Energy Efficient Routing Protocol using LPA-star algorithm with Dynamic Threshold

Ahmed A. Alkadhmawee[1], Mohammed A. Altaha[2]

College of Education for Human Sciences [1], College of Veterinary[2]
University of Basrah , Basra, Iraq[1,2]

Abstract

Uneven Energy Depletion (UED) is an innate drawback in wireless networks which dramatically reduce the network lifetime. This paper proposed an Energy Efficient Routing protocol to addressing the problem of UED and improving the WSN lifetime. The proposed method used LPA-star algorithm for choosing the appropriate optimum path from the source node to the base station. the routing algorithm using the dynamic threshold to find alternate route path to obviate choose the nodes that have low energies in order to prolong the lifetime of the network. The simulation results reveal significant improvements of the proposed approach as compared to the performance of the other related protocol.

Keywords *LPA-star algorithm, network lifetime, routing, wireless sensor networks*

I. INTRODUCTION

Nowadays, the increasing rate of wireless data communication makes the wireless sensor network (WSN) one of the most promising and revolutionary technologies around. it represents one of the primary network technologies in the Internet of Things (IoT)[1] . A WSN is commonly comprised of a plurality of sensor nodes which are deployed over a large area and communicate with each other's to monitor or collect data within the sensing range of its surrounding environment. Despite the fact that the WSN has developed a lot, energy resource constraints are one of the most critical challenges for WSNs due to the limited power resource of sensor nodes. Moreover, The energy dissipated for a communications and data transmission grows almost exponentially with the increasing transmission distance [2]. Consequently, multi-hop short-distance communication is more commonly used and much preferred in WSN. In multi-hop WSN communication, sensor nodes transmit their sensed data with shortest path toward the sink via one or more intermediate nodes, which can reduce the energy consumption for communications. [3]. The tasking for finding the multi-hop route to the sink with shortest and efficiency path poses new challenges and has received enormous interest from academic communities [4]. Therefore, the main purpose for most of the researchers on WSNs has focused on the design of computational algorithms and energy-efficient protocols [4][5].

A critical aspect in the designing of WSNs and applying the good routing protocols are to save energy and extend the network lifetime. However, achieving the saving energy is not enough to efficiently prolonging the lifetime of the WSNs. Uneven Energy Depletion (UED) is an innate problem in WSNs described by a many-one traffic pattern and multi-hop routing. The UED often lead to network partition and reduce network lifetime significantly. Therefore, there is a need for energy-efficient techniques to reduce energy consuming in sensors. These techniques should also balance the energy consumed at all layers of the network in order to prolong the WSNs lifetime.

we propose an Energy Efficient Routing protocol to investigate the balancing energy consumption problem and improving the WSNs lifetime. The proposed method used the LPA-star algorithm to determine the optimum forwarding path between the source and the sink node. Moreover, the routing method using the dynamic threshold to find alternate route path by running the algorithm from the start node to obviate choose the nodes that have low energies in order to prolong the lifetime of the network.

The rest of the paper is organized as follows: the related works are present in section 2. Our proposed method is presented in section 3. The performance evolution is discussed in Section 4 and the conclusion to this paper is presented in section 5.

II. RELATED WORKS

This section briefly reviews the literature concerning the usefulness of some existing routing protocol and the approaches that are widely used to extend the WSNs lifetime.

In [6], the authors proposed the routing algorithm to find the shortest cost path for maximizing the WSNs lifetime by use link costs that reflect both the remaining power level of sensor nodes and the communication energy consumption. In [7], the authors propose a multipath search protocol for WSNs. This protocol is capable of searching multiple paths between the sink and source nodes. The hop distances of sensors along each path and the remaining power level of nodes are combined to define the link cost function. In [8], The authors presented an even balancing energy routing protocol to distribute the load of energy between any nodes and to select the sensors whose remaining energies were more than a threshold value in order to maximizes the WSN lifetime.

In [9], proposed the new routing algorithm called WSNHA-GAHR. The protocol is using the greedy forwarding technique and the A-star algorithm to reduce the hop count and to overcome the local minimum problem. This protocol selects nodes for the transmission path without considering the residual energy in these nodes. Thus, this may spend selected nodes' power quickly. In [10], propose an efficient routing algorithm which uses an A-star algorithm to pick out an optimum path between the source node and sink node. This method defines the threshold value and the sensor which has energy of less than the threshold will be excluded from the routing operation. In [11], the authors proposed the new energy-routing protocol using the lifelong planning A-star (LPA-star) search algorithm. The protocol is using the LPA-star algorithm to find the routing path to the sink. This protocol using a static energy threshold to replace route path without considering the node's distance to the sink . Thus, this may spend selected nodes' power quickly.

III. THE PROPOSED METHOD

A. *Network Model*

In the proposed routing protocol, the WSN topology is abstracted as the graph G (N, D), where D denotes the set of directed radio communication links between the sensor and N denotes the set of n wireless sensor nodes. The direct link d= (v, u), d exists if the Euclidean distance between node v and u inside the domain of r, where r is the radius of the node transmission range. The sink is accountable for gathering sensory data from all sensors within its communication range [3, 4, 9].The model for the proposed method assumes that the WSN has the following properties :-

1. Each sensor node has different quantities of traffic load inside its queue.
2. All the sensor nodes have initial equal energy with fixed maximum transmission range.
3. Each sensor knows the location of the sink as well as its own and its neighbors.

The procedure for finding an optimum path from the initial node to the sink is related to certain parameters in each sensor node, such as residual energy, traffic load and distance to the sink. The sink must know the current level for the criteria of each node so as to find the optimum path. Therefore, at the first round, the sink node sends queries to all nodes and each node sends the above parameter to the sink. In the remaining round, only the sensor which has data to send appends its parameters with the data packet toward the sink.

B. *The Proposed method*

The main goals of this subsection is design a new efficiency routing algorithm which will enhancement and extend the network lifetime through the egalitarian distribution of power consumption as well as limiting energy cost with minimizing data packet delivery time. To realize this, our proposed method uses the LPA-star algorithm with all routing criteria (residual energy, distance to the sink node and traffic load amount) for each sensor node to an optimum route between the source node and the sink. The candidate node to represent the optimum routing path depends on the largest f-value which used the evaluation function (f (n)) to find the largest f-value. The evaluation function we used is given as:

$$f(x) = g(x) + {}^{1}/_{h} \quad (1)$$

whereas h(n) refers to the shortest distance from to the sink node of node n, g (n) refers to the node cost of node n which determine by the fitness function and takes the value [0…1].

The h (n) function can be determined by using feature scaling method by distance normalization to [0...1], as follows:-

$$h(n) = (d(n,s)/M) \quad (2)$$

whereas M refers to the maximum distance in the sensor area, d (n,s) refers to the distance from node n to the sink node which is calculated by a Euclidean distance .

The fitness evaluation function is taken into consideration the traffic numbers and the amount of residual energy of node n to determine the optimum cost value for the node n .The cost function g(n) can be calculated as follows:-

$$g(n) = \alpha\left(\frac{RE(n)}{ET(n)}\right) + \beta\left(1 - \frac{TN(n)}{TM(n)}\right) \quad (3)$$

whereas $ET(n)$ and $RE(n)$ are refer to the initial and residual energy of node n respectively, $TN(n)$ and $TM(n)$ are refer to the current and maximum traffic loads of node n respectively. α and β are weight parameters (α+ β=1).

Our routing method for the proposed model check the existing nodes in the optimum path with their neighbors after every packet sends and re-use the same path while its nodes still have the largest f-value. Furthermore, our method gets to benefit from the previous path to recalculate the new optimum path from current node that have changed in which f-value to the sink by select its neighbors that have the largest f-value without re-running from the start nodes.

When the sensor energy is less than the threshold value , the proposed algorithm tries to find alternate route path by running the algorithm from the start node to obviate choose the nodes that have low energies in order to prolong the lifetime of the network. The threshold value is a dynamic and can be obtain it from the equations below :-

$$\text{Threshold} = \frac{average\ (RE)}{Total\ (ET)} * \frac{average(d)}{M} \quad (4)$$

Whereas $average\ (RE)$ refers to the average remaining energy of all sensor nodes , $Total\ (ET)$ are refer to the total energy of all the nodes, $average(d)$ refers to the average distance of all and N is the number of sensor nodes .

IV. PERFORMANCE EVALUATION

A. Simulation Setup

In this section, we adopt MATLAB for executing the simulation. The simulation area is 200 × 200 m^2 with 50 sensor nodes randomly deployed in this topographical area. The same initial energy is set to 5 Joules for every node in the network, with maximum sensed transmission range at 80 m. The traffic load is generated randomly between [0...10] for each sensor node. There is a single base station located at the top right-hand corner of the simulated area (200 m, 200 m). A radio model discussed in [12] is used for the proposed method. It's commonly used in WSNs. In order to transmit number of bits per packet (k) over the distance (d) between the sender and receiver nodes, the dissipate energy of a node is characterized by:-

$$E_nT(k) = E_{elec} * k + E_{amp} * k * d^2 \quad (5)$$

The power consumption of a node for receiving this message is characterized by the expressions :

$$E_nR(k) = E_{elec} * k \quad (6)$$

Simulations are made using values 100 pJ/bit/m^2 and 50 nJ/bit for Eelec and Eamp respectively. The simulation parameters are presented in Table 1.

Table 1. Simulation Parameters

Parameter	Value
Topographical Area [m × m]	200 × 200
Number of sensor nodes	50
Initial energy of node / J	5
Transmission radio range [m]	80
Position of sink [(m,m)]	200 × 200
E_{elec} [nJ/bit]	50
E_{amp}[pJ/bit/ m^2]	100
Maximum traffic size [Packet]	10
Number of transmission packets	2 × 10^4
Data Packet size[k bit]	4
α, β	0.65, 0.35

B. Simulation Results

The number of nodes stays alive for each transmission round using the two approaches (the proposed method and LPA-star) is presented in Fig 1.The graph indicates that our method superior to the LPA-star protocol [11]. The lifetime of the network after all packets send is increased with our proposed over that obtained from LPA-star protocol.

The rounds of first node died are simulated using the two different approaches (the proposed method and LPA-star)). The results are listed in Table 2. Obviously, the times for the first node dies in the our protocol are much greater than the times for the first node died in the LPA-star protocol.

The Fig.3 shows the delay in transmission of a data packet for both protocols. It can be argued that the our method has the shortest delay from obtained by the LPA-star protocol.

We can note from the above simulations that our protocol outperforms LPA-star protocol in terms of maximization the lifetime of WSNs and balancing energy consumption.

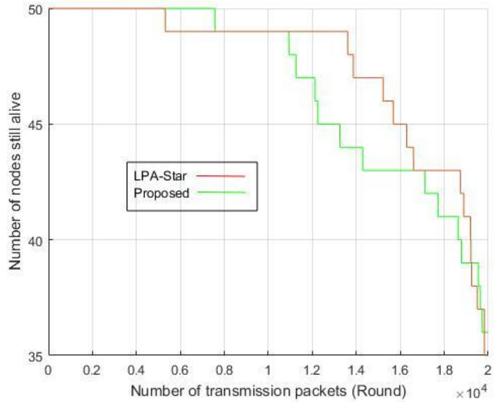

Fig 1. Number of nodes still alive for each round

Table 1. Number of transmission packets with the first node death

Approaches	The proposed protocol	LPA-star
Round first node dies	5308	7567

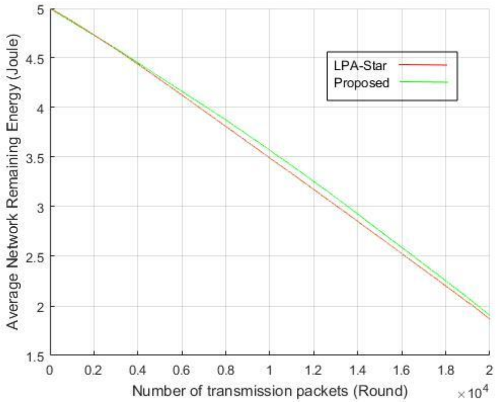

Fig. 2 Average remaining energy for each round of the two approaches

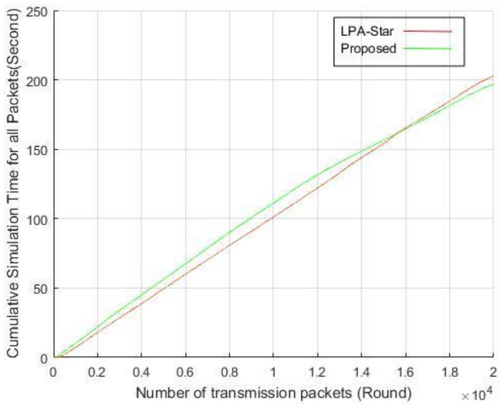

Fig. 3 Delay in transmission of a data packet in the two approaches

V. CONCLUSIONS

One of the key characteristics used for evaluating the performance of any WSN is the lifetime of the network. we proposed an energy - efficient routing algorithm uses the LPA-star algorithm to repeatedly find an optimum routing path between the source node and the sink node. Our proposed method depends on the dynamic threshold value instead of static threshold. Simulation results show the appropriateness and better performance of new protocol against LPA-star protocol with respect to the improvement of the WSNs lifetime and balanced energy consumption with fast data transmission across the network.

REFERENCES

[1] Chi-Tsun Cheng, C.K. Tse, F.C.M. Lau. A Delay-Aware Data Collection Network Structure for Wireless Sensor Networks, IEEE Sensors Journal, Vol.11, No.3, 699-710, 2011.

[2] Kumar Vasantha, S V P K Satya Devu "An Efficient and Reliable Data Transfer Protocol in Wireless Sensor Networks" International Journal of P2P Network Trends and Technology 9.2 (2019): 10-13.

[3] Y. Jennifer, M. Biswanath and G. Dipak. Wireless sensor network survey. Comput. Netw., 2008, 52(12): 2292-2330.

[4] K. S. Shivaprakasha and M. Kulkarni. Energy efficient routing protocols for wireless sensor networks: A survey. Int. Rev. Comput. Softw., 2011, 6(6): 929-9

[5] I. F. Akyildiz, W. Su, Y. Sankara subramaniam and E. Cayirci. A survey on sensor networks. IEEE Commun. Mag., 2002, 40(8): 102-114.

[6] C. Jae-Hwan and T. Leandros. Maximum lifetime routing in wireless sensor networks. IEEE ACM Trans. Networking, 2004, 12(4): 609-619.

[7] Y. M. Lu and V. W. Wong. An energy-efficient multipath routing protocol for wireless sensor networks. Int. J. Commun. Syst., 2007, 20(7): 747-766.

[8] Z. Ouadoudi, E. Mohamed and A. Driss. A uniform balancing energy routing protocol for wireless sensor networks. Wirel. Pers. Commun., 2009, 55(2): 147-161.

[9] Li X, Hong S, Fang K. WSNHA–GAHR: A Greedy and A_ Heuristic Routing Algorithm For Wireless Sensor Networks in Home Automation. IET Comm. 2011; vol. 5(13): 1797–1805.

[10] Rana K, Zaveri M. A-star algorithm for energy efficient routing in wireless sensor network. Trends in Network and Communications, Springer, 2011: 232-241.

[11] A. A. Alkadhmawee, L. Songfeng, I. S. Alshawi, "Prolonging the Lifetime of Wireless Sensor Networks using LPA-star Search Algorithm," in Indonesian Journal of Electrical Engineering and Computer Science, Vol. 1, No. 2, February 2016, pp. 390- 398.

[12] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy efficient communication protocol for wireless microsensor networks," in Proc. 33rd Ann. Hawaii Int. Conf. Syst. Sci., 2000, pp. 1–10.