Adaptive Power Control Strategy based on Spectrum Sensing for Cognitive Relay Networks

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CR 넷워크를 위한 주파수 감지에 기번한 적응적인 전력 제어 전략

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Abstract:An adaptive power control scheme is proposed for the cognitive relay networks with joint overlay and underlay spectrum sharing model. The transmit power of the secondary user is adjusted adaptively according to the spectrum sensing results and the interference channel condition. The outage probability of the secondary user is compared by Monte — Carlo simulations between the fixed power control scheme and pure overlay or underlay spectrum sharing schemes.The results show that ,by employing the adaptive power control strategy, the interference probability of the secondary user to the primary user is decreased by 70 % ~ 80 % under the same outage probability. Also, the outage probability of the secondary user is reduced by 1 ~ 2 orders of magnitude under the same interference probability. Thus, the performance of the spectrum sharing is improved effectively.

Key words: cognitive relay network;overlay spectrum sharing;underlay spectrum sharing; adaptive power control

1. Introduction

With the rapid development of the new broadband wireless communication techniques, the contradictions between the requirements of the wireless communications service and the limited wireless spectrum resources is more intense. Cognitive wireless [1] could provide a flexible, independent and intelligent dynamic spectrum sharing way which is considered as an effective way to solve the shortage of the spectrum resources and the improvement of the availability of the spectrum. On the other hand, cooperated relay tech [2] could also effectively alleviate the decline of the signal due to the multiway transmission, enlarge the network coverage and enhance the system capacity in the premise of not lowering the system power. Therefore, the combination of the cognitive wireless and the cooperated relay could effectively improve the spectrum sharing function. In recent years, cognitive relay network arouses extensive attention from the academia[3-4]。

In the system of cognitive wireless, secondary user (SU) could adopt the overlay or underlay way to share the spectrum with the primary user(PU). In the overlay model, the SU need to go to the spectrum perception. As long as the the primary user is tested free, the SU could use the authorized spectrum. In the underlay model, the SU do not need spectrum perception. Both SU and PU can transfer at the same time. But the SU should strictly control the power to satisfy the restricted conditions of the interfered power set by the PU.

Many references studies these two spectrum sharing model separately. In recent years, the combination of the overlay and underlay spectrum sharing arouses the people' s attention [5-7]. Its sharing methods is based on the spectrum sensitive results. When it tested to be H_0, it shows that the PUs are at free time and the SUs is sharing the spectrum under the overlay model. When it tested to be H_1, it shows that the PUs are at active state, the SUs are sharing the spectrum under the underlay model. Document [7] analyses the suspend function of the relay network under the cooperated overlay and the underlay spectrum sharing cognitive relay network. It calculates the closed expression of the suspend probability of the SU based on the theory. But in order to simplify the theory research ,the secondary users adopt the fixed emitting power. In fact, in daily life, the fixed emitting power has some disadvantages as follows: Firstly, under the underlay model , the emitting power of the secondary user could be a little strong and it will exceed the constraint of the disturbing power of the SUs. Secondly, under the overlay model, the emitting power of the secondary users could be a little low which will lower its spectrum efficiency . In order to overcome this disadvantage, the thesis puts forward the self-adaption power control strategy. According to the spectrum sensitive results and the disturbing channel information between the SUs' and the PUs' receiving machine, it can adjust the emitting power of the SUs itself. Monte — Carlo emulated results reveals that,Compared with the fixed power control scheme in reference [7], the adaptive power control strategy can reduce the outage probability of secondary users and the interference probability of secondary users to primary users, thus improving the spectrum sharing performance.

2. system model

The system model of the cognitive relay network is shown as Fig 1. It's consisted of a primary link and a secondary link.The secondary link contains a source point(s),and M-relay points(rm) and an aim point (d).Spectrum sharing adopts the cooperation of the underlay and overlay model. The PUs receiving machine(p)is set to be I_p.The source and relay points of the SUs link must satisfy its constraints of the disturbing power. Assuming the relay and aim points of the SUs is far away from the receiving machine of the primary users, thus, we can ignore the disturbance from the PUs to the SUs [3].in order to improve the emitting function, the SUs emits by the relay cooperation. The relay agreement adopts the Decode and Forward and the selective cooperation [2].In the first slot, all relay nodes and destination nodes receive information from the source node; in the second slot, the best node is selected as the relay to forward the message to the destination node.

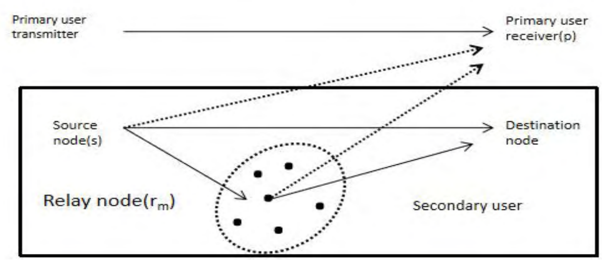


Fig. 1 System model

3. Control strategy of the self-adaption power

We assume the emitting power of the users as P_s and the permitted maximum emitting power of the emitting machine as P_t . In the self-adaption control strategy, the SUs adjust the emitting power of itself according to the spectrum sensitive results and the disturbing condition to the information channel from the SUs' to the PUs' receiving machine. The detailed description as follows: The channel gain $X = |h_{ip}|^2$,when the sensitive result is H_0, the secondary users adopts the maximum emitting power P_t ; When the sensitive result is H_1, the SUs adjusts the emitting power according to the condition of the information channel to ensure that the interference of the PUs is below the interference tolerance . When the ratio of the information channel between the SUs' emitting machine and the PUs' receiving machine is lower than I_p / P_t we adopt the maximum emitting power P_t.Otherwise, we adopt the emitting power $I_p / |h_{ip}|^2$

The control arithmetic flow of the self-adaption is shown as Fig 2.

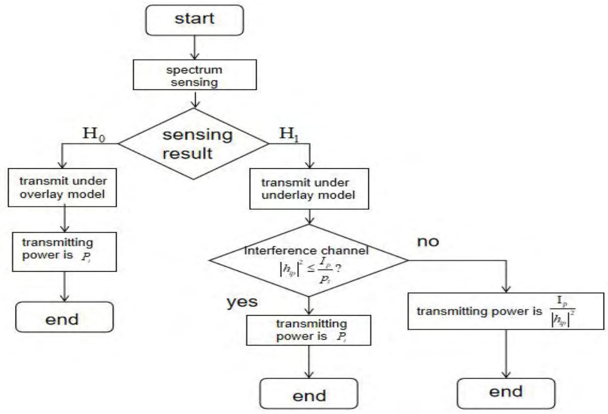


Fig.2 Flow chart of adaptive power control

4. The suspend probability analysis of the secondary users.

Assuming the probability of the primary users is P_0 . The corresponding relations of these spectrum sharing model and the spectrum sensitive results is in chart 1. The $P_d = P_r[H_1|H_1]$ means the testing probability. $P_f = P_r[H_1|H_0]$ means false alarm probability.

Primary users state	Sensitive event	Sensitive result	Sharing model
Activity(H_1)	Forget to test(1 − P_d)	H_0	overlay
Activity(H_1)	Correct(P_d)	H_1	underlay
Free(H_0)	Correct (1 − P_f)	H_0	overlay
Free (H_0)	False alarm(P_f)	H_1	underlay

The probability of the spectrum sensitive results to be H_0 and H_1 are

$$P_r[H_0] = P_0(1-P_f) + (1-P_0)(1-P_d) \ ,$$

$$P_r[H_1] = P_0 P_f + (1-P_0)P_d \quad (1)$$

When the spectrum sensitive result is H_0, the SUs adopts the overlay sharing model, and the suspend probability is P_0 . When the spectrum sensitive result is H_1, the SUs adopts the underlay sharing model. And its emitting power is adjusted by the information channel state information. And its suspend probability is P_U. When we adopt the self-adaption control strategy under the combination of overlay and the underlay spectrum sharing model, the suspended probability expression of the cognitive relay network of the secondary users is :

$$P_J = P_0 P_r[\mathrm{H}_0] + P_U P_r[\mathrm{H}_1]$$

When we only adopt the overlay sharing model, the emitting power of the SUs is p_t. And now the suspend probability is

$$\tilde{P}_0 = P_0 P_r[\mathrm{H}_0] + P_0 P_f + (1 - P_0) P_d$$

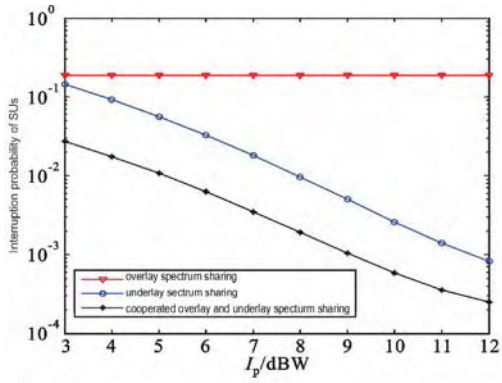
When we only adopt the underlay sharing model, the SUs adapts the emitting power itself by the information channel. And the suspend probability is

$$\tilde{P}_U = P_U$$

5 The emulated result and the analysis

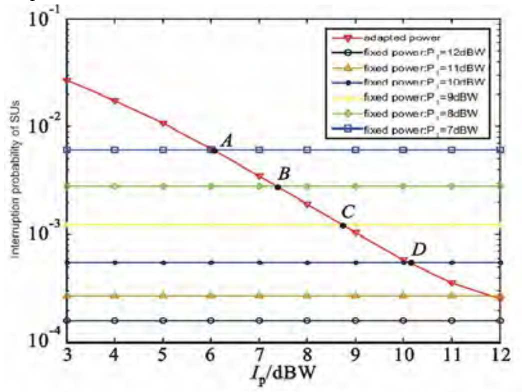
Take the small scale cognitive relay network as an example , the relay point is M = 4.. The max emitting power is $P_t = 13$ dBW. Disturbing power $I_p = 3 \sim 12\mathrm{dBW}$ information channel parameter $\lambda_{\mathrm{sd}} = \lambda_{sr_m} = \lambda_{r_m d} = 1$ $\lambda_{\mathrm{sp}} = \lambda_{r_m p} = 2$ m=1,2,...,M. Assuming the probability of the primary users are at free state is $P_r[\mathrm{H}_0] = 0.8$, the spectrum testing probability is $P_d = 0.9, P_f = 0.01$ 。Monte －Carlo emulated result is the average of 10^5 operating results.

Fig3 gives us a suspend function curve of the SUs which is under different spectrum sharing model. As we can see, when the SUs adopts the cooperated overlay and underlay sharing model can get the minimum suspend probability . And the overlay method get the maximum.. This is because under the overlay model, when the spectrum sensitive result is H_1 , the secondary users can’t share the spectrum which leads to the suspension of the transmission. The picture also shows that that there’s no relations between the suspended probability and the disturbing power in the overlay mode-l. When adopting the single underlay way, the SUs can always share the spectrum. But due to the strictly control to the emitting power, the suspended function will be influenced. Thus, the combination of underlay and the overlay model is the optimal spectrum sharing model. The cost is to increase a small amount of control channel overhead.



Fig．3 Outage probability of SU under different spectrum sharing models

Fig 4 compares the fixed power control strategy in the reference [7] and the suspended function of the SUs under the self-adaption power control strategy. P_1 is the fixed emitting power of the SUs under the fixed power control strategy. The emulated result shows that when the value of P_1 is large the suspended probability received from adopting the fixed power control strategy is lower than the self-adaption power control strategy. And when P_1 is at a small value and the disturbing power I_p is large, the self-adaption power control can get a lower suspended probability. The A/B/C/D points in the picture points out the condition of the equal suspended probability when adopting the these two strategies. In order to explain the extent of disturbance to the primary users from these two strategies, we adopt the disturbing probability as the comparing indicator and define the probability of interference as the probability that the interference from SUs to PUs exceeds the interference power constraint I_p The data in table 2 shows that under the same suspended probability, adopting the self-adaption power control strategy make the disturbing probability of the SUs to the PUs lower 70 % ～ 80 %. Conversely, if we demand lowering the disturbing probability , adopting the fixed power



Fig． 4 Outage probability of SU under different power control schemes

Power control strategy	A	B	C	D
Self-adaption power control	0.027 7	0.023 5	0.019 1	0.013 0
Fixed power control	0.101 0	0.085 4	0.074 6	0.058 1

Tab.2 Interference probability from SU to PU under the same outage probability

Fig 5 compared the disturbing probability of the secondary users to the primary users under the fixed power control strategy and the self-adaption power control strategy. The emulated results shows that when $P_1 \geq 0$ dBW, the disturbing probability caused to the primary users when adopting the self-adaption power control strategy is always lower than adopting the fixed power control strategy. The A/B/C/D points in the picture shows the conditions of getting same disturbing probability under these two power control strategy. The corresponding suspended probability numbers are in the table 3. It turns out that under the same disturbing probability and adopting different power control method, the suspended probability of the secondary users is differ from 1 ~ 2 number level. Adopting the self-adaption power control strategy will get a better uspended function.

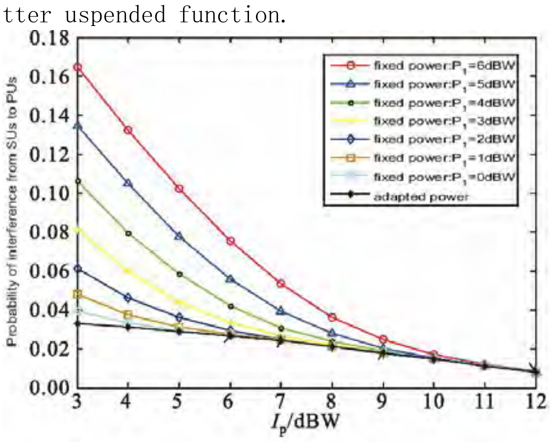


Fig. 5 Interference probability to PU under different power control schemes

Power control strategy	A	B	C	D
Self-adaption Power control	0.006 3	0.003 5	0.001 0	0.000 3
Fixed power control	0.116 9	0.090 5	0.040 9	0.012 5

Tab. 3 Outage probability of SU under the same interference probability

6. Conclusion

This thesis puts forward a self-adaption power control strategy by adopting the cognitive relay network by combining the overlay and the underlay spectrum sharing method. The secondary users adapts the emitting power according to the disturbing information channel condition and the primary users state. Compared with the fixed power control strategy in reference [7], under the given suspended probability, adopting the self-adaption power control strategy make the disturbing probability from the secondary to the primary useres lower 1-2 number levels. Therefore, the thesis put forward the self-adaption power control strategy can effectively improve the spectrum sharing function of the cognitive relay network and provide a theory solving plan for improving the spectrum availability.

The weak point is that this self-adaption power control strategy is a little complex and needs a large amount of real time information to feed back.

Next, we need to consider a neutralized one between the complexity and the function, study the power control strategy design of the cognitive relay network and the different information channel model and analyze its theoretically.

References

[1] SIMON H. Cognitive radio: brain empowered wireless communications [J]. IEEE Journal of Selected Areas in Communications, 2005, 23 (2):201 — 220

[2] LANEMAN J N, TSE D N C, WORNELL G W. Cooperative diversity in wireless networks:efficient protocols and outage behavior [J]. IEEE Transactions on Information Theory, 2004, 50(12) :3062 — 3080.

[3] ZHANG Q, JIA J C, ZHANG J. Cooperative relay to improve diversity in cognitive radio networks [J]. IEEE Communications Magazine, 2009, 47(2) :111 — 117.

[4] ZHANG W, LETAIEF K B. Cooperative communications for cognitive radio networks [J]. Proceedings of IEEE, 2009, 97(5) :878 — 893.

[5] KANG X, LIANG Y C, GARG H K, et al. Sensing —based spectrum sharing in cognitive radio networks [J]. IEEE Transactions on Vehicular Technology, 2009, 8(10) :5166 — 5175.

[6] DO T, MARK B L.Joint spatial — temporal spectrum sensing for cognitive radio networks [J]. IEEE Transactions onVehicular Technology, 2010, 59(7):3480 — 3490.

[7] CHEN P P, ZHANG Q Y. Joint temporal and spatial sensing based cooperative cognitive networks [J]. IEEE Communications Letters, 2011, 15(5) :530 — 532.