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Review article

Recent trends in multiuser detection techniques for SDMA–OFDM communication system

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ABSTRACT

The space division multiple access–orthogonal frequency division multiplexing (SDMA–OFDM) technique is emerged as a most competitive technology for future wireless communication system as it can provide high spectral efficiency and resistance from inter symbol interference (ISI). The SDMA like multiple access techniques are prone to multiple access interference (MAI) because multiple users transmit their data simultaneously. Such a receiver requires appropriate multiuser detection (MUD) scheme to detect individual user's signals correctly by mitigating MAI. Further, due to non-linear behaviour of wireless channel, the signals at SDMA receiver often become linearly non-separable. As a result, MUD becomes a challenging multidimensional optimization problem. Considering these challenges, this paper reviews various MUD techniques for SDMA–OFDM system.

Contents

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1. Introduction

Wireless communication has become gradually more important worldwide not only for professional applications but also for many fields in our daily routine. Nowadays, as the mobile users require high bandwidth applications, the demand for design of robust communication system with high quality of service (QoS) increases. However, though the wireless channel can support ideally infinite frequency bands, due to many reasons full available spectrum cannot be utilized in practice. Bandwidth limitations, propagation loss, noise and interference make the wireless channel a narrow pipe that does not readily accommodate rapid flow of data. In addition to that, the multipath nature of wireless environment makes it as frequency selective and hence inter symbol interference (ISI) is introduced. This problem can be solved by multicarrier transmission, where a serial data with high bandwidth is converted into numerous narrow band parallel data streams. One special case of multicarrier transmission is the orthogonal frequency division multiplexing (OFDM) scheme, which is first proposed by R. W. Chang [1]. However, this model using sinusoidal subcarrier generators and demodulators, which imposes high implementation complexity. As a design alternative, Weinstein and Ebert [2] suggested the OFDM modulation and demodulation processes using the Discrete Fourier Transform (DFT), which significantly reduces the implementation complexity of OFDM. Since the development of OFDM, it has received a great interest and it is successfully incorporated in several applications like high-speed modems, digital mobile communications, high-density recording and so on [3,4]. OFDM modulation technique is also adopted by IEEE 802.11a/g wireless LAN [5,6]. The operation and detailed study about the OFDM is presented in several literatures [7–9].

On the other hand, recently the multiple input multiple output (MIMO) technique has become potentially attractive for achieving high data rates. The fundamental breakthrough for MIMO technology came in the late 1980s with a pioneer work presented by Winters [10,11]. The MIMO system has significant advantageous compared to single input single output (SISO) system. The MIMO architecture can be used for space division multiplexing (SDM) of input data or space division multiple access (SDMA) of different users. The SDM/MIMO architecture may provide either diversity gain or throughput gain. In the spatial diversity techniques, the space time trellis coding (STTC) proposed by Tarokh et al. [12] and the space time block coding (STBC) proposed by Alamouti [13] are well-accepted schemes. The multiplexing gain can be improved by using Bell labs layered space time (BLAST) codes. Foschini proposed diagonal BLAST (D-BLAST) architecture by transmitting several independent data streams through different transmitting antennas [14]. This is further modified in vertical BLAST (V-BLAST), by G. D. Golden [15]. By contrast, the SDMA/MIMO also called as multiuser MIMO allows multiple users to share the same frequency band simultaneously and thus it solves capacity problem. The multiple users are distinguished by their unique user specific channel impulse response (CIR). So, as the OFDM provides resistance from ISI and the SDMA provide high capacity, the combination of these two techniques can become a promising solution for next generation communication system. This inspired numerous further contributions in the area of SDMA–OFDM system [16–18].

At the receiving end of the SDMA–OFDM systems, the channel state information (CSI) should be known for data detection. In order to obtain CSI, blind and training based channel estimation techniques can be applied [19–22]. Once the CSI is known at the receiver, the transmitted signals of all users can be detected using various MUD schemes. In recent past, there has been a significant attention paid towards developing efficient MUD techniques. The linear detectors like zero forcing (ZF) and minimum mean square error (MMSE) detect signals with the aid of a linear combiner [23,24]. The linear detectors cannot mitigate the nonlinear degradation caused by the fading channel, because the channel's output phasor constellation often becomes linearly non-separable. Hence, these detectors result in high residual error. On the other hand, the nonlinear and computationally intensive maximum likelihood (ML) detector is capable of achieving optimal performance through an exhaustive search, which prohibits its usage in practical systems [23]. Considering the trade-off between complexity and performance, some non-linear MUD techniques like successive interference cancellation (SIC) [15,25], parallel interference cancellation (PIC) [24], sphere decoding (SD) [26–28] and QR decomposition (QRD) [29–31] MUDs are introduced. Modifications of SD [32–35] and QRD [36–38] techniques are also proposed in several literatures. However, all these MUDs either fail to detect users in overload or rank deficient scenarios, where the number of users is more than the number of receiving antennas, or suffer from high complexity. Hence, S. Chen et al. proposed minimum bit error rate (MBER) MUD by minimizing BER directly rather than minimizing mean square error to support in overload condition [39]. Conjugate gradient (CG) algorithm is used for updating receiver's adaptable weights [40]. However, it requires proper selection of initial solutions and differentiable cost functions. These drawbacks can be eliminated by incorporating metaheuristic optimization techniques (OTs), as they start the search process from random positions. M. Y. Alias et al. proposed genetic algorithm (GA) based MBER MUD and implemented it for the SDMA–OFDM system [41,42]. Subsequently, the MBER MUD algorithm was modified using other well-known OTs like particle swarm optimization (PSO) [43,44] and differential evolution algorithm (DEA) [45]. The MBER MUD technique is basically designed for Binary Shift Keying (BPSK) modulation scheme. As the next generation communication systems also require high throughput, the OTs are directly used for detection of higher order modulated signal using the ML cost function [46–48]. But these techniques result in high complexity especially in block fading channels. Therefore, J. Zhang et al. proposed another minimum error rate (MER) detection technique based on minimum symbol error rate (MSER) for detecting quadrature amplitude modulation (QAM) signals [49,50]. The modified MSER MUD with invasive weed optimization (IWO) is given in [51].

Most of the discussed classical detectors assume that the channel is perfectly known at the receiver's