Efficient Channel Coordination for Multi-channel MAC in VANETs

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Abstract

Many Medium Access Control (MAC) protocols are proposed to adapt to dynamically changing vehicle traffic condition, such as bandwidth to deliver both safety and non-safety packets. One of them is combination between TDMA and CSMA schemes in the Control CHannel (CCH). With different traffic condition, the length of TDMA-based period can be adjusted to improve throughput on the service channel for exchanging non-safety packets. One of the well-known problems of TDMA-based MAC protocols is the overhead when node density is high. In this paper, we propose a modified packet transmitted in the TDMA-based period to reduce transmission overhead. The simulation results show that the MAC protocol with modified packet supports efficient packet delivery ratio of control packet in the CCH.

Key word: multichannel MAC, TDMA and CSMA schemes, transmission overhead.

1. Introduction and relative works

Vehicular Ad-hoc NETwork (VANET) consists of moving vehicles to create dynamical networks. VANET is one of special types of Mobile Ad-hoc NETworks (MANET) but it does not have an existing infrastructure or centralized administration. VANET supports many applications in safe entertainment and vehicle traffic optimization. The VANET classifies of a set of vehicles equipped with communication device and a Global Positioning System (GPS) receiver, called On-Board Unit (OBU) and a set of stationary units along roads, called Road Side Units (RSUs). Based on OBU and RSU, VANET has two essential communications: Vehicle-to-Vehicle (V2V) and Vehicle-to-RSU (V2R). To support V2V and V2R communications, the United States Federal Communication Commission (FCC) dedicated 75MHz radio spectrum in the 5.9GHz band for Dedicated Short Range Communications (DSRC) spectrum. The DSRC spectrum is divided into seven 10MHz channels: six Service CHannels (SCHs) and one Control CHannel (CCH). A Sync Interval (SI) comprises of a CCH Interval (CCHI) - 50 milliseconds and SCH Interval (SCHI) - 50 milliseconds. Both CCHI and SCHI have guard interval - 4 milliseconds to switch between the CCH and the SCH.

The multi-channel MAC protocol supports not only reliable transmission packets with low latency but also provides the maximum throughput for non-safety application. Many multi-channel MAC protocols are proposed for efficiency and reliability, such as in [1]-[3]. The IEEE 1609.4 [1] is considered to be a default multi-channel MAC standard in the family of IEEE 1609 standards for VANETs. In [1], the standard is developed to efficiently coordinate channel access on the CCH and SCHs, called globally synchronized channel coordination scheme based on the Coordinated Universal Time (UTC). The channel time is divided into synchronization intervals with a fixed length of 100ms. It consists of a CCH Interval (CCHI) and SCH Interval (SCHI) with a length of 50ms, as shown in Fig. 1. This scheme allows the safety and non-safety application packets to be transmitted on different channels without missing important packets on the CCH. However, the IEEE 1609.4 cannot utilize all SCH resources during the CCH interval.

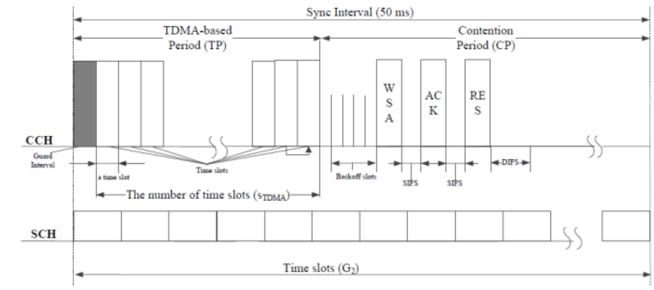

Fig. 1: The considered multichannel MAC protocol

The multi-channel MAC protocol under consideration consists of the TDMA-based Period (TP) and CSMA-based period (called Contention Period (CP) in this paper), as shown in Fig. 1. In TP, each node has to broadcast its information including safety application in its time slot. In CP, a node which has a non-safety packet will attempt to exchange WSA/ACK/RES (WAVE Service Announcement / ACKnowledgment / REsponse to Service) and piggyback with service information and the identities of SCHs to be used. In [4], HTC-MAC used an announcement packet (ANC) transmitted in the TP to efficient time slot acquisition. Dedicated Multi-channel MAC (DMMAC) [3] applies the hybrid channel access to provide the collision-free and delay-bounded transmission for safety traffic. However, the SCH resources are still wasted during the CCHI in DMMAC. HER-MAC [2] is similar to DMMAC, differing in that vehicle reserve a time slot or exchange WSA/ACK/RES handshake during the CP. HER-MAC has a higher probability of collision due to the number of packets transmitted.

The time slot selection is an important issue for TDMA-based MAC protocols in wireless networks and especially for VANET. One of the well-known problems of TDMA-based MAC protocols, such as HER-MAC [2] and HTC-MAC [4], is transmission overhead when node density is high. To solve transmission overhead problem, we propose the modified announcement packet to reduce payload size of packet transmitted in the TP.

2. Modified ANC Packet

We assume that each node has one transceiver which can switch between CCH and SCHs. Nodes based on information packets which are transmitted by two-hop neighbors adjust the length of the TP. We propose the modified announcement (MANC) packet transmitted by eliminating the IDs of neighbor nodes field in the TP including the time slots information. As shown in Fig. 2(b), MANC packet contains five fields: (i) node ID, (ii) its reserved time slot, (iii) a switched time slot, (iv) a number of time slot, (v) bits representing status of time slots in the TP and (vi) safety application packet. In the bits representing status of time slots in the TP, bit 0 means free time slot status, otherwise, bit 1 represents busy time slot status. Note that the length number of bits is also the length of time slots in the TP.

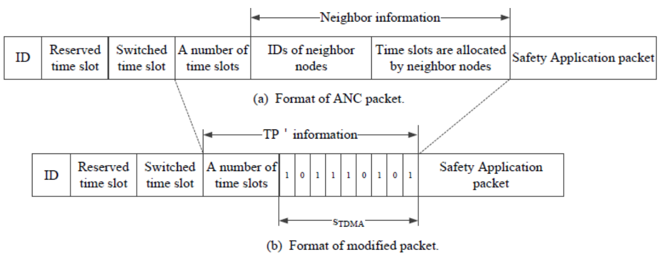

Fig. 2: Format of ANC and modified packets.

In the MAC protocol which defined MANC packet, each node considers whether it should move to available time slot without any collisions to reduce the number of time slots in the TP. If a node wants to change its time slot, it will randomly choose an available time slot. Then, this node will broadcast a switched time slot included in MANC packet in its reserved time slots. After one period of sync-interval (50ms), a switched node checks MANC packets broadcast by one-hop neighbor nodes. If all neighbor nodes broadcast MANC packets including its updated information, it successfully acquires new time slot reducing the length of the TP in the next frame.

3. MANC packet delay

We assume that the IDs of one-hop neighbor set is N_{nei} and considering node is x. If the maximum number of nodes which can exist in a one-hop neighbors set is $N_{\text{nei}}^{\max}$, we need at least $\lceil \log_2 N_{nei}^{\max} \rceil$ bits to represent a node ID, where $\lceil \cdot \rceil$ denotes the ceiling function. Therefore, the total MANC packet size (bits) S is

$$S_{\text{MANC}} = \lceil \log_2 ID \rceil + \lceil \log_2 s \rceil + \lceil \log_2 s_j \rceil + \lceil \log_2 s \rceil + \lceil \log_2 s_{\text{TDMA}} \rceil + S_{\text{safe}} + S_{\text{extra}} \quad (1)$$

where ID is the ID of a node, s is the time slot used by node x, s_j is the switched time slot if node x wants to switch to reduce the length of TP. S_{safe} is the number of bits for safety application packet. S_{extra} is the number of bits for all information in the packet, such as position, speed and direction. We assume that s, s_j and s_{TDMA} have the same number of bits. Then, we can reduce Eq. 1 to

$$S_{\text{MANC}} = \lceil \log_2 ID \rceil + 4 \lceil \log_2 s \rceil + S_{\text{safe}} + S_{\text{extra}} \quad (2)$$

As in [5] and [6], we make the following assumptions: N_{max} = 100, data rate R = 12 Mbps supported by the IEEE 802.11p OFDM physical layer for the 5-GHz band, ID = 1 byte, s = 100 time slots, S_{safe} = 200 bytes, S_{extra} = 30 bytes, we can observe the MANC packet size S_{MANC} in TABLE. I. The guard periods and the physical layer header is added, we need T_{slot}-ms slot duration. Consequently, with s = 100 time slots, the duration of one complete frame on the control channel is T_{comp}, as shown in TABLE. I. The maximum allocated latency is *10ms* [7]. In TABLE. I, a node can transmit its safety application packets once every T_{comp} which complies with the maximum delay requirements. The duration of one complete frame on the control channel using MANC packet is less than ANC packet in HTC-MAC. By eliminating the IDs of neighbor field, the T_{comp} is same in all values of N_{nei}.

TABLE I: MANC PACKET DELAY

N(x)	S_{MANC}	T_{trans}	T_{comp}	T_{comp}^{HT-MAC}
10	1864	0.16	20.53	21.28
20	1864	0.16	20.53	22.12
40	1864	0.16	20.53	23.75
60	1864	0.16	20.53	25.45
80	1864	0.16	20.53	27.12
100	1864	0.16	20.53	28.78

4. Simulation Results

To validate our model, we use an event-driven simulation program written in Matlab. The values of the parameter are summarized in TABLE. II to obtain the numerical result for the analytical model. In our model, we fix the WSA packet arrival rate λ_s at 25 packets/second. We also assume that in the CP there are N_{max} = 100 which always have available WSA packets. In our model, time slot allocation operates similar to HTC-MAC [4]. Each node had successfully acquired time slot in TP.

TABLE II: PARAMETER SETTINGS

Parameter	Value	Parameter	Value
Data Rate	12 Mbps	ACK	14 bytes
WSA	100 bytes	RES	14 bytes
Slot time	13 μs	SIFS	32 μs
Propagation time δ	1 μs	DIFS	58 μs
λ_s	25 pkts/s	W_0	16

In HER-MAC, there are 3 types packet transmitted: HELLO, emergency and WSA packets. Emergency packet is classified as the higher priority, while HELLO and WSA packets are classified as the lower priority. Because all HELLO, emergency and WSA packets are transmitted among the CP with different priorities, the transmission probability of WSA packet will be decreased when the number of HELLO and emergency packets increase. Consequently, Packet Delivery Ratio (PDR) of WSA packet also is better than HTC-MAC, HER-MAC and IEEE 1609.4, as shown in Fig. 3.

5. Conclusion

This paper proposed modified announcement packet to the given MAC protocols. The result shows that the delay and packet delivery ratio are slightly better than HER-MAC, HTC-MAC and IEEE 1609.4. However, probability of all nodes acquiring time slots decreases when number of time slot is less than number of neighbors.

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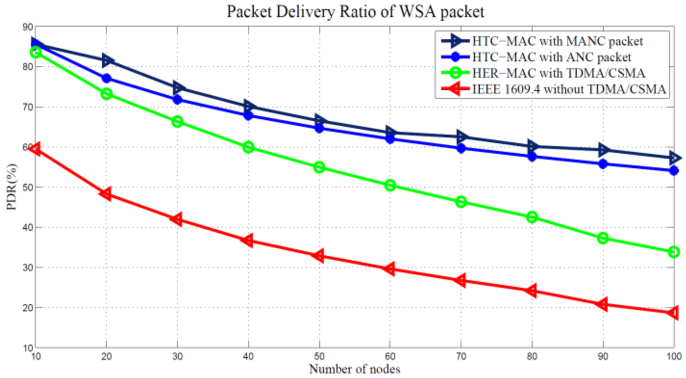

Fig. 3: Packet delivery ratio of WSA packet.

7. Reference

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