A Modified RR-ALOHA Protocol for Safety Message Broadcast in VANETs

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Abstract. MAC protocol design of VANETs is a real challenging task due to the high mobility and mobile hidden terminals (MHTs) issues. Slotted ALOHA based MAC protocols is regarded as one of the most promising solution in which hidden terminals issues are solved by broadcasting frame information (FI). However, when network topology changes rapidly, the vehicles using the same slot comes close to each other, merging collisions take place and a new round of slot reservation is required. This paper proposes a modified Reliable Reserved ALOHA (RR-ALOHA) protocol in which merging collisions are detected and an election process is employed to reduce collisions directly after one merging collision. Simulation results show that our proposal achieves better packet delivery ratio than RR-ALOHA in most scenarios.

1. Introduction

Vehicular Ad-hoc Networks (VANETs) is considered as one of the most promising technology to reduce traffic accidents and enhance vehicular entertainment [1]. The applications of VANETs consist of safety related and non-safety related ap-plications. As one of the most important safety related applications, Periodical Basic Safety Messages (BSMs) [2] are broadcasted to all one-hop neighbors. IEEE 802.11p employs a CSMA/CA based MAC protocol for all transmissions [3]. However, the contentions of channel access in dense scenario will suffer packet loss and uncertain delay. An efficient and reliable MAC protocol to deal with collisions and dynamic topology is urgent and challenging.

Various of TDMA based MAC protocols are proposed to provide bounded delay [4-5]. Since no centralized coordination is available, some control information has to be exchanged to maintain time slot scheduling. RR-ALOHA [6] is proposed in CarTALK project [7], employ frame information to exchange sensing results of channel status. However, they still suffer high dynamic topology. Frequent adjustment of slot reservation is required when network topology changes rapidly.

Collisions in VANETs is divided into two categories, merging collisions and access collisions. Access collisions happen when nodes in the same neighborhood try to access the same time slot. On the contrary, merging collisions take place when nodes with the same reserved time slot come to the same neighborhood. Most of the R-ALOHA like MAC protocols, such as VeMAC [8] and CFR-MAC [9], employed a strategy to reduce the number of merging collisions under specific traffic scenarios.
However, the occurrences of merging collisions are highly related to the network topology, which is totally uncontrollable. To further solve MHTs, reducing efforts of merging collision is considered.

In this paper, we propose to detect merging collisions and shorten the reconstruction process of slot reservation. A modified RR-ALOHA is proposed. In this protocol, each vehicle maintains a local frame information table to detect merging collisions. After that, a time slot election process is employed, one of the original vehicles keeps the slot to reduce collisions. Following the introduction, Section II describes the system model and problem formulation. The proposed modified RR-ALOHA is given in Section III in details. Simulations are provided to examine the performance of proposal in Section IV. Finally, in Section V, we conclude the paper.

2. System Model And Problem Formulation

For Integrity purpose, RR-ALOHA will be briefly discussed, and then the proposed motivation is introduced. In RR-ALOHA, vehicles employ a slotted access mechanism and time is divided into frames and slots. Time Synchronization is guaranteed by GPS like devices installed in the vehicles. Transmission range and sensing range are the same. Vehicles randomly choose a time slot to transmit messages. If the transmission is successful, the time slot is reserved in the following frames until it is released. Half-duplex is assumed so that the vehicles have no knowledges of transmission conditions by itself. As a result, transmission success is only confirmed by receiving acknowledgement from neighbors. All the vehicles keep listening to the channel when they are not transmitting and broadcast the channel status in the FIs.

2.1. Frame information and slot reservation

When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper. Fig.1 shows the structure of the frame. A frame consists of multiple time slots. A vehicle only chooses a slot once to transmit its message in one frame. Frame information contains the identity of transmitting vehicle and status of all the other time slots. In RR-ALOHA, only two conditions are reported in the FI, busy or idle. For merging collision detection, collision status is also considered.

According to the distributed and half-duplex nature of VANETs, a successful slot reservation has to be acknowledged by its neighbors. By this means, vehicles in two-hop neighbors will not use the same time slot, the hidden terminals are avoided. A vehicle succeeds to reserve a time slot when there is one or more neighbors report that this time slot is busy. When a slot is reserved, it is dedicated to the vehicle in the following frames.

![Figure 1. Structure of frame in RR-ALOHA.](image)
2.2. Mobile hidden terminals and merging collision
When network topology is fixed or slowly changed, the network will reach a stable status after all vehicles have reserved a time slot. For better explanation, we call the status of all vehicles reserved a time slot without collisions as final status. When network topology changes, for example, two vehicles reserving the same time slot come to each other, merging collision happens. This is also called mobile hidden terminals. In most R-ALOHA like MAC protocols, the collided vehicles will release the time slot and try to access another time slot when merging collisions happen. If merging collisions happen after final status is obtained, they will soon find new time slots and reach final status. Otherwise, this collision will bring a little chaos before getting final status. Fig.2 shows an example of merging collision happening. The dotted line represents a new changed topology and empty circles represent vehicles with-out reserved time slots.

![Figure 2. An example of MHTs.](image)

3. Modified Rr-Aloha
As shown in the previous section, the slot reservation pro-chess to final status is disturbed by merging collisions. In order to reduce the chaos caused by merging collision as well as topology change, modified RR-ALOHA is proposed.

Different from RR-ALOHA, slot reservation in this paper is achieved by the implicit acknowledgement. A vehicle succeeds to reserve a time slot when there are no neighbors report that this time slot is collided or empty. After choosing - a slot once and transmitting messages, one vehicle enters a status of pseudo reserved. It will use this time slot in the following frames as it is reserved until a frame information is received to overthrow the prospective. For instance, collision in this slot is detected by a one-hop neighbor. For this end, the vehicles are capable of detecting collisions happened in the transmitting range.

3.1. Merging collision detection
Merging collisions happen when two vehicles using the same time slot come to each other. It is undetectable in the perspective of themselves. However, in the view of their one-hop shared neighbors, a collision will take place in a reserved time slot. In this paper, each vehicle maintains a local frame in-formation to record channel status in advance. When merging collisions happen, the one-hop neighbors of collided vehicles will detect a collision and update the local frame information. If this slot is reserved by other vehicle in the previous local frame information, this is a merging collision.

3.2. Time slot election
In RR-ALOHA, vehicles suffering merging collisions will both release the time slot and choose another one. To minimize the effects caused by merging collisions, a time slot election is processed and one of the collided vehicles win this time slot and keep reserved. When a merging collision is detected, the vehicle will report it to all its one-hop neighbor in the FI attached with the Identity of the electing vehicle. The vehicle with the most electing neighbors wins and keep its strategy. Noted that
only sharing neighbors take part in this election because only they are able to detect the collision. Vehicles without reserved time slot receive this message and avoid collisions with them.

4. Performance Evaluation
Extensive simulations are carried out to evaluate the performance of modified RR-ALOHA and compare it with original one for two network density scenarios. For better evaluation of performance under dynamic network topology, merging collisions are controlled by periodically updating the location of one vehicle. Different update periods are evaluated. Packet delivery ratio is chosen as the main indicator. Furthermore, proportion of merging collisions to access collisions is also evaluated to validate the reduction of chaos caused by merging collisions.

![Figure 3. Packet delivery ratio under different topology change interval.](image)

Fig. 3 shows the packet delivery ratio under different topology update interval. N represents the number of vehicles and M denotes the number of time slots in one frame. Packet delivery ratio increases along with the topology change interval gets larger. When the interval is large, the network gets to the final status before the topology changes and PDR gets to 90%. When the network topology changes quickly, PDR gets much lower because merging collisions take places. Modified RR-ALOHA performances better than RR-ALOHA in all cases.
As shown in Fig. 4, proportion of merging collisions to access collisions varies with the topology change interval and network density. When the network density is low, the effects of merging collisions are not significant. There are less vehicles waiting for slot reservation when a merging collision takes place. Thanks to the merging collision detection and election process, modified RR-ALOHA performs much better than RR-ALOHA. However, when the network is dense, some vehicles without reserved slots will take part in the slot contention. Access collisions after merging collisions get more. Performance difference between modified RR-ALOHA and RR-ALOHA is not significant.

5. Conclusion

This paper focuses on the MHTs issues and merging collisions in VANETs. We propose a modified RR-ALOHA MAC protocol for safety message broadcasting. Packet delivery ratio and access collision rate is evaluated through simulations. The results show that the proposed approach outperforms RR-ALOHA under different topology change interval. For instance, when 100 time slots and 100 vehicles are involved, modified RR-ALOHA achieves nearly 20% better in terms of PDR under topology change interval of 4 frames. Access collisions per merging collisions is reduced by up to 50% under low density scenarios.

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