

Research on Sensor Network Spectrum Detection Technology based on Cognitive Radio Network

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Abstract

With the bursting development of computer science and the hardware technology, Internet of Things and wireless sensor networks has been popularly studied in the community of engineering. Under the environment of Internet of Things, we carry out theoretical analysis and numerical simulation on the sensor network spectrum detection technology based on cognitive radio network. As a means of information and intelligence, information service system is an important research hotspot in the field of Internet of things. Wireless sensor network is composed of a large number of micro sensor nodes, which have the function of information collection, data processing, and wireless communication, characterized by the integration of wireless self-organization. However, most of the methodologies proposed by the other institutes are suffering from the high complexity while with the high time-consuming when processing information. Therefore, this study is to assess the economic feasibility of using the optimized multipath protocol availability and the increased bandwidth and several mobile operators through the use of cost-benefit analysis, single path selection model is to develop more path agreement to achieve better performance. To test the robustness, we compare our method with the other state-of-the-art approach in the simulation section and prove the effectiveness of our methodology. The experimental result reflected that our approach could achieve higher accuracy with low time-consuming when dealing with complex sources of information.

Keywords: Sensor Network; Cognitive Radio Network; Collaboration for Distributed Detection; Spectrum Detection Technology; Topology Optimization.

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1. Introduction

Wireless sensor network consists of a large number of random distribution, energy consumption and resource constraints of sensor nodes, it has the perception, calculation ability and communication ability, through self-organization way constitute the wireless network, collaboration to real-time acquisition and processing of the physical world information, can realize the function of IOT comprehensive perception. If the realization of cognitive radio technology in wireless sensor network, not only can alleviate the congestion of public frequency band, and reduce the work frequency of the wireless sensor network also makes the node after single jump coverage is wide and change, which greatly simplifies the network topology. But the cognitive radio technology has brought many challenges to wireless sensor networks [1-2]. Wireless sensor network requires new algorithms and protocols to achieve the two key techniques: cognitive radio spectrum sensing and dynamic channel switching. For energy constrained wireless sensor network, to be successful introduction of cognitive radio technology, not only to achieve these two techniques, more to reduce the energy consumption in the process of implementation. Spectrum sensing to shorten the sleep time of sensor nodes which increase the burden of the nodes to monitor channel for the exchange of test results and traffic. Inevitable detect errors and will cause the sensor network conflict with major customers, further increase the additional energy consumption. In addition, frequent channel switch also consumes a lot of energy. Because often exist multipath fading wireless communication environment, hidden terminal and time-varying characteristics, in this environment, the individual is rather difficult to can realize accurate spectrum sensing. The use of space diversity characteristics, adopt the method of multiple user cooperation awareness can effectively overcome the above problems impact on the reliability of spectrum sensing.

As a result, of this study is to assess the economic feasibility of using the multipath protocol availability and increased bandwidth and several mobile operators. Through the use of cost-benefit analysis, single path selection model is to develop more path agreement. Demonstrate the use of the model, there are two potential mobile application scenarios, from increasing availability or bandwidth. In the following sections, we will discuss the issues in detail.

2. Our Proposed Methodology and Approach

2.2. The Sensor Network Spectrum Detection

With the development of wireless communication, wireless spectrum has become increasingly scarce, but some of the frequency spectrum utilization is not filling urn. For more effective to improve spectrum utilization, need to further improve the traditional spectrum management method, therefore, which used in cognitive radio spectrum analysis strategy has become a hot research topic [3]. Cognitive radio spectrum can be detected and can be adjusted according to the use of the corresponding and new technique is an effective use of spectrum. Automatic spectrum detection the basis of a variety of cognitive wireless sensor network coexistence, but how to make the spectrum detection is more reliable is still a research hot spot. In fading channel, the multipath effect, shadow effect and local interference will cause the signal to noise ratio range is lower than the threshold, tests are not complete so a single wireless sensing technology is unreliable. But due to different position signal intensity in the network, if collaboration for distributed detection, through the network can avoid detection could not be completed. Support vector machine is a kind of based on statistical learning model and structure risk minimum principle of machine learning method, is widely used in statistical classification, applicable to linear separable and linear inseparable with under the small training samples can obtain the characteristics of the good classification effect. The SVM classifier can be used to training the time-domain signal spectrum. At the same time after using compression perception spectrum detection problem can be treated as linear inseparable case classification problem [4]. In the spectrum sensing algorithm based on compression perception and energy test, the computational complexity of system are mainly concentrated in the reconstruction of the signal, so we try to avoid the compressed signal reconstruction and direct use observation sequence test spectrum. In the formula one, we define the objective function.

$$\chi = \{(x, z) : x \in R^N, x = \Psi s, \|s\|_0 \leq k, \|s\|_2 \leq R\} \quad (1)$$

Observation matrix is Gaussian random matrix, and the sparse matrix is orthogonal matrix, the two irrelevant, and compressed sensing matrix with isometric conditions for large probability constraints.

$$(1 - \varepsilon) \|s\|_2^2 \leq \|\Theta s\|_2^2 \leq (1 + \varepsilon) \|s\|_2^2 \quad (2)$$

Here we only care about the classification of the samples and not to reconstruct the original time domain signal, so does not need to know the sparse matrix. So in the time domain signal in a transform domain with known sparse features, direct observation matrix is used to change the time domain signal is mapped to a domain, and in the observational domain classifier training and sample classification, its performance and directly to classify performance close to the original time domain signal. In the architecture of wireless sensor network, a large number of sensor nodes are randomly distributed in the monitored area, to test the need of physical quantities, these sensor nodes in accordance with the self-organization mode of network, with the method of multiple hops to transmit data to monitoring center or the Internet, users can monitor center for wireless sensor networks or the Internet [8]. As a result of the common sensor nodes communication ability is weak, often in wireless sensor networks based on region divided into many clusters, each cluster to set up a communication ability strong node as the cluster head, cluster head is responsible for collecting interest within this cluster node, and then through multiple hops way to transfer the information to the gathering node, the node is responsible for the exchange of information with the outside world [9].

Wireless sensor network and cellular mobile telephone network, wireless local area network and other traditional wireless network using the wireless signal communication, but they have different features and design goals [10]. In the wireless sensor network, in addition to a small number of nodes need to move beyond, most nodes are stationary, and generally in a state of mobile cellular mobile telephone network users, how to ensure that the user call quality in mobile case, at the same time the use of the maximum save bandwidth, is a cellular mobile telephone network need to solve the problem. Suppose in a narrow band cognitive in sensor network have a primary user, it allows secondary users use the spectrum in spectrum free circumstances. In order to make full use of spectrum resources and does not affect the main users, secondary users must be able to quickly and accurately perceive the presence or absence of user signal. In order to improve cognitive performance, ordinary secondary user's perception of the local information transmitted to the fusion center, according to the fusion center receives the information of each node in the judgment [11]. Each sensor node spectrum perception can be regarded as a binary hypothesis test problem.

$$x_k(n) = \begin{cases} \xi_k(n), & H_0 \\ s_k(n) + \xi_k(n), & H_1 \end{cases} \quad (3)$$

Traditional energy detection method first received after the sampling signal modulus square, then the energy accumulation by using statistics, comparing with the decision threshold finally and makes a ruling which is shown in the formula four.

$$\begin{aligned} H_1 : T_{CED} &\geq \rho_{CED} \\ H_0 : T_{CED} &< \rho_{CED} \end{aligned} \quad (4)$$

Conclusion by statistical knowledge: if the n independent random variables are subject to Gaussian distribution, is that the sum of the squares of the N random variables to degrees of freedom for N card distribution [12]. When the average N random variables not zero, they pose of the sum of the squares of the chi-square random variables are subject to the center. When the energy accumulation points when N is large enough, the use of central limit theorem, chi-square distribution can be approximate to Gaussian distribution denoted as the following.

$$\begin{aligned} H_1 : T_{CED} &\sim \gamma(N(\sigma^2 + P), 2N(\sigma^2 + P)^2) \\ H_0 : T_{CED} &\sim \gamma(N\sigma^2, 2N\sigma^4) \end{aligned} \quad (5)$$

Because of various cognitive node distributions in different geographical location, signal sampling, the perception of the starting time is not necessarily synchronous. At the same time, the perception to the fusion center data transmission between nodes when asked delay is not the same, these factors will seriously affect the synchronous collaboration sensory perception performance of the algorithm. In addition, the signal in a certain period of when to appear, when to exit in the spectrum is unpredictable, this may result in the phase spectrum perception signals had already disappeared. Data fusion center using Bayesian optimal decision rules of the likelihood ratio as the weight of each soft decision, and according to the statistical features of authorized spectrum occupied model, the sensory information from the asynchronous data fusion, realize the signal is about the existence of a certain spectrum soft decision, so as to complete the function of cooperative spectrum sensing. In the formula 6, we define the compression sampling equation.

$$x = \sum_{i=1}^N s_i \psi_i \quad \text{or} \quad x = \Psi s \quad (6)$$

The observation sequence, resulting from the compressed sensing is numerical data, and in the process of classifier training numerical larger data in the data set plays a leading role, influence of training to get the performance of the classifier. Signal observation sequence

normalization preprocessing to interval, avoid big data in the data set plays a leading role and at the same time reduce the computational complexity. Collaboration with existing sequential detection often only does sequential detection in FC, and CSDS method in each node to do a first order penetration test. This is because for a certain period of logarithmic likelihood ratio, concrete data may be absolute value is very small, if need to directly upload the logarithmic likelihood ratio to FC, for the impact of judgment is very small, but it consumes more collaboration overhead [13-14].

At the beginning of each time slot, all nodes to check whether there is data transfer: if not, the network within the time slot to enter a dormant state; Spectrum detection. Otherwise, the network began a significant characteristics of wireless sensor network is to have a large number of intensive distribution of sensor nodes and this topology is very suitable for cooperative spectrum detection. Cooperative spectrum detection than the non-cooperative spectrum detection has higher reliability, especially in a multipath fading and shadow communication environment [15]. Assume that all sensor nodes in wireless sensor network cooperative spectrum detection on a channel at the same time. The scheduling node and the test results of each node in the fusion and decision, get the whole network of the final test results. All data in the process of testing through public control channel transmission of wireless sensor network. If the detected a main user channel is idle, each sensor node in the letter on to scheduling node to transmit data. Through the reply to confirm when the frame in data transmission, the sensor node and data transmission scheduling nodes are known results. If the sensor network transmission to the main user channel is busy state, in the current time slot for the rest of time to enter a dormant state, wait until the next time slot ran test spectrum. The Figure 1 illustrates this.

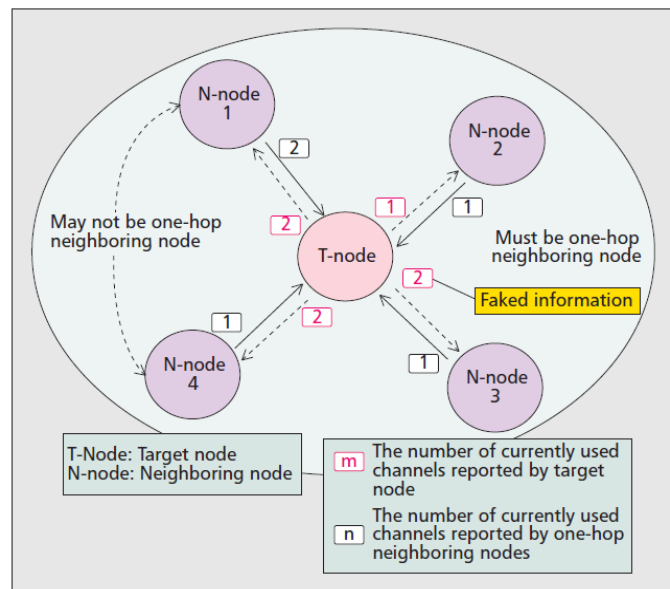


Figure 1. The Deployment of the Sensor Network Spectrum Detection

2.3. The Cognitive Radio Network

Wireless sensor network is composed of a set composed of a large number of sensors deployed in monitoring area of the wireless network and it can be used for collaboration to perceive, collection and processing network coverage of the area of perception object information, and sent to the controller. Sensor nodes structure will be designed according to different application scenarios, the structure of the wireless sensor network node is used to describe the different periods and different types of sensor nodes. The role of power supply module is to provide energy to all sensor nodes, typically the initial energy of sensor nodes is equal, but in order to guarantee the transmission task, gateway and the initial value of the base station is larger. Information processing module is composed of two parts of the computing and

storage, the sensor node itself, the collected data are stored in memory. Cluster head and base station is used to calculate function, used to allocate and manage the information transmission and will accept the information fusion processing. Sensor module main duty is to of all kinds of information collection and monitoring environment. After the commissioning of the wireless communication module, all sensor nodes can accomplish the communication between each other, work together and monitoring tasks.

The features of the cognitive radio network could be summarized as the following. (1) Sensor nodes are usually distributed in very extensive areas, in order to complete the perception of the real world, high density, sensor node deployment is also very intense. The whole wireless sensor network system reliability and quality of work rely on large-scale, redundancy of embedded devices to work together to implement and improve. In this way, through perceived information in the view of the different space signal-to-noise ratio is bigger. In a large amount of information, distributed processing method can effectively improve the accuracy of the monitoring, and lower precision requirements for a single sensor node. Due to the presence of large amounts of redundant nodes, the system fault tolerance. (2) Each sensor node in the wireless sensor network is random division in monitoring area, the location of the node can't accurate location in advance, the neighbor relationship between nodes are unpredictable, this requires that each sensor node itself has high ability of self-organization which can automatically configure and automatic management, through the network protocol and topology control mechanism automatically form forwarding monitoring data more wireless network. (3) Common cable communication distance of sensor nodes, in a few meters to hundreds of meters. Nodes can communicate with in your communication within the scope of the adjacent nodes. But if you need to communicate with more than its communication range of the other nodes, you must pass by other nodes forwarding routing. The multi-hop routing of wireless sensor network is the common network node collaboration, that is to say, sometimes sensor nodes need to act as the sponsor of the information, forwarding and the recipient the three roles [16]. (4) Sensor network is different from the address centered to the Internet, it is a task-based network and its aim is to obtain the data information. Sensor nodes in a network of all use serial number identification, the network node number is unified depends on the communication protocol of the system. Unable to determine the position of the sensor nodes in advance, the serial number of sensor nodes are depending on the system dynamic allocation, namely node number and the node position is no necessary link between the two. (5) Sensor energy supply in the wireless sensor network is usually carry from its own battery, once the battery runs out, that the sensor node will not be able to continue to work. Extend working hours of all nodes, therefore, that means the whole prolong the working life of the wireless sensor network. The node in the data transmission phase is the consumption of energy, this requests us in the case of complete the task does not affect as far as possible to reduce data transmission, so as to achieve the purpose of save energy and prolong the life of the whole network [17].

In the Internet of things, an awareness of sensing nodes will environment, so often appear this kind of condition, namely perception nodes in a network, signal is always less than spectrum allocation and it greatly reduces the benefit of a single user perception [18]. Nodes and perception of the Internet of things is numerous, so the last of the algorithm is proposed in the next chapter we consider specific spectrum users perception demand of the objective function, goal is to minimize the perception of the failed to satisfy the user benefits. In the Figure 2, we show the flowchart of the proposed method. Each user perception expressed with a node, if two users perception or conflicts between the interference and then these two users cannot use the same frequency at the same time, the need to add a cable between two nodes. Cloud computing is the core of the Internet of things intelligent information analysis. The use of cloud computing technology, make the real-time dynamic management of hundreds of millions of various types of objects. With the development of the Internet application, the increase of the number of the terminal, can process mass information, with the aid of cloud computing for auxiliary decision-making which will promote the information processing ability. Therefore, as a kind of virtualization, cloud computing solution of hardware and software operation, it can provide the Internet of things with efficient computation, storage capacity, provide extensive in the link of the Internet of things network engine.

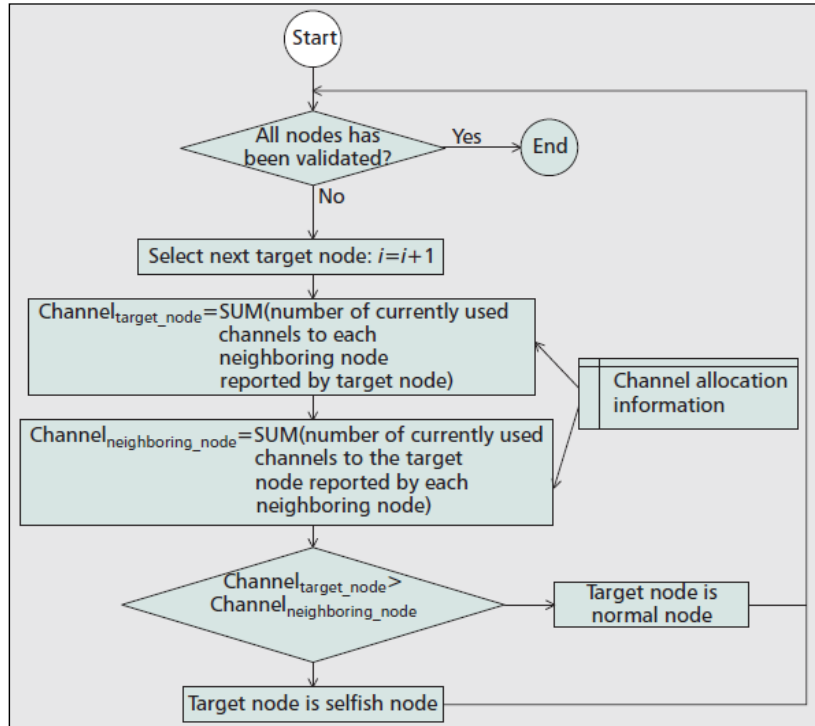


Figure 2. The Flochart of the Proposed Algorithm

From the point of the Internet of things applications, their construction industries are of the system, is not convenient to a variety of business expansion, construction standard, if there is no unified standard Internet access, integration management platform, the Internet of things will be because of differences in various industries can't produce scale effect, increase the use of complexity and cost. At the same time there is even a collection and a collection is already assigned frequency band, said in accord with the constraint conditions and the distribution of target under the premise of a collection of frequencies assigned to the user perception. Another collection can be described using spectrum. The formula 7~8 defines the process.

$$N_{idle}^s = MN - N \sum_{q=1}^M i_q - \sum_{q=1}^k j_q \quad (7)$$

$$P_i^b = \lambda_i^s / \sum_{j=1}^k \lambda_j^s P_j^b \quad (8)$$

Due to the user at the same time, in the possessive spectrum space perception cannot produce interference to primary users, and perception of users and the main location is constantly changing, so the perception of different users, its can use frequencies are generally not the same. Network layer according to the perceived extension of business characteristics, to optimize the network features, better realize the content and the communication between, content and communication among the people as well as interpersonal communication, it requires must establish an end-to-end global network. There are a lot of equipment access in the Internet of things, is a ubiquitous access, heterogeneous access. Each user perception has the two corresponding collections, namely each node has two sets associated with it. Perception of users in a certain time and space can be used on the spectrum of a collection of resources, is the available spectrum matrix. Sensing spectrum section in the user access to the collection, will not affect the main users or other perception. Spectrum is usually divided into a series of orthogonal sub band, the main users take up one of the band, to a certain power to communicate and there is no interference between frequency and frequency band [19-20].

3. Experimental Analysis and Simulation

In this section, we conduct numerical simulation on the proposed methodology to test the feasibility of our approach. The simulation platform is: PC with 2.43GHz CPU, 8GB RAM, Windows 7 operating system and MATLAB R2013a special edition. Due to the interference phenomenon of wireless, within the cluster after cluster head, if the distance between them is less than the cluster radius, can produce interference between clusters. Secondary the closer the distance between the cluster head, then the interference between the clusters will be stronger. It may even cause message retransmission, lead to additional energy costs. So, setting up secondary clustering linear wireless sensor network protocols in each subnet irrigation area, to comprehensive consideration of cluster communication energy consumption and communication distance and cluster communication coverage overlap between the two communication interference problems. First of all, the former initial cluster number is 1, the average which is 0.5, effectively reduce the choice scope of cluster heads. Make a cluster head in a reasonable range. Because of the improvement after clustering algorithm in the initial clustering is introduced connectivity, so choose a reasonable initial cluster heads. Too much of the original algorithm to form cluster number and cluster structure is more fragmented, and the improved algorithm of cluster number is 6, the formation of cluster structure size is reasonable, good network connectivity; Second in the final cluster head election season 4 times per cluster head election probability increased. Although compared with the original algorithm improves the election error probability increase 2 times. But due to the introduction of connectivity in advance to ensure the final cluster head election is in a reasonable scope, so the accuracy will not reduce, and the algorithm can pass fewer iteration elects the final cluster heads. In the Figure 3, we show the experimental comparison of the average transmission power performance, the corresponding curves are the methods proposed by us and by the literatures of [4-7]. In the Figure 4, we show the experimental comparison of the sum rate and the additional reference method is proposed by [9] as the most the right side of the curve. To test the robustness of the algorithm, we demonstrate another set of experiment as the Figure 5 and 6, respectively. From the experimental result, we could easily conclude that our method performs well. Compared with the other state-of-the-art algorithms, our methodology achieves the better performance and the stronger robustness. As for the accuracy, our methodology enhances the traditional ones by the degree of the 23%. As for the time-consuming, our algorithm reduces the overall time consumed in the extent of the 21%. The simulation result is satisfactory.

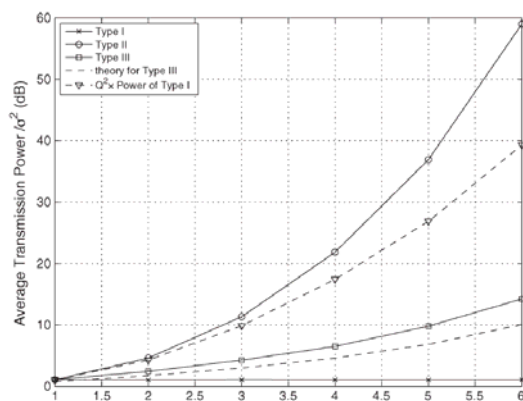


Figure 3. The Experimental Result on Average Transmission Power

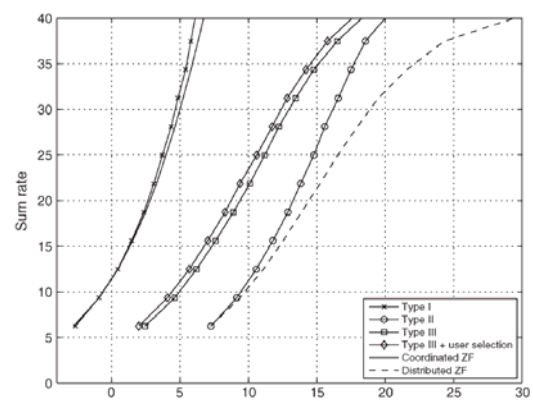


Figure 4. The Experimental Result on the Sum Rate

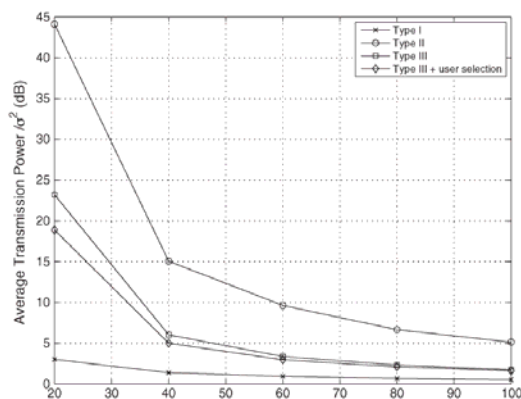


Figure 5. Result on Average Transmission Power Set Two

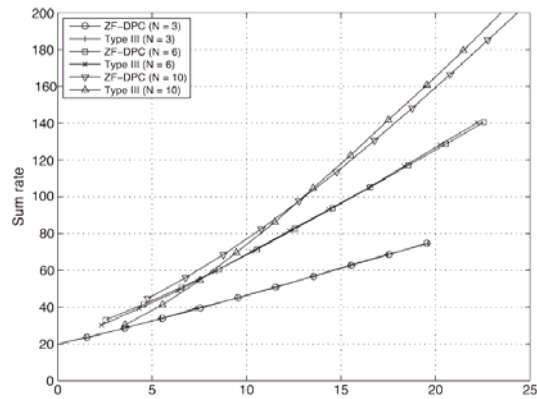


Figure 6. The Experimental Result on the Sum Rate Set Two

4. Conclusion

In this paper, we conduct theoretical analysis and numerical simulation on the sensor network spectrum detection technology based on cognitive radio network under the environment of Internet of Things. As another revolution of information industry, wireless sensor network the logical information world and the objective physical world together, changed the way of interaction between human and nature, the impact on human are comparable to those obtained with the emergence of the Internet. Along with the increasingly wide application of wireless sensor network, its security problems are brought to the attention of the people, the security problem is not only related to the network the confidentiality of information, and is of great significance for the stable operation of the network itself. Time synchronization protocol is wireless sensor network is an important part of the many applications of wireless sensor network, information query, for example, target tracking, node positioning, rely on accurate time synchronization, time synchronization protocol is also the foundation of many communication protocol run. Therefore, the safety of time synchronization protocol is the need of the wireless sensor network and stable operation which is also the foundation of multi-channel communication. Our propose methodology solves the issues well which could be reflected from the experimental result. In the near future, we plan to use the network optimization theory to modify the current method to obtain better result.

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