Research on Regional Layout and Routing Protocol Optimization of Wireless Sensor Networks

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Abstract: Sensor nodes are randomly distributed in the monitoring area. Because of their self-organization, they can form a system network without any infrastructure and are responsible for collecting the parameter information of the target area in real time. The advantage of plane routing is simple and easy to expand, but it lacks the optimal management of communication resources and has a slow response to the dynamic changes of the network. In this paper, WSN (Wireless Sensor Networks) regional layout and routing protocol optimization are studied. An optimization method of WSN node layout based on adaptive GA(genetic algorithm) and an optimization algorithm of multipath QoS guaranteed WSN routing protocol based on optimized ant colony are proposed. Adaptive GA is used to solve the optimization problem of WSN coverage in order to achieve the maximum network coverage. The routing protocol optimization algorithm selects several optimal paths from the source node to the base station through the pre-calculation of the base station, and then sends ants from the source node through these paths for routing detection, and the source node transmits normal data to the base station in a multi-path manner according to relevant information. The research results show that the network coverage of adaptive GA reaches 96.003%. Multi-path QoS guaranteed WSN routing protocol based on optimized ant colony controls the energy consumption at a low level, and sacrifices less energy in exchange for the improvement of the overall communication quality.

1. Introduction

WSN (Wireless Sensor Networks) is a network in which all nodes can move freely. As a new type of wireless communication network, it has attracted extensive attention in recent years. WSN has brought a new revolution to information perception with its characteristics of low power consumption, low cost, distribution and self-organization, and has been widely used in target tracking and environmental monitoring [1]. The problem of network coverage is how to ensure that the coverage formed by all working nodes in the network can meet the application requirements [2-3]. In plane routing protocol, nodes have equal status, and routes are generated through local operations and feedback information. The advantage of plane routing is simple and easy to expand, but it lacks the optimal management of communication resources and has a slow response to the dynamic changes of the network. In this paper, the optimization of WSN regional layout and routing protocol is studied. An optimization method of WSN node layout based on adaptive GA(genetic algorithm) and an optimization algorithm of multipath QoS guaranteed WSN routing protocol based on optimized ant colony are proposed.

2. Research method

2.1. WSN regional layout

In WSN, there are two main research directions in the network layer: one is how to solve the interconnection problem of nodes in WSN, and form a network topology by constructing data loops through nodes; The other is to realize the node energy control at the network topology level through

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routing algorithm because of the limited energy of WSN. Because WSN is difficult to deploy nodes and can be supplemented after energy consumption, how to control the energy of WSN and maximize the working time of WSN has become a hot issue for researchers [4-5].

Sensor nodes are randomly distributed in the monitoring area. Because of their self-organization, they can form a system network without any infrastructure, which is responsible for collecting the parameter information of the target area in real time. It can connect the sensor nodes in the monitoring area with the management nodes of the user terminal through satellites or the Internet. On the one hand, it can transmit the data obtained by sensor nodes to users, on the other hand, it can receive task requests such as information query and network management sent by users and convey them to sensor nodes for execution, thus realizing information interaction. The optimization of sensor node layout in WSN is directly related to the improvement of WSN coverage. In this paper, adaptive GA is proposed to solve the optimization problem of WSN coverage in order to achieve the maximum network coverage.

The monitoring area A is discretized into $m \times n$ pixels, and its granularity is determined by the solution accuracy. The position of the sensor node s_i is (x_i, y_i), and if the coordinate of any pixel point is $p(x, y)$, the distance between the target pixel point and the sensor s_i is:

$$d(s_i, p) = \sqrt{(x_i - x)^2 + (y_i - y)^2} \tag{1}$$

GA is a search algorithm based on probability distribution mechanism and one of the evolutionary algorithms [6]. GA is an algorithm that draws lessons from the idea of survival of the fittest in the biological world and evolves to search for better individuals through three evolutionary operators of the algorithm. An individual in GA refers to a solution to a problem, and a population refers to a collection of individuals. Phenotype refers to the original representation of the problem, while genotype refers to the representation after the phenotype is encoded by the corresponding encoding method [7-8]. Fitness refers to an evaluation value of individual performance. In the process of searching for the optimal solution, GA mainly involves several processes, such as coding and decoding, fitness function setting, selection operation, mutation operation, crossover operation and algorithm termination conditions.

In the standard GA, the mutation rate P_m and crossover rate P_c of individuals remain unchanged throughout the iteration process. However, improper P_m, P_c setting will make the algorithm premature or become a random search algorithm. Therefore, adaptive GA came into being. Adaptive GA can reduce the situation that the algorithm falls into local optimum by adjusting P_m, P_c adaptively, so that the algorithm can converge to a better solution.

For individuals with low fitness, higher P_m, P_c is given, which makes individuals with poor performance have greater probability of evolution, thus enhancing the diversity of the population. For individuals with higher fitness, the genes of these better individuals are preserved by giving lower P_m, P_c. Through the idea of this subject, the adaptive reconstruction strategy of crossover probability and mutation probability:

$$P_c = \begin{cases} P_{c\min} + (P_{c\max} - P_{c\min}) \dfrac{4}{\exp[A*(f_{avg} - f')] + \exp[-A*(f_{avg} - f')] + 2}, & f' \geq f_{avg} \\ P_{c\max}, & f' < f_{avg} \end{cases} \tag{2}$$

$$P_m = \begin{cases} P_{m\min} + (P_{m\max} - P_{m\min}) \dfrac{4}{\exp[A*(f_{avg} - f)] + \exp[-A*(f_{avg} - f)] + 2}, & f \geq f_{avg} \\ P_{m\max}, & f < f_{avg} \end{cases} \tag{3}$$

Where $P_{c\min}$ is the minimum crossover rate, $P_{c\max}$ is the maximum crossover rate, $P_{m\max}$ is the maximum mutation rate, $P_{m\min}$ is the minimum mutation rate, f_{avg} is the average fitness of the population, f is the fitness of individuals, $A = 0.002$. The exponential adjustment mode in the above formula makes it possible for individuals of $f \geq f_{avg}$ to make self-adaptive adjustment between $P_c, P_{c\min}, P_{c\max}$.

2.2. Optimization of WSN routing protocol

Data-centric computing is one of the important characteristics of WSN [9]. Directional diffusion protocol periodically spreads interest and forwards probe data, which leads to high energy consumption. How to reduce the energy consumed in path creation and data transmission of directional diffusion protocol is a hot issue for researchers. If a node in the network fails or runs out of energy, it will create holes in the network, which may have an impact on the overall work of the network. How to balance the energy consumption between nodes and maximize the network lifetime is also an important issue in routing protocol research.

The routing technology of network layer has an important influence on the performance of WSN. With the research and development of WSN routing problem at home and abroad, many routing protocols have been put forward. From the perspective of network topology, network routing protocols can be divided into two categories: plane routing protocols and clustering routing protocols. Clustering algorithm can reduce the number of nodes participating in routing calculation, thus reducing the calculation amount of network routing and better solving the problem of network routing search [10-11].

In this paper, a multi-path QoS-guaranteed WSN routing protocol based on optimized ant colony algorithm is proposed, and some optimization improvements are made by using the idea of ant colony algorithm for reference. According to the pre-calculation of the base station, the protocol selects several optimal paths from the source node to the base station, and then sends ants from the source node through these paths for route detection, and the source node transmits normal data to the base station in a multi-path manner according to relevant information. This protocol can not only ensure the quality of network communication, but also reduce the energy consumed by ant colony algorithm and the possible channel congestion problem to some extent [12].

In WSN, multi-path routing usually refers to establishing multiple optimal routes from the source node to the base station through some algorithm, or sending data from multiple routes to the base station at the same time. In the process of data transmission between clusters, multi-hop transmission is adopted between cluster heads, and finally the data is transmitted to the base station.

In order to avoid accidental packet loss in the channel and calculate the path packet transmission rate, the source node needs to send ant_{num} ant packets along a path when detecting the route. The base station roughly estimates the packet transmission rate K_x on the path x by calculating the ratio of the actually received packets to the preset packets sent by the source node. The calculation formula is as follows:

$$K_x = \frac{ant_{sucess}}{ant_{num}} \quad (4)$$

Where x is the path number, and ant_{num}, ant_{sucess} respectively represents the number of ant packets sent by the source node and the number of ant packets that successfully reach the base station.

3. Result analysis

In Matlab environment, traditional GA and adaptive GA are used to optimize the position of WSN nodes. It is assumed that 500 wireless sensor nodes are arranged in a square measuring area

with a side length of 50m, including 25 fixed sensor nodes and 25 mobile sensor nodes. The measuring radius of all sensor nodes is 4m, and the communication radius is 15m. The population number of adaptive GA is 20, the evolutionary algebra is 300, the initial crossover probability is 0. 9 and the initial mutation probability is 0. 2.

Fig. 1 is a comparison chart of coverage convergence under two algorithms. The experimental results show that the network coverage rate of adaptive GA is 96.003%, while that of traditional GA is 89.005%. At the same time, the adaptive GA has a fast convergence speed, and it takes 20 generations to reach the global optimal solution, while the traditional GA needs 40 generations to achieve stable convergence.

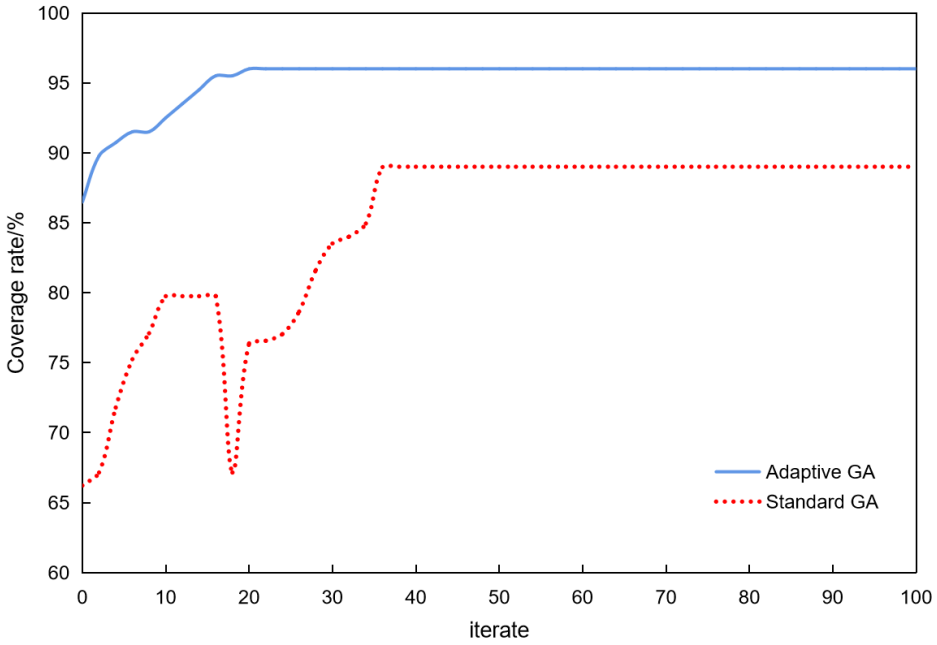

Figure 1 Comparison of coverage convergence of algorithms

Figure 2 shows the experimental results of network energy consumption. It can be seen that the multi-path routing protocol needs to consume extra energy to send ant packets to detect the path, but its growth rate is not large. Multipath routing improves the QoS of the network, and the additional consumption of these energy is completely within the acceptable range.

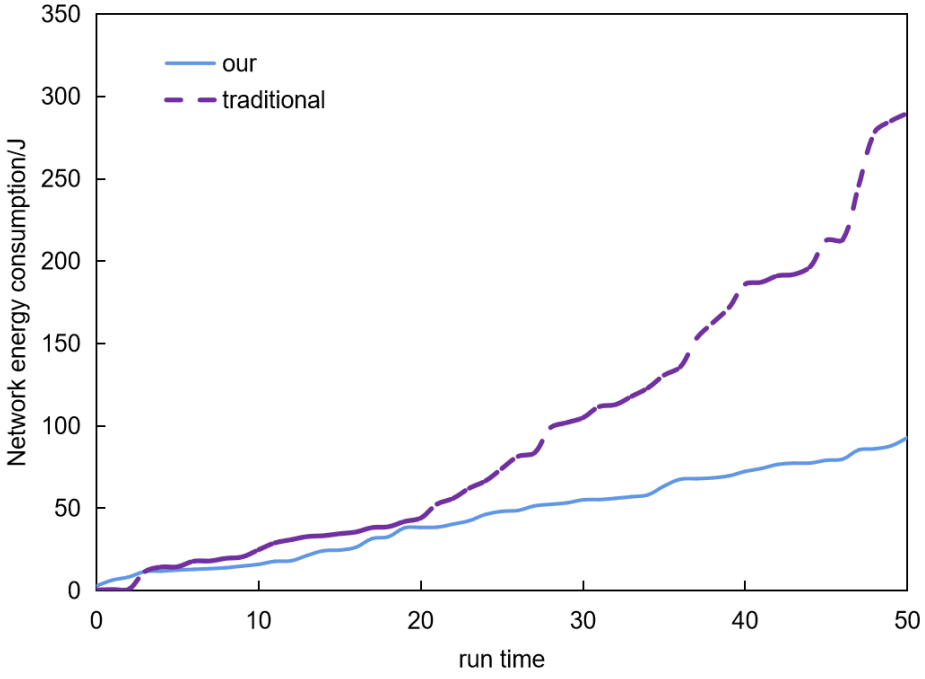

Figure 2 Experimental results of network energy consumption

In this paper, the routing protocol optimization method proposed in large-scale WSN uses ant colony to detect multiple paths in advance before data transmission, and can use backup routes to ensure communication quality when there is an abnormal situation in the theoretical optimal path. Compared with single-path routing, on the basis of significantly improving the network communication quality, the energy consumption is controlled at a lower level, and the overall communication quality is improved at the expense of less energy.

4. Conclusions

The problem of network coverage is how to ensure that the coverage formed by all working nodes in the network can meet the application requirements. In plane routing protocol, nodes have equal status, and routes are generated through local operations and feedback information. In this paper, the optimization of WSN regional layout and routing protocol is studied. An optimization method of WSN node layout based on adaptive GA and an optimization algorithm of multipath QoS guaranteed WSN routing protocol based on optimized ant colony are proposed. The research results show that the network coverage of adaptive GA reaches 96.003%, and the global optimal solution is achieved after 20 generations of evolution. Multi-path QoS guaranteed WSN routing protocol based on optimized ant colony controls the energy consumption at a low level, and sacrifices less energy in exchange for the improvement of the overall communication quality.

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