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An Efficient Coverage Scheme for Wireless Sensor Network

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Abstract— This paper presents an efficient coverage scheme for wireless sensor networks. This scheme focuses on two 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 we increase the sensing area than overlapping of sensing area is increased which is not desirable for valid data in coverage of region of interest where as in Delaunay, if we increase the sensing range of sensors than each node can communicate with other nodes in the network.

Keywords: wireless, sensor, node, Coverage issues, Delaunay Triangulation , Square Grid

I. INTRODUCTION

In computer science and telecommunications, wireless sensor networks are an active research area with numerous workshops and conferences arranged each year. 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. Basically a sensor network normally constitutes a wireless ad-hoc network, in which each sensor supports a multi hop routing algorithm where node function as forwarders, relaying data packets to a base station. Wireless sensor network are used in many application such as military, agriculture and medical monitoring and environmental surveillance.

One of the most active research fields in wireless sensor network 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. There are several issues in WSN that need to be addressed. However some of these issues create conflicts and constraints to coverage optimization. Therefore works not only focusing in maximizing coverage but also optimizing these issues. A better WSN can be achieved by enhancing the existing coverage strategies which results a superior coverage strategy and a comparative analysis is made between Square grid based coverage strategy and Delaunay triangulation computational geometry based coverage strategy.[1]

II. RELATED WORK

Despite the wealth of Previous research studies conducted separately on sensor network and coverage of sensor network and coverage of sensor network which are surveyed i.e joint consideration of those two concepts for WSN is so common. Eyuphan Bulut, Zijian Wang and Boleslaw K.Szymanski[2] concludes a neighbour graph as the graph formed by the neighbours of a node and analyses the effect of different levels of connectivity in neighbour graphs on the coverage redundancy of sensor nodes. J. Naskath, Dr.K.G.Srinivasagan, S.Pratheema[3] focuses on the sensor replacement problem in WSN consist of mobile sensors. Gao Jun Fan and Shi Yao Jin[4] presented a survey of coverage problem where two challenges are described, namely, maximizing network lifetime and network connectivity. Ridha Soua, Leila Saidane, Pascale Minet[5] proposed an approach to use a mobile robot to assist the initial sensor deployment and to improve sensing coverage and connectivity of monitored area. Fariha Tasmin Jaigirdar[6] provides a novel grid approximation algorithm for efficient and low cost deployment of inductive charger so that the minimum number of chargers along with their placement locations can charge all the sensors of the network.

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.Force Based
2.Grid Based
3.Computational Geometry Based

1. Force Based:

Force based deployment strategies rely on the sensors mobility, using virtual repulsive and attractive force, the sensors are force to move away or towards each other so that full coverage is achieved. The sensors will keep moving until equilibrium state is achieved; where repulsive and attractive forces are equal thus they end up canceling each other. In [7] the sensors and objects in the ROI exert virtual repulsive force that pushes sensors away from the objects and also from each other so that their sensing areas are not overlapping. The sensors will keep moving until static equilibrium state is reached. The static equilibrium state is reached based on the fact that the total energy is reduced with time. Although this method does ensure full coverage and full connectivity, but it extremely depends on mobility, which is a high power consumption task.

2. Grid Based:

Grid based deployment strategies used to determine sensors positions. Grid based is the sampling method in which coverage is estimated as ratio of grid points covered to total number of grid points in the ROI. The cost of this method is determined by number of grid points, name and amount of sensors deployed. The accuracy of the estimation is determined by the size of each grid, the smaller the size the more accurate the estimation is. There are three types of grids commonly used in networking; [8]

(a) Triangular Lattice
(b) Square Grid
(c) Hexagonal Grid

Triangular lattice is the best among the three kinds of grids as it has the smallest overlapping area hence this grid requires the least number of sensors[9]. Triangular Lattice is shown in figure 2(a).Square grid is shown in figure 2(b). Square grid provides fairly good performance for any parameters. Hexagonal grid is the worst among all since it has the biggest overlapping area, shown in figure 2(c).

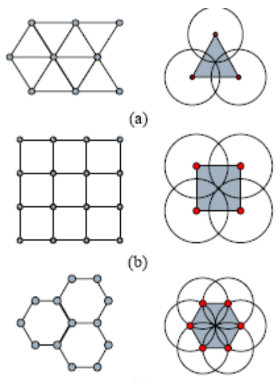


Figure 1: Types of grids (a) Triangular lattice (b) Square grid (c) Hexagonal grid

3.Computational Geometry Based:

Computational geometry is frequently used in WSN coverage optimization,[10] the most commonly used computational geometry approach are

(a) Voronoi diagram
(b) Delaunay triangulation.

Voronoi diagram is partition of sites in such a way that points inside a polygon are closer to the site inside the polygon than any other sites, thus one of the vertices of the polygon is the farthest point of the polygon to the site inside it. Therefore Voronoi diagram can be used as one of the sampling method in determining WSN coverage; with the sensors act as the sites, if all Voronoi polygons vertices are covered then the ROI is fully covered otherwise coverage holes exist.

Delaunay triangle is formed by three sites provided if and only if the sites[11] circumcircle does not contain other sites.Circumcircles of Delaunay Triangles is shown in figure 3.The centre point of the circle is a Voronoi vertex with equal distance from each of the three sites.

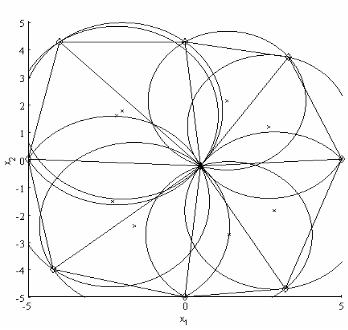


Figure 2: Circumcircles of Delaunay Triangles

IV. IMPLEMENTATION AND PERFORMANCE

Wireless Sensor Networks greatly benefit from simulation before deployment, since some of these networks may contain thousand of nodes. Network simulation is a relatively fast way to obtain an estimate of network performance and tuning. This section describes about the simulation environment i.e Matlab in which the research implementation work is done. [7]

A. **Delaunay Triangulation Coverage Strategy:** It is frequently used in WSN coverage optimization. A Delaunay triangle is formed by three sites provided if and only if the sites' circumcircle does not contain other sites .Delaunay triangulation is used in to estimate the worst and best case coverage [13].The complexity of the approach using computational complexity of computational geometry methods are controlled by the number of sensors/sites (*N*) and the algorithm used. [14]The lower bound for the computational complexity of constructing Voronoi diagram is Ω (*N* log*N*). As for the Delaunay triangulation there are several construction algorithms with computational complexity as low as *O (N logN).*

B. **ASSUMPTIONS FOR DELAUNAY TRIANGULATION:**
In the sensor network the following properties are assumed.

1. Delaunay triangulation is implemented in 2D.
2. Distance between sensors is computed by distance Formula equation
Sqrt(x2-x1) ^2+ (y2-y1) ^2.
3. Sensor communicate, if distance is <=R, where R is sensing range.
4. The sensor nodes sense information continuously and send the information continuously to the next node towards the head.

C. **ALGORITHM FOR DELAUNAY TRIANGULATION:**
Delaunay triangulation can generated by the following steps.

Step 1:

- Send a *hello* message within the distance by using distance formula.
- Upon receiving the *hello* message, acknowledge the sender alone with the location information of the current node.

Step 2:
Connect *u* with the neighbor nodes in form of triangle. Let this graph be *G*1.

Step 3:
Two nodes connect only if the other node lies within the sensing range of the node.

The resulting graph *G* is almost Delaunay triangulation. After step 2, the graph *G*1 is a non planar graph. It may contain some non-Delaunay edges, which may cause edge crossing. After removal of the edge crossing in step 3, almost Delaunay triangulation graph *G* is achieved, which is planar but still it may contain some non-Delaunay edges.

The algorithm is very simple. After the execution of the algorithm each node will need to remember only the neighbors that have edges with it in the graph and forget the other neighbors.

D**. SQUARE GRID BASED COVERAGE STRATEGY:** Grid points are used in two ways in WSN deployment either to measure coverage as used in VFA or to determine sensors positions. Coverage percentage as stated before is ratio of area covered to the area of ROI. Grid is among the sampling method commonly used such as in [15]. The coverage is estimated as ratio of grid points covered to total number of grid points in the ROI. The cost of this method is determined by number of grid points; *n*×*m* and amount of sensors deployed; *k*.[16][17]

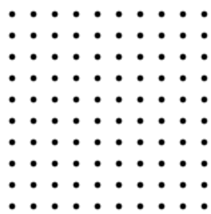


Figure 3: Square Grid

E. ASSUMPTIONS FOR SQUARE GRID BASED COVERAGE STRATEGY :
In the sensor network the following properties are assumed.

1. Square Grid is implemented in 2D.
2 Sensor sensing range is equal to size of grid.
3. Formula used to compute distance is 2*R.
4. Sensor communicate if distance is <=R, where R is sensing range.
5. The sensor nodes sense information and send the information continuously to the next node towards the head.

F. ALGORITHM FOR SQUARE GRID BASED COVERAGE STRATEGY:
Square Grid Coverage strategy can be generated by the following steps.

Step 1:

- Send a *hello* message within the distance by using distance formula.
- Upon receiving the *hello* message, acknowledge the sender alone with the location

Information of the current node.

Step 2:
Connect a node with the neighbor nodes in form of square.

Step 3:
Two nodes connect only if the other node lies within the sensing range of the node.

The resulting graph *G* is almost Square grid.

The algorithm is very simple. After the execution of the algorithm each node has static position. In some situation square grid suffers from horizontal and vertical misalignment

1. RESULT AND ANALYSIS:

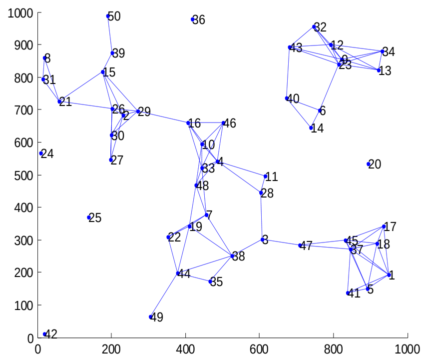
1.1 Theoretical Comparative Analysis of Coverage Strategies:

S.NO	FEATURES	DELAUNAY TRIANGULATION COVERAGE STRATEGY	SQUARE GRID BASED DEPLOYMENT STRATEGY
1	OBJECTIVE	Partion of site	SAMPLING METHOD
2	ALGORITHM	BASED ALGORITHM	Distributed Algorithm
3	COVERAGE	VORONOI BASED ALGORITHM	Better Coverage
4	SENSING RANGE	IRREGULAR SENSING RANGE	Same Size Disk
5	STRATEGY	Geometry Based	Deployment Strategy
6	COPLEXITY	O(N LogN)	O(nm)

Table 1: Theoretical Comparative Analysis of Coverage Strategies

1.2 Simulation Based Comparative Analysis of Coverage Strategies:

1.2.1 Delaunay triangulation Simulation Results: Figure 4: Random Distribution of nodes for Delaunay Triangulation



As shown in above figure 4. nodes are connected in triangle form. There are 50 nodes having same sensing range. But as shown in figure some nodes like node no 20,25,36,42 remain ideal because of low sensing range. As shown in figure 5. more nodes are connected as compared to figure 8.The node number 20, 25 and 36 is completely connected with other nodes. This is because sensing range of sensors is increased, so that three sensors can easily link to each other. Node number 42 is not connected because distance of node no 42 is greater than sensing range. But increasing sensing range results more numbers of nodes connected than number of nodes remain ideal. Figure 9 shows the achievement of Delaunay triangulation Coverage Strategy.

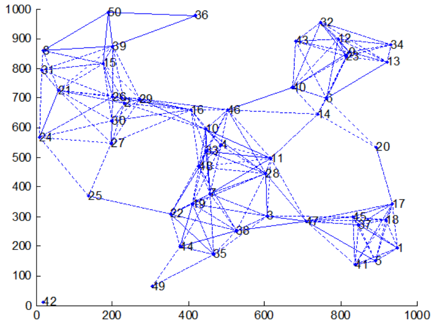


Figure 5: Matlab Simulation for Delaunay Triangulation coverage strategy

S.NO.	NO. OF NODES	SENSING RANGE	IDEAL SENSOR
1	41	220	2
2	41	230	1
3	45	200	1
4	45	220	0
5	47	250	0
6	47	220	1
7	49	220	2
8	49	250	0
9	50	210	2
10	50	240	0

Table 2: Simulation Result of Delaunay Triangulation Coverage Strategy

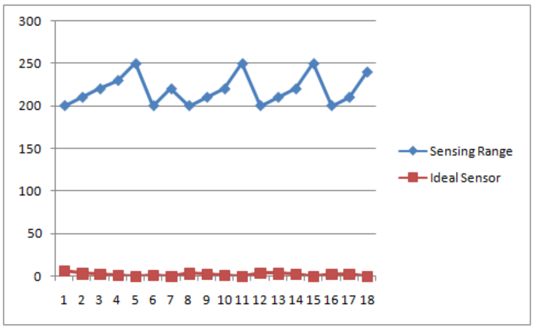


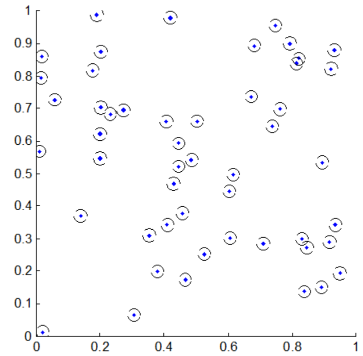
Figure 6: Graph of Delaunay Triangulation

Figure 6 shows the graph based simulation result of Delaunay Triangulation. Graph is made based on Table 3 result. It is shown in figure that if sensing range of sensors is increased than number of ideal nodes is decreased.

1.2.2 **Square Grid Simulation Results:** For the implementation of Square Grid Coverage Strategy square target Area A of size 1000x1000 is used and numbers of sensor nodes n is 50.Random distribution of the nodes in the target area A is assumed. The neighbors of the nodes are within the range of 2*R formula, where R is the sensing range of the sensor. A node will communicate with other node only if it lies in the range of 2*R area of the node.

Figure 7: Random Deployments of Sensors in Square Grid Coverage strategy

Figure 8: Square Grid Deployment



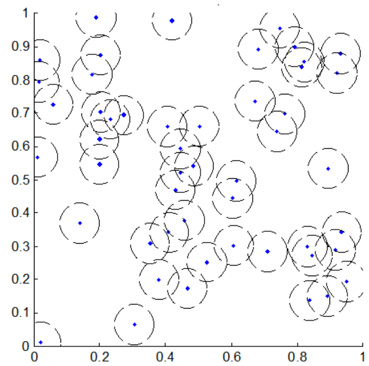


Figure 8 shows the communication of sensors increased as compared to figure 7 by increasing sensors sensing range. But overlapping is also increased in figure 8 in comparision of figure 7.

S.NO.	NO. OF NODES	SENSING RANGE	NO. OF OVERLAPPED SENSING AREA NODES
1	41	100	0
2	41	200	6
3	45	180	0
	45	200	4
4	47	140	0
	47	160	2
5	49	100	0
6	49	140	6
7	50	100	0
8	50	150	2

Table 2: Simulation Result of Square Grid Coverage Strategy

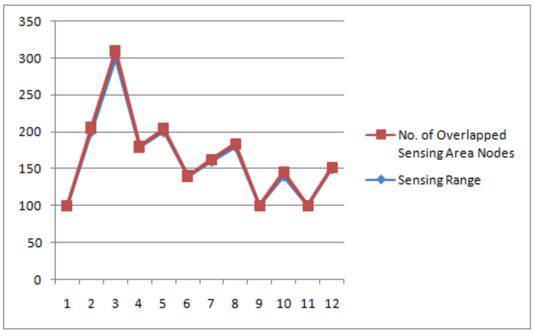


Figure 9: Graph of Square Grid

Figure 9shows graph based simulation result of Square Grid Coverage strategy. Graph is made on Table 4 result. It is shown in figure 9 if sensing range of sensors is increased the number of nodes having overlapped sensing area also increased.

V. Conclusions

In this paper two coverage strategies of Wireless Sensor Network are compared on different parameters. Almost Delaunay triangulation is more efficient coverage strategy because node are link in triangle form and if sensing range of the sensor is increased than each node can communicate with other node in the network where as square grid deployment strategy is also used in different applications but this strategy suffers Horizontal misalignment, Vertical misalignment and Random misalignment. If sensing range is increased in square grid coverage strategy than overlapping of sensing area is increased which is not desirable for valid data in coverage of region of interest.

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