approach based on AODV protocol for Clustering maintenance in VANETs (AODV-CV) according to two different parameters for cluster-head election: (i) first parameter is the average speed of the convoy. (ii) And the second one is the node's velocity vector (a vector is characterized by its direction and module). For that we assume: (i) All vehicles are equipped with similar transceivers and have the same radio range, (ii) Cluster size is only limited by its cluster head radio range, (iii) Interval speed in highway is between 80 km/h and 120km/h (Although our solution works well for less nodes' speed), and (iv) vehicles in a cluster move in the same direction.

The essence of the proposition (see fig 5) is to form mobile virtual clusters. Initially, all vehicles in the highway, even the new incoming ones, start exchanging Hello message. Its status is set to cluster member (CM) at the beginning. If the incoming vehicle doesn't receive any Hello message, it updates its status to CH to perform cluster head functions, and whenever a new vehicle joins it, they start together the cluster head election process.

The vehicles reorganization in the same cluster and the election of the CH is done as follow: each vehicle computes the average speed of its neighbors according to the formula (1).

$$Average\_speed = \frac{\sum_{i \in NL} speed_i}{\|NL\|} \quad (1)$$

Each vehicle got its neighbors' speed sent in hello message; it verifies its actual speed. If it moves with the closest speed to average speed, it proclaims itself as the cluster head. Then the elected CH broadcasts a CH\_packet that involves in addition to the CH-ID the one hope neighbor list. Vehicles which don't belong to CH neighbor list have to fetch for another cluster. And vehicles within one-hop from the CH check in their routing table with how many CHs they communicate. Vehicle how have more than one CH in its routing table change its status to Gateway (yellow vehicle in Fig 5), then sends a GW\_packet to CHs within its routing table. The rest of nodes that are neither CH nor GW update their status to cluster member (CM). The solution is drawn by algorithms in Fig 6,7,and 8.

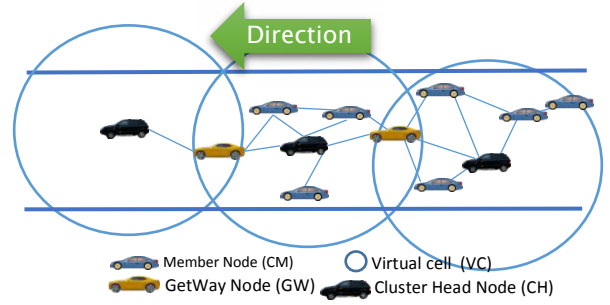


Fig 5. Virtual mobile cluster forming

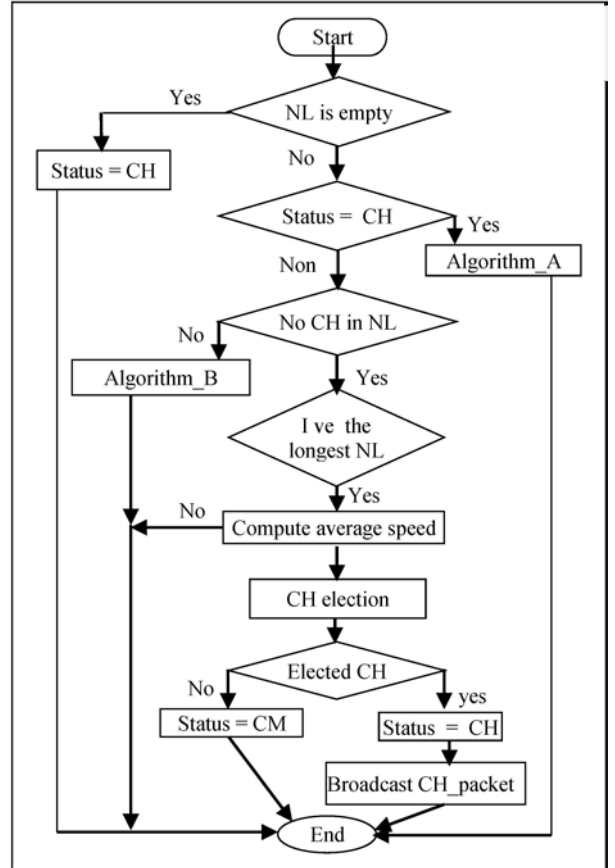


Fig 6. Proposed solution chart

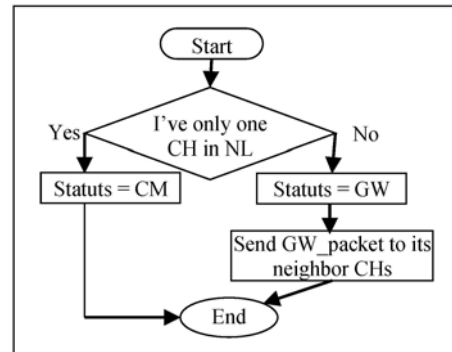


Fig 7. GW election chart (Algorithm\_B)

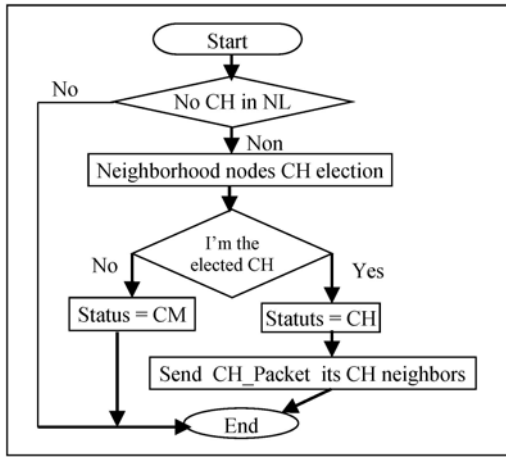


Fig 8. CH election chart algorithm (Algorithm\_A)

#### 4. SIMULATION ANALYSIS

In order to empirically evaluate the performances of our proposed solution, we adopt NS2 simulator. AODV protocol is supported and pre-defined in NS2. We implemented our protocol and compare it to AODV.

##### A. Simulation assumptions:

In our simulation tests, we focused on some of measurement parameters to analyze our protocol performances: Packet delivery ratio (or packet lost ratio, PLR), throughput (average throughput according to the formula (2)), and the connectivity parameter which is the complement to one of the packet lost ratio parameter (1-PLR). These simulations tests were done based on three major assumptions. Firstly we chose a 2-km highway fragment length as simulation environment. Secondly, we assumed that the speed moving of each vehicle is in the interval between 80 km/h and 120 km/h (22.22 m/s , 33.33 m/s). And thirdly, vehicles move in the same direction to reduce network traffic although our proposed algorithm works well in double directions road. Table 1 depicts NS2 parameters simulation.

$$throughput = ||packet|| \times \frac{\sum_i packet_i}{|time_{end} - time_{start}|} \quad (2)$$

Parameters	Values
Routing Protocol	AODV-CV
Propagation Model	Propagation/TwoRayground
MAC layer	MAC/802.11p
Radio rang	250 meters
Application Traffic	CBR
Packet's size	512 bytes
Node's speed	In [23 m/s, 32 m/s]
Network size	20 nodes
Simulation time	200 s

##### B. Simulation analysis

We draw two simulation scenarios; first we vary vehicles' velocity for a fixed network size, unlike the second scenario where we vary the network size and fix the vehicles' speed.

- *First scenario:* we fix the network size at 20 nodes and vary the network nodes' speed by increasing the speed 3 m/s each time from 23 m/s to 32 m/s speed.

As shown in Fig.9, our proposed solution AODV for Connectivity in Vanet (AODV-CV) provides high packet delivery ratio compared to AODV whenever nodes' speed don't overtake 30.5 m/s speed as drawn in Fig 9. After that AODV-CV decreases its PDR unlike AODV. This leads us to conclude that vehicles' high speed affect AODV-CV PDR and then the connectivity. But regardless to limited highway speed (120 km/h = 33 m/s), AODV-CV seems suitable than AODV to maintain connectivity.

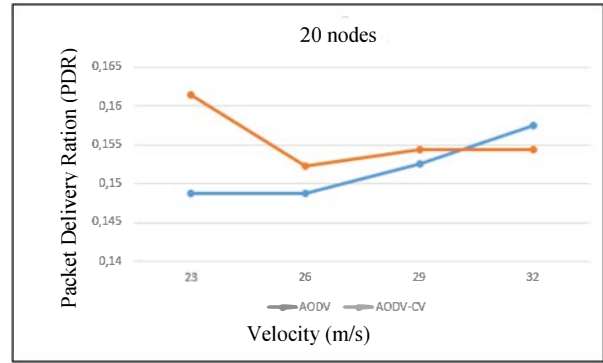


Fig 9. Packet delivery Ratio vs Velocity

Fig 10 shows AODV-CV good throughput performance. In the interval speed between 23 m/s and 31.7 m/s, AODV-CV provides a significant throughput compared to AODV. This is due to the fact that our algorithm quickly finds routes to destinations. But till 32 m/s speed, AODV-CV throughput parameter still unchanged from 31.7 m/s to 32 m/s although AODV increases its performance. 31.7 m/s speed is very close to 33 m/s the high speed limit in a highway and then there is few vehicles that move in high speed. Thus vehicles' velocity variation doesn't affect AODV-CV.

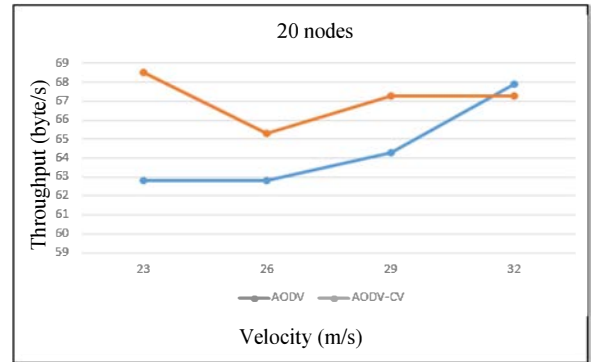


Fig 10. Throughput vs Velocity

- *Second scenario:* here we fix the network nodes' speed at 27 m/s and we vary the network size by adding 10 nodes each time starting from 20 nodes network size till 70. In this case and because all nodes have the same speed, clusters heads are predefined.



We notice in Fig 11 that both protocols provide slightly the same PDR with more performance mentioned by AODV-CV for less network density. PDR decreases when the network size increases. Thus, network size has no effect on AODV-CV compared to original AODV protocol.

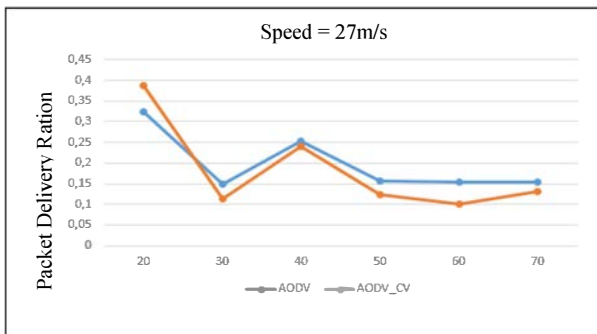


Fig 11. DPR vs Network size

In fig 12, we notice that AODV-CV provides a little more throughput than AODV for a less networks' size. But whenever the network grows, the AODV-CV throughput graph is down under AODV one. Generally graphs aren't distant from each other, and decrease when the network grows.

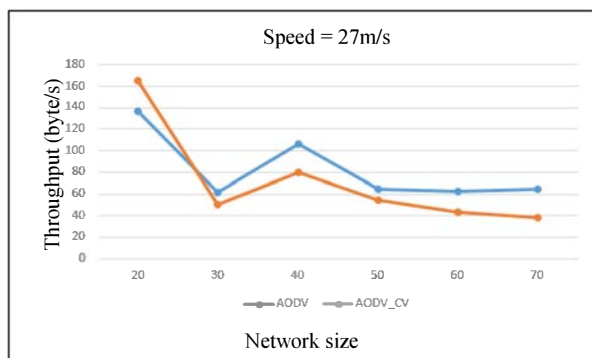


Fig 12. Throughput vs Network size

## 5. CONCLUSION

A novel cluster-based algorithm for connectivity maintenance in vehicular ad-hoc networks is proposed (AODV-CV). In this algorithm we aim to improve cluster connectivity maintenance by making stable and long-living clusters as much as possible. Idea's core resides in the cluster head election mechanism based on the average speed of a convoy of vehicles moving in the same direction and the virtual mobile cluster formation. Experimental results demonstrate that AODV-CV seems suitable to improve cluster maintenance and performances in highway where vehicles' speed limit doesn't exceed 120 km/h. In our future work and as extension to this paper, we plan to study other scenario and give another evaluation tool (mathematical one) to assess our proposed solution.

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