A Hybrid Efficient – Reliable MAC for VANET

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Abstract

Vehicular Ad hoc Networks (VANETs) should provide the vehicles with reliable safety message transmissions and efficient non-safety message transmissions. In this paper, we propose a new multi-channel MAC for VANETs, named HER-MAC, which uses both TDMA and CSMA multiple access schemes. The HER-MAC allows vehicle nodes to send safety messages without collision on the control channel (CCH) and to utilize the service channel (SCH) resources efficiently for the non-safety message transmissions.

Key word: VANETs, Multi-channel MAC, TDMA, CSMA.

1. Introduction

VANETs consist of two communication types: Vehicle-to-Vehicle (V2V) communication and Vehicle-to-Infrastructure (V2I) communication. VANETs provide a variety of safety applications and non-safety applications for more driving efficiency, comfort and safety. The IEEE 802.11p and IEEE 1609 family are standards designed for VANETs. The IEEE 1609.4 [1] is the standard of the multi-channel MAC for VANETs. However, the IEEE 1609.4 cannot provide the broadcast reliability for safety applications and the high throughput for non-safety applications.

Some recent studies propose more feasible multi-channel MAC for VANETs. The variable CCH interval (VCI) [2] multi-channel MAC scheme tries to adjust the CCH interval (CCHI) according to the network conditions. A Dedicated Multi-channel MAC (DMMAC) [3] adopts the Basic Channel reservation from RR-ALOHA [4] to provide the collision-free and delay-bounded transmission for safety messages. However, the SCH resources are not utilized during the CCHI. The Vehicular Enhanced Multi-channel MAC (VEMMAC) [5] allows nodes to broadcast safety messages twice and to exchange non-safety messages during the CCHI. The VEMMAC improves the reliability of safety message broadcast and utilizes the SCH efficiently. Since the VEMMAC still uses CSMA access scheme for safety message broadcast, it cannot guarantee the QoS of the safety message or other real-time applications.

We propose the HER-MAC as a new dynamic TDMA slot assignment technique for VANETs. Unlike the IEEE 1609.4, the HER-MAC allows vehicle nodes to broadcast their safety messages in the reserved time slot to improve the reliability. Moreover, the throughput of the non-safety message is enhanced by utilizing the SCH resources during the CCHI and providing the collision-free on the SCHs.

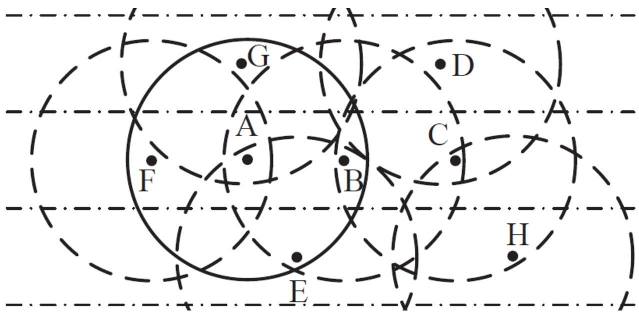

Fig. 1. Network topology

2. The proposed HER-MAC protocol

In this protocol, we assume that each vehicle node has one half-duplex transceiver which can either transmit or receive but cannot do both simultaneously. All vehicle nodes are time-synchronized using the Global Positioning System (GPS). Time is divided into 50ms Sync Interval (SI). Each SI is further divided into Reservation Period (RP) and Contention Period (CP) on the CCH, into transmission slots (TxSlots) on each SCH. The length of RP is dynamically adjusted according to the number of vehicle nodes. When a new node joins the network, it has to reserve a time slot of the RP by contending with other nodes to send the Hello message during the CP. When a node reserves a time slot of the RP successfully, it can broadcast its safety messages without any collision. Each safety message is broadcast twice in two consecutive SIs. Each node has to send the Hello message in its time slot every SI to help its neighbors know about the status of the corresponding time slot. Nodes perform WSA/RFS handshake to select a TxSlot for non-safety message transmissions during the CP. Then, nodes switch to the selected SCH during the selected TxSlot for non-safety data transmission.

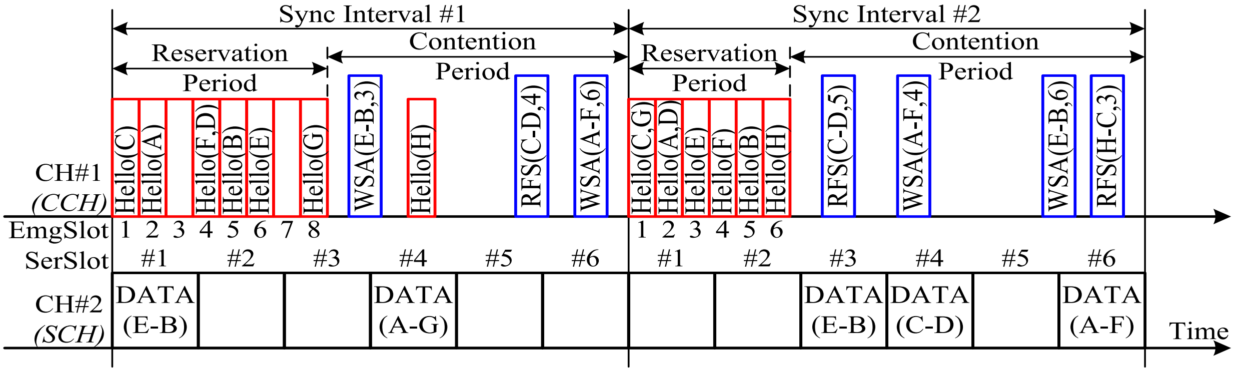

Fig. 2. The operation of HER-MAC protocol.

A. RP time slot reservation

Each node has to maintain a Frame Information Map (FIM), for example as given in Table.1. The FIM stores the maximum number of time slots used by its one-hop neighbors N. FIM also shows the status of each time slot; empty or occupied by one-hop neighbors (node ID) or two-hop neighbors (1). In the FIM of node A in SI #1, slot #1 is occupied by two-hop neighbor (marked by 1), slot #3 is empty and slot #4 is reserved by one-hop neighbor, node F (marked by F) and N = 8 because the maximum slot reserved by one-hop neighbor is 8. The Hello message (Fig. 3) contains N, the status of time slot only occupied by one-hop neighbor (0 or 1). When a node receive a Hello message in slot i from node X, it updates X to slot #i and updates other slots according to bit map in received Hello message. When a new node joins the network, it has to listen to the whole RP to get the complete information about the time slot occupation. This node tries to send the Hello message during the CP to reserve slot #(N+1) Due to the topology changed, some slots will be empty. In order to have minimum length of RP, the node which occupies the last time slot will switch to another available time slot by sending a Switch message (Fig. 3).

Sync Interval #1

Node	N	1	2	3	4	5	6	7	8
A	8	1	A		F	B	E		G
B	6	C	A		1	B	E		1
C	5	C	1		D	B	1		
D	4	C			D	1			
E	6	1	A			B	E		
F	4		A		F	1	1		1
G	8		A		1	1	1		G
H	6	C			1	1			

Sync Interval #2

Node	N	1	2	3	4	5	6
A	5	G	A	E	F	B	
B	5	C	A	E	1	B	1
C	6	C	D	1		B	H
D	2	C	D			1	1
E	5	1	A	E	1	B	
F	4	1	A	1	F	1	
G	2	G	A	1	1	1	
H	6	C	1			1	H

Table. 1. Frame Information Map.

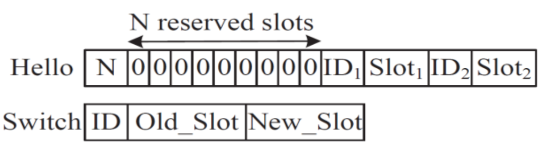

Fig. 3. Frame format.

Let us consider an example topology given in Fig. 1. The operation of HER-MAC protocol is shown in Fig. 2. Node H is a new node in the network and it tries to reverse one time slot in the RP. Node H listens to the whole RP of the SI #1. Based on the Hello message overheard from node C, node H knows the current length of the RP is 5 slots and it will try to reserve slot #6. Another thing is that node G is the node reserves the last time slot and it finds that there is available slot; time slot #1. Node G sends the Switch message to announce that it will switch from time slot #8 to time slot #1 in the next SI. Similarly, Nodes D and E also switch to time slot #2 and 3, respectively.

Node	Channel	Tx_slot
D	2	2
E	2	3
X	3	4
...	...	...

Channel	Avail_slot
2	4
3	3, 4
4	4
...	...

Table. 2. a) Node A's NIL; b) Node A's TUS

B. Non-safety message transmissions

For the non-safety message transmissions, node has to maintain the status of its neighbors and the TxSlot of each SCH through Neighbor Information List (NIL) and TxSlot Usage Status (TUS). The NIL shows the TxSlot and SCH that the neighbor nodes use to exchange non-safety messages. Based on the NIL, a node knows when its neighbor node is available on the CCH during the CP in order to perform WSA/RFS handshake. The TUS shows the availability of the TxSlot on each SCH. Note that node is not allowed to reserve the same TxSlot consecutively to avoid missing the safety messages on the CCH. An example is given in Fig. 3, while nodes E and B are exchanging non-safety messages during the TxSlot #1 on the SCH, node A broadcasts its safety messages. Since node A will rebroadcast its safety messages in the next SI, nodes B and E are not allowed to reserve the TxSlot #1 of any SCHs in the next SI.

3. Simulation Results

In this section, we evaluate our proposed HER-MAC protocol on the event-driven simulation program written in Matlab. Some simulation parameters are given in Table. 3. We consider 4 different cases as given in Table. 4, and the simulation results are shown in Fig. 4.

Parameter	Value
Sync interval	50,000 us
Safety slot duration	2,000 us
Number of TxSlot	5 slots/Sync
Safety message timeout	100,000 us
Hello message	200 us
Switch message	200 us
WSA message	400 us
Safety message	250 us
Service message	1,000 us

Table. 3. Simulation parameters.

	Case 1	Case 2	Case 3	Case 4
Number of node	20	10	10	10
Safety packet arrival rate	100	150	150	100
Service packet arrival rate	300	300	1000	300

Table. 4. Four different simulation cases

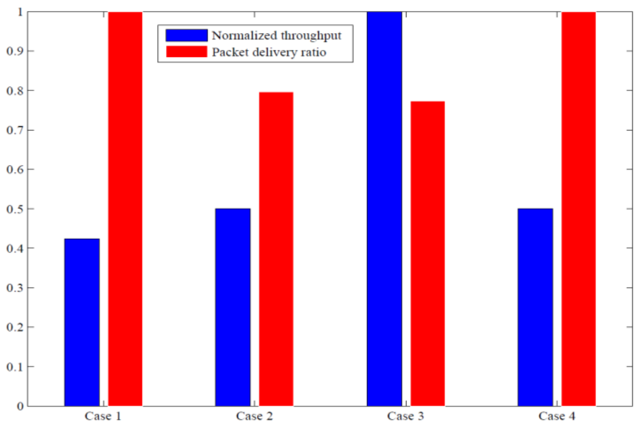

Fig. 4. Simulation results of different cases.

The packet delivery ratio (PDR) of safety message broadcast and normalized throughput of service messages are used as performance metrics in this evaluation. By using the TDMA mechanism, the PDR of safety message is high. However, when the packet arrival rate of safety message is high (cases 2 and 3), the PDR decreases because of the limited safety messages in each safety time slot. When the number of nodes increases (cases 1 and 4), the contention period decreases and limits the time that nodes contend for WSA handshake on the CCH. It leads to smaller number of reserved TxSlots, and the normalized throughput decreases. When the packet arrival rate of service message increases and there is enough time to reserve many TxSlots, the SCH utilization is improved (cases 2 and 3).

4. Conclusion

In this paper, we propose a reliable and efficient multi-channel MAC protocol for VANETs, named HER-MAC. By using the TDMA scheme, the HER-MAC has high packet delivery ratio for safety message broadcast. Moreover, the SCH resources are fully utilized in the HER-MAC protocol. The analysis of the HER-MAC is left as our future work.

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