eHER-MAC: An Enhanced HER-MAC for Vehicular Ad-hoc Networks

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Abstract

To enhance the saturation throughput in Vehicular Ad-hoc NETworks (VANETs), one of solutions is a variable Control CHannel Interval (CCHI) multichannel Medium Access Control (MAC) scheme. Recently, the HER-MAC is more reliable and efficient in both the safety message broadcast and the service channel utilization. HER-MAC which requires lower time for reservation period than IEEE 1609.4 improves the throughput of non-safety message. In this paper, we propose a new algorithm, named eHER-MAC, which reduces the length of reservation period. The eHER-MAC protocol supports more efficient in the safety message broadcast. The simulated result shows that eHER-MAC has lower average number of frames to re-sizing the reservation period and average number of time slots for reservation period than HER-MAC with the same nodes.

Key word: MAC, Control Channel Interval, HER-MAC, reservation period.

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 [1]. The DSRC spectrum is divided into seven 10MHz channels: six Service CHannels (SCHs) and one Control CHannel (CCH), as shown in Fig. 1. 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, as shown in Fig. 1.

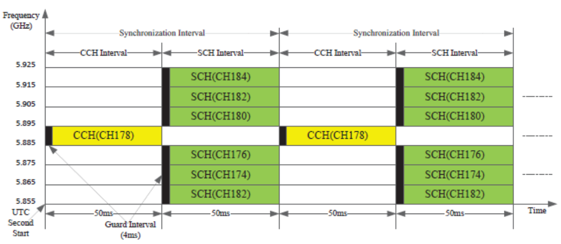

Fig. 1: Frequency channel layout of a 5.9GHz WAVE system.

One of the important services is high priority safety application proposed for VANETs. Each vehicle broadcasts its information within one-hop neighborhood [2] for the V2V applications such as pre-cash, blind spot warning, emergency electronic brake light and cooperation forward collision avoidance [3]. In V2R application such as the curve speed warning and traffic signal violation warning, RSUs broadcast to all vehicles which approach them [4]. To support the high priority safety application in VANET, the Medium Access Control (MAC) protocol is designed to provide efficient broadcast services. For instance, HER-MAC [5] supports more reliable in the safety message broadcast efficient in the service channel utilization. E-VeMAC [6] solves the parallel transmission problem in the VeMAC protocol.

The Variable CCH Interval MAC scheme [7] can support efficient channel utilization with higher saturation throughput and low service packet delay when transmitting large service packets. The CCH interval is divided into two parts. One is the safety interval and other is WAVE Service Announcement (WSA) interval. In a dynamically changing vehicular traffic condition, the VCI scheme can adjust the ratio between the CCH interval and the SCH interval. For enhancing the performance of non-safety applications in vehicular environments based the WAVE infrastructure, the Vehicular MESH Network (VMESH) protocol is supported in [8]. In VMESH protocol, CCHI is also divided into two parts, the Beancon Period (BP) and the Safety Period (SP). Based on the VCIMAC protocol, the HER-MAC [5] provides the reliable safety message broadcast

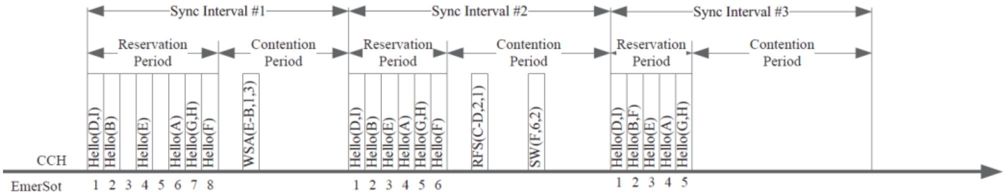

Fig. 2: The operation of eHER-MAC protocol.

through the TDMA access scheme and the retransmission mechanism. The HER-MAC protocol allows the vehicle nodes to exchange non-safety messages during the CCHI interval to improve the throughput of non-safety applications.

The rest of this paper is organized as follows. Section 2 presents network topology. Section 3 is dedicated to present an enhanced HER-MAC for vehicular ad-hoc Networks. The simulated results are presented in Section 4 and we conclude this research and suggest some future works in Section 5.

2. Network topology

In this paper, we consider that each vehicle node has half-duplex transceiver which cannot transmit and receive both simultaneously. All vehicle node has Global Positioning System (GPS) to synchronize time slot. Each node has transmission range and move on one direction, as shown in Fig. 3. Based on transmission range, we define the one-hop neighbor nodes and the two-hop neighbor nodes. The neighbor nodes of a node include one-hop and two-hop neighbor nodes.

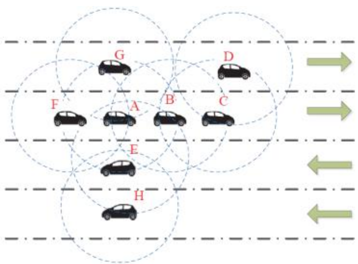

Fig. 3: Network topology.

On the CCH, each Sync Interval (SI) is further divided into Reservation Period (RP) and Contention Period (CP). In the RP, it uses TDMA scheme. In CP, we use CSMA scheme. The RP includes many Emergency Slots (EmgSlots) which is used to broadcast the safety messages. The CP is used for vehicle node to reserve an EmgSlot or to exchange control messages for 3-way WSA/RFS handshake. This operation is depicted in Fig. 2.

3. An enhanced HER-MAC for vehicular ad-hoc Networks

In each vehicle node, it stores Frame Information Map (FIM). Each node broadcasts its HELLO message to announce the status of its one-hop neighbor information. Upon the one-hop neighbor nodes overhear the HELLO packet, they update its FIM. The format of HELLO message and Switch message are given in Fig. 5. The *Serslot* field in the HELLO message confirms which *SerSlot* is used by corresponding node to exchange the non-safety message in the current SI. Each *EmgSlot* in the FIM can be empty (marked as *'0'*) or occupied (marked as *'1'* or a node ID). The *EmgSlot* occupied by a two-hop neighbor node is marked by *1*.

In eHER-MAC protocol, each node stores FIM, as shown in Fig. 4a. By considering one-hop neighbors, each node knows this empty slot(s) in the FIM. After the first sync interval, the nodes will eliminate the empty slot(s). After one-hop neighbor nodes received the first HELLO message in the next sync interval, they know the size of reservation period based on the *Reservation Slots* field in the HELLO message, as shown in Fig. 4b. After the sync Interval 2, each node considers itself to change or not to a new slot. If a node wants to change to a new slot, it will satisfy the rule 1. This node will broadcast Switch packet, as shown in Fig. 5. In figure Fig. 4c, node *G* changed to time slot *1*. After sync interval 3, no node wants to change to new time slot. The reservation period has 5 time slots.

Rule 1: In the one slot *x*, it stores only one node ID, example *a*, and/or *1* and/or *0*. Node *a* has at least one empty slot, *y*. Neighbor nodes of node a have *1* or *0* in the time slot *y*. A node satisfies both of them, it will change from time slot *x* to time slot *y*.

4. Simulation Results

In this section, we perform the simulations of the HER-MAC [5] and our proposed eHER-MAC protocol on our developed event-driven simulation tool in MATLAB.

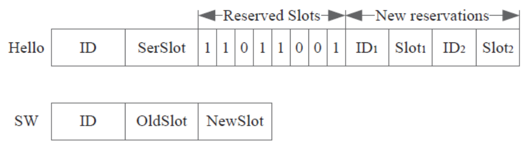

Fig. 5: Frame format.

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

(a) Sync Interval #1

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

(b) Sync Interval #2

Node	1	2	3	4	5
A	1	E	F	B	A
B	1	E	C	B	A
C	D	1	C	B	1
D	D		C	1	
E	I	E	1	B	A
G	G	1	1	1	A
I	I	E		1	1

(c) Sync Interval #3

Fig. 4: Frame Information MAP.

In the simulation, all vehicle nodes stay in the two-hop range of each other. We set up 9 nodes to compare between HER-MAC and eHER-MAC protocol. We change the number of time slots from 8 to 32 time slots. Each node broadcasts HELLO message. The transmission range is 300m. Hello message duration is 100 μs. Each simulation results are the average of 100 runs.

First, we perform the simulation to show how many sync intervals needed until all vehicle nodes reserved the EmgSlots successfully. Fig. 6 shows the comparison of average number of time slots for EmgSlot reservation according to different number of time slots. The eHER-MAC protocol required a lower average of time slots than HER-MAC. Hence, the eHER-MAC protocol is able to provide efficient channel utilization with higher saturation throughput.

Next, we perform the simulation to show how many frames to re-sizing the EmgSlot reservation. Fig. 7 shows the comparison of average number of frames to re-sizing the EmgSlot reservation according to different number of time slots. The eHER-MAC can be re-sized the length of RP faster than the HER-MAC protocol. Based on this, the eHER-MAC is able to enhance throughput of SCHs.

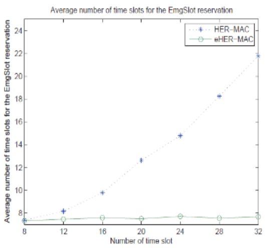

Fig. 6: Average number of time slots for the EmgSlot reservation.

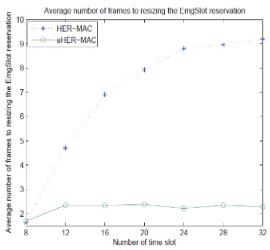

Fig. 7: Average number of frames to re-sizing the EmgSlot reservation.

5. Conclusion

This paper has proposed an enhanced HER-MAC for vehicular ad-hoc networks. A simulation experiment shows the eHER-MAC protocol has a lower average of time slots and the eHER-MAC can be re-sized the length of RP faster than the HER-MAC protocol. In the future, we will extend the research to a multihop wireless environment.

6. Acknowledgement

This research was supported by Basic Science Research Program through National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A2A2A01005900). Dr. CS Hong is the corresponding author.

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