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A Survey on Energy Efficient Hierarchical (Leach) Clustering Algorithms in Wireless Sensor Network

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ABSTRACT: In wireless sensor network, Sensor nodes are deployed randomly which are small in size with limited processing power, memory and battery life. Due to limited battery power, WSN has to extend the lifetime of network by minimizing the energy consumption. Clustering has the potential to reduce energy consumption so that the total energy consumed along the path for data transfer is minimized. They have high delivery ratio and scalability and can balance the energy consumption. In this paper, we have made a survey on various LEACHES (Low Energy Adaptive Clustering Hierarchy), Hierarchical energy efficient cluster based routing protocol which helps in booming the lifetime of wireless sensor network. We have also discussed the pros and cons of LEACH along with its descendants and a comparison is also made based on various metrics like mobility, reliability, scalability, location awareness, and Hop count.

KEYWORDS— Sensor nodes, LEACH, Hierarchical Energy efficient clustering

I. INTRODUCTION

The recent developments in making energy efficient Wireless Sensor Network is giving a new direction to deploy WSN in applications such as military reconnaissance, disaster management, security surveillance, habitat monitoring, medical and health, industrial automation, etc. Thus, WSNs have managed to establish the connection between the physical world, the computing world and human society. The growing use of these networks is making engineers to evolve innovative and efficient ideas in this field. A lot of research in data routing, data compression and in network aggregation has been proposed in recent years. A WSN consists of a large number of sensor nodes deployed in a random fashion with one or more powerful sinks or base stations (BSs) spread over a specific area where we want to monitor the changes going on there. All sensor nodes have limited power supply and have the capabilities of information sensing, data processing and wireless communication. The information from these sensor nodes are collected by these base station. All the sensor nodes are allowed to communicate through a wireless medium. The wireless medium may either of radio frequencies, infrared or any other medium, of course having no wired connection. These sensor nodes form many clusters and a node with high energy will act as the cluster head. These sensors can communicate with the base station via cluster head [1].

II. CLUSTERING

One of the important issues in wireless sensor network is how to save energy consumption to prolonging the network life time. Several WSN applications require only an aggregate value to be submitted to the viewer. Sensor nodes aggregate all the data from different sources and send to the viewer. In order to support data aggregation through well-organized network group, nodes can be divided into a number of small groups called *clusters*.

Each cluster has a controller, referred to as a *cluster head*, and a number of *component* nodes. The cluster formation process ultimately leads to a two-level ladder where the CH nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes periodically transmit their data to the corresponding CH nodes. The CH

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nodes aggregate the data (thus reducing the no of transmissions) and transmit them to the base station (BS) either directly or through the intermediate communication with other CH nodes [3].

A common solution in order balance the energy consumption among all the network nodes is to from time to time re-elect new CHs (thus rotating the CH role among all the nodes over time) in each cluster. The BS is the data processing point for the data received from the sensor nodes, and where the data is accessed by the end user. It is generally considered fixed and at a far distance from the sensor nodes. The CH nodes actually act as gateways between the sensor nodes and the BS.

III. FOCUS ON CLUSTERING

Clustering has been shown to improve *network lifetime*, a primary metric for evaluating the performance of a sensor network[2].

Load balancing:

Load balancing is an essential criteria aiming at prolonging the network longevity in WSNs. The prime factor for cluster construction is distribution of sensors evenly among the clusters, where CHs perform data processing and significant intra-cluster management duties. The responsibility of CHs is to balances the load among them so that they can meet the expected performance goals. In general, priming equal sized clusters is adopted for prolonging the network longevity, as it prevents the premature energy fatigue of CHs. Even distribution of sensors can also leverage data delay. When CHs perform data aggregation, it is imperative to have similar number of node in the clusters so that the combined data report is almost complete for further processing at the base station.

Fault-Tolerance:

Due to the pertinence of WSNs in a jarring environment, sensor nodes may suffer from energy depletion, transmission bugs, hardware malfunction, and malicious attacks and so on. Re-clustering is the most intuitive method to recover from a cluster failure, though it usually messes the ongoing operation. The most notable scheme pursued to recover from failure is to assign backup CHs.

Increased connectivity and Dwindled delay:

Sensor nodes usually transmit data to one or more BSs via a single-hop or multi-hop routing in WSNs. Successful delivery of data can be determined only by the connectivity of each node to its next hop node along the path. Thus, inter-CH connectivity is a prime requirement in many applications.

Maximal network longevity:

Network longevity is an inevitable consideration in WSNs because sensor nodes are constrained in power supply, processing capability and transmission bandwidth especially for applications in jarring environments. When CHs are richer in resources than sensors, it is imperative to minimize the energy for intra-cluster communication. If possible, CHS should be placed close to most of the sensors in its clusters (i.e) sensor nodes that are close to most of the sensor nodes must be prone to be CHs.

Minimal energy consumption:

Data aggregation helps to dwindle transmission data and save energy. Moreover, clustering with inter-cluster and inter-cluster communications can reduce the number of sensor nodes performing the task of long distance communications, thus allowing less energy consumption for entire network.

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Highly Robust:

Clustering routing scheme responds to changes in the network like node increasing, node mobility and unpredicted failures. A clustering routing scheme adapt these changes within individual clusters tomake it more convenient for management. Data replication is also avoided which leads to Data Robustness.

Quality of Service:

The network applications and the functionalities of WSNs prompt the quality of service. A quality service requires effective sample, less delay and temporary precision. Prevailing clustering routing algorithms in WSNs mainly focus on increasing energy efficient rather than QOS support. QOS metrics must be taken into account in many real time applications such as battle-target tracking, emergent-event monitoring, etc.

IV. HIERARCHIAL ROUTING IN WSNS

In Hierarchical topology, nodes perform different tasks in WSNs and organized as clusters based on different metrics. Generally, each cluster contains one or more Cluster Heads and the CHs can be organized into further hierarchical levels. The Popular clustering routings protocols in WSNs include Low-energy Adaptive Clustering Hierarchy (LEACH) Hybrid Energy-Efficient Distributed clustering (HEED), Energy Efficient Clustering Scheme (EECS), Energy-Efficient Uneven Clustering (EEUC) algorithm, Threshold sensitive Energy Efficient sensor Network protocol (TEEN), The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN), *etc*. Clustering routing is becoming an active branch of routing technology in WSNs on account of a variety of advantages, such as more scalability, data aggregation/fusion, less load, less energy consumption, more robustness, *etc*. Among these clustering algorithms, Low Energy Adaptive Clustering Hierarchy (LEACH) is the First energy efficient routing protocol for hierarchical clustering [5]. It reduces the energy significantly. Description and the comparison of the descendants of Leach protocol is discussed in the next subsections

4.1 Low energy adaptive clustering Hierarchy (LEACH):

Low-Energy Adaptive Clustering Hierarchy (LEACH) is a hierarchical and cluster based protocol in which most nodes transmit to cluster heads. The main objective of LEACH is to minimize the energy consumption in sensor networks by randomly selects nodes as cluster-heads and perform periodic reselection.

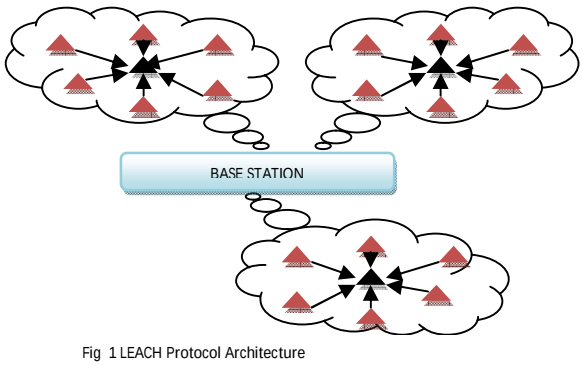

Fig 1 LEACH Protocol Architecture

- Set-up phase
- Steady-state Phase.

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During the set-up phase, each sensor node chooses a random number between 0 and 1.If this is lower than the threshold for node n, T (n), the sensor node becomes a cluster head. Each iteration of selection of cluster-head is called a round.

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

The clusters are formed dynamically in each and the time to perform the rounds is also selected randomly.When CH has selected successfully, it broadcasts an advertisement message to the other nodes. According to the received signal strength of the advertisement, other nodes decide to which cluster it will join for this round and send a membership message to its CH. In order to evenly distribute energy load among sensor nodes, CHs rotation is performed at each round by generating a new advertisement phase based on Equation (1)..

During the steady phase, data transmission takes place based on the TDMA schedule and the cluster-heads performs data aggregation through local computation, leading to energy consumption. After a certain period of time, again set-up phase will start. LEACH uses TDMA/CDMA to reduce intra-cluster and inter-cluster collisions [4].

4.1.1 Advantage of LEACH:

- LEACH is a completely distributed approach and requires no global information of network. So it is Powerful and simple.
- Network lifetime can be increased by the rotation of cluster-Head, aggregating the data by CHs, TDMA assigned to Cluster members by the CH, so that most of the nodes in sleep mode.
- Localized co-ordination and control for cluster setup and operation
- The CHs aggregates the data collected by the nodes and this leads to a limit on the traffic generated in the network. Hence, a large-scale network without traffic overload could be deployed and better energy efficiency compared to the flat-topology could be achieved

4.1.2 Disadvantage of LEACH:

- In LEACH, CH is responsible for sending data to BS directly. so
- Failure of CHs leads to lack of robustness.
- LEACH support Single Hop Routing, so it does not work well in large scale networks which need high energy for transmitting data from CH to BS directly.
- Selection of CH is random, which does not consider energy Consumption.
- Leach uses dynamic clustering which results in extra overhead such as the head changes , advertisement that reduces the energy consumption gain
- Finally, it is not suited for the applications that cover a large area that support multichip routing [8].

4.1.3 Descendants of LEACH:

Due to some drawbacks of LEACH, much research has been done to make this protocol perform better. Some of these pieces of research are: E-LEACH, TL-LEACH, M-LEACH, LEACH-C and V-LEACH [6][7].

4.1.3.1 TL-LEACH:

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Two-Level LEACH is an extension of LEACH protocol. However, in Two-Level LEACH, the CH collects data from the cluster members like LEACH, and relays the data to the base station through a CH that lies between the CH and the base station, instead of sending to the BS directly. The two-level structure of TL-LEACH reduces the number of nodes that need to transmit to the base station, effectively reducing the total energy consumption.

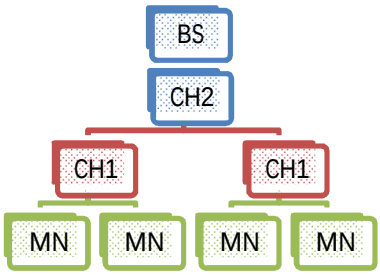

Fig.2 TL-LEACH

4.1.3.2 E-LEACH

Energy-LEACH improves the cluster head selection procedure of LEACH protocol. Initially all nodes have the same probability to be CH. But in the next round of iteration, the node with high residual energy will be chosen as CH rather than those with less energy. This protocol provides life span of network and energy saving compared to LEACH protocol.

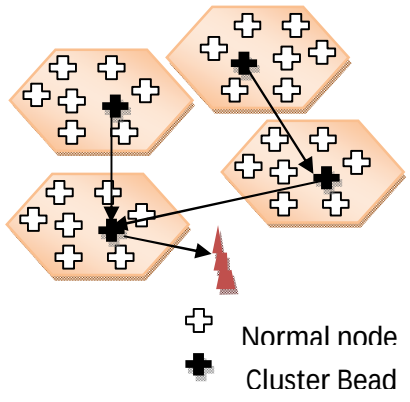

Fig 3.E-LEACH

4.1.3.3 LEACH-C

LEACH has no knowledge about the number of cluster heads and the location cluster members. Since the cluster is adaptive, there will be poor clustering. Centralized LEACH utilizes the base station for cluster formation by receiving information about the location of each sensor node and runs a centralized cluster formation algorithm to deter- mine the

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clusters for that round. However, since this protocol requires location information for all sensors in the network (normally provided by GPS), it is not robust.

4.1.3.4 LEACH-B

Balanced-LEACH use Decentralized algorithms for cluster formation in which each sensor node know only its own position and final destination, It does not have knowledge about the location of all the sensor nodes in the network. It has 3 phases: cluster Head selection, Cluster formation and data transmission with multiple accesses. Cluster Head selection is based on estimation of energy dissipated in the path between itself and final destination. It provides better energy efficiency than LEACH

4.1.3.5 LEACH-ET

LEACH-ET minimizes the number of cluster head selection by using threshold of residual energy. Each sensor node should know the energy threshold value. A node can be selected as a Cluster Head only when the energy dissipation value is less than that of energy Threshold (ET) Value.

4.1.3.6 LEACH-F

In LEACH-F-number of clusters will be fixed throughout the network lifetime. It does not provide flexibility i.e. No new nodes can be added to the system and do not adjust their behavior based on nodes dying. Furthermore, the node mobility cannot be handled by the Leach -F..

Leach –F may or may not be provided energy saving. A stable cluster and cluster head rotation concept is used by Leach - F in which clusters once formed is maintained stable throughout the network lifetime in order to avoid re – clustering.

4.1.3.7 LEACH-MOBILE

Cluster based protocols like LEACH were found best suited for routing in wireless sensor networks .LEACH-Mobile protocol was proposed to support mobility. Leach -M involves the mobility of non -cluster head nodes and cluster head during the setup and steady state phase. Selection of Cluster Head based on minimum mobility and lowest attenuation mode which then broadcast their role to all the nodes within the transmission range,

4.1.3.8 LEACH-A

In Leach Protocol, Cluster Head is responsible for transmitting data to BS directly which consumes high energy than member nodes. Advanced Leach Advanced Leach, a heterogeneous energy protocol is proposed for the purpose of energy saving and reliable data transfer. It achieves the minimum node's failure probability and for extending the time interval before the death of the first node which can be referred to as stability period.

Table 1. Comparison of LEACH and its Descendants.

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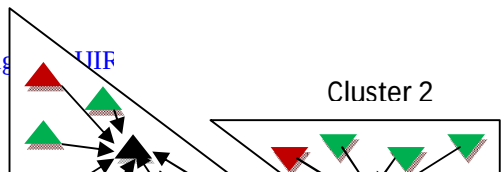
LEACH and its Descendant	Abbreviation	LEACH	Differ from LEACH
E-LEACH	ENERGY-LEACH	CH can be selected randomly.	CH selection based on residual energy.
TL-LEACH	TWO-LEVEL LEACH	CH sends the data to BS in single hop.	CH relays the data to BS through aCH that lies between the CH and BS.
M-LEACH	MULTI-HOP LEACH	CH sends the data to BS in single hop	CH sends the data to BS through multiple CH as relay nodes.
V-LEACH	VERSION OF LEACH	Single CH in the cluster.	There is a vice-CH that takes the role of the CH when the CH dies.
LEACH-C	CENTRALIZED LEACH	LEACH has no knowledge about the CHs position.	BS is responsible for forming clusters for each round by running centralized cluster formation algorithm by getting remaining energy and position of each sensor node.
TB-LEACH	TIME BASED LEACH	Formation of cluster based on randomized protocol.	Formation of cluster based on algorithm,random-timer,which doesn't require any global information,
LEACH-MOBILE	LEACH-MOBILE	LEACH – best suited for routing in WSN.	LEACH MOBILE is best suited for mobility centric environments.
LEACH-ET	ENERGY-THRESHOLD LEACH	Cluster will change for each round.	Cluster will change only when energy consumed by any one of the CH nodes reach energy threshold. Every node should know the energy threshold value.
LEACH –B	BALANNCED LEACH	LEACH does not consider the energy for the selection of CH.	LEACH-B Choose its CH by evaluating the energy need for the path between itself and destination.
LEACH-A	ADVANCED LEACH	LEACH works in homogeneous network and does not support reliability.	LEACH-A provides reliable data transfer in heterogeneous network.

4.1.3.9 V-LEACH

In LEACH protocol, Cluster contains Cluster Head which does not have sufficient energy to transmit the data collected from cluster members to the BS. The data of the particular cluster will not reach to BS in case of CH dies.. To overcome this problem V –LEACH is introduced. In V-LEACH ,there is a vice-CH that takes the role of the CH when the CH dies. Cluster nodes data will always reach the BS. There is not necessary for electing a new CH when CH dies each time. This will extend the overall network life time



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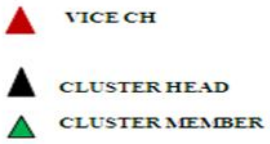

Fig. 4 .V-LEACH

4.1.3.10 M-.LEACH

In LEACH, Data transmission from Cluster head to BS through single hop.It does not consider about distance between CH and BS.If the distance is large; it consumes more energy for transmission. In Multihop LEACH,,use multihop communication within the cluster or outside the cluster in order to increase the energy efficiency of the protocol.

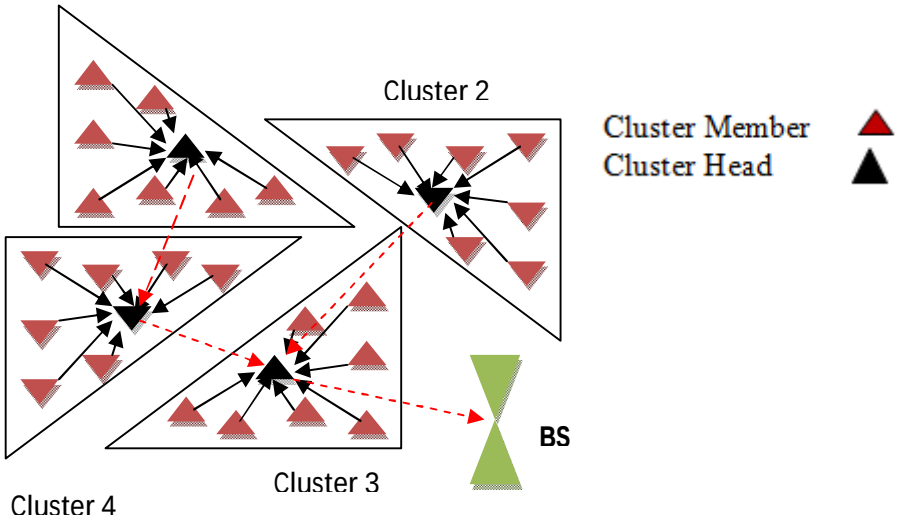

Fig 9.M-LEACH

V. CONCLUSION

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In this survey, energy efficient hierarchical and clustering protocol called LEACH is described. LEACH protocol enhanced the life time of network and saving the energy by random rotation of CH and assigns the TDMA schedule to each Cluster members to avoid Collision. Selection of CH is random, without considering the residual energy. Even though LEACH improves energy efficiency but it does not work well in large coverage area which need multi hop transmission, does not support mobility, reliability, etc…To overcome these drawbacks and make the LEACH more efficient many descendant LEACH protocol has developed like V-LEACH, LEACH-MOBILE, LEACH-A, LEACH-M,LEACH-T,LEACH-E etc…is described with the comparison of LEACH. From this survey, it can be finalized that to make sensor network more efficient and extending the lifetime, still it is needed to find more reliable, robust, adaptive clustering protocol.

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