

Response Sheet to Comments Given in MS: 1085437356921148

- *Paper Number: MS: 1085437356921148*
- *Title: A Cluster-Based Selective Cooperative Spectrum Sensing Scheme in Cognitive Radio*

Thank you for your valuable comments. According to your comments, we have revised our paper and we are re-contributing our modified manuscript to EURASIP WCN.

Reviewer 1 comments to the Author(s)

- 1) the authors seem to be unaware of many recent works on the field; their publication list needs to be seriously updated and enriched; the authors novelty, if any, compared to recent works should be clearly shown;
- 2) the ‘intelligence’ of the proposed method, as the authors claim, should be justified in the introduction;
- 3) the language needs to be revised in many parts in this paper;
- 4) Define all variables in (13);
- 5) Below (14) the authors state “the SNR of received primary signal in each cluster is identical”; they should rephrase since they most probably mean sth else or clarify; the same for the notations in (15), what Λ : a notation or a random variable?
- 6) (16) and on should be clearer;
- 7) The appendix is redundant, the result is trivial; a reference is enough;
- 8) The reasoning related to the FFT must be clearer too;

We make replies to the reviewer 1’s comments given to the authors as follows:

Comment 1

the authors seem to be unaware of many recent works on the field; their publication list needs to be seriously updated and enriched; the authors novelty, if any, compared to recent works should be clearly shown;

Authors’ reply

Thank you very much for your comment!

We have supplemented some of recent works and added some sentences to introduction section as follows:

...

CSS schemes require a large communication resource including sensing time delay, control channel overhead and consumption energy for reporting sensing data to the FC, especially when the network size is large. There are some previous works [3]- [9] that considered this problem. In our previous work [3], we proposed an ordered sequential reporting mechanism based on sensing data quality to reduce communication resources. **A similar sequential ordered reports transmission approach was considered for reducing reporting time in [4]. However, reporting time of these methods is still unpredictably long. In [5], the authors proposed to use censored truncated sequential spectrum sensing technique for saving energy. On the other hand, cluster-based CSS schemes are considered for reducing the energy of CSS [6], and for minimizing the bandwidth requirements by reducing the number of terminals reporting to the fusion center [7].** In [8], G. Chen et al. proposed a cluster-based CSS scheme to optimize the cooperation overhead along with the sensing reliability. In fact, these proposed cluster schemes can reduce the amount of direct cooperation with the FC, but cannot reduce the communication overhead between CUs and the cluster header. A similar problem can be observed in the cluster scheme in [9], though the optimal cluster size to maximize the throughput used for negotiation is identified. Another consideration of the cluster scheme is to enhance sensing performance when the reporting channel suffers from a severe fading environment [10, 11].

Some references are added as follows:

...

3. N. Nguyen-Thanh and I. Koo, "An Efficient Ordered Sequential Cooperative Spectrum Sensing Scheme Based on Evidence Theory in Cognitive Radio", *IEICE Trans. Commun.*, Vol. E93.B, No. 12, pp.3248-3257, 2010.

4. L. Hesham, A. Sultan, M. Nafie, and F. Digham, "Distributed Spectrum Sensing With Sequential Ordered Transmissions to a Cognitive Fusion Center", *IEEE Transactions on Signal Processing*, vol. 60, pp. 2524-2538, 2012.

5. S. Maleki, and G. Leus, "Censored Truncated Sequential Spectrum Sensing for Cognitive Radio Networks," *IEEE Journal on Selected Areas in Communications*, vol. 31, pp. 364-378, 2013.

6. L. De Nardis, D. Domenicali, M.-G. Di Benedetto, "Clustered hybrid energy-aware cooperative spectrum sensing (CHESS)," Cognitive Radio Oriented Wireless Networks and Communications, 2009. CROWNCOM '09. 4th International Conference on , June 2009, pp.1-6.

7. S. Hussain and X. Fernando, "Approach for cluster-based spectrum sensing over band-limited reporting channels," *IET Communications*, vol. 6, pp. 1466-1474, 2012.

8. Chen Guo, Tao Peng, Shaoyi Xu, Haiming Wang, Wenbo Wang, "Cooperative Spectrum Sensing with Cluster-Based Architecture in Cognitive Radio Networks," Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th, April 2009 , pp.1-5.

9. E. Karami, A.H. Banihashemi, "Cluster Size Optimization in Cooperative Spectrum Sensing," Communication Networks and Services Research Conference (CNSR), 2011 Ninth Annual, May 2011, pp.13-17

10. N. Reisi, M. Ahmadian, V. Jamali, and S. Salari, "Cluster-based cooperative spectrum sensing over correlated log-normal channels with noise uncertainty in cognitive radio networks," *IET Communications*, vol. 6, pp. 2725-2733, 2012.

11. C. Sun, W. Zhang, K.B. Letaief, "Cluster-based Cooperative Spectrum Sensing for Cognitive Radio Systems," in Proc. IEEE Int. Conf. Commun., Glasgow, Scotland, UK, 2007, pp. 2511-2515.

...

Comment 2

the 'intelligence' of the proposed method, as the authors claim, should be justified in the introduction;

Authors' reply

Thank you very much for your comment!

The word 'intelligence' seems inexact in our intension. Therefore, we replace the word 'intelligent' by 'efficient'. The revised manuscript was changed as follows:

- In introduction section:

In this paper, we propose a cluster-based selective CSS scheme which utilizes an **efficient** selective method for the best quality sensing data and a parallel reporting mechanism. The selective method is applied in each cluster to implicitly select the best sensing node during each sensing interval as the cluster header without additional collaboration among CUs....

- In section 3:

...However, there are three issues with the proposed scheme that need to be considered:

1. How can the scheme **efficiently** select the cluster header, which is the node with the best quality for sensing data, for each sensing interval without any extra overhead among nodes in the cluster?
2. How can the cluster header optimally make the cluster decision?
3. What is the method for reporting the cluster decision to the FC?

...

Comment 3

the language needs to be revised in many parts in this paper;

Authors' reply

Thank you very much for your comment!

We have revised grammatical mistakes carefully. After that, the paper has been also revised by a native speaker.

Comment 4

Define all variables in (13);

Authors' reply

Thank you very much for your comment!

The variables in (13) are already defined in (6) and (7). For clarifying the equation, we added some words as follows:

where $W_0 = \log \frac{\pi_1}{\pi_0}$ and

$$W_i = \begin{cases} \log \frac{p_{d_i}}{p_{f_i}} & \text{if } D_i = 1 \\ \log \frac{1-p_{d_i}}{1-p_{f_i}} & \text{if } D_i = -1 \end{cases} \quad (13)$$

Local false alarm probability p_{f_i} and local detection probability p_{d_i} are defined in (6) and (7), respectively.

Comment 5 & 6

5) Below (14) the authors state “the SNR of received primary signal in each cluster is identical”; they should rephrase since they most probably mean sth else or clarify; the same for the notations in (15), what Λ : a notation or a random variable?

6) (16) and on should be clearer;

Authors' reply

Thank you very much for your comment!

We have revised and changed the position of the index c_j such that the formulas of (15), (16) and some others are clearer.

Comment 7

The appendix is redundant, the result is trivial; a reference is enough;

Authors' reply

Thank you very much for your comment!

We agree that the derivation of (22) is trivial. However, it should be notice that in most of literatures concerning order statistic, the case of absolute value order are not considered. Therefore, it will be inconvenience to read the paper without explanation by the derivation of (22).

Comment 8

The reasoning related to the FFT must be clearer too;

Authors' reply

Thank you very much for your comment!

Recently, it is common to use an FFT block for decoding an OFDM signal. Since the parallel reporting signal received at fusion center has a similar characteristic with OFDM signal, it is possible to adopt FFT block for decoding reported signal of the proposed method. For clarifying this point, we added some words as follows:

The remainder problem with this parallel reporting method is that the FC needs to be equipped with parallel communication devices such as an FFT block, **which is usually used in OFDM receiver**, or a filter bank block to detect multiple reporting frequencies. However, this requirement is not a big issue.

Reviewer 2 comments to the Author(s)

- 1) In the abstract "strongly reduce" seems to be not a correct word. Do you mean "considerably reduce"?
- 2) Introduction, the 3rd sentence, "secondary assess is no interference...". This sentence is not clear to me. Please rephrase.
- 3) In page 2, last sentence, "PU" is not defined.
- 4) In page 3, before equation (3), "with M degrees of freedom". What is "M" here?
- 5) In equation (4), the authors used 2 notation N. I guess you want to mention Normal distribution and degree of freedom. However, you must use different symbol for Normal distribution. Perhaps, you can use different font style.
- 6) All equations from (2), (3),... to (13) are your new results? If not, please put proper references here.
- 7) Page 4, section 4.1, the first 3 lines "In this subsection ...in a cluster". This sentence is grammatically wrong. Please rewrite this sentence.

We make replies to the reviewer 2's comments given to the authors as follows:

Comment 1

In the abstract "strongly reduce" seems to be not a correct word. Do you mean "considerably reduce"?

Authors' reply

Thank you very much for your comment!

We corrected the error as the reviewer's mention.

Comment 2

Introduction, the 3rd sentence, "secondary assess is no interference...". This sentence is not clear to me. Please rephrase.

Authors' reply

Thank you very much for your comment!

We rephrased the sentence as follows:

... A prerequisite to this secondary access is no interference to primary system. This requirement makes spectrum sensing **be a key function in cognitive radio systems**...

Comment 3

In page 2, last sentence, "PU" is not defined.

Authors' reply

Thank you very much for your comment!

We added some words as follows:

2.1 Local spectrum sensing

Each CU conducts a spectrum sensing process, which is called local spectrum sensing in distributed scenario for detecting the **primary user (PU)** signal.

Comment 4

In page 3, before equation (3), "with M degrees of freedom". What is "M" here?.

Authors' reply

Thank you very much for your comment!

This is a typo. We replaced M by N in the revised manuscript.

Comment 5

5) In equation (4), the authors used \mathcal{N} notation N . I guess you want to mention Normal distribution and degree of freedom. However, you must use different symbol for Normal distribution. Perhaps, you can use different font style.

Authors' reply

Thank you very much for your comment!

We changed the symbol type of Normal distribution as follows:

$$x_{E_i} \sim \begin{cases} \mathcal{N}(N, 2N), & H_0, \\ \mathcal{N}(N(1 + \gamma_i), 2N(1 + 2\gamma_i)) & H_1. \end{cases} \quad (4)$$

Comment 6

All equations from (2), (3),... to (13) are your new results? If not, please put proper references here.

Authors' reply

Thank you very much for your comment!

The equations from (2) to (13) are popular results which belong to previous works of [9] [10] and [12]. These references are already mentioned in these sections.

Comment 7

Page 4, section 4.1, the first 3 lines "In this subsection ...in a cluster". This sentence is grammatically wrong. Please rewrite this sentence.

Authors' reply

Thank you very much for your comment!

We rephrased the sentence as follows:

4.1 Selective CSS mechanism

In this subsection, we **suggest a cluster header selection based on sensing data reliability. For each sensing interval, the CU with the most reliable sensing data in a cluster is selected to be cluster header.**

Obviously, the reliability of the sensing data can be evaluated by the log-likelihood ratio (LLR) of the sensing result....

Also, other grammatical mistakes were carefully corrected by the revision of a native speaker.