The Research of Beam Forming Algorithms In Cognitive Radio Systems

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Abstract. In view of the problem of CO frequency interference in the heterogeneous networks of cognitive radio, this paper presents a method of CO processing by macro cellular and micro cellular cells. A beam forming algorithm for maximizing the network of the user is presented, which is based on the orthogonality of multiple antennas and different geographical locations. The simulation results show that the proposed algorithm can effectively improve the transmission speed between the sub users, so as to improve the utilization of frequency.

Introduction

Cognitive radio technology can effectively use the frequency resources, improve the spectrum utilization, so it becomes the key technology of the next generation mobile communication. In the cognitive radio network, the secondary user can transmit the information through the main user's frequency band, so long as the user's communication can't interfere with the main user's communication. multi-antenna technology can be effective use of space resources. Therefore, multi-antenna technology into in cognitive radio networks, secondary users and primary user using different spatial resources to improve the throughput of cognitive radio. However, in the next generation mobile communication networks, heterogeneous networks will be widely deployed in the cellular network. In the micro - cellular, the micro - base station transmit the signal with the smaller power, so that the orthogonality of the geographical space can be utilized effectively.

The multi-antenna cognitive radio network has been widely studied in signal processing. The use of MMSE method in beam forming, ensure the main user communication interference does not exceed the fixed threshold conditions [1], Improve the reliability of sub user transmission, A user selection algorithm for maximizing the capacity of the secondary user system is presented[2], Effectively reducing the complexity of the user algorithm. In the multi-antenna heterogeneous networks, many researches on the multi-point and multi-point processing methods based on heterogeneous networks have already obtained some conclusions. A beam forming algorithm based on energy efficiency is proposed[3]. Considering the transmission delay factor between macro cellular base station and micro cellular base station, the capacity performance of the delay factor is analyzed[4].

In the previous literature studies, the combined approach of heterogeneous networks is considered in the context of cognitive environment. Based on this, a beam forming algorithm for cognitive heterogeneous networks is proposed[5]. The power does not exceed the threshold of interference to primary users under the condition, the maximum transmission rate of heterogeneous user network times.

System Model

Consider sub user heterogeneous network, There are K macro cellular base stations and multiple micro cellular base stations to use the same frequency, while the main user network also share the same frequency[6]. As shown in Figure 1, we only consider a master user base station and a master user[7]. In the secondary user system, It is assumed that there are T micro cell in each macro cell, Assuming that each of the micro cell users are configured single antenna, The macro cellular
\[ k = (1, 2, 3, \cdots, K) \quad U_k = \{1, 2, \cdots, N_i\}, \] Which \( N_i \) represents the \( K \) cellular user, And in the \( K \) cellular, the \( M \) micro cellular network users can be expressed as users \( (k, m) \).

Suppose that the base station of the macro cellular cell \( K \) is configured for transmit antennas, The received signal can be expressed as

\[
y_{k,m} = \sum_{j=1}^{K} \sum_{n=1}^{N_i} h_{j,k,m}^{H} w_{j,n} x_{j,n} + h_{k,k,m}^{H} w_{k,m} x_{k,m} + n_{k,m}
\]

For the main user interference channel, That is, the channel of the \( K \) macro cellular base station to the main user is, The interference of the main user is

\[
I = \sum_{k=1}^{K} \left\| g_k w_k x_k \right\|^2
\]

Which \( h_{j,k,m} \in \mathbb{C}^{M_j \times 1} \) is representative of the macro cellular base station \( J \) to the user \( (k, m) \) fading channel matrix[8], Including shadowing fading and path loss. \( w_{k,m} \in \mathbb{C}^{M_j \times 1} \) Represents the beam forming vector of the user \( (k, m) \), \( x_{k,m} \) is a signal for a \( K \) macro cellular base station to send to a user \( (k, m) \), \( n_{k,m} \) represents the noise of the user \( (k, m) \).

Figure 1. Sub user heterogeneous network system model.

**Optimization Problem**

In cognitive radio networks, the interference of secondary users to the main user need to control in a certain range, According to this request, in the optimization problem, Must ensure this request. At the same time, under the premise of ensuring the above conditions, always want to maximize the user's transmission rate[9]. According to the practical problem, this paper presents the following optimization functions:

\[
\max \sum_{k=1}^{N_i} \alpha_k R_k
\]
\[
\begin{align*}
\text{st. } & \sum_{m=1}^{N_s} \text{Tr}(w_{k,m}w_{k,m}^H) \leq Ps \\
& \sum_{k=1}^{K} \left\| g_k w_k x_k \right\|^2 < \eta \end{align*}
\]

(4)

The Design of Beam Forming in Macro Cell

According to the Optimization rule of \( 1 < kT \), we can construct the related Lagrange function[10]. The optimization problem can be expressed by the following functions:

\[
L = \sum_{k=1}^{N_t} a_k R_k - \sum_{m=1}^{N_s} \lambda_m \left[ \text{Tr}(w_{k,m}w_{k,m}^H) - Ps \right]
- \sum_{k=1}^{K} \mu_k \left[ \sum_{k=1}^{K} \text{Tr}(g_k w_k w_k^H g_k^H) - \eta \right]
\]

(5)

The partial derivatives of the two sides of the formula (5), thus obtained the corresponding variable. According to the derivation, the beam forming matrix of the macro cell can be obtained as follows:

\[
W_{k,m} = (h_{k,k,m}^H h_{k,k,m} + \eta \frac{g_k g_k^H}{h_{k,k,m}^H h_{k,k,m}^H} I)^{-1} \ast h_{k,k,m}^H
\]

(6)

According to the optimization problem of maximizing the capacity, the deformation mode of the beam forming is calculated as MMSE, It also proves the optimization problem of the maximum capacity equivalent to MMSE from another point of view.

Optimization Problem

Experimental Environments

Under simulation environment, Main user base station configuration 8 antennas, Main user configuration 1 antennas, In the heterogeneous network of sub users, Macro cellular base station considered 3 antennas, Micro cellular base station considered 6 antennas. Assuming the main and the secondary user system uses the largest LTE-A aggregate bandwidth, That is 20MHZ; The signal power transmitted by the sub-user base station is assumed 46dBm. The signal power transmitted by the micro cellular base station is 30 dB/m, The signal power transmitted by the main user base station is 46dBm. Assuming that the number of the transmitted antennas of the macro cellular and the micro cellular are 8 and 4 respectively[11]. The coverage of the macro cellular is 250m, but the coverage of the micro cellular is 50m, also the macro cellular distance from the main user is 180m, The average distance of the micro cellular distance is 45m, Assume that the secondary user power threshold of interference to primary users is 25 dB/m.

Experimental Results

According to the experimental environment of A, the experimental simulation of the algorithm is carried out. From Figure 2 you can see, The sub user transmission rate of the proposed algorithm increases with the SNR of the transmitted signal[12]. We can see, the same as ZF algorithm and CBF
based algorithm, The proposed beam forming algorithm has advantages over the whole process. Special relative to ZF algorithm, In the low SNR region, The advantages are more obvious.

As shown in Figure 3, The outage probability for 3 programs, The outage probability of the proposed programs is under the entire SNR[13], They were higher than the other two programs, And the proposed program limits the interference of secondary users to the main users. In the case of interference is not greater than 25dBm. The stability of the proposed algorithm is presented.

**Conclusion**

In this paper, the design of beam forming algorithm for the scenario of heterogeneous networks is considered for the first time. The transmission rate of the maximum sub user heterogeneous network is adopted. At the same time, the interference power of the main user is not exceeded. Simulation results show that. The proposed algorithm has the advantages not only in the protection of the main users, but also in the performance of the user system.
References


