Demo Abstract: Adaptive Cross-Layer Routing for Underwater Acoustic Sensor Networks with the SUNSET Framework

Chiara Petrioli
University of Rome "La Sapienza"
113, Via Salaria
Rome, Italy
WSENSE s.r.l., Rome, Italy
petrioli@di.uniroma1.it

Roberto Petroccia
University of Rome "La Sapienza"
113, Via Salaria
Rome, Italy
WSENSE s.r.l., Rome, Italy
petroccia@di.uniroma1.it

Daniele Spaccini
University of Rome "La Sapienza"
113, Via Salaria
Rome, Italy
spaccini@di.uniroma1.it

ABSTRACT

We demonstrate the use of a novel cross layer protocol for routing in Underwater Acoustic Sensor Networks (UASNs). Our protocol, named CARP [1] for Channel-Aware Routing Protocol, is able to dynamically adapt to channel dynamics and to the changes occurring in the network topology and link quality over time. CARP is implemented and tested using the Sapienza University Networking framework for underwater Simulation Emulation and real-life Testing (SUNSET) [2] in different network scenarios. Our demonstration shows that CARP is able to find the suitable routes and to deliver data to the sink node independently of prevailing packet error rates and of nodes/links addition and removal.

Categories and Subject Descriptors

C2.2 [**Computer-Communication Networks**]: Network Protocols; D.2.11 [**Software Engineering**]: Software Architectures

General Terms

Experimentation, Performance, Validation.

Keywords

Underwater sensor networks, simulation, emulation, ns-2, sea trial testing, SUNSET, CARP.

1. INTRODUCTION

Underwater acoustic sensor networks (UASNs) have become an important area of research and the enabling technology for a wide range of emerging applications, including ocean monitoring for scientific exploration and commercial exploitation, assisted navigation, safe CO_2 storage underwater, intrusion detection, etc. [3]. Emerging underwater applications require multi-hop networks where sensor nodes transmit data to one of more collection points (*sinks*) located at surface level. However, underwater communication through acoustic transmissions is quite challenging, being beset by long propagation delays, low bandwidth, sound speed variability, and many other environmental impairments. Additionally, the channel condition can rapidly change in time, which may result in significant time-varying link reliability and in asymmetric links. In such a network scenario, designing routing protocols that are adaptive to high network dynamics and can deliver data with little overhead and energy consumption is not an easy task. Although several routing solutions for UASNs have been presented their actual performance has been investigated mainly through simulation studies, often considering oversimplified underwater acoustic channel models. Furthermore, the simulators used for these studies are so varied that meaningful comparisons are difficult, if not impossible. Finally, for the few protocols that have been actually tested in water, the transition from simulations to real-life tests requires to rewrite most of the code adapting to the constraints of commercial hardware, so that the validation of simulation models is very limited, in that obtained results in the two settings could be very different.

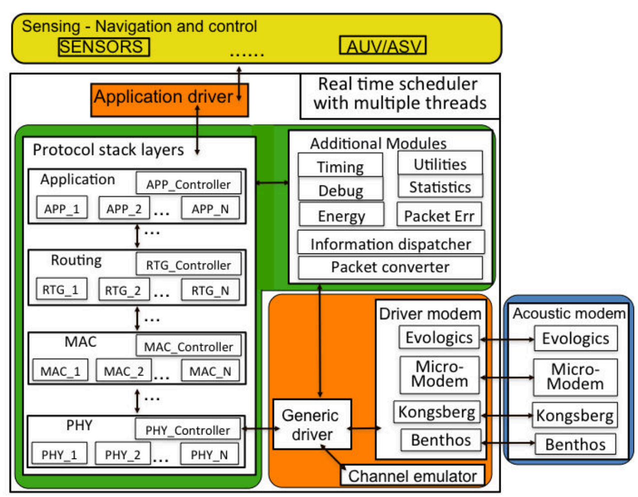
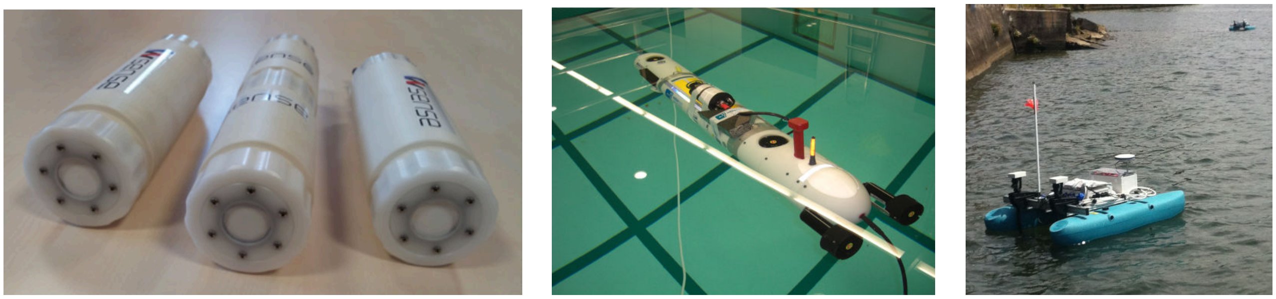


Figure 1: SUNSET emulation architecture.

In this work we demonstrate the use of a novel cross layer routing solution, named CARP [1] for Channel-Aware Routing Protocol, which is able to dynamically adjust the routes to the sink according to network changes with limited overhead. CARP has been implemented in SUNSET [2], a framework that allows us to assess the performance of underwater protocols and systems through simula-

SenSys'13, Nov 11-15 2013, Roma, Italy
ACM 978-1-4503-2027-6/13/11
http://dx.doi.org/10.1145/2517351.2517416 .



(a) Underwater monitoring node: Measurement probe with the Gumstix inside the PVC housing. (b) MARES AUV with acoustic modem. (c) INESC ASV with acoustic modem.

Figure 2: SUNSET UASN demonstration.

tion, emulation and real-life tests seamlessly. This allowed us to avoid the pitfalls mentioned above, in that the code used for simulating the protocol has been re-used for in lab emulation tests and at sea experiments.

While demonstrating the effectiveness of the CARP protocol for robust routing in UASNs, we showcase the use of SUNSET and of its back-seat driver mechanism recently introduced for remote and real-time control of an entire underwater network acoustically [4]. Using the back-seat driver feature of SUNSET we do not have to access the nodes every time protocol tuning or reconfiguration are needed. This allows to save time and money since the operations of node recovery and redeployment are usually complex and expensive, requiring specialized personnel, ships, etc.

In this demo we showcase:

SUNSET. SUNSET is a novel framework to seamlessly simulate, emulate and test at sea novel communication protocols for UASNs. SUNSET is based on the open source and well known network simulator ns-2 [5] and its extension ns2-Miracle [6]. SUNSET allows to combine communication, networking, sensing and navigation capabilities in a single underwater unit. The SUNSET architecture (Figure 1) has been successfully interfaced with different kinds of devices: Acoustic modems; sensing platforms [7] (Figure 2a) and mobile vehicles [8] (Figures 2b and 2c). SUNSET has also been successfully ported on small embedded devices, thus allowing easy usage on modem or AUVs.

Back-seat driver. The back-seat driver mechanism [4] makes use of the acoustic communications and networking capabilities provided by SUNSET to remotely operate and control underwater devices in real-time using acoustic links. Requests and commands can be delivered to any remote underwater node, via single-hop or multi-hop acoustic transmissions, to collect data and to instruct the node about actions to perform. There is therefore no need of retrieving a node for protocol reconfiguration or parameter setting after its deployment.

CARP. CARP [1] is a cross layer routing protocol. After a set-up phase for allowing the nodes to acquire hop distance information from the sink, as well as information about their neighbors towards the sink, nodes proceed to relay selection for routing. In particular, when a node x has one or more data packets to forward, it broadcasts a request packet (`PING`) to choose a suitable relay among its neighbors and waits for a given time to collect its neighbor responses. Nodes receiving the transmitted request reply with a response message (`PONG`). Each `PONG` message, sent by a node y, contains information on y status allowing x to select the more suitable relay. These information include: 1) Estimated hop distance from the sink; 2) Available buffer space; 3) Residual energy; 4) Estimated quality of the link between x and y estimated by y.[1] Node x considers the information received by its neighbors and selects as relay the node with the best history of successful forwarding towards the sink. CARP combines link quality with simple topology information (hop distance) for routing around connectivity holes and shadow zones. Relays are also chosen so that residual energy and buffer space are used as secondary choice criteria. Optimization is performed by sending multiple packets at a time and cumulative acknowledgments that are also used to keep topology information (especially hop distance) up to date.

Acknowledgments

This work was supported in part by the EU FP 7 IP project SUNRISE "Sensing, monitoring and actuating on the UNderwater world through a federated Research InfraStructure Extending the Future Internet."

2. REFERENCES

[1] S. Basagni, C. Petrioli, R. Petroccia, and D. Spaccini, "Channel-aware routing for underwater wireless networks," in *Proceedings of MTS/IEEE OCEANS 2012*, Yeosu, Korea, May, 21–24 2012.

[2] C. Petrioli and R. Petroccia, "SUNSET: Simulation, emulation and real-life testing of underwater wireless sensor networks," in *Proceedings of IEEE UComms 2012*, Sestri Levante, Italy, September, 12–14 2012.

[3] J. Heidemann, M. Stojanovic, and M. Zorzi, "Underwater sensor networks: Applications, advances, and challenges," *Royal Society*, vol. 370, no. 1958, pp. 158–175, May 2012.

[4] R. Petroccia and D. Spaccini, "Implementing a back-seat driver to remotely control the experiments in an underwater acoustic sensor network," in *Proceedings of MTS/IEEE OCEANS 2013*, Bergen, Norway, June, 10–13 2013.

[5] The VINT Project, *The ns Manual*. www.isi.edu/nsnam/ns/, 2002.

[6] N. Baldo, F. Maguolo, M. Miozzo, M. Rossi, and M. Zorzi, "ns2-MIRACLE: A modular framework for multi-technology and cross-layer support in network simulator 2," in *Proceedings of ACM VALUETOOLS 2007*, Nantes, France, October 23–25 2007, pp. 1–8.

[7] A. Annunziatellis, S. Graziani, S. Lombardi, C. Petrioli, and Petroccia, "CO2Net: A marine monitoring system for CO_2 leakage detection," in *Proceedings of MTS/IEEE OCEANS 2012*, Yeosu, Korea, May, 21–24 2012.

[8] N. A. Cruz, B. M. Ferreira, O. Kebkal, A. C. Matos, C. Petrioli, R. Petroccia, and D. Spaccini, "Investigation of underwater acoustic networking enabling the cooperative operation of multiple heterogeneous vehicles," *Marine Technology Society Journal*, vol. 47, pp. 43–58, March/April 2013.

[1]Link quality information are estimated according to recent history collected at each node about the number of control and data packets correctly received. These information can be combined and replaced with link quality information provided by the acoustic modem, if available.