Cooperative Beamforming and Power Allocation in the Downlink of MIMO Cognitive Radio Systems

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***Abstract*—In this paper, a new algorithm is proposed for cooperative beamforming and power allocation (CBPA) in the downlink of multi-input multi-output (MIMO) cognitive radio systems. Increasing the efficiency of spectrum usage is the main goal of the cognitive radio systems by servicing a number of secondary users in addition to the primary user. The proposed CBPA algorithm is developed based on a criterion in which the total signal to interference plus noise ratio (SINR) of the secondary users is maximized subject to guarantee the primary user's quality of service and a maximum transmit power. In addition, the CBPA algorithm provides the same quality of service for all secondary users. The transmitter and receiver beamforming vectors along with allocated powers to users are estimated by the CBPA algorithm in an iterative manner. The performance of the CBPA algorithm is evaluated by computer simulations and compared with that of the uplink-downlink duality method.**

***Index Terms*— Cognitive radio, MIMO systems, cooperative beamforming, power allocation**

I. INTRODUCTION

To increase spectrum usage efficiency, two kinds of users are serviced in cognitive radio (CR) systems, primary user (PU) and secondary user (SU). Although the bandwidth originally licensed to the PU, when the PU does not occupy the bandwidth, it can be allocated to the SUs. By making the use of licensed bandwidth possible for SUs, the efficiency of spectrum usage is increased in the CR systems [1]. Due to PU's priority in bandwidth usage, the main challenge is to guarantee the PU's quality of service (QoS), subject to efficient use of spectrum. Joint beamforming and power allocation methods have been proposed under different criteria in recent years to mitigate this challenge.

In [2], a joint beamforming and power allocation method was proposed for uplink of single input multi-output (SIMO) CR system under two criteria. In the first one, the sum of SUs' capacity is maximized subject to a threshold for PU's interference temperature and a maximum allowable transmit power for each SU. In the second one, the minimum SU's signal to interference plus noise ratio (SINR) is maximized under constraints similar to the first criterion. In [3], another joint beamforming and power allocation algorithm has been proposed for downlink of multi-input single output (MISO) CR system, in which transmit power is minimized subject to a PU's interference temperature limit and SUs' SINR thresholds. In [4], the authors have studied joint beamforming and power allocation under two different scenarios, in which the sum of SUs' bit rates is maximized under a limit of interference temperature for the PU and a threshold for SUs' SINR constraints. In the first scenario, each user is supported by a required QoS. In this case, a solution has been given based on nonlinear programming method. In second scenario, each SU whose SINR is below a threshold is not serviced. In this context, by defining SUs' priority classes, the SUs, which maximize system revenue function, are selected to be serviced

In this paper, we propose a new algorithm for cooperative beamforming and power allocation (CBPA) in the downlink of MIMO CR systems. The proposed CBPA algorithm is developed under a criterion with three constraints. In the criterion of the CBPA algorithm, total SINR of all SUs is maximized subject to 1) a maximum allowable transmit power, 2) a minimum threshold for PU's SINR in order to guarantee the required PU's QoS and 3) providing the same SINR for all SUs. A two-step iterative CBPA algorithm estimates the transmitter and receiver beamforming vectors of the PU and SUs by maximizing the total SINR and also computes allocated powers to the PU and SUs by applying the given three constraints.

In the following, a MIMO CR system is modeled based on one PU and K SUs in Section II. The CBPA algorithm is developed in Section III. Computer simulation results are presented in Section IV and Section V concludes the paper.

II. SYSTEM MODEL

A downlink of MIMO CR system with one primary user (PU) and K secondary users (SU) is shown in Fig. 1 where the base station (BS) , PU and ith SU are equipped by antenna arrays with N , M_p and M_{s_i} elements, respectively. When s_p and s_{s_i} are transmitted signals for the PU and the ith SU, respectively, the transmitted signal from the BS is given as

$$\mathbf{x} = \mathbf{v}_p s_p + \sum_{i=1}^{K} \mathbf{v}_{s_i} s_{s_i} \qquad (1)$$

where s_p and s_{s_i} are independent and identically distributions (i.i.d.) signals with normalized energy. Also, $\mathbf{v}_p$ and $\mathbf{v}_{s_i}$ are

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