Chapter 1
Cross-Layer Adaptive Packet Scheduling over Fading Channel: A Decision Theoretic Approach

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ABSTRACT

Cross-layer adaptive resource allocation techniques are found to be powerful techniques for achieving high throughput and high reliability over wireless fading channels. Recently, it has been revealed in the literature that cross-layer adaptation and optimization techniques can improve the overall system level Quality of Service (QoS) performance significantly over separate single layer adaptation and optimization techniques. In this chapter, the authors discuss the novel cross-layer techniques that jointly consider the physical layer channel gain as well as the upper layer buffer occupancy and traffic information in order to find transmission rate and power policies that jointly optimize transmission power, buffer delay, and packet overflow for an application specific bit error rate. They provide a conceptual study on the cross-layer adaptation and optimization techniques, which fuels necessary motivation and direction on how to implement them in different wireless standards and devices. The authors discuss the associated system modeling, problem formulation, and solution techniques as well as show the benefits of cross-layer adaptation and optimization techniques as compared to single-layer counterpart with numerical results.

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INTRODUCTION

Adaptive resource adaptation schemes in different layers of Open System Interconnection (OSI) protocol stack have proven to be powerful techniques both in increasing high throughput and in achieving high reliability over time-varying fading channels. Adaptive resource allocation has already been used in several wireless standards. The key idea of these schemes is adaptation of some of the parameters, e.g., transmitter power level, symbol transmission rate, bandwidth, frame-length, packet retransmission rate, constellation size, Bit Error Rate (BER), coding rate/scheme, or any combination of these parameters with instantaneous channel conditions. Good performance of these schemes requires accurate channel estimation at the receiver and a reliable feedback path between that estimator and the transmitter. Adaptive modulation schemes using *M*-QAM and *M*-PSK for flat fading channels are examined in (Chuang & Goldsmith, 2001). The data rate, transmit power, and instantaneous BER are varied to maximize spectral efficiency, subject to average power and BER constraints.

Adaptive hybrid automatic repeat-request schemes are another important technique for increasing both the throughput and the reliability of packet transmission over time-varying fading channels. Hybrid Automatic Repeat-Request (HARQ) schemes include parity bits for both error detection and error correction. They combine the throughput efficiency of physical-layer Forward Error-Correction (FEC) coding and the reliability of data-link layer error-detection coding. The key idea of adaptive coding schemes is to use a lower-rate coding or more error protection when the channel condition is worse, and vice versa (Vucetic, 1991).

Over the last decade, various cross-layer techniques have been developed in the literature and proposed for different wireless networks and standards. We summarize few recent works as follows. In (Pantelidou, et al., 2011), the authors studied the problem of optimal scheduling of multicast traffic in time-varying wireless networks in the framework of utility maximization. An online gradient-based scheduling and rate control policy is introduced that identifies when to access the wireless medium and with waht rates. A cross-layer design of transmitting scalable video streams from a base station to multiple clients over a shared fading wireless network by jointly considering the application layer information and the wireless channel condition is considered in (Zhang, et al., 2010). In Argyriou (2010), a cross-layer framework for optimizing the performance of opportunistic network coding in wireless multihop ad hoc networks is presented considering backlogged nodes and multiple unicast packet flows. Considering the combinatorial complexity of providing an optimal policy, Pantelidou and Ephremides (2010) studied polynomial-time suboptimal alternative for solving the problem of joint scheduling and rate control for multicast traffic in wireless networks in order to jointly maximize both the sum throughput maximization and the proportional fairness.

On the assumption of independent users' states, Poggioni et al. (2010) analyzed the QoS of scheduling algorithms for heterogeneous users in multiuser wireless systems that take advantage from a cross-layer design with both *Adaptive Modulation and Coding* (AMC) and Automatic Repeat Request (ARQ). The average delay, the Packet-Loss Rate (PLR), and the throughput of a scheduling algorithm based on the channel condition, the buffer occupancy, and the number of retransmissions, of users belonging to different service classes are analytically evaluated using FSMC channel model. Utilizing machine learning techniques, an autonomous host-based intrusion detection system for detecting malicious sinking behavior that maximizes the detection accuracy by associating MAC layer feature with other cross-layer features to define a routing behavior is studied for ad hoc networks in Joseph et al. (2011). Kuran et al. (2010) discussed cross-layer routing-scheduling