A New Load Balancing Routing Scheme for Wireless Body Area Networks

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***Abstract*— In the wireless body area network (WBAN), being constrained by the sensor size, the battery, computing and store resources of each node is very limited. In the multi-hop environment, it is necessary to save energy and balance the energy consumption in the network. At present, most of the research work selects the route with high residual energy, but does not consider the heterogeneity of the WBAN nodes. Since the energy distribution and energy consumption rate of each node in the WBAN may be different, the selection of the forwarding node needs to consider more factors. In this paper, we propose a novel routing scheme LBEE, which evaluates the cost value according to the current traffic load and residual battery of the node, selects the high-energy, low-load routes for data forwarding, and balances the network load too. The simulation show that this scheme can improve the network' s overall lifetime, throughput and loadsharing.**

Keywords—WBAN; routing; energy efficient; load balancing

I. INTRODUCTION

The Wireless Body Area Network (WBAN) consists of a series of small nodes deployed on the human body. It features low power, low complexity, small transmission range and high reliability [1]. It can continuously monitor the human body situtations and fed back it to the cloud center for the scientific and health analysis. It has broad applications in entertainment, military, especially in the medical and heathcare fields [2].

Due to the particularity of their deployment locations, the WBAN needs long-term operation. To avoid bringing trouble in daily life, the size of the node should be small, so its energy and computing resources are very limited [3]. During their operational stage, the data transmission and reception processes are the main parts of the energy consumption. As the communication distance increases, the energy consumption is increasing exponentially [4]. Because the nodes are distributed in various parts of the human body, some of them are too far away from the central node sink, therefore the multi-hop communications are required.

In the traditional protocol of AODV [5], the terminal node selects a route with the shortest distance or least hops. The energy balancing is not considered which causes the route to die quickly due to the long-term of keep forwarding tasks. In the improved protocol [6][7], it has considered the factors such as energy and distance to address this problem primarily, but the heterogeneity of WBAN and the load diversity of the nodes are not fully considered.

As a heterogeneous network, WBAN nodes has different functions and specifications [8], and there may be some differences in battery level, packet size, and packet creation frequency. Nodes with high data rates generally have more complex and important monitoring tasks, with higher battery levels and faster energy consumption speed. According to the current protocols, higher energy levels nodes has greater probability being selected as forwarding nodes, cause to the load increased.

Increased load leads to the increased speed of energy consumption. In [6], the node with the highest residual energy may provide forwarding tasks for multiple routes, resulting in a sharp drop in energy in a short time. At the same time, the surge of load may also bring about an increase in data latency and node heating, which has a certain impact on the stability of the network.

Therefore, the choice of relay nodes in WBAN should not only consider the residual energy, but also take account the energy consumption speed of the node. The additional load assumed by the node should be proportional to its energy level and energy consumption speed. Based on this, a new AODV-based routing scheme LBEE (load balance and energy efficient) is proposed in the following. In the process of discovering the routing, the terminal node selects the route with the lowest cost according to the remaining energy and the current load. The LBEE can balance the difference in energy consumption speed due to the heterogeneity of nodes, and distribute the forwarding tasks according to the current energy and load status of each node. The simulation studies below have demonstrated that this scheme can effectively improve the network overall lifetime, throughput and balancing the network load.

II. RELATE WORK

The study in [6] has improved the AODV protocol. The advanced scheme adds the minimum residual energy and total residual energy related data fields into the REEQ message. It can record residual energy of the node and the entire end-to-end route. Route with the largest remaining energy will be selected to forward the message. This solution balances the energy consumption and extends the network' s lifetime. In [7], a method for selecting a forwarding node based on the euclidean distance between the nodes is proposed. By calculating the two-dimensional euclidean distance between two nodes, the node with the smallest distance is selected as the forwarding node. The simulation studies show that the protocol has good performance in energy consumption, end-to-end delay and packet loss rate. However, the solution does not

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consider the energy balance problem. The shortest distance route will quickly run out of energy, and the distance measurement of nodes in WBAN is difficult.

The work [9] has calculated the value of the forwarding node in the sink node, reduced the computational energy consumption of the source node. In this scheme, the sink node can obtain the ID, the remaining energy and the distance to the sink of all the child-level nodes. The sink node calculates the cost of all the member nodes according to the above information, and broadcasts the result to all member nodes. After receiving the result, the member node decides whether to become the forwarding node according to its own cost. In the routing phase, the source node selects the route with the least number of hops, and the emergency information can directly send to the sink. This scheme changes the deployment of the forwarding nodes, and each node can decide whether to be a forwarding node according to its own situation. However, the transmission power of the downlink form the sink node may be too large. The work [10] proposed ESR for hospital scenes, which uses the residual energy and the inter-node distance to define the energy-aware cost function and the link-quality cost function, respectively. The energy cost function can improve the network lifetime but its only applicable to the hospital environment. The work in [11] proposed a strategy for selecting forwarding nodes based on the distance and the remaining energy. Nodes that are closer to the sink node and have more residual energy will be selected as forwarding nodes, but there will be a situation where the source node is far away from the forwarding node. Since the power of the source node is smaller, long-distance communication may generate a higher error rate.

In [12], a method for selecting a forwarding node based on the maximum forwarding time is proposed. The forwarding node can calculate the maximum forwarding time according to the packet frequency and packet size provided by the requesting node. The node with the largest forwarding time forwards the data, and when the forwarding time is exhausted, and the source node autonomously reselects the forwarding node. This scheme is applied to the two-hop structure of IEEE 802.15.6[13] and does not specify the application in a multi-hop environment. The protocol proposed in [14] can reduce the number of RREQ messages in the AODV protocol. In the process of discovering routes, only nodes that can reach the sink are selected to participate in forwarding RREQ messages, change broadcasts to multicast, which reduces energy consumption.

III. PROPOSED PROTOCOL

In this section, we propose a new routing scheme, LBEE, which considers node load and residual energy to improve network lifetime.

A. Network model

The network model is shown in Figure 1. There are several different nodes in the network. The sink is the central node. E and N can select C or D as a forwarding node. All nodes can measure their remaining energy and the traffic load per unit time (the total amount of data send in the unit time).

For the convenience of description, we use the E and N as the terminal nodes as an example to illustrate our protocol. The E and N will find the best route to the sink.

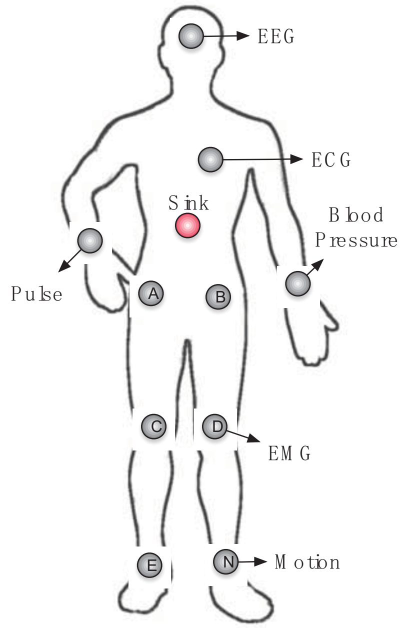

Fig. 1. WBAN Network Model

B. Cost Function

1) Node Cost Value:The cost value of the forwarding node K is calculated by the following function.

$$\text{Cost}_K = a\times \frac{T_K}{E_K} \quad (1)$$

2) Where is the constant coefficient, is the remaining energy and is the traffic load of the node K at this time. It can be seen that the cost value of the node K is inversely proportional to the current residual energy and proportional to the current load. The smaller is, the more suitable of the K as a forwarding node.

Routing Cost Value:The lifetime of the route is the same as the life of the node with the shortest life in the route [16]. Therefore, the cost value of the route takes the maximum in the set of node cost value in the route, as in equation (2), where is the node on the route.

$$\text{Cost}_{Route} = \max\{\text{Cost}_a, \text{Cost}_b, \dots\dots, \text{Cost}_n\}$$

C. Protocol Message

1)RREQ Message:The frame structure of the RREQ message is shown in Figure 2. The ID identifies the message, and when the node receives the duplicate message, it does not process to prevent the infinite loop. Source is the source node ID. Destination is the target node ID. Hop is the hop count. Cost is the node cost value, and the source node sets the value -1, if the value of the intermediate node is greater than it, the field will be replaced. Lifetime is the effective time of the message.

2)RREP Message:The frame structure of RREP is shown in Figure 3. The Cost field value is the route cost value.

ID	Source	Destination	Hop	Cost	Lifetime

Fig. 2. RREQ message frame structure

ID	Source	Destination	Cost	Lifetime

Fig. 3. RREP message frame structure

D. *Algorithm Description*

Step 1: When the node N needs to forward the information by forwarding node, it broadcasts the RREQ message within the communication range and starts route discovery.

Step 2: The forwarding node K receives the RREQ message, calculates the current load and residual energy, and calculates the value 〖Cost〗 _K according to equation (1).

Step 3: Determine whether the value of the Cost field in the RREQ message is greater than 〖Cost〗 _K, if it is, keep the value unchanged; if not, replace the value with 〖Cost〗 _K,and forward the RREQ message to the next hop node. repeat the steps 2 and step 3 until reach the sink node.

Step 4: After receiving the RREQ message, the sink constructs a RREP message. The Cost field in the RREP message is the route cost value according to equation (2), and sent the RREP message to the source node.

Step 5: After receiving the RREP message, the source node N records the route cost value and adds it to the candidate routing table, and selects the route with the lowest cost value to forward data.

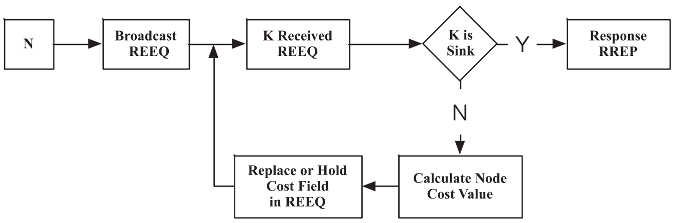

Fig. 4. Algorithm Flow Chart

IV. SIMULATION

A. *Simulation Setup*

We have conducted the simulation studies to validate the new proposed protocol by using the OMNeT++ [15] and compare with the EAODV protocol [6]. The simulation results confirm that the proposed protocol has improved the network lifetime, throughput and load sharing.

The simulation model is shown in Figure 1, we chose nodes set {sink, A, B, C, D, E, N} for the simulation. The simulation parameters are shown in Table 1, and the node parameters are shown in Table 2. Power is the transmission and reception power of the node. Energy is the initial energy of the node and Data is the data generation rate of the node itself.

This simulation consists of two parts, of which simulation 1 contains only one terminal node N, simulation 2 contains two terminal nodes E and N

TABLE I. EXPERIMENTAL PARAMETERS

Protocol	IEEE 802.11
Power	240 nj/byte
a	0.1
time	6000s
Range	2m

TABLE II. NODE PARAMETERS

Node	A	B	C	D	E	N
Energy(j)	0.5	0.4	0.3	0.2	0.1	0.1
Data(byte/s)	20	16	12	8	4	4

1) **Simulation 1:** In this simulation, the node N has two routes to choose from, named R1 (N-C-A-Sink) and R2 (N-D-B-Sink). According to equation (1) we can calculate the following:

Node	A	B	C	D
Cost	6.4	6	4	4

we can get $Cost_{R1} = 6.4$, $Cost_{R2} = 6$ from equation (2). According to the content of the protocol, node N selects R2 as the best route.Because of $E_A > E_B$ and $E_C > E_D$, the selection algorithm according to the EAODV protocol will select R1 as the best route.

2) **Simulation 2:** It can be seen from simulation 1 that under the agreement of this paper, the node N selects R2 first, and the cost value of R1 and R2 changes at this time:

Node	A	B	C	D
Cost	6.4	7	4	6

we can get $Cost_{R1} = 6.4$, $Cost_{R2} = 7$ from equation (2). According to the content of the protocol, node N selects R1 as the best route.

As in the experiment 1, the node N and E under the EAODV protocol will select the R1 route with high residual energy.

B. *Performance Metrics*

We use the following metrics to analyze the performance of the protocol.

*a)*Network lifetime:We use the same definition in [16] to define the network lifetime as the shortest node lifetime in the network, that is, the time from the start of simulation to the first node is dead.

*b)*Throughput:This indicator is the total number of packets received by the sink and can reflect the communication volumes of the entire network during the simulation period.

c) Node Load: This indicator is defined as the load assumed by the node. According to the experimental settings, when the node does not provide forwarding work, the indicator value is 100%. When the value is greater than 100%, it indicates that the node bears additional forwarding load. The larger the value, the higher the node load, the faster the energy consumption and the shorter the life.

C. Simulation result

Figure 5 is a comparison of the network life in simulation 1. We can see that the network lifetime in LBEE is about 3% higher than EAODV. Although the residual energy of R1 is higher, the node load in R1 is also higher. LBEE considers the energy and load of the node comprehensively, and selects R2 with smaller load-to-energy ratio as the best route, which improves the network life.

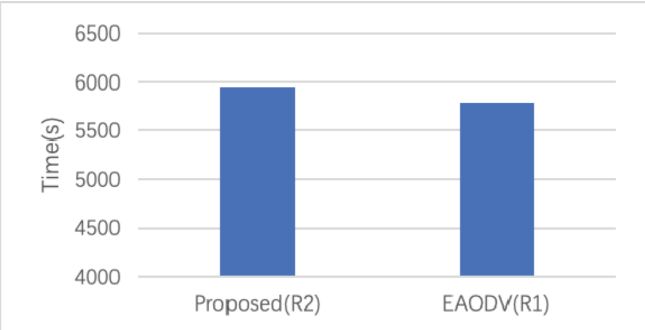

Fig. 5. Network life (Experiment 1)

Figure 6 is a comparison of network life in Experiment 2. Compared with the EAODV protocol, the network lifetime in LBEE is increased by about 11%. In EAODV, the node only selects the route with the highest remaining energy, and does not consider the energy consumption speed caused by the load of the route itself, resulting in rapid energy consumption of R1. In LBEE, the load is balanced. When the node E selects the route, R2 has higher load because the forwarding task for the node N. According to the equation (1) and equation (2) proposed in this protocol, it can be calculated that R1 is more suitable for Node E. It implements load balancing, extending network life and improving network stability.

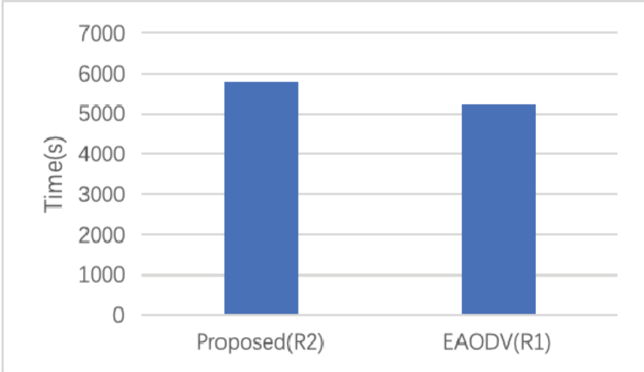

Fig. 6. Network life (Experiment 2)

Figure 7 is a comparison of the total network throughput in simulation 2. LBEE has increased by about 5% in network throughput. Since the protocol improves the network lifetime compare to EAODV through load balancing, the load and energy consumption speed of the forwarding node are limited to a reasonable range according to the battery level, and the working life is increased, resulting in an increase in throughput.

Figure 8 shows the load of each forwarding node. It can be seen from the figure that the load range of each forwarding node in LBEE is smaller than in EAODV. The load standard deviation in LBEE is about 0.218, while in EAODV is about 0.416. It proved that the LBEE balanced traffic load in WBAN.

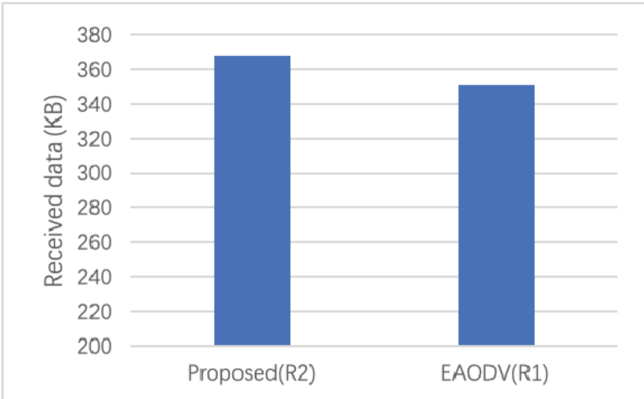

Fig. 7. Network throughput

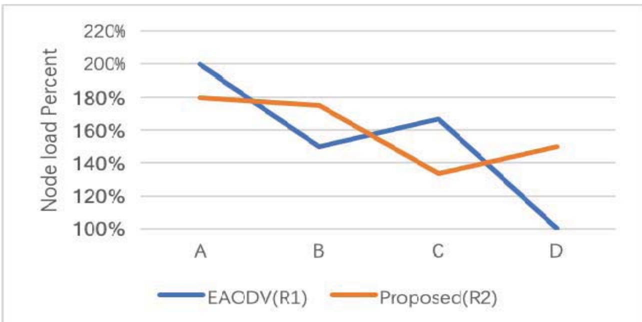

Fig. 8. The forwarding node traffic load

V. Conclusion

In the WBAN, the functions and specifications of each node are different, and these differences are causing the interference to the selection of the forwarding node. This paper proposes a load balancing based routing algorithm by considering the heterogeneous features of node group in the WBAN. The forwarding node selects the next hop both according to the current residual energy and the current workload, therefore it could balance the network load and energy consumption speed. The simulation studies have confirmed the effectiveness of the proposed protocol which has improved the overall network lifetime, throughput and load sharing.

VI. Future work

This paper does not give a special method to calculate the node instance traffic load, we will consider it in the future work and mobility is also the focus of our next research.

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