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ResVMAC: A Novel Medium Access Control Protocol for Vehicular Ad hoc Networks

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Abstract

Efficient medium access control (MAC) is a key part of any wireless network communication architecture. MAC protocols are needed for nodes to access the shared wireless medium efficiently. Vehicular Ad hoc networks (VANETs) are an emerging network technology on the verge of large-scale deployment. The dynamic network topologies in VANETs caused by high mobility rates of vehicles presents a great challenge in reliable data transfer. A MAC protocol that enables quick reservation of packet transmission slots by vehicles that wish to send packets is crucial in addressing this challenge. In this paper, we propose a new distributed MAC algorithm ResVMAC for VANETs. We demonstrate using simulations, that our algorithm outperforms two state-of-the-art algorithms in key performance metrics.

Keywords: VANETs; Medium Access Control Protocols; Time Division Multiple Access(TDMA); Intelligent Transportation Systems (ITS)

1. Introduction and Related Work

Each year road accidents cause million of deaths and non-fatal injuries[1]. Moreover, traffic congestion results in estimated losses of several billion dollars from wasted time and fuel[2]. So it is desirable to have some method of communication between vehicles that can warn drivers and passengers, and reduce the likelihood of accidents and congestion. Vehicular networks can also improve passenger comforts. Intelligent Transportation Systems (ITS)[1] are used to improve road safety, increase the efficiency of transportation and enhance passenger and driver experience. Vehicular Ad hoc Networks (VANETs) form an important part of ITS. Nodes in VANETs are vehicles that comply with street traffic regulations while moving. VANETs support both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. In V2V communications, vehicles exchange information with each other. V2I communications involve message exchanges between vehicles and traffic lights or between vehicles and roadside monitors known as road side units (RSUs). The vehicles can access the internet through RSUs. Each vehicle is equipped with a controller called on-board unit (OBU) that supports the V2V and V2I communications. The Federal Communication

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Commission (FCC) in the USA has allocated 75 MHz of frequency spectrum (5.850 – 5.925 GHz) for Dedicated Short-Range Communications (DSRC) technology for ITS[3].

In wireless networks, packets may collide when nodes contend for the shared medium. Collisions waste energy, increase packet delay, and decrease throughput. The highly dynamic topologies in VANETs, caused by fast movement of vehicles, results in increased collisions. Thus, designing VANET MAC protocols that enable fast access of the shared medium with fewer collisions is crucial for high performance. Various VANET MAC protocols have been proposed and implemented. IEEE 802.11p[4] protocol is the common standard for vehicular communication protocols. IEEE 802.11p extends the IEEE 802.11[4] standard, and utilizes the DSRC frequency spectrum. There are several limitations of IEEE 802.11p. First, it is not suitable for broadcast communications, because it uses the RTS/CTS mechanism. However, the hidden terminal problem cannot be alleviated without the RTS/CTS mechanism. Second, it does not work well when node density is very high and it cannot ensure high reliability when the traffic load is high. Distributed TDMA based VANET MAC protocols can eliminate these limitations and provide broadcast and reliable communications. We survey some TDMA-based MAC protocols next. We do not attempt to survey other classes of MAC algorithms due to space constraints.

1.1. TDMA-based VANET MAC protocols

TDMA based MAC protocols for VANETs fall in two categories those that follow the DSRC standard, and those that do not. VeMAC[5], VeSOMAC[6], TC-MAC[7], e-VeMAC[8] and HER-MAC[9] fall in the first category. The second category includes RR-ALOHA[10], CAH-MAC[11], eCAH-MAC[12], MS-ALOHA[13], RR-ALOHA+[14] and ECCT[15].

The protocols in the second category attempt to reserve packet transmission slots quickly. Notable among these are MARR-ALOHA[16] and RR-ALOHA[10]. In both MARR-ALOHA and RR-ALOHA, a vehicle cannot reserve an available time slot (or BCH) immediately after sending its REQ packet. Instead, the vehicle waits one frame to get acknowledgements from all the active one-hop neighbours about its BCH reservation attempt. It starts sending data from the next frame. Since our work improves on RR-ALOHA and MARR-ALOHA, we outline these protocols next.

1.1.1. RR-ALOHA[10]

RR-ALOHA is a distributed protocol that splits time into fixed length virtual frames. Each virtual frame consists of the previous N perceived slots $[1 \dots N]$ known as Basic Channels (BCHs). A vehicle must reserve a BCH in order to access the wireless channel. A vehicle that wants to send data monitors the channel for one virtual frame. Then it contends for a free BCH by broadcasting a FI (Frame Information) packet in that BCH. The FI packet contains the request for the reservation and the status of the perceived BCHs of previous frame: e.g., which BCH is reserved by which neighbour and which BCH is free. The FI packet that is used for reservation is known as REQ packet.

Let us suppose that a vehicle V wants to reserve a free BCH j. So it broadcasts its REQ packet in j after observing the channel for one virtual frame. Then it waits for the FI packets from its active one-hop neighbours. These neighbours broadcast their views about the previous virtual frame through their FI packets in their reserved BCHs, as shown in Figure 1. The one-hop neighbours that receive the REQ packet of V properly, assign j to V in their FI packets. If they detect collisions in j, they make j free in their FI packets. If j is assigned to V by all the active one-hop neighbours in their FI packets, then V starts to access the channel in j from the next frame and continues to broadcast its FI packets in j until a collision occurs. Thus, each vehicle knows about its two-hop neighbours by receiving the FI packets from its active one-hop neighbours which helps to avoid the hidden terminal problem.

Structure of FI packets. Each vehicle that has reserved a BCH sends its FI packet along with a payload. The FI packet contains as many fields as the number of BCHs in a virtual frame. Each field includes the following information:

- STI (Source Temporary Identifier) : The STI is used to uniquely identify the vehicle that has reserved this BCH. It is 8 bits long.
- PSF (Priority Status Field): The 2 bits long PSF sets the priority of the transmitted data.
- BUSY : If this BCH is free then BUSY bit is 0 otherwise 1.
- PTP : This bit is used to set up point-to-point communication.