ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

[1]KAYATHRI,[2]S. SELVAKUMARI, [3]CHINNASAMY
[1][2][3] ASSISTANT PROFESSOR IN COMPUTER SCIENCE,
DHANALAKSHMI SRINIVASAN COLLEGE OF ARTS & SCIENCE FOR WOMEN (AUTONOMOUS), PERAMBALUR.

Abstract -Recently, Wireless Sensor Network (WSN) hasreceived increased interest of research thanks to its many real-lifeapplications. In WSNs, the sensor nodes sense differentphenomenon from the encompassing area and forward data to thesink. Among the available routing protocols (RP), most of themused Low Energy Adaptive Clustering Hierarchy (LEACH) butdid not consider the battery energy state while selecting thecluster head (CH). This paper proposed a multi-energythreshold-based routing protocol supported LEACH, whichprovides different energy thresholds of battery energy state, called multi-energy threshold LEACH (MET-LEACH). TheMET-LEACH uses remaining battery energy state to pick theCHs. the primary node dies (FND), the half nodes die (HND), thelast node dies (LND), packet reception ratio (PRR) and therefore theapplication level latency are the performance parameters toevaluate the performance of the proposed MET-LEACHprotocol using the Castalia simulator. The simulation resultsshow that MET-LEACH gives significant improvement in termsof FND (112% to 290%), HND (76% to 161%) and LND (76%to 185%) over the performance of LEACH.

Keywords—routing protocol, wireless sensor networks, LEACH

I. INTRODUCTION

The set of small, inexpensive, low-powered sensor nodeswhich can sense the natural phenomenon from thesurrounding area is understood as wireless sensor networks (WSN)[1]. The sensor nodes sense the info from the encompassing areaand send these data from the source to the sink. The sink thenprocesses the info . WSN may be a field with rapid climb and has many real world applications like environmental monitoring[2], agriculture [3], health, industry, military, commercial andothers. Usually, non-rechargeable batteries with finite capacityare wont to supply energy to the networks. These networks arecalled battery-powered wireless sensor networks (BP-WSNs).

Routing protocol (RP) plays a big role in WSNs [4].It specifies the communication among the sensor nodes andprovides information about different routes for datatransmission. All the RPs should meet some criteria likeenergy saving, low latency, longer lifetime and lowapplication level latency. There are three sorts of RPs basedon the specification which are: 1) Flat routing protocol2) Location-based routing protocol and 3) Hierarchicalrouting protocol [5]. Hierarchical routing protocol is additionally known as the cluster-based RP. The cluster heads (CH) areselected randomly to balance the consumed energy among thenodes. The cluster members (CM) sense the info from thesurrounding and send to the CHs. After processing likeaggregation, the CHs forward the aggregated data to the sink.

Several sortsof hierarchical RPs are proposed and developed supported different applications. There are manypopular hierarchical RPs available for BP-WSNs and LEACHis one among them. LBCH-LEACH [6], I-LEACH [7], and VH LEACH [8] are several models of variation of LEACH.

Multi-Hop LEACH (MH-LEACH) in [9] proposed thetechnique which established multi hop communication amongthe sensor nodes. It improved the consumed energy ascompared to the normal LEACH protocol. Distance-BasedThreshold (LEACH-DT) in [10] proposed a distributed CH selection algorithm. This algorithm is especially supported thedistance of the sensor nodes to the sink. LEACH-DT proposedthat the nodes with smallest distance from the sink were to bechosen as CHs in each round in order that it could reduce the energyconsumption for transferring the info. This protocol showedimprovement in network's lifetime. The Hybrid LEACH (HLEACH) in [11] modified the LEACH by partitioning thenetwork area with the knowledge of nodes' location. It showed an improvement in energy conservation compared to the original Leach.

However, in H-LEACH, GPS system isrequired to understand the nodes' location which isn't cost-effective. Enhanced LEACH (E-LEACH) in [12] chose CHsaccording to the minimum distance from the sink. In the literature, only a couple of of the prevailing routingprotocols considered energy threshold of battery energy statein CH selection. The Node Ranked–LEACH (NR-LEACH) in[13] proposed a way that balanced the load of energyamong the nodes during the method of CH selection. Itshowed the development in network's lifetime also because theenergy consumption. This protocol used an algorithm callednode rank algorithm. The Energy-Efficient Centroid-basedRouting Protocol (EECRP) in [14] considered energy centroidof the clusters for choosing CHs. Also, it considered theresidual energy to calculate centroid's position. Furthermore,in [15] proposed protocol was an efficient method for CHselection. During this protocol, one threshold was calculated andeach of the node's random number was compared theretothreshold. The weighted coefficients of the residual energyand the distance of every node from the sink were wont tocalculate this threshold. The protocol showed improvement in both lifetime and therefore the energy consumption. The Multi-Threshold Long Lifetime Protocol (MDLLP) presented in [16] proposed a way to improve the lifespan of the network. It calculated the edge by considering the energyand the distance from the nodes to the sink. However, the protocol used GPS system. Therefore, the protocol was nolonger cost-effective. Additionally thereto, Energy AwareCluster-Head Selection (EACHS) developed in [17],considered battery energy state because the threshold in CHselection process, but they assumed just one energythreshold.

This work introduces multi-energy threshold-basedrouting protocol supported LEACH (MET-LEACH) for BP-WSNs. In MET-LEACH, a replacement technique is proposed toincrease the network's lifetime. This protocol sets up fourthresholds of energy levels which help to categorize thenodes consistent with their remaining energy in order that the nodeswith energy above the thresholds can participate within theCH selection process. On the opposite hand, the nodes with lessenergy become the cluster members (CM). Using thistechnique gives more CHs in MET-LEACH as compared to LEACH which ensures a extended lifetime.

Furthermore, theevaluation and comparison of both MET-LEACH andLEACH are done.

II. MET-ROUTING PROTOCOL

The proposed MET-LEACH routing protocol is describedin this section. it's proposed to enhance the networkperformance by implementing multiple energy thresholdsbased on the battery energy. The proposed protocol operates in two phases as follows:i) the setting phase and ii) the fixed phase. The proposedprotocol calculates the probability of being CH almost like thetraditional LEACH as in Eq. (1):

$$T(i, r) = P / (1- PX(r \bmod (1/P))) \qquad i \in A \qquad (1)$$

Whereith node has the probability, T(i,r) in round r to beCH. A denotes a group of nodes. In last 1/p rounds, these nodeshave not been selected because the CHs. If the probability is higher,the possibility of becoming the CH gets higher. Therefore,when there are more nodes, the prospect to become CH is additionallyless for every node.

During the set-up phase, the probability of every node iscalculated using Equation (1) and it then selects one randomvalue from 0 to 1. If the randomly selected number has lessvalue than the probability T(i,r) for the present round, the nodeis selected because the CH. Otherwise, it's a cluster member (CM).After the CH is chosen , it sends the advertisement (ADV)message to the non-cluster head nodes (NCH) to hitch thecluster. NCHs may get many ADV messages from differentCHs. Each NCH decides to hitch the CH having the very bestRSSI (Received Signal Strength Indicator) value. Thus, NCHssend join messages to CHs. After receiving the join messages,the CH forms the cluster. Next, each CH broadcasts a TDMAschedule to its CMs where individual slots are assigned to everyof the cluster members in order that they will transmit their data tothe CHs. By this, the setting phase ends. During the steady-state phase, data transmission fromsource to the sink occurs. Each cluster member transmits theindividual data through its reassigned timeslot which helps toavoid collision among CMs' data packets. During the infotransmission by a node, other nodes attend the sleep mode byturning off their radio which helps in reducing the energyconsumption. At the last slot, the CH aggregates alltthereceived data from its CMs. Then the aggregated data isdirectly sent to the sink. Figure 1 shows the phase diagram ofthe MET-LEACH protocol where it's seen that, the set-upphase is split into three sub phases. They are: i) Cluster headadvertisement ii) Cluster set-up and iii) TDMA schedulecreation . within the steady state phase, TDMA schedule is inoperation.

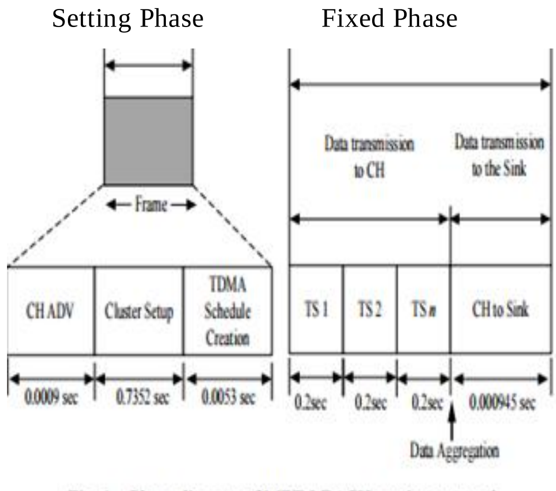

Fig. 1. Phase diagram of MET-LEACH routing protocol

In the MET-LEACH protocol, initial assumption is that each onethe nodes within the network are active, i.e. fully charged. Theremaining energy, ER of every node is compared with fourenergy thresholds, where threshold, Eth1 is 75%, Eth2 is 50%,Eth3 is 25% and Eth4 is eighteen of the battery energy state . At first,the energy threshold Eth1 is employed . When most of the nodes have energy levels below Eth1, the energy threshold Eth2 is appliedinstead. After a particular period, it sets Eth3 because the energythreshold when most of the nodes have energy below than theEth2. This process is repeated for Eth4 also .

This multi-threshold ensures that the majority of the nodes canparticipate within the CH selection for a extended period and becomeCH which prolongs the lifetime of the network. Furthermore,the nodes with less energy than the thresholds are preventedfrom participating within the CH selection process. This guaranteesthat only nodes with higher energy participate within the CHselection.

III. PROTOCOL EVALUATION

The performance of the MET-LEACH is evaluated usingCastalia simulator of version 3.3 in Ubuntu 16.04. CC2420 isused as a radio model to guage the network's performance.The performance of the proposed protocol is compared withLEACH. For the simulation, the world of the network is chosen as 100m×100m with 100 static nodes deployed randomly. Thesink of the network is placed at the centre. Besides, the initialenergy of the battery of every sensor node is 25J, and for thesink, it's 18720J. during this simulation, a complete of 10,000 packetsare generated with packet rate of 0.04 packets/second. Figure2 shows the randomly deployed 100 nodes during a 100m x 100marea of the network. Table I shows the various parameters thatare utilized in the simulation.

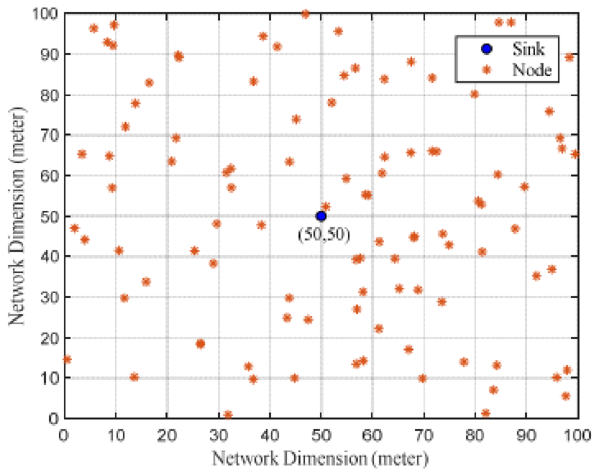

Fig. 2. A sensor network of 100m x 100m with randomly deployed 100

TABLE I: SIMULATION PARAMETERS

Parameters	Values
Sensor nodes	100
Network Size	100m x 100m
Simulation Time	2500 seconds
Location of the Sink	Center
Initial energy of the sink (J)	18720
Initial energy of sensor node (J)	25
Only Static nodes	True
Round duration	20 seconds
CH percentage	0.05
Data Payload	30 bytes
Data rate	250 kbps
Packet rate	0.04
Slot length	0.2s
netBufferSize	1000
MAC type	Tunable
Radio type	CC2420
Battery capacity	100%
Remaining energy	E_R
Energy threshold, E_{th1}	75%
Energy threshold, E_{th2}	50%
Energy threshold, E_{th3}	25%
Energy threshold, E_{th4}	1%

The lifetime of the network is one among the importantperformance parameters of the network. In a WSN, the lifetimeis calculated using three common metrics namely: first nodedies (FND), Half nodes die (HND), and Last node dies (LND).The performance matrices which are considered during this paper are as follows: i) Lifetime of the network ii) Packet receptionratio and iii) Application level latency. The FND, HND andLND are defined accordingly:

• The time span from the starting of the network's operationuntil the primary node dies defines the FND.

• The time span within the time half the entire nodes of thenetwork have consumed each of their total energy definesthe HND.

• The time span from the starting of the network's operationuntil the last node dies defines the LND.

A. First node dies (FND)

Figure 3 shows the comparison of FND between LEACHand MET-LEACH routing protocol for various number ofsensor nodes. FND is a crucial performance metric tomeasure the lifetime of a network. . In LEACH, clusteringoccurs frequently without taking the energy state of the nodesinto consideration. This leads to consumption of high energyby each sensor nodes during data transmission of the CMs andthe data aggregation by the CHs. As a result, they quickly loss energy. This is often the rationale the primary node dies sooner inLEACH as compared to MET-LEACH. On the opposite hand,MET-LEACH only allows the nodes that have high energylevel to become CHs. As a result, the clustering can continuefor a extended time and therefore the first node death are going to be delayed inMET-LEACH as compared to LEACH.

From the result, it's seen that, MET-LEACH getssignificant improvement over LEACH in terms of FND forboth low-density and high-density network. The simulationresults depict that, for 25 sensor nodes, the development is upto 290% whereas the development is 112% for 100 nodes. For50 and 75 nodes, the improvements are 120% and 112%respectively. of these results illustrate a concluding point thatMET-LEACH work efficiently with low-density network.Therefore, MET-LEACH protocol is usually recommended for low-density networks.

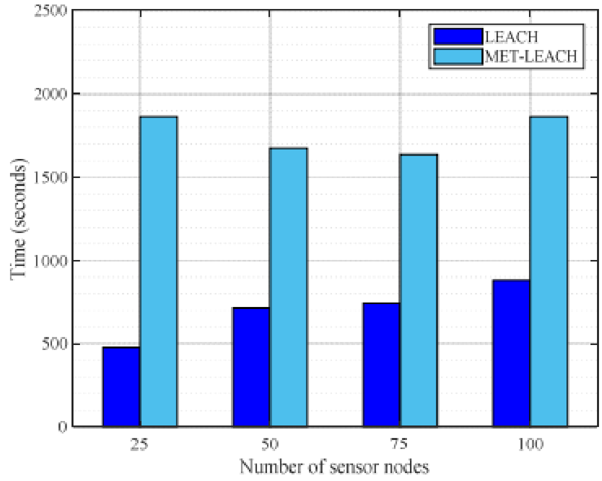

Fig. 3. First node dies (FND) for different number of sensor nodes

B. Half nodes die (HND)

Figure 4 depicts the HND for both LEACH and METLEACH for various number of nodes. The results illustratethat MET-LEACH gives improvement across all the variousnumber of sensor nodes over LEACH. Since the sensor nodesfollow multi thresholds while being chosen as CHs, it helps toutilize the energy for every node wisely. An improvement ofHND in MET-LEACH is obtained as compared to LEACH.The HND is delayed in MET-LEACH which shows that therotation of the CHs is performed during a proper way and most ofthe nodes get the prospect to become CHs. The simulation results show that, the development in termsof HND is up to 161%, 104%, 86% and 76% for 25, 50, 75,and 100 nodes respectively. These results show that the METLEACH is efficient for low-density network.

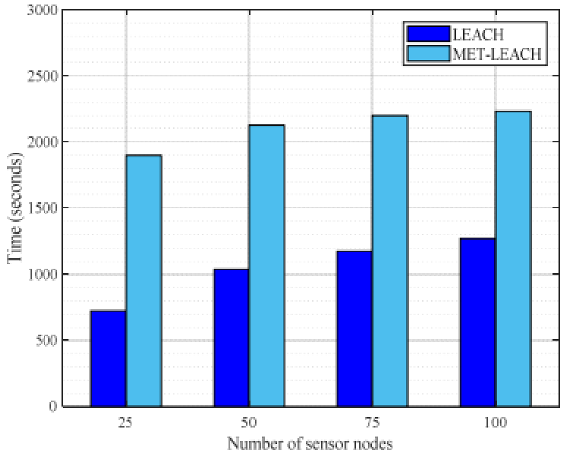

Fig. 4. Half nodes die (HND) for different number of sensor nodes

C. Last node dies (LND)

Figure 5 demonstrates the comparison between LEACHand MET-LEACH in terms of LND for various number ofsensor nodes. LND also represents the time when the operationof the network stops. This metric helps to spot thelongevity of a sensor network.

The simulation results represent that, MET-LEACH attainssignificant improvement across all the various number ofsensor nodes compared to LEACH and therefore the improvement isconsistent. the development for nodes 25, 50, 75 and 100 is185%, 105%, 86% and 76% respectively. These results help toconclude that the proposed MET-LEACH gives betterperformance if it's applied to the low-density network whichrequires a extended lifetime.

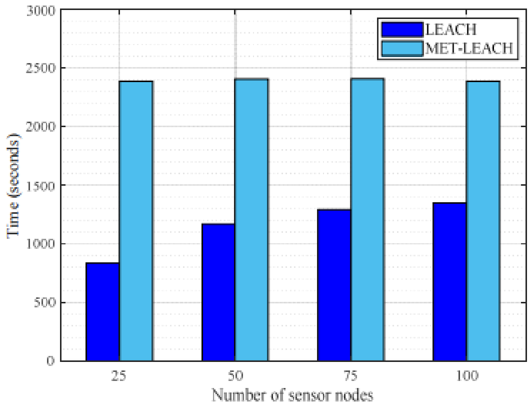

Fig. 5. Last node dies (LND) for different number of sensor nodes

D. Packet reception ratio

The ratio of total number of packets that are received bythe sink to the entire number of packets sent by the CHs isknown as packet reception ratio. In MET-LEACH, multienergy threshold has been used. It allows more nodes to beCHs supported their remaining battery energy state . thanks to thisreason, there are more CHs in MET-LEACH as comparedwith the LEACH. As a result, more aggregateddata mustbe sent from the CHs to the sink.

Figure 6 shows that, the proposed MET-LEACH protocolgives marginally better performance across all the variousnumber of sensor nodes when it's compared to the LEACH.In MET-LEACH, the sink receives more number of packets inthe same deployment area.

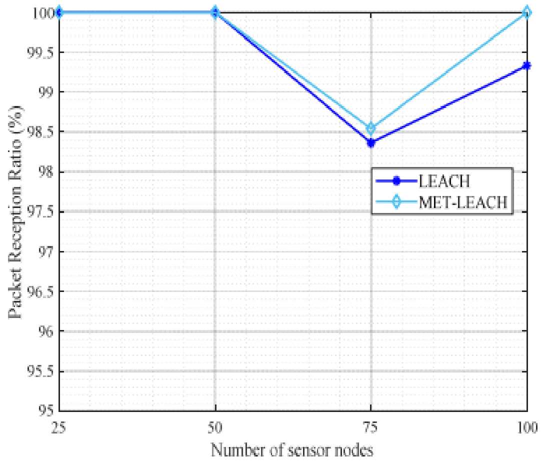

Fig. 6. Packet reception ratio

E. Application level latency

Latency is defined because the end-to-end delay experienced bythe packets that are sent from the appliance layer of the CMsto the sink through the CHs. The delay is defined because the timethat a CM sends a packet until the sink receives it. A protocolwith less end-to-end delay represents an efficient protocol. Figure 7 illustrates the latency for LEACH and METLEACH for 25 nodes. The x-axis and y-axis are the latencybands and therefore the number of packets for the corresponding bandsrespectively. it's seen that, most of the packets in bothLEACH and MET-LEACH protocol are located within the latencyband of 0 to twenty milliseconds. MET-LEACH is in a position to sendmore packets within an equivalent band as compared to LEACH.The improvement within the number of packets is 62%. Therefore,MET-LEACH gives better performance for low-densitynetworks as compared to the LEACH in terms of latency.

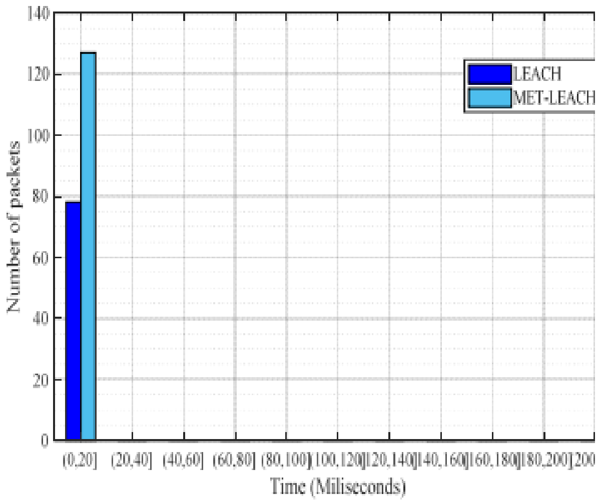

Fig. 7. Application level Latency

IV. CONCLUSION AND FUTURE WORK

The MET-LEACH routing protocol, proposed for BP-WSNs is introduced during this paper. It considers multi energy threshold for CH selection within the network. This new approachstrictly allows the high energy state nodes to be CHs.Afterward; the energy of every node is preserved forextendedperiod which helps in frequent re-clustering. This helps toincrease the longevity of the network. The performance of theMET-LEACH is evaluated in terms of network lifetime,packet reception ratio and latency on low-density and high-density networks using Castalia simulator. The results arecompared with the first LEACH. The results from thesimulation show that, the MET-LEACH got improvement in terms of FND that ranges from 112% to 290%, HND thatranges from 76% to 161%, LND that ranges from 76% to185%. Future work are often included as extending the METLEACH to be compatible with energy harvesting wirelesssensor network.

REFERENCES

[1] S. M. Bozorgi, A. S. Rostami, A. A. R. Hosseinabadi, and V. E. Balas, "A new clustering protocol for energy harvesting-wireless sensor networks" Computers Electrical Engineering, vol. 64, pp. 233-247, Nov 2017.

[2] P. Maijala, Z. Shuyang, T. Heittola, and T. Virtanen, "Environmental noise monitoring using source classification in sensors," Applied Acoustics, vol. 129, pp. 258-267, Jan 1 2018.

[3] S. A. Kumar and P. Ilango, "The Impact of Wireless Sensor Network in the Field of Precision Agriculture: A Review" Wireless Personal Communications, vol. 98, no. 1, pp. 685-698, Jan 2018.

[4] X. Yang, D. Deng, and M. Liu, "An overview of routing protocols on Wireless Sensor Network" in 2015 4th International Conference on Computer Science and Network Technology (ICCSNT), 2015, vol. 1, pp. 1000-1003: IEEE.

[5] R. A. Wagan, K. Wei-Xin, A. Sajid, and A. A. Wagan, "A Review: Threshold Based Clustering Schemes of Routing Protocols for Heterogeneous Wireless Sensor Networks" International Journal Of Computer Science Network Security, vol. 18, no. 10, pp. 120-129, 2018.

[6] R. T. Ai-Zubi, N. Abedsalam, A. Atieh, and K. A. Darabkh, "Lifetime-Improvement Routing Protocol for Wireless Sensor Networks" in 2018 15th International Multi-Conference on Systems, Signals & Devices (SSD), 2018, pp. 683-687: IEEE.

[7] Z. Beiranvand, A. Patooghy, and M. Fazeli, "I-LEACH: An efficient routing algorithm to improve performance & to reduce energy consumption in Wireless Sensor Networks" The 5th Conference on Information and Knowledge Technology, 2013, pp. 13-18: IEEE.

[8] A. Mehmood, J. L. Mauri, M. Noman, and H. Song, "Improvement of the Wireless Sensor Network Lifetime Using LEACH with Vice-Cluster Head" Ad Hoc & Sensor Wireless Networks, vol. 28, no. 1-2, pp. 1-17, 2015.

[9] J. H. B. Neto, A. Rego, A. R. Cardoso, and J. J. I. Celestino, "MHLEACH: A distributed algorithm for multi-hop communication in wireless sensor networks" ICN, pp. 55-61, 2014.

[10] S. H. Kang and T. J. I. C. L. Nguyen, "Distance based thresholds for cluster head selection in wireless sensor networks" International Journal of Computer Applications, vol. 16, no. 9, pp. 1396-1399, 2012.

[11] V. Gupta and M. Doja, "H-leach: modified and efficient leach protocol for hybrid clustering scenario in wireless sensor networks" in Next-generation networks: Springer, 2018, pp. 399-408.

[12] A. O. A. Salem and N. Shudifat, "Enhanced LEACH protocol for increasing a lifetime of WSNs" Personal Ubiquitous Computing, pp. 1-7, 2019.

[13] A. Al-Baz and A. El-Sayed, "A new algorithm for cluster head selection in LEACH protocol for wireless sensor networks" International Journal of Communication Systems, vol. 31, no. 1, p. e3407, Jan 10 2018.

[14] J. Shen, A. X. Wang, C. Wang, P. C. K. Hung, and C. F. Lai, "An Efficient Centroid-Based Routing Protocol for Energy Management in WSN-Assisted IoT," (in English), IEEE Access, vol. 5, pp. 18469-18479, 2017.

[15] A. Zahedi, "An efficient clustering method using weighting coefficients in homogeneous wireless sensor networks" Alexandria Engineering Journal, vol. 57, no. 2, pp. 695-710, Jun 2018.

[16] G. Kia and A. Hassanzadeh, "A Multi-Threshold Long Life Time Protocol with Consistent Performance for Wireless Sensor Networks"AEU-International Journal of Electronics Communications, pp. 114-127, 2019.

[17] F. Khan, T. Gul, S. Ali, A. Rashid, D. Shah, and S. Khan, "Energy Aware Cluster-Head Selection for Improving Network Life Time in Wireless Sensor Network" in Science and Information Conference, 2018, pp. 581-593: Springer.