A Multi-hop Data Gathering Method for Wireless Sensor Networks

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Abstract. In wireless sensor networks used in environmental monitoring, data collection, the data generated by the sensor nodes will be transmitted with many hops from the sources to the destinations. In order to transmit the important data quickly, as well as reduce the energy consumption and extend the lifetime of networks, a multi-hop data gathering method (MHDG) for wireless sensor networks is proposed. The method aggregated the data from sensor nodes and marked the priority for the data with the source nodes. Simulation results show that compared to existing traditional method, the proposed method achieves the goal of a longer life time of networks, a lower packet drop ratio and energy consumption.

Introduction

The wireless sensor networks (WSNs) are usually deployed among widely region for pollution monitoring, data collection and other fields. In WSNs, the data generated by the sensor nodes will be transmitted with many hops from the sources to their destinations. So designing an efficient data gathering methods is important for the WSNs [1].

Many data gathering methods have been proposed in recent years. In [1], a data gathering method is proposed for mobile sink. In the method, the mobile sink visits the overlapping areas of communication ranges of sensors instead of sensors one by one. The method delivers good results in terms of the computational complexity, and reduction of the delay time of data gathering. In order to increase the efficiency of the data gathering in sensor networks using an unmanned aerial vehicle (UAV), a priority-based data gathering framework is proposed in [2]. In [3], a decentralized method for the compressive data gathering problem (DCDG) is proposed. By classifying the nodes inside the UAV’s coverage area into different frames according to their locations, the method achieves the goal of a reduction in packet collisions and the packet loss originated from nodes in the rear-side of the UAV when the UAV moves in the forward direction. A heuristic algorithm is proposed for finding a trajectory of the sink for data gathering in [4]. The algorithm strikes the trade-off between the latency of packet relay and the tour length of the mobile sink. In [5], a stability-based and energy-efficient distributed data gathering algorithms for wireless mobile sensor networks is presented. In order to minimize the data loss rate over all sensor nodes, an optimal movement strategy among a class of strategies is used in [6]. The numerical simulations that the optimal movement strategy outperforms the standard random walk strategy under various settings of network topology, buffer size, and the number of mobile collectors. In [7], a cross-layer optimization method, namely DaGCM, for mobile data gathering for sink equipped with multiple antennas, is proposed. By considering dynamic wireless link capacity and power control jointly, the mobile sink remarkably improves the efficiency of data collection in terms of data gathering cost, latency and energy consumption.

The existed data gathering methods fail to consider the congestion avoidance mechanism and the type of the data from different sensor nodes. In order to transmit the important data quickly, as well as reduce the energy consumption and prolong the lifetime of the networks, a multi-hop data gathering method (MHDG) for WSN is proposed in the paper. In the method, the data generated by the sensor nodes are transmitted from sources to the sink hop by hop. When the data are received, the nodes fuse the same type of the data from the sensor nodes in the front hop of the path, and mark the data with different priority according to the number of source nodes. So the amount of
data transmission is reduced. And there is more probability of been successfully transmitted to the sink, which generated by the more source nodes.

The rest of this paper is organized as follows. In section II, we formulate the problem of data transmission in WSNs we aim to solve. In section III, the multi-hop data gathering method (MHDG) for wireless sensor networks is proposed. In section IV, simulations are carried out, and the performance of the method is analyzed. Section V gives the conclusions and future work.

System Model and Problem Statement

There are usually two type of nodes, sensor nodes and a sink, in a wireless sensor network aiming to monitoring the area of environment or other region of interest. The sensor nodes are monitoring the area of interest. The sink is the destination of data generated in all sensor nodes among the networks.

When sensors detect an event happens in the area, they generated data, in which contenting the event information. The information data generated in the sensor field will be transmitted to the sink finally. In a network without clustered, many paths will be built for the data transmission, and the data generated in the sensor nodes are transmitted in the paths from one sensor node to another sensor node hop by hop, as shown in Figure 1. The sink is the destination of the data from sensor nodes all over the networks.

In a sensor network with hundreds and thousands of sensor nodes, the amount of data transmission is relatively large [1]. The data gathering is large latency, even when the network congestion, emergency network, this delay or congestion will bring serious consequences. So how to improve the real-time transmission of emergency event data is a key problem in the large-scale network [3]. At present, usually adopts the method of data fusion, congestion avoidance method for reliable transmission mechanism and data to improve the efficiency of data transmission in large-scale wireless sensor network and reduce the data delay.

Multi-hop Data Gathering Method

In the section, a multi-hop data gathering method (MHDG) for wireless sensor networks is proposed. As shown in Figure 2, the data generated by the sensor nodes, are transmitted to the sink hop by hop through other sensor nodes in the networks. The data from the sensor nodes are fused by the sensor nodes at the path. For example, the data generated by the sensor nodes at the path1, will be transmitted to the sink by the sensor node S1 and S2. And these data will be fused by the sensor node S1 and S2 before being transmitted.

<table>
<thead>
<tr>
<th>Seg. A</th>
<th>Seg. B</th>
<th>Seg. C</th>
<th>Seg. ...</th>
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<tbody>
<tr>
<td>Type</td>
<td>Priority</td>
<td>ID1</td>
<td>ID2</td>
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</table>

Figure 2. The frame structure of data.
There are three segments in the frame structure of the data generated by the sensor nodes, as shown in Figure 2. The first segment in the frame of the data, Seg. A, is the type of data. The second segment of the data is the priority, Seg. B. The segment, after the Seg. B, Seg. C is the list of the source nodes of the data. All the data generated by the sensor nodes are initialized as priority one, which is the lowest priority. And there is also only one source node in Seg. C when the data generated by a sensor node before being fused. After being fused with other same type of data generated by other source nodes, the priority and the list of source nodes will be rewritten.

Here are the details of the fusion processing in a sensor node, node S1, as shown in Table 1. Now there are two types of data, which is DATA1 and DATA2, in the node S1. There is the same priority, priority two, with the two types of the data in the node S1. There two type of the data from node S2, DATA2 and DATA3. The priority of the DATA2 and DATA3 in the node S2 are two and one, respectively. Since the DATA3 in node S2 is generated itself, the priority of the data is the lowest, priority one.

<table>
<thead>
<tr>
<th>Data in node S1 (priority)</th>
<th>Data in node S2 (priority)</th>
<th>Data after fusion in node S1 (priority)</th>
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<tbody>
<tr>
<td>DATA1(2)</td>
<td>DATA2(2)</td>
<td>DATA1(2)</td>
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<tr>
<td>DATA2(2)</td>
<td>DATA3(1)</td>
<td>DATA2(3)</td>
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<td></td>
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<td>DATA3(1)</td>
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</table>

When the node S1, has received the data from node S2, it fuses these data with their sources and their types. Since the second type of the data, DATA2, are both in the two nodes, the node S1 and S2, the DATA2 is aggregated. And the priority of the DATA2 will be changed too. The node S1 reads the Seg. C, the source list of data, in DATA2, as shown in Figure 3. It can be seen in Figure 3, Figure 3 (a) are the frame of data before fusion in node S1, Figure 3 (b) are the frame of data before fusion in node S2, and Figure 3 (c) are the frame of data after fusion in node S1.

![Figure 3. The frame structure of fusion data.](image-url)
The source nodes of the DATA2 from node S1 is ID3 and ID5, and the source nodes of the DATA2 from node S2 is ID3 and ID7. There is a source, ID3, is the same as each other in DATA2 from node S1 and S2. So that the source lists, Seg. C, in the DATA2 fused, is ID3, ID5 and ID7. The priority of the DATA2 fused is three. The first type of the data, DATA1, is in the node S1, and the third type of the data, DATA3, is generated by only one node, node S2. So that the DATA1 and the DATA3 will be transmitted directly. The fusion processing and the results are shown in table 1, there are three types of data in node S1 after fusion, DATA1, DATA2 and DATA3, with priority two, three and one, respectively. The frame of data after fusion in node S1 is shown in Figure 3 (c).

Simulation Results and Analysis

To evaluate the performance of the MHDG method, several simulations were carried out. The performance of the proposed method, in terms of the lifetime, the packet drop ratio and energy consumption, is compared to the traditional LEACH protocol, as shown in Figure 4, Figure 5 and Figure 6.

There are 160 sensor nodes distributed in the 400m × 400m area randomly. The length of the data packet and the sensing data packet is 120 bytes and 20 bytes. The sensing range of each sensor node is 50 m. Each sensor node was initially given 5 J of energy. The average transmitting and receiving energy of each sensor node are set to be 5100nJ/bit and 150nJ/bit. The energy of transmit amplifier with short and long distance are set 10nJ/bit/m2 and 0.001nJ/bit/m4. The energy of aggregation of each data is set 5nJ/bit. The probability of the event, p, is the number of event among each sensor node.

Figure 4 shows the life time of the networks with different probability of the event of the methods. The life time of the networks is defined that the rounds when there are 20% sensor nodes are dead. From Figure 4, we observe that the life time of the networks decrease when the probability of the event increase in both the two methods. Moreover the life time of the networks in MHDG method is longer and decreases slower than that in the traditional method all over the probability of the event.

The packet drop ratio of the two methods is shown in Figure 5. From Figure 5, we observe that the packet drop ratio of the two methods are so much low when the probability of the event is low, and the packet drop ratio of the methods increases along with the increase of the probability of the event, when the probability of the event is more than 0.25. Moreover, the packet drop ratio of the proposed method is much smaller than that of the traditional method when the probability of the event is more than 0.25. This is because the data fused decrease the size of the data for transmission, when the probability of the event increase, the number of the data can be fused increases.

Figure 6 shows the average energy consumption of the two methods. From Figure 6, we observe that the average energy consumption of the two methods are less than 0.2 when the probability of the event is less than 0.3. The average energy consumption of the traditional method increases quickly along with the increase of the probability of the event, when the probability of the event is more than 0.3. The average energy consumption of the proposed method decreases along with the increase of the probability of the event, when the probability of the event is more than 0.5. Moreover, the average energy consumption of the proposed method is much smaller than that of the traditional method when the probability of the event is more than 0.5. This is because the data fused decrease the size of the data for transmission, when the probability of the event increase.
Conclusion

In this paper, a multi-hop data gathering method (MHDG) used in wireless sensor networks is proposed. In the proposed method, the sensor nodes fuse the same type of data from the other sensor nodes in the path according to the number of source nodes data. And the different priority is marked for the data from different number of source nodes. Simulation results show that the proposed method can greatly extend the life time of the networks, reduce the packet drop ratio and the energy consumption.

Future work should be concentrated on the development of proper routing of the networks and the data packets transmissions through multi-paths in the networks. Moreover, the methods for the data transmission with different priority are also important issues that may be brought in the future.

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References