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Using Hybrid Artificial Bee Colony Algorithm to Extend Wireless Sensor Network Lifetime

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***Abstract*—In recent years, lots of researches have explored how to extend the lifetime of wireless sensor networks. Many of them focus on how to defend against Denial of Service (DoS) [1] attacks, and focus on how to arrange the locations of sensor nodes in different wireless sensor network architectures to extend the lifetime of sensor networks and to improve network security. This paper will use artificial bee colony algorithm and Or-opt algorithm to plan a transmission route of the detect features. Patrol nodes are also exploited to reduce power depletion and to extend the network lifetime. Patrol nodes will collect sensing data of nearby sensor nodes, detecting patterns in the collection data to confirm the collection data whether is normal or not. The experiments proof our method can reduce the time consume for dada transformation between patrol nodes.**

Keywords-component; wireless sensor network; artificial bee colony algorithm; the network lifetime;

I. INTRODUCTION

A wireless sensor network is composed of many sensor nodes. In most cases, these sensor nodes are equipped with batteries as their energy sources. They usually have small hardware device, low energy consumption, very limited memory and computation resources, and limited communication between each other. Since sensor nodes can sense environmental variables such as temperature, lightness, humidity and so on, they are widely used in many scenarios such as military monitoring, habitat monitoring, environment monitoring, etc. In most applications, sensing data has confidential requirement, so how to protect data from being stolen or avoid data from being destroyed is one of the major information security challenges of wireless sensor networks.

Our previous research has proposed patrol intrusion detection system (PIDS) [2]. A patrol node is a sensor node which carries knowledge to detect intrusion. They share the work of the cluster head. Since the WSN environment includes the general events and emergencies, the patrol nodes collect information on their sensor nodes. The patrol nodes use the detect knowledge to monitor sensor nodes, integrate information and transmit it back to a cluster head. The nodes relationships were carried by the patrol node are used to detect attacks. Patrol nodes will record information into an isolation table. In normal cases, the patrol nodes send the isolation table to the CH regularly. However, if an unexpected situation occurs, the isolation table will be transmitted to the CH immediately.

Patrol node transmits the detect features to another patrol nodes for detecting the behavior of neighborhood nodes whether they are intruded by hacker or not. A patrol node is used to travel among nodes to detect and collect messages. However, the battery power of these patrol nodes is limited, so the research in this paper focuses on how to find the shortest route to transmit the detect features between patrol nodes for detecting sensing data of nearby sensor nodes and minimize the power consumption of patrol nodes.

The research will compare CPU, memory, power and so on from all nodes at beginning. Then select better nodes as patrol nodes and combine a hybrid artificial bee colony algorithm to find the shortest route, achieving the power consumption of patrol nodes are minimal in order to extend the lifetime of wireless sensor networks. Figure 1 illustrates the application scenario, where blue nodes representing normal sensor nodes and red nodes representing patrol nodes and the yellow lines representing the shortest routes for transmitting IDS data between patrol nodes.

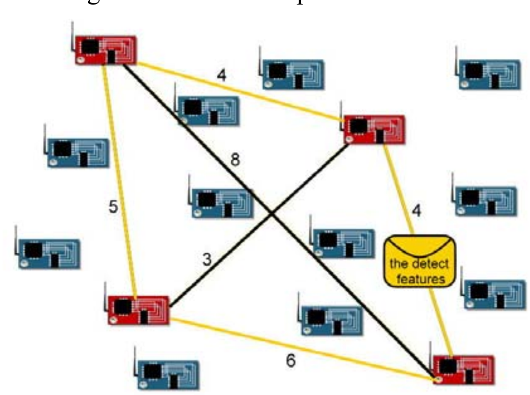

Figure 1. Patrol node on the shortest route

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The remainders of the paper are organized as follow. Section 2 is related work which will introduce original artificial bee colony algorithm and wireless sensor network topologies. Section 3 introduces a hybrid artificial bee colony algorithm. Section 4 is primary experiment results. The last section is conclusions and future works.

II. RELATED WORK

Currently, lots of researches have explored how to extend wireless sensor network lifetime. They modified wireless sensor network topologies such as clustering [3], Directed Diffusion, chain structure[4] and so on. From the viewpoint of information security explored, how to avoid nodes suffered from DoS attack to cause nodes power consumed rapidly is an important issues.

In previous research, we have used PIDS to slove security problem. The PIDS concept is the patrol nodes transmitted the node information for intrusion detection. How to let patrol nodes power consumption is minimal in transmission process? Our method will combine artificial bee colony algorithm [5] with Or-opt algorithm [6] to set up the shortest path for transmitting data between patrol nodes and nodes. Swarm-based algorithms such as particle swarm optimization (PSO) algorithm that inspired by social behavior of bird flocking and ant colony optimization (ACO) to solve traveling salesman problem. The traveling salesman problems can be mapped to routing the shortest path problem. This section contain brief introduction to wireless sensor network topologies, traveling salesman problem and above mentioned optimization algorithms.

A. Wireless Sensor Network Topologies

1. Clustering: In sensor networks, nodes will be formed a cluster or be clustered within sense field after a large number of nodes were deployed. In each cluster, one of nodes is selected as a cluster head. These cluster heads can communicate directly with base station. These cluster heads were formed a tree-based architecture that transmitted detection data to base station using multi-hop communication as shown in figure 2. If the system has not a better routing method, it will be not effective for reducing power consumption of nodes.

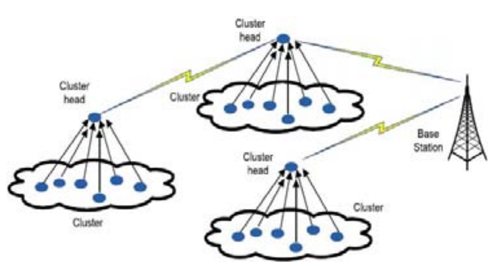

Figure 2. Clustering [4]

2. Directed Diffusion: This architecture collected data in three phases (1) The base station propagates an interest message to describe which types of data will be collected. (2) While the node receives this message, the node broadcasts the message to its neighbors. Those nodes set up gradients that contains the next hop that be used to propagate the result of the query. (3) When some nodes match the interest, they according to the gradient to query the shortest route for returning data to base station shown in Figure 3. The drawback of this architecture is while the distance between node and base station is far away, then nodes power consume are rapidly.

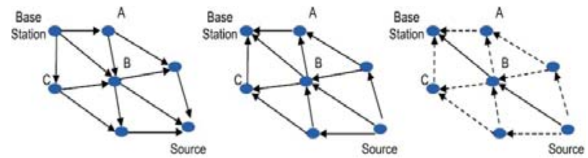

Figure 3. Directed diffusion [4]

3. Chain: The chain architecture has a node as leader node to aggregate data, then the leader node transmits the aggregated data to base station as shown in Figure 4. Each node are taking turns to be a leader for uniform the distributed of node power consumption. However, while the distance between the leader node and base station is far away, it will consume too much power. In addition, while the distance between node and node is far away, the nodes on the path will consume quite a lot of power even they are on the same chain.

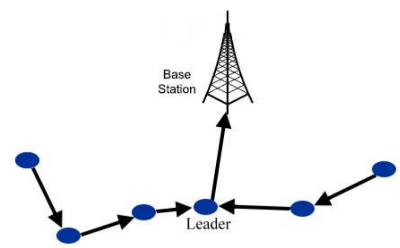

Figure 4. Chain

B. Or-opt algorithm

Or-opt algorithm was proposed by the Or in 1976 [5]. It attempts to improve the current route by moving one or two consecutive points or three consecutive points in a different location until the original route was further improved or satisfy the maximum cycle number. For example, we had five points (a, b, c, d, e) and they form Halmilton cycle as figure 5-A. If we wanted to improve path of figure 5-A, we selected a point assume that is d, change the front and rear of point d connection for forming a new path as figure 5-B.

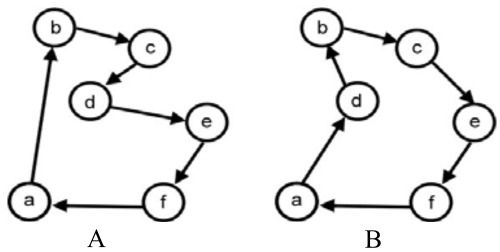

Figure 5. Or-opt algorithm

C. *Artificial bee colony algorithm*

Artificial bee colony algorithm that inspired by foraging behavior of bee by Dervis Karaboga in 2005 [6]. In ABC algorithm, the artificial bee colony contains three groups of bees: employed bees, onlooker bees, scout bees. The search carried out by the artificial bees can be summarized as follows:

Employed bees determine food source within the neighborhood of the food source in their memory and they shared about foods information with onlooker bees and then the onlooker bees select one of the food sources.Onlooker bees select a food source within the neighborhood of the food sources by themselves.Scout bees search a new food source randomly when an employed bee has been abandoned a food source.

At the beginning of ABC algorithm that generated population of food sources randomly. A food source represents a possible solution. The employed bees produce a modification on the position of the food source in their memory and the nectar amount of a food source corresponds to the quality that represents fitness value of the solution then used it to calculate probability values. While the onlooker bees selected the largest probability values of food source, then onlooker bees produce a modification on the position of the food source. The new food sources were calculated fitness value and were compared with the fitness value of the old food source than the largest fitness value of the food source was recorded as the best solution currently. The best food source was recorded in each iteration until reached the maximum number of iterations. The pseudo-code of ABC algorithm is shown in figure 6.

Step 1:	Initialization
Step 2:	Evaluation
Step 3:	cycle = 1
Step 4:	**repeat**
Step 5:	Employed Bees Phase
Step 6	Calculate Probabilities for Onlookers
Step 7:	Onlooker Bees Phase
Step 8:	Scout Bees Phase
Step 9:	Memorize the best solution achieved so far
Step 10:	cycle = cycle + 1
Step 11:	**until** cycle = Maximum Cycle Number

Figure 6. The pseudo-code of artificial bee colony algorithm

In the initialize phase, ABC algorithm generated a population of food sources randomly. $X_{i,j}$ represents the ith food source in the population, and each food source is generated as follows:

$$X_{i,j} = X_{min,j} + random(0,1)(X_{max,j} - X_{min,j}) \tag{1}$$

where i=1,2,…,SN and SN is the number of food sources and j=1,2,…,n is the dimension index of the problem and $X_{max,j}$ and $X_{min,j}$ are upper bound and lower bound respectively.

After initialization, the population is evaluated fitness value fit_i as the following：

$$fit_i = \begin{cases} \dfrac{1}{1+f_i} & \text{if } f_i \geq 0 \\ 1 + abs\,(f_i) & \text{if } f_i < 0 \end{cases} \tag{2}$$

where f_i is that $X_{i,j}$ is substituted object function to get the value.

In the employed bees phase, each employed bee generates a new food source V_i in the neighborhood of its present position. The formulation as follows:

$$V_{i,j} = X_{i,j} + \Phi_{i,j}(X_{i,j} - X_{k,j}) \tag{3}$$

where k=1,2,3,…,SN and j=1,2,3,…,n and k and j are mutually different random integer indices selected from {1,2,…,SN}. $\Phi_{i,j}$ is a random number in the range [-1,1]. Once V_i is obtained, it will be evaluated fitness value and be compared to X_i. If the fitness value of the new solution is better or equal than the old ones, V_i will replace X_i and become a new member of the population, otherwise X_i is retained.

After employed bees phase, the probability value was calculated based on the fitness of the food sources as the following:

$$p_i = \frac{f_i}{\sum_{j=1}^{SN} f_j} \tag{4}$$

In the onlooker bees phase, the onlooker bees evaluate the nectar information taken from all the employed bees and selects a food source X_i depending on its probability value. Once X_i has selected, the onlooker bees generated a modification on X_i by using (3). If the modified food source is better or equal than X_i, the modified food source will replace X_i and become a new member of the population.

In the scout bees phase, if a food source X_i cannot be improved by a predetermined number of trials, X_i is abandoned. The scout bees generated a food source randomly by using (1).

At the beginning, this section mentioned that scholars have used optimization algorithm to solve TSP in the past year.

This paper selected artificial bee colony algorithm to solve transmission path of IDS model. because the control parameters of the ABC algorithm are less than others. The control parameter not easy to influence the result in the ABC algorithm. Moreover, many modified ABC algorithms were applied to various areas, they have better result than other optimization algorithm [7][8].

III. HYBRID ARTIFICIAL BEE COLONY ALOGORITHM

Our research method referred to original artificial bee colony algorithm. Originally, it used to solve real-number optimization problems. In our study, our method combined an artificial bee colony algorithm with Or-opt algorithm to solve combined optimization problem. In other words, our method used them to find the shortest route of between patrol nodes. The System calculated the distance between patrol nodes by Euclidean distance. Table 1 illustrates the variables of ABC of the system and Figure 7 illustrates a hybrid artificial bee colony algorithm to find the shortest transmission path.

TABLE I. LIST OF VARIABLES

ABC algorithm	Definitions
CS	the number of colony size
FoodNumber	the population of food sources
MCN	the maximum number of cycles for foraging
D	the nodes were distributed range

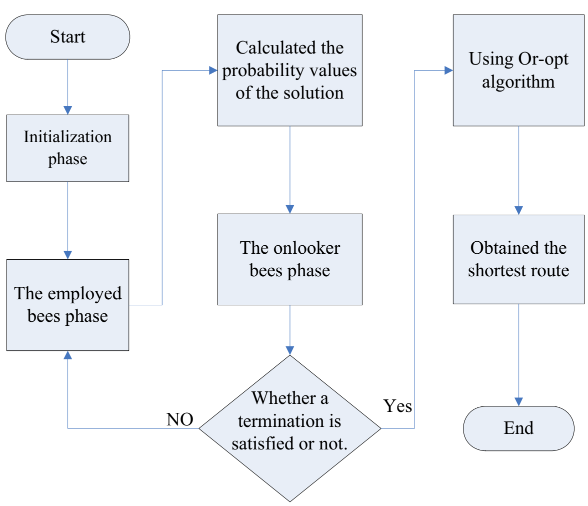

Figure 7. A hybrid artificial bee colony algorithm

A. *The initialization phase*

In this phase, patrol nodes were uniform selected randomly at every cycle for constructing a new route. After the population of the solution was obtained, the fitness value of them was calculated and compared it on employed bees phase.

B. *Employed bees phase*

In this phase, the old solution was improved from the initialization phase. The patrol node indexes were uniform selected for finding a patrol node from current route and neighbor route. According to find patrol node of neighbour route, mapped it to position of current route then interexchange them to improve the current route as show in figure 8.

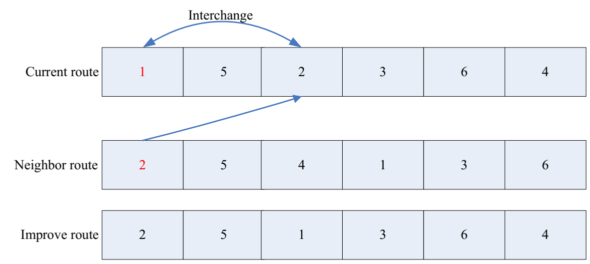

Figure 8. Interchange position in employed bees phase

After the population of the new solution was obtained, the fitness value of the new and old route were calculated. This system used the greedy mechanism to select the solutions have better fitness values. Finally, the probability values were calculated according to the better fitness values.

C. *Onlooker bees phase*

In this phase, this system selected the solution according to the best probability values then follow the below steps to improve the route.

1: Select two patrol nodes randomly from the same route.
2: Interexchange the two patrol nodes then we get the new routes.
3: Calculate the fitness value of the routes.
4: Compare the old fitness value with the new fitness value then select a bigger one.
5: If the old one is bigger than the new one, go to step 1 until satisfied maximum iteration count.
6: The new route is stored.

D. *Or-opt algorithm*

In this phase, the Or-opt algorithm is used to find the shortest route. The system selects the first index patrol node at the beginning and put patrol node to the second index, the third index until the last index patrol node respectively at each cycle. Suppose the first index patrol node was put to the fifth index then the patrol nodes among the second index patrol node to the fourth index patrol node have to be shifted left one location. If the routing length of the new one is shorter than the old one, the system stores the new route otherwise put the first index patrol node to the next index until all the nodes are exchanged and the path is evaluated shown in Figure 9.

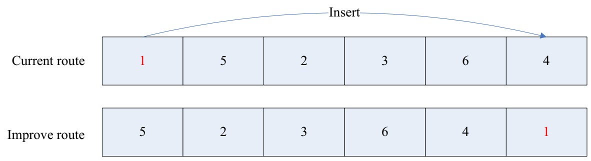

Figure 9. The exchange way of the or-opt algorithm

IV. EXPERIMENT AND ANALYSIS

This system used Network Simulation 2 (NS-2) and C# to estimate WSN lifetime. The experimental hardware environments are Intel® Core(TM) 2 Duo, 2.4GHz CPU and 2 GB memory. The whole WSN was simulated in 250,000 square meters. The field is static and the 60 sensor nodes are deployed uniformly in which 10% sensor nodes as patrol nodes. The radius of sensor nodes broadcast is 100m. This experiment compares AODV to AODV with ABC algorithm routing protocol for WSN lifetime. Network environment parameters are listed in Table 2.

TABLE II. SIMULATION PARAMETERS

Parameters	Values
Network range	500m*500m
Number of nodes	60
Patrol nodes	6
Communication range	100m
Initial energy	2J
Packet size	512kbyte
Transmission power	0.3w
Reception power	0.3w
Idle power	0.005w

In this situation, we uniform dispose 60 nodes and assign 6 nodes as patrol nodes. Those patrol nodes will transmit packet to other patrol nodes by multi-hop as shown in Figure 10.

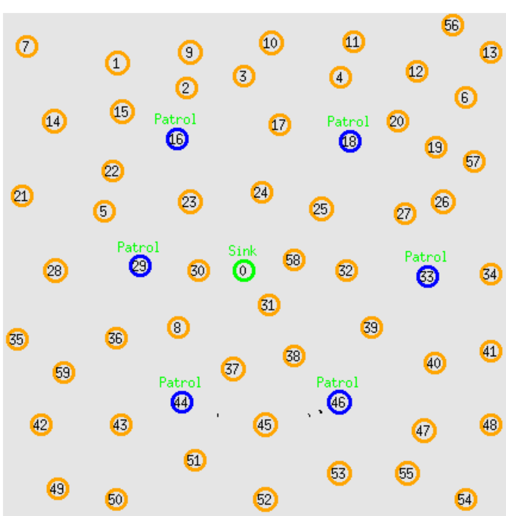

Figure 10. Patrol nodes transmit packet by muti-hop

Figure 11 is the same as Figure 10 but the patrol nodes' locations are different. Patrol nodes are nearby the sink node and they have to transmit packet by single-hop so the system selected eight sensor nodes {8, 23, 24, 25, 29, 30, 31, 58} which only have single-hop distance from sink. If sensor nodes have muti-hop distance from sink, the transferred packets have probability to be modified by their hop nodes. So, we selected the nodes with one hop distance from the sink node as patrol nodes. The system selected six patrol nodes {23, 24, 58, 31, 8, 29}, which have the shortest routing for data transmission, from the eight sensor nodes.

The route length was calculated by Euclidean distance to plan route by hybrid ABC algorithm as shown in Figure 11. The system compared average remained energy of nodes on ABC algorithm and AODV routing protocol at different time points.

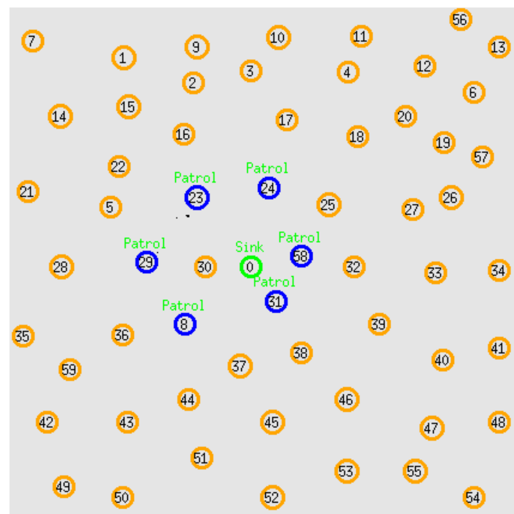

Figure 11. Patrol nodes transmit packet by single-hop

Figure 12 showed the comparison of original AODV and AODV with our ABC algorithm. The experiment run a total of 200ms and tested the average remained energy each 20ms. The battery power is the summation of remained energy of sensor nodes and divided by total number of sensor nodes. In Figure 12, using our method, blue line, the entire wireless sensor network lifetime will be increased.

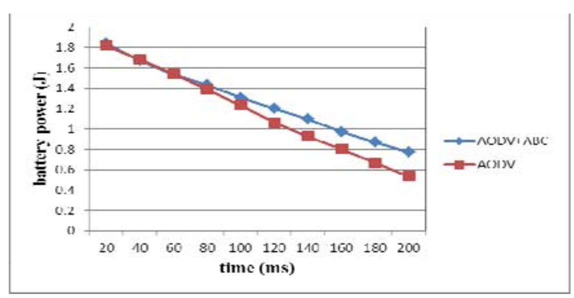

Figure 12. Average remained energy comparison

V. CONCLUSIONS AND FUTURE WORKS

In this paper, we presented a hybrid artificial bee colony algorithm to arrange the transmission path of patrol nodes for extend the lifetime of wireless sensor network. The method can reduce energy depletion. In the future, we hope to apply some applications that have to deploy a large number of nodes. We also will compare other optimal algorithm with ABC algorithm and added them to other routing protocol such as DSDV, DSR etc.

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