An Optimized LEACH algorithm in Wireless Sensor Network

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***Abstract*—LEACH algorithm as a classic clustering algorithm is widely used in wireless sensor networks, but not considers the number of cluster head, monitoring areas and other factors, and the network greatly huge consumption reduces the life cycle of the network. To this defects, on the basis of the optimal coverage theorem in Wang, a kind of CDE-LEACH algorithm is proposed, which pre-built data table to storage optimal coverage location coordinates of the ideal cluster head in the base station, and to combine with the guarantee of minimum network energy consumption goal to select the optimal cluster head, and to improve drawbacks of randomly selected cluster head of the LEACH algorithm. Experimental simulation platform of the Matalab7.0 is set up, the CED-of LEACH algorithm simulation is compared with LEACH algorithm results. The network energy consumption is greatly reduced, and the network life cycle is prolonged.**

Keywords-LEACH; energy consumption; life cycle; wireless sensor network

I. INTRODUCTION

As a new information technology, wireless sensor networks now have become one active research branch in the field of computer. Because wireless sensor networks have a feature of limited energy, the existing wireless routing technology does not fit for sensor networks[1,2]. So, it is the focus of the research on the routing protocols of the wireless sensor networks. Continuously come forth in technology of computer, network, communication, sensor and micro-electronics has promoted the development of low power, low-cost, multifunctional sensor technology, which can collect information, process data, communicate in wireless in very small volume[3,4]. The application research of wireless sensor network which compose of micro-sensor nodes focus the attention of relative domain. The sensor nodes which are volume tiny and energy limited often work on complicated and dangerous regions and their energies could not be supplemented or replaced. So looking for perfect topology control which can balance the energy consume of the sensor nodes become the target of the research in wireless sensor network[5,6].

LEACH algorithm is an classic adaptive clustering algorithm proposed by Heinzelman. The algorithm introduces the concept of round, and each round is divided into two stages of initialization and stable communication. Among them, the initialization phase is divided into selection of cluster head and establishment of cluster. In the process of cluster selection, the node produce random number between 0 and 1. If this random number is less than threshold, $T(n)$ is chosen as cluster head and give broadcasting.

$$T(n)=\begin{cases}\dfrac{p}{1-p(r \bmod \frac{1}{p})}, & if \quad n\in G \\ 0, & otherwise\end{cases}$$

p is percentage of the number of cluster head. r is the number of round. $r \bmod \dfrac{1}{p}$ represents the number of nodes chosen as cluster in this round. G represents the set of nodes, which are not chosen as cluster head. In the establishment of the cluster, the nodes which are not cluster head, receive broadcast news of the cluster heads according to the principle of the nearest to join the cluster. LEACH algorithm has solved the problem of load balance of sensor nodes and is easy to implement, but there are a lot to improve[7-9]. Such as in cluster head selection phase, nodes randomly decide whether to become a cluster head, which makes position of cluster heads and the number of nodes in a cluster very uneven. It also does not consider the residual energy of nodes[10-12]. In the stage of forming clusters, the non cluster head nodes use nearby principle to join the nearest cluster heads, and do not consider the residual energy of cluster.

The paper is organized as follows. In the next section, the biggest ideal coverage model of sensor network and establishment of base station data table are given. In Section 3, the improved LEACH algorithm is presented including wireless energy consumption model, the selection of cluster head, and select cluster members. In Section 4, experiments are done. Finally, we conclude our paper in section 5.

II. DATA TABLE CONSTRUCTION UNDER THE OPTIMAL COVERAGE

A. The biggest ideal coverage model of sensor network

When coverage aera of a node is six deformation show in Figure.1, the maximum efficient coverage area can be obtaines ,which is

$$S_A = 6\times(\frac{1}{2}\times r\times\frac{\sqrt{3}}{2}\times r) = \frac{3\sqrt{3}}{2}r^2 .$$

The area is $\dfrac{3\sqrt{3}}{2}r^2$ and the radius of circle is r.

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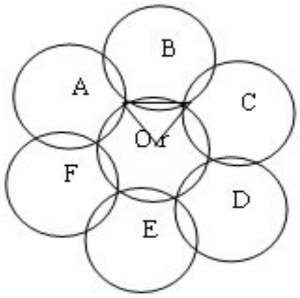

Figure 1. The biggest seamless coverage

B. The establishment of base station data table

Wireless sensor network optimal deployment model is shown in Figure.2. The sensoring radius of sensor is R, the length of rectangular area is L, the width is W, the number of line is L_n, the number of node in each line is H_n, and the number of all nodes is N^*.

The following formula is used to calculate which line the node is located.

$$L_n = \begin{cases} 1, & if \quad W < R \\ \dfrac{W-R}{3R/2}, & W > R \end{cases}$$

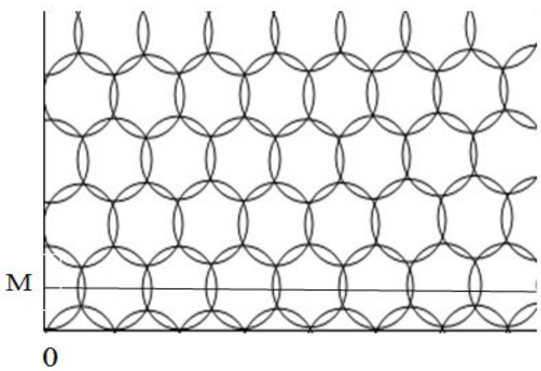

Figure 2. Wireless sensor network optimal deployment model

If L_n is odd, the corresponding odd line is $\dfrac{L_n+1}{2}$, and the corresponding even line is $\dfrac{L_n-1}{2}$.

$$N^* = \left[\frac{W-R}{3R/2}\right] \times \left[\frac{L}{\sqrt{3}R}\right] + \left[\frac{W-R}{3R/2}\right] / 2 + \left[\frac{L}{\sqrt{3}R}\right] + 1 \; .$$

If it is $\dfrac{L_n}{2}$,

$$N^* = \left[\frac{W-R}{3R/2}\right] \times \left[\frac{L-(3\sqrt{3}/2-1)R}{\sqrt{3}R}\right] + \left[\frac{W-R}{3R/2}\right] + \left[\frac{L-(3\sqrt{3}/2-1)R}{\sqrt{3}R}\right] + 1 \, .$$

So we can get coordinate (i, x_i, y_i) to record N^* number of nodes, $i = 1, \ldots, N^*$.

III. AN IMPROVED LEACH ALGORITHM

A. Wireless energy consumption model

The energy consumed by one node, when transmitting or receiving l bit of data, are

$$E_{TX}(l,d) = \begin{cases} l(E_{el} + rd^2), & d < d_0 \\ l(E_{el} + \eta d^4), & d \geq d_0 \end{cases},$$

and $E_{RX}(l) = lE_{el}$.

E_{el} represents transmitting or receiving power of circuit. d_0 represents threshold distance. rd^2 represents power amplifier power consumption when adopting the free space channel environment, when $d < d_0$. ηd^4 represents amplifier power consumption when adopting multiple path fading channel environment, when $d \geq d_0$. The total consumed energy in the reconstruction of cluster of each round is

$$E_{total} = l(2NE_{el} + NE_c + k\eta d_{tobs} + Nr\frac{1}{2\pi}\frac{M^2}{k}$$

d_{tobs} represents average distance between node and cluster node, E_c represents consumption power of data mining in the cluster head and k represents the number of cluster head nodes. E_i represents initial energy of sensor node. $E_i(r)$ is the left energy when choosing cluster head in the r-th round. $E(\text{r})$ represents current total energy.

$$E(\text{r}) = \sum_{i=1}^{n} E_i(r).$$

B. The selection of cluster head

When $k > 0$, E_{total} is a continuous function.

$$E_{total}^{'} = l(\eta d_{tobs}^4 - Nr\frac{1}{2\pi}\frac{M^2}{k^2}) = 0$$

$$\Rightarrow k_0 = \sqrt{\frac{Nr}{2\pi\eta}\frac{M}{d_{tobs}^2}}, \; k_0 \text{ is extreme point.}$$

$$E_{total}^2(k) = l(Nr\frac{M^2}{\pi}\frac{1}{k^3}) > 0 \; .(k > 0)$$

k_0 is calculated by cluster node and is calculated again after a number of predefined cycles. Now k_0 meets the condition that it needs minimum power in the reconstruction of cluster, but it can not guarantee the coverage of network. So two situations should be considered.

When $k_0 \geq N^*$, compare the coordinates of k_0 number of nodes. Calculate the node which is nearest to N^* and label it with $k_0^{'}$.

When $k_0 < N^*$, $k_0^{'}$ number of nodes are chosen and choose another $N^* - k_0$ number of nodes. Under the energy and distance, allocate probability value to undertake cluster heads for each node. The probability value of some node i in the r-th round is

$$\rho_i = \mu \frac{E_i(r)}{E(r)} + (1-\mu) \frac{d_{\max} - d_{tobs}^i}{d_{\max} - d_{tobs}}.$$

μ is weight coefficient, $\mu = 1/(1+\lambda)$.

$\lambda = \dfrac{E_i(r)}{E_i}$, $E_i(r)$ is the left energy of node i in the r-th round. μ belongs to $[1/2, 1]$ and is increasing. $d_{\max}$ is the maximum distance between node to cluster node and d_{tobs}^i is distance between node i to cluster node.

$$d_{tobs} = \sum_{i=1}^{n} d_{tobs}^i / N.$$

In the initialization phase, the base station broadcasts cluster head campaign message, and the message contains average remaining energy information in the current network. When a node receives the news, first of all, its remaining energy is compared with average residual energy of the current network. If its remaining energy is smaller than the current network average residual energy, it directly gives up the race, and then add into a cluster. If its remaining energy is greater than the current network average residual energy, it sends the message to the base station. The message includes information such as the ID and the residual energy of node, which is campaign message. When the base station receive all the campaign message, $k_0^{'}$ number of nodes are chosen as cluster head, and broadcast the message of cluster head in the whole network. The message includes the ID of $k_0^{'}$ number of cluster heads. If the nodes receive this message including their IDs in the network, the nodes are chosen as cluster heads.

C. Select cluster members

We suppose that non cluster head nodes receive broadcast message of m number of cluster nodes. Broadcast message includes cluster ID and residual energy of itself. The probability of non cluster head node adding into cluster head is

$$\rho_i = \mu \frac{E_i(r)}{E(r)} + (1-\mu) \frac{d_{\max} - d_i}{d_{\max}}, 1 \leq i \leq m.$$

$d_{\max}$ is the maximum distance between node and base station, and d_i is distance between non cluster head node and the i-th cluster head.

When non cluster head nodes adding in the cluster head, they select the nearest cluster head to them, which has more energy. Because the distance is near, energy consumption is little. The probability that non cluster head node adding in the cluster head is big. Then non cluster head node send request information to cluster head node. The request information includes node ID of itself and ID of cluster head. After cluster head node receiving request information of member nodes, it adopts TDMA strategy to allocate channel for member nodes. At last, the establishment of cluster is completed. The member nodes sent information to cluster head using allocated channel. The cluster head node fuse data from member nodes and sent data to base station.

IV. Simulation and Analysis

In the monitor area of 100×100m2, 100 number of wireless sensor nodes are deployed. The radius of node is 15, and the initial energy is 0.5J. The collection node is at the position (150,50) and the maximum running round is 5000. Life cycle comparison of different algorithms is shown in Figure.3 and data transmission comparison of different algorithms is shown in Figure.4. It can be concluded that the improved LEACH algorithm can prolong the life cycle of network.

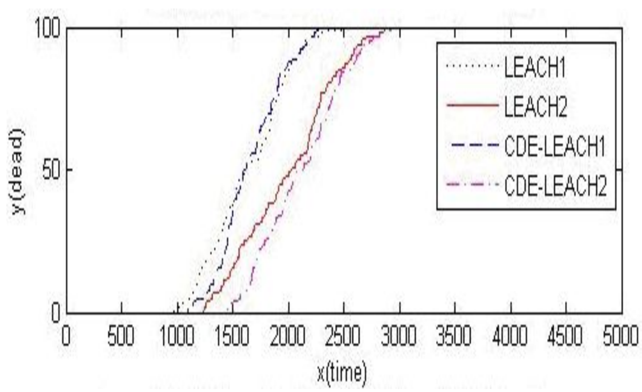

Figure 3. Life cycle comparison of different algorithms

V. Conclusions

Based on the existing mature and widely used protocol LEACH algorithm, CDE-LEACH algorithm is proposed. It can guarantee effective maximum coverage of network, and reduce the network energy consumption effectively. The improved LEACH algorithm can effectively reduce energy consumption of sensor nodes in the network and prolong the life cycle of the network.

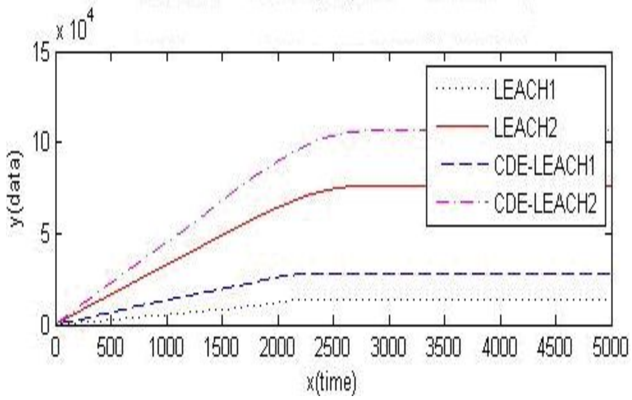

Figure 4. Data transmission comparison of different algorithms

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