Coverage Techniques and Algorithms used in Wireless Sensor Network

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Abstract - Wireless sensor networks are currently growing area for Research and Development because sensor network constitute platform for many applications related to environment monitoring, health care, surveillance, military. One major problem in wireless sensor network is coverage problem because it shows quality of the network.In this paper coverage techniques and algorithms used in these techniques are studied.Coverage Techniques are categorized into three groups;Area coverage, Point coverage and Path coverage.

Keywords - Wireless Sensors Networks, Coverage Problem, Coverage Techniques, Barrier Coverage, Algorithms.

I. INTRODUCTION

A wireless sensor network consists collection of nodes organized into a cooperative network which monitor physical or environmental conditions. Each node consists of processing capability may contain multiple types of memory, have a power source e.g., batteries and solar cells. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion.In wireless sensor network each node supports a multi-hop routing algorithm and forwards data packets to sink node.[1]

II. DESIGN CRITERIONS FOR COVERAGE TECHNIQUES

In wireless sensor networks, because energy depletion, harsh environmental conditions, and malicious attacks may result in node failures or become inoperative at any time, it is desirable to have higher degrees of coverage.The goal is to have each location in the physical space of interest within the sensing range of at least one sensor. Depended on different objectives and application requirements, there are different factors analyzed in designing coverage schemes. Generally, there are many different criterions (factors) can affect the coverage performance of WSN and that have dominating effect.

2.1 Deployment strategy

Deterministic versus RandomGrid based deployment is deterministic deployment strategy [2]. 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 [3];

- Triangular Lattice
- Square Grid
- 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).

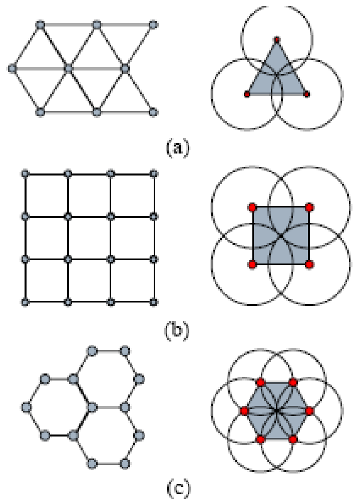

Figure 1: Types of grids (a) Triangular lattice (b) Square grid (c) Hexagonal grid

Random deployment strategy is where sensor nodes are distributed within the field stochastically and independently e.g.,air-dropped, scattered from an aircraft or launched via artillery, is required exclusively.

2.2 Sensing model

Boolean sensing model and probabilistic sensing model. In Boolean Sensing Model where each sensor has a fixed sensing area and a sensor can only sense the environment or detect events within its sensing area. The Boolean sensing model assumes that sensor readings have no associated uncertainty. In reality, sensordetection is imprecise.

In Probabilistic Sensing Model, the detection probability of object or event and the sensor's sensitivity decreases as the distance increases.

2.3 Sensing area

Where a sensor can detect an object or phenomena are inside its sensing range deterministically or probably depended on its sensing model. Generally, the sensors are assumed to have the same range.A sensor’s sensing range is not always a perfect disk it could be an elliptic shape or other shapes with the sensing strength could varies with distance from the sensor. For example, the sensing area is considered to be isotropic (e.g., a circular area in 2-D).

2.4 Sensor mobility

The coverage performance of stationary sensor network can be determined by the initial network configuration, and it remains unchanged over time after deployment. Contrarily, by mobile sensors mounted on mobile platform (such as mobile robot), mobile sensor network can improve or maintain coverage performance by sensor mobility. It is extremely valuable in situations where deployment mechanisms fail or coverage maintenance. The coverage of mobile network depends not only on the initial configurations, but also on the mobility behavior of the sensors.

2.5 Algorithm Characteristics

Centralized versus Distributed. In Centralized Algorithm, the coverage algorithm is executed in a central node. In this case, information from all nodes needs to be transferred to the central node. centralization can provide more accurate information for coverage scheme In distributed Algorithm, the coverage algorithm is executed based on information from only some nodes e.g., neighboring node within a constant number of hops in wireless sensor network, and the decision is made locally.

In addition, localization ,topology control, security, failure model, time synchronization ,scalability ,robustness, adaptivity and so on, are also factors affected for coverage schemes in wireless sensor networks.

III. COVERAGE TECHNIQUES

Extensive research efforts have been made to develop energy efficient schemes integrating coverage and connectivity for Wireless Sensor Network. Depended on the coverage objectives and applications, they can be roughly classified into three categories: Area Coverage, Point Coverage, and Path Coverage.[4]

3.1 Area coverage

In Area Coverage the main objective of the wireless sensor network is to cover (monitor) Region of Interest. Each point of the region need to be monitored because complete coverage is desired for valid data otherwise coverage holes exits.

3.2 Point coverage:

In Point Coverage the objective is to cover a set of point (target) with known location that need to be monitored. The point coverage scheme focuses on determining sensor nodes exact positions. Generally point coverage is special case of area coverage.In area coverage some points remain undetected due to some problem ,in such case point coverage is implemented. In some applications, when the network is sufficiently dense, area coverage can be approximated by guaranteeing point coverage. In this case, all the points of wireless devices could be used to represent the whole area, and the working sensors are supposed to cover all the sensors and monitor the target.

Path coverage

Path coverage is one of the monitoring examples, where WSNs are deployed to sense a specific path and report possible efforts made by intruders to cross it. In a manual network deployment, the desired level of the path coverage can be achieved by proper placement of the sensors over the

area. When it is not possible to deploy the network manually, random deployment is used, for example, dropping sensors from an aircraft. Due to the randomness of the sensors location, network coverage expresses a stochastic behavior and the desired (full) path coverage is not guaranteed.

IV. ALGORITHMS USED IN COVERAGE TECHNIQUES

4.1 Area coverage

The area coverage problem is mostly studied in coverage problem, while, it also emphasizes coverage with minimum sensor nodes and energy consumption when the region is covered by connected WSN.

4.2 Coverage Configuration Protocol (CCP) [5]

The goal of this protocol is to achieve to the guaranteed different degrees of coverage and connectivity while maximize the number of sleeping, and to allow WSN to self- configure for a wide range of applications when the communication range is more than twice as the sensing range. The work in [6] shows that coverage will imply connectivity if the communication range is greater or equal to twice the sensing range. To ensure K-coverage, a node only needs to

check whether the intersection points inside its sensing area are K-covered. Note that it cannot guarantee network connectivity when the radio transmission range is less than twice the sensing range.Therefore, by combing CCP with SPAN (a distributed connectivity preserving mechanism for multi-hop adhoc wireless networks that reduces energy consumption without significantly diminishing the connectivity of the network), the coverage and connectivity can be guaranteed in any case. In CCP, sensor nodes need accurate location information and a neighborhood table.

4.3Connected Dominating Coverage Set (CDCS) [7]

This scheme is base on the observation that all sensors can be divided into disjoint sets such as that every set completely covers all points (targets). When each set can cover all points (point coverage) and monitoring region (area coverage), by activating disjoint set successively, the sensor network lifetime can be extended.

4.4 Point coverage

For modeling purposes, the monitoring area is discretize in a set of points that require sensing, called demand points, and consider that the node coverage area is a circle of range R, where R is the sensing range. If the distance between a demand point and a sensor node is less than R, the node is able to cover this point.

4.5 Hybrid Algorithm:[8]

The Hybrid algorithm to solve Coverage and Connectivity Control Problem in WSNs is an attempt of combining the advantages of solving the problem in global and local ways. When the algorithm has the global vision of the network, it can find better nodes to compose the network, leading to better solutions regarding energy consumption.

4.6 Global On-Demand Algorithm[8]

The Global On-Demand Algorithm (GOD) is a hybrid approach that combines genetic and graph algorithms.The genetic algorithm solves the density and coverage problems, determining the set of nodes that assures the area coverage with the lowest energy consumption cost. These nodes are then connected by

Minimum Spanning Tree and Shortest Path algorithms. The algorithm is on-demand because it is triggered by the hybrid approach.

4.7 Local Online Algorithm

The Local Online Algorithm (LOA) is used every time a failure occurs. It is called to locally restore the area coverage and the nodes connectivity choosing a node to replace the one that failed.

Path coverage

Path are defined as the paths on which the distance from any point to the closest sensor is maximized (minimized). By combining computational geometry and graph theoretic techniques, specifically the Voronoi diagram, the Delaunay triangulation and graph search algorithms, polynomial time algorithms are proposed to find such paths.When monitoring region is a belt (e.g., castle surrounded by moats and International borders), the concept of barrier coverage of a belt region is defined.

- *Localized Barrier Coverage Protocol (LBCP) [9]*

Localized Barrier Coverage Protocol is designed for solving weak (strong) barrier-coverage problem and maximizing the network lifetime. The key idea is based on that the observation movements are likely to follow a shorter path in crossing a belt region, local barrier coverage guarantees the detection of all movements whose trajectory is confined to a slice of the belt region of the deployment. LBCP provides close to optimal enhancement in network lifetime, while providing global barrier coverage most of the time.

- *K- Barrier Coverage[10]*

When monitoring region is a belt (e.g., castle surrounded by moats and International borders), the concept of k-barrier coverage of a belt region is defined. An efficient algorithm for determining whether it is k- barrier covered that it is proposed in and a deterministic deployment pattern to achieve k-barrier also is designed. Furthermore, weak (strong) barrier coverage is defined as with high (low) probability guarantees the detection of intruders as they cross wireless sensor network.

V. CONCLUSION

In this paper coverage techniques are studied and existing solutions.The existing researches focus on the following consideration: evaluating and improving coverage performance of area (point) and path coverage, while maintaining connectivity and maximizing the network lifetime. Although many schemes have been proposed and progress has been made in coverage problems of WSN, there are still many open research issues.More authentic model of sensor nodes must be incorporated with the coverage schemes in order to perform various real applications excellently. Effective coverage scheme should be proposed to implement real applications but limited to theoretical study. Therefore, most existing centralized solutions need to be developed include the distributed and localized algorithms or protocols. The mobile sensor problem in WSN still must be solved perfectly.

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