Improvement of energy consumption in MIMO with cognitive radio networks

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Article Info

ABSTRACT

The employment of cognitive radio (CR) is critical to the successful development of wireless communications. In this field, especially when using the multiple input multiple output (MIMO) antenna technology, energy consumption is critical. If the principal user (PU) is present, developers can utilize the energy detecting approach to tell. The researchers employed two distinct phases to conduct their research: the intense and accurate sensing stages. After the furious sensing step was completed, the PU user was identified as having a maximum or minimal energy channel. There are two situations in which the proposed algorithm's performance is tested: channels for fading AWGN and Rayleigh. When the proposed methods' simulation results are compared with conventional approaches, the complexity of MIMO was reduced by roughly 42% at low SNR levels. With 70 samples and an acceptable drop in detection performance, the results were suitable for further testing.

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1. INTRODUCTION

Cognitive radio is used to overcome the obstacles of the communication field in the optimal utilization of the frequency band. Therefore, the idea of cognitive radio is that (secondary users) SU not having an official license can utilize the spectrum owned by (primary users) PU authorized users. In contrast, the secondary user should not confuse the primary users when they are utilizing the spectrum [1]-[3]. Power consumption is one of the common problems in the CR network. This paper aims to reduce the energy consumed in the CR network, especially when using MIMO technology. In the CR network, a secondary user must sense and measure the presence of the PU to nullify the interference with high probability. It is necessary to utilize particular spectrum sensing techniques depending on the scenario, and there are several distinct approaches available, such as matched filter detection (MFD), energy detection (ED), merit detection (MD), and others.

2. LITERATURE REVIEW

A matched filter detector is better than the equivalent unmatched filter detector when prior knowledge about the PU signal is known. However, PU information is rarely disseminated among SU [4], [5]. No prior knowledge of the PU is required before conducting energy detection in low SNR situations. In testing the energy detector, researchers analyzed its performance while the PU is operating or is not. PU

actions are conducted at completely available times, not during times of detection. When PU comes or leaves at a location, the mean sensing performance is computed depending on the performance of the conditional detection [6]. For an applied twin of comes and leaves time instants, an accurate formulation is derived from the conditional detection probability, then used to formulate the exact mean detection probability. Kumar *et al*. [7], for randomly emerging or leaving signals, a sensing strategy is proposed. The proposed method first determines a test statistic for spectrum sensing based on the cyclostationarity approach to implement the strategy. Based on the result, the procedure next derives the SAF signal's spectral auto coherence function (SAF) for better results. An energy detector (ED) with weights is proposed in the environs of non-stationary PUs in [8] for enhancing detection performance. Simulations demonstrated a higher sensor performance that avoided the danger of a false alarm with a lower chance of occurrence. While these studies offer many benefits, they have a few drawbacks as well. In this paper, readers will learn how to successfully implement MIMO technology and overcome significant energy usage. For MIMO systems, the number of antennas has a reciprocal relationship to the transmitter power, and that had historically been done to discern between the PU signals from interference. At the same time, the "probability of detection" is increased when the MIMO antenna is used and decreases the "probability of failing detection" of the target. To diagnose the problems related to spectrum sensing in CR, a new concept of MIMO technology is introduced in cognitive radio, so the system performance is increased. Here, multiple antennas are placed both on a primary user as well as a secondary user. The process of increasing the likelihood of detection includes steps where a large number of channels are detected for a short period, after which they are divided into groups according to their respective energy capacities (it's far more probable that the channel already has a PU). This channel is sampled more for verification than the other channel [9], [10].

3. THE COMPREHENSIVE THEORETICAL BASIS

Pulsed signals have typically been difficult to differentiate from other energy types. However, energy detection uses a complicated spectrum sensing technique while not requiring a prior understanding of PU signals. To provide reliable service, the CR networks scan the spectrum and confirm that the PU is missing. This alerts the SU, which then initiates the data transmission to the receiver. To ensure that no collision occurs during the PU transmission, the transmitter of SU requires performing spectrum sensing to discover whether there is a PU in the covering of the SU transmitter [11] , [12]. For transmitter detection, a hypothesis model for transmitter detection is identified ahead. Broadly, it is hard for the SUs to separate between PU signals and other pre-existing transmitter signals of SU. Therefore, all are handled as one received signal, s (t). The obtained samples at the cognitive user receiver can be expressed as:

$$y(n) = \begin{cases} n(t), & H0 \\ s\,(t) + \, n\,(t), & H1 \end{cases} \tag{1}$$

H1 refers to the PU in active mode. In contrast, H0 refers to the PU in inactive mode, s(t) refers to the signal of the PU, n(t) refers to the additive white gaussian noise (AWGN) at the SU receiver. The detection algorithm performance is dependent on some essential parameters: detection probability (Pd), false alarm probability (Pf), and missed probability of detection (Pm). Using a comparison of the metric of detector decision with the adjusted threshold [13]-[15], it is possible to evaluate the false alarm probability and the detection probability. In this definition, the decision metric energy of samples taken within the observation window t is defined as:

$$DMED = \frac{1}{N}\sum_{n=1}^{N}|y(n)|^2 \tag{2}$$

In this equation, N = t Fs denotes the amount of samples used for sensing, while Fs is the sampling rate. It is necessary to execute the detection algorithm under several critical parameters, including the detection probability (Pd), the probability of false alarm (Pf), and the probability of missed detection (Pm). The chance of missed detection Pm or (1-Pd) and the probability of false alarm Pf are added together to form the overall error rate [16]. As a result, the total error rate can be calculated as:

$$Pe \,=\, Pm \,+\, Pf \,=\, (1 - Pd) \,+\, Pf \tag{3}$$

Detection and false alarm probability are measured by:

$$Pf \,=\, P\,(DMED \,>\, \lambda|H0) \tag{4}$$

$$Pd = P(DMED > \lambda|H1) \tag{5}$$

Maximizing Pd and reducing Pf will lead to increased system performance. Pm represents the likelihood of missing the primary transmission when PU is operating in the specific band.

4.   THE PROPOSED METHOD

Figure 1 depicts a generalized MIMO system layout, in the proposed system both transmission stages and the sensing processes in the spectrum sensing process use energy. This algorithm successfully saves energy during the sense stage, and it lifts the performance illuminating in the process. In the architecture shown in Figure 2, the design phase of the suggested algorithm is made up of two stages: the beginning stage of the detection process, which is also known as the "rabid sensing stage," and the intermediate stage, which is referred to as the "accurate sensing stage". The diagram in Figure 3 depicts the suggested algorithm's flowchart. First, the sensor detects a particular spectrum measurement with a lower amount of sampled channels. Sensing samples are being utilized less frequently. It's possible that reducing the frequency of sensing operations by 25% results in considerable savings. At this time, all channels are redirecting in all of their energy. Next, this channel is put through an accurate sensing stage once the reservoir has amassed tremendous energy. When the signal has been guaranteed to be genuine, a comparison between the energy of accumulated samples with a threshold value of λ is performed to make a final conclusion concerning the existence of the primary user. Iterating the process over the spectrum to determine whether or not there is a gap is done with careful sensing conducted to the channel with the least amount of energy. In recent years, MIMO technology has gained significant importance in wireless communication, exclusively in the succeeding generation of wireless communication systems, by supporting much higher data rates than HSDPA and UMTS and 3G networks [17]-[20]. The performance of wireless communication systems is increased by the MIMO technique, which uses numerous antennas at the transmitter and receiver; the system is comprised of multiple transmit antennas (TX) and multiple receive antennas (RX). Antennas TX1……., TXN send signals respectively RX1, …., RXN to receive antennas. Every receiver antenna collects the arriving signals, which coherently add up. The arriving signals at antennas RX1,...., RXN are respectively indicated by Y1...., YNR. We express the received signal at antenna TXT; T=1, . . . , NR as [21], [22]:
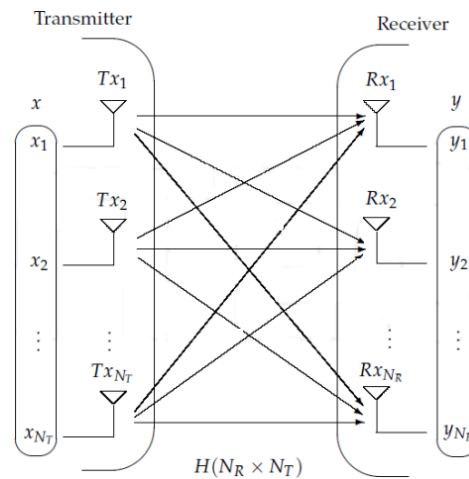

Figure 1. General MIMO system model

In the MIMO flat fading channel pattern, the (input-output) relationship is described as in (6):

$$y = H.x + b \tag{6}$$

Where H is a complex channel matrix (NR×NT) given by:

$$H = \begin{pmatrix} h_{11} & h_{12} & h_{1NT} \\ \dots. & \dots. & \dots. \\ h_{NR1} & h_{NR2} & h_{NRN} \end{pmatrix} \tag{7}$$
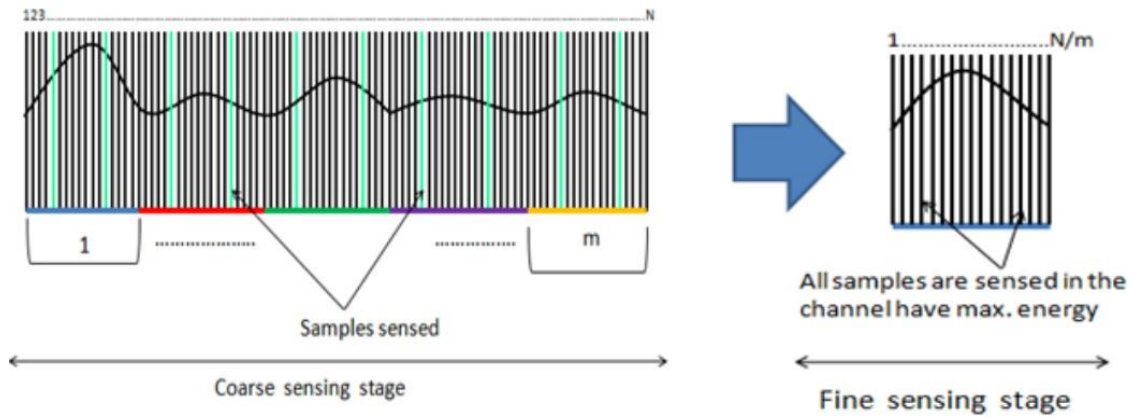
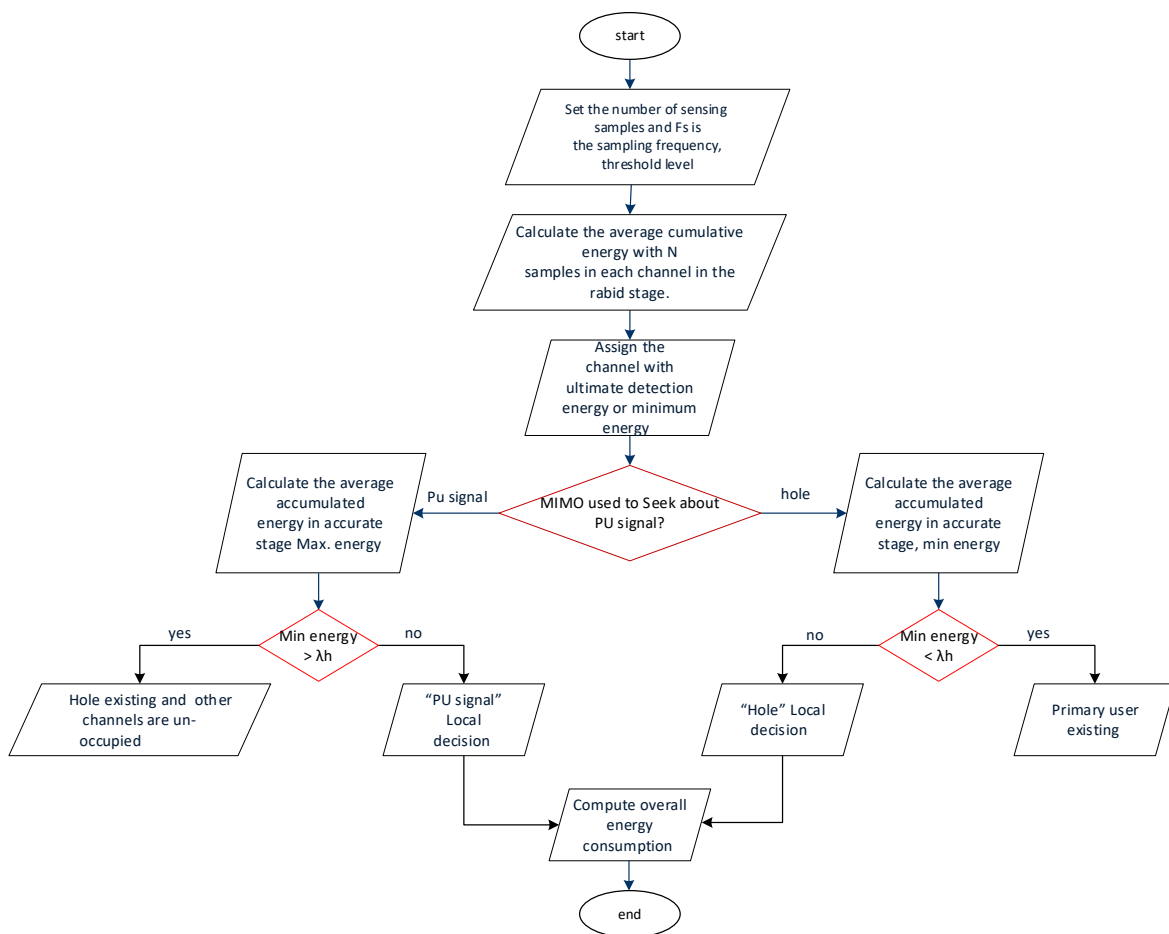Figure 2. The division of spectrum [1]

Figure 3. Flow chart of the proposed system

Many desirable functions can be achieved by MIMO technology. Transmissions that transfer a significant quantity of data, such expanding network capacity without increasing bandwidth, use space-time coding and operational co-channel interference reduction [23]. Many benefits can be obtained in next-generation WiMax, WiFi, and cellular network criterion. In cognitive radio, MIMO technology is also demonstrating useful in spectrum sensing [24]. Doubled antennas can improve the quality of transmitting dimensions in space and improve degrees of freedom for different paths transmission secondary users in frequency, space, time and reduce the interference powers at PU. Transmission of signal through different

routes provides reliable communication between PU and SU and increases both capacity and spectral efficiency. According to [1] energy consumptions can be written as:

$$Cs, j = Cco, j + Cfi, j [1] \tag{8}$$

Where $C_{co,j}$ and $C_{fi,j}$ to there numbers are, respectively, in the furious and accurate stages.

$$Cco, j = NkCss, j, Cfi, j = N/mCss, j, [1] \tag{9}$$

In terms of sensing rate, k represents the sample count, which is the total number of samples being sensed. There are a total of m sampled channels, and the values N, CSS, j reflect the energy spent by each sample. To demonstrate the suggested rabid accurte sensing method's spectral division procedure, an example is provided in Figure 2.

According to [25], [26], one piece of information consumes energy during transmission. For a data rate of 300 mb/s, a voltage of 2.1 V, in, and currents of 10 mA, the dissipated power in transmission mode of one bit across a distance d, on average, the radio spends about 70 Pj/bit. For run radio electronics and power amplifier, the dissipated power in the transmission mode, of one bit over a distance d:

$$Ctb, j = Ct - elec, j + eamp, jd2, [1] \tag{10}$$

The transmitter electronics energy represented by $C_{t\text{-}elec,j}$, $e_{amp,j}d^2$ is represented to meet the expectation sensitivity level for a given receiver. To ensure no change in the spectrum, researchers repeated the process, only this time the sensors weren't precise, so the stage was placed on the channel with the least cumulative energy. There are two different amounts of energy used to monitor and decide. A far higher amount of energy is also used to modulate, shape, and analyze a signal. Where N: Quantify the amount of energy consumed per sample for that portion [13]-[16]. This type comprises precisely mounted sensors that have no impact on the sampling rate or sensor energy consumption [27].

5. RESULTS AND DISCUSSION

Table 1 lists the simulation parameters used. This section summarizes the findings and contributions made.by using MIMO technology (4Tx4RX). With the energy detection technique, the proposed algorithm's performance is tested in two channel scenarios. Figures 4 and 5 show the performance curves of the consumption energy by the CU versus Eb/No in the AWGN and Rayleigh fading channels. Here we compare the results of the proposed method with the traditional, it can be seen that the energy consumption decrease as Eb/No increases, when using a smaller number of sensing samples in order to detect the PU signal. For instance, when Eb/No equals 6 dB, energy consumption decreases by 60% in the. Figure 5 shows the identical performance in Figure 4, but with a raise in consumption energy due to the influence of the multipath fading channel.

Table 1. The parameters that were employed

Parameter name	Value
Bit rate	300 Mpbs
Modulation type	16 QAM
Probability of false alarm	10^{-3}
The total number of samples in the spectrum N	1000
Per-symbol samples	70
Antenna type	4Tx*4Rx
Distance	100 m

Figures 6 and 7, shows the performance curves of probability of detection versus Eb/No in the AWGN and Rayleigh multipath fading channels respectively. As Eb/No increases the detection performance increases and the proposed method better than traditional method. For example, Pd is increased from 0.52 in traditional method to 0.85 in the proposed method when Eb/No equals 2 dB, Figure 7 shows the identical performance as in Figure 6, but with a small decrease in detection performance because of the effect of the multipath fading channel. The reason for the improvement in the proposed method can be listed as when using the accurate sensing stage, the channel is sensed by the ratio of 100% therefore the accuracy increased and this is shown on the performance detection. The limitations are becoming clear in our study in using

(4Tx4RX) MIMO antenna without the rest types. In terms of capacity (4Tx4RX) MIMO antenna is considered compromise and appropriate. It is also used in modern wireless communications systems.
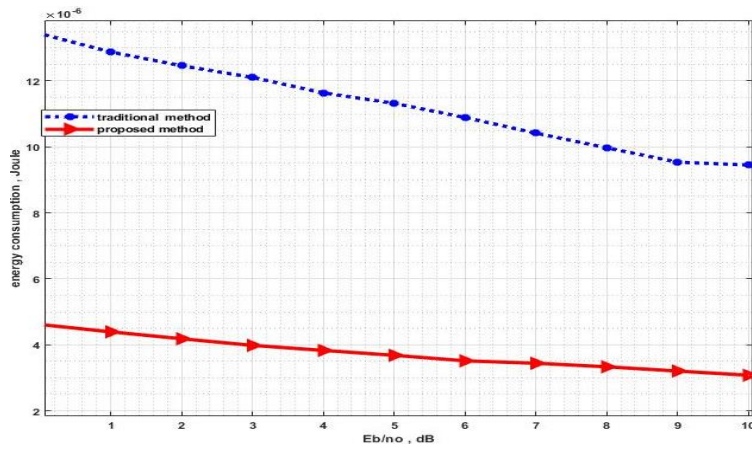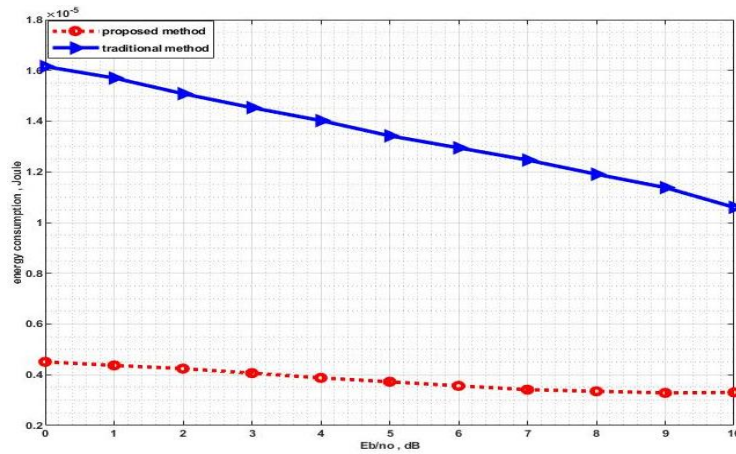
Figure 4. Energy consumed in the WGN channel

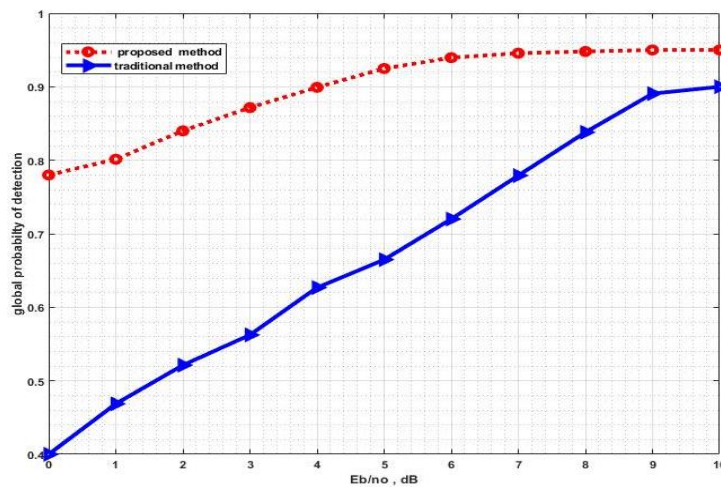Figure 5. Energy consumed in Rayleigh channel fading

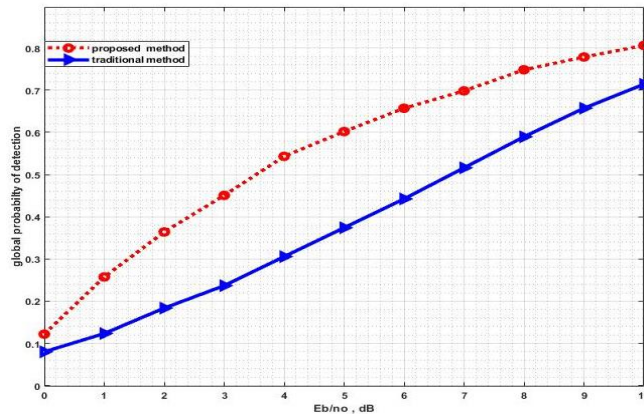Figure 6. Probability detection in the AWGN channel

Figure 7. Probability detection in rayleigh channel fading

6. CONCLUSION

A substantial impression on the advancement of wireless communication has been made by cognitive radio technology. Lone of the decisive necessities of cognitive radio networks is the capability to do trustworthy spectrum sensing. To achieve this goal, MIMO technology is employed to strike a balance between reliable spectrum sensing and the amount of power consumed; an efficient method is proposed to reduce energy consumption while simultaneously refining detection performance in CR networks. The simulation results demonstrate a comparison between MIMO-based spectrum sensing and a conventional sensing method. Antennas with greater variety have shown a significant improvement in detection probability. This has been proved to be a primary reason for a substantial improvement in reducing the amount of power required by reducing the number of detected samples. It was possible to achieve this enhancement using several samples in the particular length rabid sensing stage. A better detection performance was also achieved by incorporating a precise sensing stage into the detection process. For the outcome to be more transparent, instead of using two 2x2 MIMO arrangements, a single 4x4 MIMO configuration was used.

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