Performance Analysis of Sensing Time Parameter in Cooperative Sensing Cognitive Radio

Hemlata Patil, Dr A.J.Patil, Dr S.G.Bhirud

Abstract— Spectrum scarcity problem is well addressed by cognitive radio. The main role of spectrum sensing is to discover the empty band correctly .This is done with the help of energy detector. The sensing time is a very crucial parameter which regulates the detection probability. In this paper the impact of sensing time has been investigated. The rigorous simulations are done on sensing time parameter with varying snr and keeping probability of false alarm constant and vice versa. The simulations are done for cooperative sensing with AND and OR rule and it shows that AND rule outperforms in terms of detecting the band. Results also show that Sensing efficiency is declined with increasing sensing time.

Index Terms—Cognitive Radio, Spectrum sensing, cooperative sensing ,sensing time, sensing efficiency

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1 INTRODUCTION

Cognitive Radio has become a very promising technology to address the spectrum scarcity issues. It senses the Primary user's (PU) channel and tries to use it when it is empty. The most important factor in this is sensing time. In this paper the impact of sensing time has been investigated.

The spectrum has become more inadequate with rapid growth in wireless communication and is need for efficient spectrum utilization. It needs an intelligent device which is aware of its surrounding and learns and uses that knowledge to use the available spectrum. This concept was first conceived and written down in the article by Joseph Mitola III and Gerald Q. Maguire, Jr [1].The main objective of the cognitive radio is to use the available spectrum very efficiently for its required transmission without causing an interference to the primary user. Thus the detecting a vacant slot is very important process for primary as well as for secondary users. The most important factor in this is sensing time.

The main spectrum sensing techniques are Energy Detection, Cyclostationary Detection and Matched Filter Detection [2],[3].Energy detection is most used technique as it does not require any information about the primary user[4]. However in practice detection performance is affected by multipath fading, shadowing and receiver uncertainty issues. To overcome these issues cooperative spectrum sensing has come up as a promising solution [5].

Cooperative sensing is mainly classified as Centralised Sensing, Distributed Sensing and External sensing. The sensing results are send to Fusion center where they are combined in one of these three ways Hard Combined rule, Soft combined and softened hard rule .In hard combined rule AND ,OR and MAJORITY OR logic is used.CR tries to sense the PU individually and sends its result to FC where the decision is taken up depending upon the logic used whether the PU is present or not[5].The comparison between hard combining rules for cooperative spectrum sensing has been investigated in [6], and the k out of N rule for data fusion at the FC is proposed in [7]. In this paper, the sensing time of SU is analyzed under two operational modes, namely, the constant primary user protection and constant secondary user spectrum usability scenarios. In first scenario, probability of detection Pd is kept high at 0.9 so that primary user will not get lesser interference from secondary user and in second one the probability of false alarm is kept very low at about 0.1 so that the secondary users get the maximum chance of using the primary users spectrum [8].

The main objective of CR networks is efficient spectrum utilization. Thus, the spectrum sensing should provide more opportunities for transmission for secondary users. During the sensing period, the transmission of secondary users are not allowed, by which certainly the transmission opportunities of secondary users gets reduced which gives rise to so called sensing efficiency issue[9].

To avoid the interference the sensing has to be lengthy enough so that it can detect the spectrum accurately ie longer sensing time gives better detection accuracy and hence less hindrance. But as the sensing time increases the transmission time will get reduced. As transmission time is increased the sensing efficiency will increase but by giving interference as sensing time will get hampered. Hence, sensing time and transmission time

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are the sensing parameters that mainly influence both the spectrum efficiency [9]. Thus, the proper selection of these sensing parameters is the most critical factor influencing the performance of CR networks.

SYSTEM MODEL

The CR system works in the same band of frequencies with PU networks. Hence, there will be some interference between different PUs and CRs. System has identified a spectrum opportunity in the mentioned frequency slot and is initiating communications in it. The primary purpose of the spectrum sensing function is to detect possible other transmissions or reappearing PUs in the spectrum gap.

Energy based Detection for Spectrum Sensing

We consider here cooperative spectrum sensing done independently and local decision of all CR users sent to the fusion center. Let the model contains K number of CR users. The spectrum sensing ethos can be expressed with binary hypothesis-testing notation:

H0: Primary user is absent

H1: Primary user is active

Now sensing method is to be decided on the basis of this test, according to [2];

x(n) = w(n) ; (1)

x(n)= h *s(n) + w(n) (2)

where s(n) is primary signal transmitted through wireless channel with gain 'h' , x(n) is received signal, and w(nm is additive white Gaussian noise (AWGN), n = 0,1,2,….,K;K is the number of samples. For ease of simplicity consider impulse response of channel is unchanged during sensing process. The test statistics available under H0 is as per [5]:

Spectrum sensing decides on the two hypotheses which are high probability of detection, Pd, and low probability of false alarm, Pf. The energy detector is applied to detect unknown signals. The decision statistic of the energy detector is given by

$$T = \sum_{n=1}^{K} (x[n])^2 \quad (3)$$

The detection performance is based upon Neyman-Pearson criteria, the likelihood gives the optimum solution. Hence the detector functioning can be estimated as

Pf = P(T > β | H0) (4)

Pd = P(T > β | H1) (5)

where β is a particular threshold that tests the decision statistic. The test statistic is based upon chi-square distribution and can be approximated as Gaussian based on the central limit theorem. Then the probability of false alarm and probability of detection can be given as in [8]

$$Pf(\tau_s) = Q(\sqrt{2\gamma + 1}\, Q\text{-}1(Pdt) + \gamma\sqrt{\tau_s fs}) \quad (6)$$
$$Pd(\tau_s) = Q(1/\sqrt{2\gamma + 1}\, Q\text{-}1(Pft) - \gamma\sqrt{\tau_s fs}) \quad (7)$$

Where τs is the sensing time, fs is the sampling frequency, γ is snr of primary user ,Pdt and Pft is the targeted probability of detection and probability of false alarm respectively.

The cooperative sensing is used to detect the spectrum at very low SNR environments, it also tackles hidden node problem, where primary users are shadowed by obstacles [2]

For K number of users collaborating we have assumed two scenarios first one is that all users experience independent and identically distributed (iid) fading/shadowing with same average SNR and second scenario is they experience iid fading with different SNR's .A secondary user receives decisions from K−1 other users and decides H1 if any of the total K individual decisions is H1. This fusion rule is known as the OR-rule or 1-out-of-n rule. Two fusion schemes are used, OR- and AND-rule. In OR-rule fusion scheme, the final decision on the presence of a PU will be positive if only one SU of all collaborating users detects this PU. Assuming that all decisions are independent, the detection and false alarm probability of the SUs network under OR-rule, Pd and Pf, respectively, can then be mathematically written as

$$Q_d = 1 - \prod_{i=1}^{N} (1 - P_{d,i}) \quad (8)$$
$$Q_f = 1 - \prod_{i=1}^{N} (1 - P_{f,i}) \quad (9)$$

In AND rule rule all collaborating SU s should declare the presence of a PU in order for the final decision to be positive. Again assuming that all decisions are independent the SUs network probabilities under AND rule is

$$Q_d = \prod_{i=1}^{N} P_{d,i} \quad (10)$$
$$Q_f = \prod_{i=1}^{N} P_{f,i} \quad (11)$$

where Pd,i and Pf,i are the individual detection probability and false alarm probability, respectively. N is the number of cooperating SUs.

Sensing time and Sensing efficiency.

Sensing delay mainly depends on the sensing technique being used. The sensing time is proportional to the number of samples taken by the signal detector. General speaking, the longer the sensing time is, the better the detection will be. The more time is devoted to sensing, the less time is available for transmissions and thus reducing the CR user throughput and efficiency. This is known as the sensing efficiency. It is given by [9],

$$\mu = \frac{T - \tau s}{T} \quad (12)$$

where μ is the sensing efficiency ,T is the total frame time and ts is the sensing time , T-τs is the transmission time Therefore sensing efficiency is defined as the ratio of transmission time to the total frame time.

Numerical evaluation and results

In this section, MATLAB simulations are performed to evaluate the performance of probability of detection pd, sensing efficiency μ, cooperative detection with respect to sensing time.

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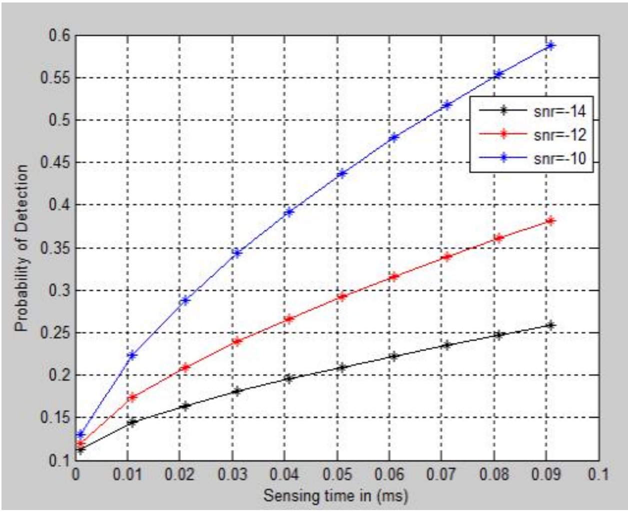

Fig 1.Sensing time v/s Prob of Det with SNR constant

Sensing time v/s Probability of Detection
The simulation parameters are frame duration T is set to 400ms, pf to 0.1, SNR is set to -14,12,-10dB,sampling frequency fs is 6Mhz.Sensing time is varied from 10ms to 100ms.The impact of varying sensing time by keeping SNR constant and observing probability of detection is seen in the graph. As sensing time increases the probability of detection also increases, and regarding SNR lesser the SNR better is the detection probability.

Sensing time and cooperative probability of detection

In this the improvement in proability of detection is cleary seen in fig 2 and fig 3
Fig 2 shows the graph between sensing time and cooperative sensing using AND rule, with varying sensing time Qd changes. Probability of false alarm is kept constant with values of 0.1,0.2 and0.3.

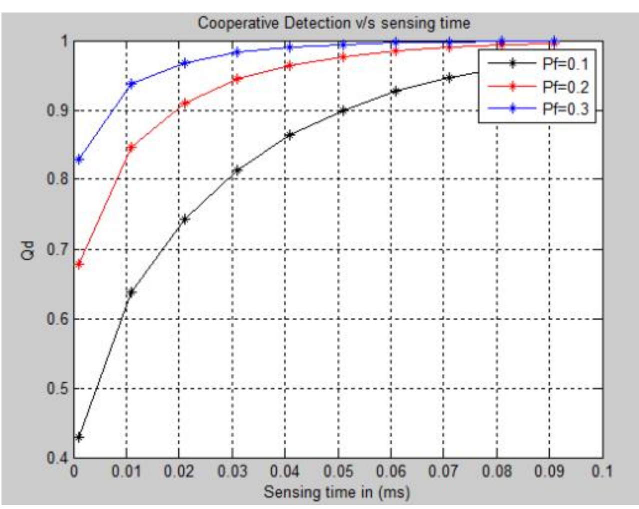

Fig 2 Cooperative Detection with AND rule

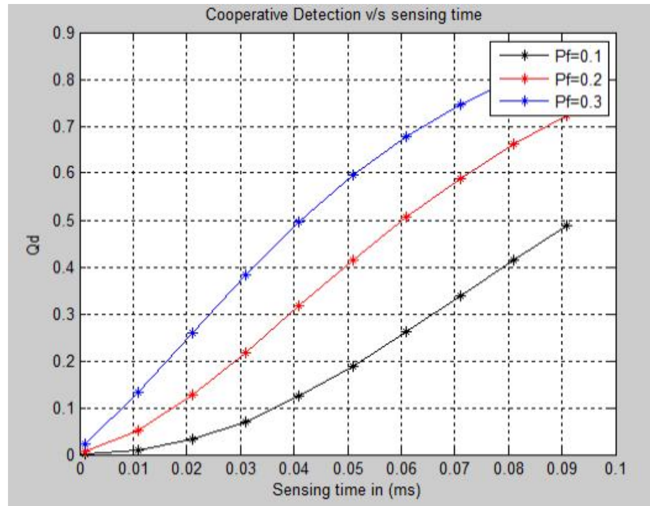

Fig 3 Cooperative Detection with OR rule

The probability of detection at sensing time =10 ms is 0.0005 for OR rule whereas for the same sensing time the probability of detection with AND rule outperforms and is 0.4284.AND rule exhibits much better performance than OR rule in terms of probability of detection. Thus achieves a good tradeoff between performance detection and sensing time.

Sensing time and Sensing efficiency.
Sensing technique used here is energy detector .The number of samples is proportional to the sensing time, Longer the sensing time the detection is better but at the same time transmission time The sensing efficiency is defined as the ratio of transmission time to the total frame time. From the graph we can verify that as the sensing time is increased the efficiency of the system decreases. The plot for sensing time and sensing efficiency is plotted with different values of T i.e Total frame time (400ms,250ms, 150ms).

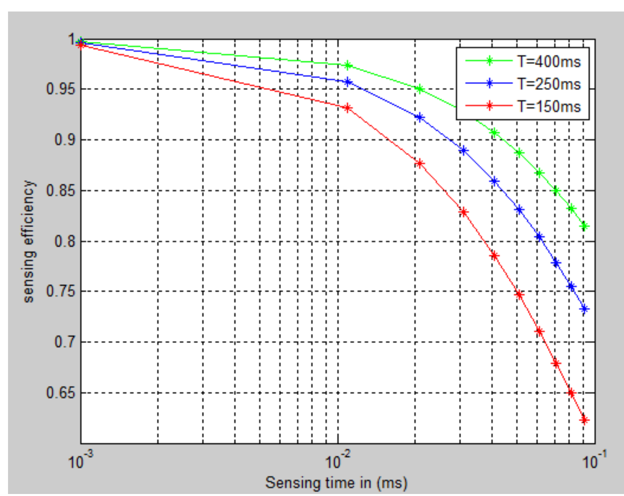

Fig 4 Sensing time v/s Sensing efficiency

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Conclusion:

Cooperative sensing method is used to mitigate the effects of fading, shadowing and receiver uncertainty issues. In this each secondary node senses the spectrum individually and shares the raw results to all neighboring nodes. Logical AND and Logical OR rules with respect to sensing time are implemented. Results indicate a significant improvement in terms of required sensing time for detection.
AND rule gives the better probability of detection than OR rule in terms of sensing time. The sensing efficiency decreases as sensing time increases. Thus the cooperative sensing methods and sensing efficiency were studied and verified

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