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Energy Efficient Threshold Based Cluster Head Selection and Optimized Routing in Wireless Sensor Networks

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Abstract— In recent years Wireless Sensor Network has become a leading area of research because of its efficiency in design. A Sensor is a device that senses input from both the physical or environmental conditions, like pressure, heat, light, etc., and then respond to that input. One of the major issues faced by the WSN is high energy consumption. This will decrease overall network lifetime. To overcome these problems, propose a new energy efficient cluster-based routing protocol(ET-LEACH) for wireless sensor network, in which clustering is used to create hierarchical WSNs that helps to extend network lifetime by efficient utilization of limited resources of sensor nodes. This protocol is an improvement for LEACH protocol. Routing must be done in energy efficient manner, dynamic routing is preferred for proposed protocol. We group sensor nodes into clusters and cluster head selection is based on node's residual energy. If we use a complicated method to select the cluster head, performance overhead increases, this will affect the overall network performance. Comparing node's energy with a threshold value, re-election of cluster head is take place. In this paper, we chose the cluster head depending upon this threshold value not by periodically. The sensed information is sent through the cluster heads and reach the base station. In wireless sensor network most important is its network lifetime, this paper help to increase the network lifetime and scalability. Also, maintain balanced energy consumption that causes efficient load balancing.

Keywords— Clustering, Energy consumption, LEACH protocol.

I. INTRODUCTION

Currently, wireless sensor network is the most relevant network employed in industrial and commercial applications. Spatially distributed autonomous devices that using sensors to sense physical or environmental conditions, this creates a network called wireless sensor network. Sensor nodes in the WSN are used to observe the surroundings like temperature, humidity, pressure, position, vibration, sound etc. These nodes are computers very small in size and perform job jointly to form the networks. The communication between nodes can be done with each other using transceivers. In a wireless sensor network, the number of nodes can be in the order of hundreds/ even thousands depending upon the application.

WSNs are used in commercial applications like seismic activities prediction and monitoring in environmental trackings, such as forest detection, animal tracking, forecasting, flood detection and weather prediction, and also. And also used in military applications, healthcare monitoring, industrial applications etc. The sensor node is the main part of a WSN. Those nodes have the capability to detect data from their environment and forward them to a central node called sink or a base station for further processing. The power module of the node offers the reliable power needed for the system, but given the nature of the WSN, the nodes are designed in tiny sizes with limited power and computation capabilities. Different applications are being implemented using WSN, but the realization of such a network needs to satisfy the constraints introduced by different factors such as energy consumption, non-rechargeable batteries and network lifetime.

Routing in the wireless sensor network must be efficient because of the limitations on the power supply, transmission bandwidth, and processing capability. Routing protocols in WSNs is classified into three categories based on the underlying network that are: flat routing, hierarchical (Cluster-based) routing and location-based routing. To achieve high scalability and increased energy efficiency and to enhance the network lifetime the researchers have highly adopted the scheme of forming clusters i.e. grouping the sensor nodes in large-scale wireless sensor network environments. Basically, a clustering scheme determines a set of nodes that can provide a backbone to connect the network to the base station. These type of nodes are called cluster heads and the remaining nodes of the network are referred to as member nodes.

The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensor's proximity to the cluster head.

Rest of the paper is organized as follows, Section I contains the introduction of the wireless sensor network and cluster based routing , Section II contain the related work of routing protocols in the wireless sensor network, Section III contain the explanation of our proposed work Section IV contains the simulation scenario and its result analysis, section V concludes research work with future directions

II. RELATED WORK

Energy consumption is the one of the main constraints of the wireless sensor network and to increase the network lifetime routes for data transfer chosen in an energy efficient manner. Clustering is an efficient method that increases the network lifetime by decreasing the energy utilization, provides the necessary scalability and better data aggregation. Main objectives of the clustering are load balancing, fault tolerance, lesser energy consumption, latency deduction, more robustness, energy-hole avoidance, collision avoidance, improved connectivity and lesser delay. Some of the cluster based routing protocols are LEACH, PEGASIS, TEEN, APTEEN, HEED, UCS, PEACH, DAIC etc. [1]. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol for WSNs, which is widely used an elegant clustering algorithm, by selecting the CHs in rounds. Power-efficient gathering in sensor information systems (PEGASIS), which is an improvement over the LEACH [2]. It is chain based protocol, in which nodes need to speak with their nearest neighbours and alternate in speaking with BS. A hierarchical clustering based protocol produced for responsive systems in which nodes respond instantly to sudden and extreme changes in the environment known as TEEN [3]. Adaptive Periodic Threshold-Sensitive Energy Efficient Sensor Network scheme (APTEEN) is related to TEEN and goes for both sending occasional periodic and respond to critical times [4]. Hybrid, Energy - Efficient and Distributed (HEED) clustering approach for ad hoc sensor networks is the prominent energy-proficient node clustering algorithm [5]. Using this approach periodically chooses cluster heads based on a hybrid of two clustering parameters, first one is the leftover energy of every sensor node and the second parameter is the intra-cluster correspondence cost as a component of neighbour vicinity or cluster density. First unequal clustering model, called Unequal Clustering Size (UCS) to adjust energy utilization [6]. This protocol makes two-layered network model and two-hop inter-cluster communication method. That will result in a shorter average transmission distance contrasted and LEACH, in this way successfully lessens the complete energy utilization. Power-Efficient and Adaptive Clustering Hierarchy (PEACH) convention is proposed for WSNs to broaden system lifetime [7]. The nodes in the system can perceive the source and destination of the information packets by overhearing attributes of wireless correspondence. Distance-Aware Intelligent Clustering (DAIC) is a progressive routing convention proposed to minimize the energy utilization and expand the system lifetime [8].

LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that performs randomized rotation of local cluster-heads to evenly distribute the energy load among the sensor nodes in the network [9]. To enable scalability and robustness for dynamic networks, LEACH utilizes localized coordination. And also incorporates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station. Data transfer to the base station take more energy, all the sensor nodes inside a cluster take turns with the transmission by rotating the group heads. This causes balanced energy utilization of all nodes and that gives a more extended lifetime of the system. A predefined value, P (the desired percentage of cluster heads in the network), is set before beginning this algorithm. LEACH works in several rounds where each round has two stages, the setup stage, and the steady stage. In the setup stage, each node chooses whether to end up a cluster head or not. Each node picks a random number p between 0 and 1, which is the likelihood to elect itself as a cluster head. If the probability p is less than a threshold for a node, that node will become a cluster head for the current round. During the steady phase, the sensor nodes can start sensing and transmitting information to the cluster heads. The cluster heads also aggregate data from the sensor nodes in their cluster and send data to the base station. After a specific time period spent on the steady phase, the network goes into another round of choosing the cluster heads. The length of the steady phase is longer than the span of the setup phase with a specific end goal to minimize the overhead. The change of the threshold equation by the remaining energy may be another issue.

Some of the LEACH improvements like LEACH-C, I-LEACH, K-LEACH, F-LEACH etc., these studies proved that the efficiency of clustering technique increases the network life-time. LEACH-C provide a centralized clustering algorithm in which base station verifies that participating node has enough energy to become cluster head [10]. In I-LEACH cluster head can be selected based on three parameters residual energy, no of neighbours and distance to base station, this will help to increase network life time[11].

K-LEACH is same as LEACH protocol only difference is threshold equation is modified, the k-medoid algorithm for uniform clustering [12]. For cluster head selection Euclidean distance and highest residual energy is used. In F-LEACH protocol, a fuzzy logic module to select cluster head and manage re-clustering process [13]. That aims to increase the network lifetime by enhancing the LEACH clustering process. If the residual energy of the current cluster-head exceeds Relative Energy Level, each node conserves his role. The cluster-heads send the TDMA (Time Division Multiple Access) schedules to other nodes in that cluster in order to send the sensed data. This fuzzy logic scheme is a distributed algorithm executed by member nodes during some rounds in order to select the optimal cluster-head. The algorithm uses three parameters: the remaining energy of the node, the remaining energy of the current cluster-head, the Position.

In clustering-based routing protocols, cluster heads are chosen among all sensor nodes that are present in the network. The main drawback is that there is no control on the distribution of cluster heads over the network. To overcome this problem, propose a swarm intelligence based fuzzy routing protocol (named SIF) [14]. The fuzzy c-means clustering algorithm is invoked SIF to cluster all sensor nodes into balanced clusters, and Mamdani fuzzy inference system is used for selecting appropriate cluster heads. This method not only guarantees to generate balanced clusters over the network but also has the strength to determine the correct number of clusters

An energy balanced clustering protocol, EBC-PSO, that using particle swarm optimization technique [15]. The main aim of EBC-PSO is to select a set of CHs that distributed uniformly over sensing area such that load on each CH is balanced. Fitness function used in PSO for the selection of CHs considers is a multi-objective function which includes three parameters such as intra-cluster distance, residual energy, and average cluster size.

III. PROPOSED METHOD

This area gives the detailed explanation of proposed protocol, ET-LEACH (Energy and Threshold based LEACH). The initial step is to partition the network filed into non-overlapping square unit based on no of common nodes and cluster size. This partition is fixed for the complete simulation, re-clustering is not take place. This partition helps to minimize network overhead and also balance the clusters in that network. After the network partition clusters are formed next step is to choose appropriate cluster head selection based on a threshold value and node's energy. Data is transferred from common nodes to cluster head and cluster head to base station. Optimal routes are discovered for intra and inter cluster routing. The Cluster head is re-elected non-periodically by comparing with a lower threshold value.

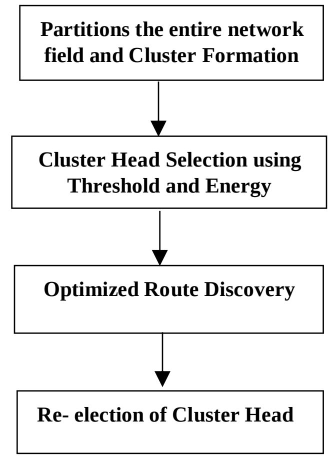

Fig: Working of ET-LEACH

A. Network Model

We make some assumptions for the simulating network field. Following assumptions are used for our approach.

- The base station is placed in centre of the network field and it has more resources compared to the common node.
- Sensor nodes are randomly deployed in a two-dimensional network field.
- All nodes are static in entire network lifecycle.
- The Heterogeneous network is considered.

B. Partition of the Network Field and Cluster Formation

At the network initialization phase base station broadcast message that contains control information like BaseStation_ID and its position information. It is received by the neighbours around the base station. They store this information in the routing table and increase the hop count. After that send to its neighbours. This will be continued until all node get this control information. Each node sends its position details to its neighbours and base station get global information about the network.

Partition the network field into a finite no of cells that form grid structure that helps fast processing. Optimum no of the cluster can be can be calculated by dividing the network field by the optimum size of the cluster.

$$c = f / k \qquad - (1)$$

Where c is the optimum no of clusters, f is the network field and k is the cluster size. These formed clusters are uniformly distributed over the field like a grid. The base station assigns unique Cluster_ID to each cluster. In many existing systems cluster head can be selected first and then suboptimal clusters are formed depending upon the Cluster head position. This will cause cluster unbalancing problem. In our approach, balanced clusters are formed by this virtual partition of the network field.

Algorithm 1 Network Partition

```
Input: no of nodes N
Output: partitioned network filed
1.  Compute aux=sqrt(N)
2.  For each node k ϵ [1:N] do
3.      Send (x_k,y_k) coordinates of node k
4.  End for
5.  Determine next x and y value for partition
        X=((node id % aux)* x)/(aux-1)
        X=((node id % aux)* y)/(aux-1)
6.  End
```

C. Cluster Head Selection

To initiate the cluster head selection calculating the common node's current energy values. First of all threshold value must be chooses. In our approach soft threshold value is used to avoid over performance overhead. The initial energy of the sensor nodes is chosen manually. So higher threshold can be set manually by half of the initial energy. In ET-LEACH protocol no of nodes used for participating in the cluster head selection is limited. We can decrease communication overhead that results in lower energy consumption. First of all comparing energy of the node with the higher threshold value, if node's energy is higher than the threshold it can participate in the cluster head selection. A node with the highest energy can be selected as cluster head among this participating node. Selected cluster head broadcasts advertise message to its members within the cluster. This message contains ClusterHead_ID, its position information, and Cluster_ID. Sensor nodes which are not in that particular cluster identify the Cluster_ID from the message and ignore that message. All sensor nodes in the cluster get the information about the cluster head. After sending the advertising message, cluster head wait for the join request from the member nodes in that cluster. Member nodes inform the cluster head by sending joining request. Then cluster head creates a TDMA schedule and broadcast within advertising message. Data sent to the base station is scheduled. In each round, this will perform continuously until there is no node for participating in the cluster head selection.

Algorithm 2 Cluster Head Election

```
Input: no of nodes N
Output: new cluster head CH
1.  for each node i ϵ [1: N] do
2.      node_id[i]= i.get_node_id()
3.      node_energy[i] = i.get_node_energy()
4.  End for
5.  Set max=-1
6.  For  each node i ϵ [1: N] do
7.     If node_id(i)> threshold then
8.         If node_energy(i)>max then
9.            Max=node_id(i)
10.        End if
11.    End if
12. End for
13. Set CH=Max
14. For each node i ϵ CHs do
15.      i.send(ADV)
16.      for each node j ϵ cluster(i) do
17.          j.response(CH[i])
18.     End for
19. i.send(TDMA time slot)
20. end for
21. end
```

D. Optimized Route Discovery

Route discovery is also important in the wireless sensor network. The less efficient route will decrease the network lifetime. Here we propose optimal routes for inter and intra cluster routing. In small-scale wireless sensor network inter cluster routing is single hop based routing that is cluster head directly forward aggregated data to the base station. But in large scale network, single hop communication will decrease the network life time. At this situation we can use multi-hop communication, which means, cluster head send data to the base station through neighbouring cluster heads. In intra cluster routing member nodes directly send sensed data to its cluster head. Cluster head aggregates the data and then send to the base station.

E. Cluster Head Re-election

A sensor node set as cluster head use more energy than other member nodes, so the possibility of node become die is high so check the node's energy with the lowest threshold value continuously. If node's energy is less than the threshold value then cluster head re-election takes place. Node with highest energy and that must be greater than the highest threshold value is taken as new cluster head, all other steps after the cluster head selection are repeated.

IV. SIMULATION AND PERFORMANCE ANALYSIS

A. Simulation Environment

In this section firstly discussing NS-2, which is used for creating wireless sensor network scenario. And then analyse the proposed method based on this simulation experiment. A patch named as Mannasim is integrated with NS-2.35 for simulating wireless sensor nodes. The scenario is created with the following parameters. Here we considered 100×100 m^2 two-dimensional network filed and 20 nodes are randomly deployed. Base station is also placed in the centre position. Transmission range is set to 25m for all nodes. Initial energy of each node is 10J. Nodes act as static in the network. Total simulation time is set to 100ms and time interval for each round is 20 s.

TABLE I
SIMULATION PARAMETERS

Parameter	Value
Network Field	100×100 m^2
Initial energy	10 J
Transmission rate	50
No of clusters	1
No of common nodes	20
Simulation time	100 ms
Round period	20

B. Simulation Analysis and Results

The upcoming section analyse the performance of the proposed protocol and compared with LEACH protocol. To analyse and compare the proposed protocol, we use the following performance metrics.

- Total no of alive nodes: This metric shows that overall network lifetime. Gives an idea about no. of alive nodes per time.
- The energy of all nodes per time: This metric indicates that energy dissipation of all node per time. Using this metric we can find cluster is balanced or not.
- Total sensed temperature values per time: This metric gives an idea about how efficiently sensing.
- Cluster Head Energy dissipation: This metric shows Cluster head node energy usage per time.

We have simulated different protocols. That is temperature sensing of nodes was done by using two protocol i.e. our proposed protocol (ET-LEACH) and LEACH. We observe that the lifetime of the network is more when using our protocol.

Figure 4.1 compares ET-LEACH with LEACH with respect to no of alive nodes per time. From the figure, no of alive nodes in ET-LEACH is more than that in LEACH with respect to time. That means network lifetime is extended in our proposed protocol.

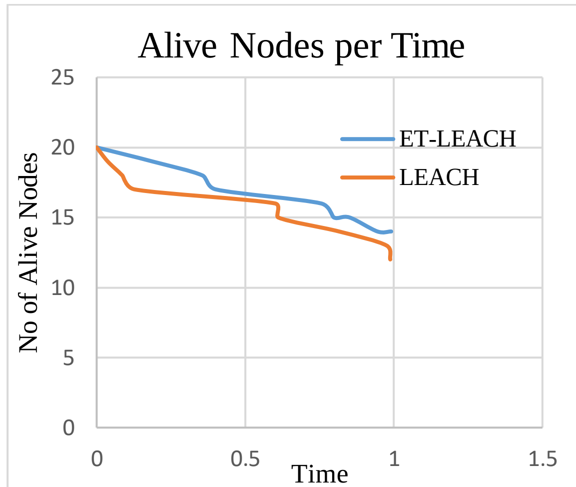

Fig 4.1 Comparison of No of Alive Nodes for LEACH and ET-LEACH

For analyzing load balancing of nodes plot xgraph with nodes energy with respect to time shown in figure 4.2 and 4.3. From Figure 4.3 load is balanced perfectly in ET-LEACH compared to LEACH in figure 4.2. This will help to increase the overall performance of the network.

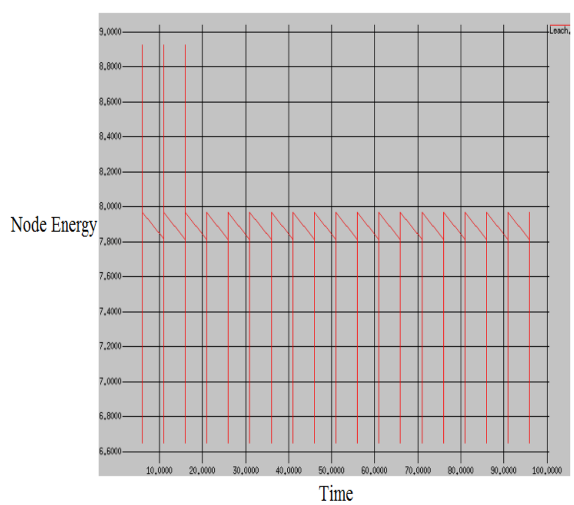

Fig 4.2 Load balancing in Leach

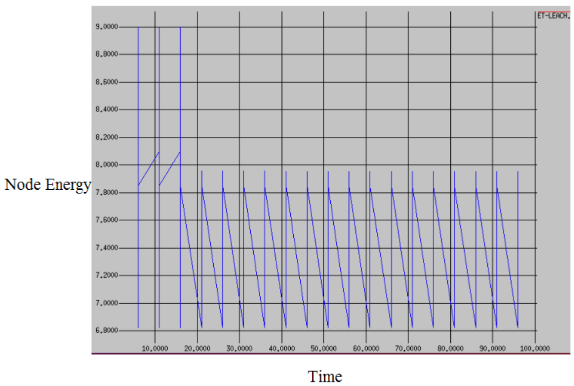

Fig 4.3 Load Balancing in ET-LEACH

Total sensed temperature value per time is plotted in Figure 4.4. From the figure, total sensed data in a given time is higher in ET-LEACH compared to LEACH. We can prove that our proposed protocol improve the node performance.

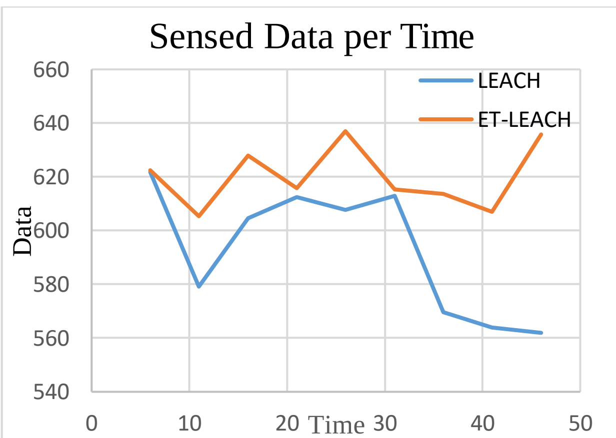

Fig 4.4 Sensed Temperature Data per Time.

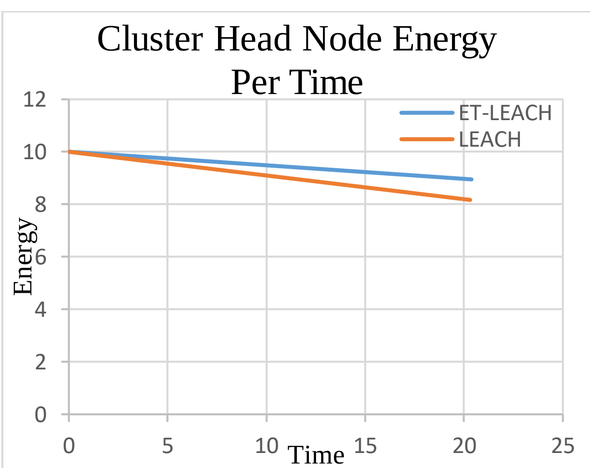

Fig 4.4 Cluster Head node Energy per Time.

The energy of the cluster head node per time is plotted for analyzing the efficiency of cluster head and its energy dissipation. Figure 4.5 shows the cluster head energy dissipation over time.

From this analysis, we can conclude that our proposed protocol is more efficient than LEACH protocol. The network lifetime of the ET-LEACH used wireless sensor network is extended.

V. Conclusion and Future Scope

Proposed protocol, ET-LEACH is an enhancement of clustering protocol, LEACH by using energy efficient, threshold based cluster head selection method. This will leads to least computational overhead. The simulation studies shows that best performance is obtained while using the proposed ET-LEACH in the network and also increase network lifetime. This new protocol compared with the existing routing protocol LEACH, clusters are balanced in ET-LEACH compared to LEACH protocol. Load balancing is also achieved in our protocol by using threshold based cluster head selection. Our work mainly concentrated in energy consumption of network. While using clustering and TDMA time scheduling congestion is avoided efficiently and packet dropping is decreased. In future non periodic cluster head selection method can be preferred to enhance the network.

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