Optimized Cooperative Spectrum Sensing Schemes for Cognitive Radio Networks

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ABSTRACT

In current developing radio networks, energy scarcity and sensing time are become depreciate corner for cognitive radio (CR) networks, as network become deliberately energy-onerous. As fast growing wireless applications are consuming huge energy, and impersonate big challenges to operators in terms of energy footmark. Energy consumptionnot only includes the greenhouse problem and operational outlay, but is an obligatory to limit the power consumption demand in spectrum sensing and signal overhead, hence it is of preeminent priority for a CR scenario compared to non-CR ones. Different degrees of cooperation are possible: from simply following the spectrum regulation and keeping transmission power below the specified mask, to accurate sensing and tracking of the primary licensee, or contribution of the SUs to the detection of the primary signal . So here we explored the effects of facilitating immoderate energy coherence in cognitive radio network from the aspect of fundamental trade-offs (i.e. what need to loss to be energy efficient). In this review paper, a given optimization problem expressed with two different strategies. In first strategy only one phase of coarse spectrum sensing is activated in situation of absence of primary user or Signal-to-Noise Ratio (SNR) quantity is quite large, which accomplished for quality spectrum sensing. And next algorithm finely exploits the local results of coarse detection.It preserves the energy and improves a detection performance in observable amount. Simulation results shows that discussed strategies can achieve target of minimum energy, less sensing time and superior performance.

Keywords

Cooperative spectrum sensing, Cognitive radio network ,Energy-Efficiency, Sensing time.

1. INTRODUCTION

The frequency spectrum is a deficient intrinsic resource and its productive use is of the utmost importance. The spectrum bands are commonly licensed to explicit services, like satellite, broadcast, mobile, to avoid unfavorable interference between different networks to influence users. Cognitive radio intensifies the pliability of personal services through language that illustrate knowledge of radio protocol, software module, proliferations,user requirements, networks, and application framework in a manner that supports automated analysis about the requirements of users [1]. To facilitate sensible green wireless networks, energy efficient CRNs minimize the environmental influence and also cuts formation costs.To assure that the unlicensed user can recognize the unoccupied spectrum quick and precisely without impeding the licensed users, cooperative sensing techniques areused to upgrade the performance of sensing by leveraging dimensional diversity [2]. It was theory of ultimate goal in which a software radio platform should develop a fully adaptive and intelligent network that adopt its communication parameters accordingly as response of user and network requirement and without interfering primary users.

As whole execution of a cognitive radio is regulating combine by the precision of two task, hence it is mandatory to achieve better detection precision and accessing capability at the same instant. Furthermore, the amount of resources is finite and they mostly reserved by detection stages, so accessing task leftover with scanty of resources. In overall, the interpretation of a cognitive radio is finite by the condition of interference channel and the movement of primary network. Especially, in intertwine systems, the cognitive network can retrieve the spectrum only when the primary network is disable.

There are multiple techniques for realization of spectrum sensing. As described in [3], the matched filter detection (coherent detection by way of gain in the signal-to-noise ratio (SNR)), the cyclostationary feature detection (oppression of the intrinsic periodicity of primary signals), entropy based detection (require a preceding knowledge of primary signal) can solve the noise uncertainty of the spectrum sensing through information entropy, and use of energy detection in the spectrum sensing is the most popular method. It is consider being a most competent technique among all others.

To assured the service quality of primary user (PUs) as well as the spectrum availability of the secondary users (SUs), authentic and expeditious detection of spectrum vacancy is challenging issue. Although multipath fading, noise suspicious, and obscurity are always present in detection performance. Cooperative spectrum sensing is the moderate solution to attenuate such influences [4]. In Cooperative spectrum sensing (CSS), all secondary user observes the spectrum separately and their determination monitor by fusion center to establish the final decision.

In hard combination CSS, to reduce the overhead only one-bit decision sends by every SU, which diminish the expenditure. But in soft combination in CSS technique is an optimal performance by using the accurate sensing results from different SUs, overall performance has been improved. Though, its fulfilment in real scenario is inconvenient because of immense overhead [5].

In optimal multiple channel sensing scheme, channel sensing duration overcome by concentrating the spectrum detector on the channels that are possibly unoccupied [5]. A sensing approach with two-stage discussed in [6] based on energy detection and cyclostationary detection. In this studies, based on certain threshold first stage performed the rough energy detection and if condition not satisfied, a next stage is executed with precise cyclostationary detection. This technique improved the detection performance.

As per the previous researches, works about the energy efficiency transmission with cooperative sensing are still in demand. The concept of cooperative sensing upgrades the sensing interpretation and wisely uses the spectrum. Though, ample of energy depleted in CSS as compare to single user sensing. So, preservation of energy is prerequisite at this moment. If spectrum sense for longer duration with big amount of cooperative SUs, result achieves accurate sensing outcomes. But with the vast amount of energy and transmit in short time. Therefore, it is necessary to make a balance between them. As discussed earlier, sensing process in CSS also affect mainly by number of bit employ in it. Hence, this work concentrate on all above factors simultaneously to attain an ideal model with minimal energy utilization in cooperative environment.

2. FUNDAMENTALS

This studyreviews the work in [5] and by adding few more equations, it elaborates the work. Here the concept of a two time saving and energy efficient one bit CSS (TSEEOB-CSS) strategies, in which spectrum sensing task done with two different phases is used. In some conditions (when PU inactive/SNR is high) only single phases of sensing is utilized, which conserve the energy and cut the time of sensing. Also, all cooperative CR users report their sensing outcome to fusion center via single bit, which additionally save the disbursement. Various feature and techniques covered in this article are listed below:

The use of same TSEEOB-CSS algorithm as used in [5] with some variation for cooperative spectrum sensing instead of conventional CSS schemes which enhance the energy efficiency with better detection performance.

- First algorithm conduct for the coarse energy detection.
- Second algorithm presents with support of first algorithm. It exploits the confined outcomes of previous stage, and explore the consequences. It furthermore gains the energy.
- The variables used in both the algorithm discussed above are modified carefully to meet the goal, and for this, some rules are described in the article to help it.
- Prevalent simulation results show the fulfilment of the algorithms and diminish the energy consumption at great extent.

3. SYSTEM MODEL

As shown in Fig. 1, the PU networks and CR networks perform together in similar band of frequencies. Hence, there may be chances of disruption between different PUs and CR users. Based on this criteria, main goal of cooperative sensing is to achieve two objectives. First to avoid any interference, CR user should keep track on primary user when spectrum is busy. Second to strengthen its overall spectrum efficiency.

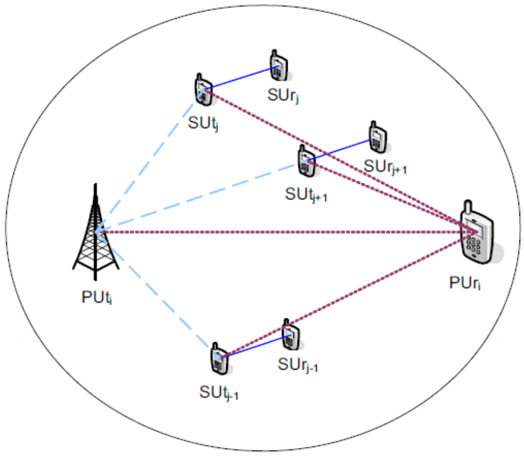

Figure 1: Mode for spectrum sensing in CRN [7]

3.1 Energy based Detection for Spectrum Sensing

The key of an interlace cognitive network is to have a powerful spectrum sensing capability. Energy detection is execute by measuring the threshold value with energy intensity of incoming signal from a PU [7]. This method does not need a foregoing perception of transmitted signal and its noise behavior, which make its practical realization simple. In moderate SNR zone, its execution may corrupt. Here in cooperative sensing, all participating CR users separately operate local sensing and outcomes of all CR users accumulate by fusion center to monitor the PU activity. Let the model contains N number of CR users. The spectrum sensing essence can be demonstrating with binary hypothesis-testing notation:

H_0: Channel is idle (PU is inactive)

H_1: Channel is busy (PU is active)

Now sensing method is to be decided on the basis of this test according to [8]. For simplification, the impulse response of channel is contemplate as consistent while sensing task.

$$\mathrm{y(m)} = \begin{cases} \mathrm{w(m)} & ;\ H_0 \\ \mathrm{h\ (m)x(m)\ +\ w(m)} & ;\ H_1 \end{cases} \qquad (1)$$

where y(m) is received signal, x(m) is primary signal transmitted via wireless channel, h is impulse response of the sensing channel, w(m) is additive white Gaussian noise (AWGN), and m = 0,1,2,.,K; where K is number of samples. The test module can be expressed as [5]:

$$Z = \frac{1}{K}\sum_{\mathrm{m}=1}^{K}|\mathrm{y(m)}|^2 \begin{cases} > \lambda & H_1 \\ < \lambda & H_0 \end{cases} \quad (2)$$

where Z is the testing quantity, and λ is fixed known threshold. Let, $\sigma_w^{\,2} = 1$ and $\gamma_p = \sigma_x^{\,2}/\sigma_w^{\,2}$ as the received SNR of primary user signal (σ_x: power of transmitted signal, σ_w: power of noise). By using energy detection, the probability of false alarm and Probability of detection of the secondary user respectively can be computed according to [5]:

$$P_f = \Pr(Z>\lambda|H_0)=Q\left((\lambda-1)\sqrt{\frac{K}{2}}\right) \qquad (3)$$

$$P_d = P_r(Z>\lambda\ |H_1) = Q\left(\left(\lambda-\gamma_p-1\right)\sqrt{\frac{K}{2(\gamma_p+1)^2}}\right) \quad (4)$$

where Q (.) is Q function.

3.2 Energy Efficient Cooperative Sensing

Energy efficiency is basically described as the number of data bits transmitted in unit of energy. Here, the goal is to raise the energy efficiency in cooperative sensing, communicating cooperative outcome to central module (FC) by fulfilment of authenticity constrain and impart specific throughput to secondary users. Also the optimization of CRinterpretation,can be achieved with energy limitation by detection accuracy control [3]. Particularly, this technique explores the trade-off among two feature of sensing time. First, a long lasting spectrum sensing expend much more energy of every CR user. Second, if spectrum sensing last for lengthy duration, detection performance enhances at every CR user and side by CR user count and relevant energy reduced. Thus, to compensate between energy depletion and its overhead owing of expected detection performance, this technique attains most favorable sensing duration and quantity of CR users.

Furthermore, in CR network a sleep mode is always present while transmission. So during sleep mode if sensing transceiver switches off, observation and transmission energy can be saved additionally [9].

4. ALGORITHM DESIGN: TSEEOB-CSS

It is basically considered that the secondary users can only transmit if the primary network is absent or if the secondary users are situatedat exterior a forbid region enclose the primary transmitter. The algorithm describes in [10] (time saving two bit CSS) attain a superior interpretation of CR design than hard combination cooperative sensing scheme. In extension of this work, other concept presented in [5] is one-bit time saving energy efficient scheme. With use of similar strategy and addition of some more facts, energy optimization and shorter sensing duration criteria fulfilled in this study.

To implement both phases of TSEEOB cooperative scheme, we consider the total K number of samples. Out of which only βK samples manipulate in first phase of detection and (1- β) K samples employ in next phase of quality sensing.

To facilitate clearness, we suppose that in these procedure active/inactive position of primary user does not modify *i.e.* received signal is consistent with observation time [5].

4.1 The First Algorithm

The two phase energy efficient one-bit scheme is shown in fig. 2. It accomplished by series of subsequent steps and Equations [5]:

Step 1: In first phase of local detection process, at every SU detection is done by βK samples (here $0< \beta < 0.5$).

$$Z1_i = \frac{1}{\beta K}\sum_{m=1}^{\beta K} |y_i(m)|^2 \tag{5}$$

$y_i(m)$ is *m*th sample of the signal to be sensed at *i*th secondary user($i= 0,1,2,\ldots,M$). Local result '$L1_i$' received as:

$$L1_i = \begin{cases} 0, & 0 < Z1i < \lambda 1 - \delta \\ no\ decision, & \lambda 1 - \delta \le Z1i \le \lambda 1 + \delta \\ 1, & Z1i > \lambda 1 + \delta \end{cases} \tag{6}$$

Action and Response

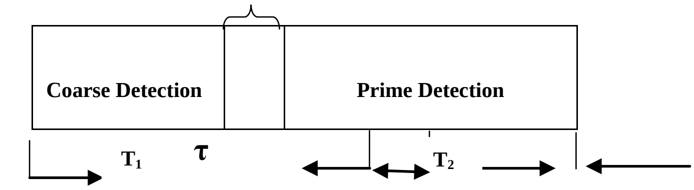

Figure 2: The two stage one- bit cooperative spectrum sensing scheme [5]

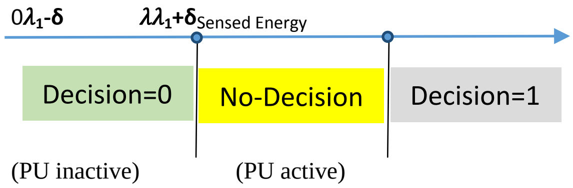

Figure 3: Illustration of local decision [11]

Step 2: Once the central module (FC) receive the local result $L1_i$, the final result F can be obtained as,

$$F= \begin{cases} 1, \text{More than half SUs indicates presence of primary user} \\ 0, \text{More than half SUs indicates absence of primary user} \\ \quad Elsewhere, Final\ resultcannotbesend \end{cases} \tag{7}$$

Step 3: If final result F is received by the SUs, detection is complete. Otherwise, about τ interval next phase of prime energy detection is executed by (1-β) K samples. Let the value of τ in fig. 2 follows; $\tau < T1 < T2$, then τ can be neglected.

Step 4: After prime energy detection done in next phase, local result L2i formulated as

$$L2i = \begin{cases} 1, & Z2i \ge \lambda 2 \\ 0, & Z2i < \lambda 2 \end{cases} \tag{8}$$

Step 5: Once the central module (FC) receive the local result L2i, the final result F can be express as Equation (9) and it finally send to central module.

$$F= \begin{cases} 1, & \sum_{i=1}^{M} L2i \ge M/2 \\ 0, & \text{elsewhere} \end{cases} \tag{9}$$

The first TSEEOB algorithm deliberates near about same interpretation as achieve from hard combination CSS.But in absence of PU or SNR is prominent, sensing time is cut and energy efficiency perhaps enhance productively.

4.2 The Second Algorithm

The Second algorithm completely utilize the energy detection scheme and prevent some more energy. This algorithm implemented near about similar steps as of first algorithm. For step 1 to 3 follow the same logic of previous algorithm. The furtherance is done as below.

Step 4: In elapse of τ interval, if the CR users does not acknowledge local result L1i in first algorithm, then by using (1-β) K samples prime energy detection perform. Local result L2i=L1i (if L1i acknowledge), else L2i calculated by similar expression as in Equation (8).

Step 5: Now, Final result F was formulated by Equation (10).

$$F = \begin{cases} 1, & \text{More than half SUs indicates presence of PUs} \\ 0, & \text{elsewhere} \end{cases} \quad (10)$$

By summarizing above two TSEEOB algorithms, with use of local result of the coarse detection in second algorithm, the level of performance detection raised and energy was reserved greatly. By using equal number of samples whole cognitive network deliberate energy efficient model.

5. OPTIMIZATION MODEL

5.1 Energy Consumption Model

Most of energy utilization done by samples of received signal at every SUs in detection process. Thus, with use of number of samples, energy utilization in ordinary cooperative sensing (CS) scheme can be calculated as [5]:

$$E_{CS} = MKe_0 \quad (11)$$

Here, M is count of total CR users present in cooperative sensing, K represent the count of total samples taken in detection process at every SU, and energy depletion for single sample in detection is expressed as e_0. The energy of the first and second presented TSEEOB algorithm can be elaborate as [5]:

$$E_1 = M\beta Ke_0 + M((1-\beta)K)e_0 \left(1 - \sum_{i=\left\lfloor \frac{M}{2} \right\rfloor+1}^{M} \binom{M}{i} P_1^i (1-P_1)^{M-i} - \sum_{i=\left\lfloor \frac{M}{2} \right\rfloor+1}^{M} \binom{M}{i} P_0^i (1-P_0)^{M-i} \right) \quad (12)$$

$$E_2 = M\beta Ke_0 + M((1-\beta)K)e_0 \left(1 - \sum_{i=\left\lfloor \frac{M}{2} \right\rfloor+1}^{M} \binom{M}{i} P_1^i (1-P_1)^{M-i} - \sum_{i=\left\lfloor \frac{M}{2} \right\rfloor+1}^{M} \binom{M}{i} P_0^i (1-P_0)^{M-i} \right)(1-P_1-P_0) \quad (13)$$

From above three equations (11-13), we can observe that

$$E_2 < E_1 < E_{CS} \quad (14)$$

So, by concluding above scenario, the energy required in second TSEEOB algorithm is considerably less than first and ordinary cooperative sensing algorithms.

5.2 Model for EE Sensing time

By mean of count of total samples taken for spectrum sensing, the sensing time in ordinary cooperative sensing algorithm can be expressed as [12]:

$$T_{CS} = K\, t_o \quad (15)$$

The general equation for sensing time is represent as:

$$\tau_s \geq \frac{2}{\gamma_p^2 f_s}\left(Q^{-1}(P_f) - Q^{-1}(P_d)\right)^2 \quad (16)$$

where τ_s is sensing time, γ_p is receivedSNR of primary user signal, and f_s is sampling frequency. From Equation (16), the minimum sensing time equation can be derived and express as [13]:

$$\tau_s = \frac{2}{\gamma_p^2 f_s}\left(Q^{-1}(P_f) - Q^{-1}(1-P_d)\sqrt{1+2\gamma_p}\right)^2 \quad (17)$$

where τ_s^{min} is minimum sensing time required by secondary user. From the throughput (energy efficiency) point of view, if sensing exhausted for longer time the extra energy is expend for overhead and only few time left for transmission. Simultaneously, the detection precision (P_d and P_f) may fluctuate the throughput of CR network [14].

From the whole study, we observe that by use of TSEEOB sensing algorithm in the situation of absence of PU or prominent SNR region of PU, the energy efficiency enhances in noticeable amount and also the sensing time diminish.

6. SIMULATION AND RESULT ANALYSIS

In this section the performance of the studied algorithms has outlined using simulation software. The sampling frequency f_s at SUs is set as 64MHz, and the symbol rate for baseband (fb) is consider to be 1Mbps. For discussed two phase algorithm value assign to all variable as, δ= 0.1, β= 0.33, and the total count of samples = 763.

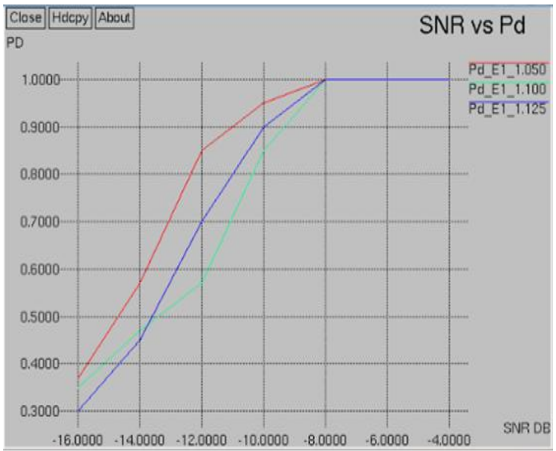

Figure 4: Correlation between SNR and Detection performance (Pf = 0.1).

Here start with detection probability in first algorithm of TSEEOB sensing scheme at distinct value of λ_1 i.e. 1.050, 1.100, and 1.125. The appearance is shown in fig. 4. With P_f = 0.1 in first proposed algorithm, the performance of detection at λ_1=1.050 is superior to λ_1= 1.100.

In second TSEEOB algorithm, without losing detection accuracy energy can be saved. Also the effect of different λ showed in table 1. The comparison for both algorithm is shown in fig. 5. From this simulation plot, it is clear that the detection capability of the second TSEEOB algorithm is similar to that of first TSEEOB algorithm with 768 samples and background noise power is consider to be unity.

In second phase with prime energy detection, the sensing is improved with lower energy consumption. By selecting the appropriate value of δ, the system model can exhibit balance between detection precision and energy efficiency. In fig 6. Probability of detection for both phases at distinct value of δ is measured.

Table 1. First stage and Second stage performance

	First Stage P_d		Second Stage P_d	
Predefined Threshold λ	SNR= -14	SNR= -10	SNR= -14	SNR= -10
1.050	0.58	0.95	0.50	0.95
1.100	0.48	0.85	0.48	0.90

1.125	0.44	0.90	0.44	0.85

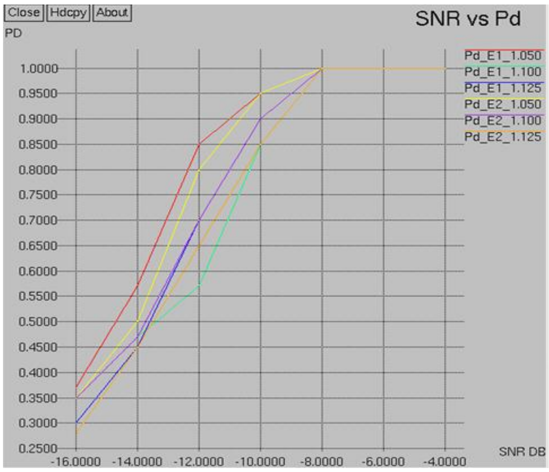

Figure 5: Correlation of detection capability among first and second TSEEOB algorithm (Pf = 0.1).

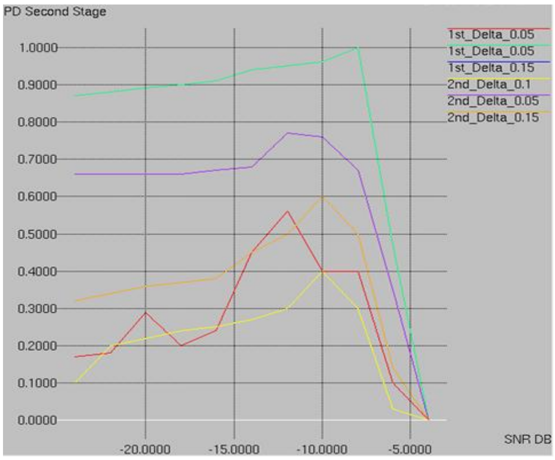

Figure 6: Detection probability of the second phase of first and second TSEEOB algorithm at distinct δ values

The energy consumption affects by received signal strength as per equation (12-13). So in fig. 7 the amount of energy varying at different signal strength at distinct λ is shown.

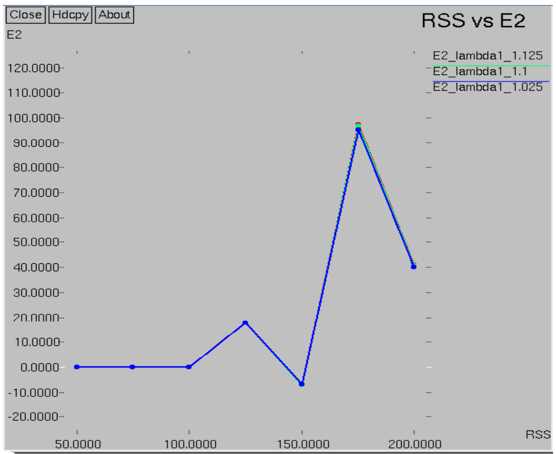

Figure 7: Received signal strength verse False alarm probability at different λ.

Now examine the effect of sensing time, by making balance between signal quality with energy efficiency and sensing time. If sensing time is large, detection probability increased and false alarm probability reduced. It is shown in fig 8.

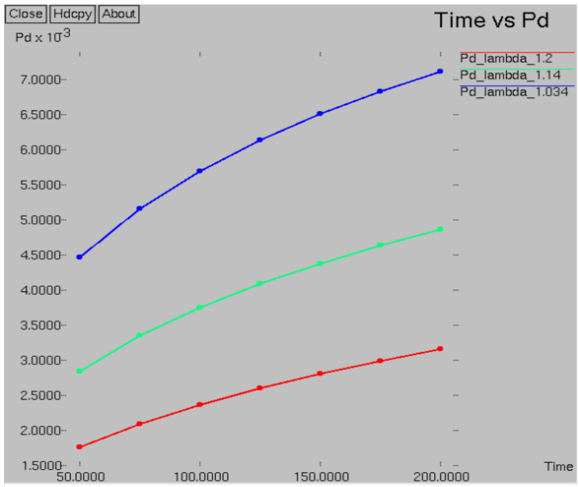

Figure 8: Detection probability verse sensing time at distinct λ_1 values

Plenty of simulation results explored in this section, demonstrate that the algorithm can attains significant detection performance with lower energy consumption and minimum sensing duration.

7. CONCLUSION AND FUTURE WORK

In this article, the numerical results convey the productiveness of the presented cooperative schemes by correlating with the traditional schemes. The goal of energy efficient CR network fulfillfirst by using one-bit decision in place of two, which reduces the overhead effectively. Second the spectrum sensing done in two phases, in which prime energy detection executed when first stage failed to deliver the sensing result.

It explores the cooperative sensing with use of energy detection for its lower computational complications. The energy utilization in spectrum sensing is mainly affected by how often the primary channel sensed by secondary users. By keeping this point in mind we have tried to reduce sensing time and also improves the detection precision by quality energy detection. By concluding whole work, a model which provide green cognitive radio network which deliberates minimum energy consumption with better accuracy is achieved here.

In future work, the concept can be elaborate with one-bit decision to optimize the sensing time and also improving the detection performance with minimal energy by using more advance optimizing parameter that effect the overall performance of the system.

8. REFERENCES

[1] J Mitola, JGQ Maguire, “Cognitive radio: making software radios more personal,” IEEE Pers. Commun Mag 6(4), 13–18 (1999).

[2] Lu Wang,Jiang Xiao, Kaishun Wu, and MounirHamdi,“ Harnessing Frequency Domain for Cooperative Sensing and Multi –channel Contention in CRAHNs,” IEEE Trans. Wireless Commun, vol. 13, no.1,Jan. 2014.

[3] SamanAtapattu, ChinthaTellambura, and Hai Jiang,“Energy detection based cooperative spectrum

sensing in cognitive radio networks," IEEE Trans. Wireless Commun, vol. 10, no.4,Apr. 2011.

[4] Ian F. Akyildiz, Brandon F. Lo, RavikumarBalakrishnan, "Cooperative spectrum sensing in cognitive radio networks: A survey," Physical Communication, vol. 4, pp. 40-62, 2011.

[5] Nan Zhao, Fei Richard Yu, Hongjian Sun and ArumugamNallanathan, "Energy-efficient cooperative spectrum sensing schemes for cognitive radio networks," EURASIP Journal on Wireless Communications and Networking, pp. 1-13, 2013.

[6] S Maleki, A Pandharipande, G Leus, "Two-stage spectrum sensing for cognitive radios," in Proceeding of the IEEE International Conference on Acoustics, Speech, Signal and Processing (Dallas, TX, 2010, 2010), pp. 2946–2949.

[7] Xiaoming Chen, Hsiao-Hwa Chen,andWeixiaoMeng, "Cooperative Communications for Cognitive Radio Networks — From Theory to Applications" IEEE communications Surveys and Tutorials, 1180-1192 (2014).

[8] Wei Zhang, Ranjan K. Mallik, and Khaled Ben Letaief, " Optimization of Cooperative Spectrum Sensing with Energy Detection in Cognitive Radio Networks", IEEE Trans. Wireless Commun, vol. 8, no.12,2009.

[9] S. Maleki, A. Pandharipande, G. Leus, "Energy-efficient distributed spectrum sensing for cognitive sensor networks", IEEE Journal on Sensors, vol. 11, no.3, pp. 565-573, 2011.

[10] N Zhao, "A novel two-stage entropy-based robust cooperative spectrum sensing scheme with two-bit decision in cognitive radio", Springer International Journal on Wirel. Pers. Commun., vol. 69, issue.4, pp. 1551–1565, Apr. 2013.

[11] HongxingXia,Guoping Zhang, and HongboXu,"A flexible cooperative spectrum sensing schemes for cognitive radio network", IEICE Electronics express, Vol. 8,no.8,542-548,2011.

[12] WonsukChung ,Sungoo Park ,Sungmook Lim ,and Daesik Hong, "Spectrum sensing optimization for energy-harvesting cognitive radiosystems", IEEE Trans. Wireless Commun, vol. 13, no.5, 2014.

[13] Mahdi Pirmoradiana, OlayinkaAdigunb, and Christos Politisb," Sensing Optimization in Cooperative Cognitive Radio Networks", Elsevier International Symposium on EICM-2014.

[14] Salim Erigit, Suzan Bayhan, and Tuna Tugcu, "Energy-efficient multichannel cooperative spectrum sensing scheduling with heterogeneous channel conditions for cognitive radio networks", *IEEE Trans.on Vehicular technology*, vol. 62, no.6,2013.