Chapter 21

Precoder Design for Cognitive Multiuser Multi-Way Relay Systems Using MSE Criterion

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ABSTRACT

In this chapter, the authors discuss the design of precoders in cognitive multi-user multi-way relay systems. When multiple secondary users intend to communicate with each other using the spectrum licensed to the primary user, how to manage the interference between primary and secondary networks as well as among multiple secondary users becomes an important design issue. They discuss one possible solution of using a relay station as well as multiple antenna techniques. Precoding design in such a relay supported multiple antenna secondary network is presented based on the Mean Square Error (MSE) design criterion. The joint design of precoding matrices at all the secondary nodes is a non-convex problem. Therefore, an iterative algorithm is proposed to iteratively optimize the precoding matrices at secondary transmitters, the precoding matrix at the secondary relay, and decoding matrices at secondary receivers. Other non-iterative solutions are also presented to strike a balance between performance and complexity.

INTRODUCTION

Cognitive radio (CR) allows unlicensed secondary users (SUs) to access licensed spectrum either opportunistically or concurrently and therefore becomes a promising technology to tackle spectrum scarcity (Fitzek & Katz (2007) and Hossain, Niyato & Han (2009)). Allowing multiple secondary users to transmit concurrently with licensed primary users can dramatically increase spectrum efficiency. However, the concurrent transmission of SUs and licensed primary users (PUs) results in interference which will limit the performance of both primary as well as secondary network. Furthermore, if multiple SUs compete for the spectrum licensed to primary network, interference among SUs may also exist. Therefore, how to
mitigate interference to PUs as well as among multiple SUs becomes a crucial design issue of secondary network. In this chapter, we focus on secondary network design that aims at improving spectrum efficiency by providing secondary users with higher throughput and yet maintain the interference to primary network at a low level such that the operation of primary network can still function normally. More specifically, we discuss a relay enabled cognitive network that supports the multi-way transmission of multiple users within this network. Both the cognitive relay and cognitive users are equipped with multiple antennas and the precoding/decoding design at transmitters and receivers is accomplished using a mean square error (MSE) criterion.

For multi-user system, both linear and non-linear precoders can be adopted to improve the overall system performance. The non-linear precoding design can be capacity achieving, however the linear precoding incurs much lower complexity while its performance is still “decent”. The non-linear precoding design is usually designed based on the concept of dirty paper coding. The linear precoding can be designed based on several criteria, such as zero-forcing, MSE, weighted sum rate, etc. To evaluate a precoder design, both its performance and complexity should be considered. A good precoder design should achieve a reason balance between performance (usually in terms of sum capacity for a multi-user system) and complexity. In this chapter, we will discuss linear precoding design based on MSE criterion. Both iterative and non-iterative algorithms are presented. While the iterative algorithm achieves a higher capacity, the non-iterative algorithm significantly reduces the computational complexity. The choice of either the iterative or non-iterative algorithm can be made according to practical system requirements.

By employing multiple antennas at the secondary transmitters, spatial dimensions can be exploited to separate desired signal and harmful interference into different dimensions. In order to protect primary users, interference can be nulled out at primary users’ receive directions provided the channel state information between the relevant transmitter-receiver pair is known. On the other hand, multiple antenna technology can further improve spectrum efficiency by providing multiplexing gain. However, in multi-user multiple-input multiple-output (MIMO) systems, inter-user interference can be a performance-limiting factor. To tackle this problem, precoding/decoding design at multiple-antenna equipped transmitters and receivers can provide an effective solution. For example, precoding design incorporating interference alignment (IA) concept can eliminate (or minimize) the interference by aligning interference from all interferers into a smaller subspace (Peters & Heath (2009) and Kumar & Xue (2010)).

While IA schemes may reduce the harmful effect of interference, its performance at low signal-to-noise ratio (SNR) regime may not be so attractive since in IA designs, the effect of noise is ignored. Also, IA only considers the “direction” of desired signal and interference, not their “power”. Therefore, in low to medium SNR regime, mean square error (MSE) is usually used as a better design criterion. In MSE based design, the goal is to minimize the mean square error in received signal, either due to inter-user interference or noise. By adopting this MSE criterion, the received power of the desired signal, interference and noise are all taken into consideration (Bogale & Vandendorpe (2012)).

To further improve the throughput of secondary network, especially in a network where multiple users have multiple datastreams for each other, a relay station could be employed to enable the multi-way transmission of all users. The transmission of secondary network consists of two phases, due to the half-duplex constraint. The first phase is usually called multiple access phase (MAC) when all secondary users transmit their signals to the relay node. During the secondary phase, namely broadcast phase (BC), the relay processes the signal received during the previous phase and re-transmits it to all the receiving secondary users. Two commonly used relaying techniques are decode-and-forward (DF) and amplify-and-forward (AF). In this chapter, we consider AF scheme because it is more applicable in the
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