Energy Management in Wireless Sensor Network Through EB-LEACH

Hitesh Mohapatra, Sourabh Debnath and Amiya Kumar Rath

June 15, 2019

Energy Management in Wireless Sensor Network Through EB-LEACH

[1]Hitesh Mohapatra, [2]Sourabh Debnath & [3]Amiya Kumar Rath
[1,3]Veer Surendra Sai University of Technology, Burla, Sambalpur, Odisha, India
[2]GIET University, Gunupur, Odisha, India

Received:

ABSTRACT *Wireless sensor network (WSN) is a trending research topic because of its remote and hostile deployment. Unlike traditional networking the WSN limited with power supply, sensing and processing capacity. A core WSN consists of a set of sensor nodes which are small in size with cost variant [1]. The hostile and remote deployment of sensor nodes demands distributed fashion of node plantation [2]. Typically, communication in WSN is an energy consuming process according to the constraints of network. The tiny size of sensor nodes constraints with memory, power and lifetime. In this paper, we have proposed an improvised and simplified cluster formation* ***E****nergy-***B***alanced LEACH (EB-LEACH) algorithm which is competent with LEACH and SEP. Here we assumed the sensor nodes are static in nature and the network is hybrid type in terms of energy level of sensor nodes (SN). In the proposed algorithm we have used sorting process as a sub-operation. The outcome of our simulation proves the optimized performance of EB-LEACH then LEACH and SEP.*

Keywords: *Wireless Sensor Network; Homogeneous; Heterogeneous; Energy Management.*

Introduction:

The WSN may be centralized or distributed according to the applications [1]. The developed nature inspired meta-heuristic approach is the cause for optimized performance. The traditional WSN limited with power resource and computational capacity. Hence, energy management for long durability is indeed. The sensor nodes are may be deployed both in smooth and harsh environment. Mostly, the harsh deployment is human unreachable. This is the main cause why so far extensive research has been done in the energy management domain of WSN. During hostile deployment manual recharging of battery is almost impossible [5]. The WSN already implemented in various fields such as defense, agriculture, habitat monitoring, industry automization, health care monitoring, volcanic monitoring, seismic effect and health care etc. [6]. The applications like volcanic monitoring, seismic effect monitoring need to attend by remote sensors where the battery replacement is a difficult task. But the WSN need to work smoothly provided with all constraints. So far, the existing methodologies are clustering and extending lifetime. Clustering of sensor nodes in both centralized and distributed environment is a common approach of energy saving.

Literature Review:

In past literature sufficient work has been done on cluster-based technique both in centralized and distributed environment. LEACH (Low Energy Adoptive Clustering Hierarchy) is one of famous approach towards clustering. The principle of LEACH protocol is to distribute the energy evenly among the motes in WSN and for this it adopts random rotation of cluster head selection [2]. As LEACH is performed in homogeneous type of WSNs, Stable Election Protocol (SEP) is the improvement of LEACH by populating a ratio of SNs with more energy than remaining nodes in the same network [3]. Due to these advanced nodes, the network is heterogeneity in term of node energy. In SEP, the probabilities for elections are weighted by the initial energy of a node to that of other nodes in the network. This extends the lifetime before the death of the first node, which is important for some applications where the input from the sensor network must be reliable [4]. According to the energy constraint environment sending of collected data is costlier in terms of energy resource. This process reduces the lifetime of WSN. In this paper, the researcher proposed PEGASIS (Power-Efficient Gathering in Sensor Information Systems), which is optimal then LEACH [7]. In PEGASIS, only close communication among neighbor node taken place which overcomes the overhead problem of LEACH. For the transmission to the base station it takes turns. In [8], combination of chaotic, based genetic algorithm and fuzzy logic has been used to increase the lifetime of sensor nodes. Basically, fuzzy logic was proposed on the basis of three variable i.e. density, energy and centrality. The combination of these three attributes helps to find out the best nodes as a cluster head candidate and later on genetic algorithm proposed for determining the cluster head position. The limitation of proposed algorithm is lack of knowledge regarding cluster formation and energy consumption. In [9] the researcher proposed an algorithm called Hybrid Energy-Efficient Distributed (HEED) clustering which focused on increasing the lifetime of network and in same time allowed for dynamic scalability. In this protocol the CH selected periodically according to the combination of RE and the node degree. [10] has proposed a Distributed Energy Efficient Hierarchical Clustering (DWEHC) where weight is distributed based on energy efficient hierarchical clustering protocol whose objective is to increase the energy efficiency by creating a balanced cluster and enhancing the intra-cluster communication. The role of each SN is to find neighboring nodes in its surrounding then it calculates its weight. Basically, weight is nothing but a function of remaining energy i.e. residual energy and the closeness to its neighbor node. In a community node having highest weight is selected as CH and the left-out nodes became its member. At this position the nodes are the primary level members due to its direct link with CH. Mostly, a node compares the minimal cost to reach a CH with its non-cluster head neighbor. In case of stability this protocol is not performing well because huge amount of energy is dissipated in finding its neighbor node. This protocol [11] is the improved version of LEACH, to reduce the energy consumed in redundant nodes and to balance the energy dissipated among SNs by piercing bulky clusters in smaller clusters. According to the researcher a mechanism called sub cluster head is induced for splitting larger clusters into smaller ones. As a result, the data frame becomes smaller and at the same time the amount frame recovered at the base station is increased. The redundant nodes are also kept in sleep mode for most of the time which is an improvement in this protocol. Here only one node is required while remaining nodes are kept in sleep mode until the energy of first node is exhausted. This helps in extending the network lifetime but this leads to unequal cluster size due to flexible cluster count.

To enhance the network lifetime this protocol [12] developed a method based on data aggregation. In ECBDA (Energy efficient cluster-based data aggregation) during the formation of cluster the network is split into a group of clusters. Here, in each layer K amount of cluster is formed which if further subdivided into set of clusters. Basically, there will be cluster head from each cluster, so here the election of cluster head for each cluster is calculated by considering the residual energy and communication cost factor. Once a cluster head is elected, its main aim is to broadcast its message to every node, cluster heads and base station. There is a third phase called as data aggregation phase in which the cluster member forwards their sensed data to their respective cluster head. There may be large amount of duplicated data or redundant data, these data are removed by using data aggregation and finally transmit it to sink node via wireless communication. The maintenance phase keeps tracks on residual energy of each cluster head in every round. Whenever, the residual energy gets below the threshold energy, from the same cluster a new CH is selected. These protocols result in scattering of small size clusters which increase the amount of energy required to transmit data to base station from cluster head which consumed large energy. It is one of the hierarchical clustering algorithms where hierarchy of sensor nodes were present. Here information's are accumulated from various sensor nodes and propagated from first level of cluster head to next level cluster head, it will continue till it reaches to base station. This TEEN [13] algorithm relies on the basis of threshold value. This algorithm was considered to be best, as it decides when the sensor should send the data which results in reducing the number of transmissions.

System Model:

The assumed constraints are:

- All nodes are static in nature.
- The BS knows the location of each node. It assumed that the CHs and nodes have the knowledge of each other location.
- CH is responsible for data aggregation or compression.
- All nodes are of same design.
- Initially all the SNs in the network are having same energy.
- The dissipated energy during transmission depends on the distance and data size.

Network Model:

In this paper, we consider a WSN which contains N sensor nodes and a sink node. Sensor nodes are deployed in a 2D monitoring area of interest. All sensor nodes are homogeneous, static and self-organizing. Sink node is a resource rich device and has a long transmission power that enable it to send its message to any sensor nodes in the network. It is assumed that all sensor nodes know its location coordinate and its value is stable. In the clustered based WSN architecture, it is assumed that each CH aggregate the sensed data received from its CMs and transmit the aggregated data of the cluster to the sink node by using inter-cluster multi-hop routing as done in this paper.

This paper adopted the energy model as used in [14] and [15]. In this energy model, energy consumption at each node depends on the size of the data packet and distance to be sent from the source node. For transmitting the l- bits of data packet from a sensor node to its d distance far away receiver node, total energy consumption of a sensor node is calculated by the following equation:

$$E_{Tx}(l,d) = l \times E_{elec} + l \times \varepsilon_{fs} \times d^2, \quad if\ d < d_0 \quad (1)$$

$$E_{Tx}(l,d) = l \times E_{elec} + l \times \varepsilon_{mp} \times d^4, \quad if\ d \geq d_0 \quad (2)$$

Radio Energy Model:

However, for receiving the l-bits of data packet at a sensor node, energy consumed by the receiver nodes is calculated by the following equation:

$$E_{Rx} = l \times E_{elec} \quad (3)$$

Where, value of the E_{elec} is the energy dissipated per bit during execution of the transmitter or receiver circuit. ε_{fs} and ε_{mp} is the amplification coefficient of the transmission amplifier for free space and multi-path model respectively. Here d_0 Represents threshold transmission distance and its value is generally [14] and [15].

$$\sqrt{\varepsilon_{fs} / \varepsilon_{mp}} \quad (4)$$

Proposed Model:

With a specific end goal to save the total energy cost of the sensor networks and to increase its lifetime, we propose a residual energy-based clustering algorithm, EB-LEACH.

In WSN generally there are two types of communication happening i.e. inter cluster communication and intra cluster communication [19]. By the concept of clustering the intra cluster communication increases. The transmission of data from CH will be via single hop or multi hop through another CH to the BS [20]. In a clustering environment, after gathering all the information from cluster member, the CH will aggregate all the data in order to remove the redundancy which is further forwarded to the BS. Thus, the amount of energy consumption by the SNs will be decreased tremendously. An issue needs to be noted here, that if only one CH will behave always as a head node, then after certain time its amount of energy level reduces. Hence, a new CH is required for this situation. The choice of picking a new CH will be completed by the EB-LEACH algorithm. Amount of residual energy is the criteria in defining and nominating a new CH. Normally, clustering based protocols comprise of four notable stages and two phases [21]. The major stages are: i) CH selection ii) formation of cluster iii) Data aggregation iv) Data communication. Whereas, the phase are setup and steady state phase [24]. Initially in each setup phase, SNs forwards their current energy level and location to BS. Based on the information acknowledge by the BS, it calculates average energy level of all the SNs in the network. As the CH is responsible for additional work such as cluster management, data aggregation and segregation. So, we have to choose CH in such a way that it must have highest energy level as compared to the other nodes. Thus, in every round SNs with higher energy level is elected as CH candidate. The above process makes sure that SNs with adequate energy are selected as CHs.

The proposed algorithm, EB-LEACH has been executed through following phases: In the initial phase the sensor network will be deployed as per traditional concept of WSN. In, normal clustering application the process of CH selection is based on Re level. In LEACH and SEP, the continuous pressure of to being CH leads to rapid energy depletion. Hence, in our algorithm we have proposed ho to reduce this CH work pressure from selective nodes by adding an energy bank to the sensor network. The normal position of sink node is at center of sensor network. As per, or algorithm we are adding an energy bank at sink position which is assumes as full of all resources. When, the R_e of CH closer towards ($TH_{en)}$ then, CH will generate at REQ message to BS. BS will cross check the trueness of REQ message and send RESP msg as acknowledgement. The RESP signal carry an ACK packet where it has two slots of data. The first slot contains the CH_{id} to identify who generate REQ and second slot have the energy for recharging the CH. This will lead to saving of energy consumption by reducing unnecessary selection rounds. Because selection of CH round itself an energy consumption process. Likewise, all CH can participate and recharge their battery.

Algorithm: EB-LEACH

Step 1: Start
Step 2: Form Cluster and Select Cluster Head (CH) according to LEACH
Step 3: Compare ($Cluster_{energy}$ with $Threshold_{energy}$)
If (C_{energy} < Th_{energy})
If (True)
CH ($_{Energy}$) $\xrightarrow{REQ}$ Energy Bank Node
Energy Bank Node $\xrightarrow{RESP}$ CH
Else
End IF
The CH remains same. (Till the condition true)
Step 4: Cluster recharged
Step 5: End

Simulation Parameters:

The proposed algorithm is simulated in PARAM SHAVAK supercomputer with Matlab R2016a. We executed the algorithm with 100 nodes in a hybrid network area of 100m x 100m. We assumed the initial energy status of all SNs are equal i.e. 0.5Joule. In order to maintain an approximate equal distance between CHs and BS, we have deployed BS at center of sensor network i.e. with coordinates (50, 50). The other parameter what we have considered are:

PARAMETERS	VALUE
Network size	100 × 100
Base Station Position	(50 ,50)
Number of nodes	100
E_{elec}	50nJ/bit
E_{mp}	0.0013pJ/bit/m4
E_{fs}	100pJ/bit/m2
$E_{aggregate}$	5nJ/bit/signal
Percentage of CHs	10% of total nodes
Packet size	4000bits
Initial Energy	0.5J/node

Results

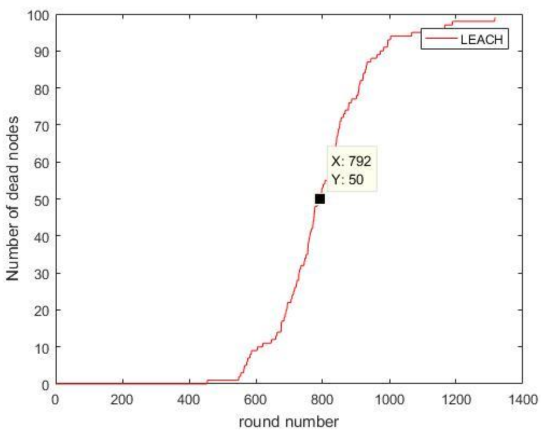


Fig.1 Dead Node Ratio LEACH

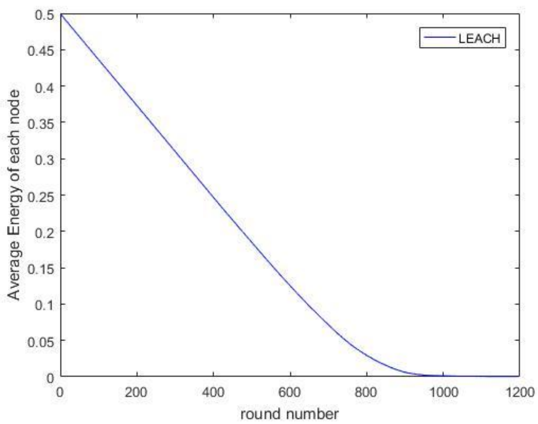


Fig.2 Performance Ratio LEACH

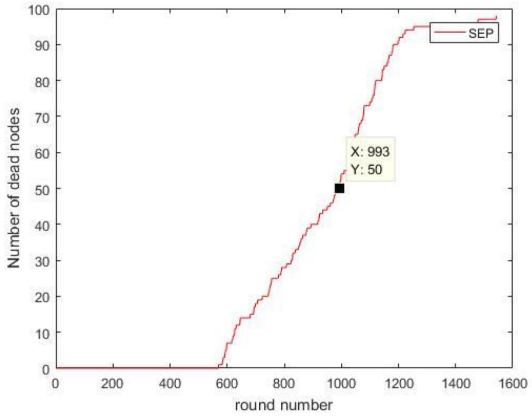


Fig.3 Dead Node Ratio SEP

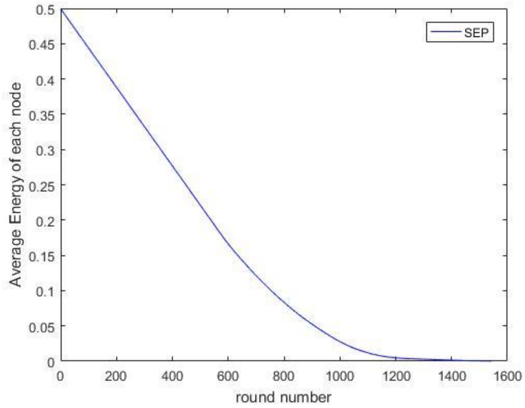
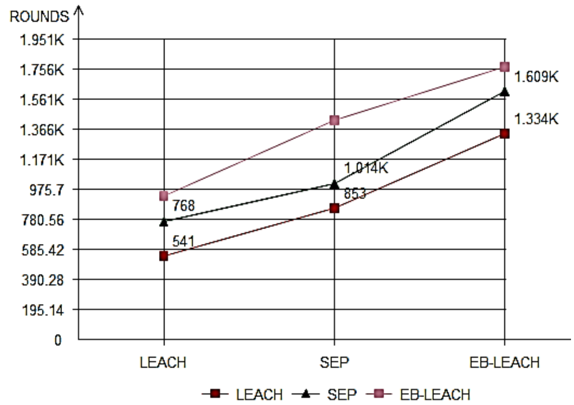


Fig.4 Performance Ratio SEP



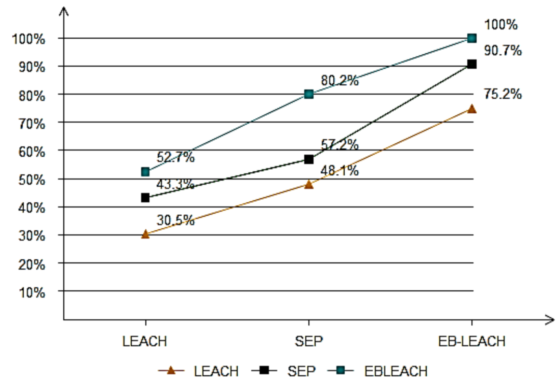


Fig.5. Dead Node Ratio EB-LEACH Fig.6. Performance Ratio EB-LEACH

Conclusion

In this paper, a bio-inspired meta-heuristic hierarchical clustering algorithm has been presented for WSN named as EB-LEACH. The simulation results validate the superior performance of the proposed algorithm which has improved cluster formation by uniformly distributing the CHs throughout the area and thus maximizing the lifespan of the network than other popular algorithms like LEACH and SEP. Performance of the proposed algorithm has been evaluated in different scenarios and the experimental results are compared with some well know clustering-based algorithms. The overall performance of our proposed EB-LEACH protocol is optimized then LEACH and SEP respectively. This work can be extended by balancing energy between multiple clusters to enhance life span of sensor network.

References:

[1] *Mohapatra H., Rath A.K. (2019) Fault Tolerance Through Energy Balanced Cluster Formation (EBCF) in WSN. In: Tiwari S., Trivedi M., Mishra K., Misra A., Kumar K. (eds) Smart Innovations in Communication and Computational Sciences. Advances in Intelligent Systems and Computing, vol 851. Springer, Singapore Govind P. Gupta, Sonu Jha., 2017. "Integrated clustering and routing protocol for wireless sensor networks using Cuckoo and Harmony Search based metaheuristic techniques". Engineering Appl. of Artificial Intelligence. 68, 101-109.*

[2] *A. Singh, S. Rathkanthiwar and S. Kakde, "LEACH based-energy efficient routing protocol for wireless sensor networks," 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Chennai, 2016, pp. 4654-4658.*

[3] *G. Smaragdakis, I. Matta, A. Bestavros, SEP: a stable election protocol for clustered heterogeneous wireless sensor networks, in: Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004), Boston, MA, 2004.*

[4] *M. Ayoob, Q. Zhen, S. Adnan and B. Gull, "Research of improvement on LEACH and SEP routing protocols in wireless sensor networks," 2016 IEEE International Conference on Control and Robotics Engineering (ICCRE), Singapore, 2016, pp. 1-5.*

[5] *Agrawal D.P. (2017) Applications of Sensor Networks. In: Embedded Sensor Systems. Springer, Singapore.*

[6] *Adnan, Md. Akhtaruzzaman, Razzaque, et al., 2016. A novel cuckoo search based clustering algorithm for wireless sensor networks. In: Proceedings of ICOCOE-2015, Advanced Computer and Communication Engineering Technology. Springer International Publishing, pp. 621–634.*

[7] *S. Lindsey and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," Proceedings, IEEE Aerospace Conference, 2002, pp. 3-1125-3-1130 vol.3.*

[8] *Abbas, K., Abedini, S.M., Faraneh, Z., Al-Haddad, S.A.R., 2013. Cluster head selection using fuzzy logic and chaotic based genetic algorithm in wireless sensor network. J. Basic Appl. Sci. Res. 3 (3), 694–703.*

[9] *Younis, O., Fahmy, S., 2004. HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. IEEE Trans. Mob. Comput. 3 (4), 366–379.*

[10] *P. Ding, J. Holliday, 2005. A. Celik, Distributed energy efficient hierarchical clustering for wireless sensor networks, In: Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS'05).*

[11] *Chong Wang and Jiakang Liu, 2009. An Improved LEACH Protocol for Application Specific Wireless Sensor Networks, IEEE: WiCOM 09 Proceedings of the 5th International Conference on Wireless Communication Networking and Mobile Computing.*

[12] *Siva Ranjani. S and Radha Krishnan.S, 2012. Energy-Efficient Cluster Based Data Aggregation for Wireless Sensor Networks, IEEE Recent Advances in Computing and Software Systems (RACSS).*

[13] *A. Manjeshwar and D. P. Agrawal, "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks," Proceedings 15th International Parallel and Distributed Processing Symposium. IPDPS 2001, San Francisco, CA, USA, 2001, pp. 2009-2015.*

[14] *Heinzelman, W.R., Chandrakasan, A., Balakrishnan, H., 2000. Energy efficient communication protocol for wireless microsensor networks. In: Proc. 33rd Annual Hawaii International Conf. Syst. Sciences, vol. 8, Hawaii, USA, p. 8020.*

[15] *Heinzelman, W.B., Chandrakasan, A.P., Balakrishnan, H., 2002. An application specific protocol architecture for wireless microsensor networks. IEEE Trans. Wirel. Commun. 1 (4), 660–670.*

[16] *Florence, M.L., Swamydoss, D.: A survey on wireless sensor network architecture, protocols and applications. J. Glob. Res. Comput. Sci. 2, 149–152 (2011).*

[17] *Akyildiz, I.F., Su, W., Sankarasubramaniam, Y., Cayirci, E.: Wireless sensor networks: a survey. Comput. Netw. 38, 393–422 (2002).*

[18] *Yick, Jennifer, Biswanath Mukherjee, and Dipak Ghosal. Wireless sensor network survey. Computer Networks-Elsevier52.12 (2008); 2292-2330.*

[19] *Al-Karaki, Jamal N., and Ahmed E. Kamal. Routing techniques in Wireless Sensor Networks: A Survey. Wireless Communications, IEEE 11.6(2004); 6-28.*

[20] *Akkaya, Kemal, and Mohamed Younis. A survey on routing protocols for wireless sensor networks. AdHoc Networks 3.3(2005); 325-349.*

[21] *Patel, Dhaval K., Milin P. Patel, and Ketul S. Patel. Scalability Analysis in wireless sensor network with LEACH Routing Protocol. Computer and Management (CAMAN), 2011 International Conference on. IEEE, 2011.*

[22] *M. Ayoob, Q. Zhen, S. Adnan and B. Gull, "Research of improvement on LEACH and SEP routing protocols in wireless sensor networks," 2016 IEEE International Conference on Control and Robotics Engineering (ICCRE), Singapore, 2016, pp. 1-5.*

[23] *H.Huang and J.Wu, ―A Probabilistic clustering algorithm in wireless sensor networks,‖ in VTC-2005-Fall.2005 IEEE 62nd September 2005,vol.3 ,pp.1796-1798.*