Chapter XII
Performance Analysis and Evaluation of IEEE 802.11E MAC in WLANs with Hidden Stations and Multimedia Applications

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ABSTRACT

Recently there have been considerable interests focusing on the performance evaluation of IEEE 802.11e Medium Access Control (MAC) protocols, which were proposed for supporting differentiated quality of services in wireless local area networks (WLANs). Heterogeneous traffic generated by wireless multimedia applications and hidden stations arisen from the wireless transmission power constraints have significant impact on the performance of MAC protocols. This study performs extensive simulation experiments and conducts comprehensive performance evaluation of the IEEE 802.11e Enhanced Distributed Channel Access (EDCA) protocol in WLANs in the presence of hidden stations and heterogeneous traffic. For this purpose, non-bursty Poisson, bursty ON/OFF, and fractal-like self-similar processes with high variability are used to model and generate heterogeneous network traffic. The performance results have shown that this protocol is able to achieve differentiated throughput, access delay, packets loss probability, and medium utilization. However, the hidden stations can degrade the throughput and medium utilization as well as increase greatly the medium access delay, packets loss probability, and collision ratio under heterogeneous traffic.

INTRODUCTION

The wireless local area network (WLAN) is a flexible data communication system that can either replace or extend a wired LAN to provide location-independent network access between computation and communication devices using waves rather than a cable infrastructure (IEEE Computer Society, 1999; Gast, 2002). WLAN is becoming more widely recognized as a general-purpose connectivity alternative for a broad range of business organizations owing to its simplicity, flexibility, and accessibility independent of location, as well as its ability for wireless stations to roam throughout the business organizations. Many practical WLANs have employed the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards ratified in 1997 that can operate at data rates up to 2 Mbps in the 2.4-GHz industrial, scientific and medical (ISM) band. But the most general business requirements cannot be well supported by the slow data rate of the legacy IEEE 802.11 standard. Recognizing the critical need to support higher data-transmission rates, the IEEE ratified both 802.11a and 802.11b standards with the rates up to 54 and 11 Mbps in the 5 and 2.4-GHz ISM band, respectively (IEEE Computer Society, 1999; Gast, 2002). Moreover, both standards identify the specification of the Medium Access Control (MAC) protocol, which is responsible for efficient control access to the wireless transmission medium.

The IEEE 802.11 MAC protocol offers two different methods to support share access to wireless channels: a Distributed Coordination Function (DCF) and an optional Point Coordination Function (PCF) (Gast, 2002). The former is the dominant MAC mechanism implemented in the IEEE 802.11-compliant products and is based on the Carrier Sense Multiple Accesses (CSMA) protocol making certain that the stations sense the medium prior to data-transmission. Moreover, the DCF applies a collision avoidance (CA) mechanism, which can reduce the collision probability using an additional random binary exponential time called back-off time. The main objective of CSMA/CA is to avoid stations transmitting at the same time, which can lead to collisions and corresponding retransmissions (IEEE Computer Society, 1999; Choi et al., 2003; Gast, 2002; Lindgren et al., 2001). However, hidden stations in WLANs often cause serious problems and performance degradation. A pair of stations are said to be hidden from each other if the transmission from one station cannot be heard by the other. As a result, two or more hidden stations may transmit data at the same time, causing a collision and MAC failure. Thus, additional collision avoidance protocol becomes necessary to combat the hidden station problem. Apart from the common CSMA/CA techniques, the DCF further reduces the possibility of collisions using the popular collision avoidance scheme that consists of channel reservation frames (i.e., Request-To-Send and Clear-To-Send). Different from DCF, the optional coordination function PCF is a centralized scheme designed for infrastructure networks that have a point coordinator operating at the access point (AP) to poll and select the next wireless station for data-transmission (Gast, 2002).

With the increasing demand of wireless services, the support of differentiated quality of service (QoS) has become a critical issue on the success of IEEE 802.11 MAC protocols for the future wireless communications. It is important to develop new medium access schemes that can support real-time multimedia applications with differentiated QoS requirements over IEEE 802.11 WLANs. As a result, the IEEE 802.11 working group has very recently standardized an extended version (IEEE 802.11e) that defines two mechanisms for the support of QoS differentiation: Enhanced Distributed Channel Access (EDCA) and Hybrid Coordination Function (HCF) Controlled Channel Access (HCCA) (IEEE Computer Society, 2005). EDCA delivers traffic based on differentiated access categories (ACs), which can be achieved by varying the amount of time when