Design of Routing Protocol and Node Structure in Wireless Sensor Network based on Improved Ant Colony Optimization Algorithm

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***Abstract*—Wireless sensor network is composed of many wireless sensor nodes with the same or different functions. A typical sensor node consists of four parts: sensor unit, information processing unit, wireless communication unit and energy supply unit. In this paper, the existing ant colony algorithm is analyzed, and an improved ant colony optimization algorithm is proposed. The paper presents design of routing protocol and node structure in wireless sensor network based on improved ant colony optimization algorithm. The experimental results show that the proposed method is effective.**

Keywords-Wireless sensor network; Ant colony algorithm; Routing protocol; Optimization; Ant colony system

I. INTRODUCTION

The sensor only as part of a survey project to analyze and study, with the development of material science, and it is especially in 1980s after the development of computer technology and chip integration level, the sensor technology also increased and developed. The sensor is not only used in the parameter measurement range of industrial automatic control, working environment and working medium, and sensor technology and computer technology, the formation of multi function and intelligent micro sensor, makes it easier to popularization and development, control of mobile equipment. Therefore, the extensive use of sensor technology in engineering machinery and it is equipment in order to improve the technology, the performance of these devices.

Wireless sensor networks should meet the following requirements: low energy consumption [1]. The requirements of low energy consumption based on two reasons: one is because the sensor node has the advantages of small volume, so the energy supply is limited; two is due to sensor network work environment is often difficult to update or not because of battery operation cost update. The energy consumption of nodes has a significant impact on the lifetime of wireless sensor networks.

Based on these rules, the ant colony algorithm constructs a heuristic algorithm for the optimal path search using swarm intelligence. Compared with other heuristic search algorithm, to solve the NP complete combinatorial optimal optimization problem, the ACA in the evolution algebra is reduced, the quality of the solution is improved, the convergence speed and solution quality balance in a certain extent. However, the complexity of the analysis shows that the number of ants and the scale of the problem are similar to the number of ants will increase convergence.

At present, many new algorithms have been proposed for the application of ant colony algorithm in wireless sensor network routing [2]. In some literatures, an ant colony algorithm for Steiner tree is proposed, which can be transplanted into WSN routing. However, there is no change in the specific requirements of the WSN, and no consideration of energy consumption is essential to the performance of WSN. It has studied three kinds of ant based WSN algorithms. However, the author only pays attention to the establishment of the initial distribution of pheromone, which has some advantages in the efficiency of the system.

Wireless sensor network is composed of many wireless sensor nodes with the same or different functions. Each sensor node is composed of data acquisition module (sensors, AID converter), data processing and control module (microprocessor, memory), communication module (wireless transceiver) and power supply (battery module, AC/DC energy converter). The node can act as a data collector, a data transfer station or a cluster head, and a cluster head node in the network. With the emergence of wireless sensor networks and the popularity of large-scale, it is possible to obtain the node data efficiently and randomly, but also can avoid the environmental damage caused by the data collection. Wireless sensor networks can be deployed in a large number of sensor nodes in the monitoring area, such as the spread of aircraft, which is practical and convenient, high reliability of the collected information. The paper presents design of routing protocol and node structure in wireless sensor network based on Improved Ant Colony Optimization Algorithm.

II. WIRELESS SENSOR NETWORK NODE ARCHITECTURE AND ROUTING PROTOCOL ANALYSIS

Wireless sensor network (WSN) is a kind of intelligent autonomous measurement and control network system based on the combination of wireless communication technology, sensor technology and network technology. Because of its random layout, the characteristics of self organization, to adapt to the environment, very suitable for wiring, difficult power supply area, inaccessible areas, has been widely used in the field of military defense, industrial and agricultural

production, environmental science, traffic management, disaster monitoring, etc..

The hierarchical network communication protocol of wireless sensor network includes physical layer, data link layer, network layer, transport layer and application layer. The physical layer is responsible for data sampling, signal modulation, transmitting and receiving, transmission is responsible for bit stream; data link layer is responsible for the implementation of monitoring data into frames, frames, medium access control, error control, to reduce conflict transmission between the nodes; network layer service.

Sensor node is an important part of wireless sensor network. A typical sensor node consists of four parts: sensor unit, information processing unit, wireless communication unit and energy supply unit. The sensor unit is responsible for the information in the monitoring area and the data of A / D conversion; information processing unit is responsible for the control of the sensor node operation, storage and processing of data and the data itself sent to other nodes; wireless communication unit for wireless communication with other sensor nodes, exchange of control information and data transceiver; energy supply the operation unit provides the energy required for sensor node [3].

When nodes and nodes are deployed in the sensor nodes used for environmental monitoring, it is necessary to choose a small volume, high precision and long life cycle as the monitoring node. As far as possible to reduce the volume of sensor nodes and it is the use of heterogeneous sensor nodes in order to adapt to the complexity of the environment and the sensitivity of the monitoring environment for external equipment. High precision sensor is more conducive to the accurate acquisition of environmental parameters. Another important factor to select the sensor is the start time [4]. The start time is the time between the sensor and the stable read data. The startup time is too long to consume a large amount of energy, which is not conducive to the continuity of the sensor nodes. Therefore, it is necessary to select the sensor with short startup time to save energy, as is shown by equation (1)

$$\begin{cases} a = \dfrac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i y_i}{n\sum_{i=1}^{n} x_i^{\,2} - (\sum_{i=1}^{n} x_i)} \\ b = \dfrac{1}{n}\sum_{i=1}^{n} y_i - \dfrac{a}{n}\sum_{i=1}^{n} x_i \end{cases} \tag{1}$$

Data fusion is an important field of integrated intelligent sensor theory, but also the focus of research, data fusion technology, in short, that is to carry out comprehensive treatment of multiple sensors or multi-source information, so as to obtain more accurate and reliable conclusions. The array consists of a plurality of sensors, data fusion technology can give full play to the characteristics of each sensor, using the complementary and redundancy information, improve the measurement accuracy and reliability, prolong the service life of the system.

Wireless sensor networks are starting from the sensor network; the sensor network has experienced the development process. The first generation of sensor networks appeared in 1970s. The traditional sensor with simple information signal acquisition capabilities, using point-to-point transmission, sensing controller connected sensor network; the second generation of sensor networks, with the comprehensive ability, access to a variety of information on the signal, and the interface (such as Rs-232, RS-485) and sensor controller connected to form a sensor network with a comprehensive variety of information; third generation of sensor networks in the late 1990s and the beginning of this century, a variety of sensors to obtain information signal with intelligence, using field bus connecting the sensor controller, constitutes a local area network, become intelligent sensor network.

The serial clock can be a continuous clock to transmit all data in a continuous burst. On the other hand, it can also be a discontinuous clock that sends information to a small number of data to AD7705. DIN pin is the serial data input. The serial data written to the on-chip input shift register is input. The data in the input shift register is transmitted to the setting register, the clock register, or the communication register according to the register selection bit in the communication register. DOUT pin is the serial data output. The output of the serial data read from the on-chip output shift register.

Dynamic characteristics are the characteristics of the output of the sensor when the input changes. In practice, the dynamic characteristics of the sensor are often used to represent the response of some standard input signals. This is because the response of sensors to the standard input signal easily obtained by experimental method, and the relationship between its response to the standard input signal and the input signal of any response, as is shown by equation(2), the former can often know the presumption of the latter. The most commonly used standard input signal has two kinds of step signal and sine signal.

$$E[(X(k)-G(k))^2] = \sum_{i=1}^{N} \left| \frac{u_i}{\sum_{i=1}^{N} u_i} \right|^2 R_i \tag{2}$$

The perception module is responsible for collecting and monitoring data and data conversion processing: processing module is the central node, responsible for data processing, communication network, with power management and positioning and other advanced services; wireless communication wireless communication module is responsible for network nodes, exchange control messages and receiving and sending data: the identity module is responsible for network node identification in number; the power supply module is responsible for the node.

With the miniaturization of the sensor node, the energy of the battery can be limited, and it is difficult to replace the battery because of the unstable environment. So how to limit

the energy consumption of nodes becomes the bottleneck of network design, which directly determines the life of the network. On the other hand, the storage capacity of sensor nodes is small, and the computational complexity is low. As a result, researchers in wireless sensor networks pose a challenge for them to design simple and efficient routing protocols for wireless sensor networks.

The communication and networking layer is responsible for point-to-point, point to multipoint wireless communication as well as ad hoc networks, and provides service support to management and basic service layer. The network communication protocol of physical layer, data link layer and network layer of wireless sensor network is studied in this paper. The main problem of physical layer is the choice of wireless frequency band and modulation technology. The research focus of the data link layer is the media access control, which is the method of allocating channel resources among competing users.

Compared with the limited processing power, storage capacity and communication ability of sensor nodes, and it is sink nodes have strong processing power, storage capacity and communication ability. The sink node is directly connected to the sensor node network and communication network, which brings forward higher requirements for the functionality of the sink node. The architecture of a typical wireless sensor network protocol stack to support dynamic and hierarchical, adaptive, programmable, self management, self recovery, multi task and proxy based it.

Modeler modeling process is divided into 3 levels: process (process) level, node (Node) level and network (Network) level. The behavior of a single object is simulated at the process level, and it is connected to the device at the node level. Several different network scenarios form a "project" to compare different design scenarios. This is also an important mechanism for Modeler modeling; this mechanism is conducive to project management and division of labor.

A high speed digital signal processor (DSP) TMS320F240 is used as the central processing unit, and the core control unit is composed of a few peripheral circuits. The main advantages of this scheme: the speed is fast, the execution speed is 20MIPS, almost all of the instructions can be completed in a single cycle of 50ns, and such a high performance is very suitable for real-time data acquisition [5].

$$H(x,y)=\begin{bmatrix}\dfrac{\partial^2 f}{\partial x^2} & \dfrac{\partial^2 f}{\partial x\partial y}\\ \dfrac{\partial^2 f}{\partial y\partial x} & \dfrac{\partial^2 f}{\partial y^2}\end{bmatrix} \tag{3}$$

Typically, most sensor nodes are stationary. In addition, the energy, processing power, storage capacity and communication ability of sensor nodes are very limited. The primary design goal of traditional wireless network is to provide high quality service and high bandwidth utilization, then considering energy saving; and the primary design goals of sensor networks is the efficient use of energy, which is one of the most important difference between sensor networks and traditional networks.

The static characteristic of the sensor is the relationship between the input signal and the output of the sensor. When the input and output are independent of time, so the relationship between them, namely sensor static characteristics available a time-dependent algebraic equation, or input as abscissa, the output characteristic curve and the corresponding longitudinal coordinate and draw to describe. The main parameters that characterize the static characteristics of the sensor are linearity, sensitivity, hysteresis, repeatability, drift and so on.

Passive routing considers that there is no need to maintain routing information for all nodes in a dynamically changing network, and it will only be "on-demand" when there is no destination node routing. According to the request of network transmission, the passive node searches from the source node to the destination node.

III. Improved Ant Colony Optimization Algorithm

The ant cycle model, which is used by the traditional basic ACA, adopts the ant model which is more close to the real ant behavior. The establishment of pheromone diffusion model, the closer distance between the ants can collaborate better, the simulation results show the effectiveness of the proposed algorithm in this paper is however required to achieve convergence in evolutionary algebra is the basic of ACA has been greatly improved. Reduce about 4 times [6]. However, the reduction of the shortest path length is not obvious, and the setting of the parameters is still based on the experiment.

The individuals in the group are distributed (Distributed) so that they can adapt to the working conditions in the current network environment. (2) There is no central control and data, such a system is more robust (Robust), not because of the failure of one or a few individuals affect the whole problem solving. (3) Such a system can be more scalable (Scalability) without direct communication between individuals, rather than through direct communication.

Based on the order of the ant system (Rank-based Version Ant System, referred to as RAS) is a AS Bullnheimer and other extensions of the algorithm proposed by Bernd. RAS after it is each iteration, the ant path will arranged according to the order from small to large, namely L1 (T) = L2 (t)..... Lm (T), and according to the length of the path with different weights, shorter path length the greater the weight. The weight of the global optimal solution is w, and the weight of the R optimal solution is max {0, w-r}, and update the information of each path according to (4) [7].

$$H_e=-\sum_{l=0}^{L-1}P(l)\log_2 p(l) \tag{4}$$

The research of ACA is more and more deep, all kinds of model ACA based on the research domain also emerge in an

endless stream, scattered from the domain to the continuous domain, at the same time ACA is combined with other algorithm in order to overcome the defects of the domestic research starts late, to affect the convergence of the parameters such as B, has been unable to determine a set of related the theory to be set, only through repeated tests to determine approximately a range of parameters, and the research about the theory simulation, applied to practice is still less. The study of these areas abroad has been more mature.

The pheromone values prescribed in the range; third, the initial pheromone value is 7, the combination, the purpose is to make the algorithm to explore more unknown; finally, when the algorithm premature convergence phenomenon, or cycle after a certain number of algorithms still did not find the shorter path, then all the information on the path each will be reset back to the initial state when looking into the current optimal path, the algorithm will update according to the global information system in the current rules of the ant optimal path pheromone update.

The idea of ACO was proposed in 1991 by Italy scholar M.Dorigo et al. From 1991 to 1996, M Dorigo et al. Ant colony search process and traveling salesman problem (TSP) food similarity, do some research by artificial ants search for food in the process, has put forward three kinds of models: ant-quantity, ant-density and ant-cycle. The main difference between the three models lies in the different mathematical formulas for the change of the pheromone concentration. M Dorigo published a comprehensive discussion on the ant system (AS), summed up the three models [8]. In this paper, the M model is introduced into ant-code Dorigo, and a series of experiments are done for the TSP problem.

$$C = \sum_{i=0}^{L-1} p_i \log_2 \frac{p_i}{q_i} \tag{5}$$

Set the cycle counter, set the initial amount of information for each path, and place the ants on a single city. The set of index set, from 1 to the ants in the starting position, set the corresponding set repeat the following steps, until the set date (this step will be repeated): setting; for from 1 to 4, according to the probability formula to determine the choice of target moving under a city step.

Ant colony optimization is based on ant colony optimization. Based on the disadvantages of AS optimization ranking elitist AS, through sorting can well restrain premature, especially when the initial state of the solution had little difference, but the effect is significant, which increase the amount of pheromone path optimal ant induced on the third.

From the perspective of the overall analysis process of ACRP, we need to empty all the ants list, initialization pheromone path value; then began to traverse the source node around the adjacent node, according to the path calculation of optimal selection probability, in order to continue to visit the next node, update the pheromone path and the list, prevent the entry of death cycle, until you reach the Sink node; Sink nodes at the optimal path, the global update pheromone on the optimal path of information; if still not many times to find a better solution to the pheromone evaporation rate update.

IV. Design of routing protocol and node structure in wireless sensor network based on Improved Ant Colony Optimization Algorithm

Wireless sensor network (WSN) is a new information acquisition technology with the development of wireless communication technology, sensor technology, microelectronics technology and distributed information processing technology after Internet. WSN combines the embedded technology, sensor technology, communication technology and distributed information processing technology, to various environmental cooperation real-time sensing, monitoring and collecting network of regional distribution of information, and the data were processed to obtain appropriate simplification and accurate information, and send to the end user.

In sensor networks, the use of the process, some sensor nodes due to energy depletion or environmental factors caused by the failure, there are also some nodes in order to compensate for the failure of nodes and increase the monitoring accuracy and added to the network, so that the number of nodes in a sensor network can dynamically increase or decrease, so that the topology of the network with dynamic changes. The self-organization of sensor networks should be able to adapt to the dynamic changes of the network topology.

Ant colony system (AS) is with elitist strategy. In the elitist AS, in order to find the optimal solution so far in the next cycle of ants are more attractive, give the optimal solution additional amount of pheromone update it is said by the ant pheromone induced by pheromone path increasing after each iteration; the number is elite ants; path length is optimal to find solutions [9]. This algorithm has fast convergence speed and short computation time, but if it is too large, the search will be limited to the extreme value, as is shown by equation (6).

$$\overline{R}_i(k) = \frac{1}{k}\sum_{j=1}^{k} R_i(j) = \frac{1}{k}\left[\sum_{j=1}^{k-1} R_i(j) + R_i(k)\right] \tag{6}$$

Hierarchical routing is a routing protocol. Hierarchical routing protocol uses cluster to classify sensor nodes, which is the concept of adjacent node clusters. The cluster head is used to complete the communication in the cluster, and the cluster head node collects the information of the nodes in the cluster, so as to reduce the traffic volume, and finally, the collected data is transmitted to the terminal node through the cluster head node [10]. Therefore, the wireless sensor network is scalable, while avoiding the energy consumption of sensor nodes to prolong the network lifetime.

In the study, the network is often abstracted as weighted directed graph G (V, A). Where V is the node set, the V element of graph nodes; a arc set, a elements (I, J) and A V (I)

for node to node V (J) of arc; arc is a weighted metric, metric operations include additive, multiplicative and minimum. Business requirements for QoS metrics are QoS constraint C= (C1, C2,,, CK). QoS routing is found in figure G, the (0) to V (V) (V) (V) (P=v) (n) (n) is found to satisfy the service QoS constraint C, from the source node to the target node (2). It should meet the quality requirements of different services and the effective utilization of resources in the whole network.

If there is no record of the ant in the node memory, the required information is saved, and the node visited by the ant is updated. If the serial number of the ant is found in the node memory, the ant will be deleted. When the node receives an ant returning is to the source node, and it is the node searches for the last node that is in the forward direction, which is regarded as the next node. If the ant does not return to the node for a period of time due to external factors, the corresponding information of the ant will be removed.

So the features and advantages of using ant colony optimization proposed a ZigBee routing algorithm based on Ant Colony Optimization Based on ZigBee routing strategy and ant colony optimization features, constructing artificial ants algorithm has the advantages of energy saving and better global optimization ability, and improve the performance of the network. Put forward its own ideas and practices to achieve the purpose of network optimization.

V. SUMMARY

Wireless sensor networks (WSN) are task oriented networks, and it is meaningless to talk about sensor nodes from the sensor network. The nodes in the sensor network are identified by the number of nodes, and whether the node number needs the whole network is decided by the design of the network communication protocol. Due to the random deployment of sensor nodes, the relationship between the sensor network and the node number is completely dynamic. The paper presents design of routing protocol and node structure in wireless sensor network based on Improved Ant Colony Optimization Algorithm. When the ant arrives at the node on the path, it collects the information of the pheromone above, and when it reaches the destination node, it updates the pheromone table with the information. Then, the destination node will send back the ant, whose task is to update the pheromone table of the source node.

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