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An Algorithm for Deployment of Hetrogeneous Sensors

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Abstract

This paper explains the deployment problem of static wireless sensor networks and how a optimal solution can be found. Static wireless sensor network deployment has several issues like coverage, connectivity and life time. However coverage is the basic problem while deploying a network. This works considers heterogeneous ranges of sensors.

Here we explore the different techniques for deployment of sensor networks and try to maximize the area covered and maintain the connectivity of the sensors within a given field of deployment using circle packing algorithm. The experiment was done to compare number of sensors deployed when communication of different range. And also a comparison of area covered when the sensors are having different communication range. For this purpose we make use of circle packing theory from the field of computational geometry which packs circles in a rectangle.

Keywords

Sensor networks, Packing, Deployment, Connectivity, Heterogeneous Sensors.

I. Introduction

Wireless Sensor Networks are networks which consist of wireless nodes which are distributed in region to monitor physical or environmental conditions like humidity, temperature and pressure. Whenever a change occurs or an event is detected, the nodes transmit the change or the data to a central sink. The sink is connected to a centrally monitoring device which can be a computer or any other processing device. A sensor node can vary in size, communication range and sensing capability. Wireless Sensor Networks were developed for applications like Military Battlefield, Forest Fire detection volcano eruption etc. Wireless Sensor Networks have issues like coverage, network connectivity and network life time. Coverage is the basic problem when sensors are deployed in a monitoring field. [3,7].The idea behind this paper is to deploy wireless sensors in a given field. With the aim to deploy both homogeneous and heterogeneous sensors with different ranges such that the monitoring field is covered to the maximum and the number of sensors required i.e. the cost of deployment should be minimum. Also when two sensors are deployed their overlapping should be minimum. So we implement and compare four variations of circle packing algorithms.

II. Related Work

[10].The idea of coverage by sensor network is introduced by Chvatal in which the deployment of WSN was similar to Art Gallery Problem (AGP). In this problem we try to minimize the number of guards and try to maximize the monitored field. This problem involves a lot of combinational optimization where we need to explore every solution, the complexity of the problem increases as the monitored field becomes large

[8].An incremental deployment algorithm in which nodes are deployed such that the coverage is maximized and line of sight of the sensors is also maintained. It also does not require prior models of the environment.

[6].Two algorithms for packing unequal circles in a rectangle where used to pack circles the basis of their degree of hole. The circles with maximum degree of hole were placed in the rectangle. (Hole degree of a corner placement)

Let p(ci,x,y) be a corner placement, u and v be the two items (circle or side) touching circle ci if ci is placed at (x, y). The hole degree λ of the corner placement p(ci,x,y) is defined as

$$\lambda=(1-d_{min} / r_i) \qquad (2.1)$$

where ri is the radius of ci, and dmin is the minimal distance from ci to other circles in M and sides of the rectangle (excluding u and v), i.e. d_{min} = min where j∈Minimum of {s1,s2,s3,s4}, j≠u,v(dij).

[1].A Sequential Packing Deployment Algorithm for the deployment of heterogeneous sensor wireless sensor networks was used to order to maximize the coverage of the monitored field and connectivity of the deployed sensors. The algorithm packed un-equal circles in a rectangle. The algorithm deploys the sensors using greedy approach and tries to maximize the area covered .The algorithm also reduces the overlapping area covered by two adjacent sensors.

III. Ideation

The idea behind this paper is to deploy wireless sensors in a given field. With the aim to deploy both heterogeneous sensors with different ranges such that the monitoring field is covered to the maximum and the number of sensors required i.e. the cost of deployment should be minimum. Also when two sensors are deployed their overlapping should be minimum. So we implement and compare two variations of circle packing algorithms.

The problem can be mathematically stated as follows.

Let S be set of the number of sensors to be deployed in the field F. Our aim is to cover the area of the field without overlapping of the sensor range.

Let l be the length of the field and w be the width of the field. Let i and j be the two sensors to be deployed in the field F. The coverage area of the two sensors i and j can be represented by circles c_i and $c_j c_i$ and c_j respectively, with centres $c_i\ (x_i, y_i)$ and $c_j\ (x_j, y_j)$

The problem can be formulated as follows:

$$\text{MAX}\left(\sum_{i \in S} \left(\frac{\pi r_i^2}{l.w}\right) \right) \qquad (3.1)$$

Such that:

$$\text{Min}(c_i, c_j) \leq \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

$i \neq j \quad i,j \in S$ (3.2)

$x_i - r_i \geq 0 \quad i, \in S$ (3.3)

$l - x_i - r_i \geq 0 \quad i, \in S$ (3.4)

$y_i - r_i \geq 0 \quad i, \in S$ (3.5)

$w - y_i - r_i \geq 0 \quad i, \in S$ (3.6)

Equation (3.1) represents our main objective.
Equation (3.2) ensures that the sensors are connected to each other.
Equations (3.3) to (3.6) take cares of the conditions that the sensors are deployed within the monitored field.

IV. Proposed Work

Algorithm for heterogeneous deployment of WSN is as follows

1) Feed the range of sensor length and breadth of the field under consideration.
2) Let x and y represent the centre point from where sensor is to be deployed.
3) Place the first circle with radius r_i (which represents the sensor).
4) Determine minimum distance $d_{min} = 2r_{i;}$
5) Determine the centre of new circle using the relation.
   $x_c = x + d_{min} + r_i * \cos\alpha$
   $y_c = y + d_{min} + r_i * \sin\alpha$
   where x and y are the co-ordinates of the centre of the circle deployed in step 2.
6) Using the centre computed in step 5 calculate the circum points of the circle as follows
   $X1 = xc + r_i * \cos\beta$
   $Y1 = yc + r_i * \sin\beta$
7) If X1 and Y1 are within the field and are not overlapping with other circle then increment β go to step 6.
8) Increment α and go to 6 as overlapping or out of field points are detected.
9) If condition 8 is satisfied for all values of β (from 0 to 360)
10) If Area remains uncovered in the field then repeat steps 4 to 9 until the circles with the given range r can be deployed.
11) If it is not possible to deploy a circle with radius r_i select the next circle with r_k ($r_i > r_k$) and repeat steps 4 to 9.

In this case the deployment is heterogeneous i.e. all the sensors have the different range of communication as shown we accept the dimensions of the monitoring field F then we accept the maximum range of sensor communication r_i (step 1). We accept the starting point for which the first sensor is to be placed. The starting point of deployment can be either centre of the field or from the corner of the field depending upon user input. We deploy the first circle here (step 3). This is initial step in our algorithm all the other circles are deployed based on the deployment of this circle. We then calculate minimum distance d_{min}.d_{min} is the minimum distance to be maintained while deploying a new circle. Now we calculate the centre of the new circle (x_c, y_c) to be deployed as,
$x_c = x + d_{min} + r * \cos\alpha$
$y_c = y + d_{min} + r * \sin\alpha$
Where x and y are the co-ordinates of the circle deployed in step 3. Now we calculate the circum points of the circle to be deployed as
$X1 = x_c + r * \cos\beta$
$Y1 = y_c + y * \sin\beta$
Every circum point X1 and Y1 should satisfy the boundary constraint and overlapping constraint, i.e it should be within the monitored field and should not overlap with other circle. This condition is checked for all values of β i.e from 0 to 360 (step 7).If these constraints are not met then the circle is not deployed at centre point (x_c, y_c) and new centre points are computed by incrementing the value of α. (Step 8).The circle is deployed in the field if condition 8 is met for all values of β and count of number circle is incremented. For each circle deployed steps 4 to 9 are repeated iteratively. Thus we try to maximize the coverage deploying as many circles as possible. When it is not possible to deploy circles for the maximum range r_i we select the next minimum range r_k where ($r_i > r_k$) and deploy the circle in the remaining area.(Step 11).Finally we compute the area covered by all circles.

V. Simulation and Results.

Simulation of the four variants of circle packing algorithm is done on Windows platform using VC++ 6.0.Here we consider two variants of the algorithm.
1) Heterogeneous deployment when the sensors are place from centre.
Here we compare the heterogeneous deployment of the sensors for various set of ranges (50,40,30), (40,30,20) and (30,20,10). The area of the field was calibrated to 400x400 sq m. The total area covered by (50, 40, 30) was 69.89% while (40,30,20) range of sensors covered 76.37% and finally (30,20,10) covered 82.26% of the field. Fig 5.1 shows the Comparison of Heterogeneous sensor deployed from centre.

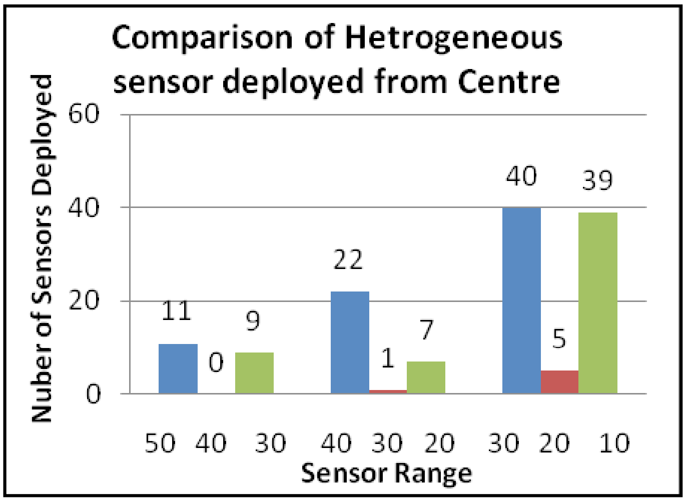

Fig. 5.1: Comparison of Heterogeneous sensor deployed from centre

Fig. 5.2 Shows the deployment pattern of the circles generated for 400x400 field when the circles are deployed from the centre of the field when the sensor range was (40,30,20).

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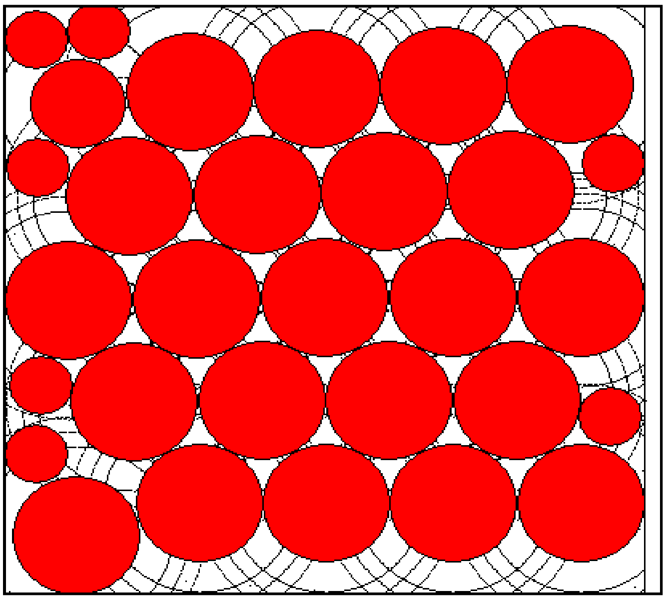

Fig. 5.2: Heterogeneous Deployment Pattern of the circles generated for 400x400 field when the circles are deployed from the centre of the field

2) Heterogeneous deployment when the sensors are place from corner.

Similar to the corner placement approach here we place the initial sensor at the centre of the field. Here we again consider the set of ranges as (50,40,30), (40,30,20) and (30,20,10). The area of the field was calibrated to 400x400 sq m. The total area covered by (50, 40, 30) was 78.9% while (40,30,20) range of sensors covered 85.6% and finally (30,20,10) covered 85.40% of the field. Fig 5.3 shows the Comparison of Heterogeneous sensor deployed from corner

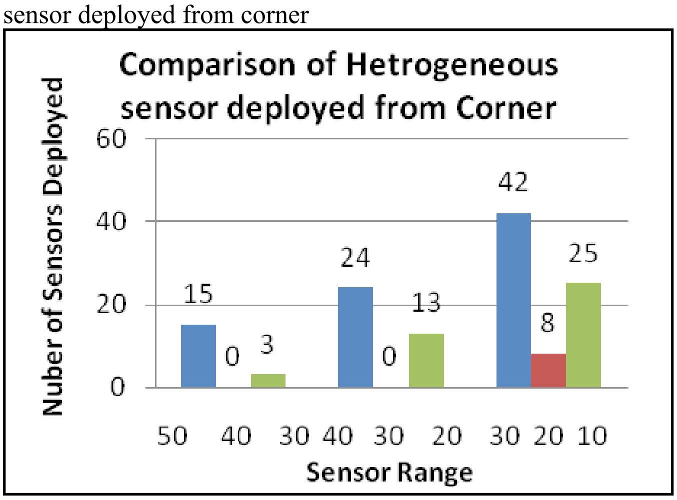

Fig 5.3 Comparison of Heterogeneous sensor deployed from corner

Fig 5.4 Shows the deployment pattern of the circles generated for 400x400 field when the circles are deployed from the corner of the field when the sensor range was (40,30,20).

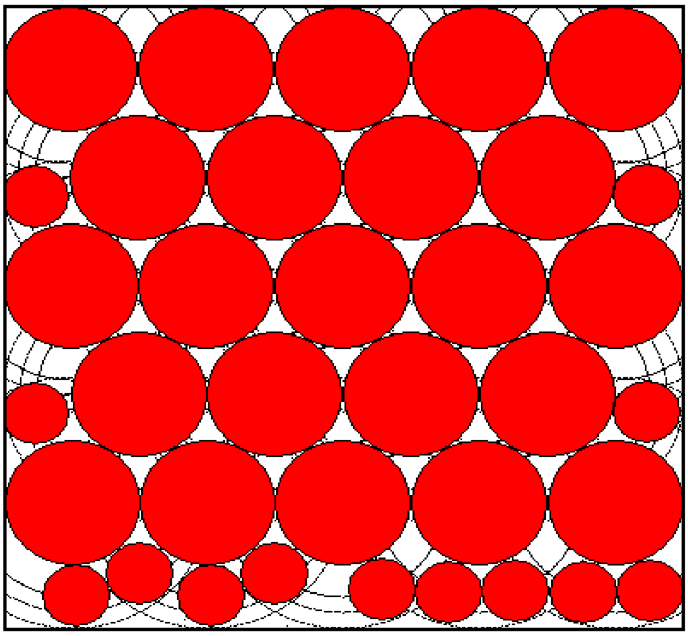

Fig. 5.4 : Heterogeneous Deployment Pattern of the circles generated for 400x400 field when the circles are deployed from the corner of the field

VI. Conclusion

Here we have compared the variants of sensor deployment. The variants used corner and centre placing of the sensors. Corner placed deployment gives a better coverage then centre one. The deployment pattern which is obtained is hexagonal in nature. The holes generated in homogeneous pattern are covered with other sensors having less range in thus improving the coverage of the network.

VII. Future Enhancement

In this work we have tried to deploy sensor which are heterogeneous in nature. The sensors are deployed sequentially. We get fare amount of coverage using this approach. However both the objectives coverage and connectivity can be improved by using a good heuristic approach. A heuristic algorithm can give better performance and a better optimal solution for the deployment of sensor networks.

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