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Reliable broadcasting using polling scheme based receiver for safety applications in vehicular networks

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ABSTRACT

Vehicular wireless communication is the enabling technology of Intelligent Transport System (ITS). However, it is broadcast in nature and error-prone, as well as it has stringent safety constraints in short contacting time. Therefore, existing Medium Access Control (MAC) protocols for vehicular networks still have many technical issues related to transmission efficiency and reliability. Moreover, at the same time, robust one-hop communications and efficient multi-hop dissemination are required for different coexisting safety-related applications. In this paper, we propose a polling scheme triggered by receivers to make broadcasting more reliable and study how reliable broadcasting affects dissemination of safety-related information. In order to evaluate our proposed polling scheme, an analytical model specified for the IEEE 802.11p standard is presented and validated with consideration of prioritized traffic, probability of error transmission and multi-channel operation. Analytical analysis shows that our polling scheme enhances significantly success ratio of broadcast messages. Also, our reliable broadcasting protocol improves the performance of dissemination. Moreover, extensive simulation results demonstrate an improvement for both one-hop communication and multi-hop dissemination when the proposed polling scheme is implemented at the MAC layer.

1. Introduction

Vehicular ad hoc network (VANET) has emerged as an interesting research topic from both academia and industry perspectives due to its potential real-life applications in ITS. In this kind of network, a wide range of information including physical environment information, vehicle status information, traffic condition are exchanged using Dedicated Short Range Communications (DSRC) in the frequency band of 5.85–5.925 GHz. The information is used for different applications such as safety, transport efficiency and entertainment applications. Among these applications, safety applications, which help to enhance driving safety, especially require a sophisticated design of MAC protocol due to their communication constraints.

To provide above applications to transportation, the IEEE 1609 standards suite is specified. In particular, the IEEE 1609.0 presents the Wireless Access in Vehicular Environment (WAVE) architecture depicted in Fig. 1. The IEEE 1609.4 describes multi-channel wireless radio operations. The IEEE 802.11p specifies MAC and physical (PHY) layers to accommodate WAVE systems.

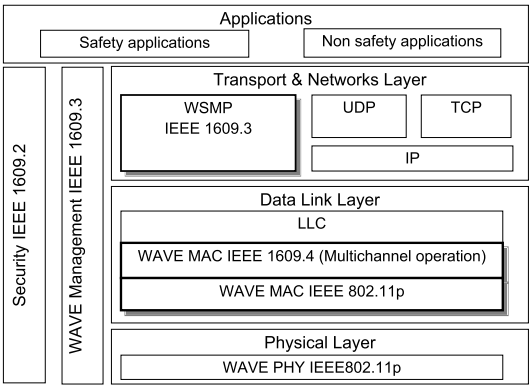

Fig. 1. WAVE architecture.

According to the IEEE 1609.4 [1], devices operate alternatively between one control channel (CCH) and one of six service channels (SCHs) within every 100 milliseconds (ms), namely sync interval. During CCH interval (CCHI), all vehicles exchange safety-related messages comprising event messages and periodical messages. Car-

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rier sense multiple access (CSMA) is used as a MAC protocol in vehicular networks. It is described in the IEEE 802.11p. To make efficient reservation of the channel and reduce collisions, a handshake protocol, Ready-to-send/Clear-to-send (RTS/CTS), is used for unicast messages. In order to gain the reliability, acknowledgment (ACK) and retransmission mechanisms are used. However, no such mechanism is applied for broadcast messages. Unfortunately, most safety applications in VANET mainly work in broadcast fashion since safety-related information is useful to all neighbors of the sender. Therefore, a reliable broadcast scheme is needed to guarantee the reception of safety-related message at all vehicles. It is challenging to design the scheme under distributed environment, unstable links caused by high mobility and limited operation time which is a consequence of multi-channel operation. They are strike characteristics of WAVE [5].

Consortia and projects around the globe have been developing lists of safety applications [27] in vehicular networks. Vehicle Safety Communication-Application Project [4] selected six safety applications to address top seven crash scenarios: Emergency electronic brake lights, forward collision warning, blind spot warning and lane change warning, do not pass warning, intersection movement assist, and control loss warning. Their usage scenarios show an importance of one hop broadcast communication since only nearby neighboring vehicles are affected by crashes. On the other hand, some other safety applications require the communication in wider range, multi-hop communication, such as immediate roadside generated warning [18] (bridge icing ahead, train coming, and ambulance operating in area). Due to their coexistence, their implementations should not interfere with each other. Therefore, we simultaneously address both types of safety applications in our work.

In vehicular networks, dissemination refers to an act of spreading packets to all vehicles in the network. As mentioned above, among two types of safety applications, multi-hop applications need dissemination to forward safety-related information to all distant vehicles that are approaching the incident. During the multi-hop dissemination, packet is forwarded hop by hop in broadcast manner. Hence, any alteration in MAC protocol related to broadcasting probably impacts the dissemination performance. Although many efforts have been made to enhance the reliability of one-hop broadcasting, it is necessary to investigate how the enhancement in broadcasting affects dissemination whenever we study safety applications in vehicular networks.

Responding to the necessity of a reliable MAC protocol for safety applications in vehicular networks and a comprehensive study of the protocol in relation with dissemination protocol, our contributions are two-fold. Firstly, we propose a polling scheme to enhance reliability of broadcasting that supports safety applications. We evaluate the proposed scheme by an analytical model which considers closely the features of IEEE 802.11p and IEEE 1609.4. Secondly, we study the effect of a reliable MAC protocol on the dissemination of safety-related messages. Our polling scheme is analyzed for non-prioritized and prioritized traffic. The dissemination protocol integrating our proposed polling scheme at MAC layer is evaluated in both urban and highway scenarios.

The remainder of this paper is organized as follows. Section 2 briefly reviews related works. Section 3 describes our proposed scheme. The analytical model of our proposed scheme is elaborated in section 4. Dissemination protocols and how a reliable MAC protocol impacts it are analyzed in section 5. Simulation results and discussions are presented in section 6. Finally, section 7 concludes this paper.

2. Related works

Safety applications in VANETs are discussed in [18,16]. From the communications perspective, they are supported by two basic types of messages: periodical messages and event messages. These two types of safety-related messages (or safety messages) are described in standardized works [3,2] of European Telecommunication Standards Institute, ETSI. According to ETSI, periodical messages, namely beacons, are cooperative awareness messages (CAMs) [3] and event messages are Decentralized Environmental Notifications (DENs) [2] that warn unexpected hazards. CAMs or beacons are transmitted periodically with the purpose of sharing information (position, velocity, etc.) among neighboring vehicles. These beacons give drivers knowledge of surrounding environment and their nearby neighbors. While DENs contain information of occurring event that may influence to not only nearby neighbors but also all vehicles situated in close neighborhoods.

CAMs and DENs issued from a given vehicle are important for its neighboring vehicles. Besides, DENs are required to be disseminated to more distant vehicles (in addition to neighboring vehicles) since they provide critical context information that surrounding vehicles may need to be aware of or react timely for their safety. Unfortunately, most existing related works consider either CAMs or DENs separately. Communication within one hop referring to CAMs is the objective of the related works in [28] and [6]. While in [15], authors propose a multi-channel dissemination protocol for event safety messages (DENs). If the DENs come during service channel interval (SCHI), they will be intermediately broadcast at all available channels. Otherwise, if they come during CCHI, they will be broadcast normally. If after CCHI, the event safety messages do not gain access to the medium, they will be disseminated with the same algorithm in the next SCHI. Delay of the event safety messages within single hop dissemination is reduced, however there is no gain for reliability of periodical safety messages. [9] also focuses on multi-hop dissemination of event messages DENs but no coexisting one-hop communication with beacons is considered. The authors in [17] take into account both CAMs and DENs, however their protocol is evaluated only for single-hop scenario.

Due to the fact that both CAMs and DENs need to be broadcast in vehicular environment, many proposals target to enhance the reliability of the existing CSMA protocol in the standard IEEE 802.11p by adding retransmission scheme or acknowledgment scheme. Blind retransmission schemes for event messages are proposed in [17]. Messages are retransmitted a fixed number of times with a given (unchanged) contention window, and a fixed number of copies are consecutively sent at interval of Short Interframe Space (SIFS). The authors in [22] suggest schemes classified for one-hop beacons and multi-hop emergency messages, on which copies of messages are rebroadcast by a relay vehicle that is chosen according to directional distance metric to the origin. Messages are retransmitted by the origin if it does not receive enough specified number of copies from selected relays within specified time duration. Copies play roles of both forwarded messages and acknowledgments. Although the repetition of beacons may improve the receive ratio, the scheme poses fixed number of duplicated beacons as each of them is always retransmitted several times. Both types of safety-related messages are addressed in this work, however, the mutual impact of reliable broadcasting on beacons and on coexisting emergency messages is not clearly stated.

The observation of how network performance depends on number of repetition and network density is studied in [13]. Simple repetitions help to increase the chance for all nodes to get messages correctly but it obviously creates redundancy that degrades the utilization of the network due to resource wasting. Moreover, under switching channel condition IEEE 1609.4, resource is extremely limited thus the redundancy is an important factor to be