A Survey on Distributed Localization Techniques in Acoustic Underwater Sensor Network

Manpreet[1] and Jyoteesh Malhotra[2]
[1,2]*Department of Computer Science & Engineering,*
Guru Nanak Dev University Regional Campus, Jalandhar, India
E-mail: [1]manpreetpawar17@gmail.com, [2]jyoteesh@gmail.com

***Abstract*—Underwater acoustic sensor network is an enabling technology for detecting the animals in water, other aquatic applications and at such situations where human operation is not possible under water. It consists of sensor nodes and vehicles deployed underwater to perform monitoring task. Recently it gained much attention. Because of unapproachable underwater situation, the task of finding a location of underwater sensor node will become pivotal. In contrast terrestrial localization, it is complicated. Various localization techniques for underwater acoustic sensor network have been proposed in the literature. This paper has thoroughly surveyed these technique, their issues and challenges have been extracted which will act as a guideline for active researches.**

Keywords: Underwater, Localization, AUV, UW-ASN

I. INTRODUCTION

Underwater acoustic sensor network (UW-ASN) is taking important place because it is needed to monitor the aquatic environment. It is useful in many applications as for underwater environment monitoring, biomedical health monitoring, detecting the river or sea pollution, oil monitoring, disaster prevention and oceanographic data collection needed to protect the aquatic life. Localization is one of the major and challenging tasks in UW-ASNs used for track the nodes, improve the medium access control and network protocols. UW-ASN consist Multiple unmanned or autonomous underwater vehicles (UUVs, AUVs), equipped with under water sensors to collect the data. To achieve this objective, sensors and vehicles self-organize in an autonomous network; all these can adapt the properties of ocean [1]. There are some vehicles exists which are used for aquatic purposes. These vehicles are used in UW-ASN localization. Localization in UW-ASN is different than terrestrial localization because of GPS un-availability under water, radio frequency signals have limited propagation and UW-ASN faced equipment failure due to corrosion attack and other attacks faced under water so terrestrial localization techniques can not apply for UW-ASN localization. Localization techniques for UW-ASNs should tackle lack of GPS, 3-D space, mobility, minimal message exchange and try to be robust under sleep/wake-up cycles [3]. Architecture of USN designed carefully so that it can efficiently adapt the UW-ASN. Architecture should be optimized whenever possible [1]. There are following types of architectures in UW-ASN:

A. *Static two-dimensional UW-ASNs*

Sensor nodes are anchored to the bottom of the water with the deep ocean anchors. It is applicable for environmental monitoring.

B. *Static three-dimensional UW-ASNs*

Sensor nodes float at different depth. Sensor nodes make a network. It is useful for monitoring pollution and other aquatic environment activities.

C. *Three-dimensional Networks of Autonomous Underwater Vehicles (AUVs)*

This architecture consist two parts. One part is fixed, consists anchored sensor nodes and mobility part contains AUV which used to broadcast the message.

The rest of the paper is organized as follows. Section II describes requirements of localization in UW-ASN. Section III describes the proposals of UW-ASN localization techniques. Section IV describes open issues and future scope before the paper is concluded in section V.

II. REQUIREMENTS OF UW-ASN LOCALIZATION

There are many terrestrial localization techniques exist. Then why UW-ASN localization required [1]. Firstly this section will describe the difference between terrestrial and UW-ASN localization:

A. *Deployment*

Deployment in terrestrial is very dense but underwater it is deemed to be sparser due to cost involved and other challenge factors.

B. *Power*

Power needed for UW-ASN is more than terrestrial localization because the equipments consume more energy and also due to channel impairments more energy needed for localization.

C. *Memory*

Terrestrial sensor nodes require less memory, but UW-ASN requires cache to collect the data for localization of sensor nodes stack.

D. Communication

In terrestrial sensor nodes communication done through electromagnetic waves but in UW-ASN for communication acoustic channels are deployed.

E. Cost

Terrestrial localization equipments are not as much expensive as UW-ASN. This is because UW-ASN is very complex and there is extra protection needed for underwater equipments to protect from corrosion and other oceanic attacks.

Considering above differences of terrestrial sensor network and UW-ASN, the terrestrial localization techniques are not suitable for UW-ASN. So UW-ASN needs different localization techniques.

III. Proposals of Localization Techniques

Considering the importance UW-ASN localization various researchers have suggested the localization techniques UW-ASN as mentioned below.

Melika Erol, Luiz F.M. Vieira, and Mario Gerla [2] proposed Dive 'N' Rise (DNR) positioning. In this technique DNR beacons used. DNR beacons float above water and get coordinates from GPS then after diving in water these broadcast its coordinates to sensor nodes which are underwater. Simple apparatus used which can dive with weight and it releases its weight into the depth of water and rise with bladder. DNR can be used with current or without current. Without current sensor nodes do not drift and only receive and process message but with current sensor node can drift.

Melika Erol, Luiz F.M. Vieira, and Mario Gerla [3] propose AUV aided localization. In this AUV receives GPS signals while floating above water then it dives and move among sensor nodes. While moving it broadcast its message among sensor nodes. It is mainly used where sensor nodes are freely scattered in water and they have no network connection. Sensor nodes are not tied with any fixed object and can freely move.

Hanjiang Luo, Yiyang Zhao, Zhongwen Guo, Siyuan Liu, Pengpeng Chen, and Lionel M. Ni [4] propose localization using directional beacons (UDB). This technique replaces the Omni-directional localization. Omni-directional localization provides more extensive coverage but directional localization is applied for some special cases [5]. In this technique there is no need of communication between sensor node and AUV. AUV broadcast message, sensor nodes only listen the AUV. This technique is very useful in strap area and reduces energy consumption of sensor nodes. UDB can provide accurate localization.

Zhong Zhou, Jun-Hong Cui, and Shengli Zhou [6] propose localization in large scale underwater sensor network. This technique consist three types of nodes: 1) surface buoys which can drift on the water surface and equipped with GPS. These nodes can get their absolute location from GPS or by some other manner.2) Anchor nodes can communicate with surface buoys and ordinary nodes. Anchor nodes get their position from surface buoys and assist ordinary nodes to do localization. 3) Ordinary nodes which can not directly communicate with surface buoys but can communicate with anchor nodes to get their location. In [7] author shows that this technique has higher energy consumption as compared to DNR localization.

Kai Chen, Yi Zhou, and Jianhua He [8] propose Detachable Elevator Transceivers localization scheme. This technique consist three types of nodes: 1) Surface buoys which can drift on the water surface and equipped with GPS. These nodes can get their absolute location from GPS or by some other manner.2) DET which are attached to surface buoys and can dive and rise in water to broadcast its position. 3) Anchor nodes can communicate with DET. If any anchor node receive message from three DET then it calculate its location and help to locate the ordinary nodes. 4) Ordinary nodes which only listen to anchor nodes. If any ordinary node receive message from three anchor nodes then it calculate its location. This technique is also employed in [9]. This technique increase localization ratio, scalability and decrease cost of the system.

A.K. Othman, A.E. Adams, and C.C. Tsimenidis [10] propose a node discovery and network discovery localization technique. This technique is named as anchor free and also employed in [11]. In this technique one node is selected as seed node and broadcast its message to gain information from its neighbors. Then on the basis of reply from neighbors its select farthest node as seed node. Seed node repeats the process. Firstly nodes define local coordination system then network coordination system.

Xizuhen Cheng, Haining Shu, Qilian Liang, and D. H.-C. Du [12] proposed silent position UW-ASN termed as UPS. This technique uses 4 anchor nodes to find location which is based on time difference of arrival. As anchor A is selected as master anchor which initiate the localization. It sends the beacon signal to B anchor and sensor nodes. B anchor reply the time of arrival of beacon signal and transmission time of its beacon signal. Then B, C and other anchor repeat the same process. Sensor nodes hear it and calculate the TDoA of beacons. It converts multiply the TDoA with speed of sound to calculate the range difference. Sensor nodes know the location of anchor nodes and do the self localization. This technique has low overhead, require no special hardware and provide silent positioning [13].

H. Tan, A.F. Gabor, Zahi Ang Eu, and W.K. G. Seah [14] proposed a wide coverage positioning termed as WPS. UPS technique is not able to find the locality of all sensor nodes. Sensor nodes which are near to anchor node need five anchors for localization which is done in [12]. WPS is same as UPS but it uses five anchors instead of four anchors. WPS is more accurately localize than UPS and also included the timeout.

TABLE I LOCALIZATION TECHNIQUES

Localization Technique	Anchor Property	Merits	Issues
AUV-Aided Localization	Propelled mobile anchor (AUV)	It Exploit the mobility of AUV to overcome the lack of GPS and sensor nodes can communicate in disconnected network	Battery of AUV drained very fast. There is high localization delay due to slow speed of AUV
Localization with directional beacons	Propelled mobile anchor (AUV)	Directional localization provides accurate localization.	AUV is restricted to float over the UASN which is not possible in practice
Dive 'N' Rise Localization	Non-Propelled mobile anchor.	It is less expensive and can localize 100% nodes with small errors	Deeper node get massage later than the node closer to the surface and it increase the localization delay
Large Scale Hierarchal localization	Underwater anchors, Surface buoys and reference node	It achieves high localization coverage with low error and low communication cost.	It has highest energy consumption and large overhead of exchanging beacons and messages.
Localization with Detachable Elevator Transceiver (DETL)	Underwater anchors, Surface buoys attached DETs and reference node	It decreases the cost of system and increase scalability.	It has large overhead.
Node discovery and network discovery localization technique	Anchor free	Local coordination system can make without need of anchor node.	Node discovery process take long time and it has high overhead and high energy consumption.
Silent position in Under water Sensor Network (UPS)	Four stationary anchors	UPS require no time synchronization and provide location privacy at under water sensor nodes.	It cannot localize the nodes which are outside area of four anchors.
Wide Coverage Positioning system(WPS)	Five stationary anchors	It claims high localizability space, high localization latency and low energy consumption as compared to UPS.	Its localization delay and communication cost is high as compared to UPS
Time Synchronization free localization in large scale under water(LSLS)	Stationary anchors	LSLS increase coverage of UPS by adding iterative phase.	LSLS has higher overhead and higher energy consumption than UPS.
Multi Anchor Node Collaborative Localization(MNCL)	Stationary anchors	MNCL increase the localization with low average error ration and low average energy consumption. It is more efficient than LSLS.	If ordinary nodes send more localization request messages, average energy consumption increases.

Wei Cheng, A. Thaeler, Xiuzhen Cheng, Fang Liu, X. Lu, and Zexin Lu [15] proposed a localization scheme in large scale under water termed as LSLS. This technique uses four anchor nodes as UPS but it adds iterative localization phase and complementary phase. Firstly it done localization as in UPS, then in iterative phase it select some nodes as reference nodes and help to localize other sensor nodes and repeat the localization process iteratively. Finally in complementary phase, un-localized nodes initiate localization and select different set of nodes as reference nodes and repeat localization.

Chenyu Zhang, Guangjie Han, Jinfang Jiang, Lei Shu, Guogao Liu, and Joel J.P.C Rodrigue [16] proposed multi anchor node collaborative localization (MNCL). MNCL divide the whole process into five sub-processes:-1) Ordinary node process. 2) Ordinary node localization process. 3) Iterative location estimation process. 4) Improved 3D Euclidean distance estimation process. 5) 3D DV-Hop distance estimation process based on two-hop anchor nodes. There are three types of nodes Surface buoys, anchor nodes and ordinary nodes. Monitoring area is divided into small cubes which are accomplished by surface buoys, each anchor node belong to one small cube region. Collaborative algorithm is applied to one cube region and to multiple cube regions. In third sub process temporary position of ordinary nodes is determined and in fourth sub process two hop anchor node help to localization with ordinary nodes.

By considering the above techniques, issues and merits of localization techniques are summarized in Table I.

IV. OPEN ISSUES AND FUTURE SCOPE

Various localization techniques have been reported in the previous section related to the UW-ASN. Considering the merits and opportunities available in the approach of localization of UW-ASN, open issues and future scope has been presented here:

Due to limited memory the recorded during the monitoring of aquatic environment is very limited. Any instrument failure fails the complete monitoring mission. Various instruments used in acoustic sensor network are very expensive. Acoustic sensor network need the location of some nodes should be known which practically very difficult task is.USN has very limited bandwidth. There is high bit error rate.

Instruments of USN usually fail due to corrosion. Use of cross layer approach is still an open issue. In future to overcome the various issue new techniques can be adopted or existing techniques can be improve in some manners. As cross layer approach can overcome the energy consuming problem of various nodes. Link quality should be considered to improve the accuracy. There is also need to consider the impact of localization techniques on location based protocols.

V. Conclusion

UW-ASN localization techniques play crucial role to find the location of sensor nodes and collect the monitoring data. Numerous localization techniques are proposed. This paper surveyed the UW-ASN localization techniques, merits and issues of those techniques. All these techniques have contributed to localize the sensor nodes but still there is a scope of holistic approach to solve the issues concerned. It is hoped that various issues highlighted here will prove to be helpful for the researchers working in this area.

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