Sink mobile routing protocol for WSNs Based on PSO

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Keyword: Wireless Sensor Networks (WSNs); PSO; "hot spot" problem; network lifetime

Abstract: In model of multi- hop wireless sensor networks, if a cluster head is more close to the sink, it will have much more transmitting tasks, therefore a head more close by the sink will consume much more energy. A new mobile sink protocol based on Particle Swarm Optimization (PSO) algorithm is proposed. The next stay the best location of the sink is determined by PSO. The definition of the fitness function of particle is based on two factors: the distance of cluster heads to sink, the energy of cluster heads around the sink. The protocol adopts the combination of single-hop and multi-hop way to transmit data to the sink. Simulation results demonstrate that the protocol can efficiently solve the "hot spot" problem, balance the consumption of the entire network and prolong the network lifetime.

1 Introduction

In a multi-hop network model of clustering algorithm for wireless sensor networks, when sink remains stationary, the nodes near sink will die earlier than the others due to the larger data. It can lead to the result that the node far from sink will be disconnected and unable to transfer. Through there are still a lot of nodes, network life cycle ends prematurely. LEACH [1] and HEED [2] protocol are two typical protocols in Clustering algorithms. In order to solve the "hot zone" problem and extend the network life cycle, a series of balanced energy policies are proposed such as the non-uniform cluster-based routing protocol UCS [3] and ACOUC [4]. As the nodes around the sink do not change, the policies don't solve the problem basically. Some scholars propose moving the sink node, continuously changing nodes around the sink to avoid "hot spots". According to the sink node path of certainty, it can be divided into two categories. One is nodes moves according to the predetermined path such as the JMR proposed by Luo and the other is that the motion path of nodes can be selected dynamically such as the linear programming method.

Developed from the HEED protocol, a sink node protocol based on PSO is presented to solve the hot zone problem.

2 PSO algorithm

Particle Swarm Optimization algorithm (PSO) [5] is learnt from the motion of groups of birds and fish. It is an evolutionary computing method based on swarm intelligence. We can assume the position in d-dimensional space can be expressed as a vector $x_i = (x_{i1}, x_{i2}, \dots, x_{id})$, the best position of particles $x_{id} = x_{id} + v_{id}$ can be remembered as $P_i = (p_{g1}, p_{g2}, \dots, p_{gd})$. The flight velocity of each particle can be expressed as $V_i = (v_{i1}, v_{i1}, \dots, v_{id})$, $i = 1, 2, \dots, m$. The velocity and position [6] of each particle are shown as:

$$v_{id} = wv_{id} + c_1r_1(p_{id} - x_{id}) + c_2r_2(p_{gd} - x_{id}) \quad (1)$$

$$x_{id} = x_{id} + v_{id} \quad (2)$$

Where w is the coefficient of inertia; c_1 and c_2 are learning factor; r_1 and r_2 are the random number between 0 and 1.

Description of MSPSO protocol

MSPSO takes centralized control strategy and the algorithm is conducted in the infinite sink nodes. The protocol has the same reincarnation mechanism with the literature [2]. Each cycle consists of 3 steps, establishment of clusters, sink location and data transfer. The sink location can also be divided into 3 steps:

- (1) Collect various information about the clusters;
- (2) Use PSO algorithm to determine the next position of sink;
- (3) Publish sink node location information;

3 Sink nodes location

The clustering method of MSPSO is similar to HEED. After clustering, the sink nodes will collect the information of all the cluster heads which can help to judge the moving condition of sink node. If the node satisfy the condition, the PSO method will be conducted and the next position of the node will be determined. If not, the sink node will be unchanged.

3.1 Using the PSO algorithm to determine position of sink node

According to the energy information of each cluster head, sink will calculate the average energy of all cluster heads in the network. The moving condition of sink nodes are that the energy of cluster near the node is lower than the average energy of all cluster heads in the network.

PSO algorithm is used in this protocol to optimize the position of sink node. Objective function not only minimizes all the cluster head node distance to sink node but balances the energy consumption of clusters, which can improve the network lifetime. Necessary conditions for the next position of sink node are shown:

- (1) Sum distances of all cluster head to sink node is minimum;
- (2) Distances variance of all cluster head to sink node is minimum;
- (3) The sum energy of cluster head one jump and the two jump from the sink node is maximum;
- (4) The variance of the energy of cluster head one jump and the two jump from the sink node is minimum;

The objective function with which sink nodes implement PSO algorithm to determine the position for the next stop, is defined as:

$$\text{cost} = \partial_1 f_1 + \partial_2 f_2 + \partial_3 f_3 + \partial_4 f_4 \quad (3)$$

$$f_1 = \sum_{k=1}^K d(CH_k, \text{sink}) \quad (4)$$

$$f_2 = \frac{1}{K} \sum_{k=1}^K (d_{(CH_k, \text{sink})} - \bar{d})^2 \quad (5)$$

$$f_3 = \sum_{i=1}^n E(n_i) / \sum_{i=1}^K E(CH_i) \quad (6)$$

$$f_4 = \frac{1}{p} \sum_{i=1}^p (E_{CH_{near_i}} - \bar{E}_{CH_{near}})^2 \quad (7)$$

Where f_1 is the sum of Euclidean distance of all cluster head to the sink node; f_2 is the distances variance of all cluster head to the sink node; f_3 is the value of all the cluster head energy divides by the cluster energy near the node; f_4 is the variance of cluster energy near the sink node; $\partial_1, \partial_2, \partial_3, \partial_4$ is the weighting factor, $\partial_1 + \partial_2 + \partial_3 + \partial_4 = 1$; According to the definition of the objective function, the minimum value of the function is the next best place of sink node.

PSO method is shown as follows:

- (1) Initialize Q particles and each particle contains k positions which represent the next location of sink nodes;
- (2) Use equation (3) to (7) to calculate particle fitness;
- (3) Determine the optimal solution of optimal solution and population of each particle

- (4) Use equation (1) and (2) to update the particle's velocity and position;
- (5) Determine the optimal solution of each particle and population of particles;
- (6) Repeat steps (2) to (5) until it reaches the maximum number of cycles;

3.2 Sink information release

After the sink node determines the position of the next move, it will release its position information to the cluster head[7].

3.3 Steady-state phase

In the steady- state phase, the cluster head firstly completes the mission of collecting and merging the data which is same with literature [2]. Then the data will be transfer to the sink node through multi-hop routing which is also same with literature [2].

4 Simulation and analysis

4.1 Energy consumption model of wireless communication

This paper uses first - order model for wireless communications. In the model, the wireless communication module can control power and send the data to the receiver with minimum energy. To ensure a reasonable signal to noise ratio, the energy consumption of data sending can be expressed as follows:

$$E_{Tx}(k, d) = \begin{cases} E_{elec} \times k + E_{fs} \times k \times d^2 & d < d_0 \\ E_{elec} \times k + E_{mp} \times k \times d^4 & d \geq d_0 \end{cases} \quad (8)$$

Where k is the number of bits sent; d is the sending distance; d_0 is the transmitting distance threshold; $E_{elec}(nJ/bit)$ is the RF energy consumption coefficient; $E_{fs}(pJ/bit/m^2)$ and $E_{mp}(pJ/bit/m^4)$ are the coefficient of energy consumption of the power amplification circuit with different channel propagation model.

$$\text{Node energy consumption for receiving data: } E_{Rx}(k) = E_{elec} \times k \quad (9)$$

During the simulation, Energy consumption model parameter is set as $E_{elec} = 50 nJ/bit$, $E_{fs} = 10 pJ/bit/m^2$, $E_{mp} = 0.0013 pJ/bit/m^4$ and $d_0 = 87m$.

4.2 Data fusion model

In the data fusion model, the assumption is that the data sent by each cluster head has k bits and no matter how many bits the cluster has, it will be compressed to k bits. The energy consumption is set as $E_D = 5 nJ/bit$.

5 Simulation result and analysis

In order to validate the effectiveness of the protocol, MATLAB is used to generate 100 nodes which are distributed in an area of $100m \times 100m$. The initial coordinate of the sink node is (50, 50). The energy of each node is 1J. The parameters of PSO method are shown as follows: population size is $Q = 30$ and $c_1 = c_2$; Inertia weight change over time ranges from 0.9 to 0.4; weighting factor is $\partial_1 = \partial_3 = 0.3, \partial_2 = \partial_4 = 0.2$; maximum iterations is $r_{max} = 3500$.

The simulation compares the LEACH, LEACH-C and MSPSO. Figure 1 shows the comparison of the three protocol. According to the figure, the network lifetime of MSPSO is longer than LEACH and LEACH-C. When the cycle reaches to 1000, the nodes begin to die in LEACH and LEACH-C. However, in the MSPSO, the node will not die until the cycle reaches to 1500. The result indicates that the energy consumption in MSPSO is more balanced than the others. When the cycle reaches to 1700, the distribution of dead nodes is shown in Figure 2. The dead nodes in MSPSO are equally distributed however the dead nodes in LEACH and LEACH-C concentrate in the hot zone.

Fig2 Number of dead nodes over time

Fig3 Distribution of dead nodes

6 Acknowledgement

On the clustering method in HEED, this paper optimizes the sink node position using PSO algorithm. Through intergenerational search in a group of particles in the solution space, optimal sink location will be found. The simulation results show that compared with LEACH and LEACH-C, this method can balance the energy consume and reduce the death rate of the nodes which can improve the network lifetime.

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