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A Survey on Coverage Problems in Wireless Sensor Networks

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***Abstract*—Wireless sensor networks are a rapidly growing area for research and commercial development. 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. The main focus in wireless sensor networks is that of coverage sensors. Coverage in wireless sensor networks is usually defined as extent or degree to which something is observed, analyzed, and reported.The various existing techniques used in coverage are coverage types, node types, deployment, energy constraints, centralized and distributed algorithm and three dimensional coverage. Coverage approaches are coverage with connectivity, probabilistic sensing, maximal support path , maximal breach path and disjoint sets. Coverage is one of the main problem to achieve energy efficiency of a wireless sensor network. This paper includes the literature survey of all coverage problems.**

***Index Terms* — Connectivity, Coverage, Performance, Reliability, Wireless Sensor Networks .**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) [1] are composed of a large number of sensor nodes which are densely deployed in a given region. All nodes collaborate to execute sensing and monitor tasks and to send sensed data to sinks. It has so far been employed in military activities, target acquisition ,environmental activities and civil engineering. On the one hand each sensor is equipped with a limited power source, and it is impossible to replenish power resources in most applications. On the other hand, many applications require a durable lifetime. Thus, a major constraint for WSNs to be widely used is network lifetime. Since wireless sensor networks are characterized by high density and limited energy.

In recent years there has been increasing interest in the field of wireless sensor networks. A wireless sensor network consists of a number of wireless sensor nodes. These nodes are characterized by being very small in size with limited energy usually supplied by a battery. They communicate via built-in antennae over RF signals. These networks are typically used to monitor a field of interest to detect movement, temperature changes, precipitation, etc. One of the most active research fields in wireless sensor networks 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. In addition to coverage it is important for a sensor network to maintain connectivity. Connectivity can be defined as the ability of the sensor nodes to reach the data sink. If there is no available route from a sensor node to the data sink then the data collected by that node cannot be processed. Each node has a communication range which defines the area in which another node can be located in order to receive data. This is separate from the sensing range which defines the area a node can observe. The two ranges may be equal but are often different.

The paper is organized as follows: in the next section address many of the issues that factor into how coverage is determined and how sensor networks are deployed. In section three, cover several approaches to coverage. Finally, give a summary of the information presented in the coverage. At the end of the paper is a list of references.

II. EXISTING TECHNIQUES

There are several factors that must be considered when developing a plan for coverage in a sensor networks. Many of these will be dependent upon the particular application that is being

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addressed. The capabilities of the sensor nodes that are being used must also be considered.

A. Coverage Types

The Coverage may be divided into three categories depending on what exactly that you are attempting to monitor. Area coverage refers to 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 the sensing range of at least one sensor node. Ideally you would like to deploy the minimum number of sensor nodes within a field in order to achieve blanket coverage. Target coverage refers [3] to observing a fixed number of targets. This type of coverage has obvious military applications to maintain target coverage while conserving energy.Both blanket and target coverage in terms of energy efficiency.

Barrier coverage refers [5] to the detection of movement across a barrier of sensors. This problem was defined as the maximal breach path. A variation of barrier coverage known as sweep coverage. Sweep coverage can be thought of as a moving barrier problem.

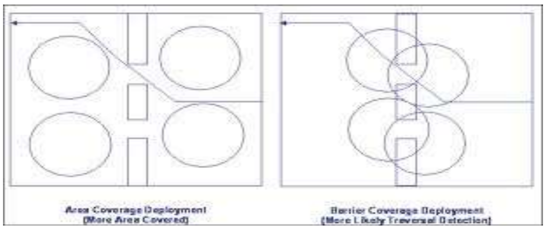

Fig " (a)":Area Coverage and Barrier Coverage

B. Deployment

The deployment scheme’s choice is basically depends on the type of sensors, application and the environment. Nodes can be placed in an area of interest either deterministically or randomly [2]. Deployment of sensors nodes in physical unattended environment is an important issue since the performance of wireless sensor networks largely depends on deployment of sensors nodes. The deployment of sensor nodes is divided into two fractions according to the function of networks and these fractions are Coverage and Connectivity. The coverage is classified into static and dynamic category and the connectivity is divided into P-connectivity and RAB-connectivity [3].To achieve maximum coverage using the bare Sensor nodes are static, they stay in the same place once they are deployed.

In the deployment algorithm, each node will communicate with its neighbours and tell them to move away until they are at a distance which maximizes coverage while maintaining connectivity. The work presented in [4] concentrates in minimizing cost and maximizing coverage by deterministic deployment of WSN.

Fig"(a)": Deterministic Placement

Fig"(b)":Random Placement

Random placement of sensor nodes ability to maintain coverage and minimizing the amount of energy expended.

C. Node Types

Sensor node can be classified into two types: Homogeneous and Heterogeneous group of nodes. In homogeneous networks all the sensor nodes are identical in terms of battery energy and hardware complexity.

In a homogeneous network [15] [16] , it is evident that the cluster head nodes will be over-loaded with the long range transmissions to the remote base station, and extra processing necessary for data aggregation and protocol coordination. As a result the cluster head nodes expire before other nodes. However it is desirable to ensure that all the nodes run out of their battery at about the same time, so that very little residual energy is wasted and system expires.

In a heterogeneous sensor network [17] , two or more different types of nodes with different battery energy and functionality are used. The motivation being that the more complex hardware and the extra battery energy can be embedded in few cluster head nodes, thereby reducing the hardware cost of the rest of the network. There are two desirable characteristics of a sensor network, viz. lower hardware cost, and uniform energy drainage. While heterogeneous networks achieve the former, the homogeneous networks achieve the latter.

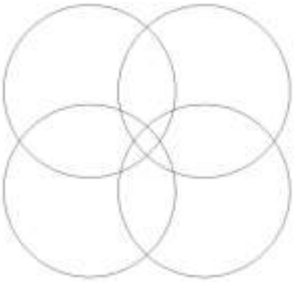

Fig "(a)":Homogeneous Sensors

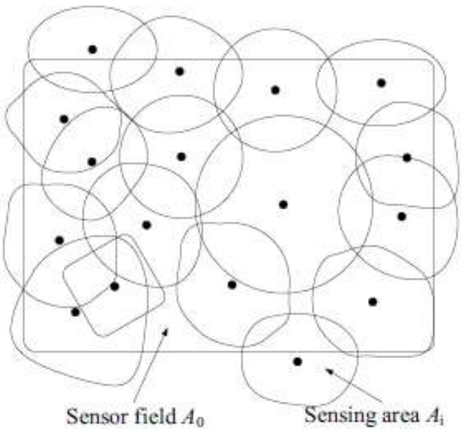

Fig "(b)":Heterogeneous Sensors

D. Energy Constraints

The important factor to consider in the development of a coverage scheme is that of energy constraints [8] [10]. Sensor nodes depend upon a battery for their energy source and battery replacement is not feasible. It therefore becomes very important to conserve energy and prolong battery life. sensors into a low energy sleep mode is a popular method to conserve energy.

Improving the efficiency of data gathering and routing is also used to conserve energy. If multiple sensor nodes are collecting the same information the network is expending energy unnecessarily. Eliminating the redundancy will allow the network to be more efficient. By using less energy for routing data, coverage is helped by having the nodes' lifetimes extended.

E. Centralized and Distributed Algorithm

Sensor are deployed an algorithm is run to determine if sufficient coverage exists in the area. This can be either a centralized or distributed algorithm. Centralized [5] [6] would be a network in one specific location and distributed [9] would be a network that is spread out over more than one location. The goal of extending network lifetime. The distributed/localized algorithms may be more complex than the centralized algorithms. Figures 6 and 7 demonstrate centralized and distributed strategies, the shaded sensors are the ones that are running part or all of the algorithm.

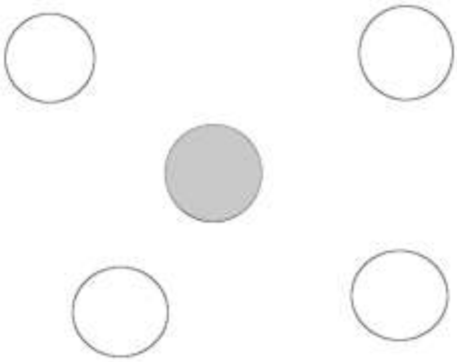

Fig "(a)":Centralized Algorithm

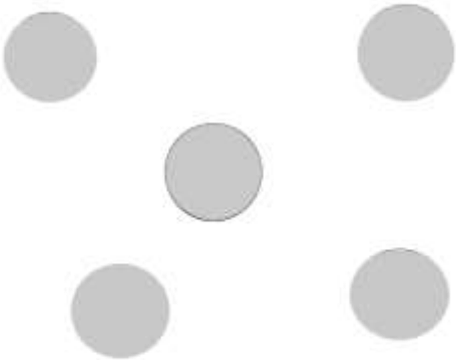

Fig "(b)":Distributed Algorithm

F. Three Dimensional Coverage

The three dimensional [11] spaces that sensor nodes would be deployed in are the atmosphere, underwater, and space. An example of three dimensional coverage is given in Figure 8. They assume that the sensors' coverage ranges are shaped in a sphere. They approach the coverage problem not by looking at the coverage of each point in the field of interest, rather they determine whether each sphere is covered. If each of the spheres have sufficient k-coverage then the entire field must be k-covered as well. If a sphere has at least k other spheres covering its entire area then the area within the sphere is k+1 covered. They reason that if the area within the sphere is k-covered then the area bordering the sphere must be at least k-covered. An algorithm is then presented which determines whether a sphere is k-covered or not. This algorithm can be fully distributed so that each sensor can determine its own coverage. If one sphere is located entirely within another sphere then those spheres will have no intersection. The smaller sphere would need to have its coverage increased by one but that does not seem to be covered in the algorithm. The algorithm does appear to mathematically feasible but it would appear that calculating the spherical caps which are the intersections of the sphere with decent precision could be very tricky for some sensor nodes.

Fig "(a)":Three Dimensional Coverage

III. COVERAGE APPROACHES

A. Coverage with Connectivity

A closely related problem to connectivity is coverage [12], where a subset of deployed nodes are activated such that any event in the monitored area is detected by at least one sensor. Similar to the communication range, the sensing range of sensors can either be modeled as a simple regular disk or assumed to follow a probabilistic model.

B. Probabilistic Sensing

Probabilistic sensing models [13] [14] capture the behaviour of sensors more realistically than the deterministic disk model This is not always the case with real sensors. Furthermore ,the overlap among sensing ranges of different sensors is not clearly defined. Therefore, the overlap minimization idea may not work with probabilistic coverage protocols that seek to optimize the number of activated sensors. For such protocols, we propose a new method for activating the minimum number of sensors while ensuring the monitored area is probabilistically covered.

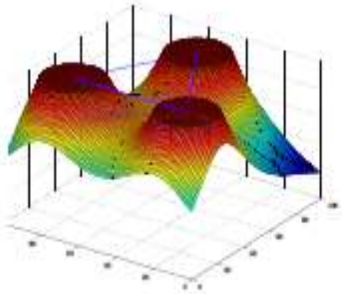

Fig "(a)" :The sensing capacity of three sensors that use the exponential sensing model and deployed at vertices of an equilateral triangle. The least-covered point by these three sensors is at the center of the triangle.

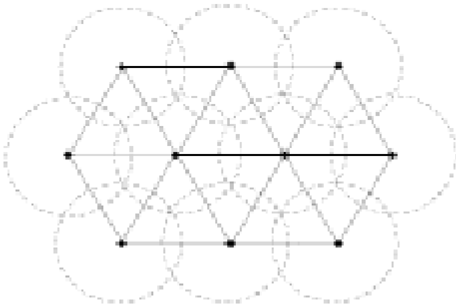

Fig "(b)" :The structure of optimal coverage using the disk sensing model. This structure minimizes the overlap between the sensing ranges of nodes.

C. Maximal Support Path(Best Coverage) and Maximal Breach Path(Worst Coverage)

Coverage in many sensor network applications can be viewed from either a best case or worst case point of view. The coverage problem, given the location of the sensors and the sensing ability of each sensor diminishes with distance, use Voronoi diagrams and Delaunay triangulation [17] [18] to compute the path that maximizes the smallest observability (best coverage) and the path that minimizes the observability by all sensors (worst coverage). The worst case coverage in terms of an sensors. The furthest distance that an agent must travel from the nearest sensor along the path is considered the best case.

D. Disjoint Sets

Divide the nodes into disjoint sets [5], such that every set can individually and successively perform the area monitoring task. These sets are successively activated and all nodes not belonging to the active set, will be in the sleep state. The coverage is no more guaranteed despite the fact that the other nodes belonging to the same set remain working. To maintain the necessary coverage while conserving battery life of the sensors.

E. Computational Geometry Techniques

The computational geometry techniques such as Voronoi diagram and Delaunay triangulation [19]. The Voronoi diagram is a set of discrete sites (points) partitions the plane into a set of convex polygons such that all points inside a polygon are closest to only one site. The Delaunay triangulation can be obtained by connecting the sites in the Voronoi diagram whose polygons share a common edge. In fact the Delaunay triangulation can be used to find the two closest sites by considering the shortest edge in the triangulation. The properties of the Voronoi diagram and Delaunay triangulation to solve for best and worst case coverages.Fig "(a)" shows an example of Voronoi diagram.

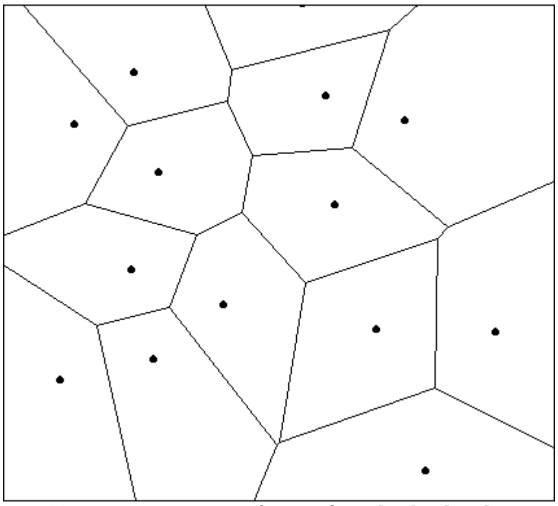

Fig "(a)": Voronoi Diagram of a Set of Randomly Placed Points in a Plane.

IV CONCLUSION

The coverage problem can be approached in many different ways. The issues faced when designing a coverage include coverage types(Area coverage, target coverage, barrier coverage).The major problem in area coverage is impractical to try to deploy sensors in such a formation and Sweep coverage can be thought of as a moving barrier problem. In deployment scheme such as deterministic and random placement, it is easier to develop a coverage scheme for deterministic placement of sensor nodes than for random placement. However in many deployments, it is either impractical or impossible to deploy sensor nodes in a deterministic way. In homogeneous and heterogeneous nodes, the problem addressed in sensing ranges are identical. In centralized and distributed algorithm ,problem in barrier coverage do not scale well. In three dimensional coverage, where the sensors float in the water and redundant nodes are needed to compensate for node failures. However, there are still many fundamental problems in coverage. The future work includes increasing the energy efficiency in coverage sensors.

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