Dynamic Cluster based Cooperation for Fair Spectrum Sensing and Sharing in Cognitive Radio Networks

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Abstract— Spectrum sensing is a decisive measure for cognitive radio networks (CRN) to shelter transmission of primary users. Cooperative spectrum sensing is considered as the utmost auspicious technique to improve the consistency of spectrum sensing. Nevertheless, such cooperation also acquaint with overhead traffic of control signaling and consequence transmission which devours more power in battery-operated mobile terminals. In this research, an energy effectual transmission structure is proposed. An energy dependent dynamic Clustering technique is implemented to save energy disbursed in broadcasting results and swapping information. All cognitive lumps are detached into a few clusters, and report indigenous decisions to cluster heads to make cluster decisions through certain data fusion scheme. Cluster decisions are forwarded to the common fusion center to decide whether the spectrum of interest is idle or not, this 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 radio.

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

introduction

Cognitive Radio (CR) is referred to as one of the best ideas to relief the conflict between the increasing spectrum demand and the inefficient spectrum utilization of licensed users (primary users, PU) [1]. In CR systems, when there are some data to be transmitted, SU should play spectrum sensing to find an idle spectrum channel as soon as possible. On the other hand, to avoid harmful interference to PU, SU will continuously perform spectrum sensing [2]. Among a variety of existing approaches, cooperative spectrum sensing is regarded as the most promising method to improve the reliability of spectrum sensing [3]-[5]. By introducing spatial diversity of data resources, cooperation can decrease the error detection probability of a single SU [4] and alleviate the negative impacts on performance caused by multipath fading and shadowing [6].

However, such above advantages of cooperation are at the cost of overhead traffic of control signalling and result transmission, which consumes more power and introduces additional transmission delay. Generally, power resource is limited, especially for battery-operated mobile terminals. Some researchers have proposed approaches to solve this problem. A censoring scheme is adopted to decrease reporting power consumption by dis-considering uninformative test statistics or local decisions in [8] and [9]. In [10], an adaptive time scheduling algorithm is proposed to decrease the number of local decisions. In [11], a voting scheme based on users' own confidence is developed to reduce the energy for information transmission by avoiding unnecessary transmission. The main idea of above methods is to reduce the amount of reporting results. However, either sensing performance loss is paid or high level management components are introduced

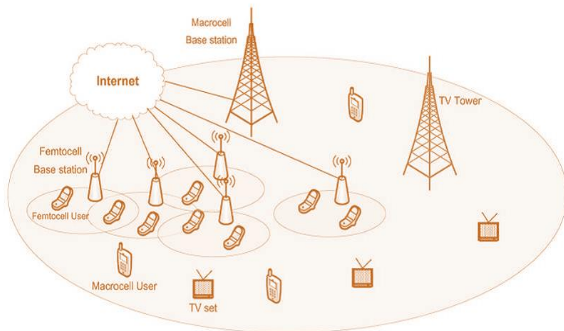

Figure 1. Spectrum sensing and sharing between cognitive radios in a CRN.

In above works, local decisions of every SU are reported to the common receiver directly. Some SU may be placed far away from the common receiver to improve the spectrum sensing performance [7], and their decisions are valuable. To ensure their results are received correctly, much transmission power is required because signal will be decayed with the increase of transmission distance. Thus, the life cycle of battery-operated mobile terminals will be shortened greatly when they are placed far away from the common receiver.

To reduce the transmission energy consumption, a cluster-based cooperation scheme is proposed in this paper. All SU are separated into a few clusters and one cluster head is set for each cluster to collect the sensing results, make cluster decisions and forward results to the common receiver. Thus the transmission energy consumption of SU will be reduced greatly because most of them are closer to cluster heads than to the common receiver and much less power is needed to transmit local decisions. Analytical results show significant transmission energy can be saved with our proposed method.

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.

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 [15]:

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

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 [12, 13, 14 and 16]. Mainly three techniques are in vogue for transmitter detection, which are described below:

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

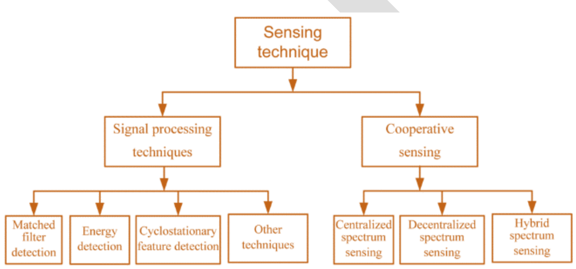

Figure 2. Main Sensing methods in terms of their sensing accuracies and complexities.

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 $\{RX_1, RX_2, RX_3,...,RX_K\}$ 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].

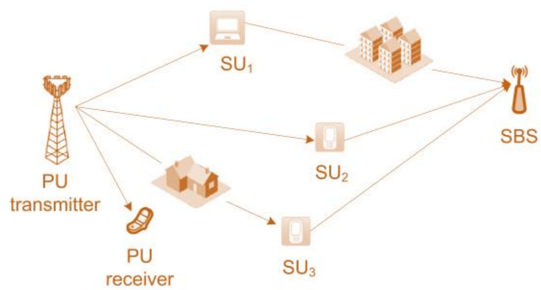

Figure 3. Cooperative sensing scenario

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

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. Section III addresses the proposed methodology and system model along with the technical specifications of proposed work including the clustering in network environment. Section IV 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 V shows a general conclusion of the paper, regarding review is presented.

RELATED WORK

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 [27].

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 [29, 30, and 31].

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. In [21], theoretical analysis is given about the energy efficiency in cognitive radio network. It mainly analyses the physical layer of the OSI model.

In [22], 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 [23].

In [24], 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 [25], distributed spectrum access is discussed.

In [26], 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.

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.
First, primary signal or noise is collected as raw data by SU to get observations or make decisions. Then observations or local decisions will be reported to the common receiver to make a final decision

Figure 4. Function model of each SU in cooperative spectrum sensing.

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. CR*j* 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.
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.

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

2. 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

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

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.

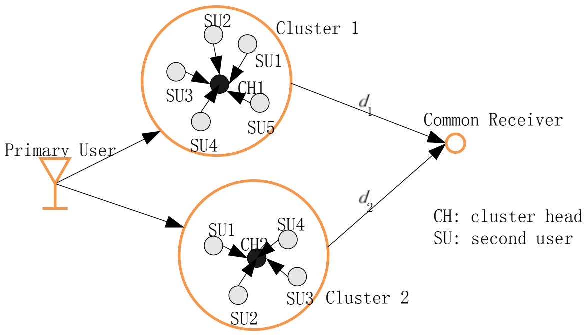

Figure 5. Cluster-based cooperative spectrum sensing.

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.

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 E_t 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.

$$Ea = E_t \times \left(\frac{1-(r/Rmax)}{n}\right) \tag{3}$$

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).

$$p(i) = \frac{p \times n \times current\ \ Energy\ \ \times residual\ \ energy}{total\ \ energy\ \times average\ \ energy} \tag{4}$$

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,

$$T(s_i) = \begin{cases} \frac{P_i}{1-P_i\left(rmod\ \frac{1}{P_i}\right)} & if\ \in G \\ 0 & otherwise \end{cases} \tag{5}$$

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.

$$E_{TX}(l,d) = \begin{cases} lE_{dec} + l\varepsilon_{fx} d^2, d < d_0 \\ lE_{dec} + l\varepsilon_{fx} d^4, d \geq d_0 \end{cases} \tag{6}$$

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.

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 available or not. When the energy of the received signal indicate that the primary user is present, which will depicted by exist 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.

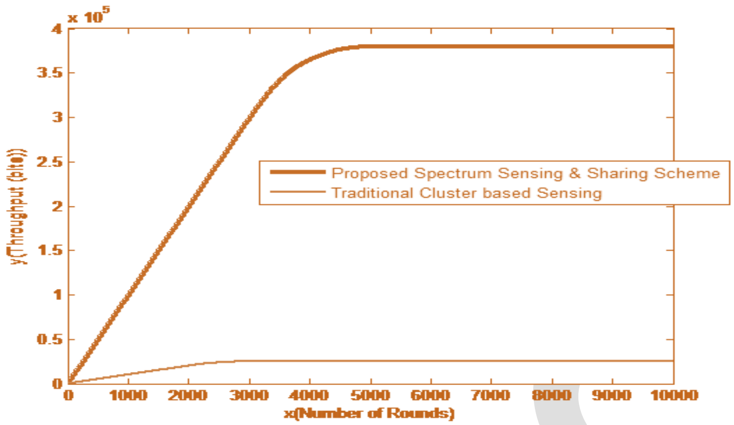

Figure 6. Figure above show a comparative view of network throughput with respect to rounds in both the proposed approach and traditional clustering approach for 100 cognitive radios

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.

$$TH = \sum \text{Transmission of Routing Packets}$$

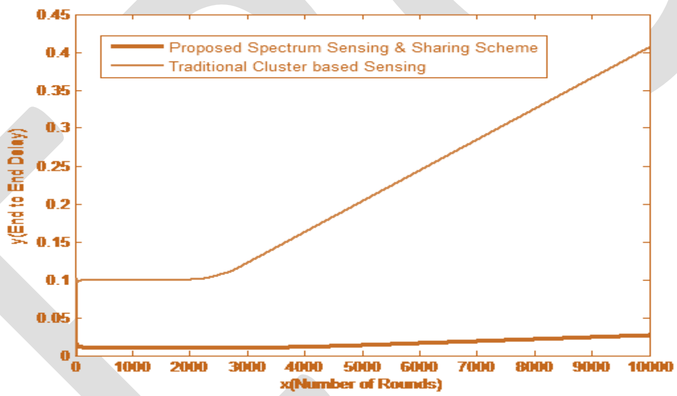

Figure 7. Figure above show a comparative view of network end to end delay with respect to rounds in both the proposed approach and traditional clustering approach for 100 cognitive radios

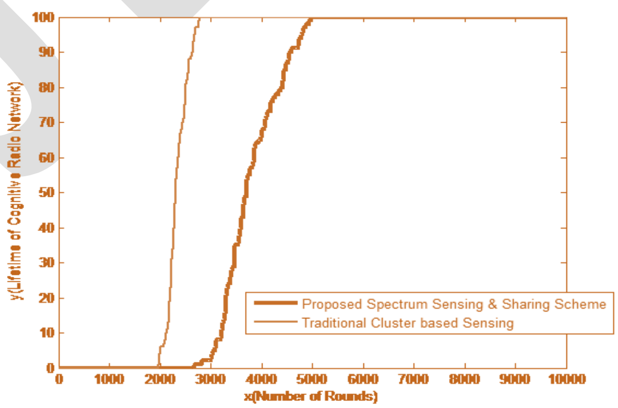

Figure 8. Figure above show a comparative view of network lifetime with respect to rounds in both the proposed approach and traditional clustering approach for 100 cognitive radios

TABLE 2. COMPARISONS OF NETWORK LIFETIMES (NUMBER OF ROUNDS)

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nodes	Protocol	Nodes Dead(in Rounds)			
		1%	20%	50%	100%
25	Traditional	968	1006	1157	1326
	Proposed	2612	3382	4186	4934
100	Traditional	947	1095	1319	1509
	Proposed	2741	3448	3862	4893

Result is taken when the base station is placed at the centre of sensor field and the selection probability is defined through the energy values considered. It is clear from the figure that both the network lifetime and stability of lifetime of network is achieved through proposed protocol.

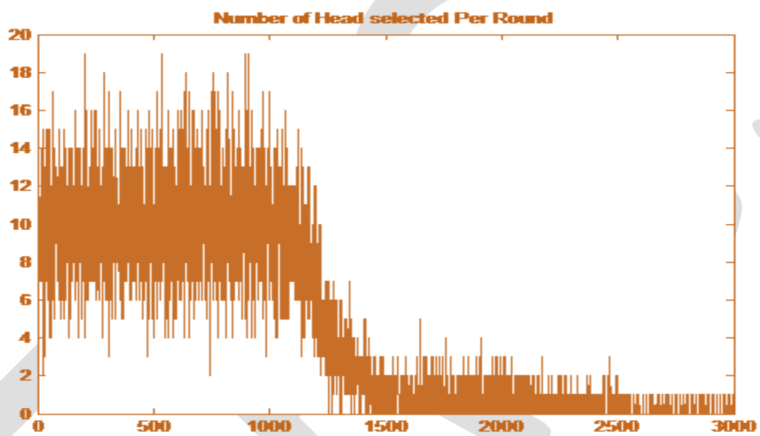

Figure 9. This figure shows the number of cluster head selected during the communication period in each round when communication is done for 3000 rounds. It is clear from the figure that maximum 19 cluster head is selected in a single round not more than that, when taking a sensor network of 100 sensors.

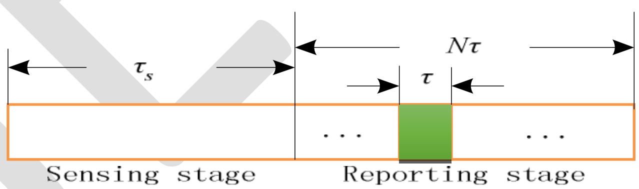

Figure 10. Sensing frame structure of CR users.

TABLE 3: Mean and variance of residual energy in both the proposed method and the WEEC method

	Range (J)	Mean residual energy (J)	Variance residual energy (J)
Proposed	98.5569	43.9161	38.5569
Traditional	29.7538	13.1419	11.7406

TABLE 4. COMPARISONS OF NETWORK THROUGHPUT (BITS)

Nodes	Method	Network Throughput (in bits)
100	Traditional	20000 bits
	Proposed	379000 bits

CONCLUSION & DISCUSSION

Cooperative spectrum sensing for CR systems has been studied under energy constraints in this paper. This is an Energy efficient and a cost effective co-operative spectrum sensing technique which performs well in fading and shadowing environment is to be developed. A cluster-based co-operative network architecture with the concept of detection center is introduced which actually helps to reduce the power consumption and in turn increase the energy efficiency. To decrease the transmission energy consumption, a scheme of cluster-based cooperative spectrum sensing was developed. The transmission energy consumption of our proposed method has been derived and compared with that of the conventional one. In addition, the transmission delay is analyzed theoretically. Simulation results demonstrate significant decrease of transmission energy consumption. Other than that, with some frequency reuse methods, the proposed method can run much faster than conventional scheme due to the parallelism benefited from clustering. 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.

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