Energy-aware-based Routing Protocol for Wireless Sensor Network

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***Abstract* — In allusion to defects in routing protocol for WSN, such as high packet loss rate, high energy-consumption and others, an energy-aware-based routing protocol for WSN is proposed. Firstly, in the process of establishing the data forwarding route, the node energy-aware mechanism is introduced, and node of larger residual energy is chosen as the next hop node to prevent node of smaller residual energy to be involved in building of routing. Then in working process of node, the periodic and asynchronous work / sleep mechanism is introduced to save energy cost of node. Finally, simulation comparison experiment of used to test the performance of routing protocol. Experimental results show that the proposed routing protocol has reduced packet loss rate of network data forwarding and has improved the energy consumption of sensor node.**

Keywords - energy-aware; packet loss rate; routing; sensor node; sleeping mechanism

I. INTRODUCTION

WSN is a wireless network constituted by large number of sensor nodes, able to sense object information in monitoring area in real-time and automatic manner, and data is transferred to the Sink through multi-hop routing, widely used in military and medical fields, etc. [1-3].

This paper presents an energy-aware-based routing protocol for WSN, testing the effectiveness and superiority of the routing protocol using simulation, and the simulation results show that the proposed routing protocol can reduce the energy consumption of nodes, which has improved network energy use efficiency, and has extended the lifetime of WSN, with high practical value.

II. NETWORK AND ENERGY-CONSUMING MODEL

Assuming that sensor nodes are randomly distributed in the monitoring area, constituting a network through multi-hop communication system, and the node is divided into ordinary node and Sink node. Each ordinary node belongs to a cluster, each cluster containing one cluster head node only, and the network model is shown in Figure 1. Ordinary node is responsible for the collection of data objects in the scope of monitoring, and cluster head is responsible for the data integration of its cluster members, also forwarding data from other cluster head nodes, and finally blending all data to Sink node. We make the following assumptions in the study [4]:

(1) All nodes can directly communicate with the cluster head, and all ordinary nodes are isomorphic.

(2) Communication capability and energy of all ordinary nodes is equal, all with unique ID and position after node deployment is fixed without movement, and energy of Sink node is unlimited [5].

(3) Each node can dynamically adjust transmit power of its own based on the signal strength.

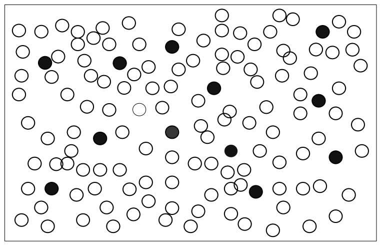

Figure 1. WSN model

Energy consumption model of sensor node in communication process is shown in Figure 2.

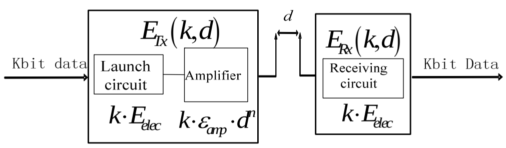

Figure 2. Energy consumption model of sensor node

l bit data is sent and received, and computational formula of energy consumed by a sensor node is as follows:

$$E_{TX}(l,d)=\begin{cases} l*E_{elec}+l\varepsilon_{fs}d^2 (d<d_0) \\ l*E_{elec}+l\varepsilon_{amp}d^4 (d>d_0) \end{cases} \quad (1)$$

$$E_{RX}(l)=l*E_{elec} \quad (2)$$

In the formula, $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}}$.

l bit data is integrated and forwarded, and computational formula of energy consumed by a cluster head node is as follows:

$$E_{da-fu}(l)=l*E_{DA} \quad (3)$$

III. ENERGY-AWARE-BASED ROUTING PROTOCOL FOR WSN

Routing protocol in this paper is divided into initialization phase and monitoring phase. Initialization stage is responsible for building the most suitable route between the sensor node and Sink node; monitoring phase is to make dynamic, real-time monitoring of sensor node status information, and status information of sensor node is sent to neighborhood node, also responsible to forward the node data to Sink node [6].

A. Initialization Phase

During the initialization phase of WSN, all sensor nodes are in working condition, and then Sink node broadcasts information in the whole WSN at maximum power. Each sensor node calculates the distance (d) between itself and the Sink node based on signal strength, and the computational formula is as follows [7]:

$$d = \sqrt{\frac{Sink_{send}}{Node_{receive}}} \quad (4)$$

Wherein, Sinksend represents the transmission power of Sink node; Nodereceive indicates the signal strength received by the sensor node.

Sink node divides monitoring area into a plurality of fan-shaped areas according to the distance, and each sensor node is distributed in the corresponding fan-shaped area, so that the fan with larger distance from Sink node has greater area, and the sensor nodes among it are more correspondingly; the fan with smaller distance from Sink node has smaller area, and the sensor nodes deployed in it are relatively small, and then each fan-shaped sector is divided into blocks, the specific as shown in Figure 3.

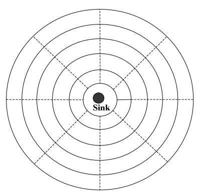

Figure 3. Initialization of WSN

Sink node can calculate the maximum diameter of each arc-shaped block area, able to determine selection of cluster head node within the cluster based on the diameter, so that all sensor nodes within each cluster can receive the message sent by the neighbor sensor nodes within each cluster.

Under normal circumstances, the next node of the best route between the nodes within each cluster and cluster heads is closer to the distance between itself and the cluster head, and therefore, when the node within the cluster are to establish a route between it and the cluster head, the best next hop node must be firstly found out, by analogy, and finally the route of smallest energy consumption is established between it and cluster head.

In working process of WSN, the next hop cluster head of the best route between cluster head and Sink node should be closer than the distance between it and the Sink node, and therefore, in establishing the cluster head and Sink node for routing, it also needs to find the neighbor cluster head with smaller distance between it and Sink node, so as to establish the most reasonable route between the cluster head and Sink node, thus the initialization phase of WSN is all completed.

B. Monitoring Phase

When the initialization phase WSN is completed, all sensor nodes in WSN enter into the monitoring status, since the synchronous sleeping mechanism has relatively high energy consumption, while sensor nodes in asynchronous sleeping mechanism can work independently and have rest, with relatively less energy consumption. Therefore, asynchronous sleeping mechanism is employed in this article [8].

Assuming that the length of sleep / work cycle of sensor nodes is T seconds, calculated as follows;

$$T = t_{work} + t_{sleep} \quad (5)$$

In formula, t_{work} represents working time; t_{sleep} represents sleep time.

1) Establishment of data routing

In the working process of sensor node, if the event occurrence is detected, then the sensor node needs to choose the next-hop routing sensor node, specific selection as shown in Figure 4. The specific thoughts are [16-17]:

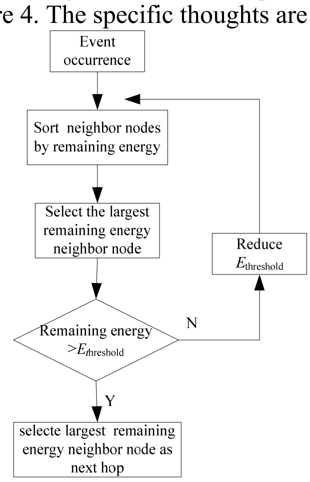

Figure 4. Building process of data routing

The node of the largest residual energy is selected from neighboring sensor node of the node.

If the residual energy of selected neighbor sensor node is greater than predetermined threshold ($E_{threshold}$), then the neighbor sensor node is taken as the next hop of sensor nodes of transmit data.

If the residual energy of selected neighbor sensor node is less than predetermined threshold ($E_{threshold}$), then the value of $E_{threshold}$ is decreased to re-select the next hop node [9].

2) Work / sleep mechanism of sensor nodes

Wake-up mechanism of sensor node for receiving data. After the next-hop sensor nodes of transmit data node are selected based on the routing policy of WSN, continuous packets of multiple request-to-send can be periodically, and then the wake-up process of the sensor nodes for receiving data is shown in Fig. In Figure 5, A and B indicate sensor nodes of send and receive data respectively, and the remaining nodes represent the neighbor sensor nodes of sensor nodes (A) of transmit data. When A periodically sends continuous packets, B replies allowed sent message immediately after receiving the message. The rest neighbor nodes receives request-to-send message in waking up. Then, A and B start process of data transfer, and in the same mechanism, a multi-hop routing is established to forward the data to Sink node.

Node work / sleep cycle optimization mechanisms. To reduce the energy consumption of sensor nodes, the nodes in entire WSN all use periodically work / sleep mechanism, each period T including work time (t_{work}) and sleep time (t_{sleep}), and the work /sleeping mode of each sensor node is not synchronized. When performing data transmission, nodes send a large number of request-to-send packets to wake receiving node, and the cycle of request-to-send packets is calculated as [21]:

$$T_s = t_{s1} + t_{s2} \qquad (6)$$

In formula, ts1 represents the time that nodes send message request; ts2 represents the time that monitors allow to send the message.

In order to ensure that the receiving node would not miss packets of sending node, it is set that $t_{work} > 2t_{s1}$. Meanwhile, in order to make all neighbor sensor nodes of transmit data sensor node can receive the request-to-send packets, the duration for transmission of the request-to-send packets is: $t_{las}t > 2t_{work} + t_{sleep}$.

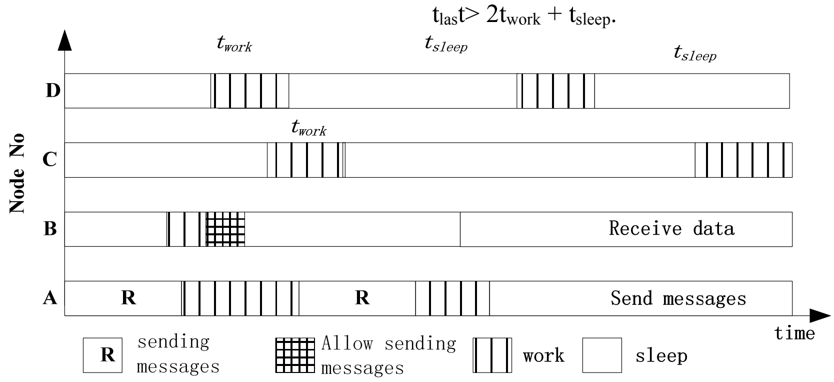

Figure 5. Wake-up procedure of reception of the sensor nodes data

IV. Simulation Experiment

In order to test the effectiveness and superiority of energy-aware routing protocol for WSN, simulation experiment is achieved using Open simulation software in the computer of Intel dual-core 2.65 GHz, 4G RAM, Windows XP operating system. In order that the simulation results of the protocol in this paper are comparable and convincing, routing protocol for WSN of literature is selected to perform control experiment, to make a comprehensive analysis of their average energy consumption, the network lifetime, packet loss rate, etc. The simulation parameters are shown in Table 1 [10].

TABLE I SIMULATION PARAMETERS

Parameter name	Value	Parameter	Value
Area size	200m×200m	Request	50bit
The total	100	Transmission	40bit
Packet size	2000bit	Eamp	00pJ/bit/m^2
Sink node	(0,0)	Eelec	50nJ/bit
Communication	20m	Ethreshold	0.05J
Maximum	4×10-3J/s	ts1	1ms
Interception	4.5×10-4J/s	ts2	1ms
Sleep power	9×10-7J/s	Initial energy	0.1J

A. Comparison of Average Energy Consumption of Nodes

The average energy consumption curve of wireless sensor nodes for protocol in literature is shown in Figure 6. It can be clearly seen from Figure 6, along with increased production cycle of events, the energy consumption of all routing protocols for WSN has been declining, which is mainly due to smaller and smaller frequency of event generation. With respect to the routing protocol in literature, the routing protocol herein has relatively small energy consumption, this is mainly because the routing protocol in this paper has not only introduced asynchronous and periodic work / sleep mechanisms, which has reduced the energy consumption of continuous transmission of synchronization information, while it has chosen the neighbor sensor node with the maximum residual energy as the next node, establishing the data forward routing with the minimum energy consumption, thus ensuring the energy balance of the entire WSN.

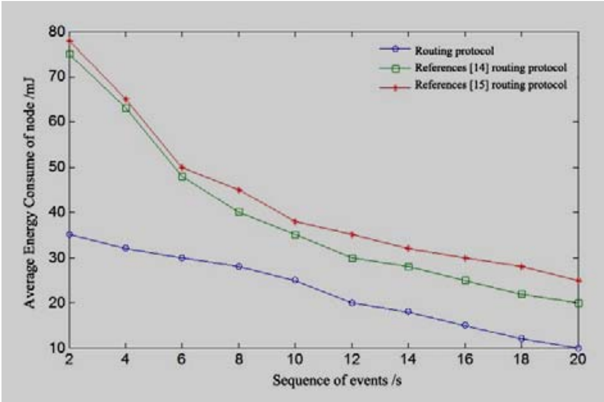

Figure 6. Comparison of average energy consumption of nodes for different routing protocols

B. Comparison of Network Life Cycle

Network life cycle is usually described using survival of network of sensor nodes. The survival curve of wireless sensor nodes for protocol in literature is shown in Figure 7. As can be seen from Figure 7, all network routing protocols are decreased continuously with the network node survival of network working hours. This paper takes 50% of the network node as the evaluation criteria of network life cycle, thus the network life cycle of the routing protocol herein is somewhat longer than that in literature.

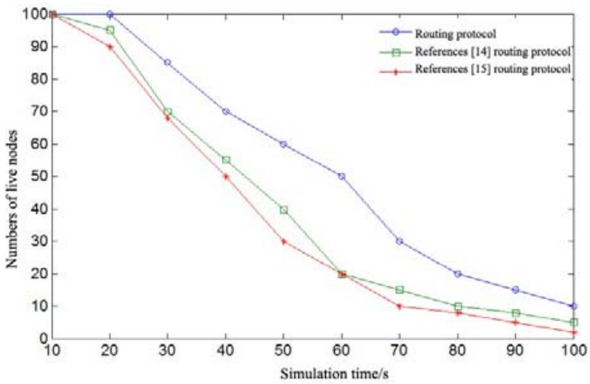

Figure 7. Comparison of network life cycle for different routing protocols

C. Comparison of Packet Loss Rate

Packet loss rate is a meaningful indicator of measuring routing protocol performance for WSN. The packet loss rate curve of WSN for protocol in literature is shown in Figure8. As can be seen from Figure 8, with the increased run time of WSN, the packet loss rate of wireless sensor is rising, which is mainly because as the network time increases, the deaths of network node are increased. If the death of sensor node in data forwarding routing occurs, it may lead to failure in the established data forwarding routing. The sensor nodes no longer play the role of relaying the data, and the packet on the route would be lost. A the same time, with respect to the routing protocol in literature, the routing protocol in this paper has smaller packet loss rate, which is mainly because the routing protocol in this paper has introduced the energy-aware mechanism, saving energy consumption, and ensuring the communication quality of the network, thereby improving the success rate of packet forwarding.

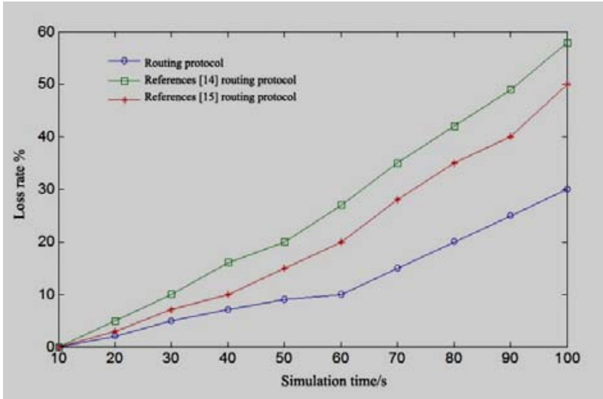

Figure 8. Comparison of packet loss rate for different routing protocols

V. CONCLUSIONS CONFLICT OF INTEREST ACKNOWLEDGMENT

To reduce defects of high packet loss rate of network and great energy consumption, etc., an energy-aware-based routing protocol for WSN is proposed, and the routing protocol has introduced node energy-aware mechanism in data forwarding to prevent node with smaller residual energy from being involved in the establishment of routing, while the periodic and asynchronous work / sleep mechanism has been introduced, which has saved energy cost of nodes. The results show that the proposed routing protocol has increased the average energy efficiency of nodes, effectively extending the network life cycle, with a wide range of applications.

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