
Rutvij H. Jhaveri


Khaled M. Rabie


Qin Xin


Marwa Chafii


Tien Anh Tran


Basem M. ElHalawany

Emerging Trends and Challenges in Internet-of-Underwater-Things

Internet-of-Underwater-Things (IoUT) is a network of smart interconnected underwater objects. Recently, IoUT has shown its applicability in numerous scenarios such as marine life monitoring, off-shore exploration, underwater lost-treasure discovery, sports, assisted navigation, location awareness, environmental monitoring (e.g., monitoring of water quality, water pollution, water pressure or water temperature), water-based disasters (e.g., tsunami or nuclear accident), defense systems (e.g., surveillance systems or submarine detection) and several other applications. Even though IoUT systems are key enabler in underwater communication, they face challenges due to unreliable transmission medium, unstable radio signals, limited range, low bandwidth, inborn noise, low transmission rate, slow propagation speed, node mobility, lower resources and limited battery capacity. These challenges cause issues in channel modeling, optimal routing, security, privacy, communication overhead, congestion control, packet error rate, packet latency, energy consumption etc. In this respect, this special issue aims to address some of the aforementioned challenges.

The Guest Editors of this special issue had great support from the Editor-in-Chief and the Associate Editor-in-Chief of IEEE IoT Magazine, and this allowed to organize a successful special issue despite the tight targeted timeline. We received 29 submissions, out of which 7 were selected through a rigorous review process with an acceptance ration of 24 percent. The authors are grateful to all authors for submitting such high-quality manuscripts as well as to the reviewers for the great support.

The first article "Breaking through the air-water interface with software-defined visible light networking" written by Enhos et al. introduced a software-defined visible light network to establish bi-directional wireless links through the air-water interface. The authors first provided an overview of the limitations of the state-of-the-art solutions for communication across air-water mediums. They then presented the building block of their new proposed solution with a mathematical channel model and simulator for the air-water interface, along with a prototype of the software-defined visible light communication model. The authors presented a series of experiments conducted in the ocean to demonstrate how the developed system can operate across the interface in real-life scenarios. Finally, the authors discussed some key concepts and applications that the proposed solution can enable.

The second article "Automatic Shark Detection via Underwater Acoustic Sensing" written by Manos et al. illustrated a design of a fully automated low-operating cost shark detection and warning system. This system exploits underwater acoustic sensing and communication to automate the spotting, providing a highly accurate alternative to visual spotting. The authors analyzed the performance of the proposed solution in terms of communication performance and accuracy in alerting water users to dangerous situations and compared with different medium access schemes to identify the most effective network design. Manos et al. also indicated that a potential research direction will include a field test of the system in a real underwater acoustic network.

In the third article by Omeke et al. "How Reinforcement Learning is Helping to Solve Internet-of-Underwater-Things Problems", the authors reviewed areas of IoUTs in which reinforcement learning (RL) algorithms find special applications. A detailed analysis of IoUTs applications which rely on RL techniques was made, highlighting specific algorithms utilized in various IoUTs contexts. Interesting open research problems in the applications of RL in the IoUTs were outlined and potential solutions are explored.

The fourth article "Blockchain-assisted Onion Routing Protocol for Internet of Underwater Vehicle Communication" by Jadav et al. provided a secure and intelligent framework to mitigate security threats in an Internet of Underwater Vehicle (IoUV) environment by adopting collaborative benefits from AI classifiers, onion routing network, and blockchain technology. The proposed framework utilized AI classifiers that are efficiently trained by the attack dataset and simultaneously were validated by the IoUV attack dataset. The proposed framework was assessed by various evaluation metrics such as accuracy decryption time and scalability. It was concluded that the proposed framework can provide considerable performance gains in comparison to conventional and existing works.

The fifth article by Victor et al. "Federated Learning for IoUT: Concepts, Applications, Challenges and Opportunities" presented a discussion of the applications of federated learning in IoUT, its challenges and open issues. The authors indicated the need and importance of federated learning in achieving desired characteristics in an IoUT environment, highlighting the possible solutions, effective methods and indicating scope of future research.

In the sixth article "A Reliable Covert Channel for Stealthy Data Transmission of Internet-of-Underwater-Things", Baker et al. considered the security issue to guarantee data privacy during IoUTs data transmission. In order to mitigate the data transmis-

sion security such environments, they introduced a payload-dependent parallel-distributed covert storage channel scheme, which is realized by selecting the normal data flow as the carrier and discretizing the data transmission. This scheme has the ability to enable stealthy data transmission under IoUTs environments.

The seventh and final article "E2E Service Class Mapping in Heterogeneous IoUT: SDN Based Architecture" by Ali et al. evaluated the applicability of a hierarchical SDN architecture for an end-to-end (E2E) traffic classes (TCs) mapping in a multidomain heterogeneous environment for IoUT networks, using simple additive weighting module on the SDN controller. The hierarchical architecture enabled the collaboration and management of heterogeneous network domains on an E2E route for mapping of service TCs. A proof-of-concept experiment of the proposed approach was performed in Mininet-Wifi emulator and ODL controller. The results clearly indicated the effectiveness of the proposed approach.

To conclude, we would like to thank the authors, reviewers, and the EiC for helping the Guest Editors to organize this timely Special Issue. We hope that this work will encourage and motivate researchers from academic and industry to develop further novel ideas and algorithms to advance IoUT systems.

Biographies

Rutvij H. Jhaveri [SM] is an experienced educator and researcher working in the Department of Computer Science & Engineering, Pandit Deendayal Energy University, Gandhinagar, India. He conducted his Postdoctoral Research at Delta-NTU Corporate Lab for Cyber-Physical Systems, Nanyang Technological University, Singapore. He completed his Ph.D. in Computer Engineerng in 2016. In 2017, he was awarded with prestigious Pedagogical Innovation Award by Gujarat Technological University. Currently, he is co-investigating a funded project from GUJCOST. He was ranked among top 2 percent scientists around the world in 2022 and 2021. He has 2300+ Google Scholar citations with h-index 25. Apart from serving as an editor/guest editor in various journals of repute, he also serves as a reviewer in several international journals and also as an advisory/TPC member in renowned international conferences. He authored 130+ articles including the IEEE/ACM Transactions and flagship IEEE/ACM conferences. Moreover, he has several national and international patents and, copyrights to his name. He also possesses memberships of various technical bodies such as ACM, CSI, ISTE and others. He is a member of the Advisory Board in Symbiosis Institute of Digital and Telecom Management, and other reputed universities since 2022. He is an editorial board member in several Springer and Hindawi journals. He also served as a committee member in "Smart Village Project" — Government of Gujarat, at the district level during the year 2017. His research interests are Cyber Security, IoT systems, SDN and Smart Healthcare.

Khaled M. Rabie [SM'21] (k.rabie@mmu.ac.uk), a Fellow of the U.K. Higher Education Academy, received the M.Sc. and Ph.D. degrees in electrical and electronic engineering from the University of Manchester in 2011 and 2015, respectively. He is currently a Reader with the Department of Engineering, Manchester Met University (MMU), U.K. His current research interest focuses on designing and developing next-generation wireless communication systems. He regularly serves on the Technical Program Committee (TPC) for several major IEEE conferences, such as GLOBECOM, ICC, and VTC. He has received many awards over the past few years in recognition of his research contributions, including the Best Paper Awards at the 2021 IEEE CITS and the 2015 IEEE ISPLC. He also serves as an Editor for *IEEE Communications Letters*, an Editor for *IEEE Internet of Things Magazine*, an Associate Editor for *IEEE Access*.

Qin Xin graduated with his Ph.D (1st Oct. 2002–30th Sep. 2004) in Department of Computer Science at University of Liverpool, UK in December 2004. Currently, he is working as a FULL professor of Computer Science and Faculty Research Leader in the Faculty of Science and Technology at the University of the Faroe Islands (UoFI), Faroe Islands. Prior to joining UoFI, he had held variant research positions in world leading universities and research laboratory including Senior Research Fellowship at Universite Catholique de Louvain, Belgium, Research Scientist/Postdoctoral Research Fellowship at Simula Research Laboratory, Norway and Postdoctoral Research Fellowship at University of Bergen, Norway. His main research focus is on design and analysis of sequential, parallel and distributed algorithms for various communication and optimization problems in wireless communication networks, as well as cryptography and digital currencies including quantum money. Moreover, he also investigates the combinatorial optimization problems with applications in Bioinformatics, Data Mining and Space Research. Currently, he is serving on Management Committee Board of Denmark for several EU ICT projects. He has produced more than 111 peer reviewed scientific papers. His works have been published in leading international conferences and journals, such as ICALP, ACM PODC, SWAT, IEEE MASS, ISAAC, SIROCCO, IEEE ICC, Algorithmica, Theoretical Computer Science, Distributed Computing, IEEE Transactions on Computers, Journal of Parallel and Distributed Computing, IEEE Transactions on Dielectrics and Electrical Insulation, IEEE Transactions on Sustainable Computing, ACM Transactions on Internet Technology, IEEE Transactions on Network Science and Engineering, ACM Transactions on Asian and Low-Resource Language Information Processing, and Advances in Space Research. He has been very actively involved in the services for the community in terms of acting (or acted) on various positions (e.g., Session Chair, Member of Technical Program Committee, Symposium Organizer and Local Organization Co-chair) for numerous international leading conferences in the fields of distributed computing, wireless communications and ubiquitous intelligence and computing, including IEEE MASS, IEEE LCN, ACM SAC, IEEE ICC, IEEE Globecom, IEEE WCNC, IEEE VTC, IFIP NPC, IEEE Sarnoff and so on. He is the Organizing Committee Chair for the 17th and 18th Scandinavian Symposium and Workshops on Algorithm Theory (SWAT 2020 and SWAT 2022, Torshavn, Faroe Islands). Currently, he also serves on the editorial board for more than ten international journals.

Marwa Chafii received her Ph.D. degree in electrical engineering in 2016, and her Master's degree in the field of advanced wireless communication systems (SAR) in 2013, both from CentraleSupélec, France. Between 2014 and 2016, she has been a visiting researcher at Poznan University of Technology (Poland), University of York (UK), Yokohama National University (Japan), and University of Oxford (UK). She joined the Technical University of Dresden, Germany, in 2018 as a research group leader, and ENSEA, France, in 2019 as an associate professor where she held a Chair of Excellence on Artificial Intelligence from CY Initiative. Since September 2021, she has been an associate professor at New York University (NYU) Abu Dhabi, and NYU WIRELESS, NYU Tandon School of Engineering. Her research interests include advanced waveform design, machine learning for wireless communications, and indoor localization. She received the prize of the best Ph.D. in France in the fields of Signal, Image & Vision, and she has been nominated in the top 10 Rising Stars in Computer Networking and Communications by N2Women in 2020. She served as Associate Editor at IEEE Communications Letters 2019–2021, where she received the Best Editor Award in 2020. Between 2018 and 2021, she was research lead at the Women in AI organization. She is currently Associate Editor at *IEEE Transactions on Communications*, serving as vice-chair of the IEEE ComSoc ETI on Machine Learning for Communications and leading the Education working group of the IEEE ComSoc ETI on Integrated Sensing and Communications.

Tien Anh Tran [M] (trantienanhvimaru@gmail.com), a Research Fellow at Seoul National University, Seoul city, South Korea. He is an Assistant Professor (Lecturer) at Department of Marine Engineering, Vietnam Maritime University, Haiphong City, Vietnam. Additionally, he is also a Honorary Professor at School of Computing Science and Engineering, Galgotias University, India. He received B.Eng and M.Sc at Vietnam Maritime University, Vietnam in 2011 and 2014, respectively. He got Ph.D. Degree at Wuhan University of Technology, Wuhan, China in 2018. He is an Editor/Guest Editor for the reputation journals indexed in SCI/SCIE such as Environment, Development and Sustainability (SCIE, IF= 4.080), IET Intelligent Transport System (SCIE, IF = 2.568), International Journal of Distributed Sensor Networks (SCIE, IF = 1.938), Sustainable Computing: Informatics and Systems (SCIE, IF = 4.923), International Journal of Renewable Energy Technology, International Journal of Energy Optimization and Engineering (ESCI, Scopus), IEEE Internet of Things Magazine. He is one among five outstanding scientists in Vietnam to be nominated for Ta Quang Buu prize in 2022.

Basem M. Elhalawany [SM] received the master's degree from Benha University, Banha, Egypt and the Ph.D. degree from Egypt-Japan University of Science and Technology, New Borg El Arab, Egypt, in 2011 and in 2014, respectively. He was a Research Fellow with Smart Sensing and Mobile Computing Laboratory, Shenzhen University, Shenzhen, China, and EJUST Center, Kyushu University, Fukuoka, Japan. He also holds the position of an Associate Professor with the Faculty of Engineering, Shoubra, Benha University. He has authored or coauthored more than 60 high quality research papers in international leading journals and primer conferences. His research interests include performance analysis, resource management, and optimization in wireless networks, NOMA, underwater and satellite communication networks, and machine learning applications in communication. He is the associate editor of Alexandria Engineering Journal.