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Review Article

A Review of Underwater Wireless Sensor Networks Deployment Techniques and Challenges

Kadoke Marco [1,*], Sonia Goyal [1], Ranjit Kaur [1]

[1] *Department of Electronics and Communication Engineering, Punjabi University, 147002 Patiala, Patiala, India.*

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ABSTRACT

Underwater Wireless Sensor Networks (UWSNs) have become increasingly important due to their critical roles in marine life monitoring, communication, ocean data collection, sampling, and military security operations. The success of UWSNs largely depends on efficient node deployment techniques that ensure optimal coverage, connectivity, cost-effectiveness, network lifetime, and energy utilization. This paper presents a comprehensive review of various node deployment types and techniques specifically designed for UWSNs. It covers depth-adjustment, movement-assisted, self-movement, and soft-computing techniques, highlighting their advantages, limitations, and application scenarios. Each technique is evaluated based on key performance metrics such as network coverage, connectivity, energy consumption, network lifetime, and deployment cost. Additionally, the paper discusses the challenges and identifies open research directions in the field, providing valuable insights for researchers and practitioners in selecting appropriate node deployment techniques for UWSNs.

1. INTRODUCTION

Underwater wireless networks are increasingly being used for deep sea surveillance, ocean monitoring, and resource location. However, the success of these applications depends on having an effective and secure node deployment mechanism. To address this challenge and ensure optimal coverage, connectivity, and data collection, a novel approach based on soft computing techniques and evidence theory has been proposed. This approach aims to enhance the performance and reliability of UWSNs, thereby enabling their efficient utilization in various underwater applications. [1]. In an acoustic area, a network of deployed sensors is established to perform monitoring and data collection tasks. This advanced technology operates wirelessly, using compact sensor devices equipped with seamless sensing capabilities, intelligent computing, and efficient communication abilities. The sensor nodes, distributed throughout the underwater environment, gather data on various parameters. These underwater wireless sensor nodes are strategically positioned at deep underwater locations, using acoustic signals for communication to ensure effective data transmission and reception [2], [3].

Sensor nodes in underwater networks can be either movable or immobile and are strategically positioned at various depths below the water's surface. These nodes are comprised of key components, including a processing unit for data analysis and manipulation, an acoustic modem that converts radio signals into acoustic signals for communication, and a power unit that supplies the necessary energy to sustain the operation of all components [4], [5].

In underwater communication, establishing network connectivity is crucial for the efficient transmission of information across all nodes. This connectivity is essential for comprehensive monitoring of the underwater environment and the successful execution of various applications. By creating robust communication links between the sink node and the sensor nodes, underwater wireless sensor networks (UWSNs) ensure the delivery of reliable and timely data. This, in turn, enables effective decision-making in critical situations, ensuring the utmost efficiency and effectiveness of operations. [6].

For limited mobility deployment, nodes have the flexibility to maneuver and adjust their depth within the underwater environment as needed. This mobility allows them to adapt to changing conditions and efficiently collect data from various

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*Corresponding author. Email: marcokadoke@gmail.com locations at different depths. By being able to move, the nodes can maximize their coverage and ensure optimal data collection across the underwater ecosystem [7].

In an autonomous movement deployment, nodes are equipped with the capability to travel independently along any route. This deployment mode enables nodes to effectively adapt to the dynamic underwater environment and adjust their positions as needed. With this unrestricted mobility, nodes can explore various areas, collect data from different locations, and optimize network coverage. This dynamic movement significantly enhances the network's efficiency and adaptability, allowing it to respond effectively to changing conditions and successfully achieve its monitoring or surveillance objectives [8].

The placement of node sensors during deployment significantly impacts the system's performance. To achieve optimal network coverage, connectivity, and efficient energy consumption, node placement techniques must carefully incorporate mobility control. This involves balancing the need for adequate network coverage and connectivity with the efficient management of the nodes' energy resources. By implementing mobility control strategies, the deployment can maximize the overall effectiveness and reliability of the system. [9]. Node placement in UWSNs are categorized into three kinds [10].

Despite the numerous beneficial applications enabled by underwater wireless sensor networks, several challenges still require comprehensive solutions. These challenges include ensuring adequate coverage, establishing reliable connectivity, prolonging network lifetime, managing energy consumption, and addressing the costs associated with deploying sensor nodes in aquatic environments. [5], [11-13].

2. UNDERWATER WIRELESS SENSOR NETWORK ARCHITECTURE

The main parts of a sensor node are the sensing unit, communication unit, processing unit, and storage unit. These components are the basic building blocks of any Wireless Sensor Network (WSN). In underwater wireless sensor networks, the design of the architecture is crucial to improve the network's reliability. There are two types of underwater network architectures: two-dimensional (2D) and three-dimensional (3D)[14].

In a standard 2D architecture, sensor nodes are placed on the ocean floor. Sensors gather data from underwater, which is then sent to surface sinks. This communication is made possible through an acoustic channel link. Underwater sinks collect information and send it to control stations on land using transceivers. These transceivers serve two purposes: horizontal and vertical. Horizontal transceivers communicate with nodes for data collection from the offshore control station, while vertical transceivers transmit data to the control station on land, 2D UWSNs are favored because they are time-efficient and tolerant of delays [15] [16].

TABLE I. ADVANTAGES AND DISADVANTAGES OF 2D ARCHITECTURE [17]

Advantages	Disadvantages
• Simple to deploy and maintain. • Suitable for shallow coastal areas only	• Tough to advance. • The number of gateways determines the limit of network deployment.

3D architectures address the challenges encountered by 2D architectures, enabling deployment in challenging, complex, and extremely deep underwater areas [17]. As per Alhumyani et al [18], The model entails deploying nodes at various ocean depths in a floating manner. To regulate node depths, wires are attached to anchors securing the nodes at the ocean floor. Another approach to controlling node depths involves the use of horizontally positioned buoys arranged on a plane. As per Bhaskarwar and Pete [19], the performance of 3D UWSN models can be improved by incorporating autonomous underwater vehicles (AUVs). Table 2 show advantages and disadvantages for 3D architecture network, while table 3 is comparison of 2D and 3D architecture.

TABLE II. ADVANTAGES AND DISADVANTAGES OF 3D ARCHITECTURE [17]

Advantages	Disadvantages
• Appropriate for deep sea • Adaptive for complex environment • Trustworthy communication • Better comprehensive performance	• Challenging to adapt dynamic changes • High cost • The deployment is complex • High requirements for the controller

TABLE III. COMPARISON OF 2D AND 3D ARCHITECTURE [17]

Two-dimensional architecture (2D)	Three-dimensional architecture (3D)
• Simple to deploy and maintain. • Less cost • Suitable for shallow coastal areas	• The deployment is complex • High cost • Appropriate for deep sea

• The performance comprehensive is not better • Monitors only two dimensional like length and width.	• Better comprehensive performance • Monitors three dimensional like width, length and height

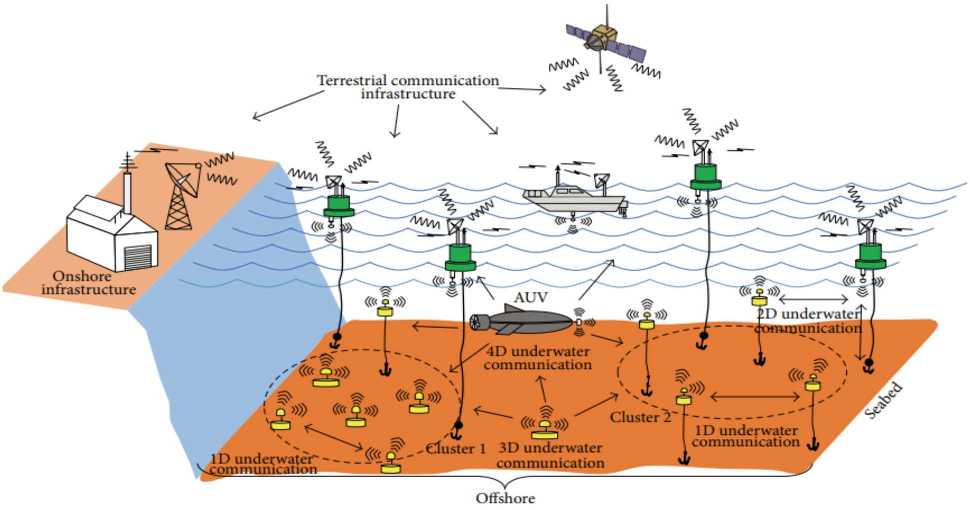

Fig. 1. Underwater sensor network architecture[19].

3. NODE DEPLOYMENT TECHNIQUES IN UNDERWATER WIRELESS SENSOR NETWORK.

The key requirement for UWSNs is node deployment, as it enables crucial network functions such as boundary detection, routing, and topology control. Deploying underwater autonomous surveillance networks (UWSNs) involves considering various aspects due to the complex three-dimensional (3D) space and challenging underwater acoustic channels [20].

The deployment of node sensors can greatly influence the system's performance. Techniques for placing nodes must incorporate mobility control to guarantee sufficient network coverage, connectivity, and efficient energy consumption [9].

Node placement in UWSNs falls into three categories. Firstly, there is static deployment, where nodes are fixed at predetermined locations and cannot move from their assigned spots. This type of deployment offers stability and consistency in data gathering but lacks adaptability to changing conditions. Secondly, movement-assisted deployment allows nodes the freedom to travel within the underwater environment and adjust their depth if needed. This type enables better coverage and flexibility in data collection, as nodes can respond to environmental changes or specific monitoring requirements. Lastly, self-movement node deployment allows nodes unrestricted movement in all directions within the underwater environment. In this category, nodes can travel spontaneously, enabling them to explore different areas of interest and dynamically adjust their monitoring locations based on changing conditions or specific targets [10].

3.1 Static node deployment technique in underwater wireless sensor network

After deployment, nodes remain stationary and do not move from their initial positions. There are two types of static deployments: static and mobile. In uniform placement, nodes are distributed homogeneously across the target area, whereas in non-uniform deployment, nodes are not evenly distributed in the target area [21].

Node positions are critical in static deployment techniques. Regular deployment of nodes simplifies the design of the deployment technique. Theoretically, this strategy maximizes performance parameters with the fewest number of node

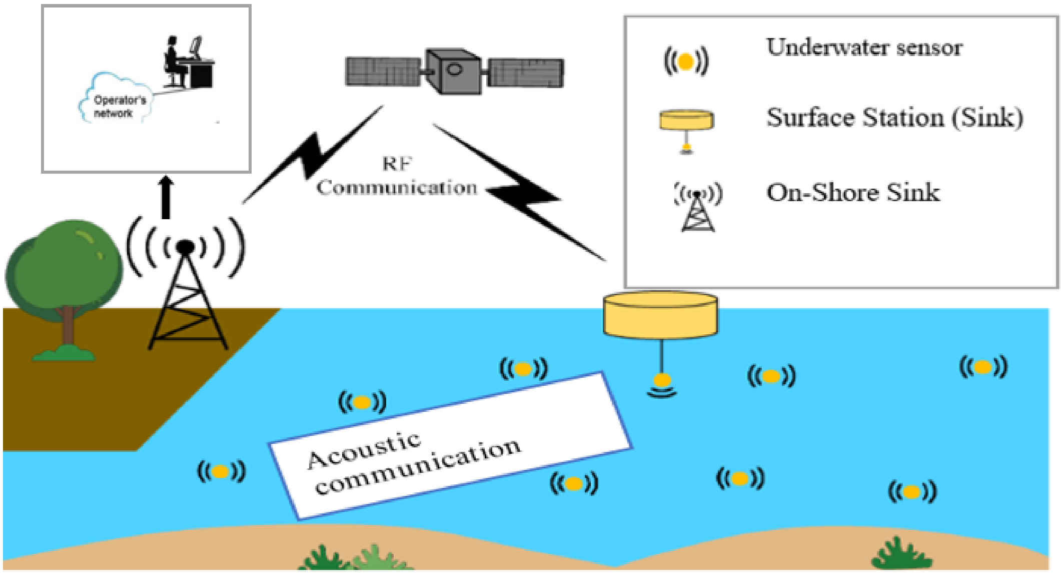

Fig. 2. Static node deployment architecture

3.2 Movement-assisted node deployment technique in underwater wireless sensor network

It is assumed that multiple mobile nodes are available to assist with node placement. Mobile device nodes, such as gliders, unmanned subaquatic vehicles, and autonomous underwater vehicles (AUVs), patrol a designated area while performing specific monitoring tasks [22], [23].

TABLE IV. EXISTING STATIC NODE DEPLOYMENT IN UWSN

Reference	Objectives Schemes	Advantages	Disadvantage
[24]	• Network lifetime maximizing	• High reliability due to multi-path distribution of data	• High computational complexity
[25]	• Gateway deployment optimization	• Enabling the dynamic redeployment of gateway nodes	• High computational complexity
[26]	• Coverage overlapping minimization	• Less complex with low energy consumption	• Complication directly exposed to planned coverage ration
[27]	• Transmission loss minimization	• Energy consumption is low	• High computational complexity
[28]	• Maintaining good network connectivity	• Outperform in terms of localization error and ratio than random and cube-based deployment	• A trade-off between the number of anchor nodes and localization error

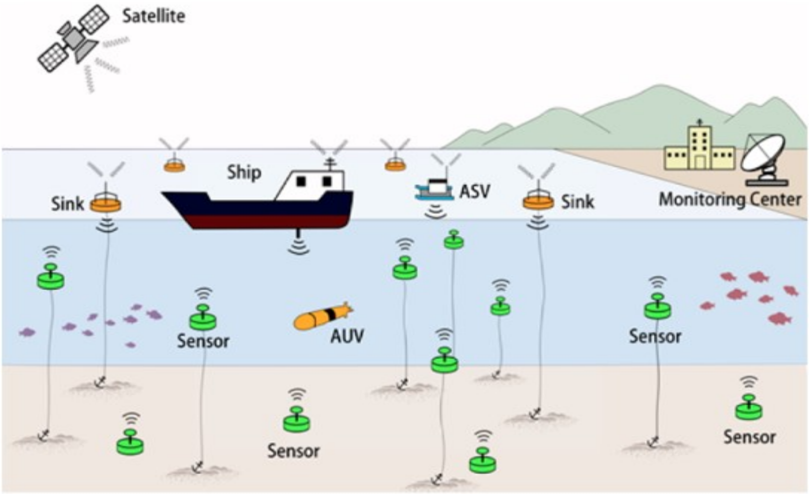

Fig. 3. Movement-assisted node deployment [17]

TABLE V. EXISTING MOVEMENT-ASSISTED NODE DEPLOYMENT IN UWSN

Reference	**Objective of scheme**	**Advantage(s)**	**Disadvantage(s)**
[29]	• Operating AUVs to target zones	• Low complexity	• High energy consumption
[30]	• Maximize network lifetime	• Energy expenditure prediction	• Computational complexity is high
[31]	• Travel time minimization	• Consider link quality into concern	• High energy consumption
[32]	• Decreasing distance and portable time	• Low computational complexity	• High energy consumption
[8]	• Minimizing end-to-end delay	• Finding a near- optimal solution	• High energy consumption

3.3 Self-adjustment node deployment technique in underwater wireless sensor network

The deployment strategy can fulfill requirements such as enhancing connection quality, reducing coverage overlaps, and improving network connectivity by allowing each sensor node to adjust its position after initial deployment Han et al. [22].

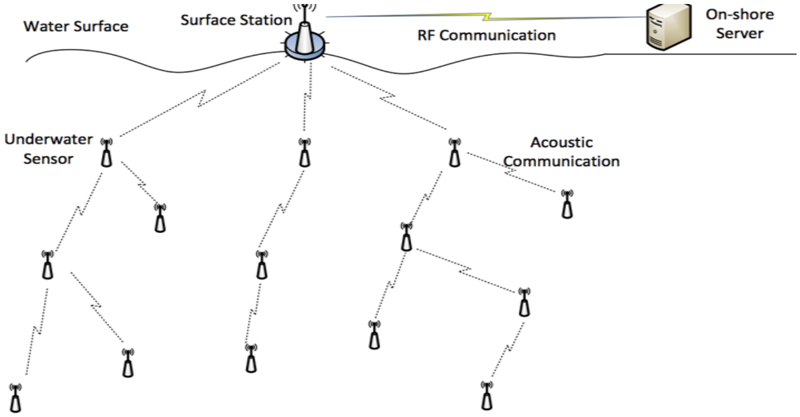

Fig. 4. Self-adjustment node deployment architecture [35]

TABLE VI. EXISTING SELF-ADJUSTMENT NODE DEPLOYMENT IN UWSN

Reference	**Objectives Schemes**	**Advantage**	**Disadvantage**
[33]	• Minimizing coverage overlapping	• Low computation complexity	• High energy consumption
[34]	• Maintenance of network connectivity	• Low computation complexity • Energy-efficient	• Routing topology is complex
[35]	• Enable sensor to follow event distribution	• Low energy consumption and event-driven coverage	• High complexity
[30]	• Self-regulating coverage of happening areas	• Low computational complexity	• High computational intake
[6]	• Maximizing coverage and guaranteeing connectivity	• High performance coverage	• Ultrasonic sensors requirement

4. CLASSIFICATION OF NODE DEPLOYMENT IN UNDERWATER SETTINGS

Below are three classifications.

4.1 Node deployment based on depth-adjustment in underwater wireless sensor network

Node deployment plays a crucial role and is closely connected with various network operations, including topology control and routing protocol design. When considering node deployment, two important metrics that need to be considered are coverage and connectivity. However, it's important to note that improving one metric independently may have a negative impact on another. Therefore, optimizing both coverage and connectivity simultaneously is essential. To address this challenge, a node depth adjustment algorithm was proposed. This algorithm aims to optimize coverage and connectivity by adjusting the depths at which nodes are deployed. By strategically placing nodes at different depths, the algorithm can enhance both the overall coverage area and the connectivity between nodes. To simultaneously optimize network coverage and connectivity, an author proposed a method for depth-adjustable node deployment optimization in UASNs. In this approach, sink nodes act as cluster heads and are evenly distributed across the water's surface. To establish a topology where sensor nodes within a cluster are arranged vertically, with the sink node serving as the network's root and connecting to every other node. The optimal node positions are selected to maximize network deployment while maintaining the same network architecture as a constraint. Additionally, the complexity of the underwater environment poses challenges for node deployment, prompting the proposal of a deployment technique for depth modification using Voronoi diagrams. This technique aims to maximize sensor coverage effectively over the system's lifetime[36].

Consequently, numerous optimization algorithms centered on depth adjustment have been thoroughly investigated and summarized in Table 7. These algorithms seek to enhance the performance and efficiency of Underwater Wireless Sensor Networks (UWSNs) by treating depth as a critical parameter. These studies have assessed parameters like coverage, connectivity, and network longevity. Nonetheless, the coverage rates attained in these studies range from 95% to 99%, indicating room for further enhancement. Additional research is required to explore novel node deployment techniques and strategies to surpass the current maximum of 99% performance.

4.2 Node deployment based on node Mobility in underwater wireless sensor network

While it's true that an underwater sensor node can relocate to gather data, larger target areas benefit from this mobility by reducing the required number of nodes. Thus, using movable antenna nodes allows data collection while minimizing node usage. In [41], a double-coverage technique was proposed to address early energy depletion in immersed wireless sensor systems due to excessive usage. This technique focused on placing movable nodes within the network, particularly in conjunction with Autonomous Underwater Vehicles (AUVs). An integration rate of a mobile node deployment scheme based on Cuckoo Search Optimization (CSO) was suggested. The scheme aimed to identify target points using the detection probability of mobile nodes. By adjusting various parameters, the effectiveness of the scheme was assessed and compared with the current fruit fly-based scheme. Simulation results confirmed that the proposed strategy outperformed the fruit fly-based system in terms of coverage ratio and suitability rate, validating its effectiveness.

The simulation results demonstrate that regardless of the ratio between transmission and sensing ranges, connectivity can be guaranteed while achieving coverage rates and connectivity rates of 2.37 and 2.25, respectively, which are comparable to a coverage-aware deployment technique. The algorithm focused on optimizing coverage deployment and energy balancing by assembling sensor nodes into a connective tree-like structure. To achieve this, a global optimal depth adjustment method and a growth ring-based scheme were introduced. In the simulation results, it was observed that this approach significantly improved both coverage and dependability of UWSNs and effectively prevented energy holes.

TABLE VII. NODE DEPLOYMENT TECHNIQUES BASED ON DEPTH-ADJUSTMENT

Reference	Simulation Parameters	Results	Future Scope
[37]	Monitoring area: 400×400×300 Nodes: 500-1600 Sensing range (m): 20-90	Coverage(varying number of nodes): >**95%** (varying sensing range): **99%** Connectivity (varying different ratio): **100%**	To focus on the mobility of the UWSNs because mobility of the nodes floating in the water due to the water currents and waves is inevitable.
[36]	Monitor area (km): 6*6*3 Sink node: 9 Sink node radius (km): 1.5 Number of nodes: $10\leq n_t \geq 150$ Sensor node radius (km): $0.5\leq r \geq 1.0$ Ratio of communication to perceived radius(k): $1.2\leq k \geq 2$	Coverage rate: 96.82% Connectivity rate**:** 100%	Other parameters such as Network lifetime and Energy consumption should be considered
[38]	Maximum depth: $1000 < H < 2500$ (m) distance threshold ratio: $1.0 < u < 2.0$ Sensing range of sensor nodes: $300 < Rs < 800$ (m) Number of sensor nodes: $50 < n < 300$.	Connectivity: **100%** Coverage:> **90%** Network lifetime: Longer than Random deployment.	To research sensor node deployment in contexts with limited resources

TABLE VIII. NODE DEPLYMENT TECHNIQUES BASED ON NODE MOBILITY

Reference	Simulation Parameters	Results	Future Scope
[33].	• Target area: 5000 * 5000 * 5000 m • Sensor nodes:10-50 • Sensing range:1-4 (m)	• Coverage (varying range and sensing range):>90% • Connectivity (varying both transmission range, sensor nodes, and sensing range): 100%	• In the future, to cut costs related to messages, movement complexity, and sensor nodes.
[39]	• Transmission/sensing range: 1.5 -2.5 (m). • Nodes: 80-160	• Coverage ratio (%) (varying node): 90 • Coverage ratio (%) (varying sensing range): 90	• Use of multiple surface stations. • Deployment of low-cost underwater cameras.
[40]	• Sensing range: 45-65 (m)	• Sensor nodes: 18000 • Reduced energy consumption • Total distance travelled: 7*10^5 • Coverage: 82.74%	• On future connectivity parameter to be considered
[41]	• Network dimensional: 200*200*200(m) • Number of mobile node: 10-60 • Target point: 8000 • Communication range: 10-60m • Sensing range:10-60m • Population size: 50 • Maximum iteration:500	• Coverage ratio (varying node): 2.37 • Coverage ratio (varying sensing range): 2.25	• Only one existing scheme was compared with the proposed. • Some parameters were not evaluated like, network lifetime and network connectivity.
[42]	• Number of nodes: 80-160	• Coverage rate: 1 • Energy consumption: 555KJ • Connectivity: 100%	• To investigate how network coverage and connectivity are affected by changes in the dynamic network topology. • To enhance the underwater wireless sensor network's deployment strategy.
[43]	• Nodes: 20-50 • Monitoring area: 50*50 • Communication range: 10-20(m)	• Coverage: 91.72%	• No deployment algorithm has been designed to allow for the ability to get around obstacles. • To provide three-dimensional coverage for the future.

Table 8 provides a comprehensive overview of the extensive research conducted in the field of Underwater Wireless Sensor Networks (UWSNs). These studies primarily focus on investigating various parameters, including network connectivity and coverage ratio. Despite significant efforts, no algorithm has achieved a coverage rate and network connectivity exceeding 99.6%. While some techniques have successfully considered factors such as network lifetime and energy consumption, important aspects like network longevity, time delay, and deployment cost have not been adequately addressed. This highlights the need for further research and development in optimization techniques specifically tailored for UWSNs. By addressing these critical parameters and improving existing techniques with a focus on node mobility, researchers can enhance the performance and efficiency of underwater communication systems. This ongoing pursuit of improvement is crucial to unlocking the full potential of UWSNs in various applications and overcoming the challenges associated with their unique underwater environment.

4.3 Node deployment based on Soft Computing techniques in underwater wireless sensor network

The distributed node deployment scheme aims to gradually expand the initial network coverage while minimizing sensing overlaps between nearby nodes. In this approach, each node is initially placed at the ocean bottom and has limited freedom for vertical movement in three dimensions. The nodes autonomously adjust their depths based on local agreements, continuously modifying their positions until no additional space is available for further coverage expansion [33].

In his study, Liu [27] proposed a placement system called UDA (Underwater Distributed Allocation) for ocean-based underwater sensor networks, aiming to optimize system lifetime. The simulation results demonstrated that the challenge of node placement optimization, considering existing impairments, was effectively addressed using an underwater sensor network restructuring technique based on Wolf Search. The study focused on optimizing node redistribution coverage in underwater wireless sensor systems to mitigate issues caused by the harsh underwater environment. In the research conducted by [44], a new optimization technique known as Sea Lion Optimization (SLO) was introduced to determine optimal sensor node locations in underwater communication networks. To assess the effectiveness of this approach, various features such as latency, coverage rate, and connectivity rate were evaluated using a MATLAB simulator. The proposed method leverages an enhanced metaheuristic technique based on the Non-dominated Sorting Genetic Algorithm-II (NSGA-II) alongside a novel fitness function. This fitness function incorporates three key parameters: network lifetime, connection cost, and quality of service. The approach defines a unique fitness function that optimizes both the number and placement of Autonomous Underwater Vehicles (AUVs). It also employs an efficient encoding strategy for population representation, which enhances the overall performance of the algorithm. The combination of these techniques aims to develop an optimal and effective deployment strategy for UWSNs, taking into consideration crucial aspects such as network longevity, connectivity, and quality.

TABLE IX. NODE DEPLOYMENT TECHNIQUES BASED ON SOFT COMPUTING TECHNIQUE

Reference	**Simulation Parameters**	**Results**	**Future Scope**
[33]	• Target area: 5000 * 5000 * 5000 m • Sensor nodes:10-50 • Sensing range:1-4 m	• Coverage (varying range and sensing range):>90% • Connectivity (varying both transmission range, sensor nodes, and sensing range): 100%	• In the future, to cut costs related to messages, movement complexity, and sensor nodes
[27]	• Monitor area:100*100*200 m • Communication radius: 25m • Sensing radius: 20m • Number of node: 10000 • Initial energy node: 200J • Unit energy consumption: 0.05J	• Lifetime: 7490 Sec	• Future research will address the deployment issue in specific applications or situations, as UWSN must be fitted to certain applications that may have different requirements.
[44]	• Monitoring area: 200 × 200 × 200 m • Sensing radius: 30m • Communication radius: 60m • Initial energy: 10J • Carrier frequency: 25khz • Sensor node: 100 • Iteration: 0-30	• Coverage rate: 0.75 • Residua energy: 0.5J	• To create various barriers and distribution models combining particular environmental elements, such water flow. • To be carried out in a particular aquatic setting.
[10]	• Sensing range: 15m • Carrier frequency: 25khz • Number of node: 20-70 • Communication range: 15-50m	• Connectivity rate: 1 • Coverage rate: 0.75 • Total communication energy: 1200J for proposed techniques	• To be in a centralized way for future.
[4]	• Number of nodes: 0-350 • Ratio of transmission range to sensing range (transmission range/sensing range): 0-3.4	• Coverage rate with node change: 0.29 • Coverage rate with transmission range/sensing range changes: 7 • Connectivity ratio %: 0.6	• To deal with coverage overlapping
[1]	• Target area: 1000*1000*1000 m • Centre frequency: 1000Hz • Sensor nodes: 0-10000	• Effective coverage rate (%): 99	• To put into practice an alternative data fusion model and approach for more effective.
[43]	• Network area: 1000*1000*1000m • Sensor node: 50-100 • Sink node: 1 • Sensing range: 20-100m • Communication range: 10-60 m • Attenuation factor: 0.01-1.0	• Connectivity rate: 96% • Coverage rate: 95%	• To consider another important parameters
[45].	• Network area: 1000* 1000 *1000 m • Transmission range: 50-100 m • Sensing radius: 30m • Nodes: 10-50 • Sink node: 1 • Frequency carrier: 25khz	• Network connectivity rate: 0.99 • Coverage rate: 0.99 • Network lifetime: 500sec	• To extend in order to fix the coverage overlap issue, hence necessitating fewer sensors to provide a complete network connection and cover the maximum area.
[9]	• Network area: 1000 m × 1000 m ×10m • Frequency currier: 25khz • Range: 200m • Initial energy: 10000J • Nodes: 25-125	• Residual energy: 119.5J • Deployment error: 0.0098 • Deployment cost: 67(KB)	• Mobility management should be considered for future.
[5]	• Network area: 200 × 200 × 200m • Number of AUVs: 10-100 • Communication range: 50-140m	• Coverage rate: 2.7 • Coverage quality: 2.36 • Connection cost: 0.35 • Coverage quality: 2.69	• To be enhanced for an underwater cognitive sensor network that is heterogeneous, meaning that AUVs may possess varying

Reference	Simulation Parameters	Results	Future Scope
	- Sensing range: 10-100m Target point: 8000 - Frequency carrier: 10-100kHz - Initial energy: 100J	- Energy consumption: 31.4J - Network lifetime: 7100sec.	degrees of communication and sensing capability.

The simulation results are summarized in Table 9, which demonstrates that at a communication range of 130 meters, the recommended technique had a greater connection cost (values of 0.39 and 0.28, respectively) than the genetic algorithm. Nonetheless, at a node count of 90, the suggested approach showed noticeably less average energy consumption—31J as opposed to 57J for the genetic algorithm. Furthermore, the suggested approach demonstrated a longer lifetime than the genetic algorithm, with over 7100 hours with 90 nodes, compared to 5100 hours with the same number of nodes [5]. More information on the effect of these methods on network connectivity would be required to offer a thorough analysis, even though exact connectivity values were not given.

It is clear that depth adjustment exhibits the highest connectivity rate among the three node deployment strategies when comparing node deployment strategies based on mobility, soft computing, and depth adjustment. Soft computing strategies offer a cost-specific measure of 67KB, whereas mobility deployment techniques do not provide precise cost information.

In terms of energy consumption, the mobility technique uses 555KJ more than the depth-adjustment and soft computing strategies combined. Soft computing approaches, on the other hand, use a lot less energy at 31.4J. A lengthy network lifetime is reported by the depth-adjustment technique; however, the mobility node deployment's specifics are unavailable. Soft computing methods, on the other hand, point to an even greater network lifetime of 7490 seconds.

4.4 Comparison of existing node deployment techniques

TABLE X. COMPARISON OF EXISTING NODE DEPLOYMENT TECHNIQUES IN UWSN

Performance Metrics	Node deployment based on Depth-adjustment technique	**Node deployment based on mobility technique**	**Node deployment based on Soft Computing Techniques**
Coverage rate	- High [1]	- Higher [41]	- Highest [5]
Connectivity rate	- Highest [37]	- Highest [33]	- Highest [33]
Cost	- Not specified	- Not specified	- 67KB [9]
Energy consumption	- Not specified	- High 555KJ[42].	- Less 31.4J[45]

5. CONCLUSION

Underwater Wireless Sensor Networks (UWSNs) consist of sensor nodes positioned beneath the water surface to monitor or regulate various activities, alongside underwater vehicles. UWSNs have garnered considerable attention due to their growing demand in underwater monitoring applications and exploration systems. Over time, extensive research has been conducted on both underwater wireless sensor nodes and UWSNs as a whole, with the expectation that this field will continue to evolve, prompting further technological advancements. The main objective of this paper is to stimulate research endeavors by establishing fundamental principles for the development of advanced node and network deployments, deployment strategies, and techniques related to node development in UWSNs. This paper delves into the practical challenges associated with achieving optimal node deployment in UWSNs and seeks to analyze and assess the performance of various node deployment techniques. By addressing these areas, the paper aims to contribute to the ongoing progress and understanding of UWSNs, fostering innovation and advancement in this domain.

Conflicts of Interest

The author's disclosure statement confirms the absence of any conflicts of interest.

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