A Survey on LEACH and its Descendant Protocols in Wireless Sensor Network

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***Abstract*—Wireless sensor network is defined as wireless network of sensor nodes in which Routing technique is one of the most challenging issues. One of the major issues in WSNs is the limited battery power of the network sensor nodes. The battery power plays an important role in increasing the lifetime of the nodes. In WSN, routing among various routing technique, energy consumption is one of the most important consideration. To minimize energy consumption hierarchical routing protocols are the best known protocols. LEACH protocol is one of the most energy efficient clustering protocols. Leach increases the network lifespan by consuming a small percentage of the total dissipated energy in the network. We have surveyed the different hierarchical routing protocols, developed from the LEACH. The paper presents survey of LEACH protocol and its various descendant protocols like E-LEACH, TL-LEACH, M-LEACH, V-LEACH, LEACH-A, LEACH-B, LEACH-S. This paper also compares the above all routing protocols with original LEACH.**

Keywords: Clustering Leach Protocol, Network Routing, Wireless Sensor Network

I. INTRODUCTION

A WSN is a collection of wireless nodes with limited energy capabilities that may be mobile or stationary and located randomly on a dynamically changing environment which spread over a specific area [2]. Nodes in WSN are compact, light in weight and battery-powered devices. Therefore these special characteristics make all sensor nodes are allowed to communicate through a wireless medium and for the purpose of close-range sensing [5]. Routing in WSNs is very challenging from other wireless networks due to these specific characteristics [1]. These nodes are arranged randomly and can communicate among themselves to make an ad-hoc network. Sensor nodes are battery-powered and it is not easy to replace the batteries or recharge the batteries because each node has a limited energy supply. A clustered network is divided into various clusters. Within each cluster, one node is chosen as a cluster head (CH) among all sensor nodes and rest are treated as cluster members (CM). All sensor nodes co-operate each other to serve the requests. In each cluster, CH collects the data from the cluster members and relays the data either directly or via multi-hop transmission. Since the CHs utilizes more energy than the non-cluster heads. So, it distributes the workload of the CHs among the sensor nodes and their role is rotated among all nodes for energy-consumption equalization. One of the challenging issues in WSN is developing an energy-efficient routing protocol which increases the overall lifetime of the sensor network [6]. Hierarchical Routing is an efficient routing technique to reduce energy consumption LEACH (Low Energy Adaptive Clustering Hierarchy) is the first hierarchical routing protocol [6].

II. LEACH PROTOCOL

LEACH is called "Low Energy Adaptive Clustering Hierarchy" is the first energy-conserving routing protocol and popular among all clustering algorithms for WSN. It reduces the energy significantly [1], [5]. In LEACH clusters are formed by distributed algorithm. First of all, a node is selected as a CH with a probability p and informs its decision to all nodes and after that each non-CH node determines its cluster by choosing the CH that can have least communication energy. The basic principle behind is that it assigns overall network's energy consumption to each sensor node periodically. Thus, it can reduce the energy consumption and the lifespan of the entire network is prolonged. The role of CH is rotated within the clusters and among the nodes periodically in order to balance the load. This rotation is performed by each node by choosing a random number or threshold value T (n) between 0 and 1. If the random number < T (n), the node will become the cluster-head for the current round r, and other nodes join in the nearest cluster. After the completion of one period of data transmission, the network starts cluster reconstruction for the new round.

The threshold value is:

$$T(n) = \begin{cases} P/1-p*(rmod1/p) & \text{if } nEG \\ 0 & \text{otherwise} \end{cases}$$

Where p is the desired percentage of CH nodes in the several sensors, r is the current round number, and G is the set of nodes which is not selected as a CHs in the last 1/p rounds [1], [4], [5], [6].

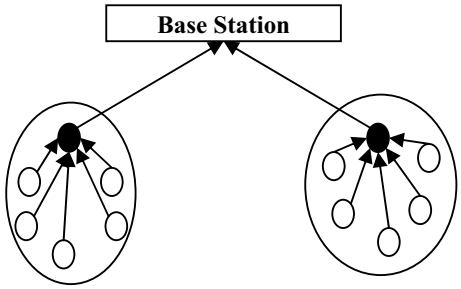

Fig. 1 Leach Clustering Hierarchical Model

III. LEACH PROTOCOL'S DESCENDANTS

A. E-LEACH-Enhanced-leach or Energy Low Energy Adaptive Clustering Hierarchy

E-LEACH is evolved in order to solve the overload energy consumption problem and based on LEACH protocol [6].

This protocol has following some objectives:

- Cluster-head failure handling.
- To handle non-uniform and dynamic residual energy of the nodes.

The E-LEACH is based on the principle of same round concept as the original LEACH. E-LEACH is the enhancement of LEACH. It involves cluster head selection algorithms which have global information about the other sensors [4]. The total number of cluster-heads is a key factor which affects the overall performance of hierarchical routing protocols. If the number of CHs is less then each CH have to cover larger region, this will results the problem that some cluster-members get away from their CHs and hence it will consume more energy [6]. By considering the residual energy of sensor nodes as the main key factor, it decides whether that node should turn into the cluster head or not in the next-round. The communication between the cluster heads and the base station requires much more energy than common node; the larger number of cluster-heads will lead in increasing the energy consumption of the whole network and reduces the network lifetime. Therefore, it is necessary to choose optimal number of cluster heads for minimum energy consumption. E-LEACH uses the minimum spanning tree among cluster heads and choose that cluster head which has largest residual energy at the root node [5], [6].

B. TL-LEACH (Two-Level LEACH)

In original LEACH protocol, the Cluster Head (CH) collects and aggregates data from sensors within its own cluster and sends the information to the Base Station (BS) directly. Most of the time the Cluster Head(CH) can be located far away from the Base Station (BS), so it consumes most of its energy in sending information and then it will die faster in comparison of other nodes. Therefore, a next version of LEACH called Two-level Leach was evolved. In this leach protocol; Cluster Head (CH) collects data from other cluster members as original LEACH, but rather than relays data to the Base Station directly, it uses one of the Cluster Heads (CHs) that lies between the Cluster Head (CH) and the Base Station (BS) as a relay station [5]. The two-level structure i.e.TL-LEACH reduces the number of nodes which is used to transmit to the base station, and then effectively reduces the total energy consumption [3].

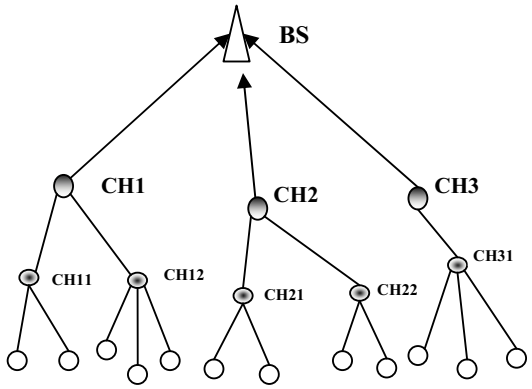

Fig. 2 TL-LEACH Protocol

C. M-LEACH (Multi-Hop Leach)

In LEACH the data is transferred from cluster head (CH) to base station (BS) node by using single hop communication and the distance between BS and CH has no effect [5]. The distance between the CH and the BS is increased when the network diameter is increased beyond a certain level [4]. Energy consumption will increase if distance is increased. Therefore in order to enhance the energy efficiency of the protocol this M-LEACH modifies original LEACH by allowing multi-hop communication used by sensor nodes within the cluster. This idea extends the existing solutions by using multi-hop communication in WSNs in which there is no direct communication between Cluster heads (CHs) or the sink due to the distance between them. Thus, the main idea of the solution is that the multi-hop approach is utilized inside the cluster and outside the cluster. Multi-hop Leach is a complete distributed clustering based routing protocol. Cluster Heads (CHs) also perform data fusion to the data receive by reducing the total transmitted and forwarded data in the network [4], [5], [6].

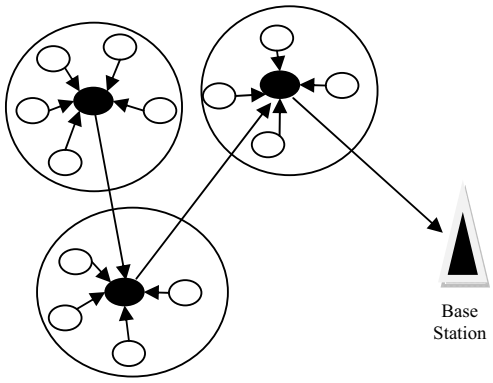

Fig. 3 M-LEACH Protocol

D. LEACH–C (Centralized LEACH)

The drawback to LEACH is that the number of CH nodes is little ambiguous to count [6]. To solve this problem LEACH-C has been proposed. LEACH-C is similar to original LEACH in operation except cluster formation [1]. In LEACH-C, centralized clustering algorithm involves. The steady state will remain the same but the setup phase of the LEACH-C is different. Each node broadcasts information about the current location and also the energy level to the base station. Thus base station utilizes the global information of the network and produce better clusters that requires less energy for data transmission [4]. The nodes with less than average energy are not consider in cluster heads selection whereas the nodes that have more than average energy, are selected for cluster heads. It uses GPS or the other location tracking method. Firstly the BS has to agree that only nodes with enough energy are allowed to participate in the selection of the CH and then after that base station (BS) broadcasts a message of the optimum cluster head IDs (Identifiers) to all nodes in the network. The node, having the same ID as the optimum cluster head ID, is nominated as a CH and transfer data by preparing TDMA schedule while remaining nodes wait for the TDMA schedule from their cluster heads [4], [6]. Leach-C gives deterministic threshold algorithm which considers the amount of energy in the node and/or whether or not the node was a CH recently. The number of CH nodes and its placement cannot give guarantee. Clusters can also be formed by using central control algorithm which may produce better clusters by distributing the CH nodes throughout the network [4]. Therefore, the selection criteria of cluster-head affect the performance and lifespan of the entire network.

E. V-LEACH (Vice-Cluster Head LEACH)

In the fundamental LEACH each cluster has a cluster head and when this cluster head does not have sufficient energy to transmit cluster member's data to the base station, it dies. This is the main disadvantage of LEACH that when the cluster head dies all the data that is with it is lost. Another disadvantage of LEACH protocol is the random selection of cluster heads. There exists a probability that the cluster heads selected are unbalanced. They may remain in one part of the network and making some part of the network unreachable [6]. To overcome this problem V-LEACH has introduced the concept of alternate Cluster Head called Vice Cluster Head.

V-LEACH includes:

1. It is the responsibility of cluster head to transmit the data to the base station the it receives from the cluster members.
2. A vice-CH defined as that node which will become a CH of the cluster when the existing CH dies.
3. Cluster nodes used in gathering data from the environment and send the gathered data to the CH.

Therefore, in V-LEACH protocol, besides having a CH in the cluster, there is also a vice-CH which has replaced the role of the CH in case the CH dies because of the reasons mentioned above [5]. But it does not give a solution to the problem when Vice-CH Dies and then the network start dissipating the energy very quickly and finally the network dies completely. In V- LEACH the CH and Vice-CH are selected on the basis of Energy, Distance and Residual Energy. The V-LEACH will increase the overall network life and improve the total communication over the network.

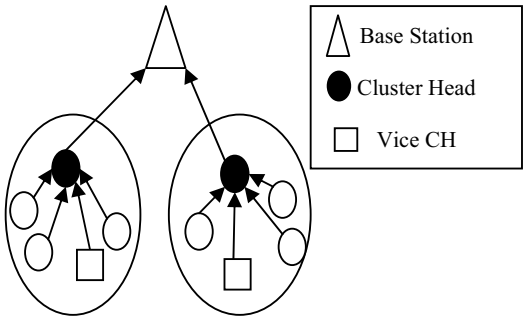

Fig. 4 V-LEACH Protocol

F. Cell-LEACH

In this proposed leach protocol, network is divided in different sections called cell. Each cell contains several sensors and one sensor is selected as cell head. Each seven nearby cells form a cluster, with a sensor known as cluster-head. Clustering will remain same as long as network is working; only cell-heads and cluster-heads change randomly. In each cell, Cell-head assign a time slice based on TDM (Time Division Multiplexing) to sensor nodes. Each cell should send its data to the cell-head in allocated time only. This method would also use for sending data from cell-head to CH. When sending information, all the nodes stay off (except the node that is already assigned slicing time). Then cell head will either remove duplicate data or aggregate received data from different sources. After deleting duplicate data and aggregate information in cell-head, this information will be send to cluster-heads and also all the functions in cell-head will be performed as well. The same technique will be used for the selection of cell-head and cluster-head. Initially after the network setup, a cell-head within each cell and a cluster-head within each cluster will be selected dynamically, because all the sensor nodes have the same energy. In next round, each old cell-head allow to choose a new cell-head dynamically and replace it with new one [5].

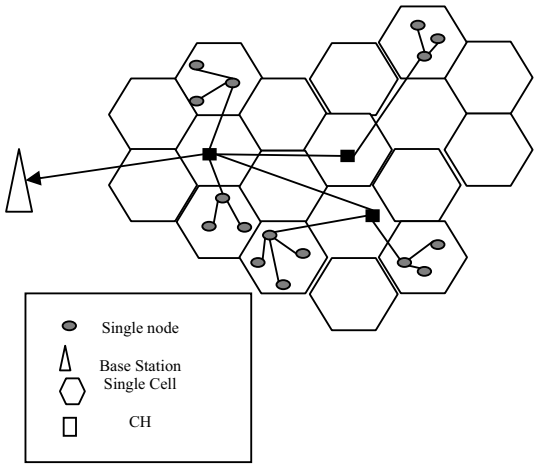

Fig. 5 Cell LEACH

G. LEACH-F (Fixed No. of Clusters Low Energy Adaptive Clustering Hierarchy)

In LEACH-F, once the clusters are formed they are fixed and there is no network setup overhead at the beginning of each round. To make the decision for clusters, LEACH-F uses the same centralized cluster formation algorithm as LEACH-C. In LEACH-F, new nodes cannot be added to the system and do not adjust their behaviour when any node dies in the network. Furthermore, the node mobility cannot be handled by the LEACH-F. Only the cluster head position is rotated among the nodes within the cluster same as LEACH protocol [4]. The advantage of this process in comparison to LEACH is that, there is no network set-up overhead at the beginning of each round. LEACH-F may or may not be provided energy saving. A stable cluster and rotating cluster head concept is followed by LEACH-F in which once cluster formed is maintained stable throughout the network lifetime in order to avoid re-clustering [8].

H. LEACH-L (Energy Balanced Low Energy Adaptive Clustering Hierarchy)

Leach-L is an advanced multi-hop routing protocol and based only on the distance. It is best suited for large area wireless sensor network and the optimum hop counts are deducted. When the base station is located close to the CH then CH can communicate directly to the BS, but when they are at far the distance from the base station, they can communicate with each other by the multi-hop way and the shortest transmission distance is limited. Sensors are allowed to use different frequencies to communicate with the base station. In each round clusters are updated where each round has two phases: set-up phase and steady phase. In each round new cluster head is chosen and the load is distributed and balanced among all the nodes of the network. Since Leach-L distribute power equally among all sensors, in the pre-period, the network's activity nodes and cover areas of Leach- L is greatly larger than that of Leach-M [4], [8].

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

LEACH-B is an enhancement of original Leach Protocol known as Balanced-LEACH uses the decentralized algorithms of cluster formation in which each sensor node has knowledge only about its own position and the final receiver or destination and has no information about the location of all the sensor nodes. Leach-B includes the following techniques:

1. An Algorithm for Cluster head selection
2. Cluster formation
3. And transmission of data with multiple access

By analysing the energy lost in the path between final receiver and itself, each of the sensor nodes chooses its cluster head. Efficiency of Leach-B is better than Leach [4].

J. LEACH-A (Advanced Low Energy Adaptive Clustering Hierarchy)

In original Leach protocol, Cluster Head is responsible for transmitting data to BS directly which consumes high energy than other member nodes in the network [3]. Hence both the energy saving is improved and reliable data transfer in LEACH-A. In Advanced-LEACH, the data is processed by using a technique called mobile agent. Advanced Leach may be defined as a heterogeneous energy protocol is developed for the purpose of energy saving, reliable data transfer, decreasing the probability of node's failure and for increasing the time interval before the death of the first node. It uses synchronized clock, through which each sensor gets the starting of each round [4], [8].

Following are the advantages of Leach-A protocol:

1. The collaboration of data reduces the amount of information that is transmitted to the BS.
2. It uses TDMA/CDMA techniques which allow hierarchy and does clustering on different levels which can save more energy.

Functions performed by the gateways:

1. Energy consumption decreases.
2. Lifetime of the cluster head extends.
3. Reduction in the nodes failure probability.
4. Extends the time interval before the death of the first node.
5. Increasing the overall lifespan of WSNs.

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

Mobility support is a fundamental issue in the Leach routing protocol. Leach-M is designed for this issue. In Leach-Mobile protocol, cluster head nodes and non cluster head nodes can move during the set-up and steady phase [7]. In Leach-M the nodes are homogeneous and obtain their location information through GPS and Base station is considered to be fixed [4]. To select appropriate cluster head Distributed setup phase of LEACH is modified by M-LEACH. The optimum cluster head can be selected on the basis of minimum mobility and lowest attenuation mode, which broadcast their status to all nodes which are in its transmission range. Another criteria for the selection of the cluster-head is mobility speed. In the steady state phase of the original LEACH protocol, another cluster head is chosen if nodes move away from the cluster-head or cluster-head moves away from its member nodes which results into inefficient clustering formation. To tackle this problem M- LEACH provides a handover mechanism for nodes to switch on to new cluster-head [4], [7].

L. LEACH-S (SOLARAWARE CENTRALIZED LEACH)

Energy harvesting is an essential application in some wireless sensor network, especially when nodes are placed in areas which are non-accessible. For such kind of applications, solar-aware LEACH (LEACH-S) has been proposed in which solar power can extend the lifetime of the wireless sensor network. Both LEACH and LEACH-C is the extension of LEACH-S [7].

1) Solar-Aware Centralized LEACH

In LEACH-S, base station uses improved central control algorithm to select the cluster head. Base station normally selects solar powered nodes that have maximum residual energy. In LEACH-S, nodes transmit its solar status to the base station along with the energy and nodes with higher energy are selected as the cluster head. The performance of the sensor network increases with the increase in solar-aware nodes. The sun duration prolongs the lifetime of the sensor network. If the sun duration is smaller cluster head handover is done in LEACH-S [7], [8].

2) Solar-aware Distributed LEACH

In this LEACH-S, choosing preference of cluster head is given to solar driven nodes whose probability is higher than battery-driven nodes [4].

TABLE: COMPARISION OF LEACH AND ITS DESCENDENT PROTOCOLS

LEACH and its Descendant	Abbreviation	Differ from LEACH
E-LEACH	Energy LEACH	Selection of ch is based on Residual Energy.
TL-LEACH	Two Level LEACH	Ch sends the Data to bs through a Ch that lies between the Ch and bs.
M-LEACH	Multihop LEACH	CH Relays the data to BS through Multiple CH as Relay Nodes.
C-LEACH	Centralized LEACH	BS is Responsible for making Clusters for each round by Running Centralized Cluster Algorithm by Getting Remaining Energy and Position of each Sensor Node.
LEACH-MOBILE	LEACH-MOBILE	LEACH MOBILE is best Suited for Mobility Centric Environment.
V-LEACH	Vice Cluster Head LEACH	There is a vice-CH that play the role of the CH when the CH dies.
CELL-LEACH	Cell LEACH	Sensor Network is Divided in Different Sections Which are called Cell.
LEACH-A	ADVANCED LEACH	LEACH-A Provides Reliable Data Transfer in Network.
LEACH-B	BALANCED LEACH	LEACH-B Choose its CH by Calculating the Energy need for the Path Between itself and Destination.
LEACH-S	Solar Aware LEACH	Selection of CH is based on Residual Energy Level.
LEACH-L	Advanced Multihop LEACH	CH Selection is based on Distance.

IV. CONCLUSION

In this paper, the most important challenge in designing routing protocols for Wireless Sensor Networks is energy efficiency, which is due to the limited energy of the sensors. The most important goal of a routing protocol is to increase the lifetime of sensor nodes. Sensors mainly consume energy during data transmission and reception. Therefore, routing protocols should be energy efficient to enhance not only the individual node lifetime, but also extend the lifetime of the whole of the wireless sensor networks. Therefore, because of this reason LEACH protocol is selected. It gives better performance in both the energy efficiency and the network lifetime. We can say the advantages of LEACH overcome the problem of WSN. Along with the advantages of LEACH it also has some disadvantages. Thus to overcome from these disadvantages and to make it energy efficient many descendants of LEACH protocol are introduced and some of them like E-LEACH, TL-LEACH, M-LEACH, LEACH-C, CELL-LEACH and V-LEACH are described in this paper. This descendant or improved LEACH gives better result than normal LEACH. Each of the descendant routing protocols has its own advantages as compared to the fundamental one.

REFERENCES

[1] Lan Tien Nguyen †1, Xavier Defago †2, Razvan Beuran *†3, Yoichi Shinoda †*4 IEEE ISWCS 2008.

[2] Nikolaos A. Pantazis, Stefanos A. Nikolidakis and Dimitrios D. Vergados, Senior Member, IEEE, IEEE Communications Surveys & Tutorials, Vol. 15, No. 2, Second Quarter 201

[3] M. Usha1, Dr. N. Sankarram2, International Journal of Innovative Research in Computer and Communication Engineering Vol. 2, Special Issue 1, March 2014.

[4] J. Gnanambigai1, Dr. N. Rengarajan2, K. Anbukkarasi3, "Leach and Its Descendant Protocols: A Survey" International Journal of Communication and Computer Technologies Vol. 01, No. 3, Issue: 02 September 2012.

[5] Ravneet Kaur1, Deepika Sharma2, Navdeep Kaur3, "Comparative Analysis Of Leach and Its Descendant Protocols In Wireless Sensor Network" International Journal of P2P Network Trends and Technology-Vol. 3, Issue 1–2013

[6] Sapna Choudhary1, Sandeep Sharma2, International Journal of Advanced Research in Computer Science and Software Engineering Vol. 4, Issue 1, January 2014

[7] M. Aslam1, N. Javaid2, A. Rahim3, U. Nazir4, "Survey of Extended LEACH-Based Clustering Routing Protocols for Wireless Sensor Networks" [cs.NI] 11 July 2012.

[8] P. Manimala1, R. Senthamil selvi2, International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250–2459, ISO 9001:2008 Certified Journal, Vol. 3, Issue 12, December 2013).