

Scheduling Algorithm for Beacon Safety Message Dissemination in Vehicular Ad-hoc Networks Increasing QOS

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Abstract. In this paper we address one research challenges in vehicular ad hoc networks (VANETs), Safety message dissemination as follows. We investigate the quality of service for beacon based safety applications in VANETs. We point out the fact that safety applications have some distinctiveness which is not addressed in the current literature. We therefore propose a new metric focusing on the significance of coverage in safety scenarios called effective range which is based on the satisfaction of very restrict quality of service. We also emphasis that beacon based safety applications may tolerate some message loss Beacon safety message dissemination in Vehicular Ad-hoc Networks (VANETs) suffers from poor reliability especially in congested road traffics. The main origin of this problem is CSMA nature of Dedicated Short Range Communications (DSRC) in MAC layer. In this paper, a scheduling algorithm in the application layer is proposed to alleviate the problem. We first divide the road into a number of geographical sections. In each section, we form a cluster between moving vehicles. Then we perform a scheduling algorithm including two levels. In the first level, nonadjacent clusters can transmit at the same time. While the second level of scheduling deals with inside of each cluster in which we implement a TDMA-like approach. Simulation results show that the proposed algorithm improves the reliability in beacon message dissemination. Moreover, the accuracy of the information which each vehicle can obtain from its neighboring vehicles is significantly increased. Thus the proposed scheduling scheme leads to considerable enhancement of the safety level provided by Beacon Safety Messages (BSMs).

Keywords: beacon message dissemination, quality of service, scheduling, VANET.

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1 Introduction

Dissemination of alarm safety messages as well as comfort messages has been widely investigated in recent literature [1-3], but there are few studies about BSM. In [4] performance of BSM dissemination is studied. The authors conclude that reliability is the most fundamental challenge in disseminating BSM. Since DSRC standard is based on IEEE 802.11, it runs a CSMA-like MAC policy which does not possess any scheduling provision in the medium access. To mitigate this problem, we propose a scheduling algorithm implemented in the application layer. The algorithm will be based on cluster networking.

We adopt the concept of Space Division Multiple Access (SDMA) presented in [5] in which it is assumed that the road has been already subdivided into a series of discrete sections and any vehicle is permitted to access the channel only at the time slot corresponding to the section in which it is located. In [6] and [7], the same concept of SDMA has been represented. In contrast to the existing SDMA scheme, [8] subdivides the road on demand which any section is covered by a cluster of network. The scheduling algorithm of this paper can be implemented among vehicles for sending BSM using method [8]. In this paper, we divide the road into a series of sections in which only nonadjacent sections transmit the beacon message simultaneously. Inside each section we subdivide the section into several subsections where only one vehicle can be placed in each subsection. Furthermore, only one subsection can transmit at the same time.

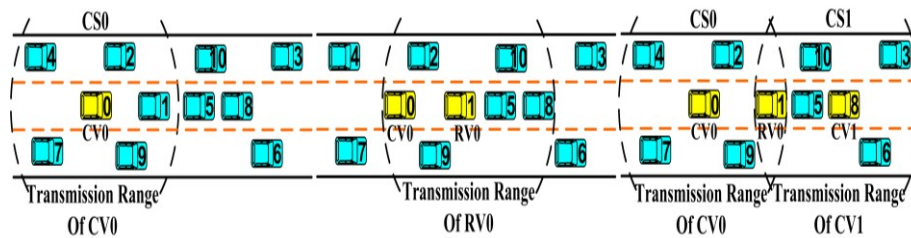


Fig. 1. Cluster formation (a) generation of CV0; (b) generation of RV0 (c) generation of CV1.

2 Proposed scheduling algorithm

2.1 Cluster formation

In this step, the network is subdivided into a series of contiguous clusters arranged along the length of the road. The details of this step are as follows. The network configuration is implemented using a Request Message (RM) containing the following control fields.

MT (1-bit): This 1-bit field determines whether the received RM has been broadcasted by a Cluster-head Vehicle (designated as CV) or a Relay Vehicle (designated as RV). If the MT is 0, the message is originated from a CV; otherwise it comes from an RV.

CV-ID (several bits): This field contains the identification number of the current CV.

MD (1-bit): The message direction field. This field indicates the direction of RM transmission with respect to traffic flow. '0' means downstream direction, '1' means upstream direction.

GP (several bits): GPS position field. This field records the GPS position of the CV (or RV) which issued the RM.

The process of cluster formation is depicted in Fig.1. As the figure shows, it is assumed that vehicle number 0 becomes CV_0 with ID_0 ($CV-ID = 0$), therefore CV_0 forms cluster space 0 (designated as CS_0). The scope of CS_0 is equal to the transmission range of the CV_0 . CV_0 sets the control fields of RM, for example $MT = '0'$, $CV-ID = '0'$, $MD = '0'$ and the GP by its current position and then broadcasts it. In Fig. 1(a), vehicles 4, 0, 7, 2, 9, 1 are within the transmission range of CV_0 thus they receive the RM and become members of CS_0 . Furthermore vehicles 2, 9, 1 recognize that they are located in front of CV_0 by checking the GP field of the received RM and their own GPS information and also the MT field of the received RM. To find the vehicle at the head of the scope, each vehicle sets a timer whose initial value is inversely proportional to its distance with the RM's sender, currently the CV. Thus, the timer of the farther vehicle will expire first and it will become RV. For instance, in fig.1 (a) the vehicle number 1 is the farthest from CV_0 among vehicles in the CS_0 . Consequently, its timer expires earlier and it'll win the competition. Thereafter, it issues Winner Message (WM) to announce its victory to the others (i.e. vehicles 2, 9). Finally, vehicle 1 takes the role of the relay vehicle and becomes RV_0 (see Fig. 1 (b)). Next, it modifies some specific fields of the RM including MT and GP fields (e.g. $MT = '1'$, $GP =$ the GPS information of RV_0) and rebroadcasts it. As shown in Fig. 1 (b), vehicles 0, 1, 2, 5, 8, 9, 10 are within the scope of RV_0 , thus they receive RM, yet vehicles 8 becomes CV among vehicles in front of RV. Note that the vehicles which are behind CV or RV do not participate in the competition and hence ignore the RM.

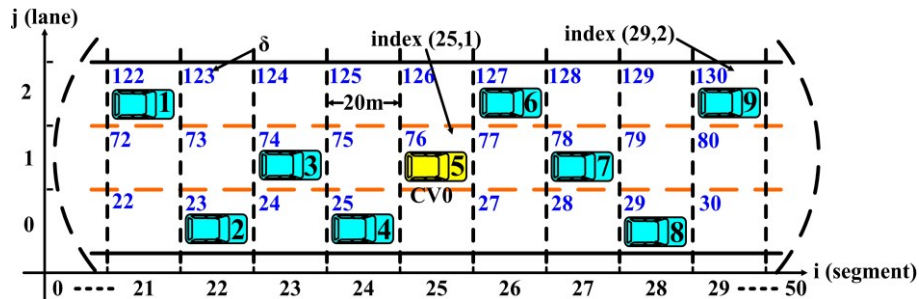


Fig. 2. Road block partitions and time-slot label assignment for $M=3$ and $N=50$.

2.2 BSM transmission

During the cluster formation step, a series of contiguous clusters are arranged along the road so that any cluster has a unique CV. In order to indicate termination of the cluster formation step, the CV₀ puts the time T in a field of RM. T is sent consecutively by CV_is and RV_is. Finally, all CVs will be aware of T to know when the network clustering is to be terminated. After the end of the cluster formation, each CV broadcasts a Hello Message (HM) to announce its current position to the other vehicles in its corresponding CS. Then in order to transmit the BSM free of collisions, a kind of Time Division Multiple Access (TDMA) mechanism is employed. To reach this goal, each CS is subdivided into N segments

$$N = \frac{2R}{L_s} \quad (1)$$

Where R is the transmission range of the CV and the L_s is the minimum allowed distance of two vehicles. Recall that 2R is the length of each CS. If the road has M lane, there are B road blocks in each CS

$$B = M \times N \quad (2)$$

Where only one vehicle can be located in each block. Each road block is identified with index (i, j) where $0 \leq i \leq N-1$ and $0 \leq j \leq M-1$. As shown in Fig. 2, each road block is assigned a time-slot label as:

$$\delta = i + j \times N + 1 \quad (3)$$

Then each vehicle sends its BSM in accordance with its own road block therefore each vehicle should be able to identify its own block. For this purpose, it should be able to determine the index (i, j). We assume that each vehicle is equipped with digital maps and it can use its own Global Position System (GPS) receiver to recognize its lane, thus j can be identified for any vehicle. Furthermore, each vehicle can determine i using the following formula:

$$\text{Segment } (i) = \left\lfloor \frac{R}{L_s} \right\rfloor + \left\lfloor \frac{X_v - X_{cv}}{L_s} \right\rfloor \quad (4)$$

Where x_v and x_{cv} are x-coordinate of the vehicle and CV_i, respectively. For example, Fig. 2 shows a part of CS₀, supposing R=500m, L_s=20m, vehicle 9 can identify index (i, j) using its own GPS receiver and (4) (x_{cv} has been already received by HM). Thus it can obtain δ using (3) and send its message at the 130t+Thello (x_{cv}=20×25, x_v=20×29), where t is the duration of sending message and Thello is when

HM was issued. As shown in Fig. 3, collisions may happen if vehicles belonging to adjacent CSs send BSMs simultaneously.

To avoid this problem, the even-numbered CVs will send HM at Thello and the odd-numbered CVs will send it at Thello+ Δ , where

$$\Delta = B \times t \quad (5)$$

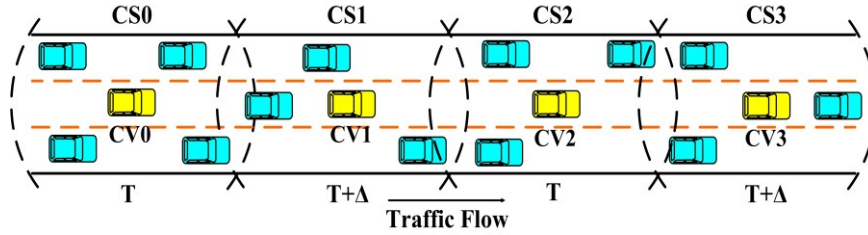


Fig. 3. Clusters synchronization.

3 PERFORMANCE EVALUATION

Performance evaluation of the proposed scheduling algorithm is done by GloMoSim library 2.03 [11]. We used IEEE 802.11 (which is the base of DSRC standard) as a MAC layer protocol and Two-ray-ground as a radio model. We also made use of realistic movement patterns published by European FleetNet [10] Project. We have assumed that each vehicle sends a BSM with size 512 bytes every 500ms [4]. In order to compare the performance of our algorithm, we also simulated a scenario in which no scheduling is applied. For this case we send information with 10% jitter in the transmission starting time. Simulations were performed with following 3 scenarios:

- 1) Traffic density is 2 veh/km/lane and the number of vehicles is 86.
- 2) Traffic density is 6 veh/km/lane and the number of vehicles is 271.
- 3) Traffic density is 11 veh/km/lane and the number of vehicles is 473.

In the following, we have compared performance of beacon message transmission in the above-mentioned scenarios with and without the proposed scheduling algorithm. Three performance metrics are considered as follows: number of collisions, beacon messages reception rate and the accuracy of neighbor information. The first two metrics are intended to measure the QoS of the BSM transmission while the aim of the third one is to quantify the success level of beacon safety dissemination application. Note that the ultimate goal of any beacon message dissemination algorithm is to provide exact information for each vehicle about its neighboring vehicles. Thus having a metric that evaluate this factor is of great importance. To the best of our knowledge this metric is firstly defined in this paper. We compute the

accuracy of adjacent list information as follows. First, we calculate the distance between any vehicle and its neighbors from the following well known equation:

$$d_i^j = \sqrt{(y_i - y_j)^2 + (x_i - x_j)^2} \quad (6)$$

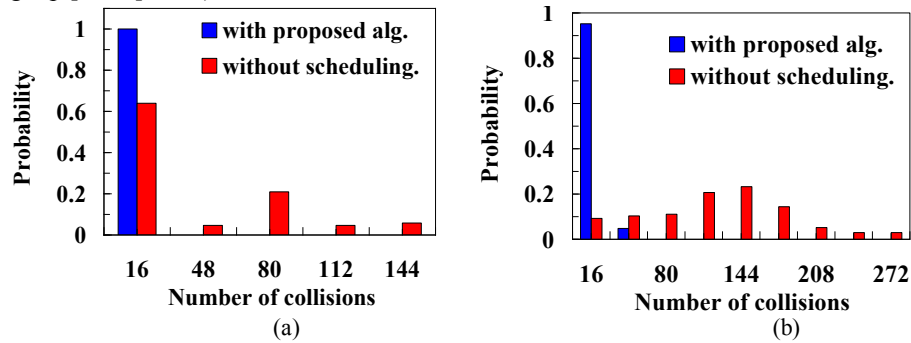
Where (x_i, y_i) are coordinates of vehicle i , and (x_j, y_j) are coordinates of vehicle j in the neighboring list of vehicle i . This distance is computed once really from the movement file, denoted by d_{i-real}^j . Then it is obtained another time from the information which vehicles i has in its neighboring list during the simulation, denoted by d_{i-sim}^j . Afterward, the relative error in distance between vehicle i and one of its neighbors (i.e. vehicle j), is calculated as:

$$E_i^j = \frac{d_{i-real}^j - d_{i-sim}^j}{d_{i-real}^j} \quad (7)$$

Then we take the average by (8) to obtain the error of vehicle i , where n is the number of neighbors of vehicles i .

$$E_i = \sum_j E_i^j / n \quad (8)$$

We consider some grouping and judge the average value of each group as its designated value (shown in X-axis). The Y-axis in the probability of events related to each group. Fig. 4 shows probability mass function for the number of collisions in three aforementioned scenarios. In this figures, each group contains 32 values (e.g., [0, 31], [32, 64] ...). The horizontal axis is designated of each group (e.g., designated of group [0, 31] is 16).



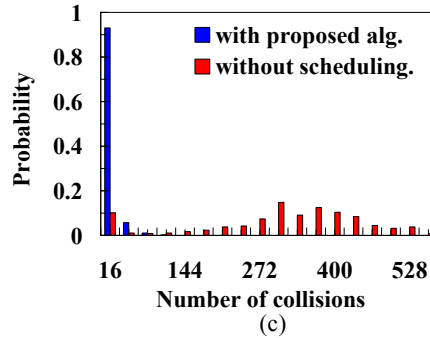
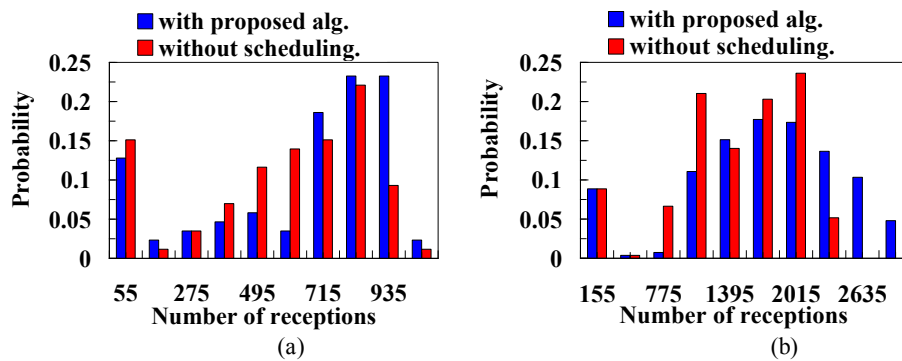


Fig. 4. Probability mass function for number of collisions in (a) scenario 1 (b) scenario 2 (c) scenario 3.

As can be concluded from the figure, the probability of large number of collisions are considerably lower in the presence of the proposed scheduling algorithm. In addition, by comparison between 3 aforementioned scenarios, one can easily find out that as the traffic becomes denser, the number of collisions increases. These results are expected due to CSMA nature of the MAC layer. Fig. 5 shows the probability mass function for the number of received beacon message. If a vehicle obtains more messages, it will have more updated information about its neighbors. As shown, there is larger number of vehicles with higher received messages in presence of proposed scheduling algorithm. Moreover, Fig. 6 illustrates probability mass function for the average relative distance error to all member of adjacent list. As the figure suggests, the probability of large average distance errors is considerably lower in presence of proposed scheduling algorithm. As we know when the average distance error is lower, then each vehicle has more accurate information about its neighbors. In other words, the adjacent list accuracy increases in presence of proposed scheduling algorithm.



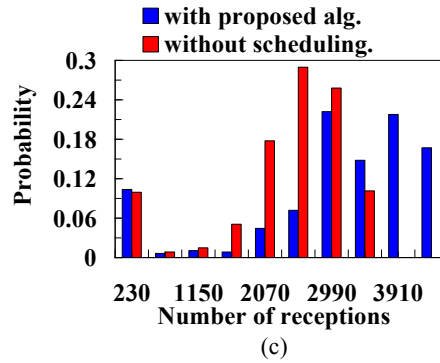
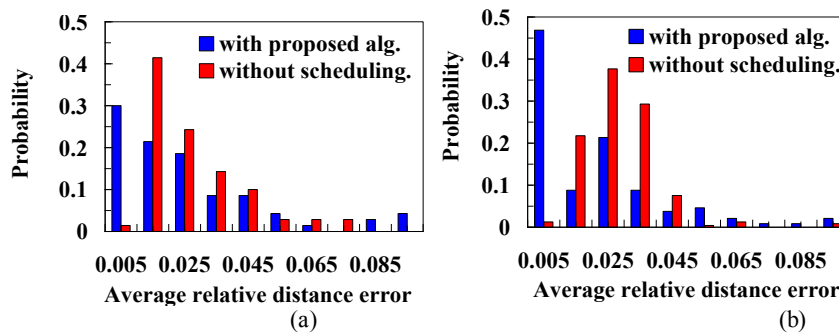


Fig. 5. Probability mass function for number of message receptions in (a) scenario 1 (b) scenario 2 (c) scenario 3.

3 CONCLUSIONS AND FUTURE WORKS

Beacon safety message dissemination by all vehicles causes saturated medium and thus the reliability is deteriorated noticeably. The main cause of this is collision in the MAC layer which is inevitable due to CSMA-like nature of DSRC. To alleviate the problem, in this paper, we proposed a scheduling algorithm in the application layer aiming at increasing the reliability. In the proposed algorithm, vehicle disseminates their beacon messages in a pre-determined time slots. Thus collisions are avoided except for few vehicles mainly because of dynamic nature of traffic. The results of our simulation show that the proposed algorithm decreases the number of collisions and increase the reception rate as well as the accuracy of vehicle's information about their neighboring vehicles. The latter, give us a direct sense on the benefits of our algorithm in provisioning an acceptable level of safety for vehicles.



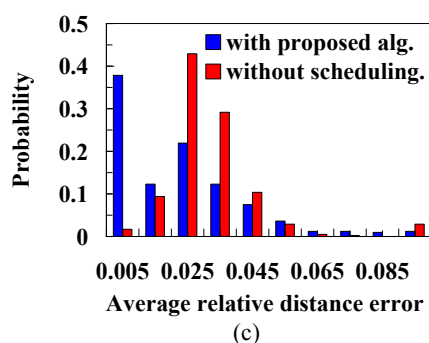


Fig. 6. Probability mass function for average distance errors in (a) scenario 1 (b) scenario 2 (c) scenario 3.

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