Spectrum Sensing and Allocation of Cognitive Radio Networks

S.Anusha[1], N.Jayanthi, M.Tech[2]
[1](PG Scholar, Department of ECE, Mahendra Engineering College, Tamil Nadu, India)
[2](Assistant Professor, Department of ECE, Mahendra Engineering College, Tamil Nadu, India)

ABSTRACT: *Cognitive Radio Networks enable efficient spectrum sharing between licensed primary users (PUs) and unlicensed secondary users (SUs). Secondary users do not generate interferences to the primary users. Secondary users should have capability of knowing the real time spectrum usage of primary users. The knowledge can be acquired in many ways, one of which is spectrum sensing. In existing spectrum sensing methods, known distribution of the received primary signals are assumed. Proposed Spectrum sensing algorithm is designed under the distribution uncertainty of primary signals. Sensing algorithm is decomposed into a series of semi definite programs. Optimal decision threshold is designed at local detector of secondary user. Iterative algorithm is used to search the licensed spectrum for secondary users.*

Keywords - *Cognitive radio network, licensed spectrum, unlicensed spectrum, spectrum sensing, decision threshold.*

1. Introduction

Today Spectrum scarcity is the main challenging in wireless communication technologies. Wireless spectrum is statically allocated to licensed primary users. The static allocation mechanism is inefficiently utilized and causes great wastage of spectrum resources [1]. For example, cellular networks are overloaded and other frequency bands like paging, amateur radio and military applications are insufficiently utilized. To improve the spectrum utilization, cognitive radio networks are used [2]. The information from the licensed spectrum is known through the information exchange between primary users and secondary users [3], which needs cooperation between PUs and SUs and introduces extra signalling overhead. Another method of knowing spectrum information of licensed spectrum is secondary users spectrum sensing and prediction [4]. This method does not need the information provided by PUs, but demanding accurate sensing algorithms.

Spectrum sensing is used to determine the presence of PUs in licensed spectrum, based on channel characteristics. Usually hypothesis testing problem is formulated, where an SU takes decision about PU by comparing the received signal samples with a pre-designed decision threshold.

In existing method of spectrum sensing, the primary signals probability distribution is a very strong assumption. It does not hold in practice. In reality, deterministic assumption about the primary signal's distribution may not always match. For example, the received signals have different distributions depending on whether there is a line-of-sight between Tx and Rx. The mobility of wireless modes often change the signal distributions which leads to unreliable detection performance. We consider the algorithm to find decision thresholds for multiple SUs when the primary signals distribution is unknown [5].

The rest of the paper consists as follows, section 2 describes about Cognitive Radio Network and its functions. Section 3 describes about system model and process flow diagram. Section 4 shows the results and section 5 concludes the paper.

2. Cognitive Radio Network

Dynamic Spectrum Access is one of the main applications of Cognitive Radio Network. A Cognitive Radio is an intelligent wireless communication system capable of obtaining information from its surrounding environment. It increases the communication channel reliability and access dynamically the unused resources, by adjusting its radio operating parameters. It leads to a more efficient utilization of the radio spectrum.

A Cognitive Radio (CR) must be able to transmit and receive in different bands. It uses different coding and modulation schemes. CR must be based on the Software Defined Radio (SDR) philosophy. Spectrum sensing is one of the technique used by a CR to locate the white spaces (WS) or spectrum holes. In spectrum sensing, received signal is processed to make a decision on the presence or not of a PU in a licensed spectrum. Spectrum sensing has low infrastructure requirements. So CR must be able to detect signals at very low SNRs in a limited amount of time. It won't cause any harmful interference to the PUs. Energy detection method is one of the most basic and effective schemes of spectrum sensing.

2.1 Cognitive Radio Network Architecture

Cognitive Radio Network Architecture consists Primary networks and Secondary networks. Fig.1 shows Cognitive Radio Network Architecture. Primary networks have right to access certain spectrum bands, e.g. cellular networks and TV broadcast networks. Users of these networks are called to as primary users. They have the right to operate in licensed spectrum. Users of certain primary network do not care of other primary or secondary network users.

Secondary networks do not have license to operate in the spectrum band. They have opportunistic spectrum access. Users of these networks are called as secondary users. They have no right to access licensed bands currently used. Additional functionalities are required to share licensed spectrum bands with other secondary or primary networks. Spectrum sensing is used to share licensed spectrum bands with secondary networks.

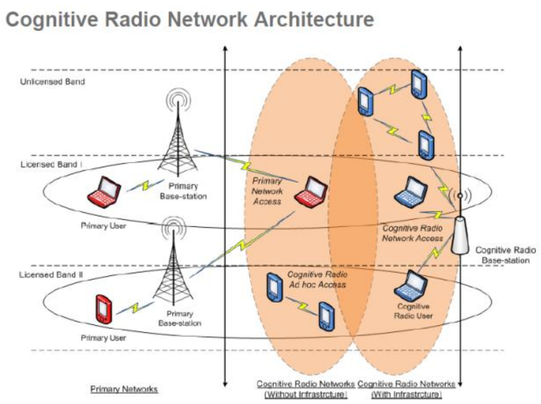


Fig.1. Cognitive Radio Network Architecture

2.2 Functions of Cognitive Radio

The functions of Cognitive Radio are as follows,
i. Cognitive Radio continuously looks for the unused spectrum which is known as the spectrum hole or white space. It is shown in the Fig. 2. This function of CR is referred as spectrum sensing
ii. Once the spectrum holes or white spaces are found, CR selects the available white space or channel. This function of CR is referred as spectrum management.
iii. It allocates this channel to the secondary user as long as primary user does not need it. This function of CR is referred as spectrum sharing.
iv. Cognitive radio vacates the channel when a licensed user is detected. This function of CR is referred as the spectrum mobility.

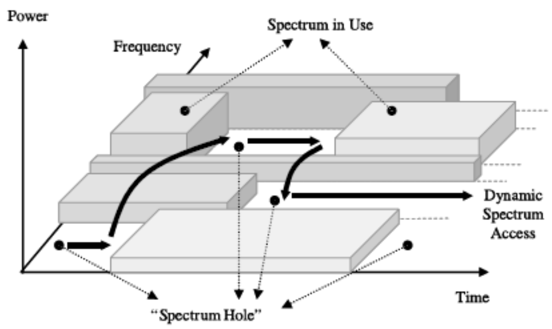


Fig.2. Spectrum holes concept

2.3. Spectrum Sensing

Spectrum sensing is a key enabling technology for a broad class of cognitive radio systems involving spectrum agility. To detect primary users, control protocol support is not available, each radio must sense the surrounding spectral environment to learn about licensed spectrum or interferers, from which it determines which frequency bands are used. Energy detection (ED) spectrum sensing method is used in this paper, which is independent of known signal properties.

3. System Model

We consider a cognitive radio network with N of Secondary Users. Multiple Primary Users are operating under the same spectrum channel. The SUs do not have prior knowledge about the PUs' transmission characteristics and application types. Due to the change of active PUs on the licensed spectrum, the received signals at SUs' receivers must be highly dynamic in terms of the statistic information. We assume that there is no signals exchange between Primary Users and Secondary Users, thus SUs use spectrum sensing to acquire the spectrum information by themselves. SUs are cooperating with each other to improve the sensing performance, since single user sensing has errors due to channel fading and shadowing [6]. So, we assume that all N SUs join the cooperation and each Secondary User has a local energy detector

3.1 Energy Detector

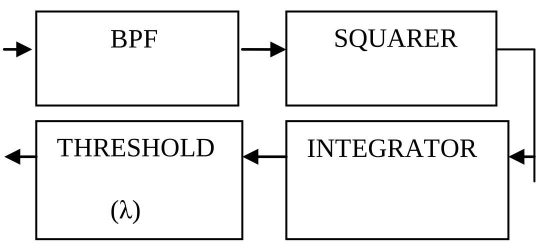


Fig.3. Block Diagram of Energy Detector
Energy detection (ED) is the most optimal choice for the spectrum sensing where CR get the adequate information about the licensed user waveform. Fig.3 shows the Block Diagram of Energy Detector. ED is

the most suitable choice when the CR has information about the power of the random Gaussian noise. The basic approach behind this technique is the power estimation of the received primary signal. In this technique power spectral density of the desired transmitted signal is detected. This detected signal is compared with a threshold value. The threshold value is a pre- assigned. If the detected signal is below than threshold value, the licensed user is not present and the spectrum is free. Oppositely, if the detected signal is above the threshold value, the licensed user is present that is the spectrum is not free.

3.2 Process Flow Diagram

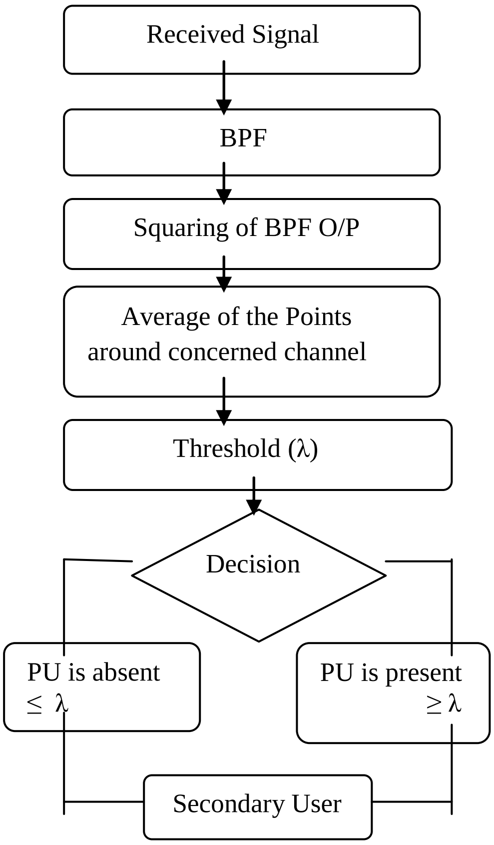


Fig.4. Process Flow Diagram

Fig.4 shows process flow diagram of spectrum sensing, in which received signal of primary channel is compared with decision threshold (λ) and takes decision about primary channel

3.3 Sensing Structure

The objective of spectrum sensing is to check whether the primary signal is present on the primary channel. We assume that the local detector of secondary user works a threshold-based decision scheme, which is commonly used in hypothesis testing problem [7]. To design the optimal decision thresholds for all SUs is more important such that the sensing performance is improved. Sensing performance can be defined properly according to Secondary Users preferences. The spectrum sensing process is divided into three steps as follows:

• Step I (Sensing): Sensing results of all local detectors are sent to the fusion center. Fusion center performs a centralized optimization over the decision thresholds. It broadcasts the computed optimal decision thresholds to all SUs.

• Step II (Detecting): Once SUs adopt the optimal decision thresholds. Signal samples from primary channel are received at local detector. By comparing signal samples with decision threshold, it makes local detection decision.

• Step III (Decision fusion): SUs send their local detection decisions to a fusion center. Then the fusion center makes a final decision about the primary signals based on a decision function as in step I. Step I can be viewed as an initialization process. After that, Steps II and III repeat in the following time slots until there is a need for reinitialization due to the environment change.

If the signal sample received from licensed spectrum at local detector is compared with the decision threshold (λ) of local detector. If it is .greater than the decision threshold (λ), the channel is considered as busy. If the signal sample at local detector is smaller than decision threshold (λ), the channel is considered as idle. This idle channel is allocated to the secondary user.

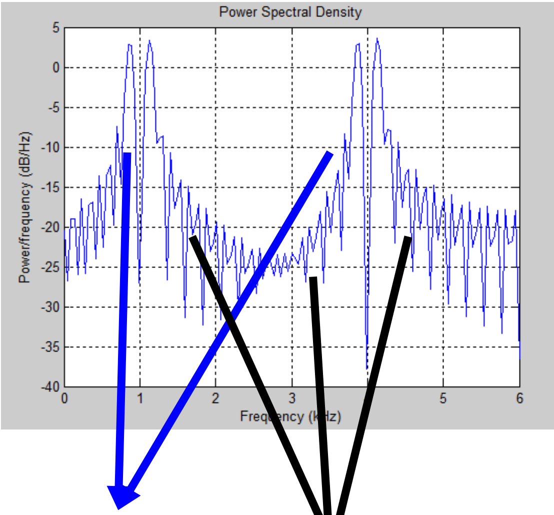
3.4 Algorithm

i. Initialize 5 frequency bands i.e licensed spectrum,
ii. Design decision threshold (λ) at secondary user's detector based on the power spectral density (PSD) of primary signal.
iii. If λ < PSD of received signal, the channel is considered as busy.
iv. If λ > PSD of received signal, the channel is considered as idle.
v. This idle channel is allocated to secondary user.
vi. Algorithm searches until all bands become busy.
vii. End.

4. Results

We consider five frequency bands. These are licensed spectrum used by primary users. Fig.5 shows five frequency bands, in which frequency bands 1 and 4 are used by primary users. Remaining frequency bands are idle. Unused frequency bands are called as spectrum holes or white spaces.

Each secondary user has local detector with decision threshold. If secondary user wants to access the licensed spectrum, signal in the frequency band (1) is compared with decision threshold. This value is greater than the decision threshold. So the channel is considered as busy. Next frequency band (2) is compared with decision threshold. This value is below the decision threshold. So the frequency band (2) is idle. This is assigned to secondary user (1). Fig.6 shows that the spectrum hole is allocated to secondary user (1).

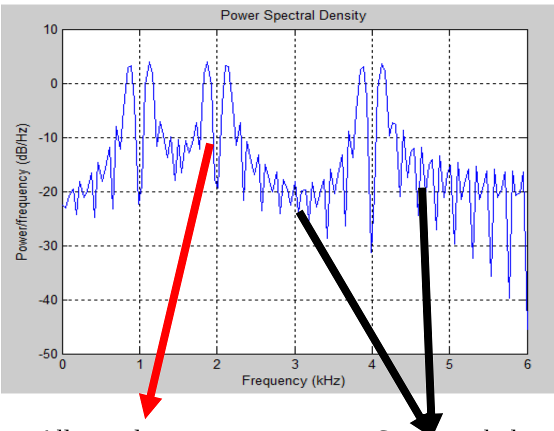


Used by Primary User

Spectrum Holes

Fig.5 Licensed Spectrum Band

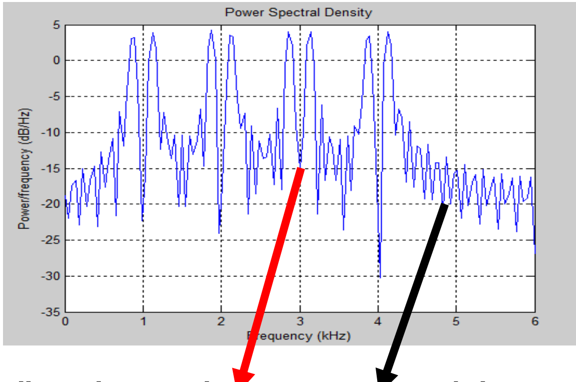
Likewise, the signal is not present in frequency band (3). This band is assigned to secondary user (2). It is shown in Fig.7. the frequency band (4) is busy. So we cannot access this channel. The frequency band (5) is idle. This idle channel is allocated to secondary user (3). The next secondary user has to wait until the channel becomes available. Fig.8 shows all the frequency bands are used efficiently. The wastage of spectrum resources can be avoided by using cognitive radio network.



Allocated to Secondary user (1)

Spectrum holes

Fig.6 Spectrum allocation to secondary user



Allocated to secondary User 2

Spectrum hole

Fig. 7 Spectrum allocation to secondary user

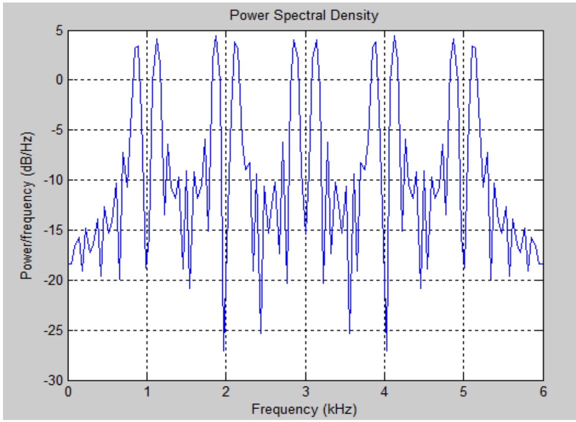


Fig.8. All the bands are in use

5. Conclusion

In this paper, we consider the problem of spectrum sensing in cognitive radio networks. The algorithm is proposed for spectrum sensing based on distribution uncertainty of primary signals. Decision threshold is designed at local dector of secondary user using power spectral density of primary signals. Each iteration, the algorithm searches the licensed spectrum band for secondary users. If the spectrum band is idle, this is allocated to secondary users. The algorithm searches the licensed spectrum until all bands are busy. Thus the all spectrum bands are utilized efficiently in cognitive radio networks.

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