Counting Credibility based Cooperative Spectrum Sensing Algorithm

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Abstract: In the cooperative spectrum sensing, if too many nodes take part in the cooperative data fusion, it would weigh the channel overhead and energy loss lot but improve the spectrum sensing performance little. This paper focuses on the channel overhead of cooperative spectrum sensing and the lifecycle of cognitive networks, and proposes a novel cooperative spectrum sensing algorithm. In the algorithm, all of the nodes are sorted by means of counting reliability. Only a part of nodes participate in the cooperative data fusion in the fusion centre. It cut down the number of nodes participating in the data fusion and save the average energy of the sensing nodes. The simulation results show that the proposed algorithm can effectively reduce channel overhead and prolong the lifecycle of cognitive network in the premise of ensuring the spectrum detection performance.

1 INTRODUCTION

With the growth of the wireless data traffic, the spectrum resources become more and more scarce (Akyildiz, 2008). Cognitive radio (CR) is an intelligent spectrum sharing technology and taken as a promising way to solve the problem (Wang et al., 2011). The main idea of CR is to access spectrum dynamically (Qu and Wang, 2009), (Yang et al., 2009), (Li et al., 2011). In the CR network, cognitive users (secondary users) opportunistically access the empty spectrum bands which has been assigned to the primary user (PU) but unused at present. The key to reuse the empty spectrum and to improve the spectrum efficiency is to ensure the CR senses spectrum accurately. However, due to the channel fading and multipath, a single cognitive node is often difficult to guarantee the validity of the spectrum sensing. Therefore, cooperative spectrum sensing is put forward to improve the performance of the spectrum sensing (Bai et al., 2013), (Mai et al., 2011), (Liu et al., 2012), (Bao et al., 2012).

The cooperative spectrum detection based on soft decision fusion makes full use of the information of sensing nodes to make accurate spectrum decision, but it increases the system overhead and the energy loss of sensing nodes (Zhang and Yang, 2003). It should be considered in cooperative spectrum sensing that how to reduce the overhead of the data transmission and the energy loss of the sensing nodes as far as possible in the premise of ensuring the spectrum sensing performance. Some algorithms were proposed to overcome these problems (Chair and Varshney, 1986), (Chen et al., 2008), (He et al., 2008). But they solve the problems only from the view of energy loss or lifecycle. A cooperative spectrum sensing algorithm based on node recognition (NRCS) was proposed to improve the spectrum sensing performance in the case of malicious nodes and reduce the system overhead simultaneously (Zhang et al., 2014). But the overhead of the data transmission and the energy loss of the sensing nodes are not lowest because all reliable nodes participate in the data fusion.

In this paper, we propose a counting credibility based cooperative spectrum sensing algorithm (CCCS) to reduce the channel overhead and prolong the lifecycles of cognitive networks. In the algorithm, all of the nodes are sorted according to their counting reliability. Only a part of nodes with largest or next larger reliability weighted factors take part in the cooperative data fusion in the fusion centre.

The rest of this paper is organized as follows. Section II presents the system model. Section III describes the cooperative spectrum sensing algorithm. Some simulation results are discussed in section IV. Conclusions are stated in section V.

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2 SYSTEM MODEL

Assume that there are one primary user and N cognitive users in the cognitive network, as shown in Figure 1. Two hypotheses, H_1 and H_0, represent the spectrum detected in the network is busy (the primary user uses the spectrum at present) and is free (the primary user does not use the spectrum at present), respectively. The spectrum sensing of the i^{th} cognitive user (sensing node), i=1······N, can be modelled as a binary hypothesis testing problem as follows

$$\begin{aligned} H_1: &\quad x_i(t) = h_i(t)\cdot s(t) + n_i(t) \\ H_0: &\quad x_i(t) = n_i(t) \end{aligned} \tag{1}$$

where $x_i(t)$ is the signal received in the i^{th} sensing node, $s(t)$ is the signal transmitted by the primary user, $h_i(t)$ is the channel gain of the i^{th} sensing node, $n_i(t)$ is the additive white Gaussian noise (AWGN) in the signal received of the i^{th} sensing node.

The cooperative spectrum sensing can be divided into two steps, local detection and data fusion. In the local detection, the i^{th} sensing node makes hypothesis testing after receiving the signal $x_i(t)$, and obtains local detection result "1" or "0". "1" represents the hypothesis H_1 is supported, "0" represents the hypothesis H_0 is supported. In the data fusion, the fusion centre fuses the local detection results from the sensing nodes, and makes final decision according to the decision rule and decision threshold.

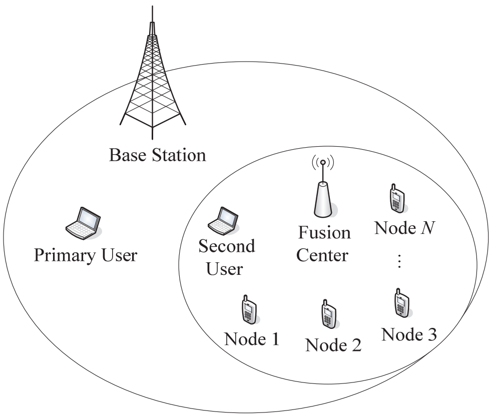

Figure 1: System model.

3 COOPERATIVE SPECTRUM SENSING ALGORITHM

It has been showed that the spectrum sensing performance in the cooperative spectrum sensing is dependant on the number sensing nodes which participate in the data fusion, and their reliabilities (Chair and Varshney, 1986). Note that the credibility of the sensing node is a accumulative result of the historical sensing information. That is to say, the present credibility of the sensing node is related to the sensing node's historical sensing results.

Definition 1. The credibility of the i^{th} sensing node in the m^{th} spectrum sensing is defined as

$$r_{i,m} = \begin{cases} r_{i,m-1}\rho + \cdots + r_{i,1}\rho^{m-1} + 1 & d_{i,m-1} = d_{FC,m-1} \\ r_{i,m-1}\rho + \cdots + r_{i,1}\rho^{m-1} - 1 & d_{i,m-1} \neq d_{FC,m-1} \end{cases} \tag{2}$$

where $r_{i,m-1}$ is the credibility of i^{th} sensing node in $(m-1)^{th}$ spectrum sensing , ρ is a attenuation factor which represents the strength of association with historical information, $0<\rho<1$; $d_{i,m-1}$ is the local detection result of i^{th} sensing node in $(m-1)^{th}$ spectrum sensing, $d_{FC,m-1}$ is the global decision result in $(m-1)^{th}$ spectrum sensing.

According to the local detection result and the global decision result in last time, the fusion center updates the credibility of the sensing node i cumulatively. When the local detection result of i^{th} sensing node, $d_{i,m-1}$, is the same as the global decision result of the fusion centre, $d_{FC,m-1}$, in $(m-1)^{th}$ spectrum sensing, "1" is added to the historical weighted credibility. And then, the credibility of the i^{th} sensing node in the m^{th} spectrum sensing is updated. When the local detection result of i^{th} sensing node, $d_{i,m-1}$, is different with the global decision result , $d_{FC,m-1}$, in $(m-1)^{th}$ spectrum sensing, "1" is subtract from the historical weighted credibility. And then, the credibility of the i^{th} sensing node in the m^{th} spectrum sensing is replaced. If the credibility replaced is smaller than 0, it will be replaced by 0. Moreover, the later credibility of the sensing node has larger weighted factor by means of the attenuation factor ρ. Therefore, the impact of accidental errors on spectrum detection caused by local detection can be eliminated as much as possible.

Definition 2. The reliability weighted factor of the i^{th} sensing node in the m^{th} spectrum sensing is defined as

$$w_{i,m} = \frac{r_{i,m-1}}{\sum_{k=1}^{N} r_{k,m-1}} \qquad i = 1, 2, \cdots N \tag{3}$$

When the fusion centre obtains the reliability weighted factors of all of the sensing nodes, it sorts them according to their reliability weighted factors and chooses the sensing node with largest reliability weighted factor, for example sensing node l,

$l \in \{1 \cdots\cdots N\}$, to participate the data fusion. Then, $d_{i,m-1}$ is sent to the fusion centre and the global detection statistics is formed as follows

$$T_{FC} = w_{l,m} \cdot d_{l,m} \tag{4}$$

Next, the fusion center makes the global decision according to the decision threshold as follows

$$\begin{cases} H_1: & d_{FC} = 1, \quad T_{FC} \geq \lambda \\ H_0: & d_{FC} = 0, \quad T_{FC} < \lambda \end{cases} \tag{5}$$

where λ is the decision threshold (Zhang et al, 2014).

If the hypothesis H_1 is supported, the fusion centre terminates the data fusion and achieves the spectrum detection result H_1 in this time. Otherwise, the fusion centre will select another with next larger reliability weighted factor, for example sensing node k, $k \in \{1 \cdots\cdots N\}$, to participate the fusion to form the new global detection statistics based on the last statistics as follows

$$T_{FC} = T_{FC} + w_{k,m} \cdot d_{k,m} \tag{6}$$

The fusion center will make the global decision again according to (5) until H_1 is supported or all of the sensing nodes have been selected to participate in the data fusion.

The cooperative spectrum detection algorithm based on the counting credibility above can be summarized as in Algorithm 1.

Algorithm 1: Counting Credibility Based Cooperative Spectrum Sensing Algorithm.

1: Calculate the credibility of all sensing nodes according to (2);
2: Calculate the reliability weighted factor of the all sensing nodes according to (3);
3: Sort all of the sensing nodes according to their reliability weighted factors;
4: Choose the sensing node with largest reliability weighted factor and form the global detection statistics according to (4);
5: Makes the global decision according to (5);
6: If the hypothesis H_1 is supported, the fusion centre ends the data fusion and achieves the spectrum detection result in this time. Otherwise, the fusion centre will select another with next larger reliability weighted factor to participate the fusion. Then it forms the new global detection statistics according to (6).
7: Go back to Step 5 until H_1 is supported or all of the sensing nodes have been selected to participate in the data fusion.
8: End.

4 SIMULATION AND ANALYSIS

We simulate the CCCS algorithm proposed in this paper in AWGN channel and compared it with cooperative spectrum detection algorithm based on node recognition (NRCS) (Zhang et al, 2014). In the simulation, the primary signal is modelled as a phase shift keying (PSK) signal with the 5000 Bauds and 10 MHz carrier frequency. The sampling frequency is 100 MHz and the number of sampling is 512. There are 8 sensing nodes in the CR network. The attenuation factor ρ of the node's credibility is 0.5.

Figure 2 shows the percentages of the nodes selected to participate in the cooperative data fusion. We compare the percentages between the CCCS and NRCS algorithms in two cases, there is one malicious node (Num = 1) and two malicious nodes (Num = 1), respectively. With the increase of SNR, the number of the nodes selected to participate in the cooperative data fusion in the CCCS algorithm decreases, but the one in the NRCS algorithm is relatively stable. In the case of one malicious node, when SNR is equal to -13 dB, the percentage of the CCCS algorithm is 0.5, while the one of the NRCS algorithm is 0.87. In the case of two malicious nodes, when SNR is equal to -13 dB, the percentage of the CCCS algorithm is less than 0.4, while the one of the NRCS algorithm is close to 0.75. Compared with the NRCS algorithm, the CCCS algorithm cuts down the number of the nodes to participate in the cooperative data fusion and reduces channel overhead effectively.

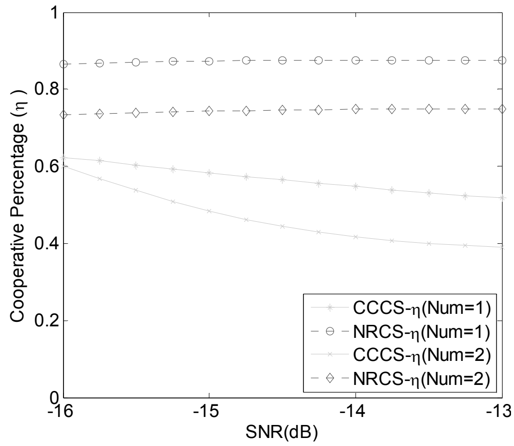

Figure 2: Percentages of cooperative nodes in the CCCS and NRCS algorithms.

Figure 3 and Figure 4 show the comparisons of the detection probabilities and false alarm probabilities of the CCCS and NRCS algorithms in the two cases respectively. It is obvious that the spectrum sensing performance of the CCCS algorithm, no matter the detection probability or the false alarm probability, is almost the same as one of the NRCS algorithm. That is to say the node selection algorithm based on the counting reliability proposed does not decrease the spectrum sensing performance of the cognitive network.

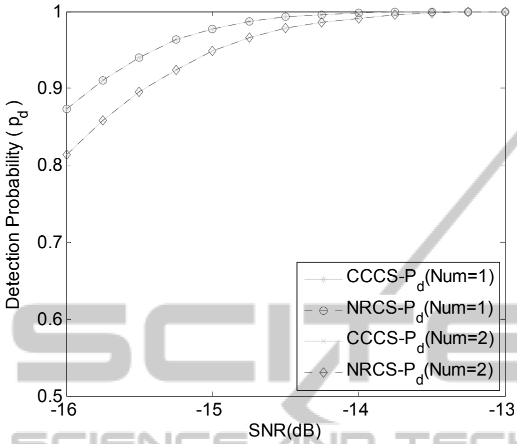

Figure 3: Detection probabilities of the CCCS and NRCS algorithms.

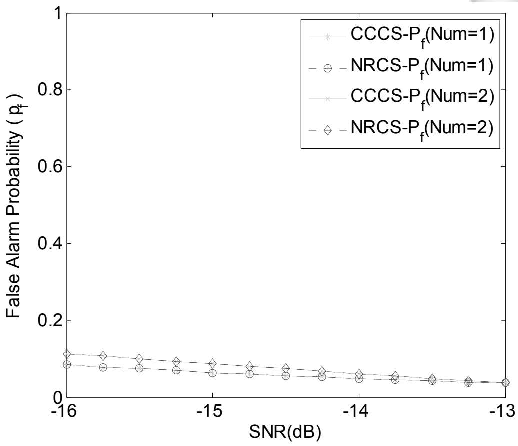

Figure 4: False alarm probabilities of the CCCS and NRCS algorithms.

Figure 5 shows the lifecycles of cognitive networks which adopt the CCCS and NRCS algorithms in the two cases. When the NRCS algorithm is used, all of the reliable nodes participate in the cooperative data fusion, every node consumes it's energy in each data fusion. Consequently, the lifecycle is shorted. When the CCCS algorithm is used, only nodes selected participate in the cooperative data fusion, the average frequencies of the sensing nodes participating in the data fusion is reduced as far as possible, the energy loss of each sensing node is minimized. Therefore, the lifecycle is prolonged.

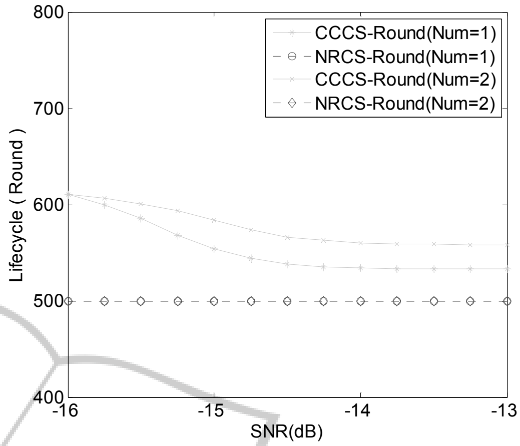

Figure 5: Lifecycles of cognitive networks with the CCCS and NRCS algorithms.

From Figure 2 to Figure 5, we see that the CCCS algorithm would cut down the number of node participating in the cooperative data fusion, save the average energy of the sensing nodes, reduce the channel overhead of the system, and prolong the lifecycle of the cognitive network. But it does not debase the spectrum sensing performance of the cognitive network.

5 CONCLUSIONS

In order to reduce the channel overhead and prolong the lifecycle of the cognitive network, a novel cooperative spectrum sensing algorithm based on counting credibility is proposed. In the algorithm, all of the nodes are sorted according to their counting reliability. Only a part of nodes with best or Sub-best reliability take part in the cooperative data fusion in the fusion centre. It decreases the number of node participating in the data fusion and save the average energy of the sensing nodes. The simulation results show that the proposed algorithm can effectively reduce channel overhead and prolong the lifecycle of cognitive networks.

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