Chapter 28
Parallel Soft Spherical Detection for Coded MIMO Systems

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ABSTRACT

This Chapter briefly evaluates different multiple-input multiple-output (MIMO) detection techniques in the literature as the candidates for the next generation wireless systems. The authors evaluate the associated problems and solutions with these methods. The focus of the chapter is on two categories of MIMO decoding: i) hard detection and ii) soft detection. These techniques significantly increase the capacity of wireless communications systems. Theoretically, a-posteriori probability (APP) MIMO decoder with soft information can achieve the capacity of a MIMO system. A sub-optimum APP detector is proposed for iterative joint detection/decoding in a MIMO wireless communication system employing an outer code. The proposed detector searches inside a given sphere in a parallel manner to simultaneously find a list of m-best points based on an additive metric. The metric is formed by combining the channel output and the a-priori information. The parallel structure of the proposed method is suitable for hardware parallelization. The radius of the sphere and the value of m are selected according to the channel condition to reduce the complexity. Numerical results are provided showing a significant reduction in the average complexity (for a similar performance and peak complexity) as compared to the best earlier known method. This positions the proposed algorithm as a candidate for the next generation wireless systems. The proposed scheme is applied for the decoding of the rate 2, 4 × 2 MIMO code employed in the IEEE 802.16e standard.

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1. INTRODUCTION

Recently, there has been considerable interest in multiple transmit and receive antennas because of capability to offer a high data rate over fading channels (Foschini & Gans 1998; Chuah, Tse, Kahn, & Valenzuel, 2002). By adopting many of the MIMO-OFDM wireless technologies, WiMAX or IEEE 802.16 (IEEE802.16, 2009; Ben-Shimol, Kitroser, & Dinitz, 2006; and references therein) and 3G LTE (3GPP TS22.146, 2009) standards are designed to achieve a peak downlink data rate of 100 Mbps. The next generations of wireless standards like LTE-Advanced are aiming to support 1 Gbps (3GPP TR36.913, 2009). Such capabilities have the potential to enable some significant new service opportunities including mobile TV and other important multicasting/broadcasting services (Hartung, Horn, Huschke, Kampmann, Lohmar, & Lundevall, 2007). Consequently, application of MIMO systems for higher-rate data transmission required by the next-generation broadcasting systems is studied in a number of articles (see Hartung, Horn, Huschke, Kampmann, Lohmar, & Lundevall, 2007; Zhang, Gui, Qiao, & Zhang, 2004; Baek, Kook, Kim, You, & Song, 2005; Baek, Kim, You, & Song, 2004; Qiao, Yu, Su, & Zhang 2005; and references therein).

In MIMO systems, a vector is transmitted by the transmit antennas. In the receiver, a corrupted version of this vector affected by the channel noise and fading is received. Decoding concerns the operation of recovering the transmitted vector from the received signal. MIMO detection techniques can be divided into two classes: i) hard detection and ii) soft detection. In the current standards, usually, MIMO detection and channel decoding are performed separately. Therefore, hard MIMO detection is mainly performed as the equalization. However, soft detection of MIMO systems in conjunction with iterative channel decoding results in a better performance. In order to achieve the capacity of the MIMO systems, the next generation of wireless systems should be able to implement APP MIMO detectors.

1.1. MIMO Decoding with Hard Information

In MIMO channels, as the received signal set has a regular structure, the maximum likelihood (ML) decoding problem is usually expressed in terms of "lattice decoding" which is known to be NP-hard. In other words, lattice decoding methods can be used for hard detection. However, the complexity of the optimum lattice decoding grows exponentially with the number of transmit antennas, and with the constellation size. Several sub-optimum MIMO detectors have been proposed. Zero-forcing (Schneider, 1979) and minimum mean-square-error (MMSE) (Xie, Short, & Rushforth, 1990) are the simplest MIMO detection methods that currently have been adopted for 3GPP LTE (3GPP TS22.146, 2009) or WiMAX (IEEE802.16, 2009) standards. These algorithms are considered the linear detection algorithms that offer low complexity with moderate performance.

More advanced algorithms include nulling and interference cancellation (IC) methods (Foschini 1996; Golden, Foschini, Valenzuela, & Wolnianky 1999), which are essentially based on ZF, MMSE, or QR decomposition (QRD) equalization. However, the performance of such detectors is significantly inferior to that of the ML detector.

Sphere decoding (SD) (Agrell, Vardy, & Zeger, 2002; Damen, El-Gamal, & Cairo 2003) is used as a detection method for MIMO systems with near ML performance. In SD, the lattice points inside a hyper-sphere are checked and the closest lattice point is determined. It is known that even the average complexity of the SD algorithm is exponential (Jalden, & Ottersten, 2005). Following this class of SD algorithms, several sub-optimal algorithms were proposed with a constraint on the complexity of SD algorithms. In these methods, by fixing the average/worst-case complexity of the SD method