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Threshold optimization in energy detection scheme for maximizing the spectrum utilization

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Abstract

Cognitive radio is a new paradigm in wireless communication for improving the spectrum utilization. Spectrum sensing is a fundamental component of cognitive radio networks. Among all the available spectrum sensing algorithms, energy detection scheme has gained more interest owing to its simple implementation. In this paper, we propose a threshold setting algorithm for energy detection scheme which aims at maximizing the spectrum utilization. A closed-form expression for adaptive threshold for maximal spectrum utilization is derived and analyzed. Numerical results demonstrate that the proposed scheme outperforms the conventional methods of determining the threshold.

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Keywords: Cognitive radio; Spectrum sensing; Energy detection; Spectrum utilization; Adaptive threshold.

1. Introduction

With the growing proliferation of wireless services and applications, networks are facing spectrum scarcity problem. Almost all the usable spectrum is already allocated to some licensed users for exclusive access. In 2002, the Federal Communications Commission (FCC) conducted a study on the utilization pattern of spectrum and found the allocated spectrum highly underutilized [1]. In 2003, FCC issued a notice of proposed rulemaking and order in which Cognitive Radio (CR) is identified as a potential candidate to increase spectrum utilization [2]. The term CR was first coined by Joseph Mitola in his PhD thesis [3, 4].

In cognitive radio networks, unlicensed users also known as Secondary Users (SUs) are allowed to temporarily

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access the licensed band if it is not being used by the Primary User (PU). PUs are the licensed users who are having proprietary rights for transmission over the band. To enable this, SUs have to sense the spectrum periodically to check the presence or absence of PU. If the band is found vacant, it can be used by SUs but the band is required to be vacated as soon as any PU activity is found. Therefore, spectrum sensing is categorized as a very important aspect of CRs. There are many spectrum sensing techniques available in the literature out of which energy detection has gained more interest because of its simple implementation and moreover, it does not require prior information about PU [5, 6]. The performance of any spectrum sensing algorithms is determined by the metrics called the probability of detection (P_d) and the probability of false alarm (P_{fa}). Probability of detection means detecting the presence of PU accurately. The higher the probability of detection, more the PU is protected. Probability of false alarm means detecting the PU present when actually PU is absent. Lower the probability of false alarm, more are the chances of spectrum utilization by SU.

The main challenge in energy detection scheme is the setting of an appropriate decision threshold. Most of the threshold setting algorithms are based on the Constant False Alarm Rate (CFAR) or Constant Detection Rate (CDR). In CFAR detectors, threshold is set by fixing P_{fa} which makes it difficult to achieve a desired detection probability over the wide SNR range especially in low SNR regions. Similarly, in CDR detectors threshold is set by fixing P_d and in this case it would be difficult to achieve a target false alarm probability. This has been illustrated in Fig. 1.

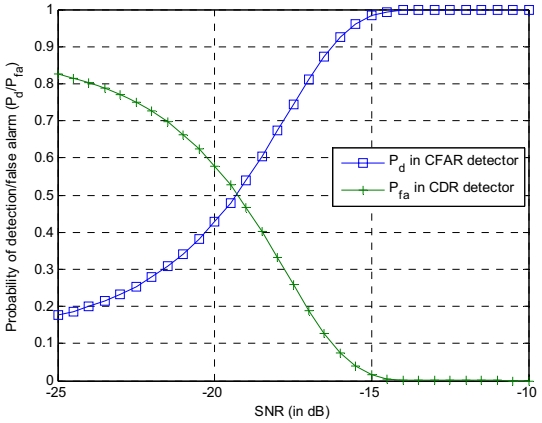

Fig. 1. Performance of CFAR (P_{fa}=0.1) and CDR (P_d=0.9) detectors.

This implies that there is a need of trade-off between the false alarm and detection probability. A number of adaptive algorithms have been proposed to minimize the miss detection and false alarm probability. In [7], a weighted combination of false alarm probability and detection probability is used to reach to optimal threshold value. By estimation noise and signal power, threshold is made adaptive to noise fluctuation. In [8], optimal threshold is derived to minimize the total sensing error probability in the presence of noise uncertainty. In [9], double threshold based energy detection method was studied to improve the performance under low SNR regions. In [10], a control parameter is introduced to vary the set threshold to obtain the desired response in accordance with the operational requirements. All of these works have assumed that PU does not appear in between two sensing epochs. Moreover, through the implementation of cognitive radio technology, the ultimate aim is to improve the spectrum utilization either by PU or SU. To the best of our knowledge, no algorithm has been developed till date which sets the threshold by maximizing the spectrum utilization. In this paper, a threshold setting algorithm is proposed for maximizing the entire spectrum utilization to study the best trade-off between the probability of detection and false alarm while taking PUs spectrum occupancy into the consideration. While formulating the expression for spectrum utilization, we have also considered the interference because of the sudden appearance/disappearance of PU between two sensing epochs. The closed-form expression for adaptive threshold is derived and simplified. Results demonstrate that the proposed scheme gives improved spectrum utilization. The rest of the paper is organized as follows: Section 2 presents the generic system model. In section 3, spectrum utilization formulation is described. Section 4 covers the proposed threshold setting algorithm. Simulation results are discussed in section 5 and section 6 concludes the paper.