Quick Detection and Assignment of Spectrum Hole in Cognitive Radio

Mohammed Mehdi Saleh, and Hemalatha Rallapall

***Abstract*—**The increasing demand for wireless communication introduces efficient spectrum utilization challenges. To address this challenge, cognitive radio (CR) has emerged as the key technology, which enables opportunistic access to the spectrum and has ability to adapt to the conditions of the environment by analyzing, observing and learning. The CR has the capability to sense the spectrum and determine the vacant bands, for the purpose of using underutilized frequency bands without causing harmful interference to legacy networks. In this paper, we have presented a model that allows secondary (unlicensed) users to transmit in FM radio environment without cause harmful interference to primary (licensed) users .This model will reduce the time required to detect an empty channel in the desirable band to be appropriately used by the secondary user. Our works based on spectrum sensing using energy detection by selecting the appropriate threshold, assuming we have a noisy channel. We have modeled the radio environment in MATLAB where the primary users transmit after random intervals with a specific band and the empty channels during these intervals in this band are used by secondary users.

***Keywords*—** Cognitive radio, spectrum sensing, energy detection, primary users, secondary users.

I. Introduction

THE spectrum is a natural resource and it is utilized by taking license from governments everywhere in the world. The license authorizes the transceivers to be operated in a specific band of the frequency spectrum. The traditional static spectrum allocation strategies cause temporal and geographical holes of the spectrum usage in LICENSED BANDS. The spectrum occupancy: completely free, partially free and fully occupied, is known as white, gray and black holes in spectrum usage [1] [2] [3]. The different spectrum occupancy studies have shown that the radio spectrum (i.e. 3 KHz - 300GHz) is inefficiently used today [4]. When primary (licensed) users do not transmit at a particular time, then a vacant space is created in the band for a specific time that can be regarded as spectrum hole. These holes can be utilized by secondary (unlicensed) user's till the time primary users are inactive. FCC spectrum policy task force permits unlicensed devices (secondary users) to make opportunistic or dynamic use of the spectrum occupied by existing services. The Cognitive Radio has a potential to improve spectrum occupancy by opportunistically identifying and exploiting the available spectrum resources without causing a harmful interference.The cognitive radio is considered as a future radio technology that should be aware of its surrounding environment and internal state and can make decisions about its radio operating behavior (transmitter parameters) to achieve the predefined objectives [5]. One of the primary functionalities in CR to realize the opportunistic use of available spectrum and dynamic spectrum access is spectrum sensing. The spectrum sensing function enables the cognitive radio to adapt to its environment by detecting the primary users that are receiving data within the communication range of a CR user [6]. In this paper, we proposed a model for efficient utilization of spectrum by allowing secondary users to detect empty channels in the spectrum using energy detection technique and then transmit for the duration of time when the primary users are inactive without occur harmful interference between users. This system is formed from subsystems, each of which is responsible for finding empty channels and also allocating appropriate channel for utilization by the secondary users. By thus method we can increase the efficiency of the system, reduce the time needed to detect the empty channels with less likelihood of error. We can also ensure that secondary users transmit through the empty holes without harmful interference. The simulation was performed using the program MATLAB.

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II. Cognitive Radio

Cognitive radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users [6]. Cognitive radio is a hybrid technology involving software defined radio (SDR) as applied to spread spectrum communications. Possible functions of cognitive radio include the ability of a transceiver to determine its geographic location, identify and authorize its user, encrypt or decrypt signals, sense neighboring wireless devices in operation, and adjust output power and modulation characteristics [7].

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A. Types of cognitive radio:

- Full cognitive radio: takes into account all parameters that a wireless node or network can be aware of.
- Spectrum-sensing cognitive radio: is used to detect channels in the radio frequency spectrum.

B. Cognitive Cycle:

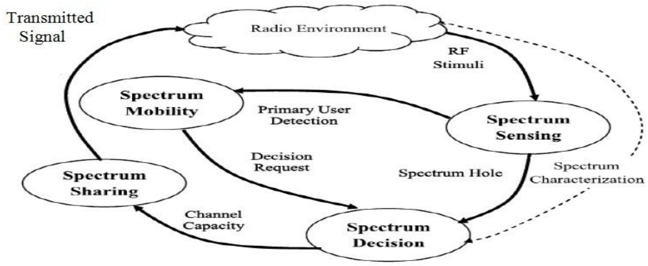

Fig. 1 Cognitive cycle [8]

There are four main steps in the cognitive cycle [8]:

1. **Spectrum Sensing**: It refers to detecting the unused spectrum and sharing it without harmful interference with other users. It is an important requirement of the Cognitive Radio network to sense spectrum holes, detecting primary users is the most efficient way to detect spectrum holes.
2. **Spectrum Management:** It is the task of capturing the best available spectrum to meet user communication requirements.
3. **Spectrum Mobility:** It is defined as the process where the cognitive user exchanges its frequency of operation
4. **Spectrum Sharing**: This refers to providing a fair spectrum scheduling method among the users. Sharing is the major challenge in the open spectrum usage.

III. Spectrum Sensing

The main function of the cognitive radio is finding unused spectrum. Can classify the RF spectrum into three types by estimating the incoming RF stimuli, thus, black spaces, gray spaces and white spaces [9], as shown in fig. 2. Black spaces are occupied by high power local interfere some of the time and unlicensed users should avoid those spaces at that time. Gray spaces are partially occupied by low power interference, but they are still candidates for secondary use. White spaces are free RF interference except for ambient noise made up of natural and artificial forms of noise, e.g. thermal noise, transient reflection and impulsive noise. White spaces are obvious candidates for secondary use [9] [10].

There are several different ways to sensing techniques can classified as transmitter detection, cooperative detection and interference-based detection. The classification of spectrum sensing techniques [9]:

- Matched filter detection
- Energy detection
- Feature detection
- Cooperative detection
- Interference-based detection

In this paper, we will use an Energy detection technique.

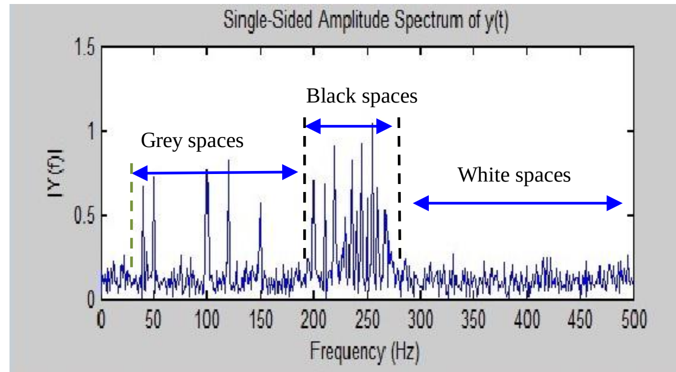

Fig.2 Classification the RF spectrum with frequency (1HZ -500HZ)

IV. Energy Detection

In this method measured the energy (Es) of available radio resource in communication range of cognitive radio and compare it against a predefined threshold level. The threshold level is measured when only a noise signal presented on the channel. All levels of energy fall below the defined threshold level (Eth) spectrum is marked as available. When the measure energy level is above the defined threshold, it's considered as occupied [8]. In order to check whether primary users is using the spectrum or not at this time, where the secondary users can use the spectrum only when primary users is inactive. The energy detection method does not require prior information about primary user, this method is less complex compared to remainder methods. This method based on decide between two hypotheses namely:

$$x(t) = n(t), H0 \quad \ldots(1)$$

$$x(t) = hs(t) + n(t), H1 \quad \ldots(2)$$

Where, X (t) is the signal received by the CR user in the communication band of CR user. S (t) is the transmitted signal of the primary user, n (t) is the AWGN noise, h is the amplitude gain of the channel. H0 is a null hypothesis, which mean the primary user is absent in other hand H1 mean primary use is in operation as showing in fig. 3 [8].

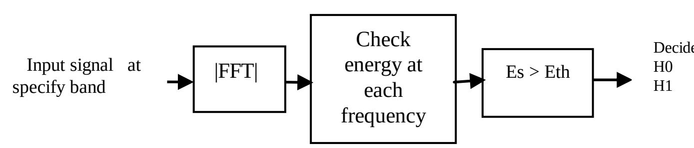

Fig. 3 Energy Detection spectrum sensing

Fast Fourier Transforms (FFT) based method shown in figure 3, are used when the spectral is analyzed in the digital domain. The received signal X (t) at a specified band frequency sampled in time window is passed through an FFT device, in order to get the power spectrum X (f).Then the peak of this power spectrum is located and after windowing the peak of the spectrum, we obtain by (f) [8]. Then the energy signal in the frequency domain will compare with threshold level and the following binary decision is made.

$$\begin{cases} H_1 \text{ If } \sum |Y(f)| \geq \lambda \\ H0 \quad \text{Otherwise} \end{cases} \qquad \ldots(3)$$

V. The Proposed Model

In this model the spectrum sensing block is formed from n sub blocks, each sub block responsible to check and specify the sub band frequency (B) for receiving signals in the communication range of cognitive radio users. A received signal will be divided into n sub band frequencies, with reduce the time required to check the whole range frequencies and increase detection accuracy. All the sub blocks will give output at the same time. As an example, let us consider the communication range of cognitive radio users is from 1 HZ to 100kHZ, the range is divided into 5 sub bands and fed 5 sub blocks, each sub band range is 20Khz, also the time required to assign one secondary user is 0.054875 seconds, as shown in fig 9. The flowchart below depicts the ongoing process of the proposed model. It uses an energy detection technique for sensing of Primary users for finding vacant frequencies, then allocates for secondary users.

VI. Scope Plots

The following figures represent the plots of “Primary signal scope”, “Secondary signal scope” and “primary and secondary signal scope” of the simulated proposed model.

In fig. 5, the peak represents generated primary signals and the noise signals in the channel where primary users was in operation. The periodogram is used to represent the signals. We generate random Primary Signals in a particular range of frequency here our range (1HZ to 100kHZ). With the addition of noise to our received signals in order to simulation, real channels. The blocks will check each spanned by Sensing the Energy level of each carrier, determines the Energy possessed by the carrier, then compare it to the threshold level, to decide primary user active at this time or not. Receives decide of the absent carrier from the spectrum sensing block and generates the secondary signal at that particular carrier frequency that is not present. Fig. 6, is shows the six primary users are inactive at the time, which is randomly selected, the vacant frequencies will be assigned to the secondary users ,as shown in fig. 7 . Fig. 8, is shows Scope plot representing primary signals with blue color and secondary signals assigned for vacant frequencies with red color. Our work implemented by using Matlab.

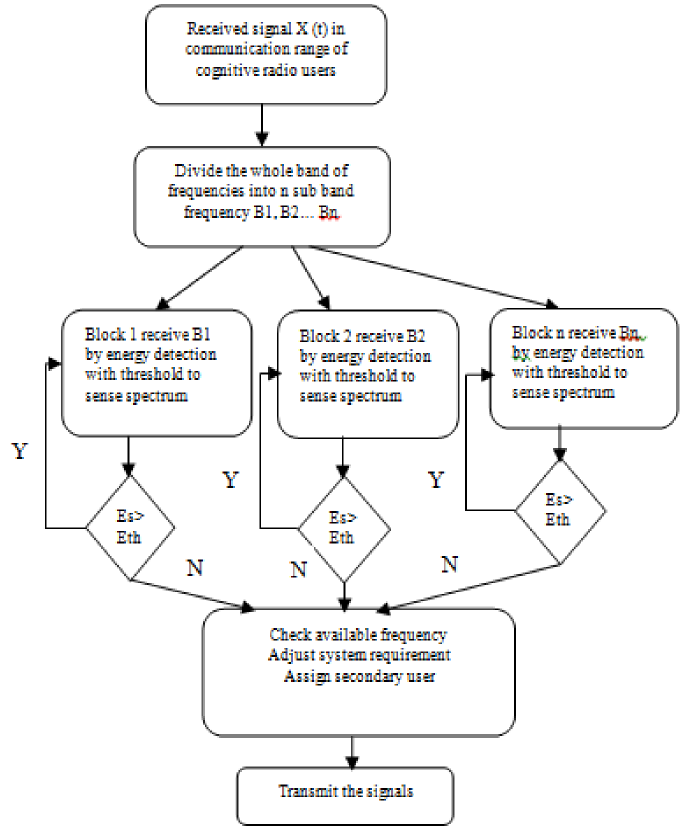

Fig. 4 flow chart of the proposed model

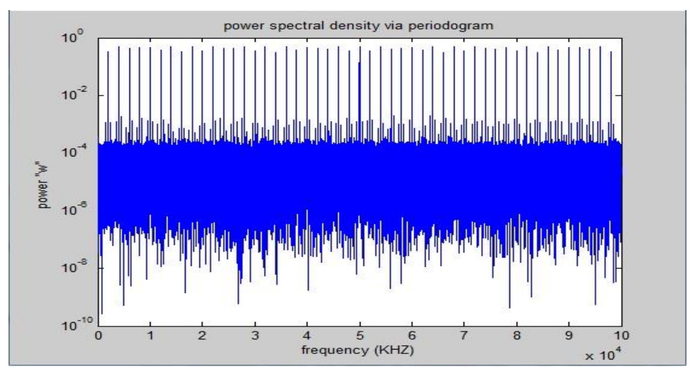

Fig. 5 Scope plot representing Primary signals

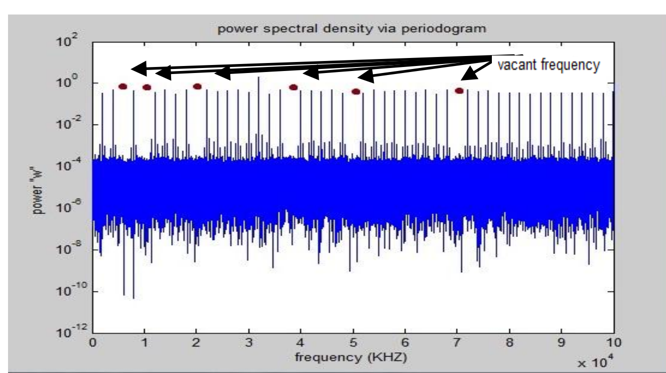

Fig. 6 Scope plot representing Primary signals with vacant frequency slots.

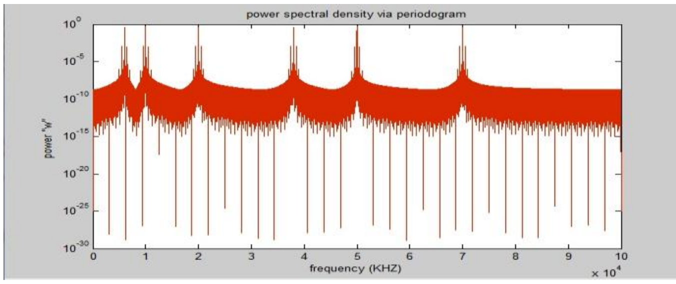

Fig. 7 Scope plot representing secondary signals assigned to vacant frequencies.

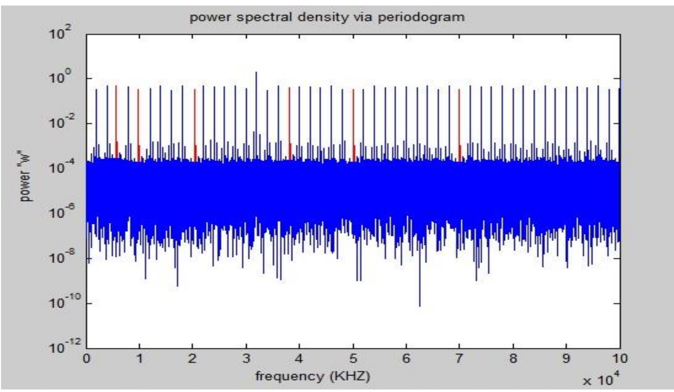

Fig. 8 Scope plot representing primary signals with blue color and secondary signals assigned for vacant frequencies with red color.

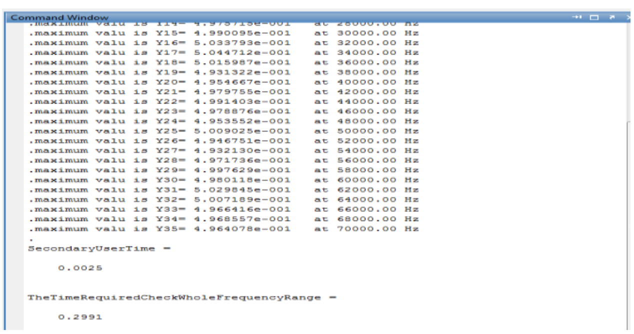

Fig. 9 Calculate the time needed for assign one secondary user and time needed to check whole frequency range.

VII. Conclusion

By using the MATLAB we are successfully able to sense the available spectrum, which is initialized and dynamically allocate the unlicensed user to that band and whenever the licensed primary user is looking for its allocated band the secondary user shifts its band to some other available bonds. The proposed model successfully reduces the time required to assign secondary user compare to FCC time limitation for the cognitive radio user.

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