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I-LEACH Protocol For Wireless Sensor Networks

Gurjot Singh Gaba, Himanshu Monga, Lavish Kansal and Rajan Miglani*

1,2,3,4 Discipline of Electronics & Communication Engineering,
Lovely Professional University, Jalandhar, Punjab, India - 144411
Email: er.gurjotgaba@gmail.com, himanshumonga@gmail.com
lavish.15911@lpu.co.in, rajan.16957@lpu.co.in

Abstract

Wireless Sensors Networks (WSN) have gained a lot of significance because of potential applications such as Marine engineering, Human body tissue study and animal life study. The scope of WSN is limited to some extent due to tiny battery inside the node, thus limiting the scope of applicability where replacing a battery is infeasible. A research to solve this issue has been proposed in this paper. The motivation behind this work is the LEACH protocol which is considered as the oldest technique for Energy Conservation in WSN. But with the advancement in the fabrication of nodes, this protocol needs to be altered to cater the needs. Analysis proved that Intelligent LEACH (I-LEACH) is better than MOD-LEACH approach (A variation to LEACH) in terms of increased lifetime. Results depict 54% increase in the lifetime of the network as compared to MOD-LEACH, which ensures longer connectivity and reliability.

Keywords*: Wireless Sensor networks, LEACH, MOD-LEACH, I-LEACH, clustering*

1. Introduction

A Wireless Sensor Networks consists of hundreds and thousands of sensor nodes which senses the data from the outside environment and routes it to the Base station for further processing [1]. These sensor nodes are called as sensing elements. Each sensor node consists of different components which are sensing unit, processing unit, transmission unit, mobility monitoring unit, and position finding unit. To supervise the distant areas; where human approach is not possible, a Wireless Sensor Network is considered as one of the best solution [2]. Because of small size of sensor nodes, limited battery capacity is available; thus forcing the node to replace its battery. Due to stringent locations of nodes in the area, it is not possible to change the battery of sensor nodes again and again after it is deployed which results in very small lifetime of the sensor nodes. So, energy efficiency is one of the major constraints observed in performance of WSN.

Various methodologies are suggested to overcome this constraint; one method out of that is Data Aggregation. Rather than all the sensor nodes send their sensed data individually to the Base station node, a single node can aggregate the whole data from all the sensor nodes and send it to the base station. This saves the energy of nodes and also increases the lifespan of the network [3]. Power is also one of the limiting factor in WSN because sensor nodes consumes lot of energy to transfer their data to the sink node which makes it difficult for the small battery operated device to work for a longer duration. Sensor nodes can be deployed in a certain area through two ways *i.e*. random deployment and planned deployment. In planned deployment, the location where sensor nodes should be deployed is already fixed. In random deployment, sensor nodes are deployed through aircrafts *etc.* in any particular area. But in random deployment, a problem persists *i.e.*

* Corresponding Author

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communication hole. It is the scenario when some of the sensor nodes may not be able to communicate with other nodes when deployed through aircrafts [4]. So communication hole limits the widespread functioning of Wireless Sensor Networks.

Energy efficiency, fault tolerance, scalability, node deployment, coverage, Quality of service is found to be the major constraints in Wireless Sensor Networks. Strategies inherited with the properties to provide guard against the discussed problems have been advised in [15]. One such method is the selection of a route through which data will be sent to Base station *e.g.* direct transmission and multi-hop transmission. In direct transmission, all the sensor nodes directly send their data to the Base station. But in this approach, nodes which are very far away from the Base station consume more energy and indirectly degrade the performance of the network. In multi-hop transmission, each node sends its data to that node which is near to the Base station which puts more loads on that particular node, thereby decreasing the lifespan of the node and network.

To mitigate these issues, clustering approach is used. In Clustering, all the sensor nodes are placed into clusters where each cluster has one Cluster Head (CH) and Cluster Member (CM). Cluster member send the sensed data to Cluster Head. Each Cluster head aggregates the data and send to the Base station. Cluster head is responsible for collecting data from the entire region of cluster and then forwards it to the sink node/base station. Cluster head selection is done on the basis of cluster based protocols. Based on the initial energy of the sensor nodes, protocols are divided into two parts *i.e.* Homogenous Protocols and Heterogeneous Protocols. In Homogenous Protocols, all the sensor nodes are provisioned with the same amount of energy *e.g.* LEACH, TEEN *etc.* In heterogeneous Protocols, all the sensor nodes are equipped with different level of energies *e.g.* ESEP, DEC and DDEC [9]. LEACH is the oldest protocol which chooses the CH on the basis of the threshold and the random value generated by the node at its own. Threshold in LEACH is calculated through this expression:

$$T(n) = \begin{cases} \dfrac{p}{1-p\times\left(r \bmod \frac{1}{p}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

The manuscript has been categorized into five subsections: (i) Introduction to the need of clustering; (ii) this sub-section gives an idea of similar working strategies; (iii) Third sub-section yields to explain the principle of proposed research followed by Results and Conclusions in the subsections (iv) and (v).

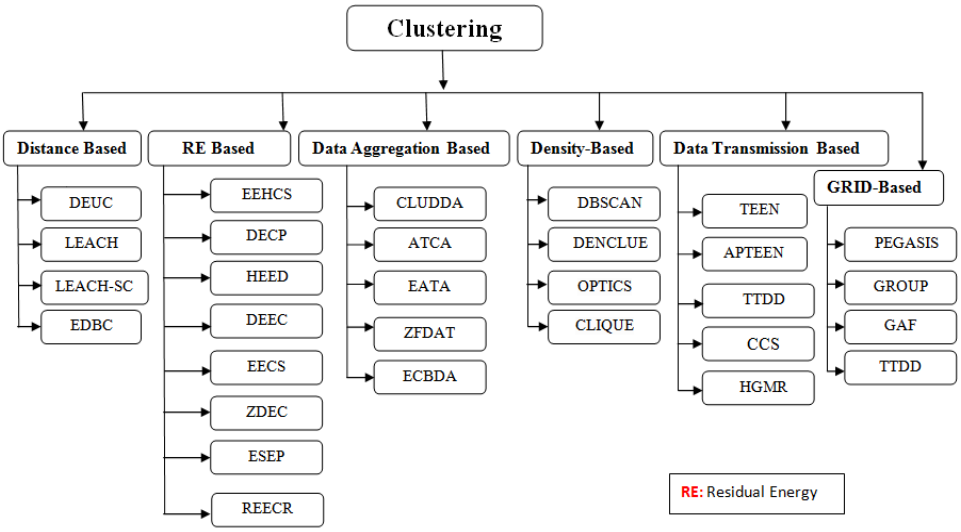


Figure 1. Category Based Classification: Conventional Clustering Strategies

2. Conventional Clustering Strategies

In the last decade, enormous advancements in the clustering techniques is observed. New techniques primarily focused on the way of electing the Cluster Head. Recent proposed techniques do not works on random selection of CH rather they work on specific inputs. Researchers have categorized the clustering strategies on the basis of CH selection method (refer fig. 1). Data propagates towards Base Station depending upon the various WSN routing protocols *i.e*. Flat routing, Location based routing, Proactive, Reactive, Hybrid routing protocols and Cluster based routing protocols which includes Block cluster based (LEACH, HEED, UCS *etc.*), Grid cluster based (GAF, TTDD *etc.*), Chain cluster based (PEGASIS, CCS, TSC *etc.*). Significance of the technique can be found by comparison of all the cluster based protocols on the parameters of delay, energy efficiency, cluster stability, scalability, load balancing, and algorithm complexity. Based on the comparison of networks performance with Cluster and without Cluster, authors found that use of Clusters in the network can lead to increased lifespan of the network along with sustainable scalability [2].

To minimize redundancy and to ensure the flow of non duplicate data towards Base station, data aggregation and scheduling algorithms are suggested for Wireless Sensor Networks *i.e*. unslotted data aggregation scheduling and slotted data aggregation scheduling. In unslotted scheduling, for a defined period of time (W_T), a node receives and aggregates the data whereas in slotted scheduling, aggregation is done on the basis of slots assigned to each node. In this paper, author has proven the effectiveness of his proposed technique over other existing solutions on the basis of data latency, accuracy, energy consumption, and collision avoidance.

A balanced energy model has been proposed to maximize the lifetime of nodes/network in randomly distributed Wireless Sensor Networks. Basically the lifespan of sensor network depends on various factors such as load balancing, transmission power control, routing. The author has initially done an analysis on load balancing on the basis of which model for the balanced energy distribution among sensor nodes in the network is created. The purpose is solely to enhance the lifespan of the network. Three algorithms were proposed under EBM (Energy Balanced Model) which are annulus formation, connectivity ensured routing and coverage preserved scheduling. Then afterwards comparison has been done between proposed model, EBTP, and EBCAG on the basis of data delivery ratio and lifetime. Results reveal that data delivery ratio and the lifetime obtained using EBM is almost double of EBTP and 50% higher than EBCAG [4]. But proposed model suffers from one limitation *i.e*. residual energy distribution among sensor nodes is higher in EBTP and in EBCAG and lower in proposed model. So, for future prospects, author has suggested to use the game theory for rationalization of residual energy among sensors in WSNs.

A scheme has been proposed, "Energy efficient Cluster Based Data Aggregation (ECBDA)" for sensor networks where Cluster Head is held responsible for the aggregation of data from all the sensor nodes in that particular cluster and then transmission of the aggregated information to the Base Station which reduces the communication overhead. The proposed technique [5] performs better over the parameters like Energy consumption, Accuracy, Packet Delivery Ratio, Network lifetime and Average delay leading to improved lifetime and energy efficient system as compared to the traditional techniques *e.g*. LEACH and LEACH-C. The technique lacks in provision of any security measures and claims to provide in future.

Lifetime of the nodes is dependent on the battery resources which usually get depleted early due to continuous operation for a longer duration. It is infeasible or costly due to human intervention to change the batteries again and again. Therefore, a new algorithm named as *Efficient Learning Automata Based Cell Clustering Algorithm* (ELACCA) [6] for Wireless Sensor Networks has been proposed. The algorithm operates in two phases: Cluster Head maintenance and Connectivity preservation. In this paper, author has

compared the proposed technique with the LEACH, EECF and HEED on the basis of parameters like cluster size, number of nodes alive, and energy consumption. During the analysis, it is found that the proposed scheme produced better results than the existing techniques. But this technique too compromises on security and reliability issues.

In [7], author has proposed an enhancement of LEACH protocol *i.e*. *En-LEACH protocol* for Wireless Sensor Network. The technique has been tested on both uniform and non uniform energy distribution scenario and the results shows that in En-LEACH, the first node dies at round 38 but in existing LEACH, first node dies at round 22 and so does for the last node in LEACH. This shows that the proposed technique is more effective than the existing technique.

The literature points out to two more methods for clustering sensor networks. In former mode, there is a deployment of multiple gateway nodes under whom sensors are segregated to form clusters. The latter mode calls for a multi-tier setup where some sensors are designated as agents to connect unreachable nodes to a single gateway. Through simulation, author has compared the multi gateway and multi-tier architecture by varying the number of sensor nodes and the probability of links failures. The objective behind the work carried is to increase the coverage cum connectivity among nodes and to efficiently set-up larger networks [8]. During the course of analysis; they found that by integrating both the methods; a flexible and efficient setup can be done which can increase the lifetime of sensors.

In [9], author has discussed some basic concepts about clustering and then compared various clustering protocols like LEACH, LEACH-C, TEEN, and APTEEN, HEED *etc.* on the basis of Network type, Sensor mobility and sensor types, cluster head selection, and clustering formation. The comparison results show the prominence of various clustering techniques over each other.

Designing of Wireless Sensor Networks by considering the battery of sensor nodes would be inadequate. In this paper author has proposed a hybrid mode which is a combination of single mode & multimode operation and data aggregation model, and also presented cost based analysis of both the single and multimode [10]. The result reveals that hybrid communication mode is more cost effective than both the single and multimode. The obtained results serves as a guideline to researchers that the optimum number of cluster heads to be used for a given application and, the required battery energies of the nodes and which mode is significant for designing better Wireless Sensor Networks.

The comparison of SEP protocol with the LEACH protocol on the basis of various measures like number of cluster heads per round, number of alive nodes per round, network lifetime, stability period, instability period and throughput has been done by the authors. The results show that SEP is resilient and its throughput is higher than other and also it extends the stable region than LEACH [11].

A new distributed energy-efficient clustering scheme for heterogeneous wireless sensor networks (DEEC) is proposed [12]. The cluster head in the proposed technique is elected on the basis of probability ratio between the residual energy of each sensor node and the average energy of the network. Nodes having low residual energy has lesser chances to become the CH. The simulation results shows that DEEC enhanced the life time of the network as compared to other clustering protocols.

An energy efficient routing protocol based on Residual energy and Energy Consumption rate (REECR) has been proposed and its comparison is done with LEACH protocol. The simulation results shows that proposed energy efficient protocol uses energy consumption data of nodes along with the residual energy of node to decide upon the selection of CH thereby increases the lifetime of the network. In [14], authors have proposed a new protocol *i.e*. Quadrature-LEACH (Q-LEACH) for homogenous networks where all the nodes have same initial energy. In this paper, authors have compared the proposed protocol with the existing protocols like LEACH, DEEC, and SEP and the

simulation results showed that Q-LEACH enhances the throughput, stability, and also increases the lifetime of the network.

Various descendants of LEACH protocol and its extended versions are found in the literature. Their analysis to verify the effectiveness is carried out in [15]. Solar aware centralized LEACH, solar aware distributed LEACH, multi-hop LEACH, M-LEACH are analyzed on the basis of network lifetime, Alive nodes, Dead nodes, and cluster heads per round.

It is observed from the literature that most of the techniques are choosing the CH randomly, or on the basis of time, or on the basis of energy consumption, residual energy *etc.* But none of the techniques predicts the future load for the selection of CH. Thus, the present techniques are not future ready and therefore cannot be suggested where the network conditions are scalable.

3. Proposed Scheme

Existing resources can be utilized in a better way if the factor of intelligence is put into it. The essence of intelligence has been poured into the existing research so that much better outcome can be observed. To make the WSN application work longer, it is mandatory to preserve the energy of nodes. Several clustering strategies have been designed so far. The proposed technique is subset of LEACH & Mod-LEACH.

In LEACH, a cluster remains as a Head until the energy value of CH goes below threshold. This is to ensure longer sustenance of node in the network. But in Mod-LEACH, CH's who have not spent much energy in the last round will remain as CH. Though this helped a lot to save energy for unnecessary changing of CH and routing the control packets to every other node for advertising of new CH. But Mod-LEACH does not take into account the traffic load of next round thereby leading to early death of CH nodes.

The proposed scheme adds intelligence into the Mod-LEACH scheme by analyzing the traffic load of next round by examining the TDMA schedule and thereby deciding to keep the node as CH or not. The suggested scheme refers to the TDMA schedule and makes an assumption that how much traffic can be expected as intake and export in the next upcoming round. Based upon the statistics, a node estimates the capability of handling all the traffic. This way of changing of cluster through predicting future has brought sufficient savings in the node energy.

4. Results and Discussions

The effectiveness of the proposed scheme has been verified over an area of 100 × 100 m^2. Simulation of the proposed technique is carried out while considering the parameter values mentioned in the Table 1.

Table 1. Network Parameters

Network Parameters	Value
Network Size (m^2)	100 × 100
Intial Energy of Sensor Nodes (J)	0.5
Packet Size (bits)	4000
Transceiver idle state energy consumption	50 nJ/bit/report
Data Aggregation	5 nJ/bit

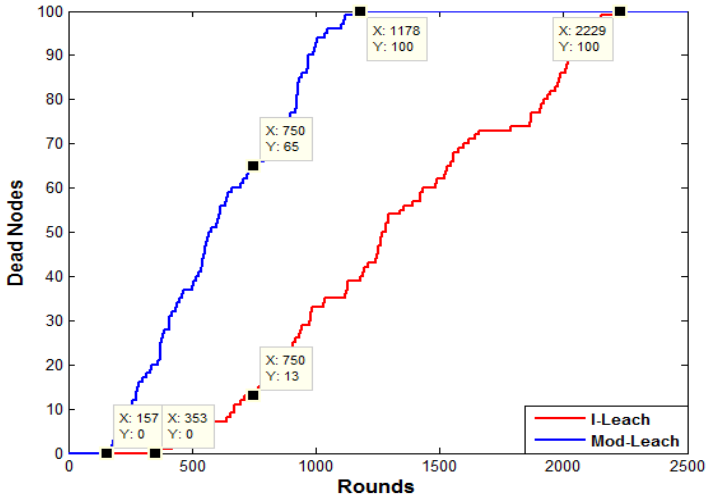


Figure 1(a). Dead Nodes Vs Rounds

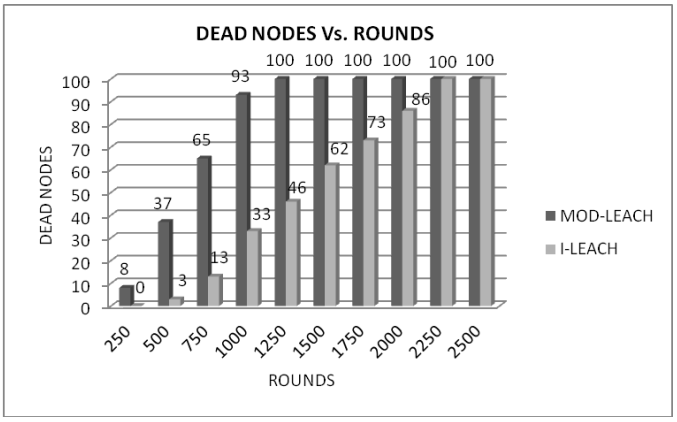


Figure 1(b). Statistics: Dead Nodes Vs Rounds

The existence of the Wireless Sensor Networks depends upon the nodes existence. Sensor Nodes are tiny modules with small battery resource. Hence continuous consumption of power leads to battery drain and node death. Figure 1(a, b) elaborates the significance of I-LEACH principle over Mod-LEACH principle. Functioning of the network continues till the nodes are alive. Simulation results revealed that I-LEACH technique loses its first node after round number 353 whereas MOD-LEACH lost it after round 157. It is further noticeable that when using I-LEACH protocol, the nodes were alive till 2229 rounds whereas in MOD-LEACH all the nodes died after 1178 rounds. The existence and operation of WSN is almost doubled (1178 X 2) by using I-LEACH protocol.

Sensor nodes are used to monitor a particular event and to report the data to the central station. But it is possible only if the nodes are alive. Figure 2 points clarifies that how increased lifetime of nodes can help the network to sustain for more time and to perform the task it was intended for. There is a drastic enhancement in the number of alive nodes while using I-LEACH. Figure 2 (a, b) is a mirror image of Figure 1. The relationship of dead and alive nodes with number of rounds has been explained in both the figures.

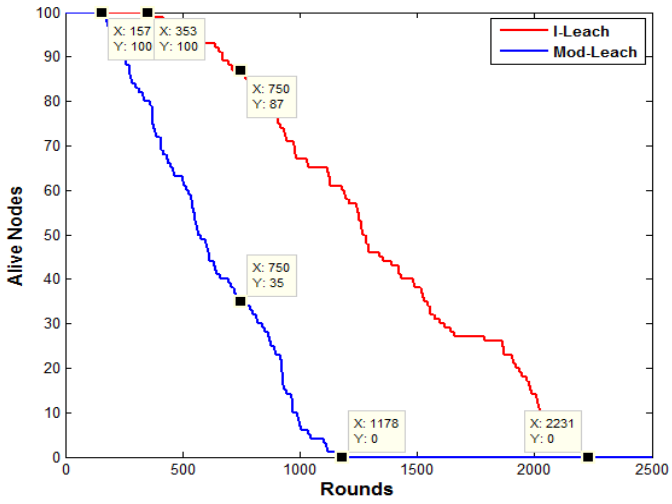


Figure 2(a). Alive Nodes Vs Rounds

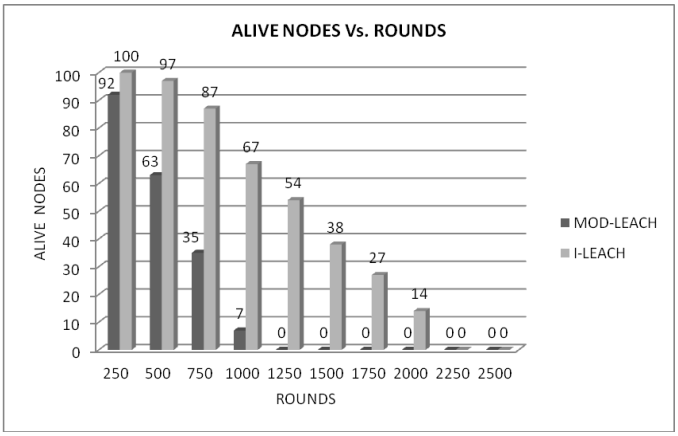


Figure 2(b). *Statistics:* Alive Nodes Vs Rounds

Cluster formation is form of assigning parent. Multiple nodes are allocated a common parent *i.e*. Cluster Head to efficiently utilize bandwidth and to avoid collisions. More the frequency of cluster heads means more wisely the network performs. The dense spectrum of red colour in Figure 3 (a, b) illustrates that by using I-LEACH protocol, network can be re-clustered more than 15000 times (considering the average number of clusters in one round as 8).

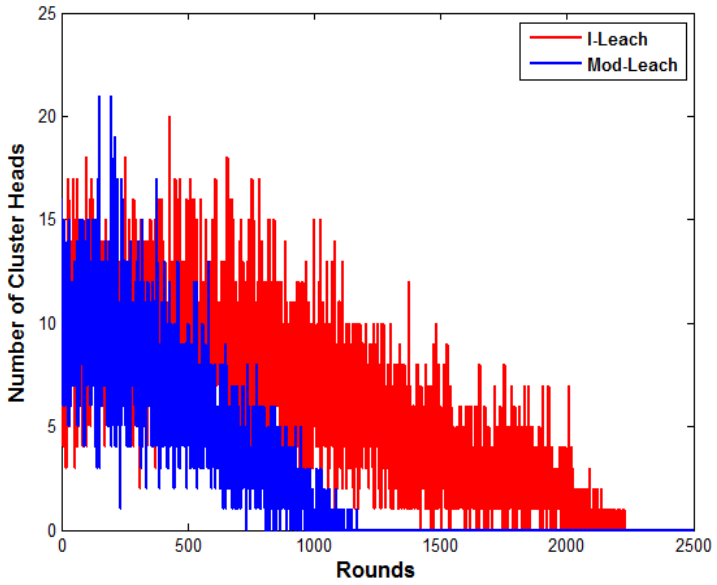


Figure 3(a). No. of Cluster Heads Vs Rounds

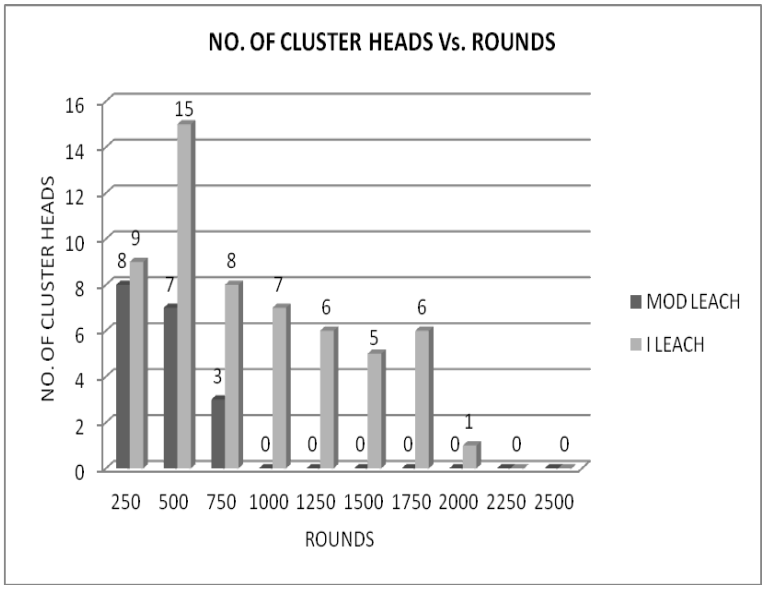


Figure 3(b). *Statistics:* No. of Cluster Heads Vs Rounds

An exponential rise in the nodes transmission characteristics can be observed in Figure 4 (a, b) as it is noticeable that more packets are sent by nodes to CH in more rounds thereby pointing the effectiveness of the technique. Similarly in Figure 5 (a, b), packets sent by CH to BS is depicted. It clearly highlights the survival of CH for more number of rounds as compared to the CH present in Mod-LEACH.

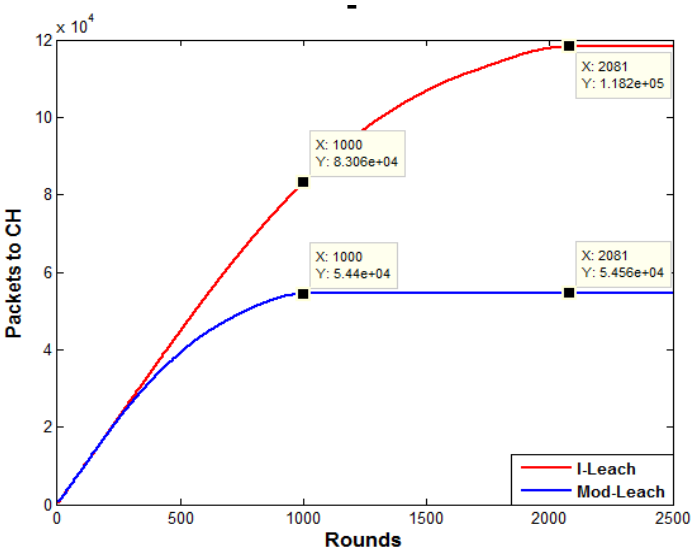


Figure 4(a). Packets to CH Vs Rounds

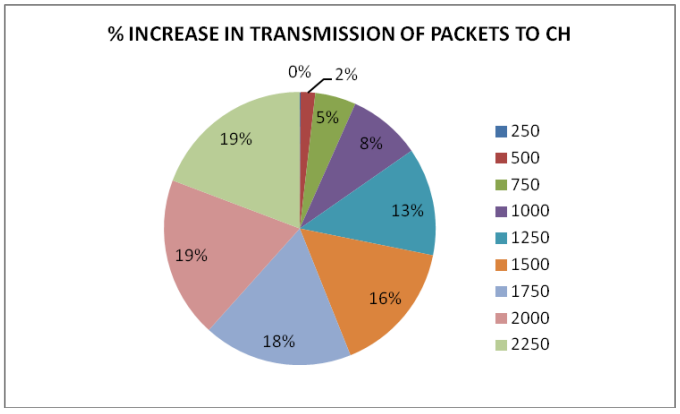


Figure 4(b). *Statistics:* Packets to CH Vs Rounds

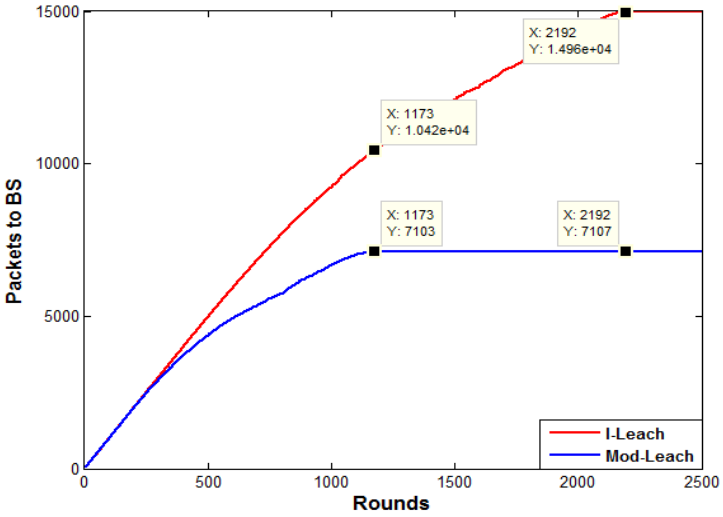


Figure 5(a). Packets to BS Vs Rounds

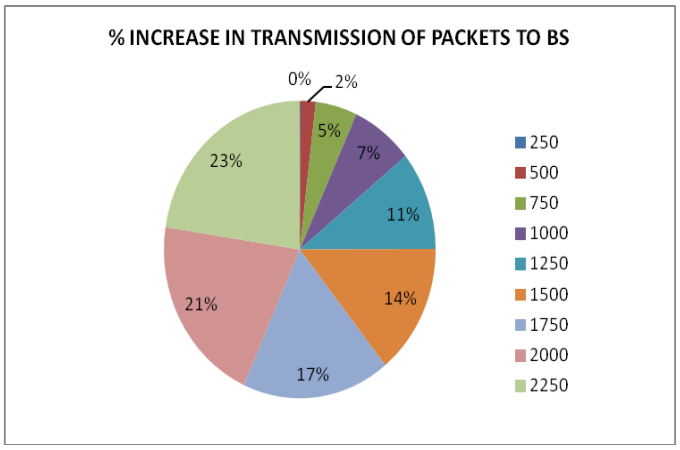


Figure 5(b). Statistics: Packets to BS Vs Rounds

During the result analysis, it has been found that I-LEACH outperforms as compared to Mod-LEACH. It is observed from Figure 6 (a, b) that 54 percent lifetime of the network can be increased if I-LEACH is incorporated in the network.

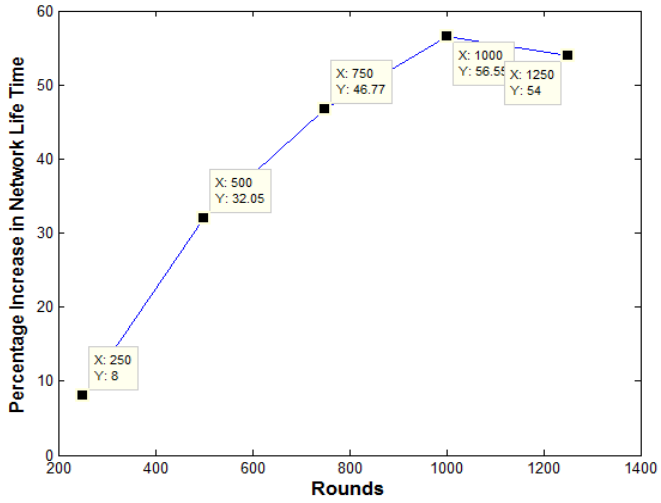


Figure 6(a). Network Lifetime in I-LEACH Incorporated Network

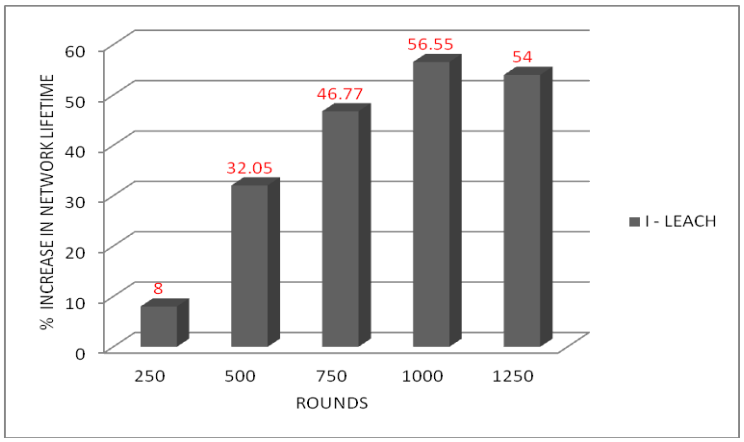


Figure 6(b). Statistics: Network Lifetime in I-LEACH Incorporated Network

Table 2. Network Simulation Statistics

ROUNDS	DEAD NODES		ALIVE NODES		NO. OF CLUSTER HEADS		PACKETS TO CH		PACKETS TO BS	
	MOD LEACH	*I LEACH*	*MOD LEACH*	*I LEACH*	*MOD LEACH*	*I LEACH*	*MOD LEACH*	*I LEACH*	*MOD LEACH*	*I LEACH*
250	08	0	92	100	8	9	22,257	22,591	2,475	2,509
500	37	03	63	97	7	15	39,155	44,867	4,370	4,992
750	65	13	35	87	3	8	49,493	65,566	5,566	7,288
1000	93	33	7	67	0	7	54,400	83,059	6,668	9,239
1250	100	46	0	54	0	6	54,564	97,010	7,110	1,0869
1500	100	62	0	38	0	5	54,564	1,06,803	7,107	1,2096
1750	100	73	0	27	0	6	54,564	1,13,222	7,107	13,237
2000	100	86	0	14	0	1	54,564	1,17,802	7,107	14,329
2250	100	100	0	0	0	0	54,564	1,18,310	7,107	14,998
2500	100	100	0	0	0	0	54,564	1,18,310	7,107	14,998

Table 2 provides the detailed analysis of the performance of the I-LEACH in comparison to Mod-LEACH. The comparison of dead nodes, alive nodes, no. of cluster heads, packets to CH and packets to BS with rounds is listed in Table 2 whereas Table 3 showcase the increase of lifetime when I-LEACH is adopted in the network.

Table 3. Network Lifetime Comparison

Rounds	Alive Nodes		% Increase in Network Lifetime
	MOD LEACH	I LEACH	
250	92	100	8
500	63	97	32.05
750	35	87	46.77
1000	07	67	56.55
1250	0	54	54

5. Conclusions

Wireless Sensor Networks are application oriented networks whose sustainability depends upon the lifetime of the node which in turn depends upon the consumption of the battery. The resources of the network can be best utilized if the network stays in working mode for a longer duration. Different strategies have been advised over the years to enhance the lifetime including the clustering scheme. Clustering helps to reduce the distance between node and BS thereby decreasing the consumption of energy. Data aggregation by CH further eliminates the redundant information. It is found from the investigation that I-LEACH Clustering strategy can widen the lifetime of the network in contrast to the existing ones. The proposed technique finds its application where huge quantity of sensor nodes is deployed in the geographical region for the same task.

References

[1] D. Mahmood, N. Javaid, S. Mahmood, S. Qureshi, A. M. Memon and T. Zaman, "MODLEACH: A variant of LEACH for WSNs", Eighth International Conference on Broadband and Wireless Computing, Communication and Applications, **(2013)**, pp. 158-163.

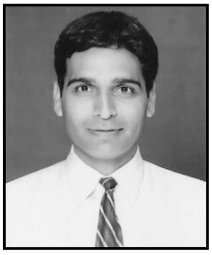
[2] S. P. Singh and S. Sharma, "A Survey on Cluster Based Routing Protocols in Wireless Sensor Network", International Conference on Advanced Computing Technologies and Applications, vol. 45, **(2015)**, pp. 687-695.

[3] M. Bagaa and Y. Challal, "Data Aggregation Scheduling Algorithms in Wireless Sensor Network", IEEE Communication Surveys & Tutorials, vol. 16, no. 3, **(2014)**, pp. 1339-1368.

[4] U. Dohare, D. K. Lobiyal and S. Kumar, "Energy Balanced Model for Lifetime Maximization in Randomly Distributed Wireless Sensor Networks", Wireless Pers. Communication, vol. 78, no. 1, **(2014)**, pp. 407-428.
[5] S. S. Ranjan, S. R. Krishnan, C. Thangaraj and K. V. Devi, "Achieving Energy Conservation by Cluster Based Data Aggregation in Wireless Sensor Networks", Wireless Pers. Communication, vol. 73, no. 3, **(2013)**, pp. 731-751.
[6] N. Kumar and J. Kim, "ELACCA: Efficient Learning Automata Based Cell Clustering Algorithm for Wireless Sensor Networks", Wireless Pers. Communication, vol. 73, no. 4,**(2013)**, pp. 1495-1512.
[7] R. Halke and V. A. Kulkarni, "En-LEACH Routing Protocol for Wireless Sensor Network", International Journal of Engineering Research and Applications, vol. 2, no. 4, **(2012)**, pp. 2099-2102.
[8] M. Younis, P. Munshi, G. Gupta and S. Elsharkawy, "On Efficient Clustering of Wireless Sensor Networks", Second IEEE Work shop on Dependability and Security in Sensor Networks and Systems, **(2006)**, pp. 78-91.
[9] L. M. C. Arboleda and N. Nasser, "Comparison of Clustering Algorithms and Protocols for Wireless Sensor Networks", Canadian Conference on Electrical and Computer engineering, **(2006)**, pp. 1787-1792.
[10] V. Mhatre and C. Rosenberg, "Design Guidelines for Wireless Sensor Networks: Communication, Clustering and Aggregation", Ad Hoc Net-works, vol. 2, no. 1, **(2004)**, pp. 45-63.
[11] G. Smaragdakis, I. Matta and A. Bestavros, "SEP: A stable election protocol for clustered heterogeneous Wireless Sensor Networks", Proceeding of the Int'1 Workshop on SANPA, **(2004)**, pp. 251-261.
[12] Q. L. Zhu and Q. Xin, "Design of a distributed energy-efficient clustering algorithm for heterogeneous Wireless Sensor Networks", Computer Communications, August, vol. 29, no. 12, **(2006)**, pp. 2230-2237.
[13] L. Xiaoya, H. Daoping and Y. Jian, "Energy efficient routing protocol based residual energy and energy consumption rate for heterogeneous wireless sensor networks", Proceedings of the 26th Chinese Control Conference, Zhangjiajie, China, **(2007)**, pp. 587-590.
[14] B. Manzoor, N. Javaid, O. Rehman, Akbar, O. Nadeem, A. Iqbal and M. Ishfaq, "Q-LEACH: A New Routing Protocol for WSNs", International Workshop on Body Area Sensor Networks (BASNet-2013) in conjunction with 4th International Conference on Ambient Systems, Networks and Technologies (ANT 2013), **(2013)**, Halifax, Nova Scotia, Canada, Proceeding Computer Science, vol. 19, **(2013)**, pp. 926-931.
[15] M. Aslam, N. Javaid, A. Rahim, U. Nazir, A. Bibi and Z. A. Khan, "Survey of Extended LEACH-Based Clustering Routing Protocols for Wireless Sensor Networks", 5th International Symposium on Advances of High Performance Computing and Networking (AHPCN-2012)in conjunction with 14th IEEE International Conference on High Performance Computing and Communications (HPCC-2012), 25-27 June, Liverpool, UK, **(2012)**, pp. 1232-1238.

Authors

Gurjot Singh Gaba, is currently pursuing Ph.D. in Electronics & Electrical Engineering with Spl. in *Cryptography and Network Security of WSN and IoT's*. He is working as an Asst. Prof. in Lovely Professional University, India since 2011. His research interest includes Wireless Sensor Networks, Computer Networks, Optical Communications and Cryptography. He is a reviewer of SCIE and Scopus Indexed Journals. He has recently been appointed as Editor of IJEEE journal. He is a member of many technical bodies including ISCA, IAENG, IACSIT, CSI, and ISTE. He is an author of six International books and more than two dozen research papers.



Himanshu Monga, has obtained Ph.D. from Thapar Institute of Engineering and Technology, Department of ECE, Patiala, India, in the field of Optical networks/coding and Wireless networks. He is presently working as a Professor and Associate Dean in Lovely Professional University, Punjab, India, in the department of Research and Development. He is member of IEEE and ISTE. He is an author of more than 65 research papers

Lavish Kansal is a passionate researcher in the field of wireless communication. He received his B. Tech degree in Electronics and Communication Engineering from PTU, Jalandhar in 2009 and M.E. degree in Electronics and Communication Engineering from Thapar University, Patiala in 2011. He is currently pursuing his Ph. D. from IKG PTU Jalandhar. He is working as Assistant Professor in the department of Electronics and communication Engineering, Lovely Professional University, Phagwara, India. He has published 35 papers in International journals. His research area includes Digital Signal Processing, Digital Communication & Wireless Communication.

Rajan Miglani, is currently pursuing Ph.D. *in Optical Communications*. He is associated with Lovely Professional University, India since 2012 as an Asst Prof in department of Communication systems. His research interests include Optical and Wireless Networks, Optical computing and processing, Cryptography and Wireless Sensor Networks. He has authored and guided numerous research papers, published in various reputed journals around the world.