Relay Location Choice for CR Networks with Multi-Group Multicast Based on Inter-group and Inner-group Cooperation Transmission

Zhiqing Tang, Shouyi Yang*, Ruizhe Zhang

School of Information Engineering, Zhengzhou University, China

*Corresponding author: Shouyi Yang, iesyyang@zzu.edu.cn

Abstract

In view of the cognitive radio network more groups of multicast, this paper proposes a multicast group matching based on collaboration between groups of information transmission mechanism. We formulate an overall rate optimization problem based on relay location and primary user (PU) location with interference constraints to the PU and peak power constraint of each user and obtain the optimal solution by theoretical analysis in this new transmission model. Numerical results show the impact of relay location and PU location on rate for every multicast group.

Keywords: *cognitive radio, multi-group multicast, relay location*

1 Introduction

As the number of wireless users and the rapid growth of wireless communications business demand, spectrum resources shortage problem increasingly prominent. Cognitive radio can make full use of the spectrum to spectrum sharing resources, to solve the frequency spectrum resource shortages, especially low frequency band, and the existing spectrum resources has not been used^[1]. In cognitive radio, as long as on the premise of not harmful interference authorized users, unauthorized users can access authorized user frequencies, improve spectrum efficiency^[2].

Due to the wireless mobile devices allows multiple terminal to receive the same signal source signals, multicast mechanism allows the same data set from a base station to send to a group of users, so multicast mechanism can improve the bandwidth consumption^[3,4].

One of the main features of the wireless multicast is that multiple users on the same channel to receive the same service^[2]. Because the multicast group transmission rate depends on the rate of the group of the worst case^[5]. Therefore, cooperative communication is applied to solve this problem, and puts forward a new form of space diversity to combat fading of negative effects, improve the performance of the whole system^[6].

Relay location problems in different application scenarios caused widespread concern. In^[7] the authors studied the selection scheme based on adaptive relay location. In^[8] the authors using vector quantization method, studied the uplink transmission in relay location optimization problem. In^[9] the authors put the system capacity as objective function, and the relay position optimization problem of two kinds of cooperation mode cell were studied.

Based on the above research results, our team proposed a new transmission mechanism called multi-group multicast (MGMC) based on inter-group and inner-group cooperation is proposed for cognitive networks^[10]. In this paper, we analyzed the effect of relay location and PU

location in the transmission mechanism.

2 System model

We'll describe the MGMC based inter-group and inner-group cooperative transmission mechanism, as shown in Fig. 1. It includes three transmission steps^[10]:

During phase 1, CR BS send data x_1 . CU_1 , Relay1 and Relay2 receive x_1 .

During phase 2, the Relay1 forwards data x_1 to CU_2 , at the same time CR BS send data x_2 to CU_3 and Relay2. Meanwhile, Relay2 also receive x_1 from Relay1.

During phase 3, Relay2 forwards data x_2 to CU_4 , which improves the system throughput.

According to DF protocol, the rate of transmitting x_1 and x_2 are

$$R_1(P_1, P_2) = \min \left\{ \frac{1}{3} \log_2(1 + \gamma_{1,1}), \min \left\{ \frac{1}{3} \log_2(1 + \beta_{1,2}), \frac{1}{3} \log_2(1 + \beta_{1,3}) \right\} \right\} \quad (1)$$

$$R_2(P_3, P_4) = \min \left\{ \frac{1}{3} \log_2(1 + \gamma_{2,1}), \min \left\{ \frac{1}{3} \log_2(1 + \beta_{2,2}), \frac{1}{3} \log_2(1 + \beta_{2,3}) \right\} \right\} \quad (2)$$

Respectively. The overall data rate of the multicast group pair in CR network is the sum rate of both group 1 and 2.

$$R(P_1, P_2, P_3, P_4) = R_1(P_1, P_2) + R_2(P_3, P_4) \quad (3)$$

Fig. 1-The structure of a MGMC CR network.

3 Overall Rate Optimization

In this paper, we study the underlay access scheme. By considering in each CR user constraints, optimization problem was prepared as follows.

$$\max_{P_1, P_2, P_3, P_4} R(P_1, P_2, P_3, P_4) \quad (4)$$

$$\text{s.t.} \quad P_1 |h_{BP}|^2 \leq I \quad (5)$$

$$P_2|h_{R1P}|^2 + P_3|h_{BP}|^2 \leq I \quad (6)$$

$$P_4|h_{R2P}|^2 \leq I \quad (7)$$

$$P_1 \leq P_{CR} \quad (8)$$

$$P_2 \leq P_{R1} \quad (9)$$

$$P_3 \leq P_{CR} \quad (10)$$

$$P_4 \leq P_{R2} \quad (11)$$

$$P_1, P_2, P_3, P_4 \geq 0 \quad (12)$$

Firstly, we consider P_1 and P_4 , the optimal value of P_1 and P_4 are^[10]

$$P_1^* = \min \left\{ P_{CR}, \frac{I}{|h_{BP}|^2} \right\} \quad P_4^* = \min \left\{ P_{R2}, \frac{I}{|h_{R2P}|^2} \right\}$$

For P_2 and P_3 , they are difficult to solve because of Eq. (6), so we will divide the original problem in some cases.

$$1) \beta_{1,2} \leq \beta_{1,3}, \beta_{2,2} \leq \beta_{2,3}$$

It is very clearly that P_3 is monotonically increasing function of R , so it should be as large as possible as long as all the constraints are satisfied. As a result, the optimal values of P_2 and P_3 are

$$P_{2,1}^* = \frac{P_1^*|h_{CR1}|^2}{|h_{RU2}|^2}, P_{3,1}^* = \min \left\{ \frac{P_4^*|h_{RU4}|^2}{|h_{CR2}|^2}, P_{CR}, \frac{I - P_{2,1}^*|h_{R1P}|^2}{|h_{BP}|^2} \right\}$$

$$2) \beta_{1,2} \leq \beta_{1,3}, \beta_{2,2} \geq \beta_{2,3}$$

When $\gamma_{2,1} \geq \beta_{2,3}$

$$P_{2,2}^* = \frac{P_1^*|h_{CR1}|^2}{|h_{RU2}|^2}, P_{3,2}^* = \max \left\{ \frac{P_4^*|h_{RU4}|^2}{|h_{CR2}|^2}, \frac{P_4^*|h_{RU4}|^2}{|h_{CU3}|^2} \right\}$$

When $\gamma_{2,1} \geq \beta_{2,3}$

$$P_{2,3}^* = \min \left\{ \frac{P_1^*|h_{CR1}|^2}{|h_{RU2}|^2}, \frac{I - P_{3,3}^*|h_{BP}|^2}{|h_{R1P}|^2} \right\}, P_{3,3}^* = \min \left\{ \frac{P_4^*|h_{RU4}|^2}{|h_{CU3}|^2}, P_{CR} \right\}$$

$$3) \beta_{1,2} \geq \beta_{1,3}, \beta_{2,2} \geq \beta_{2,3}$$

When $\gamma_{1,1} \geq \beta_{1,3}, \gamma_{2,1} \geq \beta_{2,3}$

$$P_{2,4}^* = \min \left\{ \frac{P_1^*|h_{CR1}|^2}{|h_{RU2}|^2}, \frac{P_1^*|h_{CU1}|^2}{|h_{RU2}|^2}, P_{R1} \right\}, P_{3,4}^* = \max \left\{ \frac{P_4^*|h_{RU4}|^2}{|h_{CR2}|^2}, \frac{P_4^*|h_{RU4}|^2}{|h_{CU3}|^2} \right\}$$

When $\gamma_{1,1} \geq \beta_{1,3}$ and $\gamma_{1,1} \leq \beta_{1,3}, \gamma_{2,1} \leq \beta_{2,3}$ have the similar results.

When $\gamma_{1,1} \geq \beta_{1,3}, \gamma_{2,1} \leq \beta_{2,3}$

When $P_2 \leq \frac{I - P_{CR}|h_{BP}|^2}{|h_{R1P}|^2}$

$$P_{3,5}^* = \min \left\{ P_{CR}, \frac{P_4^* |h_{RU4}|^2}{|h_{CU3}|^2} \right\}, P_{2,5}^* = \min \left\{ \frac{P_1^* |h_{CR1}|^2}{|h_{RU2}|^2}, \frac{P_1^* |h_{CU1}|^2}{|h_{RU2}|^2}, \frac{I - P_{CR}|h_{BP}|^2}{|h_{R1P}|^2}, P_{R1} \right\}$$

When $P_2 \geq \frac{I - P_{CR}|h_{BP}|^2}{|h_{R1P}|^2}$, we have $P_{CR} \geq \frac{I - P_2|h_{R1P}|^2}{|h_{BP}|^2}$.

Thus,

$$P_3 = \min \left\{ \frac{I - P_2|h_{R1P}|^2}{|h_{BP}|^2}, \frac{P_4|h_{RU4}|^2}{|h_{CR2}|^2} \right\}$$

When $\frac{I - P_2|h_{R1P}|^2}{|h_{BP}|^2} \geq \frac{P_4|h_{RU4}|^2}{|h_{CR2}|^2}$

$$P_{3,6}^* = \frac{P_4^* |h_{RU4}|^2}{|h_{CU3}|^2}, P_{2,6}^* = \min \left\{ \frac{P_1^* |h_{CR1}|^2}{|h_{RU2}|^2}, \frac{P_1^* |h_{CU1}|^2}{|h_{RU2}|^2}, P_{R1} \right\}$$

When $\frac{I - P_2|h_{R1P}|^2}{|h_{BP}|^2} \leq \frac{P_4|h_{RU4}|^2}{|h_{CR2}|^2}$

$$P_{2,7}^* = \min \left\{ \frac{P_1^* |h_{CR1}|^2}{|h_{RU2}|^2}, \frac{P_1^* |h_{CU1}|^2}{|h_{RU2}|^2}, A, P_{R1} \right\}, P_{3,7}^* = \min \left\{ \frac{I - P_{2,6}^* |h_{R1P}|^2}{|h_{BP}|^2}, P_{CR}, \frac{P_4^* |h_{RU4}|^2}{|h_{CU3}|^2} \right\}$$

$$\text{Where } A = \frac{(|h_{BP}|^2 |h_{RU2}|^2 - |h_{R1P}|^2 |h_{CU3}|^2) \delta^2 + I |h_{CU3}|^2 |h_{RU2}|^2}{2 |h_{R1P}|^2 |h_{CU3}|^2 |h_{RU2}|^2}$$

4) $\beta_{1,2} \geq \beta_{1,3}, \beta_{2,2} \leq \beta_{2,3}$

When $\gamma_{1,1} \geq \beta_{1,3}$ is similar to 3) when $\gamma_{1,1} \geq \beta_{1,3}, \gamma_{2,1} \leq \beta_{2,3}$

When $\gamma_{1,1} \leq \beta_{1,3}$

$$P_{2,8}^* = \min \left\{ \frac{I - P_{3,11}^* |h_{BP}|^2}{|h_{R1P}|^2}, \frac{P_1^* |h_{CU1}|^2}{|h_{RU2}|^2} \right\}, P_{3,8}^* = \min \left\{ P_{CR}, \frac{P_4 |h_{RU4}|^2}{|h_{CR2}|^2} \right\}$$

4 Results and Discusses

In this section, we discuss the performance of the optimal power allocation. We assume that all the channel model as Rayleigh block fading channels, and the channel gains remain

constant during all phases. The path gains are with Rayleigh distribution and depend on the distance between the transmitter and the receiver, which can be expressed as

$$|h| = \sqrt{\varphi} \varepsilon \quad (13)$$

where φ is the pathloss, which is inversely proportional to the power of the distance with a path loss exponent, α , i.e., $\varphi = d^{-\alpha}$, and the ε is a unit-variance Rayleigh distribution random variable.

We assume the location of the PU transmitter, PU receiver, CR BS, CU₁, CU₂, CU₃ and CU₄ are fixed, which are (0, 1), (2, 1), (1, 0), (3, 0), (1, -1) and (-3,0), respectively. Without loss of generality, we set the peak power constraints as PCR=10dB, PR1= PR2=10dB, and the interference power constraints as I=1.5dB. The noise power on each channel is $\delta^2 = 1$, and the path loss exponent is $\alpha=4$.

Fig. 2– Sum rate of the system for optimized power solution for different relay locations

Fig. 3– Sum rate of the system for optimized power solution for different PU locations

Fig. 2 shows relay1 for group 1 and relay2 for group2 at different locations when the system overall rate of the optimal solution. From the figure, we can find that the overall rate of the optimal solution at relay1=2.3 and relay2=-2.

We assume the location of the PU transmitter, PU receiver, CR BS, CU₁, CU₂, CU₃ and CU₄ are fixed, which are (0, 1), (x, y), (1, 0), (3, 0), (1, -1) and (-3,0), respectively.

Fig. 3 shows PU at different locations when the system overall rate of the optimal solution. From the figure, we can find that the distance from PU to CR BS is monotonically increasing function of the overall rate, but when the distance between PU and CR BS reaches a certain value, the rate is not increased.

5 Conclusion

In this paper, we analyzed the effect of relay location and PU location in a new transmission mechanism called multi-group multicast (MGMC) based on inter-group and inner-group cooperation. We considered two multicast groups as a pair for cooperative communication, and then got the optimal power allocation scheme for a given location under considering some practical constraints, such as the interference power constrain and peak power constraints.

Acknowledgements

This work is funded by the National Natural Science Foundation of China (Grant no.61271421)

References

1. FCC 02-155.Federal Communications Commission. Spectrum Policy Task Force Report, Nov 2002
2. *S.Haykin*,Cognitive radio: brain-empowered wireless communications. *IEEE J Sel Area Comm*, 2005, 23(2): 201~220
3. *J.M. Vella and S. Zammit*, A survey of multicasting over wireless access networks, *IEEE Commun. Surv. Tut.* **15**(2013) 718–753.
4. *M. Gruber and D.Zeller*, Multimedia broadcast multicast service: new transmission schemes and related challenges, *IEEE Commun. Mag.* **49**(2011) 176–181.
5. *C. Suh and J. Mo*, Resource allocation for multicast services in multicarrier wireless communications, *IEEE Trans. Wirel. Commun.* **7**(2008)27–31.
6. *J. N. Laneman, D. N. C. Tse, and G. W. Wornell*, Cooperative diversity in wireless networks: Efficient protocols and outage behavior, *IEEE Trans. Inf. Theory.* **50**(2004) 3062–3080.
7. *BIAN Li-an, HAN Chang-cai and LI Yuan*, Adaptive Relay Selection Scheme Based on Relay Location, *Computer Engineering.* **39**(2013)106–109.
8. *V.Pourahmadi, S. Fashandi, A. Saleh , et al.* Relay placement in wireless networks: a study of the underlying tradeoff, *IEEE Trans. Wirel. Commun.* **10**(2011) 1383–1388.
9. *Y.Dong , Y.Zhang , M.Song , et al .* Optimal relay location in OFDMA based cooperative networks, *The 5th International Conference on IEEE Wireless Communications, Networking and Mobile Computing*. Beijing: IEEE Conference publications, 2009:1–4.
10. *W.Hao, S.Yang and B.Ning*, Optimal Resource Allocation for CR Networks with Multi-Group Multicast Based on Inter-Group and Inner-Group Cooperation Transmission, *The 5th International Conference on Wireless Communications, Networking and Mobile Computing*. Boston, MA: IEEE Conference publications, 2015: 1–4.