The improvement algorithm of cluster-head election in Cluster-based TDMA System for VANETs

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***Abstract*—The cluster-head plays a important role of a cluster. The cluster head is responsible for gathering and broadcasting safety messages in a cluster. If the cluster-head is elected fast, the cluster is organized rapid. In cluster-based Time Division Multiple Access (TDMA) system, the cluster-head is elected is faster than IEEE 802.11p technique. However, it is suitable for a form a small-sized cluster. In this paper, we propose a new elected-head algorithm to improve cluster-based TDMA system for forming a large-sized cluster. The analytical and simulated results show that the average number of time slots for electing a cluster-head is less than cluster-based TDMA system and IEEE 802.11p.**

***Index Terms*—VANET, cluster-based, IEE802.11p, cluster-head, TDMA system.**

I. Introduction

Vehicular Ad-hoc NETwork (VANET) consists of moving vehicles to create dynamical networks. VANET is one of special types of Mobile Ad-hoc NETworks (MANET) but it does not have an existing infrastructure or centralized administration. VANET supports many applications in safety, entertainment and vehicle traffic optimization. The VANET classifies of a set of vehicles equipped with communication device and a Global Positioning System (GPS) receiver, called On-Board Unit (OBU) and a set of stationary units along roads, called Road Side Units (RSUs). Based on OBU and RSU, VANET has two essential communications: Vehicle-to-Vehicle (V2V) and Vehicle-to-RSU (V2R), as shown in Fig. 1.

One of the important services is high priority safety application proposed for VANETs. Each vehicle broadcasts its information within one-hop neighborhood [1] for the V2V applications such as pre-cash, blind spot warning, emergency electronic brake light and cooperation forward collision avoidance [2]. In V2R application such as the curve speed warning and traffic signal violation warning, RSUs broadcast to all vehicles which approach them [3]. To support the high priority safety application in VANET, the Medium Access Control (MAC) protocol is designed to provide efficient broadcast services.

In VANET, vehicle (called node) frequently enters or leaves transmission range of neighbor nodes. Therefore, the connectivity interruption occurs and this creates the high mobility model of VANET. To decrease mobility model in VANET, vehicles are organized into cluster with at least one Cluster-Head (CH) node. CH is responsible for coordination tasks of a cluster. VANET divides the network to smaller and more stable cluster. Thus, vehicles in a cluster seems similar movement patterns is less mobility model compared to the whole network.

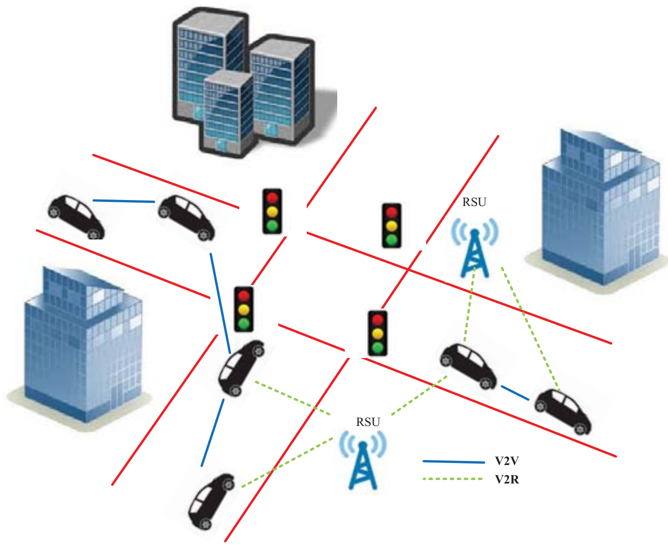

Fig. 1: V2V and V2R applications.

VANET is a very special case of MANETs. Difference with MANET, properties of VANET are variable network density, large-scale networks, predictable mobility model and rapid topology changes. Since the role of CH is very important in a cluster, many algorithm of cluster head election for MANET and VANET are proposed [4]. VANET clustering techniques focus on mostly only on position and direction of vehicle and are derived from MANET. Therefore, to enhance the stability, clustering algorithms need to refine to take care of the location, direction and speed as well.

Employing clustering technique in IEEE 802.11p is collided when the number of nodes increases in a cluster. To improve the transmission efficiency as the number of nodes is increased, recently cluster-based TDMA is proposed, such as in [5]–[7]. A CH needs to be selected to serve as the network coordinator in cluster-based TDMA. The elected CH is responsible for allocating time slots for data exchange among its Cluster Members (CMs). CMs can avoid collision and achieve fairness due to careful scheduling of time slots. In this paper, we propose a new clustering technique to elect CH faster than existing clustering techniques by using the lowest-ID algorithm.

The rest of paper is organized as follows. Section 2 presents system model. Section 3 is dedicated to present using the lowest-ID algorithm to elect CH. The analytical and simulated results are presented in Section 4 and we conclude this research and suggest some future works in Section 5.

II. System Model

In cluster-based TDMA system, we consider vehicles form cluster based on movement direction. A cluster consists of cluster head (CH), cluster member (CM), and gateway (GW), as shown in Fig. 2. Cluster head is responsible for gathering and broadcasting safety messages. In each cluster, CM can communicate with other CM or its CH, called intra-cluster communication. If the neighbor CH is in range of CH, the safety or non-safety application is broadcast among CH, called inter-cluster communication.

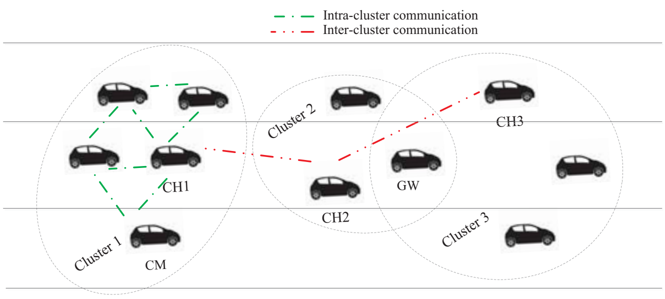

Fig. 2: Intra- and Inter-cluster communications.

Each time on the channel is divided to frames. Each node in a cluster has one slot in a frame to access the channel after a cluster is organized. To elect CH in a cluster, following [5], before each node accesses the channel, they choose random *0* or *1*. If more than 2 nodes choose *0*, this slot in frame is dismissed. Until only one node chooses *0*, it becomes cluster head. After CH is elected, each CM will assign the slot in frame. Each node also chooses random *0* or *1* until only one node chooses *0*, it assign a time slot successfully. After each CM assigns a slot in frame successfully, in the next frame, on slot *0*, CH will broadcast Slot-Allocation Map (SAM) packet included its cluster's information, depicted in Fig. 3.

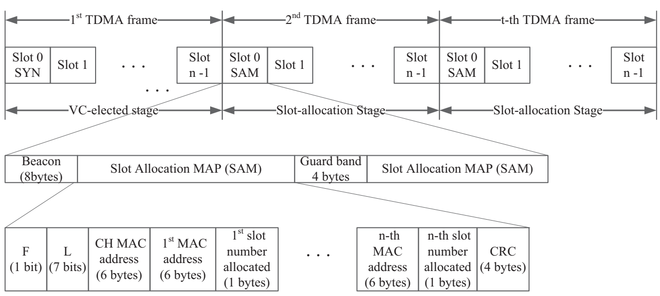

Fig. 3: Time structure in [2].

1) F (1 bit): if F=1, CH may access SAM; otherwise, it is for CHs to exchange their SAM.
2) L (7 bits): the length of SAM.
3) CH MAC Address (6 bytes): The MAC address of a CH.
4) CH Slot Number Allocated (1 byte): The ID of the CH' allocation slot.
5) CM MAC Address (6 bytes): The MAC address of a CM.
6) Slot Numbers Allocated (1 byte): The ID (from 1 to $n-1$) of the allocation slot.
7) CRC (4 bytes): to protect SAMs.

III. Using the Lowest-ID Algorithm to Elect CH

Following cluster-based TDMA (CBT) in [5], the CH is elected faster than IEEE 802.11p on the small-sized cluster. In this paper, we propose a new technique to elect CH is faster not only small-sized but also large-sized cluster. Each node is assigned a distinct ID. In initial state, each node chooses the random number before it broadcasts HELLO packet. The value is the backoff counter time. Once one node broadcasts its HELLO packet, the other nodes suspend their packets and compare their ID to sender' ID. We have two ID sets: lower and greater sets. In this paper, since we use the lowest-ID algorithm, the greater set is dismissed. In the lower set, each node based on the back-off value broadcast HELLO packet in the next slot. Lowest-ID node is chosen a CH when after among one slot no node transmits the HELLO packet. After that, the CMs choose time slots for bandwidth request. Hence, a node exists one of four states: initial, quasi-CH, CH and CM, as shown in Fig. 4. The scheme of attempt of a quasi-CH is depicted in Fig. 5.

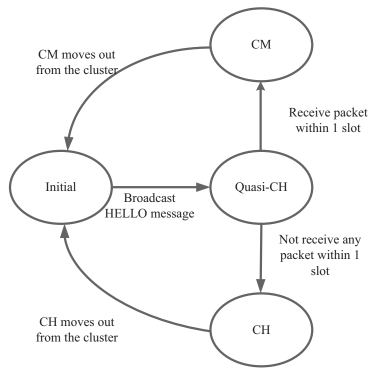

Fig. 4: State transition of intra-cluster communications.

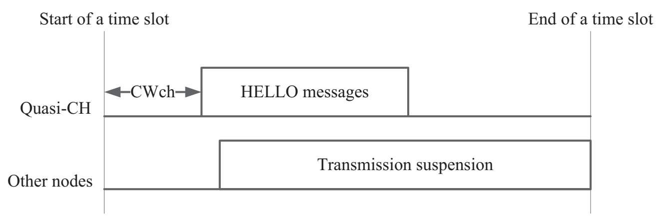

Fig. 5: The scheme of attempt of a quasi-CH.

IV. Evaluation and Simulated results

See [8] for detail and general description of the IEEE 802.11 MAC protocol, each node transmits with probability τ

$$\tau = \frac{2}{CW+1}. \quad (1)$$

Let *Ptr* be the probability that there are at least one transmission in the considered on the considered slot time.

$$Ptr = 1 - (1-\tau)^K. \quad (2)$$

where K is number of nodes in a cluster.

The probability *Ps* that a transmission occurring on the channel is successful is given by the probability that exactly one node transmits on the channel, condition on the fact that at least one node transmits

$$Ps = \frac{K\tau(1-\tau)^{K-1}}{Ptr} = \frac{K\tau(1-\tau)^{K-1}}{1-(1-\tau)^K}. \quad (3)$$

Let *Pch* be the probability of successful electing a CH,

$$Pch = Ps * \frac{1}{K}. \quad (4)$$

Let *x* be the time slots which CH is successfully elected. The probability density function of *Pch* can be expressed as

$$f(x) = (1-Pch)^{x-1} * Pch \quad (5)$$

We can calculate the average time *E[s]* slots required for the electing a CH. Note that a extra slot is added to the average, since our scheme has one slot for guarding time slot.

$$E[x] = \sum_{i=1}^{\infty} xf(x) + 1 = \frac{1}{Pch} + 1 \quad (6)$$

$$= \frac{1-(1-\tau)^K}{K\tau(1-\tau)^{K-1}} + 1 \quad (7)$$

To evaluate our proposal and CBT in [5], we use MATLAB to compute and simulate the average number of time slots for electing a CH. We ran the simulation 100 times to obtain the mean value of the final performance metric. We change the number of CMs in a cluster from 2 to 10. When the number of CMs in a cluster equal 2, 4 and 6, the average number of time slots for electing a CH in both 2 system is same. But when the number of CMs increases, our proposal requires time slots less than CBT and IEEE 802.11p. At 10-sized CMs in a cluster, our proposal about 12 time slots and CBT requires 103 time slots, as shown in Fig. 6. We observe that the mathematical results, computed from Eq. (7) are not close to the simulation result, because, simulation results are more realistic and random number is used for CMs to decide whether to transmit or listen. In addition, if lowest-ID node transmits, the processing of electing CH is stopped after one guard time slot.

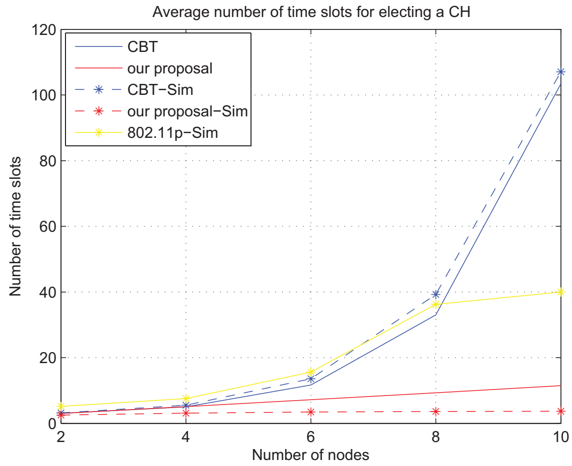

Fig. 6: Average number of time slots for electing a CH.

V. Conclusion

In this paper, a novel technique to electing CH for cluster-based TDMA system in VANET is proposed. By using the lowest-ID algorithm, the average number of time slots for electing a cluster head is less than the existing cluster-based TDMA system and IEEE 802.11p. In the future, our proposal can be extend by considering different traffic types, such as speed, velocity, ...

VI. Acknowledgement

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