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Multiple Antenna Non-ideal Channel Information Interference Alignment Method in Cognitive Radio Network

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Abstract

Interference alignment scheme, because of non ideal channel, can cause interference to primary user increases, it is worse at the same time the user's transmission rate, aiming at this problem, this paper studies the multiple antenna system is a kind of cognitive radio interference can achieve full multiplexing gain alignment method, analyses the interference alignment method under the condition of imperfect channel state information of the optimal transmission problem, and according to this problem, put forward the iteration method of interference alignment schemes, the simulation results show that this method is compared with the previous beam forming algorithm, and can obtain more transmission rate, improve the capacity of the time the user's system.

Keywords: *Multiple antenna cognitive radio Interference Alignment imperfect channel state information*

1. Introduction

At present, most of the radio spectrum has been licensed to a variety of commercial and military wireless communication system [3], which severely restricted the new radio system developed and put into use. At the same time, a large number of authorized radio spectrum in different times or areas are often idle, result in authorized spectrum utilization rate is low. According to the Federal Communications Commission (FCC, Federal Communications, appointed the investigation, the radio spectrum utilization rate is usually only between 15% and 85%. Shortage of spectrum resources and low utilization rate of increasing contradiction between, and has given rise to cognitive radio, the basic idea is to allow unauthorized users to use authorized radio spectrum, in order to make full use of the existing radio resources, maximize the utilization rate of radio spectrum resources. Cognitive radio is a kind of can interact and external operating environment, and to adjust their radio transmitter parameters. Cognitive Radio is regarded as a kind of implement the Next Generation wireless Networks (NGN, Next Generation Networks), the key technology, it can makes the Heterogeneous Radio System (HRS, Heterogeneous Radio System) in the form of opportunity Shared valuable Radio spectrum resources.

Interference alignment is raised, triggered widespread interest and research scholars try to align interference is applied to a variety of scenarios. Initial research is carried out based on the ideal assumptions, such as system there are an infinite number of subcarrier or antenna number is available, and the algorithm complexity and costs are actually design factors to consider. The basic principle of interference alignment: the transmission of precoding vector by the transmitter structure, disturbance signal received by the receiver should be aligned to less space, thus each to the receiver has more dimensions to the desired signal transmission. Interference alignment methods can be divided into two categories: 1) the signal interference alignment space; 2) signal scale interference alignment. Alignment can

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make use of multi-carrier signal space interference or multiple antenna is composed of multi-dimensional to construct algorithm, this method obtained the extensive research, this is because the algorithm design based on signal space is easy to implement in the actual system. After signal scale interference alignment is to channel gain quantitative form multi-dimensional space algorithm design. Due to time-varying characteristics of wireless channel, to accurately track channel changes to the system requirements is very high, at the same time, the estimation accuracy of channel gain of the system is also impossible to unlimited increase, which is difficult to achieve and poor feasibility.

There are two types of access to information in the cognitive radio. Is a kind of overlay, time users and users cannot be Shared spectrum, time users using main frequency spectrum hole to communicate. Is another kind of underlay, time users can share spectrum and the main users, but try to reduce the disturbance to the primary user, this way of access to the main use of spread spectrum technology. In this paper, by way of interference alignment technology based on the underlay. At present, the study of cognitive radio are mainly concentrated in the following three aspects: first, the spectrum detection technology. Cognitive radio for cognitive equipment can real-time monitoring on the surrounding of spectrum, find spectrum hole. Time, on the other hand, users in the process of communication, cannot produce harmful interference to primary users, users can quickly detect this requires time to the main user when to appear, so as to timely bandwidth let out to the main users, which does not affect the main user communication. Second, the dynamic spectrum allocation technology. Now for spectrum allocation mainly adopts the method of spectrum pool, its basic idea is will be assigned to different users spectrum spectrum is merged into a public pool, the spectrum can be discrete, the whole spectrum pool and can be divided into several sub channel, user can use the idle channel for communication. Dynamic spectrum allocation need to solve the problem of the main user and the user channel access, both to allow user to make full use of the available spectrum, and to ensure that does not affect the main users of communication, at present there are two main methods: one way is as long as there is idle channel spectrum pool, it does not interrupt the user's communication, and let the user use idle channel for communication; Another method does not consider the user's communication, as long as the users need to recycle communication channel, and channel or interrupt time users need to switch to the other free communication. Third, the anti-jamming technology. User use authorized spectrum for communication, must make the pledge that we shall not have primary user interference. In cognitive radio, the anti-interference techniques mainly include interference estimation and power control. Cognitive radio interference alignment is a new research direction which emerged in recent years. Literature [2] the earliest interference alignment technology are introduced in the application of cognitive radio system, the author studies the MIMO channel interference under only one primary user, a user's cognitive radio system. For the main users, using the method of water injection allocation power for maximum transmission rate, because of the limitation of sending power some power on does not allocate sub-channels, which means that there is no signal on the corresponding spatial dimension. Therefore, for the user, as long as the design proper precoding matrix, make the user of the interference to primary users in the main users of unused space dimensions, realize the interference alignment, which does not affect the main user communication, user can use the same frequency band to transmit data. In addition, the author also designs the user post-processing matrix, the independent user interference by bleaching. For user power allocation scheme, the authors adopted an average distribution method and water flooding. In this paper, the main users need to know their own CSI, users should know all users of CSI. The author also assumes that all of the sending end with the same number of antennas, all of the receiver also has the same number of antenna. In addition, the sender to the user, the receiver must also give priority to the user's channel matrix reversible (or with Moore - Penrose inverse), namely full rank. This paper USES the interference alignment technology, to maximize the weighted total transmission rate, the user system is more village scene, and the main user USES a point-to-point communication mode. The weighted total transmission rate maximization problem is a convex optimization problem, this paper adopts polynomial decomposition will be non convex optimization problem into a convex optimization problem, and closed form solution is obtained.

2. System Model

Assuming that exist in the cognitive wireless network K second user and a primary user, the system block diagram is shown in figure 1. Each second user base station configuration N_k transmitting antenna, suppose that some return network control signal through the cable connection on the base station side of the user. To simple derivation, primary user and user receiver antenna single configuration. So for between the second user base station and the second users communication are disturbance K of multiple input single output channel, with said first time user signal sent by a base station, the signal has a unit variance, such as $E\left\{s_k s_k^*\right\}=1$.

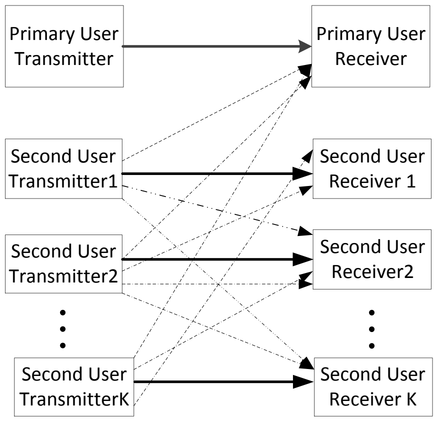

Figure 1. Cognitive Radio Interference Alignment Model

Second user base station k for its hope transmission signal s_k encoding, the beam forming matrix $\mathbf{w}_k$ ($\mathbf{w}_k \in \mathbb{C}^{N_k \times 1}$) after processing $\mathbf{x}_k = \mathbf{w}_k s_k$ (for all k). In the k th second user of the receiver, the received signal can be expressed as

$$y_k = \mathbf{h}_{kk}^H \mathbf{w}_k s_k + \sum_{j=1, j\neq k}^{K} \mathbf{h}_{kj}^H \mathbf{w}_j s_j + n_k \qquad (1)$$

Which $\mathbf{h}_{jj}^H \in \mathbb{C}^{1\times N_k}$ is defined as the vector channel, on behalf of between the second user base station j and second user receiver i channel. n_k is a complex gaussian white noise, the mean is zero, the variance is $\sigma_{n_k}^2$, such as $n_k \sim cN\left(0, \sigma_{n_k}^2\right)$. In cognitive networks, each second user to the primary users of interference power is difficult to estimate. $\sigma_{I_k}^2$ is the primaryuser stations to the second k th user's largest interference, consider the worst case, any interference from the main users to time fixed for $\sigma_{I_k}^2$, the total interference can be expressed as $\sigma_k^2 = \sigma_{n_k}^2 + \sigma_{I_k}^2$. The total weighted rate can be expressed as the time users

$$\sum_{k=1}^{K} u_k \log_2 \left(1 + \frac{\left|\mathbf{h}_{kk}^H \mathbf{w}_k\right|^2}{\sum_{j \neq k} \left|\mathbf{h}_{kj}^H \mathbf{w}_j\right|^2 + \sigma_k^2} \right) \tag{2}$$

Among them u_k was the second user k weighting coefficient, on the other hand, second users to the primary user peak interference power can be defined as $\left|\mathbf{g}_k^H \mathbf{w}_k\right|^2$ users for all the second user k . $\mathbf{g}_k^H \in \mathbb{C}^{1\times N_k}$ is between the k -th second user to the primary users of signal. In order to protect the primary user, it must be controlled within a certain range.

To make $\delta_{i,j} \in \mathbb{C}^{N_k \times 1}$ and $\zeta_k \in \mathbb{C}^{N_k \times 1}$ to channel errors, and related with the channel $\mathbf{h}_{ij}$ and $\mathbf{g}_k$. To channel errors as random variables, the signal model for the world. For its error model can be expressed as

$$\mathbf{h}_{ij} = \hat{\mathbf{h}}_{ij} + \delta_{i,j}, \left\|\delta_{i,j}\right\|_2^2 \leq \xi_{ij} \tag{3}$$

$$\mathbf{g}_k = \hat{\mathbf{g}}_k + \zeta_k, \left\|\zeta_k\right\|_2^2 \leq \phi_k \tag{4}$$

Among them $\hat{\mathbf{h}}_{ij}$ and $\hat{\mathbf{g}}_k$ respectively defined by users and main observation vector matrix, the matrix information in second user base station channel errors $\delta_{i,j}$ and ζ_k in second user base staeion did not know, ξ_{ij} and ϕ_k for error bound, with a channel model can estimate the impact on the communication.

4. Optimization Problems

In this paper, mainly through the design sent to maximize the weighted total transmission rate, beam forming matrix and its limits to meet peak interference, in addition, considering the limited time users to the total transmission power, also need to consider their own power limitation. The optimization problem can be expressed as

$$\begin{aligned} &\max_{\{\mathbf{w}_k\}_{k=1}^K} \sum_{k=1}^{K} u_k \log_2 \left(1 + \frac{\left|\mathbf{h}_{kk}^H \mathbf{w}_k\right|^2}{\sum_{j \neq k} \left|\mathbf{h}_{kj}^H \mathbf{w}_j\right|^2 + \sigma_k^2} \right), \\ &s.t. \ \sum_{k=1}^{K} \left\|\mathbf{w}_k\right\|_2^2 \leq P_T \\ &\qquad \sum_{k=1}^{K} \left|g_k^H \mathbf{w}_k\right| \leq I_M \end{aligned} \tag{5}$$

Among them, P_T is defined as the total maximum transmit power constraints. In the largest user base station sends power, assume $\sum_{k=1}^{K} P_k = P_T$, do not break general, once the k -th second user's signal to noise ratio can be defined as P_k / σ_k^2 , and I_M is to the primary user biggest interference threshold. In order to solve the optimization problem (5), limited to define interference $\gamma_{i,k} \geq \left|\mathbf{h}_{ik}^H \mathbf{w}_k\right|^2$, and $i \neq k$, according to the change, can change for its optimization problems

$$\begin{aligned}&\max_{\{\mathbf{w}_k\}_{k=1}^{K}} \sum_{k=1}^{K} u_k \log_2\left(1+\frac{\left|\mathbf{h}_{kk}^{H}\mathbf{w}_k\right|^2}{\sum_{j\neq k}\gamma_{k,j}+\sigma_k^2}\right),\\ &s.t.\ \sum_{k=1}^{K}\left\|\mathbf{w}_k\right\|_2^2 \le P_T\\ &\quad \sum_{k=1}^{K}\left|g_k^{H}\mathbf{w}_k\right| \le I_M\\ &\quad \left|\mathbf{h}_{ik}^{H}\mathbf{w}_k\right|^2 \le \gamma_{i,k}\end{aligned} \qquad (6)$$

Considering the factors of channel errors can be type (3), (4) into type (6), you can get the new optimization problem, the problem of the key to solve the boundary problem of error factors, a new optimization problem can be expressed as

$$\begin{aligned}&\max_{\{\mathbf{w}_k\}_{k=1}^{K}} \sum_{k=1}^{K} u_k \log_2\left(1+\frac{\left|\left(\hat{\mathbf{h}}_{kk}+\delta_{kk}\right)^{H}\mathbf{w}_k\right|^2}{\sum_{j\neq k}\gamma_{k,j}+\sigma_k^2}\right),\\ &s.t.\ \sum_{k=1}^{K}\left\|\mathbf{w}_k\right\|_2^2 \le P_T\\ &\quad \sum_{k=1}^{K}\left|\left(g_k+\zeta_k\right)^{H}\mathbf{w}_k\right| \le I_M\\ &\quad \left|\left(\hat{\mathbf{h}}_{ik}+\delta_{ik}\right)^{H}\mathbf{w}_k\right|^2 \le \gamma_{i,k}\end{aligned} \qquad (7)$$

5. Robustness Beamforming

According to the principle of dual decomposition, based on the Lagrangian dual problem, can be decomposed sub problem into two sub-problems, among them, the two sub-problems are restrict each other. Have a type (7) can get function is

$$\begin{aligned}L\left(\mathbf{w}_k,\tau,\eta,q_{i,k}\right)=&\sum_{k=1}^{K} f_k\left(\mathbf{w}_k,\eta,q_{i,k}\right)+\tau\left(P_T-\sum_{k=1}^{K}\left\|\mathbf{w}_k\right\|_2^2\right)\\ &+\eta I_M+\sum_{k=1}^{K}\sum_{i=1,i\neq k}^{K} q_{i,k}\gamma_{i,k}\end{aligned} \qquad (8)$$

Where

$$f_k\left(\mathbf{w}_k,\eta,q_{i,k}\right) \triangleq u_k \log_2\left(1+\frac{\left|\left(\hat{\mathbf{h}}_{kk}+\delta_{kk}\right)^{H}\mathbf{w}_k\right|^2}{\sum_{j\neq k}\gamma_{k,j}+\sigma_k^2}\right)-\eta\left|\left(g_k+\zeta_k\right)^{H}\mathbf{w}_k\right|^2-\sum_{i\neq k} q_{i,k}\left|\left(\hat{\mathbf{h}}_{ik}+\delta_{ik}\right)^{H}\mathbf{w}_k\right|^2 \qquad (9)$$

Lagrange multiplier $\tau,\eta,q_{i,k}$, respectively, in order to optimize the distributed send beam forming matrix, the optimization problem can be simplified to

$$\begin{aligned}&\max_{\{\mathbf{w}_k\}_{k=1}^{K}} f_k\left(\mathbf{w}_k,\eta,q_{i,k}\right)-\tau\left\|\mathbf{w}_k\right\|_2^2\\ &s.t.\ \sum_{k=1}^{K}\left\|\delta_{ik}\right\|_2^2 \le \xi_{ik}\\ &\quad \left\|\zeta_k\right\|_2^2 \le \phi_k\end{aligned} \qquad (10)$$

Make $\mathbf{w}_k \triangleq \sqrt{p_k}\mathbf{v}_k$, $p_k \in R_+$ and $\mathbf{v}_k \in \mathbb{C}^{N_k \times 1}$ (10) can approximate the formula is expressed as

$$\begin{aligned} & f_k\left(\mathbf{w}_k,\eta,q_{i,k}\right)-\tau\left\|\mathbf{w}_k\right\|_2^2 \\ & = u_k \log_2\left(1+\frac{\left|\left(\hat{\mathbf{h}}_{kk}+\delta_{kk}\right)^H \mathbf{w}_k\right|^2}{\sum_{j\neq k}\gamma_{k,j}+\sigma_k^2}\right)-\mathbf{w}_k^H\phi_k\mathbf{w}_k \\ & \approx u_k \log_2\left(1+\frac{p_k\mathbf{v}_k^H\hat{\mathbf{h}}_{kk}\hat{\mathbf{h}}_{kk}^H\mathbf{v}_k^H}{\sum_{j\neq k}\gamma_{k,j}+\sigma_k^2}\right)-p_k\mathbf{v}_k^H\phi_k\mathbf{v}_k^H \end{aligned} \tag{11}$$

Among them, $\phi_k \triangleq \tau\mathbf{I}+\eta g_k g_k^H+\sum_{i\neq k} q_{i,k}\mathbf{h}_{ik}\mathbf{h}_{ik}^H$, $\mathbf{g}_k=\hat{\mathbf{g}}_k+\zeta_k$ and $\mathbf{h}_{ij}=\hat{\mathbf{h}}_{ij}+\delta_{i,j}$,from (11) type (10) can be written as optimization problem

$$\begin{aligned} & \max_{\{\mathbf{w}_k\}_{k=1}^K} u_k \log_2\left(1+\frac{p_k\mathbf{v}_k^H\hat{\mathbf{h}}_{kk}\hat{\mathbf{h}}_{kk}^H\mathbf{v}_k^H}{\sum_{j\neq k}\gamma_{k,j}+\sigma_k^2}\right)-p_k\mathbf{v}_k^H\phi_k\mathbf{v}_k^H \\ & s.t.\ \phi_k \triangleq \tau\mathbf{I}+\eta g_k g_k^H+\sum_{i\neq k} q_{i,k}\mathbf{h}_{ik}\mathbf{h}_{ik}^H \\ & \quad \sum_{k=1}^K\left|\left(g_k+\zeta_k\right)^H \mathbf{w}_k\right| \le I_M \\ & \quad \left|\left(\hat{\mathbf{h}}_{ik}+\delta_{ik}\right)^H \mathbf{w}_k\right|^2 \le \gamma_{i,k} \end{aligned} \tag{12}$$

Joint optimization p_k and $\mathbf{v}_k$, for channel error message channel uncertainty, appear very difficult. In order to effectively solve this problem, can use iterative method to solve.

According to the problems after can get a reduction

$$\begin{aligned} & \max_{\{\mathbf{w}_k\}_{k=1}^K} Tr\left(\hat{\mathbf{h}}_{kk}\hat{\mathbf{h}}_{kk}^H\mathbf{v}_k^H\right) \\ & s.t.\ \phi_k \triangleq \tau\mathbf{I}+\eta g_k g_k^H+\sum_{i\neq k} q_{i,k}\mathbf{h}_{ik}\mathbf{h}_{ik}^H \\ & \quad \sum_{k=1}^K\left|\left(g_k+\zeta_k\right)^H \mathbf{w}_k\right| \le I_M \\ & \quad \left|\left(\hat{\mathbf{h}}_{ik}+\delta_{ik}\right)^H \mathbf{w}_k\right|^2 \le \gamma_{i,k} \end{aligned} \tag{13}$$

So $\mathbf{v}_k^H$ can get its can be obtained by the main characteristics of the vector $\hat{\mathbf{h}}_{kk}\hat{\mathbf{h}}_{kk}^H$. And the optimal power is

$$p_k=\left[\frac{u_k}{1n2}-\frac{\sum_{j\neq k}\gamma_{i,k}+\sigma_k^2}{c_k}\right]^+ \tag{14}$$

Finally get the iterative scheme

1：Initialization $\eta(0)$ ， $\tau(0)$ ，for all $i \neq k$ ， k

2：Set $t=0$ ，

3：While no convergence ,do

4： $t \leftarrow t+1$

5：Calculation $\mathbf{v}_k^H$ based on （13）

6：Allocation the optimal power p_k based on 14）

7：Update $\mathbf{w}_k$

8：Update $q_{i,k}$

9：Transmitting beamforming to other second user base station

10：Update $\tau, \eta,$

11: End

6. Simulation Results

In this part, uses the advanced computer simulation to show the proposed scheme; In order to simplify the simulation, this paper argues that the user to the main user distance is equal at the receiving end. General, do not lose time users to send end user receiver and time to the main user distance at the receiving end is the primary user the sender to the receiver of the main user distance of two times and three times. In this simulation, $N_t = 8$, $N_r = 2$, $K = 8$, And set the user and send equals the maximum power P, namely. In the simulation, set up different stages of boundaries are the primary user interference. In order to compare the feedback scheme under the condition of superiority, this paper simulated the iteration five times. In order to compare convenience, in this paper, the proposed scheme respectively compared with the following three solutions:

Solution 1: the optimal power allocation scheme, Figure 2 and Figure 3 in the legend of recorded as "[9] solution";

Scheme 2: to maximize the user system transmission rate, Figure 2 and Figure 3 in the legend of recorded as "[10] solution";

Solution 3: to maximize the user system transmission rate and the optimal power allocation optimization scheme, legend of Figure 2 and figure 3 for the "combination".

Figure 2 in the user's average signal-to-noise ratio ($0 \sim 30dB$), the maximum mutual information of the user's system, left feedback bits for the 6 bit is the case, it can be seen from the left, the proposed scheme and the most optimal scheme 3, 2 dB gain, the main reason for CSI plan 3 is based on the RS obtain complete under the condition of the optimal solution, without considering the quantization error exists, from another Angle, you can see that also quantization error influence on user transmission rate. Time for users to send end of CSI is more accurate, the proposed scheme advantages are more obvious, you can see have a gain of 2.5 dB. As can be seen from the Figure 2 two figure, the proposed scheme effectively overcome the influence of quantization error to the user transmission rate.

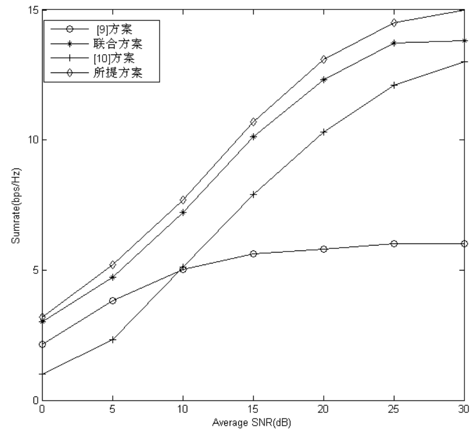

Figure 2. Maxinum Rates Comparison of 4 Schemes

Figure 3 at the same second user's average signal-to-noise ratio ($0 \sim 30dB$), the capacity performance of the four schemes are compared, left for feedback bits for 6 bit, the capacity curve, we can find that, due to the scheme optimization criteria for the MMSE, so its capacity performance advantage is more obvious, the other three schemes with the increase of SNR, the capacity curve does not decline, while the proposed scheme has a good capacity convergence, the equivalence and the convergence of mean square error (MSE) has, from the point of view of the simulation prove the convergence of the algorithm.

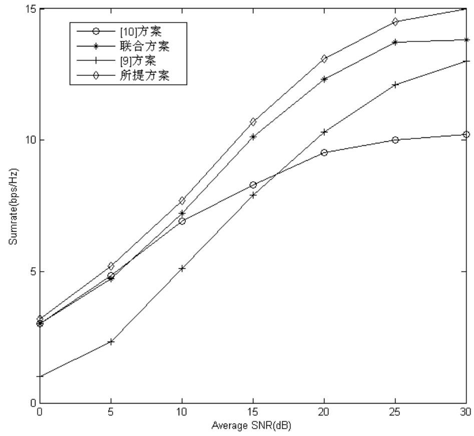

Figure 3. Capacity Comparison of 4 Schemes

6. Conclusion

This paper puts forward a kind of imperfect channel state information under the condition of cognitive radio interference alignment of community environment more optimization transmission scheme, this scheme is first put forward in the total interference power, always send limited power and random error of channel information of optimization problem, through the transformation, a convex optimization problem transformation into optimization problem, and got an iterative scheme, the advantage of the scheme is verified through simulation.

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