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A Comprehensive Study on LEACH based Routing Protocols in Wireless Sensor Network

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ABSTRACT: A network sensor which is wireless is composed of sensor nodes used for environment monitoring. The inherent power battery in the sensor nodes has a vital role for longevity the lifetime of the WSN; which is the major issue. In terms of lower energy consumption, hierarchical routing protocols are considered. LEACH is the first conventional routing protocol under hierarchical based routing technique. In this paper, variants of LEACH protocols are surveyed along with some drawbacks faced in LEACH. In the end, important features of LEACH variants protocols are compared.

KEYWORD: Sensor Network, Hierarchical routing, LEACH, Cluster head

I. INTRODUCTION

A network sensor which is wireless consists thousands of small nodes for sensing and can be expanded in constantly as a mass or placed out one by one depending upon the application like monitor pressure, temperature, humidity, etc. These sensor nodes are equipped with low powered battery, wireless communication antenna and small processing units [1]. To complete the assigned task, nodes need to collaborate with other and collaboration is done through wireless communication technique[2]. The sensed data by nodes which can sense are routed to the sink directly or by other nodes which can sense. The main challenge is to improve the lifetime of the network and to balance the energy consumption in Wireless Sensor Network[3].

There are three main categories of Routing protocols: the one based on location , data centric and clustering-based (hierarchy-based) protocols[4]. The protocols based on location handle the location data of the node which can sense to transmit the information to the necessary areas rather than the complete network. Routing protocols which are data-centric are based on query i.e. queries are discharged by base station to some specific area of interest and waits for response from the sensor nodes located in that area. Naming which is based on attribute is required to state the effects of information as data is being requested through queries. In cluster based routing protocols, concept based hierarchical structure is used. In which clusters are formed and cluster heads are responsible to relay the data to other cluster heads or directly to base station. Fig.1 represents the model of wireless sensor network.

In this scenario, various routing protocols based on hierarchy in WSN are depicted and comparison is to be done among those protocols based on their mobility, residual energy usage, homogeneity, hop count, self organisation, data aggregation etc.

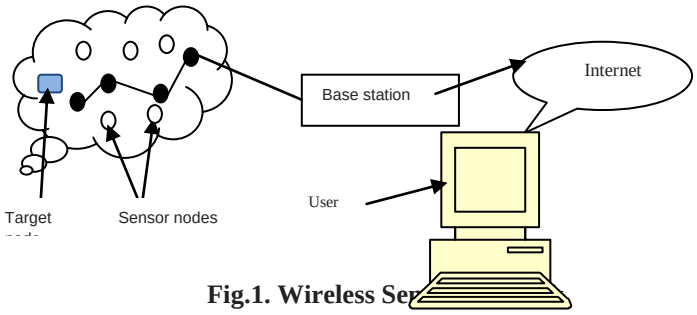

Fig.1. Wireless Se

II. ROUTING PROTOCOLS

Routing is defined as how the data are transferred from source node to destination node, it is .one of the most basic and important areas of networking. Routing protocols defines rules or procedures to follow while transferring data to the destination and helps to make that process as smooth as possible. There are different types of routing protocols that are:

- Border Gateway Protocol (BGP)
- Exterior Gateway Protocol (EGP)
- Enhanced Interior Gateway Routing Protocol (EIGRP)
- Interior Gateway Protocol (IGRP)
- Intermediate System-to-Intermediate System (IS-IS)
- Open Shortest Path First (OSPF)
- Routing Information Protocol (RIP)

Above protocols are further classified into: Classful or Classless Protocols, Distance Vector or Link State Protocols and Interior Gateway Protocols (IGP) or Exterior Gateway Protocols (EGP).

III. ROUTING PROTOCOLS BASED ON HIERARCHY

Hierarchy based routing protocols shown in Fig. 2, which is mostly energy saving protocols as compared to other routing techniques. In this technique, complete network is divided into clusters. Depending upon certain criteria, cluster head is chosen with major responsibilities like gathering of data, processing and data transfer to base station [5].

This method of data transmission is an efficient way of energy consumption in the network, in which energy is greatly reduced by performing data gatheration and processing in the cluster head. The main advantage of this protocol is to expand the life span of the network and to decrease the traffic towards the base station. LEACH, the first hierarchical protocol approach is used.

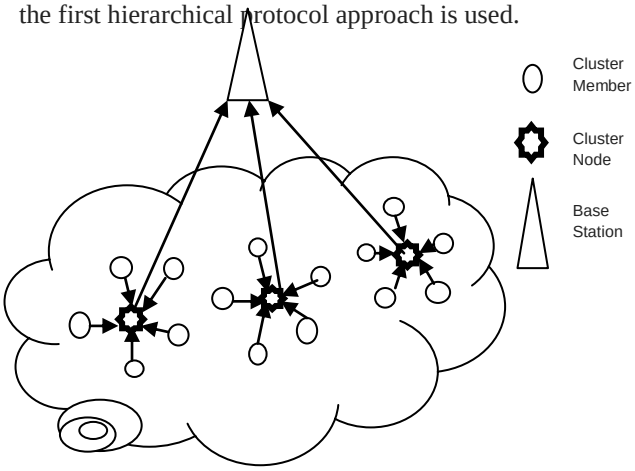

Fig.2. Architecture of Hierarchical Routing Protocol

i) Basic Operation of LEACH

LEACH [6] comes under hierarchical category of routing protocols of WSN. Some assumptions [2] are made initially in LEACH protocol.

- All sensor nodes are immobile.
- Initially, all nodes which can sense have equal energy and they sense atmosphere at fixed rate.

Base station is immobile and long distant from all sensor nodes.

ii)Phases of LEACH

There are different rounds of LEACH and every round has two phases:

1.The Set-up Phase: In this phase, each node selects a random number between 0 and 1.

The cluster head for that particular round is, the node that value is less than below mentioned threshold value (Equation 1).

$$T(n) = \begin{cases} \frac{p}{1-p*\left(r \bmod \frac{1}{p}\right)} & if n \varepsilon G \\ 0 & Otherwise \end{cases} \quad \ldots\ldots\ 1$$

Where, G is the set of nodes that never be chosen as cluster-head node before 1/p round and 'p' is the cluster-head probability.

When the formation of cluster heads are done, each cluster head transfer message via CDMA schedule to the other nodes in the network and then nodes (other than cluster head) joins the cluster head node according to their proximity. Cluster head uses the TDMA schedule to provide data transmission time to each and every node in the cluster.

2. Steady state phase: Data transmission is actually starts in this phase. According to TDMA schedule firstly, cluster member's sensed data is sent to their respective cluster head to avoid the collision. Data fusion and data aggregation are performed by each cluster member in the cluster head after receiving data and then processed data is sent to the base station.

iii)Problems in basic LEACH Protocol [4]:

Firstly, each node in the network has same probability to become a head of cluster without any consideration of its residual energy. So, if node with the low-energy is being chosen as a cluster head then the network performance will be highly affected. Secondly, as LEACH uses random selection algorithm while choosing cluster head, irrespective of their space from the base station. Greater the distance (distance between base station and cluster heads) means that the power consumption of the cluster head is greater, which further affects the network life.

Finally, Cluster Head node is responsible to process data and to send that processed information in single-hop to the base station. So, cluster head node's energy is depleted too soon as compared to other cluster member nodes.

IV. VARIANTS OF LEACH

i) LEACH-A: Classical LEACH protocol assumes all the nodes which can sense in the network have same energy whereas LEACH- A[7] is based on the concept of heterogeneous energy protocol with proliferating the stability period as the objective (i.e. the time gap before the first node dies) and decreasing the node's failure probability.

By using synchronised clock, each sensor node has prior information about the beginning of each round. Let 'n' be rhe total number of nodes and 'm' be the fraction of 'n', that have more energy as compared to other nodes in the network. Then (1-m)*n nodes are treated as normal nodes and rest nodes are termed as CGA nodes (Head of **C**luster or **GA**teways). CGA nodes, that perform the data aggregation and send the data to the base station.

Advantages of Leach-A protocol

The data gathering is performed to lower the amount of data that is to be sent. CDMA/TDMA schedules are used to prolong the lifetime of the network by saving energy. Even after the death of all normal nodes, CGA nodes continue to transmit data to the base station.

ii)LEACH-B: LEACH-Balanced protocol is advanced version of conventional LEACH by considering the remaining energy of the nodes while selecting the head of cluster. In LEACH-B [8], every node knows about its own place as well as the final receiver node position in prior and it does not have information about all other node's location in the network.

LEACH-B working process is same as LEACH with minor changes; first, each node selects a random number between 0 and 1, if chosen number is smaller than the threshold value. This selection process is mentioned in eqn.1, then that node becomes eligible for the selection of cluster head. Eligible nodes are organized based on their residual energy in descending order. Then only n*p number of nodes, out of eligible nodes are selected as a cluster head; where the total number of nodes is n and the required percentage of cluster head nodes is 'p' and remaining nodes resume their normal role as a cluster member. Steady-state phase for data transmission is

similar to that of LEACH. In [9], 3% to 5% out of 100 is the excellent number of heads of cluster is proved by authors in [9].

iii) LEACH-C: This protocol is the centralized version of LEACH, proposed in [10]. As the name suggests, the base station does the cluster head selection itself rather than by the nodes as in the case of LEACH. The base station is sent the information by each node regarding its location and level of energy. Based on received information from each node in the network, base station calculates the predetermined number of heads of cluster and then arranges the whole network into clusters. Post that, the node ids of the nodes are broadcasted by the base station in the network that has to be selected as cluster head. Then each cluster head node transmit message of advertisement to all other nodes and according to the strength of received signal, each node further acknowledges to the cluster head in their proximity for the current round.

Once the cluster is formed, the LEACH is same as steady-state phase. In LEACH-C, as base station has the global information for each node about location as well as energy level, produces better cluster formation which requires lesser energy for the transmission of data. Moreover, the number of cluster heads in every round is equal to the predetermined excellent value in Level whereas, the number of cluster heads varies in each round in LEACH.

iv)LEACH-E: LEACH-Energy protocol[11], is the enhanced version of LEACH, initially it is assumed that every node is furnished with equal amount of energy and have equal probability to be selected as a cluster head. At each round node's energy level changes and cluster head is selected.

Cluster formation process is same as in LEACH but after first phase, residual energy of each node varies and then basis of that each node decides whether they can turn in to cluster node or a cluster member in set up phase of first round. The cluster head sends advisement to all sensor nodes using CDMA-MAC protocol. Then, the nodes which are not turned in to a head of cluster transmit the message to the head of cluster to which they need to join depending upon the received strength of signal. TDMA schedule is transmitted by the head of cluster to all its members of cluster to avoid the traffic congestion in the network.

In steady-state phase, each member of the cluster transmits data to its respective cluster head, where the data is aggregated to reduce the redundancy and further transferred to base station through CDMA protocol. By consideration of energy load which is balanced among all nodes which can sense, LEACH-E improves the lifetime of sensor network.

v) LEACH-TL: LEACH-Two Level is advanced version of basic LEACH. LEACH-TL[4], shown in Fig. 3, works on the principle of two level hierarchies. In LEACH-TL, cluster heads those are near to the base station (level 1 cluster heads) transmits information to the base station. Level 2 cluster heads transmits gathering of data to level 1 cluster head as shown in figure. The energy used to send data from the cluster head to the base station is reduced and therefore the energy efficiency is improved and prolonging the life of network by using level 1 cluster heads in between the level 2 and base station as relay nodes.

LEACH TL increases the energy efficiency of complete network by introducing cluster head nodes as a relay between base station and other cluster head nodes [12]

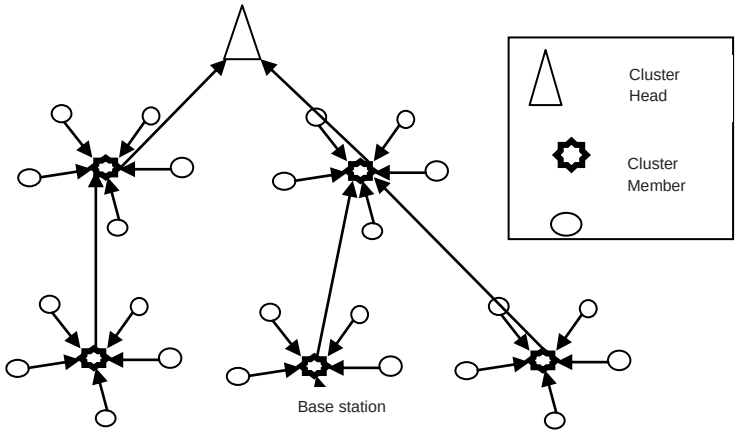

Fig.3. LEACH-TL Protocol

vi) LEACH-MH: Unlike LEACH-TL, in LEACH-MH there can be many hops in between base station to the cluster heads. In LEACH, irrespective of the distance, each cluster head is responsible for aggregated

information transmission to the base station. So, in that case cluster nodes that are far away from the base station deplete their energy at fast rate as compared to those that are near to base station. Moreover, with increased diameter of the network, the distance between cluster head and base station increases.

To enhance efficiency of energy of the whole network multi-hop routing is proposed by the author [13]. Here a data transmission takes place one cluster head to other hop wise. The cluster heads those are in the proximity of base stations are finally responsible for transmitting the gathered data to the base station. The best path between the cluster head and base station is adopted by this protocol.

vii) LEACH-VH: LEACH-Vice cluster Head [14], shown in Fig. 4, protocol is the enhanced version of LEACH. In every variant of LEACH, the transmission of data to base station is done by only cluster head. So, cluster head dies early as compared to other cluster members because of its operation of transmitting and receiving. After the death of cluster head, the whole cluster becomes unimportant as data gathered by cluster head will never be able to reach to the base station. To avoid this, LEACH-V is introduced; in which other than cluster head, there is also a vice- cluster head that becomes active and performs the same role as cluster head when cluster head dies.

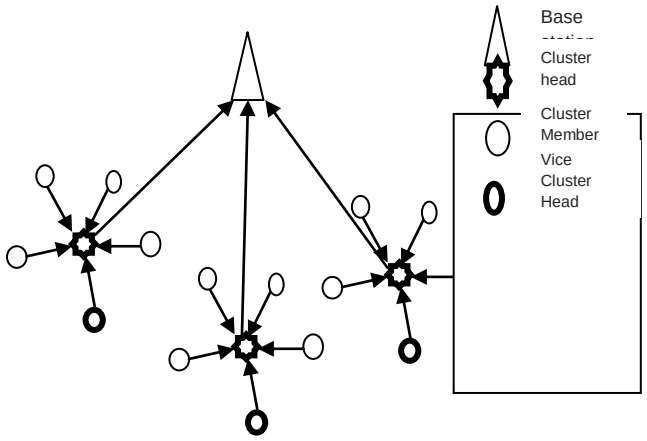

Fig.4. LEACH-VH Protocol

The election process for vice cluster head is different and mainly depends upon three factors; maximum residual energy, shortest distance and minimum energy. Depending upon the signal strength which is received, every non-cluster node finds out its head of cluster, higher the strength of signal leads to lower the distance between them and further less energy is required for transmission.

LECAH-VH improves the life span of the network; as soon as cluster head dies it is recovered by other backup vice cluster head node.

viii) LEACH-M: In LEACH, mobility of base station and sensor nodes is the major issue. LEACH-M is introduced to combat this issue. During both phases (Set up and steady state), mobility of cluster members and cluster head nodes is supported in LEACH-M [15][16]. Initially, it is assumed that all the nodes which can sense are homogenous according to their initial energy, their location is known to them through GPS and base station is immobile. The election of the head of cluster is based upon the smallest attenuation rate and less mobility. Post election of cluster head, the working process of LEACH is same as LEACH-M.

ix) Node-Ranked LEACH: This protocol improves the energy efficiency of LEACH protocol by giving away the energy load amidst all the sensor nodes. Node Ranked Algorithm (NRA) [17] is opted by this protocol that includes the cost of path and the number of connections between nodes while selecting cluster heads in each round.

Every round is classified into two phases setup phase followed by steady-state. Each node knows whether it acts as a cluster head or a member of cluster for the ongoing round during setup phase. Cluster head selection depends upon the node rank algorithm (NRA).By using equation 2, node rank score NR (n_i) is calculated for each node i. Where, NH is the set of neighbours for the k, d_{out}^{ji} is the distance from node j to node i for out link edges, PO (n_i) is the current energy of node i, and the damping factor is α. Recent studies have been checked many damping factors (α) affirming that the suitable factor is 0.85 as cited in El-Fishawy et. al.

$$NR(n_i) = PO(n_i) * \alpha * \sum_{0}^{j} NR\,(n_j) \frac{\frac{1}{d_{out}^{ji}}}{\sum_{k \varepsilon NH} d_{out}^{jk}} + (1-\alpha)$$

.....2

If a node is connected by other nodes in the network then it is to be considered as important. The calculation in each pass is repeated until convergence score is arrived according to an algorithm, which is mentioned in equation 2. A calculated node's node rank NR (n_i) is stored without characterizing the end value. In each iteration, a closer weight of an end value is achieved.

NRA algorithm[17] stores the result value and recalculates until the values halt changing. Now, the node with highest NR value will be elected as a head of cluster for present round.

V. COMPARISON OF LEACH PROTOCOLS

Table 1: Comparison among LEACH variants protocols

Hierarchical Based Routing Protocol	**Self Organisation**	**Mobility**	**Hop Count (Single)**	**Heterogenous**	**Centralized**	**Data aggregation**	**Use of location information**	**Use of residual energy**
LEACH	✓	x	✓	X	x	✓	x	x
LEACH-A	✓	x	✓	✓	x	✓	x	✓
LEACH-B	✓	x	✓	X	x	✓	✓	✓
LEACH-C	✓	x	✓	X	✓	✓	✓	x
LEACH-E	✓	x	✓	✓	x	✓	✓	✓
LEACH-TL	✓	x	X	X	x	✓	✓	x
LEACH-MH	✓	x	X	X	x	✓	✓	x
LEACH-VH	✓	x	✓	X	x	✓	✓	x
LEACH-M	✓	✓	✓	✓	x	✓	✓	x
LEACH-NR	✓	x	✓	X	x	✓	✓	✓

VI. CONCLUSION

The enhancement of life span of WSN has been always the major issue due to restricted amount of energy resource of the sensor nodes. LEACH routing protocol (Hierarchical Routing) is considered one of the energy efficient protocol. In this paper, we described the conventional LEACH routing protocol with its shortcomings and how those shortcomings are overcome by opting LEACH descendants' protocols that are the advanced versions of LEACH. LEACH descendants protocols are briefly described in order to make their performance comparison with conventional LEACH.

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