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Coverage Aware Energy Efficient Protocol Architecture for Wireless Sensor Network

Amit Singh[1], Khushbu Babbar[2] and Apeksha Malik[3]

1Roorkee College of Engineering
2Bhagwant University
3Banasthali Vidyapith
E-mail: [1]singh.amit013@gmail.com, [2]khushbu.babbar16@gmail.com, [3]apeksha.malik21@gmail.com

Abstract—*Coverage-preserving and lifetime-prolonging are essential issues for wireless sensor networks (WSNs). Coverage in a security-sensitive area such as security surveillances or military investigations is necessary for practical applications. Many energy efficient and coverage aware routing protocol has been studied but in isolation. In order to prolong the duration of full sensing coverage, we need an algorithm which increases the network life time and provides full coverage. In the following paper a new architecture is proposed which emphasis on increase the life span and coverage of the network. The following paper provides new algorithm for determining the minimum number of nodes that are needed to perform active sensing in wireless sensor network.*

Keywords: *Coverage Aware, Security sensitive area, WSN, Life time prolong, Energy aware*

1. INTRODUCTION

A sensor network is composed of a large number of tiny autonomous devices, called sensor nodes [1]. These nodes are deployed densely and coordinate amongst themselves to achieve a common task. Sensor networks are employed for a wide variety of application areas [2], including industrial, military, biomedical, and environmental areas. For the security and military applications, maintenance of the full coverage of monitored area is extremely important, because any coverage hole in a wireless sensor network can lead to crises.

2. NETWORK PRELIMINARIES

The network model is assumed to work under following assumption:

i) The BS is located far away from the sensing area.
ii) *n* sensor nodes are randomly deployed in $L \times L$ sensing field
iii) Each node has different sensing rage.

From the logical point of view, we consider an environment where great number sensors are scattered to take measurements from the environment. The network has 3 types of nodes;

i) Cluster heads (CHs),
ii) Cluster members (CMs)
iii) Coverage critical nodes (CCs).

Each cluster head is associated with some sensing node called Cluster Members (CMs). Although CHs has sensing capacities, they are the ones with higher capabilities then CMs. CMs only sense the environment and send the sensed data to the CH. CHs organize and control the CMs in their cluster and all CMs have to establish a connection with a CH to join its cluster. This connection can be established only if the distance between them is shorter than its (nodes) to distance from any other CHs in the network. All CHs and CMs can communicate with the BS. CCs are coverage critical nodes and responsible for providing full coverage to network. CCs have the sensing capability and they are not eligible to become CH. In the network all nodes are position aware and a node becomes CC when it is at the coverage critical point.

2.1 Radio Transmission Model of Sensor Node

The first order radio model, which is similar to one presents in LEACH [12] is used. We assume that the energy consumption by the sensor is due to data transmission and reception. Cluster head consumes energy for the data aggregation before it sends the data to BS. According to this model the energy consumed in transmitting one message of size *k* bits size over a transmission distance *d*, is given by

$$E_{Tx}(k,d)=k(E_{elec}+\varepsilon_{AMP}d^{\lambda})$$

$$= E_{elec}\,k + k\varepsilon_{AMP}d^{\lambda},$$

where k=length of the message,

d=transmission distance between transmitter and receiver,

E_{elec}= electronic energy,

ε_{AMP} =transmitter amplifier,

λ= Path Loss ($2<=\lambda<=4$),

Also, the energy consumed in the message reception is given by

$$E_{rx} = E_{elec}\, k,$$

There are two parameters, E_{elec} and ε_{AMP}, involved in the energy consumption model. E_{elec}, the energy dissipations per bit by the transmitter or receiver circuits and ε_{AMP}, the energy dissipations per bit by the transmitter amplifier.

E_{tx} is the energy consumption for transmitting data, E_{rx} denotes the energy dissipation in receiving the data, and λ is the pass loss exponent. In addition, when an intermediate node receives *n k*-bit message data, the node consumes energy of $k \times EDA$ units to compress the data into a packet with $\mu \times (n \times k)$ bits, where μ is the compression coefficient, and *EDA*, is the energy consumption per bit for data aggregation.

3. PROPOSED COVERAGE AWARE ENERGY EFFICIENT PROTOCOL ARCHITECTURE

In this paper an energy efficient and proposed coverage routing protocol architecture is proposed. To increase energy efficiency in architecture clustering approach is used. And to increase coverage different node state will be used. Among the numerous coverage problems the main two problems are: a) to determine the minimum number of sensor nodes that need to perform active sensing for monitoring an area, b) to decide the quality of service that can be provided by a given sensor network. The coverage goal can be achieved by keeping enough working nodes in active mode for assured system functionality and laying off redundant nodes. There can be three possible states of a node in the network: i) Sleep, ii) Active, iii)Standby. Active and standby states consume almost same amount of energy. Therefore we consider only two states: Sleep and Active.

3.1 Sensing region of a node

Due to environmental factors the sensing area of a node can be divided into two regions

i) Strong sensing region
ii) Weak sensing region

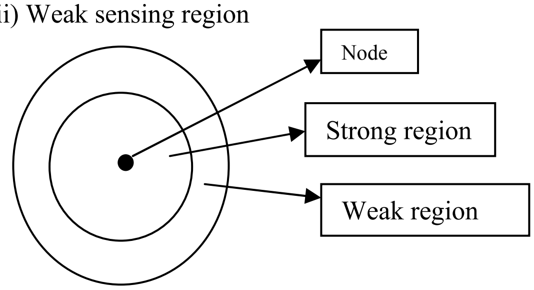

Fig. 1: Sensing region of sensor node

Proposed architecture use the above sensing region for node.

3.2 States of nodes in the network

In the network a node can have two different states a) SLEEP b) ACTIVE. The sensing node is in sleeping mode (turn off itself) can be active (turn on itself) if it satisfies the following

A) If a node is in the strong sensing range of a neighboring node then it can turn off itself.
B) If a node is in the weak region then it can turn itself off if it is in overlap weak region of two or more neighboring nodes.
C) If the node is not at coverage critical point.

3.3 Coverage Critical Points

The proposed algorithm use coverage critical nodes to enhance coverage. Network nodes are aware of position. The Coverage Critical (CC) nodes are the nodes which are critical for full coverage of monitored area. If such a node enters into the sleeping state then the coverage of the network will not be 100%. A node becomes a CC node when it is placed at the coverage critical point in the network. There can be many different approaches for determining the coverage critical points, according to deployment of sensor nodes. Here two types of grid of coverage area considered

a) By dividing the coverage area in the rectangular grid

To find the nodes which are coverage critical or to give full coverage we first find the coverage critical points. With the initial assumption that network area is a rectangle following are the steps to indentify coverage critical points

1. Let the strong range of the node be R.
2. Sub divides the network area in a grid of square of side 2R.
3. Center of the each grid cell and the edges of grid are coverage critical point.
4. If the nodes are placed manually than place the nodes at the critical point.
5. If they are randomly deployed than node at (X,Y) which are (+/-) 20% of strong range can be coverage critical points.

For the network area which is not rectangular in shape, then cover this area by rectangle. After determining the coverage critical point in this rectangles eliminate those coverage critical points, which were not in the original network area. Remaining points are the coverage critical points of the network area.

3.4 Determining coverage critical nodes (by using MATLAB simulation)

We assume area of 20* 20 meters, R=.5 meters of strong range then create a grid of square of 1 meter side in the area

Using above approach for determining number of coverage critical nodes the present scenario it is found that there are 841 coverage critical points. Nodes placed at the coverage critical points are called coverage critical nodes and these nodes are not eligible for cluster head selection.

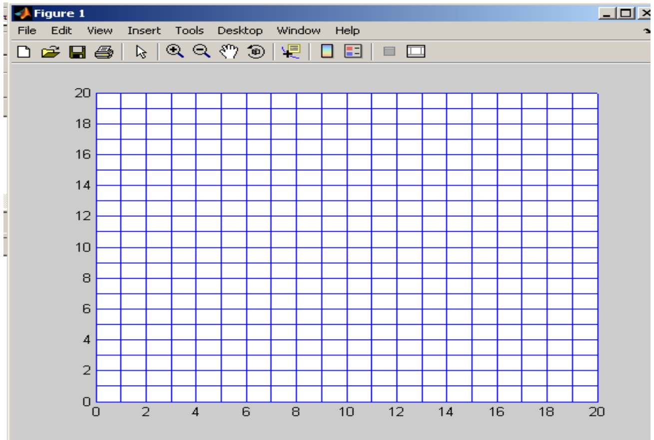

Fig. 2: Division the network area in Small Square of side 2R

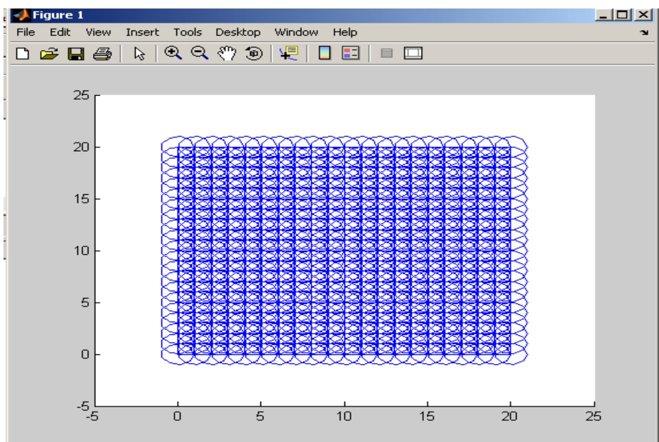

Fig. 3: Center of the each grid cell and the intersections of the grid are coverage critical point.

b) By dividing the coverage area in the Hexagonal Grid

To find the nodes which are coverage critical or to give full coverage we first find the coverage critical points. Following are the steps to find coverage critical points

1. Initially we assume that the network area is rectangle.
2. Strong range of the node is R.
3. Create a grid of hexagon with of side R.
4. Center of the each grid cell is a coverage critical point.
5. If the nodes are placed manually than place the node at the critical point.
6. If they are randomly deployed than node at (X,Y) which are (+/-) 20% of strong range can be coverage critical points.

For the network area which is not rectangular in shape, then cover this area by rectangular. After determining the coverage critical point in this rectangles eliminate those coverage critical points, which were not in the original network area. Remaining points are the coverage critical points of the network area.

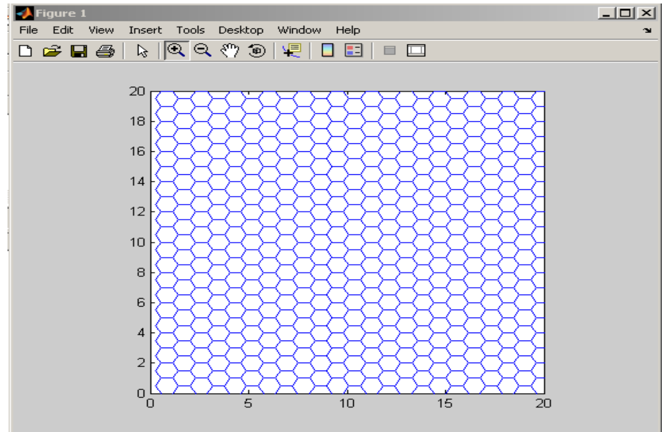

Fig. 4: Division the network area in hexagon grid

Using hexagon approach for determining number of coverage critical nodes the present scenario it is found the there are 440 coverage critical points. Nodes placed at the coverage critical points are called coverage critical nodes and these nodes are not eligible for cluster head selection.

3.5 Cluster Head Selection

Clustering is used as key for energy efficiency. In the proposed algorithm cluster head selection is based on LEACH protocol. The probability of the node becomes a cluster head will be P, p is the maximum number of cluster heads in the network (as in LEACH).In the first round cluster head selection is on random basis with cluster head probability in the network. Only those nodes are eligible for the cluster head selection, if those nodes are not deployed at the coverage critical point.

Next Cluster head selection will be done on the following criteria:

- A node has not become a CH for the past (*1/p*) round.
- The node is having the maximum residual energy in the cluster.
- The node, which is nearest to existing cluster head in cluster.
- The node should not be coverage critical node.

Next cluster head selection algorithm will be run at the cluster head when its residual energy is reached to threshold value which is decided by the network administrator. Next cluster will be from the previous cluster. But after cluster head selection new cluster will be form for each cluster head. Selected cluster head sends join request to all other nodes and a node select a cluster which is near to it.

If a cluster head is dead due to environmental issues and energy then node associated with the cluster head with the will wait for period of round time and associate with other cluster head in the next round.

4. ENERGY EFFICIENT COVERAGE AWARE PROTOCOL ARCHITECTURE

Proposed algorithm for wireless sensor network will work in rounds. Each round will consist two phase:

- State setup Phase
- Sensing Phase

In state setup phase each node will decide, whether to turn on or off. In sensing phase the node senses the environment and sends the sense data to the cluster head.

4.1 State setup Phase

State setup phase completes the selection of the state of the node and selection of cluster head. The probability of the node becomes a cluster head will be P, p is the maximum number of cluster heads in the network (as in LEACH).

Following are the steps are performed in setup phase

Step1: Selection of Coverage Critical Point

All nodes will send location information to base station. Base station selects the coverage critical points and identifies coverage critical nodes. And this information will sends to the corresponding nodes. A node has been selected as the coverage critical node can not be selected as cluster head.

Step 2: Cluster Head Selection

Then cluster head selection is done. In the first round cluster head will be selected randomly. Number of cluster heads is decided by the administrator as the function of probability.

Step 3: Cluster Head Formation

Selected cluster head sends the join request to a limited distance. The distance is set by administrator and control by the signal strength. A node can receive join request from number of cluster head. A node will select a cluster head with the minimum distance and node will sends an acknowledgement to the cluster head.

Step4: Nodes select their state for the round

In this step node will selects its state according to above mention criteria.

4.2 Sensing phase

Nodes send the sensed data to the Cluster Head and CH performs aggregation and compression on data and send it to Base Station.

5. SIMULATION SET-UP

In this section we discuss the set-up for MATLAB [22] simulations performed for performance analysis of proposed algorithm.

The simulation result gives in terms of the coverage percentage of network area. The coverage percentage is calculated on the basis of percentage of X, Y point covered by sensing range of at least one node in the network. We conduct simulations for two scenarios: a network with 100 nodes deployed over an area of size 100 x 100 m^2. The nodes are deployed either randomly or non-uniformly. In the case of the random deployment, the (x, y) locations of the sensor nodes are randomly chosen based on a uniform distribution.

5.1 Simulation parameters

Following table shows the simulation parameters

Table 1: Simulation Parameters

Parameter	Values
Simulation rounds	2000
Number of nodes	100+1 (Nodes + BS)
Topology Size	100 X 100
CH probability	0.5
Initial node power	0.5 Joule
Nodes Distribution	Nodes are randomly distributed
BS position	Located at 50, 175
Energy for Transmission (ETX)	50*0.000000001
Energy for Reception (ERX)	50*0.000000001
Energy for Data Aggregation (EDA)	5*0.000000001
Rsense	10m

6. SIMULATION RESULTS

Simulation results are represented in the terms of coverage percentage of network.

An X. Y, point is considered as covered if it is covered by sensing range of at least one node. Coverage percentage of network is calculated as percentage of X,Y points of network covered in a round.

Following table shows number of round till which specified coverage percentage is preserved in network.

Table 2: Number of round in which first dead node and all dead node occur in the network for CPCP and LEACH

	Number of round in which first dead node occur	Number of round in which last dead node occur
Algorithm CPCP	903	6051
Algorithm LEACH	821	1302

6.1 Simulation result for Coverage

In the second set we compare the CPCP algorithm with the ECHR. Both algorithm are work in round. For CPCP simulations are conducted with $R_{cluster}$ =2 . $R_{sense.}$ A random POI set is created for the ECHR of 2000. Coverage is defined as the percentage of area which is covered in network life time. In this we calculate the Location points (x,y) covered by at least one active node and then percentage of area covered. We also find the number of round in which the first dead node occur and number of round in which all nodes dead. Table 4 show the area covered by CPCP when the set of selected node will be active on the basis of coverage cost matrix and when all nodes are active.

Table 3: area covered by the CPCP when a set of selected node are active according to cost matrix and when all nodes are active.

Simulation Run	When the selected nodes are active according to cost matrix	When all nodes are active	Round number in which when selected nodes are active according to cost matrix	Round number in which first node dead when all nodes are active
Simulation Run1	83	84	912	801
Simulation Run2	86	86	840	790
Simulation Run3	79	88	890	808
Simulation Run4	92	90	912	789
Simulation Run5	80	87	902	779
Simulation Run6	83	87	812	806
Simulation Run7	85	95	892	803
Simulation Run8	89	94	801	781
Simulation Run9	93	95	905	768
Run 10	87	92	899	760

Table 4: area covered by the ECHR when a set of selected node are active according to cost matrix and when all nodes are active.

Simulation Run	When the selected nodes	When all nodes are active	Round number in which when selected nodes are active according to cost matrix	Round number in which first node dead when all nodes are active
Simulation Run1	80	75	910	830
Simulation Run2	69	85	840	870
Simulation Run3	63	71	890	808
Simulation Run4	76	79	900	801
Simulation Run5	73	78	895	798
Simulation Run6	68	83	812	813
Simulation Run7	73	85	870	805
Simulation Run8	71	86	801	796
Simulation Run9	74	80	875	786
Simulation Run10	79	84	890	879

7. CONCLUSION

In this paper, we proposed energy efficient coverage-preserving protocol architecture, which can reduce energy consumption by the use of clustering, therefore increase system lifetime, and increase coverage of network by turning off some redundant nodes. We presented a basic model for sensing range for the node in which divides node's sensing range is strong and weak sensing range and a basic coverage-based off-duty eligibility rules. In algorithm coverage critical point are used to support full coverage for the network. This kind of off-duty eligibility rule and coverage critical point for the network increase the original sensing coverage to a certain extent .The coverage critical point are calculated with rectangle grids and hexadecimal grid with the help of MATLAB[20]. The number of coverage critical point is near to double in rectangular grid (841) in comparison to hexagonal (440) for the same network area(100meter X 100 meter area with 0.5meter strong sensing for network).

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