International Journal of Engineering & Technology, 7 (4) (2018) 5151-5155

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.20731
Research paper

Spectrum sensing algorithm using ANN in cognitive radio

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Abstract

Studies of cognitive radio context raised major challenges about assigning SUs into licensed bands. Such challenges stand for time more likely, when the SU begins transmission and when it terminates the transmission? Asking this question implies that SU may limit the transmission in contrast with PU activity. In this paper, we propose a method for predicting the behaviors of PU during a particular period of time. This method reflects the schedule of spectrum utilization by PU. Time information can be directed thereafter to spectrum sharing paradigms. Artificial Neural Network is used predict the channel status and provide the information to SUs control station where interference with PUs can be averted.

Keywords: *Cognitive Radio (CR); Spectrum Sensing (SS); Spectrum Manager (SM); Base Station (BS); Primary User (PU); Secondary User (SU).*

1. Introduction

Learning is defined in [1] as skills and information that leads to facilitate people's lives and given by means of study. Furthermore, all knowledge is a mother of skills and it can be gained by multiple ways such as practical experience or teaching through a knowledgeable person; that is termed to the classical means of learning. Form the other hand, E-learning may term as gaining of knowledge in smarter way with more ease of information and knowledge delivery irrespective of location and time [2]. Many applications are used with E-learning such that: virtual classrooms, web learning, computer and mobile based leaning; another definition can be stated which is the information delivery by utilizing digital electronic and communication technologies such that internet, satellites, CD-ROM and interactive television [3]. All electronic learning systems (E-learning) are basically constructing of three functional components such content (things to be taught), service to be delivered to candidates and technology to be used for ensuring of those services. Students can be provoked for knowledge gaining by providing all interested education means such that virtual classrooms, quizzes, etc. all those facilities can be accessed distantly, the same had been developed when internet and communication technologies have been developed.

Dynamic spectrum access is using cognitive radio (CR) as an enabling technology that deals with scarcity issue. Since radio spectrum is important resource in wireless systems, spectrum sensing approach needs to be treated with care [4]. The concept of CR is forming what is so-called cognitive network that permits dynamic spectrum allocation instead of old static allocation of spectrum bands. Cognitive network involves intelligent infrastructures which are capable of sensing the surrounding environments and discovering the holes in the spectrum band dynamically. Moreover, CR is adaptable to real world conditions which make system parameters to be changed with spectrum fluctuation and radio status.

Spectrum assignment for new wireless networks are considered as fixed policy of spectrum allocation since the limited spectrum resources are inefficiently utilized. So, new paradigm for spectrum management seems to be necessary for wise utilization of radio spectrum [5]. CR approach is integrated method on the receiver or transmitter end users for updating their parameters in order to create the optimum spectrum usage. In other word, both PUs and SUs can transmit with minimal interference level if they sense and adapt each other in such way that SU detects the optimum suitable bands in spectrum and begins the communication over the same bands. Other studies are proposed that SU can sense the available spectrum and transmits in the suitable band [5], results of simulation give satisfactory data in terms of spectrum allocation performance.

Unlicensed bands are preferable by most organizations for testing their new technologies in terms of performance and its worthiness while they are deploying the same in remote and rural locations. World is in process of removing barriers from technology in order to deliver advantage to maximum possible number of beneficiaries, said by author. In order to make CR widespread, large number of research organizations and communities need to collaborate on the development of CR. However, signal processing, communication coding, radio frequency specialists, networking specialists, hardware designers, and software designers need to work side by side to establish fully cognitive network, such network is never an easy task to build. Furthermore, system player's behaviors need to be studied for ensuring perfect spectrum sharing and management in CR network within the frame of regulations made by geographical region spectrum organizations [6].

Since all slots of spectrum are allotted to various applications, studies shown that spectrum (white bands) is not a fully occupied in time by licensed users. CR concept is formed for justice spectrum distribution among variety of users [7]. Researches had discriminated the wireless communications as a system consisting of cognitive channels and non-cognitive channels. If the transceiver detects a free channel (unutilized channels) then it is named as cognitive channel; otherwise, the term non-cognitive channel is used for the busy band. The available bands of the white spectrum can be utilized for other user 's transmission in such way that minimal interference is guaranteed. Since the cognitive network is surrounded by variable conditioning environments, network should be self-upgradable. Dynamic spectrum access models are important to mitigate the scarcity of spectrum, and different techniques of spectrum management have reviewed in [7]. The recommended way to utilize the spectrum as stated in this paper is letting the network to learn from the surrounding environment and to scan the spectrum periodically for accurate channel assignment. ANN is integrated with spectrum sensing paradigm to achieve highly précises spectrum sensing [8].

2. IEEE 802.22 physical layer

It is the lowest layer in the protocol stack which looks after physical medium interfaces, this layer needs to adapt to physical medium uncertainty caused by user mobility [9]. However, modulation and coding schemes are applicable in this layer where signal is prepared prior of deploying it to physical channel. Studies noted that bandwidth is small for single channel and multiple channels are required to establish transmission with high data rate. Two links need to be established normally for such type of communication especially when base station and multiple users are presented. Downlink which takes care of transmitting data from base station to subscribers and uplink is the direction transmitting the data from subscriber (Premises Attached Equipment) to base station. Figure 1 depicts the links established between base station and user's entity.
Fig. 1 Depicts The Links Established between Base Station and User's Entity, Downlink and Uplink Are Shown.

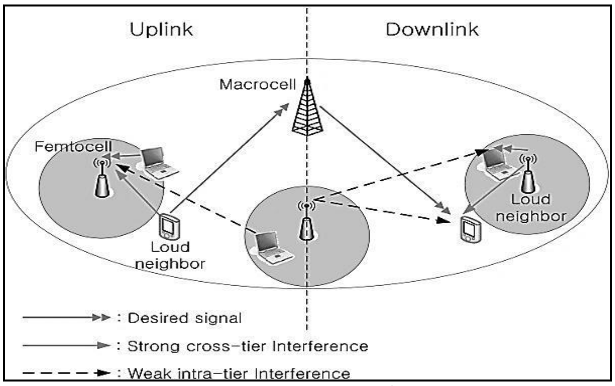

Fig. 1: Conceptual Structure of EDUSAT.

Table 1: EDUSAT Design Specifications

Subject	Details
Mass to be lifted of	1920 Kilo gram
Dimensions	2.4x1.65x1.15 (in meters)
Power supply	Solar panels 2044 w
Life of service	84 months

3. Frequency modulation

Cognitive radio (CR) network protocol stack performs modulation and coding of information prior to sending in through the channel [10]. In our approach, we let unlimited PUs to participate the predefined channel, each user data needed to be carried along the channel by higher frequency carrier signal, frequency modulation concept was used to multiplex number of user into one transmitted signal. Actually, this signal is group of subscribers who are willing to share spectrum bands. However, encoding all members of different frequencies into one signal is called as frequency modulation. If sinusoidal carrier can be transmitted as follow:
Let the transmitted single to be:

$$y(t) = \mathrm{A}\sin(2\pi\, f\, t) \quad (1)$$

$$y(t) = A\sin(2\pi\, f\, \sum_{ts=0}^{\frac{1}{fs}} t) \quad (2)$$

$$Y(t) = \sum_{1}^{n} yn(t) \quad (3)$$

Where:

$$ts = \frac{1}{fs} \quad , \; t = 0{:}1 * e^{-4}{:}\, ts$$

$$t = 0{:}1 * e^{-4}{:}\, \frac{1}{fs}$$

$$Y(t) = \sum_{1}^{n} A\sin(2\,\pi\, f * \sum_{ts=0}^{\frac{1}{fs}} t) \quad (4)$$

Where, Y (t) is referred to the transmitted signal after encoding all frequency subscribers, 'f' is carrier frequency of subscriber and 't' is time or signal length or sampling time. Frequency modulation involves two technologies; indirect modulation to be done by crystal oscillator and frequency multiplayer. Furthermore, direct modulation is done by using voltage control oscillator. Figure 2 demonstrates signals of frequency modulation and their differences from other modulation techniques.

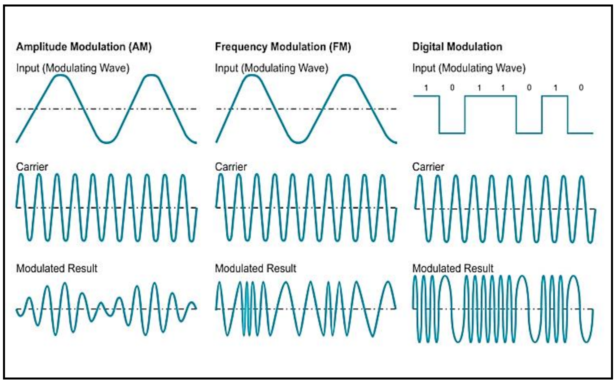

Fig. 2: Signals of Frequency Modulation and Their Differences from the other Modulation Techniques.

4. Fourier analysis

After samples are obtained from continues time signals, the discrete time components may be useful to test the response of discrete system. Stability, linearity and causality of the system can be studied by monitoring the system response of discrete input. However, Fourier transform is another approach to determine the spectrum response of the system where all frequency components can be studied. Let's see the mathematical derivation of Fourier transform [11].

$$Y[w] = \sum_{n=-\infty}^{+\infty} y[n].\, e^{-jwnt} \quad (5)$$

The equation is termed to discrete time Fourier transform where the y[n] is sampled sequence. Figure 3 depicts the discrete Fourier transform for sensorial signal.

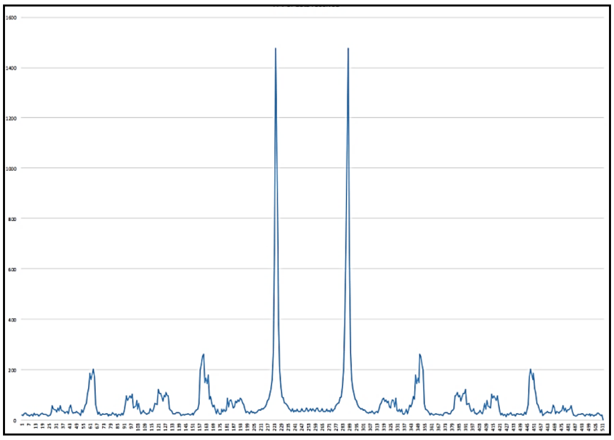

Fig. 3: Discrete Fourier Transform for Sensorial Signal.

5. Channel assignment

With availability of secondary users, all may need to send request to the base station (control room) for connection permission. SU is expecting to get connectivity through white bands by sharing the channels with original users (primary users). Collision and interference are the common obstacles raised in cognitive radio. Essential efforts need to be paid for spectrum sensing for achieving the expected performance. Figure 4 is depicting the proposed algorithm for spectrum sensing.

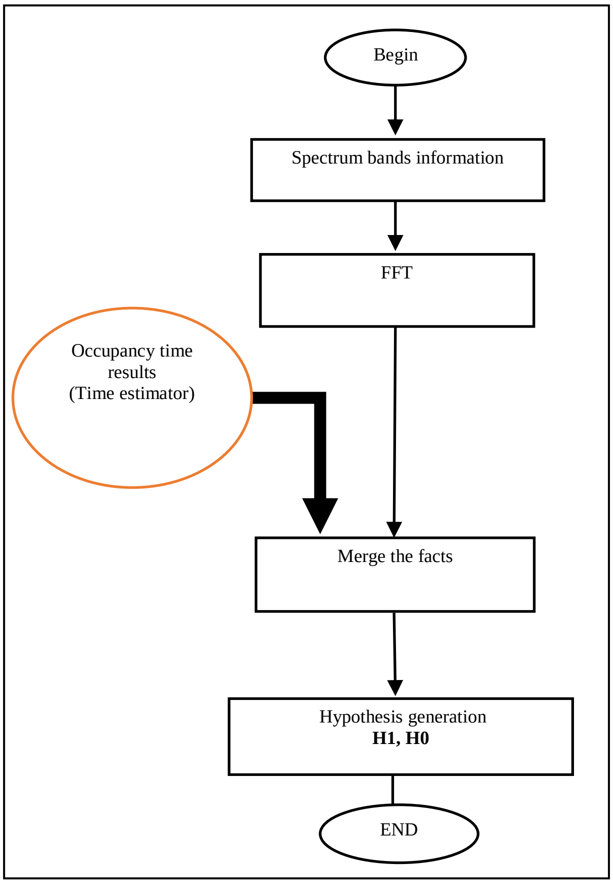

Fig. 4: Spectrum Sensing Paradigm.

Channel is practically experiencing noise such as Additive White Gaussian Noise (AWGN) and fading effects. Channel undesired participants can be listed as:

1) Noise components alike AWGN;
2) Fading alike Rayleigh fading;
3) Shadowing due to signal reflection by objects surrounding the transceiver;
4) Doppler effects due to unit mobility

In tradition spectrum sensing, systems are working with power spectrum density and forwarding the channel results into energy detectors where threshold value of energy is set for deciding the channel status [12]. In this paper, time estimation is predicted by ANN technology where the action plan of every primary user will be available for spectrum manager to perform channel assignment.

6. Practical model

6.1. Radio spectrum modelling

Three arguments are inquired during this phase: the working bandwidth, required number of licenced users, and simulation time. In here, bandwidth is divided equally among the primary users (PUs) so that following assumption is yielded: (PUBW= total BW/total PUs). Simulation time is considered here to study the random behaviours of PUs of spectrum bands occupancy; hereafter, program may calculate each licenced user frequency and prepare a frequency modulation to transmit all those users into radio medium. At the end of this model, frequencies are made available and public as variables in form of vector to be used in further procedures also, transmitted signal is prepared. For example: 100 Hz bandwidth, 20 primary users and 80 seconds of running time; system supposed to produced F-bands= [5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100]. Sinusoidal signal is assumed as carrier for above frequencies, sampling frequency is assumed as larger 1000 samples per second to produce high resolution signal. For: s(t)=sin (2π F Ts), where Ts is the sampling time (1/Fs); For transmission of twenty signals into AWGN channel, multiplexing of frequencies into this channel is required to ensure all signals transmission at one time (same time) . Figure 5 is depicting the modulated signal before it being sent through noisy environments.

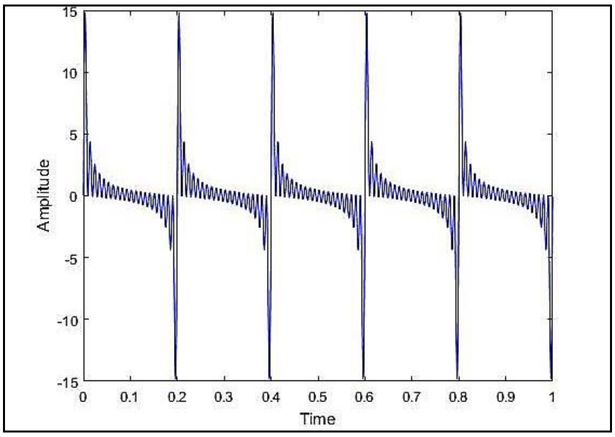

Fig. 5: Time Domain Signal Referred to Primary User Information where Noise Factor Is Not Considered.

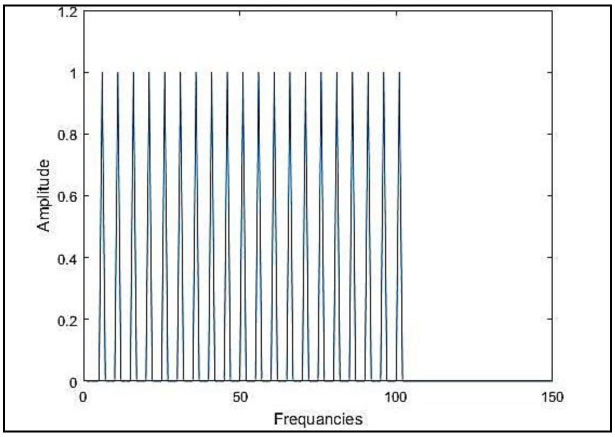

Fig. 6: Spectrum Analysis for the Transmitted Signal.

In above time domain signal, spectrum is monitored and plotted in Figure 6. In order to understand the frequency domain information, model is instructed to perform Fast Fourier Transformation (FFT).

6.2. Licenced users action plan

Hh the licenced user is taking over for a time Tw second and may return to occupy the same channel after Tw+n second. Hence, those factors are formulated as uncontrolled random variables. Each PU user can use the licenced band for Tw and exit after completion of that period; ideally, Tw is never identical for any two candidates unless other criteria are inferred. According to the time constrains, this model is instructed to initiate a matrix called as behaviours matrix; it contains of binary information stating the frequency availability for each time slot during the simulation. By segregating the time of simulation into smaller slots and generating the time matrix

TE=

5	8	16	21	3	13	4	15	14	19	11	7	6	2	18	10	9	1	17	20
13	17	8	20	1	2	18	19	7	14	5	9	3	16	11	21	4	6	15	12
17	21	4	15	16	6	1	9	7	13	2	18	10	11	14	20	5	19	3	12
10	16	7	9	3	17	19	6	14	2	5	4	12	11	13	15	1	8	21	18
7	5	3	8	19	13	18	21	17	6	4	11	15	10	16	14	9	2	20	12

For each primary user during that slot, the following time information may be yielded the matrix TE. Each row in TE matrix is reflecting the time that taken by primary user to vacant the channel. This is randomly generated time in each row, where each row is equivalent to 10 seconds. The process is repeated for five times. This data is feed forwarded to ANN controller where ANN can use this data for learning the behaviours of each primary user in the channel for different simulation times. The output off ANN will be TM' which reflecting the prediction of channel occupancy periods. System need to but threshold where it can decide whither secondary user can share the channel with primary user. Figure 7 is simulating the process of spectrum sensing using ANN.

This matrix will be directed into ANN subsystem where ANN can be train with light of this information. This process is called time estimator information. ANN will need to classify the results in such way for producing the channel availability status. ANN output will be either 'zero' which indicates channel is busy, or 'one' which indicates channel is free. The new matrix is generated for each time slot after classification process is over, the resultant matrix is nominated as TE'.

TE'=

1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1
0	0	0	0	1	1	0	1	0	0	1	1	1	0	0	0	1	0	0	0
0	0	1	0	0	1	1	1	1	0	1	0	0	1	0	1	1	1	1	0
0	0	1	1	1	0	0	1	0	1	1	1	0	0	0	0	1	1	0	0
1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0

According to the results spectrum sensing can be dine efficiently without affection of channel disturbances like noise and fading.

6.3. Monitoring model

For examining the channel during several iterations, Fast Fourier Transform (FFT) is used where frequency components can be displayed. However, here, we attempt to check the channel status in different possibilities of PU presence. For easily tracking of results, let us assume six PUs existences; hence for 50 seconds of simulation and 600 Hz of total bandwidth let us demonstrate the channel status for each 10 seconds. Results of monitoring model are demonstrated in Figures 7 through 11 where five iterations are shown.

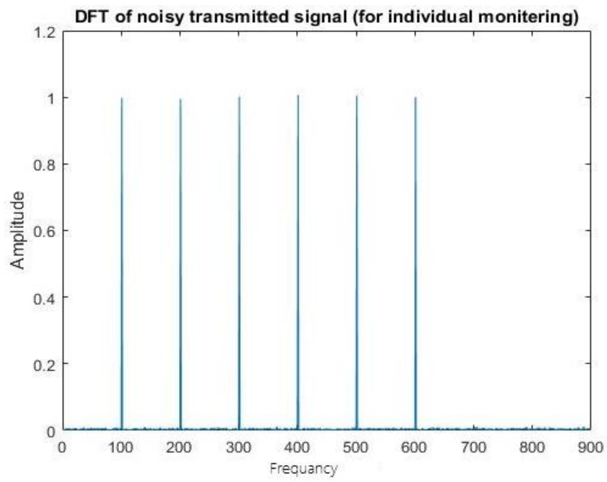

Fig. 7: Primary Users Availability in 1st Iteration.

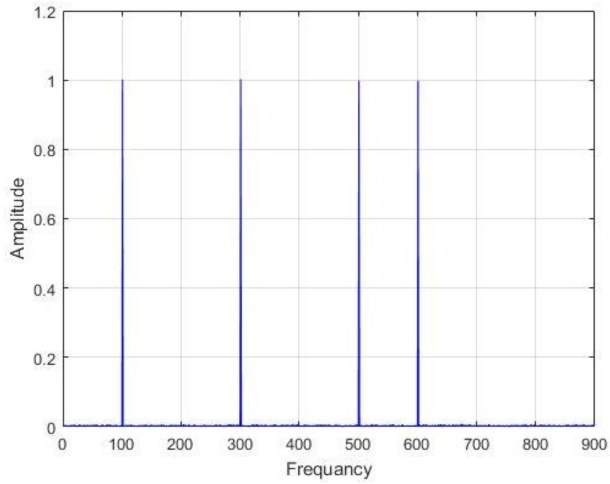

Fig. 8: Primary Users Availability in 2nd Iteration.

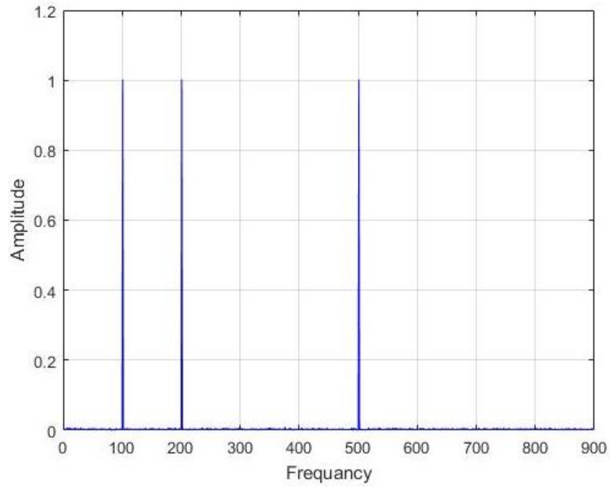

Fig. 9: Primary Users Availability in 3rd Iteration.

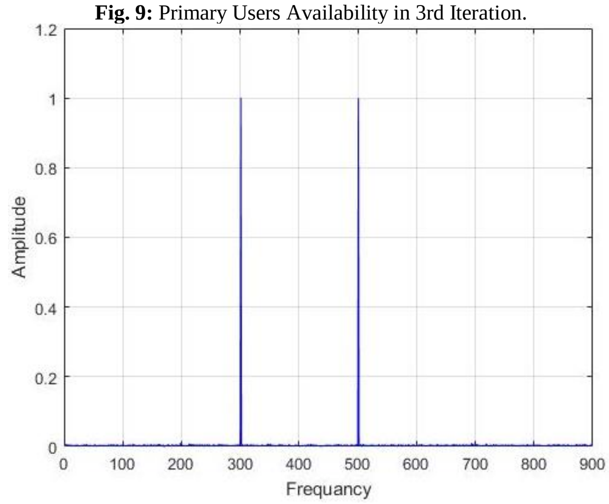

Fig. 10: Primary Users Availability in 4th Iteration.

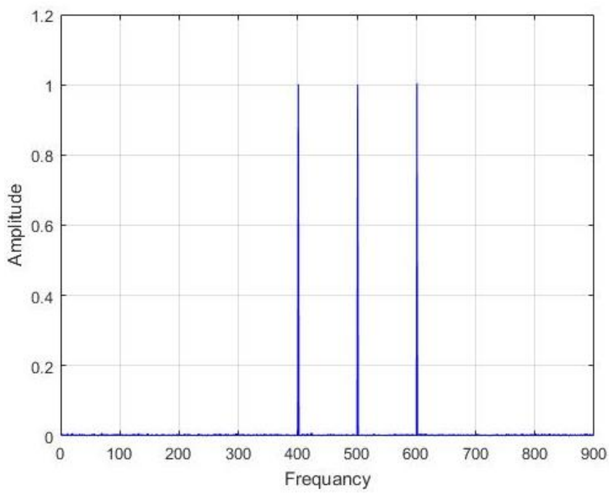

Fig. 11: Primary Users Availability in 5th Iteration.

7. Conclusion

Since licenced bands are experiencing a high uncertainty in terms of occupancy, the secondary user (SU) need to keep track of white band periodically in order to relocate such bands. Since noise and fading effects are following each transmission process, in practical simulation we observed that noise and other disturbances present in the channel may affect the decision of spectrum sensing. The same has revealed as well by previous studies in literature. It is seen that most of spectrum sensing methods are done by filtering the power spectrum density obtained for working channel and comparing the resulted samples of frequency components to validate user occupancy. This approach involves waiting time estimator combined with ANN technology to determine PU behaviours which was done by considering multiple possibilities of PU occupancy. Such possibilities are randomly generated where each user resides in the white band for 'n' seconds. User mobility condition is such that PU may re-occupy the same bandwidth again when it is used with SUs. Such problem is handled by waiting time prediction in ANN model that contains information of primary user's activity during the run time. Noise and other degradations of spectrum sensing are combated by using primary user behaviours prediction in this study.

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