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A review on Coverage factors in Wireless Sensor Networks

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Abstract—Wireless sensor networks are an increasing area of research. Wireless sensor networks are mainly used to monitor targets in the field of interest. Sensor coverage is an active area of research. Coverage is defined as how well and for how long sensor is able to monitor a field of interest. Various coverage techniques have been proposed depending on the area to be covered (area versus point coverage) and sensor deployment mechanism (discrete versus random). In this paper we will also survey the coverage issues in context of static wireless sensor networks, and also basic design considerations in coverage of WSN.

Keywords— **connectivity, coverage, nodes, wireless sensor network.**

I. Introduction

A wireless sensor network consists of a large number of distributed sensor nodes cooperatively monitoring the physical world. A WSN provides a new class of computer systems and expands people's ability to remotely interact with the physical world. Applications of wireless sensor networks include environmental and habitat monitoring, precision agriculture, asset tracking, whether forecasting, military and surveillance system. A wireless sensor network consists of a large number of sensor nodes. These nodes are characterized by having a limited energy usually supplied by a battery. Sensor nodes can be placed on predetermined positions or randomly deployed. The sensor nodes communicate via built-in antennae over RF signals.

The sensors nodes are deployed so that they can sense an event occurring in the environment and can send the sensed data to the base station. There are two types of reporting technique used based on application, [1] event-driven and on-demand. In the event-driven reporting, the reporting process is work with reactive protocol and process is triggered by one or more sensor nodes in the vicinity which detect an event and report it to the monitoring station. In the on-demand report, the reporting process is used proactive protocol in which request initiated from the base station, and sensor nodes send their data in response to a request [2].

One of the most active areas of research in wireless sensor networks is that of coverage. Coverage is a fundamental research issue in WSN because it can be considered as the measure of QoS of sensing function for a sensor network. For example, in an application of forest monitoring, one may want to know how well the network can observe or detect or sense a given area and what the chances that a fire starting in a specific location of forest will be detected in a specific time frame [1].

Coverage in wireless sensor networks is usually defined as a measure of how well and for how long the sensors network is able to observe and control the defined physical space [3]. It can be thought of as a measure of quality of service. 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.

Our major focus in the paper is on the coverage. In this paper, we mainly focus on coverage problems in the context of static WSNs (networks in which sensor nodes do not move once they are deployed.)

The paper is organized as follows in section II we give a general overview of the various design criterions in coverage problem for WSN and related work. In section III we discuss coverage problem in other fields. In section IV we discuss solutions to area coverage. The paper concludes in section V giving the conclusion

II. DESIGN CRITERION

The coverage problem is based on a fundamental question: “How well do the sensors observe the physical space?” The main objective is to cover each target location of the sensor communication range by at least one sensor.

There are several factors affecting coverage these factors are analyzed in designing coverage schemes depending on the objectives and application area and its related requirement.

Generally, there are many different criterions (factors) can affect the coverage performance of WSN. it is not possible to cover all the issues (factors) in every type of WSN. This paper gives a wide range of factors that have dominating effect.

1) Coverage Types: The first step in deploying a wireless sensor network is determining what it is exactly that you are attempting to monitor. Typically you would monitor an entire area, monitor a set of targets, or look for a breach among a barrier. Coverage of an entire area 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 to observing a fixed number of targeted points or region. This type of coverage has obvious military applications such as those covered in [4]. Barrier Sensors coverage refers to the detection of movement across a barrier of sensors. This problem was defined as the maximal breach path in [5]. This is also quantifying the improvement in coverage when additional sensors are added to a network.

2) Deployment Strategy: Deployment can usually be categorized as random or deterministic. A deterministic deployment (such as grid deployment) is where and how many of sensor nodes placed can be predetermined. Deterministic sensor placement can be applied to a small to medium sensor network in a friend environment. The exact positions and number of sensor nodes cannot be engineered or predetermined due to (a) various area like remote or inhospitable areas. (b) Military and disaster related applications, and (c) where the network size is large, [6]. Therefore, random deployment, 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 [6].

3) Sensing area and Communication Ranges: Sensor having invariable transmission range, some sensor’s radio transceiver is capable for changing its transmission power in continuous steps to achieve different communication ranges. Practically, the actual communication ranges may also be affected by many external factors such as the height of the sensor and its surrounding objects.

WSNs have sensor nodes having different or same sensing range. A factor that relates to connectivity is the communication range that can or not be equal to sensing area. The sensors should be within each other’s communication range for transmission of sensed data to base station [6].

4) Algorithm Characteristics: The algorithm for coverage can either be centralized or distributed (localized) A centralized algorithm is run on one or more nodes in a centralized location. In this case, information from all nodes needs to be transferred to the central node. A distributed or localized algorithm is run on nodes throughout the network. Distributed algorithms involve multiple nodes working together to solve a computing problem while localized algorithms imply that many or all of the nodes run the algorithm separately on the information each has gathered. They both spread the workload out more evenly than the centralized algorithm; however since it is being run on many more nodes throughout the network the distributed/localized algorithms may be more complex than the centralized algorithms [6].

5) Node Types: The set of nodes that are selected for a sensor network can be either a homogeneous or heterogeneous group of nodes. A homogeneous group is a group in which all of the nodes have the same capabilities. A heterogeneous group is one in which some nodes are more powerful than other nodes. Usually you would have a smaller group of more powerful nodes known as cluster heads which would gather data from the less powerful nodes [4, 5].

6) Constraints: The most important factor to be considered in a coverage scheme is that of energy constraints. Sensors nodes operate on battery and have a limited lifetime, it is therefore important to conserve energy and prolog network lifetime. Several mechanisms can be used for this such as switching the sensors to sleep mode when not in use. When sensors are arranged in a hierarchical network then cluster heads can be used to aggregate data and reduce the amount of information sent up to the sink. Eliminating the redundancy will also allow the network to be more efficient.

Depending on the application an area may require that multiple sensors monitor each point in the field of interest. This constraint is known as k-coverage in which the k represents the number of nodes that watch each point. Requiring a k value of more than one will add complexity to the coverage algorithm. The k-coverage constraint also deal with energy issues which is closely related to the energy constraint in that most of the research that has been performed attempts to preserve k-coverage while minimizing the energy expended in the sensor nodes [7].

7) Mobility: Mobility in sensor networks is highly essential for allowing Communication between different types connected components of the network. This also allows the operation of the sparse networks. When there is mobility in the sensor networks energy consumption is greatly reduced, so that the life time of the nodes are increased. Sensor mobility also allows better coverage [8].

8) Coverage Topology: Coverage problem is a sign of how well a wireless sensor communication area is monitored or Traced by sensors [6]. The coverage and connectivity problems in sensor networks have received considerable attention in research community in the recent year. This problem can be formulated as a decision problem, whose goal is to determine the every point in the service area of the sensor network which is covered by at least k sensors, where k is a given parameter [7].

9) Sensing probability: Sensing probability is also called coverage probability. it is the possibility that the target will be monitored by the sensor nodes. In the study of coverage algorithms, sensing probability is related to the sensing model of the defined wireless network [6].

10) Omission factor: In target covering, omission factor corresponds to the sensing probability. It is the possibility that the target can be missed by the node or the sensing area not covered due o any reason. It is closely related to the node's characteristic and it's used hardware and also the application environment for which node is used [6].

11) Sensing precision: The sensing precision of node is deal with the accuracy of the data gathered by that node. It is the ration of measured value of the node and actual value of the node.

12) Average moving distance: Average moving distance is the average value of the moving distance when the node moves to final position. If the distance is small, than the energy consumption will also be small. In practical application, this distance should be decreased and the difference between the energy consumption of different nodes should also be decreased.

13) Network lifetime: The definitions for the network lifetime are different due to the different wireless sensor network application. Various applications defines that network lifetime is directly related energy life time of node and energy utilization. If all the nodes are dead than network will also not work; some applications defines that network lifetime is over when the number of dead nodes exceed a certain threshold value; some applications defines that network lifetime is over when the coverage rate is under a certain threshold value [6].

14) Density control: One important issue that arises in such high-density sensor Networks are density control [09]. The function that controls the density of the working sensor set to a certain level. Specifically, density control ensures only a subset of Sensor nodes operates in the active mode, while fulfilling the Following two requirements:

(i) Coverage: the area that can be monitored is not smaller than that which can be monitored by a full set of sensors.

(ii) Connectivity: the sensor network remains connected so that information collected by sensor nodes can be relayed back to data sinks or controllers. Under the assumption that an signal can be detected with certain minimal signal to noise ratio by a sensor node only if the sensor is within a certain range of the signal source, the first issue essentially broils down to a coverage problem: assuming that each node can monitor a disk (the radius of which is called the sensing range of the sensor node) centered at itself on a two dimensional surface, what is

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the minimum set of nodes that can cover the whole area? On the other hand, the second (connectivity) issue can be studied, in conjunction with the first, if the relationship between coverage and connectivity can be well characterized (e.g., under what condition coverage may imply connectivity and vice versa).

15) Sensing model: there are two mainly two different sensing models: one is 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 [6]. In reality, sensor detection is imprecise hence needs to be expressed in probabilistic terms, namely the probabilistic sensing model, in which the detection probability of object or event and the sensor's sensitivity decreases if the network topology changed and the distance between nodes enhanced [1].

In addition, adaptively, data aggregation, location information, time Synchronization, scalability, failure model, robustness, and So on, is also factors affected for coverage schemes in Wireless sensor networks.

II. TYPES OF COVERAGE

***1)* Blanket/region/Area coverage:** the main objective of the sensor network in area coverage is to cover (monitor) a region (the collection of all space points within the sensor field), and each point of the region need to be monitored.

2*) Point Coverage*: the objective is to cover a set of point (target) with known location that need to be monitored. The point coverage method focuses on determining the exact location or position of sensor nodes, which gives reliable and efficient coverage for various application in which a limited number of immobile points (targets) are present. [10]. generally, it can be solved as a special case of the area coverage problem when sensor nodes' number may leave out of account.

3*) Target coverage*: measured as number of targets with known location that needs to be continuously monitored and observed (covered) [1] and a large number of sensors closely deployed to the target area and target [11].

4)* Barrier or path coverage*: Barrier coverage refers to the detection of movement across a barrier of sensors. This is useful in applications where the major goal is to detect intruders as they cross a border or as they penetrate to a protected area.

IV. COVERAGE APPROACHES AND OBJECTIVE

In this section, we provide a brief analysis of different deployment strategies for the different types of coverage areas. Area coverage, target coverage, point coverage and barrier coverage related approaches (algorithms) and objective describe in a table 1. And also specify the objectives of these approaches respectively [11].

The coverage approaches considered for area coverage and point coverage include node self-scheduling algorithm, constrained-minimally constraining heuristic, node placement algorithm (minimum spanning tree algorithm), disjoint set cover heuristic [11].

The deployment strategy considered for target coverage include bounding box heuristic using centroid approach, synchronization algorithm, logical grid routing protocol and linear programming MSC (maximum set cover) and greedy MSC heuristic.

Further, the coverage strategy/approach studied for barrier coverage includes maximal breach path algorithm, maximal support path algorithm and node density -based coverage.

Figure1

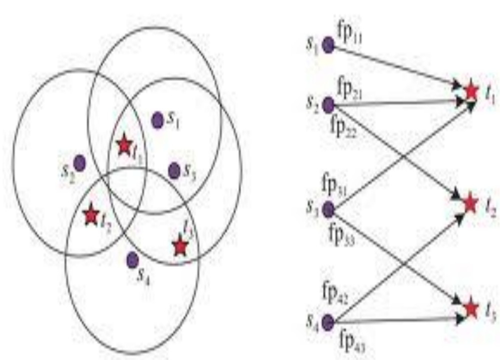

Table 1

COVERAGE TYPE	APPROACH COVERAGE	COVERAGE OBJECTIVE
Area coverage	Node self scheduling algorithm	Energy efficiency, maximize network lifetime
Area coverage	Constrained – minimally constraining heuristic	Energy efficiency, maximize network lifetime
Area coverage and Point coverage	Node Placement Algorithms (minimum spanning tree-based algorithm)	Energy-Efficiency, Connectivity
Point coverage	Disjoint Set Cover Heuristic	Energy-Efficiency Maximize network lifetime
Target coverage	Bounding Box heuristic, Synchronization algorithm, Logical Grid Routing Protocol	Target Detection, time synchronization , tracking and connectivity
Target coverage	Linear programming MSC and Greedy MSC heuristic	Energy efficient, Maximized network lifetime
Barrier coverage	Minimum Exposure Path Algorithm	minimum exposure path
Barrier coverage	Maximal Breach Path and Maximal Support Path Algorithms	Worst and best case coverage paths
Barrier coverage	Maximal Support Path Algorithm	Best case coverage path

V. CONCLUSION

Coverage is in general associated with two important properties of a WSN which is energy-efficiency and network connectivity. Sensor coverage is an important element for QoS in applications with WSNs. This paper reviewed the design considerations for coverage in WSN. It also shows the different types of coverage with different types of deployment strategies for each coverage type. We have also summarized the different approaches/strategies in a tabular form.

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