Cooperative Spectrum Sensing Algorithm based on Node Filtrating in Cognitive Radio Networks

Fang Ye, Hui Zhang, Xun Zhang, Yuan Tian
College of Information and Communication Engineering,
Harbin Engineering University,
Harbin, China
E-mails: yefang0923@126.com, zhanghui_940820@163.com, zhangxun0611@gmail.com, tianyuan347@126.com

***Abstract*—The sensing result of cooperative spectrum sensing in cognitive radio significantly depends on the reliability of local detection, and signal-to-noise ratio (SNR) difference among secondary users leads to disparate reliability in local sensing. A novel cooperative spectrum sensing algorithm based on node filtrating (NF-CSS) is proposed in this paper, avoiding low SNR nodes being involved in the collaboration by decreasing the number of nodes. Simulation results showed the algorithm eliminates the influence of low SNR nodes and effectively improves system sensing performance under uneven distribution of SNRs.**

Keywords—Cooperative spectrum sensing; SNR threshold; Accurate average energy detection

I. INTRODUCTION

Cognitive radio (CR) enhances spectrum usage efficiency by allowing secondary users (SUs) to access licensed bands intermittently unoccupied by primary users (PUs) [1,2]. In spectrum sensing, energy detection (ED) gains popularity owing to its simplicity and applicability. An improved energy detection (IED) added a test statistic to avoid misdetections caused by instantaneous drops in signal energy[3]. [4] provides more accurate average energy detection (AAED) to enhance the accuracy by removing current observation event from average energy calculation, serving as local sensing scheme in this paper.

Cooperative spectrum sensing (CSS) [5-7] eliminates shadow fading by using space diversity. Most solutions assumed SUs experience independent and identically distributed fading with the same SNR, not considering reliability difference among SUs. In [8], transmission fusion weighting parameters cause further channel congestion and sensing delay. [9] improves the reliability of single SU, but seriously degrades performance when SU experiences deeply fading. [10,11] have lower complexity. In this paper, we propose a CSS algorithm based on node filtrating (NF-CSS). SUs firstly conduct local sensing employing AAED, then transmitting sensing results to FC. Node filtrating based on the designed rule is then performed, only eligible nodes are qualified to participate data fusion, the global decision is made under the uneven distribution of SNR.

The rest of this paper is organized as follows: Section II discusses network model. Section III elaborates the NL-CSS algorithm. Section IV shows the simulation results and analysis.

II. NETWORK MODEL

Spectrum sensing in CRNs at the nth ($n=1,\cdots,N$) time instant is formulated as the binary hypothesis test problem:

$$y_j[n]=\begin{cases} w_j[n], & \mathcal{H}_0 \\ x[n]+w_j[n], & \mathcal{H}_1 \end{cases} \tag{1}$$

where $\mathcal{H}_0$ is a hypothesis stating there is no PU in the sensing spectrum band, and $\mathcal{H}_1$ indicates the presence of PU. N denotes sample numbers. $y_j[n]$ ($j=1,\cdots,M$) is the signal received by the jth SU, $x[n]$ is the signal transmitted by PU. $x[n]$ is attenuated by zero-mean additive white Gaussian noise (AWGN) $w_j[n]$ (variance σ_W^2).

The centralized CSS system model with one PU, one FC and M SUs is adopted. SUs detect the frequency band and send local binary decisions to the FC through reporting channel. OR rule is used as the final fusion strategy:

$$\begin{aligned} Q_d &= 1-\prod_{j=1}^{P}\left(1-P_{d,j}\right) \\ Q_f &= 1-\prod_{j=1}^{P}\left(1-P_{f,j}\right) \end{aligned} \tag{2}$$

where $P_{d,i}$ and $P_{f,i}$ are the detection and false alarm probability of jth cognitive node; P is the number of collaborative users; Q_d and Q_f are the global detection and false alarm probability. When at least 1 out of P cognitive nodes detect the existence of primary user, the final decision declares the presence of PU.

III. THE BASIC IDEA OF NF-CSS ALGORITHM

From previous discussion we can learn that SNRs of SUs should be considered for improving sensing performance, we propose a novel CSS algorithm based on node filtration in this paper. Under uneven distribution of nodes, the algorithm eliminates the influence of nodes with low SNR and improve the performance of cognitive system by reducing nodes number in the collaboration. Detailed implementation process of the NF-CSS algorithm are as follows:

Step 1 - SUs conduct local detection using AAED and transmit sensing results and SNR estimations $\gamma_1,\gamma_2,\ldots,\gamma_M$ to the FC;

Step 2 - After gathering SNR estimations and local results, FC calculate the SNR proportion of each SU according to the following rule and set a reasonable SNR threshold $\lambda_{SNR} \in [0,1]$ in line with actual communication environment;

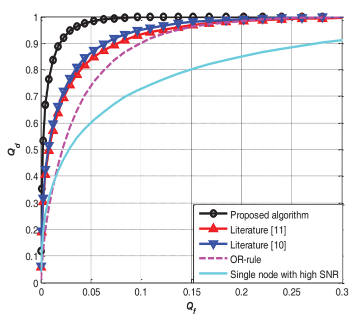
$$p_j = \frac{\gamma_j}{\sum_{j=1}^{M} \gamma_i} \quad (3)$$

Step 3 – The FC compare and filtrate SUs according to SNR proportion values. If p_j of the SU_j is greater than λ_{SNR}, then it is qualified to participate fusion, otherwise it will be abandoned. With the assistant of the nodes' SNR information, we eliminate the influence of nodes with poor properties. The new method thus improves sensing performance;

IV. Simulation Result and Analysis

We simulate the performance of the proposed algorithm with other three sensing methods: [10], [11] and OR-rule CSS. The results are presented by receiver operating characteristic curves (ROCs). Simulation environment is as follows: one PU and one FC, seven SUs randomly distributed in CRN; The received signal SNR are respectively {-9.17, -10.01, -12.85, -14.69, -18.73, -22.39, -24.05} in dB; SNR threshold is set as 0.1; Sampling number is 1024. Simulations in this paper are conducted under low false-alarm probability

Figure 1 displays ROC curves of comparative algorithms. It can be seen that the overall detection performance of the NF-CSS algorithm is superior to comparative algorithms. The detection probability of the NF-CSS and [10] respectively improved 22.96% ~ 36.18% and 13.76% ~ 23.49% compared to the OR-rule algorithm, which means that the NF-CSS exhibits better sensing performance. Hence the novel NF-CSS is more conducive to protect the authorized users from interference.



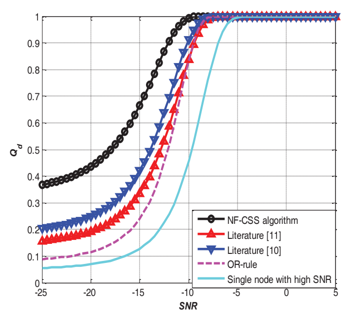


Fig. 1. Sensing Performance of Algorithms. ($Q_f - Q_d$)

Fig. 2. Sensing Performance of Algorithms. ($\mathrm{SNR} - Q_d$)

From Figure 2, we can observe that, as SNR changes between -25dB and 5dB, the difference of global detection probability between NF-CSS and [10], [11] reached the maximum when SNR is -13dB, respectively promoted by 0.2479 and 0.3468. In addition, under the same condition of SNR, the global detection probability of the NF-CSS algorithm outperforms the contrastive algorithm, which means the NF-CSS algorithm shows higher detection accuracy.

Considering the change of detection probability when SNR threshold varies within a certain scope. Figure 3 shows the simulation result with respect to the variation of detection probability as SNR threshold changes. From the curves we can infer that, the decrease of threshold leads to the increase of the number of nodes with high quality participated in CSS, thus it is not sensible to as-sign an oversize SNR threshold value.

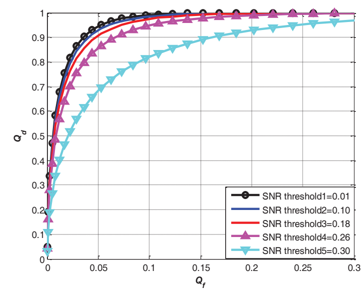


Fig. 3. Sensing Performance of Algorithms under different SNR thresholds.

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