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An Improved PEGASIS Routing Protocol Based on Neural Network and Ant Colony Algorithm

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Abstract

This paper proposes a routing protocol for the Wireless Sensor Network (WSN). It is a protocol based on the PEGASIS protocol but using an improved ant colony algorithm and neural network rather than the greedy algorithm to build the chain. Compared with the original PEGASIS, the ACON-PEG can achieve a global optimization. It forms a chain that makes the path more even-distributed and the total square of transmission distance much less. The protocol uses the thought of neural network algorithm to select the chain head, it utilizes ant colony algorithm to find the best path to send data to the BS and the whole area divided into multiple equal parts. It brings about a balance of energy consumption between nodes. Simulation results have shown that the proposed protocol significantly prolongs the network lifetime.

Keywords: *block matching, spatial similarity, variance, structure-adaptive*

1. Introduction

Recently, advances in wireless communication and digital electronics have led to the development of Wireless Sensor Network (WSN) [1]. WSN has been applied in many fields such as military investigation, medical treatment, and industry management. However, it has many restrictions such as limited energy supply, constrained computation and communication abilities. Therefore, how to prolong the network lifetime is an important and challenging issue, which is also the focus of designing the WSN routing protocol. Many routing protocols have been proposed for WSN. Based on the network topology, they can be classified as plane protocols and hierarchical protocols. As we all know PEGASIS is a typical hierarchical routing protocol The PEGASIS algorithm is based on the LEACH [3]. The core conception in PEGASIS is to form a chain among all the sensor nodes so that each node can receive and transmit to the closest neighbor. Gathered data moves from node to node, get fused, and eventually a designated node (cluster head) transmits to the BS. The process goes on until data reaches the leader. Then, the leader transmits the final fused data to the BS [3]. Each node determine the nearest neighboring nodes using the test signal of diminishing energy.

The greedy algorithm used to build the chain in the original PEGASIS only achieves a local optimization. It usually does not operate exhaustively on all the data, so it mostly fails to find the globally optimal solution. The method of choosing cluster head is not suitable for load balance. Moreover, considering that data will be transmitted along the chain, and supply of energy is the key restriction of WSN.

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2. Related Work

2.1. Current Research on PEGASIS Routing Protocol

The research status of PEGASIS is the classic hierarchical routing protocol; some scholars put forward a lot of the improved protocol on the basis research in PEGASIS [4]. Improved scheme mainly include two categories, one is still that all the nodes built into a chain in a network, but the different are methods of divide into a chain and selection methods of chain head .Another build a series of chains, forming clusters layered structure.

In the literature [5], the author proposes a new method of building chain. Main idea is that the first step and the second step to build chain are same with PEGASIS and joining chain node will be the next to be into the chain between two adjacent nodes. In this way, the energy dissipations of the data transmission is the smallest, this method of building chain in this paper is referred to the minimum energy method. The author simulates annealing algorithm to form the cluster on the basis of PEGASIS algorithm, at the same time using the factors of energy to select each round of cluster head. The chain length of the square reduced half compared with the original greedy algorithm, thus reducing the energy consumption of the whole network and extending network life time.

In the literature [6], EEPB protocol has improved PEGASIS from two aspects, EEPB adopt the distance of threshold to avoid PEGASIS forming a long chain. In order to solve the problems of the premature death of chain nodes, EEPB select the chain head according to the residual energy of nodes and the distance from the sink.

In the literature [7], the paper proposes a variant approach for chain formation in the wireless sensor network which is a modified version of chain based PEGASIS protocol. It always makes optimal decision which seems locally feasible. In the proposed approach, always a nearest neighbor-hood node selected as its next node in the chain.

In the literature[8] ,the author chose double cluster heads in one chain and used hierarchical structure in the new algorithm on the basis of avoiding the long chain existing. According to the simulation result, we could know that the new algorithm increased the efficiency of energy-using and the load balance, and extend the lifetime of the whole network.

These protocols are mostly using the greedy algorithm and these can not achieve the optimal of global energy consumption. In addition, a cluster head consume more energy, because it not only needs to receive data form chain, but also directly need sent the data to the Sink node. The above protocols that select main chain and chose a head do not consider these problems.

2.2. The Thought of the Routing Protocol Based On ACON – PEG

Considering to the problems in PEGASIS protocol, we propose an improved PEGASIS routing protocol based on neural network and ant colony algorithm. Firstly, area network will be divided into several parts and each node of the every area will build into a chain using Ant colony algorithm. Secondly, wireless sensors set up a mathematical model of competitive neural site, which use centralized ways to select cluster head in the base station. Then, ACON - PEG will build a main chain which uses every area of head node, according to the residual energy of each chain of head node and the distance to the Sink Node.

3. The Implementation of ACON - PEG Routing Protocol

3.1. Confirm the Optimal Number of Sub Chains

Hypothetical ,there are M nodes in the N * N , splitting the number of clusters K in areas such as general clusters mechanism of LEACH, members of the cluster nodes need to send the data to the cluster head nodes and members of the cluster head node need receive node data, then sends the data to the Sink node. According to the formula (1) and formula (2) shown in wireless sensor nodes energy consumption model, in the free space model, each cluster head nodes and cluster member nodes in a round of data transmission need to consume energy respectively by the formula (3) and formula (4) calculation .The consumption of energy when sending data to d distance deviation.

$$E_T(k,d) = E_{elec} \times k + \partial \times k \times d^m \quad (1)$$

The energy consumption of the node receiving the k bit

$$E_R(k) = E_{elec} \times k \quad (2)$$

Then k is the length of the packet, d is the transmission distance; is the energy consumption of the data of each transmit or receive unit; M is transmission attenuation index. In the free space model, the energy consumed by each cluster head node and the cluster member nodes is calculated by the formula (3) and the formula (4) in a round of data transmission.

$$E_{ch} = (\frac{M}{q} - 1) \times E_{elec} \times k + \left(E_{elec} \times k + \partial \times k \times d^2_{to\sin k}\right) \quad (3)$$

$$E_m = E_{elec} \times k + \partial \times k \times d^2_{toch} \quad (4)$$

Among them, E_{ch}, E_m represent a round of data transmission, nodes need to consume energy in the cluster head nodes and cluster member, M represents the number of node , q represents the number of cluster, E_{elec} represents the transmitting circuit or receiving circuit consume energy ; $d_{to\sin k}$, d_{toch} represents the distance between cluster head and sink node, the distance between and member head. Then, all nodes in the network need to consume the total energy in the transmission of data.

$$E_{sum} = q \times E_{ch} + (M - q) \times E_m \quad (5)$$

The formula (5) put into the formula (3) can be obtained the formula (6)

$$E_{sum} = (2M - q) \times E_{elec} \times k + (M - q) \times s \times k \times d^2_{toch} + q \times s \times k \times d^2_{to\sin k} \quad (6)$$

Each cluster is seen as group head for a circular area of the center of the circle, According to knowledge of circle, it can be obtained that any point gets the square of the distance of the expected value in the center of the circle :

$$E(d^2_{toch}) = \frac{N^2}{2\pi q} \quad (7)$$

The formula (7) puts into the formula (6) and ignores the value of small parts. According to the mathematical knowledge, the most value problem of derivative functions can be solved, the derivative of q was 0, the result is:

$$q \approx \frac{N}{d}\sqrt{\frac{M}{2\pi}} \quad (8)$$

Among them, q represents the number of clusters for the optimal value, N represents the length range of node distribution, M represents the total number of nodes, and d represents the average distance between D nodes and Sink nodes.

3.2. Chain Head is Identified by using the Idea of Neural Network

Through the study of the structure and working principle of the human brain, the model is constructed by using mathematical method. This mathematical model is similar to human neural network, which is named as artificial neural network. Artificial neural network (Networks NN, Neural), Artificial neural network, referred to as neural networks [8], it uses a large number of neurons develop extensive interconnection, and simulating the human brain's thinking process handling the distributed parallel information. The neuron model is equivalent to the nerve cells in the brain, which is the basic unit of the neural network. Neural network has a massively parallel, distributed storage and processing, self-organization, adaptive and self-learning ability, especially suitable for processing imprecise and fuzzy information problems. The most basic neuron model is shown in Figure 1.

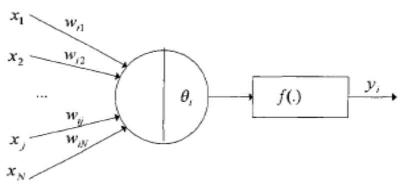

Figure 1. Artificial Neuron Model

In Figure 1, X_1, X_2, ,..., X $_n$ is called an input signal, which represents the information of each axon of the upper level of the neuron; U i is a linear combination of the input and output signals; θ i represents threshold; Vi is the deviation of adjusted value, also known as local induction neurons. Wi2, wi1,..., Win is the weight, which respectively represents efficiency of transmission information between neuron I and X_1, X_2, ,..., X $_n$.

$$u_i = \sum_j w_{ij} x_j \tag{9}$$

$$w_i^1(n_1 + 1) = w_i^1(n) + \eta \left[X_i(n) - w_i^1(n) \right] \tag{10}$$

$$v_i = u_i + b_i \tag{11}$$

F (.) is the transfer function, and y i represents the output of the No. I neuron

$$y_i = f(\sum w_{ij} + b_i) \tag{12}$$

3.3. Selection of Cluster Head

In this algorithm, the base station establishes competitive neural networks. At the start of the algorithm, each node to report the number of their location information and residual energy and number of neighbor node to the base station, these nodes represent the input vector of the competitive neural networks. Through continuous learning, the algorithm choose the most suitable to act as cluster head nodes eventually. After the neural network learning, the closer distance from the base station node, the more remaining energy of nodes, the node having more neighbor node to be the last winner .The competitive neural network proposed in this paper is divided into 3 layers: input layer, competition layer and output layer. The specific process of learning is as follows:

1) Setting variables and parameters

$X(n) = [x_1(n), x_2(n), \cdots, x_N(n)]^T$, the formula represents the input vector. $X(n)$ Represent any competing cluster head in the wireless sensor network; $X_i(n)$ represent the number of nodes to the neighbor node: the distance from the base station, the residual energy of node.

$W_i^1(n) = [x_1(n), x_2(n), \cdots, x_N(n)]^T$ Represent the weight vector of front sub-network. $Y(n) = [y_1(n), y_2(n), \cdots, y_i(n)]$ Represent the actual output vector. η is learning efficiency; n is training for the n times; n_1 is the step in the iterative process of Competitive network number.

2) Initialization: For the weights of w_{ij}^1 in self-network, it initialized with small random values, which satisfy the constraints $\sum_{j=1}^{N} w_{ij}^1 = 1 \quad i = 1, 2, \cdots, M$

$$\omega_{kl}^2 = \begin{cases} 1 & k = l \\ -\delta & k \neq l \end{cases} \tag{13}$$

K, l represents respectively the k node and the l sensor node in the network. The input neurons function f1 (.), f2 (.) is a same linear function, shown in formula (14)

$$y = \begin{cases} 0 & x < \xi \\ x - \xi & \xi < x < u_c \\ k & x > u_c \end{cases} \tag{14}$$

3) The competitive cluster heads get their own information, which includes the distance between the sensor nodes and the base station, the remaining energy of the node, the number of neighbor nodes. Transmitting the information to the base station, the base station takes these nodes as the input vector, i.e., the training sample.

4) The output results of the neural network are calculated from the front of the neural network:

$$y_k(0) = V_i^1 = f_1\left(\sum_{j=1}^{N} w_{ij}^1 x_j\right) \tag{15}$$

5) Iteration of a competitor network:

$$y_k(n_1 + 1) = f_2\left(y_k(n) - \delta \sum_{k \neq l} y_l\right), k = 1, 2, \cdots, M \tag{16}$$

6) Observing the output of the competitive sub-network, when the output reaches the requirement, then go to the seventh step, otherwise switch to the fifth step to continue the iteration.

7）The maximum output of the neurons is the winning neuron, then winning neurons represent cluster node in this study.

8）The weight vector of the neuron is updated which represent the winning sensor node:

$$w_i^1(n_1 + 1) = w_i^1(n) + \eta\left[X_i(n) - w_i^1(n)\right] \tag{17}$$

9) If training times do not achieve maximum training times, then go back to the third step for a new training, or the algorithm terminates the network training process.

4. Construction of Main Chain by Using ACO Algorithm

In the use of ACO algorithm [9], all of the chain heads construct an optimal chain in the region. The specific algorithm process as follows:

1) The number of M nodes generates the number of m frontal ants. In other words, the number of m frontal ants that are from different nodes, will begin their journey. The structure of the frontal ant is shown in Table 1.

Table 1. The Structure of the Frontal Ant

Source ID	Destination ID	Next-Node ID	Energy Value	Pre-Node ID

2) The number of m frontal ants start from the source node .When it reach the next node, every ant should check whether some ant has visited this node in the reverse routing table. If so, terminates this ant. According to formula (18), every ant calculate its transition probability and update the reverse routing table and Energy report table. The reverse routing table is shown in Table 2 and Energy report table inTable 3.

Table 2. The Reverse Routing Table

Source ID	Pre-Node ID	Sequence Number

$$P_{ij} = \frac{(I_{ij})^{\alpha}(E_j)^{\beta}\left(\frac{1}{D_{ij}^2}\right)^{\chi}(X_i)^{\delta}}{\sum_{y \in N_i}(I_{iy})^{\alpha}(E_y)^{\beta}\left(\frac{1}{D_{iy}^2}\right)^{\chi}(X_{iy})^{\delta}} \tag{18}$$

Among them, I_{ij} represents the pheromone of information on path of chain, E_j is the current residual energy of node j; D_{ij} is the distance between node i and j; The parameter α 、β、χ、δ, represent their respective weights.

Table 3. Energy Report Table

Source ID	Energy	Sequence Number

3) According to the formula (19), the sink node calculate amount of pheromone information, when frontal ant reach the destination. Then, backward ant walks along the path to the destination. ∂ is a constant element, representing the volatility of pheromone.

$$I_{ij} = (1-\partial)I_{ij} + \Delta I_{ij} \tag{19}$$

4) Backward ants update the gl obal pheromone according to the formula (20).

$$\Delta I_{ij} = (1 - \frac{D_{js}^2}{\sum_{y \in N_i} D_{ys}^2}) \times \omega \tag{20}$$

D_{ys} Represent the distance between nodes y and Sink; ω is a constant, which indicates the total amount of pheromone released by ants in a journey. When the number of loop iterations meets the specified requirements, then the optimal path is obtained.

The flow chart of ACON- PEG algorithm is shown in the following Figure 2. At beginning, there are M sensors nodes which are divided into K clusters based on our algorithm. The number of cluster nodes can be determined by the above formula (8). Based on neural network, each cluster nodes can also be selected.

Once the cluster head residual energy is lower than certain threshold, new cluster head will be selected based on the neural network above. Or else, a chair will be formed by the greedy algorithm inside each cluster. Based on our algorithm above, a main chair will be formed by the cluster head using ACO algorithm. If the average energy of main chain is above certain value, cluster heads will transmit data to sink node. Or else, new main chain will be formed using ACO algorithm. This algorithm will start again in a new round.

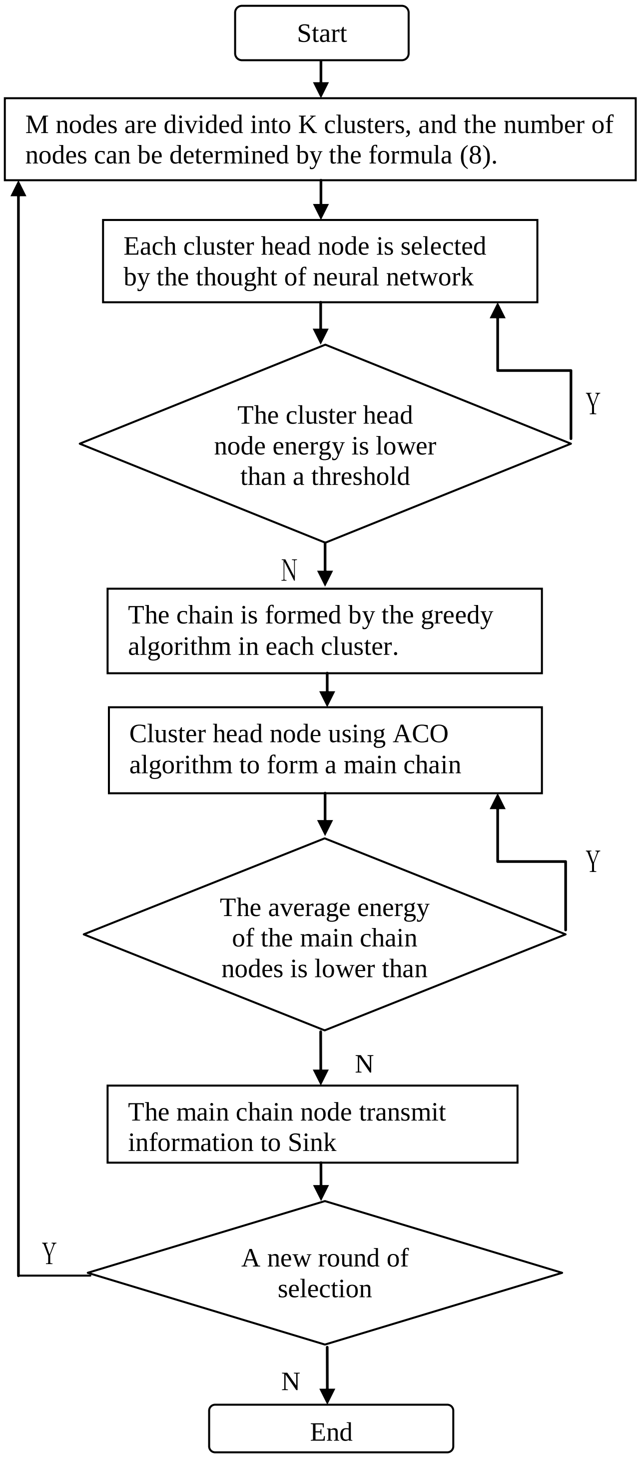

Figure 2. Flowchart of ACON-PEG Algorithm

5. Performance Evaluation

We use MATLAB to evaluate the performance of our proposed ACON-PEG algorithm. Hypothetically, 100 sensor nodes with the same initial energy are distributed randomly in a 200m×200m field. The simulation parameters are summarized in Table 5.

Table 5. Simulation Parameters

Parameters	Values
Base station Location	(50m,175m)
Number of nodes	100
Size of data packet	200bits
Initial Energy	2J
Round during	20s
Energy dissipation to run the radio device	50 nJ/bit
Multi-path model of transmitter amplifier	0.0012 pJ/bit/m4
Free space model of transmitter amplifier	15 pJ/bit/m2

In order to analyze the network performance, we compare our proposed ACON-PEG algorithm with conventional PEGASIS protocol. Figure 3 illustrates the comparison of them in terms of residual energy. From Figure 3, we can conclude that when abscissa varies from 80r to100r, the number of operation round has less influence on the residual energy of ACON-PEG, but the residual energy of PEGASIS changes very quickly. When the coordinates point from 100r to 120r, the residual energy of ACON-PEG and PEGASIS all change fast, however, when the coordinates point from 130r to 160r, the remaining energy of PEGASIS drops more quickly. The picture shows ACON-PEG is better than PEGASIS in the more experimental rounds .Therefore, in a given period of time, our proposed algorithm can save more energy and its residual energy is higher than that of PEGASIS.

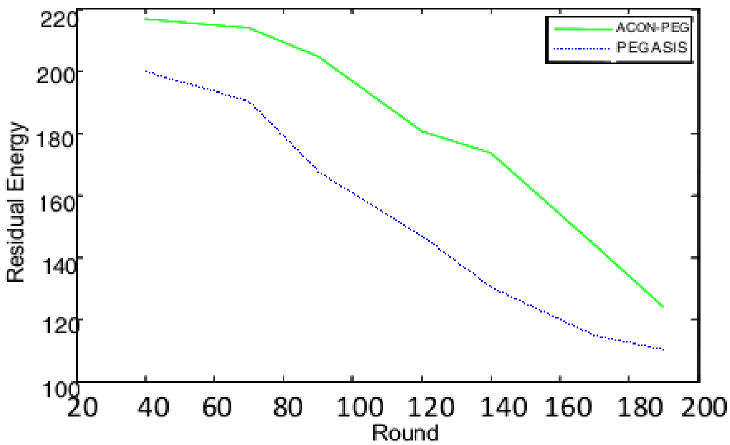

Figure 3. Residual Energy Comparison of ACON-PEG and PEGASIS

Figure4 shows the network lifetime of our proposed algorithm and LEACH with different rounds. The first lose efficacy node is at the 110th round by PEGASIS, however, the first lose efficacy node appears at the 190th round by ACON-PEG. In the network of PEGASIS, more than 25 percent of nodes have lost efficacy at the 150th round, and this situation appeared at the 180thround in the network by ACON-PEG. Nodes lost all of lose all energy at the 210th round in the network of PEGASIS, but nodes lost all of lose all energy at the 260th round in the network of ACON-PEG. It is clear that our proposed algorithm prolongs the network lifetime (both the time first node dies and the last node dies). So, the ACON-PEG protocol of life cycle is increased about 15%, and network robustness is increased about 2.4% than PEGASIS. The network lifetime can be prolonged. The round when first node and last node dies is listed in Table 6.

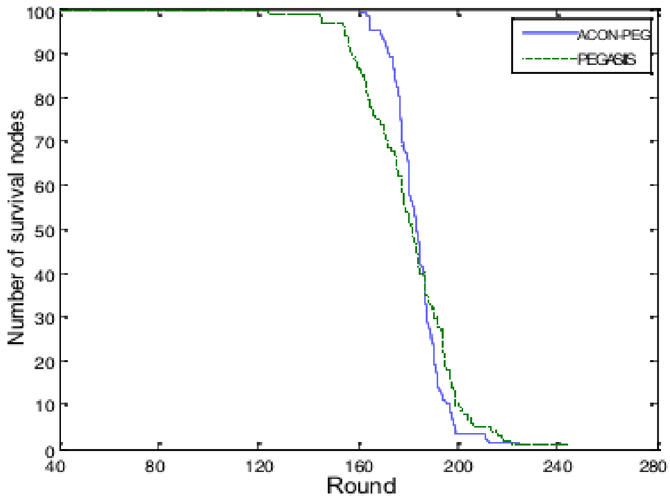

Figure 4. Lifetime Comparison

Table6. The Round when First Node and Last Node Dies

Algorithms	Rounds	
	First node dies	Last node dies
PEGASIS	120	210
ACON-PEG	190	260

6. Conclusions

In this paper, we have presented a PEGASIS routing protocol based on neural network and ant colony algorithm to construct the chain of the PEGASIS protocol. We describe the idea of our protocol in detail, and through the simulation experiment in MATLAB, the better performance of our protocol compared with the original PEGASIS which uses the greedy algorithm to construct the chain is validated. Our protocol takes the strength of pheromone and use thought of neural network which indirectly reflects the distance and residual energy into account to minimize the square sum of transmission distance and prolong the life cycle. Considering the energy factor in both chain building and leader selection, ACON-PEG reliably further prolong the life of WSN.

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