New Model and Intelligent Optimization of Spectrum Allocation in Cognitive Radio Network

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Abstract: In order to solve the bottlenecks in technology of radio communication network, this paper has put forward new model and intelligent optimization of spectrum allocation in cognitive radio network. Through the optimization of cognitive radio network and intelligent network model and spectrum, and the intelligent optimization realization of cognitive radio network has been conducted, and the results show that the new model can carry out effective intelligent optimization to nodes and sensitivity of spectrum network node, promoting the development of the spectrum allocation sharing in cognitive network greatly, and it has practical value.

Keywords: Cognitive network; New model; New model; Intelligent optimization

1. Introduction

With the development of radio communication, new technology and new business have been constantly emerging. The need of spectrum has grown in exponentially, following by the shortage phenomenon of this non-renewable resource. The traditional spectrum allocation mechanisms is static allocation, that is, divide fixed spectrum range for specific business, and this method of allocation makes spectrum utilization ratio very low. So how to improve spectrum utilization ratio under the condition of limited wireless resource, in order to ease the contradiction between the growing wireless business demand and the limited spectrum resources, has become a hot issue in the field of communications. However, the cognitive radio (CR) is a kind of more intelligent spectrum sharing technology, and it can rely on the support of artificial intelligence to perceive radio communication environment. According to some learning and decision algorithms, it can real-time adaptively change system parameters (such as transmission power, carrier frequency, modulation mode, etc.), in theory, it allows multidimensional spectrum reuse in time, frequency and space, reducing the limit of frequency and the bandwidth greatly. [1-2]

In 1999, Dr Mitola put forward the concept of cognitive radio for the first time, hereafter, and he expounded the definition of CR further: CR, this term determines such a view, namely, the radio personal digital assistant (PDA) and related network have enough computing intelligence for wireless resources and the related communication between the computers, including: monitor the user communication needs and provide the most appropriate wireless resources and service to meet those needs. Mitola, as a pioneer in the field of CR, has put forward relative ideal CR definition, however, in the given definition, the artificial intelligence has played an important role, and there is a certain gap with the current technical level. In addition, the realization of its cognitive function mainly reflects in the application layer or higher level of learning and reasoning ability. The core idea of spectrum sensing is: CR users owning the cognitive function, through intelligent perception of spectrum environment, automatic search and use the spectrum hole which already assigned to the authorized users but without occupation, achieving spectrum sharing with the authorized users [3]. For any types of network, one of the most basic requirements is its availability, if the network is not available, then the significance will not exist. Of course, the extreme case of unavailable of the whole network is very rare, and most cases are that the availability of some base station or the user equipment is damaged. Many attacks in network, such as denial of service attack and interferential attack and so on, are aiming at base station or user equipment. In the CRN, the availability is mainly refers to ensure the authorized users and CR users can access to the network attributes of spectrum at anytime and anywhere. For the authorized users, availability refers to the authorized users can transmit data at any time within the authorized spectrum range, and without the serious interference from CR users; For the CR users, availability refers to the CR users can use the spectrum hole to transfer data, under the condition of ensuring not causing serious interference to the authorized user [4].

But the current cognitive radio network has not have such learning ability and adaptability, and the related

research work has just begun, in addition, at present, the lack of mature, unified experiment platform or prototype system of cognitive radio network that can be used for reference, so in the study of routing, the environment involved in the study including media, channel, node and the network should be set, and the setting has big influence on the formation of routing algorithms and protocols, advantages and disadvantages of evaluation, the formulation of standards. All this suggests that the routing study of cognitive radio network is necessary, and full of challenging. How to scientific plan and design the routing of cognitive radio network, improve the use efficiency of radio spectrum and reliable and efficient transmission ability has become the important problem in the study of the cognitive radio network.

2. Cognitive Radio Network

Cognitive radio network is the network of cognitive radio, and its essence is bringing the cognitive characteristics into the radio communication network to study. And the general network structure is shown in Figure 1, and the network is made up of authorized network and cognitive radio network. Cognitive radio network, taking the end-to-end performance as the goal, allows the radio communication protocol stack to dynamic reconfiguration, as shown in Figure 2. The research content covered in the cognitive radio network involving the design of the network structure, cross layer design from the physical layer to application layer and different layers and many other technologies. The cognitive radio, taking wireless link performance as the goal, focuses on the study of physical and medium access layer.

In 2005, the famous scholar Thomas, gave the definition of cognitive radio network for the first time: cognitive radio network have cognitive ability, in order to obtain the current network state, and based on the state, carry out plan, decision and action, and then on the basis of these actions, inspire learning behavior and guide for subsequent behavior, in order to realize the ultimate goal -- the end-to-end transmission performance [5]. In 2008, the author Song put forward the concept of large-scale cognitive network, and merged large-scale cognitive network which had obtained spectrum availability and base station availability into universal system of wisdom planet, creating new space for the large scale development of cognitive network. In 2009, the famous scholar Ian F. Akyildiz put forward the concept of Cognitive Radio Ad Hoc Networks, CRAHNs, and this concept integrate the Ad Hoc Network and cognitive radio technology effectively, and also integrate cognitive radio function including the spectrum sensing, spectrum decision-making, spectrum move and spectrum sharing into network model of Cognitive Radio Ad Hoc Networks, and this has opened up a new research idea for the exploration of Cognitive Radio Ad Hoc Networks [6].

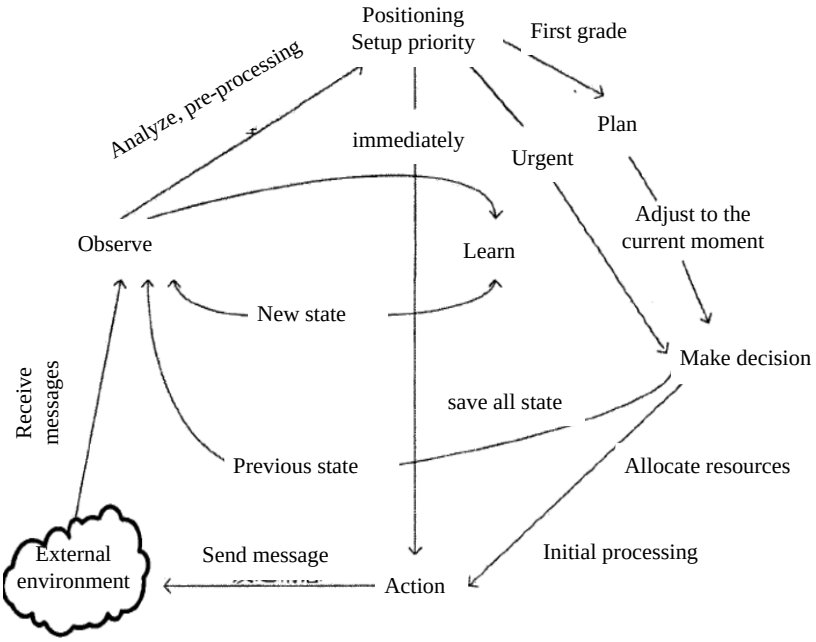

Figure 1. The framework of cognitive radio network

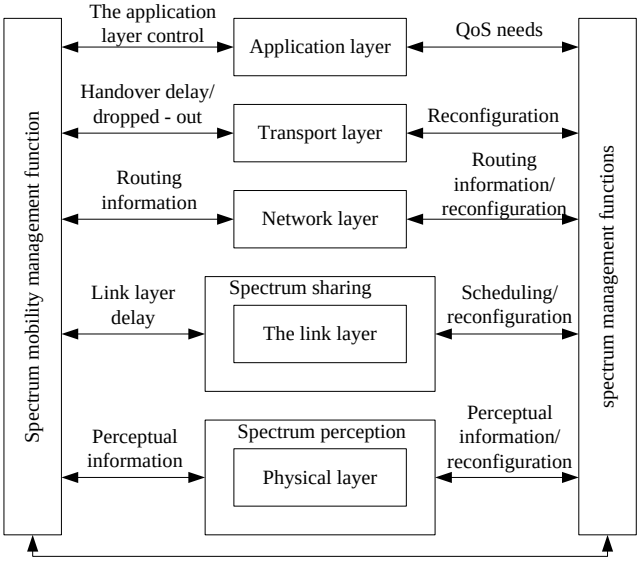

Figure 2. Cognitive radio network protocols

3. Spectrum Allocation Sharing

Spectrum allocation sharing refers to conduct spectrum allocation and spectrum access based on the results of spectrum sensing, so as to realize the efficient utilization of spectrum resources and the fair scheduling. According to literature [5], spectrum sharing method can be divided into three categories. According to the network structure, it can be divided into centralized and distributed spectrum sharing, and centralized spectrum sharing is the center controlling entity to control coordination cognitive node and conduct spectrum allocation and access, while the distributed spectrum sharing is the cognitive nodes, based on dynamic spectrum observation, deciding on their own spectrum access strategy. According to the network structure, the cognitive users, in the process of taking up free spectrum, should keep track of the activities of the authorized users, once found that the authorized users will use this frequency band, the cognitive user must leave the current spectrum and switch to the new empty space, continue to do data transmission without influencing the normal communication of authorized user at the same time. If cognitive users, in the process of switch, don't find new available spectrum, and the data will be temporarily stored in the cache, if it still not perceive available spectrum over a certain time, the communication will be interrupted. According to the spectrum access behavior, spectrum sharing can be divided into collaborative spectrum sharing and non-collaborative spectrum sharing. The collaborative spectrum sharing refers to the cognitive nodes realize the benefit maximization of the whole system based on common goal decision, a collaborative spectrum sharing refers to the cognitive nodes maximizing their interests. According to the spectrum access technology, spectrum sharing can be divided into overlapping spectrum sharing and underlay spectrum sharing, overlapping spectrum sharing scheme requires the cognitive nodes be accessed to only the authorized spectrum not using its authorized spectrum. The underlying spectrum sharing scheme allows the cognitive nodes using the authorized spectrum with primary user at the same time, but the cognitive nodes should adjust its transmission power within the scope of the interference, ensuring not bring interference to primary users.

4. The Model of Spectrum Allocation System

The requirements of cognitive radio technology is to quickly and accurately detect whether the PUs of primary users working or not. To protect the primary user without interference, SUs of cognitive nodes should be conducted periodically spectrum perception. In practical application, there are many unfavorable factors such as channel fading, shadow fading, and the uncertainty of the receiver, which causing serious damage to the performance of spectrum sensing. See figure 3, this is a typical frame diagram of double collaborative spectrum sensing system of multi-node CRAHN network, and this CRAHN network is composed of N_s pairs of collaborative cognitive nodes $pair(U_i, SR_i)(i = 1, 2, ..., N_s)$ and a cognitive base station. The U_i is located in the transmission covering range of base station of primary user, however, affected by the shadow or obstacles or close to the edge of trans-

mission coverage, at the same time receive cognitive relay nodes SR_i whose primary user signal is strong enough. Due to the effect of shadows and or obstacles, the information cannot be transmitted to perceptive base station, and there is a big uncertainty of the cognitive nodes work correctly perceiving whether the primary user working, and even produce the hidden terminal problem, thus interfere the primary users, which is the problem that cognitive nodes should be avoid in the process of using frequency spectrum. The system model of spectrum allocation is shown in Figure 3.

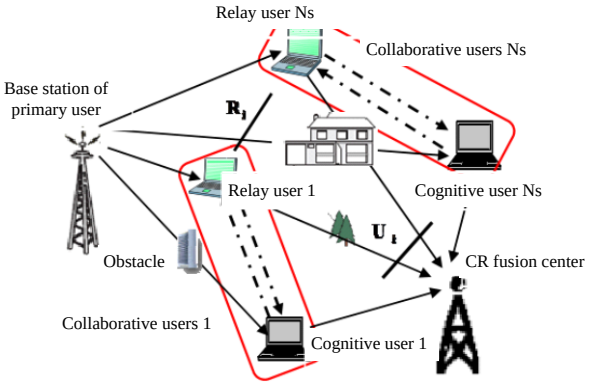

Figure 3. The system model of spectrum allocation

5. The Intelligent Optimization of Cognitive Radio Network

As for time sensitivity optimization of the average spectrum perception nodes, as you can see in figure 4, under the influence of meeting a certain amount of time detection error rate, to make the participated spectrum collaborative cognitive node reaching minimum, the simulation data reference can be set as follows: the maximum allowable range of the average detection error rate ε=0.02, energy detection threshold ζ=6, cognitive network node number 100sN = , the receive power of cognitive nodes 1P = − 10dB, the receive power of cognitive relay nodes 2P = 10dB, time slot 1 2T = T= 25ms, the mini time slot t = 0.5ms. From figure 5, and when $N_s^{opt} \geq 4$, the agility gain of average time perception adopted DCSS average time perception has reduced with the increase of number of participated collaborative cognitive node. $N_s^{opt} = 4$, although it can get maximum agility gain of average perception time, the requirements of the detection error rate is lower than ε= 0.02 cannot be meet at the moment. While $N_s^{opt} = 35$ can achieve detection error rate lower than ε= 0.02, and the corresponding agility gain of average perception time is about 2μ=1.51, 0.17 higher than the result of SCSS, and it equals to the average perception time reducing 12.6%. So, for CRN having $N_s = 100$ cognitive node, $N_s^{opt} = 35$ can meet the requirements of realizing detection accuracy and agility gain of perception time.

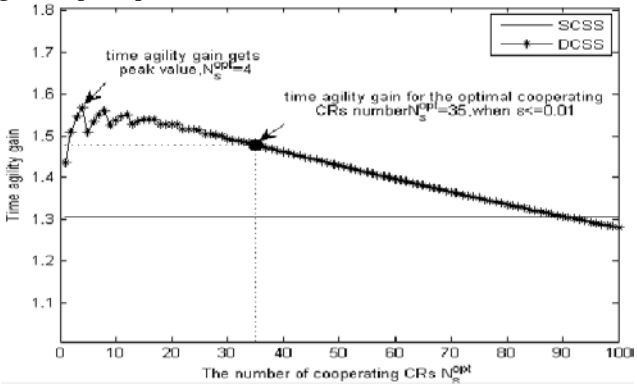

Figure 4. Node optimization of spectrum allocation cognitive network

It is not hard to see from the figure 5, the new model is reasonable and appropriate, set the simulation parameters the same as shown in figure 5, and then observe the change of energy detection threshold ζ from 1 to 22. From the figure, the agility gain of average perception time is the increased function of energy detection threshold. With the increase of ζ, the agility gain of DCSS average perception time, at the optimized red curve, is obviously better than the non optimized blue curve DCSS and black curve SCSS.

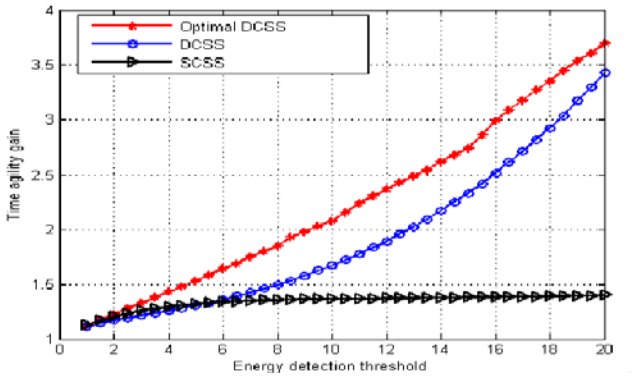

Figure 5. Comparison of spectral sensitivity of cognitive networks

6. Conclusion

With the rapid development of radio communication technology, the problem of radio cognitive network spectrum allocation has more and more serious, in order to solve the defects of spectrum sharing node in cognitive radio network, a new spectrum allocation model and its intelligent optimization of cognitive radio network have been proposed. Through the analysis of network framework of spectrum allocation and cognitive network, collaborative perception method of sensitivity and node of the double collaborative spectrum sensing has been given out. The results show that the model has greatly shorten

the time of spectrum perception, compared with traditional model in the aspect of time, and it has practical value and sensitivity.

7. Acknowledgment

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References

[1] H. A. Al-Rawi, K-LA. Yau. Routing in distributed cognitive radio networks: a survey[J]. Wireless Pers. Commun., 2013, 69 (4), pp.1983-2020.

[2] Ding, T. Melodia, S.N. Batalama, J.D. Matyjas, M. J. Medley. Cross-Layer Routingand Dynamic Spectrum Allocation in Cognitive Radio Ad hoc Networks [J]. IEEE Transactions on Vehicular Technology, 2010, 59(4), pp.1969-1979.

[3] M. Pan, C. Zhang., P. Li, Y. Fang. Spectrum Harvesting and Sharing in Multi-Hop CRNs under Uncertain Spectrum Supply [J]. IEEE Journal on Selected Areas in Communications, 2015, 30 (2), pp.369-378.

[4] M. Cesana, F. Cuomo, E. Eki ci. Routing in cognitive radio networks: Challenges and solutions [J]. Ad Hoc Networks, 2015, 9, pp.228-248.

[5] H.-P. Shiang, M. vander Schaar. Distributed resource management in multi-hop cognitive radio networks for delay-sensitive transmission [J]. IEEE Transactions on Vehicular Technology, 2009, 58 (2), pp.941-953.

[6] J. Zhang, F. Yao, Y. Liu, L. Cao. Robust route and channel selection in cognitive radio networks [C]. IEEE 14th International Conference on Communication Technology (ICCT), 2012, pp.202-8.