Performance Evaluation of Multi-channel Operation IEEE 1609.4 Based on Multi-hop Dissemination

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Summary

The Multichannel Operations IEEE 1609.4 is an emerging standard which support the co-existence of safety (CCH Channel) and non-safety (SCH Channel) message application in vehicular networks. This strictly concerns on the transmission slot synchronization of CCH/SCH based on Wireless Access in Vehicular Environments (WAVE) to achieve QoS requirements (i.e. to improve packet delivery ratio and reduce delay). In this paper, we study the performance of the IEEE 1069.4 based on multi-hop dissemination compared with the single-hop dissemination in vehicular network to get SCH and CCH channel performance. Our work also compared multi-hop with single-hop dissemination based on the performance based on the IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard in a vehicular environment to get packet delivery ratio performance in vehicular networks. On this work, we use ns 2.34 simulator to evaluate the performance of the IEEE 1609.4. From the simulation, it was found that the delay of Multi-channel Operations IEEE 1609.4 based on multi-hop dissemination has been degraded 42.77% compared with single-hop dissemination and the throughput is 65.72% better compared with single-hop dissemination. Based on IEEE 802.11p Enhanced Distributed Channel Access Function the standard in vehicular environment, we found that AC_VO (CWmin = 7 and CWmax = 15) is the highest performance based on multi-hop dissemination (i.e. the highest on queue priority scheduling and the better average of delay performance).

Keywords :

IEEE 1069.4, multi-hop dissemination, single-hop dissemination, safety and non-safety message application, Enhanced Distributed Channel Access Function

1. Introduction

Vehicular ad hoc network (VANET) is a sub-group of MANET which can support both Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications [1,2]. The main characteristic of both MANET and VANET are self-organization and movement [1,2]. Recently, IEEE 802.11 working group developed an amendment to the 802.11 standard in order to support vehicular ad hoc network [1].

This standard [2] is known as 802.11p. It defines physical and medium access control layers of vehicular wireless network. This standard [2] also explained the IEEE 1609 protocol family for higher layer specification based on 802.11p.

This standard protocol consists of [1,2]:

(i) IEEE 1609.1:describes resource manager specification
(ii) IEEE 1609.2: defines the format and processing of secure messages
(iii) IEEE 1609.3:covers the network and transport layer services
(iv) IEEE 1609.4:specifies the improvement to the IEEE 802.11p MAC to support multichannel operation

Ali J. Ghandour, et al. [3] perform modeling and simulation of the protocol IEEE 1096.4 by contributing to improve the packet delivery ratio and delay to the safety application and solve problems early in the transmission slot synchronization CCH/SCH. We use [3] to simulate and evaluate the performance of Multi-channel operations of the IEEE 1609.4. Hong K. et al. [4] proposes three alternative approaches for safety communication in a multi-channel environment, which aims to improve the performance compared to the basic IEEE 1609.4 and simulate with ns-2 [5] simulations.

Grafling S. et al. [6] evaluate the performance IEEE 1609.4 and IEEE 802.11p based on the traffic prioritization schemes selected for the standards, and simulate in the presence of multi-channel operation implemented by the IEEE 1069.4 the delay control messages and defined the QoS priority requirement standard in multi-channel operation. Said M. [7] investigates the performance of multi-hop connectivity for Inter-Vehicle Communication (IVC) systems in Vehicular Ad Hoc Network (VANET). From this paper [7] we can evaluate analytical model to determine the failure of connectivity probability according to distance headway and broadcast signaling delay.

Most of research on multi-channel vehicular ad hoc networks (VANET) focused on methods in achieving QoS requirements (i.e. to improve packet delivery ratio and reduce delay) and increasing saturated throughput based on SCH Channel. On the other hand, most of existing work above does not include the method to achieve the QoS requirements by improving the

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connectivity (multi-hop dissemination) based on Multichannel operations of the IEEE 1609.4.

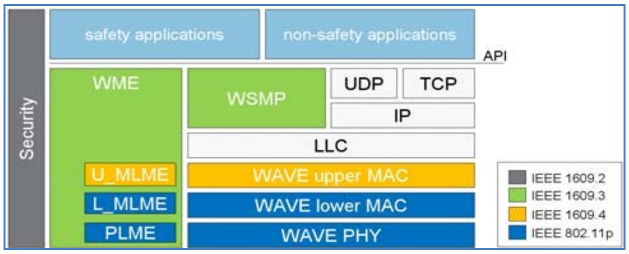

Fig. 1 DSRC standards and communication stack [9]

In this paper, we evaluate the performance of Multichannel Operations IEEE 1609.4 based on multi-hop dissemination. We compare that with single-hop dissemination in a vehicular networks to evaluate theSCH and CCH channel performance.We also evaluate the performance based on IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard in vehicular networks [2]. This paper is organized as follows. In section 2, we provide an overview of the IEEE 1609.4 protocol and IEEE 1069.4 multi-hop connectivity. In Section 3,we provide a scenario and simulation multi-hop multi-channel IEEE 1609.4. We also evaluate the performance multi-hop multi-channel IEEE 1609.4. Finally, we conclude the paper and suggest the future work in Section 4.

2. Background

2.1 The IEEE 1609.4 Protocol

The IEEE 1609.4 standard [2,3] for multichannel operation in VANETs defines a number of channels, each channel for different application, with different characteristics as shown in Figure 2. In addition to different frequency being used, different maximum transmit powers are allotted for different channels. IEEE 1609.4 has different channels, from the control channel (CCH) to the six service channels (SCH), which are utilized in time multiplexed fashion, with the control channel being served every other timeslot. The rest of the timeslots are used by the different service channels, depending on the actual application requirements.

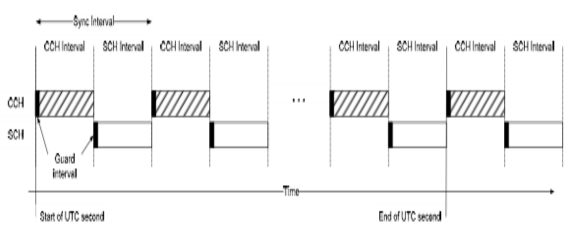

Fig. 2 Syn Interval, guard interval, CCH interval, and SCH interval [2]

2.1 Multi-hop Dissemination

Disseminating beacons in a single-hop dissemination scenario is straightforward since, in the most basic case, all vehicles use the same fixed transmit power, beaconing frequency and message size [10].
To achieve IEEE 1069.4 QoS requirements, several multi-hop broadcast protocol considers 802.11 variants in the context of intervehicular communication. Adler. C.J. et al. [11] proposed location based broadcast protocols. This protocol can quickly adapt to topology changes in vehicular ad hoc networks. The next hop transmitter is selected with a based contention-phase, in a distributed way.
Torrent-Moreno M. et al. [12] described that hop can be minimized by adjusting the parameters governing the channel access at MAC level [13,14] such as contention window in the 802.11 DCF back-off scheme. Xu, Q. et al. [15] proposed methods to increase the reception probability of the IEEE 802.11 DCF, by broadcasting a message several times within a lifetime limit.
In this study, we evaluate multi-hop dissemination, which path of forwarding data from source to destination has a multi-hop route to destination based on Multi-channel operations IEEE 1609.4.

3. Scenario and Simulation

3.1 Scenario

By using ns 2.34 simulator [5], we study the performance of Multi-channel operations of the IEEE 1609.4 based on multi-hop is compared with single-hop dissemination in vehicular networks to get SCH and CCH channel performance. We also evaluate the performance based on the IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard in a vehicular environment. We simulate this paper using scenario with payload size of 400 bytes, the bitrate 3 Mbps, and number of cars is 100. The channel configuration using default values for control and service channel intervals are 50ms, and guard intervals value is 4 ms. Meanwhile, Enhanced Distributed Channel Access Function (EDCA) values using EDCA parameter standard for IEEE 802.11p. Table 1 presents all parameters used in our simulation.While some parameters stay fixed, others are varied in order for us to observe the changing behavior of the network.

Table 1: Simulation Parameters

Number of vehicles	100
Number of channels (K)	7
Channel data rate (R)	3 Mb/s
Payload size	400 bytes

Contention Window	CWmin–Cwmax (EDCA parameter for IEEE 802.11p)
CCH slot duration	50ms
SCH slot duration	50ms
Guard Interval (GI) duration	4ms
Simulation time	20 seconds

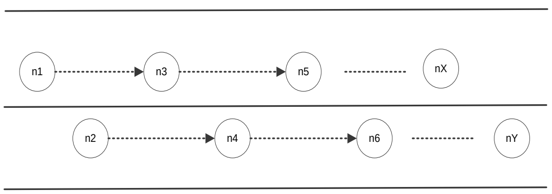

Fig.3 Path of forwading data from source to destination on Single-hop Dissemination

Fig. 3 shows the single-hop dissemination. The path of forwarding data from source to destination has a direct route to destination based on Multi-channel operations IEEE 1609.4

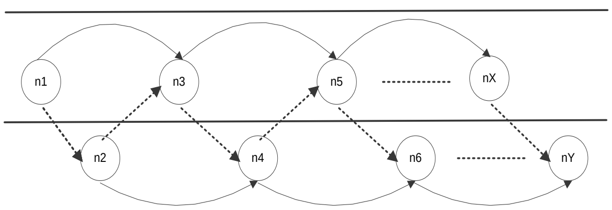

Fig. 4 Path of forwading data from source to destination on Multi-hop Dissemination

Fig. 4 shows the multi-hop dissemination. The path of forwarding data from source to destination has a multi-hop route to destination based on Multi-channel operations IEEE 1609.4

3.2 Performance Evaluation

Based on the scenario, in Fig. 5 until Fig. 9 the simulation was performed to obtain data according to four aspects to be measured. They are the average delay, packet delivery ratio, and throughput.

3.2.1 Performance comparison of single-hop and multi-hop dissemination

(i) Average Delay

Fig. 5 shows the comparison of the average delay of single-hop compared with multi-hop dissemination, by varying the number of nodes based on Multi-channel operations of the IEEE 1609.4. We focus on the average access delay which calculate on MAC layer. Delay and access will be used interchangeably on this work by varying the number of nodes. This can be seen Figure 5.

The following is the equation for the average delay E[d] derived as [3] :

$$E[d] = E[c] + E[q] \qquad (1)$$

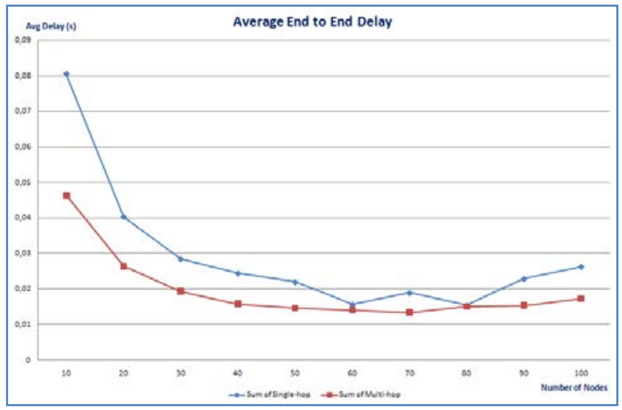

Fig. 5 Average of delay single-hop versus multi-hop dissemination

From Fig. 5, we found that the average delay of Multi-channel operations of the IEEE 1069.4 multi-hop dissemination is degraded compared with the single-hop dissemination.

(ii) Throughput

Fig. 6 shows the throughput of the single-hop compared with multi-hop dissemination, by varying the number of nodes based on the Multi-channel operations of IEEE 1609.4. Throughput T_i (t) is the rate of successful packet delivery through a network connection per unit time. We focus on the throughput which calculate on MAC layer, then T_i (t) derived as [16] :

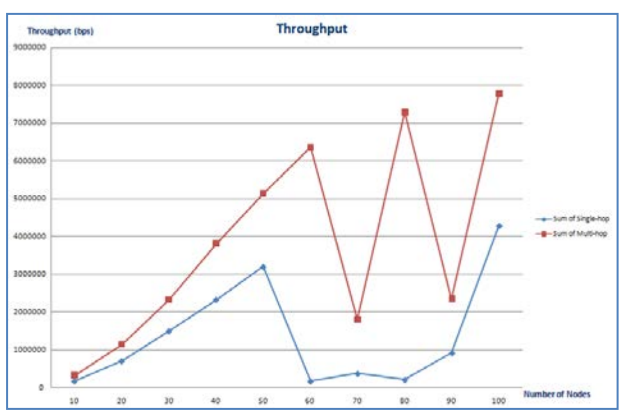

Fig. 6 Comparasion of throughput single-hop versus multi-hop dissemination

Throughput T_i (t) = x* (1-p)*d*data rate (2)

Where $d = DATA/(DIFS+PACKET+SIFS+ACK)$

x is the number of nodes

T_i (t) is the throughput

a is the distance of nodes

p is the collision probability for a transmission

From Fig. 6, we found that the throughput Multi-channel Operations of the IEEE 1069.4 based on the multi-hop dissemination is better 50% compared with the single-hop dissemination. For the number of nodes over 50 nodes based on multi-hop dissemination, the throughput was very fluctuating because the throughput is influenced by the hidden nodes.

3.2.2 Performance evaluation based on the IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard in a vehicular environment

(i) Packet Delivery Ratio

Fig. 7 shows the packet delivery ratio of the IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard based on multi-hop dissemination, by varying the number of nodes based on Multi-channel operations IEEE 1609.4. The packet delivery ratio is defined by varying number of nodes as parameters change. We focus on the packet delivery ratio which calculate on MAC layer.

Let τ be the probability to transmit in a given slot. If we assume a uniform probability distribution to select a slot within the current *Contention Window* (CW), then τ can be derived as [3,8]:

$$\tau = 1/E[CW]+1 = 2/Cw_{max}+1 \quad (3)$$

where CW_{max} is the maximum size of CW for broadcast messages. Let p_{idle} be the probability that a channel is idle in a given slot, and p_{busy} its converse [3]. Similarly, let $p_{success}$ be the probability that a slot is occupied by a successful transmission, and p_{coll} is the probability that a collision occurs during a slot. If we assume a scenario with M nodes with the above mentioned assumptions, it is easy to verify that p_{idle}, p_{busy}, $p_{success}$,and p_{coll} are as followed [3]

$$P_{idle} = (1-\tau)^{M} \quad (4)$$

$$P_{busy} = 1 - P_{idle} \quad (5)$$

$$P_{success} = M \cdot \tau \cdot (1-\tau)^{M-1} \quad (6)$$

$$P_{coll} = 1 - P_{idle} - P_{success} \quad (7)$$

From Fig. 7, we found that packet delivery ratio of the IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard for Multi-channel Operations of the IEEE 1069.4, which AC_VO (CW_{min} = 7 and CW_{max} = 15) is the highest performance based on multi-hop dissemination.

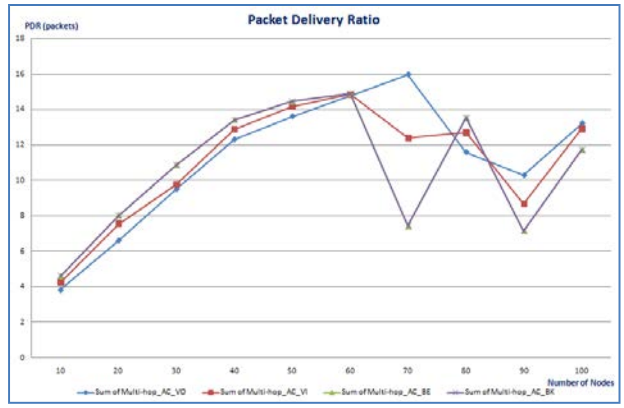

Fig. 7 Packet delivery ratio based on IEEE 802.11p EDCA standard

(ii) Throughput

Fig. 8 shows the throughput of the IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard based on the multi-hop dissemination, by varying the number of nodes based on Multi-channel operations of the IEEE 1609.4.

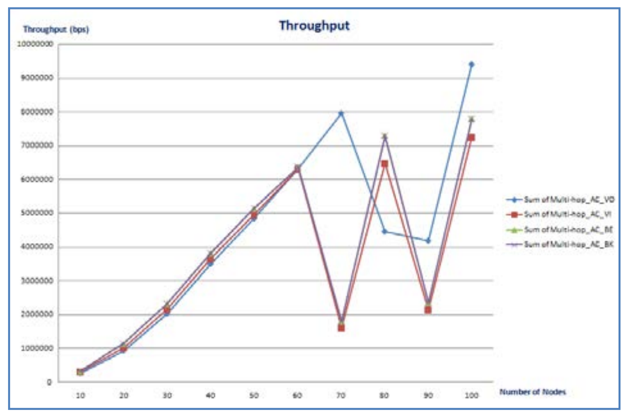

Fig. 8 Throughput based on IEEE 802.11p EDCA standard

From Fig. 8, we found that throughput of the IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard for Multi-channel Operations IEEE 1069.4, which AC_VO (CW_{min} = 7 and CW_{max} = 15) is the highest performance based on multi-hop dissemination.

3.3.3 Performance evaluation based on channel performance

(i) Average Delay

Fig. 9 shows the average delay of multi-hop dissemination based on channel performance in Multi-channel operations of the IEEE 1069.4, delay and access will be used interchangeably on this work.

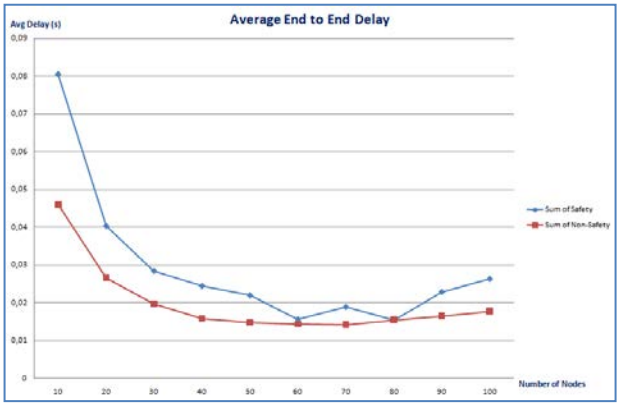

Fig. 9 Average of delay based on the channel performance

From Fig. 9, we found that the average delay of multi-hop dissemination based on channel performance in Multi-channel operations of the IEEE 1069.4, CCH channel (safety application) is better performance (appx. 40%) than SCH channel (non-safety application) based on multi-hop dissemination.

(ii) Throughput

Fig. 10 shows the throughput of multi-hop dissemination based on the channel performance in multi-channel operations of the IEEE 1609.4, by varying the number of nodes based on Multi-channel operations.

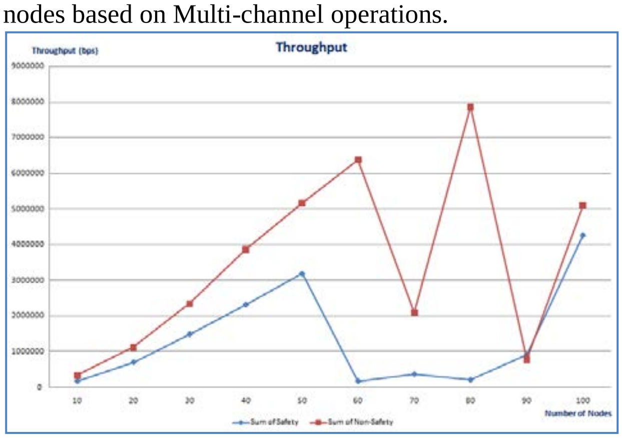

Fig. 10 Throughput based on the channel performance

From Fig. 10, we found that throughput of channel performance based on Multi-channel operations of the IEEE 1069.4 SCH channel (non-safety application) is appx. 40% compared to CCH channel (safety application) based on multi-hop dissemination. The throughput is influenced by the hidden nodes.

4. Conclusion

Based on the scenario and simulation, we can evaluate the performance of the multi-hop dissemination compared with single-hop dissemination based on Multi-channel operation of the IEEE 1609.4, was performed to analyze the delay, packet delivery ratio and throughput. Based on the analysis, several main findings can be concluded the performance of Multi-channel operations of the IEEE 1609.4 based on multi-hop dissemination the average delay has been degraded 42.77% compared with single-hop dissemination and the throughput has been 65.72% better than single-hop dissemination. Also based on IEEE 802.11p Enhanced Distributed Channel Access Function (EDCA) standard, we have AC_VO (CW*min* = 7 and CW*max* = 15) is the highest performance based on multi-hop dissemination and have better packet delivery ratio (PDR) performance. Meanwhile, based on the channel performance, CCH channel (safety application) is 40.26% better than SCH channel (non-safety application) on average delay and SCH channel (non-safety application) is better appx. 66.86% than CCH channel (safety application) on throughput based on multi-hop dissemination Multi-channel operations of IEEE 1609.4.

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