지능형 교통시스템을 위한 인지무선 시스템의 다양한 협력 센싱 기법 연구

Study on cooperative spectrum sensing scheme in cognitive radio system for ITS system

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목 차

Ⅰ. Introduction

According to wireless technologies have developed rapidly, more spectrum resources are needed to support considerable and various wireless services. Also, a recent survey of the spectrum utilization made by Federal Communications Commission (FCC) has indicated that the actual licensed spectrum is largely under-utilized in vast temporal and geographic dimensions [1, 2]. In order to relieve the spectrum scarcity and inefficient spectrum utilization, cognitive radio (CR) was recently proposed [3, 4]. CR is an intelligent wireless communication system that is aware of the radio environment and is capable of adapting its operation to the statistical variations of incoming radio frequency stimuli [4]. This is a very important feature of CR system.

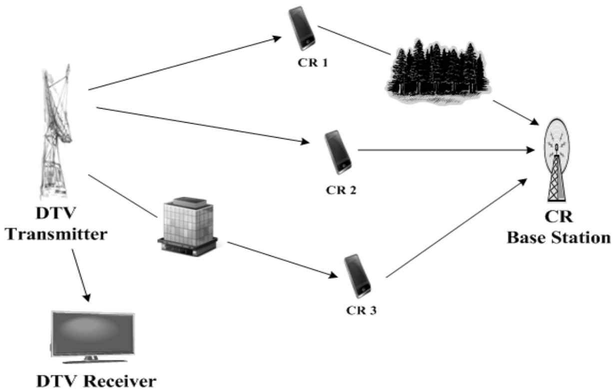
Since employing CR techniques as new frequency policies, CR system can opportunistically utilize the licensed bands when the primary user (PU) are not using the frequency. Therefore, CR systems temporarily utilize the licensed band legally without a license. That means CR system detect the signal of the PU because secondary users must use without interference. If PU is detected, CR system should vacate the licensed band and sense the other white space. This task is known as “spectrum sensing” that is very important and difficult task of CR. However, Spectrum sensing has some critical challenging issue such as hidden terminal problem that occurs when the CR systems is shadowed or in serve multipath fading. In order to improve spectrum sensing, co-operation among secondary users has been proposed [5, 6]. Cooperative communication is the promising and powerful solution that can be overcome spectrum scarcity and inefficiency of spectrum usage [7, 8].

In this paper, we propose various cooperative spectrums sensing scheme and show each sensing scheme’s performances, for example cluster-based cooperative spectrum sensing, cognitive radio Ad-hoc network and spectrum sensing with antenna diversity.

This paper is organized as follows. In Section Ⅱ, we introduce the basic cooperative spectrum sensing system model. And the various cooperative spectrum sensing scheme is described in Section Ⅲ. Finally, concluding remarks are drawn in Section Ⅳ.

Ⅱ. System Model

Spectrum sensing has some critical challenging issue such as hidden terminal problem that occurs when the CR systems is shadowed or in serve multipath fading. In Fig. 1, it shows that CR 3 is shadowed by a building over the sensing channel. In this case, the CR 3 cannot detect the PU signal due to shadowing effect. In order to relieve this problem, multiple CR systems can be designed to collaborate in spectrum sensing [5]. Recent study has shown that cooperative spectrum sensing can greatly improve the sensing performance in fading channel [9]. In general, cooperative spectrum sensing can be performed as described below.



<Fig.1> Cooperative spectrum sensing in case of shadowing.

i. Every CR system detects the radio environment individually and then makes a binary decision on whether the PU is present or not.
ii. All of the CR systems forward their local sensing result to a common receiver (Fusion center).
iii. The common receiver combines the local sensing result and then makes a final decision whether the primary user is present or not.

1. Basic Hypothesis

Generally, the cooperative spectrum sensing in CR system has binary hypotheses as follows.

$$H_0: y[k] = v[k], \quad (1)$$

$$H_1: y[k] = hs[k] + v[k], \quad (2)$$

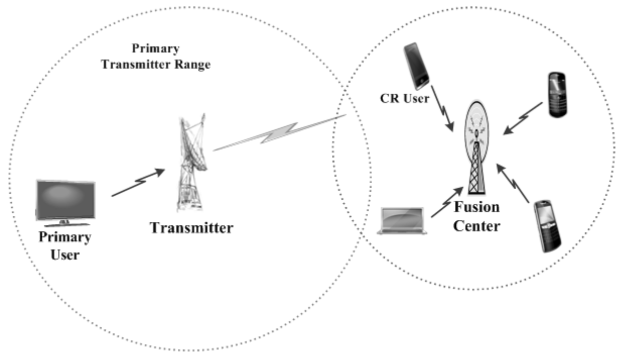
where h is the fading coefficient, $s[k]$ is the transmitted signal by primary user and k is the generated bits from the primary user.

The additive white Gaussian noise (AWGN) $v[k]$ is modeled as independent Gaussian random variable. $v[k]$ has normal distribution $N(0, \sigma_v^2)$. H_0 indicates that the primary user is absent. H_1 indicates that the primary user is present and is located closed to the secondary user.

2. General Concept

Basically cooperative system is composed of a primary user, M secondary users and a fusion center as shown in Fig. 2. In cooperative sensing, each secondary user judges whether primary user is present or not using the energy detector. In other words, the energy of i^{th} secondary user is used for detecting the primary user. The energy of the i^{th} secondary user is shown as

$$E_i[k] = |y_i(k)|^2. \quad (3)$$



<Fig. 2> System model of distributed spectrum sensing.

If the primary user is existed, the energy signal is compared with predetermined threshold (γ_i). Local sensing result of each secondary user can be expressed as

$$D_i[k] = H(E_i[k] - \gamma_i), \quad (4)$$

where $H(\cdot)$ means the Heaviside step function. In other words, if $E_i[k]$ is more than or equal to γ_i, local sensing result is $D_i[k]=1$ and if $E_i[k]$ is less than γ_i, local sensing result is $D_i[k]=0$. γ_i is determined in accordance with the constant false alarm rate (CFAR) algorithm [15].

Local sensing results ($D_i[k]$) are independently transmitted to the fusion center. In the fusion center, each local sensing result is combined and then the result is compared with predetermined threshold (γ) that is determined according to decision rules. In accordance with this process, final decision about the presence of primary user is made. Final decision result in fusion center is calculated as

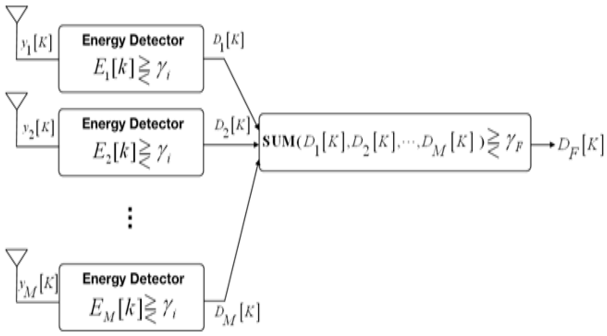
$$D[k] = H(\frac{1}{M}\sum_{i=1}^{M} D_i - \gamma). \quad (5)$$

In the fusion center, if $D[k]=1$, the primary user is present so secondary users cannot use the spectrum. But if $D[k]=0$, the primary user is absent so secondary users have right to use the spectrum. γ is determined in accordance with the decision rule.

Ⅲ. Cooperative Spectrum Sensing

Cooperative sensing systems is robust sensing system to detect the PU comparison to the single sensing. However, the sensing performance may be degraded by realistic channel environment. To alleviate this problem, we propose various cooperative sensing systems in this chapter.

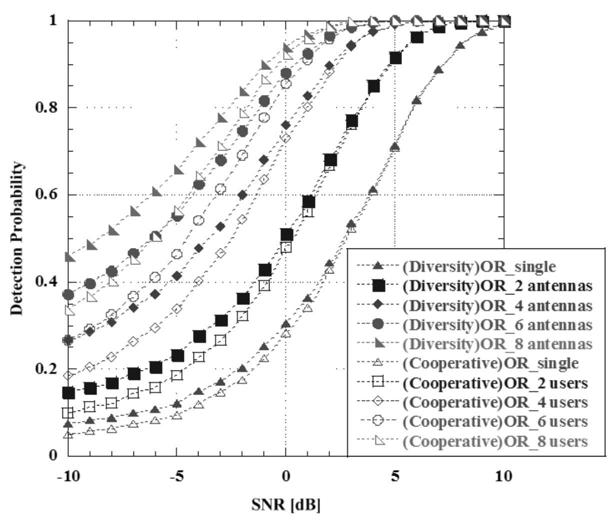
1. Spectrum Sensing with Antenna Diversity



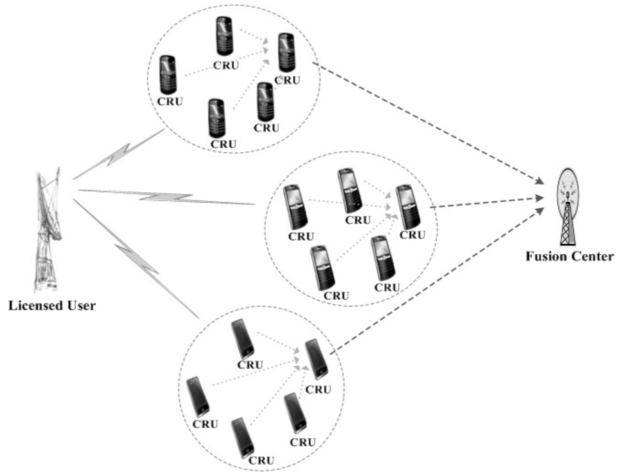
<Fig. 3> Block diagram of spectrum sensing using antenna diversity.

In the Cooperative spectrum sensing, each local sensing forward the fusion center through control channel that supposed perfect channel in conventional paper. However, real wireless channel cannot control perfectly so spectrum sensing performance should be worse than simulation results. Therefore, we propose spectrum sensing with antenna diversity. In accordance with applying antenna diversity scheme, we can expect that reducing the effect of the multi-path fading and improving the signal quality at the receiving end of wireless communication systems.

Energy signal of each antenna is compared with predetermined threshold according to the false alarm rate in order to make a decision whether the PU signal is present or not. Local sensing results are combined and then the combined result is compared with predetermined threshold that determined as decision rule. After this process, final decision to detect the PU is made in the own CR system. The Block diagram of spectrum sensing using antenna diversity is shown in Fig. 3.



<Fig. 4> Performance comparison between cooperative sensing with diversity sensing scheme when OR decision rule is used.



<Fig. 5> Cluster-based cooperative spectrum sensing structure in CR network.

The detection probability versus signal to noise ratio (SNR) about performance comparison when applying AND decision rule between cooperative sensing with spectrum sensing using antenna diversity is presented in Fig. 4.

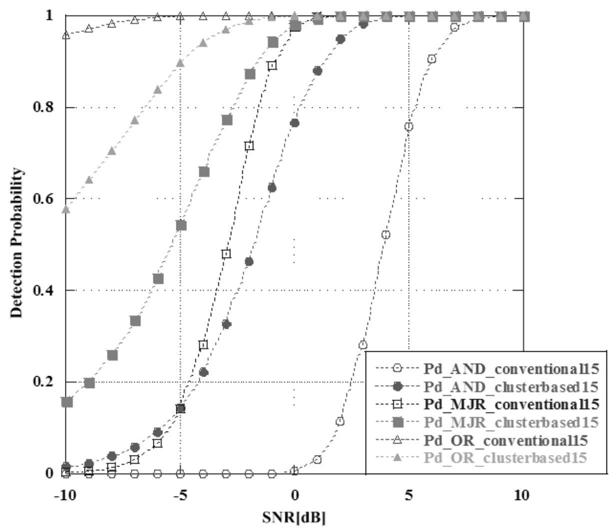
We can see that the detection probability of cooperative sensing is lower than antenna diversity sensing scheme both of above case.

2. Cooperative Spectrum Sensing Based on Clustering

A cooperative spectrum sensing system model based on clustering is shown in Fig. 6.

M CR systems are deployed in the CR network. And the N ($M = R \times N$, R is integer.) CR systems are grouped into R clusters by some upper layer distributing algorithms [10, 11]. And among the N CR systems in one cluster, a cluster head collects N sensing results, which includes its own result, and makes a cluster decision by using the collected results. Then, the cluster head transmits the cluster decision result to the fusion center through the control channel. In this paper, the CR system which is the nearest to the fusion center in each cluster is selected as the cluster head.

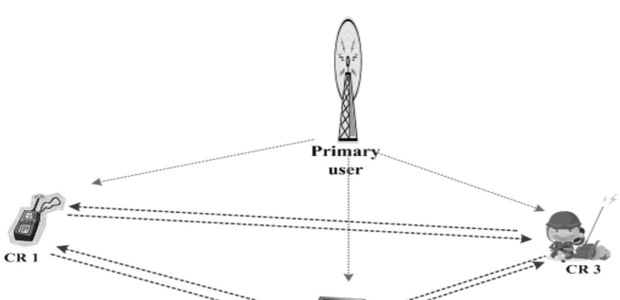
The detection probability comparison between conventional cooperative sensing and cooperative sensing based on clustering is presented in Fig. 5. In AND and Majority rule, the detection probability of cluster based cooperative sensing is higher than conventional cooperative sensing. However, in OR rule, the detection probability of cluster based cooperative sensing is lower than conventional way when SNR is degraded because the false alarm probability with OR. The false alarm probability is reduced in cluster based cooperative sensing, as a result, the detection probability is low and more reliable detection is performed.



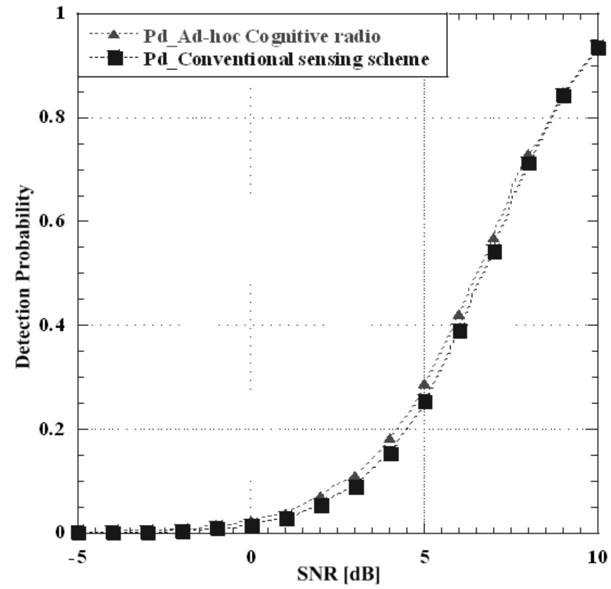
<Fig. 6> Cluster-based cooperative spectrum sensing structure in CR network.

3. Ad-hoc Cognitive Radio

According to the network architecture, cognitive radio system can be classified as the infrastructure based CR network and the CR ad-hoc network [12]. The infrastructure based CR network has a common receiver such as a fusion center. On the other hand, the CR ad-hoc network does not have also ad-hoc CR system proposed to use for emergency situations. Conventional emergency services almost depend on public networks which are not reliable in emergency situations because the public networks can get overloaded. In order to relieve the problem of spectrum shortage, ad hoc CR system is proposed. Also, since the Ad-hoc network is a self-organizing network of mobile devices without any infrastructure such as access points or central network entity, the Ad-hoc CR system do not have infrastructure support and must rely on local sensing results. In Fig. 9, ad-hoc cognitive radio system is presented and this system is composed of a primary user, M CR systems.



<Fig. 7> System model of Ad-hoc CR.



<Fig. 3> Detection probability versus SNR performance between conventional and Ad-hoc cognitive radio sensing schemes.

The network architecture of ad-hoc CR is the cluster structure network and the feature of this system is that local sensing results are shared among CR systems. In ad-hoc CR system, each CR system judges whether primary user is presence or absence using the energy detector and then sensing results are independently transmitted to the cluster head which has the best SNR performance among CR systems. We can see that the detection probability of Ad-hoc cognitive radio system is higher than conventional cooperative sensing scheme both of above case. Also, the Ad-hoc cognitive radio system do not need any infrastructure, therefore the problem of space, system complexity and cost will be improved.

Ⅳ. Conclusions

In this paper, we proposed various cooperative spectrum sensing scheme to alleviate sensing performance degradation due to fading and shadowing effects.

First, we proposed the spectrum sensing method employing antenna diversity scheme to improve the sensing performance and detection reliability. Conventional papers have been proposed collaborative sensing that assumed that the control channel can control perfectly. In real wireless communication, we can expect that spectrum sensing using diversity scheme is more reliable and effective than cooperative spectrum sensing.

Also, we proposed cluster based cooperative spectrum to relieve system overload, electric power consumption and process time of sensing information that can happen in conventional cooperative sensing system. From the simulation results, the error probability of cluster based cooperative sensing is low compared with convention cooperative sensing. Therefore, we can know that spectrum sensing performance is improved in proposer system and the reliability of detection is also improved according as the error probability is low.

Finally, we proposed Ad-hoc CR network system in order to solve the spectrum scarcity problem and the infrastructure-less systems, which was unlicensed and used the spectrum hole. From the simulation results, it was demonstrated that spectrum sensing performance of the Ad-hoc CR system was better than or similar to that of the conventional cooperative spectrum sensing system. It needs to be studied to select an optimized routing protocol and a cluster head in future.

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