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Adaptive TDMA slot assignment protocol for vehicular ad-hoc networks

YANG Wei-dong[1,3] (✉), LI Pan[1], LIU yan[2], ZHU Hong-song[3]

1. College of Information Science and Engineering, Henan University of Technology, Zhengzhou 450001, China
2. Software and Microelectronics, Peking University, Beijing 102600, China
3. State Key Laboratory of Information Security, Institute of Information Engineering, the Chinese Academy of Sciences, Beijing 100093, China

Abstract

This paper proposes a novel adaptive time division multiple access (TDMA) slot assignment protocol (ATSA) for vehicular ad-hoc networks. ATSA divides different sets of time slots according to vehicles moving in opposite directions. When a node accesses the networks, it choices a frame length and competes a slot based on its direction and location to communication with the other nodes. Based on the binary tree algorithm, the frame length is dynamically doubled or shortened, and the ratio of two slot sets is adjusted to decrease the probability of transmission collisions. The theoretical analysis proves ATSA protocol can reduce the time delay at least 20% than the media access control protocol for vehicular ad-hoc networks (VeMAC) and 30% than the ad-hoc. The simulation experiment shows that ATSA has a good scalability and the collisions would be reduced about 50% than VeMAC, channel utilization is significantly improved than several existing protocols.

Keywords media access control (MAC) protocol, TDMA, slot assignment, adaptive frame length, binary tree

1 Introduction

Vehicular ad-hoc networks (VANETs) is a distributed, self-organizing communication network built up by moving vehicles, which contains both inter-vehicle (V-2-V) communications among vehicles and vehicle-to-roadside units (V-2-R) communications between vehicles and roadside units (RSUs) which is utilized for a broad range of safety and non-safety applications [1]. As the wide application prospects and high research value, it has attracted a lot of attention [2].

Because of the special characteristics of VANETs, such as the high dynamic network topology and diverse quality of service (QoS) requirements of potential applications, higher demand for delay for security applications, not only does the MAC protocol need to consider the common problems which contains hidden/exposed terminal problem, resource allocation fairness problem in traditional ad-hoc networks, but it also should meet some new requirements [3]: 1) supports high vehicle mobility; 2) ensures real-time communication and reliability; 3) has a good scalability; 4) has a higher channel utilization; 5) supports a fully distributed or semi-distributed networking; 6) provides a fair opportunity of communication for each user; 7) provides efficient and timely broadcast mechanism.

Since in 1999, the U.S. Federal communications commission (FCC) allocated a block of wireless spectrum in the 5.850~5.925 GHz band for dedicated short range communications (DSRC) applications which contains seven 10 MHz channels: six service channels and one control channel to be exclusively used by V2V and V2R communications (FCC (1999) FCC allocates spectrum in 5.9 GHz range for intelligent transportation systems uses, http://www.fcc.gov/Bureaus/Engineering_Technology/News_Releases/1999/nret9006.html), intended to enhance the safety and efficiency of highway system [4], a large body of literature for MAC protocols for VANET have been proposed based either on IEEE 802.11 or on channelization such as TDMA. The IEEE draft standard

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Corresponding author: YANG Wei-dong, E-mail: mengguyang@163.com
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802.11p [5], included in the wireless access in vehicular environment (WAVE) protocol stack, is the only standard for MAC in V2V communications. Since IEEE 802.11p uses the basic mechanism of the distributed coordination function (DCF) that was originally designed for low mobility networks, it does not operate efficiently for a high mobility communication scenario in VANETs, such as it suffers from Orphan frames and hidden terminal problem [6].

ADHOC is based on reliable reservation additive link on-line Hawaii protocol (RR-ALOHA) to achieve dynamic allocation slots [7]. ADHOC inherently avoids the hidden terminal problem and alleviates the exposed terminal problem at a small cost of packet overhead by careful refinement. Moreover, in ADHOC MAC, each node is guaranteed to access the channel at least once in each frame, and the information of speed, location, and emergency safety can be broadcast in the frame information (FI) information. ADHOC MAC is suitable for non delay-tolerant applications in VANETs. But with the increase of node density, the nodes competition is more intense, the success rate of the nodes access the channel is decreasing and the delay will also increases correspondingly.

In order to improve the success rate of assignment slot and reduce the delay, Ref. [8] based on the ADHOC protocol proposed a new multichannel MAC called VeMAC. It assigns time slots according to the direction of vehicular. VeMAC takes full advantage of the characteristics of the multi-channel in the VANETs, and combines distributed with centralized way for assignment time slots, making nodes acquire time slots on the control channel much faster.

As for slot assignment protocol researches, Yong [9] proposed the unifying slot assignment protocol-multiple access (USAP-MA) to improve the channel utilization. In USAP-MA, the frame length can change according to network density. In order to improve the channel utilization, A-ADHOC protocol was proposed in Ref. [10]. It implements a robust mechanism supporting the adaptive frame length and focuses on the conditions of changing the frame length. Compared to the MAC protocol which has a fixed frame, the adaptive frame length can improve the channel utilization, however, with the increasing channel utilization, success rate of a node compete for a slot is reducing, A-ADHOC can also not solve the problem of merging collision in the VANETs [7].

ATSA is based on VeMAC protocol, the main motivations of our work can be concluded as follows: The adaptive frame length can sustain favorable success probability for nodes by maintaining a stable ratio of frame length and nodes density. Our goal is to enable the frame length and the ratio of left slots and right slots adapt to node density, to reduce the convergence time and enhance the runtime performance, to reduce competition collision and improve channel utilization.

The remainder of this paper is organized as follows. In Sect. 2 we introduce the VeMAC protocol and analysis the defect of it in the VANET. In Sect. 3, the system model is introduced. We show the detailed description of ATSA in Sect. 4. The theory analyses and simulation results are given in Sect. 5. Finally, Conclusions and the future work are given in Sect. 6.

2 The VeMAC protocol

2.1 Introduction VeMAC protocol

VeMAC protocol implements a TDMA mechanism that is able to provide prompt access and reliable channels for VANETs traffic message delivery. It under consideration consists of a set of RSUs and a set of vehicles moving in opposite directions on two-way vehicle traffic roads. Each frame is partitioned into three sets of time slots: L, R, and F.

On the control channel, it is full distributed based on ADHOC MAC. To obtain the slot assignment information in the contention area, every node collects FI transmitted by its neighbors. On the service channel, the assignment of time slots to nodes is performed by the providers in a centralized way.

A set-up phase is presented in Fig. 1 where the FI of every node is given; the different colors represent different time slots sets: L, R and F. If node 2 will access to channel, first, it collects neighbor information and randomly selects an available time slot of L. If it contends for slot j when this very slot j comes, it will broadcast FI packets containing the contending message in the slot j. Then it will experience a frame anxious waiting. If all FI received by node 2 in this period contain 'slot j is busy by node 2', then this contending is successful and slot j will belong to node 2 until it releases it; otherwise, node 2 needs to contend in next frame. If after a certain number of frames, say after τ frames (determine the parameter τ is a key issue) the node 2 cannot acquire a time slot and it can