Constructing Delivery Tree for Low-cost Management Sensor Networks

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***Abstract*—Toward the world accelerated with IoT technologies, many wireless multi-hop sensor network technologies have been proposed. Since energy consumption is one of the key issue to realize practical wireless sensor networks, several communication protocols for sensor networks have been proposed so far. As for routing protocols, the major approach aims at prolonging the network lifetime by consuming power of every node as equal as possible. However, in this approach, many nodes will die simultaneously by running out of power, which will stop function of sensor network when replacing battery of all sensors. In this paper, we propose a routing protocol from the opposite approach; our routing protocol concentrate power consumption on several specific sensor nodes. Since this approach saves the power of many sensor nodes, we only have to do battery replacement of a part of sensor nodes without stopping the function of wireless sensor networks.**

I. Introduction

Sensor networks are expected to play an important role in the future as a part of the IoT infrastructure. To realize long-life sensor networks, many low-energy techniques have been proposed. Among them, low-power communication protocols are regarded as one of the most important topic since communications are regarded as the most power-consuming part of sensor devices. Several low-power MAC protocols such as B-MAC [1], X-MAC [2], RI-MAC [3], etc. have been proposed so far. As for routing protocols, several routing protocols for long-life sensor networks have been proposed. They typically prolong the network lifetime by consuming power of every node as equal as possible, or minimizing total energy consumption [4] [5] [6]. However, in this approach, many nodes will die simultaneously by running out of power, and at that time, no paths to forward packets to sink nodes remains. This means that the network does not function for a long while until the battery of those nodes are replaced.

In this paper, we propose a new routing protocol from the opposite approach; instead of using power of every node as equal as possible, we use power of several specific sensor nodes, and change the paths when the power is mostly run out. (However, we preserve a little power of the node so that it can work as a non-relay node for a while.) Since this approach saves power of many sensor nodes, we can maintain the sensor network by periodically replace the battery of sensor nodes without stopping the function of sensor network collecting sensed values.

II. Constructing Delivery Tree

We assume that our sensor network deploys some low-power-consumption MAC protocols such as those proposed in the literature [7]. As a part of the deploying routing protocol, each sensor node transmits messages periodically that are received by all neighbors.

As a first step, all nodes get to know the distance in hop count from a sink node. With the control message, each node inform its neighbors of the currently recognizing distance from sink nodes. Specifically, sink nodes inform the distance zero, and a non-sink node informs the distance that is the minimum value among the received value plus one. As a result, every node gets to know the correct distance from sink nodes.

As the next step, every node selects its next-hop node to forward packets. This is done by selecting the node that is selected the most from other nodes as their next-hops. Specifically, this is done by the following steps.

(1) Every node n advertises the number of descendants using the periodical messages.
(2) When a node n receives the advertisement messages from all neighbors, n gets to know the number of descendants as the sum of the values reported from the nodes by whom n is selected as their next-hops.
(3) Each node n selects the node as its next-hop that has the largest number of descendants among the nodes whose distance is smaller than n by one.

By repeating the above steps (1)-(3), we obtains the delivery tree in which next-hops are concentrated on several specific nodes. Fig. 1 illustrates the example of the delivery tree obtained by this protocol. Note that the number in a node is the distance from sink nodes.

To improve the delivery tree, we further extend the algorithm to construct the delivery tree such that each node can select the same-distance node as its next-hop. Specifically, we changed the step (3) of the algorithm as follows.

(3') If n is not selected as the next-hop by anyone, n selects the largest-descendant node as its next-hop among the nodes whose distance is smaller than n by one or the same as n. Otherwise, among the nodes whose distance is smaller than n by one.

Fig. 2 shows the example tree constructed by the proposed algorithm. Compared with Fig. 1, the number of relay nodes

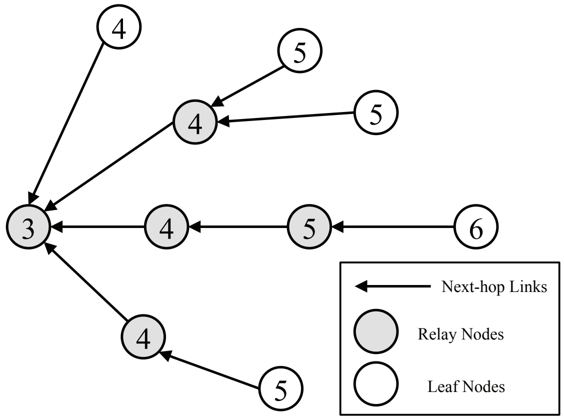

Fig. 1. Constructing Delivery Tree (Naive Approach)

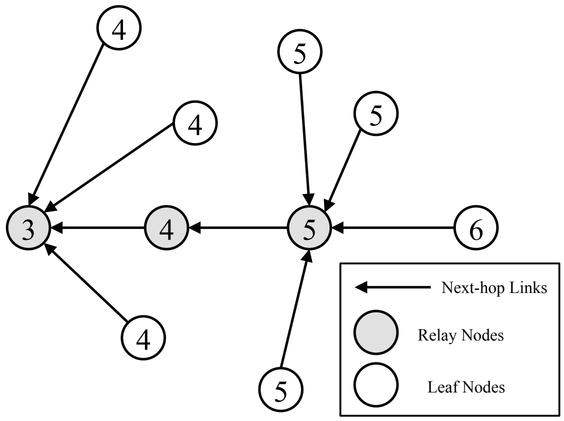

Fig. 2. Constructing Delivery Tree (Proposed)

reduces by allowing to select the same-distance node as the next-hop.

III. Evaluation

We evaluate the proposed method by measuring the number of relay nodes in several scenarios. We implemented the proposed method as a simulator with C++ language. We randomly place a set of nodes in 1000[m]$\times$1000[m] field and also place a sink node at the center of left side. We assume that the communication range of nodes is 100[m] We execute the proposed method 50 times with different random seeds. We compared the proposed method (shown in Fig. 2), the naive method (shown in Fig. 1), and the method in which nodes select their next-hop randomly among the node whose distance is less than the node by one.

The result is shown in Fig. 3. The number of relay nodes is the smallest in the proposed method, which is far smaller than the random method. Also, note that the proposed method has almost the same number of relay nodes regardless of the number of total nodes, while other methods requires the number of nodes proportional to the total nodes. The proposed

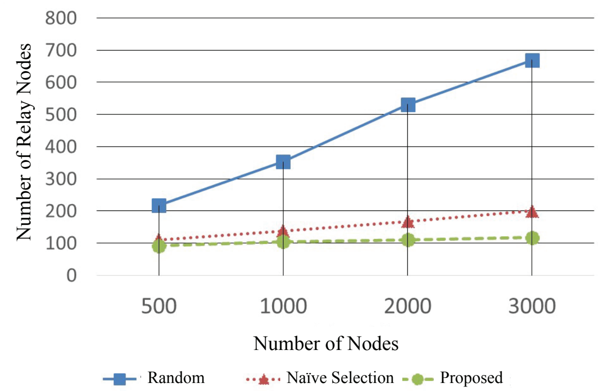

Fig. 3. Number of Relay Nodes

method requires relay nodes proportional to the area of the field, i.e., one node for about 100[m^2].

IV. Conclusion

In this study, we propose a new routing protocol that reduces the number of relay nodes for low-management sensor networks. By reducing the number of relay nodes, we can use power of several specific nodes (i.e., the relay nodes). We can maintain the sensor networks by replacing battery of those exhausted nodes periodically without stopping the function of sensor networks.

Acknowledgment

This work is supported by JSPS KAKENHI (15H02691).

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