DEMO: Time Synchronization and Localization for Underwater Acoustic Sensor Networks with the SUNSET Framework

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ABSTRACT

We demonstrate the use of SUNSET, a framework for seamless simulation, emulation and testing, through the implementation and validation of a novel time synchronization and localization algorithm for underwater acoustic sensor networks. The algorithm, implemented and tested in a multihop acoustic network, is based on node discovering and cooperation for range estimation and for achieving network level synchronization. Our demonstration shows the flexibility of SUNSET in providing a framework for simulation, emulation and in field testing over heterogeneous devices, including mobile ones. SUNSET enables the users to control network devices remotely for configuration and re-programming, and allows to use the same code for both simulation and actual tests. A video of a SUNSET-based remotely controlled submarine AUV will be shown from previous in field experimentation.

Keywords

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

Categories and Subject Descriptors

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

1. INTRODUCTION

Underwater acoustic sensor networks (UASNs) have become an important area of research with practical impact on a host of different applications such as ocean monitoring, safe CO_2 storage underwater and coastline protection [3]. Most of the solutions presented in the past to create UASNs, where multiple heterogeneous devices can self-organize and cooperate to accomplish more challenging tasks, have been mainly investigated through simulations. Only a few systems have been implemented in practice.

In this work we demonstrate a complete system to develop and remotely operate an UASN. The development of our underwater monitoring system is based on SUNSET, the Sapienza University networking framework for underwater Simulation Emulation and real-life Testing [1], which can be used to investigate the performance of underwater solutions through simulation, emulation and real-life tests in a seamless way. The SUNSET framework allows us to compare and evaluate different network designs, algorithms and protocols in a variety of settings and application scenarios and to use the simulated protocols in real deployments without any need of code rewriting. We present the use of SUNSET and of its Backseat driver mechanism [2] to remotely control and operate the entire underwater network via acoustic links. We then show the performance of a new synchronization and localization algorithm. The components of the system demonstrated in the demo are summarized below.

SUNSET. SUNSET provides a complete toolkit to seamlessly simulate, emulate and test at sea communication solutions for UASNs. It allows us to combine communication, networking, sensing and navigation capabilities in a single underwater unit. The SUNSET core components are available open source at [4]. The SUNSET architecture is highly flexible and it has been successfully interfaced with different kinds of devices: Acoustic modems; sensing platforms [5] (Figure 1a) and mobile vehicles [6] (Figure 1b).

Backseat Driver. Using the acoustic communication and networking capabilities provided by SUNSET, the Backseat Driver system has been developed for remotely operate and control underwater devices in real-time using acoustic links [2]. There is therefore no need of retrieving a node for reconfiguration or parameter setting after it has been deployed.

A new algorithm for synchronization and localization for UASNs. When the network starts, a designated *init* node gives the start to a time slotted scheduling, where time slots are assigned according to node IDs. Each time slot is made of several mini slots, one for each of the other nodes in the network. The init node broadcasts a request message to each of the other nodes in the network, according

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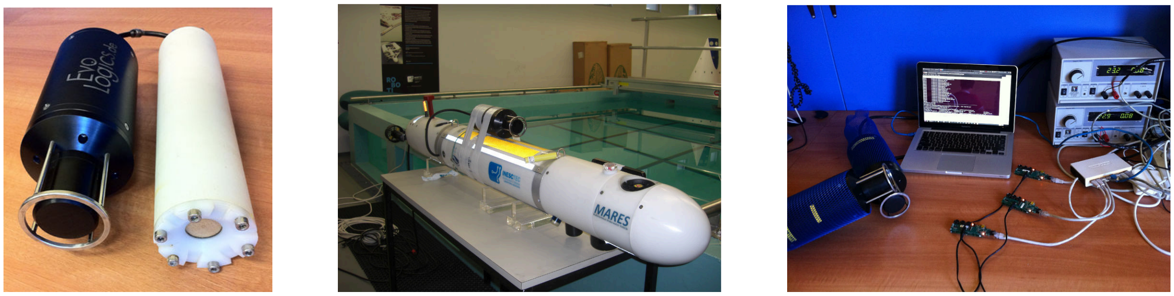

(a) Underwater monitoring node: Acoustic modem and measurement probe.

(b) MARES AUV with acoustic modem.

(c) Laboratory testbed using the channel emulator with SUNSET running on different hardware platforms.

Figure 1: SUNSET UASN demonstration.

to the mini slots. When a node receives the request message it adds the sender to the list of its neighbors and, if it is the destination of the request, it replies with a response message carrying the packet processing delay. When the sender receives the replies it computes the round trip delay to the replying nodes and estimates their distance. When listening to a request or response message, each node can determine the current time slot and mini slot and it can therefore estimate when it will be its turn to transmit. When nodes send their periodic request and response messages they add to the packet a timestamp and the estimated delay to the other nodes. This allows receiving nodes, for which the estimated round trip delay is known, to be able to estimate the clock drift with respect to the sender. Using this mechanism all the nodes in the network are progressively able to synchronize their clocks with that of the init node, thus adjusting the actual time for their slotted transmissions. Each node is also computing and collecting ranging information which, together with the position of some reference nodes, is then used to iteratively localize nodes in the network.

2. DEMO DESCRIPTION

The demo is designed to demonstrate the flexibility of SUNSET for remotely configuring and operating an UASN. A GUI will allow the user to remotely control and operate the network in real-time, and will provide information on the nodes localization and synchronization. Underwater transmissions will be performed using real acoustic modems (i.e., Evologics) to demonstrate how SUNSET interacts with real communication hardware, and by using the SUNSET channel emulator. The SUNSET emulator allows us to run several node instances on the same PC and on different platforms connected via Ethernet to emulate an underwater network composed of several devices without the need of real acoustic modems (Figure 1c). The channel emulator computes the propagation delay associated to each link according to the position assigned to the different nodes in 3D. It also allows the user to select different packet error rates and the desired network topology. In the DEMO we use the emulation and test environment to build an underwater network composed of PC and embedded devices (Gumstix), to evaluate and validate the proposed localization and synchronization algorithm and to control and instruct sensing devices remotely. The user can also address the different nodes in the network to run the desired protocol thanks to the SUNSET Backseat Driver capabilities [2] for network configuration. Once all nodes are configured and run the selected protocol, they are instructed to start communicating and cooperating to discover, locate and synchronize with the other nodes. At the same time, node status messages and sensor measurements are delivered to the control station exploiting underwater MAC and routing protocols. In the DEMO a CO2 Probe, developed by the Geochemistry group at the University of Rome "La Sapienza" is used as sensing device and data generator. This probe is an environmental underwater sensor for measuring temperature and CO_2 concentrations. Moreover, we show how to directly control and instruct the sensing platform on collecting and reporting the requested measurement to the user periodically or in case of specific events (e.g., if there is an alarm). Finally, the DEMO includes a video about field tests and experiments where SUNSET is used to control the operation of the MARES underwater vehicle (Figures 1b) in the test tank at the Ocean Systems Group laboratory.

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