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SURVEY ARTICLE

A Survey and Comparison Study of Localization in Underwater Sensor Networks

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Abstract— Underwater wireless sensor networks (UWSNs) are the enabling technology for various underwater applications, and the interest in UWSNs is growing. Applications of underwater sensing range from oil industry to aquaculture, and include instrument monitoring, pollution control, climate recording, prediction of natural disturbances, search and survey missions. Location information is important for this kind of applications. Localization is one of the major and challenging tasks in UWSNs. Because underwater environment is usually complex and hostile, and beacons are prone to move offsetting from their origin positions and underwater channel occurs error easily. Hence, the coordinates provided by some beacons for the localization of unknown nodes are possible to be inaccurate. The positioning error of beacons will affect the accuracy of unknown nodes significantly. This paper makes a comparison study about various localization schemes for UWSNs.

Keywords— Underwater sensor networks, under water localization, acoustic communication, AUV, sensor node

I. INTRODUCTION

Underwater sensor networks (UWSNs) can be used in various fields such as Pollution monitoring, naval defence, harbor surveillance, undersea archaeology, ocean bottom seismic researches like earthquake or tsunami researches, ocean life observation are among some of the fields to benefit from the wide opportunities that UWSNs offer[1]. For water pollution detection systems, mobile UWSNs can follow polluted waters as they propagate from their source to clean waters and warn authorities to take action. For earthquake or tsunami forewarning systems, UWSNs with underwater sensor nodes mounted on the ocean bottom can detect earthquakes and tsunami formations before they reach inhabited regions. In naval defence UWSNs can provide instant deployment capability and increased coverage in surveillance applications of coastal regions. UWSNs can be used in monitoring sea animals and coral reefs where human operation would provide limited information. Applications of underwater sensing [2] range from oil industry to aquaculture and include instrument monitoring, climate recording, search and survey missions. Scientific applications observe the environment: from geological processes on the ocean floor, to water characteristics (temperature, salinity, oxygen levels, bacterial and other pollutant content, dissolved matter, etc.) to counting or imaging animal life (micro-organisms, fish or mammals). Industrial applications monitor and control commercial activities, such as underwater equipment related to oil or mineral extraction, underwater pipelines or commercial fisheries. Military and homeland security applications involve securing or monitoring port facilities or ships in foreign harbours, de-mining and communication with submarines and divers.

Localization is one of the major and challenging tasks in UWSNs [3]. It is important because raw sensor data without location information from where that data is received is less use and does not provide much information. It is challenging because GPS signal does not propagate through water and positioning schemes in WSN are not applicable in UWSN due to acoustic channel properties.

Underwater communication systems today mostly use acoustic technology. Acoustic communications offer longer ranges, but are constrained by three factors: First, the power loss that occurs over a transmission distance. The second, site-specific loss due to surface–bottom reflections and refraction that occurs as sound speed changes with depth. The third, apparently random changes in the large-scale received power (averaged over some local interval of time) that are caused by slow variations in the propagation medium (e.g. tides).

With the advances in acoustic modem technology, research has moved into the area of underwater networks. The major challenges in UWSN [3][4] are acoustic signals propagate at 1500ms−1, causing propagation delays as long as a few seconds over a few kilometres. Acoustic modems are typically limited to half-duplex operation. These constraints imply that acoustic-conscious protocol design can provide better efficiencies than direct application of protocols developed for terrestrial networks (e.g. 802.11 or transmission control protocol (TCP)). In addition, for UWSNs, energy efficiency will be more important than in terrestrial networks, since battery re-charging hundreds of metres below the sea surface is very difficult.

II. LOCALIZATION

In UWSN, localization methods can be into different types based on various properties like architecture (static, mobile and hybrid localization), coverage property (2d and 3d localization), computation (distributed and centralized), on the distance measurement (range based and range free methods), the message exchange (passive and active), node cooperation (single stage and multi stage), the anchor placement (surface, under water and hybrid localization).

In the literature, static UWSN nodes are fixed at a certain location, but in a mobile UWSN, the motion of the nodes may be controlled or the nodes may be drifted by the movement of water. Controlled motion may be available by propelled underwater vehicles such as Autonomous Underwater Vehicles (AUVs), or there may be buoyancy-driven equipment that can move vertically or those that can also move horizontally. In hybrid architectures several nodes may have the capability of motion while other nodes may be stationary. Some of the localization algorithms needs time synchronization between the node and some algorithms don't need time synchronization. Localization algorithms can again classify into anchor free localization and anchor based localization. Some algorithms need special types of devices like AUV. We can also group the localization protocols for UWSNs in two categories, distributed and centralized, based on where the location of a sensor node is determined. In distributed localization techniques, each underwater sensor node collects localization related information, such as anchor positions or distance to anchors or distance to neighbours, and then runs a location estimation algorithm individually. In centralized protocols, the location of each sensor node is estimated by a sink node in the network. Centralized protocols may localize nodes at the end of a mission or periodically collect information to track sensor nodes.

III. LOCALIZATION TECHNIQUES

Earlier days localization in the traditional oceanographic systems works based on either acoustics-based approaches like Short Base-Line (SBL) or Long Base-Line (LBL). In the LBL system, acoustic transponders are deployed either on the seafloor or on moorings around the area of operation. Devices that are in the transmission ranges of several sound sources estimate their location by triangulation [5]. LBL has good localization accuracy, but it requires long-time calibration. In the SBL system, a ship follows the underwater devices and uses a short-range acoustic emitter for localization. . LBL or SBL cannot be used for UWSNs because LBL uses long range signals which create interference and disable the communication among the sensor nodes while SBL involves a ship in the operation area which is not feasible for the large-scale and mobile UWSNs.

GPS intelligent buoys (GIB) [6, 7] is also used in earlier days. This system almost like long base line system, difference is that reference points are surface buoys. GIB buoys, which have GPS receivers and hydrophones, listen to the signals that are emitted by an underwater equipment and estimate its distance via Time-of-Arrival (ToA). GIB buoys periodically send these distance measurements and self-coordinates to a central station where the location of the underwater equipment is determined. The floating buoys are easier to deploy and calibrate than LBL systems. GIB is not convenient for localization of UWSNs for several reasons. First, the underwater equipments emit signals to be tracked which means they consume high amount of energy especially when long range communications are required to reach the GIB buoys. On the other hand, if short range communications are used, a large number of GIB buoys may be needed. Moreover, GIB is a centralized technique and it does not provide location information for the sensors, it provides tracking ability for the central station.

A. *Anchor based Localization*

DNR Localization (Dive N Rise) [8] is a distributed protocol. DNRL works in large-scale networks, 3-D space, establishes minimal message exchange and considers mobility. This design has simple apparatuses (DNR beacon) that can dive with the help of extra weight. When they reach a certain depth, the weight is released and they rise/emerge with the help of a bladder. DNR beacon is responsible for getting its GPS coordinates when floating above the water. Then, while diving it broadcasts its coordinates, and assumes the sensor nodes are equipped with pressure sensors. Hence, they know their depth (z coordinate) and estimating the x-y coordinates is sufficient to determine their location. Sensor nodes listen to time stamped broadcast messages from DNR beacons. Distance measurement node to DNR beacon is done by using the time of arrival of these messages. DNRL has high coverage and provides accurate result but for that it needs large number of DNR beacons. DNR beacons are more expensive than the other underwater nodes due to their motion capability. DNRL requires synchronization since it uses one-way ranging in ToA calculations. DNR-Positioning can localize 100% nodes with small error. Moreover, no message exchange is required. Sensor nodes are able to learn their coordinates just by listening. This passive learning results in saving energy and reducing communication cost.

In “Multi-stage DNR” (MSL) method [9] lesser number of beacons are required than DNRL method. During the first stage some nodes are localized. Next stages this localized nodes broadcast its location to localize the remaining unlocalized nodes. This iterative localization approach increases the coverage and decreases the delay of DNRL. However, in MSL localized underwater nodes provide their estimated locations, which already include estimation errors. Error accumulates at the nodes that use the coordinates of localized underwater nodes instead of the coordinates of the anchor nodes. Moreover, since localized underwater nodes also send localization messages, overall energy consumption and overhead of MSL is higher than DNRL. MSL uses the ToA method with oneway ranging; therefore, it requires synchronization similar to DNRL.

In the AUV-Aided localization (AAL) [10] technique is proposed by Erol, an AUV will traverse the UWSN periodically. The AUV obtains position updates by rising to the surface to use GPS, and then dives to a predefined depth. Node sends a request packet to the AUV and the AUV replies back with a message containing its coordinates. Node finds its distance to the AUV using ToA. Each node needs a pressure sensor to measure its depth and node is either static or have the ability to calculate its motion, it can be localized after getting message from three non-collinear AUV locations. In AAL underwater nodes are not silent, they send and receive messages. This localization technique consumes high energy. Another disadvantage is that accuracy for the AAL is depend on the how often the AUV updates or calibrates its location by coming to the surface of the sea. Another drawback of AAL is that the localization process requires more time because the AUV has to move all over the network. Logic of AUV-Aided and DNR-enabled schemes are similar, the AUV-Aided scheme is more flexible, because mobile reference (AUV) can traverse both horizontal and vertical pre-programmed routes while the mobile references in DNR-enabled schemes can only traverse vertically.

Localization with Directional Beacons (LDB) [11] utilizes an AUV to localize a stationary UWSN. In LDB the AUV uses a directional acoustic transceiver to broadcast self-coordinates and the angle of its transceiver’s beam. LDB is similar to AAL except for the following differences: (i) it proposes more accurate and efficient ways for localization based on simple calculations using directional instead of omnidirectional beaconing; and (ii) it reduces energy consumption by integrating “Silent Localization” [12]. However, it takes more time to localize all the nodes using directional beacons because the AUV needs to traverse the network at least twice, and the impact of node mobility on its accuracy could be significant. LDB does not require the time synchronization process.

In [13] AAL is extended to multi-stage AUV-aided localization (multi-stage AAL) scheme nodes are localized by the AUV in the first stage become reference nodes for localizing the remaining (non-localized) nodes in subsequent stages. Improved performance with multiple stages is traded off with higher communication costs in general. Multi-stage AUVaided localization technique, aimed at improving the “Multi-stage DNR” scheme by replacing the DNR with an AUV. This expands the coverage of the mobile beacon in the first stage while utilizing the multi-stage concept to localize the remaining un-localized nodes. This scheme requires Time synchronization.

Patrick Carroll proposes a localization approach [14] based on message broadcasts from multiple surface nodes, this system has several surface nodes and multiple underwater nodes. At predetermined intervals, the surface nodes sequentially broadcast their current location and time. The advantage of this localization method is that the broadcast messages can serve an arbitrary number of underwater nodes. The underwater nodes within the broadcast range will detect a series of transmissions and decode those messages. By comparing the reception time with the transmission time encoded in the message, each underwater node can obtain estimates of the time of arrivals (or time of flights) of messages from different surface nodes, based on which it tries to compute its own position. Broadcast from the surface to underwater nodes is a one-way transmission, therefore localization quality is independent of the number of underwater nodes in the network. Disadvantage of this scheme is that for localization to take place communication from surface node to underwater node is required, if the underwater node is at a greater depth communication has to travel by long distance and that communication may be affected by the underwater characteristics.

On-Demand Asynchronous Localization (ODAL) [15] is taken advantage of a sequential transmission protocol and the broadcasting nature of the acoustic underwater medium, the entire network can be localized simultaneously with small overhead. In this design, the network has three types of nodes: initiator nodes, anchor nodes, and passive nodes. Initiator nodes performing the localization protocol, and do so by broadcasting to initiate the transmission sequence with the anchor nodes. The anchor nodes collect and broadcasting as much information as possible. Passive nodes can listen to the broadcast messages, localizing themselves without consuming additional resources. Initiator node has the round-trip information from the anchor nodes, while passive nodes do not. This gives the network two modes of localization: a high-accuracy, on-demand mode for initiators (which can be AUV’s, central collection nodes, or highly mobile sensors) and a passive, lower-accuracy listening mode (for less mobile or critical nodes that need to update their position infrequently). These nodes can all simultaneously localize while co-existing in the same network, with all nodes possessing the flexibility to transition to either mode without requiring fundamentally different hardware or software. Passive node localization was first proposed in [16].

Distributed hierarchical localization scheme [17] is used for stationary UWSNs. The hierarchical architecture of Large- Scale Localization (LSL) uses: surface buoys, anchor nodes, and ordinary sensor nodes. In the ordinary sensor localization process, anchor nodes periodically broadcast their coordinates, while ordinary nodes send short messages periodically to measure distances to their neighbours via ToA. If an ordinary node gathers enough localization messages (i.e., three messages from non-coplanar anchors), it estimates its location. If an ordinary node is unable to collect the necessary number of messages to localize itself, it broadcasts the received localization messages along with the distance measurements to the anchors and other neighbouring nodes. Its main drawback is having high energy consumption and overhead due to beacon exchanges, localization messages, and the messages forwarded by unlocalized nodes. In [18] the authors show that LSL has the highest energy consumption and the highest overhead compared to DNRL and MSL. Moreover, LSL requires synchronization similar to DNRL and MSL.

In Table 1, we present the message exchange properties of the localization schemes, as well. Some methods only allow anchors to send localization messages and the underwater nodes do not send messages. These techniques are called as ‘silent’ while in some techniques underwater nodes also send messages for localization. These methods are called as ‘active’ methods. Active localization have higher communication overhead than the silent localization. Silent protocols generally require more number of anchor nodes or anchors with long-range communication capabilities. Some algorithms need synchronized time for finding the distance between nodes. Synchronization is needed or not is given in the table. Ranging method used is also mentioned in the table. Characteristics of anchor node is also mentioned in the table and whether the localization process is distributed or centralized also given in the table.

Table-I: Comparison of Localization methods

Name of Localization methods	Distributed/ centralized	Anchor type	Ranging method	Communication	synchronization
DNRL	Distributed	Non propelled mobile anchors	TOA(one way ranging)	Silent	Yes
MSL	Distributed	Non propelled mobile anchors and reference nodes	TOA(one way ranging)	Active	Yes
AAL	Distributed	Propelled mobile anchor(AUV)	TOA(Two way ranging)	Silent	No
LDB	Distributed	Propelled mobile anchor(AUV)	Range free	Silent	No
LSL	Distributed	Surface buoys, under water anchors and reference nodes	TOA(one way ranging)	Active	Yes
Multi stage AAL	Distributed	Propelled mobile anchor(AUV)	TOA(Two way ranging)	Silent & Active	Yes
ODAL	Distributed	Fixed anchor nodes	TOA	Silent& active	No
JSL	Distributed	Anchor nodes	TDOA	Active	No

Hybrid	Centralized and Distributed	Surface buoys, Anchor nodes	Range based & range free	Anchors active & nodes silent	Yes
LABE	Distributed	Beacons equipped with GPS	Range free		No
AFLA	Distributed	Anchor less, node fixed to bottom of the sea.	Connected via cable, range free	Silent & active, less communication	No

Joint solution for localization and synchronization (JSL) [19] is the first localization scheme which compensates the stratification effect in the underwater environment. In JSL. JSL consists of four major phases, Message Exchange, Synchronization, Localization and Iteration. In Phase I, an ordinary sensor node acquires reference time and location information from neighbouring reference nodes. In Phase II, synchronization process is performed by ordinary nodes based on the information obtained in Phase I. During Phase III, JSL carries out localization process based on the estimated propagation delays in Phase II. Additionally, a tracking algorithm, called interactive multiple model (IMM), is used to predict sensor node mobility to improve localization accuracy, such that the final location estimates are combined from the estimates based on Fermat's principle and the predicted value from IMM. Phase IV is iteration process, the position estimated in Phase III acts as input to Phase II to replace the rough position. Then Phase II and Phase III are repeated until locations, clock skew and offset become stable. During iterations, the output of synchronization is fed back as the input of localization, and the output of localization is fed back as the input of synchronization. In this way, synchronization and localization are interleaved and can benefit each other by improving the accuracy of both. During the localization phase, unlike other algorithms that assume sound waves travel in straight lines in the water environment, JSL compensates the stratification effect when performing the underwater acoustic ranging, so that the propagation delay estimation will be significantly improved.

The hybrid scheme [20] consists of four types of nodes which are Surface Buoys, Detachable Elevator Transceiver (DETs), Anchor Nodes and Ordinary Nodes. Surface buoy will be equipped with Global Positioning System (GPS) on the water surface for off-shore base station communication. A DET is attached to a surface buoy that can dive and rise to broadcast its beacon (position) signal at regular interval. The anchor nodes will compute their positions based on the position information from the DETs. Then anchor nodes starts broadcasting its location to ordinary nodes and area localization method will be applied for ordinary node localization. It is assumed in network architecture that underwater sensors are equipped with pressure sensor, which will provide depth (z-coordinate) of nodes. The hybrid scheme is divided in two steps. First is anchor node localization where range-based distributed method will be used that is time based infrastructure dependent method. Second is ordinary node localization where rangefree centralized method will be used.

LABE Algorithm [21] has error beacons, the Localization Algorithm based on Beacon Error Problem (LABE) will take the beacons as unknown nodes firstly to find the error beacons one by one, until all error beacons have been selected from all beacons. After that, the localization for unknown nodes is executed by traditional localization algorithm. An iteration selection process is designed to filter the error beacons one by one. LABE can effectively find the error beacons and has low complexity.

B Anchor *free Localization*

Anchor-Free Localization Algorithm (AFLA) [22] does not require anchor nodes, and has no additional equipment and energy cost. It is a high precision and energy efficient localization method. AFLA is a self-localization scheme. It can localize all nodes without anchor node's assisting. The localization error of AFLA is much less than Anchor-based and AUVaid localization algorithm. The average error of AFLA is 55.84% of Anchor-based localization algorithm and 29.86% of AUV-aid localization algorithm. [22].

From this survey we understood most of the UWSN localization needs Time synchronization, but the time synchronization problem can be avoided by using more accurate clocks in nodes and most of the localization algorithms needs extra device having moving capability through under water. AUV-aid localization algorithm has the largest average error, as it makes use of the relationship of nodes to compute node's position. In Active-restricted under water sensor networks anchors are heavy, they keep their positions bottom of the sea, and no longer move other nodes communicate with anchor nodes to find its position. Range-based schemes are better than range free because range measurements using acoustics are much more accurate and range free methods have high communication overhead and energy consumption. TOA-based ranging techniques are generally the preferred mode of range-based schemes, but require synchronization. Nodes can be deployed on the surface of the sea or bottom surface of the sea, but we cannot deploy nodes in between surface and bottom so to monitor the area in between surface and bottom of a very deep sea is difficult. Good localization must be silent localization in which nodes can find its location receiving messages from anchor nodes and gives good accuracy even the node is moving. This paper surveys the different localization algorithms that can be applied to the domain of UWSNs, which can be broadly classified into anchor-based and anchor-free schemes. The different schemes are compared, and their advantages and disadvantages discussed.

IV. CONCLUSION

In UWSNs, localization is a fundamental task where the location of a sensor can be used for data collection, node tracking and target detection. Traditional oceanographic localization techniques and WSN localization protocols do not meet the requirements of UWSNs. Recently, a large number of localization techniques have been proposed for UWSNs. Each algorithm has some advantages and disadvantages. Localization processes in UWSN can be categorized into two groups, first group need help of propelled moving anchor in the system, which knows its current position and second group of localization systems don't have moving anchors. Possibility of node movement due to the water movement and water characteristics makes the localization in UWSN difficult.

REFERENCES

[1] Melike Erol-Kantarci, Sema Oktug, Luiz Vieira, Mario Gerla, " Performance evaluation of distributed localization techniques for mobile underwater acoustic sensor networks" , Ad Hoc Networks, Elsevier, May2011, pp 61-72

[2] Chandrasekhar V, Seah W K, Choo Y S, "Localization in underwater sensor networks: survey and challenges". *Proc. of the 1st ACM International Workshop on Underwater Network*s, Sep 25, 2006, Los Angeles, California, USA, ACM, 2006: 33-40

[3] John Heidemann, Milica Stojanovic and Michele Zorzi, "Underwater sensor networks: applications, advances and challenges". *Phil. Trans. of the R. Soc*., 2012, 370, 158–175

[4] J. Heidemann, W. Ye, J. Wills, A. Syed, and Y. Li, "Research challenges and applications for underwater sensor networking," in Proc. IEEE Wireless Communications and Networking Conference (WCNC), Las Vegas, USA, April 3-6 2006.

[5] R. Stuart, "Acoustic digital spread spectrum: an enabling technology," *Sea Technology*, vol. 46, no. 10, pp. 15–20, 2005.

[6] A. Caiti, A. Garulli, F. Livide, and D. Prattichizzo, "Localization of autonomous underwater vehicles by floating acoustic buoys: a set-membership approach," *IEEE Journal of Oceanic Engineering*, vol. 30, no. 1, pp. 140–152, 2005.

[7] C. Bechaz and H. Thomas, "GIB system: the underwater GPS solution," in *Proceedings of the ECUA*, May 2001.

[8] Melike Erol, Luiz F. M. Vieira, Mario Gerla "Localization with Dive'N'Rise (DNR) Beacons for Underwater Acoustic Sensor Networks", *WUWNet'07,* September 14, 2007.

[9] M. Erol, L. F. M. Vieira, A. Caruso, F. Paparella, M. Gerla, and S. Oktug, "Multi Stage Underwater Sensor Localization using Mobile Beacons," *Proc. of the IEEE SENSORCOMM*, pp. 710–714, August 2008.

[10] M. Erol, L. F. M. Vieira, and M. Gerla, "AUV-Aided Localization for Underwater Sensor Networks," *Proc. of the WASA*, pp. 44–51, Aug.2007.

[11] H. Luo *et al*., "LDB: Localization with Directional Beacons for Sparse 3D Underwater Acoustic Sensor Networks," *J. Net*., vol. 5, no. 1, Jan. 2010, pp. 28–38.

[12] X. Cheng, H. Shu, Q. Liang, and D. Du, "Silent Positioning in Underwater Acoustic Sensor Networks," *IEEE Trans. Veh. Technol.*, vol. 57,no. 3, pp. 1756–1766, May 2008.

[13] Marc Waldmeyer, Hwee-Pink Tan , Winston K. G. Seah, "Multi-stage AUV-aided Localization for Underwater Wireless Sensor Networks", Workshops of International Conference on Advanced Information Networking and Applications, IEEE 2011

[14] Patrick Carroll, Shengli Zhou, Hao Zhou, Xiaoka Xu, Jun-Hong Cui, and PeterWillett" Underwater Localization and Tracking of Physical Systems", *Hindawi Publishing Corporation, Journal of Electrical and Computer Engineering*, Volume 2012.

[15] Patrick Carroll, Kaleel Mahmood, Shengli Zhou, Hao Zhou, "On-Demand Asynchronous Localization for Underwater Sensor Networks", *IEEE Trans. on Signal Process*. 2014

[16] X. Cheng, H. Shu, Q. Liang, and H. C. Du, "Silent positioning in underwater acoustic sensor networks," *IEEE Trans. On Vehicular Tech.*, vol. 57, no. 3, pp. 1756–1766, May 2008.

[17] Z. Zhou, J. Cui, and S. Zhou, "Efficient Localization for Large-Scale Underwater Sensor Networks," *Ad Hoc Net*, vol. 8, no. 3, May 2010, pp. 267–79.

[18] M. Erol-Kantarci *et al*., "Performance Evaluation of Distributed Localization Techniques for Mobile Underwater Acoustic Sensor Networks," *Ad Hoc Net*, vol. 9, no. 1, Jan. 2011, pp. 61–72.

[19] Jun Liu, Zhaohui Wang, Michael Zuba, Zheng Peng, Jun-Hong Cui, Shengli Zhou, "JSL: Joint Time Synchronization and Localization Design with Stratification Compensation in Mobile Underwater Sensor Networks", *9th IEEE Commun. Society Conf. on Sensor, Mesh and Ad Hoc Commun.and Networks (SECON),* 2012

[20] Dr. C. Rama Krishna, Pankaj Singh Yadav, "A Hybrid Localization Scheme for Underwater Wireless Sensor Networks", IEEE 2014

[21] Linfeng Liu, Xiaoqi Wu, Zhiwen Zhu, Ningshen Zhang, Ye Liu "A Localization Algorithm based on Beacon Error Problem in Underwater Wireless Sensor Network" *Proceedings of ICCT2013*

[22] Ying Guo, Yutao Liu, "Localization for anchor-free underwater sensor networks", J. Computers and Electrical Engineering, Elsevier , 2013, pp 1812–21