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Detection And Recovery Of Coverage Holes In WSN Using Grid Based Clustering

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ABSTRACT: The emerging technology of wireless sensor network (WSN) is expected to provide a broad range of applications, such as battlefield surveillance, environmental monitoring, smart spaces and so on. The coverage problem is a fundamental issue in WSN.In the paper, we propose an effective approach for coverage holes detection and removal which is based on grid based clustering.In grid based wireless sensor network, cluster zones are collecting all information which is passing through sensor nodes. The network is dividing into square shape zones .Every zone is the combination of several sensor nodes. Also we have done a comparative simulation in existing scheme and our proposed scheme. Simulation demonstrates that our proposed scheme detect and recover coverage hole, and guarantee full coverage.

Keywords : clustering, coverage problem, detection holes,grid,recovery, wireless sensor networks,zones

1 Introduction

Wireless Sensor Network (WSN) is autonomous distributed network, which has spread rapidly into various potential applications such as military security[1,2], environmental protect[3,4], industrial process monitoring[5,6] ,agriculture and farming [7], structural health monitoring[8-10],passive localization or tracking[11] and so on. Many of these applications require a reliable connectivity and coverage, which can be guaranteed only if the target field monitored by a WSN contains no coverage holes. Coverage holes can be formed for many reasons, such as intrusion,explosion, environmental factors, software bugs and energy depletions [12, 13].These holes result in no uniform sensor deployments, and impair their functionality,or shorten the lifetime[14].Consequently, it is essential to detect and recovery coverage holes in order to ensure the full operability of a WSN.There is already an extensive literature about the coverage hole problems in WSNs. S. Ganeriwal, A. Kansal, et al. [15] adopt self-aware actuation for coverage maintenance in sensor networks, and present Coverage Fidelity maintenance algorithm (CO-Fi). They utilize the mobility of nodes to repair the coverage loss of the area. The dying node requests for updating the network topology, sensing neighbors of the dying node responds to request message only if it can move without losing coverage, then the dying node decides which optimization node to move. Heo et al. [17] proposed two schemes for addressing single coverage problem. In one scheme called Distributed Self-Spreading Algorithm (DSSA), which is inspired by minimizing molecular electronic energy and inter-nuclear repulsion in equilibrium of molecules. Another scheme called Intelligent Deployment and Clustering Algorithm (IDCA), which utilize low energy consumption characteristics of local clustering.W. Guiling, et al. [18] used Voronoi diagrams to discover the coverage holes, movement-assisted sensor to eliminate or reduce the size of hole. The proposed deployment protocols are VEC (VECtor-based),VOR (VORonoi-based), and Minimax, which based on the principle of moving sensors from densely deployed areas to sparsely deployed areas. Robert et al.[21] introduced means of homology for detecting holes in coverage, and give two objects: Cech complex, Rips complex from simplicial complexes based on its communication graph. The Cech complex can fully characterizes coverage properties of a WSN, but is very difficult to compute. The Rips complex is easy to construct by simple algebraic calculations, but does not in itself yield coverage data, and is at the expense of accuracy. Feng Yan et al.[22] took emphasis on Rips complex to solve triangular holes. They evaluate accuracy for triangular holes, under different ratios between communication radius and sensing radius of each sensor. Jinko Kanno et al J Yao, G Zhang et al.[24] presented sensor network coverage hole detection and patching using modeling by simplicial complexes. The hole-patching algorithm (HPA) is based on perpendicular bisector, and is dependent on previous hole detection methods. The algorithm is efficient and useful even if only partial sensor node coordinate information is available. However, it might add redundant nodes, and is not optimal in terms of the number of patching nodes. Zhiping Kang et al.[27] proposed a decentralized, coordinate-free, node-based coverage hole detection algorithm. It is based on boundary critical points, and can be run on a single node with verifying boundary critical points from neighbors. The hole patching algorithm is implemented with the concept of perpendicular bisector The patching sensor nodes are deployed on hole boundary bisectors.But the proposed algorithms are single coverage based. As alluded above,some researchers have proposed connectivity and coverage maintenance algorithms, but a majority of them using a complicated network model, or only providing partial coverage for patching. Some current algorithms are centralized which will become extremely time consuming, as the number of sensor nodes becomes significantly large. In this paper,we propose the distributed coverage hole detection and recovery scheme, and guarantee full coverage with an effective manner. The main contribution of our work can be summarized as follows. (1) We introduce a concept of zones for member calculation. (2) We bring forward a node-based coverage hole detection scheme without knowing exact locations of nodes. (3) Our proposed patching scheme is based on the concept of communication range which provide full coverage, not proportion. The remainder of the paper is organized as follows. Problem formulations with few definitions related to our work are given in Section 2. Our detection and recovery schemes are described in Section 3. Performance analysis are presented in Section 4. The conclusion and future work are made in Section 5.Acknowledments and Refrences are in Section 6.

2 PROBLEM FORMULATION

2.1 Network Model

It is considered that the sensors are distributed randomly over a large target region A, and designed to detect specified events. Each every one of sensors can sense specified events in its sensing range, and communicate with others in its transmission range. For the sake of simplicity, we assume that sensing and transmission ranges of a node S are zones with sides $\mathbf{Z_s}$ and $\mathbf{Z_t}$,accordingly, where $\mathbf{Z_s \geq 2Z_t}$, and there are no two sensors at the same location, each sensor has a unique ID. Given a set of sensors and a target area, no coverage hole exists in the target area if every point in that target area is covered by at least m sensors, where m is the required degree of coverage for a particular application .A point is covered by a Zone Z if it lies at the boundary of zone or lies within the sensing range of Z i.e $\mathbf{Z_s}$.Based on the above coverage model, we define a region A as having a coverage degree of m if every location inside A is covered by at least m nodes. Practically speaking, a network with a higher degree of coverage can achieve higher sensing accuracy and be more robust against sensing failures.

2.2 Definitions

Definition 1: Zone
We define the Zone of node S as the boundary of S's coverage region. For simplifying our geometric analysis, we assume that any point outside Zone's boundary is not covered by Z, has an insignificant practical impact.

Definition 2: Members
We use the term Members for the sensor nodes.The members of zone Z are denoted as M(Z) which are all the nodes that are within a distance of the sensing range, i.e. $\mathbf{M(Z) = \{Z_i;||Z_i\ Z= Z_s|\}}$.

Definition 3: Coverage Hole
The area H which has no member or can't be covered by any member in the target region A is a hole.

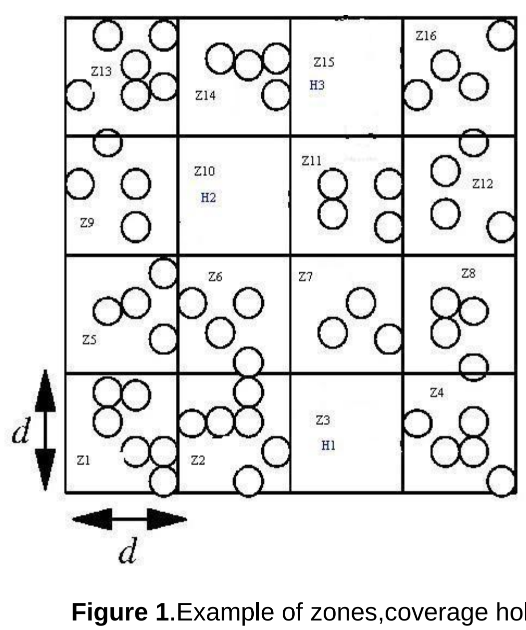

Figure 1.Example of zones,coverage holes

As shown in Figure 1, we divide the target region A into 4*4 zones i.e. $\mathbf{Z_1, Z_2, Z_3 \ldots\ldots Z_{16}}$.Then the sensor nodes are randomly deployed.When coverage degree k=1,the zone $\mathbf{Z_1}$ has six members,since these are within the sensing range of $\mathbf{Z_1}$. $\mathbf{Z_1}$ has no coverage hole as it is covered by 6 members. $\mathbf{Z_2}$ also don't have coverage hole as it is covered by 6 members.Similarly$\mathbf{Z_4, Z_5, Z_6, Z_7, Z_8, Z_9, Z_{11}, Z_{12}, Z_{13}, Z_{14}, Z_{16}}$ has no coverage holes and they are covered by the members. The zones $\mathbf{Z_3}$,$\mathbf{Z_{10}, Z_{15}}$ are not covered by any node ,since all these zones has no members. Area $\mathbf{H_1, H_2, H_3}$ are the coverage holes.

3 DETECTION AND RECOVERY ALGORITHM

In this section we decsribe the proposed scheme for detecting and patching hole.Both of them based on dividing the area into zones; one is how to find the holes; the other one is how to eliminate the holes. Also we have done a comparative simulation in existing scheme[27] and our proposed scheme. Communication range is a factor is used to find positions of new nodes for hole patching.After simulation we conclude that get less no holes in our proposed scheme and get full coverage.

3.1 Pseudo Hole Detecting and Patching

As discussed in the previous section for hole detection we need to divide the target region or network into no. of zones based on the length of the target field.The zones that are not coverd by any node or has no any member can be treated as the hole.For each hole we patch maximum two nodes to remove coverage problem.We design here an algorithm to detect and patch the coverage hole. The detail procedure is given in Table I.

TABLE I
Pseudo hole detection and recovery

Step1 : Design a Network

Design a network of 100*100 having parameters n ,xy.{ n is the no. of holes,xy co-ordinates for the zone boundary}.

Step2 : Divide the area into zones

Divide the area into 5*5 zones such that a distributed approach is achieved

Step3 : Check the existence of the node

In this the existence of the node is checked whether it exist in the zone or not.

Step4 : If any zone has no member then mark that zone as hole

Step5 : For each hole call the patching logic.

- Find the center of every zone (c=zn.center).
- Find the location where to patch the new nodes
  r=randi(commRange-3)
  pos=[-r,r]
- Insert maximum two nodes to cover the hole area.

Step7: Placed the nodes at the location within the radius of r.
Step8:Then placed the node into the zone with no coverage.
Step9: Full Coverage is achieved after each round.

Step10: We get better coverage in our proposed scheme as compared to existing one.

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Lemma 1: Any sensor node S that is deploy randomly,then $|s,z| = Z_s$ or $|s,z| < Z_s$

Proof: From the randomly deployed sensor nodes, any node that lies on the boundary of zone or lies within the sensing range of zone can be treated as member of that zone.The LEEMA 1 implies that a zone with sensing range $\mathbf{Z_s}$ can cover the sensor node.It will be useful for detecting holes.

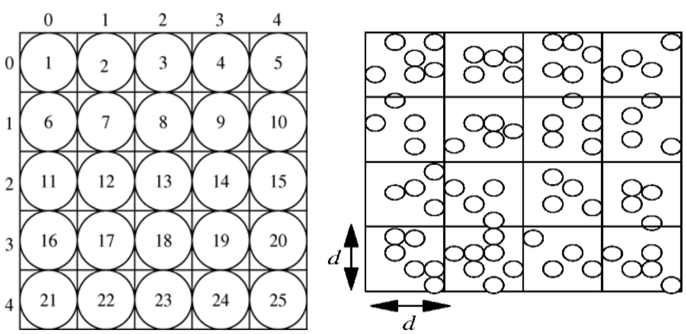
3.2 Stages for Imlementation

Our scheme is implemented by following three stages:

a) Zone configuration stage.
b) Hole detection stage.
c) Hole patching stage.

Zone configuration stage

The essential task in this stage is to divide the network field into several zones. It is divided into square shape based on zone range ($\mathbf{Z_s}$) which is determined by considering the network size, transmission range of nodes. The zones include the sensor nodes which are located within zone range.While the existing scheme[27] used the circular zones that cannot able to sense the nodes at the boundaries.While the square zones able to sense the nodes at boundaries hence less no of coverage holes.



(a) circular zones in existing Figure (b) square shaped zones in proposed

Figure 2 (a) circular zones in existing Figure, (b) square shaped zones in proposed

In figure 2 (a) in each square grids we create the sensing circles with radius of zone range (r).In the square shaped zone scheme, we create a number of grids by simply making squares with widths of zone range($\mathbf{Z_s}$) as illustrated in above figure 2 (b).

Hole Detection stage

This stage consist of detection of holes .Each zone run a scheme to check its member (sensor node).In other words each zone check whether any member belongs to it or not .If not then we mark zone as a hole.

Hole patching stage

After hole detection this stage comes .In this stage a patching logic will be call in order to cover the holes .According to our assumption we can insert maximum two nodes for the hole coverage.

Leema 2: First we find the center of every zone by using :

c=zn.center

Then find the location where to patch the new nodes by using following formula:

r=randi(commRange-3)
pos=[-r,r]

It is obviously that the rule ensure the new node coverage maximize hole areas. Above all, the whole Hole Patching can be described in Table I.

4 PERFROMANCE EVALUATION

4.1 Simulation Setup

Our algorithms are simulated using MatLab 7.10 for different number of nodes that are deployed randomly over 100m × 100m. According to our scheme we can deploy any number of nodes . For each sensor node, the sensing range is 10m, and communication range is twice of the sensing range 20m. The network is heterogeneous, and coverage degree k=1.We use square simulating different coverage holes. The simulation results are averaged over 20 independent runs. In our proposed scheme we use square zones simulating different holes, while in existing scheme[27] sensing circle was used. The result of the simulation in existing scheme[27] is the no of uncovered area or holes are more as compare to our proposed scheme.The result of simulation is that the entire region is covered and connected.

4.2 Simulation Parameter

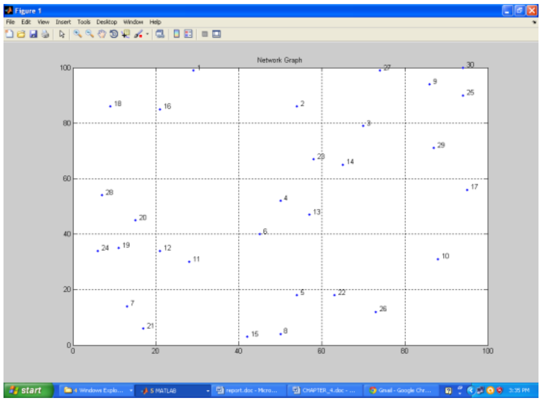
The following are the simulation parameters considered for the implementation of the developed scheme:

- An area of 100 * 100 is selected.
- Area is divided into 5*5 zones.
- Width of each zone is half the communication range i.e. 10m.
- No of deployed nodes is n.
- No of new node to cover each hole is 2.(We choose the maxnode=2 for patching in order to cover each hole ,also get full coverage,while in existing[27] some ratio of new nodes was used that not necessarily cover each hole;it may leave many fragments of holes.)

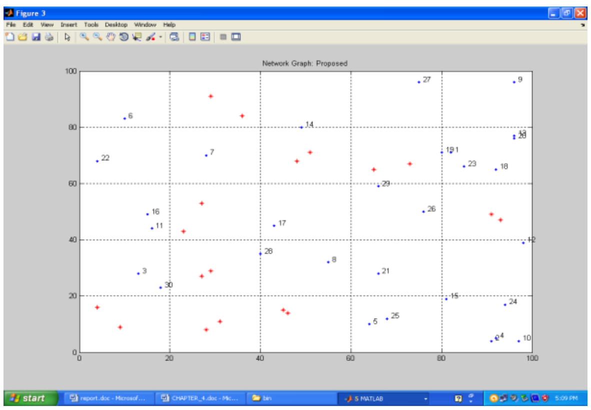
4.3 Simulation Result

Experiment I: Patching of Randomly Deployed WSNs

We randomly deployed 30 sensor nodes and divide the network into 5*5 zones.Check that whether each zone has member or not.If not then treat that zone as Coverage hole,we get 9 coverage holes , see Figure3. Simulations show that our algorithm works well when more than one hole exist in a randomly deployed network. One can see that our successfully patched the network with 30 initial nodes.



(a) Randomly deployed WSN with intial 30 sensor nodes and 9 holes exist.



(b) no hole left after patching.

Figure 3. (a) Randomly deployed WSN with intial 30 sensor nodes and 9 holes exist. (b) no hole left after patching.

Experiment II: Coverage analysis

We choose a empty square zone as a coverage hole, and length of edge is 10m. We use algorithm to recover the square zone. The graph is given in Figure 4,which show effect of increasing no. of nodes on coverage holes.It implies (as shown in TABLE II)When we add 20 new nodes ,no. of holes left 9.As we add more nodes the no. of holes decreases and we get full coverage.

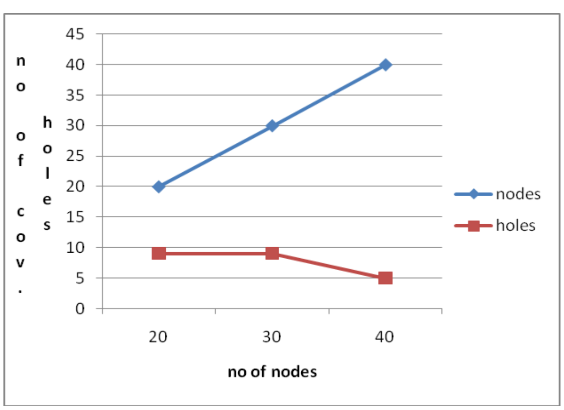


Figure. 4 Effect of Increasing No of Nodes on coverage holes in proposed

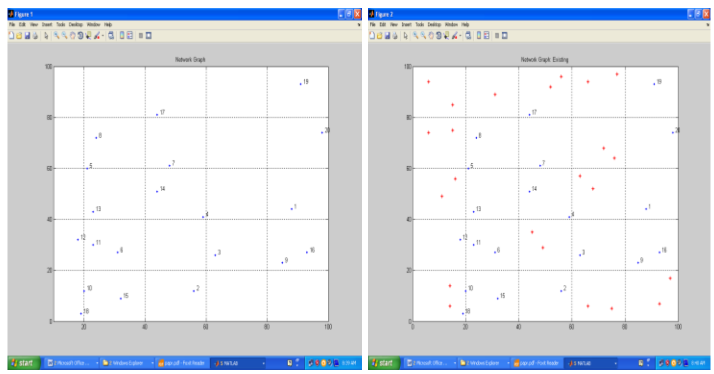
TABLE II
Experiment II coverage hole configuration

No of nodes	20	30	40
No of holes	9	9	5

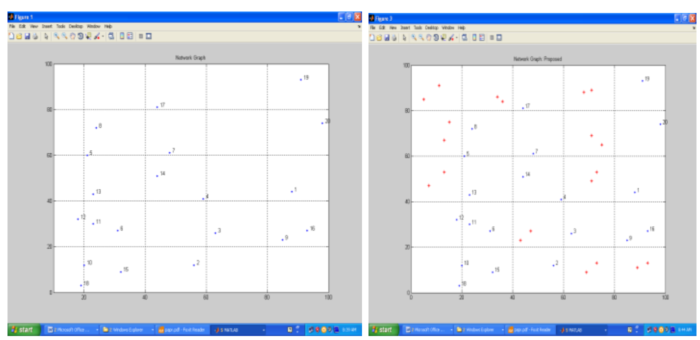
Table II Final Values For no of Node And Corresponding no of holes

Experiment III: Comparing with Existing scheme

Existing patching scheme[27] is based on the concept of perpendicular bisector line. Every hole boundary edge has a corresponding perpendicular bisector and patching nodes are deployed on hole-boundary bisectors. In order to compare with existing approach[27], we randomly deployed 20 sensor nodes in an area 100m*100m form a coverage hole. Then run two schemes independently to patch the coverage hole.



(a) (b)



(c) (d)

Figure 5. Simulation of network environment using Existing and our proposed algorithm: existing with simulation 1 (a), existing with simulation 1 (b); proposed with simulation 2 (c), proposed with simulation 2 (d).

As shown in Figure 5, instance (a) and (c) give 12 and 10coverage hole, both of Existing and our proposed adopts new sensors to patch. In (b) and (d), existing needs 24 sensors, our algorithm require 20 sensors. To all appearances, our algorithm is require less number of patching nodes. But we provide a full coverage; existing[27] brings many fragment of hole. If existing[27] also achieve full coverage, the number of sensors will much higher than the algorithm. As shown in Figure 6, we record the experiment for 7 independent runs, and

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compare the result of both proposed and existing scheme with actual.We see that at 7th run our scheme has no hole left as actual while existing scheme still has 2 holes remaining.So,we conclude that our proposed scheme provide a better solution for coverage hole detection and removal of holes,provide full coverage.

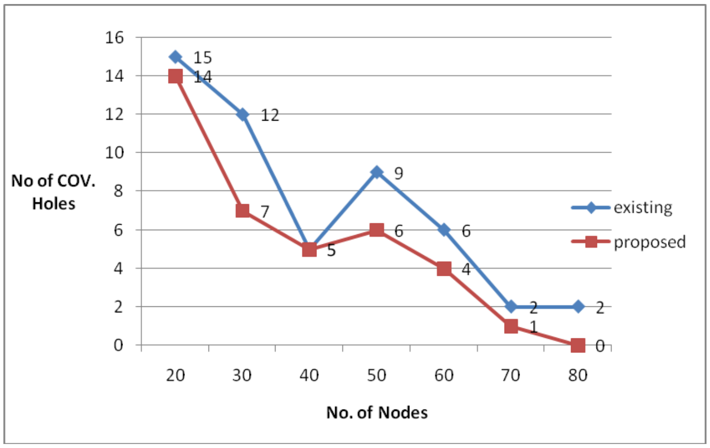

Figure 6. The relationship between deployed nodes and coveage holes(existing and proposed)

5 Conclusion and Future work

The paper proposes a solution for distributed coverage hole detection and patching in coordinate-free wireless sensor networks, which based on dividing the area into several zones. Simulation results show successful hole detection, patching and comparision in exisiting and proposed scheme for coverage. Our proposed scheme has number of advantages:

1) Benfiting from the zone-based node discovery strategy, it is able to quickly and efficiently discovery of nodes.
2) energy consumption for node replacing is distributed into multiple
 nodes, and thus prolonging network lifetime.
3) effective fault tolerance mechanism, it is robust against coverage holes.
4) By removing holes we get a network with a higher degree of coverage can achieve higher sensing accuracy and be more robust against sensing failures.

The evaluation only shows the algorithms for small area coverage , but also can run in highest coverage. The algorithm is efficient and useful even if only partial sensor node coordinate information is available. Further research and simulation will use our proposed algorithms in reality.

6 End Sections

6.1 Acknowledments

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