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Comparison between Network Coverage Strategies in Wireless Sensor Network: A Review

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Abstract— This paper presents an efficient coverage scheme for wireless sensor networks. This scheme focuses on coverage strategies of wireless sensor network which are compared on different parameters, where Delaunay triangulation is more efficient coverage strategy as compared to square grid deployment strategy because in Square grid coverage strategy if the sensing area increases than overlapping of sensing area is increased which is not desirable for valid data in coverage of region of interest. Delaunay triangulation proposes is to centralized sensor deployment method, DT (Delaunay Triangulation) -Score, aims to maximize the coverage of a given sensing area with obstacles. The DT-Score consists of two phases. In the first phase, contour-based deployment is used to eliminate the coverage holes near the boundary of sensing area and obstacles. In the second phase, a deployment method based on the Delaunay Triangulation is applied for the uncovered regions.
Keywords**—** wireless sensor network, Delaunay triangulation, DT-Score,

I. Introduction

A wireless sensor network (WSN) consist of spatially distributed autonomous sensors to cooperatively monitor physical and environmental conditions such as temperature, sound, pressure, vibration, motion or pollutants. A sensor node is a node that is capable for performing some processing, gathering sensory information and communicating with other connected nodes in the network. Their features of self-organization and dynamic reconfiguration make them a perfect choice for applications

to monitor and gather physical data in harsh environments. Sensor nodes provide absolute results in monitoring the target field. Wireless sensor network are used in many application such as military, agriculture and medical monitoring and environmental surveillance. Coverage is critical for wireless sensor networks to monitor a target field. In many application scenarios, full target field coverage is required, which means every point inside the target field must be covered in the wireless sensor network.

II. Related Work

The coverage problems for sensor networks can be categorized into three broad types [2]

- **Area coverage** where every point inside an area is to be monitored.
- **Target coverage** where the main objective is to cover a set of discreet targets.
- **Breach coverage Breach coverage** the goal here is to minimize the numbers of uncovered targets or the ratio of uncovered portion to the whole area. In this paper, we focus on area coverage in sensor deployment. Deploying sensors to provide complete area coverage is an essential design problem in many wireless sensor network (WSN) applications. Mainly three alternative deployment approaches have been proposed. One among them is application-specific deterministic deployment, another is random deployment and the third one is grid based (also known as pattern-based) deployment [9]. In deterministic deployment, the sensor nodes are placed deliberately in the required region. This type of deployment is suitable only for small-scale applications. Non-deterministic deployment is scalable to large scale applications or hostile environments. In this type of deployment, the sensor nodes are thrown randomly to form a WSN. However, it could be very

expensive since excess redundancy is required to overcome uncertainty. Grid-based deployment is an attractive approach for moderate to large-scale coverage

III. Coverage Scheme

Here this scheme focuses on the coverage strategies we used to achieve the maximum coverage .These coverage strategies are divided into three categories:

1. Random Deployment
2. Grid Based
3. Computational Geometry Based

Random Deployment: - Throwing the sensors from the flight into the target field is one of the examples of random deployment scheme. In this random deployment scheme there is a chance of occurring overlap of sensors on one another. And the deployment scheme may not cover the entire target field that means there may not be any sensor to monitor a particular region in the target field as shown in figure1. So Random deployment is not suitable for total coverage of the target filed to form the wireless sensor network.

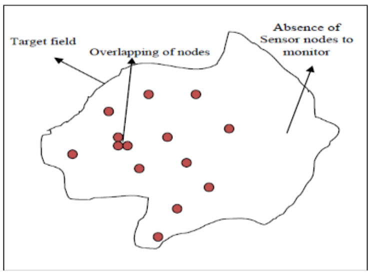


Figure 1: Random deployment

Grid Based: - In grid based deployment scheme the available deployment strategies are square grid deployment, triangular deployment and the hexagonal deployment [1]. But the target field may not be any of these shapes. Suppose the maximum possible shape that will be fitted into the target field is identified and then the nodes are deployed according to the grid based deployment, we can't achieve the total coverage as the WSN is not formed in the remaining area of the target field as shown in the figure 2.

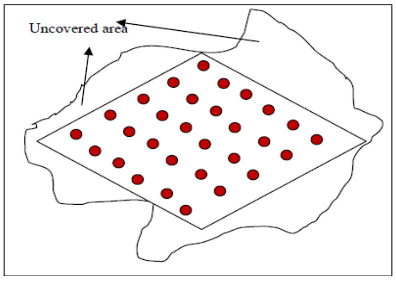


Figure 2: Grid based deployment

Then in order to deploy the nodes first the target field must be divided into the grids then the grid deployment scheme should be implemented. The target field may be divided into a collection of squares or triangles or hexagons called as tilings as shown in figure 3.

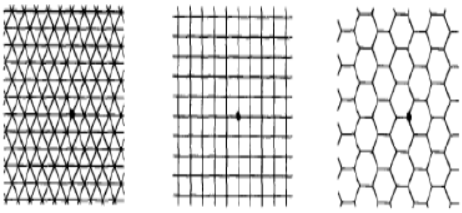
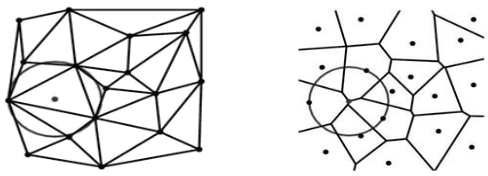


Figure 3: Homogeneous tilings

Computational Geometry Based

Delaunay Triangulation and Voronoi Diagram are important data structures in Computational geometry. Delaunay Triangulation is the dual structure of the Voronoi diagram in 2-D plane. It satisfies the empty circle property, that is, for each edge in Delaunay Triangulation, we can find a circle passes through the edge's endpoints without enclosing other points.



(b)

Figure.4 (a) Delaunay Triangulation. (b)Voronoi Diagram.

In Fig. 4(a), we can find the largest empty circle from the Delaunay Triangulation of given sensors. In Fig. 4(b) the center of the largest empty circle has the weakest detection probability for current available sensors.

IV. SENSOR DEPLOYMENT BASED ON DELAUNAY TRIANGULATION

The empty circle property of Delaunay Triangulation provides a way for us to find such region. The DT-Score algorithm consists of two phases.

- The first phase is contour deployment.
- Second phase is refined deployment.

4.2 Phase one – contour deployment

Initialization step: In this step, a sensing area is generated from a given configuration file. This file includes the size of sensing area, the parameters of sensors for the probabilistic sensor detection model, the Position and size for each obstacle, and coordinates of pre-deployed sensors.

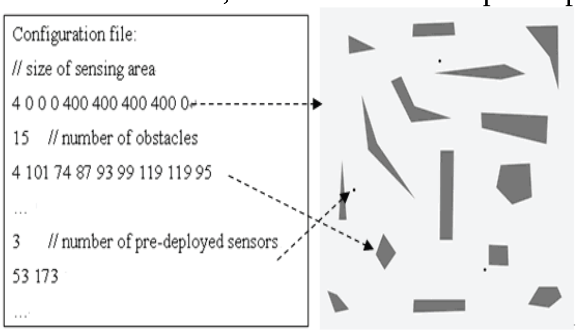


Figure. 5 Initialization step.

The sensing area is defined as a rectangle and the obstacle is modeled as a polygon Sensor vector is used to store the position of deployed sensors. Fig. 5 is an example of initialization step.

Contour points generation step : This step is used to eliminate coverage holes near the boundary of sensing area and the obstacles. Initially, contour points are placed alone the boundary of sensing area. In order to get more coverage gains, an offset is existed between contour point and boundary.

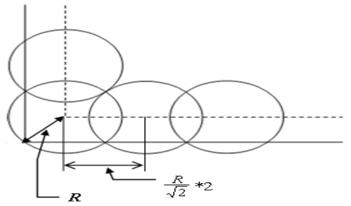
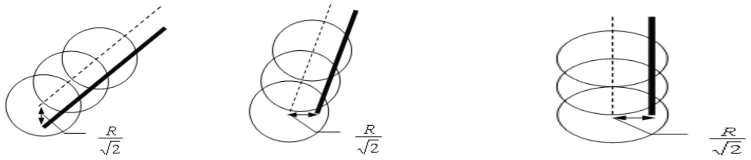


Figure. 6. Offset calculation.

Fig. 6 illustrates the calculation of offset, suppose the radius of sensing region for each sensor is denoted to R, then the offset is R/sqrt(2) . It ensures that the boundary of sensing area can be fully covered with the least number of sensors. The positions of contour points will be added to Sensor vector if they are not within any obstacles.

Next, contour points are placed around the obstacles. For each obstacle, we first calculate the line equation of the edges in point-slope form. If the slope of the edge is less than or equal to 1(See Fig. 7(a))., the contour points are placed with an offset R/sqrt(2)in y-axis away from the obstacle .If the slope of the edge is greater than 1 and less than 10, the contour points are placed with an offset R/sqrt(2)in x-axis away from the obstacle (See Fig. 7(b)). For the case where vertical edge or the slope of the edge greater than or equal to 10, the contour points are placed with an offset R/sqrt(2)in x-axis away from the obstacle (See Fig.7(c)). The distance between any two adjacent contour points is also set to 2R/sqrt(2). If a contour point is not within any obstacles or outside of the sensing area, it will be added to Sensor vector.



(a) slope <= 1 (b) 1< slope < 10 (c) vertical line or slope >= 10

Figure. 7. Offset under different slope.

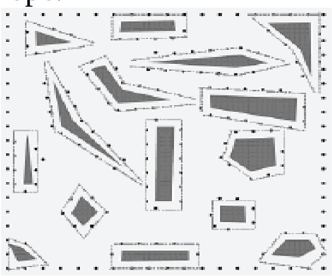


Figure. 7. Contour points generation step

4.3. Phase two – refined deployment

Candidate positions generation step. In this step, candidate positions for sensor deployment are generated. We use the Delaunay Triangulation algorithm proposed in [5] to determine these positions. Delaunay Triangulation algorithm to the sensor configuration shown in the Fig.9. The centres of these circumcircles are Candidate positions of new sensors. Except the Positions located on the obstacles, a fixed number of positions will be added to the Candidate array according to the radius of circumcircles in decreasing order.

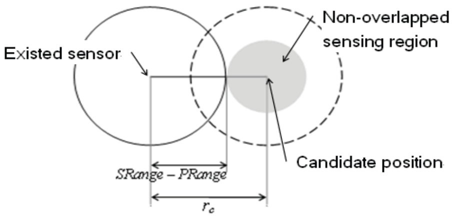


Figure. 8. Overlapping with other sensor.

Scoring step. In order to deploy a new sensor with the most coverage gains, a scoring mechanism is used to evaluate each candidate position within *Candidate* array. At first, a grid square is placed and centred on each candidate position. The length of edge is (*SRange* + *PRange*)*2. It ensures that any point within the sensing region is considered. The probabilistic sensor detection model, is used to calculate the coverage gains for a candidate position by summarizing the coverage rates at all grid points. The coverage gain is affected by two factors. The first factor is the ratio of sensing region overlapped with existed sensors. Suppose *rc =Candidate[i].radius* is the radius of circumcircles for a candidate position *i*. If *rc* is less than (*SRange –PRange*)*2, then the sensing region of sensor on position *i* will overlap with existed sensors. The ratio of non-overlapped sensing region is calculated by the area of grey region in Fig.8 divided by the area of sensing region with radius (*SRange – PRange*), where the radius of grey region is *rc* – (*SRange – Range*).Another factor is the influence of obstacles. If a line that connects a grid point and a candidate position intersects with obstacles, the grid point cannot be detected by a sensor placed on the candidate position and cannot contribute any coverage gains. At last, the score for candidate position *i* is stored in *Candidate[i].score*. The procedure of scoring step is outlined in Fig. 9.

```
Algorithm Score (Candidate [])
    k = size of Candidate [];
    for ( i=0; i < k; i++ )
    {
       Candidate[i].score = 0;    /* initialize */
       Set a grid rectangle centered on Candidate[i];
       for (all grid points within grid rectangle)
       {
          if (a grid point g is not blocked by any obstacles)
          {
             Candidate [i].score += C_g (i);
             /* coverage rate of sensor i at grid point g */
          }
       }
       if (Candidate [i].radius < (SRange - PRange)*2)
       {
       /* calculate the ratio of non-overlapped sensing region */
          Candidate [i].score *= ((Candidate [i].radius -
(SRange - PRange)) / (SRange - PRange))^2;
       }
    }
End_of_Score
```

Figure. 9. Procedure of the Score algorithm.

Sensor addition step. When all candidate

Positions are scored; the candidate position with the highest score is selected to deploy a new sensor. Thus, the position of new sensor is added to *Sensor* vector. The candidate generation, scoring, and sensor addition Steps are repeated until the target number of

A deployable sensor is reached.

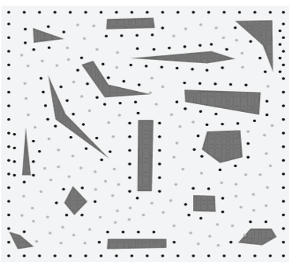
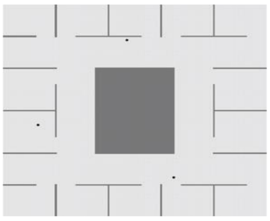


Figure. 10. The result of DT-Score.[8]

Fig. 10 shows the result of the refined deployment phase with 300 sensors. The grey points are sensors newly added in this phase.

The time complexity of DT-Score algorithm is O(*n2 log n*), where *n* is the number of sensors and the Delaunay Triangulation algorithm has time complexity of O(*n log n*) [7]. For the grid-based deployment methods [8], their time complexity is O(*N2*), where *N* is the total number of grid points in a sensing area. It is clear that the grid-based approach has higher computational overhead than DT-Score when the number of deployable sensors keeps increasing.

(a)test case 1



(b)test case 2

Figure. 11. Maps for test cases

In test case 1, there are 15 obstacles in the sensing area. From the results illustrated in Fig. 12, we can find that DT-Score is better than other algorithms except for the Min-10 when the number of deployable sensors is 200. It is because that the DT-Score deploys most of the available sensors in the contour deployment phase, and the coverage gains are smaller than the MAX_MIN_COV algorithm with larger grid distance. Besides, the characteristic of grid-based deployment is observed as well, that is, as the gird points used up, the coverage of MAX_MIN_COV reaches to a saturation point. In Fig. 14, the saturation point of Min-5 and Min-10 is 350 and 250 respectively. In contrast, Min-5 has much poor coverage than Min-10 if the number of deployable sensors is small. It is because that Min-10 has larger grid distance that reduces the overlap of sensing region, and more coverage gains can be earned. As a result, we can find that the performance of grid-based deployment is deeply influenced by the density of grid points. For random deployment algorithm, the results are represented with error bars and mean values. We can find that the performance of random deployment is poor than other approaches in most cases. In test case 2, there are 17 obstacles in the sensing area. Unlike the various shapes of obstacles in test case 1, the regular-shaped obstacles are used. The results are shown in Fig. 13. The coverage of grid based deployment is limited by the density of grid points. DT-Score can achieve higher coverage than MAX_MIN_COV as the number of deployable sensors over a threshold.

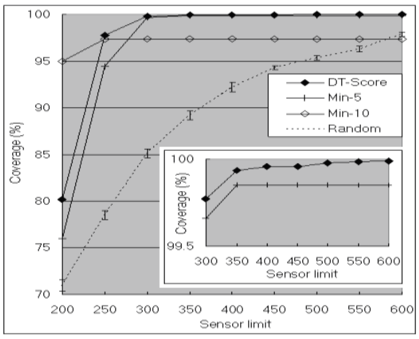


Figure. 12. Results of test case 1

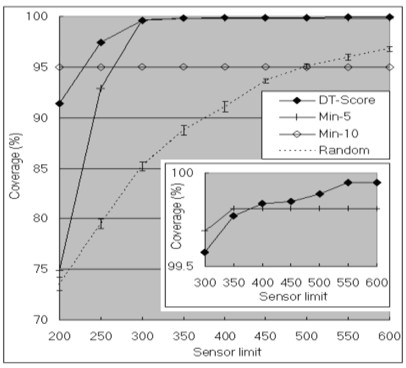


Figure. 13. Results of test case 2.

V. CONCLUSIONS

Proper information about the coverage in a Wireless Sensor Network could have high impact on the algorithms designed to provide it. Older coverage measurement tools just provide a simple ratio of covered to desired area. Finding the shape of the coverage on the field could help researchers to create more uniform coverage and to prolong the network lifetime. In this paper, we have proposed a new measurement scheme, based on DT, which gives detailed information about the areas between sensors, distance between sensors, and fat, healthy and thin sensors. This information can improve understanding of the coverage properties of different coverage promising algorithms, and comparison among them.

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