International Journal of Information & Computation Technology.
ISSN 0974-2239 Volume 5, Number 1 (2015), pp. 35-46

http://www. irphouse.com

A new algorithm for the main standby node of WSN cluster head

Liye Peng[1] and Changguang Wang[2,3*]

[1]*College of Physics and Information Engineering,*
Hebei Normal University, Shijiazhuang 050024, China
[2]*College of Information Technology, Hebei Normal University,*
Shijiazhuang 050024, China
[3] *Key Lab of Network and Information Security of Hebei Province,*
Shijiazhuang 050024, China

Abstract

The nodes in Wireless Sensor Networks (WSN) are randomly and densely distributed, while the head nodes are energy constrained. For solving such problems in WSN, we propose an improved algorithm to backup the main standby head node based on subtractive clustering. At the same time, the technology of hardware energy detection is used to detect the node energy state and make it possible to switch the main standby node. In our algorithm, the standby head starts to work from its dormant state only when the energy of the main cluster head is insufficient. Simulation results show that our algorithm of the main standby node for the cluster head can improve the survival time of the whole network.

Keywords: Wireless sensor, Subtractive clustering, Hardware energy detection, Main standby node

0. Introduction

With the development of information technology, wireless sensors are widely used in environmental monitoring, medical monitoring, family environment and business application. However, the computing power and energy storage capacity of the wireless sensor nodes are highly limited, so the simple and low-power algorithms are very dominant.

In order to save the energy consumed by sending data, the cluster head node collects the node data from the cluster and then sends to the Sink node. The energy consumption of the cluster head node is the maximum and the life span is the shortest. Therefore, a simple algorithm is needed to extend the life of the cluster head.

In order to delay the life of the network, many algorithms have been proposed. Literature [3] presented a WSN clustering algorithm based on spatial correlation, which greatly reduced the data redundancy of the network and prolonged the network lifetime. But the algorithm has still the following shortcomings:

①. The cluster head is a node with the certain degree of distortion and strong correlation, which is not necessarily the highest energy node;

② If a cluster head node encounters the virus attacks, the sink node will be forced to terminate the cluster operation. Therefore, the entire network will enter a new round of reclustering and then reelecting the cluster head. While it is unfair for those nodes in the non "hot spots" where the energy of the cluster head is rich. If the interval of the cluster head election is short, it will lead to the whole network to carry out the cluster head election, and then consume too much energy [5].

Literature [4] presented a Driven Event clustering algorithm for mobile nodes to extend the network lifetime. In the literature [5], a ACRP clustering routing protocol was proposed for the uniform distribution of nodes. In the literature [6], the cluster head is the most energy in the cluster head, but its location is not necessarily the most intensive in the node distribution, and the distribution of the cluster head is not necessarily consistent with the distribution of nodes in the cluster head. Literature [7] is also aimed at the uniform distribution node, and the HEED-LEDP routing algorithm was proposed.

This paper considers the advantages and disadvantages of the above algorithms and also takes into account of the characteristics of WSN. In this paper, we present an improved algorithm for the main standby node of WSN cluster head based on subtractive clustering algorithm [1] and the hardware energy detection technology [2]. This improved algorithm is aimed at the random distribution of the uneven density of stationary nodes.

1. Network model

In a universal region of $L \times L$, N sensor nodes are dispersed randomly.

1.1 Assumptions

(1) The base station and sensor nodes are fixed. All sensor nodes are randomly distributed, and the density is not uniform.

(2) Each sensor node has a unique identifier (ID). The initial energy of each node is equal to E0.

(3) The length of each packet transmitted by a node is equal to the length of the packet.

(4) Sensor nodes can use the GPS positioning system or positioning algorithm to get their location information, and can transmit the information to the base station. [1]

(5) Each node has a hardware energy detection module. [2] The received data of the node energy detection module will be the value of the energy consumption in a period of time t_{packet}. It can get the node's real energy consumption power of Wn (T) from time t_0 to t_{packet}. In the same time, according to the energy consumption power of the task event, the theoretical energy consumption power Ws (T) is calculated. The mutual correlation coefficient between Wn (T) and Ws (T) is calculated.

$$\mathrm{Cov}(W_s, W_n) = E(W_s, W_n) - E(W_s)E(W_n) \tag{1}$$

$$\rho_{sn} = \frac{\mathrm{Cov}(W_s, W_n)}{\sqrt{D(W_s)}\sqrt{D(W_n)}} \tag{2}$$

The condition that the node may not be reliable is:

$$\rho_{sn} < (1 - \Delta\rho 1)$$

1.2 Energy consumption model

We use the typical energy consumption model [8]. The energy spent for transmitting an *l*-bit message over distance *d* is

$$E_T(l, d) = \begin{cases} l \times E_{unit} + l \times \varepsilon_{fs} \times d^2, d < d_0 \\ l \times E_{unit} + l \times \varepsilon_{amp} \times d^4, d \geq d_0 \end{cases} \tag{3}$$

Where Eunit is the energy dissipated per bit to run the transmitter or the receiver circuit; ε_{fs} and ε_{amp} are the energy consumption of amplifying 1 bit information, which are decided by the distance of the sending node and the receiving node, respectively. If the distance between the transmitter and receiver is less than d_0, the free space (fs) model is used; otherwise, the multipath (mp) one.

To receive an *l*-bit message, the expended energy is:

$$E_R(l) = l \times E_{unit} \quad (4)$$

To aggregate an *l*-bit message, the expended energy of the cluster head is:

$$E_A(l) = l \times E_{agg} \quad (5)$$

The average energy consumption of a member of the cluster after a period of a cycle is:

$$Esuse = p \times ET(l,d) + ER(l) \quad (6)$$

The average residual energy of the cluster head after a period of a cycle is:

$$Ecuse = \min(p \times m,1) \times ET(l,d) + \max(p \times m,1) \times ER(l) + \min(p \times m,1) \times EA(l) \quad (7)$$

Where P is the probability that a member of the cluster sends the information data and $P \leq 1$.

2. Improved algorithm of main standby node of the cluster head

In the wireless sensor networks with random nodes, the following problems exist:

(1) Random distribution node has redundancy data.

Suppose all the nodes are motionless and have the same starting energy, computing power and communication ability.

For the severe or inconvenient environments, the plane layout method can be adopted, which leads to uneven distribution of nodes.

As shown in Figure 1, the star node is distributed in the most densely populated places. There are a lot of nodes distributed in the vicinity of the star node, even next to the star node. If the nodes are close with each other, a large number of redundancy data will be produced, which leads to large energy consumption and long network delay [3]. In the place away from the star node where nodes are sparsely distributed, the probability of nodes being close is very small.

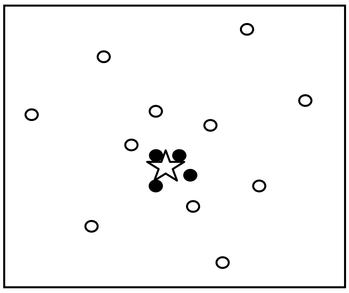

FIGURE 1

(2) The energy consumption in the cluster is not uniform.

The workload of the cluster head is higher than that of the members of the cluster, and the energy consumption is higher than that of the members, so the cluster head will die prematurely.

This paper proposes an improved algorithm for WSN to solve the problems, which is based on the subtractive clustering algorithm [1] and hardware energy detection technology [2].

2.1 Improvement of the clustering method

The traditional subtractive clustering elects only one cluster head. In this paper, we propose an improved method, according to the energy consumption of the cluster head. Our method can elect multiple cluster heads, among which the first one is the main head of the cluster, and the others are the standby heads. At first, the main cluster head works, while the standby ones are in the dormant state. When the energy of cluster is exhausted, the first standby cluster head begins to work. Then the standby head node works one by one after its energy exhaustion till the last one.

The election steps of the main cluster head are as follows.

Firstly, the node coordinates are normalized by the formula:

$$N(i) = \frac{S(i) - \min(S(i))}{\max(S(i)) - \min(S(i))} \quad (8)$$

Then, the density of nodes is calculated by:

$$Den_{(i)} = \sum_{j=1}^{m} \exp[-\|S(i) - S(j)\|^2 / (R_a/2)^2] \quad (9)$$

The first cluster head node C_1 should statisfy:

$$\max\{ \mathrm{Den}_{(i)} | i = 1,2,\dots,n\}$$

The formula used to modify the density of the remaining nodes is ：

$$\mathrm{Den}_{(i)} = \mathrm{Den}_{(i)} - \mathrm{Den}_{(k)}\exp[-\|S_i - S_k\|^2 / (R_b/2)^2] \quad (10)$$

S (k) is the node coordinates of C_1.

The next cluster head node C_l should statisfy:

$$\max\{ \mathrm{Den}_{(i)} | i = 1,2,\dots,n-1\}$$

The election of other cluster heads is similar to the next one.

The condition for the termination of the election is Den (l)/Den (k)<α.

The steps of electing the standby heads are as follows.

Step1. Calculate the distance between each member node and the cluster head
As shown in Figure 1, the nodes near the star are distributed densely, which causes too much redundancy data. In our improved algorithm, the star node is selected as the main cluster head, and the nearest nodes from the star are taken as the standby heads. The clustering is completed by the subtractive clustering method to get *j* clusters. If there are *m* members in a cluster, we can calculate the distance between each node with coordinates of (S (I).Xd, S (I).Yd) and the cluster head with coordinates of (C.xd, C.yd). The steps are as follows: for i=1:1:m

$$\mathrm{distance}\ (i) = \sqrt{(S(i).xd - C.xd)^2 + (S(i).yd - C.yd)^2} \quad (11)$$

Step2. Select the standby cluster head
A member node to become the first standby cluster head should statisfy
$\min\{ \mathrm{distance}(i) | i = 1,2,3,\dots,m \}$

Step3. $\mathrm{b} = \mathrm{ceil}\left(\frac{E_{cuse}}{E_{suse}}\right)$

If b>1, go to Step1, otherwise end the election.

Before the operation of the network, the main cluster head node and standby cluster head node should have been elected.

The number of cycles that a member node maintains in the cluster is:

$$rs = \frac{E_o}{E_{suse}} \tag{12}$$

The number of cycles that the cluster head can run is:

$$rc = \frac{E_o}{E_{cuse}} \tag{13}$$

If the time of the member nodes is equal to the running time of the cluster head, the number of the cluster heads should be:

$$nc = \frac{\frac{E_o}{E_{suse}}}{\frac{E_o}{E_{cuse}}} = \frac{E_{cuse}}{E_{suse}} \tag{14}$$

2.2 Improvement of the decision of switching the head node

2.2.1 The main cluster head being switched when its energy is exhausted

$E_{cremain}$ is the energy remaining after the main cluster head completing the task, which is detected by the hardware energy detection module. If $E_{cremain} < 0$, the task will not be executed; at the same time, the standby cluster head node is activated; then the main cluster head is invalid, and the task is assigned to the standby head.

2.2.2 When cluster head node is attacked by virus, the cluster head switching occurs

When $\rho_{sn} < (1 - \Delta\rho 1)$, the node may be attacked. Then the standby cluster head is activated, and the main cluster head is invalid.

If the main cluster head node energy is exhausted or is attacked, it is replaced by the standby cluster head. Similarly, if the first standby head runs out of its energy or is attacked, it is replaced by a second standby head, and so on.

3. The advantages of the improved algorithm

(1) To solve the problem of redundancy data.

As shown in Figure 2, due to randomly distributed and subtractive clustering, the four nodes of ABCD are very close to the cluster head (the star node). Therefore, the data collected by them are redundancy. In our improved algorithm, the four nodes (●) of ABCD are taken as standby nodes at first and are set in the dormant state.

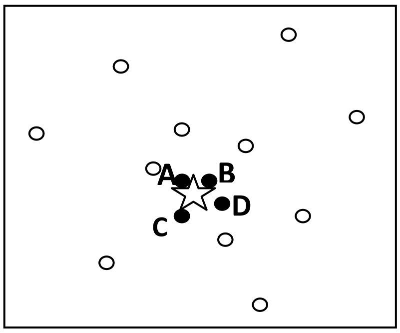

FIGURE 2

(2)Without periodically reclustering and reselecting the cluster head.

Before the operation of the network, the cluster head is selected, and the standby head is selected according to the cluster head. In the course of the network operation, only when the main cluster head fails, the backup cluster head will be activated. The whole process does not need to reselect the cluster head or reclustering, so as to ensure the fairness of the "non hot spots", and also reduce the unnecessary energy consumption.

(3) The improved algorithm is simple.

For example, if the total number of wireless sensors is *N* and there are *M* cluster heads, the calculation times of getting the *M* standby cluster heads will be *N* - *M*.

(4)The improved algorithm extends the network time.

When the energy of the main cluster head is depleted and the energy of the member nodes in the cluster is very full, this is called the premature death of the cluster head, which results in the network survival time being shortened. In this paper, the improved algorithm uses the spare cluster head to extend the survival time of the cluster, and improves the performance of the network.

4. Simulation experiments

The nodes are randomly distributed and have the GPS positioning function. In the Windows7 system, we use matlab2010a to simulate our algorithm. In a 100m * 100m area, 1024 nodes are randomly laid, and the sink node is in the middle position, as shown in Figure 3. The probability of sending a packet by a node is 50%.

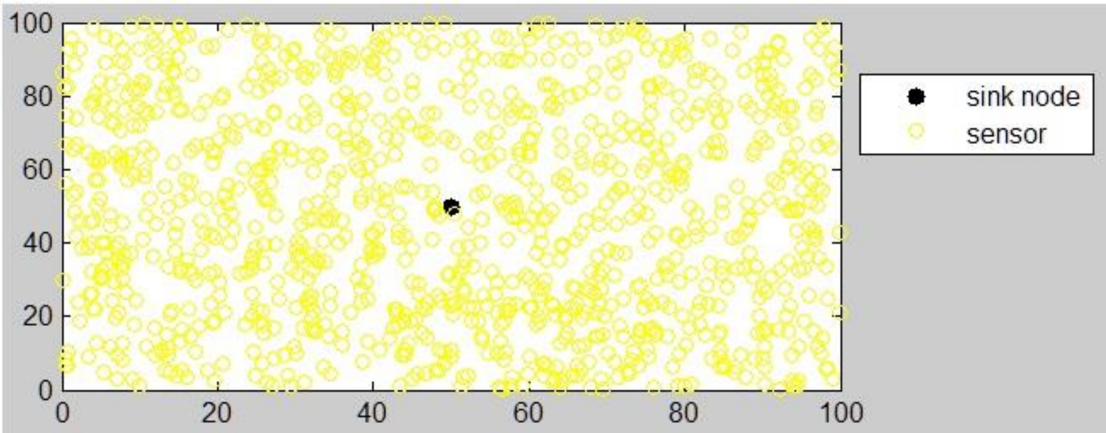

FIGURE 3: WSN node random distribution diagram

The main cluster head node is selected by the subtractive clustering, as shown in Figure 4. The standby node of the cluster head is selected from the nearest node of the cluster head. Two alternate cluster heads are selected for the simulation experiments. * denotes the main cluster head node, and + denotes the standby one.

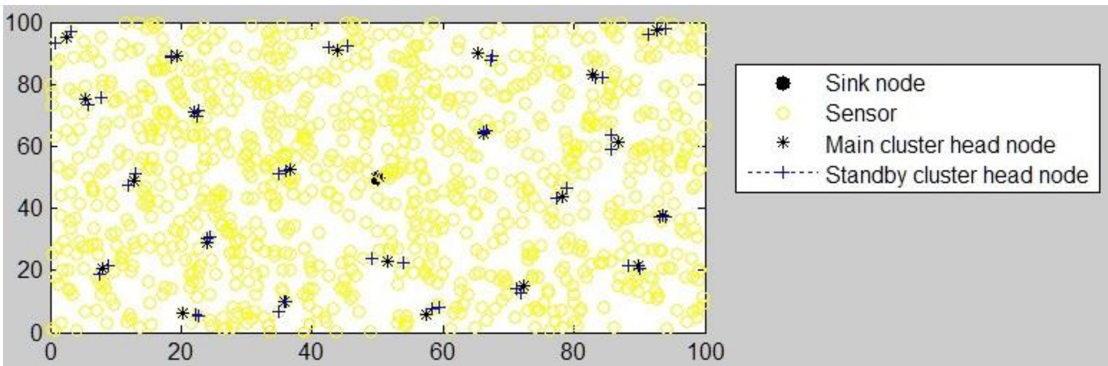

FIGURE 4: Select the primary backup cluster head

There is no wireless sensor network for standby cluster head, as shown in Figure 5.

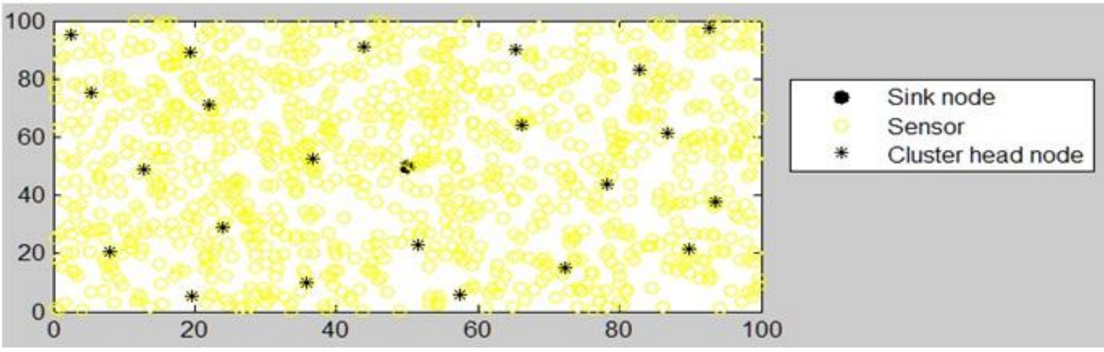

FIGURE 5: WSN without standby cluster head

The survival time of network nodes is obtained by simulating two experiments without standby head node and a standby cluster head, as shown in Figure 6. The horizontal axis is the time axis, denoting the survival time of the network; the vertical axis is the number of nodes alive. The right side has two alternate head nodes, and the left is the curve of the head node without standby head. From the graph, the network survival time of the nodes with standby cluster head is obviously longer.

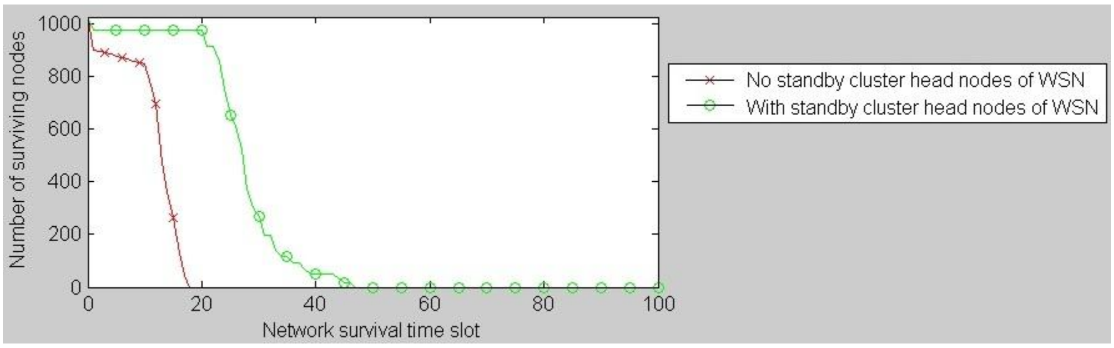

FIGURE 6: survival time contrast chart

The number of the standby cluster head is related to the probability of sending data by an ordinary node and the distance between the cluster head and the sink node. If the probability of sending data by an ordinary node is higher or the cluster head is far from the base station, the number of the cluster heads will be bigger. The number of alternate cluster heads can be selected according to the real network circumstances.

5. Conclusion

This paper is mainly focused on the algorithm for the main standby node of WSN cluster head based on the characteristics of the low node energy and the limited capability of data processing of the WSN. The survival time of the WSN with the main standby head node is analyzed and then simulated by MATLAB.

The improved algorithm has extended the survival time of wireless sensor network, and the algorithm is simple and easy to realize according to the characteristics of the wireless sensors.

The algorithm is easier to achieve with the characteristics of wireless sensor.

Acknowledgments

The authors would like to thank the anonymous reviewers and the editor for their constructive comments on this article. This work is supported by the National Natural Science Foundation of China (no.61272541), the Natural Science Foundation of Hebei Province (no.F2015205157).

References:

[1] Ma Shouming, Wang Ruchuan, Ye Ning. WSN security data fusion based on reputation degree set pair analysis[J]. Computer research and development. 2011,48（9）: 1652-1658.

[2] Fan Cunqun, Research on sensor trust evaluation method based on energy monitoring[J]. Electronic journal. 2013.04, 41 (4) : 646-651.

[3] Liu Shuai, Wu Shuci, Shen Xuejie, Clustering algorithm based on spatial correlation in Wireless Sensor Networks[J]. Computer applications and software. 2014.06, 31 (6):108-110.

[4] He Xuan, Song Yong, Hao Qun, Event driven clustering algorithm for mobile nodes[J]. Computer Engineering. 2010.05, 36 (10):118-120.

[5] Han Zhijie, Wang Ruchuan, Fan Gaojuan, Xiao Fu, A non balanced clustering routing algorithm based on WSN ARMA[J]. Electronic journal. 2010.04, 38 (4):865-869

[6] Huang Heqing, Shen Jie, Yao Daoyuan, Ma Kui, Liu Haitao, Research on adaptive energy driven cluster head rotation algorithm in Wireless Sensor Networks[J]. Journal of electronic and information. 2009.05,31 (5):1040-1043.

[7] Song Ningbo, Fan Min, Wang Lin, Load balancing routing algorithm for wireless sensor networks based on HEED[J]. Computer engineering and Application. 2015, 51 (11):83-87.

[8] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrish-nan, “An application-specific protocol architecture for wireless microsensor networks,” IEEE Transactions on Wireless Communications, 2002,1 (4): 660-670