Coverage and Connectivity in WSN: A Review

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Wireless sensor networks (WSNs) are a collection of self-contained nodes with such a limited battery life which have applications in medical services, security systems, military surveillance, and environmental monitoring, among other areas, with energy-efficiency, lifetime, and network connectivity as research challenges. In the existence of multi-state sensor node, one of the major research difficulties is to provide application – optimum coverage of the observed region and reliable transmission of obtained data. When regulating sensor sites, it is often necessary to maintain a high are of coverage ratio, and covering explicit point target to ensure extended network lifetime be also necessary at times. This review covers the concepts of coverage and network connectivity, as well as how they are studied, quantified, and how they affect network performance. In addition, an oversight of the most important key performance indicator influenced by coverage is highlighted, which may have an impact on the envisioned use cases in terms of throughput and huge connectivity.

Keywords: Area-coverage, network connectivity, Wireless sensor networks, coverage ratio.

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1. Introduction

Wireless Sensor Networks (WSNs) are networks of low-cost sensor nodes that can sense, process, and communicate data about their surroundings. WSNs are used in a variety of applications including healthcare coverage, home safety, military applications, railway surveillance, farming, infrastructures, and remote monitoring applications like biodiversity, deforestation monitoring, and wild fire prevention. Depending on the amount of application environment, sensor node deployment might be planned [1] or random [2], [3]. WSNs are randomly dispersed, that is, physically deploy into a random manner, in the area of interest in remote monitoring applications and remain unattended after deployment. External influences, such as changes in ambient variables like rainfall, humidity, and vegetation, can cause these sensor nodes to fail in a variety of ways. As well as internal factors such as noise, a lack of battery power, and hardware failure. The following two performance indicators should be considered when analyzing the deployment of sensor nodes in a WSN: one is the sensor's coverage ability, and the other is the network's total life cycle[4]. The sensors remain immobile for the rest of their lives after deployment. Due to varying node statuses, communication link failure, restricted hardware components, and battery power, connectivity and data-flow capacity fluctuate.

The coverage rate is the most important statistic of coverage, and it may be used to measure the service quality of wireless sensor networks.As a result, doing a reliability analysis before to deploying a WSN is crucial. Sensor connectivity and the network's data- driving capability have long been the subject of WSN reliability analysis [5]-[9]. One of the key aims of sensor networks, in addition to connection and data-driven capacity [10], is coverage. In the event of a node failure, coverage refers to the ability to monitor a specific area of interest. Coverage challenges include coverage area[11], point coverage[12], K –coverage[13], and m-connected K –coverage['14]. The two types of coverage area challenges that have been examined are full coverage area [15] and partial coverage area [16]. Accurate area monitoring requires sensor coverage as well as data transfer to a processing centre or sink, regardless of the type of area coverage. To put it another way, a WSN must offer sensing coverage of the monitored area that meets a series of framework coverage-area criteria, and also lead to a positive of aggregate sensor data to the sink, in order to function properly. The network infrastructure has a life cycle due to the energy limits of WSN.

The lifetime of a WSN, or the time it takes until it can no longer observe the specific location or point, is a critical factor in determining its effectiveness. Due to the state of the area coverage, sensor nodes are frequently powered by a battery that cannot be replenished or replaced. As a result, sensor location should be improved in order to extend the network's lifetime. Sensors have a limited battery life. Other nodes frequently employ sensors situated near a mobile sink to communicate their observed data to the sink node. As a result, these border nodes become obsolete faster, resulting in network failure and disconnection. The concept of numerous static sinks was invented to resolve this issue. When compared to using a single static sink, this reduced the amount of hops among source(s) and sink(s), resulting in lower average dissipation of energy per node. These static sinks, on either hand, must be positioned within the receiving area so that load is distributed uniformly across all nodes. The idea of a mobile sink was born out of the difficulties that occur with multiple-sink deployment [17].

2 Preliminary

In this section introduces the components of a sensors node in a WSN as well as the terms used in this paper. We discuss probabilistic sensor coverage and k-coverage models.

2.1 Sensor Node Components in WSNs

A wireless sensor network (WSN) is consist of many sensor nodes that could be connect by one other. A sensor node's essential components are sensing, communications, processor, and memory units. Figure 1 shows a sensor node components in a WSN.

2.1.1. Sensing Unit

In WSNs, a sensor network consists of a sensing element that communicates with the external reality around it. Sensor node could be divided interested in two kinds based on their operation: internal and external sensor nodes. The signal power had sent by the sensor node that was reflected by the targets is measured by an dynamic sensor node, which is a monitored device. For signal generation, the active sensor requires an supplementary power supply. The transmitted signal emitted by the external environment is measured using a inactively sensor.

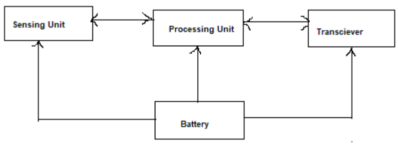

Fig 1. Classic architecture of sensor node

Figure 1 depicts the operation between dynamic and reactive sensor nodes. Sensor nodes could be classify as digital or analogue based on the output they produce. Binary or analog sensor nodes generate codes and continuous signals, which are dual and continuous signals.

a. **Communications Unit:**Sensor node of communication unit is in charge of data and control packet transmission and reception. In WSNs, one-way or else two-way communication between two sensor devices is referred to as in one direction or collaborative communication. Non - linear and non communications, according to WSN studies, can dramatically cut energy usage in large-scale WSNs.

b. Processings Unit: A processing unit connects with the elements and executes its software in a sensor node. Microchips, micro - controllers, low-power processing elements, communication processing units, and application-specific embedded processors are used in WSN sensor nodes for a range of activities.

c. **Transceiver:** In a sensor node network, the transceiver converts electrical impulses to optical (light) signals and optical information to electrical signals. It can be implanted or inserted into any device that can receive and transmit via a network.

2.2 Coverage Models

The surveillance capability of the happening events in the WSN is evaluated by coverage models in WSNs. The coverage model establishes a link between such a sensor node's Euclidean distance from a objective position and a non - negative real number defined as sensitivity. The coverage models in the literature can be categorized into two types based on the detection likelihood of activities in the WSN: probabilistic coverage's model and k-coverage model.

a. **Probabilistic Model:** We use the probabilistic model in this study, which is more realistic than the K-coverage approach. Let more realistic than the K-coverage approach. Let d(b,s_i,) signify the uncertainty in a sensing process that takes into account all available information, such as the chance of point b being covered by sensor s_i with probability $e^{-\omega d(b,s_i)^k}$ at the distance less than or equal to the sensing range S_i of the sensor node s_i.. For our issue formulation, we employ the exponential attenuation probabilistic model described , the probability of coverage decreases as the sensing distance d(b,s_i) increases.:

$$Covf(b,s_i)=\begin{cases} e^{-\omega d(b,s_i)^k} & if \quad d(b,s_i)\le S_i \\ 0 & otherwise \end{cases} \qquad \text{.......1)}$$

1) **K-Coverage- Problem:** Let's say there are N number of nodes (s1, s2,..., s_N) and M targets in the sensor field (T1, T2,..., T_M). If the distance here between sensor network s_i and the targeted point T_j is smaller than S_i and s_i will cover T_j. As an outcome, the covering matrix shown below could be created.:

$$P_{ij}=\begin{cases} 1 & if\ s_i \quad covers \quad T_j \\ 0 & otherwise \end{cases} \qquad \text{......2)}$$

where i equals to 1,..., N, and j equals to 1,..., M.

A position and energy of sensor nodes determine the network lifetime of WSNs. To present the battery lifetime, we define $b'_i = (b_i/e_i)$, where bi denotes the initial battery power and e_i is the energy utilization rate of node s_i. The lifetime upper bound can be calculated as follows:

$$V = \min_j \frac{\sum_i P_{ij}^* b_i'}{q_j} \quad \text{.........3)}$$

where q_j is a positive value that can be adjusted according the target's priority. $Tj,=j1,2,...,M$.

3. Problem Statement and its Proposed Solution

REF.	PROBLEM STATEMENT	PROPOSED SOLUTION
H. P. Gupta et al.[2016]	What is the essential sensor density of k-coverage and m-connection?	Proposed a method for calculating the critical sensor density required for the desired coverage and connectivity. The approach was also utilized to construct low-cost heterogeneous 3D WSNs with varying sensing and communication radii.
H. P. Gupta et al.[2016]	With a given sample rate of the sensors, how many sensor nodes are necessary to cover a 3D coverage area using mobile WSNs?	An methodology for finding the critic sensed density for k-coverage was suggested using a straight line mobility model. The efficient sensing range was used before sensing range due to the border effect.
C. Yang et al.[20]	Where should the least number of nodes for detecting and communicating be placed so that deploying sensor nodes covered all locations, which have a path of a sink, and energy-neutral?	A greedy algorithm is used to generate a gathering of locations using a mixed-integer linear algorithm. There were also algorithms involving direct as well as greedy searches mentioned.
H. M. Ammari et al.[2010]	How can you define critical sensor density of k-Coverage in a 3D networked WSN?	Offered a Reuleaux tetrahedron model for Solving the problem.
J. Kumagai et al.[2004]	How can you solve the partial coverage problem with a comprehensive algorithm?	To use a total coverage approach for creating full coverage groups through virtual radius and convert the coverage groups into partial coverage area by adjusting sensing radius, a method for managing measured problems for any coverage ratio was developed.
G. Wang et al. [2006]	How can the correct locations of mobile sensor nodes be estimated in order to achieve the desired coverage?	By using Voronoi diagrams, formed two kinds of linked protocols used for calculating the movement of sensor nodes, one preferring communications and the other preferring progress..
W. Wang et al. [2008]	Is there a limitation to how far a mobile sensor may travel??	Offered the hybrid network model, showing with the purpose of k-coverage can be also accomplished with a consistent sensor density of O(k), and developed a

		spread approach with all mobile sensor to find itself efficiently using only location information.
H. Zhang et al.[2006]	By using Poisson associated consequences, uniform randomized, and regular grid deployment approaches, how several sensor nodes are critical to reach a specific major of coverage?	In most cases, gridiron consumption provides non-symptotically less node density than random consumption. This result contradicts a recent study so as to found that grid consumption can lead to higher node density over random node deployments.
H. Jin et al.[2009]	In a heterogeneous WSN with boundary impacts, what is the minimum sensor densities for k-coverage area and m-connectivity?	An technique of estimating essential sensing density is given where sensor nodes are randomly planted in a circular shaped coverage area. Based on the empirical results, they offered an energy-efficient, location-independent routing system.
C.-I. Weng et al.[2018]	How might disconnected groups of sensor nodes be built to fulfill the k-barrier coverage requirement?	The purpose of decentralized barrier generation algorithms like the best-fit coverage technique and the upper one-coverage barrier method is to explore that many disjoint groups as possible..
C. Qiu et al.[2015]	In mobile WSNs, how do you tackle the k-coverage problem using distributed Voronoi cells?	Proposed distributed Voronoi-based cooperation mechanism that allows nodes to create and monitor other nodes and crucial locations around them. To avoid creating additional holes, the strategy restricts each node's movement.
X. Bai et al.[2009]	What is the optimal strategy to spread sensors in a 3D space such that the number of sensor nodes is kept to a minimum, that volume is thoroughly occupied, and k-connectedness is actually accomplished?	Formulated a series of arrangements for 6- and 14-connectivity and full area coverage, as well as illustrating their best result among regular grid patterns for any communication and sense range ratio.
G. Xing et al.[2005]	For k-coverage in linked WSNs, How will we define the relationship between sensing coverage & network connectivity?	This one has been proven that network connectivity is always present when the sensing k-coverage is at least 2 times the communications range.

4. Conclusions

This paper presents an overview of WSN coverage and connectivity issues. It covers strategies for WSN coverage analysis and improvement, as well as the benefits and drawbacks of each mechanism. Area coverage, point coverage, and barrier coverage are the three forms of coverage based on the required to observe the targets. Building coverage and connection while maintaining computing geometry and applying probabilistic methods were mentioned as problems and obstacles. In addition, for each emphasized category, a thorough state of the art on the major mechanisms for coverage enhancement is offered, together with insightful outcomes and obstacles. Coverage optimization now has a new taxonomy. This paper provides crucial insights into existing coverage options as well as implementation issues.

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