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VANETs MAC Protocol Without RSU Assistance

Weifeng Yang, Guoqiang Zheng, Junchao Li, Feng Wang

Henan University of Science and Technology, Luoyang 471000, China

Abstract: The aim of MAC protocol research without RSU is to solve some of the challenges and problems that exist in VANETs without RSU support. For example, Rsus cannot be deployed in certain regions or scenarios due to various reasons (such as cost, lack of infrastructure, etc.). In this case, the MAC protocol without RSU assistance provides a solution that does not rely on RSU for communication. In addition, in traditional VANETs, the RSU acts as an important relay node, helping vehicles communicate with each other. However, without a sufficiently dense RSU deployment, network coverage will be limited. Through the MAC protocol without RSU assistance, vehicles can communicate directly, expanding the coverage of the network. Through the MAC protocol without RSU assistance, vehicles can communicate directly, expanding the coverage of the network. Improve the reliability and throughput of VANETs networks: Due to the mobility of vehicles and the uncertainty of the communication environment, problems such as message collisions and data transmission delays are common in VANETs. By designing an effective MAC protocol without RSU assistance, message collision can be reduced, system throughput can be improved, and network reliability can be enhanced. Finally, in some application scenarios, such as vehicle safety and traffic management, real-time communication is very important. Without the support of RSU, traditional VANETs may suffer from large communication delays. By studying the MAC protocol without RSU assistance, the communication delay can be minimized to meet the needs of real-time communication.

1. Introduction

Intelligent Transport System (ITS) is an effective integrated application of advanced information technology, communication technology, sensing technology and computer technology in the entire transportation management system, which plays an increasingly prominent role in easing traffic congestion and reducing traffic accidents. Vehicular AdHoc Networks (VANETs), as ITS information carrier platform, has attracted widespread attention. Vehicular AD hoc network is a self-organizing wireless multi-hop network composed of on-board Unit (OBU) loaded On the vehicle and roadside communication infrastructure. In the vehicular AD hoc network, vehicles need to periodically exchange status information and safety information. However, characteristics such as excessive Vehicle speed, frequent network topology changes and no center [1] result in unreliable data transmission between vehicles (Vehicle to Vehicle (V2V) and between vehicles to Roadside Unit (V2R) in vehicle networking. Therefore, reliable and effective Medium Access Control (MAC) protocol is the focus of research.

MAC protocols are generally divided into competition-based and non-competition-based [2]. The conflict caused by the competitive mode is difficult to meet the delay requirements of security applications when the vehicle density is large, while the non-competitive mode is divided into centralized and distributed modes according to the distribution mode of communication resources. In the centralized mode, communication resources are usually allocated with the help of RoadSide units (RSU) to reduce conflicts and improve communication efficiency. According to the requirements of different Qualityof Service (QoS), the researchers put forward different methods. [3] This paper proposes an IGTDMA protocol, which collects the information of vehicles in its communication range and constructs a IGTDMA based on the position of vehicles and the preset width of IGTDMA, and then uses a communication link selection algorithm to determine the time slot sent by nodes. [4] The communication frame is divided into time frame management cycle (TMP), free transfer cycle (FTP) and competition cycle (CP). During TMP, the RSU estimates and predicts the number of vehicles within its radius, adaptively determining the timing of FTP and CP. [5] A QOS-aware centralized Hybrid MAC(QCHMAC) protocol is proposed, which divides the access time into reservation period (RP) and transmission period (TP). In RP, newly added vehicles allocate time slots within IP according to their priority RSU, while in TP, vehicles with successful reservation within RP communicate. [6] A capture-aware TDMA MAC(CT-MAC) protocol is proposed. The RSU optimizes the length of each communication ton based on estimates of competing vehicles within its communication paradigm. [7] A collision prediction TDMAMAC(CPTM) protocol is proposed in which the RSU adjusts the time allocation of vehicles according to the combined shock cell in the predicted upcoming time slot, and then reallocates the time slot for vehicles in different directions according to the vehicle-to-density ratio. [8] A TDMA MAC(VCAR-MAC) protocol considering the actual environmental conditions is proposed. The control channel RSU can quickly identify the number of vehicles in the coverage area according to the actual environment, determine the optimal number of time slots for vehicle competition, and minimize the collision probability. [9] The proposed multi-channel MAC (RMM) protocol makes the vehicle reserve the service channel on the control channel by means of RSU coordination, and realizes the non-competitive transmission of the service channel.

The above method requires a large number of Rsus to be placed on the roadside for communication coordination. On the one hand, it increases the cost; on the other hand, due to the high-speed moving characteristics of vehicles, frequent switching between vehicles and Rsus may also increase the probability of conflict. Therefore, many studies began to focus on distributed MAC protocols. [10] An adaptive Ad Hoc(A-ADHOC) protocol is proposed in which each node adjusts the time slot number of each frame according to vehicle density. [11] The proposed VeMAC protocol reduces transmission conflicts by allocating disjoint time-slot sets to vehicles moving in opposite directions and Rsus through broadcast services provided on the control channel. [12] The proposed mobility aware TDMA MACMoMAC protocol assigns time slots to vehicles according to the basic road topology and lane distribution, taking into account vehicle mobility. In this paper, a content-based TDMA MAC protocol (CTDMAC) with the features of competition and time division multiplexing is proposed to divide the road into several segments according to the communication radius, Each section of the road corresponds to the part of the frame, and each part is divided into static segment and dynamic segment. Vehicles in the same section communicate in the static segment using time division multiplexing, and new vehicles enter the dynamic segment to determine the transmission time slot in a competitive way. The protocol adopts distributed mode with greater flexibility.

2. System Model

In the scenario without the ability to communicate with RSU, it is necessary to design a MAC protocol that does not rely on the assistance of RSU, so that vehicles can still communicate effectively. In the model presented in this chapter, each vehicle is equipped with an OBU and GPS, and each vehicle V has its own ID, and their communication radius is r.

In this chapter, access conflict refers to the situation that multiple vehicles may request access to the same time slot during communication between vehicles due to time-slot partitioning technology, resulting in access conflict. In order to solve this problem, this chapter adopts the time-space resource overlap method, divides the road into several disjoint road segments in a certain way, and uses the time-slot division technology in each road segment. In this way, communication between vehicles in different sections of the road does not conflict. For the communication between vehicles in the same road segment, this chapter adopts the method based on reservation protocol. When vehicles want to communicate, they will first scan the surrounding communication environment to detect which time slots have been occupied by other vehicles. The vehicle then selects an unoccupied time slot reserved for itself to communicate. This avoids communication conflicts and ensures communication reliability and stability. Specifically, each vehicle can periodically poll the status of neighboring vehicles, and when the status of the time slot occupied by the neighbor vehicle changes, the vehicle will reserve the available time slot according to its own needs and available resources to achieve communication. In this way, we can avoid communication failures or delays caused by access conflicts, and improve communication efficiency and reliability. At the same time, with the help of the space-time resource overlap method, we can divide the communication between vehicles into disjoint space-time fragments, and further avoid the problem of merging collision. The specific design is shown in Figure 1.

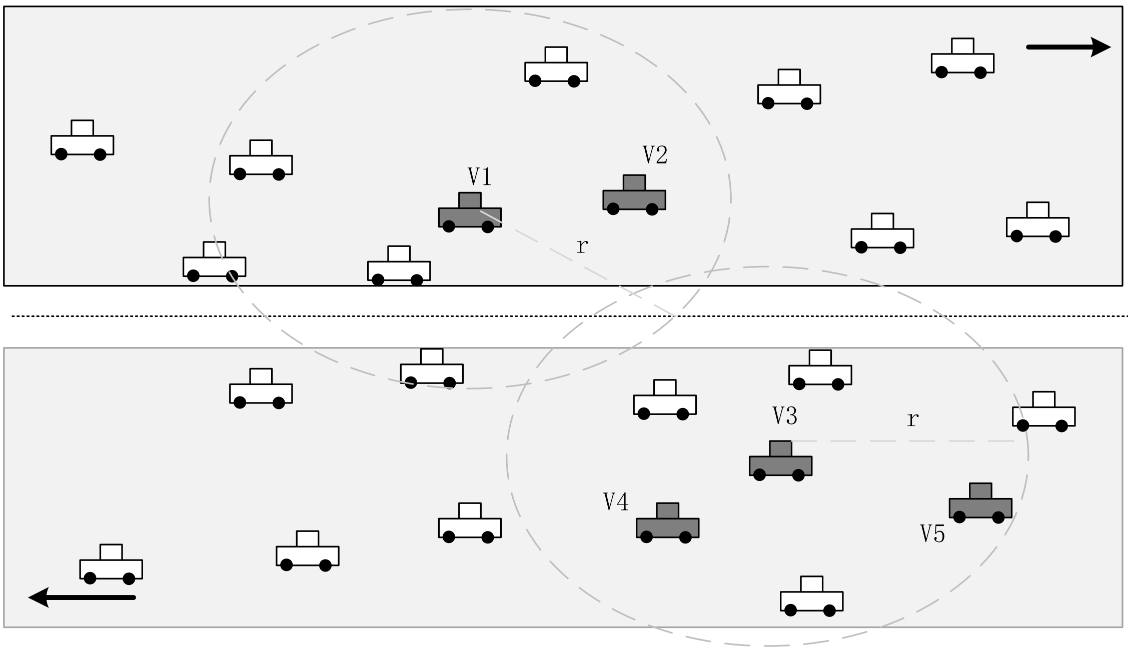

Figure 1. System design model diagram

3. MAC Protocol Without RUS Assistance

3.1. Protocol introduction

As shown in Figure 2: In this chapter, we divide the entire communication scene into several areas with a communication range of r, each area is represented by Di, and the vehicle can use the map and GPS positioning system to determine its current area and the number of the corresponding area. On this basis, this chapter proposes a protocol to correspond different time slots to different lane areas on the highway. This means that within the same timeslot group, multiple packets can be transmitted simultaneously, and these packets can be transmitted between different channel areas. By processing multiple packets simultaneously within the same timeslot group, transmission delay can be reduced and communication throughput can be improved. In this way, vehicles can communicate more efficiently with each other, enabling fast and reliable data exchange.

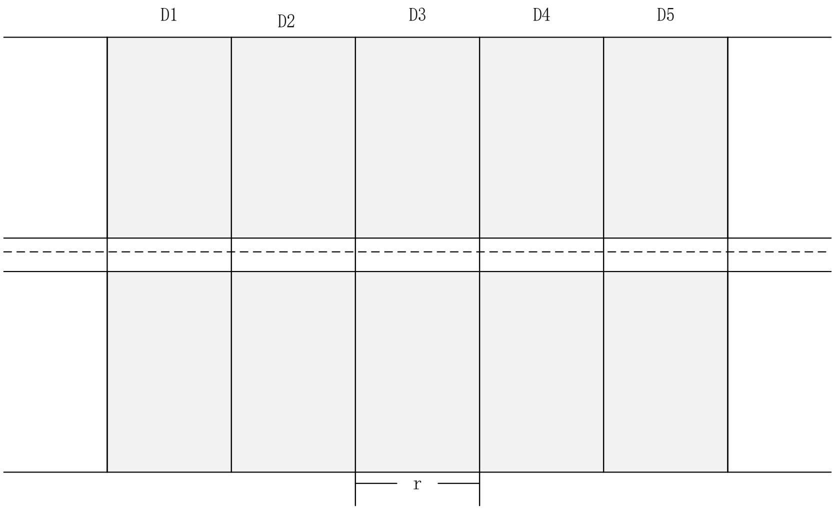

Figure 2. Road subdivision diagram

Timeslot sets and road segments are assigned according to formula (1):

$$\begin{cases} S_1 = \{Di \mid i\%3 == 1\} \\ S_2 = \{Di \mid i\%3 == 2\} \\ S_3 = \{Di \mid i\%3 == 0\} \end{cases} \tag{1}$$

As shown in Figure 3:

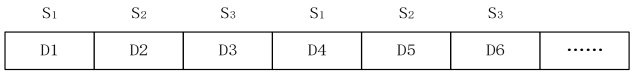

Figure 3. The correspondence between time slot set and road

3.2. Protocol frame structure

The frame structure of the proposed protocol is shown in Figure 4. The number of time slots corresponding to each static segment (Sts) and the total number of time slots in STs are n1, n2, n3 and τ, and satisfy the relation n1+n2+n3=τ.

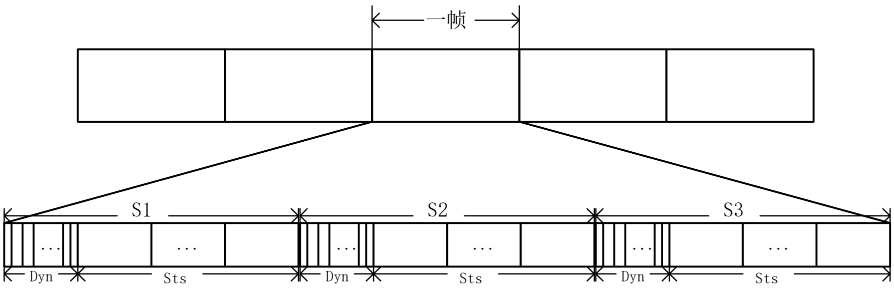

Figure 4. Frame structure

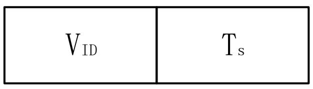

Figure 5. Competing timeslot packet structure

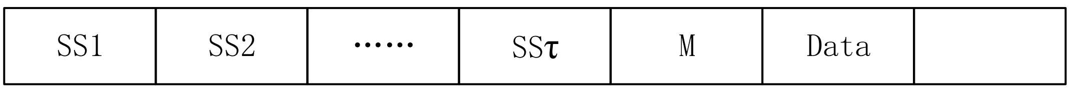

Figure 6. Send time slot packet structure

When a newly added vehicle needs to occupy certain time slots in the Sts segment, a Dyn packet is sent to nearby vehicles to inform them of the time slots they want to use. After receiving the data packet, other vehicles can decide whether to allocate the time slot to the vehicle according to their own situation and competitive strategy. If multiple vehicles want to occupy the same time slot, competition and conflict may occur. In this case, conflicts need to be detected and resolved, such as randomly waiting to re-select the time slot. Through the competition of Dyn packets, vehicles can better coordinate their communication needs, avoid communication collisions and conflicts, and improve communication efficiency and reliability. The structure is shown in Figure 5, V_{ID} indicates the vehicle number, Ts indicates the time slot of the Sts segment that the vehicle wants to use in the Dyn segment.

Sts is further divided into multiple identical time slots, The structure is shown in Figure 6. In Figure 6, SSj indicates that the current status is conflict, idle, or busy, and can clearly represent the occupation and competition status of each time slot in the Sts segment. Vehicles can detect and resolve conflicts based on this information to avoid collisions caused by multiple vehicles choosing the same time slot. In order to increase slot utilization and reduce collision probability. A message is sent when the vehicle leaves the current road section so that other vehicles can understand the departure of the vehicle and adjust accordingly if needed. To achieve this, M can be used to indicate whether node V leaves next in region Di, The definition is as follows:

$$M=\begin{cases}0,\text{车辆不离开当前区域}\\1,\text{车辆在下一帧将离开}\end{cases} \quad (2)$$

3.3. How the agreement works

Algorithm 1 is the process of vehicle slot competition. Vehicle V randomly sends a number of messages in the corresponding Dyn segment, while assigning the value of j in the Sts segment to -1. Messages sent by new nodes in the network in the Dyn segment will be received by other nodes.

算法 5.1: 车辆时隙竞争过程

```
确定车辆所在区域，通过侦听得到可用时隙集 A(v)
if A(v)≠{} then
随机选择一个竞争时隙 s 发送数据包；
SSj=IDv;
  if 其他车辆指示成功收到 s 发送的数据包 then
    车辆 v 在发送时隙 j 发送数据
    if 其他车辆收到车辆 v 的数据 then
      Successful = 1;
    else
      Successful = 0;
      SSj=0;
    end if
  end if
  if Successful ==0 then
    update A(v)
    随机在 A(v)中占用一个发送时隙 k
    if 其他车辆接收到车辆 v 的数据 then
      Successful = 1;
    else
      Successful = 0;
      SSk=0;
    end if
  end if
end if
```

4. Access Conflict Analysis

In area Di, if q new nodes are added and the number of competing time slots in Dyn is n, the success rate of sending in Dyn is as follows:

$$p_{res}=\frac{A_n^q}{n^q} \quad (3)$$

Then its probability in the Sts segment is:

$$p_{succ}=\frac{A_n^q}{n^q}\cdot\left(\frac{1}{\alpha_i-\beta_i-N_{sche}}\right) \quad (4)$$

Among N_{sche} indicates the number of nodes with allocated time slots, α_i, β_i Indicates the start time slot and end time slot corresponding to Di. The number of nodes successfully competed in the Dyn segment $Succ_\varphi$ for:

$$Succ_\varphi=m\cdot\frac{A_n^q}{n^q}\cdot\left(\frac{1}{\alpha_i-\beta_i-N_{sche}}\right) \quad (5)$$

The number of nodes that failed to occupy the time slot is:

$$Unsucc_\varphi=m-m\cdot\frac{A_n^m}{n^m}\cdot\left(\frac{1}{\alpha_i-\beta_i-N_{sche}}\right) \quad (6)$$

Then the number of free time slots is:

$$N_{re\_slot}=\alpha_i-\beta_i-N_{sheduled}-q\cdot\frac{A_n^q}{n^q}\cdot\left(\frac{1}{\alpha_i-\beta_i-N_{sheduled}}\right) \quad (7)$$

Therefore:

$$p_{ij}=\frac{A_{N_{re\_slot}}^{Succ_\varphi}}{N_{re\_slot}^{Succ_\varphi}} \quad (8)$$

Among them, p_{ij} Indicates the probability that a vehicle successfully occupies a node in Di.

$$\begin{aligned}p_{total-ac}&=1-P_{no-ac}\\P_{no-ac}&=\sum_{i=1}^{N}P_{naci}=\sum_{i=1}^{N}\sum_{j=\alpha_i}^{\beta_i}P_{ij}\cdot\prod_{k=2}^{A_i}\left(1-p_{ij}\right)\end{aligned} \quad (9)$$

5. Simulation Verification

This chapter uses MATLAB to conduct simulation experiments on the proposed protocol, Simulation parameters are shown in Table 1:

Table 1. Simulation parameter setting

Parm	Value
Road Length (m)	1200
Number of roads in each direction	2
Average speed (km/h)	120
Communication radius (m)	200
Frame length (ms)	100
Send time slot number	99
Transmit slot length (ms)	1
Number of competing timeslot frames	100
Competing Slot Length (ms)	0
Simulation time (s)	60
Vehicle density	0.1-0.6

Figure 8 is to obtain the relationship between the number of available nodes and the number of time frames, When the difference between N and K is small, the number of nodes obtained by the proposed protocol in the average available time slot is relatively large. When the network density increases, the number of messages that need to be transmitted will increase, the number of collisions will increase, and the collision rate will increase.

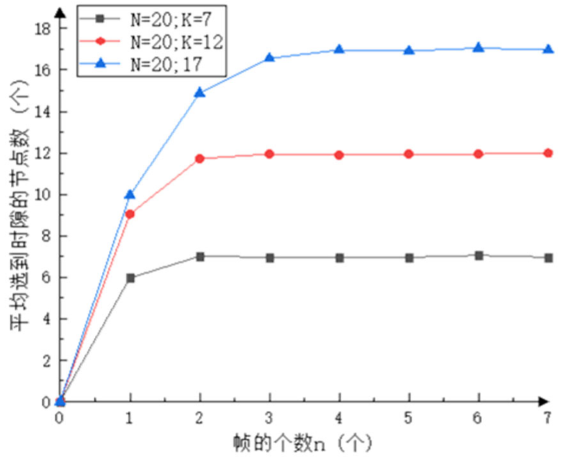

Figure 8. Gets the average number of nodes in the time slot within n frames

Figure 9 shows the relationship between DT-MAC and the proposed protocol access conflict rate and network density. As is shown in the picture, the access conflict rate of the protocol proposed in this chapter is lower than that of the existing protocol in all vehicle density scenarios, especially when the vehicle density in the network is large, the proposed protocol is much smaller than DA-MAC.

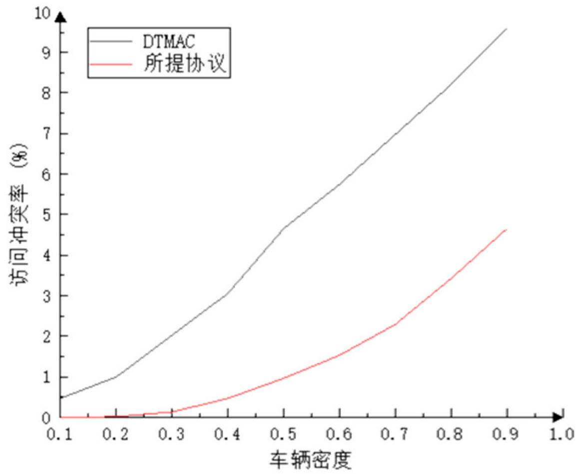

Figure 9. Access collision rate and vehicle density

Figure 10 shows the relationship between DT-MAC and the packet loss rate of the proposed protocol and the network density. As is shown in the picture, the packet loss rate of the protocol proposed in this chapter is lower than that of DT-MAC in all vehicle density scenarios, especially when the density of vehicles in the network is large, the proposed protocol is much smaller than DA-MAC.

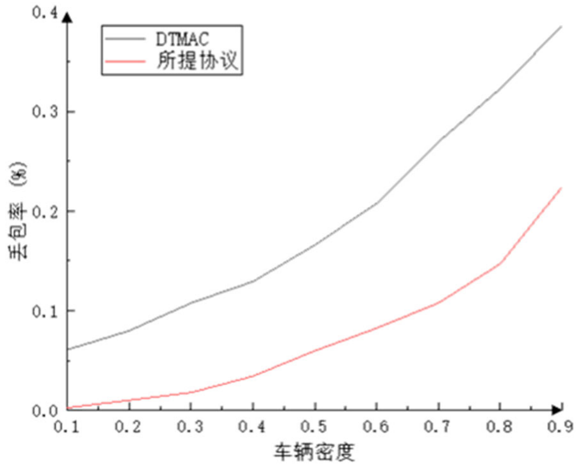

Figure 10. Packet loss rate and vehicle density

6. Conclusion

In order to reduce the collision caused by vehicle movement in VANETs without RSU, this chapter proposes a MAC protocol without RSU assistance based on TDMA. The protocol divides a time frame into two segments. Newly arrived nodes in the network compete in the Dyn segment for time slots in the Sts segment and send messages in the Sts segment. The simulation results show that when the network density is high, the data transmission loss of the proposed protocol is effectively reduced, the throughput is increased, and the reliability of VANETs network is greatly improved.

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