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Performance Comparison of Deployment Techniques in Wireless Sensors Network

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Abstract— **Recent advancement in wireless communications and electronics has enabled the development of low cost sensor networks. Wireless sensor networks are used to monitor a given field of interest for changes in the environment. They are very useful for military, environmental and scientific applications to name a few. One of the most active areas of research in wireless sensor networks is that of coverage. This review article aims to review the common strategies used in solving coverage problem in wireless sensor network. The strategies studied are used during deployment phase where the coverage is calculated based on the placement of sensors on the region of interest. The strategies reviewed are categorised in to three groups based on the approaches used; force based, grid based or computational geometry based approach. In this paper three deployment techniques square, triangular and random are compared. The metrics used for performance analysis is delay.**

Index Terms—**Connectivity, coverage, sensors, Voronoi diagram, wireless sensor network.**

I. Introduction

Recent advancement in microelectronics, digital signal processing, and low power RF techniques have enabled the deployment of large wireless sensor networks. Wireless sensor networks can be deployed in areas without infrastructure support, in hostile fields, and harsh environment. Applications of such sensor network include spatially in temporally dense environmental monitoring, battle field monitoring seismic structure response study, precision farming, traffic monitoring, etc. The deployment of wireless sensor networks we have significant impact on both scientific adventures and our daily life.

We consider a wireless sensor network where sensor nodes have both sensing ability and communication ability. Coverage and connectivity are basic requirements in a wireless sensor network. The objective of such a network is to detect events of interests or collect data and then report the obtained information to a fusion center. Therefore, connectivity, i.e., the ability to report information to the fusion center, is as critical as sensing coverage. Thus, we consider the coverage with connectivity property in sensor networks. We focus on large sensor networks. Because it is often either impossible or undesirable to deploy sensor nodes precisely, we specifically consider the case where sensor nodes are randomly deployed in a large field.

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Coverage is one of the main research interests in wireless sensor networks; it is used to determine the quality of service of the networks. The coverage is calculated based on the placement of the sensors on the region of interest.

Coverage can be classified into following categories:

Sweep Coverage: In sweep coverage a set of Points of Interests (POIs) but not all points in the monitoring area are periodically monitored instead of continuously. This type of coverage is applied in applications such as patrol inspection, in which POIs are required to be scanned once in every sweep period. The objective of sweep coverage is to move a number of elements across a coverage area while maximizing the number of detections per time and minimizing the number of missed detections per area.

Area Coverage: It is also known as the blanket coverage in the wireless sensor networks. The objective of area coverage is to achieve a static arrangement of sensors that maximizes the detection of targets appearing with in the coverage area. Examples include detecting chemical agent attacks and providing early warning of forest fires. Area coverage is also referred to as blanket coverage, field coverage and grid coverage (although this has special meaning).

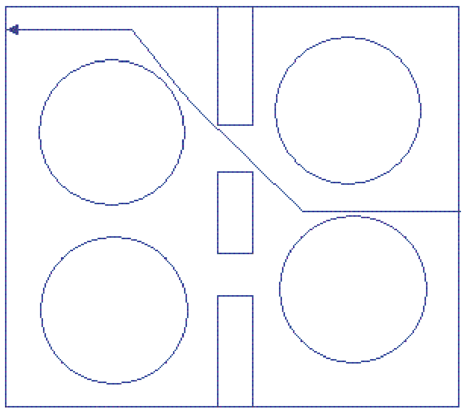

Figure 1: Area coverage (More Area Covered)

Barrier Coverage: The objective of barrier coverage is to detect the intrusion of any object in the region of interest.

To understand the difference between area and barrier coverage, consider Figure 1, Figure 2. The arrowed line passing through the sensor field indicates a possible target traversal path. When the sensors are deployed for area coverage (Figure 1) they cover more area but are likely to miss a traversing target. When the sensors are deployed for barrier coverage (Figure 2) they are certain to detect a traversing target but would have less chance of detecting an area target that may appear anywhere within the sensor field.

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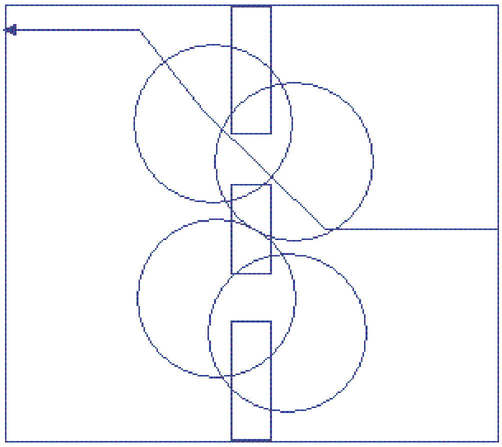

Figure 2: Barrier coverage (More Likely Traversal Detection)

II. LITERATURE REVIEW

Wireless sensor networks gather data from places where it is difficult for humans to reach and once they are deployed, they work on their own and serve the data for which they are deployed [1].

A wireless sensor network consists of sensor nodes deployed over a geographical area for monitoring physical phenomena like temperature, humidity, vibrations, seismic events, and so on .Typically, a sensor node is a tiny device that includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission [2].

Minimizing energy dissipation and maximizing network lifetime are important issues in the design of protocols and applications for sensor networks. Energy-efficient sensor state planning consists in finding an optimal assignment of states to sensors in order to maximize network lifetime. For example, in area surveillance applications, only an optimal subset of sensors that fully covers the monitored area can be switched on while the other sensors are turned off. Typically, any sensor can be turned on, turned off, or promoted as a cluster head, and a different power consumption level is associated with each of these states [3].

Coverage is usually interpreted as how well a sensor network will monitor a field of interest. Typically we can monitor an entire area, watch a set of targets, or look for a breach among a barrier. Coverage of an entire area otherwise known as full or blanket coverage means that every single point within the field of interest is within a the sensing range of at least one sensor node [5].A sensor network deployment can usually be categorized as either a dense deployment or a sparse deployment. A dense deployment has a relatively high number of sensor nodes in the given field of interest while a sparse deployment would have fewer nodes. The dense deployment model is used in situations where it is very important for every event to be detected or when it is important to have multiple sensors cover an area. Sparse deployments may be used when the cost of the sensors make a dense deployment prohibitive or when we want to achieve maximum coverage using the bare minimum number of sensors [5].

Coverage problem in WSN basically is caused by three main reasons; not enough sensors to cover the whole ROI, limited sensing range and random deployment. Since the sensors are operated using limited power supply some of them might die out therefore resulting in inadequate sensors to fully cover the whole ROI causing holes to exist. A sensor's sensing range is restricted to certain radius which consequently brings coverage problem. This problem can be solved by using sensor with larger sensing range, but this type of sensor is more expensive. One of the appealing aspects of WSN is the ability to be randomly deployed without the need to do it manually. The random deployment can be done using method such as air drop, this enable the WSN to be applied in hostile and unreachable environment such as battlefield and a steep terrain. However random deployment could cause some of the sensors being deployed too close to each other while others are too far apart. In both situations coverage problem will arise, for the first condition, the sensing capabilities of the sensors are wasted and the coverage is not maximized, while in the later state, blind spots will be formed. In predetermine deployment the WSN coverage is improved by carefully planning the positions of the sensors in the ROI prior to their deployment. The sensors later are placed according to the plan either by hand or with the help of mobile robot [4].

III. STRATEGIES

The strategies used in solving coverage problem in WSN are analysed during deployment stage. The strategies are divided into three categories force based, grid based and computational geometry based.

Force Based -Force based deployment strategies rely on the sensors mobility, using virtual repulsive and attractive forces 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 cancelling each other.

Grid Based-Grid points are used in two ways in WSN deployment; either to measure coverage as used in VFA or to determine sensors positions. The coverage is estimated as ratio of grid points covered to the total number of grid points in the region of interest (Figure 3). There are three types of grid-based deployment corresponding to three regular shapes which can tile a plane without coverage holes namely, square, equilateral triangle and hexagon.

Square grid has more overlapping area than the triangular lattice but less overlapping area than hexagonal grid. Triangular lattice is the best among the three kinds of grids as it has smallest overlapping area hence grid requires the least number of sensors. Hexagonal grid is the worst among all the grids, since it has biggest overlapping area.

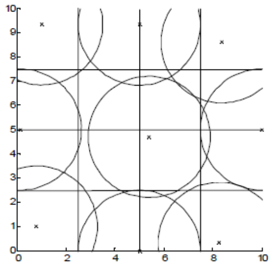

Figure 3: Grid Coverage

Computational geometry is frequently used in WSN coverage optimization, the most commonly used computational geometry approach are Voronoi diagram Delaunay triangulation. Voronoi diagram can be used as one

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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. Voronoi diagram for 3 and 4 points is presented in Figure 4 and Figure 5.

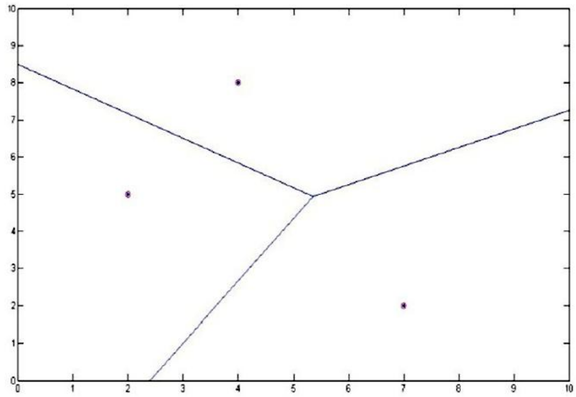

Figure 4: Voronoi Diagram for 3 points

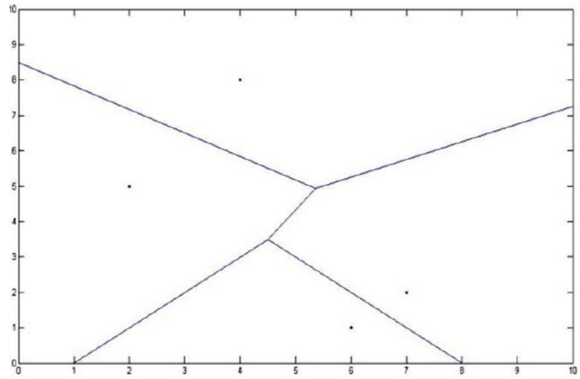

Figure 5: Voronoi Diagram for 4 points

Delaunay triangulation is the dual of Voronoi diagram. A Delaunay triangle is formed by three sites provided if and only if the site's circum circle does not contain other sites, Figure 6 Voronoi diagram and Delaunay triangulation are used in to estimate the worst and best case coverage. This work focuses in finding the maximal breach path (worst case coverage) – a path where an intruder can go through with the least probability of being detected, and the maximal support path (best case coverage) – a path with highest coverage. The work proved that a maximal breach path must lie on the edges of Voronoi diagram while maximal exposure path lie on the edges of Delaunay triangulation. The information obtained can be used in incremental deployment in order to decide where is the best place to deploy additional sensors to improve the coverage.

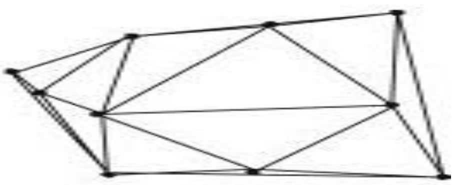

Figure 6: Delaunay Triangulation

IV. SIMULATION ENVIRONMENT

A. Simulation Model:

We have used Network Simulator (NS)-2 in our evaluation. The NS-2 is a discrete event driven simulator. NS-2 is suitable for designing new protocols, comparing different protocols and traffic evaluations. It is an object oriented simulation written in C++, with an OTcl interpreter as a frontend. NS uses two languages because simulator got to deal with two things: i) detailed simulation of protocols which require a system programming language which can efficiently manipulate bytes, packet headers and implement algorithms, ii) research involving slightly varying parameters or quickly exploring a number of scenarios

B. Simulation Parameters:

In our work the performance of deployment techniques square, triangular and random is evaluated by varying the simulation time while keeping network size (number of mobile nodes) constant.

TABLE I
SIMULATION PARAMETERS

Parameter	Value
Simulator	NS-2(Version 2.35)
Channel Type	Channel/Wireless Channel
Radio Propagation Model	Propagation/Two Ray Ground
Network Interface Type	Phy/Wireless Phy
MAC Type	Mac/802.11
Interface Queue Type	Queue/DropTail/PriQueue ,CMU Priqueue
Link Layer Type	LL
Antenna	Antenna/Omni Antenna
Maximum Packet in ifq	50
Number of Nodes	25
Traffic Type	TCP
Simulation Time	300
Routing Protocols	DSR

V. PERFORMANCE MATRICS

There are different kinds of parameters for the performance evaluation of the routing protocols. We have used the delay metrics for evaluating the performance of three deployment techniques square, triangular and random.

A. End to end delay

The total time required to reach the data packet from source node to destination node is called average end to end delay.

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VI. SIMULATION RESULT

The simulation results are shown in the following section in the form of line graph. Graph show comparison between the three deployment techniques by varying simulation time while keeping numbers of nodes constant.

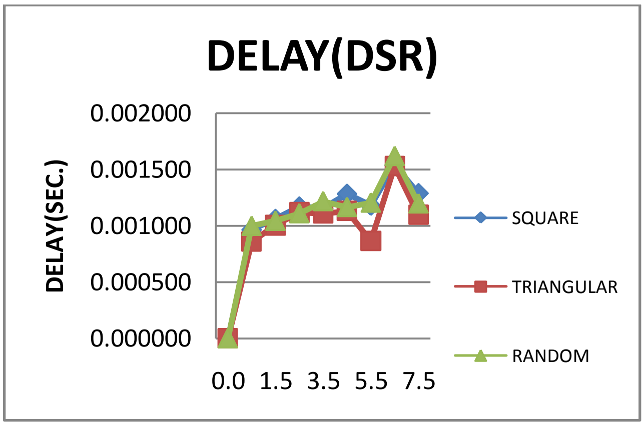

Figure 7: Delay (sec.) vs. Simulation time (sec.)

VII. CONCLUSION

The deployment of nodes is an important issue in Wireless Sensor Network. The important thing that has to be kept in mind is to maximize the network lifetime as the sensor nodes are equipped with battery and cannot be replaced once they are placed in a sensor field. We have discussed various system models and deployment strategies so that we can use minimum number of sensor nodes and increase the network lifetime with less delay time.

In this paper performance comparison of square, triangular & random deployment technique for Wireless Sensors Network is presented as a function of simulation time. Performance of these deployment techniques are evaluated with respect to performance metrics such as delay. As per our assumed scenario Triangular deployment shows best performance than square & random deployment of sensors in terms of Delay. In the future, extensive complex simulations could be carried out using other existing performance metrics, in order to gain a more in-depth performance analysis of the deployment of wireless sensor networks. Other new deployment techniques performance could be studied too.

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