

A Design and Simulation of Variable CCH Interval based on Message of V2X

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Abstract— V-Link communication is responsible for high-capacity broadband communication between vehicles. It is allowed the MAC and network service architecture specified by the IEEE 1609.3/4 standards. Also, channels are assigned as the control channel (CCH) and service channel (SCH) which operate a multi-channel. In this paper, we suggested variable control channel interval, and simulated the access time in the range of road infrastructure based on traffic message demands.

Keywords— WAVE, V-Link, Multi-channel, CCH, SCH, Alternative access

I. INTRODUCTION

Many autonomous vehicles have various sensors to recognize the environment and traffic status such as 2D and 3D laser scanners, camera, and GPS.[1,2] It has been growing the using of information from multiple sensors to control vehicle, and is needed the data transmission rate of 100Mbps and real-time reliability for V2X communication.

V-Link technology is intended that provides a reliable service to lots of vehicles at the same time. It will support the data rate of over 100 Mbps and 5ms low latency to deliver the safety and control information of the vehicle. V-Link communication is based on WAVE architecture specified in 1609 family standard. For the multi-channel operation, channels are assigned as the control channel (CCH) and service channel (SCH). The CCH is used to exchange periodic management frames and WAVE short messages for providing vehicle safety. [3] But as the number of vehicles increases, every vehicle generates messages and will lead to message pile-up.

In this paper, we designed and simulated a variable channel interval operation that can provide safety service more flexibly. It is helpful to minimize the delay of the safety message by optimizing the interval of a CCH channel is performed in the multi-channel operating environment.

This paper is organized as follows.

Section 2 describes the factors that can affect variable channel interval. In Section 3, safety messages are simulated based on dynamic vehicle topology. Finally, we review the result of packet reception ratio (PRR) and conclude our work.

II. VARIABLE CHANNEL INTERVAL ARCHITECTURE

Figure 1 shows an option of a channel switching method in WAVE standard. Channel access between CCH and SCH is specified by IEEE 1609.4. The figure (a) illustrates continuous access on the CCH. Continuous access requires no channel coordination. Alternating access (b) is illustrated for the case of switching between CCH and SCH. [3]

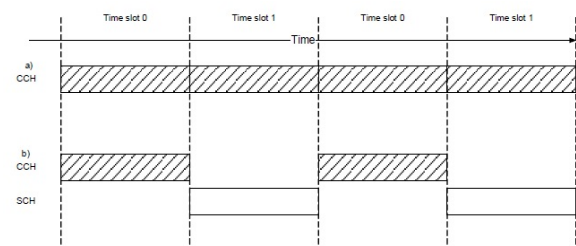


Figure 1. Channel Access of examples in 1609.4 [3]

Vehicles typically transmit message on a control channel for enhancing road traffic safety. V-Link certainly includes the CCH channel is where the most important data will be transmitted. The utilization of the control channel should be permitted enough access time such that is fair for all vehicles.

In a wireless communications between vehicles and between vehicles and road infrastructure, the performance of the network will be affected as the number of vehicles, road length, message size, and message repeat rate. We suppose that road infrastructure monitors the current traffic and vehicle density in its coverage. And it is responsible for the decision of CCH interval. As the Figure 2 indicates, periodic safety messages (1) and event-centric messages (2) share the same control channel. In particular, periodic safety messages consume a large portion of the channel bandwidth. Therefore, as the density of the vehicle increases, the collision between the messages increases, so that the PRR decreases and the latency increase.

There is a default message load that is occurred in this network. It is amount of the periodic message on the all the vehicles broadcast. In other words, the number of vehicles is a key factor affecting message load when road length, message size, and road length are determined.

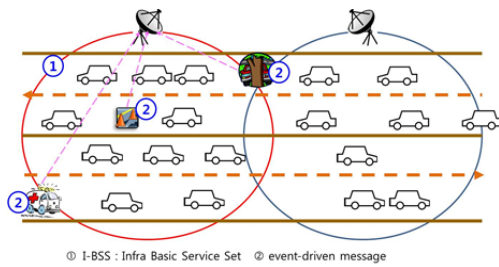


Figure 2. Topology of Vehicular Network

Service messages are not involved in this message load. It is computed the default configuration information that message load is satisfied the minimum control channel performance, 1.5Mbps. [4] The default configuration presents that all messages on CCH can be processed without changing the channel. Here, with a message size of 500 bytes and a road length of 1 km, there are about 36 vehicles in the default configuration. If the number of vehicles doubles to 72, the message load also increases, so the time to use control channel must also increase more than fixed 50ms. Vehicle topology can have hundreds of vehicles at once. It is necessary to adapt their channel interval to network density variations in order to provide a good data transfer.

III. SIMULATION OF VARIABLE INTERVAL

WAVE multi-channel operation is provided one physical module. In general, the imminent information of safety service may have higher priority than under non-emergency service, even though the content may be identical. As vehicles become more complex, priority most greatly affects delivery probability because it can exceed channel capacity. To ensure optimal time of high priority message, we suggest the way to control a CCH interval based on the message load variably from 30ms to 100ms (continuous access). Table 1 shows variable intervals of CCH depend on the number of vehicles.

Table 1. Adjustment of Interval based on Vehicle Numbers

Numbers	Min _D	MAX _D	CCH-Interval
0~8	0	0.24	30
9~17	0.25	0.4	40
18~36	0.5	1	50
37~53	1.1	1.4	60
54~71	1.5	1.9	70
72~89	2	2.4	80
90~107	2.5	2.9	85
108~125	3	3.4	90
126~143	3.5	3.9	95
144~200	4	5.56	100

Ns-3 is a free open source network simulator. [5] We installed the ns-3 in Ubuntu Linux platform, and developed the scenario using the C++ programming language. It was performed to test the transmission of basic safety messages (BSM) in the dense environment of the vehicle.

A. Simulation Configuration

Simulation configuration of a variable channel interval is to assume the following:

- Two-way road onto a four-lane, the total road length that is 1km coverage of road infrastructure. Distance from the vehicle in front also applied randomly (20m ~ 100m).
- Channel is accessed alternately the CCH/SCH at a predetermined time interval in a single PHY.
- 500byte BSM message which consists of mandatory and optional elements is broadcast. It is repeated once in every 100ms. (10 times per second).

The initial configuration of vehicle nodes is illustrated in Figure 3. It appears continuous movement in each direction.

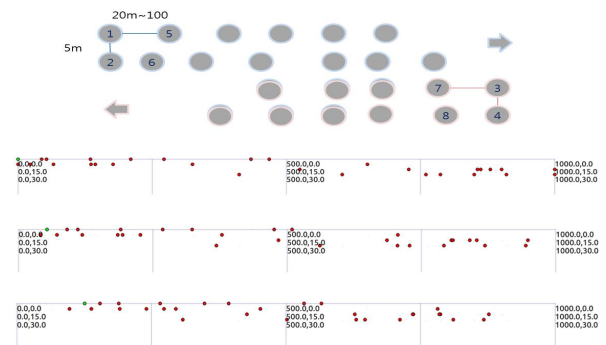


Figure 3. Configuration of Vehicles in four-lane, two-direction

The simulation is based on the packet transmission through the control channel and service channels. It changes the complexity of the vehicle in a transmission range around 1km. PRR (packet reception ratio) and average delay time is calculated by CCH messages.

$$PRR(\%) = \frac{\sum_{node=1}^k Packet_{received}}{\sum_{node=1}^k Packet_{received} + \sum_{node=1}^k Packet_{congested}}$$

$$= \frac{\sum_{node=1}^k Packet_{received}}{\sum_{node=1}^k Packet_{total\ sent}}$$

Initially, wireless communication between four vehicles should meet 100% of the basic PRR without congestion.

B. Simulation results

In a loose topology environment, even if the CCH Interval is reduced to 30ms or 40ms, PRR is not much difference from the fixed 50ms. The utilization of the SCH can be relatively increased by the decrease of CCH interval consequently. By contrast, both of CCH and SCH traffic can exceed channel capacity in high vehicular density. In this case, messages using CCH have higher priority than SCH. We decide that optimizing of control channel access time is advantageous for vehicle networks that maintain safety services.

Figure 4 displays the PRR result. According to the simulation, the PRR increases by about 8% for adding every 10ms of channel access time on average.

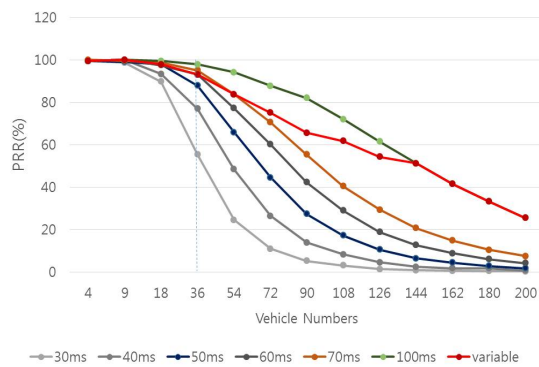


Figure 4. Packet Reception Ratio as CCH Interval & Vehicle Numbers

On the other hand, we can see the perspective of SCH where WSA and IP message are transmitted additionally. Likewise, 30ms of SCH interval is enough time to I2V service that only one node transmits service data. It is possible to send and receive all IP messages in less SCH interval even if topology includes all 200 vehicles. Thus, extra access time is available to use the CCH. We can represent the channel access method in a single physical layer as followed Figure 5.

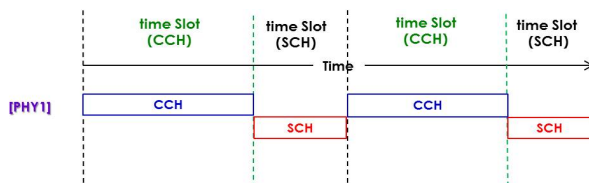


Figure 5. Single-PHY Channel Access with Variable Interval

Road infrastructure broadcasts periodically selected CCH intervals through message frame. It requires at least 3 bytes overhead in the extension field (element ID, Len, value) of WAVE information element for additional transmission of the CCH interval.

The PRR performance can be improved by not only channel interval but also data repetition rate. The service message can determine the repetition rate and message size because it is not sure to follow a period of 100ms such as basic safety message. As shown below the Table 2, if the entire data to be transmitted is divided into an appropriate size and a repeat rate, a PRR similar to the continuous access method is provided at intervals of 70 ms.

Table 2. PRR Result through RepeatRate and Interval

RepeatRate	SCH Interval	Send size	Total size	PRR	Average Delay	Over 50msec Interval
50	50 ms	350byte	3.5Kbyte	38.54%	1 ms	0.0036
25	50 ms	700byte		51.60%	2.3 ms	0.0108
17.5	50 ms	1Kbyte		66%	3.0 ms	0.017
5	50 ms	3.5Kbyte		60%	10 ms	0.04
17.5	60 ms	1Kbyte		78.40%	2.57 ms	0.0008
17.5	70 ms	1Kbyte		83.53%	2.12 ms	0
50	continuous (100ms)	350byte		84.92%	0.32 ms	0

The transmission delay of a message calculates the average time based on the received packet. The average delay time satisfies with 5ms latency in all CCH interval and vehicle density. However, in topology with more than 145 vehicles, it is clear that the PRR values drop off sharply even if the CCH Interval is supported at maximum (100ms). That is to say, it may be difficult to provide public safety service regardless delay time.

Broadcast communications do not guarantee sufficient reliability, hence it exist a physical limitation that lots of vehicles deliver messages over only single channel. WAVE occupies 10MHz fundamental frequency channel in single-PHY. In order to increase the transmission speed of vehicular communication, we plan to support the frequency bandwidth to 20MHz/40MHz and increase the number of the modems.

The access method of extended PHY is possible many channel allocations depending on the type of service. For example, the first PHY can perform continuous access of CCH and the second PHY can perform alternating access of SCHs. One way to increase the reliability of broadcast is to use the SCH to repeat the same safety message as the CCH. In this case, to consider of compatibility with WAVE, control channel maintains 10MHz.

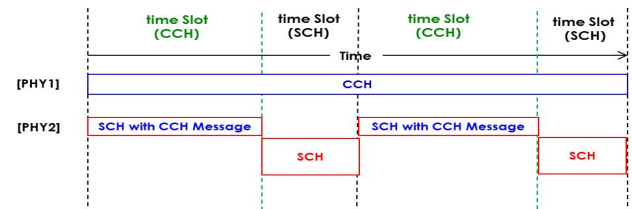


Figure 6. Dual-PHY Channel Access for CCH Reliability

IV. CONCLUSIONS

The channel interval value is a time that has the authority to pre-empt a specific channel according to the synchronized time in the wireless communication device. In order to set variable channel access time unlike the fixed channel interval of WAVE, an appropriate channel interval should be considered.

We suggested variable CCH intervals based on periodic safety message (BSM) of V2X. As the number of vehicles increases / decreases, the appropriate CCH interval adjustment improves PDR and channel utilization. However, in a dense network topology, a new PHY / MAC architecture and multi-channel operation are required to provide reliable V2X services.

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