Guest Editorial
Special Issue on Internet of Things for Smart Ocean

THE INTERNET of Things (IoT) for smart ocean is a promising paradigm that will support emerging applications in the areas of maritime transport, emergency search and rescue, security and border surveillance, environmental protection, etc. There has been a surging amount of data acquired from different maritime terminals, such as vessels, buoys, and offshore platforms. As a result, the demand for high-speed, ultrareliable, and low-latency maritime communications and data processing is proliferating. In this context, transmission and processing of maritime data have become a research hotspot. IoT technologies are expected to dramatically enhance the capacity, safety, and efficiency of connected vessels and other maritime terminals. Meanwhile, the unique characteristics of smart ocean applications create heterogeneous challenges in achieving viable, reliable, and secure communications and data processing. Addressing the challenges calls for novel approaches and consideration for the deployment of next-generation maritime communication networks. Therefore, it is essential to pursue research on new theories, architecture, and technologies to fully exploit the capability that is delivered by IoT for smart ocean to form efficient and intelligent maritime communication systems. This special issue aims to create a platform for researchers from both academia and industry to disseminate state-of-the-art results and to advance the applications of IoT for the smart ocean.

The response to our call for this special issue was overwhelming, as we received in total 93 submissions from around the world. During the review process, each article was assigned to and reviewed by at least three experts in the field, with a rigorous multiround review process. Thanks to the great support from the former Editor-in-Chief, Prof. Xuemin (Sherman) Shen, and the current Editor-in-Chief, Prof. Honggang Wang, and the dedicated work of all reviewers, we were able to accept 32 excellent articles covering various topics on IoT for the smart ocean. In the following, we will introduce these articles and highlight their main contributions.

The article "EEG-based maritime object detection for IoT-driven surveillance systems in smart ocean" by Duan *et al.* focuses on maritime object detection for IoT-driven surveillance systems in the smart ocean. An electroencephalography-based detection algorithm is proposed to detect small objects as well as to reduce the data volume for transmission and storage.

In the article "Joint relay assignment and power allocation for multiuser multirelay networks over underwater wireless optical channels," Xing *et al.* investigated the joint relay assignment and power allocation for underwater optical wireless communication, considering absorption, scattering, solar radiation noise, and oceanic turbulence. The authors propose an optimization scheme with fast convergence to find solutions for the relay assignment and power allocation.

In the article "Task allocation with unmanned surface vehicles in smart ocean IoT," Zhang *et al.* studied a task allocation scheme for unmanned surface vehicles (USVs) for smart ocean. The task allocation is modeled as an auction game and the optimal bidding strategy of USVs is derived using Q-learning.

The article "Internet of Ships: A survey on architectures, emerging applications, and challenges" by Aslam *et al.* provides a comprehensive survey on the architecture, characteristics, and applications of Internet of Ships.

The article "AUV-aided localization for Internet of Underwater Things: A reinforcement-learning-based method" by Yan *et al.* studies autonomous underwater vehicle (AUV)-aided localization. The authors design a reinforcement learning (RL)-based localization algorithm with two neural networks.

In the article "A parallel decoding approach for mitigating near–far interference in Internet of Underwater Things," Zhou and Diamant proposed parallel channel estimation and equalization to alleviate the near–far effect in underwater IoT applications.

In the article "A path planning scheme for AUV flock-based Internet-of-Underwater-Things systems to enable transparent and smart ocean," Lin *et al.* focused on multi-AUV cooperative systems and utilize software-defined networking to improve the performance of underwater wireless networks with multiple AUVs.

The article "Neural-network-based AUV navigation for fast-changing environments" by Song *et al.* proposes a neural-network-based AUV navigation method for fast-changing environments to improve the navigation accuracy.

The article "Object tracking in random access networks: A large-scale design" by Alimadadi *et al.* studies random access over band-limited and imperfect channels and rate control schemes to support the application of underwater object tracking. The authors design a random access sensor network and develop methods for adaptive adjustment of transmission rate for object tracking.

In the article "A game-theoretic and experimental analysis of energy-depleting underwater jamming attacks," Signori *et al.* considered the scenario with a malicious node that tries to perform a jamming attack and degrade the communication quality of battery-powered underwater nodes. The authors model and analyze the strategies of the jammer and the transmitter in a multistage game and conduct a sensitivity analysis to test the proposed strategies.

In the article "Routing protocol design for underwater optical wireless sensor networks: A multiagent reinforcement

Digital Object Identifier 10.1109/JIOT.2020.3020444

learning approach," Li *et al.* proposed a routing protocol based on multiagent RL for underwater optical wireless sensor networks. With the objective to adapt to a dynamic environment and prolong network life, two optimization strategies are proposed to accelerate the convergence of the RL algorithm.

The article "Noncooperative mobile target tracking using multiple AUVs in anchor-free environments" by Li *et al.* studies noncooperative target tracking with multiple AUVs in anchor-free environments. A multi-AUV cooperative localization and target tracking framework is proposed based on belief propagation.

The article "Dynamic magnetic induction wireless communications for autonomous-underwater-vehicle-assisted underwater IoT" by Wei *et al.* proposes low-power magnetic induction (MI)-based wireless communications for AUVs. Specifically, the authors have analyzed a dynamic underwater MI channel, designed a free-load MI receiver and built a system prototype.

In "A game-theoretic routing protocol for 3-D underwater acoustic sensor networks," Wang *et al.* proposed a routing protocol to address the challenges of high latency, high mobility, and low bandwidth for routing in underwater acoustic sensor networks. A novel game-theoretic forwarding strategy based on the node degree is designed.

In "Random access and detection performance of Internet of Things for smart ocean," Bai *et al.* proposed a relay-aided random access scheme with the focus on the ability to recover packets lost in collisions. The proposed scheme serves the purpose of achieving energy-efficient transmissions for the smart ocean where retransmission strategies are carried out by buoys.

The article "Value-based hierarchical information collection for AUV-enabled Internet of Underwater Things" by Duan *et al.* considers the use of an AUV as a mobile collector for reliable underwater information collection. The problems of sink node selection and AUV path planning are studied, with the value of information as the main metric.

The article "A novel method for protecting swimmers and surfers from shark attacks using communicating autonomous drones" by Li *et al.* proposes to use autonomous drones to protect swimmers and surfers from shark attacks. The authors design a drone-based system and strategy for repelling sharks.

In the article "Multiagent DDPG-based deep learning for smart ocean federated learning IoT networks," Kwon *et al.* adopted multiagent deep reinforcement for cell association and resource allocation in smart ocean applications. The proposed approach utilizes federated learning to cope with the need for distributed decisions and a time-varying environment.

In the article "An AUV-assisted data gathering scheme based on clustering and matrix completion for smart ocean," Huang *et al.* devised an AUV-assisted data gathering scheme for improving data gathering efficiency in underwater wireless sensor networks. The authors introduce mechanisms to optimize the trajectory of the AUV and minimize the amount of data transmission.

The article "Learning-automata-based confident information coverage barriers based for smart ocean Internet of Things" by Deng *et al.* focuses on ocean environment monitoring and surveillance. The authors adopt learning automata to build barrier paths for detecting intruders and trespassers.

Recognizing potential limitations of the channel and interference models from the terrestrial wireless communications for underwater acoustic channels, the article "A new acoustic channel interference model for 3-D underwater acoustic sensor networks and throughput analysis" by Zhong *et al.* investigates the features of acoustic channels and proposes a new interference model to support underwater IoT.

In the article "Toward self-adaptive selection of kernel functions for support vector regression in IoT-based marine data prediction," Sun *et al.* studied the self-adaptive selection of kernel functions in the framework of support vector machine (SVM) for IoT-based marine data prediction. In this work, the authors propose a self-adaptive SVM model and design a kernel selection criteria.

In the article "Enabling sustainable underwater IoT networks with energy harvesting: A decentralized reinforcement learning approach," Han *et al.* investigated random access in underwater IoT with tidal energy harvesting. Multiagent RL is adopted for nodes to autonomously adapt the random access parameters.

The article "Cellular communications in ocean waves for maritime Internet of Things" by Huo *et al.* investigates the impact of sea waves on radio propagation and communications link quality. The authors establish a model of the oceanic and coastal waves and utilize the model to examine the condition of the line-of-sight communications.

The article "Secure and efficient data collection and storage of IoT in smart ocean" by Hu *et al.* presents a scheme for data collection, transmission, and storage for the unreliable underwater environment. Various designs for guaranteeing data integrity, confidentiality, and reliability are discussed.

In the article "Receiver-only-based time synchronization under exponential delays in underwater wireless sensor networks," Liu *et al.* considered time synchronization in underwater wireless sensor networks with the receiver-only-based synchronization and exponential delays. The authors develop a method to jointly estimate clock offsets and skews of all nodes.

In the article "AUV-aided energy-efficient data collection in underwater acoustic sensor networks," Zhuo *et al.* introduced an AUV-aided underwater acoustic sensor network for data collection with energy constraints. The authors design a novel media access control protocol to coordinate data transmission and develop algorithms for path planning.

The article "Scalable adaptive networking for the Internet of Underwater Things" by Morozs *et al.* studies the problem of integrating new nodes into an existing underwater IoT network and propose a protocol for new nodes to join the network with minimum chance of collision. The authors test the proposed scheme in both numerical simulations and sea trials.

The article "A CNN-based structured light communication scheme for Internet of Underwater Things applications" by Trichili *et al.* designs underwater optical wireless communications to transfer information relying on a convolutional neural network for the mode identification in the underwater environment.

In the article "Localization and tracking control using hybrid acoustic–optical communication for autonomous underwater vehicles," Zhang *et al.* studied the problem of localization

and tracking of a mobile surface ship with an AUV. A hybrid acoustic-optical underwater communication solution is proposed for accurate sensing, reliable tracking, and high-rate underwater data transmission.

In the article "Privacy protection scheme based on CP-ABE in crowdsourcing-IoT for smart ocean," Yu *et al.* proposed a crowdsourcing privacy protection scheme for data sharing in IoT for smart ocean. The authors design an independent key component distribution through multiple authorities and an attribute revocation mechanism to enhance privacy protection.

The article "Information-seeking sensor selection for Ocean-of-Things" by Saucan and Win proposes a general sensor selection methodology for multiobject tracking. The authors propose a tractable information-theoretic reward function and a cross-entropy methodology for fast and accurate tracking.

We would like to express our sincere thanks to all the authors for submitting their articles and to the reviewers for their valuable comments and suggestions that significantly enhanced the quality of these articles. The articles presented in this special issue demonstrate research efforts on various topics in the field of IoT for smart ocean. We hope that this special issue will serve as a useful reference for researchers, scientists, engineers, and academics in the field of IoT-enabled smart ocean.

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