A Novel Event Transmission Protocol for Vehicular Ad Hoc Networks

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***Abstract*—In vehicular ad hoc networks (VANET), accidents or traffic congestion occurs due to driver behavior and change of lanes. Besides, people in the car may like to share some data such as games, music, and other information when they drive through the highways. Network services and road safety for the vehicles can be provided by the VANET. In IEEE 1609.4 standard, the channel application is divided into control and service channels, which is static. Due to static nature of the channel interval, transmission of safety and non-safety data cannot be handled efficiently. Though road accidents are normal, it may not occur more frequently and therefore the control channel used for broadcasting the safety message cannot be use efficiently. It will cause the wastage of channel due to fixed control channel and services channel intervals. In this paper, our goal is to increase the driving safety, prevention of accidents and efficient utilization of channels by adjusting the control and service channel intervals dynamically. Hence, we propose here a dynamic channel adjustment protocol based on IEEE 1609.4 standard that can adjust the control and service channel to transmit the message efficiently. Simulation results of our protocol shows that it can outperform the standard in terms of number of dropped packets and idle time for different number of nodes within the communication range.**

I. INTRODUCTION

In vehicular ad hoc networks (VANETs), new services are enabled for vehicles to improve safety, reduce congestion and pollution in a city transportation system. Normally vehicles are equipped with significant computing, communication and sensing capabilities to provide services to travelers. The most important feature of VANET is to provide services to the drivers with help of on-board units, smart phones and wireless devices. In order to improve road traffic safety and share data, it enables a vehicle and its driver to communicate with others. Vehicles use the on-board device and Global Positioning System (GPS) to know location, acceleration, braking, lane change information and lane conditions.

VANET is characterized by relatively high mobility and communication among vehicles plays stronger challenges as network partition may occur frequently due to infrastructure-free environments and higher dynamic network topology. Conventional IEEE 802.11 wireless LAN, Dedicated Short Range Communication (DSRC) technology is used for car-to-car communication. The Dedicated Short Range Communication (DSRC) standard is comprised of IEEE 802.11p [1] and IEEE 1609 family. Its protocol layer is developed based on physical, data link and applications layers of traditional OSI model. Its application layer includes the fragmentation and de-fragmentation of data application service and is used for a variety of applications, such as emergency warning system, vehicle safety service, electronic parking payments and data sharing among vehicles.

DSRC uses 5.9GHz spectrum for communication, which is divided into seven channels. One of those seven channels is used for control channel (CCH) and other six are used for service channel (SCH). The CCH is used to transmit safety messages, and SCHs are used to transmit non-safety messages, where vehicles need to switch between the CCH and SCHs to transmit messages. However, the standard operation of the multi-channel sync interval in VANET is divided into CCH and SCHs intervals. There are four options in CCH and SCH interval as the standard channel access option. They are: continuous, alternating, immediate and extended. As shown in Fig. 1, a vehicle stays at CCH to exchange the safety messages in the continuous option or it can continue to stay on CCH, if no service is available. In the alternating option, a vehicle accesses to the CCH to transmit safety messages at the beginning of each CCH interval and at the beginning of each SCH interval, it switches to SCHs to transmit non-safety messages.

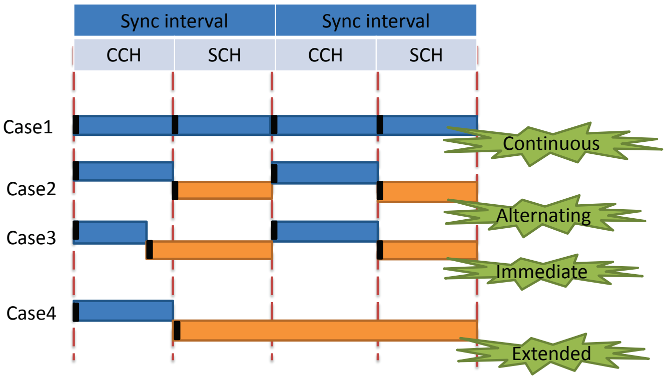

Fig. 1. Standard channel access options.

In immediate SCH access situation, vehicles are allowed for immediate communications access to the SCH without waiting for the next SCH interval. Extended SCH access allows communications access to the SCH without any pause for CCH access. In this paper, a dynamic channel adjustment protocol is design to adapt the CCH and SCH intervals on a realtime basis. The rest of the paper is organized as follows. Related work of the paper is given in Section II. Research background of the proposed protocol is given in Section III. The dynamic channel adjustment protocol is designed in Section IV. Performance evaluation of the protocol is given in Section V and concluding remarks are made in Section VI.

II. RELATED WORK

IEEE 1609.4 [2], a multi-channel extension of IEEE 802.11p standard has been proposed to improve the service differentiation capability of the 802.11p standard. There are many research focuses on application based multi channel issues of VANET. In [3], multi-channel MAC design for VANET not only ensures the reliability of safety message transmission, but also provides the high throughput for non-safety data transmission. In [4], authors utilize on board units inside vehicles and Road Side Units (RSU) inside infrastructures, and suggest that vehicles must stay on CCH during CCH interval to guarantee the reception of safety and control messages, while they may tune to SCHs to transfer the non-safety data. In [5], authors elaborate on the parallel usage of the CCH and SCH, which are direct adjacent channels, and evaluate the effects of adjacent channel interference.

In [6], authors think that a multi-channel Medium Access Control (MAC) protocol for the dense Vehicular Ad hoc Networks need to consider the channel capacity using directional antennas to achieve a higher throughput. Many researches [7], [8], [9], [10] focus on multichannel MAC protocols for IEEE 802.11p and WAVE standard of VANET. In [7], authors suggest that design of vehicular networks lies in the design of an efficient MAC protocol, which is adaptable to different traffic scenarios. In [7], authors propose to adjust the RTS and CTS with adjusted Transmit Power (TP) for establishing the communication link between the transmitter and receiver for the actual data transmission on the service channel. In [8], authors extend the MAC protocol, which can dynamically adjust the length of Control Channel (CCH) and Service Channel (SCH) intervals according to vehicle density and load conditions of the network. Authors think that the dynamic division of Sync Interval and Adjusting CCH/SCH interval duration based on the network density could make use of VANETs more efficient and reliable.

In [9], authors specify to provide dynamic adjustment of CCH interval length for safety applications under various traffic conditions. In [10], authors propose a variable CCH interval (VCI) multichannel medium access control scheme, which can dynamically adjust length ratio between CCH and SCHs as compared to the previous and current duration of CCH. The dynamic for VANET on multichannel use adjusted Transmit Power (TP) or adjusted RTS and CTS need to consider synchronization. The idle time of dynamic for VANET on multichannel, it needs to compute the time frequency. The compared previous and current time of CCH also have some question. Hence, we propose a dynamic channel adjustment protocol that can adjust the control and service channel durations dynamically based on the volume and type of the data. The dynamic change in CCH and SCH intervals depends on the length of CCH and SCH in previous case.

III. RESEARCH BACKGROUND

IEEE 1609.4 standard defines a sync interval of 100ms, which is then equally divided into control channel interval and service channel interval of 50ms duration each. According to the standard, vehicles can transmit safety message, HELLO message, and Wireless Access in Vehicular Environments (WAVE) Service Advertisement (WSA) in control channel and non-safety message in service channel. Vehicle transmits safety packets in CCH interval. At the end of CCH interval, if it does not have non-safety message to transmit, then it still continuous to access the CCH. Otherwise, it switches to SCH to transmit non-safety message, and at the end of the SCHs interval it goes back to CCH. As discussed earlier, Immediate SCH access allows immediate communications access to the SCH without waiting for the next SCH interval and Extended SCH access allows communications access to the SCH without pauses for the CCH access.

The FCC has divided 5.9 GHz spectrums into seven 10-MHz channels, in which six channels are used for service and one for control purpose. Normally, all safety messages such as road accidents are broadcast in the control channel (CCH) and non-safety messages such as audio, video and data are exchanged in the service channels (SCH). However, the number of accidents in the freeway may not be frequent, whereas download of data, audio, and video is very common as people prefer to download several services time to time. Hence, we are of the view that the control and service channel utilization in current form is not efficient and needs dynamic adjustment to improve it. Accordingly, the types of data are divided into three categories based on the priority. The safety message that is exchanged only in CCH is considered to be priority 1. The non-safety real time data is considered to be priority 2 and non-safety non-real time data is considered to be priority 3. Thus, all seven channels are divided on priority basis. CCH is totally meant for exchanging the safety message and therefore is dedicated for the data with priority 1. Channels 1 through 4 are dedicated for the data with priority 2, channel 5 is dedicated for the data with priority 1 and channels 5 through 7 are dedicated for the data with priority 3.

It is assumed that each vehicle has one antenna, and a GPS device. Communication range of each vehicle is considered to be 250m and two types of vehicles such as service provider and users are considered. Any vehicle who has data to send is termed as a Provider, and other nodes are termed as User. The protocol is designed for the VANET of highway scenario with 3 lanes in each side. In each 2KMs, it is assumed that there is a road side unit (RSU), which can upload, download and update data time to time whenever vehicles pass through it. Initially, each vehicle senses the medium and broadcasts a HELLO message if the medium is ideal. However, it goes to back off state if the medium is busy. As shown in Fig. 1, the duration of the message is considered to be 100 units, which is partly used for CCH and is partly used for SCH. The back off time is set in such a way that a node that is far away from the location of the accident can broadcast first so that vehicles away from the accident spot can get the first hand information.

IV. PROPOSED PROTOCOL

In our protocol, it is assumed that each vehicle is equipped with a GPS and single transceiver to communicate with other vehicles. The communication range of each vehicle is considered to be 250m. Taking the highway scenario, vehicles those are running on the road can be classified into as either Provider or User as shown in Fig. 2. A vehicle that has data to send is termed as the Provider and others can be termed as the User. Each side of the highway has three lanes of width 3.5m each, and there are Road Side Units (RSU) in each 2KMs. Each RSU has a unique id (RSUID) with its position information. Let us assume that there are n number of sync intervals. Each vehicle has to exchange information in the first sync interval as discussed in the initial phase.

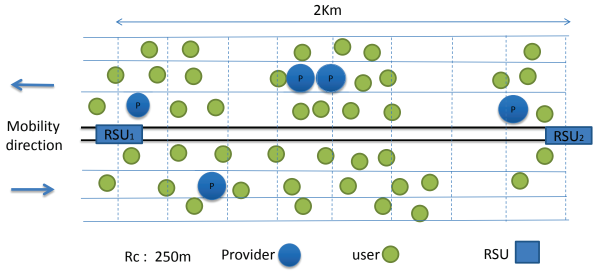

Fig. 2. The Highway scenario.

A. Initial phase

In this phase, first each vehicle has to sense the control channel. If the control channel is assessed to be idle, the vehicle broadcasts HELLO message to all, which are within its communication range. The HELLO message contains ID of the vehicle, current speed, and its location information. However, if the channel is sensed busy, the vehicle will go for a random back off, which is normal in most wireless communication. At the end of each back off mechanism, vehicle will rebroadcast the HELLO message. Upon receiving the HELLO message, each vehicle knows the ID, destination, location and speed of its one-hop neighbors.

B. Event broadcasting phase

In this phase, a vehicle broadcasts the events related to warning messages, which contains lane change information and accidents in the highway. This warning message is broadcast in the CCH intervals of the control channel. Other than the information about any accident, the message also includes Provider's ID, location, speed, moving direction, event ID, event location, and time stamp of the event. Upon receiving this warning message, a Provider's one-hop neighbors may ignore or rebroadcast the message after verifying the location and event ID of the event. A receiving node (User) goes to rebroadcast back off interval as given in equation 1 before it forwards the message to its next hop neighbors in the front. Assuming location of the User node is (x_{dis}, y_{dis}), the rebroadcast backoff time can be calculated as follows. During backoff procedure, if a vehicle receives the emergency message rebroadcast from its one-hop neighbors, it checks the event ID, stops the back off procedure and drops the warning message. Otherwise, it rebroadcasts the warning message after the backoff time. Besides, if it receives the event ID from another vehicle that is behind of it, the vehicle (User) will ignore the message.

$$\frac{1}{distance} = \frac{1}{\sqrt{(x_{self} - x_{dis})^2 + (y_{self} - y_{dis})^2}} \qquad (1)$$

C. Event transmission phase

It is o be noted that vehicles (Providers) moving along the same direction can carry the warning message until they reach at an RSU. The Provider will forward the message to the RSU as soon as it arrives near to it. The forwarded message contains the information of all events those are happened in between any two consecutive RSUs. Then the same message is forwarded by the RSU to the vehicles moving along the opposite direction to the Providers. It is obvious that the vehicles who receive message from the RSU must be moving along the opposite side of the lane. They carry the message to forward it to the vehicles before coming nearer to the location of the event. Upon receiving this information in advance, vehicles approaching nearer to the event occurrence spot may find alternate route and exit through the nearest interchanges to avoid congestion.

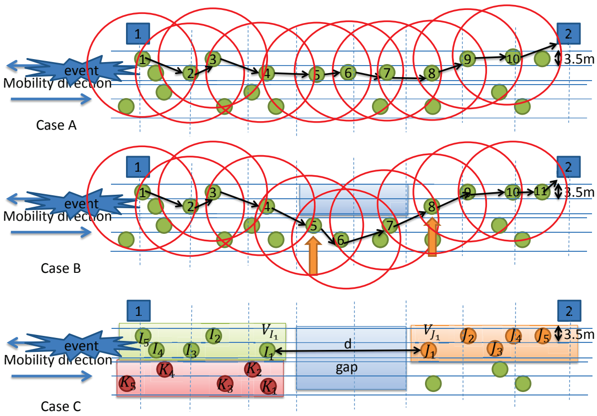

Fig. 3. All possible situations of packet forwarding.

Different conditions of packet forwarding from one RSU to the next RSU are shown in Fig. 3. It could be possible that the packet is forwarded from one RSU to another one through the vehicles moving along the same direction irrespective of their mobility in the same or different lanes. Here, the intermediate vehicles between any two RSUs can form a connecting path to forward the packet as shown in Case A of Fig. 3. Assuming the message transmission through the vehicles to the RSU along the same direction that requires s number of hops, the packet broadcast time can be analyzed as given in equation 2.

$$Broadcast\,Time = \sum_{i=1}^{s} Broadcast\,Time_i \tag{2}$$

In another scenario, though the packet can be forwarded to the RSU through the vehicles moving along the same direction, no vehicle may be present in between two vehicles moving along the same direction as shown in Case B of Fig. 3. Therefore a connecting path between two RSUs is not possible by the vehicles moving along the same direction. In this case, a connecting path is established by the vehicles moving along the same as well as the opposite direction. Assuming the message transmission by the vehicles moving along the same as well as in the opposite direction with l hops, the rebroadcast backoff time and broadcast time can be calculated as given in equation 3 and 4, respectively.

$$\begin{aligned} &Reboardcast\,backoff\,time = \frac{1}{distance} + \alpha \\ &= \frac{1}{\sqrt{(x_{self} - x_{boardcast})^2 + (y_{self} - y_{boardcast})^2 + \alpha}}, \\ &\alpha = direction\,factor \end{aligned} \tag{3}$$

$$\begin{aligned} &Broadcast\,Time = \sum_{i=1}^{s} Broadcast\,Time_i \\ &+ \sum_{j=1}^{o} Broadcast\,Time_j = \sum_{k=1}^{s+o} Broadcast\,Time_k + \alpha * o \end{aligned} \tag{4}$$

It could be possible that there is communication gap between the vehicles moving along the same direction. Hence, the network is fully partitioned as shown in Case C of Fig. 3. As shown in the figure, there are three groups of vehicles. Let Group I be the set of vehicles, who carries the event information, Group J be the set of vehicles who has no information about the event, and Group K be the set of vehicles who moves along the opposite direction and has knowledge about the event. Let, I_i be the vehicles in front of the gap, J_j be the vehicles behind of the gap, and K_k be vehicles move along opposite direction. $d_{a,b}$ is the distance between vehicles a and b and V_i, V_j, V_k are the velocity of vehicles i, j, and k, respectively. Now the average waiting time for the vehicles moving along the same direction can be calculated as follows.

$$\frac{\sum_{i=1}^{I} \sum_{j=1}^{J} \frac{dist_{J_j,I_i} - R_c}{v_{I_i} - v_{J_j}}}{I * J} \tag{5}$$

The average waiting time for the vehicles moving along the opposite direction can be calculated as follows.

$$\frac{\sum_{k=1}^{K} \sum_{j=1}^{J} \frac{dist_{J_j,K_k} - R_c}{v_{K_k} - v_{J_j}}}{K * J} \tag{6}$$

Finally, the message can be carried out by the vehicles moving along the opposite direction and is forwarded to the RSU through several hops.

D. Dynamic channel interval adjustment

In this section, we use the number of neighbors and events to calculate the value of dynamically channel interval adjustment (V_{DCA}) and use this value to setup the new CCH interval. Since, the number of events is very unpredictable, each CCH interval can be changed more frequently and dynamically. Hence, we calculate the value of CCH interval by using the average number of k times of packets transmitted within each CCH interval. The packets include safety messages(S), HELLO messages (H), and WSA. In the next k CCH intervals, each vehicle will adjust the CCH interval based on the number of neighbors and events.

$$V_{DCA} = S + H + WSA. \tag{7}$$

$$i = n\,mod\,k. \tag{8}$$

$$V_{DCA} = \frac{\sum_{i=1}^{k} CCH_n}{k}. \tag{9}$$

Since, every vehicle will have different DCA value, each one of them uses a backoff time that has larger DCA value. Vehicles having larger DCA value will broadcast this packet to its one-hop neighbors and User nodes will drop their own DCA packet upon receiving the packet from the Providers if that has larger value. Then user nodes adjust their CCH interval based on the DCA value in order to match the actual needs without wasting bandwidth so that bandwidth efficiency can be improved. In our protocol, two types of packets are considered. They are safety and non-safety packets. According to the number of packets received by a user, four possible cases can be considered. Accordingly, a node may receive few number of safety and non-safety packets, more number of safety packets and few number of non-safety packets, few number of safety packets and more number of non-safety packets, or more number of safety and non-safety packets.

In low data load, i.e. if a user receives few number of safety and non-safety packets our approach is same as the standard as safety or non-safety messages can be completed transfer. If a user receives more number of safety packets and few number of non-safety packets or few number of safety packets and more number of non-safety packets, the SCH interval can be changed to accommodate the required number of safety and non-safety messages. For example, the CCH and SCH duration is 50 units each in the standard. However, based on our protocol, the CCH duration may be 20 units and SCH duration may be 80 units if few number of safety packets and more number of non-safety packets are received. If a user receives more number of safety and non-safety packets, it is suggested that multiple number of channels should be used for the SCH and an efficient channel allocation algorithm is required, which will be our future work.

V. Performance evaluation

In order to evaluate performance of our protocol, we simulated it using C++. The safety packets are generated randomly and CCH interval is considered to be within 1 through 100ms. Our protocol is compared with IEEE 1609.4 standard and VCI [10] in terms of dropped packets and idle time in CCH interval. As shown in Fig. 4, Fig. 5 and Fig. 6, simulation results in terms of number of dropped packets of the CCH interval for less than 50ms, more than 50ms and random CCH interval between 1 to 100ms are presented.

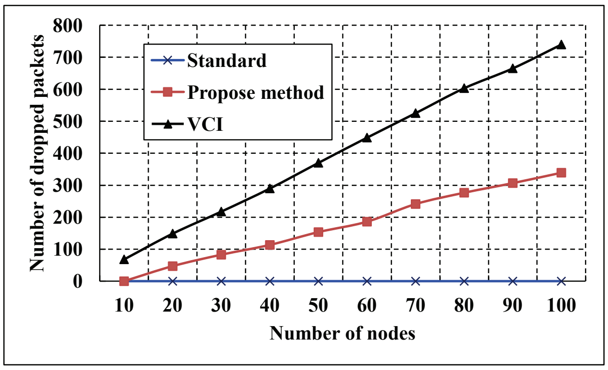

Fig. 4. Packet dropped of CCH interval of less than 50ms.

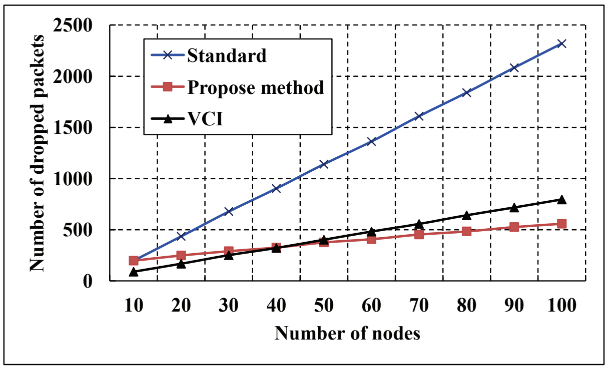

Fig. 5. Packet dropped of CCH interval of more than 50ms.

From Fig. 4, it is observed that no packet is dropped according to the standard as the generated safety packets are less than 50ms. Each time the VCI need to adapt the CCH interval using previous safety packet. Our method is using first 10 times packets same as the standard and then we calculate the average of the 10 times packets as next generated safety packets to adapt the CCH interval. In this case, the number of dropped safety packets is less than VCI. As shown in Fig. 5, we find that the number of dropped packets according to the standard is great than VCI and our protocol. As the CCH interval in the standard is fixed, it cannot complete the packet transmission. In this case, the dropped packets of the VCI is less than our protocol when number of nodes is less than 40. It is found that our method is better than VCI in terms of total dropped packets.

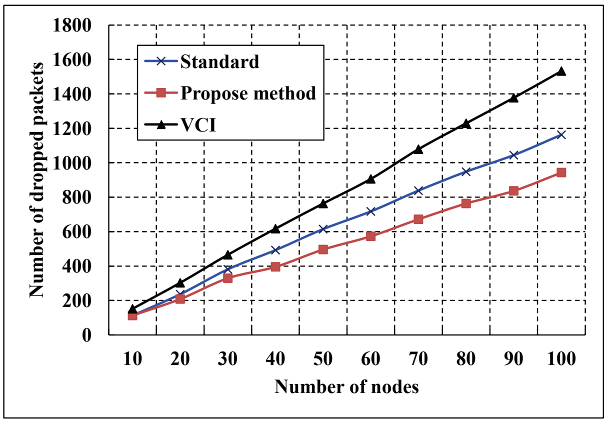

Fig. 6. Packet dropped of CCH interval within 1 to 100 ms.

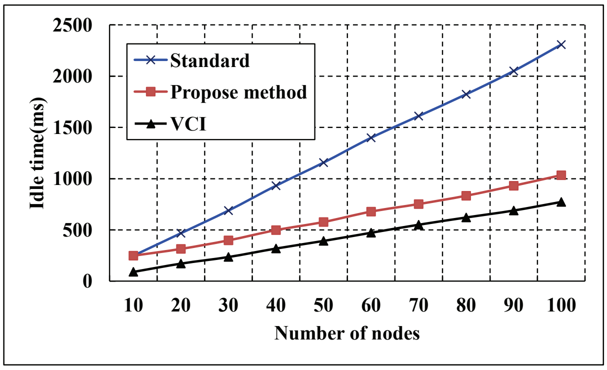

Fig. 7. Idle Time of the CCH interval less than 50ms.

In Fig. 6, packet dropped is simulated for the random duration of the CCH interval. It is observed that our protocol outperforms the standard and VCI in terms of dropped packets as the CCH interval in our protocol is dynamic. Simulation results of idle time for different duration of CCH intervals and number of nodes are shown in Fig. 7, Fig. 8 and Fig. 9. In Fig. 7, we can find that the idle time according to the standard is greater than our protocol and VCI, as the standard CCH interval is fixed. In this case, the idle time of VCI is less than ours as we use the first 10 time packets same as the standard. In Fig. 8, the idle time is simulated with different number of nodes when CCH interval is greater than 50ms. The idle time based on the standard is zero as it use all CCH interval to transmit data. In this case, our protocol outperforms VCI. In Fig. 9, we find that idle time in our protocol is less than VCI. In this case, the standard idle time is less than ours as half of the time duration of CCH interval will be utilized for transmitting data according to the standard.

VI. Conclusions

IEEE 1609.4 standard defines an architecture and a complementary, standardized set of services and interfaces to enable secure Vehicle-to-Vehicle and Vehicle-to-Infrastructure wireless communications. In this paper, we analyze the dynamic channel adaption interval for VANET. We analyze packet

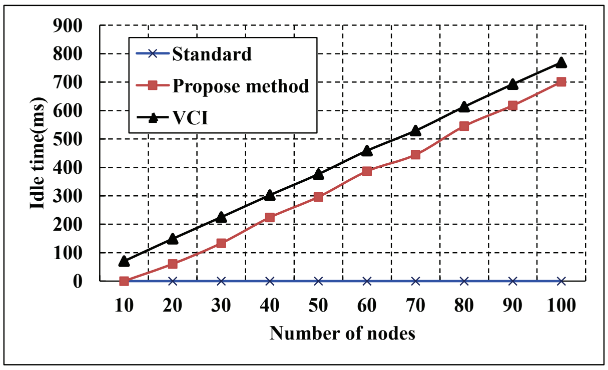

Fig. 8. Idle Time of the CCH interval more than 50ms.

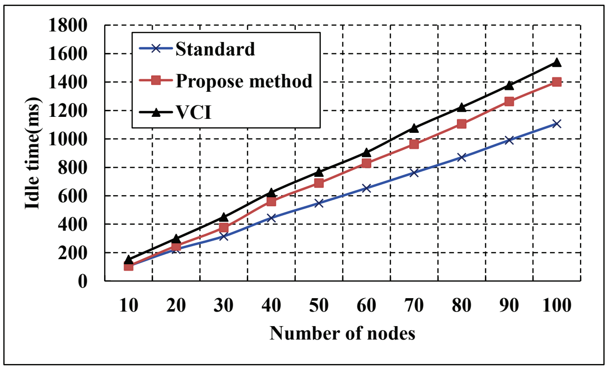

Fig. 9. Idle Time of the CCH interval during 1 to 100 ms.

transmission methods and dynamic change of CCH and SCH intervals. We compare the performance of our protocol with IEEE 1609.4 standard and VCI and find that our protocol can outperform in terms of number of packet dropped and idle time. In the future, we will develop the channel hopping algorithm when huge number of safety and non-safety messages are generated and the current form of CCH and SCH intervals are not enough to handle the demand. Besides, we will also analyze the channel utilization probability to give a theoretical basis to our work

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