

Energy And Cost Effective Routing Protocol For Wireless Sensor Network

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Abstract

Wireless Sensor network consists of large number of small sensor nodes which can communicate over wireless links. The sensor nodes are short-lived and unreliable which leads to the main design issue of maintaining long system lifetime as well as maintaining sufficient sensing coverage and reliability. To increase the lifetime and Quality of Service (QoS) various routing protocols were proposed in order to maintain full sensing coverage.

In this paper we propose an algorithm for randomly deployed wireless sensor network. The proposed algorithm increases the working time of full coverage in a given network. The main idea of this paper is to combine coverage preservation and energy balancing into routing protocols. The proposed scheme is cost effective. We have performed MATLAB simulations to analyze the results and to compare our scheme with other benchmark protocols. The expected output is 85%-90% extra lifetime and energy preservation.

Keywords- LEACH, Cost, Coverage, Energy-aware and Coverage-preserving Hierarchical Routing (ECHR)

1. Introduction

Wireless Sensor Networks (WSNs) consist of tiny sensor nodes that, in turn, consist of microprocessor, memory, transceiver, and power supply. In order to realize the existing and potential applications for WSNs, advanced and extremely efficient communication and routing protocols are required.

Routing protocols of all Wireless Sensor networks, regardless of the application, must try to maximize the network life time and minimize the energy consumption of overall network. For these reasons, the energy consumption parameter has higher priority than other factors. [1]

WSN have a great deal of research attention due to their wide range of applications which includes environment monitoring, object tracking, traffic control, 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 [2].

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 fulfil 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/m³ [3]). 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 [4].)

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.

In this paper, we analyze the performance of energy-aware coverage-preserving protocol in respect of network lifetime, energy dissipated, coverage ratio and cost. We compare our proposed scheme to LEACH.

The performance analysis of proposed scheme is evaluated in MATLAB [5]

The remaining paper is organized as follows: Section 2 describes the related work. Section 3 describes the proposed system. Section 4 describes simulation setup and results. Conclusions are drawn in section 5.

2. Related Works

Most of the previous routing protocols that have been proposed were designed to prolong the lifetime of the network [6] and [7]. 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) [8]. 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. [9] 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 [10] 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

To prolong the duration of full sensing coverage, we propose an Energy-aware and Coverage-preserving Hierarchical Routing (ECHR) protocol for randomly deployed WSNs. This protocol will maximize the working time of full coverage in a given WSN without considering deployment patterns of the sensor node. In this paper we will try to maximize the network lifetime and reduce the cost of 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 85-90% 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, \dots, P_m) and the related point coverage problem can be referred to the reference [11].

Some other assumptions made for the network model are:

- The total number of nodes in the network is 500.
- Base Station (BS) is located far away from the sensing area.
- All the wireless sensor nodes and BS is 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 BS.
- All nodes are of the same specifications.

- All nodes consume equal energy for transmission and reception.
- All nodes are homogeneous and have same capabilities with unique ID's
- 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 (CH).
- Nodes are uniformly distributed in network.

3.2. The Coverage Model

Each sensor node has sensing range r_s 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 denote a coverage set of a sensor node S_i by CS_i . The Coverage Ratio (K) of the network can be calculated by the following equation:

$$K = \frac{||CS_1 \cup CS_2 \cup \dots \cup CS_{n-1} \cup CS_n||}{m} \quad (1)$$

If a node S_1 runs out of energy, CS_1 in equation (1) will become an empty set.

3.3. Energy-Aware Hierarchy Routing Mechanism

- All sensing data of sensor nodes will be transmitted by multi-hop mechanism.
- Each node uses the hop count of received information in a neighbour table.
- 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.
- We can calculate the parent node factor P_f for the parent node S_f by:

$$P_f = (1/d_f) \times RE_f \quad (2)$$

where d_f is distance between the node S_i and the parent node S_f

- As in equation (2), each node will calculate the parent node factor according to its parent nodes and all the values of neighbouring table.
- Each node will now transmit the sensing data to its parent node.

3.4. Cluster Head selection mechanism

In our work, the cluster head selection mechanism is 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 [12] and [13]. 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:

$$P(k \text{ successes in } n \text{ rounds}) = \binom{n}{k} p^k q^{n-k} \quad (3)$$

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

Equation 3 will select the cluster heads from the active sensor nodes. The cluster head will now aggregate the sensing data from the sensor nodes and send it to the base station.

3.5. Flowchart of Proposed Algorithm

The proposed algorithm includes various steps of implementation. The first step includes selection of cluster head. Cluster head is selected with the help of uniform distribution method.

Each sensor node selects its parent node with the help of ECHR mechanism. Parent node receives sensing data from each sensor node.

Cluster head aggregates data and send it to the Base station.

Figure 1 shows the flowchart of proposed algorithm.

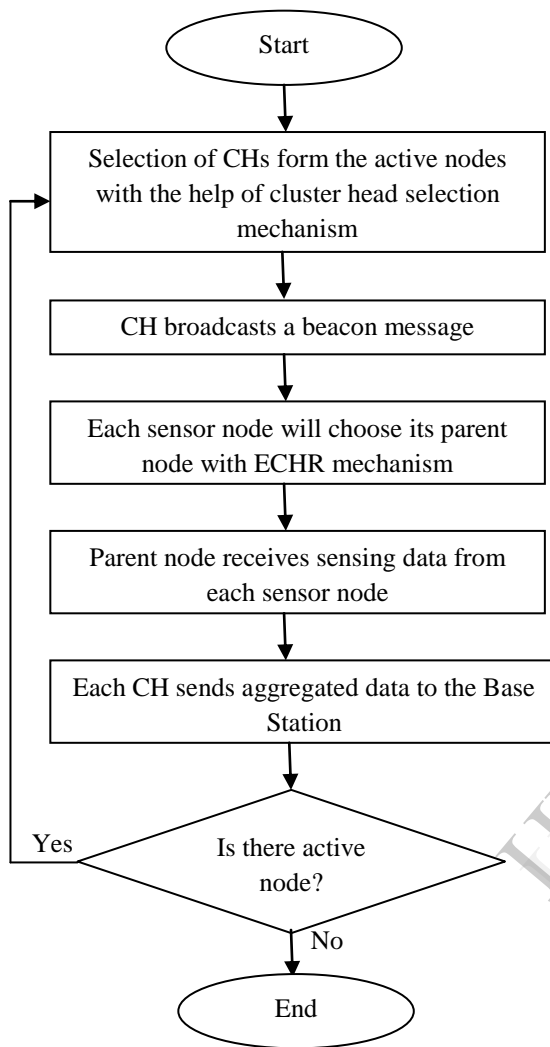


Figure 1. Flowchart of Proposed Algorithm

3.6. 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= E_o /*initial energy $E_o=0.5$
- */Plot normal nodes*/
- }
- Exit the program
- 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
-
- // **Coverage points**
- {for each round
- s_range: Range of Sensor Node
- set s_range
- { 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 = $2*s_range*\cos(\text{theata})$
- yp = $2*s_range*\sin(\text{theata})$
- 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
-
- {for each round
- // **Choosing Cluster Head**
- Threshold is set to $(P / (1 - P * (\text{round} \% 1/P)))$
- {for each node
- {if number of cluster <= 10 && energy of node > 0
- 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
- Increment cluster head count //a new cluster head has been added
- Else go to the next node}
- Else go to the next node}
- }
- }
- //Simulating Transmission and Reception
- {if distance between node and cluster head is <= the transmission range
- Transmission cost is $E_{Tx}(l, d) = E_{elec} * l + E_{fs} * l * d^2$
- Reception cost is $E_{Rx}(l) = E_{elec} * l$
- 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 and calculate residual energy of each node
 - }
 - } //rmax
 - }

4. Simulation Setup and Results

4.1. Energy Model for communication

We have used the first order radio model in this study [10]. The two parameters used in this model are, E_{elec} and ϵ_{amp} . E_{elec} denotes the energy dissipations per bit by the transmitter or receiver circuits and is set to 50nJ/bit. ϵ_{amp} denotes the energy dissipations per bit by the transmitter amplifier and is set to 0.1 nJ/bit/m ^{β} .

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

$$E_{Tx}(d, H) = k (E_{elec} + \epsilon_{amp} d^{\beta}) \quad [4]$$

$$E_{Rx}(d, H) = H E_{elec}$$

where E_{Tx} is the energy consumption for transmitting data E_{Rx} denotes the energy dissipation by receiving data, and β is the pass loss exponent. The pass loss exponent α is set to 2 for the transmission from each node, and β is set to 2.5 for the transmission from a cluster head to BS.

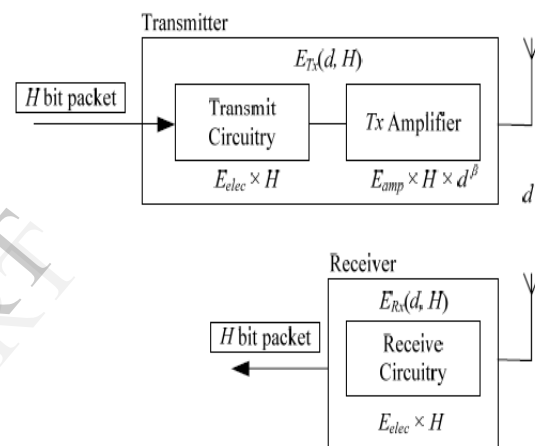


Figure 2. Energy consumption model

4.2. Simulation Parameters

We have simulated the proposed model in MATLAB 7.0. We have compared the performance of the ECHR protocol with that of LEACH via numerical simulation.

The simulation environment is a network with 500 nodes randomly distributed in an area of $200 \times 200m^2$. This monitoring area consists of 500 POIs, and the BS is located at (100, 100). The initial energy of all nodes is assumed to be 0.05 joule, and the sensing range r_s is set to be 10 m. Furthermore, the compression coefficient μ is set to 0.05, and the data packet size k is set to 2000 bits. Table 1 gives detail of simulation parameters used in our proposed scheme.

Table 1. Simulation Parameters

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

Table 2. Network Life Time (First Node dead)

No. of Rounds	Round number when first node dies	
	LEACH	PROPOSED SCHEME
100	52	0
300	179	0
600	367	0
900	452	597
1200	431	610
1500	424	641
1800	402	620
2100	389	626

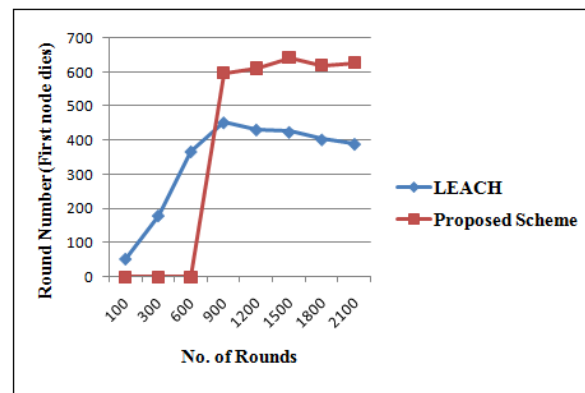


Figure 3. Network life time (First node dead) v/s No. of rounds

4.3. Network Lifetime

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 2 shows the simulation results of the two schemes.

Figure 3 concludes that in the proposed algorithm, first node dies later in the network.

4.4. Network Lifetime showing number of nodes alive

Network lifetime increases with the increase in nodes alive. Large number of dead nodes reduces life time of the network.

Table 3 and Figure 4 shows the number of nodes alive in the network with increase in rounds.

Table 3. Network lifetime with nodes alive in network

No. of Rounds	Number of Alive Nodes	
	LEACH	Proposed Algorithm
100	500	500
300	460	500
600	295	380
900	135	230
1200	120	190
1500	75	150
1800	65	105
2100	25	85

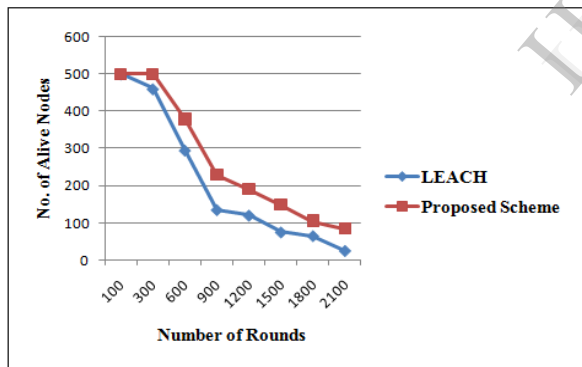


Figure 4. Network Life Time v/s number of rounds.

4.5. Coverage Ratio

Table 4 shows the values of coverage ratio for LEACH protocol and the proposed algorithm. Figure 5 concludes the results.

The proposed algorithm is able to maintain 100% coverage ratio till 1700th round whereas LEACH protocol lose full coverage ratio at 900th round. Figure 10 concludes that the proposed algorithm provides about 85-90% extra life time compared to LEACH protocol.

Table 4. Coverage Ratio

No. of Rounds	Coverage Ratio (%)	
	LEACH	Proposed Algorithm
100	100	100
300	100	100
600	100	100
900	100	100
1200	75	97
1500	55	92
1800	20	60
2100	0	0

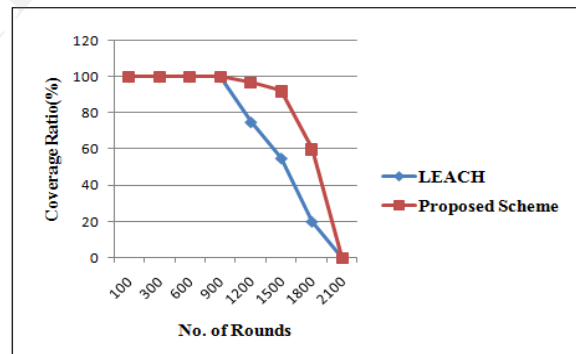


Figure 5. Coverage ratio v/s Number of rounds

4.6. Energy dissipation

Table 5 shows the comparison of average energy dissipation of the proposed scheme with LEACH protocol. Energy dissipated in the proposed scheme is less than LEACH. It shows our system is much more efficient than the existing LEACH protocol.

Figure 6 depicts the graph of comparison of energy dissipated in proposed system.

Table 5. Energy dissipation

No. of Rounds	Energy dissipated	
	LEACH	Proposed Algorithm
100	0.18	0.1
300	0.29	0.2
600	0.45	0.3
900	0.6	0.4
1200	0.79	0.6
1500	0.96	0.71
1800	0.92	0.90
2100	0.90	0.90

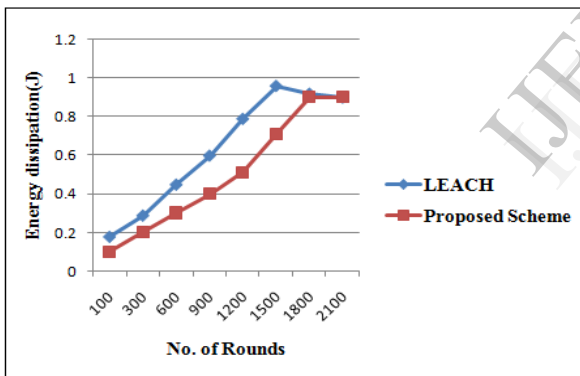


Figure 6. Energy dissipation v/s No. of rounds

4.7. Cost

A cost metric has been defined for the network to show that the proposed scenario has less costing as compared to LEACH. We have computed the cost of the network in terms of energy.

The total energy of 500 nodes consumed in each round in the network has been calculated which gives the average energy of the network consumed in each round until any node dies.

Mathematically, it is formulated as:

$$\text{AvgCost} = \sum_{i=1}^{500} S(i) \text{Eres}(r) - \sum_{i=1}^{500} S(i) \text{Eres}(r+1) \quad [5]$$

Here, i is the total number of nodes in the network, r is the round number. Eres is the residual energy of any node. S is the array of 500 nodes in simulation. $S(i) \cdot \text{Eres}$ is the residual energy of the i^{th} node.

Table 6 and Figure 7 conclude that the cost of network is more in LEACH as compared to the proposed algorithm.

Table 6. Cost Metric

Simulation Run	LEACH	Proposed Algorithm
1	0.21415	0.16713
2	0.20102	0.16674
3	0.20857	0.1701
4	0.21369	0.16334
5	0.19219	0.1666
6	0.19659	0.1626
7	0.19649	0.16993
8	0.19854	0.16504
9	0.20842	0.16883
10	0.19651	0.15842

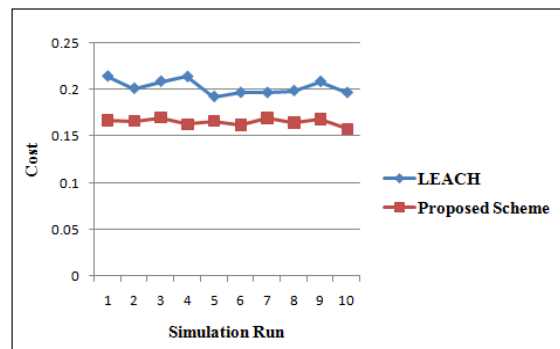


Figure 7. Cost v/s Simulation Run

6. Conclusion

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 85-90% extra lifetime comparing with LEACH protocol. We have also seen the effect of cost and concluded that the cost of network is more in LEACH as compared to the proposed algorithm. The average energy dissipated in proposed scheme is less than that of LEACH.

The proposed scheme 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 throughput in future and compare our algorithm with other benchmark protocols

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