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Research Article

Optimization of Detection Error Rate in Cooperative Spectrum Sensing Using Multi-Objective JAYA Algorithm

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ABSTRACT

In order to make the most of the available spectrum, Cognitive Radio (CR) is used. When a licensed user isn't actively utilizing the spectrum, CR may interact with each other using it. Therefore, CR places a premium on spectrum sensing, the process of observing the presence of the main user. Cooperative spectrum sensing is a method for quickly identifying spectrum gaps in cognitive radio networks (CRNs) by merging the sensing data from different cognitive radio users. Cooperative spectrum sensing's overall performance is largely affected by how well secondary users' and the fusion center's local observations are combined. The accuracy of local observations and the data acquired by the fusion center (FC) are the two main factors that affect the detection performance. That is why system performance is affected by global decision logic and the amount of bits transferred to the fusion center (FC). However, since the sensing data collection control channel has a limited bandwidth, it is essential to quantify the received data on the energy of the signal for every user. We provide a quantized cooperative spectrum sensing method after researching coordinated spectral sensing methods based on energy detection. Through the optimization approach that is based on the Multi-Objective JAYA Algorithm, we are able to create an ideal quantized data fusion scheme that optimizes the detection error probability for a precise value of threshold. Results demonstrate that the proposed framework is valid, with the multi-objective JAYA (MOJAYA) based performance being almost identical to that of the standard soft combining technique while using less bandwidth and overhead.

Keywords: Cognitive Radio, Cooperative Sensing, Hard combination, Soft combination, Multi-Objective JAYA(MOJAYA)

I. INTRODUCTION

The Federal Communications Commission is considering granting SUs opportunist access to the licensed spectrum, subject to no interference with PUs or license holders, in order to address the issue of inefficient radio spectrum utilization, when a large portion of the available spectrum goes unused [1]. Cognitive radio networks need SUs to detect the existence or absence of the main user (PU) signal in order to prevent interference with licensed users. Propagation loss and secondary-user (SU) disturbance constantly cause the PU signal to experience severe fading effects. In order to reduce the impact of fading, we may take use of the diversity benefit that comes from using many SUs so that we may collectively identify the spectrum.

When secondary users work together for spectrum sensing, the likelihood of detections increases because the users' channel conditions provide geographic variety, with each user experiencing their own unique shadowing and fading. Cooperative gain, which is an enhancement in performance via collaboration, also reduces the sensitivity needed for secondary users. Cognitive radio devices might be implemented at a cheap cost since precise radio signal measurement and detection might not be required. Energy detection is frequently simple and straightforward sensing methods. All secondary users are assumed to employ energy detection for sensing in this article. A key component of cooperative schemes and spectrum sensing in particular is the method of reporting the local choice to the fusion center. As an example, a lot of research focused on the two extremes—hard binary judgments and soft decisions.

Quantized Several publications have suggested sensing in cooperative manner schemes. The suggested method of spectrum searching in [2] makes use of Welch's periodogram and discusses the trade-off between cooperative users and sensing information. According to Dempster-Shafer theory, the sensing technique is outlined in [3]. Methods such as Lloyd-max quantization and uniform quantization are both considered. To choose the best quantizer with the least amount of error, the Lloyd-max technique is used in [4] as well. In reference 5, the Neyman-Pearson criteria is used. Using log-likelihood adds another layer of complexity to the system, as shown in [4],[5]. To increase the likelihood of detection, the two-bit quantization approach is suggested in [6].

Following is the outline of the paper. The cooperative spectrum sensing system paradigm is presented in Section II. Section III outlines several data fusion strategies for sensing of spectrum in cooperative way, including hard, soft, and quantized approaches. The optimization issue that was provided in section IV is solved using the multi-objective JAYA (MOJAYA) algorithm, which is discussed in part V. Finally, Section VII describes concluding thoughts, and Section VI presents the results of the simulations, which also compare our optimized model to the standard technique.

II. OBJECTIVES

The objective of this research is to improve the spectral efficiency of the cognitive radio so that overall quality of voice communication as well as data communication service will be improved without disturbing the Primary user or a license user using limited resources.

III. METHODOLOGY

Coopertive Sectrum Sensing

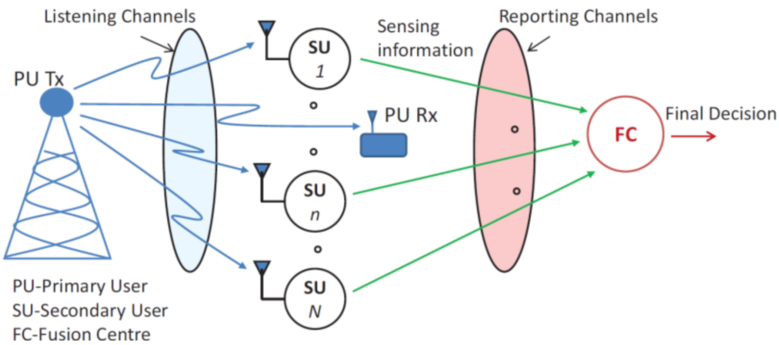

Figure 1. Modelling cognitive radio for cooperative spectrum sensing

As seen in Figure 1, let's assume that the Cognitive Radio RN has N Secondary Users (SU) and an FC. whether you want to know whether a PU is around, the fusion center receives binary choices supplied by individual SUs that perceive their local spectrum information. Choosing between the two possibilities, H_0: signal not transmitted and H_1: signal conveyed, is the purpose of the spectrum sensing [7],[8]. Regarding this matter, two probabilities are typically linked with spectrum searching: the false alarm rate (P_f), which is the likelihood of detecting a signal's presence when none exists, and the detection rate (P_d), which is the likelihood of a signal's correct detection. If the detection probability is high, the main user will be safe, but if the false alarm probability is large, the cognitive radio network's throughput will be limited. When discussing the theory of signal detection, the receiver operating characteristics (ROC)—the likelihood of detection relative to the likelihood of false alarm—is a common way to depict the detector's performance.

$$x(t) = \begin{cases} n(t), & H_0 \\ h\ s(t) + n(t), & H_1 \end{cases} \quad (1)$$

A. Optimization Problem

By maximizing P_d regardless of P_f constraints, the Neyman-Pearson optimality criteria is the best fit for spectrum sensing, which primarily aims to determine whether the channel state is vacant (H_0) or actively employed (H_1). Optimal quantized spectrum sensing collaboration and global logic for decisions are achieved by adjusting the threshold, as different values alter the quantization and the accompanying choice. Grounded on the P_f constraint. To get the best results using quantization spectrum sensing collaboratively and global decision logic, try experimenting with different threshold values; they'll affect the quantization and the decisions that follow.

Optimization problem: Minimize P_e

The methods mentioned above optimize the thresholds to discover the best ones for the quantized spectrum sensing cooperation that has been presented, taking into account the specified P_f and P_d. pathways connecting nodes in the network. Subscriber identities and other communications are safe even if an attacker takes over the channel.

B. Multi objective JAYA Based Solution

The MOJAYA algorithm is an improved version of the original JAYA algorithm, which stands for multi-objective JAYA. For optimization problems with both constraints and no constraints, the approach proposed in reference [9] is simple yet effective. One of the main ideas behind the algorithm is to steer the solution away from the worst case scenario and towards the best one [10]. Unlike parameter algorithms, multi-objective JAYA does not rely on any input parameters. A few of control settings are all that's needed.

One distinctive feature of optimization techniques, and a hallmark of the multi-objective JAYA algorithm, is its lack of parameters [11][12]. It is simpler to build the Multi-objective JAYA method than the one-step TLBO algorithm. The goals of the algorithm are to perform well (i.e., find the optimal solution) and avoid making mistakes (i.e., reject the poorest alternative).

The method is called Jaya, which means victory in Sanskrit, since it achieved the maximum value by finding the most beneficial solution. At each iteration 'i', it is important to consider 'm' design parameters (j = 1,2,3,...,m) and a population size of 'n' (k = 1,2,3,...,n) in order to maximize the objective function f(x). Here are the basic equations of the JAYA algorithm from which multi-objective JAYA is derived: for each possible solution, we compute the fitness and assign the optimal value of f(x), denoted as f(x)best. Similarly, for the candidate with the worst performance, denoted as f(x)worst, we assign the minimum value of f(x). To calculate the updated value of $x'_{j,k,i}$, these equations are also used in our optimization problem.

$$y'_{j,k,i} = y_{i,j,k} + t_{1,j,i}\left(y'_{j,best,i} - |y_{j,k,i}|\right) - t_{2,j,i}\left(y'_{j,worst,i} - |y_{j,k,i}|\right) \tag{2}$$

The function $y'_{j,k,i}$ is kept and considered acceptable if it produces a best-function value. At the last iteration, all the function values that were accepted are kept. The next iteration takes the previously specified values as input. Applying the Multi-objective JAYA method to optimization problems with constraints yields very good results. Additionally, the statistical testing has shown that the suggested method is considerably superior. The provided method depicts the Multi-objective JAYA algorithm being used to compute the weight, w_i

IV. RESULTS AND DISCUSSION

The performance of the 2-bit softened fusion approach used in CSS, which is based on the Muti-objective JAYA algorithm, has been evaluated using a simulation. We compare traditional hard combining rules like Half VOTING, MAJORITY, OR, etc., with more traditional soft combining rules such assigning equal weightage to every node (EGC) to get the detection probability for the ROC. Pe, the error rate for spectrum sensing, is the fitness function in computer simulations. Table 1 shows the values of the simulation parameters in the ideal spectrum sensing framework, which assumes an idle channel and does not include any malicious nodes.

Table 1. List of Simulation Parameter

Sr.	Parameter	Value/ Range
01	Time Bandwidth Product	10
02	Channel	Nakagami
03	SNR	10dB
04	Total CR Nodes	25
05	Samples of signal (M)	5u
06	Threshold range	0 to 25
07	Population Size	30
08	Frame duration T	10ms
09	Number of noisy reporting channel	0
10	Number of Malicious Node	0

A simulation was utilized to assess the efficacy of the 2-bit softened fusion method used by CSS, which is derived from the Muti-objective JAYA algorithm. The detection probability for the ROC is obtained by comparing classic soft combining rules, such as allocating equal weightage to every node (EGC), with traditional hard combining rules, such as Half VOTING, MAJORITY, OR, etc. In computer simulations, the fitness function is represented by P_e, the spectrum sensing error rate. The ideal spectrum sensing architecture, as shown in Table 2, uses a channel that is not in use and does not include any malicious nodes. The simulation parameter settings are aimed to set to their default levels

Table 2. Comparative table of proposed method for Nakagami Channel

Threshed\Pe	OR	MAJ	AND	EGC	MO-JAYA
0	1.00	1.00	1.00	9.95	9.95
2	0.91	0.94	0.96	0.86	0.86
4	0.80	0.92	0.93	0.76	0.76
6	0.74	0.90	0.89	0.66	0.66
8	0.69	0.87	0.86	0.54	0.54
10	0.69	0.87	0.86	0.34	0.34
12	0.51	0.76	0.75	0.22	0.22
14	0.69	0.87	0.86	0.34	0.34
16	0.69	0.87	0.86	0.54	0.54
18	0.74	0.90	0.89	0.66	0.66
20	0.80	0.92	0.93	0.76	0.76
22	0.91	0.94	0.96	0.86	0.86
25	1.00	1.00	1.00	9.99	9.99

V. CONCLUSION AND FUTURE SCOPE

The impact of data fusion schemes on performance of spectrum sensing in cooperative manner is examined in this research. We improved the quantization parameter, also known as the threshold value, and suggested a quantized spectrum sensing cooperative method. The optimized technique achieves performance that surpasses that of the hard data fusion scheme and is very near to that of the top limit of data fusion schemes, the soft data fusion strategy based on EGC. In comparison to alternative data fusion schemes, our multi objective JAYA based suggested solution uses less bandwidth, is less complicated, and has lower overhead. Depending on acceptable error rate requirements and the available reporting channel bandwidth, we may choose an acceptable data fusion technique and rule for practical implementation.

The paper's next endeavors include creating an optimum sensing framework, improving throughput and sensing time, and creating an adaptive SNR weight vector

VII. CONFLICTS OF INTEREST

"The authors affirm that they have no conflicts of interest with respect to this paper's publication"

REFRENCES

[1] S.Haykin, "Cognitive radio: Brain-empowered wireless communications," IEEE J. Sel. Areas Commun., vol. 23, no. 2, pp. 201–220, Feb. 2005.

[2] M. Mustonen, M. Matinmikko, and A. Mammela, "Cooperative spectrum sensing using quantized soft decision combining," in Cognitive Radio Oriented Wireless Networks and Communications, 2009. CROWNCOM' 09. 4th International Conference on. IEEE, 2009, pp. 1–5.

[3] N. Nguyen-Thanh and I. Koo, "Evidence-theory-based cooperative spectrum sensing with efficient quantization method in cognitive radio," Vehicular Technology, IEEE Transactions on, vol. 60, no. 1, pp. 185– 195, 2011.

[4] ——, "Log-likelihood ratio optimal quantizer for cooperative spectrum sensing in cognitive radio," Communications Letters, IEEE, vol. 15, no. 3, pp. 317–319, 2011.

[5] S. Zahabi, A. Tadaion, and S. Aissa, "Neyman-pearson cooperative Spectrum sensing for cognitive radio networks with fine quantization at local sensors," Communications, IEEE Transactions on, vol. 60, no. 6, pp. 1511–1522, 2012.

[6] J. Ma, G. Zhao, and Y. Li, “Soft combination and detection for cooperative spectrum sensing in cognitive radio networks,” Wireless Communications, IEEE Transactions on, vol. 7, no. 11, pp. 4502–4507
[7] A. Ghasemi and E. S. Sousa, “Collaborative spectrum sensing for opportunistic access in fading environments,” in Proc. DySPAN, Baltimore, MD, Nov. 8–11, 2005, pp. 131–136
[8] radios,” IEEE Signal Processing Magazine, Vol. 25, No. 6, pp. 63–70, 2008
[9] Rao RV, More KC, Coelho LS, Mariani VC (2017) Multi-objective optimization of the stirling heat engine through self-adaptive jaya algorithm. J Renew Sustain Energy 9(3):033703
[10]Berrouk F, Bouchekara HREH, Chaib AE, Abido MA, Bounaya K, Javaid MS (2018) A new multi-objective jaya algorithm for solving the optimal power fow problem. J Electrical Syst 14(3):165–181
[11] Srinivasarathnam C, Yammani Chandrasekhar, Maheswarapu Sydulu (2019) Multi-objective jaya algorithm for optimal scheduling of dgs in distribution system sectionalized into multi microgrids. Smart Sci 7(1):59–78
[12]Rao RV, Keesari HS. Rao algorithms for multi-objective optimization of selected thermodynamic cycles. Engineering with Computers. 2021 Oct; 37(4):3409-37