An energy efficient multiple mobile sinks based routing algorithm for wireless sensor networks

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Abstract. With the fast development of wireless sensor networks (WSNs), more and more energy efficient routing algorithms have been proposed. However, one of the research challenges is how to alleviate the hot spot problem since nodes close to static sink (or base station) tend to die earlier than other sensors. The introduction of mobile sink node can effectively alleviate this problem since sink node can move along certain trajectories, causing hot spot nodes more evenly distributed. In this paper, we mainly study the energy efficient routing method with multiple mobile sinks support. We divide the whole network into several clusters and study the influence of mobile sink number on network lifetime. Simulation results show that the best network performance appears when mobile sink number is about 3 under our simulation environment.

1. Introduction

With the fast development and progress of micro-electro-mechanism system (MEMS), system on chip and wireless communication technologies, a large number of tiny, and low cost sensors are produces. These nodes are randomly placed in a certain area, collecting the data of surroundings, transferring them to the sink nodes by single hop or multiple hops, and forming wireless sensor networks (WSNs). In recent years, WSNs are widely used in natural disaster monitoring, military tracking, agricultural observation, etc. [1].

Energy saving and balancing is always a hot and challenging research issue for WSNs [2]. Research shows that sensor nodes near the static sink nodes will have heavier transmission burden than other ordinary node, which make themselves hot spots and this phenomenon is known as energy holes problems [3].

In order to better utilize the energy of each node in the wireless sensor network and to balance their energy consumption as much as possible, the concept of mobile sink nodes is proposed [4-5]. Those sink nodes can move at a certain speed in the network at a specified or random path, and collect data from the nearby nodes during the mobile process. In this way, because the sink nodes are moving constantly, there will not be some nodes being always close to the sink nodes to become hot spots and the energy consumption of nodes around sink nodes is also balanced.

2. Related Work

An energy efficient routing protocol based on clustering method was proposed [6], which was applicable to WSNs with obstacles. The mobile sink moved from the starting point to the cluster head,
collecting data from the cluster head through single hop transmission, and completed a round of data collection to return to the starting point. Experimental results indicated that the network lifetime was effectively extended, and the scheduling mechanism solved the complexity of scheduling problems in networks with obstacles efficiently. The authors proposed a low energy consumption routing protocol for the constrained problem of sink nodes in sensor networks [7]. It transferred the data to the nearest next arrival location of the mobile sink node, which ensured that the data transmission path is shortest. This protocol had high robustness and low energy consumption and is suitable to be used in networks of delayed tolerance.

The authors devised an optimization framework for mobile data collection where mobile data collection was carried out by two steps [8]. First, a part of sensor nodes were selected to transmit data directly to the mobile sink node. Second, the distributed algorithm was designed to adjust the data rate and link scheduling to improve the network utilization. The authors presented a new method for maximizing the throughput of data collection [9]. First, data collection was carried out using mobile collector with fixed mobility and an optimization model was proposed, which included effective time and heterogeneous time of sensor transmission in each time slot. Second, the maximum amount of time slot available for each sensor node was determined. Last, they confirmed the constant speed of the mobile collection node and designed an online centralized algorithm to deal with the NP problem.

Another method of increasing network throughput called an opportunity data collection method was proposed [10]. The authors first put forward a new routing metric named Contact-Aware ETX, and evaluated the transmission delay caused by the packet retransmissions. Then the routing standards and routing protocols were defined to realize the CA-ETX. Finally, by combining CA-ETX with dynamic routing, an opportunity backpressure collection was proposed. The tests stated clearly that the methods proposed in the above two papers could effectively improve network throughput and reduce network latency.

3. System Model

3.1. Network Model

In this paper, we deploy N sensor nodes in the circular field the radius of which is R, denoted as: {N1,N2……,Nn} separately. The sensor field is divided into several sectors evenly and each sensor node belongs to a sector based on its position.

3.2. Energy Model

We adopt the first radio energy model as the energy model to calculate energy consumption. Energy consumption contains two parts: transmission consumption and reception consumption.

Energy consumption for transmission $l$-bit message is shown in formula 1:

$$E_{tx}(l,d) = \begin{cases} \frac{l}{\varepsilon} E_{elec} + l \cdot \varepsilon_{f} \cdot d^2, & \text{if } d < d_0 \\ \frac{l}{\varepsilon} E_{elec} + l \cdot \varepsilon_{mp} \cdot d^4, & \text{if } d \geq d_0 \end{cases}$$

where $E_{elec}$ denotes the energy consumption to run transmitter or receiver circuit. $\varepsilon_{f}$ and $\varepsilon_{mp}$ denotes the amplification coefficient for the free space model and the multi path fading model.

Reception consumption can be calculated as is shown in formula 2:

$$E_{rx}(l) = l \cdot E_{elec}$$

4. Our Proposed Routing Algorithm

4.1. Clustering phase

We divided the whole network into n parts and every part is a cluster. Each sensor node calculates which cluster it belongs to via its position. At the beginning of each round, CHs selection will be conducted. The parameters of the selection are the residual energy of each node and the distance
between node i and mobile sink. The node close to the mobile sink broadcasts its weight in the cluster and claims a tentative CH. Only the nodes with higher weight broadcast its weight and become a new tentative CH. Finally, the node with the maximal weight is selected as the CH in each cluster.

4.2. Intra-cluster communication phase

Usually, a cluster member will communicate with its CH in two ways: direct transmission and multi-hop transmission. Any cluster member can communicate with its cluster head directly and the energy consumption is calculated using the following Formula 3:

\[
E_e(S_i, CH_{S_i}) = \begin{cases} 
|E_{e_{\text{elec}}} + k_e d(S_i, CH_{S_i})^2, d(S_i, CH_{S_i}) < d_0 \\
|E_{e_{\text{elec}}} + k_{e_{\text{mp}}} d(S_i, CH_{S_i})^2, d(S_i, CH_{S_i}) \geq d_0 
\end{cases}
\] (3)

When cluster member has a long distance away from its cluster head, a relay node is chosen to forwarding the data package.

5. Performance Evaluation
5.1. Simulation Environment

In order to test our proposed algorithm, we use a MATLAB simulation environment. The radius of the mobile sink is changed to explore the optimal performance. We also test our algorithm with different WSNs network topologies for about 20 times.

5.2. Study on Mobile Sink number

We research the effect of mobile sink number to the lifetime of the network via simulations. We only use single mobile node in the beginning and then increase the number of mobile sink once a time. Simulation results show that with the increase of the mobile sink number, the performance of the network in terms of lifetime improves, as is shown in figure 1. We also attentions that the trend of the lifetime slows down with the mobile sink increased. As the mobile sinks are much more expensive than ordinal sensor nodes, 3 mobile sinks are most suitable.

![Figure 1. Different mobile sink number.](image)

5.3. Study on different methods of weight calculation

It is a common method to select cluster heads through the residual energy of nodes, but the nodes chosen by this way are usually far away from mobile sink which have high residual energy. This will increase the number of long distance communication between CHs and mobile sink, increasing the energy consumption of the entire network. Therefore, in order to achieve a balance between residual energy and the distance from CHs to mobile sink to prolong the lifetime of the system. We calculate the weight of each node via using residual energy dividing distance between node and the mobile sink as a standard for choosing a cluster head, Simulation results are shown in figure 2, and the latter approach has a better performance.
6. Conclusions
During the design of energy efficient routing algorithms for WSNs, how to alleviate the hot spot problem is an important research issue. In this paper, we proposed an energy efficient clustering algorithm for WSNs, with mobile sink support. We first give the system model and our hierarchical routing algorithm. Then, we present simulation results to validate the performance of our proposed algorithm. Simulation results show that network has the best performance when mobile sink number is around 3. Even though we continuously increase cluster number, there is no big increase while the cost from sink node will increase which is not necessary. Also, we evaluate the selection criteria of two metrics during the selection of CHs. In the near future, we will make further study on the mobile sink parameters such as moving velocity, other clustering methods on WSNs performance.

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