Cihan University-Erbil Scientific Journal (CUESJ)

RESEARCH ARTICLE

Energy Management in Wireless Sensor Networks for Internet of Things Applications

Reem Jafar Ismail[1]*, Samar Jaafar Ismael[2], Wisam H. Ali[2]

[1]Department of Computer Science, Cihan University-Erbil, Kurdistan Region, Iraq, [2]Department of Electromechanical Engineering, University of Technology, Baghdad, Iraq

ABSTRACT

Internet of things (IoT) aims to develop a smart world based on sensing environment. The energy management of wireless sensor networks (WSNs) is a big challenge in IoT since sensor nodes have limited energy and they need to have long life for collecting data and information. The aim of this paper is to propose an efficient energy routing algorithm in WSN and infrastructure based on construction an adaptive energy map of sensor nodes. The results show improvement in overall system performance and lifetime of WSN compared to traditional scenario.

Keywords: Shortest energy path, energy map, cluster region, multihop routing

INTRODUCTION

Wireless sensor networks (WSNs) consist of number of sensor nodes which are distributed over the environment to monitor various physical characteristics of the real world, especially in internet of things (IoT) applications such as health care, education, transportation, or food industry.[1,2] The life of WSN depends on energy of sensor node.[3,4]

Some proposal saves energy of nodes itself by energy power management of battery;[5] other proposals save energy by proposing efficient routing algorithm in WSN to maximize lifetime of WSN.

Many researches had proposed for routing protocol to collect data from sensor nodes depending on central or hierarchical routing. In Salim and Osamy[6] proposed a routing protocol using sink for data gathering from sensor nodes. In Khan *et al*.,[3] Heinzelman *et al*.,[7] Biradar *et al*.,[8] Mahmood *et al*.,[9] Kumar and Pal,[10] Khan and Sampalli,[11] Shi *et al*.[12] researches proposed a cluster-based routing algorithm for data gathering in WSNs.

In hierarchical cluster-based WSN, the network is divided into clusters, and hierarchy of different nodes is defined. Each cluster has a cluster head (CH). Sensor nodes in each cluster region get the information and send it to CH.[3]

In this research, we propose an efficient optimization algorithm that efficiently manages the energy of the cluster region of hierarchical cluster-based WSN.

The main contribution of this work is as follows:

- The design and implementation of routing algorithm that saves energy in WSNs to maximize lifetime of WSN.
- The development and construction of energy map of sensor nodes that are used to manage energy of cluster region when routing algorithm is implemented.

The remainder of this research described the following: We present works relate to WSN that applied in IoT applications for energy saving; then, the propose algorithm is presented and evaluated; and finally, we conclude the work.

LITERATURE REVIEW

Routing in hierarchical WSN architecture has advantage over centralized architecture since the route from source to destination is controlled over cluster regions that are led to manage the power of sensor nodes efficiently.

Chauhan *et al*. proposed a routing algorithm to consume power using minimum number of nodes from source to destination with a static shortest path using Dijkstra's algorithm.[13] The problem with their proposed algorithm is that they did not consider the energy level of the selected nodes of shortest path, where their measure was the shortest distance from source to destination.

Corresponding Author:
Reem Jafar Ismail, Cihan University-Erbil, Kurdistan Region, Iraq.
E-mail: reem_aljanabe@yahoo.com

Received: Apr 13, 2019
Accepted: Apr 17, 2019
Published: Aug 20, 2019

DOI: 10.24086/cuesj.v3n2y2019.pp48-52

In, Khan *et al.*[3] a multistage routing protocol is proposed for energy consuming in WSN, where the data are collected from sensor nodes by transferring it from stage to next stage through CH and forwarder to base station by assuming that the CH is usually at the center of the cluster region and the path is direct from sensor node to the CH in the cluster region.

Table 1 presents an overview for some of routing protocols, where most of them assume that the sensor nodes are distributed randomly in the propose region.

PROPOSED ROUTING ALGORITHM FOR EFFICIENT ENERGY MANAGEMENT

Our proposal saves energy by proposing efficient routing algorithm in WSN to maximize lifetime of WSN. In this research, we developed an efficient energy management algorithm that has the following prosperities:

- Nodes are distributed according to Boualem *et al.*[14] and not randomly, which will affect the overall energy consumption of sensor nodes compared to other protocols
- The shortest path between source and destination is not static when same source node sends to same destination node since the path will be updated according to the energy level of intermediate sensor nodes
- The controller (CH) will construct an energy map and update it with time since the energy of sensor node is changing with time.

In this research, we propose a novel optimization algorithm that efficiently manages the energy of the cluster region of hierarchical cluster-based WSN. In cluster region, we try to collect information from sensor nodes and send it to CH with consuming energy.

In our proposal routing, shortest energy path is chosen in cluster region depending on the sensor nodes that have maximum energy. Selecting sensor nodes with maximum energy and avoiding sensor nodes with minimum energy will maximize the lifetime of WSN.

When sensor nodes send their information to CH, the proposed shortest energy path is used which will maximize the lifetime of WSN.

In our proposed algorithm, the CH is responsible on finding shortest energy path and construction energy map of cluster region.

Energy map of cluster region is constructed when each sensor node in cluster region will send message to CH periodically telling the remaining energy of sensor node.

The sensor nodes location is static, but shortest energy path is chosen according to the highest battery charge of sensor nodes not according to distance between them.

The shortest energy path from source to destination is not static since in proposed routing algorithm, the shortest energy path will be dynamic according to the energy that will be received from sensor nodes since power level of battery for sensor node is decreasing within time.

The Dijkstra's algorithm is an algorithm that finds shortest distance in a given path between the source points to the destination point. Dijkstra's uses these nodes in routing and saves the points where the cost of distance is low.[15] In our proposed energy routing algorithm, the Dijkstra's algorithm is used to construct and find the shortest energy path of sensor nodes.

The overall properties of the proposed energy routing algorithm will save energy and increase network lifetime by the following assumptions:

- Multistage data transmission mechanism where an energy-efficient routing protocol for WSNs is proposed. It consists of a routing algorithm for data transmission, CH selection algorithm, and a scheme for the formation of clusters[3] also if CH within cluster region died due to energy consumption another head will be chosen for the same cluster region

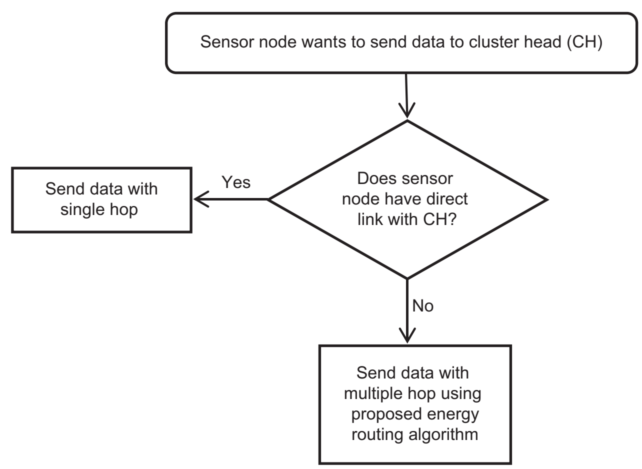

Figure 1: Sensor nodes sending data to cluster head within cluster region

Table 1: Overview of related works for energy management in WSNs

Algorithms	Topology organization	Distribution of sensor nodes in region	Control node (cluster head)	Energy map	Route from S to D within cluster region	Number of hops
Chauhan *et al.*, 2015[13]	Centralized	Randomly	None	Not constructed	Static	Single
Kayhan *et al.*, 2018[3]	Hierarchical routing	Randomly	Available	Not constructed	Static	Single hop within cluster region since cluster head is centralized
Proposed energy routing algorithm	Hierarchical routing	Enough monitoring for region and not random	Available	Is constructed	Dynamic	Multihop within cluster region

- In cluster region, the sensor nodes are not disturbed randomly since the topology of sensor nodes are optimized using semi-random deployment protocol proposed by Boualem *et al*.[14] where the area of interest is covered with a fewer sensor nodes with enough monitoring
- If the wireless sensor region is scalable, the proposed algorithm still operate efficiently since the routing is multihop and not single hop in cluster region. This means more sensor nodes could be added within cluster region and the proposed algorithm will still work efficiently.

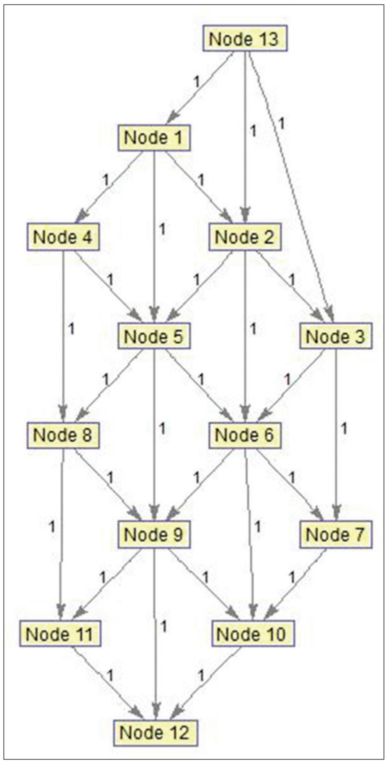

Figure 2: Proposed wireless sensor network topology

As shown in Figure 1, the sensor node will send the data from source to destination using Algorithm 1, proposed energy routing algorithm. The objective of Algorithm 1 is to maximize lifetime of sensor nodes within the cluster region.

Algorithm 1. Proposed energy routing algorithm

Input: Number of sensor nodes n, graph representation for sensor nodes (node_i, node_j) and energy map vector: [level_of_node_energy_i,……,level_of_node_energy_n]

Output: Shortest energy path from sensor node to cluster head

1: For each node_i in cluster region specify direct link for all its neighbors as (node_i, node_j)
2: While WSN is life
3: for each node in cluster region send energy level to cluster head periodically
4: cluster head construct an energy map of the cluster region
5: for each node in cluster region
6: find neighbor node which has maximum energy level
7: end for
8: find maximum energy level path from sensor node to cluster head using Dijkstra's algorithm
9: End while.

SIMULATION AND EVALUATION

In this section, we present the implementation of the proposed energy routing algorithm and then evaluate it, which we did use MATLAB R2016a (9.0.0.341360).

We ran the simulation with 13 nodes, as shown in Figure 2; initially, the sensor nodes have full charge so the source node (node no. 13) will reach to destination node (node no. 12), with shortest path using Algorithm 1. After the period of time, the energy of the sensor nodes will decrease.

As shown in Figure 3, which shows the energy map of sensor nodes inside cluster region, the initial shortest path that had been found previously could not be used again since after a period of time, the sensor node energy is decreased, here, all sensor nodes will send a message to the controller about

Node ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Charge %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

A: Initial charge of nodes

Node ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Charge %	100%	100%	**99%**	100%	100%	**99%**	100%	100%	**99%**	100%	100%	**99%**	**99%**

B: 1^{st} round, send from $node_{13}$ to $node_{12}$
path is: 13, 3, 6, 9, 12

Node ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Charge %	**99%**	100%	99%	100%	**99%**	99%	100%	**99%**	99%	100%	**99%**	**98%**	**98%**

C: 2^{nd} round, send from $node_{13}$ to $node_{12}$
path is: 13,1,5,8,11,12

Node ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Charge %	99%	**99%**	99%	100%	99%	**98%**	100%	99%	99%	**99%**	99%	**97%**	**97%**

D: 3^{rd} round, send from $node_{13}$ to $node_{12}$
path is: 13, 2, 6, 10,12

Figure 3: Energy map of sensor nodes inside cluster region where charge is changed overtime where $node_{13}$ is source and $node_{12}$ is destination

the percentage of charge and then the controller will update the energy map and ran the algorithm again according to the received information.

Table 2: Compare between traditional algorithm and proposed energy algorithm

Algorithm	Round number when the first node is died	Number of dead node
Chauhan *et al.*[13]	500	3
Proposed energy algorithm	600	1

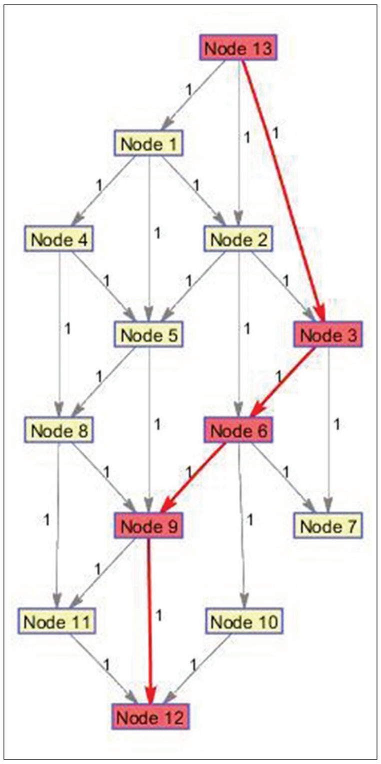

Figure 4: Shortest path from node 13 to node 12 using algorithm in Chauhan *et al.*[13]

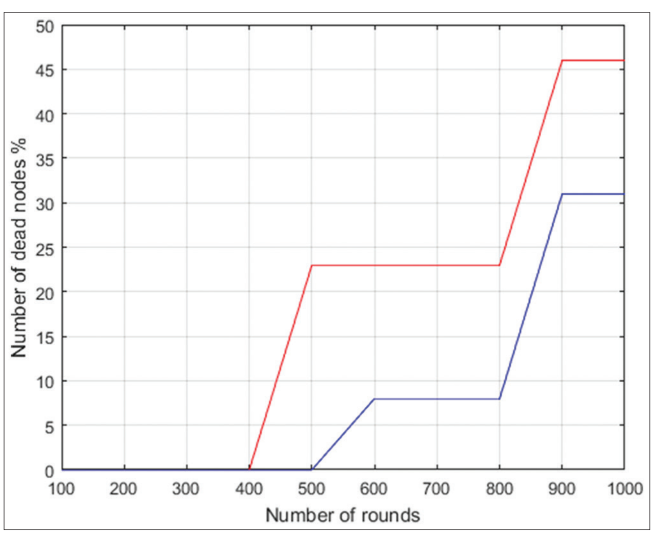

Figure 5: Compare number of dead nodes in each round between traditional algorithm and proposed algorithm

After a period of time, the shortest path for routing information will be constructed by choosing the sensor nodes which has maximum energy.

We assume that all sensor nodes are homogenous. According to Rodrigues *et al.*,[16] the energy spent in single transmission for sensor node is approximately 0.1 mJ when using ATmega328P platform. Hence, for all sensor nodes in the cluster region, we can apply the proposed Equation (1) to find energy of sensor nodes:

decrease in power level of sensor node_i

new energy node_i = current energy node_i - (0.1 X number of transmissions of node_i) - value of energy to be decreased with time ...(1)

Where we suppose the value of energy to be decreased with time is constant for all nodes and also in evaluation, the energy of senor node will be calculated as percentage of charge because sensor nodes are homogenous.

WSN lifetime performance and energy consumption evaluation consider: Scalability, energy level for each sensor node, number of alive nodes, and number of dead nodes as parameters for evaluations per round.

- Scalability, a property of network which will increase the network size by adding new nodes.
- Energy level of sensor node, this means sensor node power which will be calculated as charge percentage.
- Number of alive nodes, these are total nodes that have enough energy to communicate in routing.
- Number of dead nodes, these are total nodes that did not have energy to communicate in routing.

RESULTS

The proposed energy algorithm is evaluation and compared with Chauhan et al. proposed algorithm.[13] [Table 2] shows the comparison according to *Round number when the first node is died and Number of dead node*.

Figure 4 shows the cluster region, if we suppose that the source is node number 13 and the destination is node number 12. According to Chauhan *et al.*,[13] the route from source to destination will be static since every time 13 send data to 12 where the algorithm will use the same path which is 13, 3, 6, 9, and 12 because it is the shortest path. If we suppose that each transaction 1% of sensor node charge will decrease; then, after 100 transitions between 13 and 12, three nodes will be died due to energy consuming of same sensor nodes which are node 3, 6, and 9.

Figure 5 shows number of dead nodes compare to round number since we suppose the source is $node_{13}$ and the destination is $node_{12}$, as shown in the figure in round 600 about 23% of sensor nodes are dead in algorithm[13] while in our proposed algorithm, 8% are dead that will increase number of alive nodes approximately to 15% in each round.

CONCLUSION

Energy management in WSN needs to be saved since sensor nodes have limited power. To maximize lifetime of WSN, an efficient routing algorithm is proposed using less number of sensor nodes for transmission information with high energy.

Selecting sensor nodes with high energy instead of low energy will keep the topology of WSN stable since the number of alive node will be the same as long time as possible in WSN. Each round the energy map is constructed based of sensor nodes power and then the route is found from source to destination with optimized power consuming.

The proposed energy routing algorithm considers scalability, where we can add new sensor nodes to the cluster region, especially when some sensor node starts to die. Scalability of cluster region will increase number of nodes and then the energy level of the cluster region will also be increased.

ACKNOWLEDGMENTS

The authors would like to acknowledge Cihan University-Erbil, for their support and sponsorship of this project.

REFERENCES

1. X. Gu, X. Zhou and Y. Sun. "A data-gathering scheme with joint routing and compressive sensing based on modified diffusion wavelets in wireless sensor networks". *Sensors*, vol. 18, pp. 724, 2018.
2. W. Ejaz, M. Naeem, A. Shahid, A. Anpalagan and M. Jo. "Efficient Energy Management for the Internet of Things in Smart Cities". IEEE Communications Magazine, January 2017.
3. M. K. Khan, M. Shiraz, K. Z. Ghafoor, S. Khan, A. S. Sadiq and G. Ahmed. "EE-MRP: Energy-efficient multistage routing protocol for wireless sensor networks". *Wireless Communications and Mobile Computing*, vol. 2018, p. 6839671, 2018.
4. Y. Lu, X. Liu and M. Li. "Study on energy-saving routing algorithm based on wireless sensor network". *Journal of Computers*, vol. 28, no. 4, pp. 227-235, 2017.
5. J. A. Khan, H. K. Qureshi and A. Iqbal. "Energy management in wireless sensor networks: A survey". *Computers and Electrical Engineering*, vol. 41, pp. 159-176, 2015.
6. A. Salim and W. Osamy. "Distributed multi chain compressive sensing based routing algorithm for wirelesssensor networks". *Wireless Networks*, vol. 21, pp. 1379-1390, 2015.
7. W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan. "Energy-Efficient Communication Protocol for Wireless Microsensor Networks". In: Proceedings of the 33rd Annual Hawaii International Conference on System Siences (HICSS '00). IEEE, vol. 2, 2000.
8. V. Biradar, S. R. Sawant, R. R. Mudholkar and V. C. Patil. "Multihop routing in self-organizing wireless sensor networks". *International Journal of Computer Science Issues*, vol. 8, no. 1, pp. 155-164, 2011.
9. D. Mahmood, N. Javaid, S. Mahmood, S. Qureshi, A. M. Memon and T. Zaman. "MODLEACH: A Variant of LEACH for WSNs". In: Proceedings of the IEEE 8th International Conference on Broadband, Wireless Computing, Communication and Applications (BWCCA '13). Compeigne, France, pp. 158-163, 2013.
10. S. V. Kumar and A. Pal. "Assisted-Leach (A-Leach) energy efficient routing protocol for wireless sensor networks". *International Journal of Computer and Communication Engineering*, vol. 2, no. 4, pp. 420-424, 2013.
11. Z. A. Khan and S. Sampalli. "AZR-LEACH: An energy efficient routing protocol for wireless sensor networks". *International Journal of Communications, Network and System Sciences*, vol. 5, no. 11, pp. 785-795, 2012.
12. S. Shi, X. Liu and X. Gu. "An Energy-Efficiency Optimized LEACH-C for Wireless Sensor Networks". In: Proceedings of the 2012 7th International ICST Conference on Communications and Networking in China (CHINACOM '12), pp. 487-492, 2012.
13. P. Chauhan, A. Negi and T, Kumar. "Power optimization using proposed Dijkstra's algorithm in wireless sensor networks". *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 4, no. 7, pp. 326-330, 2015.
14. A. Boualem, Y. Dahmani, A. Maatoug and C. De-runz. "Area Coverage Optimization in Wireless Sensor Network by Semi-random Deployment". In: Proceedings of the 7th International Conference on Sensor Networks (SENSORNETS), pp. 85-90, 2018.
15. L. Parungao, F. Hein and W. Lim. "Dijkstra algorithm based intelligent path planning with topological map and wireless communication". *ARPN Journal of Engineering and Applied Sciences*, vol. 13, no. 8, pp. 2753-2763, 2018.
16. L. M. Rodrigues, C. Montez, G. Budke, F. Vasques and P. Portugal. "Estimating the lifetime of wireless sensor network nodes through the use of embedded analytical battery models". *Journal of Sensor and Actuator Networks*, vol. 6, no. 2, p. 8, 2017.