ABSTRACT

Wireless sensor networks (WSN) consist of hundreds or thousands of sensor nodes each of which is capable of sensing, processing, and transmitting environmental information. The nodes are deployed to monitor certain physical phenomena or they can detect certain objects in an area of interests. Since the sensor nodes are equipped with battery which has limited energy, energy efficient information processing is of critical importance. Coverage-preserving and lifetime-durability are important issues for wireless sensor networks (WSNs). Any coverage hole in a wireless sensor network is not feasible, so to provide full sensing coverage in a security-sensitive area is necessary in many practical applications such as security surveillances or military investigations. The routing protocols were proposed in order to increase the lifetime and the Quality of Service (QoS) of wireless sensor networks.

To prolong the duration of full sensing coverage, we propose an Energy-aware and Coverage-preserving Hierarchical Routing (ECHR) protocol for randomly deployed WSNs. The ECHR protocol maximizes the working time of full coverage in a given WSN without any concern of deployment patterns of the sensor node. It provides energy-balancing and coverage-preserving while selecting one Cluster Head (CH) for each round. The cluster head selection mechanism is essential in ECHR protocol. For selecting cluster head, uniform selection mechanism is used. To determine an optimal route for the packet, the power consumption of radio transmission and residual energy over the network are considered. The main idea of this paper is to combine both, the energy-balancing and coverage preserving mechanisms into routing protocols. In this paper we are seeing the effects of different points of interest (POIs) over the network. MATLAB simulations will be performed to analyze and compare the performance of ECHR with other protocols. The expected output of simulation is up to 80-85% extra lifetime compared to other protocols.

Keywords: Cluster head (CH), Energy-Aware Coverage-Preserving Hierarchical Routing protocol (ECHR), sensor nodes, Points of Interest (POIs).

1. INTRODUCTION

Recent technological advances have led to the emergence of pervasive networks of small, low-power devices which integrates sensors and actuators with limited onboard processing and wireless communication capabilities. These sensor networks open new vistas for many potential applications, such as environmental monitoring (e.g., traffic, habitat, and security), industrial sensing and diagnostics (e.g., factory, appliances), critical infrastructure protection (e.g., power grids, water distribution, waste disposal), and situational awareness for battlefield applications. For these algorithms, the sensor nodes are deployed to cover the monitoring area as much as possible. They collaborate with each other in sensing, monitoring, and tracking events of interests and in transporting acquired data, usually stamped with the time and position information, to one or more sink nodes.

Wireless sensor network [1] have a great deal of research attention due to their wide range of potential applications including environment monitoring, object tracking, scientific observing, traffic control, industrial sensing and diagnostics (e.g., factory, appliances), critical infrastructure protection (e.g., power grids, water distribution, waste disposal), and situational awareness for battlefield applications.

A typical large-scale WSN generally consists of one or more sinks (or base stations) and thousands of sensor nodes that can be organized into a multi-hop wireless network and deployed either randomly or according to some predefined statistical distribution over a desired geographical region.

Wireless Sensor Networks are becoming increasingly available for commercial and military applications. The first step in deploying these wireless sensor networks is to determine, with respect to application-specific performance criteria, (i) in the case that the sensors are static, where to deploy or activate them; and (ii) in the case that (a subset of) the
sensors are mobile, how to plan the trajectory of the mobile sensors. These two cases are collectively termed as the coverage problem in wireless sensor networks.

There are usually two deployment modes in wireless sensor networks. On the one hand, if the cost of the sensors is high and deployment with a large number of sensors is not feasible, a small number of sensors are deployed in several preselected locations in the area. In this case, the most important issue is sensor placement – where to place the sensors in order to fulfill certain performance criteria. On the other hand, if inexpensive sensors with a limited battery life are available, they are usually deployed with high density (up to 20 nodes/m$^2$ [2]). The most important issue in this case is density control – how to control the density and relative locations of active sensors at any time so that they properly cover the monitoring area. (Another relevant issue is how to rotate the role of active sensors among all the sensors so as to prolong the network lifetime [3].)

Although at first glance, sensor placement and density control are two different issues, they both boil down to the issue of determining a set of locations either to place the sensors or to activate sensors in the vicinity, with the objective of fulfilling the following two requirements:

(i) Coverage: a predetermined percentage of the monitored area is covered; and

(ii) Connectivity: the sensor network remains connected so that the information collected by sensor nodes can be relayed back to data sinks or controllers.

One of the most active research fields in wireless sensor networks is that of coverage. Coverage is usually interpreted as how well a sensor network will monitor a field of interest. It can be thought of as a measure of quality of service.

The coverage usually involves two basic sides

- How to evaluate the coverage performance when sensor nodes are deployed in a monitoring region.
- How to improve the coverage performance when wireless sensor network cannot effectively satisfy application requirements.

The rest of the paper is organized as follows: Section 2 describes the related work. Section 3 describes the proposed energy aware coverage preserving routing protocol. Section 4 includes the simulation results and the conclusions are drawn in section 5

### 2. RELATED WORK

Most of the previous routing protocols that have been proposed were designed to prolong the lifetime of the network [4] and [5]. However, if the network fails to maintain full coverage, there is no use of sensor network.

The routing protocols were proposed to increase lifetime of the network and to enhance the Quality of Service (QoS) [6]. In order to decrease the energy consumption of radio transmission, a Low-Energy Adaptive Clustering Hierarchy (LEACH) routing protocol was proposed by W. R. Heinzelman et al. [7] which minimizes energy dissipation in sensor networks.

LEACH is a very well known hierarchical routing algorithm for sensor networks. It makes clusters of the sensor nodes based on the received signal strength. The 5% of the total number of nodes becomes the cluster head and act as router to the sink. Transmission will only be done by cluster head. Therefore, the energy consumption of sensor node can be highly reduced by preventing it from transmitting the sensing data to the base station (BS) directly.

In addition, Tasi [8] proposed a coverage preserving routing protocol, which was enhanced from LEACH protocol. This protocol is known as LEACH Coverage-U protocol. It calculates the overlap sensing areas of all sensor nodes, and then uses this feature to select cluster head.

Hence, in this study, we present an Energy-aware and Coverage-preserving Hierarchical Routing (referred as ECHR) protocol. This protocol helps to increase the duration of maintaining the full sensing coverage in a WSN. The proposed ECHR protocol will always choose one of the overlapping nodes to be the cluster head in each round. We will also apply the energy-aware hierarchical routing mechanism to find out an optimal route for the data measured by each node.

Comparing with other benchmark protocols, the ECHR protocol can effectively prolong the duration of maintaining full sensing coverage in a WSN.

### 3. THE PROPOSED ENERGY-AWARE COVERAGE-PRESERVING ALGORITHM

In our work, to prolong the duration of full sensing coverage, we propose an Energy-aware and Coverage-preserving Hierarchical Routing (ECHR) protocol for randomly deployed WSNs. The ECHR protocol will maximize the working time of full coverage in a given WSN without any concern of deployment patterns of the sensor node. The main idea of this project is to combine both, the energy-balancing and coverage preserving mechanisms into routing protocols. In this paper we are seeing the effects of different points of interest (POIs) over the network. MATLAB simulations will be performed to analyze and compare the performance of ECHR with other protocols. The expected output of simulation is up to 80-85% extra lifetime compared to other protocols.
3.1 Assumptions
In this paper, we assume that there are \( n \) sensor nodes randomly deployed in a \( L \times L \) sensing field and the sensing field has \( m \) points of interest (termed as POI). The definition of POI (denoted as \( P_1, P_2, \ldots, P_m \)) and the related point coverage problem can be referred to the reference [9].

Some other assumptions made for the network model are:
- Number of nodes in the network are 500.
- The sink node is located far away from the sensing area.
- All the wireless sensor nodes and sink node (sink) are stationary after deployment.
- Nodes are dispersed in a 2-dimensional space and cannot be recharged after deployment.
- All nodes can send the data to the sink node.
- All nodes are of the same specifications.
- All nodes consume same energy for transmission and reception.
- Each node has power control ability which can be adjusted according to the transmission distance.
- Each Sensor node has the same initial power.
- In the first round, each node has a probability \( p \) of becoming the cluster head.
- Nodes are uniformly distributed in network.

3.2 Proposed Algorithm
The proposed algorithm works in rounds. The various models used in the new scheme are:

3.2.1 The Radio Transmission Model
The first order radio model has been adopted in this study [8]. The two parameters used in this model are, \( E_{\text{elec}} \) and \( E_{\text{amp}} \). Energy dissipation per bit by the transmitter or receiver circuits is given by \( E_{\text{elec}} \), and is set to 50nJ/bit. Energy dissipation per bit by the transmitter amplifier is given by \( E_{\text{amp}} \), and is set to 0.1 nJ/bit/d^\alpha.

The energy consumption for transmitting/receiving \( H \)-bit data message for a given distance \( d \) is formulated by:

\[
E_{\text{TX}}(d,H) = k(H_{\text{elec}} + H_{\text{amp}} d^\beta) \tag{1}
\]

\[
E_{\text{RX}}(d,H) = H E_{\text{elec}}
\]

Where \( E_{\text{TX}} \) represents energy consumption for transmitting data, \( E_{\text{RX}} \) denotes the energy dissipation by receiving data and \( \beta \) is the pass loss exponent. The pass loss exponent \( \alpha \) is set to 2 for the transmission from each node, and \( \beta \) is set to 2.5 for the transmission from a cluster head to BS.

![Energy consumption model](image)

3.2.2 Coverage Model
Each sensor node has sensing range \( \mathcal{R}_i \) and location \( \{x_i, y_i\}, i \in [1, n] \). The location of each POI is given by \( \{x_j, y_j\}, j \in [1, m] \). We also denote a coverage set of a sensor node \( \mathcal{C}_i \) by \( \mathcal{CS}_i \). The set of POIs that are covered by multiple \( \mathcal{CS}_i \) can be determined by the following equation:

\[
\mathcal{PO}_i = \mathcal{CS}_i \cap (\mathcal{CS}_{i_1} \cup \mathcal{CS}_{i_2} \cup \ldots \cup \mathcal{CS}_{i_m})
\]

Where \( \mathcal{PO}_i \) is the set of POIs that are covered by multiple sensor nodes.
The coverage ratio $CR$ of the network can be defined as:

$$CR = \frac{S_1}{W}$$

If a node $S_1$ runs out of energy, $C_1$ in equation (3) will become an empty set.

### 3.3 Flowchart of Proposed Algorithm

![Flowchart of Proposed Algorithm](image)

### 3.4 Pseudo Code

- // Node deployment
- N: no. of nodes
- S: array to store the node’s location
- XR: array to store values of X co-ordinates for N nodes
- YR: array to store values of Y co-ordinates for N nodes
- $X_m=200, Y_m=200$ /* Field Dimension*/
- For i=1 to N
  - XR (i) = random (1, 1)* $X_m$
  - YR (i) = random(1,1)* $Y_m$
  - /*Initially there are no cluster head*/
  - S(i).type='N'
  - temp_rnd = i
  - if (temp_rnd>m*n+1)
    - S(i).E=Eo /*initial energy $E_o$=0.5
    - /*Plot normal nodes*/
    - Exit the program
- /*plot base station with following co-ordinates*/
  - S(N+1).xd=0.5* $X_m$
  - S(N+1).yd=0.5* $Y_m$

- // Points of coverage
  - {for each round
  - s_range: Range of Sensor Node
  - set s_range

---

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• { for i =1 to n
  theata equals to 0 to 2*pi
  node co-ordinate x is assigned to XR(i)
  node co-ordinate y is assigned to YR(i)
  xp = 2*s_range*cos(theata)
  yp = 2*s_range*sin(theata)
  display the points
  exit the program
  }
  Extract first value from node co-ordinate x
  Extract first value from node co-ordinate y
  pts ← call circlepoints (x,y,2*s_range)
  Extract values from second node to n node
  x1 ← XR (i)
  y1 ← YR (i)
  pts ← call circlepoints (x1,y1,2*s_range)
  Exit the program

• // Choosing Cluster Head
• { for each round
  Threshold is set to (P / (1 – P * (round % 1/P)))
  { if all nodes have been cluster heads
    For each node
    Reset used to ‘*’ // * meaning the node can be used as cluster head
    Reset node renewal to 0 //start count of nodes that have been elected over
    }
  { while Cluster Head count < Needed cluster heads
    Reset node count //start at the beginning of nodes
    { while (Cluster Head count < Needed Cluster heads) && (node < the total number of nodes)
      Assign a random number
      { if (random number < threshold value) && (the node has not been cluster head)
        Node is Cluster head //assign node id to cluster head list
        Set coordinate x //assign all of node members to cluster head id
        Set coordinate y
        Set energy amount
        Set node as been used //node id has been marked used
        Increment cluster head count //a new cluster head has been added
        go to the next node
      } else
        go to the next node
    } Else go to the next node
    Exit the program

• // Generating Clusters
• { for each node
  if node is a cluster head
  go to next node
  { else
    { for each cluster head
      node coordinate x is assigned to x1
      node coordinate y is assigned to y1
      cluster head coordinate x is assigned to x2
      cluster head coordinate y is assigned to y2
      { if it is the first cluster head

the distance between node and cluster head is the least distance
cluster head id is assigned as closest cluster head to node
}
} [else
Distance between node and current cluster head is current distance
| if current distance < least distance
Current distance is now assigned to least distance
Cluster head id is assigned as closest cluster head to node
}
]

// Simulating Transmission and Reception
// if distance between node and cluster head is <= the transmission range
Transmission cost is \( E_{\text{Tx}}(k, d) = E_{\text{elec}} * k + _{\text{amp}} * k * d^2 \)
Reception cost is \( E_{\text{Rx}}(k) = E_{\text{elec}} * k \)
Subtract the transmission cost from the sending node
| if remaining energy <= 0
display node has died
exit the program
|
Subtract the reception cost from the receiving node
| if remaining energy <= 0
display node has died
exit the program
|
return the sum of transmission cost and reception cost
|

4. SIMULATION SETUP AND PERFORMANCE EVALUATION

All simulations have been implemented using MATLAB. We have assumed that 500 nodes are randomly distributed in field of 200x200 and the sink is located about 50m away from the field edge. The simulation parameters are given in Table 1. The performance of the proposed protocol is compared with that of the LEACH protocol.

4.1 Cluster Head selection mechanism
To prolong the lifetime of the network with full sensing coverage, a cluster head selection mechanism was developed which was based on energy-balancing and coverage-preserving. This mechanism is used in the ECHR protocol. We also apply the energy-aware hierarchy routing mechanism in order to determine an optimal route for packets generated by each node.

According to the radio model described above, the transmission between a cluster head and the BS could consume huge amount of energy. In the ECHR protocol, the cluster head selection is based on uniform distribution. Therefore, the cluster head selection mechanism is essential. Clustering provides resource utilization and minimizes energy consumption in WSNs by reducing the number of sensor nodes that take part in long distance transmission [11] and [12]. Cluster based operation consists of several rounds. These involve cluster heads selection, cluster formation, and transmission of data to the base station.

In our mechanism of cluster head selection the representative nodes will be selected as cluster heads based on the following equation:

\[
P (k \text{ successes in } n \text{ rounds}) = \binom{n}{k} p^k q^{n-k} \quad (4)
\]

Where
n= no. of rounds
k= no. of success
n-k = no. of failures
p = probability of success in one round
q = (1-p) = probability of failure in one round

4.2 The Energy-Aware Hierarchy Routing Mechanism
In order to reduce the power consumption of data transmission, we adjust communication range of each node. Thus, all sensing data of sensor nodes will be transmitted by multi-hop mechanism. Each node uses the hop count of received
information in a neighbor table. Thus, each sensor node knows which nodes are closer to the cluster head, and these nodes could be its parent node. However, a node $S_i$ might have multiple parent nodes available for choosing. Therefore, we calculate the parent node factor $P_{S_k}$ for the parent node $S_k$ by:

$$P_{S_k} = \frac{1}{d_{S_k}} \times \delta E_k$$  \hspace{1cm} (5)$$

Where $d_{S_k}$ is distance between the node $S_k$ and the parent node $S_k$. According to equation (5), each node will calculate the parent node factor according to its parent nodes and all the values saved in the neighbor table. After calculating the parent node factor, each node will transmit sensing data to its parent node.

### 4.3 Simulation Parameters
Table 1 shows the various simulation parameters that are used in the proposed algorithm.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation Round</td>
<td>2000</td>
</tr>
<tr>
<td>Network size</td>
<td>200*200</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>500</td>
</tr>
<tr>
<td>Node distribution</td>
<td>Nodes are uniformly distributed</td>
</tr>
<tr>
<td>Control Packet size</td>
<td>500bits</td>
</tr>
<tr>
<td>Data Packet size</td>
<td>2000bits</td>
</tr>
<tr>
<td>Distance between BS and Sensor field</td>
<td>100-100m</td>
</tr>
<tr>
<td>Initial energy of node</td>
<td>0.05 joule</td>
</tr>
<tr>
<td>Point of interest</td>
<td>500</td>
</tr>
<tr>
<td>Compression coefficient</td>
<td>0.05</td>
</tr>
<tr>
<td>Energy dissipation</td>
<td>10*0.00000000000001 Joule</td>
</tr>
<tr>
<td>Energy for Transmission</td>
<td>50*0.00000000000001 Joule</td>
</tr>
<tr>
<td>Energy for Reception</td>
<td>50*0.00000000000001 Joule</td>
</tr>
<tr>
<td>Energy for data aggregation</td>
<td>5*0.00000000000001 Joule</td>
</tr>
</tbody>
</table>

### 4.4 Simulation Results
The nodes were deployed uniformly in the proposed algorithm. Figure 3 shows the node deployment in wireless sensor network.

![Figure 3](image)

**Figure 3** A model view of the nodes randomly generated inside the square

#### 4.4.1 Cluster Head formation
The transmission between a cluster head and the BS could consume huge amount of energy. Therefore, the cluster head selection mechanism is essential. Clustering provides resource utilization and minimizes energy consumption in WSNs by reducing the number of sensor nodes that take part in long distance transmission [11] and [21]. Cluster based
operation consists of several rounds. These involve cluster heads selection, cluster formation, and transmission of data to the base station. The Cluster Heads were generated using the uniform distribution mechanism.

![Figure 4 Cluster Head formation in ECHR](image)

Table 2 shows the density of cluster head in LEACH

<table>
<thead>
<tr>
<th>Location of sink node</th>
<th>No. of Sensor Node(SN)</th>
<th>Probability of SN to be Cluster Head</th>
<th>No of alive nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>X Coordinate</td>
<td>Y Coordinate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>175</td>
<td>175</td>
<td>500</td>
<td>0.09</td>
</tr>
<tr>
<td>200</td>
<td>175</td>
<td>500</td>
<td>0.1</td>
</tr>
<tr>
<td>200</td>
<td>200</td>
<td>500</td>
<td>0.6</td>
</tr>
<tr>
<td>250</td>
<td>300</td>
<td>500</td>
<td>0.9</td>
</tr>
</tbody>
</table>

We can see from the table that as the probability of SN to become a cluster head increases, number of dead nodes increases. Figure 5(a) and 5(b) shows the graphical view of number of nodes alive in the network.

![Figure 5(a) No. of nodes still alive over no. of rounds in LEACH](image)

In Figure 5(a), the location of sink node is 175-175m in x and y coordinates respectively.

![Figure 5(b) No. of nodes still alive over no. of rounds in LEACH](image)

In figure 5(b), the location of sink node is 200-200m in x and y coordinates respectively.
The dead nodes for the proposed algorithm and the area covered by each node can be seen in the model view presented in Figure 6.

4.4.2 Network Life Time

When a node is dead in the network, it is no longer the part of the network. It shows that if a dead node occurs in early rounds of the algorithm, this may affect the life time of the network which may lead to early dead of all nodes. Table 3 shows the simulation results of the two schemes.

Table 3: Network Lifetime (First node dead)

<table>
<thead>
<tr>
<th>No. of Rounds</th>
<th>Round number when first node dies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LEACH</td>
</tr>
<tr>
<td>200</td>
<td>385</td>
</tr>
<tr>
<td>400</td>
<td>372</td>
</tr>
<tr>
<td>600</td>
<td>367</td>
</tr>
<tr>
<td>800</td>
<td>352</td>
</tr>
<tr>
<td>1000</td>
<td>345</td>
</tr>
<tr>
<td>1200</td>
<td>331</td>
</tr>
<tr>
<td>1400</td>
<td>334</td>
</tr>
<tr>
<td>1600</td>
<td>340</td>
</tr>
<tr>
<td>1800</td>
<td>342</td>
</tr>
<tr>
<td>2000</td>
<td>346</td>
</tr>
<tr>
<td></td>
<td>Proposed Algorithm</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>600</td>
<td>0</td>
</tr>
<tr>
<td>800</td>
<td>597</td>
</tr>
<tr>
<td>1000</td>
<td>683</td>
</tr>
<tr>
<td>1200</td>
<td>710</td>
</tr>
<tr>
<td>1400</td>
<td>741</td>
</tr>
<tr>
<td>1600</td>
<td>737</td>
</tr>
<tr>
<td>1800</td>
<td>721</td>
</tr>
<tr>
<td>2000</td>
<td>723</td>
</tr>
</tbody>
</table>

Figure 7 Network Lifetime (First node dead) v/s No. of Rounds

4.4.3 Network Lifetime with Number of Nodes Alive

The increase in number of nodes that are alive contributes to the increase in network life time. Table 4 and Figure 8 show the number of nodes that are alive with the increase in number of rounds. The lifetime of WSN in the proposed scheme is better compared to LEACH Protocol.
4.4.4 Residual Energy Comparison
We calculated the residual energy for the proposed scheme and compared it with LEACH protocol. Table 5 shows the values of residual energy for both the protocols and Figure 9 concludes that the residual energy of LEACH protocol decreases faster as compared to ECHR.

<table>
<thead>
<tr>
<th>No. of Rounds</th>
<th>Residual Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LEACH</td>
</tr>
<tr>
<td>200</td>
<td>0.42951</td>
</tr>
<tr>
<td>400</td>
<td>0.23434</td>
</tr>
<tr>
<td>600</td>
<td>0.04917</td>
</tr>
<tr>
<td>800</td>
<td>0.04666</td>
</tr>
<tr>
<td>1000</td>
<td>0.047687</td>
</tr>
<tr>
<td>1200</td>
<td>0.034697</td>
</tr>
<tr>
<td>1400</td>
<td>0.033972</td>
</tr>
<tr>
<td>1600</td>
<td>0.034119</td>
</tr>
<tr>
<td>1800</td>
<td>0.033004</td>
</tr>
<tr>
<td>2000</td>
<td>0.033102</td>
</tr>
</tbody>
</table>

Figure 9 Residual Energy v/s Number of Rounds
4.4.5 Coverage Ratio of Proposed Scheme

Table 6 shows the values of coverage ratio for LEACH protocol and the proposed algorithm. Figure 10 concludes the results.

![Table 6: Coverage Ratio](image)

<table>
<thead>
<tr>
<th>No. of Rounds</th>
<th>Coverage Ratio (%)</th>
<th>LEACH</th>
<th>Proposed Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>95</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1200</td>
<td>85</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td>70</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>30</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 10 Coverage Ratio v/s No. of Rounds](image)

The proposed algorithm is able to maintain 100% coverage ratio till 1690th round whereas LEACH protocol lose full coverage ratio at 900th round. Figure 10 concludes that the proposed algorithm provides about 80-85% extra life time compared to LEACH protocol.

5. CONCLUSION

Preserving coverage is the main issue in wireless sensor network. In this paper, we proposed an energy-aware and coverage-preserving hierarchy routing protocol for wireless sensor networks. The aim of this study is to prolong the duration for maintaining full sensing coverage. The main idea is to combine energy balancing and coverage-presenting mechanisms into routing protocol. Simulation results show that the proposed ECHR protocol is able to prolong the duration of the network with 100% coverage ratio, which provides 80-85% extra lifetime comparing with LEACH protocol.

The proposed protocol is for the homogeneous network and we propose to extend our work for heterogeneous network in future. We will also try to evaluate the performance of the proposed system in aspects of transmission delay and cost in future.

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