Efficient Energy Detection Technique in Cognitive Radio Ad-hoc Network

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ABSTRACT

Cognitive radio ad-hoc networks (CRAHNs) is used to solve the current problems of inefficiency in the spectrum allocation and used to deploy highly reconfigurable and self organizing wireless networks. Cognitive radio represents an efficient technology since it allows exploiting the unused radio resources. In this context, spectrum sensing plays very important role in cognitive radio communication technology. Here we considered simplified energy detection technique for spectrum sensing. Simulation results show the channel selection along with the signal to noise ratio utilized for message towards destination node by the efficient energy detection method.

General Terms

Cognitive Radio Communication

Keywords

Cognitive radio, Spectrum Sensing, Spectrum handoff.

1. INTRODUCTION

Cognitive Radio Communication technology used for supporting dynamic spectrum access [1,2,3].During the present scenario, Cognitive radio becomes a popular solution over inefficiency in the spectrum allocation. Sensing of a spectrum and throughput of a cognitive radio network [4,5] plays very important role for the proper and efficient allocation of a spectrum. An end-to-end protocol for cognitive radio ad-hoc networks [6,7] is used for the performance calculation of Cognitive Radio Ad-hoc Network .Ideal energy detection technique used for the detection of idle period of a primary spectrum. Different detection techniques [8,9,10,11] are used for the spectrum sensing .Matched filter detection, feature detection require prior information about the primary signal information .For the energy detection technique no prior information required. Energy detection technique has poor performance in comparison with feature and matched filter detection technique [12,13,14,15].Ideal Energy Detection Technique used for the detection of idle period of a primary spectrum plays very important role. Different detection techniques are used for the detection of idle period of a primary spectrum [16, 17, 18,19,20].

The rest of this paper is organized as follows. In Section 2, we describe Spectrum Sensing Method The proposed spectrum sensing algorithms are examined by numerical examples in Section 3, simulation and results are Section 4,conclusion and future work is in section 5.

2. IDEAL ENERGY DETECTION TECHNIQUE:

In cognitive radio scenarios, signal details are unknown, so we have to treat the signal received as a sample function of a random process. When the signal statistics are known, we can design suitable detectors. The schematic diagram of traditional energy detector is shown in Fig 2.

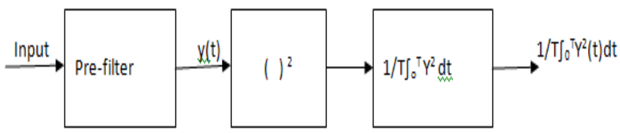

Fig.1. Schematic diagram of traditional energy detector

The energy detector [4] consists of a squaring device followed by a finite time interval integrator. Pre-filter will make a selection for a certain spectrum band, then $y(t)$ will be a band-pass signal. Suppose signal is transmitted in AWGN (Additive White Gaussian Noise) channel, then $y(t)$ will be a band-limited random process. Calculating the statistics of $y(t)$ from formula (1) under an assumption that $n(t)$ is zero mean Gaussian random process, we can write

1) H0: signal is absent.

a. y(t) = n(t)

b. E(y (t)) = 0

c. E(1/T ∫ y(t) dt) =No

2) H1: signal is present.

a. y(t) = s(t) + n(t)

b. E(y (t)) = s (t)

c. E (1/T ∫ y (t) dt) = Ps+Ns

are the average power of signal and noise respectively. For a certain time interval, only calculating signal energy in time interval T is much more convenient because it is monotonic with average power. If we assume that noise has a flat band-limited power density spectrum, then the calculation of energy can be written as a sum of squares of statistically independent random variables after sampling process.

3. SPECTRUM-SENSING METHOD

Energy detection [9] is a suboptimal and simple method that can be applied to any signal type without requiring any information about the received signal. In determining whether a signal of a certain bandwidth is present in a spectral region of interest, energy detection using a single antenna suffers from poor performance in low SNR regions.

After receiving and down converting, the received signal, $y(t)$, is sent to the energy detector. The energy, E, is calculated using

$$E=\int Y^2 t\, dt \qquad (1)$$

Here $y(t)$ could be formed by using different selection processes. It could be determined by linearly combining the signals received from each antenna. It could also be formed by selecting the signal with the highest SNR among all signals.

Ps, *No* are the average power of signal and noise respectively. For a certain time interval, only calculating signal energy in time interval *T* is much more convenient because it is monotonic with average power. If we assume that noise has a flat band-limited power density spectrum, then the calculation of energy can be written as a sum of squares of statistically independent random variables after sampling process. This energy value has a central or non-central chi-square distribution. Consequently, we can find a threshold to make a decision that whether the signal is present or not. This situation [7] is shown in Fig.2.

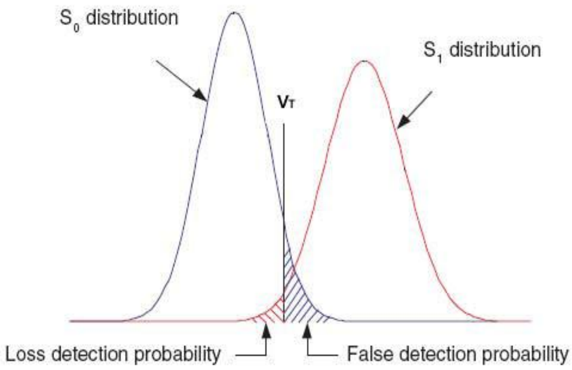

Fig.2 Illustration of false detection probability versus loss detection probability under threshold *HT*

In this way, giving some detail information about the detector, some statistic calculation results about this detection problem can be expressed as

False detection probability is:

$$P_{fa}= \frac{1}{2} erfc(H_T - 2TW/2\sqrt{2}\sqrt{TW}) \qquad (2)$$

Detection probability for Non-central parameter of chi-square distribution is P_D

$$P_D = \frac{1}{2} erfc\left(\frac{H_T - 2TW - \lambda}{2\sqrt{2}\sqrt{TW+\lambda}}\right) \qquad (3)$$

where

$$\lambda = 1/No \int_0^T S^2(t)dt = Es/No \qquad (4)$$

T: a certain time interval

H T: threshold

W: bandwidth of pre-filter

E S: signal energy of during time T

*N*0*:* noise power spectrum density (two sided)

From formula (2) and (3) we know that if we deal with signals with same bandwidth in same time interval using the same threshold we will get same false detection probability. But with same false detection probability, due to formula (3), we can conclude that as parameter increases, detection probability will be highly improved. This situation is shown in Fig.2.

Performance will be improved. So we should find ways to increase. Referring to formula (5), essentially, we should decrease noise power spectrum density *No.*

3.1 Efficient Energy Detection For The Calculation of SNR

To improve detection performance many kinds of method can be applied. However, when initial condition has been given, such as time interval, sampling frequency, and the bandwidth of pre-filter are defined parameters, it seems not easy to find way to improve the detection probability.

Fortunately, according to discussion above and Fig.3, we got an idea that if parameter increases, detection performance will be improved. So we should find ways to increase □ . Referring to formula (5), essentially, we should decrease noise power spectrum density *No.*

Now suppose a situation, signal received with bandwidth *W* and duration time *T*, sampled by pulses frequency 2*W*, which is Nyquist sample frequency, the hypotheses (1) would be rewritten as

$$y[m] = n[m] = Ho$$

$$s[m] + n[m] = H1 \qquad (5)$$

Where m=1,2,3……2TW

For the digital series x[n] with length N, Parseval relation is given as

$$\sum_{n=0}^{N-1} x(n)^2 = \sum_{n=0}^{N-1} x(k)^2 \quad (6)$$

DFT series of signal $x[n]$, expression (7) means that signal energy can be calculated using the sum of squares of its DFT series. Then, problems existed in time domain can be solved in frequency domain. In this paper, to restrain noise power spectrum density N_0, a special scheme is applied. Firstly, dividing signal series $y[m]$ into S segments which share the same length

Applying DFT to each segment:

Segment 1:

$$Y1[k] = \sum_{m=0}^{Ns-1} y[m] e^{-\frac{j2\pi km}{Ns}}$$

$$Y1[k] = \sum_{m=0}^{Ns-1} (s[m] + n[m]) e^{-j2\pi km/Ns} \quad (7)$$

$$Y1[k] = \sum_{m=0}^{Ns-1} s[m] e^{-j2\pi km/Ns} + n[m] e^{-j2\pi km/Ns} \quad (8)$$

Segment 2:

$$Y1[k] = \sum_{m=Ns}^{2Ns-1} s[m] e^{-j2\pi km/Ns} + n[m] e^{-j2\pi km/Ns} \quad (9)$$

Segment r:

$$Y1[k] = \sum_{m=(r-1)Ns}^{rNs-1} s[m] e^{\frac{-j2\pi km}{Ns}} + n[m] e^{\frac{-j2\pi km}{Ns}} \quad (10)$$

K=0,1,2,……Ns-1 and r=0,1,2,3….S

For deterministic signal $s(t)$, it is easy to find following relations:

$$\sum_{m=0}^{Ns-1} s[m] e^{-\frac{j2\pi km}{Ns}} = \sum_{m=Ns}^{2Ns-1} s[m] e^{-\frac{-j2\pi km}{Ns}}$$

$$= \sum_{m=(r-1)Ns}^{rNs-1} s[m] e^{\frac{-j2\pi km}{Ns}} \quad (11)$$

r= 1, 2,3,……S

For r =1,2,..., S , calculating the average value of $Y[k]$

$$Y[k] = \frac{1}{s} \sum_{s} Y_r [k]$$

Y[k]=

$$\frac{1}{s} \sum_{s} \left(\sum_{m=(r-1)Ns}^{rNs-1} s[m] e^{\frac{-j2\pi km}{Ns}} + \sum_{m=(r-1)Ns}^{rNs-1} n[m] e^{\frac{-j2\pi km}{Ns}} \right)$$

=

$$\sum_{m=0}^{Ns-1} \left(s[m] + \frac{1}{s} (n[m] + n[m+Ns] + \cdots + n[m+(s-1)Ns]) e^{\frac{-j2\pi km}{Ns}} \right)$$

$$= \sum_{m=0}^{Ns-1} (s[m] + n'[m]) e^{\frac{-j2\pi km}{Ns}} \quad (12)$$

Where

$$n'[m] = \frac{1}{s} \left(n[m] + n[m+Ns] + \cdots + n[m+(s-1)Ns] \right) e^{\frac{-j2\pi km}{Ns}}$$

K=0, 1,2,…..Ns-1

Since n[m], n[m+Ns],n[m+(s-1)Ns] are independent Gaussian random variables with $N(0,\sigma^2)$,then $n'[m]$ also is Gaussian random variables with $(0,\sigma^2)$. Because of the monotonic linear relation between power spectrum density 0 N and variance σ^2, the corresponding spectrum density of $n'[m]$ will be SN_0 .Above all, from formula (3) and (5) detection performance will be improved. Applying formula (7) and (11) to (6), signal energy will be written as.

$$\sum_{m=0}^{2TW} y[m]^2 = \frac{1}{2TW} \sum_{m=0}^{2TW} y[k]^2$$

B. Detection decision

From formula (2), we can conclude that given a certain value of *Pfa*, threshold can be defined as follows:

$$H_T = 2TW + 2\sqrt{2TW}\ \mathrm{erfc}^{-1}(2P_{fa})$$

Also, define decision parameter

$$\Delta_D = \frac{1}{N0} \sum_{m=0}^{2TW} y[m]^2 \quad (13)$$

Using formula (11) and (13) we can make computations on expression (14). Then according to formula we can decide that which is true, the two hypotheses H0, H1.

$\Delta_D > H_T > 1$

$$\Delta_D < H_T < 1 \quad (14)$$

4. SIMULATION RESULTS

In this section simulation results are presented to illustrate the simplified energy detection algorithm and compare its performance with conventional detection method[17] as shown in fig 3. At last, when some parameters change, the corresponding algorithm performance is shown. The initial conditions of simulation are QPSK modulated signal transmitted in AWGN channel, noise power spectrum density N_0 =1, false alarm probability P_{fa} =0.1, the length of signal series $2TW$=256. The comparison of simplified mode and conventional mode is shown in Fig. 10, Fig.12 using 2 channel and 5 channel cognitive radio ad-hoc network. Algorithm for the development of efficient energy detection technique is as follows.

Algorithm: For the Efficient Energy Detection in CRAHNs

- Formation of cognitive radio Ad-hoc Network
- Set the channel decision associated with current node
- Return the channel decision associated with current

node
- Broadcast channel info over all channel
- Get the Rx power from CR PHY
- Store Receive Pr from PHY layer
- Obtain the interference information for current node
- Find out channel with min interference
- Find minimum energy/power
- Find out whether there is an unused channel
- Find out the minimum interference channel
- Updates the position of a mobile node every N seconds, where N is Based upon the speed of the mobile and the resolution of the topography Compare it with the received energy
- If received energy of the user is less than the assumed one then select that particular channel as a free channel for the transmission of packets.
- Calculate signal energy and noise power
- Calculate signal to Noise ratio for different packet length using multichannel wideband frequency band.
- Calculation of probability of false alarm and probability of detection of primary user in a cognitive radio ad-hoc network.

Energy detection using our energy detection method is as shown in fig.3, fig.4 and fig.5 gives us actual value of the energy required 45dB,20dB and 12dB respectively for the transmission of message for different packet size from source node towards destination node [16, 17].As no of packets increased , the signal to noise ratio gets decreased. We have been compared our work with conventional technique, we obtained 20% increase in the signal to noise ratio in cognitive radio network as shown in fig6. Depending on the signal to noise ratio and energy detected by the cognitive radio, selection of primary user is possible by using our simulation model [18,19,20].

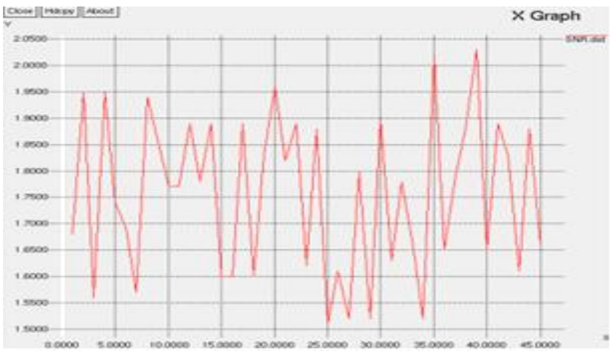

Fig.3.Signal to Noise Ratio for 300 Packets transmission in cognitive Radio Ad-hoc Network

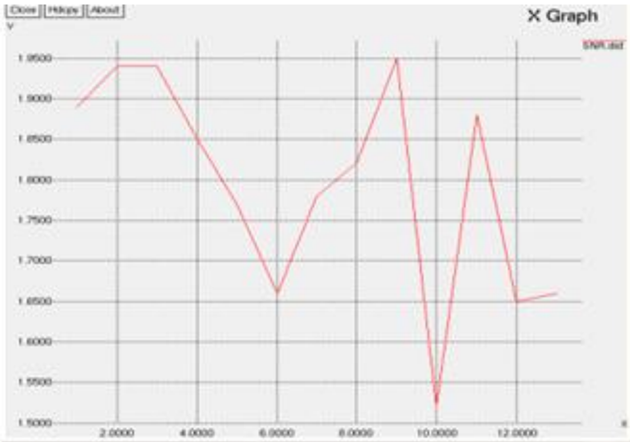

Fig.4.Signal to Noise Ratio for 1000 packets transmission in Cognitive Radio Ad-hoc Network

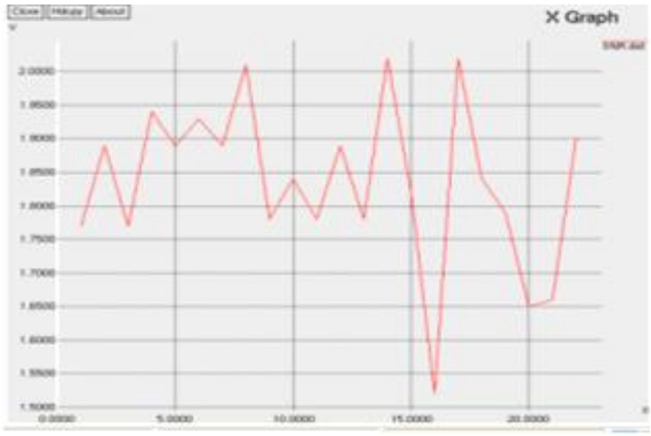

Fig.5.Signal to Noise Ratio for 1000 packets transmission in Cognitive Radio Ad-hoc Network

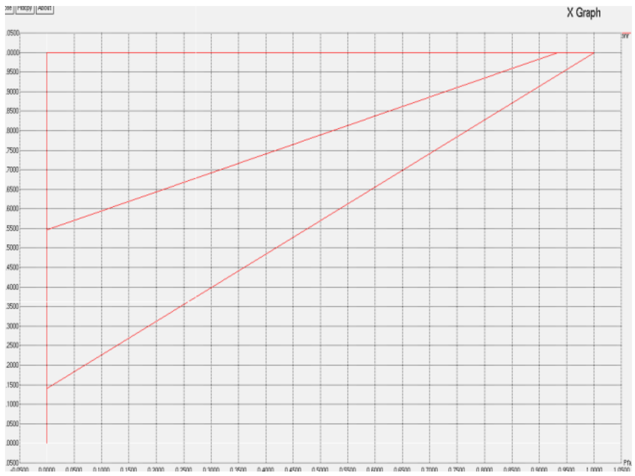

Fig.6 Comparison of SNR of Conventional and Efficient Energy detection Technique

5. CONCLUSION AND FUTURE WORK:

A new method in energy detection of spectrum sensing for cognitive radio has been introduced in this paper. The performance of the cognitive radio Ad-hoc network in terms of signal to noise ratio is used in this paper. For this purpose we have been used efficient energy detection technique.

Performance results of the proposed modified spectrum sensing method under theoretical analysis were studied using 2 channels and 5 channels CRAHNs. Simulation results showed that a significant improvement of detection performance had been achieved under the proposed spectrum method. As well it concludes that if numbers of channels are more then system performance will be more. It is well known that energy detector's performance is susceptible to uncertainty in noise power and our work have only studied the proposed method in AWGN channels. This work will be useful for the development of a greedy channel algorithm for the handoff mechanism in case of Cognitive radio Ad-hoc Network.

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