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RESOURCE ALLOCATION FOR OFDMA BASED COGNITIVE RADIO SYSTEM USING JOINT OVERLAY AND UNDERLAY SPECTRUM ACCESS MECHANISM

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ABSTRACT

In this paper, we propose an optimal scheme for subcarrier and power allocation in a orthogonal frequency division multiple access (OFDMA) based cognitive radio system. Here we consider subcarrier and power allocation for both underlay and overlay spectrum access mechanism. So this is called joint underlay and overlay spectrum access mechanism (JOUSAM). As such, for a given power budget, the total transmission rate of the CR users is maximized, whereas the interference introduced to the PUs' receiver is kept below the given limits with certain probability. We propose an optimal power-and-subcarrier-allocation scheme for an OFDMA-based CR system with a JOUSAM. As the complexity of the optimal power and-subcarrier-allocation scheme can be high, we propose a low-complexity suboptimal power-allocation scheme. Presented numerical results demonstrate that, for given interference constraints, a significant improvement in the transmission rate is achieved with the JOUSAM, as compared with either the OSAM or the USAM. Selected simulation results also show that the fairness performance in terms of data rate sharing of the individual CR user for the optimal algorithm can be poor. Therefore, we finally propose a suboptimal subcarrier-allocation algorithm that can improve the fairness performance.

Keywords: cognitive radio, convex optimization, orthogonal frequency division multiple access (OFDMA), overlay spectrum access, underlay spectrum access, fairness among CR users.

1. INTRODUCTION

In order to meet growing demand of high data rates applications in modern communication networks, the spectral efficiency must be further improved [1]. However, the current static spectrum allocation policy, in which governmental agencies assign spectrum to licensed users on a long-term basis for large geographical regions, faces spectrum scarcity in particular spectrum bands and cannot satisfy the increase in spectrum demand [2]. Furthermore, because of a large portion of the assigned spectrum being used sporadically, a ignificant amount of spectrum is under-utilized [3]. Hence, a new communication paradigm, who's key enabling technology is referred to as Cognitive Radio (CR), was recently proposed to solve these spectrum inefficiency problems [4]. Since the CR technology enables the unlicensed users to share the spectrum with the primary/licensed users in an opportunistic manner, the spectrum utilization can be increased.

To exploit unused and underused spectrum bands, two different approaches for a dynamic spectrum access mechanism, namely *the underlay spectrum access mechanism (USAM) and the overlay spectrum access mechanism (OSAM),* have been proposed in literature [5]. According to the OSAM, the spectrum utilization can be increased by granting secondary or cognitive users to opportunistically exploit unused frequency bands of primary users (PUs). As such, the secondary users and PUs may coexist in the side-by-side spectral bands [6][7]. In the OSAM, although secondary users and PUs may coexist in the side-by-side bands, there are mutual interferences between the PUs and cognitive users due to the non- orthogonality of the transmitted signals [7]. On the other hand, as per USAM, the PUs and CR users can coexist in the same spectral band [8]. In other words, the USAM allows simultaneous sharing of underutilized frequency bands by the secondary users along with the PUs. For this scenario, the interference comes mainly due to the coexistence in the same spectral band.

Orthogonal frequency Division Multiple technology has been considered as an appropriate modulation candidate for a CR system [9]. In OFDM system the frequency band is divided into a large number of small bands called subcarriers that use specific frequencies so as to be completely orthogonal to each other, which can not only reduce the mutual interference between the subcarriers, but also improve the spectrum efficiency. In a wireless network where both the primary system and the secondary system employ OFDM transmission technology, the SUs can flexibly fill the spectral gaps left by the PUs [9] or transmit over the unused subcarriers left in the primary system [7]. Even if there are no unused subcarriers left in the primary system, SU can flexibly share the subcarriers with PUs on condition that PUs are sufficiently protected [10].

Due to the above reasons, OFDM-based CR systems have attracted wide attention and the related resource allocation problems have become hot research topics. In conventional OFDM systems, with a total transmit power constraint, it is proved that water-filling over the subcarriers is the optimal power allocation strategy [11]–[13]. However, the conventional water-filling power control policy is found to be inefficient for OFDM-based CR systems due to the interaction with the

ARPN Journal of Engineering and Applied Sciences

PUs. In [10], when SU and PU coexist in the same bands, with individual interference power constraint imposed on each subcarrier to protect the primary transmission, the optimal power allocation strategy to maximize the rate of SU is derived. While in [7], for the case that SU and PU coexist in side-by-side bands, with a constraint in the form of an upper bound on the cross band interference incurred to PU to protect the primary transmission, the optimal and suboptimal power allocation strategies to maximize the sum rate of the SUs are derived.

In particular, optimal and low-complexity suboptimal power-allocation algorithms have been proposed in [7] and [14] for an OFDM-based CR system, which considered that a single CR user opportunistically accesses unused spectrum in an overlay approach. These algorithms improved the downlink transmission rate of the CR user while maintaining the interference introduced to nearby PUs' bands below certain thresholds. Improved water-filling power-allocation and subcarrier-allocation algorithms are proposed for OFDMAbased CR Networks in [15]–[17] assuming OSAM. Optimal power allocation for OFDM based CR network is proposed considering underlay network in [18]. Instead of using the conventional interference power constraint to protect the primary users in the primary system, a new criterion referred to as rate loss constraint is proposed for primary transmission protection. An optimal subcarrier-and-power allocation scheme for OFDM-based CR multicast networks, which uses unused PU bandwidth with an OSAM, is proposed in [19]. In [10], resource-allocation algorithms have been proposed where power is loaded in a USAM, i.e., the power is allocated to the frequency bands where a PU is already present and only cochannel interference between a PU and CR is considered. A joint subcarrier assignment and power allocation for an OFDMA-based ad hoc CR network is considered in [20].

Most of the existing works considered either USAM or the OSAM for developing power-allocation and/or subcarrier-allocation algorithms. However, the CR systems may need to utilize not only the unused bands in a given geographical location in a particular time but also the nearby underutilized bands to increase the overall spectrum utilization. Therefore, it is very important to study and design a resource-allocation scheme for a *joint overlay and underlay spectrum access mechanism (JOUSAM)*. While allocating power for the OSAM, the entire power is allocated in overlay subcarriers. For a given interference threshold, allocating power in overlay subcarriers can maximize the transmission capacity. On the other hand, loading power in underlay CR subcarriers introduces more interference to the PU band. However, underlay CR subcarriers may experience relatively better channel qualities. In addition, the channel quality between the CR transmitter and an overlay CR subcarrier can be poor. By restricting transmission of the CR users only in the overlay subcarriers, underlay subcarriers remain underutilized.

A power-allocation problem for the JOUSAM is considered in [21], where Bansal *et al.* considered that a CR transmitter is transmitting information to a single CR user. A hybrid overlay and- underlay CR model is proposed in [22]. In particular, by simultaneously exploiting both unused and underused spectral regions, a soft-decision CR approach, whereby the transmitted power spectral density in each region is determined by the spectrum usage in that region, was proposed. In [23], a joint overlay-and-underlay two-switch model is presented, which either transmits in an overlay spectrum or in an underlay spectrum. Subcarrier allocation and power allocation for OFDMA based CR systems have been studied in [24] and [25]. In these works, the interference constraint at the PU receiver is satisfied in an average (averaged over short term) sense and in a probabilistic manner. Motivated by these works, in this paper, we study subcarrier-and-power-allocation schemes for the JOUSAM. In this paper, for practical reasons, we assume that the instantaneous channel quality between the CR transmitter and the PUs' receiver is not known. Rather, the statistics of the channel gains are known at the CR transmitter, and the Instantaneous interference introduced to the PUs' receivers is guaranteed in a statistical manner.

The organization of this paper is as follows. Section II describes the system model and formulates the subcarrier and- power-allocation problem as an optimization problem. In section III the optimal power-and-subcarrier-allocation scheme is proposed. In Section IV, we present a low-complexity suboptimal power-allocation scheme and compared with Power-allocation schemes for the OSAM and the USAM in section V. Some selected numerical results for various schemes under consideration are presented in Section VI. The fairness issue among the CR users is discussed in Section VII. Finally, this paper is concluded in Section VIII.

2. SYSTEM MODEL AND PROBLEM FORMULATION

A. Overall description

We consider a downlink transmission for CR system where there is a single CR transmitter, transmitting information to K CR users using the spectrum of bandwidth W. We assume that, in a given geographical location, a contiguous portion of radio spectrum of total bandwidth W is divided into M bands with respective bandwidth, i.e., Wi (i = 1, 2, . . . , M). These spectrum bands are assigned to different group of

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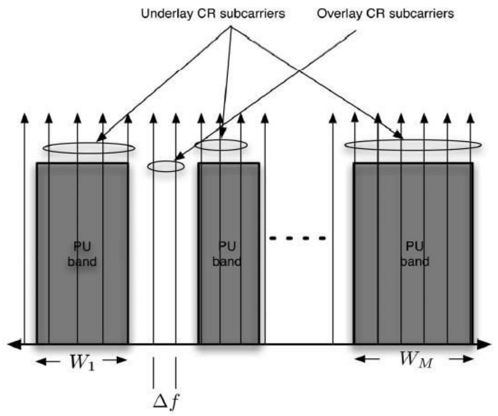

Figure-1. Example of joint overlay and underlay spectrum access mechanism.

PUs, and a particular band may not be used in a given time in a given geographical region.

The CR system uses OFDMA as the multiple-access mechanism, and it divides the whole spectrum into Z subcarriers with spectral distance between two adjacent subcarriers, i.e., $\Delta f = W/Z$. In a given spectrum band, the PUs' system may use any access mechanism that is not known to the CR system. A spectrum sensing mechanism is implemented in the CR system that can identify whether a given subcarrier falls in the bands that are currently occupied by the PUs or not. Without loss of generality, we assume that, in a given time, there are N overlay subcarriers and L underlay subcarriers, where $N + L = Z$. For notational convenience, we denote the underlay subcarriers by set SU and the overlay subcarrier by set SO, where $|SO| = N$, and $|SU| = L$. One possible coexistence scenario of the PUs and CR users in the spectral domain with the JOUSAM is depicted in Figure-1.

B. Modeling

By assuming an ideal Nyquist pulse shaping at the CR transmitter. The power density spectrum of the kth subcarrier will be written as

$$\varphi_k(f) = p_k \;\; T_s \left(\frac{\sin \pi f T_s}{\pi f T_s}\right)^2 \tag{1}$$

Where T_s will be the symbol duration and p_k represent the power loaded in the kth subcarrier. The total interference introduced to the lth PU receiver will be written as [6],[7]

$$i_l^{PU} = | h_l^{SP} |^2 \sum_{u=1}^{K}\sum_{k=1}^{Z} \rho_{u,k}\, p_{u,k}\, T_s \times \int_{d_{k,l}-\Delta f/2}^{d_{k,l}+\Delta f/2} \left(\frac{\sin \pi f T_s}{\pi f T_s}\right)^2 df \quad \text{for } l \in S_U \tag{2}$$

In this the $d_{k,l}$ denotes the spectral distance between the kth CR subcarrier and the l^{th} PU subcarrier and $\rho_{u,k}$ takes value 1 if the kth subcarrier is allotted to the CR user u or otherwise it will take the value of zero. $p_{u,k}$ will be the transmitted power by the u^{th} CR user in the kth subcarrier and h_l^{SP} will be the complex fading coefficient between the CR transmitter and the l^{th} PU receiver. Here a spectral distance factor $0 \leq (d\ ,) \leq 1$ is given as

$$f(d_{k,l}) = T_s \int_{d_{k,l}-\Delta f/2}^{d_{k,l}+\Delta f/2} \left(\frac{\sin \pi f T_s}{\pi f T_s}\right)^2 df \tag{3}$$

Using the shannon capacity formula, the theoretical transmission rate of all CR users will be written as

$$C = \Delta f \; \sum_{u=1}^{K}\sum_{k=1}^{Z} \rho_{u,k} \; log\left(1 + \frac{| h_{u,k}^{SS}|^2 p_{u,k}}{+j_{k,u}}\right) \tag{4}$$

In which the $h_{u,k}^{SS}$ represents the complex channel channel fading coefficient between the CR transmitter and the uth CR user in the kth subcarrier , σ^2 represents the additive white Gaussian noise variance and $j_{k,u}$ denotes the interference introduced to the kth subcarrier of uth CR user.

C. Problem formulation

The design goal is to maximize the total transmission rate of K CR users while keeping the total *instantaneous* interference introduced to the underlay subcarriers below a threshold for a given total *instantaneous* transmission power budget for given values of $h_{u,k}^{SS}$. Mathematically, the problem can be written as an optimization as follows

$$\max_{\rho_{u,k}, p_{u,k}} \Delta f \; \sum_{u=1}^{K}\sum_{k=1}^{Z} \rho_{u,k} \; log_2\left(1 + \frac{| h_{u,k}^{SS}|^2 p_{u,k}}{\sigma^2 + j_{k,u}}\right) \tag{5}$$

$$Pr\left(| h_l^{SP} |^2 \sum_{u=1}^{K}\sum_{k=1}^{Z} \rho_{u,k}\, p_{u,k}\, f(d_{k,l}) \;\leq\; I_{TH}^{(l)}\right) > a, l \in S_U \tag{6}$$

$$p_{u,k} \geq 0 \;\forall\; u,k \tag{7}$$

$$\sum_{u=1}^{K}\sum_{k=1}^{Z} \rho_{u,k}\, p_{u,k} \;\leq\; P_T \tag{8}$$

$$\rho_{u,k} = \{0,1\} \;\forall\; u,k \tag{9}$$

$$\sum_{u=1}^{K} \rho_{u,k} = 1 \;\forall\; k \tag{10}$$

Where Pr denotes the probability.

Now, assuming the amplitude fading gain, i.e. h_l^{SP} , to be Rayleigh distributed with known parameter λ_l , the distribution of $| h_l^{SP} |^2$ is an exponential distribution with parameter λ_l^2 Hence, the interference constraint in (6) can be written as

$$1 - exp^{-\frac{I_{TH}^{(l)}}{2\lambda_l^2 \sum_{u=1}^{K}\sum_{k=1}^{Z} \rho_{u,k} p_{u,k} f(d_{k,l})}} \tag{11}$$

Equation (11) can be rewritten as

ARPN Journal of Engineering and Applied Sciences

$$\sum_{u=1}^{K}\sum_{k=1}^{Z}\rho_{u,k}\, p_{u,k}\, f(d_{k,l}) \leq \frac{I_{TH}^{(l)}}{2\lambda_l^2\,(-\ln(1-a))},\ l \in S_U \quad (12)$$

3. OPTIMAL SUBCARRIER-AND-POWERALLOCATION SCHEME

Here, we provide the optimal subcarrier-and-power allocation algorithm for the optimization problem formulated in (5), (6), (8)-(10), and (12). We decouple the joint subcarrier and power-allocation problem into two separate problems: a *subcarrier-allocation* problem and a *power-allocation* problem.

A. Subcarrier allocation

To maximize the total transmission rate, we allocate a particular subcarrier to a CR user that has the highest signal-to- interference- plus-noise ratio for that subcarrier. Thus $\rho_{u,k} = 1$ for $u = u^*$ or 0 if otherwise, where

$$u^* = \ arg \max_u \frac{|\, h_{u,k}^{SS}|^2}{\sigma^2 + j_{k,u}} \quad \text{for k = 1,2,..Z} \quad (13)$$

Theorem 1: The decoupling of the joint power- and subcarrier- allocation problem into two separate problems where subcarrier allocation is performed according to (13) is optimal.

B. Power allocation

After performing subcarrier allocation according to (13), the optimization problem in (5) can be written as

$$\max_{p_{u,k}} \sum_{u=1}^{K}\sum_{k=\Omega_u} log_2\left(1 + \frac{|\, h_{u,k}^{SS}|^2 p_{u,k}}{\sigma^2 + j_{k,u}}\right) \quad (14)$$

where Ωu is the set of subcarriers assigned to user u by performing subcarrier allocation according to (13).

Theorem: The optimal power for the *k*th subcarrier that is allocated to the *u*th CR user can be written as

$$p_{u,k} = \left[\frac{1}{\alpha_l\, f(d_{k,l}) + \gamma} - \frac{\sigma^2 + j_{k,u}}{|\, h_{u,k}^{SS}|^2}\right] \quad (15)$$

Where α_l, γ Lagrange constants

4. SUBOPTIMAL POWER-ALLOCATION SCHEME

In the optimal scheme proposed earlier to calculate the optimal power as per (15), it requires to calculate the Lagrange parameters using a numerical method. In this the optimal scheme should be computationally complex. The complexity of subcarrier allocation scheme is represented as O (KZ), and the complexity of power allocation scheme will be exponential in Z and is $O(Z^3)$. The proposed Sub-optimal power allocation scheme the complexity will be lower. With the help of heuristic algorithm the underlay subcarriers will introduce higher interference to the PU receivers when compared with the overlay subcarriers, so we propose to allocate less power to the underlay subcarriers when compared with overlay subcarriers. The subcarriers are allocated in the ladder profile. This ladder profile will be based on the heuristic algorithm. The power profile with for underlay subcarriers that are allocated ith equal amount of power will be given as

$$p_l^{subopt,un} = p^{un} \qquad l \in S_U \quad (16)$$

In this the overlay subcarriers are allocated power in a ladder type of fashion where the step size will be constant. Mathematically the power profile for the overlay subcarriers can be expressed as

$$p_l^{subopt,ov} = p^{ov} \times i_n \quad (17)$$

where $i_n = \left|\frac{\Delta n}{\Delta f}\right|$ and Δn is the spectral distance between the *n*th overlay subcarrier and the closest PU band. Now we introduce design factor x by which the power in the underlay networks subcarrier will be less than the overlay subcarrier which will be closest to the PU band, mathematically it will be written as

$$p^{ov} = x \times p^n \quad (18)$$

Now the power profile can be determined if the value of P^{un} is determined such that both the power budget constraint and the L interference constraints will be satisfied. In each of the (L+1) constraints a corresponding value of P^{un} is determined.

The power values in the CR subcarriers which satisfy the total power constraint will be written as

$$\sum_{l=1}^{L} p_l^{subopt,un} + \sum_{n=1}^{N} p_l^{subopt,ov} = P_T \quad (19)$$

5. COMPARISON WITH THE OVERLAY SPECTRUM ACCESS MECHANISM AND THE UNDERLAY SPECTRUM ACCESS MECHANISM

Here we compare our proposed optimal and suboptimal power and subcarrier allocation algorithms for the JOUSAM with the existing spectrum access mechanism. For the comparison we present subcarrier and power allocation for the OSAM and the USAM.

A. Power and subcarrier allocation in OSAM

The subcarrier and power allocation algorithm for the OSAM in which the power is allocated to N overlay subcarrier and the L underlay subcarriers are nulled. The power profile for the OSAM will be obtained by the following optimization problem.

$$\max_{p_{u,k}{}^{ov}} C^{ov} = \sum_{u=1}^{K} \sum_{k\in\Omega_u} \rho_{u,k}\, log_2\left(1 + \frac{|\,h_{u,k}^{SS}|^2 p_{u,k}{}^{ov}}{\sigma^2 + j_{k,u}}\right) \quad (20)$$

The power for each subcarrier for overlay spectrum access can be written as

$$p_{u,k}{}^{ov,*} = \left[\frac{1}{\alpha_l\, f(d_{k,l}) + \gamma} - \frac{\sigma^2 + j_{k,u}}{|\,h_{u,k}^{SS}|^2}\right]^+ \quad (21)$$

B. Power and subcarrier allocation in USAM

The power for the kth subcarrier with underlay spectrum access $p_{u,k}{}^{un}$ will be obtained by solving the optimization problem.

$$\max_{p_{u,k}{}^{un}} C^{un} = \sum_{u=1}^{K} \sum_{k\in\Omega_u{}^{un}} \rho_{u,k}\, log_2\left(1 + \frac{\left|h_{u,k}^{SS}\right|^2 p_{u,k}{}^{un}}{\sigma^2 + j_{k,u}}\right) \quad (22)$$

The power for each subcarrier for underlay spectrum access can be written as

$$p_{u,k}{}^{un,*} = \left[\frac{1}{\alpha_l\, f(d_{k,l}) + \gamma} - \frac{\sigma^2 + j_{k,u}}{|\,h_{u,k}^{SS}|^2}\right]^+$$

6. NUMERICAL RESULTS

In the numerical results which is presented here we assume that there are 4 number of CR users that is K=4, N=8 overlay subcarriers and L=8 underlay subcarriers. The value of Ts and Δf is assigned to 4µs and 0.3125 MHz. The channel fading gain between the CR transmitter and the uth CR receiver in the kth subcarrier is assumed to be Rayleigh distributed having the mean of -52.39 dB. The channel fading amplitude gain between the CR transmitter and the lth PU receiver h_l^{SP} ,l=1,2,….8 is assumed to be Rayleigh distributed with the mean values of -44.02,-46.03,-49.01,-44.02,-46.03,- 49.01,-44.02 and -46.03 dB having the corresponding path loss of -87,-91.01,-96.99,-96.99,-87,-91.01,-96.99,-87,-91.01 dB.

For the particular value of interference threshold I th = 500 × σ^2 W for all values of l we have plotted the total achievable transmission rate of the CR users versus the total power budget (Figure-2) for the proposed optimal and suboptimal subcarrier and power allocation for the JOUSAM, OSAM and USAM. In this the achievable transmission rate with the optimal and suboptimal schemes for the JOUSAM will be greater than that of OSAM and USAM.

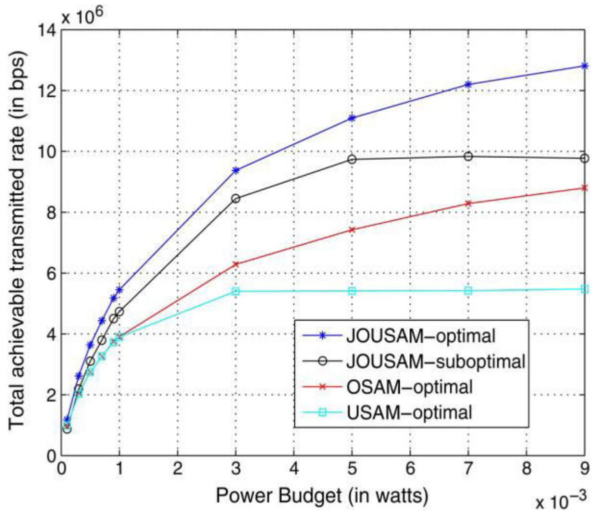

Figure-2. Total achievable transmission rate versus total power budget for various schemes.

In Figure-3 we have plotted the total transmission power for the different schemes under consideration. From this figure it is noted that the amount of power that can be transmitted for the given interference constraints with the OSAM will be equal to the optimal subcarrier and power allocation scheme for the JOUSAM. The reason is some of the underlay subcarriers may have relatively better channel quality between the CR transmitter and the CR users while these subcarriers may overlap with the PU receivers that experience poor channel equality from the CR transmitter. In this case the CR system will potentially use those subcarriers to achieve higher transmission capacity for given interference thresholds.

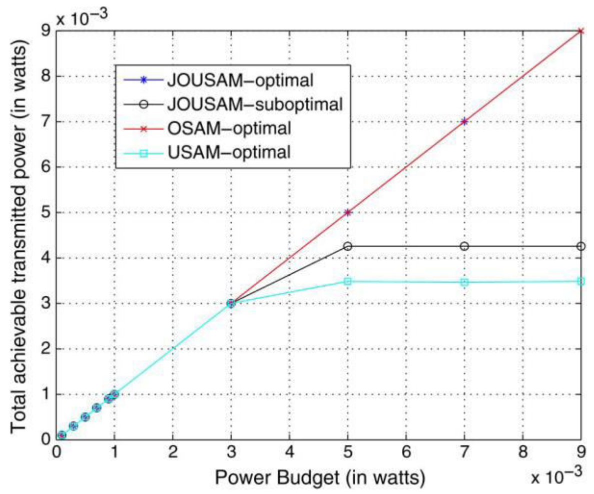

Figure-3. Total achievable transmission power versus total power budget for various schemes.

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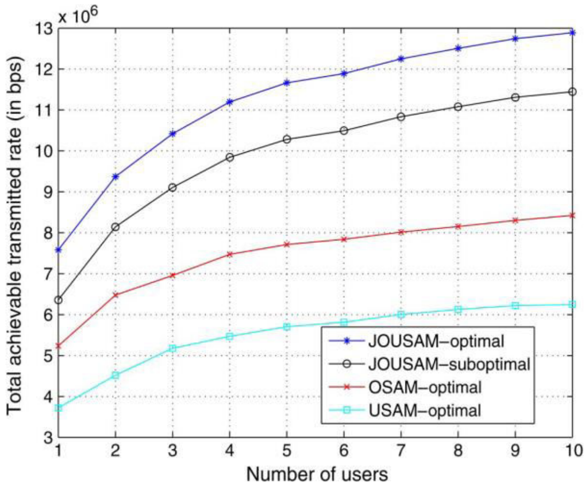

Figure-4. Total achievable transmission rate versus number of CR users for various schemes.

In Figure-4 the number of CR users versus achievable transmission rate of CR users is plotted. It is observed that the transmission rate that is obtained by various schemes will increase as the number of CR users in the system increases.

7. FAIRNESS AMONG COGNITIVE RADIO USERS

The proposed optimal and suboptimal algorithms for JOUSAM will allocate a given subcarrier to the CR users which have the highest channel quality in the particular subcarrier. This will significantly improve the overall transmission rate of the CR system and will degrade the performance in terms of individual CR user data rate. To achieve a certain level of fairness among the CR users a ratio among the transmission data rate of CR users is maintained. It is given as

$R1 : R2 : \ldots Rk = \beta 1 : \beta 2 : \ldots : \beta k$ ....

Where Ru is the transmission rate achieved by the uth user and βu is the positive constant. By imposing this fairness constraint the optimization cannot be solved optimally until decoupling the subcarrier allocation and power allocation. Basically it will become a NP-hard problem. So we propose a low complexity suboptimal subcarrier power allocation algorithm which will achieve a desired ratio among the transmission rates of the CR users.

A. Subcarrier allocation with Fairness Constraint

For the subcarrier allocation, we assume the power will be equally allocated among the subcarriers and the subcarriers are allocated to the CR users while the ratios among the transmission rates of CR...... users are satisfied. For our convenience we define variable $S_{u,k} \triangleq \frac{|h_{u,k}^{SS}|^2}{\sigma^2 + j_k}$ to be the set of subcarriers which is assigned to the user u. The proposed algorithm can be written as follows.

Initialization

-set R u,k = 0, $A = \{1,2, \ldots, Z\}$, and Ω_u fair = φ for u = 1, 2, . . . , K.

For $u = 1$ to K

– find k to satisfy $S_{u,k} \geq S_{u,j}$ for all $j \in A$

– assign $\Omega_u^{fair} = \Omega_u^{fair}\ U\{k\}$and $A = A - \{k\}$, and Update Ru,

While $A \neq \varphi$

- find u to satisfy $\sum_{k=1}^{Z} \frac{R_{u,k}}{\beta_u} \leq \sum_{k=1}^{Z} \frac{R_{i,k}}{\beta_i}\ \forall\ i, 1 \leq$ i K;

- for u found in previous step, find k to satisfy

$S_{u,k} \geq S_{u,j}$ for all $j \in A$;

- for u and k found in previous steps, assign $\Omega_u^{fair} = \Omega_u^{fair}\ U\{k\}$ and A=A- {k} and update R u,k

After allocating subcarriers according to the algorithm mentioned power is allocated using optimal power allocation algorithm.

B. Numerical results with a fairness constraint

In Figure-5, we have compared the maximum transmission rate achieved by the optimal subcarrier and power allocation scheme with that of the subcarrier allocation scheme having a fairness constraint. In this we have assumed that there are two CR users in the system having a mean channel fading amplitude gain of -47.91 dB for the CR user 2 and -52.39 dB for the CR user 1.In this the values if β1 and β2 is assumed to be equal to 1. From the Figure-5 we can it is observed that the total transmission rate of the optimal scheme will be higher than the schemes that guarantees the fairness. However it will try to achieve an equal transmission rate for both of the users. It is seen from the figure that the transmission rate of user 1 is much higher when the subcarrier is allocated with a fairness constraint when compared with that of the optimal scheme.

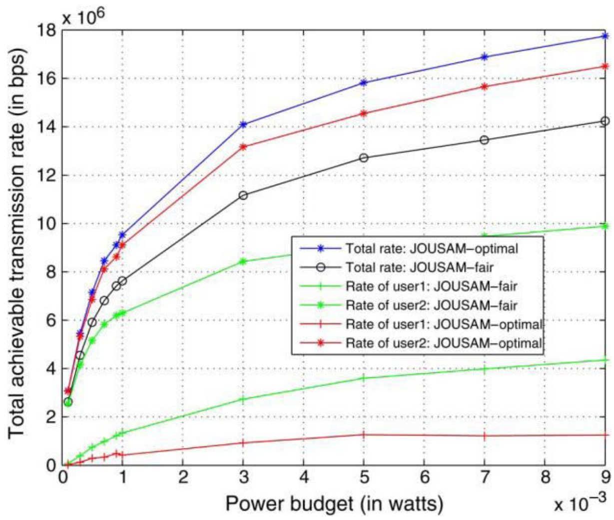

Figure-5. Total achievable transmission rate versus total power budget for optimal and fairness scheme.

CONCLUSIONS

In this paper, for a OFDMA based CR system that uses a JOUSAM, we have developed an optimal subcarrier and power allocation algorithm. In this the total transmission rate for CR users for a particular transmission power budget is maximized while keeping the interference that is introduced to the PU receivers below particular value with certain probability. We also propose a suboptimal scheme as the complexity of optimal scheme is high. The numerical results that are showed have a significant gain in the total transmission rate that can be achieved over either USAM or OSAM. This can lead to the unfairness among the CR users in terms of sharing the total transmission rate. So we finally propose a method of suboptimal subcarrier allocation scheme which will guarantee a certain level of fairness among the CR users at the expense of certain amount of transmission rate. But in this paper we have not considered any channel sensing errors. In future the channel sensing errors can be done as its extension work.

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