An Enhanced Localization Strategy for Underwater Wireless Sensor Network

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Localization problems are a major concern in Underwater Wireless Sensor Networks (UWSNs). Underwater environments provide distinct obstacles in achieving accurate and reliable localization of underwater sensor nodes. Factors contributing to this challenge include the absence of a Global Positioning System (GPS) beneath the water's surface, the influence of ocean dynamics on sensor node mobility, high propagation delays, and signal distortions. In order for UWSNs to reach their full potential in applications like underwater surveillance, environmental monitoring, and oceanographic research, these obstacles in underwater localization must be resolved. Many innovative approaches and algorithms are being explored by the researchers to enhance the accuracy and effectiveness of localization techniques in the challenging underwater environment. This research outlines a crucial localization strategy to achieve this objective. In this paper, a range-based strategy that incorporates the Azimuth technique for distributed localization method for Underwater Acoustic Sensor Networks (UWASNs) is proposed. The outlined localization scheme consists of three key phases: the angle determination phase, the projection phase, and the localization phase. During the angle determination phase, the scheme determines the angle at which the signal arrives at the sensors. In the projection phase, the challenge of 3-dimensional localization is simplified into a 2-dimensional problem by projecting the sensor nodes onto a virtual plane. Finally, the Azimuth ranging algorithm and distance information from nearby nodes are used to determine the sensor nodes' locations during the localization step. Simulations show that the suggested approach uses minimal energy while achieving a high localization ratio. The findings show that, with minimal energy consumption, the localization ratio surpasses 95%.

Keywords: Localization, Azimuth technique, UWSN, range-based localization, Underwater Wireless Sensor Networks

1. Introduction

Over the past few years, underwater environment monitoring and exploration have become essential for scientific research, environmental management, and a variety of industrial applications. Underwater Wireless Sensor Networks (UWSNs) are a state-of-the- art technology that facilitates real-time data acquisition and communication in difficult aquatic environments. The purpose of this research is to explore the recent advances in UWSNs and the creative localization strategies used to improve their performance.

Numerous sensor nodes that have been placed strategically throughout the underwater area of interest make up UWSNs. The sensors on these nodes are intended to monitor on a variety of environmental factors, such as salinity, temperature, pressure, and even marine life. Since radio frequency transmissions are greatly attenuated in water, acoustic signals are the main means of communication in underwater wireless sensor networks (UWSNs).

Low bandwidth, large propagation latency and limited energy resources are some of the unique difficulties that underwater communication brings. These obstacles make it difficult to transmit data and network efficiently. In order to overcome these obstacles, scientists have been creating effective modulation strategies, error- correction methods, and energy-efficient communication protocols specifically designed for underwater conditions. Many applications in underwater environments, including as environmental monitoring, disaster response, and underwater exploration, depend on accurate localization of sensor nodes.

Conventional terrestrial localization techniques face limitations in direct applicability due to the distinct challenges present in underwater area. Therefore, novel localization techniques have been developed, integrating a combination of acoustic, magnetic, and hybrid methods to achieve precise location information. Localization, which entails determining the spatial coordinates of sensor nodes, is a crucial element of UWSNs. Localization strategies are grouped into two: range-based and range-free. Range- based localization schemes determine the position of a sensor node by estimating its distance or angle concerning a reference node. Different techniques are utilized for range estimation, including:

(i) Received Signal Strength Indicator (RSSI): This calculates the distance information by measuring the signal strength at the receiving end.

(ii) Time of Arrival (ToA): ToA determines the distance by assessing the time discrepancy between signal transmission and reception.

(iii) Time Difference of Arrival (TDoA): TDoA estimates distance by contrasting the reception times of signals sent at different frequencies from the same sender.

(iv) Angle of Arrival (AoA): This method determines the signal angle to facilitate localization.

Conversely, range-free localization systems eliminate the need to compute angles or distances in order to achieve localization.

These schemes do not provide precise locations; instead, they offer an estimation of the general area where the sensor nodes may be located.

In devising a localization scheme, it's crucial to prudently consider energy consumption due to limited battery power. Underwater acoustic modems, grappling with challenges like low bandwidth and significant propagation delay, tend to consume substantial power. Compared to radio channels, acoustic channels consume energy at a level five orders of magnitude higher. To tackle this issue, a localization method can decrease the number of messages exchanged between sensors which may reduce energy consumption.

The proposed scheme seeks to attain precise localization outcomes efficiently and straightforwardly, all without necessitating time synchronization. In the proposed localization, initially all unknown nodes determine the direction of the signal emitted from the reference node. In the next step, sensor nodes are placed onto a virtual plane. The system then calculates the distance between the projected point and the reference node. By utilizing the angle and distance acquired in the previous steps, the precise positions of the sensor are determined. The outcomes demonstrate that the proposed localization scheme achieves a localization ratio exceeding 95% while conserving energy effectively.

2. Literature Review:

In this section localization schemes of Underwater Wireless Sensor network are clearly explained. These localization systems can be broadly divided into two categories: distributed and centralized. All range computations in the centralized localization system are carried out at a central node, usually the UW-sink node, utilizing its computational advantage over ordinary sensor nodes. In a distributed localization scheme, all sensor nodes are tasked with estimating their own locations. Sensors are deployed sparsely in UWSN but in terrestrial network it is deployed densely[1-3]. Localization schemes can be categorized based on the following factors: Localization techniques are divided into two main categories: range-based and range-free, and additionally sub-divided into Standard, movable and hybrid, based on node position.

Based on the available techniques and data used for determining the positions of nodes localization schemes are divided into estimation-based and prediction-based methods.

The first technique is based on the most advanced information for the forecast of the contemporary spot of the nodes, whereas the second technique combines both past and present scenarios. Various researchers classified the node localization schemes into range-based and range-free(Mahajan et al., 2018). In the network, the sensor node uses sustaining information to find out the location corresponding to other nodes, called range- based Localization. Range–free does not use TDOA, TOA, and RSSI to find the distance to other nodes. The authors also described many technical aspects such as channel modelling factors, modulation, and allowable communication links for UWSN, node localization, Routing protocols, and coding techniques. Huang et al. (2018) explained a state-of-the-art mobile node localization approach for UWSN, which involves sound ray tracing, non-convex optimization tools, and Kalman-filter based time alignment. The suggested approach entails adjusting the timestamps from neighbouring anchor nodes using a Kalman filter, followed by a feedback controller. This method swiftly initiates the Kalman filter while preventing divergence.

3. System Model:

The proposed Schemes contains 3D network which consists of three types of nodes: Surface buoy, Anchor node, and Ordinary node, as depicted in the following figure.

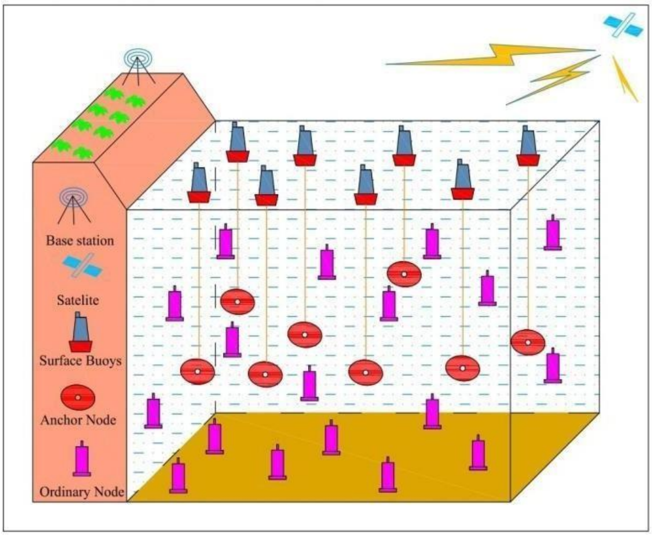


Fig 1 - Structure of Network Model

Surface buoys floats on the sea surface which is equipped with GPS technology and derive their location directly from satellites. Anchor nodes, which are stationary nodes connected to surface buoys, maintain fixed positions relative to these buoys. Additionally, these anchor nodes play an important role in the localization process and are strategically positioned at equal distances from one another. The term "reference node" is used interchangeably with anchor nodes as they contribute significantly to localization efforts. The third type of nodes, known as unknown or ordinary nodes float freely underwater, influenced by ocean currents. Ordinary nodes feature pressure sensors that measure the water pressure around them and the correlation between water pressure and sea depth provides z coordinates for these sensor nodes.

Each ordinary node retains a distance table containing the distances to all neighbouring nodes. It is assumed that every node in the network can measure the angle at which a signal reaches it. Nodes in the underwater network transmit signals, typically using acoustic waves. Sensor nodes receive signals transmitted by neighbouring nodes or reference points. Nodes are equipped with sensor arrays that may consist of multiple sensors or hydrophones arranged in a specific configuration. The sensor array analyses the incoming signals to determine the wave front, which is the shape of the signal as it propagates through the water. This analysis allows the sensor node to infer the direction of the signal arrival. The sensor node calculates the angles at which the signals reach the sensor array using the wave front analysis as a basis. The sensor node determines the angles of arrival using the measured angles and maybe the known geometry or placements of reference nodes.

By combining the angle information with additional data, such as distance measurements or anchor node positions, the sensor nodes compute their own locations within the underwater environment. Given the energy constraints of underwater sensor nodes, the proposed technique may involve optimizing energy consumption. This can involve power- saving techniques like duty cycling, in which nodes switch between active and sleep modes on a regular basis.

3.1 Azimuth Technique:

The azimuth technique is vital in this technology UWSN for pinpointing the direction of signal transmission or reception underwater. Initially, sensors or nodes are placed underwater in a designated area to establish a network. These sensors are equipped with acoustic transceivers capable of transmitting and receiving signals. A signal is received when communication is necessary between two nodes. As the signal propagates, neighbouring nodes within the network receive the signal. These nodes utilize their sensing capabilities to detect the arrival of the signal. Using the azimuth technique, each receiving node estimates the direction from which the signal arrived.

Each node within the network possesses its own axis, termed the orientation axis, against which the angle of arrival is gauged clockwise from the north. The angle is referred to as absolute when the orientation aligns with the north direction; otherwise, it is deemed relative. During deployment the orientation of each node is identified. “Radial” refers to angle measurement from view point where object is observed."Bearing" indicates the measuring angle relative to another object. The bearing angle of a node's major axis with respect to the north is indicated by the term "heading," which refers to each node's absolute orientation.

The orientation of the nodes is depicted by the arrowed line. The relative angle of arrival of node Q and node P at node P and node Q respectively are depicted as θpq and θqp. The angles $\Delta\theta$p and $\Delta\theta$q indicate the orientations of nodes P and Q respectively. The angles $\bar{\theta}$pq and $\bar{\theta}$qp denote the absolute arrival angles corresponding to the relative angles (θpq and θqp). Precise measurements of the arrival angle establish the following relationship:

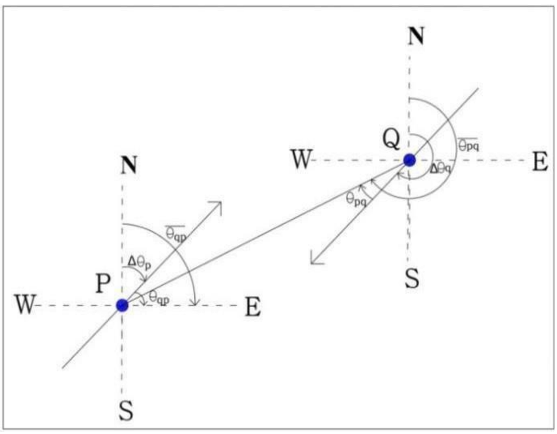


Fig 2 – Azimuth Technique

The bearing angles θpq and θqp can be determined using the equation provided below.

$|\theta pq - \theta qp| = \pi$

Where,

(θpq, θqp, $\Delta\theta$p $\Delta\theta$q, $\bar{\theta}$pq $\bar{\theta}$qp) €[0,2π]

All the angles are calculated according to the following equations.

$\bar{\theta}$qp = (θqp + $\Delta\theta$p) ($mod\ 2\pi$)

$\bar{\theta}$pq = $\bar{\theta}$qp + π $\bar{\theta}$qp < π

$\bar{\theta}$qp - π $\bar{\theta}$qp > π

$\Delta\theta$q = ($\bar{\theta}$pq - $\bar{\theta}$qp) ($mod\ 2\pi$)

4. Localization using Azimuth for UWSNs:

The localization process comprises three distinct phases: angular assessment, projection, and localization.

4.1 Angular Assessment:

In this phase, the sensor nodes determine the position based on the signals from the reference or anchor nodes. Each sensor nodes calculates the angle of signal arrives. This can help in triangulating the node's position. A reference node (R) sends out a localization packet that includes its own position data. This packet is broadcasted throughout the network. Unknown nodes, which do not have their positions determined yet, receive these packets passively. They collect the information without actively sending out queries. If an unknown node receives localization packets from multiple reference nodes, it needs to choose one for determining its position. To streamline this process and improve power efficiency, the proposed model selects the nearest reference node. The unknown node uses the positional data of the chosen reference node and the calculated angle of arrival to compute its own location. By selecting the nearest reference node, the unknown node reduces the amount of distance and angle measurements required, which helps in conserving power and improving the accuracy of the localization process. For example, a typical sensor node such as node P evaluates the relative angle of arrival (θpr) at the selected reference node R. By factoring in

θpr and the node's orientation angle P($\Delta\theta$p), the absolute angle of arrival θpr is established.

4.2 Projection:

In the projection phase of the localization process, the goal is to simplify the problem of determining node positions by reducing the dimensionality of the data from 3D to 2D. Before this phase starts, the angle of arrival of signals from reference nodes has been estimated. This information is crucial for accurate localization. Each node in the network, which needs to be localized, is projected onto a horizontal virtual plane known as the localization plane. This plane is essentially a 2D representation where the z-dimension (depth) is not directly represented. To facilitate the conversion from 3D coordinates to 2D coordinates, depth information is needed. This depth information is obtained using a pressure sensor or a similar device that measures the z- value (depth) of each sensor node. The depth information (z-value) obtained from the pressure sensor is used to project the node's position from 3D space onto the 2D horizontal plane. This is done by effectively 'flattening' the depth component. During this phase, all nodes that are targeted for localization are orthogonally projected onto the horizontal virtual plane,Pf. The depth at which this projection occurs is denoted as Zf, which is the depth of the localization plane. This means that nodes are mapped to the plane at the depth Zf,ignoring their original z-coordinates. The diagram demonstrates the projections of nodes P(xp,yp,zp) and Q(xq,yq,zq) onto the horizontal plane Pf as P P'(x'p,y'p) and Q'(x'q,y'q) respectively.

4.3 Localization:

This localization phase is used to determine the distance between the projection points on horizontal localization plane. In Fig 3 the distance d between the two unknown nodes P and Q in 3D space is given, along with their azimuth data. The azimuth data helps in understanding the direction of the signal arrival and hence the relative orientation of the nodes. Each node is projected onto a horizontal plane, reducing the problem from 3D to 2D. After projection, nodes P and Q will have new positions on this plane. The distance d′ between the projection points of nodes P and Q on the horizontal plane can be calculated based on the 2D coordinates of these points.

$d' = \sqrt{d2} - (zp - zq)2$

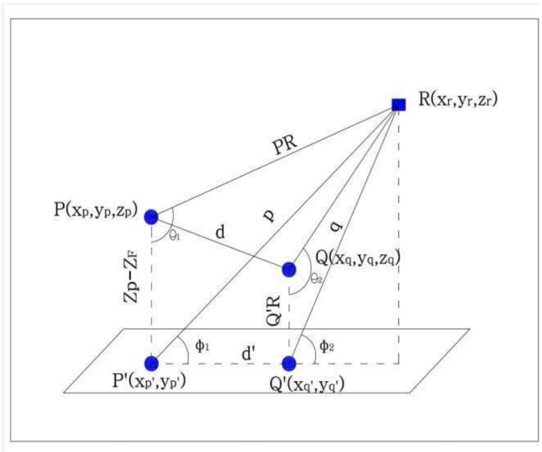


Fig 3-Localization using distance and angle

The following equation can be used to calculate the distance (p) between the node's projection point and the reference node. p=SQRT(PR2+(Zf -Zp)2-2PR(|Zf -Zp|) Cos θ1

θ1 = | π - $\bar{\theta}$pr | Likewise, the distance denoted as q between the

projected point of Q and the reference node R is calculated as follows.

b = SQRT(QR2+Q'R-2(QR)(Q'R)) Cos θ2

In ΔA'B'R, the angle ϕ can be calculated as:

ϕ1 =cos-1

The node A's coordinates can be estimated utilizing the following equation.

Xp = xr – p cos ϕ1

Yp= yr – pcos ϕ1

The following algorithm summarizes our localization process which systematically calculates the positions of sensor nodes relative to the reference point using projections, distance measurements and angle calculations.

Algorithm:

1. **Node Selection**:
If there are multiple neighboring nodes(|NN| > 1), randomly select one neighboring node.

2. **Projection to Virtual Plane:**
Project all sensor nodes onto a virtual plane to simplify calculations

3. **Distance Calculation between Nodes:**
Calculate the effective distance d′ between projection points of nodes:

$$d' = d^2 - (z_p - z_q)^2$$

4. **Distance between Node P to Reference Node point R:**
Calculate distance p from node P to reference point R using

$$p = SQRT((PR^2 + (Zf - Zp)^2 - 2PR(|Zf - Zp|)\ Cos\ \theta_1)$$

5. **Distance between Node Q to Reference Node point R:**
Determine the distance between q from node Q to reference point R using

$$q = SQRT((QR^2 + Q'R - 2(QR)(Q'R))\ Cos\ \theta_2)$$

6. **Angle Calculation:**
Calculate angle ϕ using the cosine rule

$$\phi_1 = \cos^{-1} \frac{p^2 + (d')^2 - q^2}{2pd'}$$

7. Coordinate Calculation for Node P:
Computer the coordinates of Node P as

$$x_p = x_r - p \cos \phi_1$$

$$y_p = y_r - p \cos \phi_1$$

5. Simulation Results:

The simulation used for the proposed localization scheme is MATLAB simulations. Table 4.1 presents the parameters utilized in these simulations. In a cubic region measuring 1000 meters in each dimension, both regular sensor nodes and anchor nodes are deployed. The evenly scattered sensors contain acoustic modem to gauge signal arrival angles. Evaluation criteria contains coverage metric, localization success, and energy consumption.

Simulation Parameters	**Value**
Area of Localization:	1000m ×1000m
Speed of Sound:	1500 m/s
Anchor Proportion	3%, 5%, 8%
Data Transmission Rate	80 bps
Received Power:	0.3 W
Maximum Depth level:	1000m

Table 4.1

5.1 Coverage Metric:

In Underwater Acoustic Sensor Networks (UWASNs), sensor nodes have a limited sensing range. The combined coverage of all sensors in the network determines the network's overall sensing coverage [101]. The percentage of the total area that all sensors cover within the network's entire area is referred to as the coverage percentage.

The coverage is calculated using the following equation:

$$\text{Coverage} = \frac{4\pi}{3} a^3 - \pi d \left(a^2 - \frac{}{d2}\right) \quad 2$$

Where a= the anchor nodes' transmission range d=distance between the anchor nodes

5.2 Localization success:

The localization ratio indicates the fraction of nodes that have been successfully localized compared to the total number of nodes deployed in the network. By using the total number of deployed nodes (N) and the volume of the deployment region, the number of localized nodes can be calculated with the following equation:

relative to the anchors. The equation provided computes the energy consumption for m anchor nodes and n ordinary nodes within the scheme..

E = $mEan+nEon$

n

= $m(Esp+nErp)+nm(Esp+Erp)$

n

= (1+1) $mEsp$ + $2mErp$

Since there are more number of ordinary nodes(n), Energy consumption can be calculated as

E = lim $m(Esp + 2Erp)$

$s\rightarrow\infty$

5.3 Energy consumption:

Energy consumption refers to the total energy used by both anchor and ordinary nodes for transmitting and receiving packets. The following equation offers a method to calculate the energy consumption linked with sending and receiving a single packet.

Etp = Ptp x Packet_size

$Data\_rate$

Erp = Prp x Packet_size

$Data\_rate$

Where Etp, Erp are the energy consumption of transmitting and receiving a packet respectively. Ptp,, Prp are the energy required to transmit and receive a packet. Average energy consumption is calculated as follows

Etotal = Ean+Eon N

Where Ean = Energy usage at the anchor node Eon= Energy usage at the ordinary sensor node

N=Total number of sensor nodes

In the Localization Scheme utilizing the Azimuth technique for Underwater wireless Sensor Networks, every anchor node sends out a ranging packet that ordinary nodes can detect. This packet contains information that helps ordinary nodes ascertain their distance from the anchor nodes. By capturing the Angle of Arrival of the received signals, they can create a geometric representation of their position

5.4 Coverage Area Vs Transmission Range: The following Figure illustrates the outcomes of a simulation conducted using predefined values for simulation purposes. The vertical axis illustrates the coverage percentage, while the horizontal axis denotes the transmission range, spanning from 100m to 250m, with associated coverage percentages plotted. The graph showcases different distances (d) between anchor nodes, specifically 30m, 40m, and 50m. As the transmission range of the nodes increases, the coverage percentage also rises. Moreover, as the distance between anchor nodes decreases, the coverage exceeds 90%.

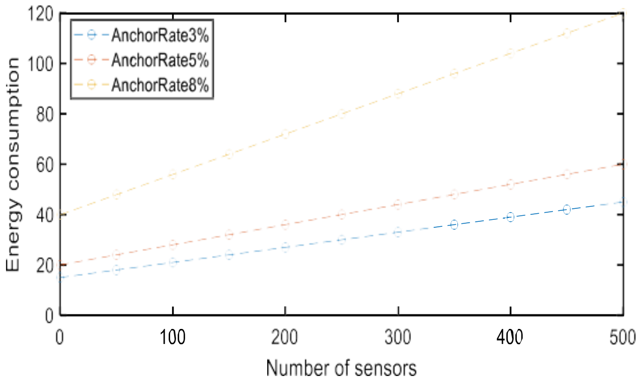
Localized_nodes=N x $(4\pi\ a3 - \pi d\ (a2 - d2))V312$

5.5 Localization Ratio Vs Distance:

The depicted figure demonstrates how the localization ratio with respect to sensor nodes count is influenced by the distance between anchor nodes. Initially, the distance is configured at 5m and gradually increased in 5m intervals up to 50m. The figure clearly illustrates how the localization ratio decreases as the node distance increases. This decline happens as a result of certain nodes do not receive messages sent by the anchor nodes. At an inter-node distance of 10m, the localization ratio surpasses 95%.

5.6 Energy Consumption Vs nodes:

The depicted Figure showcases the correlation between energy consumption and the network's node count. Energy efficiency stands as a pivotal goal for any localization scheme, particularly given the demanding conditions of underwater environments. The figure illustrates how our proposed scheme enhances energy efficiency by reducing energy consumption. Its clear from the figure that as the number of anchor nodes increases the energy consumption is also increases because of the increasing message exchange between nodes. Tests on the system with anchor node percentages of 3%, 5%, and 8% were conducted. The findings suggest that lower percentages of anchor nodes result in superior performance compared to higher percentages.



6. Conclusion:

We proposed a distributed range-based localization scheme tailored for Underwater Acoustic Sensor Networks (UWASNs), leveraging the Azimuth technique. This scheme encompasses three key phases: Angle Estimation, Projection, and Localization. During the Angle Estimation phase, sensor nodes gauge the angle of the incoming signal. Subsequently, in the Projection phase, sensor nodes are projected onto a virtual plane, and the distance between the projected points and the reference node is computed. Finally, in the Localization phase, the sensor node's position is established utilizing the measurements acquired from the preceding phases.

Simulation outcomes reveal that our scheme can attain a notable localization ratio and network coverage while upholding comparatively low energy consumption. Furthermore, we investigated the trade-offs encompassing localization ratio, network coverage, energy consumption, transmission range, anchor percentage, and distance between anchor nodes. These parameters exhibit variability across networks, and modifying them empowers us to manage the trade-offs accordingly.

References

1. Aroba, O.J., Naicker, N., Adeliyi, T.T., 2023. Node localization in wireless sensor networks using a hyper-heuristic DEEC-Gaussian gradient distance algorithm. Sci. Afr. 19, e01560. https://doi.org/10.1016/j.sciaf.2023.e015
2. Chen, K., Zhou, Y. and He, J., 2009. A localization scheme for underwater wireless sensor networks. International Journal of Advanced Science and Technology, 22(2017), pp. 9-16. 116
3. 2.J. Murali & T. Shankar., "A survey on localization and energy efficiency in UWSN: bio-inspired approach" Discover Applied Sciences., 2024., Springer.
4. 3.Saha S., Arya, R., 2022. ARCMT: Anchor node- based range free cooperative multi trusted secure underwater localization using fuzzifier. Comput. Commun. 193, 246–265.

https://doi.org/10.1016/j.comcom.2022.07.01 6
5. Cheng, X., Shu, H.S.H. and Liang, Q., 2007, August. A range-difference based selfpositioning scheme for underwater acoustic sensor networks. In International Conference on Wireless Algorithms, Systems and Applications (WASA 2007) (pp. 38-43). IEEE.
6. Cheng, X., Shu, H., Liang, Q. and Du, D.H.C., 2008. Silent positioning in underwater acoustic sensor networks. IEEE Transactions on vehicular technology, 57(3), pp.1756-1766.
7. Erol-Kantarci, M., Mouftah, H.T. and Oktug, S., 2010. Localization techniques for underwater acoustic sensor networks. IEEE Communications Magazine, 48(12), pp.152- 158.
8. Khandelwal, D., Mahajan, R. and Bagai, D., 2018. Underwater wireless sensor network: A review. International Journal of Advanced Research in Electronics and Communication Engineering, 7(5), pp.424-428.
9. Chen, K., Fu, Y., Cheng, E. and Huang, L., 2018. Performance evaluation of an improved APIT localization algorithm for underwater acoustic sensor networks. Journal of Compuers., 29(1), pp.132-142.
10. Teekaraman Y, Praneshsthapit M and Kim K. Energy analysis on localization free routing protocols in UWSNs. Int J Comput Intell Syst 2019; 12(2): 1526–1526.
11. Dong, B. and Mahdy, A.M., 2010. Underwater Wireless Sensor Networks: Efficient Localization Schemes using SemiDefinite Programming. International Journal on Advances in Networks and Services Volume 3, Number 1 & 2, 2010. Pp. 186-195.
12. Erol, M., Vieira, L.F. and Gerla, M., 2007, September. Localization with Dive'N'Rise (DNR) beacons for underwater acoustic sensor networks. In Proceedings of the second workshop on Underwater networks (pp. 97- 100).
13. Fengzhong, Q.U., Shiyuan, W., Zhihui, W.U. and Zubin, L.I.U., 2016. A survey of ranging algorithms and localization schemes in underwater acoustic sensor network. China Communications, 13(3), pp.66-81.
14. Goyat, R., Rai, M.K., Kumar, G., Saha, R. and Kim, T.H., 2019. Energy efficient range-free localization algorithm for wireless sensor networks. Sensors, 19(16), pp. 1-20.
15. Guo, Y., Kang, X., Han, Q. and Wang, J., 2019. A localization algorithm for underwater wireless sensor networks based on ranging correction and inertial coordination. KSII Transactions on Internet and Information Systems (TIIS), 13(10), pp.4971-4987.
16. Isik, M.T. and Akan, O.B., 2009. A three- dimensional localization algorithm for underwater acoustic sensor networks. IEEE Transactions on Wireless Communications, 8(9), pp.4457-4463.
17. Nain, M. and Goyal, N., 2022. Energy efficient localization through node mobility and propagation delay prediction in underwater wireless sensor network. Wireless Personal Communications, 122(3), pp.2667-2685.
18. Qi, X., Liu, X. and Liu, L., 2018. A combined localization algorithm for wireless sensor networks. Mathematical Problems in Engineering, pp. 1-11.
19. Shakila, R. and Paramasivan, B., 2021. An improved range-based localization using Whale Optimization Algorithm in underwater wireless sensor network. Journal of Ambient Intelligence and Humanized Computing, 12(6), pp.6479-6489.
20. Sunitha, M. and Karunavathi, R.K., 2019, May. Localization of nodes in underwater wireless sensor networks. In 4th International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT) (pp. 820-823). IEEE.
21. Tuna, G. and Gungor, V.C., 2017. A survey on deployment techniques, localization algorithms, and research challenges for underwater acoustic sensor networks. International Journal of Communication Systems, 30(17), pp.1-21.
22. Ullah, I., Liu, Y., Su, X. and Kim, P., 2019. Efficient and accurate target localization in underwater environment. IEEE Access, 7, pp.101415-101426.
23. Wang, S., Chen, L., Hu, H., Xue, Z. and Pan, W., 2013. Underwater localization and environment mapping using wireless robots. Wireless personal communications, 70(3), pp.1147-1170.

24. Wu, Z. and Li, X., 2015. An improved underwater acoustic network localization algorithm. China Communications, 12(3), pp.77-83.
25. Xu, T., Wang, J., Shi, W., Wang, J. and Chen, Z., 2019. A localization algorithm using a mobile anchor node based on region determination in underwater wireless sensor networks. Journal of Ocean University of China, 18(2), pp.394-402.
26. Yuan-bo, Y. and Yong-gang, W., 2010. MFALM: An active localization method for dynamic underwater wireless sensor networks. Computer Science, 1, pp.1-36.
27. Zhang, S., Chen, K., Fan, Z., Cheng, E. and Su, W., 2019. The localization algorithm based on symmetry correction for underwater acoustic networks. IEEE Access, 7, pp.121127-121135.
28. Zheng, C., Sun, D., Cai, L. and Li, X., 2018. Mobile node localization in underwater wireless networks. IEEE Access, 6, pp.17232- 17244.
29. Zhou, Z., Cui, J.H. and Zhou, S., 2007, May. Localization for large-scale underwater sensor networks. In International Conference on Research in Networking (pp. 108-119). Springer, Berlin, Heidelberg.
30. Gupta, O., Kumar, M., Mushtaq, A. and Goyal, N., 2020. Localization schemes and its challenges in underwater wireless sensor networks. Journal of Computational and Theoretical Nanoscience, 17(6), pp.2750-2754.
31. Al-Salti, F., Alzeidi, N. and Day, K., 2020. Localization Schemes for Underwater Wireless Sensor Networks: Survey. International Journal of Computer Networks and Communications, 12, pp.113-130.
32. Beniwal, M. and Singh, R., 2014. Localization techniques and their challenges in underwater wireless sensor networks. International Journal of Computer Science and Information Technologies, 5(3), pp.4706-4710.
33. Chen, H.Y., Liu, M.Q. and Zhang, S.L., 2018. Energy-efficient localization and target tracking via underwater mobile sensor networks. Frontiers of Information Technology & Electronic Engineering, 19(8), pp.999-1012.
34. Nagarajan, M. (2014). A New Approach to Improve Life Time Using Energy Based Routing in Wireless Sensor Network. International Journal of Science and Research (IJSR). 3(7), 1734-1738.
35. Nagarajan, M., and S. Karthikeyan. (2012). A new approach to increase the life time and efficiency of wireless sensor network. International Conference on Pattern Recognition, Informatics and Medical Engineering (PRIME-2012). IEEE, 2012. 231-235. https://doi.org/10.1109/ICPRIME.2012.62083 49.