A Cross-Layer Design for Video Streaming Over 802.11e HCCA Wireless Network

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ABSTRACT

Video transmission over wireless networks has quality of service (QoS) requirements and the time-varying characteristics of wireless channels make it a challenging task. IEEE 802.11 Wireless LAN has been widely used for the last mile connection for multimedia transmission. In this paper, a cross-layer design is presented for video streaming over IEEE 802.11e HCF Controlled Channel Access (HCCA) WLAN. The goal of the cross-layer design is to improve the quality of the video received in a wireless network under the constraint of network bandwidth. The approach is composed of two algorithms. First, an allocation of optimal TXOP is calculated which aims at maintaining a short queuing delay at the wireless station at the cost of a small TXOP allocation. Second, the transmission of the packets is scheduled according to the importance of the packets in order to maximize the visual quality of video. The approach is compared with the standard HCCA on NS2 simulation tools using H.264 video codec. The proposed cross-layer design outperforms the standard approach in terms of the PSNRs of the received video. This approach reduces the packet loss to allow the graceful video degradation, especially under heavy network traffic.

Keywords: *Cross-Layer Design, HCF Controlled Channel Access (HCCA), IEEE 802.11e Wlans, Quality of Service (QoS), Video Streaming*

1. INTRODUCTION

Because of the increase of the multimedia data and wireless networks, there is an increasing demand for wireless multimedia transmission over the Internet. IEEE 802.11 Wireless LAN (WLAN) is widely used for the mobile and ubiquitous multimedia networking because of its low cost and ease of configurations. Video transmission has its quality of service (QoS) requirements, such as bandwidth, packet loss and delay. Because of the dynamics of the wireless channels, the quality of service (QoS) poses challenges to the design of the wireless networks.

Since IEEE 802.11 WLAN cannot provide QoS for multimedia applications, the IEEE 802.11 Working Group has proposed 802.11e (IEEE Computer Society, 2003) as a new enhancement with QoS features. It can provide differentiated services for real-time multimedia applications, such as video and audio. 802.11e standards specified two QoS medium access mechanism: Enhanced Distributed Channel

DOI: 10.4018/jmdem.2011070102

Access (EDCA) and HCF (Hybrid Coordinator Function) Controlled Channel Access (HCCA). EDCA is a contention based channel access mechanism which provides differentiated services for different traffic categories. HCCA is a polling-based and contention free medium access. It uses a centralized scheduling scheme at the Access Point (AP) to allocate the transmission opportunities to the stations. However the current design of 802.11e still cannot guarantee the QoS for multimedia applications. There are lots of researches on the EDCA and HCCA of 802.11e MAC layer to improve the QoS. A major research issue for HCCA is the design of an efficient scheduling algorithm to provide QoS for different traffic.

Cross-layer design of wireless multimedia transmission (Van Der Schaar & Shankar, 2005) provides a promising direction to improve the overall performance of wireless networks since it takes into account the interactions among layers. In this paper, a cross-layer design for video streaming over 802.11e HCCA WLAN is proposed. Our approach involves interactions between the application layers and MAC layers to exchange information about the traffic. The actual queue length of wireless stations is provided as feedback information to the central controller. To maximize the quality of video, the proposed approach is designed to minimize the loss rate of the packets of high importance and provide a bounded delay for the packets. The length of transmission opportunity (TXOP) allocated to each wireless station provides an efficient bandwidth management, at the same time the scheduling of the packets maximizes the video quality under the allocated TXOP. In our previous work (Luo & Shyu, 2009; Luo, 2009), an optimized TXOP allocation algorithm was proposed for 802.11e to achieve a small delay for video packets. This paper extends our previous work to optimize the end-to-end video quality over IEEE 802.11e HCCA wireless networks with the consideration of importance of video packets.

The rest of the paper is organized as follows. Section 2 gives a brief introduction of the IEEE 802.11e MAC layer mechanisms. Related research in the QoS support in the IEEE 802.11e is reviewed in Section 3. The cross-layer scheduling algorithm is proposed in Section 4. Section 5 presents the simulation results of the cross-layer design. Finally, Section 6 gives the conclusions.

2. IEEE 802.11E MAC

This section gives a brief introduction of IEEE 802.11e MAC layer, which is composed of HCCA and EDCA.

2.1. IEEE 802.11e HCCA

IEEE 802.11e HCCA provides a centralized polling scheme to allocate the access to the channel to traffic flows according to their QoS requirements. A beacon interval is divided into contention period (CP) and contention-free period (CFP). During the CP, the access to the medium is controlled by the EDCA. But the hybrid coordinator (HC) can initiate controlled access periods (CAPs) at any time. HCCA is in charge of the contention-free medium access and collocated at the access point. A transmission opportunity (TXOP) is an interval of time in which a wireless station (STA) or the HC can transmit a burst of data separated by a short interframe space (SIFS) interval. The major responsibility of the HC is to perform bandwidth allocation via assigning TXOPs to each STA.

A reference scheduler was proposed by the IEEE 802.11 working group to determine the TXOP for each traffic flow. Each traffic flow declares its QoS characteristics in traffic specification (TSPEC). The reference scheduler uses several TSPEC parameters for the calculation, such as the mean data rate, nominal MAC service data unit (MSDU) size, and maximum service interval (SI). N_i is the number of MSDUs that arrive at the mean data rate for each traffic stream during one SI for stream i, which is calculated as follows:

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