A Scheduling Algorithm for Beacon Message in Vehicular Ad Hoc Networks

Heithem Nacer[1(✉)] and Mohamed Mazouzi[2]

[1] Department of Informatics, Faculty of Siences of Gabes, University of Gabes, Gabes, Tunisia
nacerheithem@gmail.com
[2] Higher Institute of Business Administration of Sfax, Member of CES-Laboratory, University of Sfax, Sfax, Tunisia
mohammad.mazouzi@yahoo.fr

Abstract. Vehicular Ad hoc NETwork (VANET) was proposed in order to prevent accidents and to improve road safety. Indeed, IEEE 1609.4 was developed to support multi-channel mechanism to provide both safety and non-safety applications. The CCH interval is also a key parameter for the 802.11p MAC protocol. In order to get a wide view of the different techniques used to broadcast a message, we evaluate the performance of the 802.11p MAC protocol with various vehicle densities and different CCH interval settings. Moreover, we propose SABM, a Scheduling Algorithm for vehicles attempting to transmit a Beacon Message, which firstly adjusts the CCH interval according to the road traffic and then schedule the safety messages based their priorities. The simulation results show that SABM outperforms the IEEE 802.11p MAC protocol. On one hand, we can significantly reduce the delivery delay and the collision probability, on the other hand, at the same time equilibrating the channel utilization ratio during CCH interval.

Keywords: Vehicular ad-hoc networks · IEEE 802.11p · MAC · Beacon messages · Broadcast · Collision · Delay · Throughput

1 Introduction

Vehicular Ad Hoc Networks (VANETs) are considered as a special case of mobile ad hoc networks (MANET) [1]. The IEEE 1609.4 protocol was presented to improve the dissemination of messages in VANETs by adding the concept of multi-channel standard IEEE 802.11p. These networks provide many types of applications, such comfort applications and road safety applications to avoid traffic jams and reduce time spent on roads. The DSRC standard, Dedicated Short Range Communication [2], was specifically designed for communications in vehicular networks by reserving specific radio frequencies to these networks [3]. The Federal Communications Commission (FCC), responsible for the allocation of frequency bands in the US, has assigned a bandwidth of 75 MHz spectrum in the 5.850–5.925 GHz. DSRC presents seven different channels; each one is of 10 MHz, as shown in Fig. 1. These seven channels include a control channel CCH (Ch.178) and six service channels SCH (Ch.172, Ch.174, Ch.176, Ch.180, Ch.182 and Ch.184).

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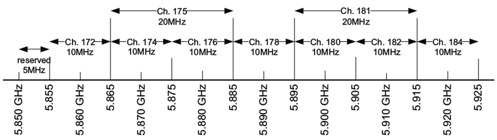

Fig. 1. The channel assignment of DSRC [4]

It divides the synchronization interval, with duration of 100 ms, into two equal times of 50 ms. The first one is for sending safety messages on the CCH channel in order to maximize the receipt of these priority messages. During the second interval, the vehicles are free to choose their listening channel. To allow the switch of listening channel, a guard interval of 4 ms is triggered. During the guard time, the channel is considered busy, and no vehicle can transmit message. The CCH interval is used for periodic broadcast of control information. However, in the high density of vehicles, the limited length of the CCH may be unable to provide sufficient channel capacity to provide a wide range of road safety messages. Indeed, if the node density is low, the CCH resource will be wasted. We shall focus on safety messages because they have strong constraints in terms of messages delivery time and quality of service.

The rest of this article is organized as follows. In the second section, related works are discussed. After that, IEEE 802.11p MAC is reassessed in the third section. Then, in the fourth section our proposed algorithm SABM for the MAC 802.11p will be detailed. Finally, the conclusions and possibilities for future studies are provided in the last section.

2 Related Works

Dedicated Multichannel MAC protocol (DMMAC) has been proposed in [6] to perform a variable length of the CCH interval based on adaptive broadcast mechanism for a safety message transmission without collision and limited delay. However, the dynamically adjusting of the synchronization interval has not been considered.

Based on [8], Variable CCH Interval (VCI), a multi-channel MAC mechanism is proposed that divides the CCH interval in two, one for safety messages and the other for the warning service (WAVE Service announcement). Depending on network conditions, this mechanism can dynamically adjust the relation between CHC and SCHs intervals. Although the VCI mechanism is able to provide an efficient use of CCH and SCHs channels to some extent, it allows working well only in limited scenarios with low utilization channel.

The authors in [10] proposed a MAC protocol (VER-MAC) that enables the nodes to broadcast safety messages twice during both CCH and SCH intervals which increases the reliability of the secure broadcast. However the VER-MAC average delay is greater than that of the IEEE 1609.4 since it requires the addition of complex data structures, thus it suffers from further delay of emergency packets.

In [11], VEMMAC (Vehicular Enhanced Multichannel MAC) has been proposed. It adopts the IEEE 1609.4 standard with sequences of CCH intervals and alternative

SCH. VEMMAC allows nodes to transmit non-safety messages during the CCH interval and dissemination of safety messages twice with each CCH and SCH interval. However the system is unable to monitor the high collision in the beginning of CCH and that of SCH intervals. Therefore, the nodes could lose emergency packets on the CCH interval due to the extended transmission mode.

3 Performance Evaluation of IEEE 802.11p MAC Protocol

This section presents the performance evaluation of the IEEE 802.11p MAC [13] protocol in safety applications. Its evaluation is based on OMNET++ [14] for network simulation framework and Veins [15] as the core of vehicular simulation framework, which extends the network simulator to cover vehicular communication. For the road traffic simulator and providing realistic node mobility, SUMO (Simulation of Urban Mobility) [16] is integrated to OMNET++ and Veins framework. To evaluate our work performance, we vary the traffic load on the channel, so we change the number of vehicles sharing the same network range and introduce the mobility.

As shown in Fig. 2, the generated traffic scenario used in our performance evaluation is presented. The realistic highway map has been imported from Open Street Map (OSM) [17] covering 1000 m highway. Each direction of the highway consists of two lanes. The scenario includes a number of vehicles varying from 20 to 200 where they are moving along a 1000 m long road with maximum speed of 120 km/h. In this scenario, each vehicle has a maximum communication range of 1000 m and disseminates messages with 39 bytes packet size. Every 100 ms, each vehicle sends one status safety message called Beacon. The Beacon messages are generated randomly during the CCH interval called (CCHI). The CCHI is set respectively as [10, 20, 30, 40, 50, 60, 70, 80, 90, 100] in order to evaluate the performance of 802.11p MAC at various CCH intervals. Table 1 shows the value parameters that are used in the simulation scenarios.

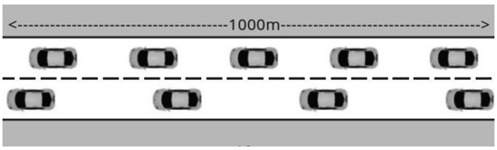

Fig. 2. Simulation test scenario

The following three metrics are used to evaluate the 802.11p MAC performance.

- Average End-to-End Beacon Delay: measures the average duration taken by a message to travel from the source node to destination node.
- Throughput of Beacon: measures the average number of successfully delivered packets.
- Collision probability: measures the average collision probability can be occurred.

Table 1. Parameters settings.

Parameter	Value
Size of beacon message Lbeacon	39 bytes
Size of MAC header Lmac	32 bytes
Data rate (Rate)	6 Mbps
Communication range	1000 m
Maximum transmission power	760 mw
Receiver sensitivity	-82dBm
Simulation time	20 s

Figure 3 shows the average beacon delay for different vehicle density and CCH interval settings. In general, we note that the beacon delay in low density is higher than in high density so it can be seen that the delay increases according to the increase in vehicle density.

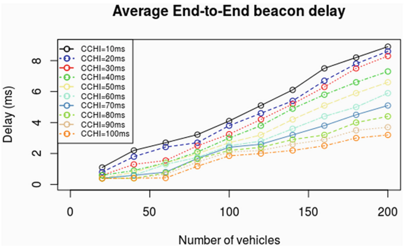

Fig. 3. Average End-to-End Beacon delay

As shown in Fig. 4, system throughput performance comparison of the different scenarios with various numbers of vehicles and CCH settings is evaluated. In this scenario, it can be noticed that for safety application the beaconing throughput increases according to the increase in number of vehicles, this is due to large number of nodes in the network then large number of beacons will be broadcasted.

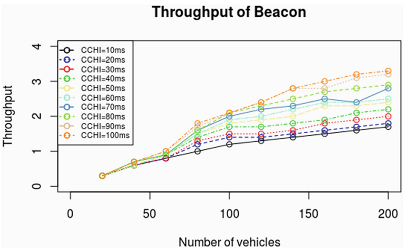

Fig. 4. Throughput of Beacon

Figure 5 presents the average collision probability obtained from the different scenarios. It can be seen that the beacon loss probability due to collisions increases with

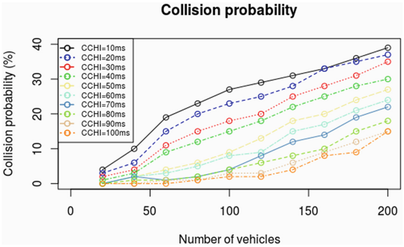

Fig. 5. Collision probability

the traffic load increase and CCH interval decrease. Moreover, the scenario with higher density and shorter CCH interval suffer from higher lost messages than the scenario with lower number of vehicles and longer CCH interval.

To conclude, in VANET safety applications, the performance of the IEEE 802.11p MAC protocol can be improved significantly in terms of collision, delay and throughput first by adjusting the CCH interval according to the vehicle density and then by scheduling the beacon message.

4 SABM: A Scheduling Algorithm for Beacon Message in Vehicular Ad Hoc Networks

In this section, we propose an enhanced scheduling algorithm for beacon message during CCH interval (*SABM*). At the first we adjust the CCH interval according to the road traffic. Then, we schedule safety messages by their priority for accessing the wireless channel. *SABM* aims firstly to minimize the collision probability and the delivery delay. Secondly, it maximizes the number of vehicles that receive the message. Thirdly, it equilibrates the channel utilization ratio during CCH interval.

For that reason, *SABM* contains three steps: CCH interval adjusting, CCH interval dividing to sub-intervals, Priority-Based message scheduling.

4.1 CCH Interval Adjusting

This algorithm contains two sub-steps: Vehicle counting and CCH interval calculating.

Vehicle counting: In this work, our first step is to adapt the CCH interval in accordance with the average number of vehicles in a highway. So this algorithm aims to calculate the number of vehicles registered by each Road Site Unit (RSU). The detail of the vehicle counting algorithm is presented in Algorithm 1. As shown in this algorithm, N_i indicates the number of vehicles registered by RSU_i. Furthermore, to simplify the algorithm the collision is supposed to result only between two vehicles. As presented in Fig. 6, the N_i will be sent to the control center to calculate the new duration of CCH interval in accordance with the average number of vehicles in a highway.

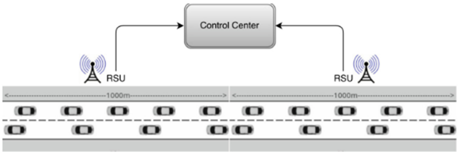

Fig. 6. CCH interval adjusting example

Algorithm 1. Vehicle counting algorithm:

```
Ni←Numbers of contention vehicles 0
if received beacon message successfully then
Ni = Ni+1
else if (failed to receive a clear message without collis ion) then
Ni = Ni+2
end if
```

CCH interval calculating: The previous step has given us N_i, the number of vehicles registered by RSU_i. All N_i will be collected periodically by the control center, responsible for calculating the CCH interval. Suppose a route segment contains j RSUs; the average number of contention vehicles N_{ave} can then be determined as:

$$\frac{N_{ave} = \sum_{1}^{j} N_i}{j} \quad (1)$$

To determine the duration T_{cch} of the CCH interval, we will use N_{max} the maximum number of existing vehicles in a well-defined road segment. The Eq. 2 is used to calculate the CCH interval length T_{cch}.

$$T_{cch} = \alpha \times SI \quad (2)$$

Where $\alpha = \frac{N_{ave}}{N_{max}}$ and *SI* is the synchronization interval 100 ms.

The details of CCH interval calculating algorithm are shown in Algorithm 2.

Algorithm 2. CCH interval calculating algorithm:

```
N←0
Nave←0
j←Numbers of RSUs
for (i=1; i<=j;i++) do
  receive Ni from RSUi
N = N+Ni
end for
Nave=N/j
Nmax←Maximum number of existing vehicles in a highway segment
 = Nave/Nmax
SI←100ms, the length of the synchronization cycle
Tcch= α × SI
Broadcast Tcch to all RSUs
```

4.2 CCH Interval Dividing

After calculating the CCH interval and in order to use a scheduler in the MAC layer level to decide what message to transmit the first, we divide the CCH interval with its new value T_{cch} to N_{ave} periods, each one is of length (t = *MessageLength/Rate*). During this period, a vehicle can send its message. We assume T = $\{T_1 \ldots T_{Nave}\}$ a set of period's time for sending a message.

4.3 Message Priority-Based Scheduling

After the division of CCH interval to sub periods and to determine which message to transmit the first, safety messages will be scheduled based on the *PriorityQueueing* parameter as defined in the below equation:

$$PriorityQueueing = MessageArrival + MaxLatency \tag{3}$$

As discussed previously, we have N_{ave} messages to be transmitted during the CCH interval and a set of periods T = $\{T_1 \ldots T_{Nave}\}$ for sending a message. Therefore, the message with the lower value of *PriorityQueueing* was the most critical content and must be transmitted first so this message will have the period of time T_1 contrary to the message of great value *PriorityQueueing*, which occupies the period T_{Nave}.

5 Simulation Results and Discussions

The proposed algorithm is evaluated utilizing the same simulation configuration as discussed in Sect. 3.

5.1 Average End-to-End Beacon Delay

In Fig. 7 the average End-to-End beacon message delay for different vehicles density is presented. The results showed the better performance of proposed solution SABM in terms of delay. In dense vehicular environments SABM is good compared to the 802.11p. When the vehicles density is less than the threshold (30), the delay of the proposed solution is slightly longer than the 802.11p and it is slightly shorter when the vehicles density is greater than the threshold (30).

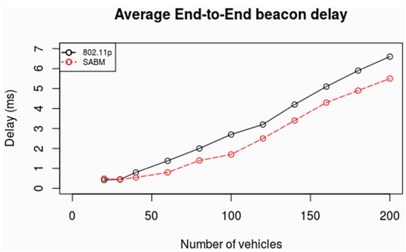

Fig. 7. Average End-to-End Beacon delay

5.2 Throughput of Beacon

As shown in Fig. 8, the beaconing throughput rapidly increases with the increase in the number of nodes since more number of beacons will be broadcasted in a network. Moreover, the throughput is strongly related to the collision problem but in our proposed scheme this problem is relatively resolved using the scheduling mechanism so we have less collision compared to 802.11p then more successfully reception messages as a result a higher value of beaconing throughput.

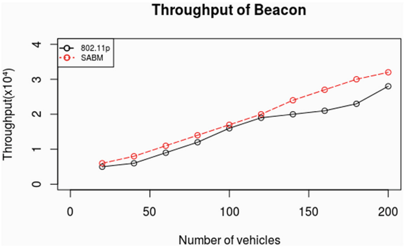

Fig. 8. Throughput of Beacon

5.3 The Collision Probability

As presented in Fig. 9, it is shown the better performance of our proposed scheduling mechanism SABM in the terms of collision probability. When the number of nodes is greater than the threshold (30) obtained in this simulation scenario, our proposed approach is good compared to 802.11p scheme. It decreases the number of collisions therefore increase the reception rate.

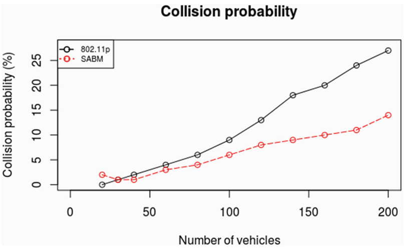

Fig. 9. Collision probability

6 Conclusions and Future Work

In this paper, we proposed a Scheduling Algorithm for Beacon Message in Vehicular Ad Hoc Networks during CCH interval, called SABM. It adjusts CCH interval according to the road traffic. Then, it schedules safety messages based on their priorities for accessing the wireless channel. We have testified it and the results of our simulation show that it better outperforms the original one defined in IEEE 802.11p.

In this work, we focused on safety messages during CCH interval and for the future work; we will implement and evaluate an algorithm to IEEE 802.11p standard for non-safety messages during SCH interval.

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