OFDM- Based Cognitive Radio Networks Spectrum Sensing and Monitoring Techniques

Dr. C. M. Jadhao1,
Department Of EXTC,
Principal,
MGI-COET, Shegoan,
India
cmjadhao@gmail.com

Prof. Santosh S. Mhaske2,
Department Of EXTC,
HOD & Associate Professor
MGI-COET, Shegoan,
India
mhaskesantosh12@gmail.com

Manish A. Gawande3
Department Of EXTC,
MGI-COET, Shegoan,
India
gawandemanish90@gmail.com

Abstract — This paper presents a spectrum monitoring algorithm for Orthogonal Frequency Division Multiplexing (OFDM) based cognitive radios using which the primary user reappearance or availability can be detected during the secondary user transmission. Nowadays, we use static spectrum access method for wireless communication under this policy fixed channels are assigned to licensed user or primary users (PUs) for exclusive use while unlicensed secondary users or secondary users (SUs) are prohibit from accessing PUs channels even when they are not occupied. The idea of a cognitive radio (CR) was proposed to achieve efficient utilization of the RF spectrum. In cognitive networks uses the network model in which SUs seeks to use the spectrum when the PUs is idle. Primary and secondary user channel are not allow to operate simultaneously. In this method, secondary users must sense the spectrum to sense whether it is available or not prior to communication. If the primary user (PU) is idle, the SU can then use the spectrum, but it must be able to sense very weak signals from the primary user. The proposed method or technique reduces the frequency with which spectrum sensing must be performed and greatly decreases the elapsed period between the start of a primary transmission and its detection by the secondary network. This is done by sensing the change in signal strength throughout a number of reserved OFDM sub-carriers so that the availability of the primary user is easily detected. In this case we are using the energy ratio algorithm can effectively and accurately detect the appearance of the primary user. This method achieves more immunity to frequency-selective fading channels for both single and multiple receive antenna systems, with a complexity that is approximately twice that of a conventional energy detector. Cognitive radios offer the promise of being a disruptive technologies innovation that would enable the future wireless world. Cognitive radios network is programmable wireless devices that could sense their environment and dynamically adapted their transmission waveform, channel access methods, spectrum used, and networking protocol as needed for better network and application performance

Keywords: *cognitive radio network, orthogonal frequency division multiplexing (OFDM), multiple input multiple outputs (MIMO), Energy Ratio Algorithm*

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I. INTRODUCTION

Nowadays, static spectrum access is the main policy for wireless communications. Under this policy, fixed channels are assigned to licensed users or primary users for special use while unlicensed users or secondary users (SUs) are prohibited from accessing those channels even when they are unoccupied. The idea of a cognitive radio was developed in order to achieve more efficient utilization of the RF spectrum. One of the main approaches utilized by cognitive networks is the interweave network model in which secondary users seek to opportunistically use the spectrum when the primary users are idle. Primary and secondary users are not allowed to operate simultaneously. In this method, secondary users must sense the spectrum to identify whether it is available or not prior to communication. If the PU is idle, the SU
can then use the spectrum, but it must be able to detect very weak signals from the primary user by monitoring the shared band in order 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 dumb while the frequency band is sensed. Since the CR users do not utilize the spectrum during the detection time, these periods are also called quiet periods (QPs). In the IEEE 802.22 system, a quiet period consists of a series of consecutive spectrum sensing period using energy detection algorithm to determine if the signal level is larger than a predefined value, which indicates a non-zero probability of primary user transmission. The energy detection is followed by feature detection to distinguish whether the source of energy is a primary user or noise or some disturbance. This mechanism is repeated periodically to monitor the spectrum. Once the PU is detected, the SU abandons the spectrum for a finite period and select another valid spectrum band in the spectrum pool for communication.

If the secondary user must periodically stop communicating in order to detect the emergence of the PU, two important effects should be studied. During quiet periods, the SU receiver may lose its synchronization to the SU transmitter which causes an overall degradation in the secondary network performance. This is a problem when the radical communication technique is sensitive to synchronization errors as in OFDM. The throughput of the secondary network during sensing intervals is minimized to zero which degrades the Quality of Service for those real-time applications like Voice over IP (VoIP). The impact becomes more severe if the duration of the sensing intervals is too large as the average throughput of the secondary network becomes very low. On the other hand, if this duration is too small, then the interference to the primary users is increased since spectrum sensing does not provide information about the frequency band of interest between consecutive sensing intervals. In this area, there have been researching efforts which attempt to reduce the time duration for spectrum monitoring by jointly optimizing the sensing time with the detection threshold. The primary user throughput statistics are considered to prevent the primary user while the sensing time is minimized.

II. CONVENTIONAL SYSTEM

In conventional systems, traditional spectrum sensing is applied once before the SU communication and is not be repeated again unless the monitoring algorithm indicates that a primary signal may be present in the band. If monitoring determines correctly that there is no primary signal in the band, then the time that would have been used performing spectrum sensing is used to deliver packets in the secondary network. Therefore the spectrum efficiency of the secondary network is improved. If spectrum monitoring identifies a primary signal in the band during a time period in which spectrum sensing would not have been scheduled, then the disruption to the primary user can be terminated more quickly and hence the effect of secondary communications on the primary user is reduced. Based on this description, the SU receiver should follow two consecutive phases, specially sensing phase and monitoring phase, where the former is applied for a predefined period.

III. LITERATURE SURVEY

[1] A. Ghosh and W. Hamouda, "Cross-layer antenna selection and channel allocation for MIMO cognitive radios", *IEEE Trans. Wireless Commun.*, vol. 10, no. 11, pp. 3666–3674, Nov. 2012**.**

In this paper A. Ghosh and Hamouda had proposed algorithm to address the spectrum efficiency and fairness issues of multi band multiuser Multiple- Input and Multiple-Output (MIMO) cognitive ad-hoc networks. To improve the transmission efficiency of the MIMO system, a cross layer antenna selection algorithm is proposed. Using the transmission efficiency results, user data rate of the cognitive ad-hoc network is determined. Objective function for the average data rate of the multi band multiuser cognitive MIMO ad-hoc network is also defined. For the average data rate objective function, primary users interference is considered as performance constraint**.**

Disadvantage: In this paper they are not commenting on OFDM impairments. With this they have just explained Cognitive MIMO ad-hoc network.

[2] W. S. Jeon, D. G. Jeong, J. A. Han, G. Ko, and M. S. Song, "An efficient quiet period management scheme for cognitive radio systems", *IEEE Trans. Wireless Commun.*, vol. 7, no. 2, pp. 505–509, Feb. 2014**.**

In this paper author try to explain cognitive radio (CR) systems, the channel sensing scheme for detecting the presence of primary user directly affects the quality-of-service of CR users and primary user. They had proposed a sensing scheme that consists of a series of consecutive energy detections followed by feature detection, where the energy detection time is much shorter than the feature detection time. With the proposed scheme, multiple energy detections decrease the feature detection due to false alarm and the overall channel sensing time. The performance evaluation using Markov analysis shows that the proposed scheme can heighten the maximum channel utilization of CR users, while maintaining the detection delay of primary user under a predefined value**.**

Disadvantage: Author explained new method for detection of primary user, with this scheme they are used markov analysis which makes cognitive network analysis more complex.

[3] D. Cabric, S. M. Mishra, and R. W. Brodersen, "Implementation issues in spectrum sensing for cognitive radios", in *Proc. Conf. Rec. 38th Asilomar Conf. Signals, Syst. Comput.*, vol. 1, pp. 772–776, Nov. 2013**.**

There are new system implementation challenges involved in the design of cognitive radios, which have both the ability to sense the spectral environment and the flexibility to adapt transmission parameters to maximize system capacity while co-existing with legacy wireless networks. The critical design problem is the need to process multi-gigahertz wide bandwidth and reliably detect presence of primary users. This places severe requirements on sensitivity, linearity, and dynamic range of the circuitry in the RF front-end. To improve radio sensitivity of the sensing function through processing gain they investigated three digital signal processing techniques: matched filtering, energy detection, and cyclo-stationary feature detection. Our analysis shows that cyclo-stationary feature detection has advantages due to its ability to differentiate modulated signals, interference and noise in low signal to noise ratios. In addition, to further improve the sensing reliability, the advantage of a MAC protocol that exploits cooperation among many cognitive users is investigated.

Disadvantage: This paper shows author had worked only to improve radio sensitivity by using traditional spectrum sensing method. This method is slow, require more time to detect primary user power leakage with this method is large.

[4] R. Saifan, A. Kamal, and Y. Guan, "Efficient spectrum searching and monitoring in cognitive radio network", in *Proc. IEEE 8th Int. Conf. MASS*, pp. 520–529, 2014**.**

In this paper author has classified in enhancing false alarm probability and detection probability optimizing inter-sensing time, in-band sensing (monitoring) time optimization, and out-of-band sensing (search) time optimization. The PU model used in most of these work was a simple two states model (busy/idle renewal process). In this work, they developed a model for the PU in its idle state. The model enables the CR node to benefit from its previous measurements. It assumes that there are multi-idle states, each with specific length and known probability of staying in it. This model is used to find the best sensing time, energy detection threshold, and false alarm probability of the channel being sensed in monitoring. . The formulation finds the best number of channels to sense, the threshold of each channel, the sensing time of each channel, and Pf of each channel such that the PU is protected, the sensing time is minimized, and the CR will find an available channel with very high probability.

Disadvantage: With this model they are unable to comment on selective frequency fading. They had not explained OFDM impairments.

[5] H. Mahmoud, T. Yucek, and H. Arslan, "OFDM for cognitive radio: Merits and challenges", *IEEE Wireless Commun.*, vol. 16, no. 2, pp. 6–15, Apr. 2011.

CR is an exciting and promising technology that offers a solution to the spectrum crowding problem. On the other hand, the OFDM technique is used in many wireless systems and has proven to be a reliable and effective transmission method. OFDM can be used for realizing the CR concept because of its inherent capabilities that are discussed in detail in this article. By employing OFDM transmission in CR systems, adaptive, aware, and flexible systems that can interoperate with current technologies can be realized. However, the challenges identified in this article must be researched further to address the open issues. Practical CR systems can be developed using two approaches: current wireless technologies can evolve to support more cognitive features over time, or new systems that support full cognitive features can be developed. In either case, Author foresee that OFDM will be the dominant PHY technology for CR.

Advantages: In this paper author had explain all merits and demerits of OFDM system for cognitive network. They explained how OFDM is reliable to cognitive network.

[6] W. Hu *et al.*, "Cognitive radios for dynamic spectrum access—Dynamic frequency hopping communities for efficient IEEE 802.22 operation", *IEEE Commun. Mag.*, vol. 45, no. 5, pp. 80–87, May 2013.

In this paper W. Hu et.al. explains wireless cognitive radio network and spectrum monitoring for WRANs network. One of the key challenges of the emerging cognitive radio-based IEEE 802.22 wireless regional area networks (WRANs) is to address two apparently conflicting requirements: ensuring QoS satisfaction for WRAN services while providing reliable spectrum sensing for guaranteeing licensed user protection. To perform reliable sensing, in the basic operation mode on a single frequency band (non-hopping mode), one must allocate quiet times, that is, periodically interrupt data transmission that could impair the QoS of WRAN. This critical issue can be addressed by an alternative operation mode proposed in 802.22 called dynamic frequency hopping (DFH), where WRAN data transmission is performed in parallel with spectrum sensing without interruptions. DFH community, as described in this article, is a mechanism that coordinates multiple WRAN cells operating in the DFH mode, such that efficient frequency usage and reliable channel sensing are achieved.

IV. SYSTEM MODEL

The secondary user physical layer model is designed in order to investigate and verify our spectrum monitoring algorithm. This model is very close to the OFDM system. At the transmitter side, data coming from the source is firstly segmented into blocks where each block is randomized, channel encoded, and interleaved separately. After interleaving, the data is modulated by the constellation mapper. The frequency domain OFDM frame is constructed by combining: (a) One or more training symbols or preambles that are used for both time and frequency synchronization at the receiver side. (b) The modulated data. (c) The BPSK modulated pilots which are used for data-aided synchronization algorithms employed by the receiver. Each Ns encoded complex data symbols generated by the frame builder are used to construct one OFDM symbol by employing the IDFT block that is used to synthesize the OFDM symbol, where Ns denotes the number of sub-carriers per one OFDM symbol. Thus, the nth time-domain sample of the mth symbol can be expressed as given by (1) where C(k,m) is the modulated data to be transmitted on the mth OFDM symbol with the kth sub-carrier.

$$s(n,m) = \frac{1}{N} \sum_{k=\frac{-N_s}{2}}^{\frac{N_s}{2}-1} c(k,m) e^{j2\pi kn/N_s} \quad \ldots. (1)$$

To reduce the effect of Inter-Symbol Interference (ISI), the last Ng samples of the time domain OFDM symbol are copied to the beginning of the symbol in order to form a guard time or cyclic prefix. Therefore, the OFDM block has a period of Ts = (Ns + Ng)/Fs where Fs is the sampling frequency. At the receiver, the inverse blocks are applied. After timing synchronization (frame detection, start of symbol timing, and SFO estimation and compensation) and frequency synchronization (CFO estimation and correction), the cyclic prefix is removed. Then, the received OFDM symbol is transformed again into the frequency domain through an Ns point DFT. The channel is then estimated and the received data is equalized. The complex data output is then mapped to bits again through the De-mapper. De-interleaving, decoding, and De-randomization are applied later to the received block to recover the original source bits.

From the network point of view, we consider a cognitive radio network of K SUs and one PU. The PU occupies a spectrum of a certain bandwidth for its transmission, while the same spectrum is shared by the SUs. In fact, the spectrum is totally utilized by one SU (the master node or the fusion node) to send different data to the other K−1 SUs (the slave nodes). This model was originally introduced for Frequency Division Multiple Access (FDMA) [11] but it has been modified later to suite the OFDM environment. Currently, this model particularly matches two promising solutions, namely Ecma392 and IEEE 802.11af, that employ OFDM as the underlying physical transmission technique. The standards introduce cognitive radio approach to the TV white space. Usually, a secondary user should get necessary information from TV white space database which maintains a list of the unused TV channels geometrically. However, the standards specify channel power management functionality in order to update the available channel lists. The current Ecma-392 standard supports spectrum sensing functionality to periodically check the existence of incumbent signals on the current operating channel. Ecma-392 has specified the operation in only single TV channel which can be one of three channel bandwidths of 6 MHz, 7 MHz, or 8 MHz according to regulatory domain. The objective is that the secondary user can utilize the full band on which the primary user operates. The IEEE 802.11af standard is an extension to the Wireless Local Area Network (WLAN). The channel bandwidths in this standard can be adaptively changed when several adjacent TV

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18 – 24

channels are available. Again, the fusion node (the access point) utilizes the whole primary user band to broadcast the downlink signal to all slaves. In reality, our algorithm is demonstrated by a more general model which does not perfectly match the implementation of either Ecma392 or IEEE 802.11af. The main difference is that our model has no limitations on the channel bandwidth, the channel characteristics, or even the frequency tolerances.

In our model, the fusion node constructs OFDM frames in the downlink path such that the same pilots are transmitted to all slaves but the data sub-carriers are allocated in time and frequency for different users based on a predefined scheduling technique. For the return path, Orthogonal Frequency Division Multiple Access (OFDMA) is assumed to divide the spectrum and the time into distinct and non-overlapping channels for different slaves, so that interferences between the slaves is avoided. The fusion node fully controls the timing of each slave, possibly by letting the slave know the required time advance or delay, so that the combined signal from all slaves seem to be synchronized at the fusion node receiver. In this case, the fusion node can convert the signal back to the frequency domain in order to extract the data and control information from different slaves. A valid assumption is that the slaves can send important information such as spectrum monitoring decisions and channel state information over a logical control channel in the return path. The master node can simply apply a majority rule based on the received monitoring decisions to decide whether to stop transmission or not.

V. ENERGY RATIO ALGORITHM

On the time-frequency grid of the OFDM frame and before the IDFT, a number of tones, NRT, are reserved for the spectrum monitoring purposes. These tones are reserved for the whole time except the time of the training symbol(s) in order not to change the preamble waveform, which is used for synchronization at the receiver. The proposed OFDM frame is shown in Fig. 1. Notice that we allocate the reserved tones dynamically so that their indices span the whole band when successive OFDM symbols are considered in time. The tones are advanced by Δr positions every OFDM symbol. When the last index of the available sub-carriers is reached, the spanning starts again from the first sub-carrier. Hence, by considering small values for Δr, the reserved tone sequence injected to the energy ratio spans the whole band. The reasons for this scheduling are: (1) the primary user may have some spectrum holes because of using OFDM as well. If the reserved tones from the SU are synchronized with those spectrum holes in the PU side, then the algorithm will fail. On the contrary, if the PU uses a traditional single carrier modulation technique like QAM, this issue does not have a harm effect on the algorithm since the PU signal has a flat spectrum over the entire band. (2) The reserved tones typically occupy narrow band and the primary to secondary channel may introduce notch characteristics to this narrow band resulting in detecting lower primary power level, which is referred to the narrow band problem. Therefore, it is recommended that the reserved tones are rescheduled by changing the value of Δr over time to mitigate the channel effect and to protect the reserved tones from falling into primary holes. Of course, all SUs should know the code for this scheduling in prior.

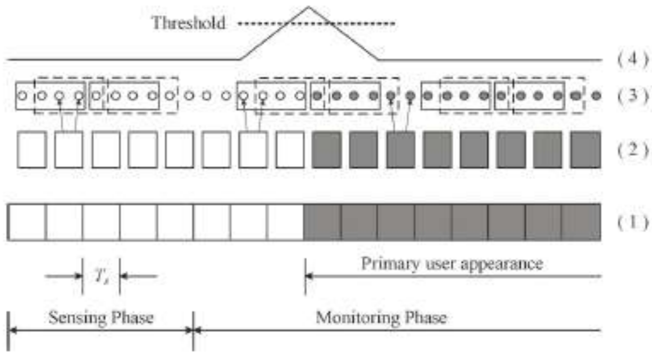

Fig.2. Energy ratio processing details (1) the time domain sequence for the OFDM blocks (2) frequency domain sample (3) reserved tones processing with two sliding windows for N_{RT} = 2 & N= 4.(4) Decision making variable X_k

Based on the signal on the reserved tones at the receiver, the secondary user can monitor the band and test the primary user appearance. In fact, the traditional radiometer may be employed to measure the primary signal power and the secondary noise power by accumulating the energy of those reserved tones. As a consequence, the primary signal power can be detected if this energy exceeds a predefined threshold. However, this approach does not necessary guarantee the primary user detection as the spectral leakage of the neighboring sub-carriers will affect the energy at the reserved tones even for no in-band primary signal . Here, we propose another decision making criterion that has a powerful immunity for this power leakage. In fact, the power leakage, the ICI resulted from the residual CFO and SFO errors, and even the effect of NBI can be overcome by our approach.

The overall algorithm is illustrated by Fig. 2. It is assumed that the primary signal appears after some time during the monitoring phase. At the secondary receiver, after CP removal and frequency domain processing on the received signal, the reserved tones from different OFDM symbols are combined to form one sequence of complex samples. Two consecutive equal-sized sliding windows are passed over the reserved tone sequence in the time direction. The energy of the samples that fall in one window is evaluated and the ratio of the two energies is taken as the decision making variable and hence the name energy ratio.

The algorithm aims to check the change in variance on the reserved tones over time. In a mathematical form, let Zi be the ith sample of the reserved tone sequence. The decision making variable, Xk, can be defined as given by (2) where N is the number of samples per window, Uk is the energy of the second window, Vk is the energy of the first window, and k is an integer such that k = 1, 2, 3, ...

$$X_k = \frac{U_k}{v_k} = \frac{\sum_{i=N+k}^{2N+k-1} |Z_i|^2}{\sum_{i=k}^{i=k+N-1} |Z_i|^2} \quad \text{..................} \ (2)$$

It should be mentioned that the reserved tones processing done by the energy ratio algorithm starts from the beginning of the sensing phase. Meaning that, the decision making variable is evaluated during both sensing and monitoring phases. However, it provides decisions only during monitoring phase. During the sensing phase, if the decision from the spectrum sensing algorithm is that the PU is inactive, then the energy ratio algorithm has been properly calibrated to be able to detect the appearance of the PU during monitoring phase. Calibration means that both sliding windows are filled with pure unwanted signals. 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 power change on the reserved tones which perhaps due to the primary user appearance and it is time to vacate the band. If not, the secondary user can continue transmission. Indeed, if there is no primary user in band, then the energy of each window still involves only the strength of the unwanted signals including the noise, the leakage from the neighboring sub-carriers, and the effects of ICI produced by the residual synchronization errors. Therefore, if N is large enough, the ratio will be very close to unity since the strength of the unwanted signals does not offer significant changes over time.

Once the primary user appears, the second window will have two types of signaling which are the primary user interference and the unwanted signals. Meanwhile, the first window will only maintain the unwanted signals without the primary user interference. The ratio of the two energies will result in much higher values when compared to one. The value will of course depend on the primary user power. When the two windows slide again, the primary signal plus the unwanted signals will be observed by the two windows and the decision making variable returns to the initial state in which the ratio is close to unity. Thus, we can expect that the decision variable produces a spike when the primary user is detected. Otherwise, it changes very slowly maintaining the energy ratio close to one as shown in Fig. 2 part (4).

This approach can resist the different impairments involved in the received signal on the account of reducing the throughput of the secondary user by the ratio of the number of reserved tones to the number of useful tones. However, this reduction can be easily overcome since OFDM systems allow adaptive modulation where good conditioned sub-carriers are loaded with higher modulation order.

For the previous discussion, it is assumed that the primary user should appear at the boundaries of the OFDM blocks. Therefore, the reserved tones should have the full power, that is supposed to be for those sub-carrier indices, of the primary user when it is active. In reality, the primary user may appear any time within any OFDM block in the monitoring phase. In this case, we have to consider two effects. (1) The FFT window applied by the SU receiver will have a time-shifted version of the PU signal which involves a phase rotation to the PU sub-carriers. Since the energy is the useful parameter for our algorithm, the phase shift is acceptable to happen with no effect on the algorithm. The power on the reserved tones will not have the full power transmitted by the primary user on those sub-carriers since part of the signal is truncated. However, the next OFDM symbol will have that full power. Similar to the near-far problem, if the PU power is large enough, then the reserved tones form the first OFDM symbol, in which PU signal appears, are considered to be full. Otherwise, the reserved tones from this OFDM symbol are considered as noise if $N \gg NRT$.

VI. ENERGY RATIO ANALYSIS FOR AWGN CHANNELS

To verify the algorithm, we first analyze the energy ratio technique assuming perfect synchronization and neglecting the leakage power effect. However, these issues will be considered and their effects will be studied in the next section. Throughout the analysis, we assume that the signal to be detected does not have any known structure that could be exploited. Therefore, the reserved tone sequence is modeled via a zero-mean circularly symmetric complex Gaussian distribution (this is also true in case of frequency selective fading channels as discussed in section VI). The target of this analysis is to find the receiver operating characteristics (ROC) represented by the probability of detection, PD, and probability of false alarm, PFA. The detection probability is the probability of detecting a primary signal when it is truly present while the false alarm probability is the probability that the test incorrectly decides that the primary user is present when it is actually not.

Since we are dealing with a two state model in which the channel is assumed to be idle or busy by the primary user, then we wish to discriminate between the two hypotheses H0 and H1 where the first assumes that the primary signal is not in band and the second assumes that the primary user is present. Using the energy ratio algorithm, one can define these hypotheses as given by (3) where it is assumed that the samples contained in the first window have a variance of σ^2_v and the samples enclosed by the second window have a variance of σ^2_u.

$$\begin{cases} \mathcal{H}_0 : X = \frac{U}{V}, & \sigma_u^2 = \sigma_v^2 \\ \mathcal{H}_1 : X = \frac{U}{V}, & \sigma_u^2 > \sigma_v^2 \end{cases} \tag{3}$$

The performance of the detector is quantified in terms of its ROC curve, which represents the probability of detection as a function of the probability of false alarm. By varying a certain threshold γ, the operating point of a detector can be chosen anywhere along the ROC curve. PFA and PD can be defined as given by (4) and (5), respectively.

$$P_{FA} = Prob[X > \gamma \,|\, \mathcal{H}_0] \tag{4}$$
$$P_D = Prob[X > \gamma \,|\, \mathcal{H}_1] \tag{5}$$

Clearly, the fundamental problem of detector design is to choose the detection criteria, and to set the decision threshold γ to achieve good detection performance. Detection algorithms are either designed in the framework of classical statistics, or in the framework of Bayesian statistics . In the classical case, either H0 or H1 is deterministically true, and the objective is to maximize PD subject to a constraint on PFA; this is known as the Newman-Pearson (NP) criterion. In the Bayesian framework, by contrast, it is assumed that the source selects the true hypothesis at random, according to some priori probabilities. The objective is to minimize the so-called Bayesian cost

VII .ENERGY RATIO ALGORITHM FOR MIMO SYSTEM

To evaluate the energy ratio from complexity point of view, we propose architecture for the algorithm and then analyze the corresponding complexity and compare it to the traditional energy detectors. In the proposed architecture First, the reserved tone sequence is injected to be squared. Next, two first-In first-Out (FIFO) memories are used to store the squared outputs to manage the energy evaluation for the two windows. The idea depends on the sliding concept for the windows where the total energy enclosed by one window can be evaluated by only adding the absolute squared of the new sample and subtracting the absolute squared of the last sample in the previous window as given

$$V(k) = \sum_{i=k}^{N+k-1} |Z_i|^2 \quad \text{…………..} (6)$$

$$V(k) = V(k-1) + |Z_{N+k-1}|^2 - |Z_{k-1}|^2$$

The ratio may not be evaluated directly, instead we can multiply the energy of the first window by the threshold and the multiplication output is then compared to the energy of the second window.

We conclude that the proposed architecture typically uses double the components applied for the traditional energy detector. Moreover, traditional spectrum sensing which is applied prior to spectrum monitoring surely involves multipliers and accumulators. To further reduce the complexity, these modules can be reused and shared with the *energy ratio* algorithm during spectrum monitoring as sensing and monitoring are non-overlapped in time.

VIII .RESULTS

Simulations for spectrum sensing are carried out in MATLAB2014b, Project simulation is carried out in three part, first part is for spectrum sensing in this part depending upon probability of detection and probability of false alarm we will decide whether the spectrum is available or not. If spectrum is available then spectrum is used for secondary user. In second part of simulation we are transmitting the actual data over the CRN channel. OFDM trans-receiver is used for data transmission and for data reception. In third part we calculate the graph for throughput versus total error rate. This graph shows the optimized threshold value for the energy detection algorithm.

A. Roc Curve For Energy Detection

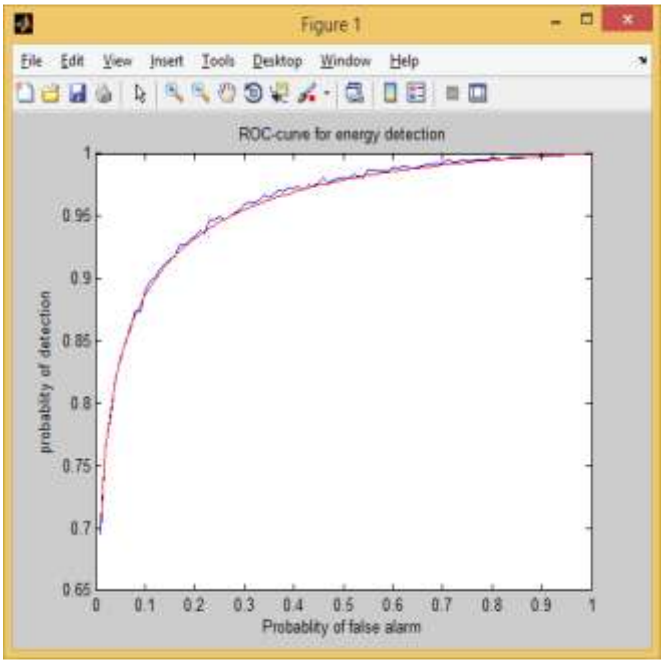

Fig. (4) ROC-curve for energy detection

This graph is plotted between probabilities of false alarm vs probability of detection. Graph is calculated with SNR value -10 db. Graph shows that probability of false alarm should be minimum for better throughput and probability of detection should be maximum shows better detection of primary user

IX. CONCLUSION

We 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 such as Ecma-392 and IEEE 802.11af systems.

For computational complexity, the energy ratio architecture is investigated where it was shown that it requires only about double the complexity of the conventional energy detector. When frequency-selective fading is studied, the energy ratio algorithm is shown to achieve good performance that is enhanced by involving SIMO or MIMO systems. Therefore, our 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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