Study on Adaptive Variable Period Spectrum Detection of Cognitive Radio

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Abstract: To improve the detection performance and increase detection efficiency of user recognition and frequency spectrum utilization ratio, the conventional detection method was improved by using detection period that can be adjusted with actual requirement instead of the fixed detection period. In our simulation, the new method increases spectrum access chance of recognition user, reduces lost time of detection and cuts down the cost of detection effectively while protecting primary user against interference.

Keywords: adaptive; primary user; recognition user; detection

1 Introduction

With the rapid growth of wireless communication technologies, especially the high development of wireless local area network technology, wireless personal area networks technology and wireless metropolitan area network, people call for higher requirement on broadband wireless communication application, while wireless networks is facing conflict in spectrum scarcity and various services need more spectrum. The current spectrum authorization mechanisms use fixed frequency allocation, and they reduce spectrum utilization rate and waste spectrum resources. Cognitive radio is a new agent spectrum sharing technology [1], it can initiatively detect and opportunistically use spectrum holes in the licensed band[2]. It makes nonrenewable spectrum be used again, and opens new channels for solving the problem that spectrum is scarcity and utilization rate is low.

A novel strategy that utilizing the idle spectrum resources named spectrum pooling is being studied [3-4]. In spectrum pooling system, the owner of licensed frequency band is called primary user, while the user that opportunistically accesses spectrum and has cognitive function is called secondary user. The secondary user opportunistically can utilize idle spectrum and avoid interfering primary user. Once primary user of the frequency band appears, recognition user must give up the channel for the primary user in time. In the process, it need secondary user to detect spectrum continually. Spectral detection can classified as local sensing and cooperative sensing. We will face the problem that how to select the long of detection time in concrete detecting processes. In this paper we use detection cost as our research objective, construct a new mathematical model that is different from the conventional detection period method, and induce control coefficient of detection period in analysis. Based on the above process, a new cognitive radio spectrum detection method is proposed. Comparing with the conventional fixed detection period method, it can control detection cost efficiently.

2 Variable Detection Period Mathematical Models

Cognitive radio system should have the detecting ability of distinguishing whether the frequency band is being used or not. Therefore, cognitive radio system must detect primary user signal of certain frequency band. The performance of local spectrum detection will drop with the received signals intensity decreasing which is caused by multi path and shadow fading. Besides, the detection itself has some restrictions [5]. Simulation and analysis show that it can get higher detection probability and lower false alarm probability by using cooperative diversity method [6]. In this paper, we use cooperation detection mechanism to detect primary user signal and get the information of spectrum utilization of primary user.

The primary user spectrum state can be classified as occupied spectrum and idle spectrum. The spectrum state of primary user is determinate, so the persistent period of two states can be expressed by random sequence

Z_i and K_i respectively, where i is sequence index. $(Z_i + K_i)$ is mutual independence, so we can use model to express the alternating process of occupied spectrum and idle spectrum. State alternative period is

$$T_i = Z_i + K_i \tag{1}$$

The primary user detection period is T_{pu}, and in conventional detection methods, T_{pu} is a fixed constant, so it can not avoid errors between cognitive user detection time and primary user state change (see figure 1).

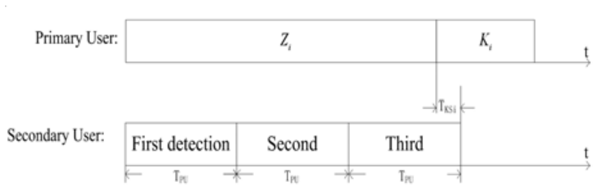


Figure 1. Fixed period spectral detection

Cognitive user needs some delay time to detect the vacant channel of primary user. This delay time is defined as accessible lost time T_{ks}, it means that cognitive user does not use primary user idle channel within the T_{ks} period. When primary user become busy status from idle one, cognitive user also needs some delay time to detect the state change of primary user, the delay time is defined as interference lost time T_{gs}. While two user signals appear in the same channel, they are mutual interference and make communication quality reduced. T_{ks} and T_{gs} are named detection lost time.

$$T_{ks(i)} = m_i T_{pu} - Z_i + T_{gs(i-1)} \tag{2}$$

$$T_{gs(i)} = n_i T_{pu} - K_i + T_{ks(i-1)} \tag{3}$$

Where $T_{gs(i)}$ and $T_{ks(i)}$ are respectively interference lost time and accessible lost time of the current detection, $T_{gs(i-1)}$ and $T_{ks(i-1)}$ are respectively interference lost time and accessible lost time of the last detection, m_i and n_i are the detection time of occupied channel state and idle channel state of the primary user respectively.

In cognitive wireless network, we expect to minimize T_{gs}, T_{ks}, m and n, so

$$\min\{\sum_i T_{ks(i)}, \sum_i T_{gs(i)}, \sum_i m_i, \sum_i n_i\} \tag{4}$$

Equation (4) is a multi parametric optimization issue, in which various parameters are dependent. When we improve some parameter, the other parameter must be weakened. To simplify the complex problem, we construct a new detection issue as following by inducing detection cost

$$\min\{C = \sum_i T_{ks(i)} + \sum_i T_{gs(i)} + \sum_i m_i + \sum_i n_i\} \tag{5}$$

Where C is detection cost of the cognitive user. It is the sum of lost time in detection and times of detection.

3 Detection Process Descriptions

For Space forbidding, we only talk about the status of primary user occupied, the detection method for idle status is also the same. Because the time long of primary user occupied has some centrality, we can set detection period T_{pu} in the concentration zone, so most status changes can be detected from little detection. It cuts down detection lost time and reduces detection cost efficiently, and in the same time realizes efficiently control detection cost for network.

Conventional detection method is to optimize equation (5), using fixed detection period. In this paper, we induce control coefficient a of detection period and adaptive coefficient b, and set detection time as M in the per state change period of primary user. Detection time can be set as $M_{\max}$, according perennial statistical results, which can make the detection period adjusted with actual demand, so detection cost is reduced. Detection process description is as follows

(1): analyzing statistics use status of primary user spectrum, initializing detection period T_{pu} and $b = 1$, and starting the first detection.

(2): if it does not detect the change of primary user state in the fist detection, detection period is multiplied by $\log(a)$, then we get the second detection period $\log(a)T_{pu}$.

(3): using new detection period to start detection, go back to step (2), until detecting the change of primary user state at the same time getting the detection time M.

(4): estimating detection time M is larger than $M_{\max}$ or not, if $M > M_{\max}$, it shows the initialization of detection period control coefficient a is too small, we should set adaptive coefficient $b > 1$.On the contrary, we don't need adjust b.

(5): in the second detection, b adopts the last time detection decision value. This means that we fist set detection period as bT_{pu}, then detect the next status changing period of primary user.

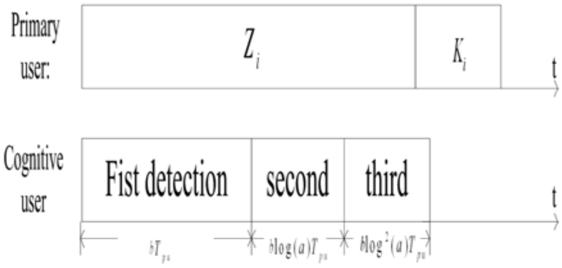


Figure 2. adaptive variable period spectral detection

From the above description, if $a = 10$, then it is conventional detection method. To reduce lost time of detection, let $a < 10$, so the progression that is constructed by all detection period converges to $T_{pu}/[1-\log(a)]$. If the channel time of primary user occupied exceeds $T_{pu}/[1-\log(a)]$, and then it will not detect state change. So we need to set the upper limit number of detection period of a status change, if the number of change of detection period exceeds this upper limit number, then set $a = 10$.

4 Adopting T_{pu}, a and b

From equation (2) and (3), we know the statistics of detection lost time and detection number are obtained in a status changes period. In the time of computing detection cost using equation (5), we can get the optimum solution by maximizing method.

$$\left.\frac{\partial C}{\partial T_{pu}}\right|_{T_{pu}=T} = 0, \left.\frac{\partial^2 C}{\partial T_{pu}^2}\right|_{T_{pu}=T} > 0$$
$$\left.\frac{\partial C}{\partial a}\right|_{a=A} = 0, \left.\frac{\partial^2 C}{\partial a^2}\right|_{a=A} > 0 \quad (6)$$
$$\left.\frac{\partial C}{\partial b}\right|_{b=B} = 0, \left.\frac{\partial^2 C}{\partial b^2}\right|_{b=B} > 0$$

Compared with fixed period detection method, it has better flexibility.

5 Simulation and Discussion

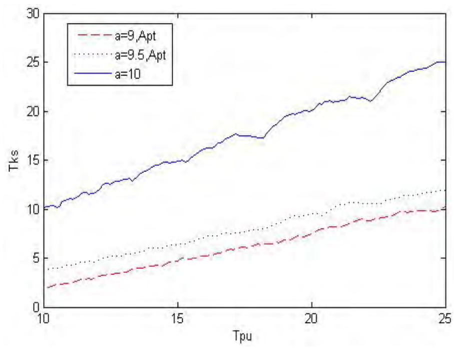
In our simulations, we verify the performance of the proposed algorithm by analyzing the relationship between T_{pu}, T_{ks} T_{gs} and C in 5000 times detection when b changes. The random variable Z is channel of occupied by primary user, Y is duration of the idle channel.

As seen in figure 3, we observe that the accessible lost time T_{ks} and interference lost time T_{gs} increase as the T_{pu} increasing, and have some fluctuant change. After using the adaptive detection method (in figure $a = 9$, $a = 9.5$), compared with other methods, T_{ks} and T_{gs} is smaller. This shows that adaptive spectrum detection method has better performance for reducing accessible lost time and interference lost time.

Figure 4 depicts the relation curves of T_{pu} and m that detection time of primary user occupied channel. When the value of T_{pu} increases, detection number will decrease gradually. Compared with other detection method, adaptive detection method has faster convergence ra te.

Figure 5 depicts curves of detection cost. As seen in picture 5, when a is certainty value. C can get minimal value in a some range, the minimal value will become small with a increasing. If a is some certainty value, when T_{pu} is smaller, detection cost C can be smaller as inducting adaptive method, but when T_{pu} is bigger, the detection cost is increasing as inducting adaptive method. This shows adaptive spectrum detection m-ethod is suitable for the situation that T_{pu} is bigger, if user need shorter detection time, we can use adaptive method.

Based on analyzing the simulation data, in the detection of primary user, comparing the algorithm that is based on variable period with fixed period, accessible lost time, interference time and detection cost of the proposed algorithm reduce distinctly. But the status change also has some limitation, in figure 5, when T_{pu} is smaller, detection cost C increase as a deducing. If we can make T_{pu} or a change as time long changing of primary user occupied and channel idle in the detection process, it will be next research area.



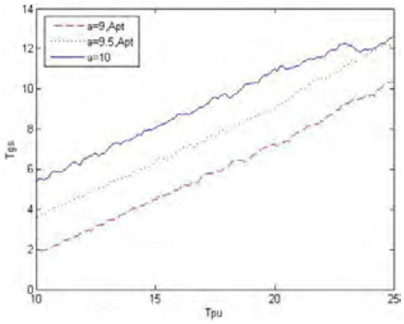


Figure 3. Relationship curves of lost time T_{ks} 、 T_{gs} **and** T_{pu}

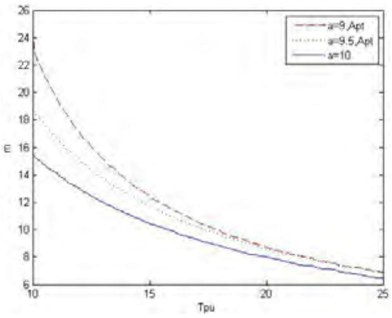


Figure 4. Relationship curves of detection time m **and** T_{pu}

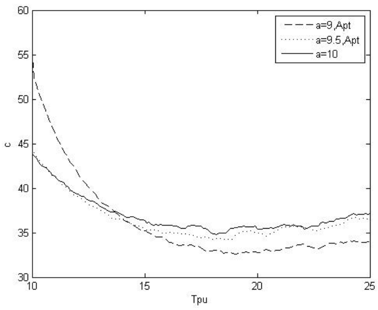


Figure 5. Relationship curves of detection cost C **and** T_{pu}

6 Conclusion

For Space forbidding, we only talk about the status of primary user occupied, and the detection method for idle status is also the same. Because the time long of primary user occupied has some centrality, we can set detection p-eriod T_{pu} in the concentration zone, most status changes can be detected from little detection. It cuts down detection lost time and reduces detection cost efficiently, and at the same time realizes efficiently control detection cost for network.

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