Chapter 16

Cross-Layer Design for Packet Data Transmission in Maximum Ratio Transmission Systems with Imperfect CSI and Co-Channel Interference

Trung Q. Duong
Blekinge Institute of Technology, Sweden

Hans-Jürgen Zepernick
Blekinge Institute of Technology, Sweden

ABSTRACT

Multiple-Input Multiple-Output (MIMO) systems, where multiple antennas are deployed at both ends of the wireless links, can significantly increase the transmission rate and reliability of wireless networks. However, due to the increasing demand for high data rates and Quality of Service (QoS), the prosperous performance of MIMO systems may reach its limit. In particular, deployment of many antennas at user devices is constrained by the desired compact designs of mobile equipment. On the other hand, by exploiting the time-varying nature of wireless channels, Adaptive Modulation and Coding (AMC) at the physical layer is utilized to enhance the throughput. In addition, Automatic Repeat Request (ARQ) at the link layer may be applied to circumvent the deleterious effects of fading channels where packets detected with errors can be retransmitted.

In an attempt to maximize the spectral efficiency of co-located MIMO wireless systems under prescribed QoS constraints, the authors consider a cross-layer design that jointly combines Adaptive Modulation (AM) at the physical layer and ARQ at the data link layer. The main purpose of this chapter is to present a general framework for performance analysis of such a cross-layer design. The presented mathematical

DOI: 10.4018/978-1-4666-0960-0.ch016

analysis can be extended to many transmission schemes with MIMO systems including spatial multiplexing schemes (e.g., the V-BLAST system), spatial diversity schemes (e.g., orthogonal space-time block codes), and opportunistic schemes (e.g., maximum transmission ratio).

This chapter will therefore present some new results for the cross-layer design for packet data transmission applied to co-located MIMO with maximum ratio transmission. In this context, closed-form expressions for the average packet error rate, average achievable spectral efficiency, and outage probability are derived. This enables one to evaluate the performance of the cross-layer design under predetermined delay and packet loss constraints. Some important results in the high Signal-to-Noise Ratio (SNR) regime are also provided, revealing insights on how system and channel parameters affect system performance. More importantly, a mathematical analysis is proved to be a powerful tool to investigate the impact of practical issues such as channel estimation error, feedback delay, antenna correlation, and rank-deficient MIMO channel matrix, on the performance of cross-layer design.

INTRODUCTION

With the enormous growth in demand for multimedia services, wireless communications has become the bottleneck in end-to-end wired-wireless networks because radio resources are very scarce and expensive. In addition, the transmission of high data rate demanding services faces fundamental limitations due to impairments inflicted by multipath fading channels. Hence, achieving high data rates with reliable transmission over error-prone mobile radio channels is a major challenge for a mobile radio system design. Recently, being an efficient solution, the so-called cross-layer design paradigm has been proposed where a set of parameters across multiple layers of the protocol stack are exchanged. With this strategy, the overall system performance can be enhanced while keeping the Quality of Service (QoS) satisfactory.

In this chapter, we will investigate a cross-layer design that jointly considers Adaptive Modulation (AM) at the physical layer and Truncated-Automatic Repeat Request (T-ARQ) at the data link layer. As signal traversing from transmitter to receiver may experience reflection, diffraction, and scattering, it can be severely degraded. Instead of circumventing the time-varying effects of the wireless channel, we can exploit these rapid fluctuations to improve spectral efficiency. Specifically, adaptive modulation is deployed by changing to an appropriate modulation constellation, i.e., selecting suitable signal constellation size in accordance with the variation of the end-to-end received Signal-to-Noise Ratio (SNR) (Webb & Steele, 1995; Goldsmith & Chua, 1997, 1998; Alouini, et al., 1999; Alouini & Goldsmith, 2000). However, applying pure adaptive modulation cannot maximize spectral efficiency since the number of available signal constellations is limited. The ARQ scheme at the data link layer is often used to enhance transmission reliability by retransmitting packets detected being in error. Due to the finite buffer size and stringent delay constraints for multimedia services, the maximum number of retransmissions should be limited by using T-ARQ (Malkamaki & Leib, 2000). Under a predefined threshold, e.g., packet lost rate and delay, a cross-layer design combining AM and T-ARQ has gained great attention in the research community (see e.g., Liu, et al., 2004a, 2004b; Maaref & Aïssa, 2004a, 2004b, 2005; Qi, et al., 2010; Wu & Ci, 2006; and references therein).

Multiple-Input Multiple-Output (MIMO) systems, where multiple antennas are deployed at transceivers to significantly improve the system performance compared to its single antenna counterpart, can be subcategorized into spatial