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Special issue on “Underwater communications”

Editorial

The underwater environment presents unique challenges for communication and sensing systems. Unlike terrestrial wireless networks, underwater communications rely primarily on acoustic signaling, which is characterized by limited bandwidth, long propagation delays, multipath effects, and high error rates. These constraints make the design of reliable underwater networks particularly difficult. At the same time, there is growing demand for underwater communication technologies driven by applications such as oceanographic monitoring, offshore infrastructure inspection, disaster prevention, environmental observation, and maritime security.

Recent advances in Autonomous Underwater Vehicles (AUVs), underwater sensor networks, signal processing, and artificial intelligence are creating new opportunities to address these challenges. This special issue brings together several contributions that explore emerging techniques for underwater sensing, networking, coordination, and system optimization.

The first paper, “**Topology optimization of deep sea acoustic sensor networks for tsunami warnings**,” by Lin et al., investigates the design of underwater acoustic sensor networks for tsunami detection and early warning systems. Reliable and timely detection of tsunamis is essential for mitigating the impact of natural disasters in coastal areas. The authors formulate the deployment of deep sea acoustic sensor networks as an optimization problem and analyze how network topology influences coverage and communication efficiency. Their results demonstrate that optimized sensor placement can significantly improve the reliability and performance of underwater monitoring systems used for disaster warning.

The second paper, “**Restoring underwater images from turbidity and motion blur: A three-step framework**,” by Iqbal and Töreyin, addresses the problem of degraded underwater imagery caused by turbidity and motion blur. Optical imaging is widely used for underwater exploration and inspection tasks, yet suspended particles and vehicle motion often significantly reduce image quality. The authors propose a three-step restoration framework that combines image enhancement and deblurring techniques tailored to underwater environments. The proposed approach improves visual clarity and feature visibility, which can support downstream tasks such as object detection and scene analysis in underwater applications.

The third paper, “**Enhancement of geometry-based time synchronization (UWGS) with packet loss management under dynamic node trajectories in underwater acoustic networks**,” by Ghalkhani et al., addresses the critical problem of time synchronization in underwater acoustic networks. Accurate synchronization is essential for functions such as localization, coordinated sensing, and medium access control. However, underwater channels introduce significant challenges due to long propagation delays, node mobility, and packet loss. The authors extend a geometry-based synchronization framework by incorporating packet loss management and dynamic node trajectories into the synchronization model. Simulation results show that the proposed approach maintains reliable synchronization performance even under realistic network conditions.

The fourth paper, “**Decentralized underwater AUV search and self-allocation for multiple targets using ad hoc networking-aided firefly scheme**,” by Yang and Hong, studies decentralized coordination for AUV swarms performing multi-target search missions. Due to the limited bandwidth and high latency of underwater communications, centralized control strategies are often impractical. The authors propose a bio-inspired firefly-based optimization framework that enables AUVs to autonomously allocate themselves to targets while maintaining distributed decision-making. Simulation results show that the proposed approach improves search efficiency and coordination performance

compared to baseline strategies, highlighting the potential of swarm intelligence methods in underwater robotics.

Finally, "**Toward AI-enabled autonomous underwater acoustic networking: Challenges, opportunities, and research directions**," by Alshawabka et al., provides a forward-looking perspective on the role of artificial intelligence in underwater acoustic networking. The paper reviews key challenges in underwater networking and discusses how machine learning techniques can enable more adaptive and intelligent communication systems. It also outlines several open research directions for AI-driven underwater networking and autonomous system design.

Together, the papers in this special issue highlight the multidisciplinary nature of underwater communications research, spanning sensing, network design, synchronization, swarm coordination, and AI-enabled networking. We hope that these contributions will stimulate further research toward more reliable, efficient, and autonomous underwater communication systems.

The Guest Editors would like to thank the authors for their contributions and the reviewers for their careful evaluations. We also express our gratitude to the Editor-in-Chief and the editorial staff of the ITU Journal on Future and Evolving Technologies for their support in preparing this special issue.

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