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Directional Aware Cluster Based MAC Protocol for VANETS

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ABSTRACT

This paper proposes a Direction Aware Clustering Medium Access Control protocol (DA-CMAC) for VANETs. In the opposite direction form clusters. Clustering based on the direction of travel can reduce the reconfiguration due to the short communication period. Cluster Head (CH) is elected based on the eligibility function and Cluster Membership is assigned based on the number of connected neighbours, average speed detection, and the average distance between neighbours.CH manages the channel access and allocates time slots to its Cluster Members (CMs). It aims to reduce access and merging collisions in the channel, by grouping the time slots into two sets based on the direction of vehicle movement. The simulation results show that DA-CMAC protocol increases the packet reliability and reduces the access collisions due to vehicular mobility.

Index terms: Clustering, Medium access control, Reconfiguration, and Vehicle ad hoc network.

1. INTRODUCTION

An ad hoc network is defined as a collection of nodes actively forming a network without any existing infrastructure or centralized organization. Is a special type of mobile ad hoc network Vehicular Ad Hoc network(VANETs).It is an important component of Intelligent Transportation Systems (ITS) [1]; it can apply information technologies in vehicles and transportation infrastructure. As shown in Figure 1,the messages are exchanged between vehicles, between vehicle and Road side Unit (RSU) [2]. It is to increase safety on the road and to provide comfort to drivers and passengers with increased transportation efficiency.

IEEE has developed the 1609 family of standards for Wireless Access in Vehicular Environments (WAVE) for VANETs. In WAVE, the IEEE 1609.4 trial standard [3] operates on top of IEEE 802.11p in the MAC layer. IEEE 1609.4 focuses on multichannel operations of a DSRC radio. The Synchronization Interval (SI) of the length of 100 msec that consists of a Control Channel Interval (CCHI) and aService Channel Interval (SCHI), each separated by a guard interval, as shown in Figure 2.

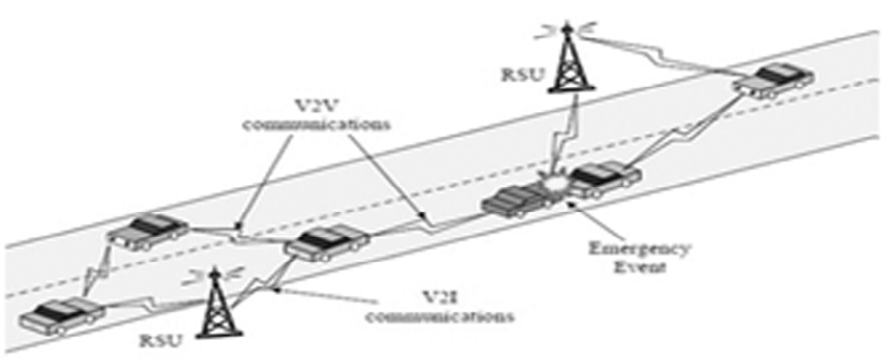

Figure 1: VANETs example

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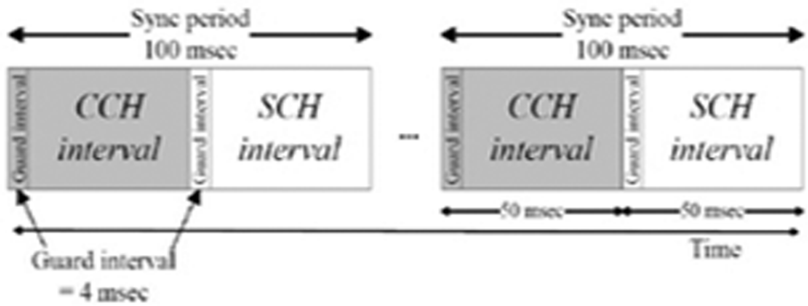

Figure 2:Time is divided into CCHI and SCHI

Some of the vehicles moving in opposite direction can be neighbours for a short period of time. Moreover, by grouping vehicles travelling in the same direction can increase the stability of the cluster structure. Furthermore, clustering schemes [4]–[5] combined with MAC protocols can reduce the channel access delay, data collisions and improve the reliability of safety and non-safety applications. It is very challenging to design a stable and efficient cluster based MAC protocol for VANETs.

In this paper, DA-CMAC Protocol that creates a stable and reliable cluster structure is proposed by forming clusters based on the direction of travel. In each cluster DA-CMAC selects a CH based on the ability function. Ability function is based on the number of connected neighbours, speed detection and distance to its neighbours. Moreover, the elected CH will schedule the channel access for its CMs. In DA-CMAC the time is divided into cycles; then the each cycle is equally divided into Control Channel Period (CCP) and Service Channel Period(SCP). The SCP and CCP are divided into equal time slots. The time slots in both SCP and CCP are formed into different disjoint sets like Right (R), Light (L) and RSU (U) based on the direction of vehicle movement. This disjoint set helps to improve the reliability of DA-CMAC protocol. Additionally, the vehicles moving in both direction acquire at least one slot in CCP and SCP and generate the safety and non-safety messages to be delivered within the fixed deadline delay. Moreover, assigning each vehicle with one slot shows the fairness in channel access.

2. RELATED WORKS

In [6], authors proposed a Hierarchical Clustering Algorithm (HCA), new formation of clusters with a range of maximum four hops. This protocol schedules transmission within the cluster to ensure reliable communication. It is suitable for non-real time safety applications. Packet loss is increased due to inter cluster interference. It did not consider the direction of movement which reduces cluster stability and CH duration.

In [7], authors proposed a TDMA Cluster based MAC for VANETs (TC-MAC) is introduced to reduce interference and provide fairness in access channel among vehicles in the cluster. TC-MAC is a combination of centralized technique of cluster management and TDMA channel access.

In [8], Region based Clustering Mechanism (RCM) is to improve the scalability of MAC protocol for VANETs. The network is divided into number of space division units. The results show that the contention is reduced and increase the throughput.

In [9], ADHOC MAC is mainly developed for Vehicle to vehicle (V2V) communications and it is based on the TDMA. The CMs in the cluster allocated the time slots for vehicles.ADHOC MAC reduces throughput due to vehicular movements.

3. CLUSTERING

Clustering is to group a small number of vehicles with common components and manageable entities called cluster as shown in Fig 3. Clustering solves the routing, allocation of bandwidth and channel access.

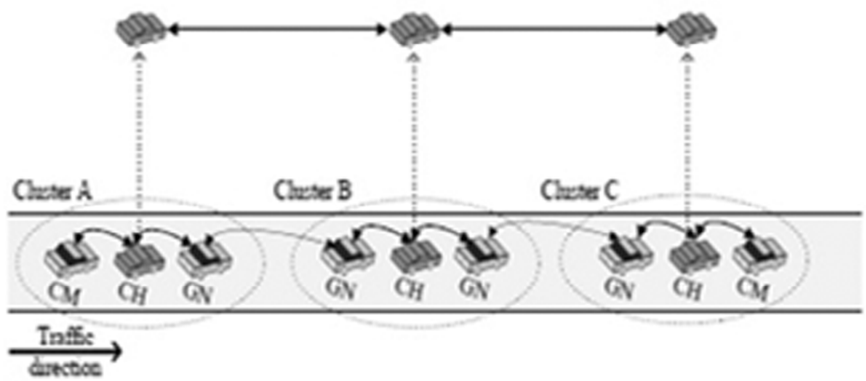

Figure 3: Cluster environment

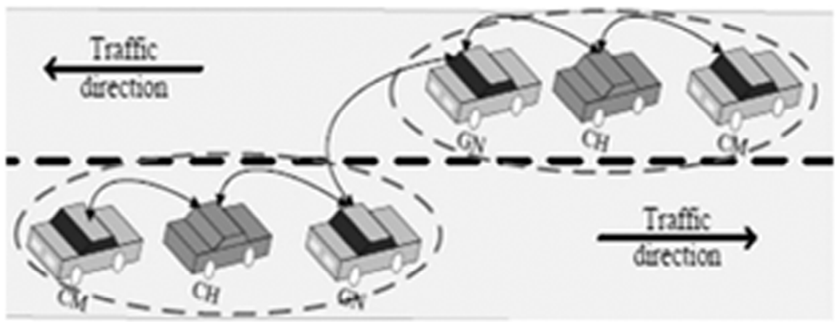

Figure 4: GNs are connected to CHs

Vehicles in a cluster are divided into different states such as Undecided States (US),Cluster Heads (CHs),Cluster Members (CMs),Backup Cluster Head (BCH), and Gateway Vehicles or Nodes (GVs or GNs).Backup CH (BCH) is based on the future position of the vehicle and number of connected vehicles. Undecided states (US) are the initial role of the all vehicles. GVs or GNs are linked to the more than one CHs as shown in Fig 4.

GVsare used to forward control or slot information from one cluster to another cluster. They help to increases the cluster topology and reduce the number of CH changes.

3.1. Cluster Formation in VANETs

The Lowest-ID algorithm is to be elementary and reliable for MANET;but this algorithm is not suited for VANET because of the movement of the vehicles. The Highest-degree algorithm is also not optimal for VANETs. VANET is not stable because of the vehicle movement. The connectivity level is changed, when the CH behavior changes at any moment.

The Utility Function [10] algorithm in VANET clustering has better performance than the previous two algorithms, Lowest-ID and Highest-Degree. It is based on a multiple-metric weighting algorithm, such as speed, velocity and position. In the process of the CH selection, calculation of the average position and average velocity of all vehicles in the connectivity level determines the most stable CH.

The grouping of vehicles based on the order of the mobility [11]. Vehicles with close speeds will be grouped together in one cluster. This may lead to having clusters overlapped. The aim of direction based clustering is to achieve relatively stable cluster topology, by grouping vehicles travelling in the same direction. It increases the lifetime of members and reduces the overhead.

3.2. Selection of Cluster Head

CH estimates priority for all registered vehicle based on the received messages. To calculate the priority two assumptions are considered. In one hop neighbor or cluster; no two vehicles can receive same priority. However, no two neighbouring vehicle can have the same speed during their travel in the network. The speed difference between two vehicles cannot be zero always. If the following conditions satisfied a vehicle becomes CH.

1. To calculate the average distance between all neighbours and itself in each vehicle using equation (1). These criteria will decrease the packet delay and the CH lifetime is increased[8].

$$D_{xi} = \frac{Dx1 + Dx2 + ... + Dxn}{n}$$

$$D_{yi} = \frac{Dy1 + Dy2 + ... + Dyn}{n}$$

$$\delta_i = \sqrt{(Dxu - Dxi)^2 + (Dyu - Dyi)^2} \quad (1)$$

2. To calculate the average speed between one hop vehicle and all its CMs using equation (2).This criterion is used to avoid the elected CHs losing connectivity. Thus, a vehicle with large speed detection is assigned lower priority [8].

$$S_x = \frac{S1 + 2 + ... + Sn}{n}$$

$$i = |Su - Sx| \quad (2)$$

4. CLUSTER MAINTENANCE

Due to the movement of the vehicles, the cluster is not same for long duration. The changes of topology of the cluster is depends on the number of vehicles.

A. A CH moving out of the cluster

B. A US joining the cluster as CM

C. A CM moving out of the cluster

D. Changing status from CM to GV

E. Merging two clusters

The changes of cluster topology will be detailed in this protocol.

4.1. Cluster Head movingout of the Cluster

The CH predicts changes in the movement it start to be an unstable CH, it will arrange for giving up its responsibility as a CH. The stability of the cluster increases, when the CH elects a BCH after formation of the cluster. BCH is the vehicle it has maximum rate among CMs. To calculate the future positions of the each CH of all its CMs based on the received speeds $P(t_n) = P(t_1) + {}_1(t_n\text{-}t_1)$, where $P(t_1)$ is the position of vehicle at t_1, t_n is the end of the vehicle, and ${}_1$ is the speed of the vehicle at time t_1. If higher of the current CMs of the CH become out of the transmission range at t_n but are still within the BCHs range, the present CH will hand the responsibility to the BCH. When the CH is ready to leave. Before this happens, the CH transfers local ID to BCH to be a CH. The reason for that is to have a one-hop cluster even after the present CH leaves. This case will be done by switching the local ID between the current CH, ID 1, and the new CH[12].

4.2. Undecided State Vehicle Joining Cluster as CM

The new vehicle listens to neighbouring CM vehicles update/safety messages. This message uses the slot and mini slot information of other vehicles inside the cluster. When the US vehicle moving in the same direction as the cluster is trying to combine the single hop cluster. In the cluster US can receive update messages from other CMs, and it's not in a transmission range of CH. When the distance between US and CH is not greater than 300m, US will try to transmit in one of the empty mini slot in the slot set L or R based on the travelling direction. Assume that the mini slot access to CH was successfully delivered and CH receives the request from US to join the cluster. If empty slots in the CH, it will assign the lowest possible ID and assign a time slot in the next frame. If no empty slot means cluster size has reached the largest number of vehicles. Then CH check, if there is any possible slot in the GHL or GTL. If available slots, CH allocate in the ID and slot to US as GVs. If no slots available in the two sets CH will not allocate ID and slots. When US collect the CH message and came to know that there is no available slot allocation, the US will one more time send the request to mini slot until it gets a slot in the CH.

4.3. Cluster Member removing the Cluster

When a CM mobility changes using $P^1(t_n) = P(t_1) + {}_1(t_n\text{-}t_1)$, where $P^1(t_n)$ is the position of CM^1 at t_1, t_n is the end of the next frame, and $s1$ is the speed of the CM^1 at time $t1$. CH position at t_n is $P^{CH}(t_n)$. If $|P^1(t_n) - P^{CH}(t_n)| > 300$m, the position of CM is not in the range which may lead it to leave the cluster. CM will broadcast that to the entire cluster using its particular time slot in CCH. If CM fails to do so, the CH will make the CMs local ID available after a certain distance of time (2T). If a US vehicle wants to combine with the cluster, the CH allocates the US vehicle to one of the available local IDs. The CH will send information about the table of the CMs, GVs, BCH and their local IDs to all vehicles in the cluster [12].

4.4. Changing Status from Cluster Member to Gateway Vehicle

Due to the movement of vehicles on the road, CMs of single-hop clusters may contact with different CHs. When a CM is in the transmission range of two different CHs that are moving in the same direction and it receives number of two consecutive update messages from the other CH. Then CMs will start the conversion from CM to GV. The conversion from CM to GV will be initial role by CM. CM request the CH for a membership by accessing the mini slot in other CH. When other CH receives request, the CH assigns available GV ID in GTL or GHL. The total number of GVs in both clusters is lower than the maximum number of the GV size in DA-CMAC, the transformation will be continued. This procedure detecting outsiders will be performed. During this communication, CH will instruct their CMs and other CM will inform the old CH about the conversion process. Then CH of the old cluster will make the ID working by the CM available for new US vehicles.

4.5. Merging two clusters

Due to the movement of vehicles in the road, CMs of single-hop clusters may contact with different CHs. When a CM is in the transmission range of two different CHs that are moving in the same direction and it receives more than two consecutive update messages from the other CH [12]. Then CMs will start the conversion from CM to GV. The conversion from CM to GV will be initial role by CM. CM call the CH for a membership by accessing the mini slot of other CH. When other CH receives request, the CH assigns available GV ID in GTL or GHL. The total number of GVs in both clusters is lower than the maximum number of the GV size in DA-CMAC, the transformation will be continued. This procedure detecting outsiders will be performed. During this communication, CH will instruct their CMs and other CM will inform its old CH about the conversion process. Then CH of the old cluster will make the ID working by the CM available for new US vehicles.

5. SIMULATION RESULTS

This section presents Matlab simulation results to evaluate the performance of DA-CMAC as compared with HCA in highway scenario. The wireless channel assumes a 6Mbit/s data rate and 10MHz bandwidth at 5.9 GHz for all communication. A highway traffic scenario is used in the 20Km highway with two lanes in each direction and 2000 vehicles randomly distributed in these lanes. The vehicle travel with a velocity between 20 - 40 meters/sec in the free traffic flow.

It considers the frame length for DA-CMAC is 100 msec and 50 msec for both CCP and SCP. In efficient and reliable transfer information they need the stable clustering. Simulation parameters are listed in Table 1.

Table 1
Simulation setup

Data rate	6Mbit/s
Packet size	200 bytes
Highway length	20km
Number of vehicles	1000
Number of cluster	10
Speed of vehicles	20-40(m/s)
Cluster radius	300m
Transmission range	150m

The stable clustering method lowers the communication load of reformation of the clustering and led to an efficient use of the available bandwidth. Cluster stability depends on the selection of a suitable CH and cluster formation is to increase cluster residence times by decreasing cluster change events. If vehicles are changing their mode very frequently and continue only for a short period of time in the CH state, reliability of CH is low.

As shown in Fig 5, the delivery rate decreases as the CMs increases. In DA-CMAC is provides the higher than compared to HCA protocol. This is due to its implement of selecting a stable CH and a backup CH to take over the main CHs responsibilities. The DA-CMAC protocol to maintain a high reliability and predictability compared to HCA in highway networks.

The cluster radius decreases when the number of connected set decreases. As shown in Fig 6, shows the number of CH changes decreases when the cluster radius is increased for the variable speed.

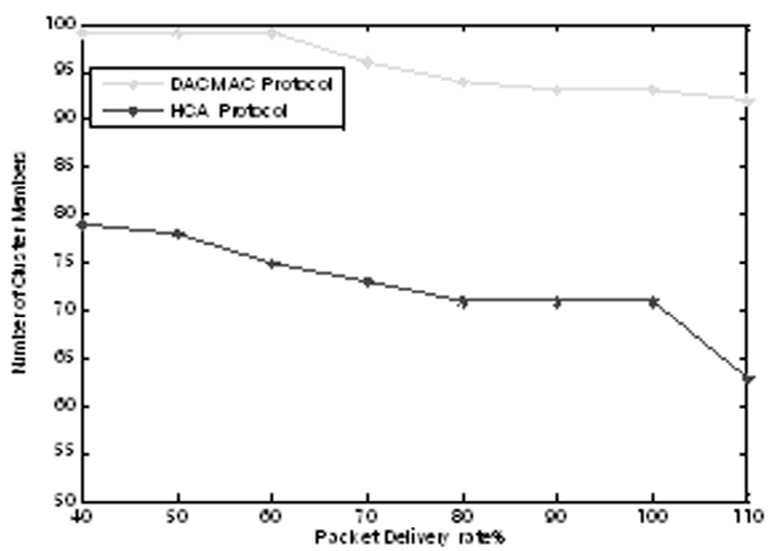

Figure 5: Packet delivery rate

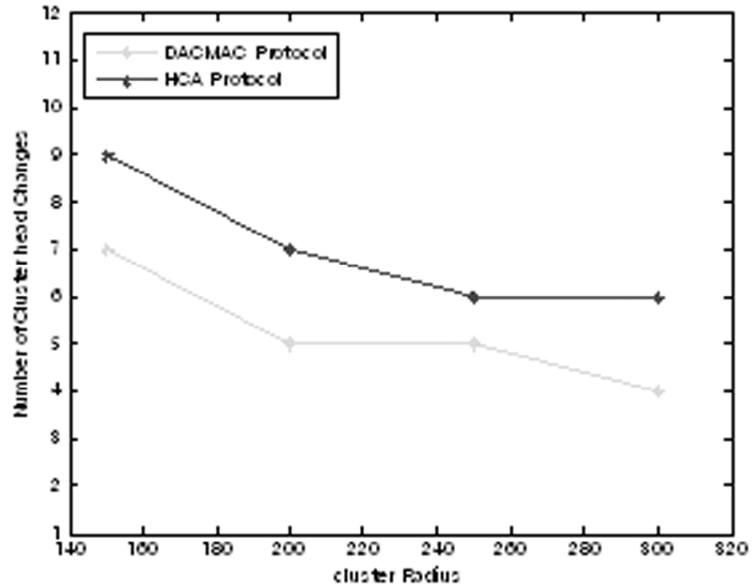

Figure 6: CH changes vs cluster radius

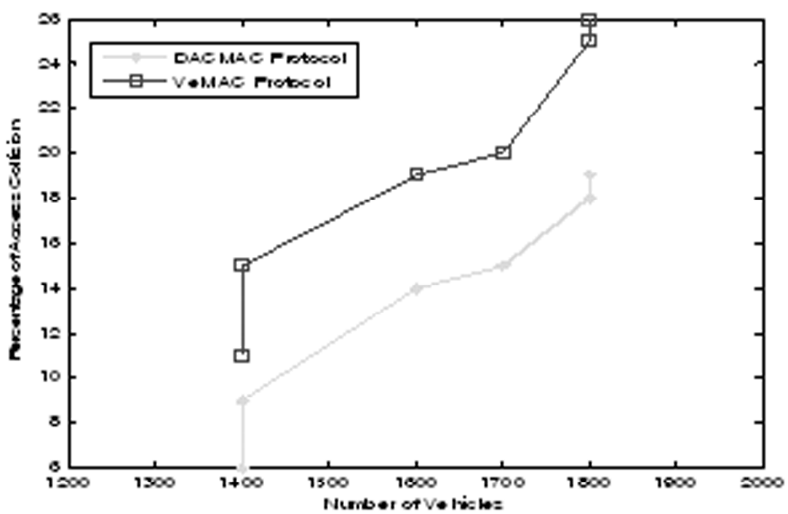

Figure 7: Access collisions

Access collision rate is deûned as the average number of access collisions that happen within a slot in one hop neighbour. The overall access collision rates of all the DACMAC and HCA protocols under trafûc densities as shown in Fig 7. Access collisions in HCA increases with the increasing trafûc density in one hop neighbourhood. In DA-CMAC is not higher as compared to HCA due to the assigned of different sets of mini slots for vehicles moving in opposite directions. The DA-CMAC protocol is lower collisions compared to other protocols.

6. CONCLUSION

In this work, DA-CMAC protocol is proposed to improve the reliability, predictability and scalability of VANETs. A cluster is formed based on the direction of travel and selects a stable CH based on the ability function. Additionally, the CH tests the number of CMs in its transmission range in the next frame using the velocity of CM. Furthermore, the channel access time is divided into cycles and each cycle is divided into CCP and SCP periods. CCP and SCP period is sub divided into three sets like Left, Right, and U based on the direction of the movement and characteristic of the vehicle. CH manages the channel access and schedules transmission for all its CMs and GVs. The simulation results show that DA-CMAC protocol provides the lesser number of access collisions in the CCH and higher number of successful packets compared to VeMAC protocol. Simulations show that DA-CMAC has the compared with other protocol it provides less access collision.

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