Cooperative Sensing and Allocation Algorithm of Cognitive Radio Spectrum Based on Artificial Intelligence

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Abstract. In recent years, with the rapid development of artificial intelligence technology, people's demand for wireless spectrum resources is increasing, which poses a huge challenge to the originally tight and limited wireless spectrum resources. On the other hand, the traditional fixed spectrum cooperative sensing and allocation algorithms result in extremely low spectrum utilization for a considerable part of the licensed spectrum. The purpose of this paper is to study the cooperative sensing and allocation algorithm of cognitive RS (radio spectrum) based on artificial intelligence. This dissertation focuses on cooperative perception and cognitive radio systems, respectively, from the aspects of cooperative perception of user fairness, maximization of system energy efficiency, and user detection when user access is busy. Firstly, a joint optimization model of fairness cooperative spectrum sensing and allocation is established to compensate the sensing overhead of cooperative users to ensure its fairness; then, define and analyze the energy efficiency of the cognitive system, and establish a joint optimization model of cooperative spectrum sensing and allocation based on artificial intelligence to maximize energy efficiency, and optimize wireless sensing and allocation parameters while ensuring maximum system energy efficiency. The experimental results show that when \( \eta = 0.7 \), the algorithm proposed in this study has reached 100% of the RS perception performance, while the traditional algorithm only has 93%. The algorithm proposed in this paper has greater advantages in perception and distribution performance.

Keywords: Artificial Intelligence, Cognitive Radio, Cooperative Spectrum Sensing, Allocation Algorithm

1. Introduction
With the continuous development of science and technology, society has entered the era of artificial intelligence [1-2]. The application of radio covers all aspects of human life, and radio communication must communicate through the wireless spectrum [3-4]. After basic cooperative sensing and allocation of cognitive RS sources, the original cognitive spectrum allocation algorithm no longer meets the
ever-increasing demand for human communication, and the lack of spectrum sources also hinders the development of science and technology and social progress [5-6]. People's demand for spectroscopy is increasing, which makes the emergence of cognitive radio technology in a timely manner. The effective distribution of the cognitive RS directly determines the use of resources in the cognitive spectrum [7-8]. Therefore, the research of artificial intelligence-based cognitive RS cooperative sensing and allocation algorithms has become the focus of research in various fields [9-10].

In the artificial intelligence-based cognitive RS cooperative sensing and allocation algorithm, many scholars at home and abroad have conducted in-depth discussions on it, and have achieved good results. For example, Hossain MA et al. The antenna cognitive radio sensing algorithm effectively improves the detection probability of energy detection and reduces the probability of false alarms, and overcomes the noise sensitivity problem of energy detection [11]. In addition, Yelalwar R et al. studied the optimization of cooperative spectrum sensing parameters, and proposed a method of selectively weighting system resource utilization and channel utilization to maximize system sensing efficiency, and achieved good research results [12].

This research optimizes and improves the cognitive RS writing perception and allocation problem based on artificial intelligence. By consulting relevant domestic and foreign research documents, the problem and shortcomings of the cognitive RS allocation algorithm are obtained. In view of the low utilization rate of spectrum resources due to the static spectrum allocation method, several algorithms of cognitive radio dynamic spectrum allocation are introduced, and the principle and application process are mainly introduced. At the same time, the application of the smart water drop algorithm to the cognitive RS allocation has a difference in the perception environment of the SU participating in cooperative sensing in the CSS, and a dynamic dual-threshold CSS algorithm is presented. Secondly, under the condition that the Fusion Center (FC) is in the notification channel fading relative to the SU, combined with the weighted CSS technology and the CSS technology based on the clustering structure, a multi-cluster weighted CSS algorithm is presented.

2. Cognitive RS Cooperative Sensing and Allocation Algorithm Based on Artificial Intelligence

2.1 Cooperative Sensing and Allocation of Cognitive RS
(1) Cooperative spectrum sensing
   Affected by factors such as shadow effects and multipath fading, the "hidden terminal" problem greatly attenuates the signal energy perceived by cognitive users, leading to misjudgment of the status of the primary user, thereby reducing the perception performance of the system. Cooperative spectrum sensing can perceive the primary user in a cooperative manner among the secondary users, prompting the secondary users with better channel environment to assist the poor secondary users to perform detection, and improving the overall sensing performance of the system. Each collaborating user transmits the detected main user information to the fusion center, and the fusion center finally makes a decision on the information fusion.

(2) Periodic collaborative perception
   The primary user has the priority to use the authorized frequency band. The prerequisite for the cognitive radio system to work is that it does not cause interference to the primary user. Therefore, real-time and efficient detection of the primary user's status is required. An effective method is to use periodic spectrum sensing. Divide the transmission time into several sensing time slots. In each sensing time slot, the method of "listening before transmission" is implemented, that is, the status of the current channel primary user is sensed first, and if the primary user does not exist, the transmission will be performed within the remaining time. Otherwise, it enters the waiting state and repeats the above operation until the next cycle.
   When using collaborative sensing, the sensing time is divided into local sensing and collaborative overhead. Each cooperative user independently detects the status of the primary user in the local perception phase, and uses the common channel to send the perception information to the fusion center during the collaboration overhead, and the fusion center makes the final decision.
(3) Cooperative perception and distribution of energy efficiency maximization

In communication systems, very high transmission power is often required to achieve a high communication signal-noise-ratio (SNR), which will also lead to a reduction in system bit-error-rate (BER) and therefore bring higher system throughput. However, higher transmission power also means that the battery life of the communication terminal will be reduced, and this will also have an impact on the ecological environment, which does not meet environmental protection requirements. Therefore, the objective function of energy efficiency can be defined as a trade-off between system throughput and total power loss in a unit time slot, where the total power loss includes two parts: the perceived loss power of the system and the transmission power.

(4) Joint optimization of fairness and cooperation for cognitive RS sensing and allocation

Although cooperative sensing can solve the "hidden terminal" problem and improve the overall perception performance of cognitive radio, the participation of secondary users in cooperative sensing will consume a certain amount of sensing power overhead. Under normal circumstances, the maximum transmission power is set for each user transmitter. If a certain user participates in cooperative sensing, a certain sensing power needs to be allocated to it, so the power used for transmission is reduced accordingly. This is unfair to cooperating users. The reduction of its transmission power will not only reduce the data transmission capacity, but also reduce the bandwidth allocated by the users. Therefore, it is necessary to compensate the perceived overhead of cooperative users to promote fairness among users.

2.2 Cooperative Sensing and Allocation Algorithm of Cognitive RS Based on Artificial Intelligence

(1) Cooperative perception and allocation of cognitive RS based on graph theory coloring model

In the wireless sensor network, the surrounding environment data is collected through sensor nodes, and the available spectrum holes in the network area are sensed, and the allocated spectrum is obtained through the spectrum allocation algorithm and data transmission is performed. The network structure of the wireless sensor network is characterized by the fact that WSNs nodes do not move or rarely move, and the number of nodes is huge, most of which are many-to-one or one-to-many transmission. The cooperation between nodes to complete the monitoring task needs to be based on the characteristics of the wireless sensor network, improve on the basis of the traditional model.

(2) Dynamic Dual-Threshold Cooperative Spectrum Sensing Algorithm

Suppose there are M SUs participating in the CSS, of which K SUs make a local decision, and the energy detection values of the SUs are in the fuzzy area. Based on the traditional dual-threshold energy detection model, this paper adopts the "soft-hard combination" fusion decision method, which makes full use of the perception data of SU while reducing the complexity. First, the hard fusion decision method of the "OR" criterion is adopted for users who can make a local decision, and the decision result is obtained; then the soft fusion decision method of EGC is used for the users who fall into the uncertain area to obtain the decision result; finally, FC evaluates the two Part of the result is judged for fusion. The specific judgment process is as follows:

(1) Hard judgments of K SUs that made judgments using the "OR" criterion:

\[ D_1 = \begin{cases} 
1, & \sum_{i=1}^{K} L_i \geq 1 \\
0, & \sum_{i=1}^{K} L_i = 0 
\end{cases} \quad (1) \]

(2) Soft decision of M-K SU using equal gain fusion:

\[ D_2 = \begin{cases} 
1, & \sum_{i=1}^{M-K} Y_i \geq \lambda_E \\
0, & \sum_{i=1}^{M-K} Y_i < \lambda_E 
\end{cases} \quad (2) \]

In the formula, the judgment threshold of \( \lambda_E \) —— EGC fusion.
3. Experimental Research on Cognitive RS Cooperative Sensing and Allocation Algorithm Based on Artificial Intelligence

3.1 Location-Based Clustering Algorithm
Step 1: Select reference node and initialize.
According to the distance from the participating SU to the FC and the distance between the SUs, J SUs are selected as the central reference user, and the user set of J clusters is initialized \( C_J = \{ m_j \} \).

Step 2: Cluster into clusters.
Gather the remaining \( N-J \) SU average classes into a cluster of user sets \( C_j = \{ m_j \} \), and assume that the number of SUs in each user set is \( D = N/J \) (take an integer). In the clustering process, the SUs with similar distances are grouped into a cluster.

Step 3: CH user selection.
Calculate the distance between all the SUs in each cluster and the FC, find the SU with the smallest distance as the CH user, and record the distance as \( d_j (j=1, 2, ..., J) \). The multi-cluster weighted fusion algorithm in this paper is to perform weighted fusion decision among multiple clusters on the basis that the upper layer has completed clustering and selected CH users.

3.2 Weighted Fusion Algorithm
Step 1: Local energy detection.
The SU in each cluster uses the energy detection method for local perception. Assume that the energy information collected by the first SU in the first cluster is \( y_{j,i} \), \( j=1, 2, ..., J \), \( i=1, 2, ..., D \), where \( J \) represents the format of the cluster, and \( D \) represents the number of SUs in the cluster.

Step 2: Fusion decision within the cluster.
The SU in each cluster transmits the energy value of its own local energy detection to the CH user. The CH user uses the EGC algorithm to make a fusion decision on the SU of the cluster. Then the CH user of the first cluster obtains the statistical decision value \( Y_j \) according to the EGC fusion rule.

Step 3: Calculate the weighting factor between clusters.
From the first stage of clustering algorithm, the distance between the CH user and FC in each cluster can be obtained, and the influence of the distance and the signal-to-noise ratio of the notification channel on the FC decision can be comprehensively considered, and the weighting factor for these two factors calculation.

Step 4: Weighted fusion decision between clusters.
CH users of all clusters report the decision result \( B_j \) ("0" or "1") of the cluster to FC through the notification channel, and the FC makes a decision after weighted fusion.

4. Cognitive RS Cooperative Sensing and Allocation Algorithm Based on Artificial Intelligence

4.1 Global Theoretical Detection Probability of the Three Algorithms under Different Notification Channel SNR
The parameters of the simulation in this experiment are set as follows: one PU, one FC, the number of SUs \( N=30 \), the number of clusters \( J=5 \), the number of SUs in each cluster \( D=6 \), each SU can only support the local sensing signal Familiar \( M=200 \), simulation times is 2000 times. Since this experiment is mainly to compare the performance of each algorithm in the notification channel fading environment, it is assumed that the perceptual channel SNR of the SU in each cluster is the same. Set to \( \gamma_{j,i} = 5dB \), it is assumed that when the SNR is -14dB, the recognition of the multi-cluster weighting algorithm is Knowing that the RS sensing and detection probability has reached 100%, the traditional clustering algorithm only reaches 100% when the SNR is13dB. The specific simulation results are shown in table 1:
Table 1. Global theoretical detection probability of three algorithms under different notification channel SNR(%)  

| SNR(dB) | OR fusion algorithm | Traditional clustering algorithm | Multi-cluster weighting algorithm |
|---------|---------------------|----------------------------------|----------------------------------|
| -20     | 0.29                | 0.35                             | 0.39                             |
| -19     | 0.36                | 0.43                             | 0.49                             |
| -18     | 0.44                | 0.55                             | 0.6                              |
| -17     | 0.55                | 0.68                             | 0.73                             |
| -16     | 0.69                | 0.8                              | 0.85                             |
| -15     | 0.82                | 0.91                             | 0.93                             |
| -14     | 0.92                | 0.97                             | 1.0                              |
| -13     | 0.98                | 1.0                              | 1.0                              |
| -12     | 1.0                 | 1.0                              | 1.0                              |

Figure 1. The global theoretical detection probability of the three algorithms under different notification channel SNRs(%)  

Figure 1 is the detection performance curve when the notification channel SNR is in the range of [-12 dB -20 dB]. It can be seen from figure 1 that under the same notification channel SNR, the global detection probability of the multi-cluster weighted CSS algorithm proposed in this study is significantly better than the other two algorithms, and the traditional clustering algorithm is better than the "OR" decision fusion algorithm. This is because when there is no difference in the SNR of the notification channels of all SUs, the clustering algorithm reduces the data transmission with FC and reduces the bit error rate of the converged channel in a channel fading environment. In addition, the improved algorithm also reduces the bit error rate of the converged channel. The distance fading factor is weighted, so even under the same SNR, the detection performance will be improved to a certain extent.
4.2 RS Sensing Performance of Three Algorithms in Simulation Environment 2
The parameters of the notification channel in the simulation environment 2 are: the average SNR of the CH in the four clusters is -20dB, -18dB, -16dB, -14dB, assuming that the distance between each cluster and the FC is different, and the cluster with high SNR is close the ROC simulation performance is shown in Table 2. When \( P_f = 0.7 \), the algorithm proposed in this study has reached 100\% of the RC perception performance, while the traditional algorithm only has 93\%. The specific simulation results are shown in Table 2:

Table 2. RS sensing performance of three algorithms in simulation environment 2(\%)

| \( P_f \) | OR fusion algorithm | Traditional clustering algorithm | Multi-cluster weighting algorithm |
|----------|---------------------|-------------------------------|----------------------------------|
| 0        | 0.03                | 0.05                          | 0.21                             |
| 0.1      | 0.28                | 0.41                          | 0.77                             |
| 0.2      | 0.42                | 0.59                          | 0.87                             |
| 0.3      | 0.55                | 0.71                          | 0.92                             |
| 0.4      | 0.67                | 0.78                          | 0.95                             |
| 0.5      | 0.73                | 0.85                          | 0.98                             |
| 0.6      | 0.82                | 0.89                          | 0.99                             |
| 0.7      | 0.88                | 0.93                          | 1                                |
| 0.8      | 0.92                | 0.97                          | 1                                |
| 0.9      | 0.98                | 1                             | 1                                |
| 1        | 1                   | 1                             | 1                                |

Figure 2. RS sensing performance of three algorithms in simulation environment 2(\%)

It can be clearly seen from Figure 2 that the algorithm proposed in this paper has great advantages in perceptual performance, while the other two algorithms have basically the same perceptual performance in these two environments. Even in simulation environment 2, the fusion SNR of each
cluster However, due to the different error rates of the notification channels of each cluster, FC did not treat the data separately during data fusion, resulting in a decrease in perception performance. However, the algorithm in this paper uses the method of weighting between clusters to reduce the perception difference caused by different environments. It has good robustness and is more suitable for the actual wireless channel environment. At the same time, because there are only clusters the head user transmits the sensing information to the FC. Compared with all the SUs transmitting the sensing information to the FC, the algorithm complexity is slightly reduced.

5. Conclusion
The efficient cooperative sensing and allocation of spectrum in cognitive radio can make use of artificial intelligence to adopt a certain allocation strategy with cognitive radio technology, so that the cognitive radio system can obtain the maximum communication benefits. In order to enable the cognitive system to effectively and dynamically allocate the perceived inertial resources to cognitive users, this paper uses the rapid convergence and robustness of artificial intelligence algorithms to apply the intelligent algorithm to the study of spectrum detection and segmentation, while considering To understand the influence of users and users of the RS, familiarize users with authorized users. Use spectrum for cognitive users when authorized users do not use spectrum. When you realize that users have no influence on authorized users, you can allocate spectrum resources to knowledgeable users to improve spectrum utilization. Through the combination of models and algorithms, parameter adjustment and experimental analysis, a better solution to the problem of spectrum cooperative sensing and allocation is provided.

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