Extended LEACH-Based Clustering Routing Protocols For WSN: A Survey

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***Abstract*—Wireless Sensor Network is the collection of tiny sensor nodes which are commonly used to collect information and data from different target area. A sensor network system includes sensor node (end device), sink node (sink) and coordinator node (coordinator). The routing protocol of WSN is to find the optimal route between the source node and destination node. In WSN, energy is crucial challenges for sensor node for sensing and transferring the data to the nearest node or to the sink as per clustering approach. The main requirement of a wireless sensor network is to prolong network energy efficiency and lifetime. Communication stops when these nodes lose their energy completely. In this survey paper, We present energy efficient hierarchical routing protocol, developed from conventional LEACH routing protocol. Furthermore, this paper also highlights some of the issues faced by LEACH and also explains that how these issues are tackled by extended version of LEACH.**

***Index Terms*— Wireless Sensor Network, LEACH Protocol, Cluster Head.**

I. INTRODUCTION

Wireless Sensor Network (WSN) [1] is rapidly growing in the information world and this is the area of research in recent days. WSN area is the collection of the tiny sensor nodes equipped with integrated sensing, data gathering, processing ability and limited storage space as well. WSN provides the platform to the sensor nodes for sensing and monitoring the network area. The platforms of wireless sensor network are dependents on battery power. WSNs have been used in crucial and sensitive applications to save the lives such as hospitality, homeland security, environmental monitoring, and infrastructure systems. WSNs have been used in military application also.

Sensor nodes are tiny devices, every individual sensor node has capability of data sensing from own sensing range and processing then transmits to the one or more data collection point. Every tiny node has specific non rechargeable and irreplaceable battery which has a limited energy power. Saving the energy of the node is the big challenge because every sensor node has its own separate non replaceable battery with limited lifetime and cannot be recharged during sensing the data.

In this area, the different energy efficient routing techniques are already proposed to improve the lifetime of the network. The very popular scheme LEACH (Lower-Energy Adaptive Clustering Hierarchy) [2] [3] is used for WSNs.

II. LEACH

LEACH (Low Energy Adaptive Clustering Hierarchy) is first proposed by Wendi B. Heinzelman of MIT [4]. This protocol provides a conception of round. LEACH protocol runs with many rounds. Each round contains two phases: cluster set- up phase and steady phase. In the setup phase, each node decides whether or not to become a cluster head for current round. The selection depends on decision made by the node by choosing a random number between 0 and 1. If the number is less than the threshold $T(n)$ [5], the node becomes a cluster- head for the current round. The threshold is set as:

III.
$$\text{IV.}\quad T(n) = \begin{cases} \dfrac{P}{1-P*(r \bmod 1/P)} & \text{if } n \in G \\ \text{V.}\quad 0 & \text{Otherwise} \end{cases} \qquad (1)$$

Where p is the probability of the node being selected as a cluster-head node, r is the number of rounds passed, and G is the set of nodes that have not been cluster-heads in the last $1/p$ rounds, *mod* denotes modulo operator. Nodes that are cluster heads in round r shall not be selected in the next $1/p$ rounds.

VI.
Once the cluster-head is selected, all nodes join the corresponding cluster according to the broadcast signal intensity of the cluster-head node. Then, the cluster set-up phase of this round is completed. When the cluster-head assigns time slots for members using TDMA mode, the network will enter the steady phase. The steady phase is divided into frame, where nodes send their data to the cluster head at most once per frame during their allocated transmission slot.

VII.
Fig.1 depicts a wireless sensor network protocol based on LEACH which is divided into three clusters, the black circle in each cluster represents the cluster head, and the rest of the white circles indicate non-cluster head nodes. Each cluster has a cluster head node. The protocol randomly selects cluster head node circularly, the energy of the entire network load is equally

distributed to each sensor node which can achieve lower energy consumption and improve the network lifetime.

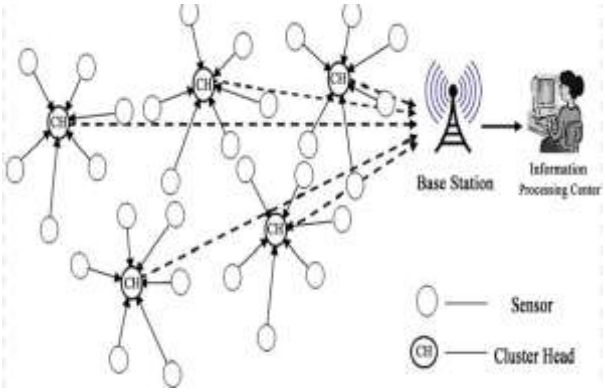

Fig.1: Architecture of LEACH

III. MULTIHOP-LEACH

Each cluster head directly communicates with sink no matter the distance between cluster head and sink is far or near in LEACH protocol. It will consume lot of energy if the distance is so far. A further modified LEACH protocol (denoted Multi-hop-LEACH protocol) which selects optimal path and adopts multi-hop between cluster head and sink is presented here. First, multi-hop communication is adopted among cluster heads. Then, according to the selected optimal path, these cluster heads transmit data to the corresponding cluster head which is nearest to sink. Finally, this cluster head sends data to sink.

Multi-hop-LEACH protocol is almost the same as LEACH protocol is almost the same as LEACH protocol, only makes communication mode from single hop to multi-hop between cluster heads and sink.

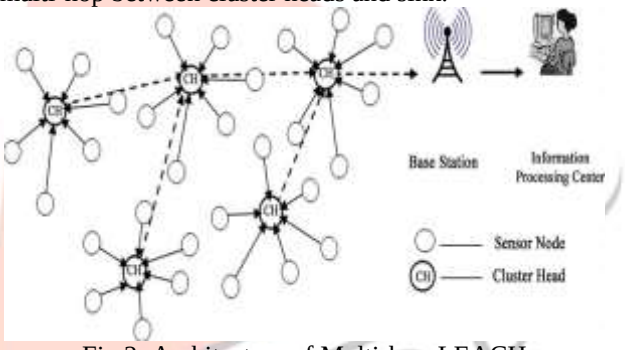

Fig.2: Architecture of Multi-hop-LEACH

IV. S- LEACH (SOLAR AWARE-LEACH)

Energy harvesting is essential in some applications of wire- less sensor network, especially when sensor nodes are placed in non-accessible areas like battlefield [6]. For such kind of applications solar-ware LEACH (sLEACH) has been proposed by authors [6] in which lifetime of the wireless sensor network has been improved through solar power. In sLEACH some nodes are facilitated by solar power and these nodes will act as cluster-heads mainly depending upon their solar status. Both LEACH and LEACH-C are extended by sLEACH.

1) Solar-aware Centralized LEACH: In solar-aware Centralized LEACH cluster head are selected by Base station with help of improved Central control algorithm. Base station normally select solar powered nodes as these have maximum residual energy. Authors improve the conventional cluster-head selecting algorithm used in LEACH-C [7], [8]. In sLEACH nodes transmit their solar status to base station along with en- ergy and nodes with higher energy are selected as cluster-head. Performance of sensor network is increased when number of solar-aware nodes is increased. Sensor network lifetime also depends upon the sunDuration. It is the time when energy is harvested. If sunDuration is smaller cluster-head handover is also performed in sLEACH [6]. If node serving as cluster- head is running on battery and a node in cluster send data with flag, denoting that its solar power is increased this node will become cluster-head in place of its first serving cluster-head. This new cluster-head is selected during steady state phase that also enhance the lifetime of the network.

2) Solar-aware Distributed LEACH: In Solar-aware Distributed LEACH choosing preference of cluster-head is given to solar-driven nodes. Probability of solar-driven nodes is higher than battery-driven nodes. Equation 1 is needed to be change to increase the probability of solar-driven nodes. This can be achieved by multiplying a factor sf (n) to right side of the equation (1) as:

$$T(n) = sf(n) \times \frac{P}{1-(cHeads/numNodes)} \quad (2)$$

Where sf(n) is equal to 4 for solar-driven nodes, sf (n) is equal to for battery driven nodes. P= is the percentage of optimal cluster-heads. The cHeads is number of cluster-heads since the start of last meta round. The numNodes is total number of nodes [9], [6].

V. M-LEACH (MOBILE LEACH)

LEACH considers all nodes are homogeneous with respect to energy which is not realistic approach. In particular round uneven nodes are attached to multiple Cluster-head; in this case cluster-head with large number of member ode will drain its energy as compare to cluster-head with smaller number of associated member nodes. Furthermore mobility support is another issue with LEACH routing protocol, to mitigate these issues, M-LEACH is proposed in [10].

M-LEACH allows mobility of non-cluster-head nodes and cluster-head during the setup and steady state phase. M- LEACH also considers remaining energy of the node in selection of cluster-head. Some assumptions are also assumed in M-LEACH like other clustering routing protocols. Initially all nodes are homogeneous in sense of antenna gain, all nodes have their location information through GPS and Base station is considered fixed in M-LEACH. Distributed setup phase of LEACH is modified by M-LEACH in order to select suitable cluster-head. In M-LEACH cluster-heads are elected on the basis of attenuation model. Optimum cluster-heads are selected to lessen the power of attenuation. Other criteria of cluster-head selection are mobility speed. Node with minimum mobility and lowest attenuation power is selected as cluster- head I M-LEACH. Then selected cluster-heads broadcast their status to all nodes in transmission range. Non-cluster-head nodes compute their willingness from multiple cluster-heads and select the cluster-head with maximum residual energy.

In steady state phase, if nodes move away from cluster-head or cluster-head moves away from its member nodes then other cluster-head becomes suitable for member nodes. It results into inefficient clustering formation. To deal this problem M-LEACH provides handover mechanism for nodes to switch on to new cluster-head. When nodes decide to make handoff, send DIS-JOIN message to current cluster-head and also send JOIN-REQ to new cluster-head. After handoff occurring cluster-heads re- schedule the transmission pattern.

VI. O-LEACH

The construction of the clusters the nodes choose randomly the CH which can be concentrated in a specific part of the work field. As a result, the remaining part of the field will not be covered Fig.3 the nodes will be outside the network. The values received by the Orphan nodes will not be transmitted to the base station. The problem of the Orphan nodes requires to find a solution allowing to join these nodes to the remaining part of the network. Orphan LEACH present two scenarios, the first scenario consists, a cluster member will be able to play the role of a gateway which allows the joining of Orphan nodes. The gateway node has to connect a number of Orphan nodes, thus the gateway node is considered as a CH' for connected Orphan. As a result, Orphan nodes become able to send their data messages to the CH' which performs in turn data aggregation and send aggregated data message to the CH. The second scenario consists, if in an area not covered, the number of Orphan nodes is very important, if number of cluster member is superior to number of orphan nodes, a sub-cluster will be created. The first Orphan node reached the gateway (member of cluster) will be a CH'. CH' plays the same role as CH.

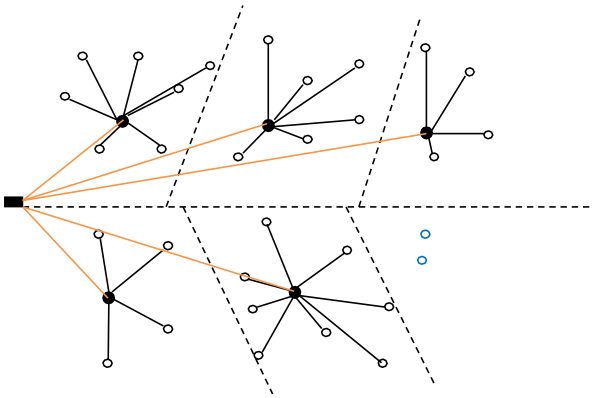

Fig.3: O-LEACH with orphan nodes

Proposed Solution-1: In a round i, an area can be not covered by the CH, or CHs cannot cover this area. These nodes will not be within the reach the CHs, a cluster member will be called Gateway (CH'). As illustrated in Fig.4:

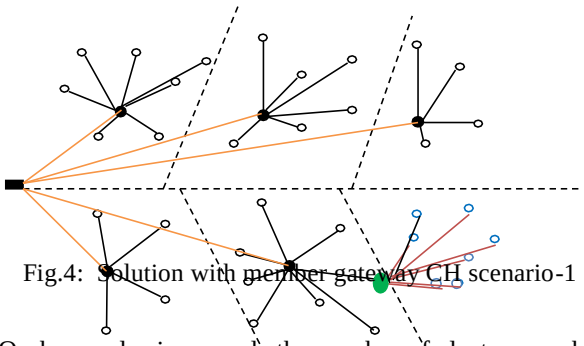

Fig.4: Solution with member gateway CH scenario-1

Proposed Solution-2: The number of Orphan nodes is exceeds the number of cluster members of CH, therefore the creation of sub-cluster Fig. 5 . The sub-cluster is composed of CH' and Orphan nodes. The first Orphan node (CH') has accessed to the gateway will be called CH'. CH' informs the Orphan nodes neighbor of its new status. CH informs the CH' about the number of slots was reserved to the Orphan nodes. The CH' plays the same role as the CH. The data received by the Orphan nodes, will be compressed by CH', and thereafter data will be aggregated to a CH through a Gateway.

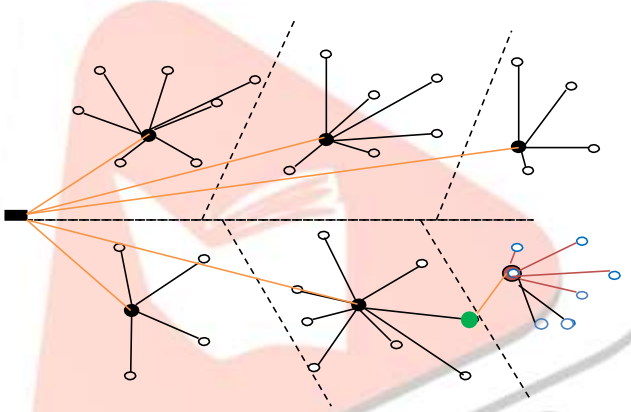

Fig.5: Solution with Sub Cluster scenario-2

VII. P-LEACH

An enhancement over the LEACH protocol was proposed [11]. The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain-based protocol.

The PEGASIS protocol [12], a chain of sensor nodes is formed and leader node is selected for each round randomly. Leader of a particular round collects the data, fuses the data, and sends the data to the base station. Although clustering overhead is avoided, PEGASIS still requires dynamic topology adjustment since a sensor node needs to know about the energy status of its neighbors in order to know where to route its data. Such topology adjustment can introduce significant overhead, especially for highly utilized networks.

LEACH and PEGASIS are the most well-known energy efficient protocols for wireless sensor networks. LEACH considers a dynamic cluster approach and energy efficiency during wireless transmission, while PEGASIS considers the power consumption, reduced traffic overload, increased network lifetime and cost efficiency, but doesn't take into account a dynamicity. The combination of the two protocols is to design an ideal routing protocol for wireless transmission and networking. The cluster head set is responsible for data forwarding in LEACH, while in PEGASIS, hierarchical chain formation is implemented through an energy efficient algorithm for the same. We propose the new protocol P-LEACH that combines the chain formation technique within the clusters for data forwarding.

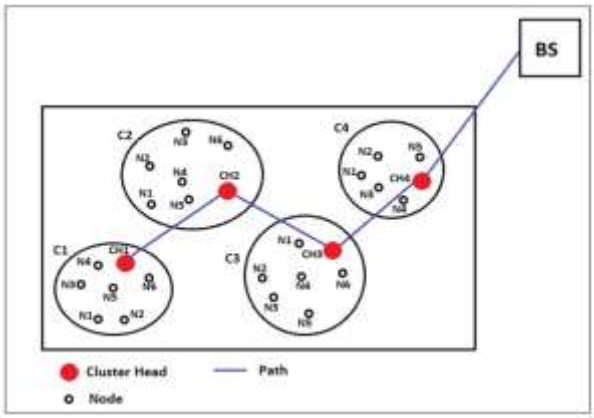

Fig.6: Architecture of P-LEACH

In Fig.6, the hollow circles represent the nodes, and the black spots represent the cluster heads. The line represents the optimized path from nodes (cluster-heads) to the Base Station. The nodes in a cluster select an active cluster head having the highest energy amongst them. Each cluster head communicates with other cluster heads in the network and thus form a chain to the base station. The cluster head having the nearest distance to the base station is selected as a leader of the chains, who is responsible for sending the data to the base station directly.

VIII. Conclusion

In this survey paper we have discussed LEACH, Multi- hop LEACH, M-LEACH Solar-aware LEACH, O-LEACH, P-LEACH hierarchical routing protocols for wireless sensor network. The main concern of this survey is to analysis and compare the different types of LEACH routing protocols versions.

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