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Optimal frame aggregation level for IEEE 802.11 PCF protocol

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ABSTRACT

In this paper, we analyze the effect of the frame aggregation level on the PCF (Point Coordination Function) MAC performance in IEEE 802.11 wireless LANs and analytically derive the optimal frame aggregation level for maximizing the PCF MAC performance. For various values of unit data frame size and transmission error probability, we propose the optimal frame aggregation levels. By computer simulations, we show that the derived optimal frame aggregation level significantly enhances the PCF MAC performance in IEEE 802.11 wireless LANs.

1. Introduction

Since the fundamental wireless LAN PHY and MAC standard was developed for supporting the data rate of up to 1 or 2 Mbps per BSS (Basic Service Set) in 1997, the PHY protocol enhancements have focused on increasing the PHY data rate per BSS and the MAC protocol enhancements have focused on efficiently distributing the PHY data rate to STAs (Stations) with as little unnecessary overhead as possible [1–6]. IEEE 802.11a and IEEE 802.11b standards released in 1999 are the PHY enhancements to respectively provide the PHY data rates of up to 54 Mbps in 5 GHz frequency band and 11 Mbps in 2.4 GHz frequency band [2,3]. In 2003 IEEE 802.11g standard was released to provide the PHY data rate of up to 54 Mbps in 2.4 GHz band [4]. Furthermore, IEEE 802.11n standard was finalized in 2009 to provide the PHY data rate of more than 200 Mbps using the MIMO (Multiple Input Multiple Output) OFDM (Orthogonal Frequency Division Multiplexing) technology [5]. The DCF (Distributed Coordination Function) and PCF (Point Coordination Function) are the basic MAC protocols that the IEEE 802.11a, IEEE 802.11b, IEEE 802.11g and IEEE 802.11n versions of wireless LANs are based on [1]. To enhance the DCF and PCF, the EDCA (Enhanced Distributed Channel Access) and HCCA (Hybrid Coordination Function Controlled Channel Access) were developed to provide the prioritized QoS (Quality of Service) [6]. Furthermore, the new MAC techniques for IEEE 802.11n wireless LANs was developed to provide the higher MAC throughput of at least 100 Mbps [5].

In the literature, the performances of the DCF, EDCA, HCCA and the enhanced schemes such as the AEDCA (Adaptive EDCA) and AHCCA (Adaptive HCCA) have been investigated in [7–10]. In [7], the performance of the DCF under both congested and error-prone channel condition was accurately analyzed. The throughput and delay performances of the EDCA and HCCA were evaluated in [8], and the AEDCA and AHCCA were proposed and their performances were analyzed in [9]. Furthermore, the analytical model for the IEEE 802.11e block ACK scheme was proposed in [10].

According to [5], two frame aggregation techniques were proposed to aggregate multiple MSDUs (MAC Service Data Units) into a single MPDU (MAC Protocol Data Unit) and aggregate multiple MPDUs into a single PSDU (PHY Service Data Unit). By transmitting the MPDUs and PSDUs into which multiple MSDUs and MPDUs are aggregated, we can reduce the MAC protocol overhead such as the DCF or EDCA contention process, the ACK frame transmissions, the inter-frame spacing. For instance the large transmission overhead can be resulted if we transmit the RFID (Radio Frequency Identification) tag codes in wireless LANs without the frame aggregation techniques because the RFID codes are shorter than or equal to 195 bits, which is extremely smaller than the maximum wireless LAN MAC payload length of 18,496 bits [1,11]. Additionally, in [12], the AFR (Aggregation with Fragment Retransmission) scheme was proposed to aggregate multiple fragments into a single MPDU and allow the fragments to be selectively retransmitted by inserting the additional fragment headers. The selective MSDU retransmission is not possible in the IEEE 802.11n frame aggregation technique aggregating multiple MSDUs into a single MPDU.

In the literature, it has been proved that the DCF, PCF, EDCA and multipolling MAC performance can be improved by combing the protocols with the IEEE 802.11n frame aggregation techniques and the AFR scheme [12–17]. However, the frame aggregation needs to be optimized considering that the frame aggregation can increase the retransmission overhead in wireless LANs. In [12,15], the AFR scheme and the IEEE 802.11n frame aggregation techniques were

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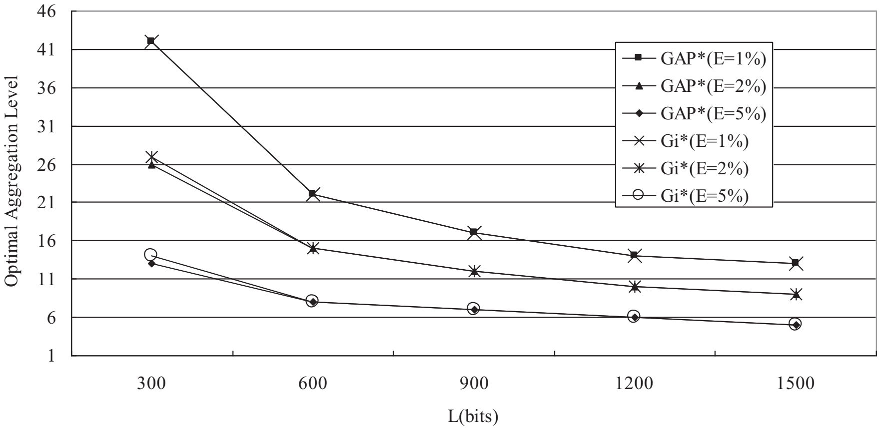

Fig. 1. Optimal frame aggregation levels.

optimized to be combined with the DCF. The PCF is the basic MAC protocol targeted for real-time traffic service. However, the research has not been done to optimize the frame aggregation combined with the PCF.

In this paper, we analyze the effect of the IEEE 802.11n frame aggregation technique aggregating multiple MSDUs into a single MPDU on the PCF MAC performance and derive the optimal frame aggregation level for best PCF MAC performance. For this aim, we propose the analytical performance analysis model for expressing the PCF MAC performance in terms of the traffic parameters, and derive the optimal frame aggregation levels for various values of unit data frame size and transmission error probability. By computer simulations, we show that the derived optimal frame aggregation level significantly enhances the PCF MAC performance in IEEE 802.11 wireless LANs.

2. PCF transmission procedure combined with frame aggregation technique

The PCF targeted for real-time traffic service controls the MAC transfer during CFPs (Contention Free Periods) and each STA can start the PCF MAC transfer only when it is polled by the AP (Access Point).

The AP and each STA can access the channel when the channel is determined as idle for one PIFS (PCF Inter-Frame Space) period and one DIFS (DCF Inter-Frame Space) period, which is one PIFS period plus one slot time, respectively. For this reason, the AP has the higher priority for accessing the channel than other STAs. The AP does not use the priority for accessing the channel during CPs (Contention Periods) where the DCF controls the MAC transfer and uses the priority for accessing the channel to start CFPs. The AP starts a CFP by broadcasting the beacon frame after sensing the channel as idle for one PIFS period. One SIFS (Short Inter-Frame Space) period after the beacon frame transmission, the AP grants the uplink transmission opportunity to a STA by transmitting a polling frame to the STA. The STA responds to the polling frame by transmitting its data or null frame. After the reception of the data or null frame, the AP transmits a polling frame to another STA and the polled STA responds to the polling frame by transmitting its data or null frame. If a STA fails to respond to a polling frame within one SIFS period, for the error recovery the AP transmits a polling frame to another STA after one PIFS period, which is one SIFS period plus one slot time, from the end of the previous polling frame transmission. The data frames can be piggybacked on the polling frames. In this manner, the process of the AP's polling and the STAs' responding continues until the CFP ends.

The frame aggregation levels for the AP and STA i are denoted as G_{AP} and G_i, respectively. Generally, the AP and STA i respectively aggregate G_{AP} and G_i MSDUs in their transmission buffers into a single MPDU and transmit the MPDUs into which G_{AP} and G_i MSDUs are aggregated. However, when the AP and STA i that are given the transmission opportunities find less than G_{AP} and G_i MSDUs in their transmission buffers, respectively, the AP and STA i can transmit the MPDUs into which less than G_{AP} and G_i MSDUs are aggregated to satisfy their transmission delay bound requirements.

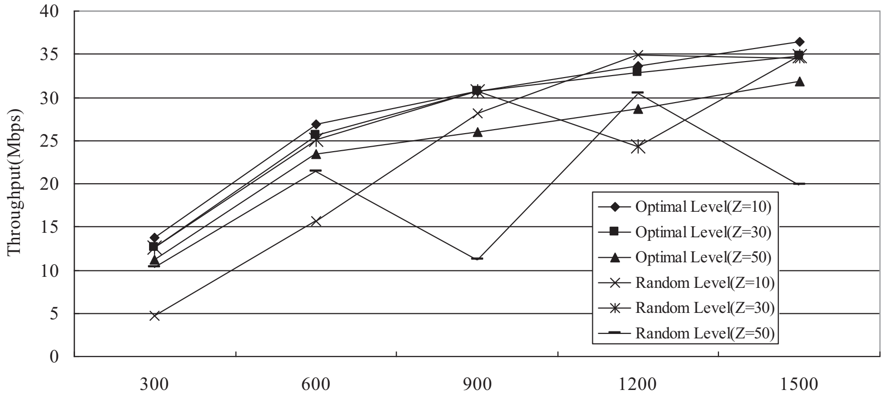

Fig. 2. Bounded-delay MAC throughput versus L when $E = 1\%$.