Cognitive Radio를 위한 새로운 협력 스펙트럼 감지기법 연구

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New Cooperative Spectrum Sensing Scheme using Three Adaptive Thresholds

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요 약

Cognitive radio 기술은 유망한 동적 주파수 스펙트럼 할당 기법으로 연구되어왔다. Cognitive radio의 주파수 스펙트럼 감지 기술은 주파수 면허대역에서 주사용자(면허대역 사용자)에게 간섭을 유발하지 않으면서 부사용자(비면허 사용자)가 면허대역을 사용할 수 있는 방법을 제공한다. 그러나 스펙트럼을 감지함에 있어서 면허대역을 주사용자가 사용하고 있는지 여부를 한 개의 부 사용자가 판단하여 결정하면 무선채널에서의 페이딩, 잡음 불확실성에 의한 새도우잉, 그리고 히든 노드 문제 등 의해 오류가 발생할 수 있다. 이를 해결하기 위해 협력 스펙트럼 감지 기술이 등장하였다.

본 논문에서는 면허대역 사용여부를 퓨전센터에서 결정하는 협력 스펙트럼 감지기술을 제안하였다. 부사용자는 세 개의 threshold를 사용하여 주사용자 존재여부를 판단하며, 판단 결과를 퓨전센터로 전송한다. 퓨전센터의 협력 스펙트럼 감지기술로 OR 기법을 사용하였고, 컴퓨터 모의실험을 통해 성능평가를 수행하였으며, 성능평가 결과에 따르면 OR 기법의 성능이 가장 우수함을 알 수 있었다.

ABSTRACT

Cognitive radio has been proposed as a promising dynamic spectrum allocation paradigm. In cognitive radio, spectrum sensing is a fundamental procedure that enables secondary users (unlicensed) employing unused portion of spectrum of primary users (licensed) without causing harmful interference. However, the performance of single-user spectrum-sensing scheme was limited by fading, noise uncertainty shadowing and hidden node problem. Cooperative spectrum sensing was proposed to mitigate these problem.

In this paper, we observe cooperative sensing scheme with energy detection using three adaptive thresholds for local decision, which can mitigate sensing failure problem and improve sensing performance at local node. In cooperative scheme we employed OR rules as decision combining at fusion center. We evaluate our scheme through computer simulation, and the results show that with OR combination rule our scheme can achieve best performance than other schemes.

키워드

Adaptive threshold, cooperative spectrum sensing, energy detection

Ⅰ. Introduction

Spectrum sensing is a fundamental procedure from the whole process in cognitive radio. Its enable secondary user employing unused portion of spectrum of primary users without causing harmful interference. There are various technique was proposed for spectrum sensing and some of them are matched filter technique, cyclo-stationary detection, and energy detection. Among them, energy detection is the simplest technique that needs minimum prior knowledge of primary user and does not require complex computation. However, the spectrum sensing performance of single user was limited by fading, noise uncertainty shadowing and hidden node problem. One of possible technique to mitigate this problem is cooperative spectrum sensing.

In cooperative spectrum sensing, secondary users are located at different location and they will collaborated for determining decision of spectrum availability by sent their local decision to fusion center. Fusion center will aggregate all the result of each secondary users and make decision according to fusion rule that has been applied in fusion center. By applying cooperative spectrum sensing we can also improve sensing accuracy and probability of detection.

In this paper, we present cooperative spectrum sensing using three adaptive thresholds based on energy detection. We applied three adaptive threshold at each secondary user and perform the cooperative sensing to improve sensing accuracy and probability of detection. We evaluate cooperative sensing result by applying OR fusion rules at fusion center.

Ⅱ. Cooperative Spectrum Sensing Using Three Adaptive Thresholds

In order to improve sensing accuracy and probability of detection, we applied cooperative spectrum sensing scheme. As shown in Figure 1, each secondary users will make local decision using three adaptive sensing and forward the result to the fusion decision. Three different thresholds are combined from double adaptive threshold technique and one adaptive threshold that we put in confused region to overcome sensing failure and get the better performance of spectrum sensing due to noise uncertainty [1]. The upper bound threshold will be selected based on maximum noise variance, and the lower bound threshold will be selected based on minimum noise variance $\left(\sigma^2 \in \left[\frac{1}{\rho}\sigma_\omega^2, \rho\sigma_\omega^2\right]\right)$.

If the energy falls in confused area, it will be compared with single adaptive and dynamic threshold that applied dynamic threshold factor $\left(\lambda' \in \left[\frac{1}{\rho}\sigma_\omega^2, \rho\sigma_\omega^2\right]\right)$ to decide the presence of Primary User. According to conventional single threshold case, the false alarm probability P_f can be expressed as:

$$P_f = Q\left(\frac{\lambda - N\sigma_\omega^2}{\sqrt{2N\sigma_\omega^4}}\right)$$

And based on given target false alarm probability, the threshold can be determined as

$$\lambda = Q^{-1}(P_f) \times \sqrt{2N\sigma_\omega^4} + N\sigma_\omega^2$$

According to single threshold, we can derive maximum threshold and minimum threshold by applied max-min noise variance. The thresholds can be determined as

$$\lambda_1 = Q^{-1}(P_f) \times \sqrt{2N/\rho\sigma_\omega^4} + N/\rho\sigma_\omega^2$$

$$\lambda_2 = Q^{-1}(P_f) \times \sqrt{2N\rho\sigma_\omega^4} + N\rho\sigma_\omega^2$$

And we can derive the threshold for the confused region ($\lambda_{confused}$) as

$$\lambda_{confused} = \left(Q^{-1}(P_f) \times \sqrt{2N\rho\sigma_\omega^4} + N\rho\sigma_\omega^2\right)/\rho'$$

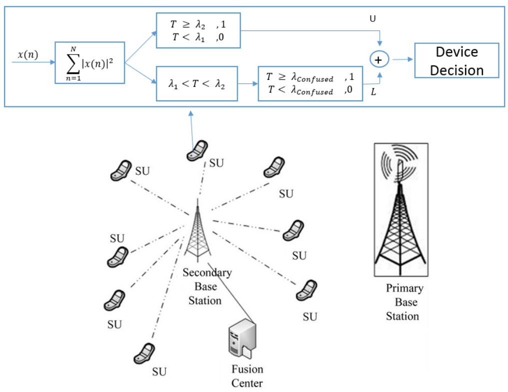

Figure 1. Proposed Scheme: Cooperative sensing using three adaptive threshold

After receive all local decision, fusion center will combine the result using hard decision combining and make decision for the actual status of spectrum [2]. In this scheme, we applied OR Rules in fusion center as decision combining and compare with two previous scheme. The first scheme is the double adaptive thresholds without considering confused region, and the second is the single adaptive threshold or Constant False Alarm Rate (CFAR) scheme. We also applied OR and AND fusion rule for each comparison scheme.

When fusion center received local decision from number of users and decides primary signal is present (H_1) when total sum of user number decision is H_1. It means all secondary users decides primary user signal is present at local decision, this fusion rule is known as OR rule. In the opposite way, when at least one of secondary user decide primary user signal is present at local decision and the fusion center will sent final decision is H_1. This fusion rule is known as AND rule [3].

The probability of detection (Q_d) and probability false alarm (Q_f) cooperative sensing based for OR rule can be express as

$$Q_d(M) = 1 - \prod_{i=1}^{M}(1 - P_{d,i})$$

$$Q_f(M) = 1 - \prod_{i=1}^{M}(1 - P_{f,i})$$

Where M is the number of secondary user subscribing cooperation, $P_{d,i}$ and $P_{f,i}$ are probability of detection and probability of false alarm at each secondary user respectively. For AND rule, Q_d and Q_f can be express as

$$Q_d(M) = \prod_{i=1}^{M}(P_{d,i})$$

$$Q_f(M) = \prod_{i=1}^{M}(P_{f,i})$$

Ⅲ. Simulation and Numerical Results

The simulation was implemented using MATLAB. We assumed that the number of secondary user is 3, total number of samples (N) is 1000, SNR values changes from -30 dB to 5 dB, P_f = 0.1, noise uncertainty factor (ρ) =1.05, dynamic threshold factor (ρ')=1.09, and QPSK modulation is considered in AWGN channel. In this simulation we compare with two previous scheme using same fusion rules. The first scheme is the double adaptive thresholds without considering confused region, and the second is the single adaptive threshold or Constant False Alarm Rate (CFAR) scheme. The result show that with OR fusion rule our scheme can hardly improve sensing accuracy than other schemes.

In Figure 2, it shows the performance when there is three secondary users subscribing cooperation. It can be noticed from Figure 2 that when there is decrease SNR in the local node, there is decreasing in probability of detection dramatically. Moreover, the result show that with applying OR fusion rule in fusion center can achieve best performance than AND fusion rule. And applying OR fusion rule in our scheme can hardly improve sensing accuracy than other schemes.

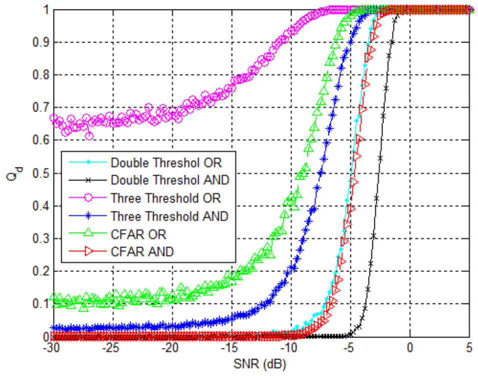

Figure 2. Performance comparison as a function of SNR when primary user is present

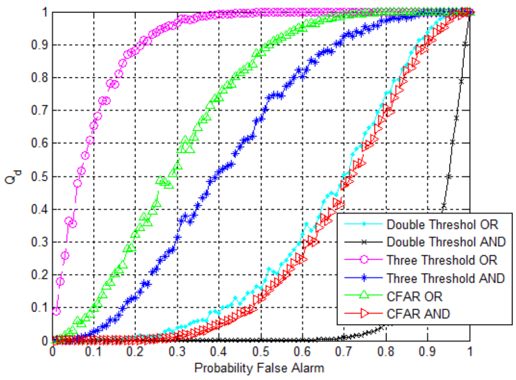

Figure 3. Performance comparison as a function of P_f when primary user is present

In Figure 3, we observed when all scheme produce the threshold using variant of probability of false alarm. We assumed there are three secondary users, SNR is -25 dB, and P_f start from 0.01 until 1. And we can see from the Figure 3, when OR fusion rule is used in our scheme with P_f = 0.01 our scheme can obtain P_d approximate 0.1 where other scheme just obtain 0. Also when P_f = 0.1 our scheme can obtain P_d approximate 0.7 where other scheme just obtain less than 0.15. Therefore, our scheme showed no bad effects related to the changes in the probability false alarm to produce the threshold.

In Figure 4, we observed when all scheme perform cooperative sensing with increasing number of secondary user that subscribing cooperative scheme. We assumed all secondary users has the SNR value of -25 dB, number secondary users start from 2 until 10 users, and $P_f = 0.1$. The result shows that increasing number of secondary users that are populated in the range of primary transmitter can improve sensing performance and achieve high probability of detection. And it is confirm that primary signal can be detected more accurately by increasing number of secondary users that collaborated in cooperative sensing.

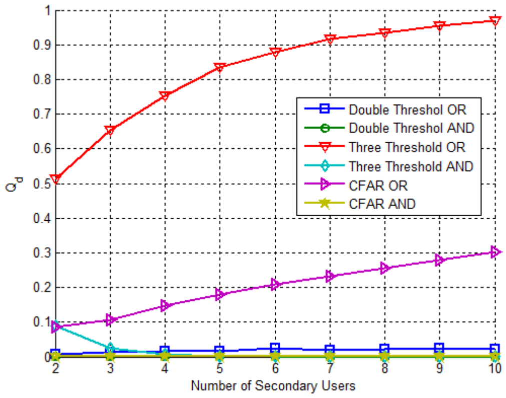

Figure 4. Performance comparison of cooperative sensing schemes when primary user is present

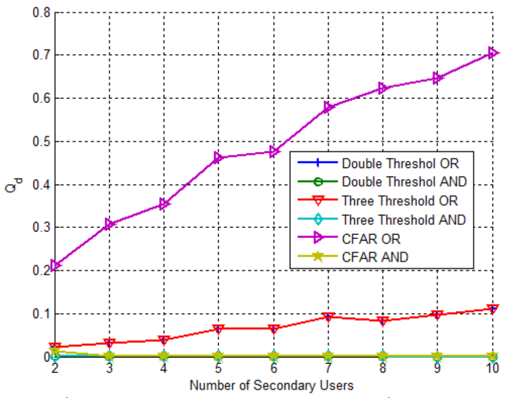

Figure 5. Performance comparison of cooperative sensing schemes when primary users is absent

Moreover, in Figure 5, we observed cooperative spectrum sensing when primary user is absent and using P_f = 0.1 for derive local threshold. Based on result, cooperative sensing using CFAR with OR fusion rules achieve more high false detection as increasing in number of secondary users. According to spectrum sensing standard, maximum requirement for probability of false alarm is 0.1 [4]. Hence, the CFAR cooperative sensing with OR fusion rule is impossible to implement because it cannot achieve the requirement. Moreover, our proposed scheme can achieve requirement probability of false alarm as increasing in number of secondary user. It is proved that our proposed scheme is possible to implement because we can improve probability of detection and keep the maximum value for probability of false alarm according to the standard.

Ⅳ. Conclusion

Based on this observation, applying three adaptive threshold at local decision and cooperative sensing can improve the sensing accuracy and provide high probability of detection for spectrum sensing. With OR fusion rule, our scheme can achieve higher probability of detection than other scheme.

Acknowledgement

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