Indonesian Journal of Electrical Engineering and Computer Science
Vol. 1, No. 1, January 2016, pp. 119 ~ 125
DOI: 10.11591/ijeecs.v1.i1.pp119-125

Localization Schemes in Underwater Sensor Network (UWSN): a Survey

Mukhtiar Ahmed*, Mazleena Salleh
Department of Computer Science,
Faculty of Computing, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

Abstract

Underwater Wireless Sensor Networks (UWSNs) is much more attractive area for the researchers due to its versatile applications like tactical surveillance, assisted navigation, equipment monitoring, oceanography data collection, pollution monitoring, offshore exploration, disaster prevention and seismic monitoring. The researchers are also collecting the scientific data from underwater environment for observing mission. Due to the continuous node movement in underwater environment creates the majority of the problems for localization. Localization is one of the major issues in underwater environment. This survey paper focuses the different valuable localization schemes which focus the open issues and challenges for researchers.

Keywords: *ToA, TDoA, Range free, One way, Synchronization*

1. Introduction

In underwater sensor networks (UWSNs), determining the location of every sensor is important and the process of estimating the location of each node in a sensor network is known as localization [1]. For aquatic applications, it is important for every sensor node to know its current location information and synchronized timeliness with respect to other coordinating nodes [2]. Due to GPS impracticality, UWSNs can rely on distributed GPS-free localization or time synchronization schemes known as cooperative localization. The schemes related to this technique, especially for mobile networks, strongly depend on range and direction measurement processes [3]. The commonly used approach for terrestrial networks of measuring Time-Difference-of Arrival (TDoA) between the RF and acoustic signals is not feasible due to failure of the RF signal under water [4]. Receiver-signal-strength-index (RSSI) schemes are highly vulnerable to acoustic interferences such as multi-path, Doppler frequency spread and near-shore tide noise, so these cannot provide the accuracy for more than few meters [5]. Next, the schemes like Angle-of-Arrival (AoA) require special devices for directional transmission and reception which can increase the cost of the network [6]. Finally, the approaches like Time-of-Arrival (ToA) seem promising; they even provide accuracy at short ranges due to the acoustic mode of communication. Moreover, the acoustic signal is affected by the water currents, and variations in temperature and pressure, which requires sophisticated signal processing in order to overcome these error sources [3]. Localization is the main issue in underwater sensor network; localization of sensor nodes is necessary because the identified data is only significant when sensor node is localized. The terrestrial localization schemes cannot be used in underwater environment because the characteristics of the WSN are different than UWSN. For the underwater environment the localization schemes are divided into two categories: (1) Distributed localization and (2) Centralized localization.

2. Related Work

2.1. Distributed Localization

In distributed localization the each underwater sensor node itself calculate the position or distance of anchor node or neighbor node through its location estimation algorithm. This technique further divided into two categories: (i) estimation-based and (ii) prediction- based.

Received August 20, 2015; Revised November 19, 2015; Accepted December 11, 2015

2.1.1. Estimation-Based Schemes

The some famous schemes are like: Dive and Rise Localization (DNRL) is the distributed estimation-based localization can be used for mobile underwater acoustic sensor networks [7].

The DNRL scheme using the coordinate system with GPS when floating on sea surface and then dive in a sea to a definite depth and rise again. During the dive and rise period DNR message format and broadcast time will be prepared for the sensor nodes. Sensor nodes passively listens the two or three DNR messages and will able to calculate their location. This scheme uses the Time of Arrival (TOA) for calculating the distance. DNRL has high coverage and provides accurate estimation because the mobile anchors incline to the vicinity of the underwater nodes, and they update their locations periodically. Due to the motion capability the DNRL is the more expensive scheme.

Multi-Stage Localization (MSL) is the advanced version of DNRL [8]; because there are some issues with the DNRL; the DNRL beacons are not boosted, they are notable to move fast. This means that deeper node receives the DNR messages very late in comparison of those nodes which are closer to the surface; so due to that the localization information diffuses non-homogenously. The MSL is iterative localization; the authors have defined the localized nodes as beacons. These new beacons send the self-coordinate. DNR beacons dive only to a small depth rather than to cover whole monitoring area in this scheme. A node localized by mobile beacons becomes new anchor node and helps to localize other nodes if it lies below maximum dive depth of mobile beacons. The MSL approach increases the coverage and decrease the delay of DNRL. MSL also uses the Time of Arrival (TOA) like DNRL. The Mobility Current Model (MCM) has been used for node mobility. The overall energy consumption and overheads of MSL are higher than DNRL due to the calculation of location with error estimation factor.

Acoustic underwater vehicle-Aided Localization (AAL) as in [9] defines the deployment of sensor nodes in underwater environment are stationary and the acoustic underwater vehicle (AUVs) are able to localize the underwater sensor nodes. The AUV broadcast the wake-up message to the sensor nodes and on this wake-up message the sensor node will start the process of localization. The distance between sensor node and AUV can be calculated by sensor node on basis of round-trip time. Round-trip time parameters are ToA and request/response. Request/response is the communication method between sensor node and AUV; sensor node transfers the packets to the AUV and AUV will response back the message to the sensor node with the containing of its coordinates.

This kind of localization technique faces some strong issues like: (i) due to the communication overhead the sensor nodes consumes the more energy. (ii) The speed of the AUV is slow then localization process will be delayed. (iii) The accuracy of AAL will be affected due to the frequency updating of the AUVs.

Localization with Directional Beacon (LDB) [10] also uses the AUVs and underwater sensor nodes like AAL scheme. When AUV is on surface it will receive the coordinates from GPS and dives to the certain depth and will assign the coordinates to the sensor nodes as given in Figure 1. The coordinates assigning mechanism is described in Figure 2. On the trajectory path the AUV will assign the x_1, y_1 and x_2, y_2 coordinates with the time factor t_1 and t_2. LDB does not require the synchronization and it is range free technique. Underwater sensor nodes only listens the message of AUVs and are passive nodes that’s why the LDB is energy efficient scheme.

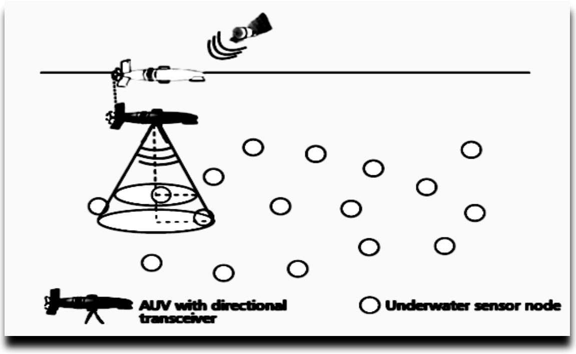

Figure 1. AUV with directional beam in LDB Scheme [10]

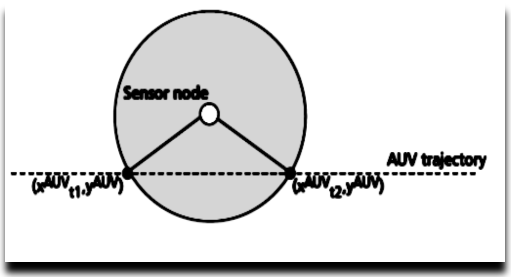

Figure 2. Localization of sensor node in LDB [10]

According to practical phenomena the LDB scheme has one drawback that is the authors have focused the movement of the AUV above the underwater sensor node; so this kind of movement practically is not possible. The accuracy depends on the frequency of the AUV messages. On sending of beacon signals the AUV consumes the long period; so may be the sensor node cannot estimate the localization within the time period and in resultant the delay factor will be increases or another possibility is that may be two sensor nodes estimate the same localization.

Large Scale Localization (LSL) scheme [6]; this scheme has utilized the three types of the sensor nodes: surface buoys, anchor nodes and ordinary sensor nodes. Surface buoys are deployed on surface of the water and will pick up their coordinates through GPS. The anchor nodes and ordinary sensor nodes are deployed under the water. On the early stage of the deployment the anchor nodes have got their localization by surface buoys. LSL is only reserved for the localization of the ordinary sensor nodes that’s why it is called the ordinary sensor nodes process. On arrival of three messages from co-planner anchor node the ordinary node will estimate its location. The ordinary sensor node will transfer the short message for to measure the distance to the neighbor nodes with the usage through ToA. The ordinary node can be the reference node after being localized and calculated the value of confidence. There is a responsibility of the reference nodes to send the localization messages to the sensor nodes. If the ordinary node is fail to collect the necessary number of messages to localize it then it will broadcast the received localization messages along with distance measurement to the neighbor and anchor nodes. The LSL is large scale hierarchical scheme. The major drawback of this scheme is that it is high energy consumption and overheads due to the localization messages, beacon exchanges and messages forwarded by un-localized nodes.

Underwater Positioning Scheme [2]; the authors of UPS have focused that the UPS is time difference of arrival (TDoV) scheme. The scheme is consists on anchor nodes and beacons signals as described in Figure 3. The anchor node A is called the master node and it will transfer the beacon signal for initiating the localization process the sensor node and anchor node B both will hear the beacon signal and in same way the anchor node B will send the beacon signal and anchor node A and sensor node will also hear the beacon signal. The anchor node A and B will also generate acknowledgement between each other for time difference received times of beacon signal for A or B and also transmission time of beacon signal. Same process is also for anchor node C and D. After this the TDoA measured by the sensor node are converted to the range differences by using the speed of sound. The range difference can be calculated by trilateration Equation to find out the location of the sensor node. The UPS scheme is silent and energy efficient because it will not send the localization messages and is purely silent.

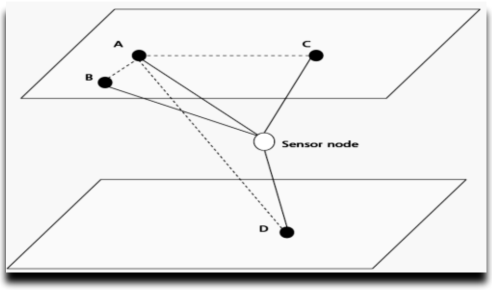

Figure 3. UPS Schemes with TDoAs & Beacon Signals [2]

However UPS drawback is when we deploy this scheme in large scale the majority number of anchor nodes are needed then the cost of overall localization will be increased and majority number of localization in this kind of scenario practically is not possible.

Large Scale Localization Scheme [11]; in this kind of localization scheme the authors have adapted the three phases: (i) surface anchor localization, (ii) iterative localization and (iii) complementary localization. In the surface localization phase the authors have used the UPS technique for localization for to communicate with the small group of anchor nodes. In iterative phase certain nodes are selected as reference nodes for localization and rest of the nodes works like UPS for localization. In the complementary phase the two phases already have initiated the localization request; this request resultant for the selecting the different set of reference nodes. The LSLS purely has inherited the advantage of UPS. The LSLS has higher overheads and energy consumption than UPS.

Underwater Sensor Positioning [12] is the projection based localization technique. In this technique the authors have focused that the underwater sensor nodes have ability to know its depth and with this information it will map the anchor nodes on horizontal plane on which it resides. In this technique they have converted the projection 3D into 2D. This kind of technique remained failure in comparison of other schemes.

2.1.2. Prediction-Based Schemes

Scalable Localization with Mobility Prediction (SLMP) [13] is the prediction-based scheme for mobile underwater acoustic sensor networks. The ordinary sensor node and anchor nodes are able to calculate their location on their previous coordinates and with their mobility patterns. Anchor node will check the mobility pattern with periodic behavior and it will trigger their update when fell necessarily. Anchor node when predict its location then with the help of surface buoys coordinate and distance measurement to buoys it will estimate its location. If the difference between estimated and predicted location is less than the threshold the anchor node assumes that its mobility model is accurate. If the mobility model is not accurate than anchor node will use the mobility prediction algorithm and will determine new mobility pattern and broadcast its coordinates along with the updated patterns. When ordinary node receives the messages from anchor node; the ordinary node will run its mobility prediction algorithm and updates the mobility pattern and location estimates. In this scheme if mobility patterns cannot change frequently the communication overheads in resultant will be low. SLMP scheme is appreciated well due to the water current but the drawback is that the relationship between localization protocol and mobility pattern is not clearly defined.

2.2. Centralized Localizations Schemes

Centralized localization further divided into two parts like distributed localization; one is estimation-based and other is prediction-based.

2.2.1. Estimation-Based Localization

Motion Aware Self Localization (MASL) [14]; in this localization scheme the underwater sensor node collects the distance estimation between itself and its neighbors. MASL uses the iterative estimates algorithm for to store the distance estimates. At each iteration, the algorithm refines position distributions by dividing the area of operation into smaller grids and selecting the area in which the node resides with the highest probability, and uses it in the next iteration [14]. MASL is centralized and there is no need of anchor nodes because whole the computation burden is on sensor nodes. In this scheme the data is collected and delivered to central station, and the relation between data and location is resolved at the post-processing stage.

MASL faces some drawbacks like: (i) in real sense this scheme is not suitable for UWSN because of the real time location information is necessary. (ii) MASL uses the synchronization so it will face high overheads due to continuous messaging.

Area-based Localization Scheme (ALS) as described in [15]. ALS is range free and coarse grained localization scheme. ALS estimates the area where the sensor node resides. In this scheme the sensor node passively hear the messages of anchor nodes with its power level and will send same messages to the sink node. The sink node knows the coordinates of the anchors; so the sink node easily determines the location of the sensor node. In this scheme there is no need of synchronization. The major drawback of this is that it is less energy efficient due to the high communication overheads with power levels of anchors.

2.2.2. Prediction-Based Localization

Collaborative Localization (CL) as defined in [16]. CL focuses the fleet of drifter technique in which the mobile underwater sensor nodes have ability to set the underwater columns with the ability of ascend and descend. CL scheme is used for specific applications where the sensor nodes are responsible to collect the information from the depth of the water and will carry that information towards the surface. CL architecture is based on *profiler;* who tells the follower sensor node for estimates the future locations. Profiler can measure the distance on basis of ToA. Major drawbacks of CL are: (i) it requires synchronization and (ii) CL architecture is only for sparse or non-homogenous networks; so its performance significantly will be degraded.

3. Performance Analysis

Table 1 focuses the overall summary and evaluation method of the localization schemes under which the characteristics according to calculated parameters are given.

Table 1. Summary of localization schemes

Scheme	Distributed	Centralized	Estimation	Prediction	Syn	Communication	Rang / Method	Anchor Type
DNLR	√	x	√	x	Yes	Silent	ToA One way	Mobile anchors
MSL	√	x	√	x	Yes	Iterative	ToA One way	Mobile anchors with reference nodes
AAL	√	x	√	x	No	Silent	ToA Two way	AUV as Mobile anchors
LDB	√	x	√	x	Yes	Silent	Range Free	AUV as Mobile anchors
LSL	√	x	√	x	No	Iterative	ToA One way	Surface buoys, underwater anchors and reference nodes
UPS	√	x	√	x	No	Silent	TDoA	Stationary anchors
LSLS	√	x	√	x	No	Active	Not specified	Stationaru anchors and reference nodes
USP	√	x	√	x	No	Active	Not specified	Stationary anchors
SLMP	√	x	x	√	Yes	Iterative	ToA One way	Surface buoys, underwater anchors and reference nodes
MASL	x	√	√	x	Yes	Active	ToA One way	No anchors
ALS	x	√	√	x	No	Active	Range free	Anchors with power levels
CL	x	√	x	√	Yes	Active	ToA One way	No anchors

4. Conclusion

This survey paper focuses the centralized and distributed localization schemes. The both of the schemes are further divided into estimation based and prediction based schemes. The survey paper focuses the weaknesses of every scheme. The Schemes further analyzed through the Table 1; in which its different parameters are defined like: synchronization, communication, range method and anchor types used by schemes. This survey paper focuses the open issues for the researchers in the field of localization.

References

[1] V Chandrasekhar, WK Seah, YS Choo, and HV Ee. "*Localization in underwater sensor networks: survey and challenges*". in Proceedings of the 1st ACM international workshop on Underwater networks. 2006: 33-40.

[2] AY Teymorian, W Cheng, L Ma, X Cheng, X Lu, and Z Lu. "3D underwater sensor network localization". *IEEE Transactions on Mobile Computing*. 2009; 8: 1610-1621.

[3] M Ayaz, I Baig, A Abdullah, and I Faye. "A survey on routing techniques in underwater wireless sensor networks". *Journal of Network and Computer Applications*. 2011; 34: 1908-1927.

[4] A Wahid, S Lee, D Kim, and KS Lim. "MRP: A Localization-Free Multi-Layered Routing Protocol for Underwater Wireless Sensor Networks". *Wireless Personal Communications*. 2014; 77: 2997-3012.

[5] S Climent, A Sanchez, JV Capella, N Meratnia, and JJ Serrano. "Underwater acoustic wireless sensor networks: advances and future trends in physical, MAC and routing layers". *Sensors*. 2014; 14: 795-833.

[6] Z Zhou, JH Cui, and S Zhou. "Efficient localization for large-scale underwater sensor networks". *Ad Hoc Networks*. 2010; 8: 267-279.

[7] M Erol, LF Vieira, and M Gerla. "*Localization with Dive'N'Rise (DNR) beacons for underwater acoustic sensor networks*". in Proceedings of the second workshop on Underwater networks. 2007: 97-100.

[8] M Erol, F Vieira, A Caruso, F Paparella, M Gerla, and S Oktug. "Multi stage underwater sensor localization using mobile beacons". in *Second International Conference on Sensor Technologies and Applications, 2008. SENSORCOMM'08.* 2008: 710-714.

[9] M Erol, F Vieira, and M Gerla. "AUV-aided localization for underwater sensor networks". in *International Conference on Wireless Algorithms, Systems and Applications, 2007. WASA 2007.* 2007: 44-54.

[10] H Luo, Z Guo, W Dong, F Hong, and Y Zhao. "LDB: Localization with directional beacons for sparse 3D underwater acoustic sensor networks". *Journal of networks*. 2010; 5: 28-38.

[11] W Cheng, A Thaeler, X Cheng, F Liu, X Lu, and Z Lu. "Time-synchronization free localization in large scale underwater acoustic sensor networks". in *29th IEEE International Conference on Distributed Computing Systems Workshops, 2009. ICDCS Workshops' 09.* 2009: 80-87.
[12] X Cheng, H Shu, Q Liang, and DC Du, "Silent positioning in underwater acoustic sensor networks". *IEEE Transactions on Vehicular Technology*. 2008; 57: 1756-1766.
[13] Z Zhou, Z Peng, JH Cui, Z Shi, and AC Bagtzoglou. "Scalable localization with mobility prediction for underwater sensor networks". *IEEE Transactions on Mobile Computing*. 2011; 10: 335-348.
[14] D Mirza and C Schurgers. "*Motion-aware self-localization for underwater networks*". in Proceedings of the third ACM international workshop on Underwater Networks. 2008: 51-58.
[15] V Chandrasekhar and W Seah. "An area localization scheme for underwater sensor networks". in *OCEANS 2006-Asia Pacific*. 2007: 1-8.
[16] D Mirza and C Schurgers. "Collaborative localization for fleets of underwater drifters". in *OCEANS 2007.* 2007: 1-6.