Wireless Sensor Networks: New Deployment Topology and DV-hop Algorithm Improvement

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ABSTRACT: *Wireless sensor networks (WSN) have become an integral part of our daily lives due to their small size, smart technology, lower cost, and wireless communication capabilities. In this paper, we propose a new WSN topology based on a hierarchical routing protocol. Additionally, we propose an enhancement to the DV-hop algorithm. Our proposed topology differs from existing approaches, and our enhanced algorithm improves upon the original DV-hop algorithm. The performance evaluations are globally satisfactory.*

Subject Categories and Descriptors: [C.2.1 Network Architecture and Design]; Wireless communication [C.2.2 Network Protocols]: Routing protocols

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1. Introduction

In recent years, the development of wireless networks has grown in popularity in scientific and industrial communities. Due to the recent advances in wireless communication technologies, WSN has become a major player in today's network architecture. WSN is a series of sensors that communicate with each other over wireless connections, and are implemented to cover an area of interest. These sensors can work independently to collect, process, and send data from their environment to a base station (BS). The captured data is transmitted to a central collection point known as a sink, which can connect to the network user through either the Internet or a satellite connection.

This type of network faces number of challenges, with one of the main problems being the limited energy capacity of the sensor node batteries, which are neither rechargeable nor replaceable. To address the issue, researchers have focused on developing energy-efficient communication protocols and deployment strategies that take into account the network energy consumption to extend lifetime of the network.

Many WSN applications rely on sensor self-positioning, such as battlefield monitoring, environmental monitoring and others, which depend on knowing the location of the sensor nodes. Due to the power limitation and the cost of the sensor nodes, the investigation of efficient location algorithms that meet the basic precision requirements for WSN faces a new challenge.

Many localization algorithms have been proposed for sensor networks. These algorithms can be categorized into two main groups: range-based and range-free methods. Range-based methods use various ranging techniques such as angle-of-arrival (AOA), received signal strength indicator (RSSI), time-of-arrival (TOA), or time-difference-of-arrival (TDOA). On the other hand, range-free methods estimate the distance instead of the measuring it directly, and examples of such methods include the centroid algorithm [32] and the DV-Hop algorithm [29].

This paper focuses on range-free algorithms and node deployment strategies for WSNs. In this context, we propose an enhancement of the DV-Hop algorithm, as well as new effective deployment strategy. The proposed algorithm can improve location accuracy and coverage without increasing the hardware cost of sensor nodes. This strategy is based on a deterministic deployment method for nodes, where we study the position of each node and how data is captured and transmitted to the BS. The position of nodes in this strategy helps extend the network's lifespan and reduce energy consumption, while ensuring full coverage of the surveillance zone.

The rest of this paper is organized as follow: In section 2, we give a background and related works on deployment strategies and routing process. The section describes our enhanced DV-HOP algorithm and also our proposed deployment strategy.

Section 4 gives the performance evaluation of these two proposals. Finally, we conclude and give some future works.

2. Related Works on Deployment Strategies

Power source, it is crucial to utilize their power capacity efficiently to maximize network's life span. When a sensor's battery is depleted, it becomes non-functional, leading to disruptions and potential disconnections within the network. Therefore, it is essential to implement an effective strategy that extends the network's lifespan by minimizing energy loss. This can be achieved by employing a routing protocol that focuses on delivering information efficiently to the base station while also reducing overall energy consumption. By optimizing the routing process, the network can transmit data swiftly and minimize unnecessary energy expenditure, thus prolonging the operational life of the network.

2.1. Node Deployment Strategies

Wireless Sensor Networks (WSNs) have emerged as crucial components in various domains, encompassing intelligent environments and cutting-edge technologies like the Internet of Things (IoT). These networks play a pivotal role in efficiently discovering and monitoring targets, rendering them indispensable for capturing and collecting data on environmental factors such as temperature, pressure, and pH. The primary objective revolves around achieving optimal coverage of the region of interest (ROI). Subsequently, the collected data is intelligently routed to a central control center known as the base station (BS) [1].

Within the scope of this paper, our primary focus lies in addressing the intricate challenges associated with wireless sensor networks (WSNs). Unlike traditional network designs, the placement of sensor nodes within the designated area is not predetermined during the initial stages of WSN deployment.

However, the precise placement of sensor node plays a crucial role in enhancing various network factors. These factors encompass network cost, routing efficiency in terms of energy consumption, network longevity, achieving complete coverage of zone, and ensuring reliable communication between sensors. Each sensor node within the network serves as a relay node for reception and transmission of data. It is essential to minimize the distance between nodes to optimize energy consumption and mitigate potential issues. To address these challenges, diverse deployment strategies and routing protocols have been proposed to extend the network's lifespan and maximize within the target zone. The duration of network operation plays a critical role, as consumption directly impacts the overall lifespan of the sensor network.

Given that the sensors in a wireless sensor network rely solely on limited-life batteries as their power source, it is crucial to utilize their power capacity efficiently to maximize network's lifespan. In wireless sensor networks, the depletion of a sensor's battery can result in its inability to function properly, leading to disruptions and possible disconnections within the network. Hence, it is of paramount importance to employ a well-crafted strategy that aims to optimize the network's lifespan by minimizing energy loss. This can be accomplished by implementing a sophisticated routing protocol that prioritizes the efficient delivery of information to the base station while concurrently minimizing the overall energy consumption. Through meticulous optimization of the routing process, the network can achieve rapid and seamless data transmission while mitigating unnecessary energy expenditure, thus significantly extending the operational longevity of the network.

2.2. Strategies Related to Target Objectives

Many factors and constraints must be studied and taken into account when designing and deploying these types of networks. Additionally, several objectives must be considered to ensure an optimized deployment.

Depending on the specific goal to be achieved, the node positioning strategy can be tailored accordingly. These goals may include maximizing the coverage of the surveillance zone, improving network connectivity, and extending network service life duration.

2.2.1. Coverage Optimization Strategies

The concept of coverage can be viewed as a measure of the quality of service in a Wireless Sensor Network (WSN), reflecting how well the sensor nodes observe each point within the surveillance zone. Various deployments strategies for nodes are employed to optimize coverage in the surveillance zone and efficiently utilize available resources.

In their work [5], the authors introduced an iterative heuristic approach aimed at achieving complete coverage of the surveillance zone using the minimum number of sensor nodes. The proposed method assumes that the sensor nodes are positioned on a grid. In each iteration, a sensor node is placed at a specific point on the grid. The algorithm continues until full coverage is guaranteed or a predefined limit on the number of deployed nodes is reached.

In their research [6], the authors present a model aimed at achieving high probability target detection using the minimum number of sensor nodes. Their approach focuses on optimizing the placement of sensor nodes. Another study by the authors in [2] proposes a triangular grid placement strategy for sensor nodes to maximize the coverage of surveillance zone. By adjusting the distance between the sensor nodes (denoted as d), the coverage can be controlled. The authors mathematically prove that achieving 100% coverage is possible when the distance between the nodes is set to $d = \sqrt{3}\, r$, where r represents the detection radius. The figure provided visually demonstrates the placement strategy of the sensor nodes on a triangular grid.

To maximize the coverage of the surveillance zone, an alternative approach utilizing sensor node mobility is explored in [7]. This approach focuses on dynamically repositioning sensor nodes to optimize network performance. Unlike random initial deployments, which may not ensure full coverage and can lead to non-uniform distributions across the surveillance zone, this approach aims to address coverage deficiencies. It takes into account environmental factors and changes in network that may occur during network operation, such as adding or losing nodes. By moving nodes to areas with weak or non-existent coverage, the network can adapt and maintain operational efficiency.

The issue of network connectivity is closely linked to network coverage, as highlighted by the authors in [8], [9], and [10]. They emphasize the importance of ensuring both coverage and connectivity in WSN. A fully covered network can only function effectively if the constituent nodes are interconnected, enabling the transmission of collected data to the sink node. If the communication radius of a node is similar to the detection radius, network connectivity becomes a challenge. In [11], the authors investigate and compare various node deployment strategies that achieve both full coverage and good network connectivity while minimizing hardware resources (sensor nodes). Additionally, in [8] and [9], the authors propose node placement strategies based on regular grids, including square grids (refer Figure 2), hexagon grids (refer Figure 3), and in band deployment (refer Figure 4). These strategies aim to maximize total network coverage with a minimal number of sensor nodes while maintaining robust connectivity.

2.2.2. WSN Life Duration Optimization Strategies

Figure 5 illustrates the multilayer architecture composed of regular hexagonal cells.

The determination of network life duration is complex task as it is influenced by various factors, including the application and protocols employed, as mentioned in [12]. For instance, according to [13], network life duration is

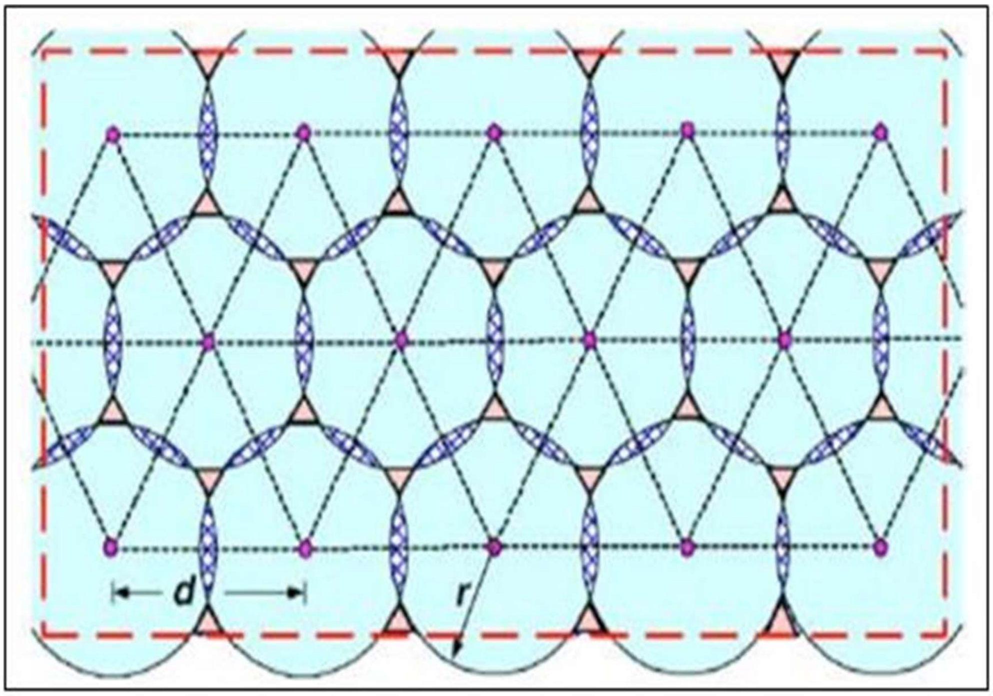

Figure 1. Placement strategy of sensor nodes on a triangular grid

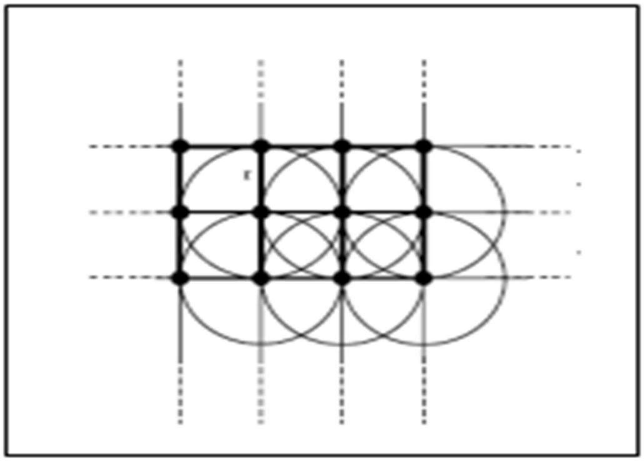

Figure 2. Square topology

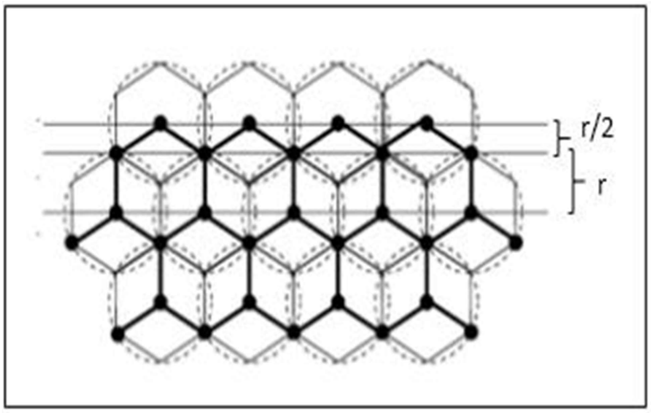

Figure 3. Hexagon topology

closely tied to the lifespan of sensor node, the accessibility of sensor nodes to the network based on [14] [15], the quality of service as discussed in [16], and the spatial distribution of the nodes according to [17], among other considerations. Certain studies have specifically addressed the issue of network life duration, particularly in scenarios where a dense network of sensor nodes is available to ensure coverage and connectivity within the surveillance zone. In such large-scale networks, which span large geographical areas, energy conservation becomes a critical concern [18], especially when aiming for prolonged deployment periods. To address this, numerous techniques for sensor nodes placement have been proposed in the literature to extend network's life duration.

One method used to achieve this objective is to reduce the average power consumption per sensor node. In [19], the authors assume that sensor nodes are capable of mobility within the surveillance zone. They repeatedly propose moving the sensor nodes, if necessary, while considering coverage constraints. The underlying idea is to distribute the network data traffic evenly among the sensor nodes. In [20] the authors suggest an optimal redistribution of sensor nodes ideal redistribution of sensor nodes based on a standardized distribution. This approach aims to equalize the power consumption across the network by maintaining identical distances between sensor nodes. Consequently, this strategy positively impacts the network's life duration.

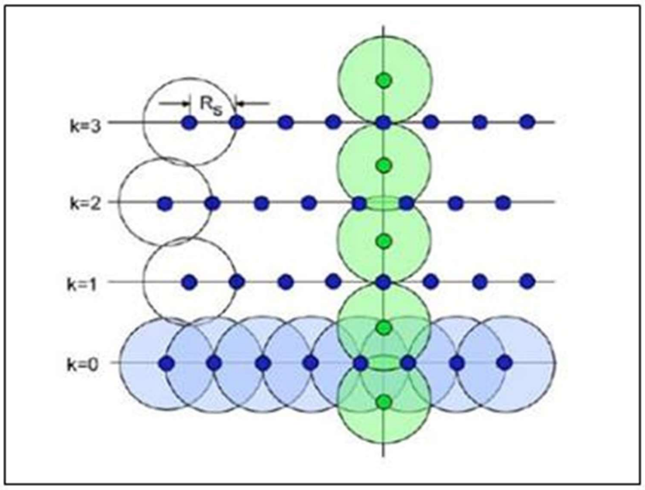

Figure 4. Band topology

The sensor nodes located near the hole tend to consume more power compared to the ones farther away. In [21], the author proposes an irregular distribution function for the sensor nodes in the network, aiming to balance the power consumption among groups of sensor nodes located at the same distance from the hole. The suggestion is to deploy multiple sensor nodes near the hole to ensure sufficient total energy for data transfer.

In [19], the authors propose a predetermined strategy for deploying irregular sensor nodes to achieve a balance in energy consumption across different layers, thereby extending the network's lifespan while maintaining connectivity and coverage. The approach involves creating a multi-layer structure in the network's coverage zone, where each layer consists of regular hexagonal cells (primary and secondary cells) as depicted in Figure 5. The deployment of sensor nodes occurs in two stages. In the first stage, sensor nodes are deployed at the center of each cell to provide communication and network coverage (refer Figure 5). The conditions $DR \geq 2r$ and $CR \geq r$ ensure that the sensor nodes' detection and contact radius (with r being the cell radius) are met respectively. In the second stage, additional sensor nodes with priorities ranging from 1 to 3 (shown in Figure 6) are placed at the boundaries between adjacent layers. This is done when some of the sensor nodes deployed in the first stage are not involved in data routing or identification processes.

Instead of extending network's lifespan while reducing the average consumption per sensor node, certain authors, such as [15] and [22], propose the use of a heterogeneous network consisting of sensor node (SNs) and collector node (CN's) with superior capabilities. Their focus is on determining the optimal number and / or position of CNs in a wireless sensor network to maximize its lifespan. In [23], the authors suggest the use of

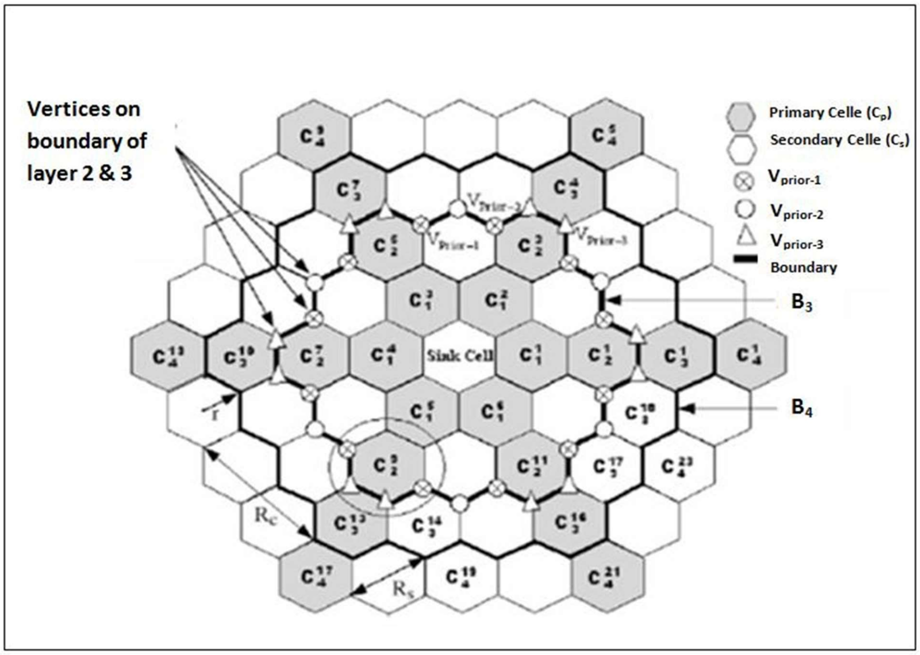

Figure 5. Illustrates the multilayer architecture composed of regular hexagonal cells

distributed and localized heuristics to identify the number and optimal locations of relay sensor nodes.These relay nodes ensure that all the SNs are directly served by a CN, forming 1-hop groups where each relay sensor node acts as the cluster leader. To achieve this, the source sensor nodes collaborate to determine the intersection of their connectivity zones, and the relay sensor nodes are placed atthe intersections that cover the majority of source sensor nodes.

In [15], the authors propose an iterative heuristic to reduce the number of collector nodes (CNs) while considering limitations on the network lifespan. They employ an aggregation algorithm with k-hop to connectivity to determine the number of CNs required. This algorithm aims to partition the sensor nodes (SNs) into subnets or distinct groups, thereby reducing the average Euclidean distance between the source SNs and their corresponding collectors. Each collector node is placed at the centre of its designated collection area. Another solution presented in [24] involves formulating a linear program to address the problem. By utilizing a centralized graph partitioning algorithm, as suggested in [22], the network is divided into relatively large subnets, each corresponding to a sensor node, while having prior knowledge of each SN's position. Subsequently, a collector node is randomly deployed to each subnet. However, it should be noted that the sensor nodes located near the collectors may experience faster energy depletion due to their involvement in relaying SN data to the CNs.

In their work, authors such as [25] and [26] [27] [22] focus on utilizing collector node (CN) transportation to extend the lifespan of WSN's. Their research involves periodic investigations to identify optimal positions for the CNs. The objective is to achieve a uniform distribution of the traffic load across the entire network system and determine the optimal paths for transmitting data to the CNs. By strategically positioning the CNs and efficiently routing the data, these approaches aim to prolong the WSN's lifespan.

2.3. Related Works on Localization

In this section we review the most relevant research results for our work.

Many research papers have suggested methods of localization in WSN. Since each one was developed to achieve a different goal, they differ greatly in many parameters (precision, cost and security ...).

As briefly discussed previously, there are several techniques proposed to achieve the location error optimization in this section, our focus is on range-free algorithms.

In the range-localization algorithms, Niculescu et al propose [29] the DV-Hop free localization algorithm. In this algorithm, each node counts the minimum hop number between it and the anchor node and then computes the distance by multiplying minimum hop number and average distance of each hop. At last, the node estimates its position through a position derivation algorithm.

He et al. proposes the approximate point-in triangulation test (APIT) algorithm in [30] uses beacon transmissions from anchor nodes. It employs an area-based approach to estimate location by isolating the environment in triangular regions between beacon nodes. The presence of a node inside or outside these triangular regions allows this node to reduce the area in which it can potentially reside. By using combinations of anchor positions, the estimated area diameter in which a node resides can be

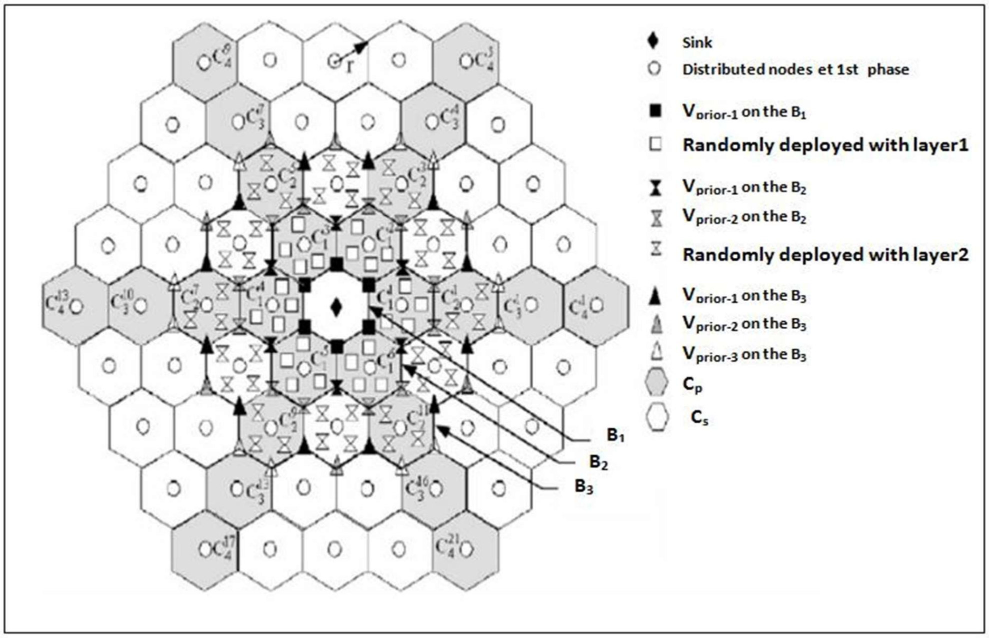

Figure 6. Nodes deployment

reduced to provide precise location estimates.

Amorphous [31] is similar to the DV-Hop algorithm, which uses offline hop distance estimation. It suggests generating a coordinate system with rotational accuracy in the distributed processor through local information.

Centroid [32] suggested by Bulusu, Heidemann and Estrin. In this method, a number of anchor nodes are placed in advance. Each anchor node sends a “beacon” message contains its position. A node that wants to locate itself listens to the beacons for a certain time. It selects a certain number of anchor nodes and calculates its position by taking the center of gravity of the positions of the selected anchors.

3. Propositions

This paper proposes a deterministic deployment strategy based on hierarchical protocol, as well as an improved algorithm based on DV-hop algorithm. Each of those propositions is clarified separately in the following sections.

3.1. Deployment Strategy Proposition

3.1.1. Deployment Phase

The deployment of sensor nodes in wireless sensor networks is always a significant and sensitive problem. It is considered a crucial phase in setting up a wireless sensor network as it serves as first step, essential for the network’s functioning and performance.

A deterministic deployment is preferable because we can have prior knowledge of the terrain. Moreover, the physical or physiological parameters captured by the sensor nodes must be precise, relevant, and of good quality. This necessitates an appropriate placement of the sensor nodes. The same applies to the positioning of base stations, as they are crucial for ensuring the acquisition, integrity, and processing of captured measurements.

In this section of this article, we present our proposed deployment topology for studying the positioning and placement of various sensor nodes in wireless sensor networks, our aim is to extend the network’s lifespan while ensuring coverage and connectivity. This proposal is based on the clustering technique of nodes, which aim to minimize energy consumption.

This topology offers an optimal deployment of sensor nodes while ensuring a uniform distribution.

This approach enables the standardization of network energy consumption. Our network architecture consists of regular hexagonal cells, with sensor nodes deployed at the centre of each cell. To ensure network coverage, we adjust the distances (d) between each pair of nodes such that $d = \sqrt{3}r$, where r presents the radius of the cell. This strategic adjustment of distance has positive impact on the network’s lifespan.

3.1.2. Routing Phase

Data collection in this topology is based on the clustering technique, where each cluster contains seven sensor nodes. The cluster-head that receives information captured from their group members, which are the six adjacent sensor nodes creating a circle around it. To route this collected data to the base station, we apply the LEACH (Low-energy Adaptive Clustering Hierarchy) protocol on this topology. The LEACH protocol, introduced by Heinzelman and others [28], is an efficient hierarchical routing protocol that minimizes energy consumption in wireless sensor networks.

We chose the LEACH protocol because it is based on clustering. The selected cluster-heads (CHs) collect data captured by member nodes belonging to their own cluster periodically over a round using the Robin Round management policy (also known as the turnstile mechanism). They then send the aggregated data packets to the sink node (SB), thereby reducing the amount of information transmitted to the sink and ensuring fair energy dissipation between nodes.

The LEACH protocol functions in two phases: the setup phase (also known as the device phase) and the steady-state phase (also known as the communication phase). In the setup phase, cluster-heads are selected and clusters are formed. In the steady-state phase, data is transmitted to the sink node (SB) using the MAC CSMA protocol. One major advantage of the LEACH protocol in our topology is its ability to divide the network into clusters based on received signal strength. Initially, cluster-heads are randomly selected and they rotate dynamically to distribute the load and balance the energy dissipation among the nodes. Additionally, this protocol enables 1-hop communication between cluster-heads and their member nodes, as well as k-hop data routing to the base station (BS). This approach aligns with our topology, where each sensor node can transmit directly to the cluster-head and to receive messages from it, as shown in figure 7.

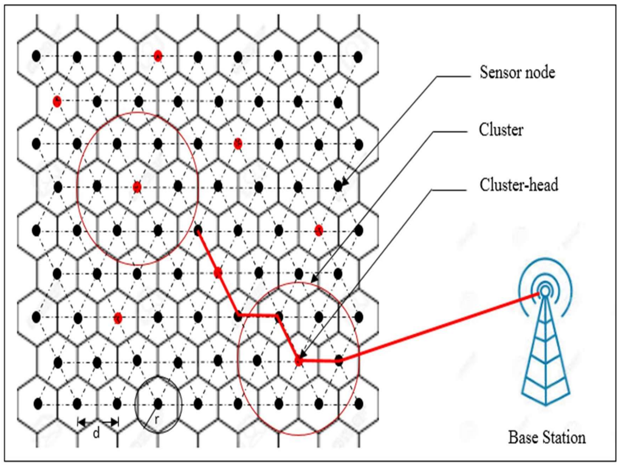

Figure 7. Nodes deployment strategy proposal

3.2. Localization Proposition

Our proposition consists to present an improved method for DV-hop algorithm which we'll explain in the following.

3.2.1. DV-Hop Algorithm

DV-hop [29] is proposed by Niculescu and Nath, it's a reference location algorithm used to give the estimated position of any unknown node in the network based on the number of hops using a reduced number of known location nodes that are most likely equipped with GPS. This algorithm consists of three steps described as follows:

In the first step, each anchor node i sends a beacon message $[id, x, y, hop]$ for the other sensor nodes, where id is the identifier of the anchor $node\ i$, (Xi, Yi) are its coordinates obtained by GPS and hop is the number of hops which the beacon message passes through, initially $hop = 0$. At the reception, each sensor node manages a table which contains the information of each anchor node and stores the minimum number of hops which separates it from the different anchor nodes. Beacon messages containing the highest number of hops are simply ignored. It then retransmits the beacon message to its neighbours after the number of hops is increased.

In the second step, each anchor node calculates the distance between it and the other anchor nodes, then it estimates the average HopSize using the formula (1).

$$HopSize_i = \frac{\sum_{i\neq j}^{n} \sqrt{(x_i-x_j)^2 + (y_i-y_j)^2}}{\sum_{i\neq j}^{n} h_{ij}} \qquad (1)$$

Where n is the number of anchor nodes, (X_i, Y_i) and (X_j, Y_j) are the coordinates of the anchor nodes i and j respectively and h_{ij} is the minimum number of jumps between them.

Each anchor i diffuses the average of the hop over the entire network.

In the third step, each sensor node receiving this value estimates the distance between it and the anchor node using the formula (2).

$$distance_{ie} = HopSize_i \text{ x } hops_{ie} \qquad (2)$$

Where $hops_{ie}$ is the number of jumps between the anchors i and the unknown node to be located, denoted as e.

In the fourth step, the algorithm estimates the positions of each sensor node using trilateration method, after calculating at least three distances between them and at least three anchor nodes.

3.2.2. Improved DV-Hop Algorithm

In this section, we presented the improvement of the DV-hop algorithm based on a hybridization of two versions of this algorithm proposed in [33] and [34].

Our proposal consists of five stages, in which combine the first two stages of the improved DV-hop algorithm proposed in [34] with the third and fourth stages of the improved DV-hop algorithm in [33].

The first step in our proposal, after distributed the sensor nodes randomly in the surveillance zone, is to select certain anchor nodes to avoid using GPS, which is expensive and consumes more energy. Each anchor node transmits a beacon message. At the reception, each sensor node saves the minimum number of hops that separate it from the different anchor.

In the second step, each anchor node calculates the distance between it and the other anchors in the network, then it estimates the average hop distance ($HopSize_i$) to each anchor node found to improve the accuracy of localization using the formula (3).

$$HopSize_i = \frac{\sum_{i \neq j} (hop_{ij} \times d_{ij})}{\sum_{i \neq j} (hop_{ij})^2} \qquad (3)$$

Where d_{ij} is the straight-line distance between the anchor *nodes i and j*.

In the fourth step, we average whole of the hop-size of different anchor nodes using the formula (4).

$$HopSize_{ave} = \frac{\sum_{i \neq j} HopSize_i}{n} \qquad (4)$$

Where n is the number of anchor nodes? After getting the average of the hop-size, the unknown node uses the formula (5) to calculate the distance between it and the anchor i :

$$distance_{ie} = HopSize_{ave} \times hops_{ie} \qquad (5)$$

Where $hops_{ie}$ is the number of jumps between anchor i and *node e*.

In the last step, when unknown nodes get three or more distance information from anchor nodes, we propose to use a least square method to estimate the positions, it is assumed that (x, y) are the location of the unknown *node*, (X_i, Y_i) are the location of anchor node i and d_i is the distance between them calculated by the formula (6).

$$d_i = \sqrt{(X_i - x)^2 + (Y_i - y)^2} \qquad (6)$$

Then, we have

$$\begin{gathered}(x - X_i)^2 + (y - Y_i)^2 = d_i^2 \Rightarrow \\ X_i^2 + Y_i^2 - 2X_i x - 2Y_i y + x^2 + y^2 = d_i^2\end{gathered} \qquad (7)$$

The coordinates of unknown node are coputed by the following formula (8)

$$\begin{gathered}A = -2[X_i - X_n \;\; Y_i - Y_n] \\ \cdot \\ \cdot \\ X_{(n-1)} - X_n \; Y_{(n-1)} - Y_n\end{gathered} \qquad (8)$$

And

$$\begin{gathered}B = d_i^2 - d_n^2 \;\; X_i^2 + X_n^2 - Y_i^2 + Y_n^2 \\ \cdot \\ \cdot \\ d_{(n-1)}^2 - d_n^2 - X_{(n-1)}^2 + X_n^2 - Y_{(n-1)}^2 + Y_n^2\end{gathered} \qquad (9)$$

Where $Z = (x, y)$ (10)

$$Z = (A^T A)^{-1} A^T B \qquad (11)$$

Then, the coordinates of the unknown *node*, (x, y) is expressed as:

$$\begin{gathered}x = Z(1), \\ y = Z(2).\end{gathered} \qquad (12)$$

4. Performance Evaluation

In this section, we present the simulation results of our proposed approach using MATLAB software

4.1. Proposed Deployment Strategy Simulation Results

To conduct our simulation, we deployed 66 sensor nodes at the center of 66 regular cells in a measurement area 50 units by 40 units. Figure 8 depicts the deployment of the nodes.

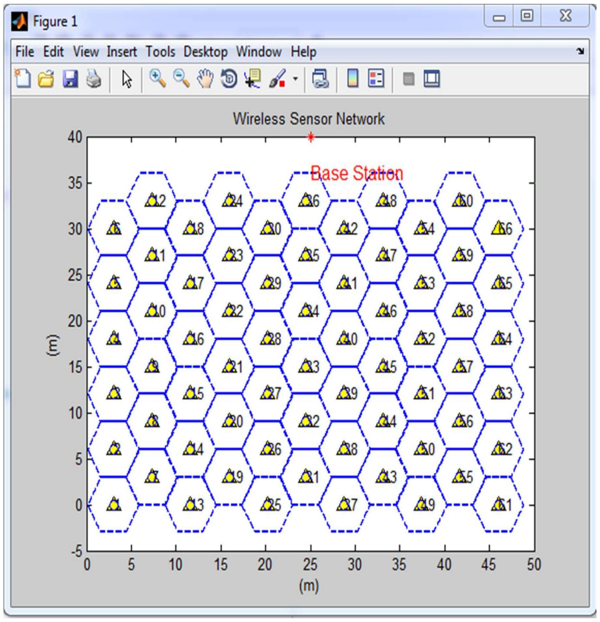

Figure 8. Nodes deployment

After applying the LEACH protocol to the topology, we will present the results of our simulation and evaluate the performance using various performance measures.

Figure 9 illustrates the relationship between the number of operational nodes and the number of transmissions made. It is observed that the number of operational nodes starts to decrease around the 2200th transmission and eventually reaches zero around the 6700th transmission.

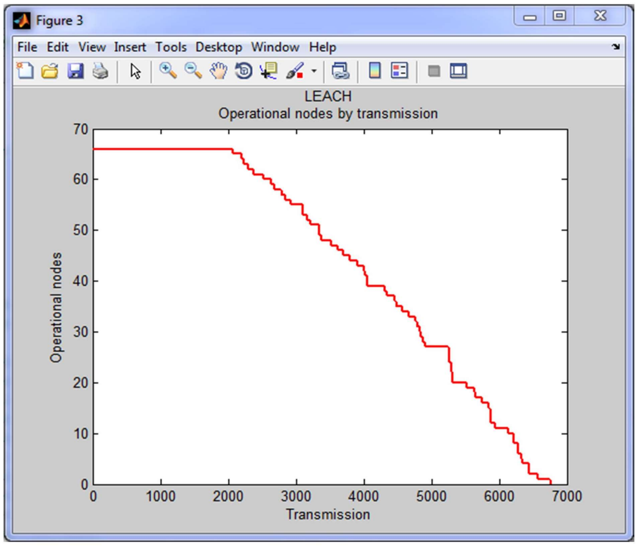

Figure 9. Variation of operational nodes depending on the number of transmissions

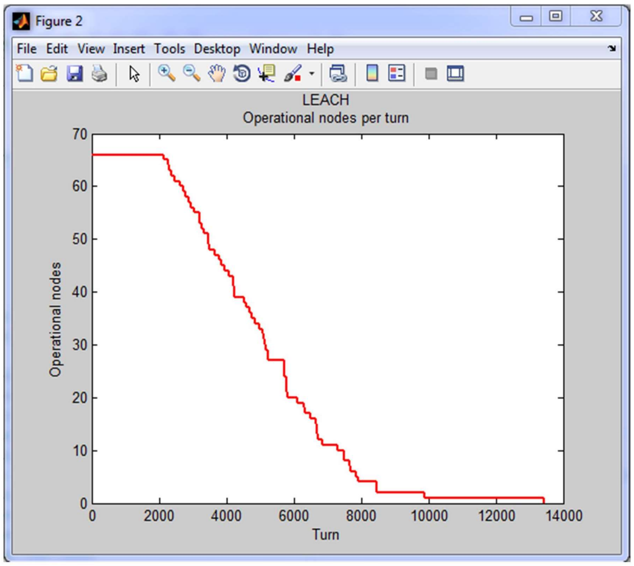

Figure 10. Variation of operational nodes depending on the number of turns

Figure 10 depicts the variation in the number of operational nodes in relation to the number of turns. It can be observed that the number of operational nodes starts to decrease after a certain number of turns, specifically at around 2200 turns. As the turns progress, the network gradually exhausts its nodes, resulting in the termination of all node operations by the 13100th turn.

Figure 11 displays the variation in energy levels as a function of the number of transmissions. It is evident that the total network energy remains relatively stable throughout the majority of transmissions, until it starts to decline at transmission 2200. At this point, the first node depletes its energy, leading to the subsequent loss of operational nodes in the network, eventually resulting in the network's demise.

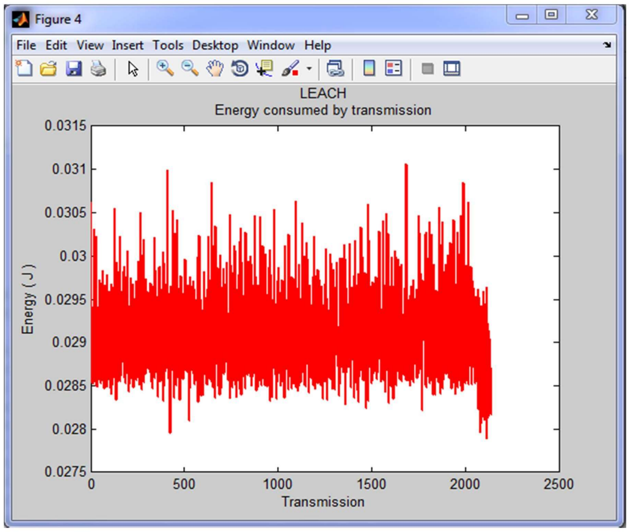

Figure 11. Variation of energy nodes depending on the number of transmissions

4.2. Proposed Localization Method Simulation Results

In this section, we compare the performance of our algorithm and the traditional DV-hop algorithm by changing the number of anchor nodes, the node density and the communication range.

4.2.1. Simulation Platform and Distribution of Nodes

MATLAB simulation software can be used to verify the feasibility of the proposed algorithm. Network deployment area is 100 × 100 measurement units, the number of nodes is 100 which are generated randomly, there are 5 anchor nodes, and the communication range is 25 measurement units. Distribution of nodes is shown in Figure 12.

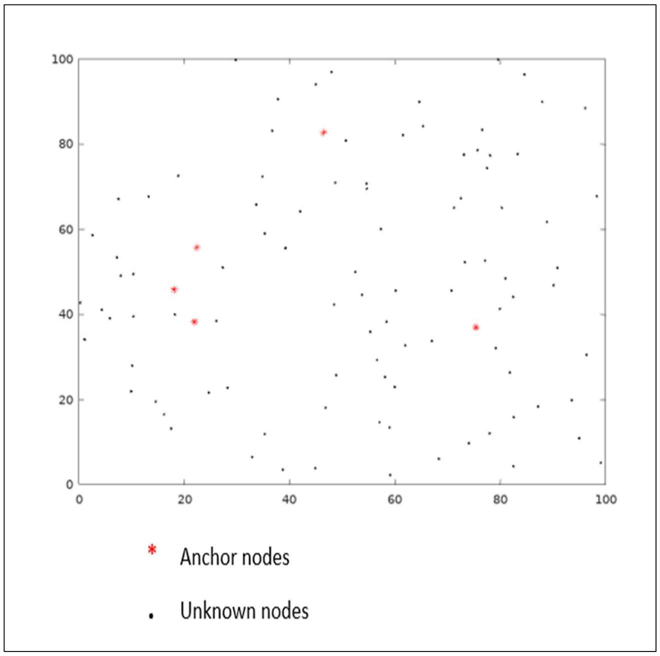

Figure 12. Distribution of nodes in a surveillance area

4.2.2. Definition of Localization Error

Localization errors are extremely important indicators for evaluating localization performance. Formula (13) is used to calculate the localization error:

$$LE = \sum_{i=1}^{N} \frac{\sqrt{(x' - x)^2 + (y' - y)^2}}{R} \tag{13}$$

Where (x', y') is the actual location of the unknown node and (x, y) is the estimated location, where R is the wireless range.

4.2.3. Simulation of DV-hop Algorithm and our proposed Algorithm

The simulation results show that our improved DV-Hop algorithm achieves better performances than the traditional DV-hop algorithm.

The average location error decreases as the ratio of anchor nodes increases. For example, with 5 anchor nodes (5%), the improved DV-Hop has an average error of about 48%, whereas the traditional DV-Hop has an average error of about 49.5%, as shown in Figure 13. In Figure 15, the average location error decreases as the communication range increases. For example, with a communication radius of 25m, Improved DV-Hop has an average error of about 48%, whereas the traditional DV-Hop has an average error of about 52%. However, as shown in Figure 14, the average location error increases with an increase in the total number of nodes deployed in the network for both algorithms. For example, with 100 nodes, improved DV-Hop has an average error of about 45.9%, whereas the traditional DV-Hop has an average error of about 46.2%.

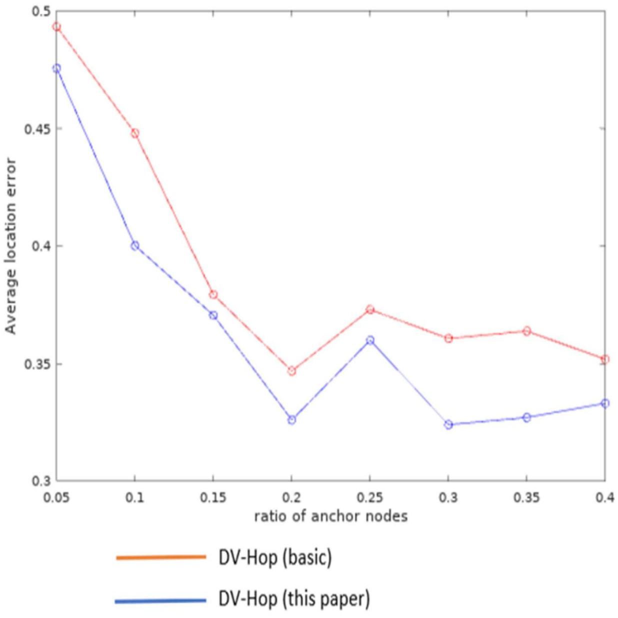

Figure 13. Localization error with different ration of sensor nodes

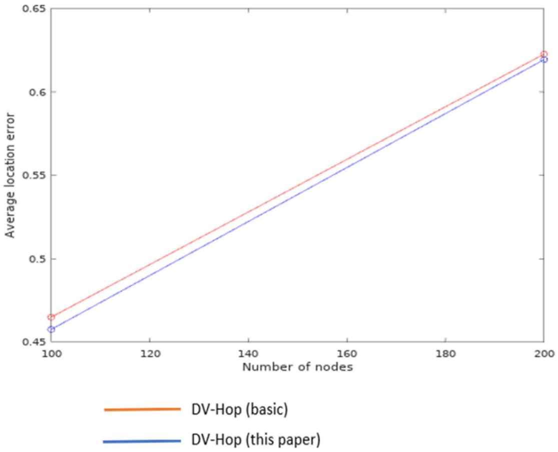

Figure 14. Localization error with different number of sensor nodes

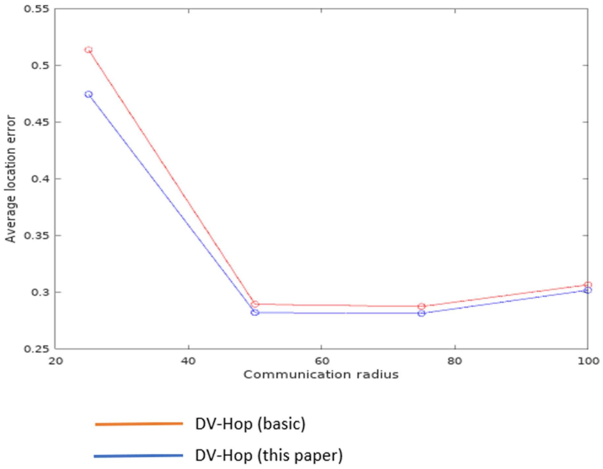

Figure 15. Localization error with different communication radius ranges of sensor nodes

5. Conclusion and Future Works

In this paper, we propose a deterministic deployment topology to minimize costs and increase the network's lifespan while ensuring coverage and connectivity using the LEACH protocol for data routing. We also present an improved version of the Dv-hop algorithm by hybridizing two new versions to enhance its location performance.

Simulation results demonstrate that our proposal and improvements are generally satisfactory, and our algorithm can improve locating accuracy compared to the original the DV-hop algorithm.

Our future work will be focused on the following five aspects:

1. Replace the trilateration algorithm that calculates 2D coordinates in our improved DV-hop algorithm with the ABC (Assumption Based Coordinate) algorithm, which allows the determination of positions in 3D.

2. Incorporate the AT Free technique intoour improved DV-hop algorithm to limit the number of deliveries an anchor can handle.

3. Evaluate the energy consumption of our improved DV-hop algorithm.

4. Apply different protocols on our topology and compare the results.

5. Compare deterministic and random deployment results with the LEACH protocol.

The simulation results indicate that our algorithm outperforms the original DV-Hop algorithm and is better suited for WSNs. Furthermore, we present simulation results of our deployment strategy applied to the LEACH protocol for routing captured data.

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