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Spectrum Monitoring In OFDM-Based Cr Networks By Window Based Energy Ratio Algorithm

Aswathy Anilkumar, Revathy G Nair,Jismi Babu
PG Student, College of Engineering Kidangoor,Kottayam ,Kerala
aswathy7740@gmail.com
PG Student , College of Engineering Kidangoor, Kottayam ,Kerala
ammugopalakrishnan93@gmail.com
Assistant professor, College of Engineering Kidangoor, Kottayam ,Kerala
Jjsmibabu@yahoo.com

Abstract: *This work presents a spectrum monitoring algorithm for OFDM based cognitive radios and in this, monitoring algorithm the primary user reappearance can be detected during the secondary user transmission. The proposed technique reduces the frequency with which spectrum sensing must be performed and greatly decreases the elapsed time between the start of a primary transmission and its detection by the secondary network. The analysis and simulation show that the algorithm can effectively and accurately detect the appearance of the primary user.*
Keywords: Cognitive networks, cognitive radio, fading channels, OFDM, spectrum sensing/monitoring.

1. Introduction

In this era the radio spectrum is becoming increasingly congested everyday with the increasing number of wireless devices. Static spectrum access is the main policy used in nowadays for the wireless communication. Under this policy, fixed channels are assigned to licensed users or primary users (PUs) for exclusive use while unlicensed users or secondary users (SUs) are prohibited from accessing those channels even when they are unoccupied. So a CR can be defined as a radio that can be programmed and configured dynamically to use best wireless channels in its vicinity. This type of radio automatically detects the available channels in wireless spectrum and then it changes the transmission and reception parameters to allow more concurrent wireless communication in a given spectrum band at one location. One of the main approaches utilized by cognitive networks is the overlay network model in which secondary users seek to opportunistically use the spectrum when the primary users are idle. In this method, secondary users must sense the spectrum to detect whether it is available to communication. If the PU(primary user) is idle, the SU(secondary user) can then use the spectrum, but it must be able to detect very weak signals from the primary user by monitoring the shared band to quickly vacate the occupied spectrum. During this process, the CR system may spend a long time, known as the sensing interval, during which the secondary transmitters are silent while the frequency band is sensed. Since the CR users do not utilize the spectrum during the detection time, these periods are called quiet periods (QPs). The energy detection is followed by feature detection to distinguish whether the source of energy is a primary user or noise. This mechanism is repeated periodically to monitor the spectrum. Once the PU is detected, the SU abandons the spectrum for a finite period and choose another valid spectrum band in the spectrum pool for communication.

When the secondary user utilizes OFDM as the physical transmission technique, a frequency domain based approach can be employed to monitor the spectrum. The OFDM can overcome many problems that arise with high bit rate communications. Also the OFDM which provides advantages like high spectral efficiency, scalability and fast implementation. The IEEE 802.22 is an OFDM based CR System. So this is a work proposes a spectrum monitoring technique, namely the *energy ratio* (ER) technique, that is suitable for OFDM-based cognitive radios.

2. Early Works

Traditional spectrum monitoring requires the transmitters of the secondary user must be silent. In that time a receiver statistics method is developed for spectrum monitoring and this method need not silence the secondary transmitters[1]. In this method the spectrum is monitored by the CR receiver during reception of packets. So the communication can be occurring at the same time as the monitoring is performed. In this method, for each received packet is compared with a threshold value. If the number of detected errors is above certain value, the monitoring algorithm indicates that the primary user is active. Otherwise the primary user absent. The threshold is obtained by considering the hypothesis test. The error-control codes in the fig1. Are turbo, and low-density parity check (LDPC) codes. There is source data sequence which is formed from the binary symbols at the encoder output in the transmitter and the destination data sequence is formed from the sequence of binary hard decisions at the output of the demodulator. The soft decision from the demodulator is used by the decoder and the hard decisions in the destination's data sequence are used for the receiver's error count[3]. The error count (EC) for the packet is the number of positions in which the source and destination data sequences are different. The REC is defined only for correctly decoded packets. When a packet does not decode correctly, then the receiver cannot be determine the destination's data sequence, so it cannot determine the EC. The REC remains the same as the EC, for such packets. When a packet decodes correctly but has a large value for the REC, then it means that the received signal was corrupted. The REC and the EC are identical for a correctly decoded packet. The receiver statistic known as the iteration count (IC) is used to detect the emergence of a primary signal, when the secondary receivers employ iterative decoding. When the IC is large for a packet, then it is likely that the received signal representing the packet was corrupted, and the corruption might be due to the presence of a primary signal in the frequency band. But the receiver statistics are subject to change by varying the system operating conditions. There are many parameters that can affect the receiver error count. So the receiver statistics may change from one receiver to the other. So it is difficult to characterize the receiver statistics for all CR receivers. So an algorithm called *energy ratio* is developed to overcome these issues and performing spectrum monitoring in an efficient way.

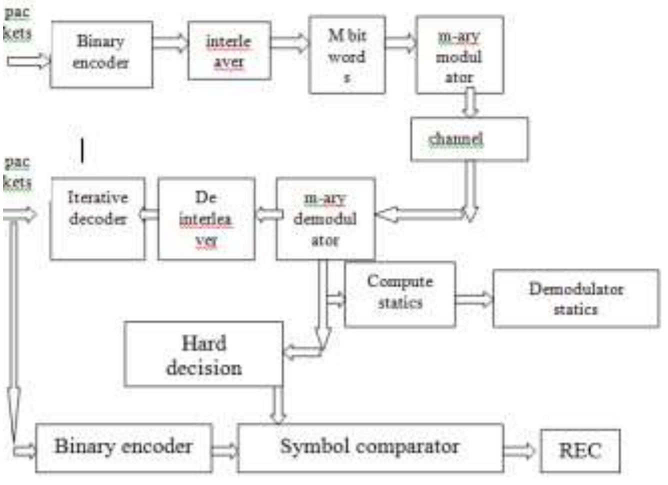


Fig1:transmitter and receiver models with receiver statistics

3. Proposed System Model

To verify the spectrum monitoring algorithm the secondary user physical layer model must be considered. For this the data coming from the source is segmented into blocks where each block is interleaved and encoded individually [3]. The frequency domain OFDM frame is the combination of training symbols. But in CR networks there are k secondary users and one primary user. The primary user occupies a spectrum and it also share the same spectrum with the secondary users. More specifically the spectrum shared by the secondary user is called master node and it gives information to all other secondary users and they are slaves. The master node is responsible for constructing OFDM frames. The frames are constructed such that the data subcarriers are allocated time and frequency for different users. The timing of each slave is controlled by the master node by allowing time delay in advance. The master node have the capacity to convert the signal back to the frequency domain and the control the information from the slaves. The slaves are able to send the monitoring decisions over the channel. Based on the received monitoring decisions the master node can apply a majority rule and decide whether to stop transmission or not.

4.Energy Ratio Algorithm

Before applying IDFT a number of tones are reserved for the spectrum monitoring purpose. These type of tones are reserved for the whole time except the time of training symbols not to change the preamble waveform. The reserved tones are allocated dynamically so their indices span the whole band. For every OFDM symbol, the tones are advanced by Δ_r positions. Based on the signal on the reserved tones the secondary user can monitor the band and test the primary user appearance.

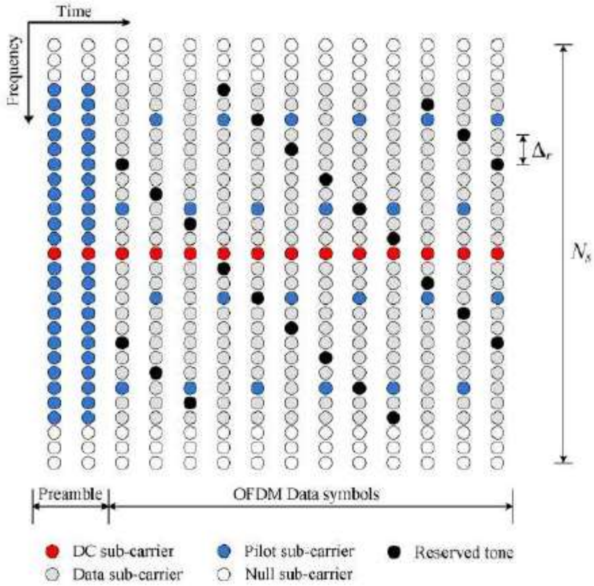


Fig2:OFDM frame

Fig1 shows the OFDM structure and in this N_s is the number of subcarriers over one OFDM symbol[1]. Assume that the primary signal appears after some time during the monitoring phase. The reserved tones from different OFDM symbols are combined and form a single sequence of samples. Over the reserved tone sequence two equal sized windows are passed and the energy of samples that fall in one window is calculated and the ratio of two energies is taken as the decision making variable. The decision making variable is calculated both sensing and monitoring phase but the decisions are provided only during the monitoring phase. When the decision from the sensing phase shows the primary user is inactive then the presence of primary user can be detected during the monitoring phase.

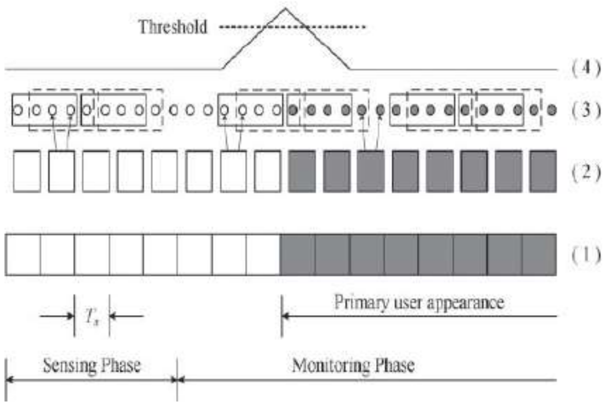


Fig3:Energy ratio algorithm[1]

Fig2 gives the details of energy ratio algorithm. The figure depicts the time domain sequence of the OFDM blocks, frequency domain samples, reserved tones processing with the two sliding windows and the decision making variable. The algorithm aims to check the change in variance over the reserved tone sequence. The decision making variable is X_k.And it is determined by[1]

$$X_k = \frac{U_k}{V_k} = \frac{\sum_{i=N+k}^{2N+k-1} |Z_i|^2}{\sum_{i=k}^{k+N-1} |Z_i|^2}.$$

N is the number of samples and Vk &Uk are the energies in the first and second window. During the monitoring phase, the receiver monitors the reserved tones by evaluating the parameter, Xk. If it exceeds a certain threshold, then the secondary user assumes that there is a presence of primary user appearance and it is time to vacate the band. If not, the secondary user can continue transmission. And when the presence of primary user is determined the decision variable which produces a spike. To verify the algorithm, first analyze the energy ratio technique assuming perfect synchronization and neglecting the leakage power effect. The reserved tone sequence is modelled via a zero mean circularly symmetric complex Gaussian distribution[2] .The analysis is to be done to determine the receiver operating characteristics represented by the probability of detection and probability of false alarm. The detection probability is the probability of detecting a primary signal when it is truly present. And the other one is the probability that the test incorrectly decides that the primary user is present when it is actually not. The performance of the detector is quantified in terms of its receiver operating characteristics curve, which represents the probability of detection as a function of the probability of false alarm. The objective of this criteria is to maximise the probability of detection subject to the constraint on probability of false alarm.

Algorithm

Step1: Set the time for sensing and spectrum usage .
Step2: QAM modulation is applied to the generated data. This is used in both Transmitter and receiver side.
Step3:In transmitter section apply IFFT and assign pilot symbols for each subcarrier. Also a CP is added .
Step4:In the receiver section, the CP is removed and extracting the pilot symbols and spectrum sensing begins.
Step5: Two sliding windows are passed through the extracted symbols. And then taken the ratios of the energies of the symbols.
Step5:Check the ratio value continuously to find the PU.
Step 6:Spectrum plot is obtained as the output.
Step7:To modify the spectrum output use different sized windows and take the energies over the windows and continuously check the energies and get the modified spectrum output.

By using the three different sized windows, there is one window which gives high probability of detection for the SPR value. SPR is the secondary to primary power ratio. For SPRs of 14db it give the probability of detection of .95.In this method the threshold is obtained from the beta function and this threshold value is compared with energies of each window and detect the presence of primary user.

5. Simulation Results

In the simulation, we used an OFDM system that employs a total of *Ns* = 1024 sub-carriers, 224 of which are used as guard bands on both ends of the signal band. There are 32 pilot sub-carriers and *NRT* =4 reserved tones, distributed across the entire 800 sub-carriers. the reserved tone spacing Δ_r =1.

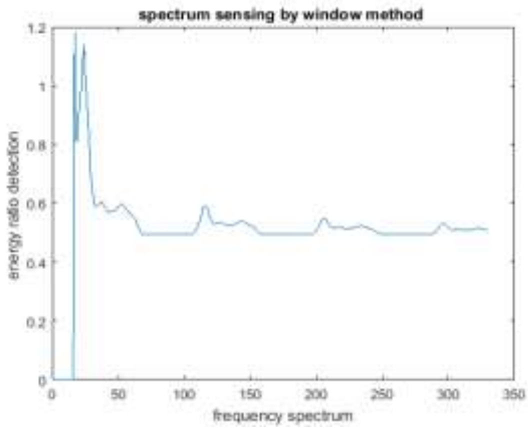


Fig4:spectrum sensing by window method

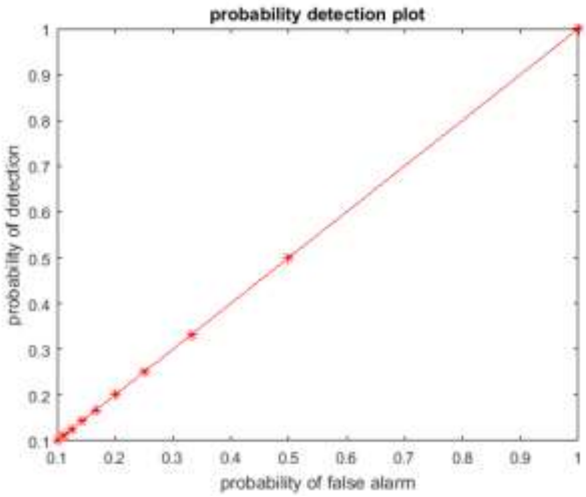
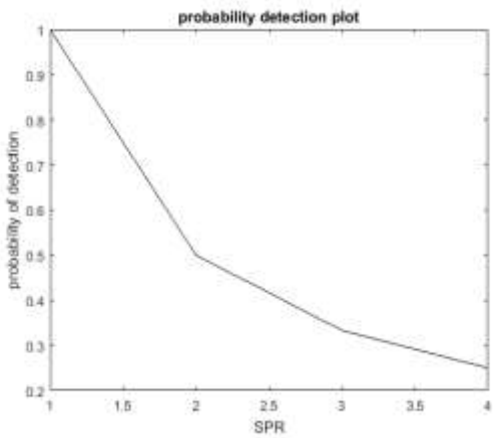


Fig5:probability detection plot



By using equal sized window	• Get probability of false alarm is equally increasingwith probabilityof detection. • So the Probability of detection plot is a straight line.
By using different sized window	• Probabilityof detection is higher than probability of false alarm. • For an SPR of 14db getting probability of detection as 0.9.PU appearance can be easily detected.

Fig6:probability detection plot of probability detection vs. SPR

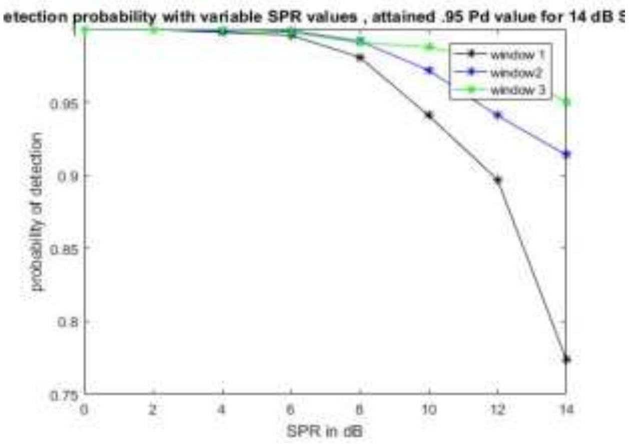


Fig7:probability of detection with variable SPR values

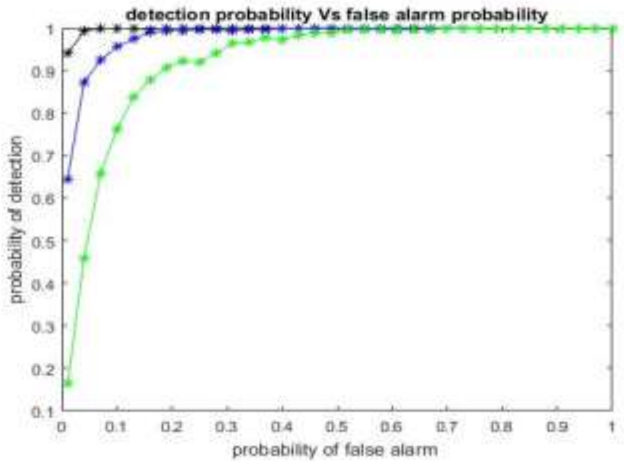


Fig8:probability of detection Vs probability of false alarm

The fig4 is the spectrum sensing by window method and from this there is peak occurs this means the presence of primary user.Fig5 is the probability detection plot and it is a straight line curve obtained and it means that the probability of detection is increased with probability of false alarm. And the fig6 gives the probability of detection with different SPR values and which is related to primary to secondary noise ratio (PNR) such that PNR|dB =SNR|dB − SPR|dB, where SNR is the secondary power to noise power ratio. SPR is assumed to be the main parameter by which a monitoring algorithm is evaluated.Fig 7 and Fig 8 are obtained by the use of different sized windows .From the fig7 it is clear that for 14db SPR value a .95 probability of detection is obtained. So the detection of primary user is become easy.

6.Conclusion

This work proposed a spectrum monitoring algorithm that can sense the reappearance of the primary user during the secondary user transmission. This algorithm, named "*energy ratio*" is designed for OFDM systems. We also derived the detection probability and the probability of false alarm for AWGN channels to analyze the performance of the proposed algorithm. In this the probability of detection plot is a straight line. That means the probability of detection is linear with probability of false alarm. For better performance use different sized windows are used.And in this case the improved detection performance is obtained along the SPR vs. probability detection curve. By the improvement in the detection, the primary user appearance can be easily detected. Therefore, this proposed spectrum monitoring algorithm can greatly enhance the performance of OFDM-based cognitive networks by improving the detection performance with a very limited reduction in the secondary network throughput.

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