Research on Spectrum Sensing in 230MHz Power Wireless Private Network

Guo Zhi1, Guan Jiuhao1, Wang Hua1, Wu Peng1, Li Guangchen*1
1 State Grid Chaoyang Power Supply Company, Chaoyang, Liaoning, 122000, China
*Corresponding author’s e-mail: sg_eiconf@126.com

Abstract. With the proposal of ubiquitous electric power internet of things, the power industry's demand for communication network is more and more intense, and the development of power wireless private network also puts forward higher requirements and more stringent standards for the wireless communication technology involved in it. Therefore, a spectrum sensing technology for 230MHz power wireless private network is proposed in this paper. By taking advantage of the relationship between the two threshold values and the signal-to-noise ratio, adjustment factors are set to achieve different two threshold values corresponding to different signal-to-noise ratios on the premise of avoiding frequent adjustment of threshold values. On the one hand, when the channel condition is good, the distance between the double threshold is reduced also reduce the system computation. On the other hand, when the channel condition is poor, the distance between the double threshold is increased to increase the extraction opportunity of the trust function, so as to improve the detection probability of the system. Finally, experimental results show that the proposed algorithm can effectively improve the communication performance of 230MHz power wireless private network.

1. Introduction
In centralized spectrum perception model, single threshold not only local detection is sensitive to noise, and difficult to distinguish between signal information near the threshold, double threshold detection can effectively overcome the above problems, but the traditional double threshold energy detection is to set a fixed threshold, the threshold not only not make full use of the information, it is hard to adapt to complex channel condition, influence the detection performance of the system. In this paper, according to channel the good situation of adaptive adjustment two-door threshold, the threshold between the uncertainty of information with the method of building trust function is used, which, when sensory channel is in good condition, reduce the distance between the two threshold, which reduce the DS evidence theory the scope of operation, reduce system integration costs, to reduce the computation complexity; When the channel condition is poor, increase the distance between the two thresholds, that is, increase the scope of DS evidence theory operation, determine more fuzzy information, so as to improve the detection performance of the system.

2. The concept of DS evidence theory
DS evidence theory by identifying the framework, Basic Probability distribution (Basic aim-listed Probability the Assignment, BPA), trust function and likelihood function, such as concept, build up the hypothesis proposition and possibility of one-to-one correspondence relationship between collections, the establishment of the corresponding relation between the realized the transformation of different problems, it will change the uncertainty problem in some proposition into a collection of uncertainty
problems, theory of Probability density function and distribution function with the Basic Probability distribution function of the DS theory of evidence and the corresponding trust function.

In spectrum sensing, two hypotheses are made for the existence of PU signals: $H_0$ means the weight signal does not exist, $H_1$ means the weight signal exists. Introducing the DS evidence theory, then it forms two focal elements in recognition frame $\Theta$, represented as $\Theta = \{H_0, H_1\}$. The steps of multi-user collaborative perception detection algorithm based on DS evidence theory are divided into three parts. Secondly, the sensory terminal makes a double-threshold decision on the energy information to obtain the decision result or the corresponding trust function. Third, the fusion center fuses all the local judgment results and trust function received according to certain criteria to obtain the final judgment.

3. Spectrum sensing detection based on DS evidence theory

Associated with DS evidence theory algorithm for collaborative spectrum sensing detection calculations, if double threshold energy detection, the test results of different energy segment there are generally two kinds of processing method: one is the three energy segment data not sentence processing, all perception directly to the end of basic trust function is sent to the fusion center; The other is to send the data part that can be judged first and then to send the basic trust function directly to the fusion center for the data part that cannot be judged directly. The latter is adopted in this paper, and the system model is shown in figure 1.

![Figure 1. Collaborative spectrum sensing based on DS evidence theory.](image)

In this paper, the local perception adopts the energy detection algorithm, and the signal reception of the sensing terminal can be regarded as a binary hypothesis testing problem:

$$
\begin{align*}
H_0 & \quad x_i(t) = n_i(t) \\
H_1 & \quad x_i(t) = h_i(t)s(t) + n_i(t)
\end{align*}
$$

Where, $M$ is the number of sensing terminals in the sensing system; $x_i(t)$ is the signal received by the $i$th SU. In this paper, SU is 230 perceptron. $s(t)$ is the transmitting signal of PU. In this paper, PU is 230 digital radio signal. $h_i(t)$ is the perception channel gain between the $i$th sensor terminal SU and authorized user PU; $n_i(t)$ is the noise signal in the sensing channel. Here, it is set as AWGN with mean value 0 and variance $\sigma_i^2$, and it is assumed that the signal and noise are independent of each other.
In the case of single threshold, false alarm probability and detection probability of local perception can be expressed as

\[ P_f = Q\left(\lambda - \mu_0 \right) / \sigma_0 \]  

(2)

\[ P_d = Q\left(\lambda - \mu_1 \right) / \sigma_1 \]  

(3)

Where, \( Q(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-t^2/2} dt \) is the standard gaussian complementary cumulative distribution function.

According to the uncertainty of the actual channel environment, the signal information received by the sensing terminal is also uncertain, so it is difficult to make a correct judgment when the signal energy value received is near the threshold. In this paper, the double-threshold energy detection algorithm is used to determine the received signal energy, and the initial double-threshold threshold is defined according to the noise uncertainty.

\[ \begin{align*}
\hat{\lambda}_1 &= \frac{1}{k} \lambda \\
\hat{\lambda}_2 &= k \lambda
\end{align*} \]  

(4)

Where, \( \lambda \leq \hat{\lambda}_2 \), \( [\hat{\lambda}_1, \hat{\lambda}_2] \) is defined as the fuzzy region. \( k \geq 1 \) is defined as the range adjustment factor of the fuzzy region.

The sensing process can be summarized as follows: first, all sensing terminals SU conduct local spectrum detection to obtain the signal detection statistics of authorized users PU, and then set the initial dual-threshold threshold according to the dual-threshold energy detection algorithm proposed in

---

\[ \lambda \]

---
this paper. Then, the energy statistics of the perceptron are compared with the two threshold values to judge the result of the comparison, and different data information is transmitted to FC. If $Y_i > \lambda_2$, $D_i = 1$ is sent to FC. If $Y_i > \lambda_1$, send $D_i = 0$ to FC; If $\lambda_1 \leq Y_i \leq \lambda_2$, at this point, the signal energy statistics are in the fuzzy zone. Then, based on DS evidence theory, extract the trust function and send it to FC. Finally, FC fuses the received according to DS evidence synthesis rules. The data sent by all perceptrons makes the final decision.

4. Analysis of simulation results
Set the simulation parameters are as follows: participate in collaborative perception SU number is 5, only a FU, a FC, according to the current 230 digital radio spectrum usage, set FU launch for MSK modulation signal, among them, the carrier frequency 800 MHZ, the sampling frequency of 153.6 KHz, sampling points to 1000, set the initial $k=3/2$, $a=0.03$, and $P_f^r = 0.01$ set the expected false-alarm probability, $P_d^r = 0.8$ set the expected detection probability. Assuming that the signal transmission channel is unaffected by fading and that the channel gain is constant, the reporting channel is error-free.

This paper compares the performance of traditional dual-threshold detection spectrum sensing, a fixed dual-threshold algorithm based on DS evidence theory, and a dynamic dual-threshold algorithm based on DS evidence theory. The simulation results adopt the receiver ROC (Receiver Operating Characteristics) curve to indicate the relationship curve between $P_d$ and $P_f$, and use the height of the curve to indicate the strength of the detection performance.

As shown in Figure 3, DS evidence theory can significantly improve detection performance. The DS evidence theory is also used in the dynamic adjustment of the double threshold algorithm used in this paper. As can be seen from Figure 3, the algorithm in this paper obtains a better detection probability. The DS evidence theory algorithm with a fixed double threshold has improved the
detection performance of this algorithm. When the false alarm probability is 0.1, the detection probability of this algorithm reaches 0.81, while the DS evidence theory algorithm with a fixed double threshold The detection probability is 0.75. At the same time, the two detection algorithms based on DS evidence theory are significantly better than the simpler "OR" and "AND" criteria, which fully shows the correctness of introducing DS evidence theory in the spectrum sensing process and superiority.

![Detection probability under different SNR cases.](image)

Among the 5 SUs, the SNRs of 4 SUs are set to 0 dB, and the SNRs of the remaining SUs are set as simulation variables. As shown in Figure 4, through comparison, the detection probability of several algorithms under different SNR conditions is shown intuitively. It can be seen that the detection performance of the traditional "AND" criteria and "OR" criteria is far inferior to that of the DS evidence theory algorithm. Detection performance; when the channel condition is good, that is, when the channel SNR is greater than 0, both the algorithm in this paper and the fixed-threshold DS theory algorithm can complete the task of spectrum detection, but in practical applications, the channel condition is not always good. The improved algorithm proposed in this paper can well perform the task of detecting the frequency spectrum in the case of low signal-to-noise ratio. It can be seen from Figure 4 that although the DS evidence theory can reach a detection probability of 52% at -10dB, the detection probability of the algorithm in this paper is as high as 83%, which illustrates the superiority of the algorithm in this paper.

5. Conclusion
In this paper, the spectrum sensing technology of 230MHz power wireless private network is studied, the energy between double gates is sensed by DS evidence theory, and the fixed double threshold is optimized, that is, the dynamic adjustment is carried out to meet the different double threshold values under different signal-to-noise ratios (SNR), and the accurate detection of the main user signal is realized.
Acknowledgments
The authors greatly acknowledge the support from Science and Technology Project of State Grid Corporation of China.(2019YF-42)

References
[1] Guo Haiyan, Yang Zhen, Zhang Linghua, et al. Power-Constrained Secrecy Rate Maximization for Joint Relay and Jammer Selection Assisted Wireless Networks[J]. IEEE Transactions on Communications, 2017, 65(5):2180-2193.
[2] Kamal Rahimi Malekshan. Joint Scheduling and Transmission Power Control in Wireless Ad Hoc Networks[J]. IEEE Transactions on Wireless Communications, 2017, 16(9):5982-5993.
[3] Hao Chi, Ying Chen, Yuan Mei, et al. Microwave spectrum sensing based on photonic time stretch and compressive sampling[J]. Optics Letters, 2013, 38(2):136-138.
[4] Saman Atapattu, Chinthia Tellambura, Hai Jiang, et al. Energy Detection Based Cooperative Spectrum Sensing in Cognitive Radio Networks[J]. IEEE Transactions on Wireless Communications, 2011, 10(4):1232-1241.
[5] Hua-Dong Y U, Qing-Hai O U, Zhang Z, et al. Antenna Directionality of Micropower Wireless Communication Module in Smart Meter[J]. 2017, 35(1):11-20.