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Studies on Sensor Node Deployment and Target Coverage in WSN: A Review

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Abstract- In the modern world, information communication is faster than ever in human history. Sharing information in any form does have a significant influence on mass decisions. However, data collection is still prevalent, and many new techniques have been tried and implemented. Still, there have been a few drawbacks, and thanks to wireless communication, without which we could not have achieved this feat of faster data transfer/communication and collection. However, the potential of wireless communication is yet to reach its height. A few factors like the landscape's geography and area coverage hinder the full potential of using wireless sensor-based communication. The Proposed work aims to solve these problems without compromising network efficiency. This paper discloses the studies and the proposed solutions in a detailed manner. The proposed algorithm has a longer network lifetime than existing approaches because there are more sensors set covered.

Index Terms—Wireless Sensor Networks, Sensor Node, Network Lifetime, Target Converge

I. INTRODUCTION

Wireless Sensor Network is generally defined as a self-configured and infrastructure-less wireless network. Wireless Sensor Networks (WSN) [1] is constructed with low-power sensors that detect and filter physical and environmental factors. Figure 1 shows the architecture of wireless sensor networks. WSNs have been applied in various applications for a long time, including target detection and monitoring, disaster response, ecological monitoring, surveillance systems, building monitoring, pollutant level identification from air content, and other real-time applications as shown in Figure 2. [2]

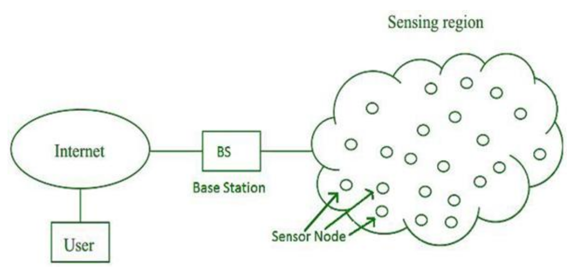

Figure 1: Architecture of wireless sensor networks

WSN uses sensor nodes with an inbuilt CPU to manage and monitor a specific area's environment. All the nodes are connected to the Base station, which serves as the WSN System's processing unit. In a WSN system, a base station is linked to the Internet to share data. The Wireless Sensor Network (WSN) is a relatively new advanced technology in various disciplines and settings.

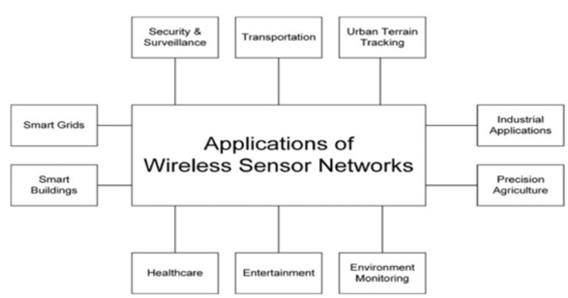

Figure 2: Application of wireless sensor networks

II. REVIEW OF LITERATURE

Wireless Sensor Network has been around for quite a while and has been studied extensively. Previous research has established different algorithm models serving particular application-based services and everyday application purposes. Theoretically, most algorithm designs and current existing models have a higher work efficiency range. Still, the efficiency does not seem to match the same content in the practical application due to the few significant factors that affect wireless communication. Numerous researches have been done to overcome the troubles to reach higher efficiency.

Sensor networks are constructed based entirely on different areas of science – sensing, communication and computation. Sensor networks were initially started as a military project and made an active improvisation during the Cold war era. Later on, it was eventually developed for serving customized applications that can be applied for various defined purposes [3].

The crucial task is deployment behind the scenes of installing the network and running the application. Deployment of sensors is vital because it is the backbone structure of the whole algorithms‟ practical application. Deployment is a crucial task which comes with a few fundamental issues. The primary challenge is precise area coverage, maximizing longevity, and energy efficiency because these factors significantly influence the network's execution [4].

Network coverage is a crucial step in establishing the communication network; [5] put forth the simulation of an algorithm that can show the coverage efficiently. They accomplish this by assigning sensor nodes to random active subsets. The subsets are intentionally positioned with partial functionality to reduce the energy consumption rate. They propose a distributed approach, split into field partition and coverage improvement. Voronoi based construction is used in algorithm construction.

The [6] detailed and addressed the goal, strategy, and limitations of WSN deployment and an outcome-oriented assessment of several deployment strategies. The principal purpose of sensor deployment is to categorize various methodologies into four categories: computational geometry-based techniques, force-based techniques, grid-based techniques, and grid-based techniques on Meta-heuristics [7]. The location of nodes is an essential but crucial factor that affects the functioning of a WSN. Some nodes are positioned randomly, while others are placed in a particular order. Random node deployment is routinely used in difficult climatic conditions or hostile scenarios. When establishing nodes, several variables must be considered, including connection, coverage, and security.

Target area coverage and continuous connectivity are the major factors that hinder the WSN application potential. The target coverage problem either covers the target continuously without any break or covers the specific target area by deploying minimum sensor nodes and verifies the target area is covered precisely [8]. Currently, great attention is paid to target coverage and connectivity problems, especially by the surveillance industry. To provide a better and more efficient methodology, several algorithms and methods have been proposed in the earlier research works.

The nature of ad hoc sensor networks mostly becomes hostile and unpredictable due to the environments. The review suggests a randomized solution that provides both simplicity and applicability to different environments to tackle the challenging environment. It improves both speed and energy conservation of the deployment process [9].

III. ELABORATING WIRELESS SENSOR NETWORK

Wireless Sensor Network is one of the emerging networks which configure automatically. It functions with an undefined number of sensor nodes connected logically and physically with the help of various communication mediums. Various WSN applications have deployed different sensors for monitoring purposes in a deterministic manner. Sensors are the most critical component of any programmed system. Sensor nodes are distributed in a defined region to be watched. Sensors can sense, gather data, process and perform the assigned tasks. Deploying the sensor in

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the designated area is a crucial factor that should satisfy the coverage and lifetime of WSN [10].

Establishing the Wireless Sensor Network concerns, including deployment, community routing, and power consumption, are surfaced and investigated. Coverage is a crucial metric for extending the life of a local region. Several factors cause coverage issues in WSNs, primarily based on ad hoc deployment and a limited detection range. Whenever sensors are deployed randomly, their coverage is disrupted or their accuracy is reduced when some are placed too far away and others are too close together. Usually, only a few nodes will rapidly connect with the receiver in more considerable area coverage. They result in the participation of just a few nodes to cover this scenario. The restricted detection range can be adjusted by choosing a sensor with a more extensive detection range; anyway, the cost would be more expensive and energy consuming. Figure 3 shows coverage issues in wireless sensor networks.[11]

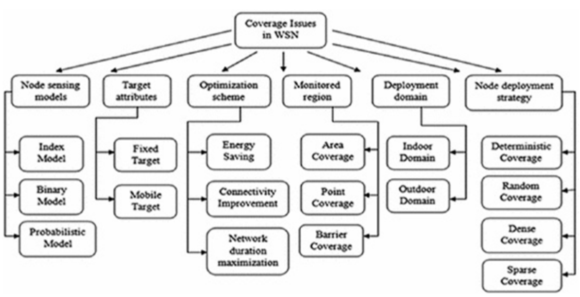

Figure 3: Coverage issues in wireless sensor networks [12]

The power supply constringent would result in some of the sensor's activity ending abruptly. It will lead to the shortage of the sensors to conceal the whole region. So, coverage is basically dependent on application. The detection range of a sensor node might be around 1-50m, although the transmission assortment of that sensor might be about 50-100m to guarantee the coverage.

In WSNs, usually, the nodes are not portable. Still, it is denser than ad-hoc mobile networks, and it takes a lot of time or causes a significant inconvenience to recharge or change the batteries. In the direction of restricting energy usage at the nodes, the clustering algorithm has been used to organize the network. K-means is a model-based clustering algorithm in which a solitary model is used for each cluster, i.e., the Centroid of the cluster [13]. The proposed work intends to imply a clustering algorithm exclusively dependent on the Voronoi diagram. Voronoi was developed with the intent of efficient planning of the coverage and density of the nodes. Upon the arrangement of the nodes, the activity is terminated by methods for the K-Means algorithm.

The proposed work intends to adjust the sensor nodes after their initial deployment using vehicles or mobile robot scans to improve network area coverage and eradicate coverage gaps. On the other side, moving the sensor nodes introduces significant challenges in terms of power conservation because node mobility structures consume more power. A battery serves as the sensor nodes' primary power source [14]. Naturally, the sensor nodes are often placed in places that are difficult to reach physically by people, so it is a significant challenge to change the batteries in these many sensor nodes as they're established in areas where users can't reach them physically. Considering the difficulty of changing batteries, the main concern is to avoid quick battery depletion and to conserve energy. It is wise to implement energy-saving technologies rather than dealing with consistent changing of batteries.[15]

WSN is used for different applications; however, the target area coverage range does not remain even as the land surface is unevenly distributed naturally. This does affect the network coverage efficiency. Due to the target node's mobility, speed, sensing region, and coverage area, most target nodes cannot be covered in scenarios like restricted sensing range and the distance between the sensor nodes and target nodes. The design of the target coverage model for the application of forest fire detection is shown in Figure 4.

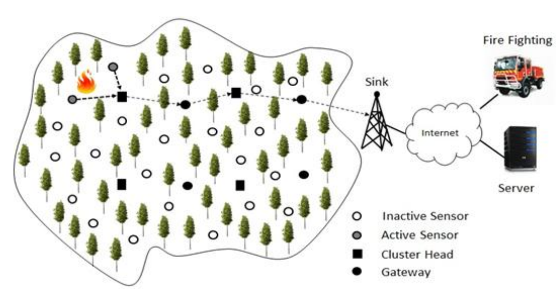

Figure 4: Architecture of target coverage model [16]

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Usually, most targets can be monitored /sensed only within a certain distance in target monitoring. The restrictions are due to the difference in the distance between the locations of the sensor from the target location. The problems above can be sorted quickly in a homogenous environment. Still, in the case of heterogeneous WSNs, the surveillance applications can have different types of sensors with various behaviors such as sensing ability, power utilization, battery limit, etc. Numerous earlier research works have assumed that sensing and communication range follows a binary disk model, while this model is unsuitable for reality.

Network coverage is increasingly becoming one of the most critical factors impacting the quality of WSN services. When sensors are placed, they can cover targets within that coverage area, and the coverage relationship can be calculated if all sensors, target locations, and coverage areas are known. The coverage challenge aims to discover a subset of the sensor and extend its life while considering the remaining resources' life limit and overall power consumption.

The Voronoi diagram tool can help to make better decisions while expanding the target coverage. Target, geographical, and connectivity are the essential variables to be considered in a WSN. Monitoring a set of target nodes using a set of sensor nodes is known as target coverage. Suppose any node fails while monitoring; it disrupts the entire network communication. Applications that require η-coverage, such as those used in the military, necessitate a higher environmental monitoring capability. This is a decision-making problem in which the goal is to identify the distance between the sensor nodes and the target nodes, which does not change, and the pre-assigned number of sensors covers the target. When the target moves, the sensors move in lockstep with it. The network should be trustworthy and accurate because of the target coverage challenge.

Briefly, a Wireless Sensor Network is a network of sensors communicating wirelessly. The sensors are built to detect physical and environmental inputs such as pressure, heat, and light, thus monitoring different terrains and similar applications. The sensor's output is typically an electrical signal sent to the controller for additional processing. A base station and multiple nodes comprise of a wireless network. There are two sensor nodes in a WSN: static and mobile sensor nodes. A static WSN sensor node is inflexible because it cannot manage topology changes induced by sensor node failure. Because of its dynamic nature, a WSN with moveable sensor nodes is adaptive. Real-time WSN applications where the number of deployed nodes cannot be regulated include border monitoring, restricted geographic surveillance, and catastrophe management. The proposed work presents node activity scheduling strategies to overcome this problem.[17]

In general, sensors are positioned randomly from planes at the intended location. Moreover, most sensors have two modes of operation: active mode and sleep mode. The sensors consume significant energy in an active condition to accomplish essential activities such as sensing, computation, and communication. On the contrary, the sensor in sleep mode consumes extremely little energy and can be activated at any time to perform its essential functions. Based on this concept, in a target region, if a subset of sensors has covered the critical area, the remaining sensors in the region can be subjected to enter the sleep mode, thus conserving the energy; in case there are more significant number of subsets, the WSN lifetime will be significantly increased.

Figure 5 depicts an example deployment where five sensor nodes (S1, S2, S3, S4, S5) continuously monitor three targets (T1, T2, T3). Every target is entirely covered by the deployment, as indicated above. The application will determine the required amount of coverage. The coverage requirement can be partially reduced for specific applications, but some applications require 100% coverage at all the times.

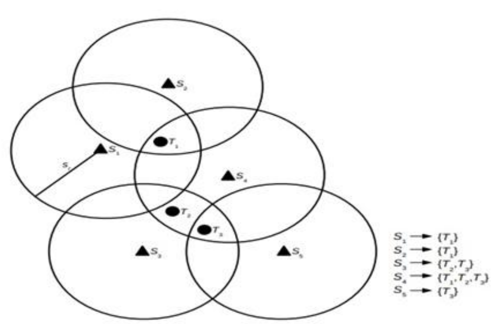

Figure 5: Target coverage

Network coverage is gradually becoming a significant aspect in influencing the WSN service standard. When all sensors, targets, and coverage areas are known, then the coverage relationship can be calculated based on the locations of all sensors, targets, and coverage areas. The coverage challenge focuses on extending the life of a subset of the sensor while considering the total power consumption and the original remaining resource life constraint.

Coverage is one of the most significant features of the Wireless Sensor Network service quality. Regarding sensor deployment, a sensor may cover targets within its coverage range. Coverage relations can be determined after all sensors and targets' positions and detecting fields are known. The target's coverage [18] challenge aims to locate subsets of sensors and increase their life span while maintaining their initial‟s resource remaining lifetime limit and overall energy consumption rate. The Voronoi diagram's features can help simplify decision-making while enhancing target coverage. Tracking an event or target is critical in Wireless Sensor Network which requires special consideration. Monitoring, controlling, and maneuvering moving objects or a vehicle necessitates target tracking. In a smart city, a network of connected automobiles can track vehicles, direct them to the best routes to their destinations, and assist them in collisions and emergencies.[19]

Humans, medical vehicles, automobiles, wild animals, drones, military aircraft, ships, and submarines are all targets. Target tracking is helpful for both civilian and military purposes. A sensor scheduling technique is provided to optimize network lifetime. Only the smallest sensor nodes required to deliver the specified coverage are active at any time. It outperforms all other approaches currently in use [20].

IV. IMPORTANCE OF TARGET COVERAGE

The wireless sensor network has an increasing demand for creating innovative real-time applications. Some highly used real-world applications are surveillance monitoring, agriculture, airport, other significant building monitoring, pollutant level identification from the air content, etc. Target coverage is crucial for these applications to achieve the desired function. Monitoring terrorists, the water level in a dam or sea, and animal monitoring in forests are some of the application's operations based on the target coverage methods. Though WSN usage is tops in most areas, it also faces some crises. A Wireless Network Sensor combines sensors that can be controlled remotely. A typical WSN must comprise of various sensors and deploy according to the application requirements [21]. The primary purpose of WSN is to monitor the given environment and complete surveillance of the surroundings. The mainframe controls and connects a sensor to a network. Every sensor includes three central components/units: the communication unit, the power unit, and finally, the sensing unit. To accomplish the said goals, all three elements must work in tandem. The low power absorption and the ability to survive short-circuiting are critical features of an efficient sensor.

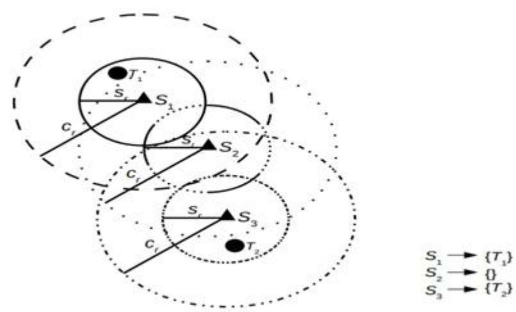

Figure 6: Connected sensor coverage

The primary objective of the sensors is to gather and transmit valuable information about the environment to the base station. Target Coverage (TC) is one of most crucial aspects in WSN‟s [22]. Three sensor nodes (S1, S2, and S3) are deployed in Figure 6 to monitor two targets (T1, T2). Each sensor node has a communication range Cr and a sensing range Sr. S1 and S3 activation, which is necessary for direct base station linked simple coverage to be met. However, as S2 connects S1 and S3, S2 must also be turned on for related coverage in addition to S1 and S3.

WSN's TC is a crucial and relatively new breakthrough for progress tracking. Power consumption is an issue with the TC process. The sensor has a large coverage area as well. The range of coverage for each sensor is different. Without increasing the number of sensors, the target coverage range is expanded. Beside range and coverage limitations, connectivity issues are also a concern.

Connectivity issues cause data loss. The connection between the sensor and the mainframe must be intact. WSN is currently dealing with these issues [23]. Several techniques and efficient programming are required in a sensor network. The region that has to be observed is known as the target coverage. Mixed development necessitates a wide range of sensors.

Many real-world problems have been rephrased as optimization problems to find the best solutions. Several scholars have worked together to create new, practical methods and tools to address these domain-specific optimization problems. These optimization problems aim to find the best solution for an objective function under a given set of choice factors within a given range. These optimization problems can be mathematically described without compromising generality as minimization or maximization of problems.

Swarm-based algorithms are essential for handling optimization problems because they perform better than traditional techniques. Various related swarm-based algorithms have been developed and tested in the past. Although for most of these swarm-based algorithms, the main limitations are their complexity and the huge number of input parameters that need to be tuned; these methods also have the benefit of providing a reasonable answer promptly. In this Target Coverage, a new swarm-based technique called Termite Fly Optimization (TFO), inspired by nature, is offered. The approach was developed by taking inspiration from a termite colony's response to light. The following are the advantages of the algorithm: Its exploration and exploitation approaches are efficient, its convergence rate is faster, its computing complexity is reasonable, and it has a sufficient number of algorithm-specific parameters [24].

Termites are the wood-eroding insects that are most frequently seen. They are social beings live in colonies. Each of these colonies has male termites, queen termites, soldiers, workers, and reproducer. The male and queen termites are responsible for carrying out the reproductive process. Soldiers monitor the colony to keep it safe from outsiders. The worker termite's responsibility is to feed and grow the colony. When the nymph reaches the winged adult stage, they depart the present colony and build a new nest in a different area. Figure 7 shows the stages of a termite's life cycle.

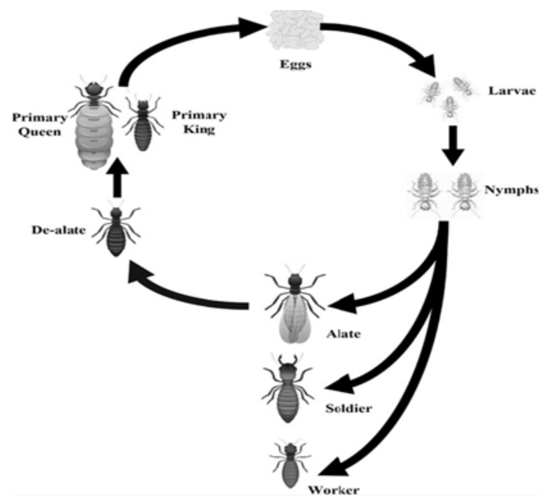

Figure 7: Termite life cycles

Values for a set of variables are found by minimizing or maximizing a function under particular constraints in the area of mathematics known as optimization. Almost all real-world scenarios now include the application of optimization, from developing new products to launching rockets. Among all other techniques, meta-heuristics is an essential tool in the optimization field. The primary argument for using meta-heuristics in optimization is because of its ability to address real-world problems with high complexity and nonlinearity. These approaches also have the advantage of delivering a good response quickly. Meta-heuristics may be divided into two categories: those that get their inspiration from nature and those that do not. Natural phenomena, including human behavior, photo taxi behavior, realistic assessment, food locating strategy, and physics- and chemistry-based theories, are copied to produce the methodologies employed in nature-inspired meta-heuristics.

IV. CONCLUSION

This research has to contribute in developing efficient network creation, sensor node deployment, and node deployment customized to application requirements. To achieve this, all the hurdles observed from the past search attempts must be overcome to improve the effectiveness of the area coverage problem. Accordingly, the Voronoi approach is used in the proposed study to assess and deploy sensor nodes based on node activity to cover a region efficiently. The issues must be approached individually; all the problems are resolved concurrently when deploying the nodes and shaping the connection. The target coverage issue in directional sensor networks is when targets have different requirements for the quality of their coverage, and sensors can spin in infinite directions. Target coverage depends on having enough sensors to monitor each target. Target coverage aims to increase the directional sensor network's lifespan and achieve the required levels of coverage quality for all targets. The coverage issue is complicated due to several factors. In contrast to wireless sensor networks, directional sensor networks deal with coverage on both sensor location and direction. This characteristic makes arranging target coverage challenging.

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