An Underwater Communication and Sensing Testbed in Marina del Rey

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Extended Abstract

Sensing, monitoring, and communication underwater is increasingly important to scientists who study the oceans, rivers, and lakes, as government and industry seek to observe, protect, exploit, and control resources underwater. With growing awareness of environmental concerns such as runoff pollution and global climate change, and significant underwater events such as oil spills, volcanic activity, and the like, more people are seeking innovative ways to observe and communicate underwater.

Despite these needs, research progress in underwater communication and sensing is more difficult than on land for several reasons. Pragmatic considerations such as *limited access to the underwater environment* come together with technical considerations such as *difficulty in modeling the behavior of underwater acoustic signals*. These difficulties make simulations problematic, thus research in this area requires realistic (i.e. in the water) experiments in order to perform credible research.

To assist in overcoming these challenges, we have made some progress on building a flexible, configurable underwater sensing and communications testbed within the waters of Marina del Rey, California. Our insight is that *remote access can allow 24x7 use of an underwater testbed* and so accelerate research progress.

TESTBED DESIGN

To deploy our testbed in the underwater environment, we have rented five dock boxes at Pier 44 located next to the USC Information Sciences Institute (ISI) building in Marina del Rey, California. These boxes provide power, shelter, and access to the marine environment surrounding this pier. Our intention is to utilize these dock boxes through several generations of testbed development and deployment.

As an initial step, we designed, constructed and deployed two prototype testbed nodes based on an existing underwater modem developed by WHOI [WHOI], integrated with a general purpose PC to provide modem control and data communication functions. A high gain 802.11 antenna is connected to the embedded PC at each node to support wireless connection to a central point. This hardware configuration is shown in Figure 1. The prototype wireless underwater communication nodes were deployed in two of the dock boxes, with the radio links providing direct access to users as shown in Figure 2.

This deployment of the initial underwater communication nodes was successful in validating our ability to deploy underwater equipment, the physical robustness of the equipment in our environment, and our ability to maintain communications between the testbed nodes and our central control point.

However our initial design's value as a research tool is limited by the purpose-built design of the modem. The modem's fixed-purpose design imposes strong restrictions on the communication waveforms it can generate, as well as creating significant limitation in terms of modem control.

To address these limitations and create a flexible testbed node capable of supporting a very broad range of research objectives, we are developing a second-generation node architecture that implements a fully software-based acoustic signal path. By analogy with "software radio", *all* of the signal processing functions in this design, with the exception of the transmit power amplifier, receive preamplifier, and transducers, are implemented in software. This allows the node to support a wide and flexible range of signal processing algorithms and communication protocols, allowing new algorithms and functions to be developed and tested at all layers of the protocol stack.

This task is greatly simplified because, unlike radio frequencies used in air communications, the frequency of acoustic signals commonly used in underwater sensing and communication does not exceed 40KHz. This lower frequency requirement greatly relaxes software acoustic modem (SAM) implementation constraints when compared to software radio, allowing the use of standard CPUs and hardware, and expanding the role of software. At the cost of higher energy consumption (when compared to a hardware based modem), it is possible to minimize the hardware components of a node and offload all of the low level data processing to software.

Figure 1: Network relay (right) eeePC and WHOI modem (left)

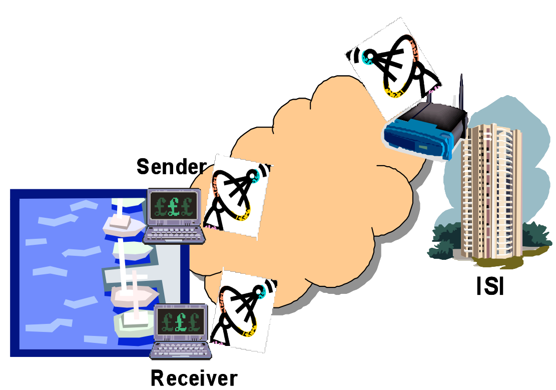

Figure 2: Remote communications infrastructure.

Benefitting from the relatively low signal frequencies and processing requirements of a SAM, our node is designed entirely with off the shelf hardware, using an embedded computer with sound card, a car audio amplifier, a guitar pre-amplifier, and a hydrophone, as shown in Figure 3. In order to facilitate collaborative sensing functionalities, we integrate GPS units to obtain accurate time information.

The software subsystem in this second-generation node is a modified version of *GNURadio* [GNUR], with modules enabling modulation and demodulation of acoustic signals. In addition to data communication, we have built software modules to send and receive acoustic chirps for measuring time of flight of acoustic signals sent from one node to another. Data communications have been tested at 60 meters, while the chirp and timing mechanisms have been tested in the laboratory and will be deployed to the dock boxes in the near future.

Although our work on these second-generation nodes is preliminary, we believe that complete access and software programmability of the low level communication tasks in our testbed will become the key factor in enabling innovative underwater research.

FUTURE PLANS

More novel than the details of the testbed hardware, the next phase of our work will focus on infrastructure to support shared use and remote access to the testbed. One option that we are considering is leveraging existing software resources and prior expertise in ISI's computer network emulation testbed DETER, to build the underwater testbed management system. The DETER infrastructure is an Emulab clone that allows its users to share computation and networking resources on a computer network testbed to conduct network security research. We find that the requirements for sharing and controlling our underwater testbed is similar enough to DETER that integration with DETER is possible. Upon successfully integrating with DETER, the testbed can be conveniently configured, shared, and accessed through web interfaces and ssh clients.

In parallel to the above mentioned effort, we will develop prebuilt software modules and templates that expose different levels of underwater communication; starting from raw signal transmission up to application-level communication. Our goal of this effort is to provide reference design(s) for basic underwater communication as well as simplified development mechanisms for the researchers to design and modify underwater communication at all levels.

Once sufficient infrastructure and development tools are in place, we will increase the number of accessible nodes to five to enable small scale underwater networking research. This task will simply require duplication of two node testbed and their integration into the management system.

Ultimately, we strive to build a testbed that will easily allow researchers across the community access to in-water equipment 24/7. We hope that this kind of access will support underwater research in several areas. Since our testbed will give the researchers access to the raw signals and tools to process them, it will enable research in novel signal processing techniques (applicable to data communication research at the PHY level), new underwater communication protocols including low power MAC, acoustic sensing technologies such as ocean acoustic tomography and 3-D beam-forming using distributed sensors.

Our poster will discuss the initial deployment and the challenges we faced, the current work with our software-based node and a detailed look at some of the new and novel underwater sensing and communications work we hope to do.

REFERENCES

[WHOI] http://acomms.whoi.edu/umodem/

[GNUR] http://gnuradio.org/

Figure 3: Aquarian Audio H1 (left) AOpen DE2700 (right)

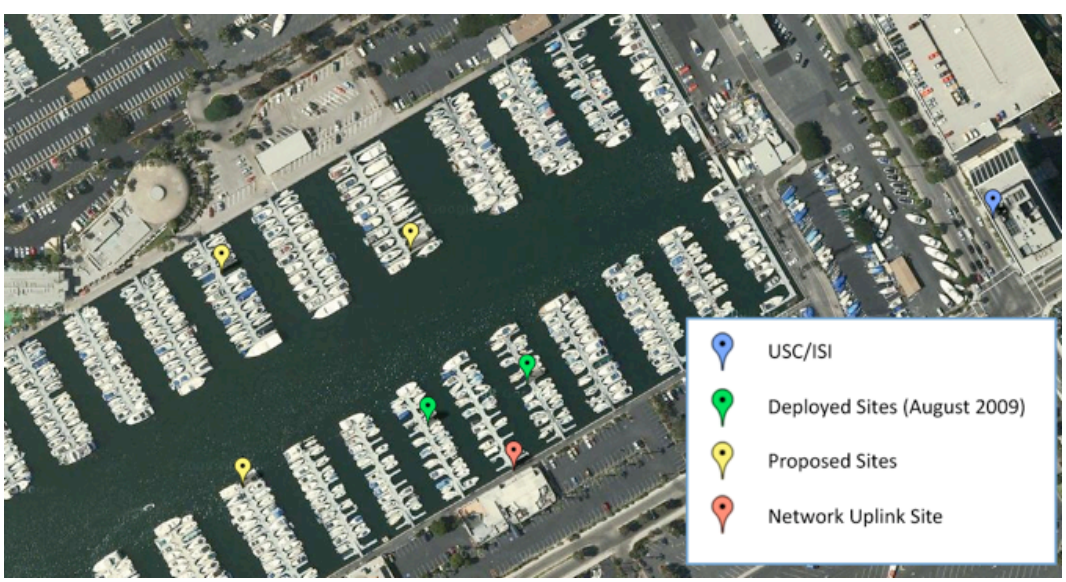

Figure 4: Current and proposed testbed node locations