QoS-Based Spectrum Access Control in MIMO Cognitive Radio Networks

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Abstract. Cognitive radio (CR) is a promising technique to solve the conflict between the scarcity and underutilization of spectrum. Underlay spectrum sharing is one of the most attractive schemes to increase the sum rate of cognitive users (CUs) as well as reduce the interference at primary users (PUs). However, the adoption of an empirical value as interference constraint may result in outage of PUs or degrade the performance of CUs. By introducing interference variables and calculating interference constraints according to the quality of service (QoS) of PUs with different transmission requirements in every slot, a QoS-based spectrum access control (QSAC) scheme for multi-input multi-output (MIMO) cognitive radio networks is proposed. Besides, CUs with larger signal-to-interference-ratio (SIR) are selected and block diagonalization (BD) is applied to enhance the sum rate of CR system. Performance analysis and simulation results show that, compared with previous methods, the QSAC scheme leads to improved performance of both achievable sum rate of CUs and outage probability of PUs with the same order of complexity, and the gain of achievable sum rate of CUs is about 33% when the total power of CR system is 100w.

Keywords: spectrum access control, cognitive radio, interference variable, quality of service.

1 Introduction

In the past decade there has been an explosive growth in spectrum demand due to the deployment of a wide variety of wireless services. On the other hand, the current utilization efficiency of the licensed radio spectrums could be as low as 15% on average [1]. Cognitive radio (CR), which can solve the conflict between scarcity and underutilization of spectrum [2], is a promising technique for the next generation mobile communication systems [3]. Generalized CR systems [4] have attracted extensive attention for cognitive users (CUs) can coexist with primary users (PUs) in the same band if the interference to PUs is constrained to be below a tolerable limit. Spectrum access control of CUs has become an important part of spectrum sharing strategies in order to exploit multiuser diversity to increase the sum rate of CUs and reduce the interference to PUs.

Access control algorithms of the traditional cellular networks prefer to select users with better channel condition to access [5], which have taken the advantage of multiuser diversity so as to maximize the sum rate of network or satisfy the quality of service (QoS) of users. In order to guarantee the transmission of PUs, interference to PUs has

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been considered in access control method [6], and hybrid priorities of users including the PUs with the highest priority has been established [7, 8]. The PUs' QoS has been taken into account in [7, 8], however, the absence of attention to the interference from primary (PR) system to the CR system degrades the performance of CUs. Considering the interaction between CR and PR systems, Hamdi et al. provided the spectrum access control schemes that chose CUs whose channels are less correlative with all PUs and other selected CUs to access [9–11].

Nevertheless, the varied QoS requirements of PUs, e.g., different QoS requirements between multiple PUs, or time-varying QoS requirements of each PU, leads to different interference tolerance. The adoption of an empirical value as interference constraint [10, 11] may result in outage of PUs in CR networks, where the QoS of PUs should be considered as a prerequisite. Therefore, a spectrum access control scheme based on the QoS of PUs is proposed in this paper. Interference variables are introduced and compared with interference constraint of each PU calculated according to its QoS, and the results control the access of CUs to guarantee the transmissions of PUs. Moreover, CUs with larger signal-to-interference-ratio (SIR) are pre-selected to enhance the sum rate of CUs. By exploiting multiuser diversity of CUs and setting the interference constraints more properly, the QoS-based spectrum access control (QSAC) scheme can provide larger sum rate of CUs as well as satisfy the QoS requirements of PUs. In the QSAC scheme, block diagonalization (BD) [12–15] is adopted to separate selected CUs, based on which, interference variables from CR system to PUs can be calculated. CUs satisfying interference constraints are permitted accessing, and parallel sub-channels are constructed for them by singular value decomposition (SVD). Analysis and simulation results confirm the performance gain of QSAC scheme over all the relevant schemes.

The rest of this paper is organized as follows. Section 2 describes the system model and formulates the problem of spectrum access control in the CR network. Section 3 puts forth the QSAC scheme. The signal-to-noise-ratio (SINR) and complexity performance of the QSAC scheme are evaluated in Section 4, which is followed by the simulation results and discussions in Section 5. Finally, Section 6 concludes the paper.

2 System Model and Problem Formulation

We consider the downlink of a single-cell multiuser system in underlay scenario, including K_p single-antenna PUs and K_c CUs each with N_c antennas. Two base stations are assumed in the cell, one primary base station (PBS) and one cognitive base station (CBS), both equipped with M antennas. The CR network is shown in Fig.1.

Both PR and CR system are assumed to be OFDM systems, so the channels between users and BSs can be considered as quasi-static flat Rayleigh channels [16]. $\mathbf{H}_{c,k}$ and $\mathbf{G}_{c,k}$ are the channel matrices between the kth CU and the CBS and PBS. Meanwhile, $\mathbf{h}_{p,l}$ and $\mathbf{g}_{p,l}$ denote the channel vectors between the lth PU and the CBS and PBS, respectively. Their entries are independent complex Gaussian random variables with mean zero and variance one. The set of active CUs is called $\mathcal{A}$, and $|\mathcal{A}| = N_{ca}$. $\mathbf{x}_k$ and $\mathbf{s}_l$ denote the transmit signals to the kth CU and the lth PU, while $\mathbf{y}_k$ and $\mathbf{r}_l$ denote the receive signals at the kth CU and the lth PU, respectively. The equivalent channel

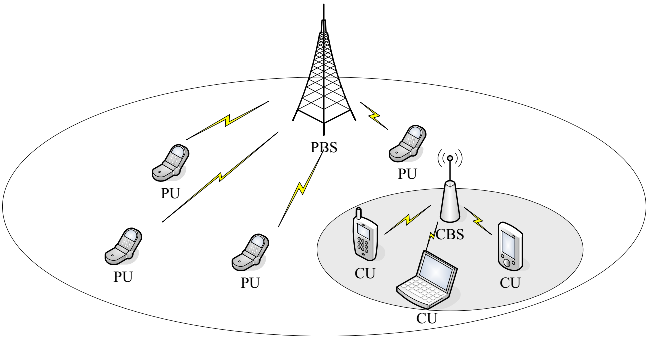

Fig. 1. Cognitive radio network

between PBS and PUs are assumed to be represented as a diagonal matrix Σ since the operations of PR system are beyond the scope of this paper. The equivalent channel gain between PBS and PU$_l$ is σ_l. The signal model is

$$\mathbf{y}_k = \mathbf{H}_{c,k}\mathbf{x}_k + \mathbf{H}_{c,k}\sum_{\substack{i=1\\ i\neq k\\ i\in\mathcal{A}}}^{N_{ca}} \mathbf{x}_i + \mathbf{G}_{c,k}\sum_{l=1}^{N_p} \mathbf{s}_l + \mathbf{z}_k, \tag{1}$$

$$\mathbf{r}_l = \sigma_l \mathbf{s}_l + \mathbf{h}_{p,l}\sum_{\substack{k=1\\ k\in\mathcal{A}}}^{N_{ca}} \mathbf{x}_k + \mathbf{n}_l. \tag{2}$$

$\mathbf{z}_k$ and $\mathbf{n}_l$ are Gaussian noise vectors whose entries are assumed to be independent Gaussian random variables with mean zero and variance σ_0^2. CBS is aware of $\mathbf{h}_p$, $\mathbf{G}_c$, $\mathbf{H}_c$, and Σ as the assumption in [17].

In order to design the constraints satisfying different QoS requirements of multiple PUs and adapting to the time-variance of QoS requirements, we describe the spectrum access control problem as

$$\begin{aligned}
\max_{\mathcal{A},\mathbf{R}_k} C = \max_{\mathcal{A}} \sum_{\substack{k=1\\ k\in\mathcal{A}}}^{N_{ca}} \max_{\mathbf{R}_k} \log_2 \left| \mathbf{I} + \frac{\mathbf{H}_{c,k}\mathbf{R}_k\mathbf{H}_{c,k}^H}{\mathbf{G}_{c,k}\mathbf{S}\mathbf{G}_{c,k}^H + \sigma_0^2\mathbf{I}} \right| \qquad (3)\\
\text{s.t.} \sum_{\substack{k=1\\ k\in\mathcal{A}}}^{N_{ca}} \mathrm{Tr}\left(\mathbf{R}_k\right) \le P\\
\sum_{\substack{k=1\\ k\in\mathcal{A}}}^{N_{ca}} \mathrm{Tr}\left(\mathbf{h}_{p,l}\mathbf{R}_k\mathbf{h}_{p,l}^H\right) \le \delta_l, \qquad l = 1,\ldots,N_p\\
\mathbf{R}_k \succeq 0, \qquad k\in\mathcal{A}, k = 1,\ldots,N_{ca},
\end{aligned}$$

where $\mathbf{R}_k = \mathrm{E}[\mathbf{w}_{c,k}\mathbf{x}_k(\mathbf{w}_{c,k}\mathbf{x}_k)^H]$ is the autocorrelation matrix of precoded $\mathbf{x}_k$, and $\mathbf{w}_{c,k}$ is precoding matrix. $\mathbf{S}$ denotes the autocorrelation matrix of signals from PBS. P and δ_l are total power from CBS and the interference constraint of the lth PR user, respectively. $\mathbf{I}$ denotes the identity matrix. The spectrum access control problem is formulated as the process of finding N_{ca} CUs and designing $\mathbf{R}_k$ properly to maximize the sum rate C under all constraints.

The following notations are used in this paper. We use uppercase boldface letters for matrices and lowercase boldface for vectors. The Euclidean norm of a vector or a matrix is denoted by $\|\cdot\|$. $|\cdot|$, $(\cdot)^T$, $(\cdot)^H$ and $(\cdot)^\dagger$ stand for the determinant, the transpose, the conjugate transpose and the pseudo-inverse, respectively.

3 QoS Based Spectrum Access Control

The receiving SINR is considered as the measurement of QoS [18]. The power of CBS is assumed to be allocated to each antenna equally. As a result, SINR of the lth PU is

$$\mathrm{SINR}_{p,l} = \frac{P_{p,l}\sigma_l^2}{\frac{P}{M}\mathbf{h}_{p,l}\mathbf{w_c}\left(\mathbf{h}_{p,l}\mathbf{w}_c\right)^H + \sigma_0^2}, \tag{4}$$

where $\mathbf{w}_c = \left[\mathbf{w}_{c,1}{}^T \cdots \mathbf{w}_{c,N_{ca}}^T\right]^T$. Based on this observation, the following QoS based spectrum access control scheme is proposed.

First, the constraint δ_l is calculated from $\mathrm{SINR}_{p,l}$ as

$$\delta_l = \frac{P_{p,l}\sigma_l^2}{\mathrm{SINR}_{p,l}} - \sigma_0^2, \tag{5}$$

where $P_{p,l}$ denotes the power from PBS to the lth PU.

Second, $N_{ca} = \left\lfloor \frac{M}{N_c} \right\rfloor$ best CUs are selected satisfying $k = \arg\max_i \frac{\|\mathbf{H}_{c,i}\|}{\|\mathbf{G}_{c,i}\|}$ to exploit multiuser diversity. Then interference between selected CUs is canceled by BD. The complementary channel matrix of the kth CU is

$$\widetilde{\mathbf{H}}_{c,k} = [\mathbf{H}_{c,1}^T\ \mathbf{H}_{c,2}^T\ \cdots\ \mathbf{H}_{c,k-1}^T\ \mathbf{H}_{c,k+1}^T \cdots\ \mathbf{H}_{c,N_{ca}}^T], \tag{6}$$

and the singular value decomposition (SVD) of $\widetilde{\mathbf{H}}_{c,k}$ is

$$\widetilde{\mathbf{H}}_{c,k} = \widetilde{\mathbf{u}}_{c,k}\widetilde{\mathbf{s}}_{c,k}(\widetilde{\mathbf{v}}_{c,k}\ \widetilde{\mathbf{r}}_{c,k})^H, \tag{7}$$

where $\widetilde{\mathbf{r}}_{c,k}$ is composed by the columns of right singular vectors corresponding to the zero singular value. Precode $\mathbf{x}_k$ with $\widetilde{\mathbf{r}}_{c,k}$, i.e. project $\mathbf{x}_k$ onto the null-space of other CUs. This operation is repeated on each selected CU, and the interference between them is avoided. The equivalent channel matrices are

$$\hat{\mathbf{H}}_{c,k} = \mathbf{H}_{c,k}\widetilde{\mathbf{r}}_{c,k}. \tag{8}$$

After that, check whether each constraint is satisfied. The interference variables are described as

$$vio_l = \frac{P}{M}\mathbf{h}_{p,l}\widetilde{\mathbf{r}}_c\left(\mathbf{h}_{p,l}\widetilde{\mathbf{r}}_c\right)^H, \tag{9}$$

where

$$\widetilde{\mathbf{r}}_c = \left[\widetilde{\mathbf{r}}_{c,1}\ \widetilde{\mathbf{r}}_{c,2}\ \cdots\ \widetilde{\mathbf{r}}_{c,N_{ca}}\right]. \tag{10}$$

Then go to Step 3 unless $vio_l \leq \delta_l,\quad l = 1, 2, \cdots N_p$, are all satisfied.

Third, harmful pre-selected CUs are removed. Compute the interference to each PU, and remove the most seriously interfering CU. Then go back to Step 2. If we cannot find N_{ca} CUs satisfying $vio_l \leq \delta_l$, reduce N_{ca} to $N_{ca} - 1$.

Fourth, to separate sub-channels, SVD for each accessing CU is carried out, such as

$$\hat{\mathbf{H}}_{c,k} = \hat{\mathbf{u}}_{c,k}\hat{\mathbf{s}}_{c,k}\hat{\mathbf{v}}_{c,k}^H. \tag{11}$$

Precode $\mathbf{x}_k$ at the transmitter side with $\hat{\mathbf{v}}_{c,k}$, and shape it at the receiver side with $\hat{\mathbf{u}}_{c,k}^H$, so the final equivalent channel matrices can be denoted by diagonal matrices as $\mathbf{H}_{c,k}^f = \hat{\mathbf{s}}_{c,k}$. The desired precoding matrices are $\mathbf{w}_{c,k} = \tilde{\mathbf{r}}_{c,k}\hat{\mathbf{v}}_{c,k}$ and $\mathbf{w}_c = \left[\mathbf{w}_{c,1}^T\ \mathbf{w}_{c,2}^T\ \cdots\ \mathbf{w}_{c,N_{ca}}^T\right]^T$.

Algorithm 1. Procedure of QoS Based Spectrum Access Control

1.Calculate interference constraints according to PUs' QoS;
2.Select N_{ca} CUs and check whether the interference variables satisfy the interference constraints;
3.Remove harmful pre-selected CUs and go back to Step 2;
4.Construct parallel sub-channels for accessing CUs.

4 Performance Analysis

4.1 SINR Analysis

The QSAC method is compared with opportunistic spectrum sharing (OSS) method [11]. When our method is adopted, the SINR on the ith sub-channel of the kth accessing CU is

$$\mathrm{SINR}_{c,i,k}^Q = \frac{P_{c,i,k}\hat{\mathbf{s}}_{c,i,k}^2}{\sum_{l=1}^{N_p} P_{p,l}\left\|\hat{\mathbf{u}}_{c,k}^H\mathbf{G}_{c,k}\right\|^2 + \sigma_0^2}, \tag{12}$$

where $P_{c,i,k}$ denotes the power on the ith sub-channel of the kth accessing CU. The SINR of the lth PU is

$$\mathrm{SINR}_{p,l}^Q = \frac{P_{p,l}\sigma_l^2}{\sum_{\substack{k=1\\k\in\mathcal{A}}}^{N_{ca}}\sum_{i=1}^{N_c} P_{c,i,k}\left\|\mathbf{h}_{p,l}\widetilde{\mathbf{r}}_{c,k}\hat{\mathbf{v}}_{c,k}\right\|_{i,i}^2 + \sigma_0^2}, \tag{13}$$

where $\|\mathbf{A}\|_{i,i}^2$ is the square of the ith diagonal element in matrix $\mathbf{A}$. Compared with the OSS method in [11], we can get

$$\frac{\mathrm{SINR}_{c,i,k}^{Q}}{\mathrm{SINR}_{c,i,k}^{O}}=\frac{P_{c,i,k}\hat{\mathbf{s}}_{c,i,k}^{2}\left(\sum_{l=1}^{N_p}\left\|\mathbf{G}_{c,k}\right\|^{2}P_{p,l}+\sigma_0^2\right)}{\left(\sum_{l=1}^{N_p}\left\|\hat{\mathbf{u}}_{c,k}^{H}\mathbf{G}_{c,k}\right\|^{2}P_{p,l}+\sigma_0^2\right)\left(\left\|\mathbf{H}_S\mathbf{H}_S^{\dagger}\right\|_{n,n}^{2}P_{c,i,k}\right)},\tag{14}$$

$$\frac{\mathrm{SINR}_{p,l}^{Q}}{\mathrm{SINR}_{p,l}^{O}}=\frac{P_{p,l}\sigma_l^2\left(\sum_{\substack{k=1\\k\in\mathcal{A}}}^{N_{ca}}\sum_{i=1}^{N_c}P_{c,i,k}\left\|\mathbf{h}_{p,i+(k-1)N_c}\right\|^{2}+\sigma_0^2\right)}{\left(\sum_{\substack{k=1\\k\in\mathcal{A}}}^{N_{ca}}\sum_{i=1}^{N_c}P_{c,i,k}\left\|\mathbf{h}_{p,l}\widetilde{\mathbf{r}}_{c,k}\hat{\mathbf{v}}_{c,k}\right\|_{i,i}^{2}+\sigma_0^2\right)P_{p,l}\sigma_l^2},\tag{15}$$

where $\mathrm{SINR}_{c,i,k}^{o}$ and $\mathrm{SINR}_{p,l}^{o}$ denotes the SINR on the ith sub-channel of the kth CU and the lth PU when OSS method [11] is adopted, and $n = i + (k-1)N_c$.

Due to the elements of matrices are random variables, we compare the expectation of SINRs. Since $\sum_{i=1}^{N_c}\left|\hat{\mathbf{s}}_{c,i,k}\right|^2 = \left\|\hat{\mathbf{H}}_{c,k}\right\|^2 = N_c^2 = 4$, $E\left(\left|\hat{\mathbf{s}}_{c,i,k}\right|^2\right) = N_c^2/N_c = N_c = 2$, so

$$\frac{E\left(\mathrm{SINR}_{c,i,k}^{Q}\right)}{E\left(\mathrm{SINR}_{c,i,k}^{O}\right)}=E\left(\hat{\mathbf{s}}_{c,i,k}^{2}\right)>1.\tag{16}$$

Because $\widetilde{\mathbf{r}}_{c,k}$ is a part of a unitary matrix, the multiplication of $\mathbf{h}_{p,l}$ and $\widetilde{\mathbf{r}}_{c,k}$is equivalent to projecting $\mathbf{h}_{p,l}$ onto a subspace of $\mathbb{C}^M$, $\left\|\mathbf{h}_{p,l}\widetilde{\mathbf{r}}_{c,k}\right\| < \left\|\mathbf{h}_{p,l}\right\|$.

$$\frac{E\left(\mathrm{SINR}_{p,l}^{Q}\right)}{E\left(\mathrm{SINR}_{p,l}^{O}\right)}=\frac{E\left(\sum_{\substack{k=1\\k\in\mathcal{A}}}^{N_{ca}}\left\|\mathbf{h}_{p,l}\right\|^{2}+\sigma_0^2\right)}{E\left(\sum_{\substack{k=1\\k\in\mathcal{A}}}^{N_{ca}}\left\|\mathbf{h}_{p,l}\widetilde{\mathbf{r}}_{c,k}\right\|^{2}+\sigma_0^2\right)}>1.\tag{17}$$

So QSAC scheme has better performance than OSS method [11] in both PR and CR system.

4.2 Complexity Analysis

Here the complexity in terms of the time for a multiplication or an addition is analyzed. The time for calculating δ_l is $3N_p = 3M$, and for computing F-norm of CUs is $(2MN_c - 1)K_c$. Putting these norms in descend order costs K_c^2 times of a multiplication. In the selection step, we consider the worst case, i.e. there is no CU can access. The time includes two parts, called searching null-space and calculating interference variables, which is $\sum_{N_{ca}=1}^{M/N_c}(K_c - N_{ca} - 1)\left[N_c(N_{ca}-1)M^2N_{ca} + MN_cN_{ca}\right]$ in all. It takes $MN_p/N_c = M^2/N_c$ times for comparing interference variables with constraints, and $N_{ca}N_c^3$ times for acquiring parallel sub-channels. For $K_c \gg M$, $K_c \gg N_{ca}$, $K_c \gg N_p$, $K_c \gg N_c$, the complexity of QSAC method is $\mathrm{O}\left(K_c^2\right)$.

Table 1. The complexity of two methods

	Calculate δ_l	Select CUs	Compare	Separate
QSAC	$\mathrm{O}(M)$	$\mathrm{O}\left({K_c}^2\right)$	$\mathrm{O}\left(M^2/N_c\right)$	$\mathrm{O}\left(N_{ca}{N_c}^3\right)$
OSS [11]	-	$\mathrm{O}\left({K_c}^2\right)$	-	$\mathrm{O}\left(N_{ca}{N_c}^3\right)$

Table 2. The feedback quantity of three methods

	QSAC	OSS [11]	AUS [10]
$\mathbf{H}_c$, $N_c \times M$	K_c	K_c	K_c
$\mathbf{G}_c$, $N_c \times M$	K_c	-	-
$\mathbf{h}_p$, $1 \times M$	N_p	N_p	N_p
G_p, $M \times 1$	1	-	-
Over All (in bits)	$4N_cMK_c + 2M(N_p + 1)$	$2N_cMK_c + 2N_pM$	$2N_cMK_c + 2N_pM$

OSS method has the complexity of $B_{\max} = MN_cK_c + K_c^2 + \xi\left(\sum_{i=1}^{J} |S\ (i)| + K_c\right)$ [11]. Because of the same relationship between M, N_{ca}, N_p, N_c and K_c, the complexity is $\mathrm{O}\left(K_c^2\right)$. From Table 1 and the analysis above, we conclude that the QSAC method is in the same order of complexity with the OSS method [11].

4.3 Acquirement of Channel State Information (CSI) and Feedback Quantity Analysis

In academic research, perfect CSI is always assumed [4, 6, 7, 9–11, 15, 17]. Here we discuss the details. The channel matrices from PBS and CBS to CUs can be obtained by the feedback from CUs. On the other hand, the CBS can get the channel matrices form PBS and CBS to PUs through the feedback from PUs [17, 19]. In practice, for a fading environment, there are cases where it is difficult for the CBS to perfectly estimate instantaneous channels. In such cases, the results obtained in this paper provide capacity upper-bounds for the secondary transmission in a CR network [20]. Moreover, we give the quantity of feedback in Table 2.

From Table 2, we can note that the feedback quantity of the QSAC method is comparable to the other methods and acceptable.

5 Simulation Results and Discussions

A cellular system including a PBS and a CBS each equipped with 8 antennas, as well as 8 single-antenna PUs and 50 CUs each with 2 antennas is considered in this paper. The elements of channel matrices are independent complex Gaussian random variables with mean zero and variance one [10,11]. The energy of noise is $\sigma_0^2 = 1$. For fair comparison, we set the near-orthogonal factors δ_p and δ_c to be 0.8 and 0.4, respectively, the same as in [11]. The QoS of the lth PU is assumed to be SINR = $l/4$, which is comparable with the QoS of 3G.

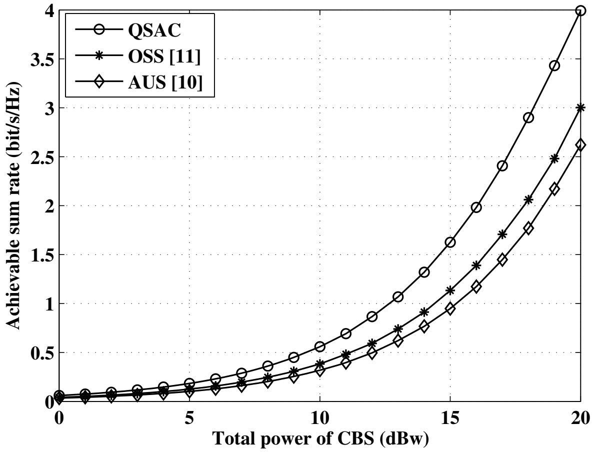

Fig. 2. Achievable rate of CR system

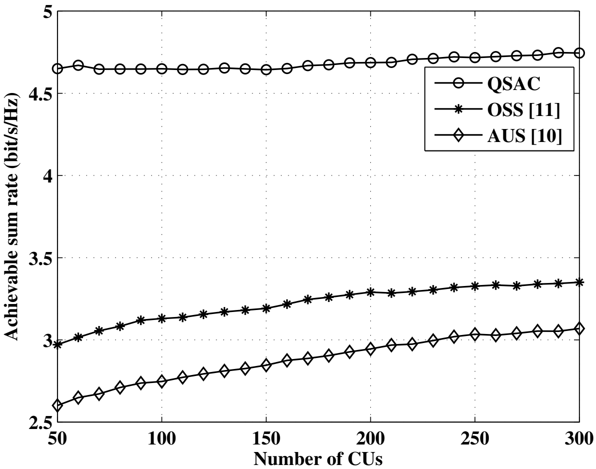

Fig. 3. Achievable rate of CR system with different K_c

The achievable sum rate of CR system in Fig.2 shows that the QSAC method provides the largest achievable sum rate of CUs because of the consideration of interference from PBS to CUs and the adoption of BD. In stead of choosing the CUs with larger channel gain [10, 11], we select CUs with larger SIR to exploit multiuser diversity more effectively. Moreover, the adoption of BD brings more spatial freedom of degrees than zero-forcing [10, 11], so as to enhance the performance of CR system. Since interference variables are introduced and compared with interference constraint of each PU calculated according to its QoS, the spectrum band is exploited more efficiently than the other two methods. The achievable rate of CR system with different

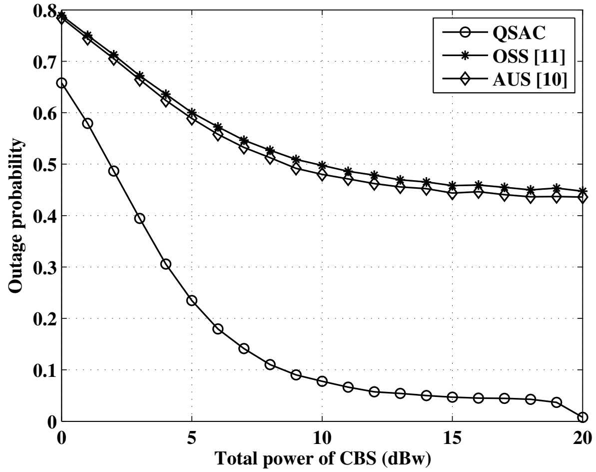

Fig. 4. Outage probability of PUs

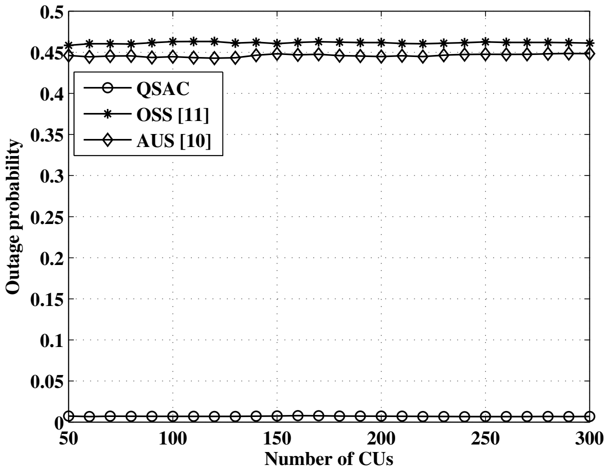

Fig. 5. Outage probability of PUs with different K_c

numbers of CUs is shown in Fig.3. In the simulation, we constrain both the total transmit power of PBS and CBS to be 40w. As shown in the figure, our method can achieve larger sum rate than the other methods by selecting CUs with larger SIRs to access and adopting BD.

Fig.4 and Fig.5 show the outage probability of PUs. The QSAC method calculates interference constraints for PUs according to their QoS. Compared with methods setting interference constraint as an empirical value, our method can alleviate the harm to PUs, and get less outage probability. From the outage probability of PUs with different K_c, it is evident that the increase of K_c cannot reduce the outage probability of PUs without changing the value of δ_l, δ_p and δ_c. Meanwhile, the figures show that calculating the interference constraints more properly, as adopted in our method, is an effective way to guarantee PUs' QoS.

To sum up, the combination of selected CUs in the QSAC method is a better trade-off between maximizing the sum rate of CR system and meeting the interference constraints of PUs than that of other methods. Firstly, we guarantee the transmission of PUs by properly setting the interference constraints. Secondly, the performance of CR system is also improved by permitting CUs with larger SIRs to access and adopting BD. So we obtain better performance than the other two schemes.

6 Conclusions

In this paper, the spectrum access control based on QoS of PUs in MIMO CR networks has been investigated. The concept of interference variable is introduced, based on which, an interference constrained spectrum access control method is developed for MIMO CR networks with heterogeneous QoS requirements of PUs. Through spectrum access control of CUs, the method can exploit diversity from multiuser CR system as well as guarantee the QoS of PUs. Performance analysis and simulation results show that compared with existing methods, our method can increase achievable sum rate of CR system by selecting the CUs with larger SIRs to access and adopting BD, as well as reduce outage probability of PUs by calculating interference constraint for each PU according to its QoS.

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