TELKOMNIKA, Vol. 11, No. 10, October 2013, pp. 5734 ~ 5740
ISSN: 2302-4046

Application of Wireless Sensor Network in Target Detection and Localization

Hui Ding
Department of Information Engineering, Changzhou Institute of Light Industry Technology
213164 Changzhou, China
e-mail: dhui126@126.com

Abstract

Wireless sensor network is a novel network with embedded system technology, communication technology and sensor technology as a whole, it is one of the wireless network form that is very rapid development at present, wireless sensor network has the characteristics of flexibility, adaptability, stable performance, wide coverage etc, so it is widely used in environmental monitoring, community security, military reconnaissance and other fields, the construction of target detection and location system in this paper are built by the application of wireless sensor network system platform, to realize the level of detection and localization of multiple targets. In this paper, wireless sensor network is first given a brief overview. On this basis, this paper also designs the target detection and location system, to presents a multi-objective hybrid location algorithm. Finally, the experiments verify that this algorithm has the accuracy, stability and robustness.

Keywords: *wireless sensor network, target detection and localization, multi-objective compound localization algorithm*

1. Introduction

Wireless sensor network is a competitive mode of wireless communication in 21st century, and it is made of a large number of static or dynamic nodes [1]. The nodes have self-organization, and they can dynamically sense all kinds of information in the covered area. Then they use sensor technology to convert them into signals, and through the wireless communication technology the signals can be transmitted to management system center [2, 3]. The development of embedded system technology makes the wireless sensor node become more compact, intelligent and low power consumption, therefore the wireless sensor network has good application prospect in the field of environmental monitoring, security of community and military reconnaissance. The structure diagram of typical wireless sensor network is shown in Figure 1.

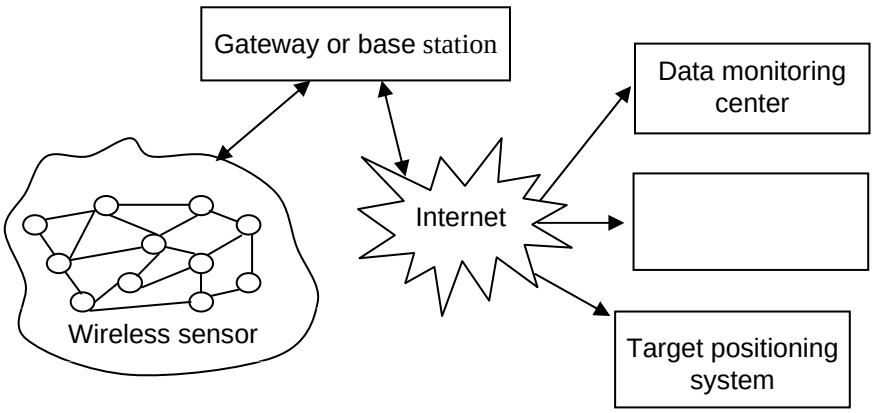

Figure 1. Structure diagram of typical wireless sensor network

Received March 27, 2013; Revised July 1, 2013; Accepted July 15, 2013

Target detection and localization is divided into the detection of self-positioning and target detection. When the target is in the covered area of wireless sensor network, the nodes are able to perceive its positional information. In order to accurately have the target positioning, each network node firstly has the detection of self-positioning to build the "map" of the nodes of wireless sensor network [4]. When the signal of the node changes, they can judge the coordinates of the node in the "map" and it is the location of the target. So we can say that the wireless sensor network provides a new method for the target detection and localization technology.

2. Introduction of Wireless Sensor Network

Wireless sensor network consists of large number of nodes in the network dynamic composition of organization form, the communication channel between nodes is changing according to the actual situation, such as when a node's energy can not be normal supply channels, other nodes will automatically disconnect and communication, and dynamic connected to its nearest the node, so as to ensure the whole network channel. The original data sent by the node to compression by the source encoder, and efficient use of the bandwidth of the channel, but also the need for the channel coding, improve the disturbance tolerance ability, reduce the bit error rate signal, when the data through the channel to reach the receiving end, need to loop through the channel decoder and source decoder data reduction [5]. The communication system of wireless sensor network diagram is shown in Figure 2.

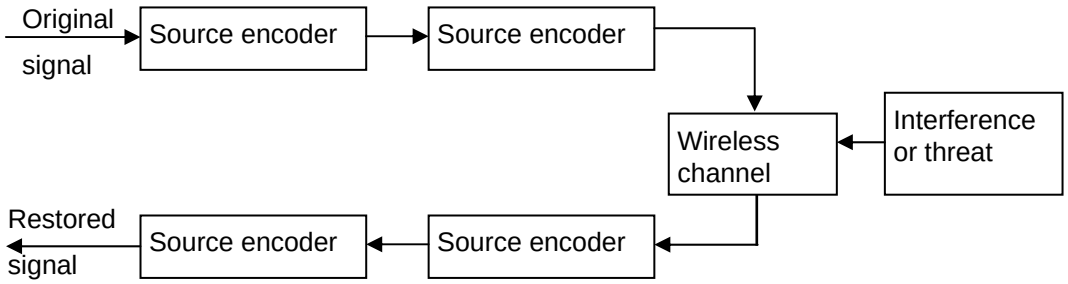

Figure 2. Schematic diagram of the wireless sensor network communication system

The nodes of wireless sensor network plays the functions of data collection, data collection and data transmission and reception, the node is composed of sensor unit, microprocessor unit, data sending or receiving unit and power supply unit. According to the measured data's different, it needs to select the appropriate sensors, such as temperature sensor, pressure sensor and so on; microprocessor is as far as possible to choose the low power type, which is conducive to prolong the node life; the power supply unit can choose active power supply or passive power, in which the active power includes batteries, lithium batteries and so on, and passive power supply includes solar power, wind power generation etc. Wireless sensor network node structure is shown in Figure 3.

The communication protocol of wireless sensor network adopts five layer structure' WSN protocol stack, which often uses IEEE802.15.4 standards, Zigbee standards, etc., when it carried out the source code, it needs to consider the MAC layer's data frame transmission rate that should be synchronous with the modulator, which requires the task management system to coordinate and solve [6]. In the channel coding, it is the need of network layer structure docking with MAC model, this MAC common part sublayer can be better resistance interference of external signals, to achieve efficient use of MAC layer management entity. Data transmission model of MAC layer is shown in Figure 4.

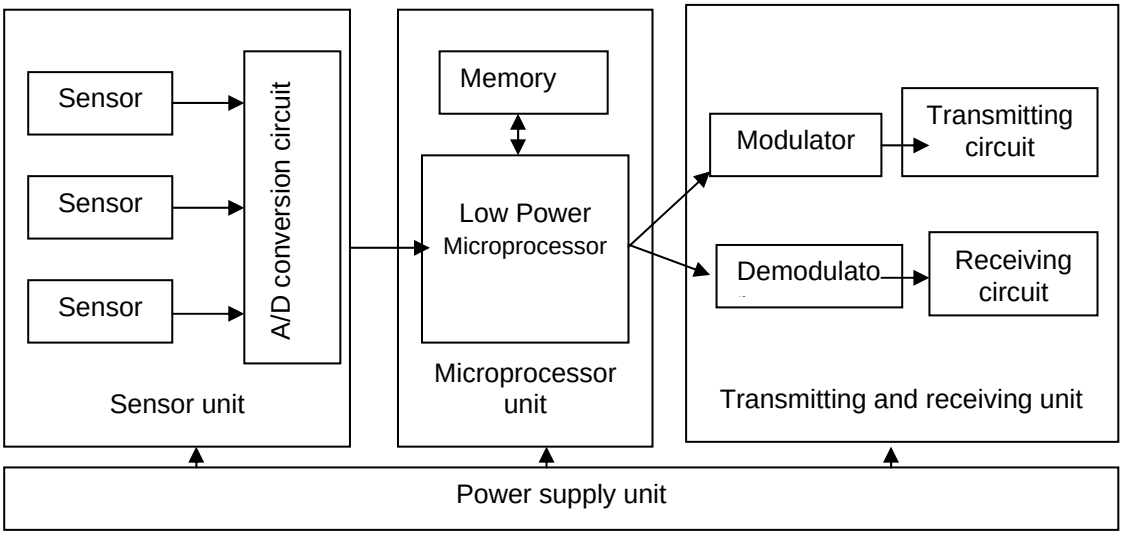

Figure 3. Wireless sensor network node typical structure

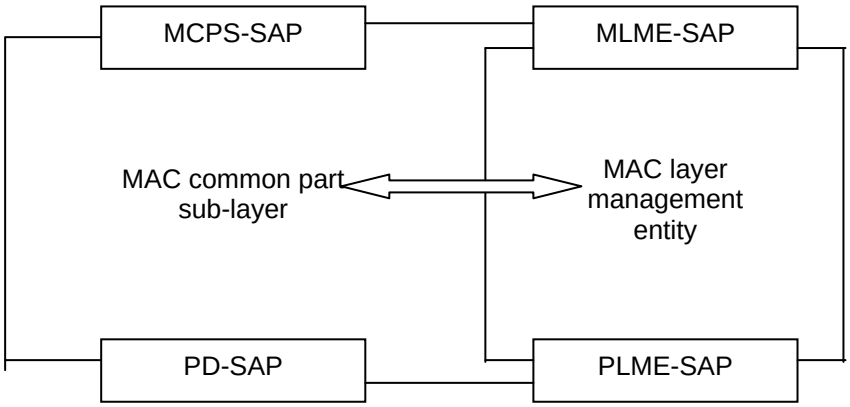

Figure 4. MAC layer data transmission model

3. The Algorithm of Target Detection and Localization

The nodes of wireless sensor network are randomly distributed in the covered area, and they are through the way of self-organization to have data communication. Wireless nodes use self-localization to determine the detection basis points, and the target position is determined on the basis of reference nodes. Because most of the target is in motion, the nodes that on the path of the movement can have self-organizing dynamic communication [8]. At the same time, target is not necessarily single, and sometimes many targets can appear at the same time, so it has to study the characteristics of algorithm to carry on the target detection and localization.

This paper presents that the multi-objective compound localization algorithm can be used in the target detection and localization system. The algorithm uses node sensor to detect the time of occurrence of the respective target, and it calculates the propagation time of the target signal. Then according to the targets' speed of movement, it can compute the distance, finally it is through the reference node to determine the target location. In order to ensure the accuracy of the propagation time of the signal, it requires each node to maintain strict clock synchronization. In this way there may appear some time delay between the nodes' communication. So the propagation speeds of the signals can be set as v, and the communication delay can be set as t. In this algorithm, it has to use three sensors to record the time delay between the targets' current position with the sensor, so the distance can be represented as:

$$L_i = v_i t_i \tag{1}$$

The matrix of target location can be expressed as

$$\begin{bmatrix} (x_1 - x)^2 + (y_1 - y)^2 + (z_1 - z)^2 \\ (x_2 - x)^2 + (y_2 - y)^2 + (z_2 - z)^2 \\ ..... \\ (x_n - x)^2 + (y_n - y)^2 + (z_n - z)^2 \end{bmatrix} = \begin{bmatrix} R_1^2 \\ R_2^2 \\ ..... \\ R_n^2 \end{bmatrix} \tag{2}$$

The wireless sensor nodes are distributed in the covered area of the entire network, and each node has a corresponding coordinate, and the coordinate can be set as (x_i, y_i, z_i). The coordinate of each node is the center of the circle, and the radius of the circle is R_i.The intersection is the actual position of the coordinate, and the coordinate of the target can be set as (x, y, z). We can get the first i-1 rows of type 2 to carry on the matrix operations, and there has

$$J \cdot h = K \tag{3}$$

Therefore, the formulas can be obtained:

$$A = -6 \times \begin{bmatrix} (x_1 - x_n)(y_1 - y_n)(z_1 - z_n) \\ (x_2 - x_n)(y_2 - y_n)(z_2 - z_n) \\ ..... \\ (x_{n-1} - x_n)(y_{n-1} - y_n)(z_{n-1} - z_n) \end{bmatrix} \tag{4}$$

$$h = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{5}$$

$$K = \begin{bmatrix} R_1 + x_1^2 - x_n^2 + y_1^2 - y_n^2 + z_1^2 - z_n^2 \\ R_2 + x_2^2 - x_n^2 + y_2^2 - y_n^2 + z_2^2 - z_n^2 \\ ..... \\ R_{n-1} + x_{n-1}^2 - x_n^2 + y_{n-1}^2 - y_n^2 + z_{n-1}^2 - z_n^2 \end{bmatrix} \tag{6}$$

In order to get the position coordinates (x, y, z) of the objects, we can make the above equation have maximum likelihood operations, and there has:

$$h = KJ^{'}(J^{'}J)^{-1} \tag{7}$$

When we carry on the delay detection, firstly sensor 1 sends a signal to sensor 2, and sensor 2 receives the signal to send answering flares to sensor 1. So the double time of one-way communication and internal delay sensor of hardwires in signal 1 constitute the total communication delay. In the whole process, each sensor has to ensure the internal clock synchronization, only in this way it can ensure the accuracy of time delay.

4. Target Detection and Localization System

The target detection and localization system in this article is based on the communication platform of wireless sensor network. The sensors detect whether the target has come into the covered area, when the target is found, the sensor begins to have trajectory tracking on the target. Because the wireless node has ability of multitasking, it can detect and track multiple targets. In the whole wireless network, wireless nodes are through the function of self-organization to build the channel, and its core management module is the time synchronization system. It makes the internal time of all the sensors keep pace with each other, and this can realize the consistency of the data of the sensors. The collected data uses the proposed multi-objective compound localization algorithm to have operation, and this can determine the position of the multiple targets. The diagram of target detection and localization system is shown in Figure. 5.

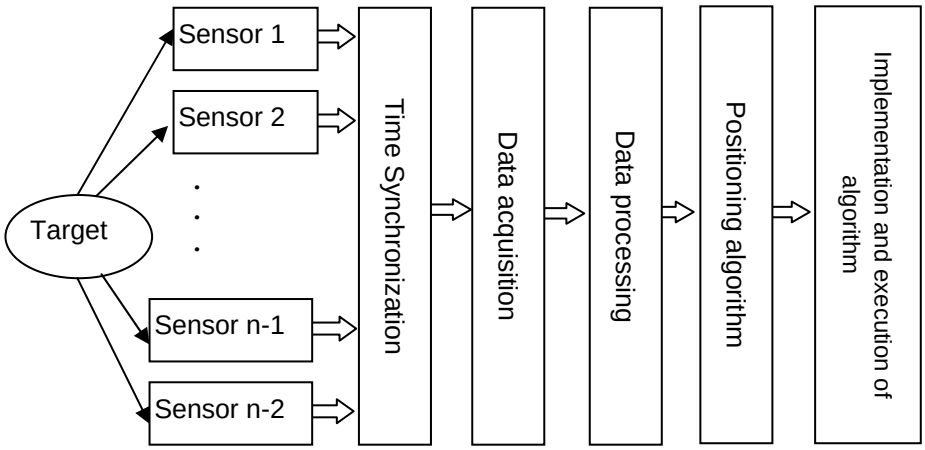

Figure 5. Target detection and localization system

There are mainly two kinds of influence factors of the time synchronization, and they are the hardware factors and external factors. The crystal oscillator that used by the microprocessor of wireless node has different craftsmanship, and this situation makes some differences exist in the various crystals. The target detection and localization system has high requirement on the properties of delay, so the difference has certain influence on time synchronization. Due to the different obstacles, the weather and the pressure, the time of signal transmission are different, and to some extent, this also has influence on time synchronization. In order to overcome these factors, it has to carry on the transformation of the noise cancellation of the localization algorithm, and this can make the time synchronization become better.

5. The Experiment Results and Conclusions

In order to verify the performance of target detection and localization system that based on wireless sensor network, this paper established the modelling and simulation of the system's structure, and it also used the multi-objective compound localization algorithm to calculate the data of wireless nodes. And then the algorithm can be evaluated from the aspects of nodes' energy consumption and the accuracy of the positioning, and the basic parameters of modeling and simulation are shown in Table 1.

Using 10 nodes can build a small wireless sensor network, the low-power monitoring radius of wireless network is 100m, and the high-power monitoring radius is 135m, so that we can test positioning system's ability of adapting to the low-power and high-power areas. The distance between each node is set as 80m, and the data-transfer capacity is set as 1000bit, then we can count the average energy consumption values of the nodes, and the results are shown in Table 2.

Table 1. The basic parameters of modeling and simulation

Parameters	Values
Low-power monitoring radius(m)	100
High-power monitoring radius(m)	135
Communication range(m)	80
Data-transfer capacity(bit)	1000
Speed of movement of target nodes(m/s)	10,20,30,40,50

Table 2. Comparison of results of energy consumption

The number of nodes	Energy consumption value that didn' t use algorithm (mW)	Energy consumption values that used the algorithm (mW)
2	27.56	21.21
4	50.13	45.6
6	83.8	71.82
8	105.62	90.79
10	132.19	116.32

We can let multiple targets with different speed of movement respectively come into the area, and then we use the target detection and localization system to capture the target. When the value of target's speed of movement is small, there are many sensors that can detect the target, and the obtained position data will be rich. When the value of target's speed of movement is bigger, the less available data could be collected. There has 200 experiments of target positioning, and the result is shown in Figure. 6.

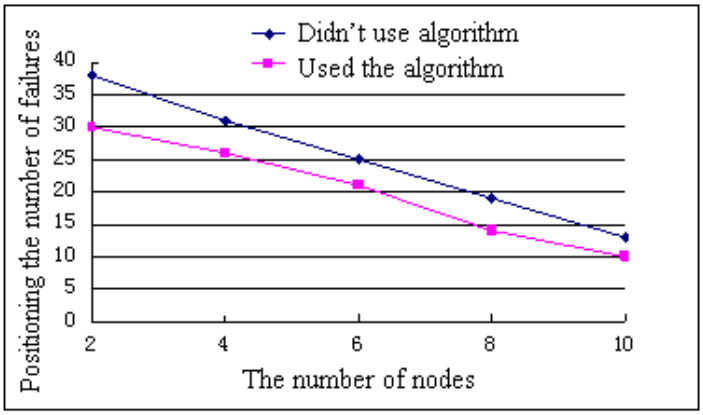

Figure 6. Result of experiments of target positioning

From the experiment we can see that after using the algorithm, the energy consumption of wireless sensor nodes has effective reduction, and this can make the efficient use of time get extension and enhance the stability of the positioning system. At the same time target localization algorithm can effectively improve the rate of target acquisition and decrease the times of fail positioning, and it also improves the accuracy of the positioning system. Therefore the target detection and localization system that based on wireless sensor network has stronger robustness, and this has very important significance for its applications in various fields.

References

[1] Xunxue Cui, Zhan Zhao, Cheng Wang. *The application and design technology of wireless sensor network*. National defence industry press, Beijing. 2011; 33-36.
[2] Li Cui, Yong Miao. Research progress of wireless sensor network. *Research and development of computer*. 2010; 11(5): 71-73.
[3] Ya Tian, Aihuang Guo. Design of ZigBee wireless sensor network based on the MC13193. *Modern electronic technology*. 2010; 12(8): 12-15.
[4] Kwang - il Hwang, Sang Soo Yeo, Jong Hyuk Park. The Adaptive Multi - channel Utilization Scheme for Coexistence of IEEE802.15.4 LR - WPAN with Other Interfering Systems. *2009 11th IEEE International Conference on High Performance Computing and Communications.* 2009: 297-304.
[5] Zhibin Lin, BoLing Xu. Three-dimensional Localization of Multiple & Sources Using Spherical Microphone Array. *Journal of Nan Jing University (Natural Sciences)*. 2011; 7(3): 21-23.
[6] Xiaoping Zhang, Guixiong Liu, Songbin Zhou. The usage of the least squares to support vector machine (SVM) to realize the targets of wireless sensor network. *Optical precision engineering*, 2010; 7(9): 60-63.
[7] X Xiaohua Chen, Zhen Xu, Liyang Rui. Fast optimization algorithm of observer trajectory of bearing target localization. *Journal of sensor technology*. 2011; 5(5): 19-21.
[8] Y Yong Wang, Xue Wang, Xinyao Sun. Reconstructed target localization of wireless sensor network based on sparse signal. *Journal of instruments and meters*. 2010; 3(3): 63-66.