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Comparative Analysis of Delaunay Triangulation and Square Grid Coverage Strategy for Wireless Sensor Network

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Abstract : Wireless sensors networks are a rapidly growing area for research and commercial development. One fundamental problem in wireless sensor networks is the coverage problem, which reflects the quality of service that can be provided by a particular sensor network. In this paper the coverage problem is defined and coverage strategies are studied which are used in deployment stage. Strategies are categorized into two groups; Grid Based and Computational Geometry Based Approach. In this paper comparative analysis of Square Grid and Delaunay Triangulation is done on theoretical basis.These strategies are also implemented using MATLAB and their results were compared on the experimental basis.It is found that Delaunay triangulation coverage strategy is efficient than Square grid coverage strategy.

Keywords : Wireless Sensors Networks, Coverage Problem, Coverage Strategies,Delaunay Triangulation Coverage strategy and Square Grid Coverage Strategy.

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. A sensor node is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. A sensor network normally constitutes a wireless adhoc network, in which each sensor supports a multihop routing algorithm where nodes function as forwarders, relaying data packets to a base station [1].

II. COVERAGE ISSUE OF WIRELESS SENSOR NETWORK

One of the most active research field 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. Coverage can be measured in different ways depending on the application. Coverage in a wireless sensor network can be thought of as how well the wireless sensor network is able to monitor a particular field of interest. Ensuring sufficient coverage in a sensor network is essential to obtaining valid data. The needs of a particular deployment will heavily influence the coverage scheme chosen[2]. This paper focused on various coverage schemes and their comparations.

A. Coverage Strategies:

Coverage strategies used in solving coverage problem in Wireless sensor network which are done during deployment stage. The strategies are divided into following categories.

i. Grid Based:

ii. Computational Geometry Based:

III. 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 Region of Interest [3]. 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;

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. Triangular Lattice is shown in figure 1(a). Square grid is shown in figure 1(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 1(c).

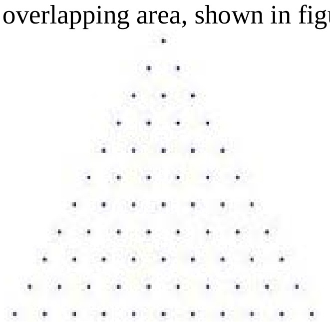

Figure 1(a). Triangle Lattice

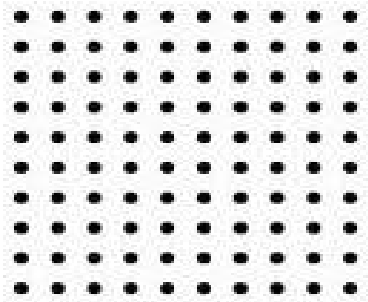

Figure 1(b). Square Grid

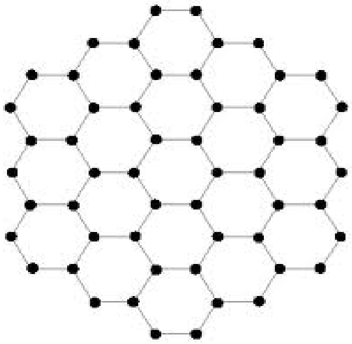

Figure 1(c). Hexagonal Grid

IV. COMPUTATIONAL GEOMETRY BASED

Computational geometry is frequently used in WSN coverage optimization [4], 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.Voronoi diagram is shown in figure 2. Therefore Voronoi diagram can be used as one of the sampling method in determining wireless sensor network coverage; with the sensors act as the sites, if all Voronoi polygons vertices are covered then the Region of Interest is fully covered otherwise coverage holes exist[5].

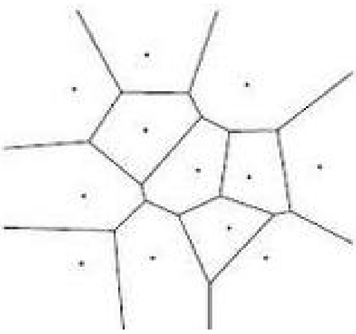

Figure 2. Voronoi Diagram

Delaunay triangulation is the dual of Voronoi diagram. Delaunay triangle is formed by three sites provided if and only if the sites 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. [6]

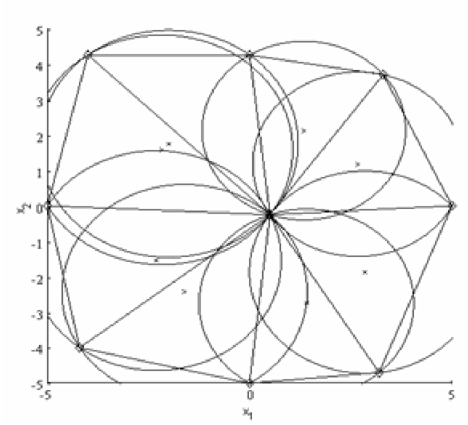

Figure 3. Circumcircles of Delaunay Triangles

V. IMPLEMENTATION ENVIRONMENT

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 in which the research implementation work is done.

A. Simulation Tool:

Matrix Laboratory(MATLAB)

B. MATLAB Description:

Matlab is a numerical computing environment and fourth generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

Although MATLAB is intended primarily for simulation environment, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model Based Design for dynamic and embedded systems.Matlab is widely used in networking simulation.

C. Input parameter for MATLAB:

Input parameters for MATLAB are Total number of nodes, Maximum number of nodes, Distance between nodes, Coverage Area/Region, and Node Coverage Range etc.

D. Output Parameter for MATLAB:

Output parameters for MATLAB are Throughput, Number of ideal nodes,Communication Delay, Sensing range etc.

E. Simulation Based Comparative Analysis of Coverage Strategies:

a. Delaunay triangulation Simulation Results:

For the implementation of Delaunay Triangulation Strategy we have used square target Area A of size 1000x1000 and numbers of sensor nodes n is 50. We have used random distribution of the nodes in the target area *A*.

The neighbors of the nodes are within the range of distance formula.

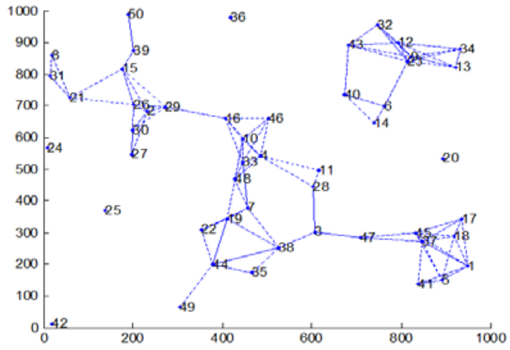

Figure 4. Random distribution of nodes for Delaunay Triangulation

As shown in 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. One node link to other two nodes if and only if distance<=R, where distance is computed by distance formula and R is sensing range. So if sensing range is increased, then node can easily link to the other nodes.

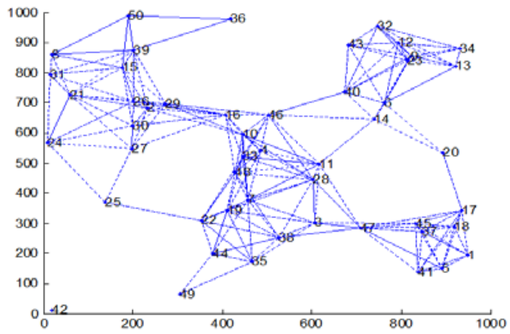

Figure 5. Matlab simulation for Delaunay Triangulation coverage strategy

As shown in figure 5 more nodes are connected as compared to figure 4.This is because sensing range of sensors are increased ,so that sensors can easily linked to each other.

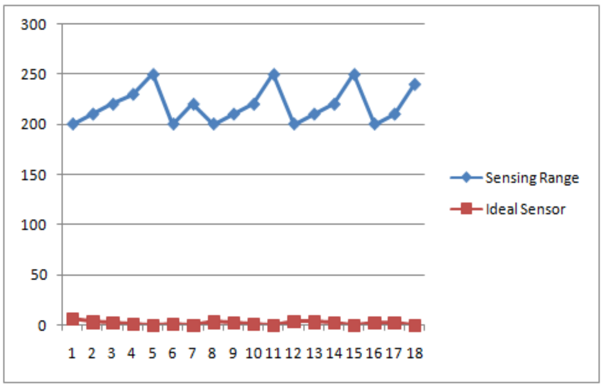

Figure 6. Graph of Delaunay Triangulation

Figure 6 shows the graph based simulation result of Delaunay Triangulation. It is shown in figure that if sensing range of sensors are increased than number of ideal nodes are decreased.Because if Sensing range is increased of a node,it can communicate to far deployed node.If less number of nodes are there,it shows more active network is achieved and more coverage is their.

b. Square Grid Simulation Results:

For the implementation of Square Grid Coverage Strategy we have used square target Area A of size 1000x1000 and numbers of sensor nodes n is 50. We have used random distribution of the nodes in the target area *A*. 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.

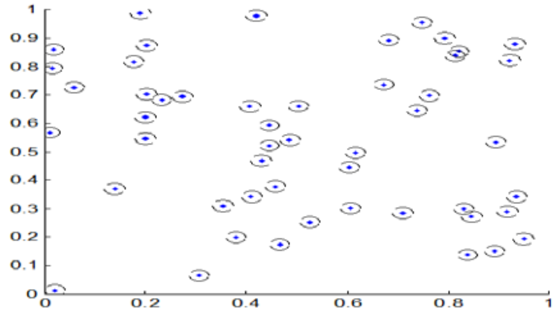

Figure 7. Random Deployment of Sensors in Grid

Figure 7 shows random deployment of sensors in grid. There are 50 nodes deployed in the region of interest. Nodes are deployed independently and overlapping of sensing area of nodes are negligible. In order to achieve square grid coverage strategy sensing range is to be increased. We use formula for sensing is twice of sensing range. As much we increase sensing range twicely sensing area would be increased. So figure 7 shows need of increasing sensing range of the sensor.

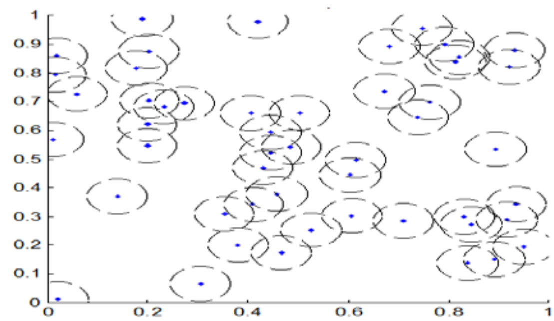

Figure 8. Square Grid Deployment Coverage Strategy

As shown in figure 8 linking between nodes is increased but overlapping of sensing area is also increased.

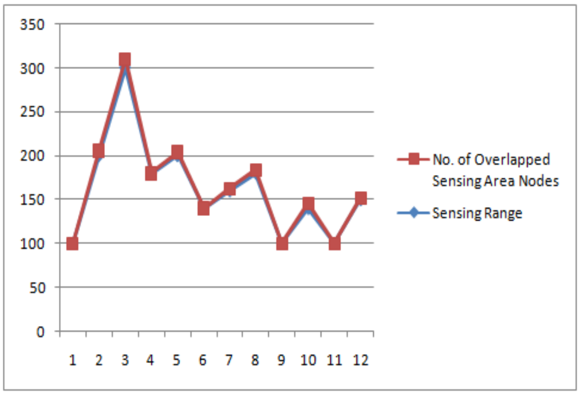

Figure 9. Graph of Square Grid

Figure 9 shows graph based simulation result of Square Grid Coverage strategy. It is shown in figure 9 if sensing range of sensors are increased then number of nodes having overlapped sensing area also increased.Because if sensing area of a node is increased,overlapping of sensing area of neighbor node is their.If more increament in sensing range more increament in overlapped area of neighbor node.For valid data overlapped coverage is not desirable.

From experimental result it is found that Delaunay triangulation is more efficient than Square grid coverage strategy in condition of increasing sensing range.Because with increased sensing range Delaunay triangulation provides active network having less number of ideal nodes where as in Square grid provide more coverage but with overlapped sensing area,which is not desirable for valid data.

VI. RESULT AND ANALYSIS

We compare the Delaunay Triangulation Coverage Strategy with Square Grid Based deployment coverage strategy.

Delaunay triangulation Coverage strategy is based on partition of site in triangle form. In Delaunay Triangulation three sensors are joint in form of triangle, so that sensing area of one node of triangle could not be overlapped by another node's sensing area.

Square grid based deployment coverage strategy is sampling method. Sensors are deploying in form of square grid.

This section includes theoretical comparation of Delaunay triangulation and Square grid coverage strategy.

A. Theoretical Comparative Analysis of Coverage Strategies:

Table I. Theoretical Comparative Analysis of Coverage Strategies for Wireless Sensor Networks

S.No	Features	Delaunay Triangulation Coverage strategy	Square Grid Based Deployment strategy
1	Objective	Partition of Site	Sampling Method
2	Algorithm	Voronoi Based Algorithm	Distributed Algorithm
3	Coverage	Optimization Coverage	Better Coverage
4	Sensing Range	Irregular Sensing Range	Same Size Disk
5	Strategy	Geometry Based	Deployment Strategy
6	Complexity	O(N log N)	O(nm)

VII. CONCLUSION

We compare two coverage strategies of Wireless Sensor Network Delaunay triangulation and Square grid on distance and sensing range parameters.

Delaunay triangulation Coverage strategy is based on partition of site in triangle form. Square grid based deployment coverage strategy is sampling method. Sensors are deploying in form of square grid.

From experimental results and theoretical comparation it is found that Delaunay triangulation is more efficient coverage strategy than Square grid 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,if sensing range is increased in square grid coverage strategy coverage is increased but with overlapping of sensing area of neighbor nodes which is not desirable for valid data in coverage of region of interest.

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