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A Collision Alleviation Scheme for IEEE 802.11p VANETs

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Abstract IEEE 802.11p protocol, also known as Wireless Access for the Vehicular Environment, provides dedicated short range communication for future Vehicular Ad Hoc Networks (VANETs). According to the IEEE 802.11p standard, the highest priority traffic transmission often suffers from the consecutive collisions in bursty arrival or congested scenarios because of the naive pre-assumption of a low level of congestion in the system, and thus results in emergent messages delayed. In this paper, we propose a simple, but yet well performing collision alleviation scheme to alleviate intensive collisions between highest priority access categories which usually used to schedule emergency message since safety is the most critical and promising issue in VANET. In addition to theoretical analysis, simulations are conducted to evaluate its performance. The simulation results show that the proposed scheme can not only increase the achievable channel throughput of the legacy protocol at most 15%, but also reduce the average packet access delay of the legacy protocol at least 5% and the packet collision probability at most 60% in congested VANET environments.

Keywords IEEE 802.11p · VANET · Contention window · Collision alleviation · Performance analysis

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1 Introduction

With the increase of the population and industrial development all over the world, the road traffic is getting heavier and heavier, and thus increases the probability of traffic accidents. Therefore, the IEEE 802.11 working group is drawing up the IEEE 802.11p to support Intelligent Transportation Systems (ITS) applications. These applications include data exchange between high-speed vehicles and between these vehicles and the roadside infrastructure in the licensed ITS band of 5.9 GHz (5.85–5.925 GHz). The goal of IEEE 802.11p protocol provides the minimum set of specifications required to ensure interoperability between wireless devices attempting to communicate in potentially rapidly changing communications environments and in situations where transactions must be completed in time frames much shorter than the minimum possible with infrastructure or ad hoc 802.11 networks.

As shown in Fig. 1, IEEE 802.11p is a part of a group of standards related to all layers of protocols for WAVE operations. The upper layer IEEE 1609 standards dealt with all knowledge and complexities related to the DSRC channel plan and operational concept. In particular, the IEEE 1609.3 standard covers the WAVE connection setup and management [1]. On the other hand, the IEEE 1609.4 standard sits right on top of the IEEE 802.11p and enables operation of upper layers across multiple channels, without requiring knowledge of PHY parameters [2].

According to the IEEE 802.11p standard, the highest priority traffic transmission often suffers from the consecutive collisions in bursty arrival or congested scenarios since it selects a small initial value of backoff window by a naive assumption of a low level of congestion in the system, and thus results in emergent packets delayed. In other words, this strategy might allocate an initial size of contention window, which can become not enough when the load increases later. Then, the size of contention window must then be reallocated with a larger size, but each increase in the contention window parameter value is conducted at the cost of collisions. Furthermore, after a successful transmission, the size of contention window is re-set again to the minimum value without any memory of the current channel status. However, based on our observations, the packet access delay can be greatly reduced to deliver high priority emergency message without seriously degrading the throughput of other traffic types by a proper choice of the initial contention window size.

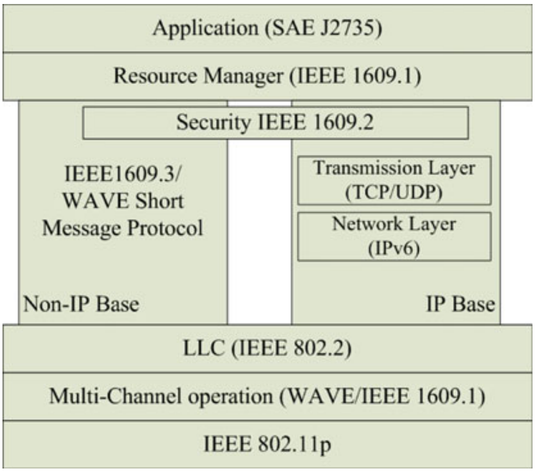

Fig. 1 WAVE architecture

In the literatures there has been excellent discussion on the issues on IEEE 802.11p protocol and its performance analysis [3–12]. Besides, in [13], the authors provided a performance evaluation of the WAVE standard, considering collision probability, throughput and delay. This paper shows that WAVE can transmit prioritize messages. Besides, in dense and high load scenarios the throughput is decreases while the delay is increasing significantly. In [14], the authors used NS-2 simulator to measure the performance of the WAVE protocol. Specifically, the simulations measured aggregate throughput, average delay, and packet loss metrics. Simulation results showed that vehicle speed proved to be an insignificant factor when judging the performance of the system. However, these studies do not propose any mechanism to force the mobile vehicles to adopt an appropriate contention window size in order to reduce the access delay of high priority packets. In addition, most of these schemes were designed for WLANs, and we did not know whether the proposed algorithm can be applied to VANETs.

In this paper, we propose that the initial contention window size should be proportional to the number of competing vehicles in the system. Furthermore, the size of initial contention window should better generally be maintained large to reduce the collision rate (or at least equal to the number of competing vehicles in the system). Hence, in this paper, we propose a simple, but yet well performing collision alleviation scheme in order to alleviate intensive collisions between highest priority access categories and minimize the average access delay of high priority emergency messages in VANETs. In addition to the analytical analysis, we have also carried out comprehensive simulations implemented by network simulator NS2 [15] to evaluate the performance of the proposed scheme. The results confirmed that the proposed scheme achieves lower packet collision rate, lower average packet access delay, and higher system throughput compare to the legacy IEEE 802.11p standard.

The remainder of this paper is organized as follows. In Sect. 2, we present the proposed scheme in detail. Simulation results are reported in Sect. 3, followed by Sect. 4 which concludes this paper.

2 Proposed Scheme

As an effort to improve on the previous schemes, we introduce in this section our proposed scheme in detail, which is based only on carrier sensing and can be implemented easily in most present IEEE 802.11p VANET systems without requiring any complicated computation and additional hardware support.

2.1 Proposed Collision Alleviation Scheme

As far as prediction algorithm is concerned, many research results could be applied to approximately estimate the number of active stations in the wireless networks [16–20]. However, in addition to the difficulties in acquiring sufficient knowledge of the system, these type of approximations tend to be very computationally complex, and subject to significant errors, especially in high traffic load situations. In [21], the authors proposed a distributed algorithm that allows a station to dynamically optimize its initial contention window size based on turn-around-time measurement of channel status. This paper directly uses this result. Please refer to [21] for the details with regard to this technique.

Generally speaking, a low transmission collision rate experienced by a vehicle implies that the number of competing vehicles is low, and the initial contention window should be set small. On the other hand, consecutive transmission collisions experienced by a vehicle