Review of Coverage Specific Problems in Design of Wireless Sensor Network

Poornima Lavania [1], Akhilesh Bansiya [2],
[1,2]Department of Computer Science & Engineering,
[1]RKDF University, Bhopal, India

Abstract: Wireless Sensor Networks (WSNs) have tremendous application in research and industrial applications, now it is equipped with modern Internet of things (IoT). Generally, hundreds or thousands of tiny, battery-power sensor nodes are deployed in the wireless interconnected manner in WSN which have limited coverage area. It is a key challenging issue to ensure that deployed sensors supply the needful coverage within the area of interest, in sensor networks, while ensuring connectivity of the deployed network. This paper provides a comprehensive categorization for the several methods and protocols applied in WSNs for increasing network coverage after initial deployment.

Keywords: Wireless Sensor Networks, Coverage, Sensor Nodes, Connectivity, Deployment strategy.

I Introduction

Wireless Sensor Networks (WSNs) attracted researchers and industrial communities in this modern sensor technology. Sensor nodes detect environment, take measurements and collect information from different conditions [1]. The information collected includes a variety of types, such as light, distance, vision, location, acceleration, sound, compass, rotation, magnetic, gravity, atmospheric pressure, temperature, and humidity, etc. With the rapid development of Micro-Electromechanical Systems, cheap and powerful sensors, which are viewed as lightweight "nodes", are massively produced. WSNs are composed of many such "nodes" dynamically without the help of any pre-defined infrastructure [2–4]. The number of nodes can reach up to hundreds, even thousands, or millions.

Coverage problem is a fundamental problem in WSNs. When building WSNs, a set of sensors are deployed in a region of interest. Each active sensor can detect objects in its "detection range", which is a disk region centered at the location of the sensor [5]. Therefore, we say an object in the region of interest is "covered" if it can be detected by at least one sensor in WSNs. Consequently, the coverage problem is to determine whether the objects located at different places in the region of interest can be covered by WSNs. Specially, we sometimes refer to "coverage quality" as the percentage of objects to be covered successfully by active sensors among all sensors deployed. Correspondingly, the coverage problem is also defined so as to study whether a coverage quality is achieved and how to achieve the required coverage quality for WSNs [6].

II Coverage Categorization

Coverage determines how well each point inside a WSN is sensed by a sensor node. To sense each point, number of nodes should be higher in order to achieve optimal accuracy [7]. But again higher number of node advocates higher expenditure. Therefore, optimal coverage with minimum number of nodes is a challenge when the sensed region is unknown as well as adverse. Categorization of coverage can be done on the basis of node sensing models, target attributes, optimization schemes, monitored region, deployment domain, and node deployment strategy [8, 9].

In this paper, we are studying the coverage issues based on the monitored region. In Figure 1, classification of coverage problem is shown. Nodes in a WSN are supposed to be exposed to inconsiderate conditions. Even WSN faces great challenge with respect to network lifetime, nodes are fully dependent on battery power. Under such circumstance, deployment of nodes in a predetermined way might not be successful [10]. To get effective coverage of the sensing field, generally, a large number of sensor nodes are deployed. If one sensor is unable to sense data or is inactive due to power failure, rest of the sensors can share its burden, thus providing better coverage [11].

III Related Work

Kong *et al.* [12] proposed a new model for the coverage problem called surface coverage to better capture real-world application challenges. Two problems pertaining to surface coverage were in focus: the expected coverage ratio with stochastic deployment and the optimal deployment strategy with planned deployment. Comprehensive simulation experiments show that though the performance bound of the greedy algorithm is not the best, it often outperforms the other two algorithms. To our best knowledge, this is the first attempt to describe and resolve the surface coverage problem in WSNs.

The expected coverage ratio C of the sensor node is given

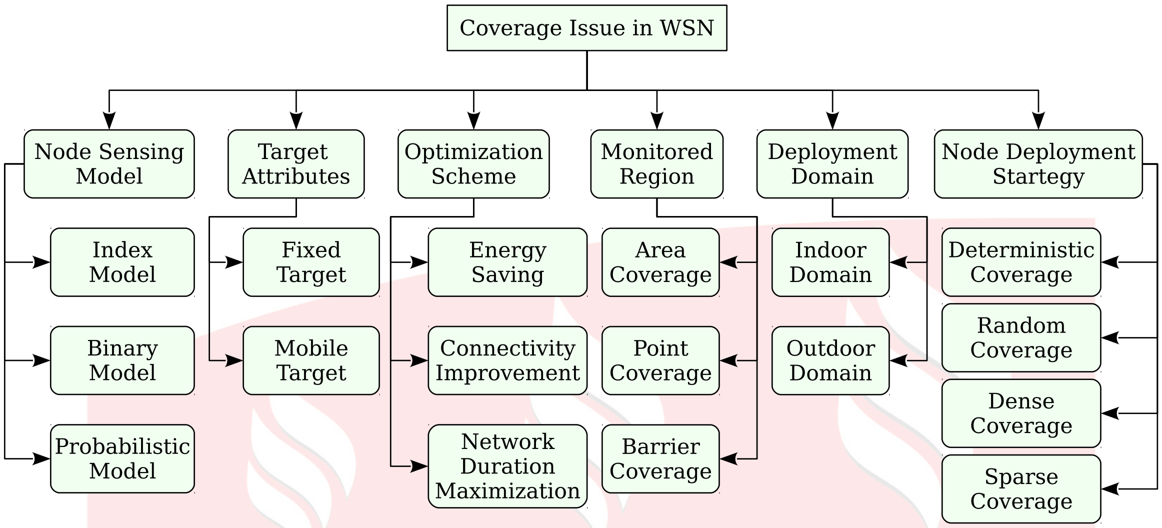

Figure 1: Coverage Categorization of WSN

by

$$C = 1 - \left(1 - \frac{2\pi^2 r^2}{2\pi\left(\pi r^2 + A\right) + 2\pi r L}\right)^N \quad (1)$$

where,
A is the coverage area.
r is the sensing radius.
L is the perimeter on the plane.
N is the number of sensors which are stochastically placed on the plane.

Singh *et al.* proposed a method which gave the good results and hence saves 67% of battery and after utilizing this battery we can increase the lifetime of the network more than two times of the lifetime before applying the proposed method. Tessellation (rectangle) formed by the proposed placement technique is also good. So this method can be used to deploy the sensors in a disastrous area. The analytical and simulation results showed that it can increase the coverage lifetime by more than two times of the original lifetime.

Das *et al.* [13] studied various research on area, point and barrier coverage to review the existing work, summarize their important qualities, and formulate some research challenges from the recent literature. In case of area coverage, getting maximum coverage with minimum number of nodes was the prime challenge and further works may be done in this aspect. In point coverage, additional works may be carried out in identifying the point of interests with respect to nodes in the network. Finally, recognizing the location errors and developing a fault-tolerant system in case of barrier coverage are the prime focus. The critical points in all these types of coverage are computational geometry-based approach, random deployment, distributed algorithm, and prior node location information.

IV Proposed Methodology

The WSN network coverage ensures that every point in the deployment region is covered by at least one node. Consider a number of sensors (S), where $S = s_1, s_2, \ldots, s_n$ to be deployed in a deployment region (R), which can be a region of any shape. Each sensor s_i has a sensing r_s, and a communication range r_c. A point is considered covered by a sensor, if it is within a distance less than its sensing radius. Therefore, R is said to be fully covered if:

$$\cup_{s \in S} \|s\| \geq \|R\| \quad (2)$$

where,
$\|R\|$ is the area of the deployment region R.
$\|s\|$ is the area covered by the sensing radius of node s.
S is the set of deployed sensors.

Equation 2 can be modified to reflect other coverage types. If a point can covered by more than one sensor, the total coverage of a point is

$$C(p) = \sum_{i=1}^{K} C_{s_i}(p) \quad (3)$$

therefore $K-$coverage can be achieved if:

$$C(p) = K \forall p \in A \quad (4)$$

Coverage alone is not sufficient for a WSN to operate. Nodes must be able to communicate with each other, either directly or through relay nodes, in order to transmit sensed data to the sink node for further processing.

The minimum node degree of a network graph G can be defined as follows:

$$d_{\min}(G) = \min_{\forall s \in G} d(s) \quad (5)$$

where,
$d_{\min}(G)$ is the minimum node degree of a network graph.
$d(s)$ is the number of neighbors of node s.
A network can be connected or $K-$connected, if there are at least $K-$disjoint paths between every point of nodes in the network.

V Conclusion

WSN has been used recently in a large number of applications ranging from monitoring to security and surveillance. Typically, nodes are either deployed deterministically or randomly according to the application requirements. This paper surveys different deployment patterns proposed for deterministic deployment. In addition, recent approaches used to improve coverage by exploiting the mobility of the nodes is surveyed. Several models that are used in WSNs and affects coverage are defined such as: sensing models (typical disk sensing, probabilistic sensing, and irregular sensing models), mobility models, and their impact on coverage. This paper presents a formulation of different coverage types, surveys and classifies recent approaches used to maintain full coverage. The paper surveys recent approaches used to improve and maintain coverage in WSN.

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