Path optimization strategy for charging nodes in wireless sensor networks

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Abstract

This paper proposes a path optimization strategy (POSC) for charging nodes in wireless sensor networks. The algorithm of POSC for the remaining energy of the nodes in the wireless sensor network, the sensor wireless charging car is used to charge the node. The wireless sensor network adopts a clustered energy efficient routing algorithm. The mobile charging car only charges the cluster heads elected in each round, maintains the usage period of the wireless sensor network, balances the network energy consumption, and reduces the death time of the node. During charging of the node, the charging car collects the energy information of the nodes in each cluster, and returns the energy information to the base station. The base station uses the Markov prediction model to predict the energy consumption of the node, and finally determines the charging target of the next round. Simulation experiments show that: The algorithm of POSC balances network energy consumption, improves charging efficiency of charging car, and prolongs the life cycle of the network.

Keywords

Wireless sensor network;directed charging;clustered energy efficient routing algorithm; Markov prediction model.

1. Introduction

In Wireless Sensor Network (WSN), sensor nodes are usually deployed in harsh environments, and it is difficult and costly to replace the battery by sensors. Not only that, the energy of the sensor node is limited[1], and the energy is generally provided by the disposable battery, which makes the energy of the node become the main factor restricting the life cycle of the wireless sensor network.

Replenish energy from sensor nodes by taking environmentally friendly energy sources (such as solar, wind, and vibration) from the natural environment. The literature proposes an accurate solar and wind energy acquisition prediction model to help nodes acquire energy. The literature proposes solar-aware routing, which takes into account natural energy acquisition in routing design[2]. However, the operation of energy harvesting technology relies too much on the surrounding environment, and the uncontrollability of the environment leads to a reduction in the effectiveness of actual use, and the device for energy harvesting is much larger than the sensor node. Many conditions limit the feasibility of extracting energy from the surrounding environment. So how to improve the life of the wireless network and maximize the network life cycle become the primary issue.

Reference [3] assumes that the network contains several sites, each site can deploy one or more rechargeable sensor nodes, MC can simultaneously charge all sensor nodes of one site; each sensor node has multiple transmission energy levels, corresponding to different Communication distance. The goal of this paper is how to assign a certain number of sensor nodes to each site; for each node's sensor nodes, how to determine their next hop route and the corresponding transmission energy level, so that all nodes generate data It can be delivered to the base station node and has the highest charging efficiency. To solve this problem, this paper proposes an iterative method, constructing a routing tree with minimum energy-load concentration in each iteration, and determining the routing strategy of the sensor nodes in each station; Then a given sensor node is placed in these sites to evaluate the optimization target value until the result of the two adjacent iterations changes less than a certain threshold. The literature [4] based on the WISP platform [14], consider the MC simultaneously The sensor node's RFID signal can be read and the sensor nodes within the signal range can be charged. Since the sensor node's power is above a certain value In order to transmit and receive data, the delay of the charging request greatly affects the delay of the communication, so it needs to be reduced as much as possible[5]. By planning the optimal charging circuit of the MC and the corresponding charging position,to minimize the average charging delay for all sensor nodes. To achieve this goal, a linear programming method and a heuristic approximation algorithm are proposed to solve the problem[6].

Therefore, based on the wireless transmission technology, the mobile charging device is used to supplement the wireless energy of the rechargeable sensor nodes deployed in a complex environment, which can effectively solve the network energy bottleneck problem[7]. This method can effectively reduce the mortality of nodes, which can greatly improve the survival time of the network. Therefore, it has broad prospects and research value, and is gradually becoming a research hot issue.

This paper proposes a wireless sensor network node charging algorithm based on the energy prediction clustering model POSC. In the mode of network non-uniform clustering, the mobile charging car only charges the cluster head in each round of charging scheduling. The remaining energy information of the nodes in each cluster is collected, returned to the base station in the form of multi-hop, and the next charging sequence is predicted by the mobile car carrying information, thereby prolonging the service life of the wireless sensor network.

2. Model and problem description

Assume that in the wireless rechargeable sensor network, N nodes $N_k(n_1, n_2 ... n_n)$, $(1 \le k \le n)$ are randomly and evenly distributed in a 1000×1000 rectangular sensor network region, and the center point of the rectangle is used as the coordinate origin.The location of the base station BS is fixed at the origin.A base station with a known and fixed location outside the monitoring area is used as a sink node in the network to manage data generated by all nodes. And deploy a special charger libero at the origin of the coordinates[8]. A mobile charging vehicle MC provides energy for the node and collects energy information of the node; Schedule the charging schedule of the network and charge and maintain the MC. MC wireless chargers Cj (c1, c2...cm), $(1 \le j \le m)$, start from a service station outside the sensor network area, and come to the respective charging areas.

The literature [Wireless networks with RF energy harvesting: A contemporary survey] [9] proposed a charging model based on the classical Friis' model for long-distance transmission in space, which is suitable for indoor close-range transmission:

$$P_r = \frac{G_s G_r \eta}{L_p} \left(\frac{\lambda}{4\pi(d+\beta)}\right)^2 P_0$$

Approximate charging power is:

$$P_{ij} = \frac{\alpha}{(d_{ij}+\beta)^2}$$

Assume that N sensor nodes are statically deployed in the network, where the location of node i is (W_x^i, W_y^i). The location of the mobile charging energy source is (R_x^j, R_y^j). When the mobile charging energy source stays at position (R_x^j, R_y^j), The residence time is B, and the distance between the position point and the node i is $d_{ij} = \sqrt{(W_x^i - R_x^j)^2 + (W_y^i - R_y^j)^2}$.

Through the algorithm, finding the optimal stay point of the mobile charging energy source in the deployment area of the wireless sensor node and the residence time at each stop point toensure the total delay charging under the premise of ensuring the node charging energy accumulation threshold.

3. Model and problem description

The specific steps of running the K-means algorithm in the WRSN are as follows: Step 1, randomly select K locations as initial cluster centers in a certain area; Step 2, all nodes in the network calculate their and K cluster centers by calculating Distance, and choose to join the nearest cluster center until K clusters are generated; in step 3, the generated K clusters are calculated according to the distance between the nodes in the cluster, and the location of the cluster core is obtained; step 4 If the position of the cluster heart no longer changes or meets the set qualification conditions, the algorithm is terminated, and the obtained cluster is the expected result. Otherwise, step 2 is repeated, and the iteration is continued until the appropriate cluster is obtained[10].

This paper proposes and designs a fixed path charging scheme in clusters. In this charging scheme, the charging process of the WCE to the node is similar to the periodic charging, that is, charging the node according to the planned route; and the charging time is selected in an event-driven type, similar to the on-demand charging. That is, charging is only performed for nodes that have charging needs[11]. The charging scheme proposed in this paper realizes simultaneous charging of cluster nodes, so it can ensure that WCE can get higher charging efficiency; compared with the on-demand charging proposed in the general article, we propose a fixed charging path charging. The solution is easier to guarantee that the node won't die.

When analyzing the fixed path based WRSN charging planning problem, first assume that WCE is using a constant moving speed v m/s.When charging a node, which charging power q is constant.

Total charging time is T_n:

$$T_n=T_{n-1}+t_n+\tau_n$$

T_{n-1} is the total time that WCE completes charging for the node n_{n-1}; t_n is the time required for WCE to move from node n_{n-1} to node n_n. τ_n is the time required for WCE to charge Node n_n.

$$\text{s.t.} \quad t_n = \frac{d}{v}$$

$$\tau_n = \frac{E_{inital} - E_{residual}(n) - E_{selfcon}}{q_{charger}}$$

$$E_{selfcon} = R_n \times (T_{n-1} + t_n)$$

d is the distance from node n_{n-1} to node n_n. E_{inital} is the initial energy of the node n_n. $E_{residual}$ is the residual energy after node n_n works for a period of time.$E_{selfcon}$ E is the energy consumption of the node itself when the charging car completes the charging of the previous charging node n_{n-1} and the time when the trolley moves to the current charging node n_n.

4. Algorithm Design

After each scheduled task is completed, the MC carries the collected energy information and reports back to the BS. At this time, the nodes in the network are still working and consuming energy. At this time, the energy information received by the BS is not accurate. In order to effectively find the charging target in the next scheduling and obtain a new charging path, this paper uses the Markov prediction model to predict the energy consumption of the node after the MC leaves the charging node.

Assuming that the wireless sensor network is a square area with a side length of 100 m, 100 sensor nodes other than the base station are randomly distributed in the monitoring area, and such a sprinkling method is a general problem for researching problems. The initial energy of the sensor node and the distance between the nodes are preset, so that the mobile charging energy source can charge the required node according to the planned path in the case of limited energy, and finally return to the mobile energy source to store the power at the starting point. . The battery charging rate of the charging trolley is maximized while controlling the charging time of the mobile charging energy source[12]. The charging path is optimized by an improved genetic algorithm. The algorithm steps are as follows:

(1) Initialize n network nodes and base station points, the coordinates are known, calculate the distance between each node, and generate a distance matrix.

(2) Set algorithm parameters: crossover probability, chromosomal variation, etc., and treat each record in the population as a traversal path.

(3) Evaluate the degree of goodness and badness of each path by the fitness function value, and calculate the fitness. Because the shortest path value, that is, the minimum value, the commonly used method is CF(x) or C/F(x) (C is a constant). Here, the former method is used. Thus, the relative fitness can be further calculated. In this context, the convenient path length of the mobile charging energy source is considered to be the fitness function value.

(4) Selection and copying. Using the roulette algorithm, a random value is generated, and its relationship with the cumulative relative fitness is compared to select a good individual to enter the next generation.

(5) Cross. In the chromosomes Tx and Ty representing the path, two loci (not the starting locus) i and j are randomly selected, and each locus between the i locus and the jth locus is defined as a cross domain, and The contents of the intersection are memorized as temp1 and temp2, respectively.

(6) Variation. The chromosomes are coded from 1 to 11 without repetitive coding, so it is not possible to use a general alternative to generate a random number. The exchange variation method is used here. That is, two numbers are randomly generated, and the order of the two nodes is exchanged.

(7) After reaching the number of global iterations, the individual of the best route is output and the best path is obtained.

5. Experimental Results and Analysis

The wireless rechargeable sensor network designed in this paper is 1000m×1000m. There are 1000 sensor nodes randomly distributed in this area. Base station B (50, 50) is located in the center of the network. The mobile charging energy source energy is 30kJ, the period value is 500s, the charging speed of the charging car is 2m / s, the charging efficiency of the charging car is 5J / s, the average power consumption of the car is 3J / s, and the maximum energy value of each node. It is 200J. The residual energy threshold of the node is set to Emin = 80J, and the data transmission energy consumption is 50nJ / bit. According to the above parameters, the simulation experiment was carried out, and the simulation tool was MATLAB 2017a, which was compared with the traditional GA algorithm.

Fig. 1 is an effect diagram of grid clustering, dividing a monitoring area into several virtual grids, nodes in the same grid self-organizing into clusters, and constructing a spanning tree in a distributed manner for routing, thereby reducing communication costs within the cluster. According to the remaining energy of the node, the timer is started to select the local cluster head, and the multi-hop communication is used to complete communication with the base station, thereby avoiding energy imbalance. At the same time, balanced grid clustering ensures low communication latency

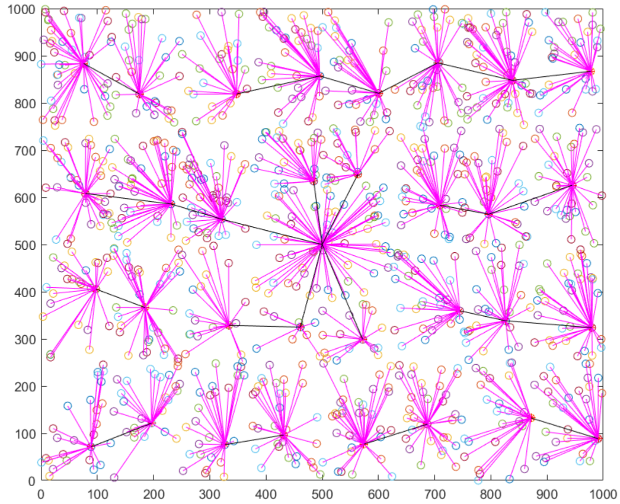

Figure 1 Grid Clustering

Through the random distribution of the points of the network nodes, multiple simulation experiments were carried out on the 40-200 node areas. In order to make the optimal value of the solution more efficient, the average of the optimal values of multiple sets of optimizations is taken. The following is an analysis of the simulation results. Figure 2 shows the path distance curve of TSP, GA and POSC optimized from 40 to 200 nodes. From the curve change, GA and TSP perform well when the number of nodes is small, but the number of nodes increases. Large, it is obvious that the result obtained by POSC is not very satisfactory. When the number of nodes is increased to 160, the charging path solved by SFLA is the longest, and the path solved by TSP and GA is always shorter than the other two.

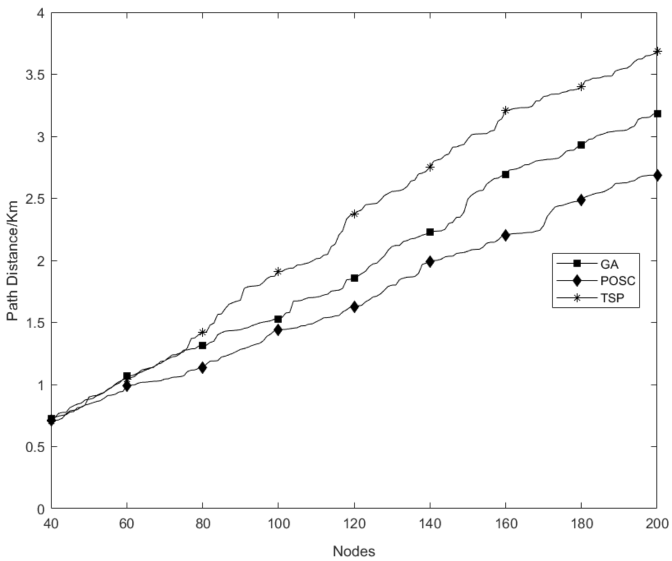

Figure 2 Optimized charging path curve

When the number of nodes is small, the utilization of the TSP-optimized charging car is the lowest. As the number of nodes increases, the curve changes gradually toward POSC. When the number of nodes increased to 120, POSC increased by 22.5% compared with GA energy utilization, and TSP optimization results were still not ideal. When the number of nodes increases to 200, the energy utilization rate of POSC is 20.4% higher than that of TSP, and the GA energy utilization rate is the lowest at this time. This is because the late GA is in a local optimum, resulting in the accuracy of optimization. high. The energy utilization after POSC optimization is always higher than the other two algorithms. In summary, the effectiveness of the improved algorithm is verified.

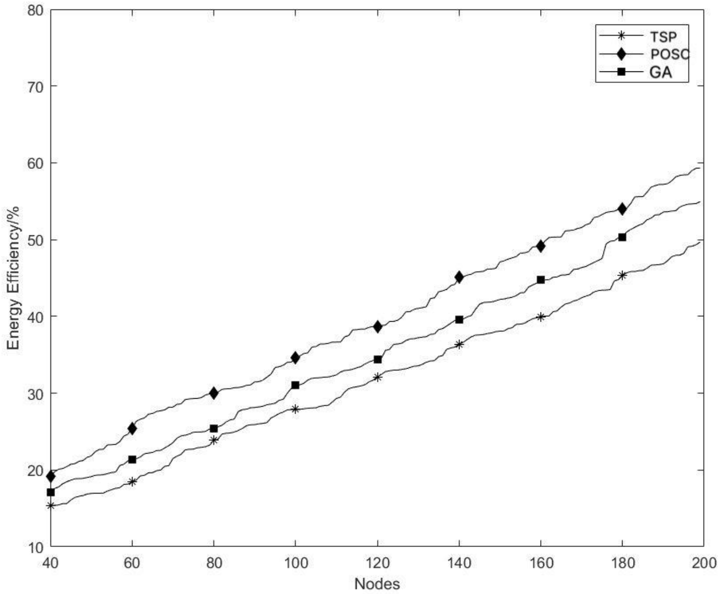

Figure 3 Energy Efficiency

6. Conclusion

In this paper, the charging scheduling problem in wireless rechargeable sensor networks is studied. Considering the actual situation, considering the limited energy carried by the charging car, the battery energy utilization rate of the charging car is converted into the shortest path in the research process, and it is optimized by POSC . In a small-scale network, simulations were performed using GA, TSP, and POSC. The results show that the path obtained by POSC is the shortest and the energy utilization rate is the highest.

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