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Decision fusion using fuzzy threshold scheme for target detection in sensor networks

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ABSTRACT

Spectrum sensing is a fundamental surveillance task and is used to detect target signal. Energy detection is a popular spectrum sensing technique. But detection performance of energy detector deteriorates in low signal-to-noise ratio (SNR) conditions and under noise uncertainty. In this paper, we proposed an energy detector with fuzzy threshold scheme for spectrum sensing, in which each sensor node sends local decision to the fusion center depending on the region in which the observed energy lies. Fusion center then makes a final global decision by combining local decisions. Analysis and simulations show that the proposed fuzzy threshold scheme could improve the detect probability effectively under 'OR','AND' and 'K-out-of-N' fusion rules, and overcome the confused region problem. Monte Carlo Simulation results also show that proposed scheme achieves better detection performance and outperforms both conventional energy detector of both single and double threshold, respectively.

1. Introduction

With the advancements in technologies, it is becoming increasingly feasible to conceive and deploy the sensor networks for a wide variety of applications such as traffic control, homeland security, military surveillance, and environmental monitoring [15]. The interest in these sensor networks applications have increased the last few years. The reason for this is the technical evolution that has taken place the last decade resulting in new small, inexpensive, and low power sensor [6]. The Bluetooth concept for communication has also influenced the design this type of network. Therefore, the significant researches have gone into the development of approaches to perform a variety of tasks including detection, localization, classification, identification and fusion more sensors in the surveillance field. In this paper we focus on target presence detection. The target detection sensing techniques, which already have been proposed, are energy detection technique [13], matched filter detection technique and cyclostationary feature detection technique [8,11]. However, energy detection is the most popular technique due to its simplicity, and even when any prior information about the signal is not available. In these basic energy detection techniques, single threshold of energy detection is generally used [8], but the performance of this technique was limited by noise uncertainty. Double threshold energy detection was proposed in order to solve the problem of noise uncertainty. However, there is a new problem for these techniques, "Confused Region Problem" [19]. This problem will happen when all the energy lies between two thresholds, spectrum sensing will fail [20]. So that accurate detection becomes impossible, and choosing a suitable threshold in spectrum sensing also becomes more difficult. In this paper, firstly, we investigate spectrum sensing problem with the objective of achieving enhanced detection accuracy in the presence of noise uncertainty and to overcome spectrum sensing failure problem. Fuzzy theory could help dealing with noise uncertainty or uncertain conditions in case of spectrum sensing environment [4,1]. We proposed a fuzzy threshold scheme that put at confused region to get the better performance of spectrum sensing due to noise uncertainty. Meanwhile, when a target enters the monitoring region, it could be detected by multiple sensor nodes depending on their measurements from the target. Typically, nearby sensors produce larger measurements while distant sensors receive less quantity of the measured signal. Another objective is to fusion the decisions made by individual sensor nodes to achieve system detection performance beyond individual sensor nodes. Therefore, in this paper, energy detection based spectrum sensing is adopted in the local spectrum sensing and using fuzzy threshold scheme for local decision is implemented at individual sensor node which depending on the region in which the observed energy lies. Energy detection is

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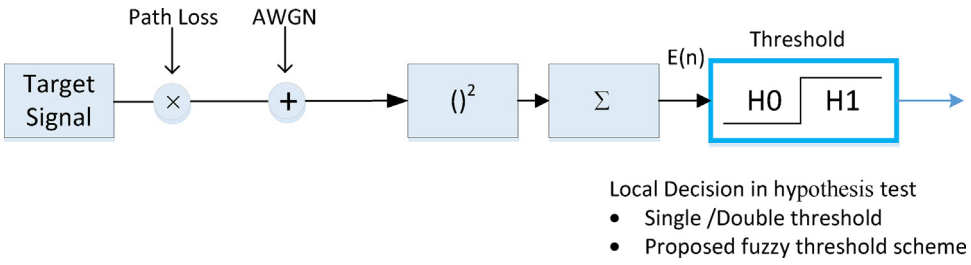

Fig. 1. Conventional energy detection model.

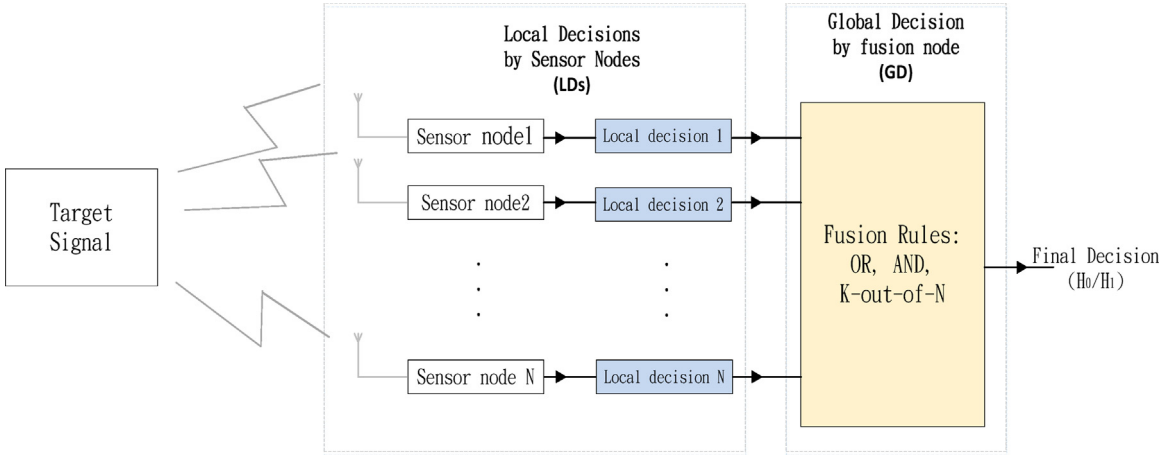

Fig. 2. Cooperative spectrum sensing based fusion of local decisions.

used to detect target signal in the local spectrum sensing due to the distributions of the target signal and noise might not be known in advance. Furthermore, the distributions could change from time to time caused by the unpredictable and variant physical environment conditions. After local spectrum sensing is performed, each sensor node sends their local decision results to the fusion node and compared with fusion rules such as logical AND, OR, K-out-of-N fusion rules and gives the final decision. The final decision fusion rules are used to realize cooperative sensing and made final decision while maintaining low communication overhead and improvement to the detection performance in low-SNR environment. In the proposed approach, we also study the analysis of the performance of the SNR and some performance metrics used are probability of detection (P_d), probability of false alarm (P_f), probability of miss (P_m) using single, double, and fuzzy threshold under OR, AND, K-out-of-AND fusion rules.

The rest of the paper is organized as follows: Section 2 highlights the related work on energy detection. Section 3 describes system modeling for energy detection based single/double threshold spectrum sensing technique and spectrum sensing failure problem. The investigation of different type of fusion rules are discussed in Section 4. In Section 5, proposed fuzzy threshold scheme has been presented. Simulation results are presented and analyzed in Section 6. Finally conclusions are drawn in Section 7.

2. Related study

Energy detection is widely used for spectrum sensing due to its low sensing period, low complexity, low computational and implementation cost. Moreover, energy detection has been a preferred approach because of its ability to work even when any prior information about the signal is not available. Conventional energy detector uses single threshold [13]. For reliable spectrum sensing it is desirable to set optimum threshold level since sensing performance depends on the threshold level [16]. Due to noise uncertainty, it is difficult to set optimum threshold hence reliability degrades. Moreover, at low SNR this uncertainty about the noise distribution leads to an SNR Wall which is the SNR below which robust detection is impossible for the given detector [10]. Several ideas have been proposed in literature to mitigate noise uncertainty in cooperative cognitive radio systems [19]. In Akyildiz et al., 2010 a cooperative sensing based on energy detection with various types of thresholds are reviewed to overcome with noise uncertainty. Covariance and eigenvalue based cooperative detection technique was proposed in [18]. In [12], sensing decisions taken by individual sensor nodes are forwarded to fusion node through reporting channels. Hence more bandwidth of control channel is occupied and overheads are increased. Meanwhile, a censoring based double threshold method is discussed for reducing the overhead at the cost of performance loss [2]. The authors in [9] have also shown the increased performance using 'n ratio based logic with two thresholds. But when all detected values lie between two thresholds, then no value is sent to fusion node which causes spectrum sensing failure [17]. Spectrum sensing failure problem is solved by sending detected values between two thresholds to fusion node [14]. This scheme increases system hardware requirement as fusion node is needed to take final decision. In [3], spectrum sensing failure problem is solved by individual user taking only the difference of measured energy and threshold value into consideration. But this is not sufficient to quantify the reliability of each sensor node in confused region which lies between two thresholds. It indicates that more parameters are required to quantify the reliability of each sensor node. In [7], a new combining scheme is proposed for cognitive spectrum sensing based on fuzzy logic. This approach provides good sensing performance and high the flexibility for decision fusion. However, in most of papers, fuzzy logic is implemented at fusion node [5]. If fuzzy logic is implemented at local node level, it can further improve the performance by improving local sensing

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