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Charging scheme for wireless sensor network based on area scanning and energy detection

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Abstract. With the development of wireless sensor networks, the demand for wireless sensors increased sharply. At the same time, there is a problem that the storage of energy is relatively low due to the small size of wireless sensors, which means that it needs to replace when sensors are out of charge. It will cost huge finance and pollute the environment. Consequently, many scholars propose using wireless sensors that can recharge instead of primary wireless ones. In this case, choosing a suitable route to charge wireless sensors has become a significantly critical problem as there is a relationship between energy loss and the charging path. Since it is unstable or unsuitable to use solar energy and wind energy to charge, charging wireless sensors using drones, proposed by Kulaea T. Pauu1, Han Xu, and Bang Wang [1], has become a feasible solution. However, this solution still has some drawbacks as it only uses energy to charge the point with the lowest energy level by drones without considering the priority, the rest of the power, and the efficiency of time and energy. This report will use the data about the utilization rate of energy and make some comparisons to improve this solution.

Keywords： Wireless Communication Networks, Drones, Priority Based On Energy, Optimized Path, Energy Transfer.

1. Introduction

In the relatively wide area, there is a general method to monitor this area in real-time through the wireless sensor network contributed by spreading wireless sensors. There is an example given by paper. [2] Based on the data provided by temperature and humidity sensors, sprinklers and ventilators of the farm can be used to monitor and adjust the temperature and humidity of the farm. Utilizing a wireless sensor network can save energy, and it is suitable for wisdom farms and houses because the price of wireless sensors is relatively low and convenient to spread.

In paper [1], there is much research about the strategy of wireless charging, such as the traveling salesman problem and the shortest path. However, these strategies are unsuitable for this situation due to the particularity of wireless sensor networks. When the cluster energy or the level of energy in an area is too low, this area will be out of work, and the wireless sensor network may be destroyed. In

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this essay, we focus on area energy in wireless sensor networks and cluster energy using the collective transfer of information in the area of wireless sensor networks. We mainly focus on these topics because of the specialty of wireless sensor networks.

2. Related work

Before knowing how to optimize the route choice and increase the drone's efficiency, the wireless sensor network's structure should be illustrated. The basic structure of a wireless sensor network is similar to the internet. Each sensor is a node. Sensors collect information from the environment and send information to a central computer. The central computer makes decisions by calculating data that send by sensors. The structure of sensor communication has several types. There are three basic types: star, cluster, and mesh. Each structure is compared to the other [3]. The best type of communication is determined by different situations and information that needs to be transmitted. There is a similarity between them, which is that they are all centralized. Sensors will transmit information to clusters, which makes clusters much more critical than others. Back to the charging scheme, the original scheme only focused on the energy that sensors left, which may not be the best scheme for a drone to charge sensors.

The next part that should be mentioned is how to choose the best route for the drone. There are lots of famous shortest route algorithms that can be used. This paper will discuss three methods: Brute Force, Dijkstra algorithm [4], and Greedy algorithm [5]. Brute Force can always get the best route that the drone moves. Sadly, Brute Force is the best way to find the shortest route (only focus on the result). Dijkstra algorithm is similar to Brute Force, which can also find the best route that the drone travels. However, the Brute Force and Dijkstra algorithm have the same obvious disadvantage: complexity. The complexity of Brute Force is O(n*m). Dijkstra algorithm’s complexity is O(n^2). In contrast, the Greedy algorithm has minor complexity, which is O(n).

3. Theory

3.1. Energy base route

In paper [1], the path is chosen based on the energy level. All sensors will be checked in a period. The route consisting of all sensors with throughput energy will be chosen by software after checking all sensors. Drones will use this path to charge every point. The benefit of this algorithm is that the sensors' energy level will not be too low. However, this algorithm will waste tremendous energy on the charging way. Consequently, the efficiency of power is significantly low.

3.2. Comprehensive priority value (route+ energy)

Based on the original scheme, it is determined whether to pass the adjacent points by detecting the remaining energy of drones. Consequently, we need to get the points with the highest priority and calculate the required energy and choose a path. The distance and energy needed to reach the adjacent point are calculated after a point is reached. If the drone's energy is smaller than the energy required to pass the needed point, there is remaining energy, and then go back to the original path and recharge the point. Otherwise, it will go back to the original to gain energy.

3.3. Give priority to sub-region

Optimizing the efficiency of power while the remaining energy of sensors will not be too low becomes a serious problem to be solved. The algorithm of prioritizing areas is used to reduce the waste of energy on the charging way. Firstly, giving basic priority to clusters to make sure there is no cluster with relatively low energy levels that cannot work. Secondly, check every point of energy level and then update every priority point based on their energy level. Basic formula equation 1 is used:

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```
if node_pow(index) < 2.2
    prio(index) = prio(index) * 4;
end
if node_pow(index) < 1.2
    prio(index) = prio(index) * 10;
end
if node_pow(index) == 3
    prio(index) = prio_base(index);
```

Figure 1. Finally, the route with higher priority is used by calculating the overall priority value.

3.4. Scanning area and give priority

Although the method of giving priority to the sub-region can avoid the situation of low energy levels during the charging way, the path is still not optimized. We can scan different areas and choose the optimal point by calculating the priority of different areas to reduce the possibility of a suboptimal solution generated. Once the energy in this final area is still too low or too high, the scan area will increase or decrease until a suitable solution is shown.

4. Experiment

In this experiment, we aim to use Matlab to simulate that drones take enough energy and choose a route to charge 200 wireless sensors in a random position in an area. We use different path planning algorithms and get some data, such as total energy, energy efficiency, and the number of sensors that cannot gain enough energy to work. We will compare these data and analyze the pros and cons of these algorithms.

4.1. Parameters the experiment use

10*10 square area
200 points randomly spread
Divide the square into 16 areas of 2.5*2.5
Randomly select 3 clusters and 1 node in area of 2.5*2.5
The energy consumed by the single sensor in a time unit is a normal distribution (mean=0.25, standard deviation=0.1) limited in the range of 0 to 0.5

4.2. How System Works

Firstly, randomly generate 200*2 values and then generate 200 x and y axis based on these values. Secondly, grouping these 200 random values according to the x and y axis and randomly selecting clusters and nodes in the different grids. Finally, use a relatively large energy consumption to have a pressure test on the entire system and use distinct ways to simulate this situation.

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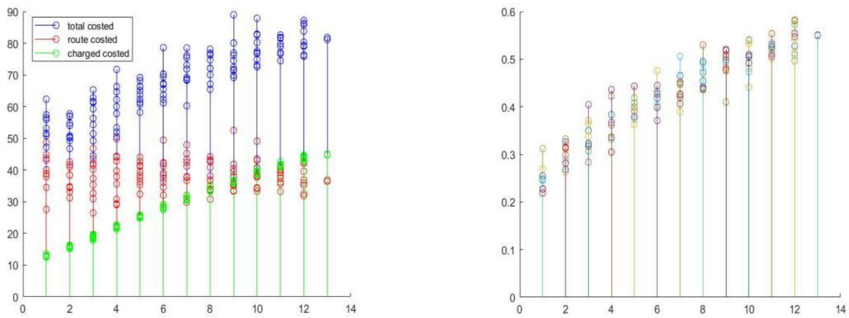
4.3. Data & figure

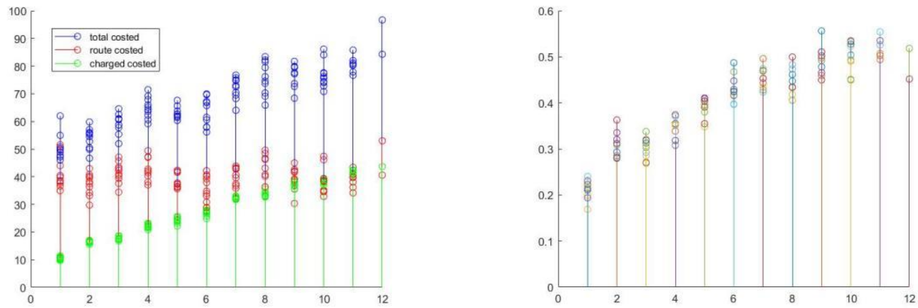
1）Route choice based on energy



(a) (b)

Figure 2. (a)Energy cost, (b)Efficiency.

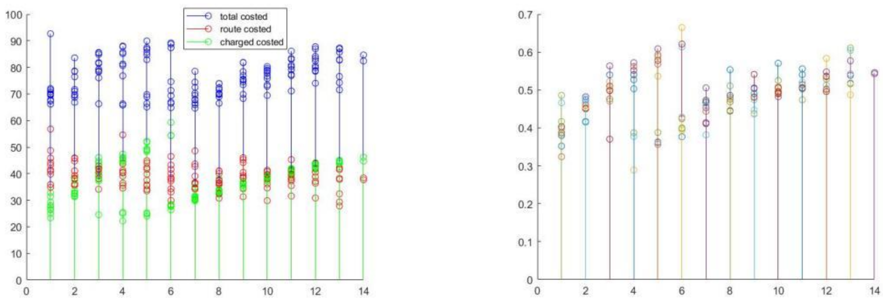
2）Route choice based on energy and priority of flexible grid



(a) (b)

Figure 3. (a)Energy cost, (b) Sufficiency.

3) Comprehensive priority value (route+ energy)



(a) (b)

Figure 4. (a)Energy cost, (b) Efficiency.

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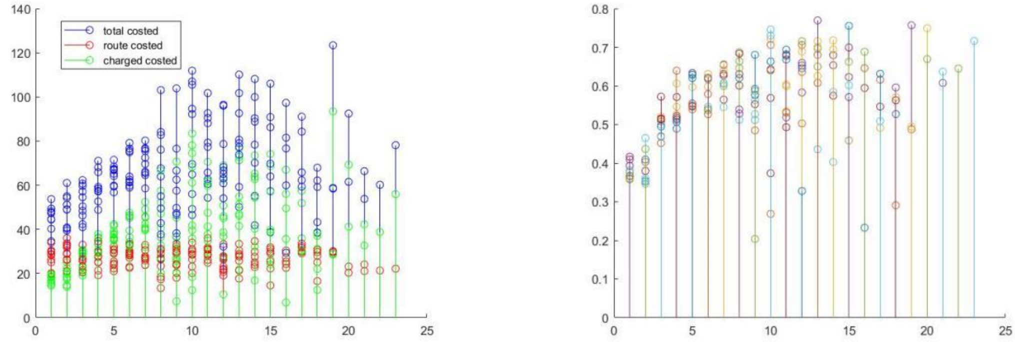
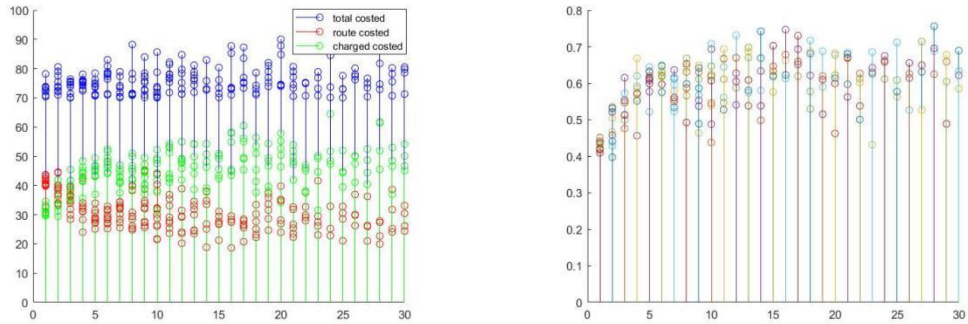
4）Route choice based on energy and priority



(a) (b)

Figure 5. (a)Energy cost, (b) Efficiency.

5）Route choice based on energy and priority of grid



(a) (b)

Figure 6. (a)Energy cost, (b) Efficiency.

Table 1. Summary of different datas based on Matlab.

	Mean total energy costed	Route energy costed	Charged energy costed	Efficiency	Test turn
1	68.46	35-45	13-40	0.2-0.5	12.2
2	68.63	35-45	10-40	0.2-0.5	10.9
3	76.35	35-45	25-50	0.4-0.6	12.7
4	66.87	30-40	range	0.3-0.7	16.8
5	75.82	20-45	30-60	0.4-0.75	20.8

The figures above show different methods' energy cost (figure 1,3,5,7,9) and the efficiency (figure 2,4,6,8,10). Table 1 summarizes data from different methods. Since the energy that is charged is various and changing in different circumstances, hence, all figures contain ten times experiments. For method 4, the energy cost is not constant nor trendy, and the range will be put in the table. The efficiency is rising because the energy sensors need to charge is rising. The energy change lends a rising trend of efficiency.

This method is provided by the original paper [1]. In this paper, the sensors that need to be charged are determined by the rest energy. According to the paper, we resume the algorithm by comparing the energy level in the whole area, choosing the most minor 15 energy sensors, and then using the Greedy algorithm to plot the shortest route that passes all nodes. After that, the total cost is calculated. From the result of the experiment, the energy caused by routing is relatively equal, floating around 40. The charging energy is rising and making total energy cost and efficiency increase. The performance under the high-pressure system is expected to be 12.2 turns.

In order to cover the priority of clusters in wireless sensor networks, this algorithm added priority to clusters. The fundamental priority of each normal node is 1. For cluster and sub-cluster, the priority is alternatively set in 5 and 3. Through this basic idea, this algorithm uses priority as a standard instead of using energy. Nevertheless, the node that can be charged is still the same. Energy costs in the route are similar, but energy for charging decreases, causing a worse performance. Paying too much attention to cluster lower the efficiency of this algorithm. The system also gets much easier to crash, which can only survive 10.9 turns and has the same efficiency as method 1. In summary, this algorithm may have a better performance in a system that pays more attention to priority, but not this system.

By taking the previous experiment, we decided to develop an algorithm that focuses on energy, improving efficiency considerably by selecting 15 initial nodes as method one. This algorithm detects if there are any adjacent nodes around those which are selected. The algorithm should raise the efficiency and keep cost energy as low as possible. In the end, the range of energy is set from 70 to 90. As a result, the efficiency reaches 0.4-0.7 from 0.2-0.5. Meanwhile, energy growth is relatively low, which is eight on average.

To solve the problem of energy loss during the path and increase energy efficiency, we used experiments based on the overall energy and priority brought by a grid. In the same unit of time, we found that when charging the same grid, the energy consumption is only about 20, compared to about 70 for the other two. For a relatively fair comparison, we increased the number of wireless sensors charged per unit time from one to two. The experimental results show that charging the wireless sensor in different areas can increase energy efficiency and perform better in the pressure test. However, this method is unstable because the system will increase the priority value of the uncharged sensor when detecting the remaining energy. When a sensor reaches the second level for the first time and its energy consumption slows down, it will be given a high priority value. Some sensors that consume too much energy cannot gain energy promptly. Furthermore, this also limits energy utilization and the method's overall performance.

How to optimize this algorithm of path planning? The solution is to scan different areas many times and use some calculations to find which grid has high priority. In the beginning, we used a 2.5*2.5 grid and examined it, but the result was unsatisfactory. The energy cost cannot be stable, so we are trying to change the way of scanning. We are controlling the size of the grid based on the energy level. The grid size should vary when the energy is smaller than 70 or higher than 100. The energy limit is set according to 1 and 2. This approach significantly performs in the pressure test and has high energy efficiency. Although the total energy consumption is substantial due to the minimum value of the energy being 70, the energy loss can be controlled, and this method is feasible. At the same time, it also has high performance in the number of test turns.

5. Conclusion

The fifth approach performs best in this simulation based on energy and path planning. This procedure is suitable for wireless charging path planning for wireless sensors. With enough charging base stations, using sub-regional charging can also reduce the loss of energy on the path. The shortest path algorithm used in this paper is a greedy algorithm. Although it can reduce the computational complexity well, in some cases, the algorithm still performs poorly and needs to be optimized.

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