Research on the Application of an Improved LEACH Algorithm in Smart Home

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Abstract

In recent years, the cluster head of the wireless sensor network in the smart home system networking system not only comprehensively considers the remaining energy of the data node but also the location information of the data node in the wireless sensor network and the node density of the data node. Factors to be considered. The LEACH algorithm has the disadvantage of slow convergence in the smart home networking system. This paper proposes an improved LEACH algorithm. The LEACH algorithm introduces the optimization of cluster head node selection by introducing the Voronoi diagram and the division of “hot zone” clusters and “non-hot zone” clusters, and then introduces improvements such as dynamic adjustment of the cluster radius. In the smart home networking system, the wireless sensor network not only greatly reduces the node energy consumption of the data node, but also reduces the load of the cluster head, so that the survival time of the data node of the wireless sensor network in the entire smart home network is extended to a certain extent. This improves the survival time of wireless sensor networks.

Keywords: LEACH algorithm, Smart home, Wireless sensor, Data node

1. Introduction

In recent years, the collection, storage, processing, and information transmission of target information have mainly relied on a large number of microsensor nodes. These miniature sensor nodes are deployed in a certain area for information and data communication and data exchange in a self-organizing and collaborative work mode to realize the monitoring of the area. Because its cost is lower than other equipment, it is currently widely used in the military, industry, agriculture, medicine, rescue and disaster relief, and other fields [1][2][3][4][5][6][7]. A large amount of data loss in the smart home networking system is mainly due to the limited battery energy of the data nodes of the sensors in the wireless sensor network when the cluster head is selected. At the same time, data communication and information exchange such as data forwarding between data nodes and clusters are consumed too much [8]. Most of the energy-consuming energy-saving technologies between the data nodes of the wireless sensor network in the smart home networking system and the data communication mode of the entire sensor network are concentrated in low-energy media access control technology [9], compressed sensing technology [10][11], Low duty cycle working technology [12], low energy routing technology [13][14], etc. Literature [15] proposed a clustering routing algorithm based on
artificial bee colony, using this algorithm to select the cluster head of the wireless sensor network in the smart home system networking system not only comprehensively considers the remaining energy of the data node. At the same time, a series of factors such as the location information of the data nodes in the wireless sensor network and the node density of the data nodes are also taken into consideration. Although this method is reasonable when selecting cluster heads for wireless sensor networks, its shortcoming of slow convergence speed is also obvious. Aiming at the above problems of the LEACH algorithm in the smart home networking system, this paper proposes an improved LEACH algorithm. First, use the method that the Voronoi diagram can change the geometric figure to determine that the data node is elected as the cluster head of the wireless sensor network, and then further divide it into "hot areas" based on the distance from the data node to the central node by dynamically determining the cluster radius Clusters and "non-hot zone" clusters.

2. LEACH algorithm

The traditional LEACH algorithm is a hierarchical network topology control protocol that introduces the concept of "round". The establishment of cluster head elections in wireless sensor networks and stable information transmission between data nodes are necessary tasks for each round. Process [16]. When the traditional LEACH algorithm selects the cluster head of the wireless sensor network, each data node in the wireless sensor network will generate a random number in a one-to-one correspondence, and the range of the random number is between 0 and 1 [17]. The random number is further used to compare with the threshold $T(n)$ determined by the threshold calculation formula (1), and it is determined whether the data node can serve as the cluster head of the cluster.

$$T_i(n) = \begin{cases} \frac{p}{1 - p\lfloor r \mod \left(\frac{1}{p}\right)\rfloor}, & n \in G \\ 0, & n \notin G \end{cases}$$  

Among them, the current number of rounds of elections for cluster heads in the wireless sensor network is represented by $r$, and the ratio of the number of cluster heads elected in each round to the number of data nodes in the entire wireless sensor network is represented by $p$, and $G$ is a collection of data nodes that do not cluster heads.

3. LEACH algorithm improvement

3.1. The division of "hot zone" and "non-hot zone"

In the smart home networking system, the control of each data node in the entire wireless sensor network is usually achieved through the control of the central node. To achieve the control of each node through the control terminal, there must be a central node. This node should have two major components. Features. First of all, it must have data transmission capabilities and networking capabilities, and secondly, it must have data collection capabilities. The central node broadcasts messages to the target monitoring area and divides the target monitoring area into "hot areas" according to the sub-areas close to the central node, and sub-areas far away from the central node called "non-hot areas" and other sub-areas. Each data node will determine whether the area it is in is a "hot zone" or "non-hot zone" based on the received signal strength. The upper and lower boundaries of the I-th subarea are:
In the formula: $d_{\text{max}}$ represents the maximum distance between the data sub-node and the central node; $d_{\text{min}}$ represents the minimum distance between the data sub-node and the central node; $m$ represents the number of "hot areas" and "non-hot areas" in the sub-regions of the target monitoring area.

### 3.2. Principle of dynamic adjustment of cluster radius

The number of member data nodes in each cluster in the "hot zone" cluster and the "non-hot zone" cluster is mainly determined by the monitoring radius $R$ and the node density $\rho$ of the data nodes, the calculation formula of the number is:

$$m = \pi R^2 \rho$$  \hspace{1cm} (4)

In the entire smart home networking system, each round of cluster head election in the wireless sensor network will be accompanied by the node energy consumption of the data nodes. The calculation formula for the energy consumption value of the cluster head is:

$$E_{\text{total}} = E_{\text{rec}} + E_t = (\pi R^2 p \times k + 1) \times E_e + b \times (E_e + \varepsilon_{\text{amp}} d^2)$$  \hspace{1cm} (5)

In the formula: $b$ represents the data volume of the member nodes in the cluster; $l$ represents the data volume forwarded by other cluster heads.

In the smart home networking system, the relationship between the competition radius of the data node of the wireless sensor network and the position of the cluster head is determined by equation (6) [18].

$$R = \left(1 - c \times \frac{d_{\text{max}} - d}{d_{\text{max}} - d_{\text{min}}} \right) \times R_0$$  \hspace{1cm} (6)

In the formula: $d$ represents the distance between the cluster head and the central node; $c$ represents the influence of the distance between the cluster head and the central node on the competition radius of the "hot zone" clusters and the "non-hot zone" clusters. The calculation formulas for the competitive radius of "hot zone" and "non-hot zone" are shown in formulas (7) and (8) respectively.

$$R_{\text{hot}} = \left[\varepsilon_1 \times \left(1 - c \times \frac{d(S_i, BS) - d_{\text{min}}}{d_{\text{max}} - d_{\text{min}}} \right) + \varepsilon_2 \times \frac{E_{\text{res}}}{E_{\text{init}}} \right]$$  \hspace{1cm} (7)

$$R_{\text{unhot}} = \left(1 - c \times \frac{d_{\text{max}} - d(S_i, BS)}{d_{\text{max}} - d_{\text{min}}} \right) \times R_0 + \left[\beta_1 \times \text{sgn}(E_{\text{res}} - E_{\text{ave}} + \beta_2) \times \frac{x}{m} \right] \times \Delta R$$  \hspace{1cm} (8)

Where: $E_{\text{res}}$ represents the remaining energy of the sensor node. $E_{\text{ave}}$ represents the average value of the remaining node energy of two adjacent data nodes in the wireless sensor network. $d(S_i, BS)$ represents the distance from node $S_i$ to the central node. $\Delta R$ represents the adjustment value of the competition radius between "hot zone" and "non-hot zone". $x$ and $m$ respectively represent the number of nodes in the area and the entire area.
3.3. Cluster head selection

In the smart home networking system, the energy consumption of data nodes in the process of selecting the cluster head of the wireless sensor network is very large, and each round of the selection of the wireless sensor network cluster head means that it has to be re-localized. Or global networking. Therefore, with the gradual increase in the number of cluster head elections in the wireless sensor network, the remaining energy of the data node of each sensor in the network will decrease over time, until finally the energy of each data node in the entire wireless sensor network will be depleted. Different from the random and equal probability cluster head selection of the traditional LEACH algorithm, the improved LEACH algorithm uses the Voronoi diagram to select the cluster head of the wireless sensor network, which will increase the remaining energy of the data node and the location of the data node and other decisive factors. Considering. This will not cause the data node to consume too much remaining energy of the data node in the stable phase of the cluster establishment and cause it to die prematurely.

As with the traditional LEACH algorithm, when the cluster head of the wireless sensor network is selected in the initial state, each data node in the network will also generate a random number, and the range of the random number is between 0 and 1. The random number is further used to compare with the new threshold $T(n)$ calculated by equation (9). If the random number is less than the new threshold $T(n)$, it will broadcast in the entire wireless sensor network and determine that the currently broadcast data node has been selected as the new cluster head in the wireless sensor network.

$$T(n) = \left\{ \begin{array}{ll}
\frac{p}{1 - p^*(r^* \text{mod} \frac{1}{p})} \times \left( \frac{E_{\text{cur}}(n)}{E_{\text{init}}} \right) + \lambda_2 (1 - \frac{d_{\text{cos}}}{d_{\text{max}}})_n \in G \\
0, n \notin G
\end{array} \right.$$  

Among them, the LEACH algorithm, which is different from the traditional LEACH algorithm, introduces new parameters $E_{\text{cur}}(n), E_{\text{init}},$ and $d_{\text{cos}}$ to more comprehensively consider the selection of the wireless sensor network cluster head. $E_{\text{cur}}(n)$ represents the remaining node energy of the current data node; $E_{\text{init}}$ represents the initial total energy of the data node; $d_{\text{cos}}$ represents the distance between the current node and the sink node; adjust the weights of the entire network parameters through $\lambda_1$ and $\lambda_2$, where $\lambda_1 + \lambda_2 = 1, \lambda_1 \geq 0, \lambda_2 \geq 0$.

3.4. Data communication method

In this paper, the optimization of data communication methods in wireless sensor networks is mainly based on the division of "hot zone" and "non-hot zone". The process is as follows.

1) If the selected cluster head node $S_i$ is located in the pre-divided "hot zone" cluster group, the data node does not need to forward the data information with the cluster head nodes of other clusters. The cluster head data node directly communicates data and information with the central node to save node energy.

2) If the position of the cluster head node $S_i$ is in the "hot zone" that is not pre-divided, it is necessary to recreate a cluster headset adjacent to it, and find the node with the smallest value as the new data by calculating the cost function of data communication The forwarding node $S_j$, repeat the above operations until all data forwarding nodes are found to send data to the central node. The calculation formula of the cost function of data communication is shown in equation (10).
\[ W = u \times \frac{d^2(S_i, S_j) + d^2(S_j, BS)}{d^2(S_j, BS)} - v \times \frac{E_{res}}{E_{init}} + w \times \frac{N_{member}}{N} \] (10)

3.5. Self-repair of networking

Since the failure of a very small number of wireless communication nodes in the smart home control system does not change the characteristics of the network structure, it is designed to use the characteristics of the smart home control system in the four cases of a node failure, node addition, node deletion, and node movement. A set of the local repair mechanism.

1. Node failure

The communication node will fail when the power supply is short-circuited or the power supply runs out of energy. At this time, the communication line needs to be repaired. The repair process is shown in Figure 1.

![Node failure repair diagram](image)

Figure 1. Node failure repair diagram

It can be seen from [Figure 1] that when the data node of 01 fails, the three links 00-01, 01-05, and 01-08 related to data node 01 will respectively fail accordingly. The data node 01 that fails without data transmission will not be discovered in time. Only when the data node of 01 is required for data transmission, will the data communication be found to be broken, and the link needs to be repaired. The specific automatic node repair process is as follows. 1) If central node A wants to transmit data to node 09, then according to the original routing information, it should be transmitted according to 00-01-05-07-09. When the data is transmitted through node 01, it is found that node 01 cannot be found. At this time, node 00 will return an instruction to the control terminal to tell the control center that node 01 is invalid and needs to be repaired. First, query whether node 05 is a neighbor node of node 00 according to the routing information recorded during networking.

2. Add node

The node addition is based on the original routing information in the formed network environment, and each data node contains its routing information. Whenever a new data node sends a request instruction to join the adjacent cluster, the smart home networking system will often find the central node according to the reply instructions of other data nodes and obtain the address code according to the route of other data nodes.

3. Node move

There are also different solutions for the two types of node movement for more data node movement and individual data node movement. In the case of a lot of data node movement, the central node is usually used to initiate a networking command again to rebuild the network, while for the case of individual data nodes that move less, you only need to re-insert a new data
node to solve the problem. The central node re-initiates the networking command on a large scale.

4. Simulation test

To test the performance improvement effect of the LEACH algorithm in the article, MATLAB2016a is used as the simulation software platform and compared with the simulation test results of the traditional LEACH algorithm. The data comparison is mainly from the survival rate of nodes and the remaining rate of network energy. The setting parameters of the wireless sensor network are shown in [Table 1]. The specific simulation comparison is shown in [Figures 2] and [Figure 3].

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{init}}$</td>
<td>0.5J</td>
<td>CTL</td>
<td>200bit</td>
</tr>
<tr>
<td>L</td>
<td>400bit</td>
<td>X×Y</td>
<td>100m×100m</td>
</tr>
<tr>
<td>N</td>
<td>100</td>
<td>c</td>
<td>0.5</td>
</tr>
<tr>
<td>u</td>
<td>0.5</td>
<td>v</td>
<td>0.2</td>
</tr>
<tr>
<td>w</td>
<td>0.3</td>
<td>$\varepsilon_{\text{amp}}$</td>
<td>0.0015</td>
</tr>
</tbody>
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From the trend of the broken line in [Figure 2], it can be seen that the remaining energy of the wireless sensor network data node of the algorithm used in this paper is higher than the remaining energy of the traditional LEACH algorithm without improvement, and the remaining energy of the data node gradually increases with the number of rounds, depleted. In the traditional LEACH algorithm, the remaining energy of the data node is consumed in 1200 rounds. The remaining energy of the data nodes of the improved LEACH algorithm is consumed in 1300 rounds, which saves the energy of the data nodes in the smart home networking system to a large extent to improve the survival rate of the data nodes.
Figure 3. Network survival nodes

From the analysis in [Figure 3], it can be seen that compared with the unimproved LEACH routing algorithm, the first data node of the improved LEACH algorithm in this paper has a lead time of 1350 rounds. The death time of the first data node of the improved LEACH algorithm is 1,700 rounds. The big difference in the survival time of the data nodes of the two algorithms is mainly because the improved LEACH algorithm not only introduces the dynamic adjustment and determination method of the cluster radius. When the cluster head election of the wireless sensor network is carried out, not only the location of the data node and the remaining node energy of the data node are comprehensively considered, but also the data nodes in the monitoring area are divided into "hot zone" clusters and "non-hot zone" clusters. To improve the data communication mode of the data node. The LEACH algorithm introduces the optimization of the selection of cluster head nodes by introducing the Voronoi diagram and the division of "hot zone" clusters and "non-hot zone" clusters, and then introduces improvements such as dynamic adjustment of the cluster radius. The wireless sensor network in the smart home networking system is not only the node energy consumption in the data node is greatly reduced and the load of the cluster head is reduced, so that the survival time of the data node of the wireless sensor network in the entire smart home network is extended to a certain extent and the survival time of the wireless sensor network is improved.

5. Conclusion

Aiming at the problems of unreasonable node cluster head selection, node energy consumption, and premature death of nodes in the LEACH algorithm, this paper uses MATLAB2016a simulation software for simulation testing. Comparison of simulation test results shows that the improved LEACH algorithm not only solves the problem of premature death of wireless sensor network data nodes in the smart home networking system but also better balances the node energy consumption of each data node to increase the lifetime of the entire wireless sensor network.
References


