Report on the First ACM International Workshop on Underwater Networks (WUWNet'06)

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I. Introduction

The first ACM International Workshop on Underwater Networks (WUWNet'06) was held on September 29, 2006 in conjunction with MobiCom'06 in Los Angeles, California, USA. The goal of the workshop was to bring together researchers and practicing engineers from the areas of underwater communications and networking who are interested in applying their expertise to the development of future underwater networks. The call for papers attracted 30 submissions from the United States, Australia, India, South Korea, China, Singapore and Italy. The program committee, ably headed by the Technical Program Committee Chairs (Kevin Fall of Intel Research and Milica Stojanovic of the Massachusetts Institute of Technology) accepted 10 full-length papers and 6 posters, included as short papers (in the workshop proceedings). The program also included three invited speakers, a panel session, a demonstration session, and a work-in-progress session. The presented papers covered a variety of topics in underwater communications, networking, and applications. Specifically, they addressed acoustic modem technology, applications of autonomous underwater vehicles, methods for localization, network topology discovery, medium access control, routing protocols, and deployment considerations. The workshop benefited tremendously from the generosity of the Boeing Corporation, the Defense Advanced Research Projects Agency, the National Science Foundation and the MIT Sea Grant Program. In addition to the sponsorship by ACM SIGMOBILE, technical sponsorship was also provided by the IEEE Oceanic Engineering Society. All technical papers and demonstration information can be found on the workshop website: *http://wuwnet.engr.uconn.edu*.

II. Panel and Demonstration Sessions

A very lively panel session was moderated by Dr. Kevin Fall. The panel participants were: Dr. John Heidemann (ISI/USC), Dr. Richard Neilsen (Boeing), Dr. Daniel Nagle (NUWC Newport), Dr. Jason Redi (BBN Corporation) and Dr. Thomas Torgersen (University of Connecticut – UConn). The panel members were drawn from academia, industry and government organizations with expertise in networking, physical layer communications, radar and sonar systems as well as marine sciences. The panel members were very effective in raising challenges unique to key applications that would benefit from underwater networks.

Figure 1: Panel members and conference organizers: (from left to right) Jason Redi, Richard Neilsen, Kevin Fall, Thomas Torgersen, Dan Nagle, John Heidemann, Milica Stojanovic, and Jun-Hong Cui (Urbashi Mitra is behind the camera).

A unique feature of the WUWNet workshop was an extensive demonstration session of various underwater systems. There were two MIT developed systems: a reconfigurable acoustic modem for high data rate underwater communications and a low-data rate sensor system which incorporated acoustic modems, optical communications, static sensor nodes and robotic sensor devices. University of California, Santa Barbara (UCSB) demonstrated the Mooring Modem for vertical underwater communication, the design of which was presented in the technical paper sessions, constructed with off-the-shelf elements. The UCSB system was actually demonstrated in water at the

workshop. The small-footprint, low-power, acoustic Micro-Modem developed at the Woods Hole Oceanographic Institution (WHOI) was also exhibited. Finally, there was the University of Southern California (USC) Networked Aquatic Microbial Observing System which is designed for marine monitoring such as algae detection. This system exploits autonomous boat navigation, sensor networking and employs wireless radio communication.

III. Paper Sessions

The first session, chaired by Dr. Milica Stojanovic, had three tutorial presentations which served to expertly outline the challenges of underwater networks. The first presenter was Dr. John Proakis, University of California, San Diego, who provided an overview of the current state-of-the art in underwater acoustic communications and signal processing. He focused on the physical layer methods of modulation/detection, coding/decoding and diversity combining which have proven instrumental in achieving reliable wireless communication over acoustic channels. This presentation was followed by Dr. Ian Akyildiz of the Georgia Institute of Technology, who spoke about the next level of communication system design, namely the candidate protocols for underwater sensor networks. After a survey of existing methods used in the wireless radio networks, he focused on the particular requirements imposed by the acoustic environment: the poor quality of the physical link and the high channel latency resulting from the low speed of sound underwater, and their implications on the design of network protocols in this environment. The final presentation, by Dr. James Preisig of WHOI, was on acoustic propagation considerations for underwater network development. This presentation focused on the laws of acoustic propagation, highlighting the differences between this environment and the better-known radio environment, and pointing out the difficulties that acoustic propagation imposes on the signal processing algorithms and the network protocol design.

In the second session, chaired by Dr. Jun-Hong Cui (UConn), the papers addressed system-level design issues. Notable among the workshop papers was the first paper presented in this session by Mr. James Partan (University of Massachusetts, Amherst and WHOI). He gave a comprehensive survey of practical issues in underwater network design, focusing on those system characteristics that make the underwater networks so different from the land-based networks:

Figure 2: Dr. Ian Akyildiz presents while Dr. John Proakis looks on.

the difficulty of deployment, the harshness of the environment, the large size of the sensor nodes and the associated cost and power requirements. In the second paper, Dr. Sumit Roy of the University of Washington presented an outline of the research carried out at the University of Washington using field deployment of underwater systems, and discussed large-scale issues related to the deployment geometry. The final paper in this session was presented by Mr. Vijay Chandrasekha of the Institute of Infocomm Research, Singapore, who addressed localization in underwater sensor networks.

The third session, chaired by Dr. Urbashi Mitra (USC), was devoted to research papers that targeted high-level system analysis and algorithm design. This session contained three papers. The first paper, by Dr. Milica Stojanovic, discussed the impact of acoustic propagation laws on the bandwidth and capacity of the underwater channel, showing that the acoustic channel capacity depends on the transmission distance, a fact that bears significant implication on the network design, favoring short-distance multi-hop transmission over long-distance single-hop transmission. The second paper, presented by Dr. Dario Pompili (Georgia Institute of Technology), considered a deployment analysis in underwater acoustic networks, focusing on the issues related to the network topology uncertainties and its implications on the system performance. The final paper was presented by Dr. Michele Zorzi (University of Padova), who addressed an optimization framework for joint sensor deployment, link scheduling and routing in underwater sensor networks, identifying a number of pertinent issues in higher-layer network design, a new area in the design of underwater systems.

The fourth and final session, chaired by Dr. Kevin Fall, contained papers that addressed the subject of specific system design. The first paper, presented

Figure 3: MobiCom General Chair Mario Gerla congratulates Milica Stojanovic on a successful workshop and partakes in the WUWNet refreshments.

by Dr. Michael Frater (University of New South Wales), took us along a different route in underwater sensor networking by discussing a short-rang electro-magnetic communication within a swarm of autonomous underwater vehicles. Ms. Bridget Benson followed by presenting a research project carried out at the University of California, Santa Barbara, which focuses on the development of a simple, but low-cost acoustic modem for moored oceanographic applications. Another low-cost acoustic modem design was presented by Mr. Jack Wills of the University of Southern California's Information Science Institute. The session concluded with a presentation by Mr. Matthew Haag (Worcester Polytechnic Institute) on store-and-forward routing for underwater networks based on status packet deprecation.

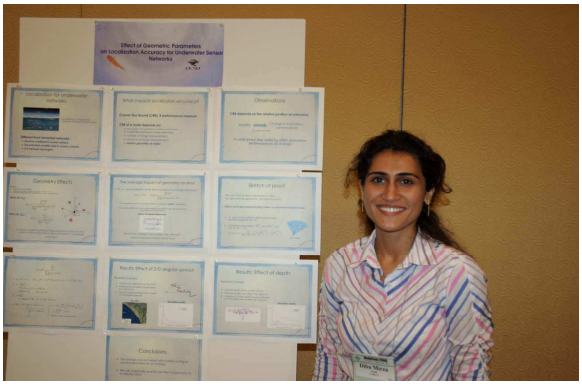

Figure 4: UCSD graduate student, Diba Mirza, presents her new work on localization in the work-in-progress session.

IV. Conclusions

The workshop was a resounding success. Of the eight workshops held with MobiCom'06, WUWNet tied with VANET for the largest participation with 65 registered participants. The strong attendance, coupled with the generous support of the financial sponsors also lead to excellent coffee breaks, refreshments and lunch. The high quality of the workshop is due in large part to the participation of the technical program committee who actively solicited many of the papers. The workshop co-chairs also wish to recognize the exceptional efforts the WUWNet organizing team: Volkan Rodoplu (UCSB) and Wei Ye (USC/ISI) for publicity, Shengli Zhou (UConn), finance chair, Xiuzhen Cheng (George Washington University) for publications, Zheng Peng (UConn), webmaster, and James Nash (Boeing) for local support. The workshop co-chairs would like to thank the authors for their excellent research paper submissions, the participants who travelled from all corners of the globe to attend the workshop, the volunteers who generously organized the workshop and our financial supporters, all of whom ensured the success of the first WUWNet.

A WUWNet steering committee has been formed and it is comprised of: Ian Akyildiz (Georgia Institute of Technology), Jun-Hong Cui (University of Connecticut, Chair), David Du (National Science Foundation/University of Minnesota), Kevin Fall (Intel Research, Berkeley), John Heidemann (University of Southern California/Information Science Institute), Urbashi Mitra (University of Southern California), Milica Stojanovic (Massachusetts Institute of Technology). Plans are currently underway for WUWNet'07, which will be ably co-chaired by Dr. Ian Akyildiz and Dr. David Du. We look forward to seeing everyone again in 2007.