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Research of The WSN Routing based on Artificial Bee Colony Algorithm

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Abstract. *To improve poor performance of LEACH protocol in the energy consumption, an improved algorithm based on ABC algorithm is proposed. Through the introduction of data fusion, propose a WSN Routing Protocol, and example the process of the artificial colony algorithm improved LEACH protocol cluster head election. The simulation results show that, compared with traditional LEACH protocol, this algorithm can effectively balance the load of network, decrease the energy consumption of nodes, reduce network traffic by about 10%, and improve network lifetime by 33.83%.*
Keywords: Wireless sensor networks; Artificial bee colony algorithm; Load balancing factor; Data fusion.

1. **Introduction.** In social insects, each individual behavior is simple but a swarm show a very complex pattern behavior in finding food and nest. This kind of behavior is called swarm intelligence. For this kind of behavior, people put forward many bionic swarm intelligence optimization algorithm. Such as artificial fish swarm algorithm, ant algorithm and artificial bee colony algorithm and so on. Artificial bee colony algorithm (ABC) is derived from bees foraging behavior, which is a kind of typical swarm intelligence model. The algorithm simulates an intelligent behavior of the bees to find food source [1].

Because the cluster heads task is arduous in the wireless sensor network (WSN) [2], the selection strategy is similar to swarm to find the best sources of updating strategy, this process can be transformed to the process of the entire colony optimization [3]. So the model is more suitable for practice. This paper proposes a new protocol LBFABC (Load Balancing Factor Artificial Bee Colony Algorithm) based on ABC algorithm. Firstly, we use an improved fitness evaluation to complete the selection of cluster heads of the network, and to solve the problem of uneven distribution of cluster heads. Secondly, we combine with the data fusion technology to reduce the traffic from each member node in the cluster to a cluster head and from a cluster head to the base station. Finally, we apply these improvements into LEACH protocol to reduce the energy consumption of the whole network.

The rest of this paper is structured as follows. In Section 2, we give a brief introduction of ABC algorithm. In Section 3, we describe the implementation process of our algorithm. In Section 4, experiment results are analyzed to state the eciency of our proposed method. In Section 5, we summarize our main works.

2. **Artificial Bee Colony Algorithm.** ABC algorithm is put forward as a kind of bionic swarm intelligence optimization algorithm by D.Karaboga in 2005. It is applied in the non-numerical calculation optimization problem successfully at first [4]. The algorithm has simple operation, strong robustness, strong search ability, etc. By dividing the bees into employed bees, onlookers and scouts these three kinds of elements, to imitate the real bee behavior. The position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution [5].

Firstly, the population initializes. Generate SN group of random solutions, SN is the number of employed bees. Each solution X_i is a D dimensional vector. Then, every employed bee determines a new candidate solution by (1), and computes the quality of it. The employed bee chooses the new solution, if it is better. Otherwise, it keeps the previous solution.

$$v_{ij} = \chi_{ij} + \theta_{ij}(\chi_{ij} - \chi_{kj}) \tag{1}$$

where j is a randomly selected parameter for candidate solution v_i, current solution x_i, a neighbor solution x_k, and θ_i is a random number between $[-1, 1]$.

Secondly, onlookers choose a better quality nectar solution at a higher probability by setting the "fitness" mechanism. At the same time, the scout comes out when a solution cannot be improved further within a limit parameter. In that position, a new solution is randomly generated by the scout, given in (2), where x_i is a solution that will be abandoned, $j \in \{1,2,...,D\}$, D is the dimension of the solution vector.

$$\chi_i^j = \chi_{\min}^j + rand(0,1)(\chi_{\max}^j - \chi_{\min}^j) \tag{2}$$

By the cycle of employed bees and onlookers, improve nectar sources location information step by step. The whole process executes repeatedly, and records the optimal solution of every step, until meets the stop condition, then stops the execution [6].

3. **WSN Cluster Routing Strategy Using ABC Algorithm.** The strategy is applied to a wireless sensor network model consist multiple stable sensor nodes and a base station. In WSN, energy is the important index of network. The first part of the network energy consumption is data transmission, and another part is the process of data processing. On the data transmission, energy consumption is mainly decided by the communication distance. On the data processing, data fusion is a key technology [7]. Energy constraints are deduced by the distance between the nodes. We change the original cluster head election method based on ABC algorithm and Combine with the data fusion technology to improve the traditional LEACH protocol.

3.1. **The energy consumption model of LEACH protocol.** The majority part of WSN energy consumption is the process of data transmission, data transmission is necessarily involved in the network routing protocols. LEACH is one of the popular protocols in the hierarchical routing protocol of WSN. Use wireless energy consumption model that is put forward in the literature [8] to calculate the nodes energy consumption in the network communication, the model is shown in Fig.1.

A candidate cluster head should provide enough energy of receiving messages (E_{RX}) from the nodes in the cluster and retransmitting the message (E_{TX}) to the base. Where energy consumptions of E_{TX} and E_{RX} are modeled as in [3]. E_{elec} represents the circuit energy dissipations of sending or receiving k bits data; ε is the magnification of amplifier amplification; The value of β is associated with distance d (Friss free space model $\beta = 2$).

The energy consumption of nodes sending and receiving k bits data:

$$E_{Tx}(k, d) = E_{elec} \cdot k + \varepsilon \cdot k \cdot d^2 \tag{3}$$

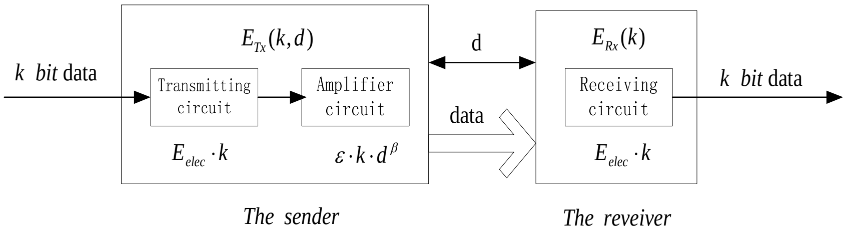


Figure 1. Energy consumption mode of LEACH protocol

$$E_{Rx}(k) = E_{elec} \cdot k \tag{4}$$

In the model, every node has the ability of data fusion, the energy consumption of fusing 1 bit data is E_{DA}.

The Friss free space equation shows that as a result of the limitation of its parameters, only when the receiving signal intensity P_r is greater than or equal to the receiving sensitivity S, the data can be successfully received,

$$P_s \geq \frac{S(4\pi)^2 L_0}{G_s G_r \lambda^2} d^2 \tag{5}$$

where P_s respectively mean transmitted power; G_r and G_s respectively mean receiver gain and transmitting gain; λrepresents working wavelength; d represents the communication distance between nodes; L_o is related to the system packet loss rate.

For a cluster that contains n member nodes within the cluster, set the distance from cluster head node to the base station is l, and cluster head node to node i is d_i, so the cluster energy consumption in t time can be expressed as:

$$E \geq \frac{\mathrm{S}(4\pi)^2 L_0}{G_s G_r \lambda^2} t \cdot (\sum_{i}^{n} d_i^2 + l^2) \tag{6}$$

3.2. **Improve LEACH protocol cluster head election process based on ABC.** From the analysis above can be achieved the fitness function of the ABC algorithm applied to LEACH protocol.

$$fit = [\max_{j=1,2,\cdots m} (\sum_{i}^{n_j} d_{ij}^2 + l_j^2)]^{-1} \tag{7}$$

where, j is the number of the cluster heads. n_j is the number of nodes in cluster j. d_{ij} is the distance between node i with cluster head j. l_j is the distance of the cluster head to the base station.

3.2.1. *The improvement of energy consumption model.* The selection of cluster heads by ABC algorithm can ensure network to reduce energy consumption, however, due to the limited node energy, it cannot guarantee that the node elected as the cluster heads has enough energy to complete the data receiving, transmitting and data fusion [9, 10]. To make sure the cluster heads energy enough, we also need to consider the remaining energy of nodes, to make the probability of the nodes enough remaining energy to be elected as the cluster heads greater. Namely to meet:

$$Ej = \begin{cases} \alpha E_{Tx}(k,d) \cdot k + n_j \cdot E_{Rx}(k) + (n_j+1) \cdot E_{DA} \cdot k; & E_{DA} \leq (1-\alpha) E_{TX} \\ E_{Tx}(k,d) \cdot k + n_j \cdot E_{Rx}(k); & E_{DA} > (1-\alpha) E_{TX} \end{cases} \tag{8}$$

where E_j is the remaining energy of candidate cluster heads; α is data fusion rate; $\alpha = m/k$ is the number of data after fusion.

It can learn from formula (8), the selection of cluster heads by ABC should guarantee the candidate cluster heads remaining energy not only greater than energy consumption of receiving data and sending data, but also consider whether to use data fusion when send date to the base station. If the remaining energy of candidate cluster heads is less than the given energy value, it cannot be elected as the cluster heads.

3.2.2. *The adjustment of onlookers selection way.* We found that onlookers use roulette way to choose the appropriate food sources greedily via many simulation experiments, the same as random selection process of cluster heads of LEACH protocol. This selection method cannot guarantee the position distribution uniform of the cluster heads. Easy to occur cluster heads concentrated in particular local area, scattered in particular local area [11]. To make the onlookers uniform distribution avoid the local optimal, the paper introduced LBF (load balancing factor) to adjust the onlookers selection way. LBF is defined as

$$LBF = \begin{cases} \frac{1}{\sum\limits_{j=1}^{n_c}(n_j-u)}; & \text{otherwise} \\ 1; & n_j = u \end{cases} \tag{9}$$

where n_c is the number of clusters and n_j is the number of cluster $j$member nodes.$u = \frac{n-n_c}{n_c}$ is the average neighbor nodes of every cluster head in the network. n is the total number of sensor nodes, $LBF \in (0, 1]$. Obviously, the greater the LBF value, the better the network load balancing degree.

As a result, we propose the improved ABC algorithm probability selection formula:

$$p_i = LBF \cdot \frac{fit_i}{\sum\limits_{i=1}^{SN} fit_i} \tag{10}$$

where fit_i is the fitness value of the solution i proportional to the nectar amount of the food source in the position i.

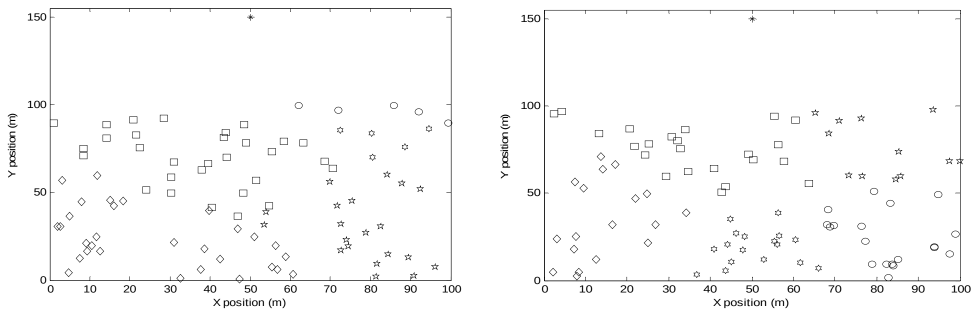
As we can see from the formula above, the onlookers' selection process of source (that is, the cluster heads) by improved probability selection formula not only guarantees the fitness function value, also equalizes the network load balance. Make the probability of nodes selected as the cluster heads bigger.

4. **Performance Simulation and Analysis.** A radio model is used as specified where radio electronics dissipates *Eelec* (50nJ/bit) for receiving and transmitting units, and E_{DA}(5nJ/bit) for the data fusion. The simulation model consists of 100 nodes randomly deployed on an area of 100x100 m^2, and base station placed at the point of X=50 m, Y=150 m.

Use Matlab to simulate, we call the algorithm referred to this paper as LBFABC. We compare the distribution of network nodes, the number of alive node, the data transmission and remaining system energy. The comparing results are as follows.

Fig.2 (a) shows the nodes distribution of LEACH. Fig.2 (b) is the nodes distribution of LBFABC. As can be seen from the figure, due to the cluster head chosen randomly, LEACH is easy to cause a cluster's member nodes very large, a cluster's member nodes very little. The cluster heads election process of LBFABC fully considers the load balancing, illustrate LBFABC can cluster well-distributed, can improve the network load balancing.

Fig.3 shows the alive nodes number contrast figure of LEACH protocol and improved LBFABC algorithm. With the increase of running rounds, it is seen that LBFABC algorithm survival nodes number larger than traditional LEACH. When all nodes in the network are death, LBFABC has run 2931 rounds, but LEACH only has run 2190 rounds.



(a) The LEACH protocol before improvement

(b) The LBFABC algorithm after improvement

Figure 2. Distribution of sensor nodes using LEACH protocol and LBFABC algorithm

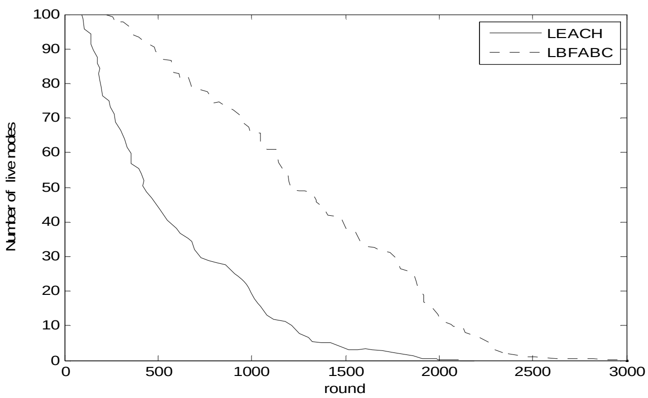


Figure 3. Alive nodes of LEACH protocol and LBFABC algorithm

It shows that LBFABC algorithm improves network lifetime over than LEACH protocol by about 33.83%, prolong the network lifetime efficiently.

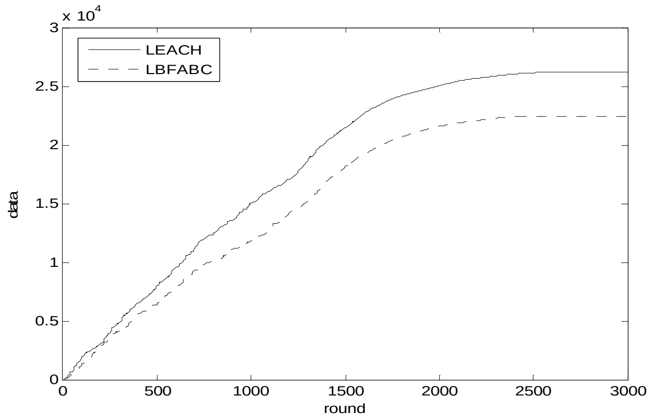


Figure 4. The data transmission of LEACH protocol and LBFABC algorithm

Data fusion is an important technology to handle redundant and unreliable data in WSN. We take sink nodes receiving the number of packets after the construction of routing as the basis of data transmission. The traditional LEACH protocol cannot involve data fusion, the number of packets received by the sink nodes is large, and the nodes energy consumption is large. Taking the model of this article into account, $E_{DA} \leq (1-\alpha)E_{TX}$, it has the need to introduce data fusion. Add the common average data fusion algorithm to reduce the data transmission. Compared with the data transmission before and after data fusion, it is not hard to see from Fig.4, the sink node receives the packets decreased by about 10% by using the improved routing protocol. The decline of network data transmission means that sensor nodes transmit data decrease, which will reduce the energy consumption of nodes, so as to prolong the lifecycle of the network.

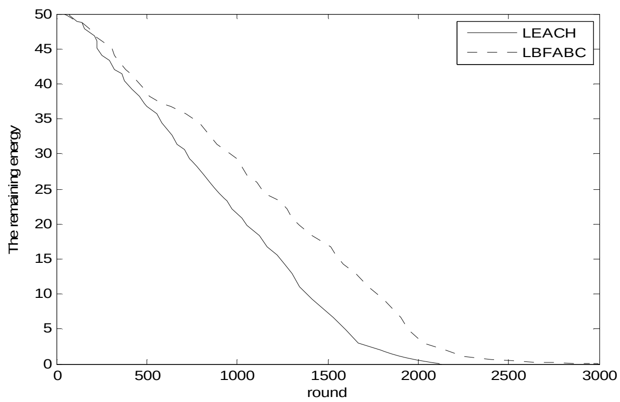


FIGURE 5. The system remaining energy of LEACH protocol and LBFABC algorithm

With the increase of running round, traditional LEACH nodes remaining energy presents a trend of linear decrease, but LBFABC system energy consumption decreased quite gentle, as shown in Fig.5. When the system runs about 2200 rounds, most of the LEACH node energy has run out to death, but LBFABC node remaining energy can insist 800 rounds than LEACH. LEACH is easy to induce low energy node was elected as cluster heads, lead to energy consumption too quickly to go death. To the contrary, we consider the factors such as distance, energy of nodes and data fusion, the node will not appear premature death, thus to lead the entire network paralysis.

5. **Conclusion and Future Work.** In this paper, we improve the artificial colony algorithm "fittest" cluster heads selection mechanism, and put forward the mechanism of combining with network load balancing factor. This is achieved by joining the data fusion technology to process the data. Simulation results show that LBFABC algorithm is effective to consider the distance between the nodes, node remaining energy, and the network load balancing factor, make the cluster head position distribution more reasonable, and reduce the node data transmission of WSNs, so as to prolong the network lifetime. The proposed protocol outperforms than traditional LEACH protocol, and seems to be a promising solution for successful operations based WSNs. We are planning to compare the performance of LBFABC algorithm with other implementations based on other well-known algorithms as future work.

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