Prolonging Network Lifetime for 6LoWPAN/RPL Wireless Sensor Network using Mobile Sink with Dynamic Sojourn Time

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Abstract—This paper proposes a method of prolonging network lifetime using the mobile sink node in 6LoWPAN/RPL. According to dynamically changing the sojourn time of the sink node, the proposed method prolongs the network lifetime. By deciding sojourn time appropriately based on [12], proposed method to reduce the power consumption of the node load is concentrated. Simulation results show the effectiveness of the proposed method.

1. Introduction

A smart metering and the environmental sensing are considered as application of the wireless sensor network. Many sensor network communication methods have been proposed so far. However, the need for large-scale wireless sensor networks is increasing for use in various applications.

The IPv6 networking of the sensor network is expected to facilitate cooperation of other application. 6LoWPAN(IPv6 over Low power Wireless Personal Area Network) [1][2][3], which enables IPv6 communication over IEEE 802.15.4, has been standardized by the IETF. In addition, RPL(IPv6 Routing Protocol for Low power and Lossy Network)[4], which is a routing protocol for the purpose of the operation on 6LoWPAN, is standardized. Operating in an environment with poor communication quality is assumed in 6LoWPAN / RPL.

Load of sensor nodes near the sink node is increased in order to relay sensing data to the sink node in multi-hop wireless sensor networks. Therefore, the batteries of sensor nodes near the sink node run out early, which is called the hot spot problem. Hot spot problem also occurs in 6LoWPAN/RPL. The methods in [6]-[11] reduce the occurrence of hot spot problem by using multiple sink nodes and the mobile sink node. The methods in [7]-[11] need to collect information of the whole network to decide movement conventionally. Because the operation in the large-scale network is assumed, in 6LoWPAN/RPL, it is difficult to apply [6]-[10] in such a network. A method for determining the sink-movement without collecting information of the entire network in 6LoWPAN/RPL has been proposed[11]. However, sensor nodes of high power consumption may exist as well as the sensor node of the hotspot. It depends on the built topology. Such a sensor node causes running out of battery early, and network lifetime decreases. [6]-[11] do not consider the sensor nodes with high power consumption. It is difficult to identify the sensor node having high power consumption without building topology. Therefore, unlike the conventional method, after moving the sink node, a method of prolonging the network lifetime is required.

This paper proposes a method of prolonging network lifetime using the mobile sink node in 6LoWPAN/RPL. According to dynamically changing the sojourn time of the sink node, the proposed method prolongs the network lifetime. By deciding sojourn time appropriately based on [12], proposed method to reduce the power consumption of the node load is concentrated. Simulation results show the effectiveness of the proposed method.

2. Related Work

2.1. 6LoWPAN/RPL

RPL is a routing protocol for the purpose of operation at 6LoWPAN. RPL has been standardized by the ROLL working group of the IETF. Directed graph that has been oriented to the sink node called DODAG(Destination Oriented Directed Acyclic Graph) is built in RPL. Sensor node transmits data to a sink node along DODAG.

Figure 1 shows the construction process of DODAG. At first a sink node transmits DIO(DODAG Information Object) message by link local multicast as DODAG root. The node that received DIO decides the rank of own according to OF. The node transmits DIO message including the rank of own. In the process when DIO message is transmitted to, each node which received DIO message decides the rank of own and a recommended parent. Each node transmits DIO according to the Trickle timer[5] which a transmission period increases exponentially regularly once when DODAG is built. The node calculates a rank again and maintains DODAG. In addition, DAO(Destination Advertisement Object) message is implemented in RPL. DAO is a message for a node to introduce the information to the designated destination into the upper part. When a sensor node requires the information from a sink node, DAO is used. The node that received DAO performs the route construction of the downlink. With network constitution by DODAG and the func-
tion of Trickle timer, RPL can reduce a control packet for construction and maintenance of the routes. Therefore RPL can lower power consumption in comparison with AODV and OLSR.

2.2. Hot Spot Problem

Hotspot problem has been pointed out in the wireless sensor network. In the case of data collection application such as the environmental sensing, the sensor node transmits data with a multi-hop for a sink node. Thus, the sensor nodes near the sink node to increase the relay of data compared to other sensor nodes. The spot where such a sensor node is concentrated is called a hotspot.

Because the node of the hotspot has much relay of data, the node uses much electricity. As a result, the battery is depleted early, relay of data becomes impossible. And the whole network does not function. This problem is called a hotspot problem.

Method for collecting data while changing the position of the sink node as a technique to avoid the hot spot problem has attracted attention[6]-[11]. This is because the distribution of the hotspot is possible by the change of the position of the sink node. As a method of changing the position of the sink node, methods used by switching multiple sink nodes[6] and methods for moving the sink node[7]-[11] is proposed. The methods of the movement sink node is greatly classified in three. Mobile sink may move in a fixed path[8], may take a random path[9] or may move in optimal locations in terms of network lifetime or energy conservation[10].

By in turn switching the multiple sink nodes, [6] is proposed method of building a path power consumption of the sensor node becomes uniform. The multiple sink nodes maintain a single backbone path. And the sink node that sensing does expands the backbone path and collects information. However, power consumption increases in [6] as a problem. This is because the resources of a node is small, 6LoWPAN / RPL can be used in environments with poor communication quality.

In addition, it is necessary to collect information of the whole network to decide the next position of the sink node by the methods[6]-[10] to change the position of the sink node conventionally. Thus, in the large-scale network, heavy calculation load depends on a sink node and is unsuitable for 6LoWPAN with a few resources. Therefore, method to determine the optimum position of the next sink node without information from all sensor nodes has been proposed in [11]. [12] proposed method to obtain the sojourn time of the sink node by using a linear programming. [12] aims for maximization of the network lifetime. However, [12] is not suitable for 6LoWPAN/RPL because topology is fixed as assumed.

2.3. Next Sink Node Location Determination Method

To reduce the calculation load of the sink node, [11] limits sink node movement to only leaf node neighborhood. The leaf node calculates $\omega$ to use for decision of the sink movement regularly and transmits information to a sink node. And the sink node moves near a leaf node of biggest $\omega$. The calculation of the $\omega$ is as follows.

$$\omega_i = \beta h_i e_i + \gamma b_i$$  \hspace{1cm} (1)$$

$h_i^2$ is the number of the hops from sink node $k$ to sensor node $i$, $e_i$ is residual energy of sensor node $i$, and $b_i$ shows the number of the neighbor nodes of sensor node $i$. $\beta, \gamma$ is coefficients of weight.

By considering residual energy and the number of hops, new sink node can be moved to the sensor nodes near the residual energy is high, and far from the old sink node. In addition, by considering the number of neighbor nodes, the sink node will be allowed to move to an area with high density of the sensor node. A sink node moves to the next position regularly and begins the transmission of DIO at a new position. It succeeds in prolonging network lifetime because a sink node moves near a leaf node of biggest $\omega$. However, the power consumption of a far sensor node from a sink node may increase depending on DODAG. This is caused by the concentration of the link. The node causes running out of battery earlier than the sensor node of the hot spot. We call such a sensor node a hot node. [11] does not consider the hot node.

3. Proposed Method

This study proposes a method to improve the network lifetime by using a mobile sink node in 6LoWPAN / RPL. Early movement of the sink node reduces the power consumption of the hot node by calculating sojourn time and improves network lifetime. In 6LoWPAN/RPL, it is difficult to identify the hot node. Because [11] considers only a sensor node of the sink node neighborhood, it is difficult for it to suppress the power consumption of the hot node. In the proposed method, the sink node does not move regularly but moves when the sink node reaches the sojourn time which is set to a time shorter than the lifetime of a hot node.
4. Simulation Results

The simulation implements proposed method and [11] in simulator COOJA and evaluates it. The simulation places sensor nodes in the area of 100 m * 100 m at random and places one sink node. Each sensor regularly generates the same amount of data and no aggregation of data is made. A time-driven sampling application of data collection is considered. Table 1 shows simulation parameters. Also, it is assumed that 0 seconds travel time of mobile sink node as well as the [11]. The value of Energy consumption uses a default value of Cooja. The battery capacity assumes it 1/1000 of the manganese dry cell. 

This study evaluates network lifetime and packet delivery rate. The network lifetime is defined as the time until the first sensor dies (i.e., it uses up its residual energy). Despite the fact that there are many definitions of the network lifetime, the most used is this one because the death of a node is soon followed by the death of its neighbors. Packet delivery rate is defined as the ratio of number of packets that a sink node received for the number of packets that all sensor nodes generated. The proposed method, [11], and the method with the fixed sink-node-position are evaluated.

Table 1: Simulation parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Simulator</td>
<td>Cooja</td>
</tr>
<tr>
<td>Radio medium</td>
<td>Unit Disk Graph Medium (UDGM):Distance Loss</td>
</tr>
<tr>
<td>RX success ratio</td>
<td>0.9</td>
</tr>
<tr>
<td>Data size</td>
<td>24 bytes</td>
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<tr>
<td>Sensing interval</td>
<td>5 min</td>
</tr>
<tr>
<td>Sink travel time</td>
<td>0</td>
</tr>
<tr>
<td>Battery capacity</td>
<td>1.0 mAh</td>
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<tr>
<td>Energy consumption</td>
<td>LPM 0.1635 mW</td>
</tr>
<tr>
<td></td>
<td>CPU 5.4 mW</td>
</tr>
<tr>
<td></td>
<td>Listen 60.0 mW</td>
</tr>
<tr>
<td></td>
<td>Transmit 53.1 mW</td>
</tr>
</tbody>
</table>

Figure 2 shows network lifetime as a function of the number of sensor nodes. The network lifetime of the proposed method is the longest of three methods at any number of sensor nodes. The method that fixed the position of the sink node has a large power consumption of the sensor node for a hotspot. Therefore, the network lifetime is shorter. Because [11] changes the position of the sink node every 30 minutes or 60 minutes, network lifetime is prolonged. This is for the dispersion of the hotspot. The proposed method achieves long network lifetime by considering the lifetime of the hot node.

Then, figure 3 shows packet delivery rate as a function of the number of sensor nodes. The method that fixed a sink node becomes highest in a delivery rate. This is because DODAG is not greatly changed for the sink node does not move. The possibility of packet loss is high when the DODAG to rebuild topology changes significantly. When the movement interval of the sink node was short, [11] improved in network lifetime. However, delivery rate fell. This is because time to rebuild DODAG increases if a movement interval is short. The packet loss increases when rebuilding of DODAG takes time. In the proposed method, delivery rate decreases in order to move a sink node frequently when simulation is about to be over.

5. Conclusion

In the routing protocol RPL that operates in 6LoWPAN on, this study proposed a method of moving the sink node while considering the dynamic sojourn time. Improvement of the network lifetime is an aim. While taking into account the lifetime of the sensor nodes of high power consumption and far away from the sink node, the proposed method move the sink node. It is possible to reduce the power consumption of the hot node thereby. Consequently, the proposed method achieves increase in network lifetime.
In addition, the simulation results show that the proposed method is effective by comparing the conventional method by using a simulator Cooja.

We will examine method to derive most suitable in future while suppressing the drop of the delivery rate.

References