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A Literature Review of Measurement Techniques, Challenges and Applications in Underwater Localization

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ABSTRACT

Localization in underwater has gain great significance in the field of research and can support variety of military and civilian applications. Underwater sensor nodes should have the knowledge of their reference location.The way in deciding the physical co-ordinates of sensor nodes is known as localization or positioning. The factors that affect the underwater communication are multipath propagation, low bandwidth, attenuation, propagation delay. So acoustic communication is more convenient for localization in underwater wireless sensor network (UWSN).In this paper, we provide a literature reviewof techniques, challenges and applications in localization of UWSN.

Keywords*-Underwater Sensor Network (USN), Localization*

I. INTRODUCTION

USN's provides tremendous opportunities to explore the ocean and understand conditions related to ocean environment. Underwater sensor networks use acoustic communication to enhance warfare capabilities that can be used in submarine detection,surveillance by the naval force.Situating utilizing RF signals is not practical for ranges more than 10 meter because of high weakening of RF in water while optical signals disperse.In addition, the fading caused by acoustic signals is less and can travel more territory than RF signals and optical signals. So acoustic communication is well suited for underwater communication. But there are several challenges such as low bandwidth and low data rates. We can increase data rates using short range for communication. Besides, the nature of the acoustic channel connect is low [2] due to multi-way engendering and fluctuation at the time of medium.These characteristics constitute severe difficulties towards designing localization schemes to satisfy the following alluring properties [3]

- Localization accuracy: The location of the sensors for which the detected information is inferred ought to be precise and unambiguous for significant translation of data.Localization schemes usually reduces the distance between actual and estimated location.
- Localization coverage: It should ensure that most of the nodes should be localized within the network.
- Fast Computation: Due to uncertainties in water currents sensor nodes drift, hence the localization method should compute the actual location.
- Cost of deployment: The communication overhead should be reduced.

- Good Scalability: Due to high attenuation and long propagation delay underwater acoustic channel pose scalability problem.
- Power Consumption: The USN's should consume less power as battery cannot be recharged frequently.

Along with these properties simplicity and cost of setting reference nodes and other required infrastructure ought to be considered as well.Terrestrial sensor networks are classified into three categories: geometric investigation approach, nearness approach and scene investigation approach (Hightower and Borriello, 2001) but these techniques cannot be employed directly on submerged networks.

The rest of the paper researches the accompanying zones. In segment 2 we portray the fundamental confinement strategies which are range dependent and range independent. In segment 3 we give an examination of these plans. In segment 4 we examine a few uses of submerged sensor systems. Henceforth the conclusion of the paper is presented in segment 5.

II. BASIC LOCALIZATION TECHNIQUES

Localization has attracted great attention in the field of underwater.In localization few objects whose areas are known (anchors) are utilized to quantify the separation or point from these anchors to the object that must be localized (area is obscure). The anchors can get their locations by different courses, for example, they can be set at fixed area or can get their co-ordinates from Global Positioning System (GPS).Two basic localization procedures are angulation and lateration. Angulation method decides the area using the bearing data and the geometric models of triangles, while lateration uses the separation between two nodes. Fig 1 indicates trilateration with three anchor nodes (S1,S2,S3). The converging point of the three circles decide the location of the node. In Fig 1 the converging point is represented by T. Multi-lateration is a speculation of the traditional trilateration where n directions can be assessed by n +1 non-coplanar anchor co-ordinates. To appraise the co-ordinates of the nodes, denoted by (x_p,y_p,z_p) we use the equation :

$$(x_p-x_j)^2+(y_p-y_j)^2 +(z_p-z_j)^2 = dst_j^2 \quad (1)$$

Where (x_j,y_j,z_j) are the co-ordinates of the nodes whose areas are known and dst_j is the calculated separation between the anchor and the node whose area should be resolved. In UWSN the separation and point can be ascertained by the range-based plans, though range free plans can just get approximate of the area, range based plans are generally utilized.

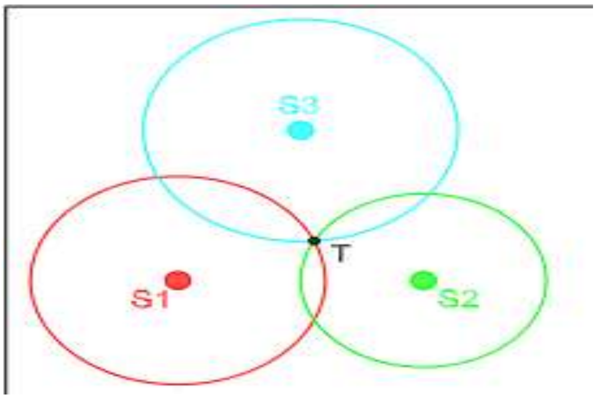

Fig 1 Graph depicting Trilateration with three anchors

2.1Range-based Localization

The range based localization scheme is classified as Angle of Arrival (AoA), Received Signal Strength Indicator (RSSI), Time of Arrival (ToA) and Time Difference of Arrival (TDoA).

2.1.1 Angle of Arrival (AoA)

The AoA estimation are otherwise called the bearing estimations or the direction of arrival estimations.In [4] the author has proposed AoA submerged localization method for Ad-Hoc sensor in 2D and 3D. The distance of the unknown object is estimated with reference nodes via multi-hops. The proposed localization scheme has achieved better accuracy compared to DV-distance and DV-hop schemes. In [5] new approach to deal with sonar is intended for AUV's. This approach depends on the idea of joining horizontal beam-forming with vertical AoA estimation. This approach is viable as far as power utilization and size is concerned.

2.1.2 Received Signal Strength Indicator (RSSI)

In RSSI each node determines its separation from the anchor by estimating the received signal strength quality. RSS is monotonically decreasing for the evaluated separation. The relationship is displayed by theaccompanying log-normal model:

$$P_{rss}(d_r)[dBm]=P_i(d_i)[dBm]-10n_p\log_{10}\left(\frac{dr}{di}\right)+X_s \quad (2)$$

where $P_i(d_i)$[dBm] is a reference power at d_i from the sender, n_p is the path loss exponent , Xs is a zero mean. Both $n_p$and s are affected by environment. In [6] the sensor model relationship between RSSI and distance is shown.In [7] the RSSI method for RF sensors is used to evaluate the separation and the optical image is combined for the directional data.In [8] grouping of nodes using random access method is proposed.The collision can be reduced in a group of nodes, by choosing the subcarriers based on the RSSI level for each node.

2.1.3 Time Difference of Arrival (TDoA)

In underwater the difference in time between different reference nodes using acoustic signalling can be used for localization. This technique requires three reference nodes whose locations are known to predict the location of an unknown node. Errors caused by synchronization affect the accuracy. In [9] TDoA algorithm for passive localization is proposed.An experimental investigation of robot localization based on particle filter (PF) in underwater is shown in [10]. It also provides a comparison PF method with least square method. We can observe target localization in inhomogeneous underwater environment [11] using TDoA. In [12] the author has implemented underwater positioning in shallow water environment using short baseline (SBL).

In ToA calculation, the separation between n0des is being evaluated by estimating the time taken for propagation of the transmitted signal.This calculation requires more exact synchronization among the nodes and their time stamp.

2.2Range free localization

Range free method does not use range or bearing data and just gives close approximate of node position.Range-free algorithms can be extensively divided into Hopcount-based algorithms, Area-based algorithms and Centroid algorithm.

2.2.1Hopcount-based algorithm

In Hopcount-based, reference nodes are set at the corners or along the limits of square framework. Three classic schemes are DV-Hop, DHL and robust positioning. InDV-Hop the average hop distance estimate and counted number of hops to calculate the distance to anchor is used. The limitation of this method is it can only be applied to isotropic network [13].DHL uses density awareness to estimate distance dynamically and Robust positioning algorithm are used to increase DV-Hop.

2.2.2 Area-based algorithm

For extensive WSN, perceiving the right co-ordinates of every sensor makes the cost high and may not be possible.A rough computation of the sensors areas is sufficient for a few applications.Area Localization Scheme (ALS) and Approximate Point-In Triangle (APIT) are based on area covered. ALS is a centralized range independent scheme which has major advantages such as simplicity, no need of synchronization and is not vulnerable to varying speed of sound underwater [14].Recently algorithms based on ALS are proposed such as 3D Multi-power Area Localization scheme (3D-MALS).3D-MALS combine two ideas, reference points having varying power level during transmission[15], and reference nodes with vertical mobility of buoys.Compared with other range-free localization algorithms, APIT algorithm can achieve higher precision, position estimation with small communication cost [16].

2.2.3Centroid Algorithm

It is a range-free proximity-based and coarse-grained localization method. One of the limitation of centroid localization algorithm lies in its high location error because of centroid equation; Where X_{es}, Y_{es} are the estimated location of receiver.

$$Xest, Yest = \frac{Xp1+Xp2+Xp3+\cdots Xpn}{n}, \frac{Yq1+Yq2+Yq3+\cdots+Yqn}{n} \qquad (3)$$

III. COMPARISON

In table 1 we have examined different localization schemes that have been discussed in this paper. Range dependent schemes can provide high level of accuracy if more number of anchor nodes are placed. As the no.of anchor nodes rise better is the accuracy. One of the challenge faced underwater is it is difficult to deploy several anchors nodes with precision in location. If precision in locations are not required, then range independent schemes can be used. In case of routing of data from sensors range independent schemes could be used.

Table 1. Comparison of different Localization schemes

Schemes	Range-based or Range-free	Distributed/ Centralized	Accuracy
AoA	Range-based	Distributed	Accurate:1 to10 m for fixed anchor location
RSSI	Range-based	Distributed	For small areas it provides better accuracy
TDoA	Range-based	Distributed	More accurate:1 to10 m for fixed anchor location
Hopcount-based	Range-free	Distributed	Less accurate: O.5*(RF) to 1*(RF)
DV-Hop	Range-free	Distributed	Less accurate
ALS	Range-free	Centralized	Less accurate
APIT	Range-free	Distributed or Centralized	Less accurate
Centroid algorithm	Range-free	Distributed	Not Accurate

IV. APPLICATIONS OF USN's

Submerged sensor organize applications in perspective of acoustic correspondence are rapidly grabbing predominance for enabling impels in the zone ofocean monitoring and observatory structures, reconnaissance and tracking of marine animals. UASNs discover their applications in fields like seaward oil and gas extraction,mine detection, monitoring pollution,surveillance,coral reef and observing of marine life and fish cultivation are some of the examples. This area shows a study of late improvements in the area of UASN applications

4.1 Oceanographic monitoring

Ocean process are dynamic, complicated and happen on various spatial and transient rates. To obtain a concise viewpoint of such techniques, ocean analysts accumulate data over draw out extend of period. Genuinely, estimations were reliably given by settled sensors, e.g., moorings, or gathered from ships.Starting late, an extension in the utilization of AUV's has engaged a more remarkable data getting approach. Marine sensor frameworks, while sending serves a magnificent favorable position to the on-shore oceanographers.Utilizing the information gathered by sensors, oceanographers enable us to pick up a superior comprehension of how the ocean and living animals in them, are functioning as an ecosystem. In the paper [17] the underwater glider monitors a patch of ocean.

4.2 Environmental monitoring

USN’s are used in environmental monitoring such as pollution, weather forecast, ocean current monitoring, chemical monitoring, tracking of aquatic animals and micro-organisms.Acoustics can be utilized to distinguish, find and classify polluting matter and results of contamination like green growth sprouting and other natural impacts.Amid the most recent few years Simrad Subsea has been examining the capability of our acoustic hardware.Echosounders for scientific research are used for fisheries examining and can be utilized to screen the natural status of the water volume and the ocean bottom separately. Some of the applications in submerged network are kelp monitoring, sewage monitoring and sea mapping.In Fig 2 we can observe Echogram depicting small aquatic animals.In [18] a brief outline of these applications is provided. In [19] the plan and development of a submerged actuator network is depicted to distinguish outrageous temperature.

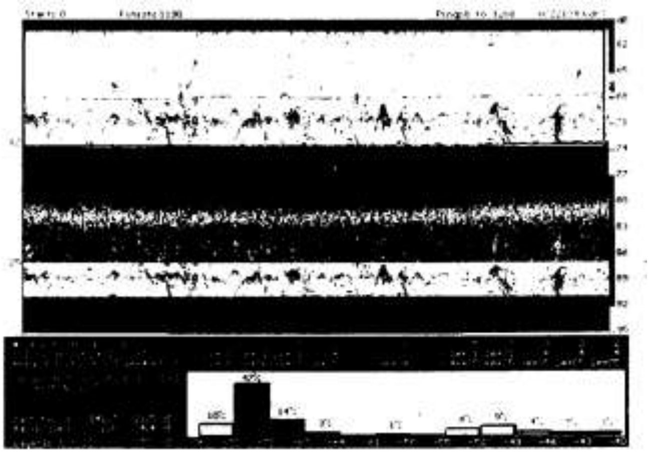

Fig 2 Echogram depicting small aquatic animals [18]

4.3 Disaster prevention

Seismic monitoring is a prominent application of USN's for extracting oil from underwater fields [2]. When seismic waves are detected across remote location it can provide early warnings of tsunami shown in Fig 3.

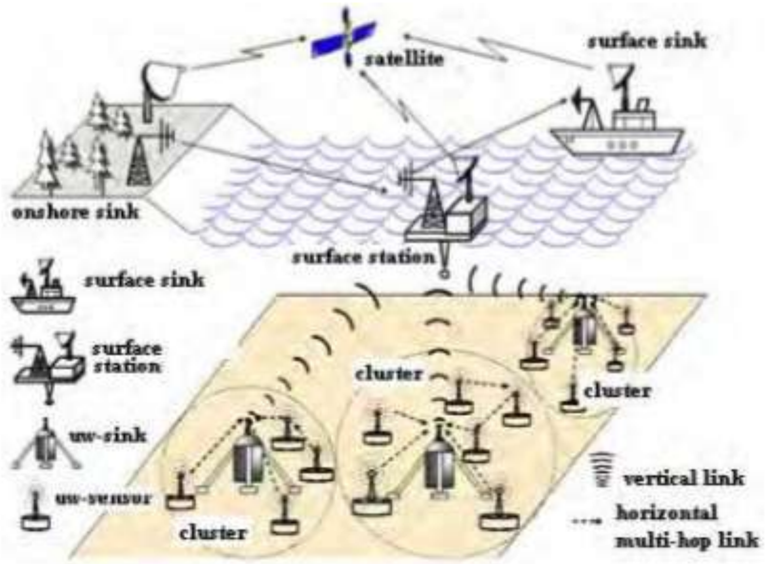

Fig 3Setup to provide early Tsunami warnings [20]

4.4 Distributed Tactical Surveillance

Sensors and AUV's can monitor intrusion detection, surveillance and reconnaissance. In [21] a strategic reconnaissance framework that can recognize and portray submarines, little conveyance vehicles (SDVs) and navigators based on information that has been detected is intended for 3D USN.

4.5 Equipment monitoring

The equipment's that are deployed in water need to be monitored, pre-configured and care has to be taken for maintenance of these equipment's.Long haul gear observingmight be finished with pre-installed framework. But transitory observing would benefit from low-control and remote correspondence.Transitory observing is most valuable when hardware is first setup, to confirm fruitful arrangement amid introductory task, or when issues are identified.We are not thinking about node arrangement and recovery as of now, yet potential outcomes incorporate remote-worked or automated vehicles.Once submerged hardware are associated with acoustic sensor systems, it turns into a simple assignment to remotely control and work some gear. Current remote activity depends on links associating with each bit of gear. It has high cost in organization and support. Conversely, submerged acoustic systems administration can significantly decrease cost and give substantially more flexibility.

V. CONCLUSION

In this paper we have led an extensive review on the estimation strategies, difficulties and applications with respect to submerged sensor systems.In addition we can also understand that range dependent estimation provides higher precision and has complex mathematical calculations whereas range independent estimation provides a close approximate and it can be used in applications that does not require exact location. This paper has also included the recent research work done in this area and also describes the several applications of localization in submerged networks.Depending on the requirement of application such as distance,accuracy and number of reference nodes we can use the suitable estimation method.

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