ENERGY EFFICIENCY OPTIMIZATION IN MASSIVE MIMO COGNITIVE RADIO NETWORK USING SMART RADIO ALGORITHMS

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Abstract : To attain the maximum EE (energy efficiency) of any network is an important task. The assurance of impartiality of energy efficiency between cognitive users (CUs) in the network is very difficult. It becomes more difficult when network is a cognitive radio network (CRN) with massive multiple input and multiple output (MIMO) network. In this paper we studied two power optimization problems. The first one is network energy efficiency optimization problem (NEP) and second one is fair energy efficiency optimization problem (FEP) by using practical model of power consumption. Both optimization problems are non-convex and NP- hard due to its fractional nature of energy efficiency and interference. To grab these type of issues, we proposed algorithms in this paper and tried to resolve the problems.

Keywords: *CRN, CU, EE, FEP, MIMO, NEP, Optimization, Qos, Radio, SE.*

I. INTRODUCTION

Energy efficiency is causing more and more attentions due to its gradually rising energy costs and environmental concerns. At the same time, spectral efficiency (SE) is also an importance because of the spectrum shortage and the cumulative data rate request for multimedia applications. Nowadays, EE which events that how effectively the resources of energy are expended, and SE estimates how resourcefully narrow available spectrum bands resources are utilized, are two an important performance metrics for fifth generation wireless communications network. Though, attaining such a large capacity by basically ascending up the transmit power is evidently difficult or impossible. This phenomenon would lead to electromagnetic pollution, additional emission of greenhouse, and uncontrollable energy request. The high-pitched enhancement on energy efficiency, at a level of similar, power consumption is measured to be an efficient and effective way to achieve such goals. Nowadays, Cognitive Radio is a sizzling issue in the area of wireless telecommunication network. For its advantages on considerably enhancing the spectrum consumption.

The power controlling is an effective and efficient technique to increase the performance of EE and SE in a cognitive radio systems. To similar, massive MIMO is believed to be a favourable applicant technology of fifth generation, for its prevalence for improving EE & SE with minimum difficulty. In the system of massive MIMO, however the multiplexing gain can be attained with equivalent power allocation and control scheme, among cognitive users can support to produce all the profits taken by massive antenna arrays. To encounter the great service requirements in upcoming wireless communication network, massive MIMO cognitive radio networks will be very helpful to obtained maximum efficiency. The system of massive MIMO has a huge number of BST antennas. The inevitable problem in massive MIMO cognitive radio network is that the impartiality among CUs, when they share the spectrum and guarantees of individual quality-of-service (QoS).

The large scale fading can exist in massive MIMO system but small scaling fading doesn't exist. The existence of large scale fading causes the injustice among CUs nearby and faraway from the base station (BS). In this paper, consequently, our main aim is to exploiting the network EE of massive MIMO cognitive radio network and ensuring the EE fairness between cognitive users by enhancing the transmit power of uplink. According to previous studies we investigated EE maximization problem in massive MIMO systems [1]-[3]. In [1], the authors delivers visions on the ideal and optimal design of the active users, different number of antennas and transmit power of network for exploiting energy efficiency in multiuser MIMO systems. In [2], a new model for power consumption in massive MIMO systems is proposed, where the number of base station (BS) antennas is intended for EE maximization. In [3], the authors investigated quality-of-service (QoS) for EE maximization with equal and unequal power allocation.

II. RELATED WORK

The two power optimization problems for massive MIMO cognitive radio network are discussed in [4]. In this paper, system model includes world-wide transceiver hardware impairments at both the single-antenna user equip-ments (UEs) and the BSs (equipped with large antenna arrays). As opposite to the predictable circumstance of idyllic hardware, the hardware impairments generate restricted maxima during channel estimation accuracy and on the uplink/downlink capacity on each UE which is discussed in [5]. To attain the better results in massive MIMO cognitive network, the enhancement of the QoS parameters gives better outcome which is discussed in [6].

To acquire the power optimization problem of local transmit power for the max-min EE fairness among CUs in MIMO cognitive radio networkis discussed in [7]. Power control algorithms and convex optimization problem for downlink MIMO systems are discussed in [8]. An algorithm is proposed for an interference-limited wireless network where trade-off exists between spectral efficiency and spectrum efficiency for massive MIMO and heterogeneous network [9]. The fractional programing and proposed algorithms are developed for an optimization of energy efficiency which is discussed in [10].

The power allocation is tremendous problem to get maximum throughput and minimum rate for an interference-limited wireless network which is conversed in [11]. In interference-limited wireless network the trade-off exists between spectral efficiency and spectrum efficiency which is nonconvex and NP hard problem. A general algorithm for these type of problems is discussed in [12]. To attain the large coverage area and low complexity in wireless network algorithms are proposed which verifies that the MEP assurances the fairness of energy efficiency among cognitive users, in addition to that it disclose the differences between NEP and MEP. MEP pledges the fairness of EE among cognitive users, as well as expose the variances between the NEP and the MEP, where all concepts are discussed in [13]. To maximize the global EE in massive MIMO system, a power control algorithm is discussed in [14].

For achieving the sum spectral efficiency an optimal resource allocation scheme is used to select the training signal power, training duration and data signal power by using maximum ratio combining technique which is discussed in [15]. To attain the total energy and low power consumption for sub urban and dense urban multi macro cellular network a new model is proposed in [16]. In wireless networks for achieving the global maximum energy efficiency is a big challenge now a days. To solve this problem the development of general and new framework are discussed with the help of sequential optimization and fractional programming in [17]. To achieve the high spectrum efficiency utilization in the environment of cognitive radio with MIMO network, the centralized and distributed optimization algorithms are discussed in [18].

For channel model that contains only small-scale fading, the trade-off is discussed between spectral efficiency (terminal/ channel/bits) and energy efficiency (bits/J) in [19]. To achieve the guaranteed Qos and lower complexity with the higher energy efficiency one method is proposed in [20]. This paper proposed a method for OFDM (orthogonal frequency-division multiple-access) systems to maximize the energy efficiency optimally allotting wireless assets. The MIMO (Massive multiple input multiple output) has an important and fundamental benefits for fifth generation network like cognitive radio network. The MIMO with their fundamental benefits are discussed in [21]. The survey on improvement of energy efficiency and spectrum efficiency with the help of power amplifier facts in wireless communication system is discussed in [22].

III. SYSTEM MODEL AND FORMULATION

In this paper, first we consider massive multiple input multiple output (MIMO) cognitive radio network (CRN). This network introduces two users first one is primary users and second one is secondary users or cognitive users. The primary users (PUs) are licensed users and they can use the allocated spectrum, while cognitive users are allowed to share those licensed spectrum which are assigned for primary users in an underlay coexistence mechanism, if primary users are absent or if their produced interference to primary users is below a threshold. After consideration of this network we formulated general forced energy efficient (EE) optimization problem using two power control algorithms to it.

A. System Model of Network

The figure 1 demonstrates the system model for massive multiple input multiple output (MIMO) Cognitive Radio Network (CRN) where the uplink of single cell contains two interactive networks primary network and cognitive network. The primary network consists of multi-antennas primary base station (PBS) and single antenna primary user (PU). The other network which is cognitive network embedded within this communication area, and cognitive network consists of M multi-antennas and K single-antenna cognitive users (CUs), where M >> K always. We assume that all the cognitive users share the same time-frequency resources with the primary users. After this assumption both users will communicate with, their own base station at the same time or simultaneously, there must beoccur mutual interference among them.

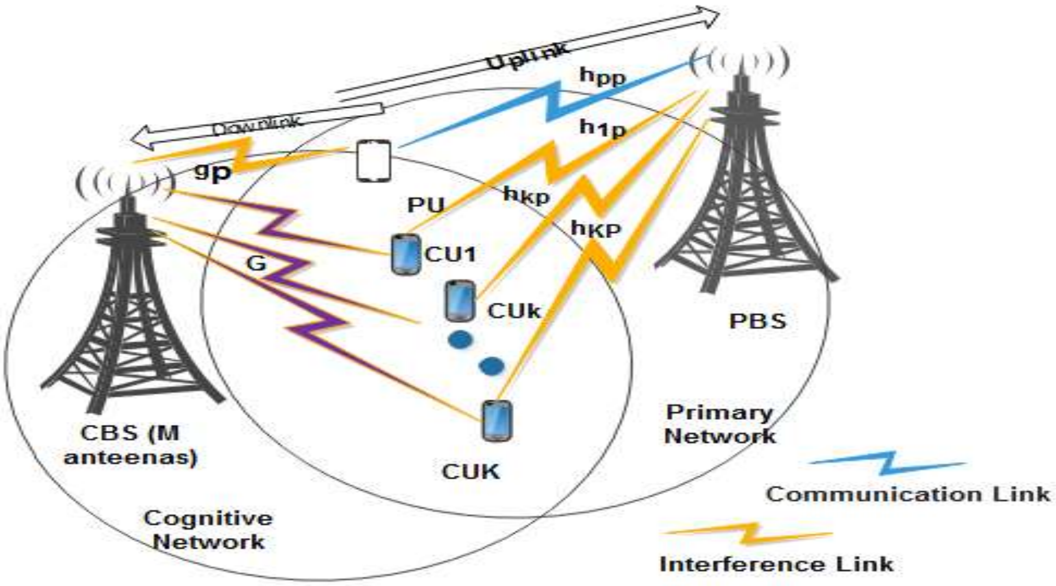

Figure 1: System Model.

B. Signal Transmission

The data are transmitted from cognitive users and primary users to their own base station, after transmission of data, the M×1 received signal vector at the cognitive base station (CBS) can be given by

$$\boldsymbol{y} = \boldsymbol{G_X} + \boldsymbol{g_p x_p} + \boldsymbol{n} \qquad (1)$$

Where, $x = [x_1, x_2, \ldots\ldots x_k]^{\mathrm{T}}$ and $p = [p_1, p_2 \ldots\ldots\ldots p_k$, where $x_k = \sqrt{}P_k S_k$ is a transmitted signal from $k - th$ CU, P_k is i where G cognitive users (CUs) and cognitive base station (CBS), $g_p \triangleq [[g_p, \ldots, g_p]^T$

$$r_k = g_k^H g_k \sqrt{P_k S_k} + \sum_{i=1, i \neq k}^{K} g_k^H g_i \sqrt{P_i S_i} + g_k^H g_p \sqrt{P_p S_p} + g_k^H n. \qquad (2)$$

$$R_k \geq \tilde{R}_k$$

$$= log_2(1 + E[\frac{|g_k^H g_k|^2 P_k}{\sum_{i=1,i\neq k}^{K} |g_k^H g_i|^2 P_i + \left|g_k^H g_p\right|^2 P_p + \left||g_k|\right|^2 \sigma^2}]$$

$$= log_2\left(1 + \frac{(M-1)\beta_k P_k}{\sum_{i=1,i\neq k}^{K} \beta_i P_i + \beta_p P_p + \sigma^2}\right). \qquad (3)$$

$$SE_{tot} \triangleq \sum_{k=1}^{K} \widetilde{R_k} = \sum_{k=1}^{K} log_2(1 + \frac{(M-1)\beta_k P_k}{\sum_{i=1,i\neq k}^{K} \beta_i P_i + \beta_p P_p + \sigma^2}) \qquad (4)$$

$$\sum_{\boldsymbol{k=1}}^{\boldsymbol{K}} \alpha_k P_k \leq T, \qquad (5)$$

All these equations are discussed in [4] which are using for signal transmission.

C. Power Consumption Model

The hardware of ideal power model considers only the radiated power and because of it the design of practical network becomes complicated and confusing. To reduce this deceptive things we shall consider the more accurate energy efficiency metric. In this model we shall consider both radiated power and dissipated power, consumed for transmitting and dissipated in the other circuit block respectively of the CBS and CUs. The entire power consumption of whole network for uplink transmission in massive multiple input multiple output cognitive radio network can be given by:

$$PC_{tot} = P_{amp} + P_{\ cir} \tag{6}$$

$$P_{amp} = \frac{1}{\varepsilon}\sum_{k=1}^{K} P_k\,, \tag{7}$$

Where P_{amp} = power consumption for all the amplifiers of cognitive users.

$$P_{cir} = M\rho_c + \varrho\sum_{k=1}^{K}\widetilde{R_k} + \xi, \tag{8}$$

$$PC_{\ k} \triangleq \frac{1}{\varepsilon}P_k + M\rho_c + \varrho\widetilde{R_k} + \xi. \tag{9}$$

The above equations are discussed in [4] for power consumption model.

D. Energy Efficiency:

The energy efficiency can be defined as a ratio between spectral efficiency (bits/ channel) and total power consumption (Joules/channel). The expression are

$$\eta_{tot} = \frac{SE_{tot}}{PC_{tot}}$$

$$\eta_k = \frac{SE_k}{PC_k} \tag{10}$$

IV. PROBLEM WITH NETWORK EE OPTIMIZATION (NEP)

There are two steps which evaluates the optimization problem of network EE in massive multiple input multiple output cognitive radio network

Step 1: For Maximum Network EE:

$$\max_P \eta_{tot}(P)$$

$$s.t. C_1: \sum_{k=1}^{K}\alpha_k P_k \le T \tag{11}$$

$$C_2: R_k(P) \ge r_{k_k}^{req}, \forall k$$

$$C_3: 0 \le P_k \le P_k^{max}, \qquad \forall k. \tag{12}$$

$$\eta_{tot}^{opt} = \frac{SE_{tot}(P^{opt})}{PC_{tot}(P^{opt})} = \max_{P\epsilon C_1,C_2,C_3}\frac{SE_{tot}(P)}{PC_{tot}(P)} \tag{13}$$

$$F(\eta_{tot}) = \max_{P\epsilon C_1,C_2,C_3}[SE_{tot}(P) - \eta_{tot}PC_{tot}(P)]$$

$$F(\eta_{tot}^{opt}) = \max_{P\epsilon C_1,C_2,C_3}\left[SE_{tot}(P) - \eta_{tot}^{opt}PC_{tot}(P)\right] \tag{14}$$

$$= SE_{tot}(P) - \eta_{tot}^{opt}PC_{tot}(P) = 0 \tag{15}$$

$${}_P\max SE_{tot}(P) - \eta_{tot}^{n}PC_{tot}(P)$$

$$s.t. C_1, C_2, C_3 \tag{16}$$

For step-1 in [4] some equations are used which introduces how we can obtain the maximum energy efficiency in massive MIMO cognitive radio network. The above equations are used to solve the optimization problem

Step 2: For Power Optimization (P^{opt}):The second step introduces two algorithms which help to obtain the power optimization. Power controlling of any network is very difficult or you can say it is impossible. But enhancement of power consumption using power consumption model is an easy way for massive MIMO cognitive radio network. This step describes a model which is discussed in [4]. Some equations are also available to understand this power consumption model.

V. PROBLEM WITH FAIR EE OPTIMIZATION (FEP)

The energy efficiency fairness among the CUs is significant task due to heavy traffics in wireless communication network. It becomes more difficult when we consider massive MIMO network. The chances of mutual interference can exist among cognitive users due to massive MIMO cognitive network. This section also introduced two steps.

Step 1: For Maximum Fair EE:This step 1 presents an algorithm and some equations to attain fairness of EE which is discussed in [4].

Step 2: For Optimal Transmit Power P^*:The step two also has an algorithm which implies that how we can optimize the optimal transmit power which is discussed in [4].

VI. CONCLUSION

We investigated two optimization problem in this paper, for an energy-efficient power. The first one is NEP and second one is FEP. Both are used to exploit the energy efficiency of network and guarantee the energy efficiency fairness among cognitive users, respectively, in cognitive radio network with MIMO environment. In this paper, we proposed two power controlling algorithms on the basis of interchanging sequential convex programming and fractional programming for grabbing the non-convexity and NP-hard features of an optimization problems. The results of this paper clarified the effects of cognitive base station antennas number and power consumption of circuit on the SE and EE network. Generally, at applied wireless communication system, the network energy efficiency drops with a huge number of antennas of CBS and the rise of circuit power consumption. On the other hand the network spectral efficiency keeps increasing with the rising amount of antennas of CBS but it is slightly affected by the circuit power consumption.

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