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A Distributed Energy Efficient Spectrum Sensing and Sharing Scheme in Cognitive Radio Networks

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Abstract*— Spectrum sensing is the key constituent in cognitive radio (CR) networks for detecting the primary users. Due to the destructive circumstances of sensing channel such as multipath fading and shadowing, local sensing is not apposite for the requirements for consistent detection. Consequently, cooperative spectrum sensing is acquaint with to perceive the primary user more precisely. Clustering methodology is considered as an effectual method that is used in cooperative spectrum sensing to confront the degradation in the performance of spectrum sensing due to fading and shadowing of reporting channel, and also to lessen the control channel overhead when the numeral of cooperative users becomes very large. Nevertheless, most prevailing cluster-based cooperative spectrum sensing methodologies have only been concentrated on the sensing performance, whereas the power consumption leftovers rarely deliberate. In this research Exertion, This paper proposed a distributed energy criteria clustering based cooperative spectrum sensing scheme using Centralized energy based selection scheme which can reduce the power consumption and prolong the network's lifetime. Results show that the spectrum sensing approach overwhelmed the traditional clustering based approaches in terms of network throughput, end-to-end delay and in terms of network lifetime of cognitive radios.

***Keywords*— Cognitive radio; cooperative spectrum sensing; clustering technique; energy efficiency.**

I. INTRODUCTION

The usable electromagnetic radio spectrum--a precious natural resource--is of limited physical extent. However, wireless devices and applications are increasing daily. It is therefore not surprising that we are facing a difficult situation in wireless communications. Moreover, given the reality that, currently, the licensed part of the radio spectrum is poorly utilized [1], this situation will only get worse unless we find new practical means for improved utilization of the spectrum. Cognitive radio, a new and novel way of thinking about wireless communications, has the potential to become the solution to the spectrum underutilization problem [2], [3].

Building on spectrum sensing and other basic tasks, the ultimate objective of a cognitive radio network is twofold:

- Provide highly reliable communication for all users of the network, wherever and whenever needed;
- Facilitate efficient utilization of the radio spectrum in a fair-minded and cost-effective manner.

After initially being proposed in [1], cognitive radio is being touted as the next Big Bang in wireless communications. As [2] asserts, conventional fixed spectrum allocation results in a large part of frequency band remaining underutilized. Channels dedicated to licensed (primary) users are out of reach of unlicensed users, while the licensed users hardly occupy the channel completely, at all times. Cognitive radio revolution hopes to tap into this inconsistency and attempts to utilize the channel in its full capacity. In this paradigm, "either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. This alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behaviour and network state." [3]. While the above description is essentially that of full cognitive radio, the present work will be primarily focused on spectrum sensing cognitive radio. In this paradigm, the secondary unlicensed users keep sensing the spectrum to determine if a primary user is transmitting or not; and then they occupy the idle band and leave it as soon as the primary user kicks in. So it is extremely important that we employ efficient and robust spectrum sensing techniques to determine the presence of the signal from the primary user, and a review of those techniques is the basis of this term paper.

Spectrum sensing, defined as the task of finding spectrum holes by sensing the radio spectrum in the local neighbourhood of the cognitive radio receiver in an unsupervised manner. The term "spectrum holes" stands for those sub bands of the radio spectrum that are underutilized (in part or in full) at a particular instant of time and specific geographic location. To be specific, the task of spectrum sensing involves the following subtasks [4]:

1. Detection of spectrum holes;
2. Spectral resolution of each spectrum hole;
3. Estimation of the spatial directions of incoming interferes;
4. Signal classification.

A. Cognitive Radios

Cognitive Radio (CR) is a system/model for wireless communication. It is built on software defined radio which an emerging technology is providing a platform for flexible radio systems, multiservice, multi-standard, multiband, reconfigurable and reprogrammable by software for Personal Communication Services (PCS). It uses the methodology of sensing and learning from the environment and adapting to statistical variations in real time. The network or wireless node changes its transmission or reception parameters to communicate efficiently anywhere and anytime avoiding interference with licensed or unlicensed users for efficient utilization of the radio spectrum.

Cognitive modules in the transmitter and receiver must work in a harmonious manner which is achieved via a feedback channel connecting them. Receiver is enabled to convey information on the performance of the forward link to the transmitter. Thus CR by necessity is an example of a feedback communication system [1, 2, 3 and 5].

B. Signal processing techniques for transmitter detection

Mainly three techniques are in vogue for transmitter detection, which are described below:

1. *Matched Filter*
2. *Energy Detector*
3. *Cyclostationary Feature Detector*

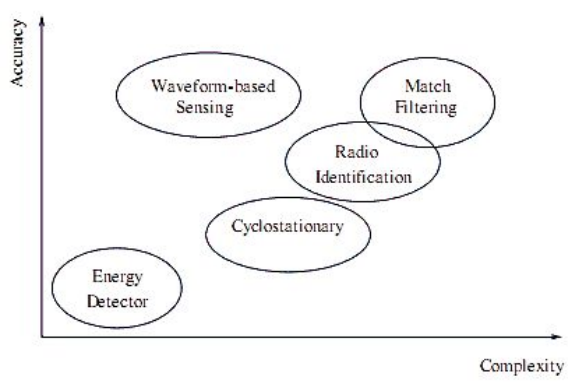

Figure 1. Main Sensing methods in terms of their sensing accuracies and complexities.

C. Cooperative Spectrum Sensing

While for simple AWGN channels most classical approaches perform well, as we have seen, in the case of fading these techniques are not able to provide satisfactory results due to their inherent limitations and to the hidden node problem. To this end, several works have looked into the case in which cooperation is employed in sensing the spectrum.

Consider the scenario depicted in figure below, in which primary users (in white) communicate with their dedicated (primary) base station. Secondary receivers $\{RX_1, RX_2, RX_3, \ldots, RX_K\}$ cooperatively sense the channel to identify a white space and exploit the medium. The main idea of the cooperative sensing techniques is that each receiver RX_i can individually measures the channel and interacts on their findings to decide if the medium is available. The main drive behind this idea is that each secondary receiver will have a different perception of the spectrum, as its channel to the receiver will be different from the other secondary receivers, thus decreasing the chances of interfering with hidden nodes [8].

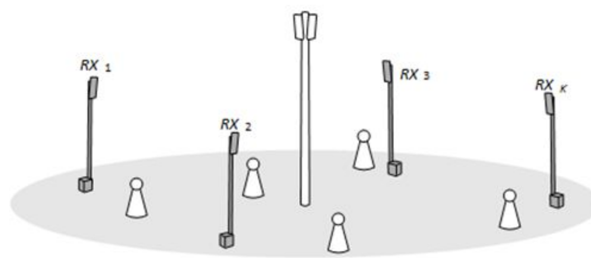

Figure 2. Cooperative sensing scenario

Alternative scenarios exist, we will concentrate on the one pictured in Figure below, although all sensing techniques presented herein can be also applied to scenarios such as the one in which a deployment of a secondary network exclusively for spectrum sensing is considered.

The cooperative spectrum sensing can be:

- Centralized, in which a central entity gathers all information from all secondary receivers to make a decision about the medium status, which is then transmitted back to the receivers;
- Distributed, in which the receivers share their information in order to make their own decision.

In both of these situations, the cooperative spectrum sensing is plagued with one problem: how to report or distribute the measures in a resource constrained network. In fact, if these measurements are the basis for deciding whether a transmission can be made or not, then it does not make any sense to propagate the measurements before the decision is made. To overcome the problem, one could create a dedicated channel for signalling or use unregulated band (such as ISM) [9].

The association steps of this paper is as follows. The Introductory Section ends with a brief introduction of Spectrum sensing and its necessity in cognitive radio network. The part in introduction shows a brief explanation about cognitive radio, techniques for spectrum sensing and cooperative spectrum sensing in brief.

In Section II, explains a General review and related work of energy based spectrum sensing in cognitive radio, many techniques have been proposed for the spectrum sensing in cognitive radio network which are categorized in this section.

Section III provides the information about the basic problem definition for the selected problem area. The energy problem becomes more and more important these days. Three aspects are defined as the reasons why it gains more attention.

Section IV addresses the proposed methodology and system model along with the technical specifications of proposed work including the clustering in network environment.

Section V gives details about the simulation results, it also shows some comparative graphs which prove that the proposed approach overcome the traditional clustering based approach.

Section VI shows a general conclusion of the paper, regarding review is presented.

II. RELATED WORK

As mentioned before, the energy problem gets more attentions nowadays. Since energy problem is considered to be more serious these days, a plenty of research are done to study it. Actually, the energy efficiency problem in cognitive radio networks is a wide concept which can be sorted into many sub-problems. Some problems are related to the practical wireless cognitive networks. Some are based on a general theory model and the analysis of simulation result.

In [10], theoretical analysis is given about the energy efficiency in cognitive radio network. It mainly analyses the physical layer of the OSI model. Many factors are taken into account to explain the energy consumption problem. Also, problems in upper layers also affect the energy utilization. It gives a guideline of how to standardize the energy management in cognitive network.

In [11], two spectrum sensing strategies are introduced to improve the energy efficiency. The simulation results show that 10% to 40% transmission energy is saved by using Confidence Voting (CV) algorithm and 65% to over 95% energy is saved by using Cluster-Collect-Forward (CCF) instead of broadcasting scheme. Also, energy detection in cognitive radio networks can be optimized by using a voting rule [12].

In [13], the energy efficiency is considered in transmission. The transmission duration and power allocation methods are come up with. However, this is based on the full information is known to the transmitter and receiver. In [14], distributed spectrum access is discussed.

In [15], the design of transmission frame is studied. Optimal frame duration can be found out to maximize the throughput. In this report, we build a system model and analyse the simulation result.

III. BASIC PROBLEM FORMULATION

The energy problem becomes more and more important these days. The reasons why it gains more attention than before can be included into the following three aspects.

The first aspect is the limitation of the device's power. Since most devices in the cognitive radio networks are mobile devices, thus they are not able to get power provided all the time when they are in the network. That is to say, the power of the devices can be run out if it cannot get charged in time. Because of this reason, we need to improve the energy efficiency so that the devices can work for longer time with the same energy consumption.

The second reason is the requirement of increasing data transmission. The data transmission throughput amount increases a lot during recent years. Users have more data to be transmitted by using their mobile devices. Obviously, the more transmission throughput, the more energy are consumed. If we can use energy in a more efficient way, the data transmission throughput can be improved.

The last but not least reason why energy problem should be considered more is that we need an environment-friendly society. Energy problems in every field of our daily life affect our living environment a lot. Therefore, we have to pay more attention to protect our planet.

The trade-off between periodic sensing and spectrum handoff is an important topic in energy efficiency of a cognitive radio system. This paper discusses the energy consumption of transmitting data when there is conflict between a primary user (PU) and a secondary user (SU).

Generally, the energy efficiency includes main several aspects: energy consumption of transmission, energy consumption of channel switching, energy consumption of spectrum sensing.

In addition, there are more other energy consumptions in the cognitive network. In this paper, we only focus on the energy efficiency problem considering these aspects [16].

A channel cannot be used by SU when it is currently using by a PU. The SU has to make a decision whether to wait if the current channel is occupied or choose another vacant channel to send the data. Waiting results saves energy with getting time delay. On the other hand, switching channel consumes more power but getting a better performance in data transmitting efficiency. How to balance these two factors is a key for the energy efficiency. In other words, a suitable activity (spectrum handoff or waiting channel) should be taken into account to make the energy consumption minimized [17].

There are three constraints needed to be considered in the energy consumption problem: reliability of sensing, the throughput, the delay of SU. Reliability of sensing can be measured by two probability of detection: probability of detection and probability of false alarm. The probability of detection is the probability in the following situation: if the channel is busy, it is sensed as busy. The higher probability of detection means, SU can catch a PU communication more accurately. The probability of false alarm is the probability under this situation: the channel is idle, it is sensed busily. False alarm probability shows the probability of error happen. The lower it is, the more chances that channel can be used [18, 19, and 20].

IV. PROPOSED CLUSTER BASED APPROACH

In this paper, we propose cluster-based cooperative spectrum sensing algorithm using our new energy distribution check mechanism based protocol for cognitive radio networks. We demonstrate that our clustering approach extends the lifetime of cognitive networks and try to maintain a balance energy consumption of CR users. Furthermore, we present a reporting strategy that reduces the average number of reporting decisions, by allowing only the CR with detection information to send its binary decision (0 or 1) to CH.

System Model for proposed work

In proposed system model, this work consider a cognitive radio network with M cognitive radio users (CRs) that act as local sensing devices are assumed to be organised into clusters, where each cluster has a cluster head that makes a cluster decision based on the local decisions received from its cluster members and report the result to the cognitive base station that acts as a fusion centre FC. We assume that the primary user signal at CRs is not initially known, therefore, we adopt an energy detector to conduct the local sensing, which is suitable for any signal type. In this energy detection algorithm, only the transmitted power of the primary system is known. Therefore, this power will be detected firstly, and then compared with a predefined threshold to determine whether the spectrum band is greater than the detection threshold λ, the detector will available or not. When the energy of the received signal indicate that the primary user is present, which will depicted by exist hypothesis H_1, otherwise, the primary user is absent, which will be represented by null hypothesis H_0.

The system structure of a cognitive radio network according to our clustering approach is illustrated in Figure below. First, all CRs are grouped into clusters using our proposed energy distribution based protocol, which proposed for cooperative cognitive radio network. This protocol provides an efficient clustering configuration algorithm, in which the cluster heads CHs are selected by the FC in centralised and intelligent way, with minimisation of data transmission energy between a CH and other members in a cluster, according to the best reporting channel gain and the energy level of the CRs.

The process of our cluster-based spectrum sensing algorithm is conducted through the following steps:

1. CRj in cluster i conducts spectrum sensing individually and makes a local decision D_{ij} for i $=1,\ldots,K$, $j=1,\ldots,N_i$, where K is the number of $=\sum M_i$, where M is the total number of CRs clusters, N is the number of CR in cluster i and in the network.
2. Then, only the CR_{ij} that has a local binary decision will report its results to the CH_i to make a cluster decision C_i based on OR-rule data fusion method, otherwise no reporting decision is taken. If the CH_i receives local decision 0 instead of 1 due to imperfect reporting channel, it considered as a reporting error and this is auto corrected to 1.

$$= \begin{cases} 1, & \sum_{j=1}^{N_i} D \\ 0, & otherwise \geq 1 \end{cases} \quad (1)$$

3. Finally, all the CHs_i for $i = 1,2,\ldots,K$ that have a cluster decision $C_i = 1$ are allowed to send their results to FC and then a final decision F is made by a FC using OR-rule, as

$$F = \begin{cases} 1, & \sum_{i=1}^{K} C \\ 0, & otherwise \geq 1 \end{cases} \quad (2)$$

If no cluster decision is reported (i.e. $C_i = 0$), which means no primary signal is detected, and then a final decision $F = 0$ is taken.

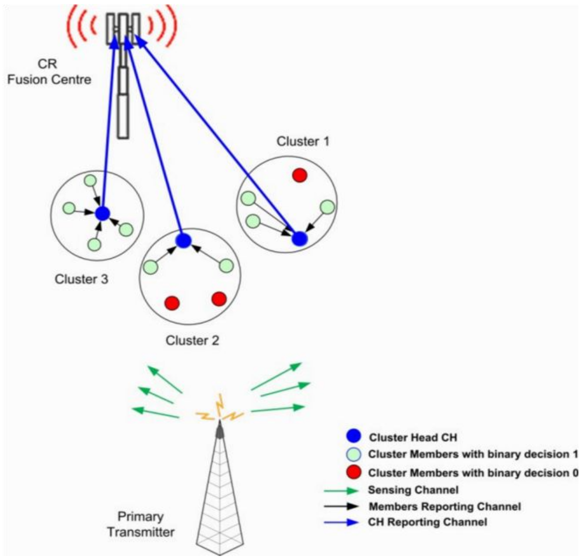

Figure 3. Cluster-based cooperative spectrum sensing.

This energy efficient spectrum sensing protocol maintains such clustering hierarchy. In our protocol, the clusters are re-established in each round. New cluster heads are elected in each round and as a result the load is well distributed and balanced among the nodes of the network. Moreover each node transmits to the closest cluster head so as to split the communication cost to the sink (which is tens of times greater than the processing and operation cost.) Only the cluster head has to report to the sink and may expend a large amount of energy, but this happens periodically for each node. In this energy efficient routing scheme there is an optimal percentage p_{opt} (determined a priori) of nodes that has to become cluster heads in each round assuming uniform distribution of nodes in space.

This work apply Method in a Wireless Field of Area 100×100 m. However we can change the field area as per the result variations. Also, the base Station is Placed at the Centre of CR Field initially, however we can change the Position of base Station. Initially the dissipated energy is Zero & residual energy is the Amount of initial energy in a Node, Hence Total energy also the Amount of residual energy because it is the sum of dissipated & residual energy.

Also we can calculate the average energy Ea of a Node after the particular round with the Knowledge of Total Energy and a particular number of round numbers.

(3)

This work calculated the Dead Statistics before assigning a Cluster Head, and its value renewed every new round. The New Expression for Optimum Probability can be calculated from Different Energy Levels and Optimum Probability Defined Earlier. The selection probability mentioned in equation 4 for the selection of cluster head is taken as 0.1 (user defined).

(4)

Here, a Node will becomes Cluster Head, if a Temporary number (between 0 to 1) assigned to it is less than the Probability Structure Below,

(5)

Here, *Pi* is come out from New Expression for Optimum Probability P (i)

Hence only the nodes with higher energy amongst the other nodes can fulfill the criteria above and hence a node can transmit data as a cluster head for a longer period which results in increment of network lifetime and throughput.

After a higher energy node becomes Cluster Head, Energy Models are applied to calculate the Amount of Energy Spent by it on that Particular Round and complete the round of steady state phase.

(6)

If a Node will not a higher energy node and Discarded from the criteria above, than it goes to a Set of Normal node, and follow the behavior of normal node and complete the round of steady state phase.

V. Results & Discussion

In this detection algorithm, only the transmitted power of the primary system is known. Therefore, this power will be detected firstly, and then compared with a predefined threshold to determine whether the spectrum band is greater than the detection threshold λ, the detector will be available or not. When the energy of the received signal indicate that the primary user is present, which will be depicted by existing hypothesis H1, otherwise, the primary user is absent, which will be represented by null hypothesis H0.

Simulations are carried out in MATLAB R2013b (Version 8.2.0.703), graphical user interface is created for the simulation of proposed work on energy efficient clustering solution for cognitive radio networks.

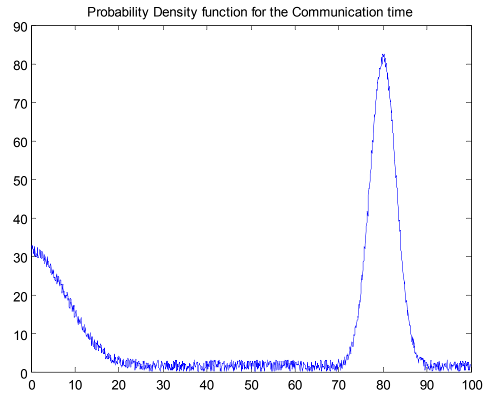

Figure 4. Probability density function of different cognitive radios with respect to time of communication rounds.

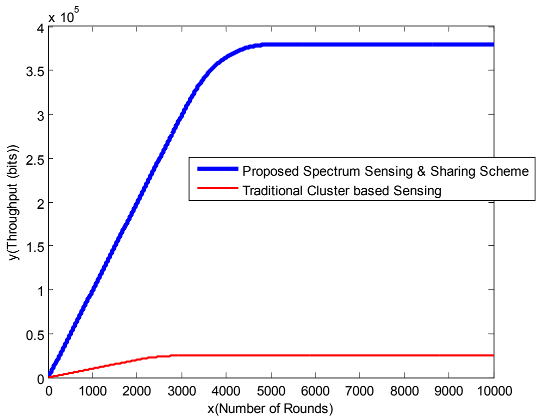

Figure 5. Figure above shows a comparative view of network throughput with respect to rounds in both the proposed approach and traditional clustering approach for 100 cognitive radios

The above figure shows the Network throughput in bits/sec with respect to number of rounds or pause time of packet delivery in the network for the protocols we considered. Throughput is the number of the packets received at the destination with respect to the packet sent from the sources.

Throughput of receiving bits: It is the ratio of the total number of successful packets in bits received at destination in a specified amount of time.

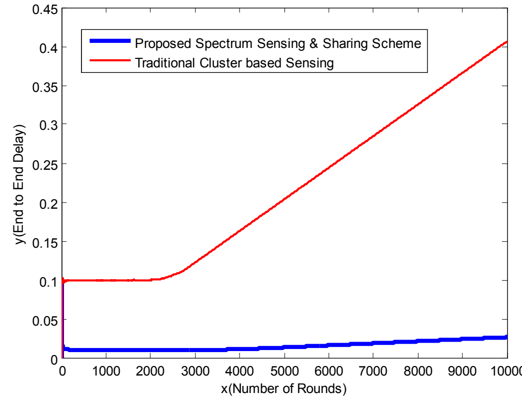

Figure 6. Figure above shows a comparative view of network end to end delay with respect to rounds in both the proposed approach and traditional clustering approach for 100 cognitive radios

End-to-End Delay: It is the delay that could be caused by buffering during route discovery, queuing delays at interface queues, retransmission delays at the media, and propagation and transfer times.

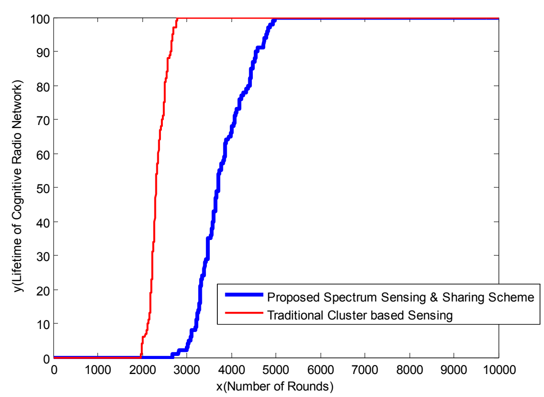

Figure 7. Figure above shows a comparative view of network lifetime with respect to rounds in both the proposed approach and traditional clustering approach for 100 cognitive radios

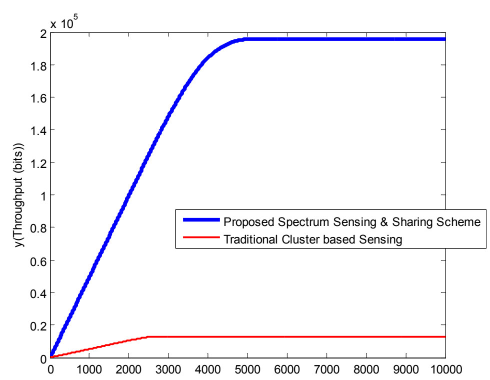

Figure 8. Figure above show a comparative view of network throughput with respect to rounds in both the

proposed approach and traditional clustering approach for 50 cognitive radios

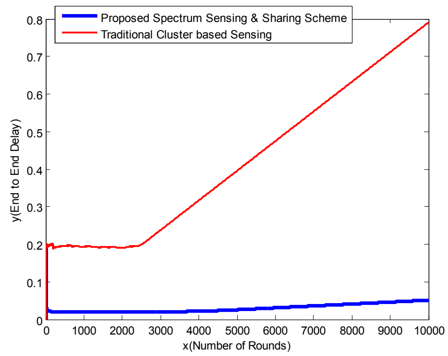

Figure 9. Figure above show a comparative view of network end to end delay with respect to rounds in both the proposed approach and traditional clustering approach for 50 cognitive radios

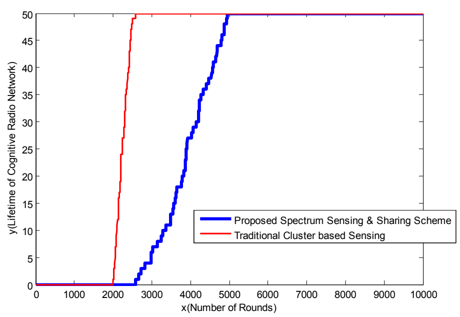

Figure 10. Figure above show a comparative view of network lifetime of cognitive radios with respect to rounds in both the proposed approach and traditional clustering approach for 50 cognitive radios

VI. Conclusion & Discussion

Spectrum sensing is the key element in cognitive radio networks for detecting the primary users. Due to the destructive conditions of sensing channel such as multipath fading and shadowing, local sensing is not fitting the requirements for reliable detection. Therefore, cooperative spectrum sensing is introduced to detect the primary user more accurately. Clustering approach is considered as an effective method that is used in cooperative spectrum sensing to tackle the degradation in the performance of spectrum sensing due to fading and shadowing of reporting channel, and also to reduce the control channel overhead when the number of cooperative users becomes very large. However, most existing cluster-based cooperative spectrum sensing approaches have only been focused on the sensing performance, whereas the power consumption remains rarely studied. In this thesis, focus was on exploration of cooperative spectrum sensing technique in the field of the cognitive radio. The features of the energy efficient spectrum sensing was also carried out.

The major contribution to the Paper was to implement a clustering based energy efficient spectrum sensing approach for cognitive radios which was then put to test for primary user signal for different SNR conditions. The performance evaluation was done for various numbers of users with ROC curves being the performance criteria. A scheme for optimal number of users in order to decrease the overhead and speed up performance along with techniques for adapting the threshold have also been examined.

Simulation results indicate that the optimal scheme varies the number of users so that error is kept as minimum as possible without compromising the detection probability. With the increase in false alarm probability the minimum number of users required for satisfactory performance decreases. Thus instead of keeping a fixed number of users for fusion schemes in co-operative spectrum sensing, the number can be varied in accordance with the false alarm probability. Results show that the spectrum sensing approach outperforms the traditional clustering based approaches in terms of network throughput, end-to-end delay and in terms of network lifetime of cognitive radios.

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