Maximize the Life Time of Wireless Sensor Network

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Abstract
A wireless Sensor Network (WSN) consists of low cost, low power, small in size and multi functional sensor nodes. Routing protocols in WSNs emphasize on data dissemination, limited battery power and bandwidth constraints in order to facilitate efficient working of the network, thereby increasing the lifetime of the network. Routing protocols in WSNs are also application specific which has led to the development of a variety of protocols. This paper presents an energy-efficient wireless sensor network routing algorithm IQEA based on the improved quantum evolutionary algorithm. The algorithm will divide the network into multiple clusters, and in the building cluster process, we consider the residual energy of the node and the distance from the target node, because these are the keys to balance the consumption of whole network energy. Each node within the cluster is formed into a multi-hop route, then by improving the quantum evolutionary algorithm to reduce the total distance of the link, and then come to the best clustering method.

Keywords
Wireless Sensor Networks, Routing Protocols, Energy Efficient Protocols

I. Introduction

A wireless sensor network consists of a large number of tiny, low-powered, energy-constrained sensor nodes with sensing, data processing and wireless communication components. Sensor nodes in WSN are small battery powered devices with limited energy, combined with wireless sensor networks are often run in the harsh environment, so their batteries cannot be recharged. Once the batteries run out of energy, the nodes can not continue to work (death). Because the energy is limited and not easy to replace, so how to reduce the energy consumption and prolong the network lifetime have became the core issue in wireless sensor networks. Routing protocol is the key technology in wireless sensor networks, wireless sensor networks own characteristics for the research of routing protocol put forward new technical problems.

One of the most important goals of designing the routing protocol is to reduce the node energy consumption and prolong the network lifetime. Therefore, minimizing energy consumption is an important issue in the design of WSN. Cluster routing is an effective solution in reducing energy consumption, prolonging the lifetime of the networks and providing network scalability. In the cluster routing, sensor nodes are divided into groups and form clusters. Each cluster has a leader, often referred to as the cluster head. Each cluster head can collect the data from nodes in the cluster, integrate those data and send them to base station. Through data fusion, the total amount of data transmitted to the base station will be significantly reduced. It also saves energy and bandwidth resource.

II. Existing System

LEACH is a classic cluster-based, hierarchical routing algorithm for the fully distributed wireless sensor network (e.g. [2-3]). LEACH randomly choose the cluster head, and through cluster head to distribute the energy of the entire network evenly to each sensor node, use data fusion and compression technology to process data, reduce traffic, which can reduce network energy consumption, extend the lifetime of the entire network. But LEACH assumes that all nodes can be directly related to the cluster head and communicate with cluster node. All communications are single-hop, and its over-reliance on random numbers, therefore it is not applicable in large-scale network.

PEGASIS algorithm through a long path to link nodes within the network, the fusion data are sent to the unique cluster head along the path in multi-hop, and ultimately sent to the base station. This can reduce the distance which is from the node that is to transmit data, and reduce the number of receive data of cluster heads and energy consumption throughout the network. However, the algorithm is a single cluster architecture to increase the network delay, there is a single point of failure risk, but also greedy algorithm used to build links, easy to fall into local optimal solution, so the path at the end of the node spacing is too long, affecting the network of lifetime (e.g. [4]). Considering the advantages and disadvantages of LEACH and PEGASIS, as for the shortcomings of them, a clustering routing algorithm based on the improved quantum evolutionary algorithm is proposed.

III. Proposed System

A. Network Model and Energy Model

We assume that sensor nodes randomly distribute in the M×M square area, and base station deployed out of the area. Nodes have the following properties.

- All sensor nodes once started are rest and time synchronization.
- All sensor nodes are the same type, with power control capability, and they have limited energy and a proprietary ID logo.
- A communication connection is symmetric, the distance of the originator and the receiver can be estimated.

The sensor nodes energy consumption module including a sensor module, a processor module and wireless communication module, etc, where in the wireless communication consumes the most energy, (e.g. [5]). Node sends the l bit data to the distance d receiver, the energy consumed by the transmitting circuit loss and power loss is composed of two parts, as the formula shown below:

$$E_{TX} = \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2, d \le d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4, d \ge d_0 \end{cases}$$

Where Eelec is the wireless transceiver circuit energy consumption, εfsd^2 and εmpd^4 are the energy consumption required by the signal amplifier, if $d<d^0$, nodes in the transmission of data using the free space channel model, else if $d>d^0$, using the multipath fading channel model.

The receiver that receives l bit of data requires the energy:

$ERX(l)=Eelec$ (l)

In the WSN, cluster head need data fusion, we assume the energy consumption of data fusion is EDF.

B. Construct Network Route

Firstly, we can calculate the optimal topology by the improved quantum evolutionary algorithm, internal network nodes according to the topological structure to complete the corresponding clustering and the path of cluster establishment. Then, choose the cluster. In LEACH, the single hop route selection mode is used to replace the multihop path choice model. We regard others cluster head nodes as transit nodes, which produces a cluster head nodes to constitute a link, then selecting a cluster head from the cluster head chain communicating with the base station, named it by "parent node". For the method of data transmission, use the way of PEGASIS.

C. Mathematics Model

We assume that the network contains N nodes, and these N nodes are divided into m clusters. Each of clusters has a path that can traverse nodes in the cluster. Defining the distance between any two nodes i, j as dij, the target of solution is to minimize the sum of the squares distance between nodes.

The mathematical model (e.g. [6]) is as following:

$$\min(G) = \min\left(\sum_{k=1}^{m}\sum_{i=1}^{N}\sum_{j=1}^{N} d_{ij}^{2} w_{ijk}\right)$$

Where G is objective function,

$$w_{ij} = \begin{cases} 1, k \in i \to j \\ 0, k \notin i \to j \end{cases}$$

$$\mu_{ik} = \begin{cases} 1, i \to k \\ 0, i \mapsto k \end{cases}$$ are variables. And

In order to constraint each node is accessed by only a

$$\sum_{k=1}^{m} \mu_{ik} = 1, i = 1,2,\ldots,N$$

path, we assume We also assume that

$$\sum_{i=1}^{N} w_{jk} = \begin{cases} \mu_{jk}, else \\ 0, \quad i \in D, k = 1,2,\ldots,m \end{cases}$$

and

$$\sum_{j=1}^{N} w_{ijk} = \begin{cases} \mu_{ik}, else \\ 0, i \in A, k = 1,2,\ldots,m \end{cases}$$

to eliminates on loops

Where A is the set of the source nodes, D is set of the target nodes.

1. Improved Quantum Evolutionary Algorithm

The Quantum Evolutionary Algorithm (QEA) is an intelligent optimization algorithm that combines with quantum mechanism and basic evolutionary algorithm (e.g. [7]). In order to obtain the optimal solution of the mathematical model, the traditional quantum-inspired evolutionary algorithm is improved. The convergence speed of improved algorithm is improved, at the same time; the global searching ability is enhanced.

2. Quantum Coding

When the algorithm evolves to t generation, P(t)= {p1 t,p2t, …, pnt} is a quantum group, where n is the scale of group, and defining Best(t) as the best individual in the group(e.g. [8]). For the convenience of operation, we assume real numbers α, β are corresponding state probability.

The quantum bits Ψ is expressed as follows:

$|\Psi\rangle = \cos(\theta)|0\rangle + \sin(\theta)|1\rangle$

We assume that each of quantum individual p includes a set of quantum bits R, a 0-1 observation matrix M and a sequence of array S. Where R is a three-dimensional matrix (L=N+m-1), and its size is L * L * 2. M is a two-dimensional matrix (L * L) that is composed by observations obtained from R; and S is a L length sequence array, obtained by matrix M decoding through the observation, used to express route path arrangement. Considering the normalization conditions of α, β, in this, only α component operation is described, steps are as follows:

- Generate a temporary component α' for α and a L length of longitudinal random of sequence Sq1;
- According to the sequence of Sq1 , operate the i line of α, and then get a random number α belonging to [0, 1] and a L length of the transverse random sequence Sq2;
- According to the sequence of Sq 2 choose the corresponding column j from α, and then observe α′ij in the α′, if |α′ij|2 is lager than the value of random number a, then the corresponding location is set to 1 in the matrix M, while return the i line, the j column of α to zero, continue the next step. Otherwise choose the next number from Sq2, and go to the third step;
- If Sq 1 is executed to final, then end the operation. Or jump to the second step, select the next number from Sq 1 to continue.

After the above operation, we will finally observe that the matrix M, each row and each column there is only a 1. 1 of the matrix coordinates as the order of line in path; the first N columns of the vertical axis represent the number of nodes, next the m-1 column data that represent path delimiter 0, so the arrangement of the sequence array S for the path can be shown.

3. Update the Quantum Gate

According to the appropriate change of quantum gate obtaining the new species p(t), commonly used quantum gate transform matrix includes exclusive-OR gates, Hadamard gates transform and the revolving gates(e.g. [9]). By comparison, the quantum rotation gate is suitable for solving combinatorial optimization problems, so using the quantum rotation gate to achieve the status updates. And we will carry on some improvement before use it.

Introduced the reward function f(x), according to certain rules, gave proper incentives to bits that promoted the evolution in prior knowledge, other bits were punished, and thus speeding up the convergence of quantum bits.

Used the optimal retention mechanism to retain the best individual, as updating rotation angle of quantum rotation gate, to replace the Genetic evolutionary Algorithm (GEA) with current best individual updated method of quantum gate.

Based on the optimal strategy in the genetic algorithm, each time the first n species were crossed, rearranged , migrated to generate new x species, and observed these (n+x) species. According to the fitness function taking the first m (m≤ n) most elite group to achieve the optimal species expansion and expand the search range of species. In the remainder of the species used a certain probability to select (n-m) species and added them into the optimal species, and improved species diversity.

D. Calculate the Degree of Adaptation

In order to get the path code, the quantum individual should be observed and decoded after each time when the quantum location has been updated. According to the objective function value G

can calculate the degree of adaptation F:
F=1/G

E. Solving Steps

According to the improvement strategies of quantum evolutionary algorithm, the solving procedure is as follows:

- Initialize the quantum species;
- t=1, start observing the species, and obtain the degree of adaptation, record the optimal species and add its observations into Best (t);
- t=t+1, through the crossover operation, generate C×NN new species (C is the species expansion coefficient);
- Rearrange the new species (set probability of rearrangement), and then migrate internal of species (set migration probability);
- When complete the t times of observation, calculate the fitness of the species. And Compared with the t-1 times observation results, put the optimal observational species and add its results into Best (t);
- Sorting all C×N species, taking the maximal first N-b (b is varied coefficient), and then in the remaining species by annealing selection probability, select b individuals into the best individual, maintain the number of optimal individual in the observations is N. The annealing selection probability obtained by formula is as follows:

$$P(x_i) = \frac{e^{f(x_i)/T}}{\sum_{i=1}^{N-b} e^{f(x_i)/T_i}}$$

Where f(xi) is the fitness of observation species, Ti is Annealing temperature.

To compare the best of observation individual with Best (t), search for the table of quantum rotation gate, update the N optimal individual of observation.

To determine whether they meet the end conditions or not. If it is yes, then quit the algorithm, and export the result. Otherwise, go to the third step.

1. Cluster Head Selection Strategy

The selection scheme for cluster head using the minimum spanning tree strategy (e.g. [10-11]). Assuming the existence of 100 nodes uniformly distributed in the 100×100 area, divided into 10 clusters, sink node position is located at (50,150). We use a method that is the perpendicular direction of regional center between paths and sink nodes

In order to balance energy consumption of cluster head nodes, considering the residual energy and the distance to target node and other factors, we improved the cluster head selection scheme.

Cluster head selection steps as follow:

- Select a node with high ratio of residual energy and the distance to the base station within the network as cluster head node, and add it to the cluster head chain;
- At the end of the cluster head chain circular as target node, from the chain of cluster head which has not yet joined the cluster select nodes to find the minimum weight as the cluster head node, then add it into the cluster head chain, at last form a cluster head chain.

Weight calculation formula is defined as:
W= E/d2
Where d is a distance to target node, E is residual energy of the node.

IV. Conclusion

Routing algorithm has already been used as a way to improve energy efficiency and increase the scalability of wireless sensor networks. For energy-efficient routing algorithm based on improved quantum-inspired evolutionary algorithm, each node not only balances the load of energy consumption, but also improves the reliability of the entire network.

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