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Modelling and Simulation of Energy Efficient Spectrum Sensing Mechanism Using Hybrid Mechanism

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Abstract- To identify the present or absent of licensed users, spectrum sensing techniques are used. Matched filter detection, Energy detection, and Cyclo-stationary feature detection are the three conventional methods used for spectrum sensing. Matched filter spectrum sensing technique needs prior knowledge about the received signal for every primary user. The performance of energy detector is susceptible to uncertainty in noise power. Cyclo-stationary feature detection requires a lot of computation effort and long observation time. This thesis discusses the conventional energy detection method and proposed improved energy detection method using double-squaring and addition of squaring operation. Mathematical description of energy detection based spectrum sensing techniques is also illustrated over fading channels.

KEYWORDS: Additional Squaring, Cubic Operation, Squaring Operation, Energy Detection, AWGN Channel, Rayleigh Channel.

I INTRODUCTION

Increase in wireless devices and applications lead to the demand of effective utilization of radio spectrum and current radio spectrum is underutilized due to static allocation, as this allocation makes it inflexible to operate in a certain frequency band. So to remove underutilization of radio spectrum cognitive radio technology has been employed. Cognitive radio technology provides effective utilization of the radio spectrum and reliable communication among all the users of the network. Cognitive radios are made so intelligent that it has the capability to sense the external radio environment and change its parameters according to the situation. To improve the spectrum efficiency, it can also access underutilized radio spectrum dynamically without interfering the primary users. Spectrum sensing have a very prominent role in cognitive radio for efficient utilization of current radio spectrum. The primary task of every cognitive radio user is to keep track of primary users whether they are present or not and this process is known as spectrum sensing. Spectrum sensing techniques may be categorized as: Frequency domain approach and time domain approach. In frequency `domain method, computation is carried out directly from signal whereas in time domain approach, computation is performed using autocorrelation of the signal.

II COGNITIVE RADIO

Cognitive radio may be defined as part of radio systems that perform spectrum sensing in a continuous manner which identify spectrum holes (unused radio spectrum) dynamically and then perform operation in a time domain when it is not used by primary users. “A cognitive radio may be defined as a radio that is aware of its environment and the internal state and with knowledge of these elements and any stored pre-defined objectives can make and implement decisions about its behavior. Cognitive radio has four main functions which are: Spectrum sharing, Spectrum Management, Spectrum Mobility and Spectrum Sensing.

III RELATED WORK

In this paper [1], the impact of varying the transmission power on the probability of false alarm of single CR has been investigated. The investigations have shown that increasing transmission power is not always effective to meet probability of false alarm target. To meet the target, designing an optimal energy efficient CBSS that satisfies the sensing accuracy metrics has been considered in this letter. The problem of design has been formulated and analysis has also been provided. An iterative algorithm with low computational complexity has been proposed to jointly determine the optimal design parameters of CBSS system that maximize the energy efficiency while satisfying all detection accuracy metrics.

In this paper [2] a new method was proposed to form all the subsets of sensors which can cooperatively provide the network with desired false alarm and detection probabilities. For each subset of sensors with such conditions, the average energy consumption for CSS per frame was computed. Then, a new heuristic algorithm was proposed to select the subset minimizing the average energy consumption for CSS in each frame. The simulation results show that the proposed algorithms have better performances in terms of maximum network lifetime, energy consumption for reporting the results to FC and CSS compared to other existing methods. It can be seen that the average energy consumption for CSS per frame is reduced up to 35% in comparison to the state-of-the-art research works. In addition, the total reporting energy for CSS is reduced up to 67% compared to the existing methods. However, since the reporting energy is a part of energy consumption for CSS, the total energy consumption for CSS is decreased for at most 36%. Finally, the proposed algorithm increases the maximum network lifetime up to 39%. To reduce the complexity of the proposed algorithm, a sub-optimal algorithm was proposed which has the same performance from energy-efficiency point of view. However, the computational complexity of the suboptimal algorithm is significantly lower than the proposed heuristic algorithm.

In this paper [3], an FSCHT based entropy detection for spectrum sensing is presented. The results of histogram based Shannon entropy detection is compared with kernel based entropy detection. The detection performance of FSCHT based Shannon entropy is not promising. However, the FSCHT with Parzen entropy easily captures the randomness of the signal, stimulating the detection. The proposed detection technique depicts an exceptional performance in sensing the DVB-T signals at an SNR wall of -60 dB with the appropriate BIN size. In particular, this algorithm can be implemented in hardware that supports high-speed processing in real time applications.

In this paper [4] the results show that the analysis matches the simulations well, and both of them verify that our proposed LRT and SLRT based NED-CS schemes can improve the sensing performance by taking the difference of each SU's sensing reliability into account. Specifically, the LRT and SLRT based NED-CS schemes can achieve substantially better sensing performance than EGC method and MNE detector in heterogeneous CR networks, where the differences of SU's sensing reliability are relatively large.

In this paper [5], they have investigated the secure collaborative spectrum sensing for CRSNs, from the energy efficiency perspective. They theoretically analyze the impacts of independent and collaborative SSDF attacks on the accuracy of collaborative spectrum sensing. The analysis and simulations show that the number of spectrum sensing nodes and associated global decision rule have significant impacts on the accuracy of collaborative sensing results. To achieve the tradeoff between security and energy efficiency, they determine the minimum number of spectrum sensing nodes to guarantee desired security requirements. Moreover, they have developed a trust evaluation scheme, named Fast D-tec, to evaluate the spectrum sensing behaviors and identify the compromised nodes. By determining an adaptive and optimal detection threshold, Fast D-tec can fast and accurately identify compromised nodes. In addition, taking advantage of Fast D-tec to isolate the identified compromised nodes from spectrum sensing, they have proposed a secure and energy-efficient collaborative spectrum sensing scheme to further enhance the energy efficiency of collaborative spectrum sensing. Extensive simulation results demonstrate that the proposed collaborative spectrum sensing scheme can effectively resist SSDF attacks, and fast and accurately identify compromised nodes, as well as improving energy efficiency.

In this paper [6], we have considered fundamentals of CRs, various sensing methodologies, ED and CSS. We have seen ROC curve and Pd vs. SNR at different N and Pf for ED. One of the very expensive and limited resources is spectrum in digital communication which can be efficiently utilized through CRs. Cooperative sensing resolve the problems related with local sensing. It can be seen that the selecting all SUs might not help in achieving highest throughput. However, it can be achieved through optimizing number of cooperating SUs. Hence we optimize the number of cooperating SU to improve throughput and reduce network overhead. It is seen that as N increases from 50 to 200 at Pf of 0.1, the number of optimal users decrease from 12 to 4.

In this paper [7], they focus on the EE optimization of the CSS with the parallel of spectrum sensing frame and data transmission frame. We propose an optimization problem to maximize the EE. Meanwhile, the detection probability and false alarm probability are effectively protected. Two parameters including sensing bandwidth Ws and PSD Nt are optimized for the best EE. We propose the search algorithms to find the optimal ones. Numerical results show that the optimization scheme greatly improves EE of CR networks.

This paper [8] has provided the recent advances in the spectrum sensing framework as the main enabling technology for the inter-weave cognitive radio model. In addition to presenting an overview for the conventional narrowband and wideband spectrum sensing approaches, the advances in each direction are addressed as well. An overview for the new approaches to tackle the trade-off between system performance and practical system implementations for both narrowband and wideband spectrum sensing branches are provided. Furthermore, the up-to-date effort in the direction of cooperative sensing is introduced for each of the cooperative communication element including hypothesis testing, control channel and reporting, data fusion, and knowledge base. The practical system considerations with respect to implementation have been presented. The advances for different aspects for the implementation side such as complexity, power consumption, throughput, and performance are considered. The recent industrial effort in terms of standard specifications is addressed while presenting the main concepts for the recent cognitive radio standards. The next generation cognitive radio networks such as the heterogeneous model and the cooperation with IOT is demonstrated as part of the advances to cognitive radio networks.

In this paper [9], analyze the probability of detection with respect to SNR for the two stage spectrum sensing under noise uncertainty and noise certainty. The proposed scheme is ED to AIC two stage spectrum sensing. Firstly received signal at the receiver is monitored by the ED technique. It gives reliable detection at high SNR also time taken by the spectrum sensing is less. In second stage AIC sensing technique is used, It gives accurate result at low and high SNR under noise uncertainty but it is complex and sensing time is high that's why AIC method is used as second stage. In two stage spectrum sensing, probability of detection is more accurate with respect to single stage AIC and ED also sensing time is improved with respect to single stage.

In this paper [10], the accuracy of the spectrum sensing is a necessary condition in order to make the cohabitation between the primary and the secondary systems possible. In this paper, we consider cooperative spectrum sensing techniques to improve the reliability of the sensing decision by exploiting the diversity of the secondary users. For this reason, fusion rules are required to derive a final decision. Hence, analytical performance of AND, OR and two witnesses fusion rules based on censored energy detection is presented. Analytical expressions of the probabilities of detection, false alarm, missed detection and occupancy are detailed. Finally, the coherence between the simulation results and the analytical ones proved the accuracy of these expressions.

IV PROPOSED METHODOLOGY

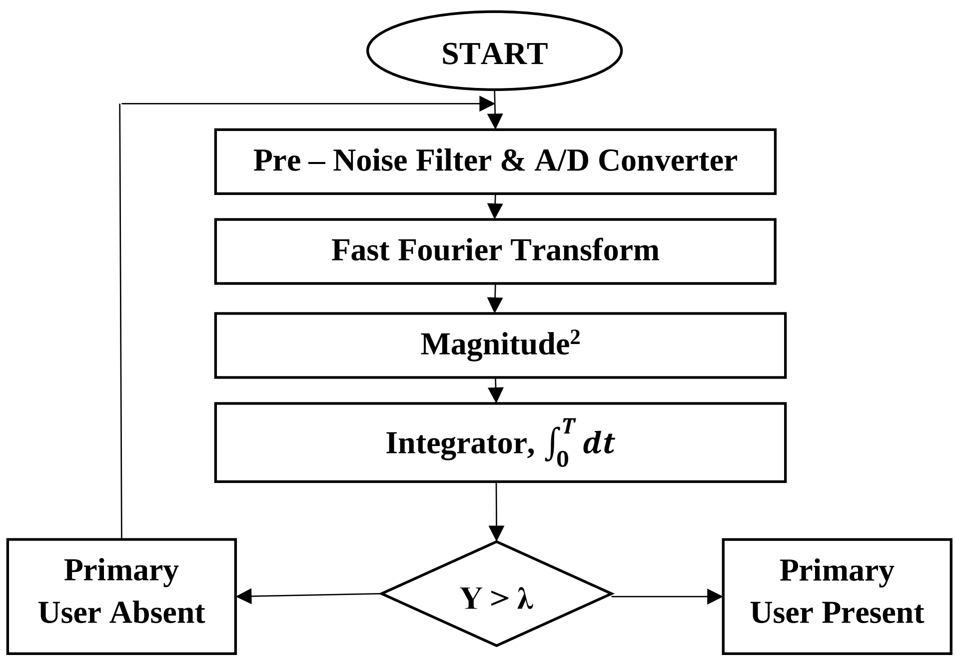

Figure 1 Flow Chart of Energy Detector

Step 1: First, the input signal is filtered with a Pre - Noise filter in order to limit the noise and to select the bandwidth of interest and A/D converted.

Step 2: The spectral component on each spectrum sub-band of interest is obtained from the Fast Fourier Transform (FFT) of the received signal.

Step 3: The power spectral density (PSD) is intended for continuous spectra. The integral of the PSD over a given frequency band computes the average power in the signal over that frequency band

Step 4: Finally the output of the integrator, Y is compared with a decision threshold value λ to decide whether primary user is present or not.

V SIMULATION RESULTS

AWGN Channel

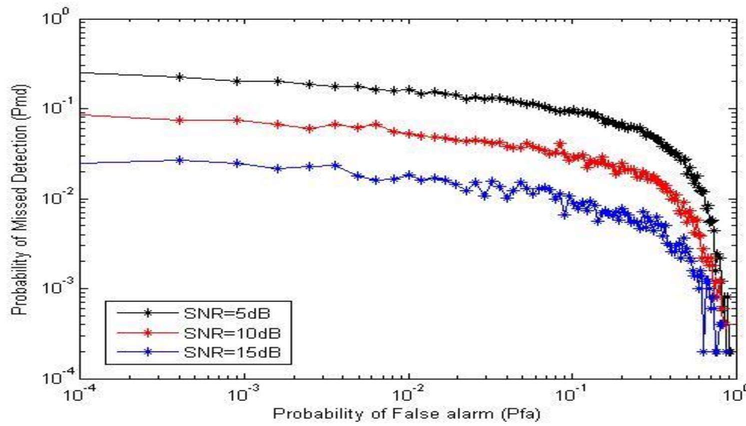

Figure 2: ROC Curve for Double-Squaring Operation over AWGN Channel.

Figure 2 illustrates the ROC (Receiver Operating Characteristics) curves i.e. $P_{m\,d}$ versus P_f using Energy detection method for spectrum sensing. This improved method uses double squaring operation. The graph is plotted for different SNR values over AWGN channel and it shows that with increase in SNR (Signal-to-Noise Ratio), the probability of detection increases and is quantified in Table 1.

Table 1: Improvement in P_d with increase in SNR using Double-Squaring

Probability of False Alarm ($P_{f\,a}$)	Probability of Detection (SNR = 5 dB)	Probability of Detection (SNR = 10 dB)	Improvement (in times)
0.0001	0.7502	0.9158	0.220
0.0121	0.8542	0.9498	0.111
0.1225	0.9098	0.9300	0.022
0.5776	0.9822	0.9942	0.012
0.8464	0.9994	0.9996	0.002

Operation for AWGN Channel.

Table 1 shows that 5 dB increase in Signal to Noise Ratio; increases the probability of detection (at SNR=10 dB) up to 0.22 times as compared to probability of detection (at SNR=5 dB) for AWGN Channel.

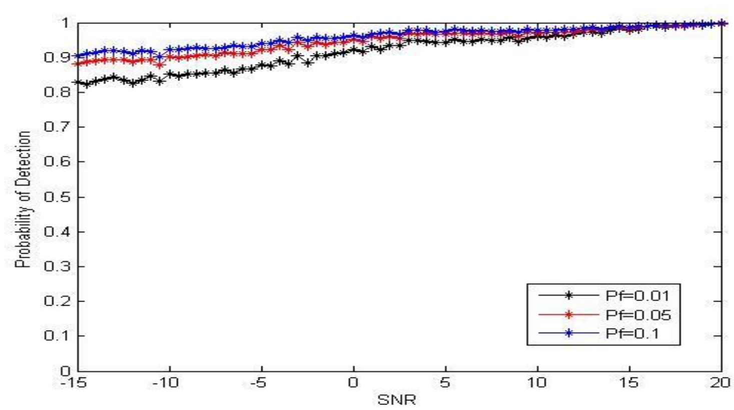

Figure 3: $P_{d\ versus}$ SNR Curve for Double-Squaring Operation over AWGN Channel.

Figure 3 shows the plot for probability of detection versus Signal-to-Noise Ratio over AWGN Channel using double-squaring operation in Energy detection. The graph is plotted for different values of Probability of False alarm and it shows that increasing the probability of false alarm, improves the probability of detection. Table 2 illustrates this improvement in performance.

Table 2: Improvement in P_d with increase in P_f using Double - Squaring Operation for AWGN Channel

Signal to Noise Ratio (in dB)	Probability of Detection (P_f = 0.01)	Probability of Detection (P_f = 0.05)	Improvement (in times)
-15	0.8293	0.8817	0.063
-10	0.8537	0.8832	0.034
-5	0.8797	0.9227	0.048
0	0.9233	0.9521	0.031
5	0.9437	0.9760	0.034

Table 2 shows that 5 % increase in probability of false alarm; increases the probability of detection (for P_f = 0.05) up to 0.063 times as compared to probability of detection (for P_f = 0.01) over AWGN Channel.

Rayleigh Channel:

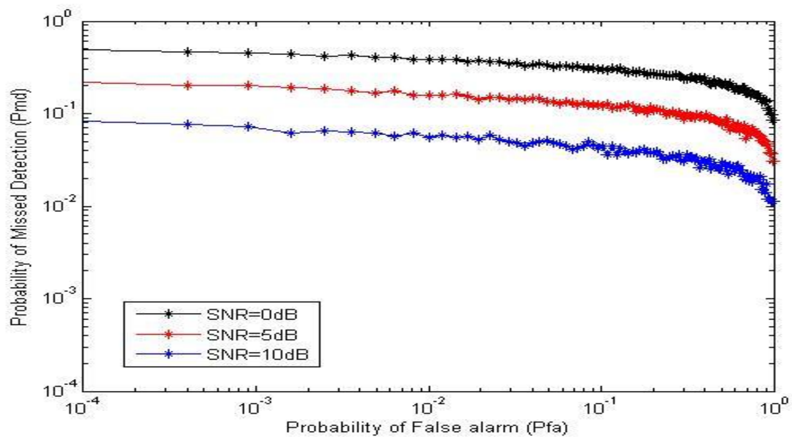

Figure 4: ROC Curve for Double-Squaring Operation over Rayleigh Channel.

Figure 4 illustrates the ROC (Receiver Operating Characteristics) curves i.e. P_{md} versus P_f using Energy detection method for spectrum sensing. This improved method uses double squaring operation. The graph is plotted for different SNR values over Rayleigh channel and it shows that with increase in SNR (Signal to Noise Ratio), the probability of detection increases and is quantified in Table 3.

Table 3: Improvement in P_d with increase in SNR using double - Squaring Operation for Rayleigh Channel

Probability of False Alarm (Pfa)	Probability of Detection (SNR = 5 dB)	Probability of Detection (SNR = 10 dB)	Improvement (in times)
0.0001	0.5034	0.7818	0.553
0.0121	0.6160	0.8426	0.367
0.1225	0.6962	0.8830	0.226
0.5776	0.7892	0.9110	0.154
0.8464	0.8620	0.9532	0.105

Table 3 shows that 5 dB increase in Signal to Noise Ratio; increases the probability of detection (at SNR=10 dB) up to 0.55 times as compared to probability of detection (at SNR=5dB) for Rayleigh Channel.

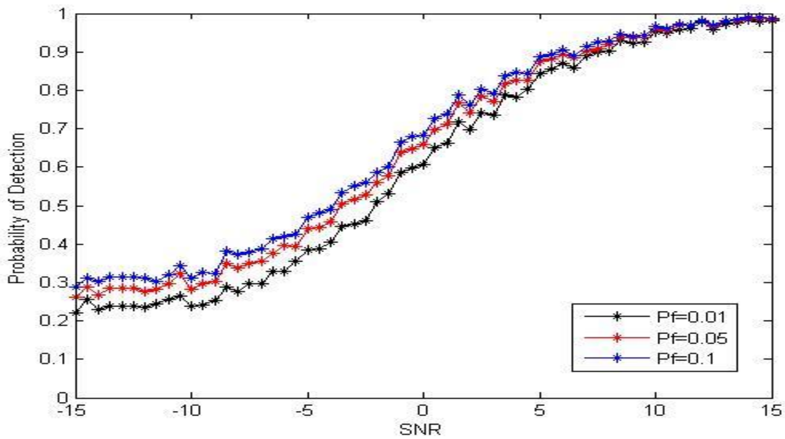

Figure 5: Pd **versus SNR Curve for Double-Squaring Operation over Rayleigh Channel**

Figure 5 shows the plot for probability of detection versus Signal-to-Noise Ratio over Rayleigh Channel using double-squaring operation in Energy detection. The graph is plotted for different values of Probability of False alarm and it shows that increasing the probability of false alarm improves the probability of detection. Table 13 illustrates this improvement in performance.

Table 4: Improvement in $P\ d$ **with increase in** Pf **using Double-Squaring operation for Rayleigh Channel**

Signal to Noise Ratio (in dB)	Probability of Detection (P_f = 0.01)	Probability of Detection (P_f = 0.05)	Improvement (in times)
-15	0.2200	0.2630	0.195
-10	0.2371	0.2831	0.194
-5	0.3840	0.4392	0.143
0	0.6082	0.6630	0.090
5	0.8443	0.8867	0.050

Table 4 shows that 5 % increase in probability of false alarm; increases the probability of detection (for P_f = 0.05) up to 0.2 times as compared to probability of detection (for P_f = 0.01) over AWGN Channel.

VI CONCLUSION

It has also been observed that increase in probability of false alarm improves the probability of detection of a particular spectrum sensing method. 5% increase in probability of false alarm increases the probability of detection up to 2.8 times for AWGN Channel and 0.6 times for Rayleigh Channel in case of conventional energy detection method (i.e. using squaring operation). While in case of cubing operation, this improvement is up to 0.29 times for AWGN Channel and 0.25 times for Rayleigh Channel. And if we use double-squaring operation, this improvement is up to 0.07 times for AWGN Channel and 0.2 times for Rayleigh Channel.

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