Research on Blind Detection Method of Shortwave Communication Electronic Signal Based on Wireless Network

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Abstract: The field of wireless network communication is further developed under the deepening of science and technology. The wide application of short-wave communication electronic signals is to promote its accelerated development. However, in the case of short-wave communication electronic signal detection, the traditional covariance test algorithm has many restrictions, and requires multiple cognitive nodes and channel condition information to participate. In this paper, by analyzing the difference of the covariance matrix between the main user signal and the noise signal, this paper proposes a blind detection algorithm based on eigenvectors based on wireless network. In the false alarm probability and threshold of the algorithm, Derive a closed expression. This algorithm does not require any prior information, only requires 2 cognitive nodes, and has strong adaptability in terms of uncertain noise. The simulation results show that the algorithm has better performance than the conventional covariance blind detection algorithm.

1. Introduction

Wireless network refers to a radio computer network in any type. Universal and telecommunication networks are combined with each other, and interconnections between nodes can be realized without using a cable[1]. In the process of wireless network construction, cognitive radio technology is the core key, which is an important way to improve spectrum utilization efficiency and alleviate the shortage of spectrum resources. The key technology of cognitive radio lies in spectrum detection. Multi-user collaborative spectrum detection can effectively solve hidden terminal problems and improve detection performance and overall system stability. The traditional multi-user cooperative spectrum sensing method is based on energy detection, but requires channel state information. It is difficult to effectively detect short-wave communication electronic information, that is, PU (primary user) information in a low SNR environmen[2t. In order to improve the detection efficiency, it is necessary to break the defect of the existing covariance blind detection algorithm. The difference between the transmitted signal and the noise will cause different degrees of eigenvector perturbation. Based on the random matrix theory, the eigenvector perturbation of different degrees is applied. This paper proposes a covariance blind detection algorithm based on cognitive wireless network, which has high performance characteristics, and analyzes the algorithm in detail, and derives the mathematical expression of false alarm probability and threshold value. Under the same conditions, through simulation Verify its superior performance.

2. Modeling of short-wave signal blind detection system based on wireless network

This study proposes a short-wave multi-antenna short-wave signal cognitive detection system. The system assumes that a single PU sends a signal out of time on a fixed channel and, within a perceptible range, uses two CR (multi-antenna cognitive) relay users to acquire air shortwave signals. Among them, the relay users are equipped with several antennas, the angle between the antennas and the distance are exactly the same, and the wireless correlation matrix is represented by R. The relay forwards the sampled data to the PU (fusion center) for processing[3]. The system model makes a corresponding consideration for the actual scene conditions. The CR uses GPS to ensure that the short-wave signal is transmitted synchronously with the data, as shown in Figure 1 below.

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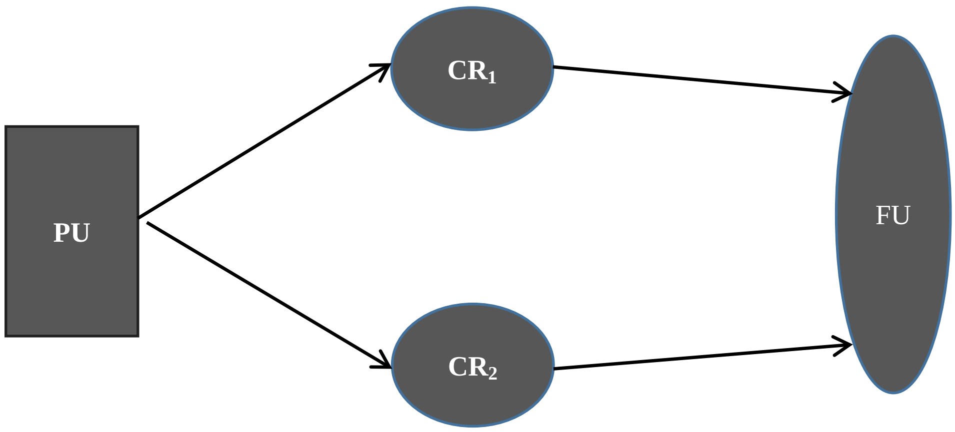

Figure 1 cognitive system network structure

Assume, $s_i(n)=[s_{i1}(n),s_{i2}(n),\cdots s_{ik}(n)]^T$, that it is represented as the PU signal vector received by the root antenna of the i CR node; $x_i(n)=[x_{i1}(n),x_{i2}(n),\cdots,x_{ik}(n)]^T$ is represented as the i CR signal vector received by the FU, where in the matrix is $(\cdot)^T$ transposed. At this time, the channel conditions are all recognized as Gaussian channels, and then the noise vector is expressed as $v_i(n)\sim N(0,\sigma_v^2 I)$. Suppose that within one cycle, the number of samples is N_s. The FU can accurately receive user information of the CR[4]. In the adoption period, the signal can be expressed as:

$$x_i(n)=s_i(n)+v_i(n), 0\le n\le N_s, i=1,2 \tag{1}$$

It is assumed that the short wave signal and the noise signal are independent of each other. Then, the i t CR signal feature received at the PU can be expressed as:

$$x_i(n)\sim\begin{cases}N(0,\sigma_v^2 I),H_0\\N(0,R+\sigma_v^2 I),H_1\end{cases} i=1,2 \tag{2}$$

The PU is an independent random signal with a mean of 0 and a variance of 1, $R=E(ss^T)$, and the received signal of the FU can be regarded as a covariance matrix, and the matrix obeys the same mean and variance. The mathematical expectation is $E(\cdot)$, $\lambda_N\le\lambda_{N-1}\le\cdots\le\lambda_1$ expressed as an eigenvalue whose feature vector is $l_N\cdots l_1$,indicating the reception state when the PU signal is present or absent.

3. Description of short-wave signal blind detection algorithm based on wireless network

The algorithm mainly includes three stages. First, the two CRs N_s synchronously sample the short-wave signals in the air; secondly, send the N_s*N signal samples to the PU; third, the PU receives, processes and analyzes, and the PU signals exist and No judgment is made.

The data processing mainly consists of the following process: First, calculate the sample covariance matrix as follows:

$$\hat{R}_i=\frac{1}{N_s}\sum_{i=1}^{N_i}x_i(n)x_i(n)^T,\quad i=1,2 \tag{3}$$

Secondly, the eigenvector a_1,b_1 corresponding to the maximum eigenvalue $\hat{R}_1,\hat{R}_2$ is obtained. Finally, the correlation coefficient of the two eigenvectors is compared and compared with the threshold value ε . $a_1^T b_1 > \varepsilon$,Then, the system has a PU signal, and vice versa, it does not exist, namely:

$$T(n) = a_1^T b_1 \sum_{H_0}^{H_1} \varepsilon \tag{4}$$

3.1 Principle analysis of blind detection algorithm for short-wave signals

Among them, the maximum eigenvalue R is λ_1 the corresponding eigenvector l_1 , and the expression between them is:

$$Rl_1 = \lambda_1 l_1 \tag{5}$$

This can be derived from:

$$\left(R + \sigma_s^2 I\right) l_1 = \left(\lambda_1 + \sigma_v^2\right) l_1 \tag{6}$$

σ_1^2 , σ_2^2 , is a constant, the value is fixed, and $R + \left(\sigma_1^2 + \sigma_2^2\right) I$ is also the feature vector corresponding to the largest eigenvalue R .

Based on the matrix perturbation theory, the principle of the algorithm can be explained as follows. The sensitivity of the feature vector is mainly represented by the interval between its corresponding feature value and the other feature value, and is negatively correlated with it[5]. When the PU signal does not exist, the covariance matrix is evaluated and $\left(\sigma_1^2 + \sigma_2^2\right) I$ approximated. When the interval is very small and approaches 0, then the sensitivity of the eigenvector will be highly expressed. At this time, the disturbance is very large, resulting in the largest feature $\hat{R}_1, \hat{R}_2$ the correlation between the corresponding eigenvectors a_1, b_1 has a very low performance; however, when the PU signal is present, the covariance is evaluated and $R + \left(\sigma_1^2 + \sigma_2^2\right) I$ approximated. At this time, the interval is far, far greater than 0, then the disturbance will be small. The system is relatively sTable, and the correlation between the two a_1, b_1 has a strong performance. Therefore, in this algorithm, whether the short-wave communication electronic signal, that is, the main user signal exists, is mainly determined based on the correlation between the two a_1, b_1 .

3.2 False alarm probability and threshold solution

In the cognitive wireless network system, the false alarm probability is an important parameter for evaluating the detection performance of the system. The main content can be expressed as follows. When the PU signal does not exist, the system detection algorithm infers the probability of the existence of the PU signa[6]l. The false alarm probability expression is expressed by (4) and the algorithm:

$$P_{\mathrm{f}} = p\left(a_1^{\mathrm{T}} b_1 > \varepsilon \mid H_0\right) \tag{7}$$

The PU signal does not exist, in real time, according to (3):

$$\hat{R}_1, \hat{R}_2 \sim \frac{1}{N_s} \text{ wishart } \left(N_s, \sigma_v^2 I\right) \tag{8}$$

Among them, wishart is the distribution function, according to the distribution characteristics and the normalization theory, a_1, b_1 corresponds to the largest eigenvector corresponding to the covariance matrix C_1、C_2 , and C_1、C_2 obeys the following distribution:

$$C_1, C_2 \sim \text{ wishart } \left(N_s, I\right) \tag{9}$$

Assume that, $A=\left[a_1, a_2, \cdots, a_1\right], B=\left[b_1, b_2, \cdots, b_N\right]$ for the corresponding normalized feature vector matrix C_1、C_2, then, A^T, B^T both obey the Haar invariant distribution. As far as the invariant matrix Haar is concerned, if the P order orthogonal matrix has a correlation distribution E so that EQ^T has the same distribution for all Q, then it has a Haar constant distribution.

Since A、B is a full-rank normalized eigenvector matrix, which is also a unitary matrix, B^T is also a unitary matrix, which yields:

$$f\left(A^T B\right)=f\left(A^T\left(B^T\right)^T\right)=f\left(A^T\right) \tag{10}$$

It will be distributed in the same way as the element that A^T and B^T wants to expand, and at the same time, $a_1^T b_1$ and a_{11} will be distributed in the same way. Where the first column element of the first row in the matrix is represented as a_{11}, the probability density function is expressed by $f(\cdot)$:

$$f\left(a_1^T b_1\right)=f\left(a_{11}\right) \tag{11}$$

a_{11}^2 obey the distribution *Beta*, its parameters are $\alpha=1/2$ and $\beta=(N-1)/2$, then, $T(n)=a_1^T b_1$ is available, subject to the following distribution:

$$f(T \mid N)=\frac{\Gamma\left(\frac{N}{2}\right)}{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{N-1}{2}\right)}\left(1-T^2\right)^{(N-3)/2}, \quad -1<T<1 \tag{12}$$

The false alarm probability is obtained by (7):

$$P_f=p\left(a_1^T b_1>\varepsilon \mid H_0\right)=\frac{\Gamma\left(\frac{N}{2}\right)}{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{N-1}{2}\right)}\int_{-1}^{\varepsilon}\left(1-T^2\right)^{(N-3)/2} \tag{13}$$

The inverse function is derived to obtain the threshold expression:

$$\varepsilon=-1+\frac{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{N-1}{2}\right)}{\Gamma\left(\frac{N}{2}\right)}\int_0^{p_r}\left(1-u^2\right)^{-(N-3)/2}\mathrm{d}u \tag{14}$$

It can be known from equation (14) that the threshold value is only related to the dimension of the covariance matrix, and the PU channel information has no correlation with the prior information. Therefore, this algorithm does not require PU and channel information and is a fully blind algorithm.

4. Simulation results

The theoretical analysis results of the algorithm are simulated and verified, and the performance is compared with the traditional algorithm. In the actual simulation, the CR uses the same clock source to realize synchronous acquisition of the short-wave communication electronic signals in the air. It is assumed that the PU is a single antenna, the channel is a Gaussian channel, the transmission power is P, and the signal-to-noise ratio is $SNR=P/\sigma_s^2$, $N=rank\left(\Sigma_N\right)=4$ is the receiving antenna root. number. Among them, the covariance matrix of the correlation coefficient of the wireless network is a full-rank positive definite symmetric matrix. In addition, the number of sampling points N_s is =10000, that is, the number of Monte Carlo simulations is 10000.

The detection algorithm and the MME、MET、CAV detection algorithm are compared in the low SNR environment, assuming that N_s = 10000, the covariance matrix correlation coefficient $r = 0.8$, below SNR=-18dB, the curves of the other three algorithms are close to ROC coincide, however, the performance of the detection algorithm is significantly better than other Three algorithms.

In addition, in the environment of noise uncertainty, the detection algorithm and the MME、MET、CAV detection algorithm are compared with the detection performance of the change of SNR. Among them, the 2dB noise uncertainty offset, the covariance matrix order N=5, and N_s=100 the simulation condition r=0.9. At this time, the false alarm probability P_f=0.1 is assumed, and the threshold is inversely derived from the false alarm probability. The other three algorithm thresholds are obtained from the reference documents. It is known that, according to the analysis results, under the environmental conditions with uncertain noise, the wireless network-based blind detection method based on eigenvectors based on eigenvectors, in the blind detection performance, the other three The algorithm is higher and more accurate. For example, at the time SNR=-15dB, the probability of detecting the covariance blind detection based on the feature vector based on the wireless network detects the probability P_d=0.25, however, the detection probability of the other three detection algorithms is smaller than 0.2. Therefore, the wireless network-based blind detection method based on eigenvectors based on eigenvectors shows superior blind detection performance in complex and variable communication environments.

5. Conclusion

In the process of wireless network construction, cognitive radio technology is the core key, which is an important way to improve spectrum utilization efficiency and alleviate the shortage of spectrum resources. The key technology of cognitive radio lies in spectrum detection. This paper makes full use of the correlation of each node to accept the main user signal, and constructs a new blind detection model that only needs 2 CRs. Based on the wireless network, the difference between the correlation between the transmitted signal and the noise will cause different degrees of eigenvector perturbation. Based on the random matrix theory, different degrees of eigenvector perturbation are utilized, and a covariance based on cognitive wireless networks is proposed. Blind detection algorithm with high performance features. The blind detection algorithm. Compared with other blind detection algorithms, this algorithm has better detection performance, simple steps, strong implementation, no need for any prior information, and theoretical and practical significance for the field of blind detection in cognitive radio.

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