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Autonomous Underwater Vehicle in Internet of Underwater Things: A Survey

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Abstract. Water, mostly oceans, covers over two-third of the earth. About 95% of these oceans are yet to be explored which includes 99% of the sea-beds. The introduction of the Internet of Underwater Things (IoUT) underwater has become a powerful technology necessary to the quest to develop a SMART Ocean. Autonomous Underwater Vehicles (AUVs) play a crucial role in this technology because of their mobility and longer energy storage. In order for AUV technologies to be effective, the challenges of AUVs must be adequately solved. This paper provides an overview of the challenges of IoUT, the contributions of AUVs in IoUT as well as the current challenges and opening in AUV. A summary and suggestion for future work was discussed.

1. Introduction

It is well known that more than two-third of the earth is covered by water which are mostly ocean bodies. However, about 95% of these oceans are yet to be explored. This includes 99% of the sea-beds. At present scientists know more about Mars, Venus and the Earth's Moon than they know about sea-beds. The need to know more about the ocean is therefore paramount.

The Introduction of Internet of Underwater Things (IoUT), an extension of Internet of Things (IoT) underwater has become a powerful technology necessary to develop the SMART Oceans. IoUT are systems consisting of SMART Underwater objects inter-connected in a network which enable the monitoring and exploration of the maritime environment for various purposes [1].

The concept of IoUT is buttressed by a network system called Underwater Wireless Sensor Network (UWSN). Although there has been growing research in the improvement of IoUT applications, there are still quite a number of challenges to be addressed in the design and implementation of the IoUT applications. Challenges worth noting are those in the viewpoints of communication, energy storage, mobility and reliability.

Autonomous Underwater Vehicles (AUVs) play a crucial role in this technology due to their mobility and energy (long battery life) among other factors. AUVs are self-propelled and unmanned vehicles that can operate in six degrees of freedom (6DOF) independently and also conduct planned missions [2]. AUVs have applications in military and homeland security where they are used to secure port facilities, in de-mining and communication with submarines and divers and also industrial and commercial applications such as oil and mineral extraction, commercial fisheries, underwater pipelines etc. [3-4].

Over the last two decades, a lot of multifaceted research has been done to address IoUT technologies and AUVs as it relates to improving the Smart Ocean. This paper looks in-depth into the main challenges



of IoUT (section 2), examples of methods and techniques where AUVs assist IoUT (section 3), the main challenges of AUVs as in regards IoUT technologies (section 4) and future directions of research (section 5).

2. Challenges in Internet of Underwater Things

Underwater Wireless Sensor Network (UWSN), which is the paradigm to support the concept of IoUT, faces numerous challenges due to the harsh conditions of the underwater channel. This section discusses some of the main challenges from the viewpoints of communication, energy storage, mobility and reliability.

2.1 Communication

The electromagnetic spectrum dominates communications outside water because it includes radio and optical signals that give long distance communication (meters to kilometers) with high bandwidth and low power. However, in water almost all electromagnetic signals are absorbed and dispersed and barely travel a few meters and require high power or large antennas. Acoustic waves however offer longer ranges in water making it a preferred communication choice for underwater for distances beyond tens of meters. They are constrained by limited and distance-dependent bandwidth, time-varying multipath propagation and low speed of sound [3].

Underwater acoustic communications are mainly influenced by path loss, noise, multi-path, Doppler spread, and high and variable propagation delay. The fact that the transmission frequencies are low, and the transmission range is longer giving room for inferences and collisions during transmission. This is therefore very challenging in IoUT. Table 1 shows the difference between TWSN and UWSN.

Table 1. TWSNs vs UWSN

Features	TWSNs	UWSNs
Transmission Media	Radio wave/Optical waves	Sound wave/Acoustic
Transmission Range	10m – 100m	100m – 10,000 m
Propagation Speed	300,000,000m/s	1500m/s
Transmission Rate	~250 kbps	~10 kbps

2.2 Energy Storage and Consumption

Energy Storage has always been the issue in sensor networks whether in terrestrial or under-water. The turbulent nature of the underwater environment causes inefficient energy consumption [5]. Therefore, the entire lifespan of an underwater sensor network is much lower than a terrestrial sensor network even as the cost of underwater equipment is higher. These issues way in on the achievement of reliability in the network as reliability is often energy intensive [6].

2.3. Mobility and Reliability

Underwater sensor objects are very mobile by nature as compared to TWSN nodes. They suffer position adjustable and hence network topology changes during water currents. This is significant in shallow water and not so much on an issue in deep waters [7]. These changes lead to high latency and network failures affecting the general performance of the network.

Reliability is measured by the ratio number of data packets that successfully gets to the sink (or receiver node) to the number of data packets sent initially from the sensor node (or sender node) [8]. The acoustic communication used underwater is often disturbed by surface noise, temperature gradients, multipath propagations caused by reflection and refraction and node failure caused more often by the relatively low battery lifespan of underwater equipment(nodes).

3. Benefits of Autonomous Underwater Vehicle in Internet of Underwater Things

AUVs play a crucial part in IoUT majorly because of its mobility and energy storage. For example, an average AUV has more battery life than an underwater sensor node. Therefore, AUVs can assist to solve the underlining challenges of the Internet of Under-water Things through various methods and schemes. This section discusses some of the assistance AUV gives IoUT from recent literature.

3.1. Data Gathering and Collection

Due to the unpleasant and unpredictable underwater environment coupled with the energy constraints of acoustic communication, designing energy efficient routing protocols is very challenging. [9] notes that traditional data collection methods lead to high power consumption and high imbalance in energy consumption among network nodes. With the assistance of AUVs, [10] shows that average data collection completion time is efficiently reduced, and data latency is decreased.

3.2. Localization and Time synchronization

Node localization is an important requirement in the deployment of an underwater sensor network as most UWSN applications are location dependent. The absence of GPS, the use of asynchronous clocks, the presence of water stratification and mobility features of the underwater environment makes accurate node localization challenging and difficult [11]. For localization, the autonomous underwater vehicle can dive into the underwater network after getting its position from the GPS and sends data packets to unknown nodes which in turn calculate their positions [12].

3.3. Void Prediction, Avoidance and Repair

The presence of voids in an underwater network degrades its reliability and performance. AUV can assist in the prediction and repair of routing voids as shown by [14]. The researchers propose that Autonomous underwater vehicles can be utilized to carry sensor nodes to the repair position based on particle swarm optimization algorithms.

3.4. Topology Optimization

Network topology is adversely affected by the high mobility of the underwater nodes therefore it is important to optimize topological structure of the network for UWSNs. An optimized network topology reduces latency in the network. In [13], a mechanism is used to optimize the network topology with the assistance of AUVs. The results show positive impact, lower energy consumption, lower latency and higher connectivity (reliability).

4. Challenges of Autonomous Underwater Vehicles

AUV technologies are not without challenges. In order for AUV technologies to be effective, the challenges of AUVs must be recognized as well as addressed. This section discusses current issues facing AUVs in IoUT and some of the proposed solutions.

4.1. Slow AUVs and Delay

While AUVs have aided the data collection in IoUT and effectively decreased the energy usage among sensor nodes, it is noted that AUV-aided solutions experience serious data collection delay issues especially in large scale networks. [15] also notes that AUVs can be slow given the underwater conditions, and this slowness could cause time-dependent data to be useless if not delivered to the sink at the appropriate time as in security, environment monitoring, and emergency applications. To solve these challenges, a prediction-based delay optimization data collection algorithm (PDO-DC) is proposed by [16].

4.2. Path Planning and Task Assignment

Path planning and task assignment of AUVs is a crucial aspect and usually takes place before the mission [17]. For multiple AUVs in a three-dimensional network, the absence or lack of efficient task assignment and plan planning can cause problems such as reducing energy efficiency, unnecessary delays and as well as general failures which will in turn have adverse effect on the underwater sensor network [18-20].

5. Conclusion

From this study, it is seen that though Autonomous underwater vehicles (AUVs) play a major role in the technology of Internet of Underwater Things (IoUT) and in the actualization of the development of Smart Ocean. However, there are still issues and challenges that need to be addressed. Majority of the issues are based on multiple AUVs in a large-scale network and involve load balancing, task assignment among others. This study therefore gives focus to future research. Majority of the issues are related to use of multiple AUVs, this shows that there should be more research into efficient and effective usage of the Multiple AUVs. The concept of cooperative game theory and persistence autonomous where the network lifetime is extended is also a direction that should be looked at more closely

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