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# A Pragmatic Study of LEACH and its Descendant Routing Protocols in WSN

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***Abstract- A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous sensors to monitor physical or environmental conditions. The battery power in these sensor nodes plays an important role in increasing the lifespan of the nodes. Hierarchical routing protocols are the best known protocols to minimize the energy consumption. Low-Energy Adaptive Clustering Hierarchy (LEACH) is a classical cluster based routing protocol for WSNs having good performance, energy efficiency, and effective in prolonging the network life time by consuming a small percentage of the total dissipated energy in the system. This paper surveys the state-of art of different hierarchical routing protocols that have been developed from the LEACH. This paper highlights some of the drawbacks and issues of LEACH; how these issues are conquered by the descendants of LEACH. Assessment of descendents of LEACH routing protocol in briefed in terms of scalability, self-organization, and distribution of nodes, network control, hop count, energy efficiency, and use of location information.***

Keywords- LEACH, Routing Protocol, WSN

## I. INTRODUCTION

Wireless sensor networks have potential to monitor environments for both military and civil applications. The ability to add remote sensing points, without the cost of running wires, results in numerous benefits including energy and material savings, process improvements, labor savings, and increases productivity [1]. Opposed to traditional ad hoc networks, routing in WSNs is more challenging as a result of their inherent characteristics. Firstly, resources are greatly constrained in terms of power supply, processing capability and transmission bandwidth. Secondly, it is difficult to design a global addressing scheme as Internet Protocol (IP) [2].

Based on network structure, routing protocols in WSNs can be coarsely divided into two categories: flat routing and hierarchical routing [2]. In a flat topology as shown in Figure 1(a), all nodes perform the same tasks and have the same functionalities in the network (every node transmits data independently to the BS). On the other hand, in a hierarchical topology as shown in Figure 1(b-c), nodes perform different tasks in WSNs and typically are organized into clusters according to specific requirements or metrics (only Cluster head (CH) nodes transmits data to BS using single or multihop). Hierarchical clustering protocols with single-hop communication as in Figure 1(b) and multi-hop communication as in Figure 1(c) based on data transmission. This paper is an attempt to comprehensively review and critically discuss the most prominent LEACH based routing algorithms that has been developed for WSNs. The design factors that affect clustering are: Fault Tolerance, Scalability, Production costs, Hardware Constraints, Sensor Network Topology, and Environment of nodes deployment, Transmission Media and power Consumption. LEACH uses localized allocation to enable scalability and robustness for dynamic networks and integrates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station. In the last few years, a relatively large number of routing protocols which are extension of LEACH have been developed for WSNs. Section II briefs about the LEACH in terms of its working and problems associated with LEACH. Section III discusses about the various descendents of LEACH, followed by conclusions in Section IV.

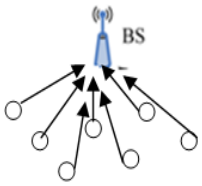


Figure 1. Flat Topology

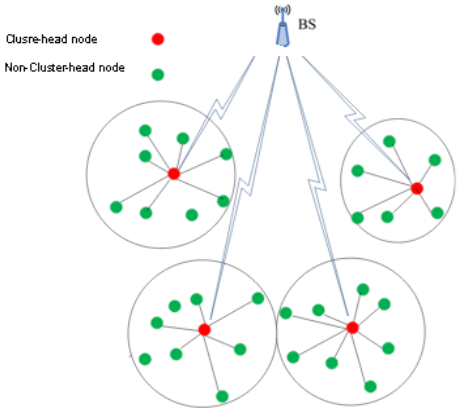


Figure 2. Hierarchical Topology -Single hop

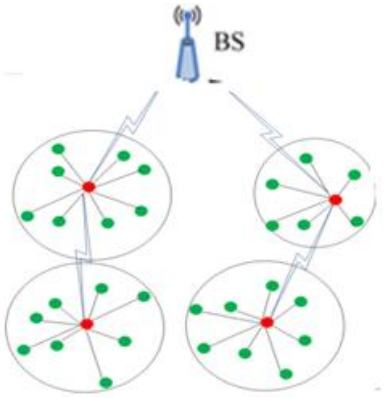


Figure 3. Hierarchical Topology - Multi - hop

## II. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

LEACH, a clustering based protocol that exploits randomized rotation of local cluster based station (cluster-heads) to evenly distribute the energy load among the sensors in the network. LEACH is a hierarchical clustering–based protocol that utilizes randomized rotation of local Cluster heads [CH] to evenly distribute the energy load among sensors in the network. It uses localized co ordination to enable scalability and robustness for dynamic networks and incorporate data fusion into the routing protocols to reduce the amount of information that must be transmitted to the base station [3].

LEACH Algorithm: The operation of LEACH is broken up into rounds, each round incorporates 2 phases: Set-up phase and steady phase. To minimize the overhead, the steady phase is longer than set-up phase.

In setup phase, nodes decide whether to become a CH or not for current round based on the suggested percentage of CH for the network. Nodes choose the number between 0 and 1. If selected number is less than T(n) as in equation 1, the node becomes CH.

$$\mathrm{T}(n) = \frac{p}{1-p*\left(rmod\,\frac{1}{p}\right)} if n \in G \quad (1)$$

where, p the desired percentage of CHs, r the current round, and G is the set of nodes that have not been selected as cluster-heads in the last 1/p rounds. The node selected as a CH broadcast advertisement message to rest of the nodes. Non CH decides to join the cluster based on the signal strength received from the CH. Nodes inform the CH by transmitting the join request to the CH. CH receives all the messages from the nodes and schedules a TDMA for each of the nodes in its cluster.

In steady state the sensed information will be transmitted to the CH during its scheduled time. CH collects frames from all the nodes in the cluster and aggregates the data and transmits the data to the BS using CDMA code. Some of the problems with the LEACH protocol are:

*a) It assumes that nodes always have data to send and all the nodes including CH are have same initial energy.*

*b) It requires the user to specify probability for use with the threshold function.*

*c) Number of clusters is predefined.*

*d) The CHs are randomly selected rotationally and residual energy of the node is not considered for cluster formation*

*e) CHs send aggregated data to BS in single hop manner.*

*f) It does not guarantee good CH distribution and it involves the assumption of uniform energy consumption for the CHs*

*g) The operations are carried out in rounds; all nodes in the network are considered while reconstructing new clusters, hence consumes lot of energy.*

*h) It may be unstable during the setup phase which depends on the density of sensors.*

*i) The CH used in the LEACH consumes a large amount of energy if they are located far away from sink.*

*j) LEACH uses dynamic clustering which results in extra overhead such as the CH changes, advertisement that reduces the energy consumption gain*

By analyzing the advantages and disadvantages of conventional LEACH routing protocol, researches have modified certain design convention in LEACH so as to improve the overall performance mainly in terms of energy consumption and network lifetime. In next section few of the improved LEACH protocols are briefed.

## III. DECENDENTS OF LEACH

Various descendents of LEACH are described as follows:

### *A. A-LEACH (Angled Low Energy Adaptive Clustering Hierarchy)*

LEACH protocol assumes that some of the nodes in the network which does not belong to any of the cluster that is being formed in the network would transfer their sensed data directly to the sink. This would cause high amount of traffic load balancing at the sink and it also affects the energy efficiency factor. A-LEACH protocol calculates the angles among the nodes in such a way that, the nodes would be transferring the data to their respective CHs should belies at an angle less than or equal to 45° to the CH, it reduces the traffic. The angles of the nodes to their respective CHs and the sink node is been calculated by the dot product of the position of the nodes, CHs and the sink [4].

### *B. LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy)*

In LEACH it should maintain details of all the nodes in cluster are at least within the cluster. But, in LEACH-B each sensor node only knows about its own position and the final receiver and does not know about the position of all the sensor nodes. LEACH-B involves the following techniques CH selection algorithm, Cluster formation and data transmission with multiple access. By evaluating the energy dissipated in the path between final receiver and itself, each of the sensor nodes chooses its CH [3, 4].

### *C. LEACH –C (LEACH- Centralized)*

In LEACH the nodes in the network dissipates large amount of energy in setting up of cluster, this problem is concentrated in LEACH-C. In this protocol an optimum CH is selected with minimization of data transmission energy between a CH and other nodes in a cluster. In LEACH-C, the base station receives information about residual node energy and node positions at the set up phase of each round. The received data can compute an average residual energy for all nodes. The nodes with less than average energy are excluded in selection of CHs. Among the nodes, those nodes which have more residual energy than average energy, CHs are selected with use of the simulated annealing algorithm. The base station sends all nodes a message of the optimum CH identifications [ID]. The node, the ID of which is the same as the optimum CH ID, is nominated as a CH and prepares a TDMA schedule for data transfer. Other nodes wait for the TDMA schedule from their CHs. Although LEACH-C solves the problem of uncertainty on the number of cluster-head at each round in LEACH, it still has problems such as pre-selection cluster-head, equal opportunities for cluster-head selection mechanism, and the unbalancing energy loads [5,6].

### *D. C-LEACH (Cell Low Energy Adaptive Clustering Hierarchy)*

In case of LEACH the selection of the CH is done based on only its probability does not consider location of sensor node from BS, there may be chance of CHs being nearby. In C-LEACH sensor network divides area in different sections called as cell and each cell includes several sensors. One sensor node in the cell is selected as cell head. Cluster is being formed by combing seven nearby cells, and each cell will have a CH. The cell-CH and CHs would change dynamically in every round of transmission of information in the network. In the time of transmission, the entire cell will remain off, except the node which has been given the slice time for transmission of information to the cell-head. The cell head will aggregate the information and it send to its respective CH [6].

### *E. LEACH-ET(LEACH-Energy Threshold)*

In LEACH protocol at the end of each round even if the CH node has residential energy more it is not continued, by this more amount of energy is dissipated in formation of the cluster itself. In LEACH-ET

minimizes the number of CH selection by using threshold of residual energy. Each sensor node should know the energy threshold value. If any sensor node acts as a CH in a certain round, and has energy value more than the energy threshold (ET) value then it continues to be CH for the next round [5][7].

*F. LEACH-E (Energy-LEACH)*

LEACH protocol considers all the nodes have same initial energy, which is not practically possible. LEACH-E is the enhancement of LEACH which involves a CH selection algorithm which has non-uniform starting energy level among the sensors having global information about the other sensors. In order to minimize the total energy consumption the required number of CHs has to scale as the square root of the total number of sensor nodes and this can be determined by LEACH-E. By making the residual energy of the sensor node as the main factor, it decides whether the sensor nodes turn into the CH or not in the next-round [8].

*G. LEACH-F (Fixed number of clusters)*

In case of LEACH, re-clustering is done after every round which reduces the network energy in turn. But in LEACH–F protocol it considers a stable cluster, in which cluster once formed is maintained throughout the network lifetime. In order to avoid re-clustering only the CH position is rotated among the nodes within the cluster. In each round, new CHs are elected and the load is distributed and balanced among the nodes in the network. However in LEACH-F new nodes cannot be added to the system and do not adjust their behavior based on nodes failure [7].

*H. I-LEACH (Improved Low Energy Adaptive Clustering Hierarchy)*

I-LEACH protocol serves two main functions namely: Detection of Twin nodes and Assignment of Sub-CH (SCH) nodes. The two nodes which are close to each other in the network are called as Twin node. These kinds of node obviously would sense the same information. Therefore it is necessary to keep one among the two twin nodes in sleep mode, until the first node runs out of energy. I -LEACH addresses the uniform distribution of CH in the network so that it does not run out of energy for longer distance transmission. I-LEACH also elects sub-CH along with CH in each clusters, so that whenever the CH dies within the round then sub-CH continues to be CH for that particular cluster for that round so as to assure no loss of data [9,10].

*I. K-LEACH*

The main idea in K-LEACH is to apply K-medoids to form a uniform clusters. As energy retention of the network is dependent on grouping, transmitting and receiving, it considers least distance from the center of the cluster as a criterion for a node to choose as a CH during selection procedure. The operation is divided into rounds with 2 phases during the setup phase the K-medoids algorithm is used for cluster formation and selection of CH using Euclidian distance at near or at the center of cluster always. In second round onwards, CH are selected based on the next nearest node to the first round CH and so on. The nodes which turn into CH inform other nodes. The other non-CH join cluster. The CH prepares TDMA schedule and transmit to nodes. In steady phase, CH collects the information and transmits to BS [7,11].

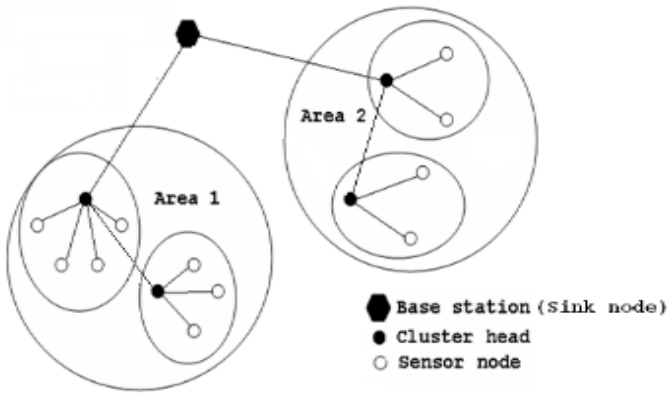


Figure 4. M-LEACH [16]

*J. LEACH-L (Low Energy Adaptive Clustering Hierarchy)*

LEACH does not take into consideration the distance of the CH nodes to BS. If CHs are located far from BS, then the CH looses energy in transmitting data to BS. This problem is overcome in LEACH-L using advanced multihop routing [12]. The CHs can communicate directly to the base station when they are located close to it. When they are located far away from the base station, they can communicate by multi-hop. In LEACH-L, the sensors are allowed to use different frequencies and gaps to communicate with base station. The clusters are re-established in each round. . It is suitable for large scope wireless sensor network [7,11].

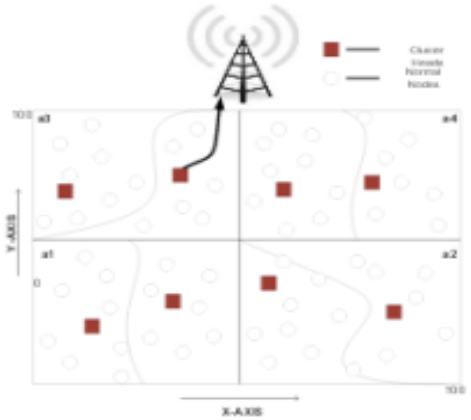

Figure 5. Q-LEACH [15]

*K. M-LEACH (Multi-hop Low Energy Adaptive Clustering Hierarchy)*

In LEACH protocol the information is transmitted from CH to the BS through single hop communication. When the network size is increased beyond a certain level, the distance between the CHs and the sink node may increase, which is one of the disadvantage of the LEACH protocol. Energy consumption will also be more if distance is far. Multihop-LEACH is a cluster based routing algorithm in which self-elected CHs collect data from all the sensor nodes in their cluster, aggregate the collected data by data fusion methods and transmit the data through an optimal path between the CH and the BS through other intermediate CHs and use these CHs as a relay station to transmit data through them as shown in Figure 4 [13].

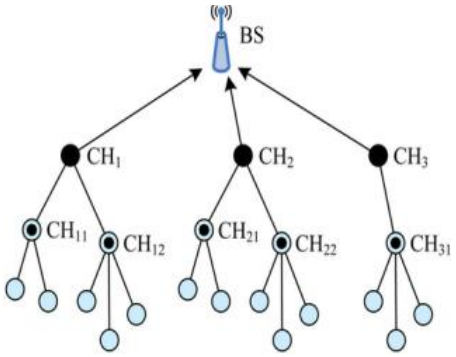


Figure 6. TL-LEACH

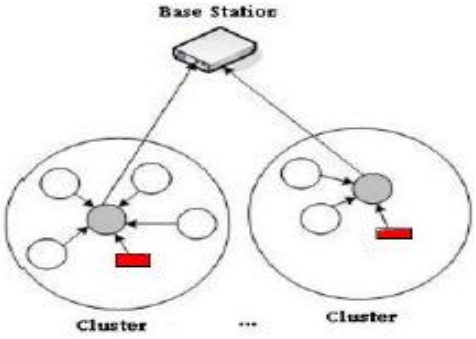


Figure 7. V-LEACH [20]

*L. LEACH-M (Mobile Low Energy Adaptive Clustering Hierarchy)*

LEACH considers all nodes as homogeneous and static, which is not a realistic approach. The LEACH-M is proposed to overcome the mobility issue. During the setup and steady state phase, LEACH-M provides mobility to the non-CH nodes along with CH. The nodes location is provided by GPS along with the characteristics of the nodes. The CHs are selected on the basis of minimum mobility of the node and lowest attenuation mode of the node. After selection of CH, the status of the CHs is being broadcasted within its transmission range [14].

*M. O-LEACH (Overlapping-LEACH)*

In LEACH, each node in a network belongs to only one cluster. But some applications need some nodes to affiliate to more than one cluster. O-LEACH has capability to control the overlapping between clusters by maintaining balance in energy consumption. In the algorithm a mechanism is inserted, that is capable of controlling the overlap among clusters. In O-LEACH, as in original LEACH, a non-cluster-head (non-CH) will choose to join to a cluster-head (CH) that has largest received signal strength. Further OLEACH will ask the node to affiliate to other CH that has received signal strength larger than X% from main CH. The X limit value is determined based on the expected overlapping degree [12].

*N. Q-LEACH(Quadrant Based LEACH)*

In case of LEACH cluster formation is done in the beginning of each round, it works well if the size of the network is smaller. But, if the size of network increases accessibility is a problem. This problem is considered in Q-LEACH, in this approach sensor nodes are deployed in the territory. In order to acquire better clustering the network is partitioned into four sub-sector quadrants. Doing such process of partitioning better coverage and load distribution of the whole network is achieved among nodes as shown in Figure 3. Through this division optimum positions of CHs are defined. Moreover, transmission load of other sending nodes is also reduced. Therefore, nodes are well distributed within a specific cluster and results in efficient energy drainage. Concept of randomized clustering for optimized energy drainage as LEACH is applied in each sector [15].

*O. LEACH-S (solar aware centralized LEACH)*

The nodes in the LEACH are based on renewable energy like battery, so in solar-aware Centralized LEACH [17] nodes are solar-aware. In this protocol CH are selected by BS with help of improved central control algorithm. BS normally select solar powered nodes, as these have maximum residual energy. In solar aware LEACH, nodes transmit their solar status to base station along with energy and nodes with higher energy are selected as cluster-head. The sun duration increases the lifetime of the sensor network. The CH handover takes place if the sun duration is smaller [16,17].

*P. T-LEACH (Threshold LEACH)*

In LEACH protocol, due to the random clusters forming, the energy of CH is very different, so do the distances between CHs and BS. T-LEACH is a threshold-based CH replacement scheme for clustering protocols of WSN. T-LEACH reduces the number of CH selection by using threshold of residual energy. Lifetime of the entire networks can be extended when compared with existing clustering protocols by reducing the amount of head selection and replacement cost [7,11].

*Q. TL-LEACH (Two-Level LEACH)*

In LEACH protocol, the CH collects and aggregates data from sensors in its own cluster and passes the information to the BS directly. CH might be located far away from the BS, so it uses most of its energy for transmitting and will die faster than other nodes. A new version of LEACH called two-level LEACH was proposed. In this protocol, the CH collects data from other cluster members as original LEACH, but rather than transferring data to the BS directly, it uses one of the CHs that lies between the CH and the BS as a relay station as shown in Figure 4 [18].

*R. V-LEACH (ViceCH LEACH)*

In LEACH, the CH always receives and transmits data to/from the cluster members. So, there are more chances of CH to die earlier than the other nodes in the cluster. When the CH die, the cluster will become useless because the data gathered by cluster nodes will never reach the base station. In VLEACH [19] is proposed with the aim of reducing the energy consumption within the wireless network. In LEACH the cluster contains only CH and nodes, but in VLEACH it includes vice-CH along with the CH and normal nodes as in Figure 5. The V-CH will become a CH of the cluster in case the current CH dies and hence there is no loss of data transmission to the BS, and also avoid the need of selecting a new CH each time the CH dies and hence extends the overall network time [19,20].

Brief comparisons of descendents of LEACH routing protocol in terms of scalability, self-organization, and distribution of nodes, network control, hop count, energy efficiency, and use of location information are shown in Table 1. All these hierarchical routing protocols prove to be better than the conventional LEACH routing protocol.

TABLE I. COMPARISON OF DESCENDENTS OF LEACH ROUTING

| Clustering routing protocol Decedents of LEACH | Scalability | Self organization | Work Distributed | BS Centralized Control | Hop count | Energy efficiency | Use of location information | Improvements over LEACH |
|---|---|---|---|---|---|---|---|---|
| A-LEACH Angled-LEACH | Good | √ | √ | X | Single-hop | Very High | √ | Every node in a network is affiliated to a one of the cluster in the network. In LEACH farther nodes (not belonging to any cluster) sends data directly to BS. |
| LEACH-B LEACH-Balanced | Good | √ | √ | X | Single-hop | High | X | Communication between non-CH and CH is allowed and not among non-CH nodes. In LEACH distance between every pair of nodes is known. |
| LEACH-C LEACH-Centralized | Good | √ | X | √ | Single-hop | High | √ | Selection of CH nodes is done at BS and not among the nodes of each cluster as in LEACH |
| C-LEACH Cell-LEACH | Very Good | √ | √ | X | Single-hop | Very high | √ | Cell formation with in a cluster is done to transmit between CH to BS. In LEACH nodes send data to CH in turn transmit to BS. |
| LEACH-ET LEACH-Energy Threshold | Very Good | √ | √ | X | Single-hop | Very high | √ | Based on threshold energy the CH nodes continued to act as CH for next round. There is no threshold concept in LEACH |
| E-LEACH Enhanced-LEACH | Good | √ | X | X | Single-hop | Very high | √ | Number of cluster is pre- determined in E-LEACH |
| LEACH-F LEACH-Fixed | Limited | X | X | √ | Single-hop | Very high | √ | Number of Clusters and total number nodes ( CH and non CH ) are fixed |
| I-LEACH Improved-LEACH | Very Good | √ | √ | X | Single-hop | Very high | √ | Detection of Twin nodes ( one among the two twin nodes in sleep mode, until the first node would run out of energy )and Assignment of Sub-CH (SCH) nodes in addition to CH. |
| K-LEACH K-Mediods LEACH | Limited | X | X | X | Single-hop | High | √ | Based on K-Mediods technique network is partioned into clusters |
| LEACH-L LEACH-Advanced Multihop | Very Good | √ | √ | X | Multi-hop | Very high | √ | Advanced multi-hops for transmission of data between CH and BS. |
| M-LEACH Multi-hop LEACH | Very Good | √ | √ | X | Multi-hop | Very high | √ | Multi hop between CH and BS |
| LEACH-M LEACH-Mobile | Very Good | √ | √ | X | Single-hop | High | √ | Mobile nodes are considered where as in LEACH nodes are static. |
| O-LEACH Overlapping-LEACH | Limited | √ | √ | X | Single-hop | Very high | √ | Nodes manage overhearing |
| Q-LEACH Quadrant-LEACH | Limited | X | X | X | Single-hop | High | √ | Network is partitioned into four sub quadrants and LEACH is applied to each quadrant |
| LEACH-S LEACH-Solar | Good | √ | √ | X | Single-hop | Very high | X | Nodes are solar-aware |
| T-LEACH Threshold LEACH | Good | √ | √ | X | Single-hop | Very high | √ | CH nodes continue to act as CH for next round if their energy is more than threshold |
| TL-LEACH Two-Level LEACH | Very Good | √ | √ | X | Multi-hop | Very high | √ | Assistant CH lie between CH and BS using multi-hop, but in LEACH transmission is single-hop. |
| V-LEACH Version LEACH | Very Good | √ | √ | X | Single-hop | Very high | √ | Vice-CH is selected in addition to CH in each cluster, but in LEACH only CH node is selected. |

## IV. CONCLUSION

One of the main challenges in the design of routing protocols for WSN is energy efficiency due to the scarce energy resources of sensors. The ultimate objective behind the routing protocol design is to extend the network lifetime of sensors of WSN. This paper briefs about LEACH protocol and its descendents. It can be concluded from survey, that for an energy-efficient and prolonged wireless sensor networks, there is still a need for finding much more efficient, scalable and robust clustering scheme for better performance. As part of future work, author would like to explore the role of bio-inspired computing algorithms for improvement of LEACH protocol.

## REFERENCES


[1] Mian Ahmad Jan, Muhammad Khan, "A Survey of Cluster-based Hierarchical Routing protocols", in IRACST – International Journal of Computer Networks and Wireless communications (IJCNWC), Vol.3, April 2013, pp. 138-143.

[2] SandeepVerma, Richa Mehta, Divya Sharma, Kanika Sharma, "Wireless Sensor Network and Hierarchical Routing Protocols: A Review", in International Journal of Computer Trends and Technology (IJCTT), Vol. 4, Issue 8, August, 2013, pp. 2411-2416.

[3] Heinzelman W.B.,Chandrakasan A.P.,Balakrishnan H., "An application specific protocol architecture for wireless micro sensor networks," IEEE Trans on Wireless Communications,Vol.1, No 4,2002,pp. 660-670, doi: 10.1103/TWC. 2002.804190.

[4] Shio Kumar Singh, M P singh D K Singh, "A Survey of Energy -Efficient Hierarchical Cluster-Based Routing in Wireless Sensor Networks", in Int. J. of Advanced Networking and Applications, Vol. 02, Issue 02, 2010, pp. 570-80.

[5] A. Depedri, A. Zanella and R. Verdone, "An Energy Efficient Protocol for Wireless Sensor Networks" In Proc. AINS, 2003, pp. 1-6.

[6] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks", IEEE Transaction on Wireless Communications, 2002, Vol. 1, No. 4, pp. 660–670.

[7] Naveen Kumar, JasbirKaur, "Improved LEACH Protocol for Wireless Sensor Networks", in Proceedings of 7th International Conference on Wireless Communications Networking and Mobile Computing, Wuhan, China, 2011.

[8] Rupesh Mehta, AbhishekPandey, Pratik Kapadia, "Reforming Clusters Using C-LEACH in Wireless Sensor Networks", in International Conference on Computer Communication and Informatics, 2012.

[9] L. Lijun, W. Hunt, and C. Peng, "Discuss in a round rotation policy of hierarchical route in wireless sensor networks", in proceedings IEEE International Conference WiCOM, 2006, pp. 1–5.

[10] Ali Norouzi1, Abdul HalimZaim, "An Integrative Comparison of Energy Efficient Routing Protocols in Wireless Sensor Network", Scientific Research of Wireless Sensor Network, Vol. 4, 2012, pp. 65-67.

[11] Thiemo Voigt, Hartmut Ritter, Jochen Schiller, Adam Dunkels, and Juan Alonso, " Solar-aware Clustering in Wireless Sensor Networks", In Proceedings of the 9th IEEE Symposium on Computers and Communications, June 2004.

[12] G.Santhosh Kumar, V. Paul M V , and K.Poulose Jacob "Mobility Metric based LEACH-Mobile Protocol"16th International Conference on Advanced Computing and Communications, 2008. ADCOM pp. 248 – 253.

[13] B. Manzoor, N. Javaid, O. Rehman, M. Akbar, Q. Nadeem , A. Iqbal, M. Ishfaq," Q-LEACH: A New Routing Protocol for WSNs", arXiv:1303.5240v1 [cs.NI] 21 Mar 2013, Procedia Computer Science (2013) pp. 1-6.

[14] VinayKumar, Sanjeev Jain and SudharshanTiwari," Energy Efficient Clustering Algorithms in Wireless Sensor Networks: A Survey", IJCSI International Journal of Computer Science Issues, Vol.8, Issue 4, No 2, September 2011, ISSN(Online): pp. 1694-0814.

[15] Suharjono, A, SepuluhNopember, Surabaya, Indonesia, Wirawan, Hendrantoro G, "Dynamic overlapping clustering algorithm for Wireless Sensor Networks", in proceedings of Electrical Engineering and Informatics (ICEEI), 2011 International Conference,17-19 July 2011, ISBN 978-1-4577-0753-7

[16] B. Manzoor, N. Javaid, O. Rehman, M. Akbar, Q. Nadeem , A. Iqbal, M. Ishfaq," Q-LEACH: A New Routing Protocol for WSNs", arXiv:1303.5240v1 [cs.NI] 21 Mar 2013, Procedia Computer Science (2013) pp. 1-6.

[17] Rajashree.V.Biradar, Dr.S.R. Sawant, Dr. R. R. Mudholkar , Dr. V.C.Patil, "Multihop Routing In Self-Organizing Wireless Sensor Networks", IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 1, January 2011

[18] J.Gnanambigai, Dr.N.Rengarajan, K.Anbukkarasi, "LEACH and Its Descendant Protocols: A Survey", International Journal of Communication and Computer Technologies, Vol. 01, No.3, Issue 02, September 2012, pp. 15-21.

[19] Loscri, V, Morabito. G, Marano, S. "A Two -Level Hierarchy for Low-Energy Adaptive Clustering Hierarchy", In Proceedings of the 2nd IEEE Semiannual vehicular Technology Conference, Dallas, TX, USA, 25–28 September 2005, pp. 1809–1813.

[20] M. BaniYassein, A. Al-zou'bi, Y. Khamayseh, W. Mardini, " Improvement on LEACH Protocol of Wireless Sensor Network(VLEACH) ", International Journal of Digital Content Technology and its Applications. Vol 3, No. 2, June 2009.