Underwater Wireless Sensor Network Localization

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ABSTRACT
This paper reviews the existing localization techniques and parameters in Wireless Sensor Networks (WSNs) and few schemes are discussed in term of Terrestrial WSNs. The fundamental differences between Underwater and Terrestrial WSN are highlighted. Furthermore, the paper analyzes the few existing aquatic localization schemes and presents a discussion in two parts including general localization problems and particular underwater localization challenges. As conclusion, the paper introduces the necessary future works in term of Underwater WSN localization.

Keywords
WSN, Underwater WSN, Terrestrial WSN, Localization protocol

1. INTRODUCTION
Nowadays, Wireless Sensor Network (WSN) and its applications have caught the interest of many researchers. The applications enable human to monitor, track, surveillance variety of objects within different environments such as habitat monitoring, animals’ movement tracking, health monitoring, environment exploration, and natural disaster prediction. While many of these applications were not implementable, environments were not accessible for human before the genesis of this new technology. Generally, WSNs are designed based-on application’s objectives and operational environment. It can be classified to five main categories Terrestrial WSN, Mobile WSN, Underground WSN, Underwater WSN, and Multimedia WSN [38]. However, the sensor node has its own specifications and resource constraints including un-replenished energy supply, limited communication range, low bandwidth, limited processing ability and storage, and random deployment. Additionally, the networks work in an ad-hoc manner on a large area. Apart from sensor constraints, environments, and applications, there is a unique trans-prerequisite requirement for all applications which is the origin of information. It is essential to be aware about the location of information; otherwise knowing about phenomenon without location-knowledge would be useless. The procedure to find the location of sensor which has emitted the signal is called localization. Although, localization is a mature field in cellular networks and also robotics but it is more challenging and complicated in WSNs. Additionally, mobile phones and robots in their respected area are more powerful and flexible than sensor nodes because the power is rechargeable, size is immaterial, and processing ability is much higher. Generally, there are two important properties in sensor localization- accuracy and cost. Based on granularity of information, [8] defines two different localization categories include fine-grained and coarse-grained. The fine-grained techniques use signal ranging parameters which are more accurate with higher cost. To achieve accuracy, there are few signal ranging parameters that can be employed to measure distance. The signal ranging parameters are - Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), and Received Signal Strength Indication (RSSI). However, the range measurement is a mature enough in signal processing field, but they are mostly challenging in sensor networks because of the node constraints. Despite the high accuracy, ToA and TDoA are depended on precise synchronization between nodes; AoA demands special antenna arrays which are very costly for sensor networks and needs one distance measurement technique (typically uses TDoA); and RSSI is the only solution that does not need any extra hardware and processing ability but suffers from environment reflections and interferences. However, applications like healthcare monitoring and target tracking need more accuracy and can employ ranging parameters. On the other hand, when precise accuracy is not needed, there are few well-known methods such as connectivity and hop-counting that can provide a coarse-grained estimation. But they rely on existing resources of sensor nodes and normally the schemes are low-cost and power-efficient. Applications such as disaster prevention and environment monitoring that do not need precise location can employ these types of low-cost techniques. The costs within sensor network include power-consumption, size, and price. On the other hand, accuracy and cost are closely related to each other and normally higher accuracy equals more cost. During last few years, numerous efforts have been done to develop an efficient localization technique either the low-cost with a coarse estimation or precise but costly approaches. But the main barrier is that the sensor network characteristics are variable and they are typically dependent on the environments and application objectives.
Localization techniques have been extensively investigated for Terrestrial WSNs. As Terrestrial WSNs, Multimedia WSN, Mobile WSN, and Underground WSN (inside caves and mines) have a common property for data communication, so communication media is air; then it is possible to involve Terrestrial WSN protocols in Mobile, Multimedia, and Underground WSNs. Although it is possible to apply many of Terrestrial WSN criteria within Aquatic WSN, but there is a fundamental challenge, the nodes intercommunicate within water which is different communication media.

The paper is organized as follows: The motivation of this research is discussed in section two. The literature review and related works are presented in section three. Section four presents a discussion and critical analysis on the existing works. Finally, the paper is concluded with necessary future works.

2. MOTIVATION

Most techniques in localization focus on terrestrial WSN. This could be conceivable because of several reasons - the number of feasible applications is high, the possibility of commercialization and variety of simulators and real equipments are available to experiment and evaluate the designed protocol. Recently, the significance of Aquatic WSN applications has attracted the attention of many researchers. It is believed that the potentiality of remote sensing for coastal management and surveillance tasks, or ocean monitoring for disaster prevention and recovery applications be supported by deployment of an underwater acoustic sensor network [16]. In the presence of numerous literatures and while many of terrestrial protocols are applicable in Underwater WSN, however, aquatic environment must be researched carefully because of three fundamental differences [18] which are:

1. Radio is not suitable for aquatic communication because of highly limited propagation.
2. The shift from radio-frequency to acoustics change the physics of communication from speed of light (3x10^8 m/s) to the sound velocity (1.5x10^3 m/s).
3. Energy conservation of aquatic WSN is different from Terrestrial because the sensors will be larger, and some applications require large amounts of data but infrequently (once per week or less).

Although many of Terrestrial WSN principles could be applied in Aquatic WSN, but the propagation delay has profound implications on localization and synchronization [18].

3. LITERATURE REVIEW

As discussed in section I, the importance of wireless sensor network is due to its applications, while within the variety of applications, different data are collected from environment such as temperature, pressure, movement, humidity, and pollution. Undoubtedly, in such manner that data is collected from a large number of deployed nodes within a large area, the knowledge of where the data were gathered is indispensable. Otherwise, having the data in hand without positioning-knowledge is meaningless. Due to significance of localization, many efforts have been done to propose an efficient algorithm and variety of parameters and techniques are employed based-on application needs, environment, and the sensor constraints. Therefore, in this section, the basic elements and popular parameters which are extensively used in WSN localization are briefly introduced as follows:

1. Signal ranging parameters including Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), and Received Signal Strength Indication (RSSI). In fact, these are matured techniques in term of ranging estimation within signal processing field and further have been widely used to measure mobile users location in cellular networks [35].
2. Non-signal-ranging metrics include connectivity, proximity, and hop-count. Connectivity metric considers whether there is any node available within the communication range. Obviously, proximity takes place via connectivity, so hereinafter connectivity is used within the paper for classification. Hop-count refers to the methods which employ traditional distance vector routing concepts to resolve positioning problem in WSN. The categories will be discussed in detail within next section.
3. Mathematical techniques include triangulation, trilateration, and multilateration.
4. There are several nodes involved in WSN localization which include sink, beacon, and unknown-node. The sink is a special node that sends commands to sensor nodes and collecting data from them. The data are processed by the sink itself or passed to a central agent [37]. The beacon (also called anchor, landmark, and seed, hereinafter simply calls beacon to prevent of phraseology redundancy) is a special node with extra capabilities and pre-knowledge of its position. It disseminates its coordinates periodically, in addition to passing the received signals from sensor nodes to a central agent like sink. The unknown node is an ordinary sensor node with the ability to detect phenomena with no position-knowledge.

3.1 Classification and related terrestrial works

In such manner that there are numerous literature and approaches, classification of algorithms and analysis of the used parameters seem a necessary task that could be helpful to lead future works and may prevent from probable repetitive methods. Thus the available categories of sensor network localizations are discussed here. [8] is one of the pioneer literatures that classify the WSNL techniques to fine-grained and coarse-grained. The signal-ranging-parameters-based algorithms are applied to the fine-grained branch while connectivity and hop-count are aoolied to coarse-grained localization. On the other hand, there is a popular classification that divides WSNL approaches to range-free and range-based proposed by [17]. Moreover, [35] classifies the methods to localization with beacons, localization with moving beacons, beacon-free localization. Moreover, signal concepts, connectivity, proximity, and hop-count based on one-hop and multi-hop are manipulated as classification parameters in [28].

Ranging means estimating the distance between two communicating nodes [17]. Fundamentally, ranging is the distance measurement process between two positions, initially
applied on mobile nodes like cellular networks. Characteristically, most of WSNL approaches estimate the node-position based on measuring the distance to the beacons as reference points whether the method uses signal ranging parameters to precisely measure the distance between sensor nodes, or handle non-signal-ranging techniques to estimate the distance and so extract a coarse estimation. For example, hop-count approaches extract average-hop-distance (see section 2.4.2) to determining a coarse positioning knowledge. Unlike mobile ad-hoc network, the coordinates of a node is a crucial matter in WSN applications. Using range as main classification parameter might not be fair because of aforementioned causes. Apart from ranging factors, classifying the WSNL methods based on moving beacon, stationary beacons, and none-beacon is not scalable, because it makes small groups in moving beacon and none-beacon sides versus a very large group in localization with beacons group. Also the classification proposed by [28] looks too broad because it considers range-based and range-free in term of hop numbers. Consequently, the fine-grained and coarse-grained categories are used for classification within this paper because of their generality. Additionally, an overall view of existing Terrestrial WSN localization schemes is presented in Figure 1.

3.1.1 coarse-grained localization Techniques

Coarse-grain technique does not employ any signal ranging parameters in calculating the exact distance between a beacon (as reference node) and an unknown node [8]. There are two main parameters to extract node position which are connectivity and hop-count. The main advantage of coarse-grained techniques is that they do not impose any extra cost on sensor nodes since they do not require any extra hardware. However, they are less accurate and less scalable compared to the fine-grained techniques. The following subsections briefly discuss both techniques.

Connectivity-based.

The existence of connectivity is the measurement used based on quality or possibility of being in communication range of nodes. The unknown node extracts its position based on better proximity to other beacons or location-aware nodes within its bounds communication range. Thus this category is also called proximity-based localization. So the existences of connection between nodes enable unknown nodes to estimate its position. The proposed schemes can be divided into two subcategories based on the computation manner either distributed or centralized.

- Distributed. Centroid [8] is the pioneer algorithm in this category as a receiver connectivity-based localization approach which defines the beacons (as reference nodes) situated in known position propagate beaconing messages consist of their coordinates periodically. It is assumed that beacons are synchronized to avoid collisions. When unknown node listens to the beacons for a distinct time, it collects as many as possible messages from beacons and calculates its coordinates based on these information using equation (1); where \( k \) is the number of received beaconing messages.

\[
(X_{est}, Y_{est}) = \left[ \frac{X_{1} + \ldots + X_{k}}{k}, \frac{Y_{1} + \ldots + Y_{k}}{k} \right]
\]  

Moreover, the authors have used an idealized radio frequency (RF) model with two assumptions including perfect spherical radio propagation and identical transmission range for all radios for predicting bounds. The receiver-based indicates that each unknown node estimates its coordinates by itself based on distributed connectivity algorithm. However, the synchronization is the main weak point and the accuracy of this algorithm depends on the beacons density, thus the authors present three adaptive beacon placement algorithms in [9] to improve the accuracy. Moreover, [6] has proposed weighted centroid localization (WCL) algorithm that is derived from centroid determination and calculates the position of devices by averaging the coordinates of reference points. To improve the calculated position in real implementations, WCL uses weights to attract the estimated position to closer reference points and thus provide the coarse localization. On the other hand, [4] has presented two connectivity-based algorithms called Centroid-based Preplaced Beacon Localization (CPBL) and Centroid-based Scalable Node Localization (CSNL). Correspondingly, CPBL utilizes the geometry localization algorithm in order to set the beacon nodes whereas in CSNL, normal nodes can upgrade as beacons. Besides, the method employs RSSI to obtain the distance which is ignored in the original centroid because of unpredictable variation due to fading, multipath, and interferences [8]. There is another connectivity-based approach that handles Multi-Dimensional Scaling (MDS) as a data analysis technique that transforms proximity information into a geometric embedding [34]. In the field of connectivity-based localization of mobile nodes, [20] introduces the sequential Monte Carlo Localization (MCL) method to WSNL and argues that it can exploit mobility to improve the accuracy and precision of localization. Although the MCL has widely studied in robotic localization, but there are some essential differences between the robot and sensor abilities such as memory to keep a pre-planned map, controlled movement, and high-computing skills. Recently, [2] has proposed new algorithm upon Monte Carlo localization Boxed (MCB) while they changed utilization of beacon information and sample-drawing method of MCL to achieve better result.

There is another type of distributed connectivity-based localization which divides the terrain into triangular regions based-on all sets of three beacon nodes. Approximate Point-In-Triangulation Test (APIT) is proposed by [17] such that each node chooses three audible beacons and calculates the Center Of Gravity (COG) to find the best three beacons which have the best COG result and consequently estimates its position by triangulation.

- Centralized. [12] proposed an approach that all nodes send information to a central computer (sink) to estimates the position of nodes. Furthermore, the authors define a proximity constraint according to the maximum frequency range of nodes so that the separation of all nodes should be less than this maximum range and form the convex position estimation. They also manipulate a polynomial-time algorithm based on in-
terior point to solve linear programs and semi-definite programs. Area Localization Scheme [37] is another approach such that sensor nodes convey all localization calculation to the sink where the position of nodes is calculated based on the received signals from few beacons.

**Hop-count-based.**

Similar to classical distance vector routing, each node maintains a table of three parameters \( \{X_i, Y_i, H_i\} \) recorded from all available beacons, X and Y are the coordinates of beacon i and H is the number of hop between them. Update message is sent to only immediate neighbors. [30] proposed this approach in WSNL to estimate the node position which is called Ad-hoc Positioning System (APS), however it is widely known as DV-Hop measurement method. Unlike the traditional DV-Hop, the authors have added one more phase to the technique that is calculating the average hop size in meter as a correction metric for each beacon using equation 1.2 and disseminating these corrections to the nodes. However, each node normally store and forward the correction metric of its closest beacon and drops all subsequent ones. Finally, the nodes calculate their distance to three available beacons by \( H_{1,2,3} \times C_{node} \) and employ triangulation to estimate their position.

\[
C_i = \frac{\sum \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}}{\sum H_i}, \quad i \neq j \tag{2}
\]

Although, APS based on DV-Hop measurement showed good results in sparse deployments and requires just few number of beacons to cover the terrain, but it suffers from large communication overhead for large and dense networks. Furthermore, errors of distance computation are high because of handling the average hop size for distance calculation. [21] proposes two improvements towards the DV-Hop algorithm: the beacon placement strategy and the Weighted DV-Hop algorithm. For the placement strategy, they placed the beacons on the boundary of the network, so that the beacons are far enough from each other and equally spaced on the boundary. Another improvement was proposed by [7] which is called Distributed Voronoi Localization (DV-Loc). Using the Voronoi diagram in DV-Loc algorithm limits the flooding scope and also limits the position-computations error.

### 3.1.2 Fine-grained Techniques

Fine-grained techniques [8] are referred to types of algorithms which infer the position of unknown nodes by manipulating signal ranging parameters (Time of Arrival (ToA), Time Difference of Arrival (TDoA), Received Signal Strength Indication (RSSI), and Angle of Arrival (AoA)) to extract precise distances and angles, and manipulation of the mathematical techniques to calculate the coordinates. The ranging parameters are mostly mature fields in other technologies such as in cellular networks but as mentioned before WSN differs because of the unique sensor characteristic and constraints. Numerous algorithms have been proposed in fine-grained category to obtain accurate positioning with respect to the applications needs during last few years. However, the accuracy of such estimation is subject to the transmission medium and surrounding environment and usually relies on complex hardware [33]. The following subsections discuss some localization techniques according to the manipulated parameters.

- **Time of Arrival.** Time of Arrival (ToA), also called Time of Flight (ToF), the exact time that a signal

![Figure 1: Overall Chart of Localization Classification and Existing Methods](image-url)
travels over a transmitter to a receiver. It is divided to one-way and roundtrip propagations. One-way propagation calculates the distance between nodes based on the difference of sending time at the transmitter and receiving time at the receiver. Obviously, it demands an extremely accurate synchronized clocks on both sides what makes this technique very costly for WSN. On the other hand, roundtrip approach determines the distance of a node from another by different of the times when a node emits a signal and when it receives the returned-signal from the destination node. There is no synchronization problem because the calculation is using same clock, but the presence of delay from the second node to process the received-signal and send it back to the originator is not appropriate [28]. However, extra hardware demanding is the main drawback for ToA technique in WSNL despite of good accuracy. Global Positioning System (GPS) [19] is the most well-known approach based on this technique, but it could not be a global solution for Wireless Sensor Network Localization because of drawbacks like environment limitations (does not work in indoor or foliage terrains), size, and cost, while several atomic clocks are manipulated by satellites in order to extract the global positioning.

- **Time Difference of Arrival.** In Time Difference of Arrival (TDoA), the different arriving time to/from three beacons (2D) or four beacons (3D) is the main parameter used in calculating the exact position. Based on timing-metric specifications, there are two different global methods in handling TDoA technique. The first one is using two different signal structures, which mostly employed radio-frequency (RF) and ultrasound. Obviously, because of different rates they arrive to the receiver with a delay time and the delay of ultrasound signals enable the node to calculate its distance from originator. Second, an approach that assumes a precise of synchronization that enables them to measure the exact distance. The first approach is more feasible because it does not demand any accurate synchronization while it uses the same clock to extract the delay on the receiver side. However, the later one mostly based on proposed synchronization approaches which are out of this study scope. [32] presents Cricket that handles a one-way propagation of radio-frequency and ultrasound signal to measure the distance between nodes by calculating the delay of arrival time of signals. Additionally, Cricket defines a decoding algorithm to prevent ultrasound multipath and RF interference effects by using the minimum of modes from different beacons to calculate a maximum likelihood estimation of location. Despite of the algorithm handles both of RF and ultrasound to cope with synchronization problems, it is costly in term of size, money, and also demands more processing ability due to decoding algorithm and ultrasound transceivers. However, it obtains a reasonable accuracy for static and mobile nodes. Meanwhile, [39] proposed another approach that utilizes a combination of RF and ultrasonic transmitters via a mobile beacon node which flies over the terrain and employs GPS as its position detection, and broadcasts the location information to the stationary nodes. The beacon transmits a RF and ultrasonic signals simultaneously, when the stationary node receives the signals it calculates the distance upon the difference time of arrivals. [29] presented another TDoA-based approach that defines beacon nodes, a synch node, and a location server while the synch node just synchronizes the beacons to achieve the precise synchronization. In this manner, the target node and synch node emit signals with two-nano seconds pulse width while the beacon node calculates the difference time of arrivals per each received signals and forward the result to the location server where the coordinates of target node determines upon the beacon and synch nodes pre-defined coordinates.

- **Received Signal Strength Indication.** Received Signal Strength Indication (RSSI) is the most popular metric which is widely used in variety of localization algorithms. Employing this parameter does not require any extra or special hardware and it is supported by most of wireless standards and devices. It simply calculates the distance based on the attenuation of signal increases as the distance between transmitter and receiver increases. In term of wireless sensor network, RSSI suffers from few drawbacks like multipath propagation and signal interference. Although RSSI is a mature field, it is not easy to resolve these problems because of the hardware constraints on sensor nodes. RADAR, an RF-based system for locating and tracking users inside a building is one of the early applications that handles RSSI metric in WSN localization [3]. RADAR employs the Signal Strength information collected from three receiver to extract the node coordinates as the observed location, i.e., $S(X, Y, Z)$ and compare it with the recorded location, i.e., $S'(X, Y, Z)$ to calculate the distance based on Euclidean metric equation (3). Generally they call this technique as nearest neighbor(s) in signal space (NNSSS) and accordingly pick the location that minimizes the distance. Moreover, since a radio-frequency in an indoor environment is dominated by reflection, diffraction, and scattering of radio waves caused by building structures [3], RADAR also proposes Wall Attenuation Factor (WAF) to consider the effects of walls as obstacles on radio-frequency.

$$\sqrt{(X_s - X_r)^2 + (Y_s - Y_r)^2 + (Z_s - Z_r)^2}$$ (3)

- **Angle of Arrival.** Angle of Arrival (AoA) is a technique that relies on angle or direction of received signals on an antenna array. Triangulation is the approach involved in AoA measurement to calculate the distance. Accordingly, the angles of two received signals and one distance are necessary to fulfill this approach. Generally, the distance of nodes is extracted by TDoA, and the difference between TDoA and AoA returns to the number of acoustic or antenna array modules. TDoA with more than one set of transceiver modules is called AoA [31]. Three drawbacks of AoA are: first, the cost of special antenna array module is high, second, angle-based or direction-based methods are not effective in indoor environments and third, it does not work properly in case of dense environments. Since AoA measurement relies on a direct line-of-sight (LOS) path
from a transmitter to the receiver, a multipath component may appear as a signal arriving from an entirely different direction and can lead to very large errors in AoA measurements [28].

[31] has suggested an algorithm that handles AoA metric as distance measurement within APS (discussed in coarse-grained section). The authors present a fine-grained version of APS by giving AoA measurement capability to the fraction of nodes (called capable nodes) so that each capable node is equipped with an antenna array or several ultrasonic receivers. The measuring method is similar to APS (DV-Hop), while simply calculates the distance between nodes and beacons by AoA parameter and triangulation method instead of average-hop-size to get more accurate location. [22] presents another AoA-based algorithm which is called Cooperative AoA Localization Scheme (called CALS or Co-AoA). The scheme defines groups of 2, 3, or 4 nodes that are in a certain range of each other. The nodes are ready to co-operate the localization in each group and further beacons are AoA capable. The beacons disseminate their coordinates and the groups calculate their own location by angle of the received signals and distance. This algorithm uses only one set of acoustic modules per each node. [22] presented a modified version of DV-Hop called m-DV-Hop that is a range-based algorithm which involves CO-AoA approach and RSSI as distance measurement parameter within AoA instead of TDoA to calculate accurate distance between Super-Nodes and landmarks.

- **Hybrid Parameters.** Nowadays, literature shows a growing tendency to combine the different parameters and even techniques in providing better localization procedure in order to achieve better accuracy and less power-consumption. Fundamentally, localization based on hybrid measurements can achieve a performance improvement over that based on a single measurement because noise measurement for different type of measurement comes from different sources [28]. In this manner, Data Fusion is commonly regarded as an efficient method that can improve precision of localization [27]. The hybrid techniques are classified as fine-grained approaches because most of them at least have involved one of the signals ranging metrics to obtain more accurate location.

[27] proposes an almost novel method based on non-parametric estimation techniques and Radial Basis Function (RBF) Neural Networks to decrease the indeterminacy of Time Difference of Arrival and Received Signal Strength Indicator measurements. Moreover, the authors theoretically demonstrate that the data fusion based on RBF networks could achieve location estimation with the Minimum Mean Square Error (MMSE). Dual Merit Signal of Localization (DSML) [24] is another recent approach that uses two signal characteristics consisting of RSSI and TDoA simultaneously. [24] suggested range check technique in term of reducing the number of received beacon messages from sensor nodes. By DSML, the reception cost can be reduced between 15% to 60% [24]. DSML manipulates both TDoA and RSSI to establish an energy-efficient distance measurement, while a sensor node receives three beacon messages use TDoA and each sensor node receives only one or two beacon messages employs RSSI.

### 3.2 Underwater Localization Techniques

There are only few underwater localization techniques available compared to the existing Terrestrial because of the aforementioned reasons. Furthermore, there is one more different node within Aquatic WSN which is called UUV (Unmanned Underwater Vehicle) or AU (Autonomous Underwater Vehicle). AUVs are widely used in AUVs as mobile beacons or mobile sensor nodes. Based-on applications, different techniques have been employed for location estimation within water world. Furthermore, there are three reference network architectures within Underwater WSN as follows [1]:

1. **Static two-dimensional UWSN for ocean bottom monitoring.** The nodes and beacons are established on the bottom of Deep Ocean while the beacons are interconnected to one or more sinks.

2. **Static three-dimensional UWSN for ocean column monitoring.** Three dimensional underwater networks are used to detect and observe phenomena that cannot be adequately observed by means of ocean bottom sensor nodes, i.e., to perform cooperative sampling of the 3D ocean environment. In three-dimensional underwater networks, sensor nodes float at different depths in order to observe a phenomenon.

3. **Three-dimensional networks of Autonomous Underwater Vehicles (AU).** These networks include fixed portions composed of beaconed sensors and mobile portion established by AUVs.

To the benefit of the slow propagation of sound, time-based parameters are employed in UWSN. [26] has proposed a ToA-based localization algorithm which divides localization procedure to three steps including - distance/angle estimation, position computation, and localization algorithm. The method is considered two-dimensional network architecture while the speed of sound is a constant parameter. Regarding to three-dimensional architectures, [14], [36], [15], [24], and [5] have proposed localization schemes based on Time-Of-Arrival but within a static three dimensional network. The work of [15] is the only technique that considers the variability of sound speed within water. However, it uses a long range acoustic wave (4KM) which is not cost-effective and power-efficient for small sensor nodes. [13] has proposed another ToA-based localization method to estimate target location within a three-dimensional networks of AUVs in a multi stage manner. While AU beacon periodically ascend and descent in the water column and get new location information via GPS and propagate the information, unknown nodes can estimate their respect position by ToA measurement. To make the procedure of getting information above the surface and dive to depth for propagation faster, they predict a multi layer of UUVs to convey the information to bottom in a multi-hop manner. Despite of fine accuracy, this signal ranging parameter suffers from time synchronization in one-way trip and return signal delay in roundtrip which are discussed in ToA. [11] has developed a TDoA-based localization which is called silent positioning. Recently, [4] has proposed a RSSI-based target localization and has employed
acoustic signal modeling within a static three-dimensional network to track mobile targets. [25] proposed a hybrid technique which employs TDoA/AoA to enable mobile target tracking like whale tracking in a static three-dimensional architecture. In term of coarse-grained estimation, [10] has developed a connectivity-based technique which divides the operational field to few subsections by different power-level signal dissemination. Additionally, a summary scheme of underwater localization methods can be find in Figure 2 which includes the method specifications.

Generally, the unique characteristics of aquatic environment make localization more difficult compared to Terrestrial trials due to many affective factors that must be considered and the environment is not mostly accessible and observable by people. To design an aquatic localization technique, few properties must be considered including - power-efficient, low-cost, and reliability. Figure 2 shows the specification of existing underwater localization schemes.

Sound waves are defined as compression waves that have frequency within the audible spectrums and further need a medium to transfer like air, water, and metal. The frequency ranges between 20Hz to 20KHz is audible for humans. Generally, the frequencies below 20Hz is called infrasonic, while ultrasonic have frequencies above 20KHz. Additionally, the speed of acoustic waves is dependent on the transfer-medium parameters such that the speed within a high density media is few magnitude higher; for example the speed through iron is more than 5000 m/s while underwater is 1.5x10^3 m/s. However, the sound propagation speed varies within liquid based on other significant factors including - temperature, salinity, and pressure (depth). As the mentioned factors affect the acoustic waves within water, naturally they also affect signal propagation modeling and attenuation. This study divides the affective parameters on acoustic waves in two main categories including transmission-medium and environment factors. Temperature, salinity, pressure (depth), and acidity are occupied in transmission medium factors that affect on acoustic wave propagation within water. Air bubbles, sediment absorption, sea surface, and obstacles are the parameters that influence sound dissemination from environment.

4. DISCUSSION AND ANALYSIS

This paper analyzes the existing localization schemes in two parts - localization as a general concept and underwater localization. Generally, the localization approaches differ in term of calculation methods, hardware demands, and process-complexity. However, the common objective in localization is to propose an algorithm which estimates the best possible location by least cost. The simplicity of techniques is another basic objective of practical protocols design in WSN whereby the sensor node must consumes extremely low power, communicates at bit rates measured in kilobits per second, and potentially need to operate in high volumetric densities [24].

Apart from the employed parameters, there are two approaches to calculate the location including sensor-based-computation (distributed) and none-sensor-based-computation (centralized) methods. The sensor-based-computation or pure distributed localization refers to the methods that fulfill the localization procedure on generic sensors and the next group calculate the location based on other nodes like beacons or sink. This method requires two essential conditions memory and power limitation to be considered. Ignoring the 2 conditions may cause scheme not practical or scalable in a large and dense deployment whether the technique manipulates signal ranging parameters or non-signal-ranging parameters. For example, Centroid in a dense deployment of beacons does not work well because each node receives many beaconing massages whereas the node has to keep the messages, calculate connection metrics, and estimate its coordinates, while there are RF interferences due to beaconing messages. Furthermore, DV-Hop suffers from similar problem when nodes have to save a table of beacon information from many beacons. So coarse-grained sensor-based-computation methods might not be scalable, while the fine-grained category is more complicated whereas ToA,TDoA, and AoA techniques mostly demand more process-ability, extra hardware, and synchronization, and RSSI is not robust and accurate enough by itself. On the other hand, there is less attention and comprehensive solution in term of none-sensor-based-computation methods, while it may be more practical to fulfill localization based-on received-signals from unknown-nodes and regarding to the sensor constraints.

Furthermore, localization techniques generally are based on ideal conditions and many assumptions what might be look impractical or not close to real-environments, the assumptions like - circular radio range, additional modules, no interference, no multipath effects, no none-line-of-sight node, special terrain, and no obstacles. Despite numerous proposed studies, problem still exists.

Most works on underwater localizations do not consider the affective parameters on wave propagation within water as shown in Figure 2. Additionally, the time ranging parameters are completely based on speed of sound, which varies on temperature, salinity, and pressure. Ignoring the variation of sound velocity may increase estimation error. The only scheme that considers the parameters is proposed by [15], however, the scheme is developed for long range communication which is based on traditional underwater sensor networks. Additionally, AoA-based methods are expensive because it requires an antenna array and further it needs other method for distance measurement such an time-difference-of-arrival.

5. CONCLUSION

As discussed within this paper, Underwater WSN is still in the beginning of its way and localization is one of the major problems due to high estimation error, a localization scheme that considers the affective parameters, which include transmission-media and environment factors, is needed. Future works of this research will focus on developing an efficient localization scheme that will consider parts of the affective parameters.

6. REFERENCES

<table>
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<tr>
<th>Scheme</th>
<th>Type of Technique</th>
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<td>medium</td>
<td>No beacon</td>
<td>50 nodes, 20km x 10km, 0 to 2000 depth</td>
<td>Required precision, synchronization, considers transmission medium parameters, 2D</td>
<td></td>
</tr>
<tr>
<td>Sparse 3D Localization</td>
<td>ToA</td>
<td>Distributed</td>
<td>High</td>
<td>3 beacon on surface</td>
<td>1000 nodes, 10km x 10km units</td>
<td>Synchronization, 3D, keep neighbor coordinates, infrastructure-based</td>
<td></td>
</tr>
<tr>
<td>Area Localization Scheme</td>
<td>Connectivity based</td>
<td>Distributed</td>
<td>Low</td>
<td>8 beacon grid topology</td>
<td>100 nodes, 500m x 500m</td>
<td>Assumes the nodes are static, 2D, no transmission medium parameters, infrastructure-based</td>
<td></td>
</tr>
<tr>
<td>Target Localization</td>
<td>RSSI</td>
<td>Centralized</td>
<td>medium</td>
<td>No beacon</td>
<td>30 nodes, 10km x 10km x 3km</td>
<td>Target localization, multipath calculation, high positioning error, 3D</td>
<td></td>
</tr>
<tr>
<td>Multi Stage Underwater using Mobile Beacon</td>
<td>ToA</td>
<td>Distributed</td>
<td>medium</td>
<td>Mobile beacon</td>
<td>100-250 nodes, 5km x 5km x 0.5km</td>
<td>Low reliability, air-missing to deploy, nodes keep a table, high cost, infrastructure-based, consider underwater currents</td>
<td></td>
</tr>
<tr>
<td>Using two reference points</td>
<td>TDoA &amp; AoA</td>
<td>Distributed</td>
<td>medium</td>
<td>Three static beacons</td>
<td>1km x 1.5km x 2km</td>
<td>Target localization, 3D</td>
<td></td>
</tr>
<tr>
<td>LaVIM</td>
<td>ToA</td>
<td>Distributed</td>
<td>High</td>
<td>4 beacons</td>
<td>100 nodes, 5km x 5km</td>
<td>Infrastructure-based, 2D, large intercommunication, synchronization</td>
<td></td>
</tr>
<tr>
<td>AUV-Aided Localization</td>
<td>ToA</td>
<td>Distributed</td>
<td>High</td>
<td>Mobile beacon</td>
<td>100-200 nodes, 1km x 1km x 0.1km</td>
<td>Infrastructure-less, 3D, consider depth, no current</td>
<td></td>
</tr>
<tr>
<td>TOA-based localization</td>
<td>ToA</td>
<td>Distributed</td>
<td>medium</td>
<td>variable</td>
<td>50-500m range</td>
<td>150-800 nodes, 1km x 1km</td>
<td>Static sound speed</td>
</tr>
</tbody>
</table>

Figure 2: Summary of Underwater Localization Schemes


