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# An Efficient Routing Protocol design and Optimizing Sensor Coverage Area in Wireless Sensor Networks

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**Abstract:** ***Wireless sensor networks (WSN) represent a new paradigm shift in ad-hoc networks. Wireless Sensor Networks consists of small nodes with sensing, computation and communication capabilities. The sensor networks task is to sense the environment, and relay the information back to a remote base station using multi-hop infrastructure less architecture, where the user can access it. Also since power awareness is an essential design issue in designing a routing protocol for Wireless Sensor Networks, a novel hierarchical based clustering protocol called Efficient Routing Protocol (ERP) for data gathering and aggregation is also proposed for long-lived sensor networks. This proposed protocol handles the redundancy of data problem by using a proper routing tree construction method, thus, ensuring that only effective data is being transmitted through the network. Also it ensures good performance in terms of lifetime by minimizing power consumption for in-network communications and balancing the power load among all the nodes.***

**Keywords:** sensor, power, energy, base station

## 1. Introduction

Sensing devices have the capabilities of sensing, computation, self organizing and communication known as sensors [1]. Sensor is a tiny device used to sense the ambient condition of its surroundings, gather data, and process it to draw some meaningful information which can be used to recognize the phenomena around its environment. These sensors can be grouped together using mesh networking protocols to form a network communicating wirelessly [2] using radio frequency channel. The collection of these homogenous or heterogeneous sensor nodes called wireless sensor network (WSN).

## 2. Sensor Network Architecture

The basic entities in sensor nodes are sensing unit, power unit, processing unit and communication unit and memory unit to perform these operations shown in Figure 2.1. Sensor is a hardware device used to measure the change in physical condition of an area of interest and produce response to that change. Sensors sense the environment, collect data and convert it to fundamental data (current or voltage etc) before sending it for further processing. It converts the analogue data (sensed data from an environment) to digital data and then sends it to the microcontroller for further processing. This unit of sensor node is used to store both the data and program code. A node consist a power unit responsible to deliver power to all its units [1].The Processing unit is responsible for data acquisition, processing incoming and outgoing information, implementing and adjusting routing considering the performance conditions of the transmission.

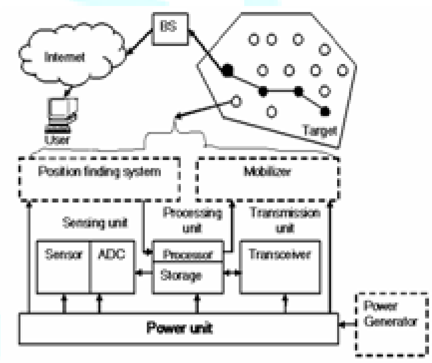


**Figure 2.1:** Architecture of sensor network

## 3. Literature Survey and Related Works

In hierarchical-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes' positions are exploited to route data in the network. A routing protocol is considered adaptive if certain system parameters can be controlled in order to adapt to the current network conditions and available energy levels. The classification is shown in Fig 3.1 where numbers in the figure indicate the references.

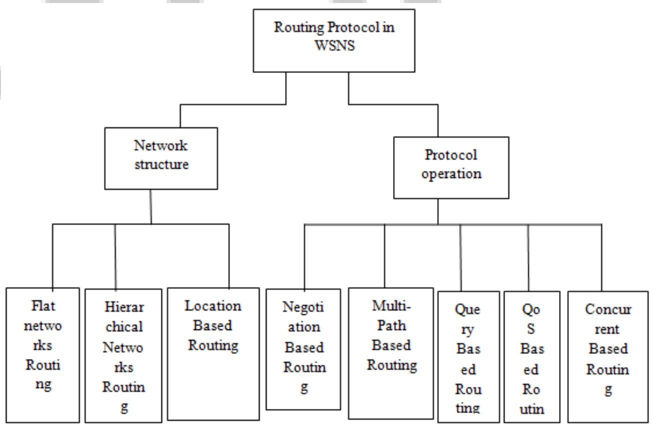


**Figure 3.1:** Taxonomy of routing protocols in WSN

Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing [4].

### 3.1 LEACH protocol

A hierarchical clustering algorithm for sensor networks, called Low Power Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the power load among the sensors in the network. In LEACH [2], the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station.

The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the base station takes place. A sensor node chooses a random number, r, between 0 and 1. If this random number is less than a threshold value, T (n), the node becomes a cluster-head for the current round [2].

The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G. It is given by

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \quad if\ n \in G$$

Where G is the set of nodes that are involved in the CH election. Each elected CH broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster-heads. All the non-cluster head nodes, after receiving this advertisement, decide on the cluster to which they want to belong to. This decision is based on the signal strength of the advertisement. The non cluster-head nodes inform the appropriate cluster-heads that they will be a member of the cluster [3].

After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster. During the steady state phase, the sensor nodes [5] can begin sensing and transmitting data to the cluster-heads [6] [7]. The cluster-head node, after receiving all the data, aggregates it before sending it to the base-station [8] [9].

## 4. Proposed Approach

Proposed approach presents a general distributed hierarchical clustering scheme called ERP (Efficient Routing Protocol) for saving power consumed by communication. In LEACH, the nodes organize themselves into local clusters, with one node acting as the cluster head. All non-cluster head nodes transmit their data to the cluster head, while the cluster head node receives the data from all the cluster members, performs signal processing functions on the data (e.g., data aggregation), and transmits data to the remote BS (Base Station). Therefore, being a cluster head is more power intensive than being a non-cluster head node. If the cluster heads were chosen a priori, and fixed throughout the system lifetime, these nodes would quickly use up their limited power. Once the cluster head runs out of power, it is dead. On the other hand, in ERP, after the cluster formation phase, the node with the higher ratio of residual power to average residual power of its cluster range will have a higher probability to become the cluster head.

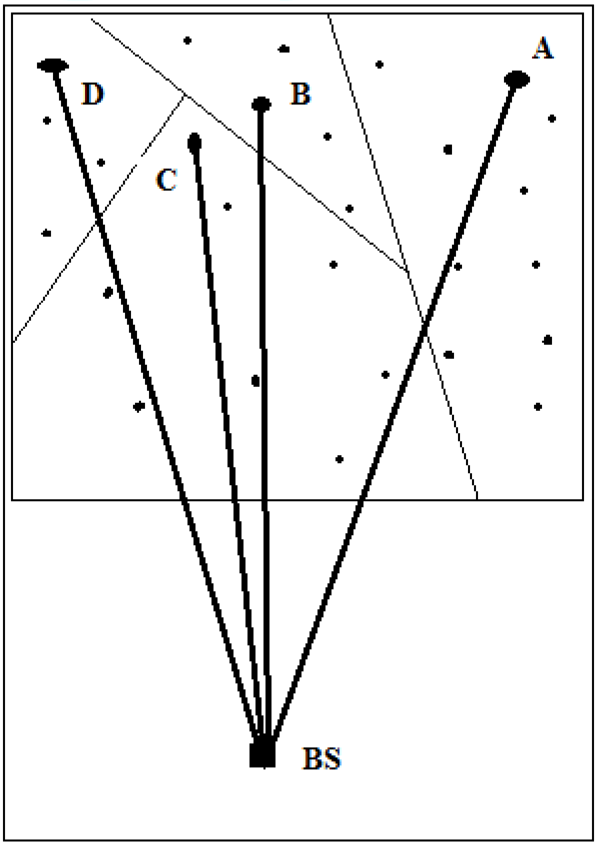


**Figure 4.1:** Illustration of LEACH Protocol

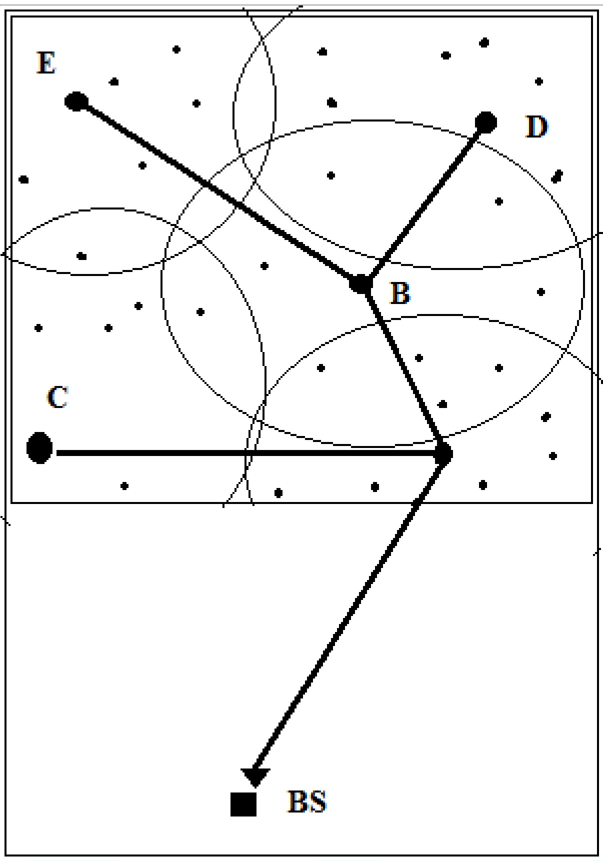


**Figure 4.2:** Illustration of ERP Protocol

Once, the cluster heads are elected in all the clusters, one node is selected among the cluster heads as the only node (called the root node) to communicate with the BS (also known as the sink node). Thus, all the other cluster heads collect the data from their respective clusters and then send them to the root node. After data aggregation, this data is then sent to the BS as the effective data.

### 4.1 ERP Protocol

ERP also follows the round operation. Each round includes three phases: Tcluster, Ttree, and Tdata. In the phase of Tcluster, after the cluster head selection, the selected cluster head receives the messages sent by all the member nodes that are about to join the cluster head. According to the number of its member nodes, the cluster head creates the TDMA schedule and broadcasts it to all the member nodes in the cluster. In the second phase, Ttree, which begins after clustering, one cluster head is selected from the set of other cluster heads as the only node CHb (Cluster Head at the base or BS) to communicate with the Sink node, so as to increase power efficiency. With CHb treated as the root, other cluster heads as the offspring of CHb are organized to form the appropriate minimum spanning tree.

In the phase of Tdata, the member node in one cluster [10], according to the assigned slotted time, sends data to the cluster head. The cluster head continues to wait till it receives the data sent by all its offspring nodes in the spanning tree, and then it sends the aggregated data to its parent node. The above steps are repeated till the aggregated data reaches the BS, which sends the final aggregated data to the sink node.

The time line showing the ERP operation is shown below:

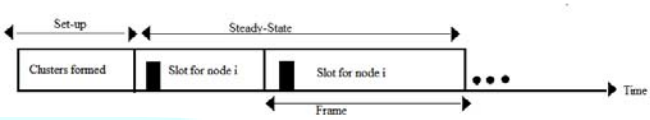


**Figure 4.3:** Time line showing ERP operation

Tcluster and Ttree belong to the Set-up phase. Tdata belongs to the steady-state phase. In the steady-state phase, to reduce power dissipation, each non-cluster head node uses power control to set the amount of transmission power based on the received strength of the cluster head advertisement. Furthermore, the radio of each non-cluster head node is turned off until its allocated transmission time. Since, the design for this approach is going to be optimized when all the nodes have data to send to the cluster head, using a TDMA schedule is an efficient use of bandwidth and represents a low-latency and power-efficient approach.

Pseudo Code of ERP

```
If (round=1)
Bs_str=Receive_Str ("hello")
Broadcast (its E_Msg)
Receive (E_Msg from its neighbor)
Update (neighborhood table)
If (Eresidual<=Emin)
P=0
Else p=pinit
IS_CH=false
While (p<1)
Receive (other messages from its neighbors)
Update (CH_Set)
If (CH_Set=empty&& p<1)
If (random (0, 1) <=p)
Broadcast (ID, temp, PRI)
Else if (CH_Set=empty and p=1)
Broadcast (ID, CH, PRI)
Is_CH=true
Elseif (CH_Set! =empty)
HEAD_ID=Max_PRI (CH_Set)
If (Si Ɛ CH_Set && Si'PRI is largest)
If (p=1)
Broadcast (ID, CH, PRI)
IS_CH=true
Else Broadcast (ID, Temp, PRI)
p=min (2*p, 1)
If (IS_CH+true)
Broadcast (ID, CH)
Else
If (CH_Set=empty)
Broadcast (ID, CH)
Else
Join_Cluster (HEAD_ID, ID)
```

## 5. Simulation Using OMNet++

### 5.1 LEACH Protocol

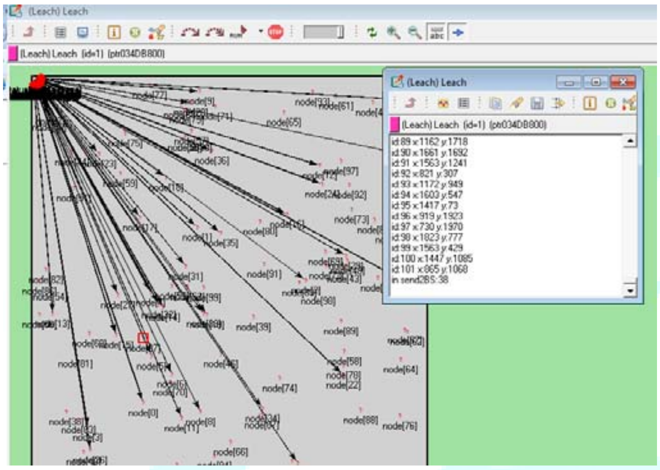

**Figure 5.1:** Sensor nodes registering with Base station

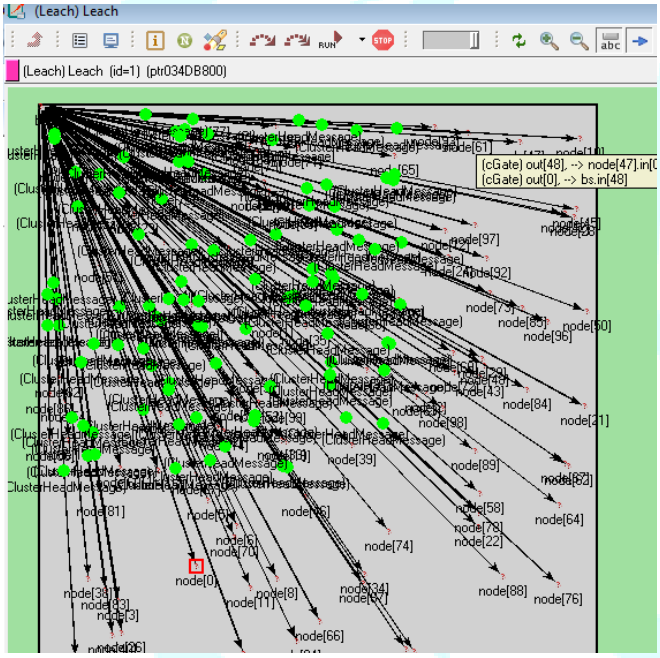

**Figure 5.2:** Base station sends the ACK to Sensor nodes

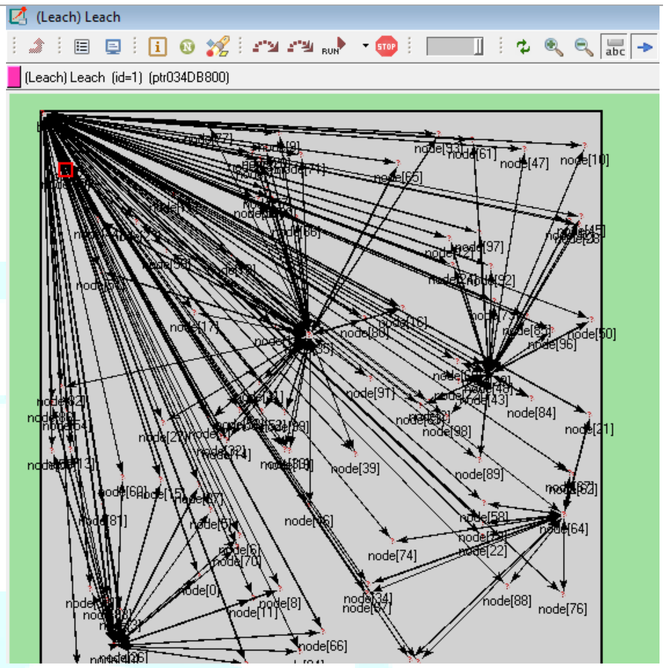

**Figure 5.3:** LEACH Cluster Formation

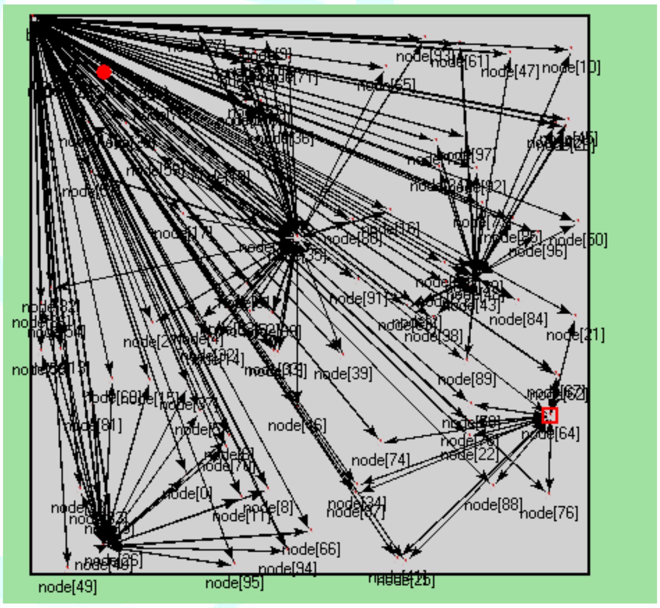

**Figure 5.4:** Data Transmission phase

**Figure 5.5:** Trace file Results for LEACH

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## 5.2 ERP Protocol

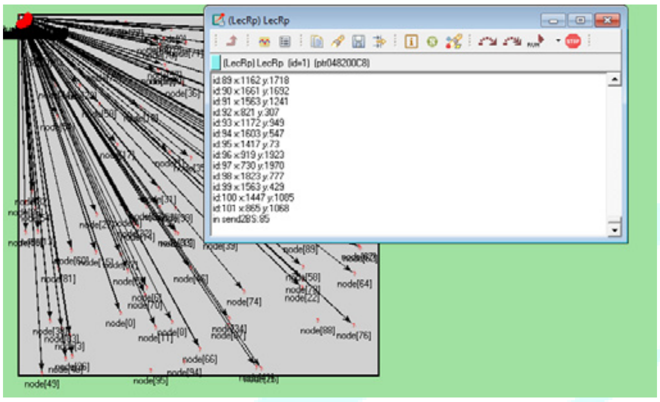

**Figure 5.6:** Sensor node registering with base station

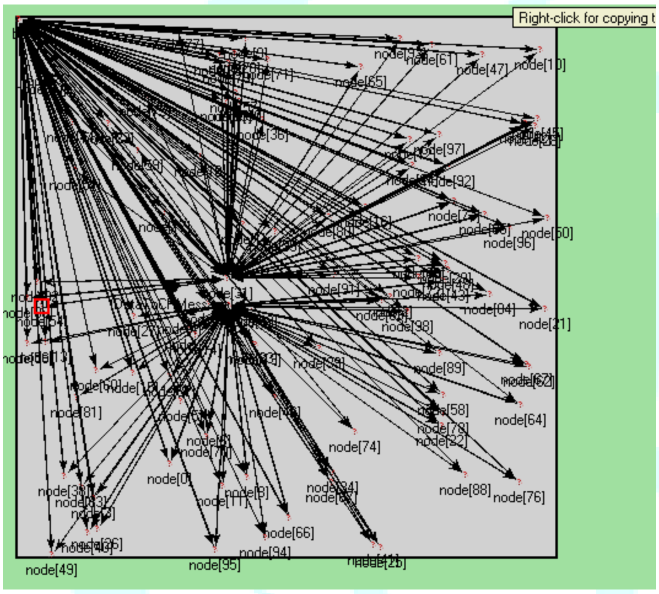

**Figure 5.7:** Data transmission phase

```
tdma 78done
** Event #391  T=1  LecRp.node[78] (Node, id=81), on `{}' (TDMAMessage, id=439)
80: received TDMA frameTime 53
80: found slot time 41
loop done
tdma 80done
** Event #392  T=1  LecRp.node[81] (Node, id=84), on `{}' (TDMAMessage, id=440)
83: received TDMA frameTime 53
83: found slot time 42
loop done
tdma 83done
** Event #393  T=1  LecRp.node[83] (Node, id=86), on `{}' (TDMAMessage, id=441)
85: received TDMA frameTime 53
85: found slot time 43
loop done
tdma 85done
** Event #394  T=1  LecRp.node[84] (Node, id=87), on `{}' (TDMAMessage, id=442)
86: received TDMA frameTime 53
86: found slot time 44
loop done
tdma 86done
** Event #395  T=1  LecRp.node[87] (Node, id=90), on `{}' (TDMAMessage, id=443)
89: received TDMA frameTime 53
89: found slot time 45
loop done
tdma 89done
** Event #396  T=1  LecRp.node[88] (Node, id=91), on `{}' (TDMAMessage, id=444)
90: received TDMA frameTime 53
90: found slot time 46
loop done
tdma 90done
** Event #397  T=1  LecRp.node[89] (Node, id=92), on `{}' (TDMAMessage, id=445)
91: received TDMA frameTime 53
91: found slot time 47
loop done
tdma 91done
** Event #398  T=1  LecRp.node[94] (Node, id=97), on `{}' (TDMAMessage, id=446)
96: received TDMA frameTime 53
```

**Figure 5.8:** Trace file results for ERP Protocol

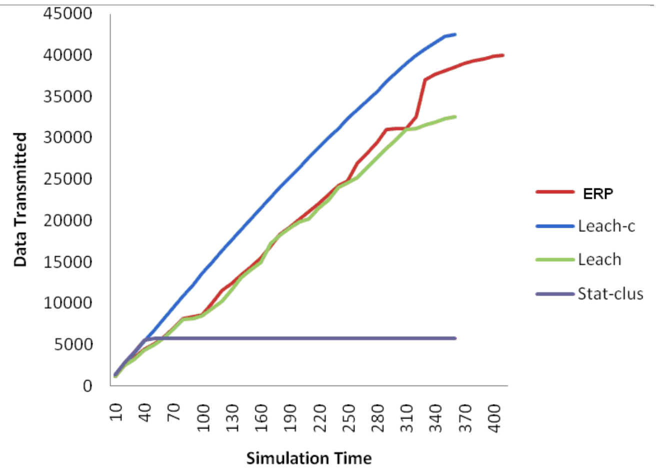


**Figure 5.9:** Total data received with time

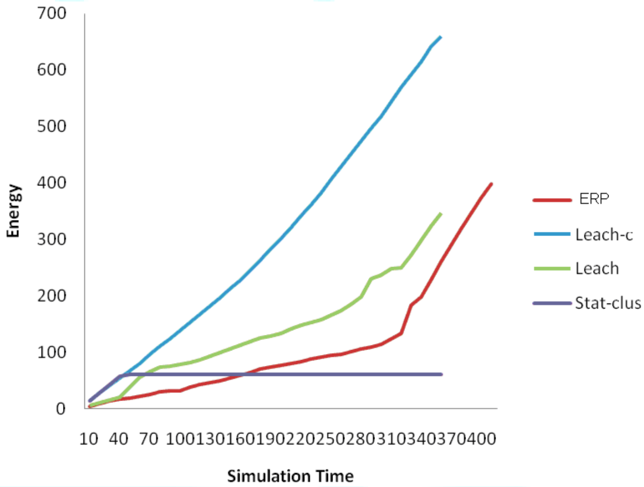


**Figure 5.10:** Power of the node with Time

From Figure 5.10 which is the illustration of Power, No of nodes alive with respect to simulation-time of the network, we can observe that the power consumed is more in LEACH-C than all the other protocols. ERP performs better than other protocols in terms of power Since ERP protocol lets the power consumption of the network be uniformly distributed in each node, the interval between the deaths of the first node and that of the last node is so short. ERP degrades more slowly than other three protocols in most cases and afterwards it will decrease sharply.

## 5.3 Optimizing Coverage Area in WSN

### 5.3.1 Delaunay triangulation Method

A Delaunay triangulation of a vertex set is a triangulation of the vertex set with the property that no vertex in the vertex set falls in the interior of the circumcircle (circle that passes through all three vertices) of any triangle in the triangulation. Figure 5.11 depicts the Delaunay Triangulation method for sample WSN.

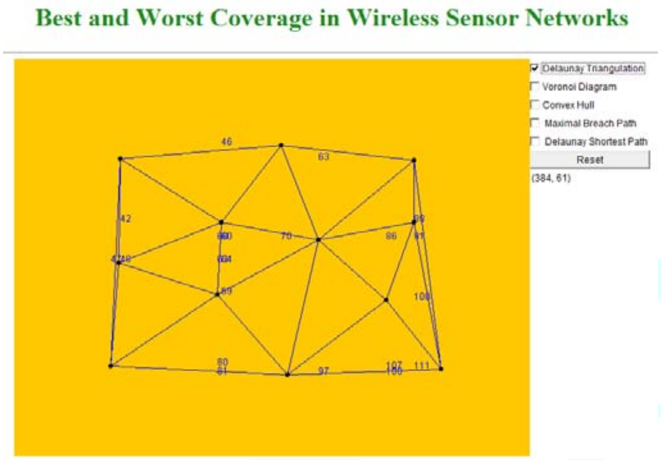


**Figure 5.11:** Delaunay Triangulation

### 5.3.2 Voronoi Diagram

A Voronoi diagram of a vertex set is a subdivision of the plane into polygonal regions (some of which may be infinite), where each region is the set of points in the plane that are closer to some input vertex than to any other input vertex. The Voronoi diagram is the geometric dual of the Delaunay triangulation.

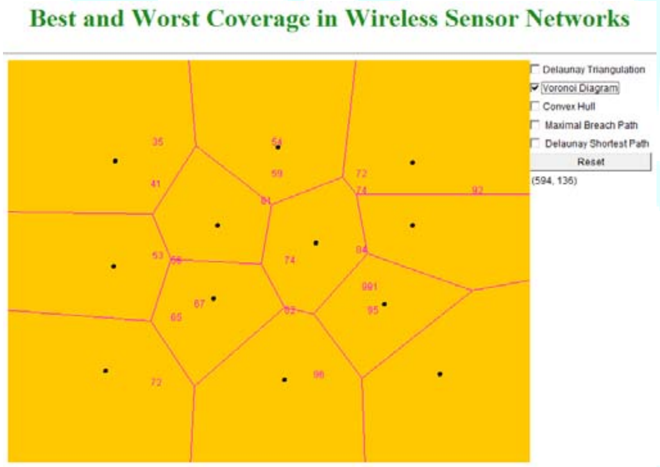


**Figure 5.12:** Voronoi diagram

### 5.3.3 Convex Hull

Let S be a set of points in the plane. The convex hull of S is the smallest convex polygon that contains all the points of S. The Convex Hull for the sensor positions in the sample WSN are described in figure 5.13

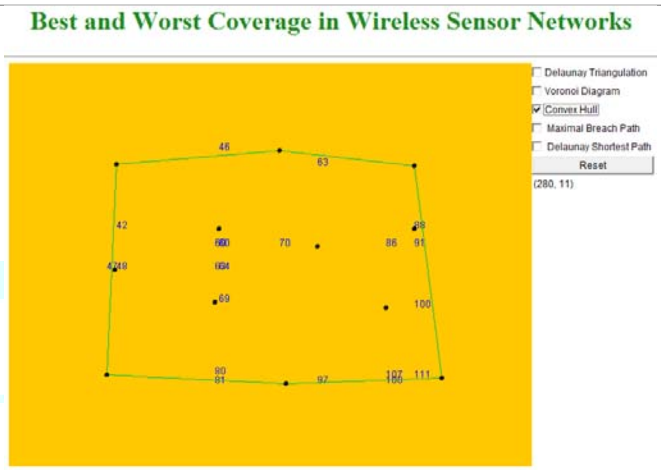


**Figure 5.13:** Convex Hull

## 6. Conclusion

In the proposed Efficient Routing Protocol (ERP) for sensor networks, a node independently makes its decision whether or not to compete as a cluster head. After the selection of the cluster heads, the non-cluster head nodes choose to join the closest cluster head and for a cluster. In order to reduce the power consumption, a cluster head, called the base station, is selected from among the other cluster heads as the only node to communicate with the sink node. The cluster head remote from the sink node sends the gathered data, in a multi-hop pattern, to the sink node. Moreover, in ERP protocol, the execution of a simple coverage algorithm helps to prolong the network lifetime with the increase in node density.

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