Energy Efficient Routing Algorithm for Wireless Sensor Networks Supporting Mobile Sinks

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Abstract. Nodes close to static sink node will deplete their limited energy more rapidly than others, since they have more data to forward during multi-hop transmission manner. This will cause network partition and much shortened lifetime. Thus, how to balance energy consumption becomes a very important research issue. In this paper, we propose energy efficient routing algorithm supporting mobile sinks. We focus on study the impact of the selection of mobile sink node number and the selection of sojourn positions on network lifetime. Simulation results show that our proposed routing algorithm has better performance than LEACH in terms of energy consumption, and both mobile sink node number and the different parking position have very important influence on network lifetime.

Keywords: Wireless sensor networks, mobile sink, energy, network lifetime

1 Introduction

Wireless sensor networks (WSNs) are usually composed of tiny and multi-functional sensor nodes which can sense, process and transmit monitored data [1][2]. Due to the limit of energy, the main objective is to save energy and balance energy load. Thus energy efficiency becomes a key challenge issue for WSNs. Generally, nodes close to the static sink node bear more traffic burden and deplete their energy much faster, leading to disconnection and much shortened lifetime. To improve energy utilization, sink mobility technology is applied to the routing. With the change of mobile sink nodes position, their neighbor nodes will also change. Thus it can effectively reduce energy overhead at nodes, and enable sensor network to last for longer duration.

In this paper, we proposed energy efficient routing algorithm supporting mobile sinks for WSNs. We assume that mobile sink nodes are installed on certain public transportation vehicle surface like public buses and sightseeing vehicles, which can periodically move along certain predefined trajectory with certain schedule. Our proposed routing algorithm aims at balancing the energy consumption and prolonging network lifetime. Our goal is achieved by using multiple mobile sink nodes and choosing appropriate sojourn position intervals. Based on the distribution of boundary neighbor nodes and their transmission range, parking positions are determined and stored when there is only one mobile sink node working for data collection in sensor network. Sojourn positions with several mobile sink nodes are also chosen from park-
ing locations.

2 Related Works

Some relative studies have shown this technology can significantly improve network performance [3][4][5]. In [3], the authors studied a novel mobility control solution in which sensor nodes cooperatively determine the sink trajectory, and navigate mobile sinks for delay and energy optimized data collection. In [4], the authors proposed a data collection scheme, and solved the maximum amount shortest path (MASP) based on genetic algorithm. In [5], the authors first proposed a general MADC model that includes many important parameters such as the number of mobile sinks, mobile sink velocity, and traveling path. Then they developed a comprehensive theoretical approach to obtain achievable throughput capacity and lifetime. By applying the proposed approach, they investigated the behaviors of sensor network with one or more mobile sink nodes.

3 Our Proposed Routing Algorithm

3.1 Routing set-up phase

Initially, there is only one mobile sink node existing in network, and it is located at one special point in sensing field. On the basic of the distance $d_{sn}$, neighbor nodes of mobile sink in each parking position are chosen. If $d_{sn}$ is much smaller than the transmission radius, nodes will transmit their monitored data directly; otherwise, relay nodes need to be elected. Relay nodes will be elected mainly based on the link cost. Link cost is determined by the relative distance and the residual energy, as shown in Equation (1). Node with the minimum link cost will be chosen to act as the relay node.

\[
\text{link\_cost}(i,j) = (1-\omega) \times \frac{d(s_i, s_j)^2 + d(s_j, P_i)^2}{\max (d(s_i, s_j)^2 + d(s_j, P_i)^2)} + \omega \times \frac{\max (E(j)) - E(i)}{\max (E(j))}, \quad \omega \in [0,1]
\]

(1)

Neighbor nodes of mobile sinks are elected based on the node distribution. Along the moving direction, neighbor nodes with the longest distance will be defined as boundary nodes. Thus parking position $P_i$ can be determined mainly based on the transmission range of sensor nodes and boundary nodes. Boundary nodes are chosen from neighbor nodes, and located in the forward direction. According to the transmission range of boundary node, parking position $P_i$ can be determined. Mobile sink will sojourn at each parking position with enough time to collect monitored data from sensor nodes. When mobile sink node $MS_i$ moves to a parking position $P_i$, it will broadcast a notification message, which includes an $ARRIVAL\_MSG$ message and a $NEXT\_POSITION\_MSG$ message.

Each parking position will be kept in a table $PP\_TABLE$, and each mobile sink node will moves from the origin of coordinates in succession. Multiple sink mobility strategy is briefly described in Fig.1. At the point of departure, only one mobile sink
$MS_1$ can receive data. After leaving the origin of coordinates, another mobile sink $MS_2$ participates in data collection. Each mobile sink node will chose one parking position from table $PP\_TABLE$ as its sojourn position to collect data. Nodes within the transmission range will communicate with mobile sinks directly, and will be responsible for other nodes to forward data.

![Fig. 1. Multiple sink mobility strategy](image)

3.2 Routing steady phase

After completing the sojourn location selection for mobile sinks, neighbor nodes will be elected primarily depending on $d_{sn}$. These neighbor nodes broadcast a $NEIGHBOR\_STATUS$ message, communicate with their mobile sinks directly and wait for $JOIN\_REQUEST$ from other nodes. In data transmission phase, they need to forward the monitored data packets sensed by the relatively remote node, and a TDMA schedule can be used to allocate transmission time and achieve low latency.

To reduce the energy consumption, each node can set transmit power based on the distance to the receiver. The multi-hop route can be set up once all nodes find relay nodes. In order to avoid data packets collision, each neighbor sensor node of mobile sink nodes will use a unique spreading code, which will be sent to all next hop nodes. Thus each transmission path has a unique code and all nodes transmit their monitored data to neighbor nodes successfully.

3.3 Routing maintenance phase

Along with the network operation, data communication makes energy of each node gradually decrease. A sensor node on certain link is likely to fail, and unable to forward data to mobile sinks, causing network partition. Therefore, considering the residual energy is quite necessary, and other alternative forwarding nodes need to be elected to replace the failure node or node with insufficient energy.

Before the data transmission, node will broadcast a message including its ID, residual energy and status to mobile sinks. If the residual energy of $s_i$ is not sufficient for the next data transmission, it will send a $REJECT\_MSG$ message to its peripheral node, and quit the next data forwarding. During the data transmission, if $s_i$ in the
transmission link is already failure, an adjacent node nearing $s_i$ with the highest residual energy will be elected to act as the substitute forwarding node. Thus all nodes in each link can be work properly and have enough energy to forward data.

4 Performance Evaluation

We use MATLAB simulator to evaluate the performance of our proposed routing algorithm. In an $100 \times 100$ $m^2$ rectangle network, there are 100 sensor nodes randomly distributed. Initial energy of each node is $2J$. Comparison of network residual energy using our routing algorithm and LEACH respectively is shown in Fig.2. The energy in LEACH network gets drained away much earlier, and performance of our proposed routing algorithm outperforms LEACH.

![Residual energy comparison](image)

**Fig. 2.** Residual energy comparison

Comparison of network lifetime using different number of mobile sink nodes is illustrated in Fig.3. The first failure node appears in the 2490 rounds when there is only one mobile sink working in network. By contrast, nodes can last longer using multiple mobile sinks, and the first failure node appears in the 4004 rounds when there are three mobile sink nodes. However, the cost of mobile sink is relatively higher than normal sensor node. We need to decide the number of mobile sink node according to the actual demand. Thus we analyze the lifetime of the network with two mobile sinks, and the network topology is shown in Fig.4.
Fig. 3. Network lifetime comparison

Fig. 4. Network with two mobile sink nodes

The influence on network lifetime where mobile sinks chose different sojourn locations is shown in Fig.5. Network lifetime is the longest when the interval of mobile sinks is two parking positions. The first failure node appears in the 7087 rounds which last longer than the others. Thus we can conclude that when the interval of parking positions is set to 2, the network performance will be superior to the others.
5 Conclusions

In this paper, we proposed energy efficient routing algorithm supporting mobile sinks for WSNs. We first compare the network residual energy respectively using our routing algorithm and LEACH, and find that mobile sink node clearly contributes to saving energy. Then we mainly study the network performance with different mobile sink node number and different sojourn location selection. Through a series of experiment analysis, we can see that mobile sink nodes can significantly prolong network lifetime, and different number of mobile sink node used in sensor network also greatly influence network lifetime.

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