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Research Article

The Research of Sink Mobile Strategy based on Gravitational Field in WSN

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Abstract: The mobile trajectory design of sink in WSN is the core research issue. This study models the data-gathering process in WSN as gravitation attraction between any two objects and proposes a moving strategy of sink in WSN based on Gravitational field. Sink tends to move to the direction where the sensor node with the highest gravitational field intensity. The strategy considers several factors affecting the network performance, including sensor node residual energy, the sink access time interval for sensor node and the distance between sensor node and sink. The simulation results show that this strategy can effectively balance node load, reduce the packet overflow rate, prolong network lifetime and improve network performance.

Keywords: Gravitational field intensity, network lifetime, overflow rate, WSN

INTRODUCTION

With the rapid development of information processing and communication technology, people have paid more and more attention to WSN which consists of a large number of sensor nodes with the capability of sensing, computation and wireless communication. Wireless Sensor network can be widely applied to national defense military, environmental monitoring, medical care and many other areas.

Due to the fact that sensor nodes are powered by battery, so the energy of sensor nodes is limited. It is common knowledge that the data-gathering way of the traditional WSN generally uses a static sink through multi-hop transmission. However, in this way, theenergy of nodes near sink will be exhausted quickly, because they have to relay data from other sensor nodes far away from sink, thus the phenomenon of energy holes will inevitably emerge near sink. Consequently, this uneven energy consumption will decrease network lifetime. In order to solve the problem above, currently, more and more scholars have developed a method using sink. Consequently, this uneven energy consumption will decrease network lifetime. In order to solve the problem above, currently, more and more scholars have developed a method using mobile sink for lifetime improvement in wireless sensor networks.

For the reason that mobile sink is introduced into wireless sensor network, it will result in no real-time data collection. Therefore, how to design sink mobile trajectory with minimum possible packetdelivery delaywhile collecting data is the essential issue influencing the network performance. Qu *et al*. (2010), defining a concept named placement pattern (pp), have built a linear optimization model to solve sink node placement problem. In this case, however, the sink mobility is limited, namely, sink can only mobile within the placement location. Chen and Liu (2011) have proposed a scheme named HS-BDM, including fixed sinks and mobile sinks. Chatzigiannakis *et al*. (2006) have discussed the random motion of sink in the traditional WSN. Compared with the static sink, it can increase network lifetime. But the random mobile way of sink will lead to uneven sensor nodes load. Zhang *et al*. (2008) have proposed a strategy of the fixed trajectory of sink for single-hop, but this method brings about the data forwarding delay and cannot be applied to high real-time scene. Guo and Li (2007) have discussed a cluster-based autonomous mobile routing algorithm of sink, which takes the node residual energy as a basis for cluster head election. However, this algorithm is easy to fall into local optimum situation. Sun *et al*. (2006) have developed a one-eighth circle-based partitioning algorithm, sink moves to the area where sensor nodes have high residual energy. In the moving process, if sink finds other nodes with more residual energy, it will frequently change direction so that it will cause more invalid motion and lead to additional energy consumption. Sha *et al*. (2010) have researched mobile sink from the point of view of safety.

In order to gathering data more efficient in the aspect of lower packets overflow rate, this study proposes a new strategy for mobile sink based on gravitational field-Gravitational Field Intensity-Highest (GFI-H), which considers several factors affecting the network performance, including sensor node residual

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energy, the sink access time interval for sensor node and the distance between sensor node and sink. According to the similarity between the data-gathering behavior of sink and the attraction among any two objects, the strategy models the WSN as a gravitational field which is aroused by sensor node. Sink moves to the direction where the node has the highest gravitational field intensity. This strategy has low complexity and can effectively reduce the packet overflow rate to prolong network lifetime.

NETWORK MODEL

The WSN which has been discussed in this study is mainly used for data-gathering in the monitoring area. In our setting, we make the following assumptions:

- The network is composed of many static sensor nodes with limited energy and a mobile sink with enough energy.
- Sensor nodes and sink have the same communication range.
- Sensor nodes have the same initial energy and sink has the capability to get their residual energy at any time.
- Sink moves at a fixed speed.
- The energy consumption of WSN mainly comes from data sending and receiving between sensor node and sink.
- Every node is equipped with GPS and every node has the capability to get the location information of sink at any time.

Definition 1: According to graph theory, WSN can be expressed as an undirected graph, namely G = (V, E), where Vis the collection of all sensor nodes and sink, Eis communication link between any two nodes which can communicate with each other directly. In mathematics:

$$V = V_N \bigcup V_S \quad (1)$$

In (1),
V_N : The collection of all sensor nodes
V_s : The collection of all sinks

Because there is only a sink in the WSN we research and sensor node can only communicate with sink, so communication link can be expressed as following:

$$E = \{(i, S) \mid i \in V_N\} \quad (2)$$

In (2), S is the sink.

Moving strategy of GFI-H:

Gravitational field intensity: In classical physics theory, gravitational field is produced because of attraction between any two objects. Gravitational field intensity is defined as E = F/m, where F is the gravitation and m is mass of the particle m. It is known to all that the law of universal gravitation is $F = Gm_1m_2/r^2$, so gravitational field intensity can also be expressed as $E = Gm/r^2$, in which, m is mass of the object which arouses the gravitational field, r is the distance between the object and the field, G is the gravitational constant.

Given that sensor nodes have to transmit the collected data to sink in WSN, so sink moves to sensor nodes to gather data. This motion of sink seems that the data collected by node attracts sink. Based on this phenomenon, we can model the scene as gravitational field.

Definition 2: We define the gravitational field intensity of sink from the sensor node at the location of (x, y) as following:

$$E = \frac{1}{\Delta \tau} \frac{Q}{d^2} \vec{d} \quad (3)$$

In (3),
Q : Residual energy of sensor node
$\Delta\tau$: The sink access time interval for sensor node
$\vec{d}$: The movement direction of sink
d : The distance between sensor node and sink

To describe the movement characteristic of sink, we give the following two formulas:

- Direction of moving to sensor node i for sink:

$$\vec{d_i} = (x_{\sin k} - x_i, y_{\sin k} - y_i), i \in V_N \quad (4)$$

- Distance between sensor node and sink:

$$d = \sqrt{(x_{\sin k} - x_{sensor})^2 + (y_{\sin k} - y_{sensor})^2} \quad (5)$$

The design of mobile trajectory: In this study, we propose a mobile strategy of sink based on Gravitational Field Intensity (GFI-H). The basic idea of the strategy is as following. First, every sensor node calculates the gravitational field intensity of sink and saving it in node information table which is described as Table 1. Second, sensor node forwards its node information table to sink. Sink gets the coordinate information of sensor node with the highest gravitational field intensity by comparing the node information tables from every sensor node. Third, sink moves to the direction according to the formula (4).

When sensor node collects data, it needs to transmit the collected data to sink. Then, the data will be transmitted to server by sink. The gravitational field intensity describes some factors which make influence to the performance of network. If one sensor node has higher gravitational field intensity, it means that the node has more residual energy, less access time interval relatively and it closes to sink. Based on this

Table 1: Node information table

Node coordinate	Node residual energy	Access time interval	Gravitational field intensity
(x_i, y_i)	Q_i	$\Delta\tau_i$	E_i

relationship, when sink selects the strategy of moving to the direction of node with the highest gravitational field intensity, it can balance energy consumption of WSN efficiently and obviously improve the accuracy and reliability of data-gathering. In order to describe the process of the algorithm in detail, we give the following two definitions:

Definition 3: We regard the sensor node in the communication range of sink as the direct connection node.

Definition 4: We regard the sensor node which is out of the communication range of sink, but is the nearest to sink as the transitional node.

Now, we give the following algorithm steps:

Step 1: Compute the distance d_i ($i \in V_N$) between every sensor node and sink according to formula (5).

Step 2: Compute the gravitational field intensity E_i ($i \in V_N$) of every sensor node to sink according to formula (3).

Step 3: Judge whether or not there is direct connect node nearby sink by comparing d_i ($i \in V_N$) with the communication range of sink. If there is more than one direct connection node nearby sink, we select the node with the highest E from direct connect node as the goal node. And then, sink moves the node according to formula (4) until it moves out of the communication range of the node. If there is no direct connect node nearby sink, we select the node nearest to sink as transitional node, thus let sink move towards the node a fixed time slot, such as one second. And then, repeat the above steps.

RESULT ANALYSIS

In this section, we present some preliminary experimental results of the comparisons between overflow rate and network lifetime performance of GFI-H and that of another data-gathering scheme: a fixed-moving scheme where a mobile sink moves along with the fixed trajectory in the network region.

The two schemes are implemented in MATLAB 7.1. The simulation network space consists of some sensor nodes which are deployed randomly in a 100×100 m^2 area. The communication range of both sensor nodes and sink is 10 m. Initial, for simulation, the energy of sensor node is 1J. Additionally, we define the size of every packet is 1023B. The packet collection rate is 0.2 packet/s and the packet transmission rate is 30 packet/s. The same time, the initial number of packets of node is 10^3 and the maximum storage of sensor node is 5×10^3. In addition, node will consume 90 nJ energy for collecting or sending 1 bit data.

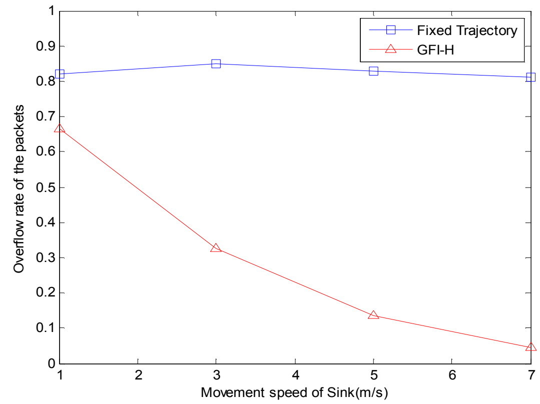

Fig. 1: The overflow rate with the increase of sink movement speed

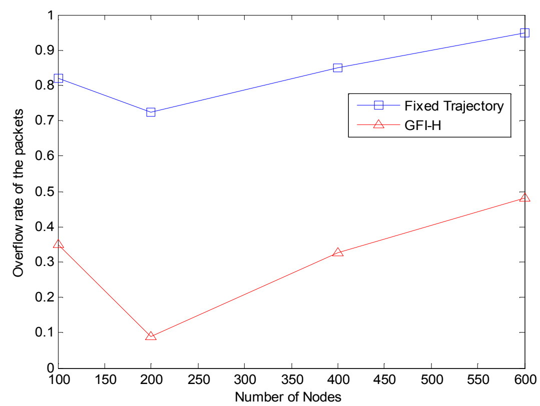

Fig. 2: The overflow rate with the increase of the number of sensor nodes

Definition 5: If the collected data of a sensor node passes its maximum storage, we regard it as an overflow node. Here, overflow rate can be indicated as following:

$$overflow\ rate = \frac{number\ of\ overflow\ nodes}{number\ of\ sensor\ nodes} \tag{6}$$

Definition 6: We define network lifetime as the duration (in seconds) from the time epoch that the WSN is deployed to the time epoch that the overflow rate is 1 in WSN.

Figure 1 shows the variation tendency of overflow rate in condition that 400 sensor nodes are deployed randomly in the monitoring area. The result shows that, with the increase of sink movement speed, the overflow rate isgradual declineintheway of GFI-H, but theoverflow rate is maintained at more than 0.8 in the way of fixed trajectory. Obviously, the strategy of GFI-H is superior to the fixed trajectory.

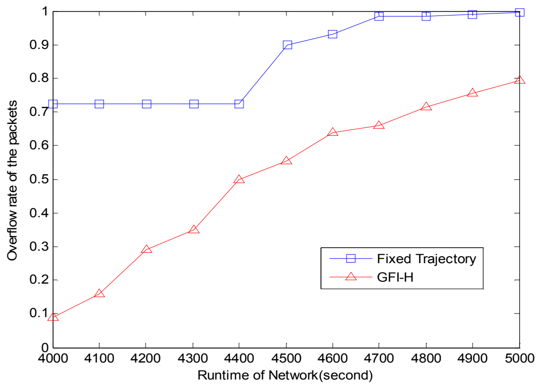

Fig. 3: The overflow rate within network lifetime

To illustrate the relationship between overflow rate and the number of sensor nodes in WSN, Fig. 2 demonstrates the variation tendency of overflow rate where the movement speed of sink is 3 m/s. In Fig. 2, we can see that with the increasing of the number of sensor nodes, the variation tendency of the overflow rate in the way of GFI-H is similar to the fixed trajectory, but in general, the overflow rate of the former is superior to the latter. In addition, we can see the phenomenon that when the number of sensor nodes in the area is 200, the overflow rate is lowest both the strategy of GFI-H and the fixed trajectory.

Figure 3 shows the variation tendency of overflow rate within network lifetime in condition that the movement speed of sink is 3 m/s and the number of sensor nodes in the area is 200. From the result, we can see that, with the operation of the network, although the whole tendency of the overflow rate is increasing both the strategy of GFI-H and the fixed trajectory, the overflow rate in the way of GFI-H is obviously lower than the way of fixed trajectory in the process of rise. From Fig. 3, in addition, we also know the network lifetime under the way of fixed trajectory is about 5000s and the network lifetime under the strategy of GFI-H is far more than 5000s. Consequently, the strategy of GFI-H prolongs the network lifetime and collects data more completely.

From the above, compared with the way of fixed trajectory, the strategy of GFI-H proposed in this study has more advantages in both reducing packet overflow rate and prolonging network lifetime, thus improving the performance of WSN. This is because, in case of GFI-H, sink has more flexibility and mobility. So, in condition of uneven distribution of sensor nodes, the strategy of GFI-H avoids the phenomenon that the isolated sensor node cannot forward data to sink.

CONCLUSION

In this study, a new mobile strategy of sink in WSN based on gravitational field is proposed. In the process, we consider the factor of sensor node residual energy which avoids the formation of energy hole near sink. Moreover, the access time interval for sensor node is also been considered which is beneficial to balance network node load. As a whole, the strategy of GFI-H compared with the fixed trajectory can reduce the overflow rate of packets effectively, improve the performance of network and prolong the network lifetime.

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