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Design of Rechargeable Wireless Sensor Network for new energy micro grid

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Abstract. In traditional wireless sensor networks, the node battery capacity is very limited, which seriously restricts the sensor network long time monitoring operation. Therefore, how to improve the life cycle of WSN has always been the focus of research. In order to ensure the normal operation of WSN as long as possible, the energy of nodes must be utilized to the maximum extent. In this paper, based on the wireless transmission technology, mobile wireless charging equipment, energy supplement of rechargeable sensor nodes deployed in the complex environment, solve the network energy bottleneck problem essentially, effectively reduce the node failure rate, greatly improves the network lifetime, has broad prospects and research value.

1 Introduction

In general, the power of the sensor node is provided by the disposable battery. In order to ensure the normal operation of the WSN for as long as possible, the energy of the node must be utilized to the maximum extent. Most of the research is devoted to formulating a reasonable energy allocation and management strategy. But this approach can only extend the life cycle of the network as much as possible and cannot fundamentally maintain the lasting and normal work of the network[1]. Where the environment allows, the battery can be artificially changed, but for special applications such as environmental monitoring systems, field expedition, etc., this regular replacement has become difficult to achieve. And drawing natural energy from the environment does not guarantee continuity and controllability[2].

On the basis of wireless transmission technology, the use of mobile charging devices to supplement the rechargeable energy sensor nodes deployed in complex environments is gradually becoming a hot issue in recent years[3]. The research on charging wireless sensor networks mainly focuses on charging strategies. Wireless charging devices are expensive and their mobile costs are quite large. Therefore, it is necessary to develop a reasonable and effective charging strategy and node energy supplement scheme.

Rechargeable sensor node with all the advantages of traditional sensor nodes, such as low power

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consumption, micro-size, easy deployment, scalable, ad hoc network, robustness and other characteristics, but also has the following potential: battery life is strong, at Rechargeable sensor network, the sensor node energy from the surrounding environment to obtain their own, and these energy sources are usually renewable. There are many sources of energy[4]. The node can be based on the specific characteristics of the environment and the implementation of the work to choose the appropriate Energy collection module. low maintenance cost, energy source is controllable and in the rechargeable sensor network, energy charge chess strategy can be optimized by controlling the energy source to the network. good service quality, environmental damage is small and the energy collected by rechargeable sensor nodes usually comes from the surrounding nature, which belongs to renewable green energy, so it is more environmentally friendly.

2 Charging mode of rechargeable sensor node
Wireless charging technology is developed based on wireless power transmission technology, is not by physical (wire, cable) connect the electric power transmission in a wireless way directly or indirectly out, charging the electronic equipment or wireless sensor nodes for target[5]. At this stage, the diversification of wireless energy transmission technology makes wireless charging have different charging methods. According to the principle of wireless charging technology, there are mainly three charging technologies: inductive coupling technology, electromagnetic radiation technology and magnetic coupling resonance technology [6-8]. These three kinds of wireless charging technology have their own advantages and disadvantages to meet different application requirements, the specific comparison in Table.1.

| Wireless charging technology | Transmission power | Transmission distance | Advantage | Shortcoming |
|-----------------------------|-------------------|----------------------|-----------|-------------|
| Inductance coupling technology | A few to a few hundred watts | 3-4m | Achieve simple, in the very close distance has a higher transfer rate | Effective transmission distance is short |
| Electromagnetic radiation technology | Highest 100mW | Up to 10m | Can maintain a high transmission rate over long distances | Transmission between the two sides can not be obstructed by obstacles, the equipment is very large |
| Magnetic Coupling Resonance Technology | A few kilowatts | Less than 1m | Maintain a higher transmission rate, without alignment, allowing blocking, without environmental impact | Transmission efficiency decreases sharply with increasing distance, efficient transmission distance is very short |

3 Rechargeable Sensor Network Design for New Energy Microgrid
3.1 Mobile charging base station model
In the periodic charging model, the Wireless Charging Vehicle (WCV) initially moves from the service station (i.e., the maintenance station) to the network and transmits the sensor nodes wirelessly at certain fixed points for energy supplement. After all the sensor nodes in the network have been given an energy supplement, the WCV returns to the service station for its own energy supply. The interval at which WCV starts charging twice from the service station is an energy replenishment period, denoted by \( T \).

In an energy replenishment cycle \( T \), WCV has three states: moving state, charging state, rest state. Rest state refers to WCV service station for its own energy supply and maintenance of rest, we can use (3-1) to said \( T \):

\[
T = T_p + T_{vac} + \sum_{i \in N} T_i
\]

(3-1)

The total time that WCV consumes movement in one charging cycle is \( T \), the charging time of any node \( i \) means the idle time staying at the service station to be adjusted, and the optimization goal of the periodic charging model is to maximize the totalizing time of MC Replenishment period ratio: \( T_{vac} / T \).

In the periodic charging model, according to whether the mobility of the base station or not, it can be further divided into a fixed base station periodic charging model and a mobile base station periodic charging model. Mobile base station model is the base station and charger together on a mobile device, the implementation of the charging task.

### 3.2 Fixed charging base station model

The location of the base station remains unchanged throughout the charging process. The sensing data generated by the sensor nodes are transmitted to the base station through direct or multi-hop transmission. The nodes in the monitoring process are generated per unit time, and the data flow received and transmitted remains constant. The MC periodically traverses the nodes for point-to-point charging. The MC is charged only when it is as close as possible to the node. Each sensor node charging receive power is \( U \), any sensor node \( i \) unit time to receive and generate data volume is \( \sum_{j \in N} f_{ij} \) and \( G_i \), sent to the remaining nodes and base station data volume is \( \sum_{j \in N} f_{ij} \) and \( f_{IB} \), follow the flow conservation constraint:

\[
\sum_{k \in N} f_{ik} + G_i = \sum_{j \in N} f_{ij} + f_{IB}, \quad i \in N
\]

(3-2)

Then node \( i \) energy consumption per unit time \( r \) is:

\[
r_i = \rho \sum_{k \in N} f_{ik} + \sum_{j \in N} C_{ij} f_{ij} + C_{IB} f_{IB}, \quad i \in N
\]

(3-3)

Where \( \rho \) denotes the energy consumption of the receiving unit data, \( C_{ij} \) is the energy consumption of sending unit data from node \( i \) to node \( j \), and \( C_{IB} \) is the energy consumption of transmitting unit data directly to the base station (\( C_{ij} \) and \( C_{IB} \) are all distance related). The maximum battery capacity of ordinary nodes are \( E_{MAX} \). node failure when the power is lower than \( E_{MIN} \). All nodes in the network can work normally, then the remaining energy \( e_i(t) > E_{min} \) of the node at any moment \( t \), namely:

\[
E_{max} - (T - T_i) \cdot r_i > E_{min}, \quad i \in N
\]

(3-4)

In order to maintain the continuity and periodicity of node work, it is necessary to meet the node energy consumption equal to the amount of charge in each cycle in a cycle:

\[
T \cdot r_i = T \cdot U_i, \quad i \in N
\]

(3-5)

WCV to get the maximum body-building time in one charging cycle means that the WCV moves all the nodes in the network as far as possible and the WCV reaches all nodes when all the nodes are still valid and can be charged more energy to reduce the frequency of charging. Shi proved that maximizing the station idle time of mobile chargers is to minimize the movement time, and thus the shortest path traversing all nodes is actually the Traveling Salesman Problem (TSP), so (3-1) can be transformed into:
\[ T = T_{\text{top}} + T_{\text{vac}} + \sum_{i \in N} T_i \]  

(3-6)

After the movement path of WCV is determined, the periodic charging problem that maximizes the station time ratio can be transformed into a linear programming problem by introducing auxiliary variables and relaxing the constraints, and the approximate optimal solution is obtained by using the CPLEX solving tool solution.

Define the maximum distance between sensor node and WCV when the received power is not less than the threshold value \( \delta \) is the chargeable range \( D_{ij} \). For node \( i \), the received power \( U \) is a distance-related parameter:

\[
U_i = \begin{cases} 
\mu(D_i) \cdot U_{\text{max}}, & \text{if } D_i(\rho) \leq D_{ij}, \ \text{0} < \mu(D_i) < 1 \\
0, & \text{if } D_i(\rho) > D_{ij}, 
\end{cases}
\]  

(3-7)

Where \( U_{\text{max}} \) is the maximum charge output power of WCV, \( \mu(D_i) \) is the charge transfer efficiency, which is determined by the distance between WCV and node \( i \). Based on this charging model, the entire network area is divided into regular hexagonal cells of side length \( D \) centered on the base station, as shown in Figure 1.

**Figure 1** Periodically traversing the cell's point-to-multipoint charging

**4 Simulation results**

The matlab simulation software is used to simulate and compare the performance of LBRWRSN protocol and LEACH routing protocol proposed in this paper. In the simulation, the monitoring area of the wireless sensor network is set to a square area of 200m × 200m. 400 wireless sensor nodes are randomly arranged in the monitoring area. The Sink node of the network is set in the upper right corner position (200,200). Within the monitoring range, 4 charging stations are laid at (50, 50), (150, 50), (50, 150), (150, 150), the charging station is fixed, and cannot move, as shown in Table 2.

**Table 2** Simulation parameters setting

| parameter | Set up | parameter | Set up |
|-----------|--------|-----------|--------|
| Sensing area size | 200 × 200 | \( \varepsilon_{fs} \) | 10Pj/bit/m² |
| Number of sensor nodes | 400 | \( \varepsilon_{np} \) | 0.0013Pj/bit/m⁴ |
| Initial energy of sink nodes | 5J | \( \alpha \) | 0.2 |
| Initial energy of ordinary node | 1J | \( \beta \) | 2.0 |
| \( E_{\text{elec}} \) | 50nJ/bit | \( R \) | 10m |

The initialization energy of all nodes in the simulation wireless sensor network is the same, set as 1J. All nodes in WSN can move, the maximum moving speed \( \text{VMAX} \) is 2m / s and the actual moving speed of nodes \( \text{VT} \) is a random value between 0 ~ VMAX. The length of the data packet between nodes is 5 kbit, the length of the control packet is 150 bits, the charging radius of the charging station...
is 4 meters, and the energy consumption of node data fusion is 4 nJ / bit.

Figure 2 shows the relationship between the number of network survivors and the number of network runs. The figure shows the change curve of the number of surviving nodes in a wireless sensor network when the network size is 400 nodes. The proposed algorithm LBRWRSN can effectively delay the emergence of the first node in the network and ensure that there are enough surviving nodes in the network to complete the related monitoring tasks. The improvement of LBRWRSN performance is due to the introduction of a charging station to charge the nearby sensor nodes, and the algorithm of node communication radius adjustment and improved cluster head election mechanism are introduced.

Figure 2 The number of network survivors
Figure 3 Average energy consumption

Figure 3 shows the relationship between nodes average energy consumption and network running times. The figure shows the average remaining energy curve of nodes during the operation of wireless sensor network. As can be seen from the figure, by using the LBRWRSN algorithm proposed in this paper, the average energy consumption of its nodes is reduced to a certain extent relative to the LEACH algorithm, which can effectively improve the life cycle of the network.

5 Conclusion
In this paper, based on the wireless transmission technology, a mobile charging device is used to add wireless energy to rechargeable sensor nodes deployed in a complex environment. Different charging models are set up for different situations to analyze. Finally, the simulation results show that the introduction of charging station pairs The charging of nearby sensor nodes has obvious advantages in prolonging the working time of the wireless sensor network and providing a favorable foundation for the reliable operation of the wireless sensor network.

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