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Review

Review of Localization and Clustering in USV and AUV for Underwater Wireless Sensor Networks

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Abstract: Oceanographic data collection, disaster prevention, aided navigation, critical observation sub-missions, contaminant screening, and seaward scanning are just a few of the submissions that use underwater sensor hubs. Unmanned submerged vehicles (USVs) or autonomous acoustic underwater vehicles (AUVs) through sensors would similarly be able to explore unique underwater resources and gather data when utilized in conjunction with integrated screen operations. The most advanced technological method of oceanic observation is wireless information routing beneath the ocean or generally underwater. Water bottoms are typically observed using oceanographic sensors that collect data at certain ocean zones. Most research on UWSNs focuses on physical levels, even though the localization level, such as guiding processes, is a more recent zone. Analyzing the presenting metrics of the current direction conventions for UWSNs is crucial for considering additional enhancements in a procedure employing underwater wireless sensor networks for locating sensors (UWSNs). Due to their severely constrained propagation, radio frequency (RF) transmissions are inappropriate for underwater environments. This makes it difficult to maintain network connectivity and localization. This provided a plan for employing adequate reliability and improved communication and is used to locate the node exactly using a variety of methods. In order to minimize inaccuracies, specific techniques are utilized to calculate the distance to the destination. It has a variety of qualities, such as limited bandwidth, high latency, low energy, and a high error probability. Both nodes enable technical professionals stationed on land to communicate data from the chosen oceanic zones rapidly. This study investigates the significance, uses, network architecture, requirements, and difficulties of undersea sensors.

Keywords: network of underwater sensors; arrival time; arrival time difference; signal intensity; communication over acoustics; transmission; cluster; localization

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1. Introduction

Water covers the majority of the surface of the Earth. Recently, there has been a flow of concentration aimed at discovering relatively uncharted regions. A configurable number of sensors are deployed using Underwater Acoustic Sensor Networks (UW-ASN) to carry out monitoring operations over a specific area [1]. As a result of multiple previous tragedies, humans now continuously monitor ocean ecosystems for various reasons, including scientific, environmental, and military purposes. For these monitoring tasks, industries are interested in immersing sensor nodes.

Emerging technologies such as autonomous cars and sensor deployment capabilities inspired the underwater sensor networking system. Even though there are communication problems, the idea can be implemented using acoustics technology. For short-range communications, interdependent communication strategies have been proposed [2]. The Underwater Acoustic Networks are unique and can be used for industrial and commercial purposes [3]. This research raises several unresolved issues which are shown in Figure 1.

In order to determine the natural facts of oceanic resources and collect scientific data for monitoring, AUVs and UUVs are equipped with underwater sensors that may also be viewed. Various problems can be resolved using underwater sensor networks because of the technology's effectiveness. The network's diverse technologies, such as localization and energy efficiency, help to solve issues such as node scattering, high attenuation, and absorption impact [4].

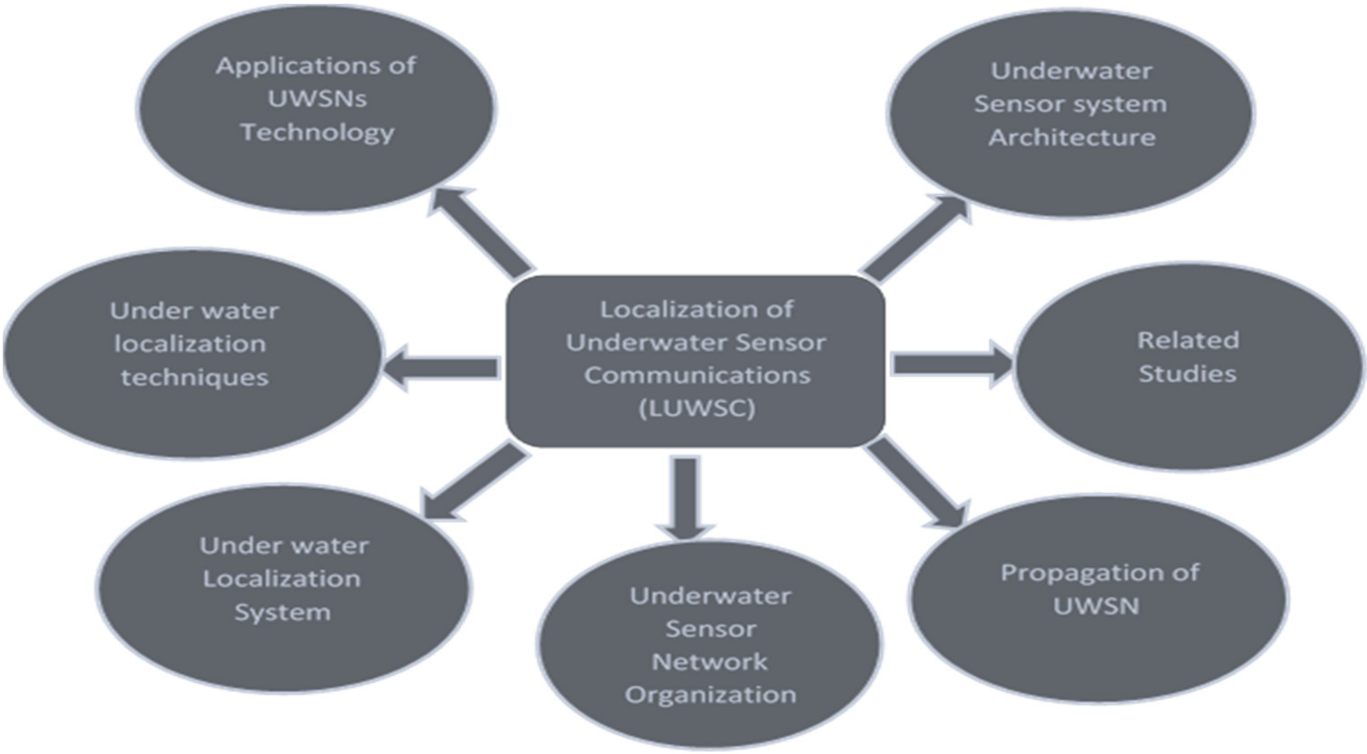

Figure 1. Organization of the paper.

High concentrations of saline water, electromagnetic, optical, and radio waves can travel great distances underwater and be dispersed in numerous directions [5]. Because of this, the situation can be managed by utilizing various methods, such as a subterranean setting, and data might be easily conveyed using an acoustic transmission is depicted in Figure 2. Multi-hop networks are required because underwater sensor nodes are more significant, consume more power, and must be replaced frequently [6]. It is challenging to replace nodes and batteries in multi-hop networks that penetrate downward at the surface and transfer data once or several times. Information can be advanced to onshore control stations through data sinking. Higher bandwidth-demanding routing techniques have considerable end-to-end delays; hence, they should not be used in these conditions. Underwater communication is challenging due to propagation delay, a high bit error rate, and a limited bandwidth [7,8].

Motivation and Contribution

USWNs, used to monitor the marine activities of marine species by using acoustic device networks, are preferred by researchers due to their self-organization and transmission. In this context, the choice of UWSN protocols can communicate information from one sensor to another to transmit maritime environmental conditions. The information gathered can then be utilized to create ecosystem models that can forecast changes in the undersea environment and climate changes. Such UWSNs have an application in monitoring seismic activities such as oil extraction from fields under the water. A 4D model is used to study the oil reservoir's fluctuation over time to evaluate the oil field operation and apply ad hoc treatments. Onshore fields are often routinely monitored using permanent instruments on a daily, quarterly, or annual basis [9,10]. Conversely, sub-merged oil fields are more demanding because the deployment of sensors is not presently permanent in the oil fields underwater.

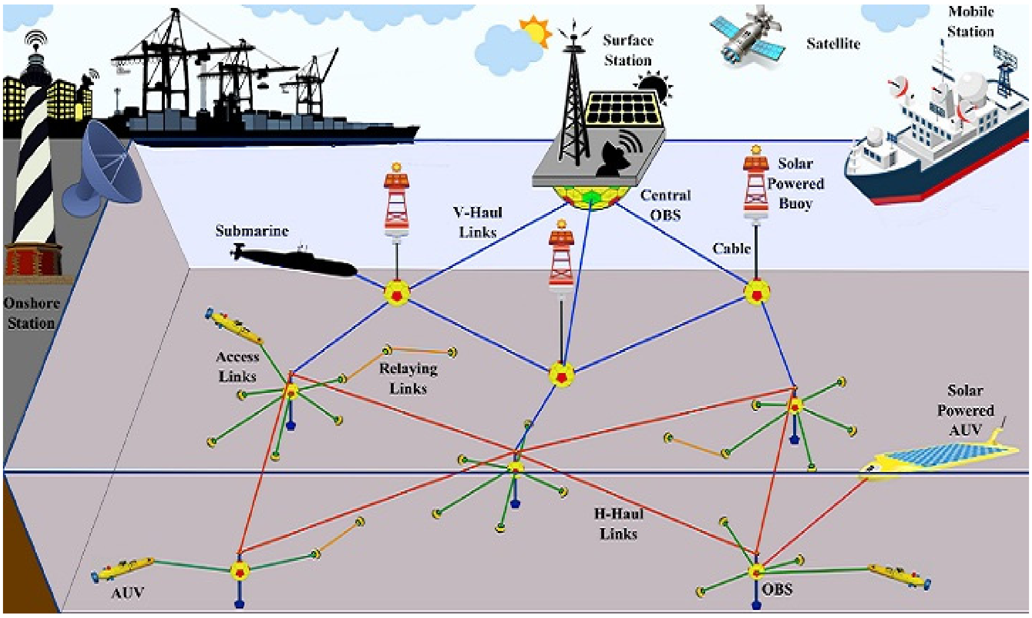

Figure 2. Underwater Sensor System Architecture.

The main contribution of the manuscript is highlighted as follows: Firstly, the review of a UWSN system, including sensing capabilities, wireless conveyance of information to a distantly situated station on the ground, a visualization of measured data, and an alert system in the event of anomalies, was analyzed. Secondly, a rudimentary system, which uses a cluster or a topology of stars for direct information transfers to a buoyant gateway, is discussed. Thirdly, underwater acoustic communication characteristics, namely, sound propagation speed, transmission loss, noise, and propagation delay models, are reviewed. Finally, the underwater localization method is classified into three key categories; namely, the distance measurement, network scale, and anchor use are described. In addition, future research directions for localizing underwater sensor nodes utilizing UWSNs are described in detail.

2. Underwater Sensor's Internal Structure

The internal components of a submerged or acoustically isolated sensor organize include the CPU-on-board control, sensor interface HW, acoustic modem, memory, power supply, and sensor. Every application of an acoustically isolated sensor contains these parts, which comprise most of the main body.

The primary control is linked to the sensor via a sensor interface circuitry [11]. The CPU or control collects the sensor's data, stores them in memory, analyzes them, and then sends them via an acoustic modem to other sensors is shown in the Figure 3. Occasionally, bottom-mounted instrument frames are designed to authorize unidirectional messages to protect all sensor components from potential trawling gear damage [12].

Submerged acoustic message channels are centrally influenced by factors such as water heat, commotion, multi-path, Doppler spread, and sign lessening. Every one of these components causes a high-piece mistake and a deferred change [13]. Accordingly, message connections in UWSNs are particularly blunder-inclined. Additionally, sensor hubs are mostly powerless in cruel, submerged conditions. In contrast, their earthly, submerged systems have a higher hub disappointment rate and parcel misfortune likelihood [14]. UWSNs are generally sent in a three-dimensional space. This situation is different from the two-dimensional sending of most earthly sensor systems. These qualities of submerged sensors raise numerous crisp difficulties and make the current directing conventions for earthbound sensor systems unsatisfactory here. For UWSNs, the directing conventions ought to have the option of dealing with the hub versatility and the unreliable message joins with high vitality proficiencies [15].

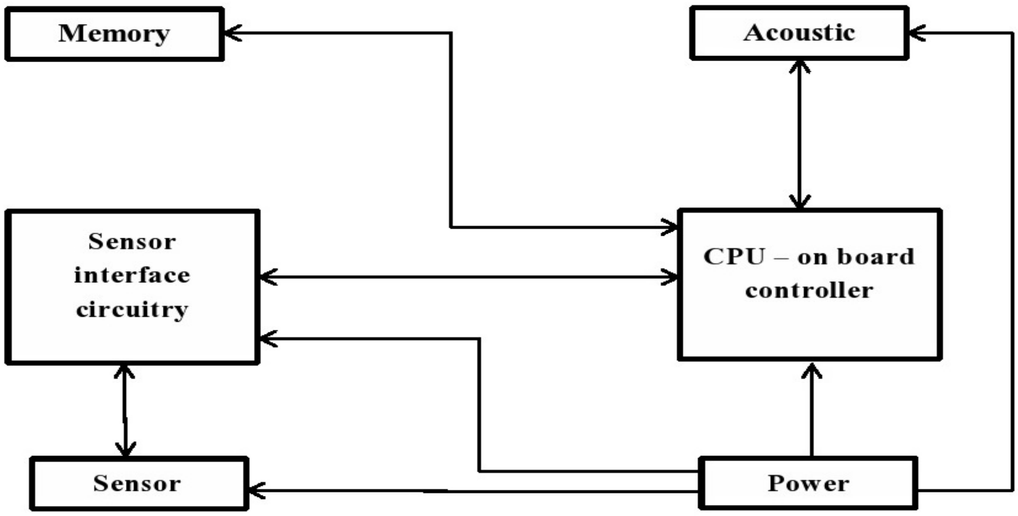

Figure 3. Submerged sensor's internal structure.

3. Related Studies

Sung Hyun Park et al. modified the well-known ALOHA (Medium Access Convention) model in 2019. Thus, channel utilization might be enhanced. The new model features an enhanced ALOHA-Q (UW-ALOHA-Q). Unusual activity, a reduction in the number of openings per outline, and a unified arbitrary conspiracy are suggested to improve the UW-ALOHA-Q. The suggested methodology comprehensively improves utilization regarding the number of openings per outline while providing yet another arbitrary back-off mechanism to achieve impact-free planning. For subsea systems with a range of 1000 m, UW-ALOHA-Q boosted channel usability by up to 24.6 times [16].

Khalid Mahmood Awan et al. provided a study of the UWSN's multiple borders and an overview of the network. They also examined a few additional categories, including MAC, routing protocols, natural elements, restriction, and channel associations. They also clarified the nonlinear sound growth of acoustic indicators. The media and directing receive organized control measures when dealing with rising channel utilization [17].

A detailed analysis of UWSN routing algorithms by Tariq Islam and Yong Kyu Lee was released in 2019. Using this framework, they assessed the proposed solutions in light of the routing protocol's core principles. "Localization-based" and "Localization-free" routes are two different router protocols. There are several issues in designing routing protocols that consider issues like energy constraints and void avoidance requirements, as well as recognizing position, mobility, and 3D deployment. As more guiding tactics use the versatility offered by such conditions, the prevalence of underwater acoustic sensor systems is growing. Their main concern was maximizing network performance through energy balance [18].

Bhattacharya et al., in 2019, created a cluster-based energy-efficient UWSN that can reduce energy costs and increase effectiveness in underwater situations. The supplied cluster-based underwater wireless sensor network (CUWSN) is designed with a UWSN architecture that benefits from CH and multi-hop transmission. As mentioned above, the multi-hop transmissions of the CUWSN extend the network's lifetime [19].

Xin Su et al., who surveyed the current best-in-class underwater problems, audited the UWSNs. It was discovered that the study's main focus was on the currently used undersea limitation techniques. There is much interest among researchers aimed at lifting undersea constraints on the UWSN. As a result of their study, several faults in the current procedures were fixed. "Evaluated" and "forecast-based" classifications are additional subcategories. Different underwater limitation techniques are explored and compared based on their feasibility [20].

For data transmission in the Underwater Acoustic Sensor Network, Rajeswari A et al. used Rajeswari's Lion Optimized Cognitive Acoustic Network (LOCAN) algorithm to handle packet deferral and bundle misfortune (UWASN). The proposed model uses Doppler impact and geometric spreading techniques (GS). Currently, salinity and temperature are the only variables being taken into account. The main driving forces behind the first method are the movement of the sensor hub and changes in the ocean's surface. Because of the profundity, the waves' wavefront areas change around the hub, and the second technique is utilized. The amount of sound dispersion influences bundle transmission. A multifaceted strategy is used to construct the suggested procedure. By fitting a channel choice based on the variety of water segments, the LOCAN technique outperforms COCAN, by a significant margin, in enhancing the hub's productivity and battery life under Doppler and geometric spreading (GS) conditions [21].

A low-energy adaptive clustering hierarchy (LEACH) approach was used by Nguyen et al. to reduce this node's power consumption and lengthen its network life. The network areas are separated into layers based on the depth levels. The nodes collect data, which is then sent to a central node via multi-hop routing channels. The depth of the node determines which CHs are employed. To transport data from the nodes to the SN, the CH gathers the data packets from each cluster member and delivers them to the SN's upper layer [22].

Transmission techniques based on electromagnetic (EM), free space optical (FSO), and acoustic waves are all consistent with Yadav and Kumar's recommendation for the ideal clustering for UWSNs. Based on the ideal clustering and energy use, these underwater transmission systems are examined and contrasted for their efficiency [23].

Yu et al. created an Energy Optimization Clustering Scheme (EOCA) for multi-hop underwater cooperative sensor networks since underwater sensors have limited energy. These systems reflect numerous issues, including the remoteness amongst the sensors and the sink nodes, the number of nearby nodes, the Residual Energy (RE) of all the nodes, and the sensor movement brought on by ocean currents [24].

N. Subramanian et al. aimed to improve the MCR-energy UWSN's efficiency while addressing issues such as the underwater current, low bandwidth, high water pressure, propagation latency, and error probability. The MCR-UWSN technique seeks to route to the required location by choosing a productive set of cluster heads (CHs). The MCR-UWSN approach uses cultural emperor penguin optimizer-based clustering to produce clusters (CEPOC). The multi-hop routing and grasshopper optimization (MHR-GOA) algorithms are also derived using a variety of input parameters. The MCR-UWSN approach's performance was assessed using various indicators, and the outcomes were examined. The MCR-UWSN approach fared better than the newest cutting-edge techniques, according to the results of the experiments [25].

The IMCMR-UWSN technique was created for underwater wireless sensor networks by improving meta-heuristics-based clustering and multi-hop routing protocols; see P. Mohan et al. This method's primary goal is to identify the best cluster heads (CHs) and the quickest routes to a particular location. The two fundamental elements of the IMCMR-UWSN approach are SA-GSO multi-hop routing and CKHA clustering. Several variables, such as residual energy, intra-cluster distance, and inter-cluster distance, are considered when the CKHA technique selects CHs. The SA-GSO algorithm's fitness function considers remaining energy, latency, distance, and trust. Energy economy and service life can be considerably improved by using IMCMR-UWSN [26]. The IMCMR-UWSN technique was tested in several simulations, and the results showed that it was more effective in terms of some metrics as shown in Table 1.

Table 1. Related paper study.

Author	Method	Description	Environmental Parameters	Protocols	Advantages
[27]	Data driven	Low target location error	Sound speed, noise removal, high depth, and reflection loss	Co-UWSN NC S-DCC HAMA EOCA	Computational Limitation. Low packet loss
[28]	Software and hardware data analysis	AUV operation with acoustic modem telemetry	Ocean prototypical, acoustic prototypical	ECR CSRP LLIPR RSTP VAQS	High-level communication. Increases the lifetime of sensor node
[29]	Localization of RSSI	Sensor activity and target tracking	Sensor node analysis, horizontal and vertical node deployment	HCRP LLDR V-SDEDA T-DMAMAC	Understand the sensor extract position. Region of network detection.
[30]	Deployment of UWSN	Node deployment extraction for node filtering algorithm	Doppler node classification, protocol-based routing, flush time, delay of time	D-TAN RIP RIPv2 IGRP BGP	Easy to develop AUV
[31]	Two-dimensional architecture	Different deployment strategies	The latter is more appropriate for identifying and observing occurrences that cannot be adequately noticed when monitoring the ocean floor	EIGRP V-ECA D-TDOA	The application-dependent target sensing and communication coverage
[32]	The theoretical framework for target tracking localization	Attacker's location and the timing	Modules for underwater user attacks, tracker sensor routing strategies, adversary models, privacy evaluation models, and security analysis	LLDP EHCRP CS-RT	Weak adversary model

4. Concerns about and Encounters with Underwater Wireless Sensor Network

4.1. Underwater Sensor Network and a Terrestrial Sensor Network

The underwater and terrestrial sensor networks are very different from one another. Below is an illustration of how terrestrial and underwater sensor networks compare.

Underwater sensor networks will use acoustic rather than radio signals since they operate at incredibly low frequencies and cannot travel very far underwater, rendering them unusable for terrestrial sensor networks [33].

Power: Compared to terrestrial sensor networks, underwater sensor networks require greater power because the signal will travel through water. Other factors include a high sensor-to-sensor distance and a complicated environment [34].

Memory: Terrestrial sensors have a certain amount of storage space. However, it may be necessary for underwater sensors to be able to perform some data caching. Therefore, they need additional memory.

Cost: While terrestrial sensors are less expensive than underwater ones, the latter requires an additional hardware protection system. Underwater sensor networks are often more sparsely distributed, whereas terrestrial sensor networks are frequently widely installed.

Spatial Correlation: Due to the more significant separation between sensors in underwater networks, spatial correlation is less likely to be observed than in signals from terrestrial sensors [35].

4.2. Underwater Sensor Network Organization

A node takes into account 100 homogenous sensor nodes that are dispersed at random in a 100 m $\times$ 100 m field. Both uniform and non-uniform deployments are possible. It is assumed that the BS is located at coordinates (150, 50) and (300, 50). This uses a strong BS that can transmit data from the CHs to the designated recipients.

4.2.1. Parameters

The following Table 2 illustrates the characteristics of underwater wireless sensor networks.

Table 2. Characteristics of UWSN.

Characteristics	**Ocean**	**Deep Ocean**
Death	0~100 m	100~10,000 m
Temp	Higher	Lower
Node validate	0.2 Mn	0.04 to 0.68 Mn
Sensor connectivity	1000 Mhz	1000 Mhz to 4000 Mhz
Lifetime	1.0 ns	1.0 ns to 4.0 ns
Channel	0.98	1.0 to 3.78
Simulation time	30.0	50.0
Dimension of topography	Z, Y, and X	Z, Y, and X
Arrival Time	/802.22/MAC depended	/802.10/Deep RSTP

4.2.2. Use of Static Clustering to Form Equal-Sized Clusters

The BS divides the entire sensing region into a set number of equal-sized rectangular clusters. We will use the example of the nine clusters that the BS generated to explain how the protocol functions. UWSN offers consistent connectivity and coverage. Equal-sized clusters consuming the same amount of energy assure energy-efficient cluster formation.

4.2.3. Network Process

Each sensor is linked to the user's mobile nodes by creating a connection between the user and the sensor is shown in the Figure 4 that includes the neighboring node [36].

4.2.4. Network Formation Based on Clusters

The clusters are divided into two zones: the close zone and the far zone. The near zone is the area close to the BS, while the far zone is the remainder of the playing area. While the far zone has six clusters, the near zone has three. Two subzones are included in the far zone. The zone-based architecture prevents the establishment of hotspots, supports multi-hop communication, and balances traffic among the zones. The close zone limits the number of transmissions exceeding the threshold distance.

4.2.5. Cluster Head Selection Procedure

The UWSN scheme is entirely centralized, and the BS assigns CHs. The BS broadcasts the CH IDs, and when a sensor node matches one of the CH IDs, the node transforms into a CH. Otherwise, the node receives its data transmission time slot. Two CHs, one main cluster head (MCH) and one auxiliary cluster head, are presented in each near zone cluster (ACH).

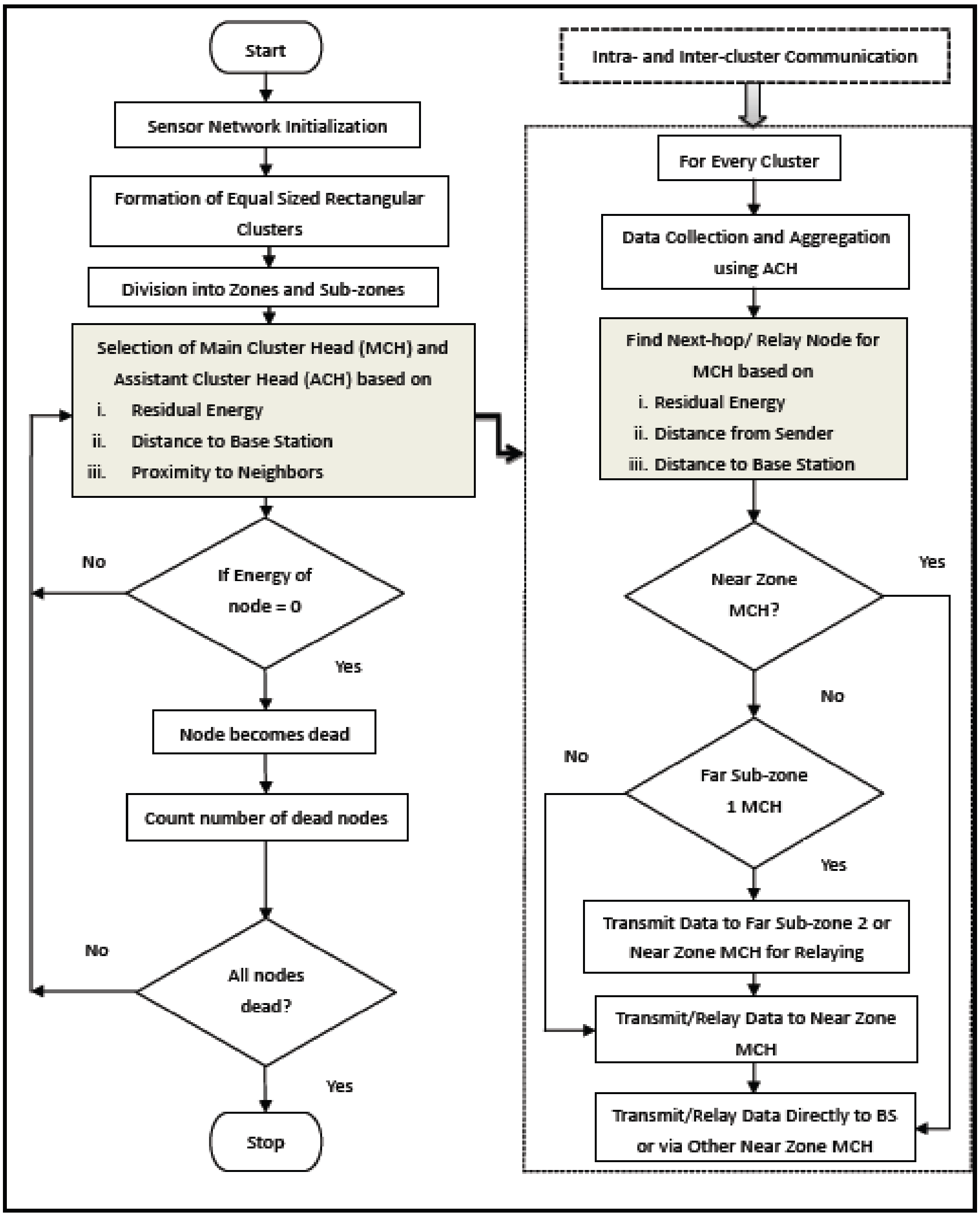

Figure 4. Flowchart of the process flow in clustering.

4.2.6. Navigating Destination

The user asks the sensor to show him or her a certain escape route during an emergency. The centralized server then verifies the user's source, chooses the appropriate path, and displays it to the user using maps.

4.3. Underwater Acoustic Communications Characteristics

Based on the direction of the sound beams, acoustic connections are categorized as either vertical or horizontal. Acoustic communications are reliable regarding time dispersion, multi-path spreads, and delay variance. According to the theory of sound transmission, normal molecular motion within an elastic medium spreads to nearby particles. This circumstance is based on Urick's explanation of acoustic wave theory. A sound wave is a form of mechanical energy that moves swiftly across the ocean and from particle to particle. Diverse environmental factors, such as the ocean's surface and the seafloor, can impact sound transmission in underwater acoustic communication. Because the impedance of the aquatic and terrestrial environments differs, the reflection of the acoustic waves from the water surface is virtually flawless. Nevertheless, surface waves differ from one another. The figure and residues of the seafloor could similarly change [37]. The marine atmosphere is not an isotropic atmosphere because of the pressure and density of seawater [38]. There are extra considerations while transmitting underwater, including the noise formed by aquatic life, ships, external noise, fall noise, and clatter brought on by changes in hydrostatic pressure.

4.3.1. Sound Propagation Speed

How sound travels underwater depends on the properties of the watering stake. This is transitory from side to side. Any changes to the surroundings could result in delays when sound travels by a different path or at a different pace. Table 3 states the salinity contingent on the water depth.It should be remembered that the signal's frequency affects the sound wave's course and absorption [39,40].

Table 3. Salinity contingent on the water depth.

Depth (m)	Salinity (PPM)
0	38.46
50	37.01
100	36.01
100	36.22
500	35.80
1000	36.90
1500	35.05

The calculation provided below shows how quickly sound moves over space:

$$C \ = 1449 + 4.6\,t \ + 0.055t^2 + 0.003\ t^3 + (1.38 - 0.013)\ (S - 34) + 0.0169d)$$

T—temp. of the water (in degree Celsius).
Water has a salinity of s. (in PPM).
The depth of the node is d. (in mts).

4.3.2. Transmission Loss

The term "transmission loss" refers to the decrease in the sound volume from the source to the receiver (TL). This made a variety of empirical formulations to quantify the transmission loss. Trop calculated the signal transmission loss as follows [41]:

$$\alpha = \frac{0.12f^2}{1+f^2} + \frac{44f^2}{4100+f^2}\left[\frac{dB}{Km}\right] \tag{1}$$

$$ss = 20logr \tag{2}$$

$$TL = ss + \ \alpha\ \alpha^{*}0.001 \tag{3}$$

f: freq. in kilo Hz, r: distance in mts, ss: spherical signal spreading, α: attenuation.

The phrase suggested in Thorp's formula was then offered as a more precise expression for the attenuation factor.

$$\alpha = \frac{0.12f^2}{1+f^2} + \frac{44f^2}{4100+f^2} + \left(2.75 * 10^{-3}f^2 + 0.003\right) \tag{4}$$

4.3.3. Noise

Numerous publications have presented representations for a submerged auditory connection that takes into account hooked-on interpretation variables, similar to salinity: hotness, complexity, and meddling from the environment, to name a few. Other physical ocean factors, such as medium noise, thermal noise, wind, turmoil, and ship noise, are also taken into consideration in these calculations, depending on the frequency and the following variables [42–44]:

$$10\log \mathrm{N_t}\ (\mathrm{f}) = 18 - 31\mathrm{logf} \tag{5}$$

$$10\log \mathrm{N_s}\ (\mathrm{f}) = 50 - 30(\mathrm{s} - 0.11) + 36\mathrm{logf} \tag{6}$$

$$10\log \mathrm{N_w}(\mathrm{f}) = 60 + 7.5\ \mathrm{w} + 30\mathrm{logf}(\mathrm{s} - 0.11) + 36\mathrm{logf} - 50\mathrm{log}(\mathrm{f} + 0.5) \tag{7}$$

$$10\log \mathrm{N_s}\ (\mathrm{f}) = 21 + 26\mathrm{logf} \tag{8}$$

where $\mathrm{N_t}$ is turbulence-related noise, $\mathrm{N_s}$ is shipping-related noise, $\mathrm{N_w}$ is wind-related noise, and $\mathrm{N_{th}}$ is thermal noise.

The complete noise PSD for a specified freq. f is formerly:

$$\mathrm{n}\ (\mathrm{f}) = \mathrm{n_t}\ (\mathrm{f}) + \mathrm{n_s}\ (\mathrm{f}) + \mathrm{n_w}\ (\mathrm{f}) + \mathrm{n_{th}}\ (\mathrm{f}) \tag{9}$$

A cross-layer design method is the most significant way to increase network efficiency, especially in critical conditions, even if conventional layered approaches have historically been employed in underwater networking research [45]. As a result, we describe the difficulties underwater sensor networks confront with the conventional layered method. Cross-layer design ideas are essential for the undersea environment. To make the best use possible of the limited resources at hand. Even though a cross-layer design is encouraged to improve the network speed and prevent a function duplication, employing a modular design approach is crucial when keeping design simplicity in mind. This situation allows for upgrading and improving certain functionalities without completely reinventing the communication infrastructure [46].

4.3.4. Propagation Delay Models

A UWSN node must simulate the transmission of the acoustic wave in order to send data to another node. A wide range of models, from the most straightforward ones founded on the theory of wide circulation to additional intricate and composite ones that established the physics of audio sound transmission, are published in the literature [47–50]. In this section, we will discuss many auditory broadcast replicas that, although offering different degrees of complexity and accuracy, reflect various approaches to the same problem. So that we are aware of the parameters that are taken into account for each approach's prediction of propagation acoustics, we will list them in descending order of complexity. The Monterey–Miami Parabolic Equation model is based on Fourier analysis. The prediction of an underwater sound transmission using a parabolic equivalence is given by the Helmholtz wave equation. The little, broadminded changes in the range and depth of the sound pressure are arranged in a grid. It makes approximations of unpredictability and wave motion, employing a vigorous transmission loss computation [51–55]. The writers show how even minor variations in penetration and node distance can significantly impact route loss due to the influence of ocean wave motions on audio propagation.

$$pl\ (t) = A = \pi r^2 + w(t) + e(0) \tag{10}$$

where $pl(t)$ is the propagation loss when sending data from node A to node B.

When using MMPE data for regression, the expression m () represents propagation loss devoid of random and periodic components.

F is the frequency of the audio waves being broadcast (in kHz).

dA is the depth of the sender (meters).

The receiver complexity in dB is in meters.
In the MMPE model, the range refers to the parallel coldness among A and B bulges (mts).
S is the Euclidean distance separating the nodes (mts).
w(t) is the periodic function to simulate the wave motion-induced signal loss.
e() is the random noise or error-related signal loss.

$$m(fs,\ d_a, d_p) = \log\left(\left|\frac{s}{0.914}\left((d_a - d_b)2^0\right)a^0 a^{10} S\ a^7 (d_a) a^9\ \right|\right)(s^* d_b) 10^{a5} \tag{11}$$

$$f^2 = \frac{a1}{1+f^2} + \frac{40}{4100+f^2} + \left(0.00275 + 0.003 * \left(\frac{s}{914}\right) +\ a^6 * d_b + a^8 * s\right) \tag{12}$$

The w() function contemplates the velocity of an element, which will vacillate sinusoidally all over the place. The circular oscillations that get smaller in radius as the particle's depth increases serve to represent this motion. The wave energy has an impact on the radius's size, which is proportional to the wave height. The common waves can have an impact on things up to 50 m below the surface and have a wavelength of hundreds of meters [56,57].

We shall take into account the following while calculating the effects of the waves:

$$w(t) = h(l_w, d_{bt}, h_w, T_w)E(t, T_w) \tag{13}$$

where the lost signal by the movement of the waves is estimated using the periodic function w(t).

h (meters) is the lw of an ocean wave and a function for scaling factors.
dB stands for the complexity of the telephone node.
The upsurge stature in HW is in meters.
T is the wavelength (seconds).
E() is the node's wave consequence function.

This function includes the components that resemble the movement of a node, first calculating the scale factor h() and then the wave effect at a specific point in the movement. The following are the calculations for the scale factor:

$$h(l_w, d_{bt}, h_w, T_w) = \frac{\left(h_w\left(1 - \left(\frac{2d_b}{l_w}\right)\right)\right)}{0.5} * \left|\sin\left(\frac{2\pi(\text{mode } T_w}{T_w}\right)\right| \tag{14}$$

The e() function characterizes a seemingly arbitrary word to describe circumstantial noise and the equation shown below:

$$e(0) = 20\left(\frac{s}{s_{max}}\right)R_n \tag{15}$$

For a cylinder-shaped symmetry:

$$\frac{dr}{ds} = c\varepsilon(s),\ \frac{d\varepsilon}{ds} = \frac{1}{c^2}\frac{1\partial c}{\partial r} \tag{16}$$

$$\frac{dr}{ds} = c\varepsilon(s),\ \frac{d\varepsilon}{ds} = -\frac{1}{c^2}\frac{1\partial c}{\partial z} \tag{17}$$

Anywhere the r(s) then z(s) characterize the glimmer, there is a synchronization in the tubular organizes, then s is the length of the glimmer; the couple $c\varepsilon(s)$ $[\xi(s), \zeta(s)]$ signifies the lengthwise curvature of the ray.

Initial conditions for and $r(s)$, and $z(s)$, $\xi(s)$ and $\zeta(s)$ are:

$$r(0) = r_s\ , z(0) = z_s,\ \varepsilon(0) = \frac{\cos\theta_s}{c_s},\ \varepsilon(0) = \frac{\sin\theta_s}{c_s} \tag{18}$$

where θ_s represents the launching angle, (rs,zs) is the source position, and cs is the sound speed at the source position. The coordinates are sufficient to obtain the ray travel time:

$$r = \int \frac{ds}{c(s)} \tag{19}$$

One of the most popular simulation tools is the Bellhop Ray, and numerous studies confirmed its accuracy in deploying real data scenarios in different places. If the environment is defined correctly, the outcomes delivered by the Bellhop are reasonably comparable to the experimental data gathered during experimentations. East of Vilamoura on the Portuguese south coast, an experiment incorporating elements of these studies—such as the Bellhop and modeling actual data collection circumstances—was conducted in June 2010. Actual measurements were gathered during underwater simulations on Italy's Pianosa Island to verify the Bellhop model. In order to evaluate the MAC practices, The bellhop and real measurements were compared in the Italian region of Calabria. The results of the experimental testing conducted in the Portuguese town of Setubal, some 50 km south of Lisbon, and the theoretical analysis of the underwater signal transmission were in perfect agreement.

5. Parameters Influencing the Propagation of UWSN

The process of converting acoustic energy into heat becomes more efficient as distance and frequency rise. Its applications include scattering, reverberation, refraction, and dispersion. In contrast to horizontal channels, which can have extremely long multi-path spreads, vertical channels have restricted time dispersion, which is limited by the water depth, high delay, and high variance in delay.

- The throughput of the framework is severely decreased by the underwater acoustic channels' engendering speed, which is five significant degrees slower than that of the radio channel.
- It degrades the exhibition of advanced correspondences due to the Doppler spread. Correspondences with high information rates make different neighboring images medal at the recipient, which requires modern signs; it degrades the exhibition of standard correspondence conventions.
- To ensure trustworthy data delivery from sensor nodes to sink, two-hop provides a dynamic security paradigm. Which determines the ideal data packet size for effective data transport in the two-hop paradigm. Two-hop routing to boost wireless sensor network communication performance are tabulated in the Table 4.
    - Data Transmission Dynamic security
    - Bandwidth Aggregation
    - Load balance transmission
    - Congestion-free transmission
    - Low latency transmission

Table 4. Findings of propagation of UWSN.

S.no	Area Focused	Findings	Metrics
1	Difficulties with UWSN routing and upcoming work	The speed of sound rises with rising ocean temperature and falls with falling ocean temperature; an increase in ocean temperature of 10C can bring the sound speed up to almost 4.0 m/s.	as the temperature rises
2	Wireless Communication Prospects and Challenges for Underwater Sensor Networks	Temperature differences, surface noise, and the multi-path effect due to reflection and refraction all have an impact on auditory communication.	Communication's effects
3	An analysis of how temperature changes affect underwater wireless audio transmission	Temperature, depth, and salinity of the undersea environment all have an impact on sound speed. These elements cause changes in the sound speed in the water.	varying the speed
4	The underwater audio communication channel's capacity might vary depending on the depth and temperature.	Larger temperatures and depths result in higher channel capacities and throughput rates when computing the acoustic channel capacity over short distances.	expanding throughput
5	Simulation of an underwater channel	The temperature at the sea's surface is substantially higher than the temperature at the bottom. As depth, salinity, and temperature increase, so does the sound's velocity.	grows when the temperature rises

6. Continuous Transmission of Packet Traffic

UWSNs can be classified as either small-scale or large-scale networks. The numeral of sensor nodes and the deployment scope determine the network scale's size. For various network scales, however, different localization techniques are needed. Small-scale UWSNs generally employ a single-stage localization technique in which existing nodes do not facilitate the deployment of other sensor nodes. The sensor nodes located using the two-stage localization method for large-scale UWSNs

Despite the many challenges in this area, many pertinent researchers optimize and investigate the localization approach based on UWSNs from various perspectives. As new studies on a localization algorithm based on UWSNs are consistently published, an analysis of the pertinent and best literature is required [58].

Distance measurement

Depending on how differently distance is determined, the two categories of localization approaches are both range-free and range-based schemes. We introduce the two sub-classes' traditional and cutting-edge underwater localization techniques. We summarise and compare all the approaches mentioned above and highlight the benefits and drawbacks of specific algorithms [59].

Range based Algorithms

The localization accuracy may be impacted by the partial loss of the wave signal intensity caused by the geometric dispersion and acoustic energy absorption by the propagation medium. This circumstance occurs during the process of underwater acoustic wave propagation. The authors developed a brand-new underwater acoustic localization technique based on energy (EB) for such conditions [60]. The algorithm's concept may be broken down into two phases. One method is to analyze the signal energy and strength of the target. The other involves determining a signal transmission model and the UWSN's design to predict the target's best placement. The outcomes of the numerical simulation demonstrate the particular reference value used by this approach for the localization of underwater nodes based on energy [61].

In [62], an iterative technique is described for an asynchronous target locating method based on the time difference of arrival (TDOA) for a heterogeneous underwater propagation medium. The method can achieve the Cramer–Rao Lower Bound (CRLB) with an improved convergence and fewer positioning errors. Because waves' propagation speeds are not constant, this work contributed by considering how waves move around curves. Its disadvantage is that anchors must be used to position the sensor nodes simultaneously.

A. AOA based

Arrival Access can discern among signals delivered concurrently by numerous devices because codes scatter the user signal throughout the whole available band, making it resistant to the frequency selective fading caused by multi-path. Rake filters can be used at the receiver to take advantage of the time variation in underwater acoustic channels, thereby reducing the multi-path effect. This approach decreases the data packet retransmissions while boosting channel reuse, assisting the AOA in managing energy more efficiently.

UW-MAC

UW-MAC is a UWSN-specific distributed medium access (DMAC) protocol. The transmitter-based AOA system, known as UW-MAC, uses a ground-breaking closed-loop distributed method to determine the proper transmit power and code length to reduce the near–far impact [63]. On equipment with numerous resources, such as superficial positions, gateways, and vehicles, UW-MAC uses a multi-user detector.

In order to lessen the near–far impact, a low-complexity yet optimal solution to the distributed power and code self-assignment problems is also proposed. The earlier works only looked at AOA from the perspective of the physical layer, but UW-MAC takes advantage of AOA features to enable multiple accesses to the constrained underwater bandwidth. The results of experiments demonstrate that UW-MAC outperforms other MAC protocols in every network design scenario and simulation situation.

B. Use of TOA

Signals can be split in time deterministically (Time of Arrival—TOA). Users who access resources depending on their turn avoid interference by avoiding time-overlapping signals [64]. While TDMA may be more flexible, a user synchronization is required to guarantee that each user can access a separate time slot. Many systems and protocols are built on this type of underlying time-division structure, but it also calls for some synchronization and lookout times to account for abnormalities in handling the transmission delays.

Multi-Cluster

It is advised that networks featuring autonomous underwater vehicles use a multi-cluster protocol. The plan is to separate the network into several clusters, each consisting of several nearby vehicles. TDMA is paired with extended band protectors inside each cluster to lessen the effects of the underwater propagation delay. TDMA is relatively efficient in this scenario because of the proximity of the vehicles in the same cluster. Therefore, the propagation delay impact is negligible. Separate clusters are given various spreading codes to avoid interfering with one another. Additional tools for cluster reorganization following node mobility are included in the suggested procedure.

Protocol Used in Two-Hop Model

Limited resource availability and ongoing node relocation are significant risks to the consistency of data transmissions. Given these limitations, when creating a protocol that may maximize the dynamic security of these networks, a two-hop dynamic security mechanism to guarantee secure data transfers to the sink is challenging. Without using more resources, two-hop dynamic security can achieve higher delivery ratios than one-hop dynamic security. When we are interested in gathering information, most of these applications demand long-term monitoring of the chosen locations. Transmission Control Protocol (TOA) and similar congestion control techniques have proved highly problematic for wireless multi-hop networks. The three-way handshake process will undoubtedly be simple for such a small volume of data, even if the actual data is only a few bytes. Due to their single-hop nature, these sensor nodes, intended to transport the detected data inside the network, induce congestion in various locations at various times [65].

C. Time Difference of Arrival (TDOA)

Time Difference of Arrival (TDOA) is an ALOHA evolution that consists of a channel-sensing mechanism. This protocol significantly minimizes channel collisions compared to the ALOHA protocol without adding more signaling.

The propagation delay significantly impacts the performance of the protocol. It is improbable that another station will be prepared to emit and detect the channel once one station starts sending. A collision occurs if the second station senses an open channel and begins sending a frame even when the first station's signal has not yet arrived [66]. These collisions are influenced more by increased propagation times toward transmission times, which results in worse protocol performance.

There will still be a collision even if there is no propagation delay. A collision occurs when three stations are ready, and two of them wait until the third station has finished transmitting before commencing to transmit simultaneously. Because both stations had the decency to refrain from intervening during the third season, this protocol is still far superior to the Pure ALOHA. As a result, performance will undoubtedly be superior to the Pure ALOHA.

The uncertainty of the channel is previously in use, and the station does not keep an eye on it to see when the current transmission is over. Instead of immediately repeating the algorithm, it pauses for a predetermined period. This algorithm's use should result in more significant delays and better channel utilization as a natural outcome.

7. Underwater Localization Techniques

All antenna nodes should be completely aware of the corresponding positions and should stake clock data with other sensor nodes for global synchronization, per the assumptions for the localization process. Each node should be able to retrieve all readings and carry out the localization beforehand, sending all the data to the energetic nodes. This circumstance implies that data sharing should be possible between all nodes at all times. Every sensor node in the pertinent target frame can connect with the other nodes and is free from any interference or accident-related difficulties. The listening nodes obtain a message from the active sensor node asking for the position, which is sent one message at a time. Every node estimates the message's Doppler speed after it has been sent. After gathering all sensor data, all estimates are gathered by a master node, which then conducts localization and provides the complete estimate back to the active node. Alternatively, the data may be recorded and sent to the active node, where localization would occur [67].

7.1. Localized Centralization (CL)

The sensor node is unaware of its location until the sink explicitly provides this information. The location of the individual sensor node in the regulator center or sinks is first estimated using this technique. This method can randomly gather nodes for sensor node monitoring or insert them after any action, such as the post-processing step. The sensor node locations are centralized, and a central organization (such as the control center) gathers all necessary information or estimates by centralized methods [68]. The central organization finds the sensor nodes and notifies the connected sensor nodes of their locations.

7.2. Localization with AUV (AAL)

An AAL-based strategy is recommended for a hybrid 3D UASN with stationary underwater sensor nodes and an AUV moving across the UASN sector. The AUV can use dead reckoning to find its location underwater. The expensive inertial piloting system allows for dead reckoning, and the position is regularly calibrated. To acquire GPS coordination from a satellite, the AUV occasionally makes its way to the water's surface. A wake-up message may be transmitted from a different place along the AUV's moving route at any time during its operating cycle. The AUV receives this signal as the underwater sensor node, which initiates the localization by sending a request signal. The underwater node may measure its location by using the alteration process after exchanging messages from three different non-coplanar AUV locations owing to the two-way technique. It was offered by the pair of requests and responses and the return packet's inclusion of the AUV coordinates. While AAL uses a two-way display to do away with the need for synchronization, a sensor node may consume more energy on a quiet algorithm than necessary, raising the protocol's overhead communication. The localization calibration frequency of the AUV has an impact on the AAL accuracy as well.

7.3. Sound Localization (SL)

In AUV-assisted localization systems, there are three types of communications: wake-up, demand, and reaction messages. There are three processes involved in situating [69]. Upon entering the sensing active region, the AUV transmits a wake-up signal. Each sensor node will emit a request signal or packet as soon as it has received the wake-up signal from the other sensor nodes. After that, the AUV replies with a packet comprising its coordinates. For this phase, the AUV must communicate with each detector node at least once. As a result, it is usual to need more energy for localization. Better than the AUV and the AUV is that throughout the localization era, the sensor nodes only receive beacons and do not connect with other nodes due to the high energy consumption of the sensor nodes' communication. An example of this kind of strategy is a "silent localization technique." Beacons were previously swapped between the sensor nodes and the AUV. Last but not least, it is possible to drastically lower the underwater localization power usage by a silent localization.

7.4. Proxy Localization (PL)

The top of the network is located by the PL using the DNRL approach. Half of the 3D USN depth is reached by the DNR beacons. Localized nodes thus serve as proxies for the locations of nodes floating in higher concentrations. Location proxies promote their own coordinates to aid in further localization at the proxy location. The proxy coordinates can later be used to find nonlocalized underwater nodes. A nonlocalized underwater sensor node selects the trusted proxies between nodes using the hop count measure. The hop count is the number of hops between a proxy node and a beacon. At the proxy nodes far from the beacons, errors build up when localization procedures are iterative [70].

7.5. Underwater Sensor Positioning (USP)

In order to be able to determine their depth position while using USP for underwater localization, underwater nodes are designed to be equipped with pressure sensor nodes. A node on a horizontal surface submerged in water uses depth information to map the reachable anchors. While mapping from 3D to 2D, several anchor nodes may be close to one another. A submerged node can choose a different set of the anchor's sensor nodes when appropriate. At each iteration of USP, localized underwater nodes estimate their positions based on messages they receive from nearby nodes and broadcast where they are located. The localized nodes use just two anchor nodes to produce localization; this process is known as dilatation. If the node does not calculate a new position, it will wait until it learns from nearby nodes that the two anchors have already been localized. Before the same localization operation is started again, a predetermined amount of sleep time has passed. The authors offer a locating method for underwater sensor networks [71]. The authors suggested a weighted Gerchberg–Saxton algorithm to address the multi-path acoustic propagation problem of various potential distance estimates between two nodes. A standard positioning method is used to determine the distance between two sensor nodes based on the more robust path or the initial arrival, but neither node can agree on the direct acoustic path in the water.

8. Applications of UWSN Technology

Health Care Surveillance

Wearable and implantable medical applications are the two main categories. Wearable technology is employed on a human's body surface or near the user. Medical gadgets implanted inside a person's body are called implantable devices. Other uses include tracking a person's location and body position and general patient monitoring in hospitals and at home. Body-area networks can gather data about a person's fitness, well-being, and energy usage [72].

Air Pollution Surveillance

In order to monitor the concentration of hazardous chemicals for inhabitants, wireless sensor networks were installed in several cities, including Brisbane, London, and Stockholm. Instead of wired systems, these can benefit from ad hoc wireless communications. This also increases their mobility for checking readings in various locations.

Detection of Landslides

A landslide detection system uses a wireless sensor network to detect minute soil movements and changes in several parameters that may happen before or during a landslide. It may be feasible to predict the occurrence of landslides using the data collected well before when they occur [73,74].

Monitoring Water Quality

Monitoring water quality entails examining the water characteristics of dams, rivers, lakes, seas, and subsurface water reservoirs. The deployment of permanent monitoring stations in hard-to-reach sites is made possible by using wireless dispersed sensors, which also allows for producing a more accurate map of the water status.

Natural Disasters

The effects of natural disasters, including floods, can be efficiently avoided with the help of wireless sensor networks. Rivers requiring the real-time monitoring of water level changes successfully deployed wireless nodes. Machine health monitoring is one example of industrial monitoring. In order to significantly reduce costs and enable additional functionality, wireless sensor networks were created for the condition-based maintenance (CBM) of industrial machinery. In wired systems, the expense of wiring frequently prevents the installation of enough sensors. Wireless sensors can now access previously inaccessible places, rotating machinery, dangerous or restricted areas, and mobile assets.

- Wireless sensor networks are also used to collect data for environmental information monitoring. This can be as basic as monitoring a refrigerator's temperature to as complex as monitoring the water level in a nuclear power plant's overflow tank. The performance of the systems can then be demonstrated using statistical data. The ability to receive "live" data feeds is what sets WSNs apart from traditional loggers.
- Monitoring the quality and level of water involves many different activities, including determining the quality of the surface or subsurface water and ensuring a country's water infrastructure for the benefit of humans and animals.

Structural Health Monitoring

- Wireless sensor networks can be used to log data over extended periods of time and monitor the condition of pertinent geophysical processes and civil infrastructure in close to real time by using properly interfaced sensors. The scope for future work in potential applications is listed in Table 5.

Scope for Future Work

Table 5. Scope for future work in UWSN.

Literature Study	Year	Main Role	Scope	Limitation
Sung Hyun Park et al. [75]	2019	As a result, channel utilization could be improved. ALOHA-Q was upgraded in the new model (UW-ALOHA-Q)	Improvements to UW-ALOHA-Q	Due to heavy weight and environment
Khalid Mahmood Awan et al. [76]	2019	They also examined a few additional categories, including MAC, routing protocols, natural elements, restriction, and channel association	Rising channel usage, media, and directing receive structured control protocols	The underwater acoustic channel places significant restrictions on localization systems due to its unique characteristics of high bandwidth, substantial delay, and high error rates
Xin Su et al. [77]	2020	Data aggregation, fault tolerance, directional search, load balancing, energy efficiency, and control signal distribution	To enhance the hub's performance and battery life under geometric and Doppler spreading (GS)	High computational complexity is matched by significant energy consumption
Rajaram et al. [78]	2021	CH and underwater sensor node for minimizing the overlapping issues	Effectively utilizes the bandwidth and battery lifetime of sensors	The edge nodes are not taken into account
Our survey	2022	Due to bandwidth restrictions, sluggish propagation, media access control, routing, resource exploitation, and power limits, and UWSNs experience issues and challenges	Includes a variety of components, like sensors set in a certain acoustic zone to perform cooperative monitoring, localization, and data gathering tasks	High computational complexity is mirrored by high energy consumption

9. Conclusions

This paper discusses UWSNs, underwater localization, localization techniques, and current challenges in the underwater environment. The main subject of the paper was the recent methods for underwater localization. The crucial topic of localization for the UWSN is one of considerable interest for scientists researching underwater localization. This paper provides detailed explanations of the specific underwater localization characteristics. The paper also looked at the localization's foundational ideas, structure, and methods for underwater localization. The effectiveness of several underwater localization techniques is explored and contrasted. A range-based localization technique that uses TDoA, ToA, AoA, and RSSI is also covered. This paper's conclusion discussed the difficulties and problems surrounding underwater audio communication and localization. Because each localization approach has unique benefits, drawbacks, and consistencies for a particular context, it is hard to declare that one is better than all others. This review's primary objective is to advance young researchers in the field by setting the framework for the previously proposed underwater localization. Even if the arena of USNs, in addition to localization, is expanding rapidly, numerous issues still call for additional study.

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Abbreviations

CH	Cluster Head
M2M	Machine-to-Machine
MCH	Master Clustering Head
SDN	Software Define Networking
TOA	Time of Arrival
ROVs	Remotely Operative Underwater Vehicles
TTL	Time to Live
OCH	Optimize Cluster Head
TDOA	Time Difference of Arrival
Mbps	Megabits Per Second
SDN	Software Define Networking
UWSN	Underwater Wireless Sensor Networks

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