



Improving throughput through dynamically tuning contention window size in dense wireless network

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Abstract

With the boom of wireless devices, the number of wireless users under wireless local area networks (WLANs) has increased dramatically. However, the standard backoff mechanism in IEEE 802.11 adopts fixed initial contention window (CW) size without considering changes of network load, which leads to a high collision probability and low channel utilization in bursty arrivals. In this paper, a novel CW dynamic adjustment scheme is proposed to achieve high throughput performance in dense user environment. In the proposed scheme, the initial CW size is dynamically adjusted to optimum according to the measured packet collision probability. Simulation results show that the proposed scheme can significantly improve the throughput performance.

Keywords wireless local area network (WLAN), dense user environment, contention window (CW), dynamic optimization

1 Introduction

WLANs become a popular access technology for last mile and are widely deployed in recent years for its characteristics of high bandwidth, flexibility and convenience. Meanwhile, wireless devices with IEEE 802.11 standard such as smart phones, laptops, have become increasingly widespread. The density of wireless users has dramatically increased in the past few years and will continue to grow in the future network [1]. However, the traditional IEEE 802.11 media access control (MAC) protocol [2–3] is not designed for such a dense user environment, and its drawbacks become even more obvious with the number of wireless users increasing.

In Refs. [4–7], Cali et al. analyze the binary slotted exponential backoff mechanism for carrier sense multiple access with collision avoidance (CSMA/CA) via mathematics modeling. They all point out that some parameters in the protocol, such as initial CW size, have a

significant influence on the network's performance. And in Ref. [8], Parker et al. show how sensitive the system throughput is to the initial CW size and indicate that an appropriate CW size selection scheme can greatly improve system throughput. Furthermore, several CW optimizing schemes are proposed to enhance the efficiency of WLANs with dense users. In Ref. [9], a time fairness-based MAC algorithm is proposed. The algorithm can maximize the throughput under the time fairness constraint. However, each station must know the bit rates of all stations within its communication range and calculate its own optimized CW size. That is, all stations need modifications and global information, which is difficult to implement in practice. In Ref. [10], the active number of stations is estimated from the measured packet collision probability, and then the optimum CW size is derived through a theoretical analysis model based on Markov chain. By repeating this periodically, the CW size is fixed to an optimum size. It obtains a theoretical optimal CW size, but there are some estimations during its calculations, so the optimality of the calculated CW size in practice remains to be verified. Moreover, it takes very frequent operations to

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keep the CW size optimal all through since the actual wireless environment is changing all the time. An extended Kalman filter based method to estimate the number of competing stations is proposed in Ref. [11]. Although it is an accurate estimation method, there are rigorous assumptions and complex computations, which make it hard to be used in real wireless network. In Ref. [12], CW size is also adjusted based on the estimated number of active stations. And in this scheme, the number of active stations is estimated from observed idle slot. However, it is difficult to accurately estimate the number of active stations in this way for that the number of active stations has a complicated relation with idle slot. And in Ref. [13], the CW size is optimized by estimating the number of stations using the channel status and bit error rate. However, since the channel condition is obtained by estimating, it is not likely to estimate the number of stations correctly by this method.

These mechanisms in Refs. [10–13] all tune CW size according to the estimated number of active stations. It can be seen from above analysis that the estimation processes are usually accompanied by complex calculations and necessary assumptions, furthermore, an accurate estimated value is hard to be obtained. To overcome this drawback, some researches avoid the estimation process. CW size is directly tuned based on the average successive idle slot number in Refs. [14–15], but the CW size of stations are different from each other, which means that the fairness among stations is inconsistent with that of the standard CSMA/CA. Furthermore, the behavior of idle sense based CW size control algorithm when stations have different CW sizes is analyzed in Ref. [16]. It indicates that a fairness problem can be caused in this way, resulting in two classes of stations, one of which gains most of the channel resources while the other stays idle. And in Ref. [17], Ito et al. optimize CW size based on measured active stations and calculated channel utilization. However, it specifies the CW size to some specific values with little flexibility. The CW size can be optimized in this way, but far from optimum.

To overcome above drawbacks, we propose a dynamic CW control scheme which tunes the CW size directly based on the measured collision probability. In the proposed scheme, the access point (AP) measures collision probability and system throughput periodically. Then, the most appropriate initial CW value that maximizes system throughput is obtained based on the measured values. The

updated initial CW value is notified to all stations by AP via a beacon broadcast [18]. Our contributions can be summarized as follows:

1) No modifications are required for stations. The optimized initial CW size are obtained by AP through dynamic searching, and notified to all stations via a beacon frame which already exists in IEEE 802.11 protocol. Therefore, the proposed scheme can be implemented by simply modifying AP.

2) The transmission opportunity fairness among stations is the same as that of the standard CSMA/CA. All the stations that receive the beacon frame are set to the same initial CW size, so the fairness among them can be guaranteed.

3) An optimal initial CW size which maximizes the system throughput is obtained. As we all know, if the CW size is too small, a high collision probability will be caused. While an excessive large CW size may result in the waste of channel resource. Both high collision probability and waste of channel resource can lead to poor performance of throughput. Therefore, we directly aim at maximizing the system throughput, and obtain the most appropriate initial CW value by dynamic search.

The rest of the paper is organized as follows. In Sect. 2, we discuss the standard CSMA/CA protocol and its drawbacks. Sect. 3 describes the proposed scheme in detail. We evaluate the performance of the proposed scheme, and compare it with other CW size adjustment algorithm in Sect. 4. Finally, we conclude the paper in Sect. 5.

2 CSMA/CA

The medium access process of CSMA/CA in IEEE 802.11 MAC protocol is shown in Fig. 1, where STA represents station, T refers to the time sequence. As can be seen from Fig. 1, the stations with data to transmit first listen to the shared channel. If the channel is detected as idle and maintains a distributed inter-frame spacing (DIFS) time, each station generates a random backoff time Eq. (1) which is a multiple of the slot time.

$$T_{\text{backoff}} = \sigma \text{rand}(0, W) \quad (1)$$

where W is the CW size, $\text{rand}(0, W)$ is an integer randomly generated between 0 and W , σ denotes the duration of a slot time. For the first trial of a packet transmission, W is set to be an initial value, W_{\min} , in the backoff algorithm of IEEE 802.11 standard. Each station generates a T_{backoff} according to Eq. (1), that is, they

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