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Fair Routing for Overlapped Cooperative Heterogeneous WSN's

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ABSTRACT: We introduce one or a few shared nodes that can use multiple channels to relay data packets. Assuming that sinks and shared nodes can communicate with any WSNs here, different WSNs can use cooperative routing with each other since shared nodes allow sensor nodes to forward data from another WSN as the function of interchange points among respective WSN planes. When receiving a packet, a shared node selects the route to send the packet, according to proposed route selection methods. This cooperation prolongs the lifetime ofeach network equally as possible.

KEYWORDS- Sensor Network, Cooperative Routing, Fairness, Heterogeneous Environment, Load Balancing.

I. INTRODUCTION

Wireless Sensor Network (WSN) is a distribution of autonomous sensors, which cooperatively monitor physical or environmental conditions, such as temperature, vibration, pressure, sound and so on. WSNs are used in many areas, including home automation, health monitoring or other healthcare applications, industrial process control and monitoring, etc. Applications of WSNs are expanding and the implementation of multifunctional and reliable WSNs is of utmost importance. The detection process in WSNs mostly depends on sensor node's physical conditions and the solutions of detection problems are largely based on hardware rather than software. After detection, the node has to find whom and how to transfer the sensed data. After that, the turn passes to data transfer process. This process doesn't take much effort from sensor node due to the small size of desired data.

Low energy consumption is a critical task in WSNs, especially in sensor networks comprised of nodes that are considered lightweight with limited battery power. The most critical process in sensor networks is the routing because of high energy consumption, end-to-end delay, and control of

packetoverhead. Thus, it is required to have a routing mechanism for reducing energy consumption in sensor nodes and for increasing the network lifetime. The faster is the routing process, the longer is the sensor node lifetime and the less is the energy consumption. Hence, the development of efficient routing algorithms is a crucial task in WSN. On one hand, low energy consumption is an important limitation in sensor networks, which are comprised of lightweight nodes with limited battery power. Hence, preserving the energy becomes a critical task in such networks. On the other hand, routing is a critical process in sensor networks due to concerns about energy consumption, end-to-end delay, and packet overhead. Thus, it is required to have a good routing mechanism in WSNs for reducing energy consumption in sensor nodes and for increasing the network lifetime.The process of setting up the routes during the initialization is influenced by energy considerations. Furthermore, load-balancing the resources evenhandedly prevents bottlenecks from forming and this is another challenging task [1, 2].

To increase the performance of WSN routing, multiple paths can be used concurrently. In coherent routing, the data is propagated after such processing as duplicate prevention, time-stamping, etc. The performance of routing protocols is linked to the architectural model and depends heavily on the implementation model. Design constraints might further impact the performance [3].

In this paper, we consider the heterogeneity of networks and propose a fair cooperative routing method, to avoid unfair improvement only on certain networks. We introduce one or a few shared nodes that can use multiple channels to relay data packets. Assuming that sinks and shared nodes can communicate with any WSNs here, different WSNs can use cooperative routing with each other since shared nodes allow sensor nodes to forward data from another WSN as the function of interchange points among respective WSN planes. When receiving a packet, a shared node selects the route to send the packet, according to proposed route selection methods. This cooperation prolongs the lifetime of each network equally as possible.

II. RELATED WORKS

Clustering [7] is one of the most famous methods because of its good scalability and the support for data aggregation. Data aggregation combines data packets from multiple sensor nodes into one data packet by eliminating redundant information. This reduces the transmission load and the total amount of data. In clustering, the energy load is well balanced by dynamic election of cluster heads (CHs) [14]. By rotating the CH role among all sensor nodes, each node tends to expend the same amount of energy over time. Nevertheless, as with usual multihop forwarding, a CH around a sink tends to have higher traffic than other CHs. As a result, nodes around sinks die earlier than other nodes, even in clustered WSN [15].

In general, a single WSN has a single sink. The amount of traffic increases around the sink, therefore nodes around the sink tend to die earlier. This is called energy hole problem. Moreover, in a large-scale WSN with a large number of sensor nodes, the energy hole problem is more serious. Then, some researchers have proposed construction methods of multiplesink networks [16], [17]. In a multiple-sink WSN, sensor nodes are divided into a few clusters. Sensor nodes within a cluster are connected with one sink, which belongs to that cluster.

In contrast to a single-sink WSN, in which nodes around the sink have to relay data from almost all nodes, nodes around each sink relay smaller amount of data only from nodes that are in the same cluster. Therefore, the communication load of nodes around sinks can be reduced. However, there are some problems such as how to determine the optimal location of each sink and the optimal number of sinks.

III. THE PROPOSED APPROACH

A. Assumed Environment

In this paper, we assume the following environment. In a sensing field, m different WSNs are constructed, and different applications are operating on each WSN independently. Fig.1 shows an example where two WSNs are constructed. If heavy loaded nodes are in different places among the WSNs as indicated in the example, it is possible that data packets via heavy loaded nodes are forwarded by other nodes in another WSN. However, each network adopts different channel, hence sensor nodes are unable to communicate with a node belonging to another WSN. To overcome this limitation, q shared nodes, which are high-end nodes with multi-channel communication unit, are deployed in the area. Shared nodes and sinks are able to communicate with any nodes belonging to all WSNs.

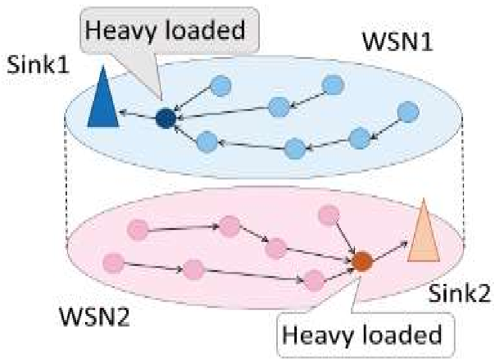

Fig. 1. Two WSNs deployed at the same area

Sensor nodes consume their energy only by communication, which is a reasonable assumption in sensor networks with simple sensors. Sinks and shared nodes have sufficiently large batteries or power supply. We define the WSNs' lifetime as the time when a first sensor node depletes its all battery energy. For heterogeneity, the battery capacity of a sensor node, the number of nodes, nodes' locations, energy consumption by communication, packet size, data transmission timing andoperation start time are different by each WSN. Note that the sensing area is the same in all WSNs since we aim at the cooperation in overlapped multiple networks. In this subsection, we formulate the overlapped

WSNs model for fair cooperation routing. In a sensing field, m different WSNs N1, · · · , Nm are constructed, and each network Ni , 1 ≤ i ≤ m, has a set of unique sensor nodes Ni ={ni1, ni2,. . ., ni|Ni |} and the sink BSi. q shared nodes s1,. . ., sq also exists in the area. All WSNs are able to use these shared nodes as relay node for packet forwarding. For guaranteeing the lifetime improvement by the cooperation, we define network lifetime Li , the estimated lifetime of Ni , is obtained by Eq. (1).

$$L_i = \min_{n_{ij} \in N_i} L_{ij} \ (1 \leq j \leq |N_i|) \ \ldots\ldots\ldots\ldots\ldots \quad (1)$$

L_{ij} is the estimated lifetime of the sensor node nij here. We call it node lifetime. In other words, the estimated lifetime of a WSN is a minimum estimated lifetime of its all sensor nodes. Each sensor node measures its own energy consumption during specific time τ and calculates Lij by using it. Let eijt be the remaining energy of node nij at time t, then, energy consumption per unit time is described by

$$\frac{e_{ijt} - e_{ij(t+\tau)}}{\tau} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

and Lij is represented by Eq. (3).

$$\boldsymbol{L_{ij}} = e_{ij(t+\tau)} \cdot \frac{\tau}{e_{ijt} - e_{ij(t+\tau)}} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

By exchanging Lij periodically among neighboring nodes, each node updates Li. In addition, minimum lifetime L0 i , the estimated lifetime in the case of no cooperation, is calculated by each sensor node. Specifically, each WSN operates without any cooperation from time t = 0 to t = 0 + τ = τ, and after the duration, L0 i is calculated by Eq. (4)

$$\boldsymbol{L_i^0} = e_{ij\tau} \cdot \frac{\tau}{e_{ij0} - e_{ij\tau}} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

A shared node sk (1 ≤ k ≤ q), has m routes Rkl i to the sink BSi via network Nl (1 ≤ l ≤ m). Hence, sk selects one of the m routes when sk receives a data packet from network Ni . If i = l, Ni rents the energy resource from Nl. Moreover, we define route lifetime L Ri klas the estimated lifetime of the route Rikl. The detailed definition is as follows.

$$L_{R_{ki}^{i}} = \min_{n_{ij} \in R_{ki}^{i}} L_{ij} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

We focus on this fact in the proposed method, whereby a node that is far from a sink in its own network, but near asink in another network, can forward a packet from a node in another WSN to the corresponding sink. In this paper, we call the former network the home network and the latternetwork the visitor network. The method achieves load balancing between a heavy-load node in a home network and a light-load node in a visitor network. As a result, the lifetime of both networks can be extended. Specifically, each network constructs a path along which a node can't forward a packet from a node in another WSN in advance. It is based on the well-known Ad hoc On-Demand Distance Vector (AODV) protocol), making it easy to implement. In addition, some nodes construct routes to the sinks of visitor networks.

B. Node Function

As described above, the proposed method enables a node that is far from a sink in its home network, but near a sink in a visitor network, and can forward a packet from a node in the visitor network. Each node has a routing table that includes not only an entry for a sink in its home network but also an entry for a sink in the visitor network. When a node overhears a data packet from its visitor network, it decides whether to receive and forward it or to ignore it. This procedure is explained later in more detail.

C. Routing Table Creation

This subsection explains how to create the routing table. Initially, each node sends an AODV-based route request packet to create an entry in its routing table for a sink in its home network. After this creation process, each node broadcasts an additional route request packet named B-REQ to the sinks of all visitor networks. (Nodes on the path from the node to the sink will create an entry in their routing table to the sink.) In addition, as a metric to decide the next hop, min Energy is also notified. This refers to the minimum residual energy of nodes along the path to the sink.

D. Cooperative Routing Method

In the proposed method, when a node sends its sensing data, it attaches the value of its residual energy in a header field of the packet. When a node relays a packet, it compares the residual energy of the node itself and that recorded in the packet, and the recorded value is replaced by smaller one. As a result, the minimum energy along the path from its source node is recorded. According to this procedure, a node can record a value of minimum energy along the paths every networks and select the path for the maximum value of this energy. Fig.2 demonstrates how the proposed method works. After node P has the created path in its home network (Sink1), it broadcasts a B-REQ to the visitor networks Net2 and Net3. When node Q and node R receive this B-REQ, they write their network ID in the header of the B-REQ and transmit it to their sink. After this procedure, the routes from node P to the sink via Net2 and Net3 are created, as shown in Tables I and II, respectively.

When node P receives a data packet for Sink1, it selects a suitable route from the entries in its routing table as shown in Table I. In this case, node P selects node R, which has the maximum value for min Energy, as the next-hop node. As we described below, the proposed method tries to extend the lifetime of each network by cooperative forwarding. However, it may result in a case where a network shortens its lifetime by the burden of forwarding for visitor networks. To avoid such a situation, in the proposed method, a node which has less residual energy does not relay packets from visitor networks. Specifically, we define a value of cooperation threshold in each network as a metric to decide whether to forward packets from visitor networks or not. For this metric, each sink broadcasts the minimum value of residual energy among all the nodes in its home network to the nodes in its home network. When a node acquires the value, it compares with its own residual energy. If its own residual energy is smaller, it refuses to forward packets from visitor networks and applies itself to relay packets in its home network.

IV RESULT AND DISCUSSION

A. Simulation Environment

We evaluated the performance of the proposed method with the network simulator in Matlab 2013b. We observed the receiving rate, which is the rate of sensor nodes that send data packets to their sinks successfully. Therefore, we counted a node that cannot communicate with its sink as a dead node, in spite of its remaining battery. The maximum value of receiving rate is 1.

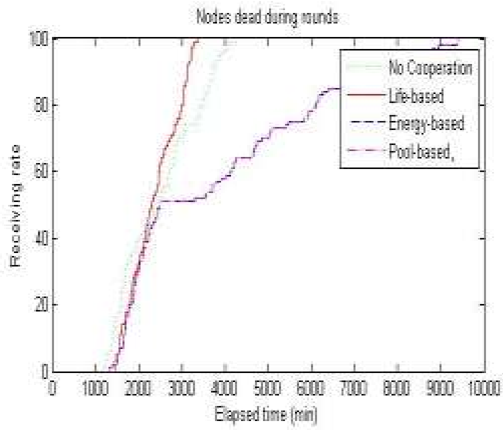

Fig.2 Nodes dead during rounds

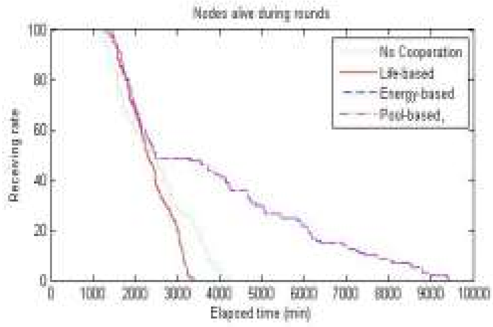

Fig.3 Nodes alive during rounds

In this simulation model, we set the node configurations using datasheet and information provided by MEMSIC. We simulated four WSNs, WSN 1, WSN 2, WSN 3 andWSN4 as follows. Each WSN had 100 nodes based on a random topology. The sensing field was a 100m ×100m square.

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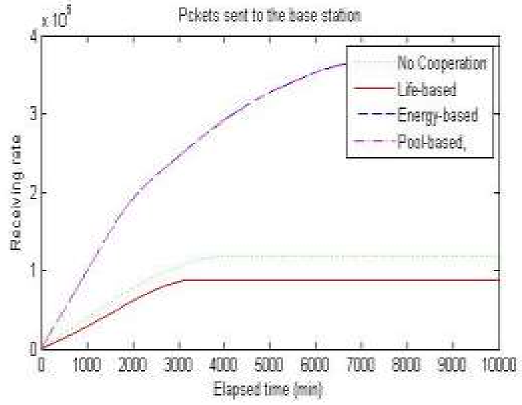

Fig.4 Packets sent to base station

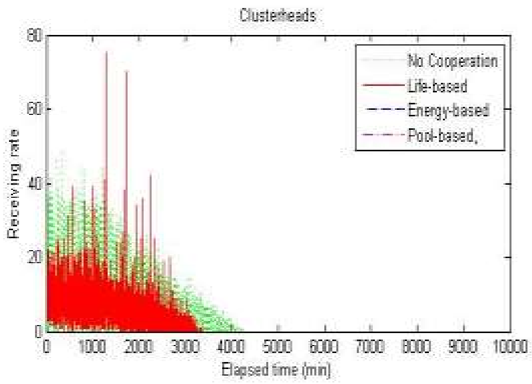

Fig.5 Clusterhead in the process

IV. CONCLUSION

In this paper, we longing for about heterogeneous overlapped sensor networks that have been built on the same area. In this kind of predicament, it is expected that the lifetime of all networks must be expanded by way of cooperation in a couple of networks. We proposed a fair cooperative routing process with shared nodes, with the purpose to gain fair lifetime growth in heterogeneous overlapped sensor networks. Simulation outcome showed that the proposed approach elevated the network lifetime. In targeted, Pool-based cooperation finished quite small variance of lifetime improvement, that's, it offered really reasonable cooperation.

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BioData

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