# DEMO: Real-Time Control of an Underwater Sensor Network using the SUNSET Framework

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***Abstract*—Our demo presents a novel framework, named SUNSET [1], which can be used to control the operations of submerged underwater devices in a real-time and online way using acoustic communications. SUNSET provides acoustic communication capability and a complete protocol stack to transmit acoustic commands and instruct underwater devices on the operations to perform. SUNSET has been successfully interfaced with different external devices: off-the-shelf acoustic modems, environmental sensors, autonomous underwater and surface vehicles. Moreover, SUNSET has been extensively validated and evaluated during several at sea experimental campaigns in the past few years resulting in a flexible, reliable and efficient platform to be used for real-life testing.**

## I. Introduction

Currently, one of the main limitation of underwater systems is the interaction and control on the operation of the different devices, such as sensing platform and underwater vehicles, while they are underwater. For what concerns ocean monitoring systems, they are typically based on one of two different approaches:

1) Deployment of underwater nodes that record data during the monitoring mission, and then recover the instruments to retrieve the data.
2) Cabling of the underwater nodes to a surface station in order to collect the data on-line and in real-time.

In the first approach, the deployment of the nodes is easy but there is no control on the system to collect data, detect HW/SW problems or nodes disappearing from the deployment area due to strong currents or intense marine activities. This may result in significant degradation of the monitoring quality and accuracy. The second approach enables complete control on the monitoring system. However, the deployment of underwater cables usually involves sea trips, specialized personnel, and sometimes dangerous operations, significantly increasing the cost and complexity of deployment. Moreover, cables are more vulnerable to fisher activity, which can cause cables and equipment damages and require recovery expeditions.

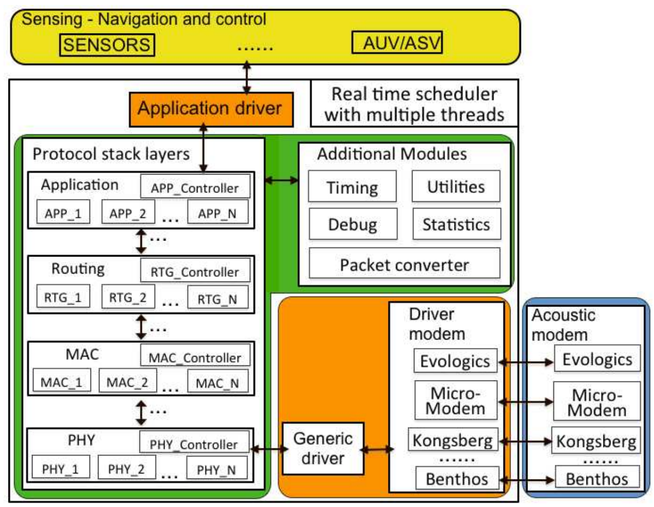


Figure 1: SUNSET architecture.

For what concerns underwater vehicles, usually preloaded missions are used when operating with this kind of devices and there is no real-time interaction with the vehicle once it is underwater. In same cases a point to point communication over the acoustic link is used to send basic instruction to the vehicle while it is underwater but the interaction of several vehicles through the acoustic channel is still an open challenge. This kind of approach strongly limits the operations and task that underwater vehicles can perform and limits also the possibility of cooperation and interaction among different devices: Static and mobile nodes, at the surface or underwater.

Using the acoustic communications and networking capabilities provided by SUNSET, requests and commands can be delivered to a remote node (via single-hop or multi-hop transmissions), thus allowing the remote control of the device using acoustic links in a real-time and on-line way. Sensing platform and underwater vehicles can then be instructed by the control station on the operations to perform and can cooperate together, thus significantly improving the flexibility of the system and the operations which can be performed.

SUNSET architecture (Figure 1) is really flexible and it has already been successfully interfaced with different kinds of devices: Acoustic modems (WHOI Micro-Modems, Evologics modem, Kongsberg modem and Teledyne Benthos modem); sensing platforms (environmental underwater sensors for temperature, $CO_2$ and methane concentrations [2]) and vehicles (MARES AUV and ASV - developed by the INESC TEC/University of Porto, Folaga AUV -developed by Graaltech). For each of these devices, specific drivers have been implemented and extensively tested in field. SUNSET has also been successfully ported on small portable devices (Gumstix, PC104 or other ARM-based systems), thus allowing the user to embed it inside modem or AUV housings, making easier the deployment at sea.

Figure 2: Underwater monitoring node: acoustic modem and measurement probe with the Gumstix inside the PVC housing.

## II. Demo Description

This demo will present the flexibility of the SUNSET framework when configuring the networking solutions, selecting and combining together different MAC and routing solutions in a easy way, and the possibility to use SUNSET to control a CO2 Probe, which is an environmental underwater sensor for measuring temperature and $CO_2$ concentrations developed by the Geochemistry group at the University of Rome, La Sapienza. Evologics modems will be used for the acoustic communications (Figure 2). One laptop running SUNSET will be connected to one modem and will act as the control station. A second Evologics modem will be connected to CO2 Probe which will have a Gumstix embedded device inside its housing. SUNSET running on the Gusmtix will control sensors and modem operations. There is no wired connection between the control station and the CO2 Probe. The control station will acoustically instruct in a real-time and online way the CO2 Probe to: Collect data; retrieve data; change system settings, such as sampling rate, frequency with which data are reported, alarm thresholds etc. In order to show that the proposed approach is not limited to point to point communications and that commands and data can be delivered over multiple hops in a real underwater network, several underwater nodes will be emulated using the S2C Modem emulator [3]. This emulator allows to create several emulated Evologics modems, to place them in the 3D space, to create a desired topology and it also introduces propagation delay among the nodes and the possibility of errors on the links according to a given probability. When emulating the network, several instances of SUNSET will run on the control station, each of them connected to a different emulated modem. Also the Gumstix controlling the CO2 Probe will be connected to an emulated modem. Commands and data will flow this time through the emulated network over multiple hops from the control station to the CO2 Probe and vice versa. Moreover, a video about the first

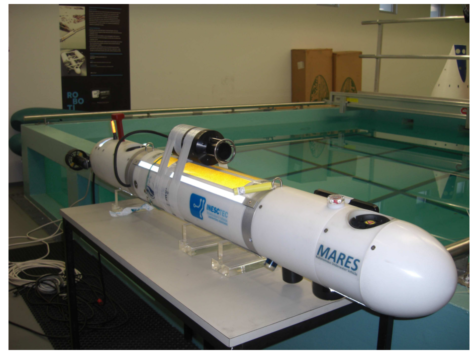


Figure 3: MARES AUV with acoustic modem.

tests conducted in February 2012, where SUNSET was used to control the operation of the MARES vehicle (Figures 3) in the test tank at the Ocean Systems Group laboratory, will be showed. During this test, one Evologics modem was connected to a control station running SUNSET on a PC and another one to the Gumstix inside the vehicle. Acoustic commands were sent from the control station to make the vehicle execute different maneuvers, according to the limited size of the test tank: Variations of pitch and yaw angles (and rates) and of vehicle depths. The obtained results confirmed the validity of the proposed solution when controlling the vehicle using acoustic communications.

## III. Space and Equipment Requirements

The space requirement for this demo is merely a table to setup two netbook computers, two Evologics modems, and one CO2 Probe. We further require a 24V power supplier to power the modems and the CO2 Probe. If possible a water tank or aquarium which would allow us to submerge the modem and the sensor would be useful, otherwise acoustic transmission in air will be used. Also an additional monitor would help displaying at a higher resolution the video about the MARES vehicle control. The S2C Modem emulator will run on a server machine accessible via Internet. Therefore, Internet connection would be needed to remotely access the Evologics emulator.

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