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Research on Improved Routing Algorithms of Wireless Sensor Network

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Abstract: Because of the influence of energy consumption of wireless sensor network, the location information of nodes in wireless sensor networks is very important, the current general localization algorithm is not suitable for harsh environment. This paper proposes a scheme based on the ranging node localization to improve the overall performance of the network. The routing algorithm is designed to directly affect the energy consumption of the system, in order to prolong the network lifetime, an improved LEACH routing algorithm was proposed. In the cluster head selection phase, using the residual energy of cluster head node selection mechanism to avoid low residual energy node to be cluster head, then the data transfer phase, using single-hop and multi-hop hybrid transmission mode, to balance the whole network energy and prolong the life of the entire network. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Wireless sensor network, Positioning design, Energy-efficient, Cluster head selection, Routing algorithm.

1. Introduction

Sensor nodes with limited battery life and can't be replaced, limited energy and computing power is an important feature of the sensor, and the routing algorithm designed to survive a direct impact on the efficiency of energy consumption of sensor nodes and networks. Therefore, research on node localization and routing scheme has become a hot issue in wireless sensor networks.

Many routing algorithm is based on the energy chart enhance routing sensor network technology used by the development of new technologies, such as spectrum aggregation packet stream to form traffic [1]; focuses on some other method by taking the minimum cost path [2], or considered as a linear programming problem [3], and some studies concern the diffusion routing protocols assume minimal overhead for synchronous communications, to try to extend the life of the system. However, the factors considered in these programs are too simple and little practical value. This paper presents a localization solutions in harsh environment, adopt effective mechanisms of sleep, and energy consumption as the main metric to a method of generating a minimum cost path routing, optimizing the overall performance of the network. Since wireless sensor networks produce, in-depth study of its routing algorithm. Currently, there are two routing algorithms, which are flat routing and clustering routing, has being proposed by scholars [4, 5]. Flat routing algorithm structure is simple, easy to implement, requires more storage space, only suitable for simple, small-scale wireless sensor networks [2]. Clustering routing algorithm is the entire network into clusters, each cluster has a cluster head, scalability is a major current routing algorithm for wireless sensor networks [3].

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LEACH (low-energy adaptive clustering hierarchy) algorithm is the first clustering routing algorithm, LEACH algorithm is using to solve a certain extent, a flat storage space occupied by the routing algorithm more defects and poor scalability, effectively extending the lifetime of the entire network [4]. LEACH algorithm is mainly based on the existence of the problem is: First, do not consider the residual energy of sensor nodes, the remaining energy is less sensor nodes increase the probability of becoming a cluster head node, thus reducing the network lifetime. Then, data transmission using single or multi-hop single means of communication, so that some of the energy cluster head prematurely exhausted, network energy imbalance. For current wireless sensor network routing algorithm problems in this paper provides an improved LEACH routing algorithm, focused on solving the residual energy of sensor nodes become less cluster head node and inter-cluster communication problems, so that the whole network load more evenly, thus prolonging the whole wireless sensor network lifetime.

2. Energy-saving Optimization of Routing Algorithms

Usually due to frequent participation in active sensor detection and data transmission, it consumes a lot of energy, in order to avoid energy waste sensor detects if a job requires only part of the sensor can be completed, it is not necessary to activate all of the sensors, allowing part of the sensor in sleep. For example, the base query message issued humidity (Humi, Range), which means that the query Humi humidity, Range indicates that the query range, the sensor receives the message, extract the two query value, if they meet the conditions (both within the range of the humidity sensor check again), then activate and start testing work; otherwise, it will turn off the transceiver device goes to sleep, the next sleep / active cycle (by the system according to the specific application requirements decision) when the arrival of a new re-awakening to listen query message.

Some features of the sensor is only necessary when it is turned on, such as the method of literature for which grading security components of the sensor settings and demand starts, you can ensure that the system under the premise of safety, try to save energy consumption [6]. When the remaining energy of the sensor is below a predetermined threshold value can go to sleep, until the latter part of the emergency network lifetime use. When the network into late life, very few number of active nodes, it is difficult to support the normal functioning of the entire network, this time, the station will broadcast a request message requesting all nodes involved in the work. Sleep node receives the message at the time of the periodic wake, will enter the active state, has been working to energy depletion and death.

The above method can be very effective in saving the energy consumption of the network. The network is organized in clusters manner, the sensor nodes join the cluster according to the type of location information, each cluster having a cluster head. The first cluster is only valid within a particular cluster period ‘t’, t values can be pre-determined based on various factors. In a hostile environment for the exchange of information may be lagging in, ‘t’ values may be larger; in case of need for timely delivery of information, ‘t’ values may be small; ‘t’ value must be greater than RTT / 2 (RTT is a sensor node round-trip time of the first cluster communication), the value of RTT is usually based on the simulation results, the average estimate in advance to take out. Cluster head at least during the time t is strong, when the first cluster fails, another cluster head sensor will promptly take responsibility.

3. Routing Algorithm for Wireless Sensor Networks to Extend Life Time

3.1. Basic Idea

Since wireless sensor networks produce, scholars in-depth study of its routing algorithm. There are currently clustering routing plane and two routing algorithms [7, 8]. Flat routing algorithm structure is simple, easy to implement, requires more storage space, only suitable for simple, small-scale wireless sensor networks [9]. Clustering routing algorithm is the entire network into clusters, each cluster has a cluster head, scalability, is currently the main routing algorithm for wireless sensor networks [10]. LEACH (low-energy adaptive clustering hierarchy) algorithm is the first clustering routing algorithm, LEACH algorithm to solve a certain extent, a flat storage space occupied by the routing algorithm more defects and poor scalability, effectively extending the lifetime of the whole network [11].

The main problem about the network which based on LEACH algorithm is: First, not consider the residual energy of sensor nodes, the remaining energy is less sensor nodes increase the probability of becoming a cluster head node, thus reducing the network lifetime. Then, data transmission using single or multi-hop single means of communication, so that some of the energy cluster head prematurely exhausted, network energy imbalance [12]. For current wireless sensor network routing algorithm problems in this paper provides an improved LEACH routing algorithm, focused on solving the residual energy of sensor nodes become less cluster head node and inter-cluster communication problems, so that the whole network load more evenly, thus prolonging the whole wireless sensor network lifetime.

3.2. System Model

3.2.1. Wireless Sensor Network Model

Assuming network monitoring area is a square area of side length is M, a total of N sensor nodes randomly distributed in which the base is located outside the sensor area, and only one. Meanwhile, the wireless sensor network should have the following characteristics:

1) After the base station and sensor nodes deployed, can't be moved, that is stationary.

2) Adequate energy base, each sensor node has a unique ID number, the same initial energy, and energy can't be replenished.

3) The communication distance between the sensor nodes and the base station can be tested out by the signal strength. And can dynamically adjust the transmission power according to the distance.

3.2.2. Energy Model

Wireless sensor node energy consumption is consumed mainly in data transmission, during data transmission, node transmission distance is 'd', the consumed energy for transmission of 1 KBit data is:

$$E_{Tx}(k,d)=\begin{cases} E_{Tx-elec}(k)+E_{Tx-amp}(k,d) & (d<d_0) \\ E_{elec}\left|\times k+\varepsilon_{amp}\times k\times d^{2}\right. & (d\geq d_0) \end{cases} \quad (1)$$

Wireless sensor nodes receiving energy consumption for 1kbit data is:

$$E_{Rx}(k)=E_{Rx-elec}(k) \quad (2)$$

$$E_{Rx}(k)=E_{elec}\times K \quad (3)$$

In the formula, ε_{amp} is the magnification of signal amplifier, E_{elec} is indicated that the sending circuit and receiving circuit energy consumption.

3.2.3. Mathematical Model of Life Time for Wireless Sensor Networks

Wireless sensor network survivability is generally defined as the effective data collection rounds, denoted by $LT(lifetime)$, LT specifically described as follows:

$$LT=f(\mu,\zeta), \quad (4)$$

where μ is the mean energy consumption, ζ is a measure of energy consumption distribution function.

4. Improved LEACH Routing Algorithm for Wireless Sensor Networks

4.1. The Design of Residual Energy Level for Sensor Nodes

For a better comparison between the residual energy of sensor nodes, this paper provides the concept of residual energy levels of sensor nodes. To the initial energy of the wireless sensor node, the initial energy is divided into levels, each level represents the energy, then:

$$E_{plevel}=\frac{E_0}{m} \quad (5)$$

When the wireless sensor network is in the initial state, the residual energy of the individual sensor nodes are level with the energy consumption of sensor nodes, each sensor node remaining energy level of the energy will be reduced, at some point node 'i' in a wireless sensor network the residual energy levels are:

$$ELE_{i\_cur}=[\frac{E_{i\_cur}}{E_{plevel}}], \quad (6)$$

E_{i_cur} represents the current node residual energy. Therefore, the remaining energy level at any time between the sensor nodes. In wireless sensor cluster head selection, improved LEACH routing algorithm to determine the priority level based on the current residual energy of sensor nodes.

4.2. Cluster Heads Selection based on Priority of Sensor Network

In the traditional LEACH routing algorithm, using random selection of cluster head, cluster head is easy to focus on one area, uneven distribution of cluster head, cluster head nodes distance too far premature exhaustion of energy. Secondly, for while selecting the cluster head, without considering the residual energy of sensor nodes in the network, can't prevent the node residual energy of cluster head nodes become wireless network [13]. In order to solve these two problems, this paper considers the residual energy levels of sensor nodes to the cluster head selection, is controlled by a sensor node priority delay on the sensor node sends the cluster head election news, sensor node residual energy level increases higher chance of becoming cluster head nodes, at the same time by election broadcasting radius on the cluster head of reasonable standard, ensure that the cluster head distribution is more uniform and reasonable, so that the entire wireless sensor network is prolonged survival.

4.3. Establishment of the Clusters

A wireless sensor network cluster is the sensor nodes to select the best cluster head nodes, and join messages sent. In the traditional LEACH routing algorithm, each sensor node selects the nearest cluster join, this method does not consider the load with low residual energy of cluster head. This paper introduces the residual energy of sensor node and selects the best cluster head index, if the sensor node receives only a cluster head node campaign message, so the sensor node is sent to the corresponding cluster head nodes join message. If you receive a plurality of the cluster head node campaign message, calculates each cluster head weight value, select the sensor node weight minimum (maximum energy), the nearest cluster head as the best cluster head, and sends a message to the cluster head node. Define the weight functions are as follows:

$$w(N_k, C_i) = \frac{d(C_i, N_k)}{d_{\max}(C, N_k)} + 1 - \frac{E_{res}(C_i)}{E_{\max\_res}(C_k)}, \quad (7)$$

where N_k is the member of the sensor node, $d(C_i, N_k)$ is the distance of cluster head node set ' C_i ' to the cluster head sensor node ' N_k ', $E_{\max\_res}(C_k)$ represents the maximum residual energy of cluster head nodes in the cluster head set.

When each received a sensor node join message, the cluster head node is sent to the sensor node confirmation message, and for the members to assign time slots to nodes, the nodes in its own time slot can send data to the cluster head node, the other time dormant. When all the members of the sensor nodes are added to the cluster, the cluster head nodes broadcast routing messages, each cluster head node access to the relevant information to neighbor cluster head node, cluster establishment phase is over.

4.4. Method of Data Transmission Between Sensor Nodes

Data transmission between sensor nodes are divided into two types: communication within the cluster communication between sensor nodes and cluster. The intra cluster communication sensor nodes to a single hop data transmission mode of traditional LEACH routing algorithm. Transmission mode of inter cluster data transmission using way of single hop and multi hop combination. The cluster head sensor node residual energy level under the first jump of cluster heads and their own, if the residual energy level of residual energy level next hop cluster head above the cluster head node, or by using multi hop mode to send data to the base station, the cluster head nodes, through single hop mode data directly to the sent to the base station. The basic process of LEACH routing algorithm in data transmission phase improved as follows:

1) In the time slot assigned, cluster sensor nodes will collect data in a single hop transmission of cluster head nodes, not in the time slot assigned, cluster sensor nodes in a dormant state, when the sensor nodes in the cluster of data collection is completed, to the cluster head node will receive a data fusion.

2) According to the formula (8), the cluster head node ' C_i ' from the candidate cluster head selection of a higher level of residual energy and the distance from the base station than their more recent cluster head as the next hop cluster head:

$$C_{i\_CH} = \begin{cases} C_j \,|\, d(C_j, BS) < d(C_i, BS) \\ \wedge\, d(C_i, C_j) < d(C_i, BS) \\ \wedge\, REL_{C_{i\_cur}} \geq REL_{C_{i\_cur}} \end{cases} \quad (8)$$

3) If it is empty, then that candidate cluster head node residual energy level is lower, or the distance from the base station than the farther, the cluster head node directly transmits the data to the base station.

4) If C_{i-CH} has only one candidate cluster head node ' C_j ', then choose the next hop node as cluster head ' C_j ', and transmits the data to the cluster head ' C_j ', and jump to step (2).

5) If there are multiple candidate cluster head node belong C_{i-CH}, then select a data transfer overhead from the smallest cluster head node as the next hop node, and the data is transmitted to the text of the cluster head, overhead is calculated as follows:

$$cost = d^2(c_i, c_j) + d^2(c_j, BS) \quad (9)$$

6) The base station receives the data sent from the cluster head node ' C_i '.

4.5. Flow Chart of Wireless Sensor Routing Algorithm

Compared to traditional LEACH routing algorithm, this paper improved algorithm based on the difference between the residual energy level of the candidate cluster head sensor nodes and cluster head sensor nodes, and the use of single-hop and multi-hop hybrid transmission combines the energy consumption more evenly distributed sensor nodes in the cluster head, the distance from the base station to prevent the premature death of sensor nodes farther, effectively extending the lifetime of the whole wireless sensor networks. Improve LEACH routing algorithm for wireless sensor is shown in Fig. 1.

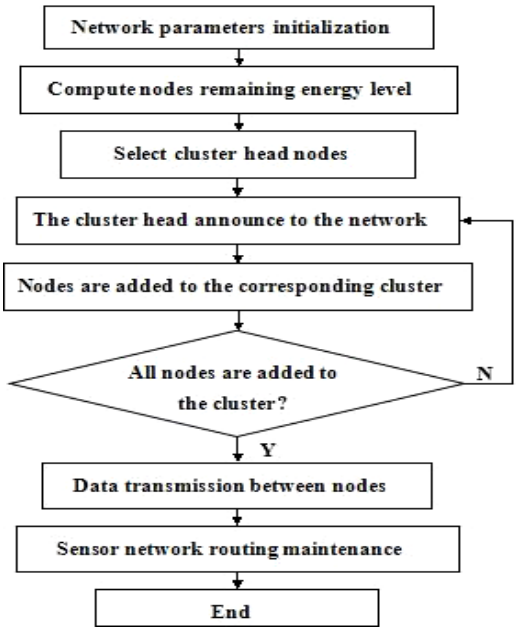

Fig. 1. The improved LEACH routing algorithm workflow.

5. Simulation Study

5.1. Simulation Environment

There provided a wireless sensor network node 100, sensor nodes are randomly distributed in the monitoring area 100 m × 100 m, the initial energy of each node 2 J, each node has to know the coordinate sensor, the network bandwidth is 2 m/s, the length of the message is 500 byte, the node distribution as shown in Fig. 2.

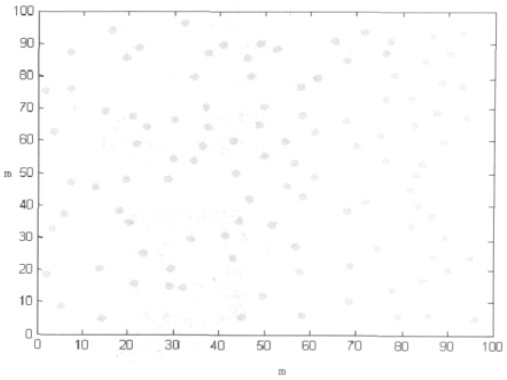

Fig. 2. Deployment of wireless sensor nodes.

5.2. The Relationship Between Initial Node Energy Level and Life Time of the Network

The initial energy level of m values of wireless sensor nodes have an important effect on the performance of network routing algorithm, so the first test value much best, relationship network survival time of wireless sensor nodes and the initial energy level as shown in Fig. 3. From Fig. 3, when the initial energy level is very small, the survival time of the network is very short, the best value is greater than 100, so that the network lifetime is longer, and relatively stable, so the simulation value is 100.

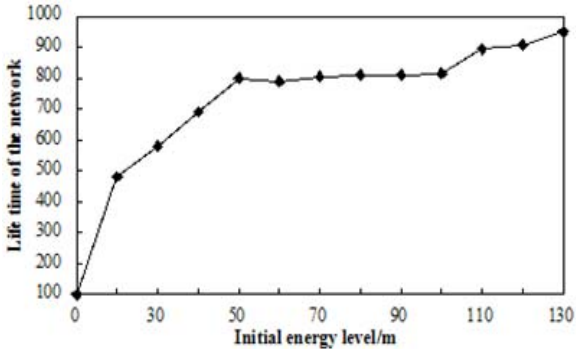

Fig. 3. Relationship between initial energy level and life time of the network.

5.3. Analysis of Network Survival Time

Under the same conditions, were running 100 simulation of the improved LEACH routing algorithm and the traditional LEACH routing algorithm. The network lifetime is defined as the death of sensor nodes accounted for 50 % of the total number of sensor nodes when lasts a number of rounds, sensor nodes and sensor nodes below its initial definition of death energy for the residual energy of 80 %. The number of dead nodes two algorithms each wheel running process is shown in Fig. 4.

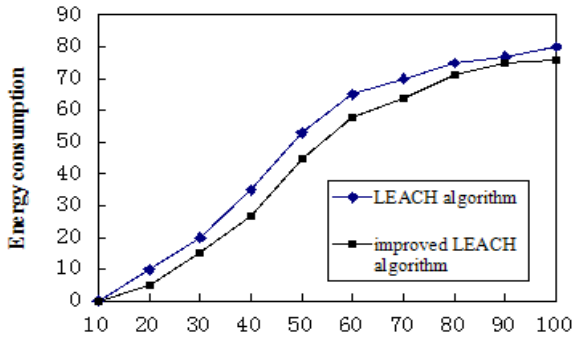

Fig. 4. The number of dead nodes of the two algorithms.

From Fig. 4, the improved LEACH routing algorithm in the 10 round before the death of sensor nodes, but the traditional LEACH routing algorithm in about first round when he appeared the death of sensor nodes, traditional LEACH routing algorithm runs the 55 round, 50 % sensor nodes is dead, so that in accordance with the definition of network lifetime, the whole wireless sensor network death. While the LEACH improved routing

algorithm in the 65 round of the time, the whole wireless sensor network to death, this algorithm can significantly prolong the survival time of the network, is mainly due to the improved LEACH routing algorithm considering the cluster head sensor node residual energy, and with hybrid transmission mode single hop and multi hop combination, the energy consumption of the whole network is more balanced, prevent premature sensor nodes to the death, prolong the survival time of wireless sensor network.

5.4. Test and Analysis of Energy Consumption

Fig. 5 shows the node LEACH algorithm improved the average energy consumption percentage, from Fig. 5, two routing algorithms with the running wheel to increase the number of sensor nodes, the average energy consumption increased, but in the same round number, the average energy consumption of traditional LEACH algorithm, mainly because it does not consider the remaining energy of the nodes, once again to prove the effectiveness of this algorithm.

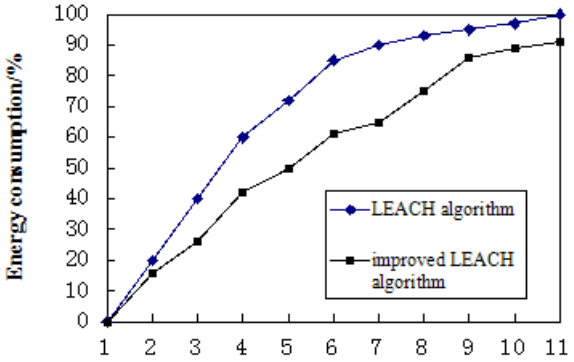

Fig. 5. Average energy consumption of the nodes of the two algorithms.

6. Conclusions

As the wireless sensor network nodes with limited battery power, and efficient use of energy is very important, through a least-cost routing algorithm path as the best path, the lowest cost saving mechanism established paths. By adopting the sleep / active, selective opening function and other means, greatly saves the energy consumption of sensor nodes. Routing algorithm of wireless sensor network is the focus of current research, aiming at the defects of the traditional LEACH routing algorithm, the improved LEACH routing algorithm can effective use the energy of nodes in wireless sensor network, balancing the energy of sensor network, prolong the life time of wireless sensor network.

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