2018 NSF Workshop on Underwater Wireless Communications and Networking

Washington, DC

March 19-20, 2018

Executive Summary

The 2018 NSF Workshop on Underwater Wireless Communications and Networking was held in Washington DC, March 19-20, 2018. Sixty-one participants from academia, industries, and governments attended the two-day workshop. They represented the international communities in North America, Asia, and Europe that consistently invest in the underwater wireless communication research or have significant interests in using the related technologies. The goal of the workshop was to develop application-driven roadmaps and to formulate grand challenges to spur future technological development in this field.

The presentations and discussions were partitioned into four technical areas: Applications, Physical Layer, Networks, and Implementation. On the second day, the workshop put forward the roadmap for each of the four areas. Essential discussions for the future directions were focused on applications related to underwater robotics. The workshop participants unanimously recognized the urgent need across the four technical areas to achieve unified, realistic modeling of acoustic communication channels since it is the key to understanding the communication limits and conducting meaningful comparative analyses of various techniques. The consensus among the participants was that we need to broaden research participation by multidisciplinary collaboration as well as by reaching out to the industries who have interests in underwater wireless technologies. Common test grounds, open-source software, affordable & miniaturized hardware, and software-defined networking infrastructure were considered to be the key elements to achieve this goal. It was well recognized that there is no one-size-fits-all solution.

In the area of **Applications**, open-source software and affordable miniaturized hardware are critical to expanding application domains. Underwater swarming and human-robot interactions are the promising applications of underwater wireless communications. Sensing, communications, and networking in the under-ice Arctic environment are challenging, yet exciting directions. Deployments in lakes and rivers are of interest to many applications as well, for example, pollution monitoring and water quality survey. Power solutions, biofouling, and equipment maintenance are important issues for permanent underwater deployments.

In the area of **Physical Layer**, there is an urgent need to establish a public repository of channel responses and measurements, referred to as common test grounds, for research development, algorithm validation, and performance prediction. The IEEE Oceanic Engineering Society is a potential venue to develop such a repository. Transmitter adaptivity via receiver feedback is the next challenge that needs to be addressed, as it has not been demonstrated in the ocean. Among many features that feedback will enable, spatially directional transmission is prominent. Capacity analysis, interference management, multi-modal communications, asymmetric links, underwater localization, cooperative distributed communications, and full-duplex modems are important research directions.

In the area of **Networks**, software-defined, information-centric, mobility-aware architecture is the key to address large delay and low network efficiency in the underwater domain. Application-optimized, hierarchical, hybrid architectures are often needed. Therefore, both peer-to-peer networks and centralized cellular-like networks are of interest. Routing over spatial variability is the next important issue. In addition, it is critical to bridge the performance gap between network simulations and field experiments, an issue that again highlights the need for standardized channel modeling. Underwater IoT, underwater security, and authentication are important research areas as well.

In the area of **Implementation**, the top priority is to develop an encompassing framework within which different technologies will be coupled. The next challenge to the research community and the industries is to develop industry-acceptable standards for all components of implementation, including hardware, software, networking, testing, and assessment, to ensure interoperability. Hardware-in-the-loop testbeds, benchmark implementations, hardware/software development kits, and mapping algorithms into hardware processor structures are important topics.

The grand challenge to the research community is to implement an underwater wireless communication network on-the-fly. The network is expected to operate over multiple spatial scales with different platforms and gateways to deliver data to users and provide command and control. The immediate action item toward the grand challenge is to launch combined robotics and communication student competition for the underwater environment.

WORKSHOP GENERAL CHAIRS

Milica Stojanovic, Northeastern University

Aijun Song, University of Alabama

STEERING COMMITTEE

Grant Deane, Scripps Institution of Oceanography

Lee Freitag, Woods Hole Oceanographic Institution

Dale Green, Teledyne Benthos, Chief Scientist (retired)

Robert Headrick, Office of Naval Research

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Division of Computer and Network Systems

Workshop Program

Day 1: March 19, 2018

8:00 to 8:20 Welcome & opening remarks

   Thyaga Nandagopal, Deputy Division Director, CCF, NSF

   Lisa Clough, Section Head, OCE, NSF

   Milica Stojanovic, Professor, Northeastern University

   Aijun Song, Assistant Professor, University of Alabama

8:20 to 9:20 Applications I
   8:20 to 8:30 Fumin Zhang, Georgia Tech

   8:30 to 8:40 Jules Jaffee, Scripps Institution of Oceanography

   8:40 to 8:50 Julius Kusuma, Schlumberger

9:20 to 10:20 Networks I
   9:20 to 9:30 Robert Headrick, Office of Naval Research

   9:30 to 9:40 Tommaso Melodia, Northeastern University

   9:40 to 9:50 Pierre-Philippe Beaujean, Florida Atlantic University

10:30 to 11:30 PHY I
   10:30 to 10:40 Milica Stojanovic, Northeastern University

   10:40 to 10:50 Henrik Schmidt, Massachusetts Institute of Technology

   10:50 to 11:00 Andy Singer, University of Illinois at Urbana-Champaign

11: 30 to 13:00 Lunch break + Poster session

13:00 to 14:00 Implementation I
   13:00 to 13:10 Dale Green

   13:10 to 13:20 Lee Freitag, Woods Hole Oceanographic Inst.

   13:20 to 13:30 Dale Green (in place for Joao Alves)

14:00 to 15:00 Applications II
   14:00 to 14:10 Grant Deane, Scripps Inst. of Oceanography

   14:10 to 14:20 Stephane Blouin, Defence R & D Canada

   14:20 to 14:30 Ubli Mitra, University of Southern California

15:10 to 16:10 Networks II
   15:10 to 15:20 Paul van Walree, Norwegian Defence Res. Est.

   15:20 to 15:30 Dario Pompili, Rutgers University

   15:30 to 15:40 Xiaoyan Hong, University of Alabama

16:10 to 17:10 PHY II
   16:10 to 16:20 Rosa Zheng, Missouri Univ. of Sci. & Tech.

   16:20 to 16:30 Paul Gendron, UMass Dartmouth

   16:30 to 16:40 Francois Socheleau, IMT Atlantique, France

17:10 to 18:10 Implementation II
   17:10 to 17:20 Mandar Chitre, National University of Singapore

   17:20 to 17:30 Geoff Edelmann, Naval Research Laboratory

   17:30 to 17:40 David Brown, UMass Dartmouth

18:30 to 20:00 Dinner + Poster session + Social hours

Day 2: March 20, 2018

8:10 to 8:30 PHY and Networks
   8:10 to 8:20 Ali Abdi, New Jersey Institute of Technology

   8:20 to 8:30 Roee Diamant, University of Haifa, Israel

8:30 to 10:30 Parallel break-out sessions

10:40 to 13:00 Summarizing presentations and grand challenges

12:10 to 14:00 Lunch

14:00 Adjourn