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ON THE SHORTEST RECYCLE PATH ALGORITHM OF WIRELESS SENSOR NODE

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ABSTRACT

Along with the spreading application of wireless sensor network, once the node energy is exhausted, it will cause environmental pollution. Therefore, the problem of node recovery becomes increasingly important. The automatic recycling of robot will become one of the feasible methods. The key is how to use less time and energy consumption to recycle all nodes as well as prolong the lifespan of wireless sensor network. This paper proposes a recovery algorithm based on the greed algorithm. Through quantitative tests, the results show that the proposed new algorithm can save the energy consumption and maintain the lifespan of wireless network, thus reaching a balance.

Keywords: *Wireless Sensor Network; Node Recovery; Shortest Path Algorithm*

1. INTRODUCTION

Wireless sensor network (WSN) is a network made up of a large number of small sensors. These small sensors are generally called sensor node or mote (dust). This network, in general, also has one or several stations (sink) to put the data collected from the small sensors.

The wireless sensor network is a new generation of sensor network. It has a very wide range of application, and its development and application will affect all fields in human life profoundly [3]. IEEE is trying hard to promote the application of wireless sensor network. Recently, Boston University started the Sensor Network Consortium to promote the technology development of sensor network. Except the Boston University, the Consortium also includes the BP, Honeywell, Inetco Systems, Invensys, L-3 Communications, Millennial Net, Radianse, Sensicast Systems and Textron Systems.

The wireless sensor network can get the objective physical information, and have the wide application prospect. It can be applied to military defense, agricultural and industrial control, urban management, biological and medical treatment, environment examination, emergency rescue and relief, remote control of dangerous areas, etc. Wireless sensor networks can also be deployed on moving objects, dynamic organization network structure for the collection and delivery of information, such as vehicle network [5-7]. Therefore, it is expected that the wide application of wireless sensor network is an inexorable trend, which will bring great changes to human society.

The wireless sensor network consists of a large number of cheap micro sensor nodes deployed in monitoring area. It forms a multi-hop self-organized network system through the wireless communication. Its purposes are to cooperatively perceive, collect and process the information of sensed object network in the coverage area, and send the information to the observer. The sensor, sensed objects and observer form the three elements of wireless sensor network.

The sensor node is usually made of plastic and the source of power is mainly from the battery. Sensor has a certain life cycle [1, 2]. Once depleted, it will be difficult again supplementary power to become an abandoned node. Therefore, on the one hand need to study how energy and extend the life cycle of the sensor [4]. On the other hand, you need to study how to reclaim these abandoned nodes. But the two materials of sensor are no degradable, and it

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results in severe pollution. Thus, recycle work should be done before the expiration of the sensor nodes. The automatic recycling by robot will become one of the feasible methods. The key is how to use less time and energy consumption to recycle all nodes as well as prolong the lifespan of wireless sensor network. This paper proposes a recovery algorithm based on the greed algorithm. Through quantitative tests, the results show that the proposed new algorithm can save the energy consumption and maintain the lifespan of wireless network, thus reaching a balance.

The structure of this paper: the second part is to describe the recycle problem; the third section proposes a kind of recycle algorithm; Section 4 presents the results and analysis of simulation test; Section 5 is the conclusions.

2. DESCRIPTION ON RECYCLE PROBLEM

The following two questions should be considered while using robots to recycle the wireless sensor network.

1. Firstly, how to keep a minimum energy loss in the recycle process. The energy loss results from two aspects, one is the energy consumption when the robot moves, and it is always proportional to the moving distance; the other is the remaining power of recycled nodes since the entire recycling process takes a long time. If we recycle the node after the exhaustion of power, the mobile distance of robot will increase, thus increasing the robot's energy consumption. In order to keep a minimum energy loss in the recycle process, the energy consumption in the two aspects should be controlled at the minimum.

2. Secondly, how to prolong the lifespan of wireless sensor network as much as possible. If most of the wireless sensor nodes in a certain area can communicate mutually, the wireless sensor network can be called active. Suppose that in the wireless sensor network $G(V,E)$, the biggest radius coverage of node signal is r . If the two nodes $v,v'\in V$ meet $Dist(v,v')\le r$, then v and v' have an edge $e\in G(V,E)$. Suppose $G'(V',E')$ is the biggest connected sub-graph, given the threshold $p\in(0,1]$. If $|V'|/|V|\ge p$ |, then G is an active wireless sensor network.

In the recycle process, in order to make the active time of network as long as possible, the recycle order should be adjusted. If the recycling node v leads to two large connected sub-graphs, then delay the recycle.

Unfortunately, the actual situation can not give a recycle strategy that satisfies the above two requirements at the same time. Based on the second point, in order to avoid multiple connected sub-graphs, a better strategy is to collect the nodes on the edge and the non-critical nodes, which makes the moving distance of the robot increase and affects the first point.

Thus a balance between the two aspects should be reached. It is proved that the recycle algorithm which can satisfies the above conditions is the NP-hard problem.

3. RECYCLE ALGORITHM

This paper proposes three algorithms at different levels based on the node recycle problem described in the second part.

First of all, the node energy factors will be omitted. The moving distance of robot is considered. The node near the robot will be recycled first. The greedy method can obtain the shortest path algorithm of the nodes in the traversal graph.

Based on the algorithm1, the effects of energy loss are further considered. It is hoped that the total energy remained in all nodes can be kept as large as possible. Therefore, a long path is needed to recycle the nodes that nearly power exhausted. But as a whole, it is worthwhile since it can make all the nodes in the state of working. To introduce the effect of energy dissipation, it is assumed that the energy consumption of robot for moving a unit distance is m, the speed is v_s, the distance between the robot and node k is d_k, the remaining power of node k is q_k , the power consumption per unit is q . Thus the weight of the node k in modified algorithm 1 is $md_k+q_k-q(d_k/v)$, and algorithm 2 can be obtained. The time complexity in algorithm 2 is $O(n^2)$.

To improve algorithm 2, communication factors between nodes are considered in algorithm 3. According to the above conclusion, to guarantee an active wireless sensor network, a simple threshold $p=1$ is set. Recycling should be avoided for the kinds of nodes: once the node is recycled, a connected sub-graph will split into two connected sub-graph. Such a node is called a critical node. In

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the algorithm 3, the critical nodes need to be judged. If only one is left in the graph, this node will not be the key node, and can be recycled. If there is no other node in radius r range, then the node becomes the acnode. The acnode is not critical node and can be recycled. If the node v is not a isolated point, then the v begins to traverse.

The connected sub-graph G_v include v, after deleting v, traverses from a neighbor node to and generates connected sub-graph G_{-v}. If the number of nodes of G_{-v} is different in just 1 compare with G_v, then v is not the critical node, and can be removed.

Algorithm 3

Input：$G(V,E)$, position of robot is P

Output：Sequence of node S

Initialization: $S=\phi$

While ($|V|$) {

For any node v_k in V, calculate the weight $Q_k = md_k + q_k - q(d_k/v)$;

Sort the nodes on Q_k in ascending order, and get the sequence of node S'

Traverses S' until finding the first non-critical v,

$S=S+v$;

$V=V-v$;

}

Figure 1. Recycle Algorithm Concerns The Lifespan

In algorithm 3, the complexity of sorting is $O(n^2)$. The complexity of generate connected sub-graph is $O(n)$, Thus the complexity of getting the first non-critical node in S' is $O(n^2)$, It can be proved that the time complexity in algorithm 3 is $O(n^3)$.

4. EVALUATION

In order to carry out experiments and analyze the results of the above algorithms, the following parameters are set: the node number is 10, power consumption of node per unit is 1, initial power of robot is 10000, energy consumption per unit is 5, the moving speed is $v_s = 0.3$. It indicates that the energy consumption of robot per unit is 16.7. The communications radius of node is 100. The positions of all nodes and electricity value are produced by random functions. The random number of electricity between 0-10000 is shown in table 1.

Table 1: Table Of Remaining Power Of Nodes

Remaining nodes	Total power of the remaining nodes			
	Alg1	Alg2	Alg3	increased of alg2 compared with alg1
10	48960	57747	56847	15.36%
9	41536	53444	52667	24.02%
8	39143	50879	49779	22.91%
7	37199	46234	43769	15.01%
6	30237	39702	39030	22.52%
5	24510	31276	30376	19.31%
4	16368	28673	24913	34.29%
3	10038	19364	17285	41.92%
2	148	8278	7513	98.03%
1	0	0	0	0

Table 2: Time Consumption

Remaining nodes	time consumption		
	Alg1	Alg2	Alg 2
10	6.96	10.24	12.43
9	5.48	15.73	10.25
8	3.68	12.02	9.32
7	6.86	9.83	12.45
6	3.30	12.49	11.33
5	13.85	9.51	7.32
4	3.57	10.87	4.75
3	1.97	16.25	17.34
2	1.39	9.65	9.43
1	19.38	8.18	11.24

From table 1, it can be seen that algorithm 3 increases the total power at least a proportion of 15.01% compared to algorithm 1. Thus greatly reduces the energy waste. It is an effective algorithm.

Table 2 shows the time consumption of different algorithms. It can be seen that the algorithm cost the minimum time, and the algorithm 2 and 3 cost a lot of time. This suggests that the robot energy consumption is greater, but the remaining energy of the system is better than algorithm 1 which results from the reducing remaining power of recycled node.

In figure 2, the abscissa represents the time recycling all the nodes; y-coordinate denotes the total energy of the remaining nodes. The figure shows that the algorithm 1 costs the least time, and the energy declines fast; Algorithm 3 costs the longest time, but it can keep energy as well as possible; all the data of algorithm 2 are between

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algorithm 1 and 3, and it can avoid the recycle of key nodes and keep the whole network in a working state. Therefore, performance of the algorithm 3 is the best.

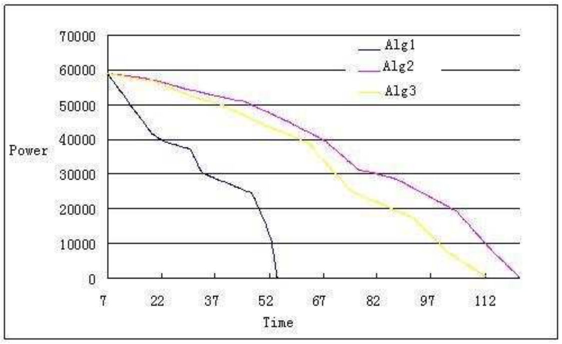

Figure2. Relationship Between Remaining Power And Time

5. CONCLUSION

This paper is the first study on the recycle problem of wireless sensor nodes. It analyzes and describes the problem and gives out two objectives of the solution: minimize the energy consumption in the recycle process, which includes the energy consumption of robot and the remaining power of recycled nodes; maximize the lifespan of wireless sensor network, thus making the network and the network nodes keep working state as long as possible and greatly increasing the power utilization of nodes.

At the same time, this paper proposes three algorithms at different levels: the shortest path algorithm, the minimum energy consumption algorithm and the longest network lifespan algorithm. Moreover, experiments are done to compare the performance of the algorithms. Experiments show that these algorithms can achieve the desired objectives.

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