An Energy Efficient Multipath Routing Algorithm in Wireless Sensor Network

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***Abstract*—Due to the energy and resource constraints of a wireless sensor node in a wireless sensor network (WSN), WSNs adequately need effective mechanisms for data forwarding to enhance the energy efficiency in networks. To solve this problem, Multipath routing protocols are often used to balance the network energy consumption. In this paper, we propose an energy efficient multipath routing algorithm (EEMR) for WSN that considers wireless interference and load balancing. The algorithm establishes multiple paths with minimum interference between the source node and the destination node. In this way, the quality of wireless communication is improved because the effects of wireless interference can be reduced as much as possible. Meanwhile, the proposed algorithm allocates traffic load reasonably according to the total link cost of each path, which can prolong network lifetime. Simulation results show that the proposed routing algorithm achieves lower energy cost and longer network lifetime than that in the literature.**

Keywords—WSNs; multipath; energy efficient; load balancing

I. INTRODUCTION

In the recent years, the advances in microelectro mechanical systems and technology have led to small and low cost sensor network, which can observe and react to changes in physical phenomena of their surrounding environments [1]. Energy sources in WSNs are limited and unrechargeable. Moreover, sensor nodes are deployed over large geographical area, it is not possible for human beings to recharge or replace these batteries. Hence, one of the main design goals in WSN is energy conservation at sensor nodes. There is a wide attention towards reducing the power consumption on the WSN [2].The distributed nature and dynamic topology of WSNs introduces very special requirements in routing protocols. In order to minimize the energy consumption in WSNs, several energy efficient routing protocols and algorithms has been developed. Efficient utilization of sensor's energy resources and maximizing the network lifetime were and still are the main design considerations for the most proposed protocols and algorithms for sensor networks and have dominated most of the research in WSNs[3]. Utilization of single path results in early failure of nodes along the path, which will greatly reduce the lifetime of the network. In order to cope with the limitations of single-path routing techniques, the multipath routing approach has become as a promising technique in WSNs[4]. Multipath routing protocol selects multiple paths simultaneously, extending the network lifetime through the efficient use of network resources, while other network performance will also be promoted. Interference-minimized multipath routing protocol (I2MR) [5] tries to construct zone-disjoint paths and distributes network traffic over the discovered paths by assuming a special network structure and the availability of particular hardware components. The problem is I2MR protocol does not take the remaining energy of nodes into consideration. As a result, this will cause premature death of some network nodes and reduce the network lifetime. In this paper, an energy efficient multipath routing algorithm in WSNs is proposed, which can discover multiple paths with minimum interference and distribute traffic loads reasonably. Thus, the network lifetime was extended and the network's overall performance was improved as well.

The remainder of this paper is organized as follows: Section II gives network models and problem description. Section III describes the proposed energy-efficient multipath routing protocol considering wireless interference for wireless sensor network. Section IV describes the simulation experiments followed by results and discussions. Section V concludes the paper.

II. NETWORK MODELS

A. Node energy model

The sensor node consumes power for sensing, communicating and data processing. Rather, more energy is required for data communication than any other process. Power consumed during transmission and reception of data is useful. The energy cost is determined by the data packet size and radius of the transmission, and the energy cost model of the receiver module and the transmitter module is based on the first-order radio model. The energy cost for sending *k*-bit packet to a node with distance '*d*' is shown below:

$$\begin{aligned} E_{Tx}(k,d) &= E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \\ &= E_{elec} \times k + E_{amp} \times k \times d^2 \end{aligned} \qquad (1)$$

.

To receive a k-bit message, a sensor consumes the energy

$$E_{Rx}(k) = E_{Rx-elec}(k) = E_{elec} \times k. \qquad (2)$$

Where E_{elec} is the dissipated energy by the radio to run the transmitter or the receiver circuitry and E_{amp} is the required energy by the transmit amplifier.

B. System model

The wireless sensor network can be expressed by a connectivity graph *G* = (*V, E*), where *V* is the set of *N* nodes and *E* is the set of directed links connecting the nodes in *V*. Let $n_i \in V$, $\forall i$, where $1 \le i \le N$, denote a node in the network and $l_{i,j} \in E$ represent a directed link from node n_i to nod n_j and every link represents a communication link between two adjacent nodes. Consider the communication between a source node $n_s \in V$ and a destination node $n_d \in V$. A loop-free path *k* from n_s to n_d comprises of the source node n_s , the destination node n_d , and a set of normal nodes represented by $R = \{n_k^i\}$, where $1 \le i \le |R_k|$ and $\{n_k^i\}$ represents the *i*th normal node along path *k*. $|R_k|$ represents the total number of normal nodes along path *k* [6]. The goal of the routing protocol is to achieve the smallest network energy cost and balance the node energy cost in the network.

III. EEMR Algorithm

The EEMR algorithm consists of two parts. The first part is the path establishment, selecting multiple paths between the source node and destination node .The second part is the load distribution. After paths have been established, the source node allocates traffic loads based on the total link costs of each path. Finally, the source node transmits traffic loads among these paths simultaneously to the destination node.

A. Path establishment

In EEMR algorithm, the process of route establishment can be divided into the establishment of the primary path stage, marking interference nodes, and the subsequent paths discovery stage. After all sensor nodes were deployed to the target area, initiate path discover phase, to construct multiple disjoint path route and mark the node interference range, then start data transmission. The proposed energy efficient multipath routing algorithm (EEMR) works as follows:

Step 1: When the source detects an event or has the data to transmit and if there is no route to destination established yet, it will start the route request procedure. The source node floods RREQ packet to the surrounding nodes. When the node is not the first to receive RREQ data, it will discard the RREQ data. By analogy, RREQ data will flood broadcast from the source node to destination node. When the destination node receives RREQ packets, it will select the primary path with the consideration of residual energy and hop-counts and send back the RREP packet. The RREQ packet format is shown in the following TABLE I.

TABLE I. RREQ packet format

Msg ID	Sink ID	Node ID	Residual energy	Hop-count

Step 2: As the node transmitting antenna is omnidirectional, nodes can receive the RREP within a communication radius of the routing node. After receiving the RREP packet, confirming the receiver ID is not itself, the node will mark itself as interference node and will no longer participate in routing establishment later

Step 3: The method of establishing the subsequent path is similar to establishing the primary path, but nodes with the interference flag set do not participate in the process of establishing the path.

When routing discovery is completed, the source node sends data using the two paths at the same time, and other nodes enter the sleep state until the start of the next task. Interference awareness and energy saving are achieved by avoiding interference nodes taking part in the routing process. This helps to maximize the network lifetime

B. Load distribution and data transmission

Reasonable load distribution at source node can protect the main path from premature failure which result from excessive use, and utilize the network resources more efficiently. To run an appropriate load balancing algorithm in the source node, the link cost of each path must be known. Suppose there are K nodes in the first path A, and the total path link cost is P_A , is defined in formula (3). The second path B, contains J nodes, and the total path link cost is P_B , is defined in (4).

$$P_A = l_{1,2} + l_{2,3} + \cdots\cdots + l_{(k-1),k} = \sum_{i=1}^{K-1} l_{i,(i+1)} \tag{3}$$

$$P_B = l_{1,2} + l_{2,3} + \cdots\cdots + l_{(j-1),j} = \sum_{i=1}^{J-1} l_{i,(i+1)} \tag{4}$$

According to the calculated total link cost of each path, the source node distributes traffic loads reasonably. *r* indicating total transmission rate of the source node, r_A representing to the first path data forwarding rate, r_A is on behalf of the second path data forwarding rate. The specific equations are shown as (5) (6).

$$r_A = r \times \frac{P_B}{P_A + P_B} \tag{5}$$

$$r_B = r \times \frac{P_A}{P_A + P_B} \tag{6}$$

The source node allocates traffic loads based on equations (5) (6), and then transmits on their own path

IV. Simulation Analysis

In the simulations, we assume two paths are discovered only in the routing protocol. In order to verify the performance of EEMR algorithm, simulation experiments are conducted using NS2. Sink node is in the network center, the other nodes are randomly deployed around the Sink node, and nodes are densely distributed. The source nodes periodically send data to the Sink node. The number of Sink node is set to 1. The number of source nodes is set to 4. The energy cost of transmission and reception is computed according to equations (1) and (2). The simulation environment is shown in the following TABLE II.

TABLE II. SIMULATION ENVIRONMENT

Network Range/[m]	Communication Radius/[m]	Initial energy of the node/[J]	Number of node	Simulation time /[s]
120×120	15	2	100	1000

The number of network survival nodes. The survival node is refer to the node that its remaining energy is greater than 5% of the initial energy.Fig.1 shows the number of survival nodes of two algorithms. From the Fig.1 we can find that the number of survival nodes decreases as time goes on. It also can be seen from Fig.1 that EEMR algorithm has more survival nodes than that with I2MR in the network.

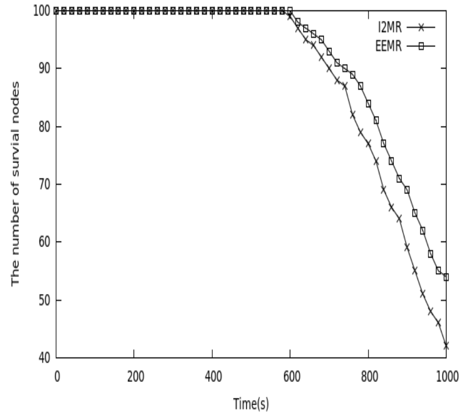

Fig.1. The number of survival nodes

The network energy consumption .The network energy consumption is refer to the total energy consumed by all the nodes during the network operation. Fig.2 shows the network energy consumption of two algorithms during the simulation time. Fig.2 indicates that the total energy cost with EEMR algorithm is lower than the I2MR.

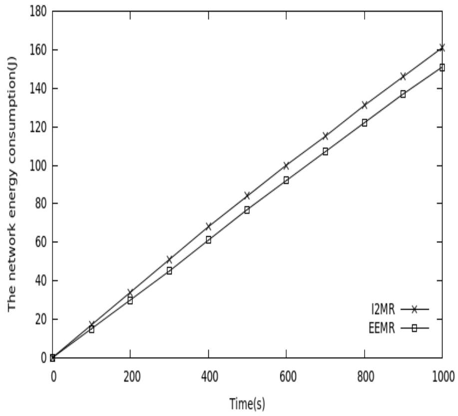

Fig.2. The network energy consumption

The simulation results show that EEMR algorithm proposed in this paper showed a better performance of the total energy consumption in the network and number of network survival nodes than the I2MR algorithm. EEMR algorithm also balances the energy consumption of nodes in the network more effectively to extend the network life cycle.

V. CONCLUSION

The energy efficiency is a very important issue for the networks especially for WSNs which are characterized by limited battery capabilities. In this paper, an energy efficient multipath routing algorithm(EEMR) in WSN was proposed ,which fully considered wireless interference and load balancing. The EEMR algorithm establishes multiple paths with minimum interference between the source node and the destination node. In this way, the quality of wireless communication is improved because the effects of wireless interference can be reduced as much as possible. The EEMR algorithm also proposes a reasonable load distribution mechanism, which can prolong network lifetime. The simulation results show the much better performance of our proposed protocol than that of the existing ones.

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