Design of a UAN Node Capable Of High Data Rate Transmission
Dual-Link Multinode Underwater Communication Access Point Allows Transmission of Large Amounts of Data to Shore

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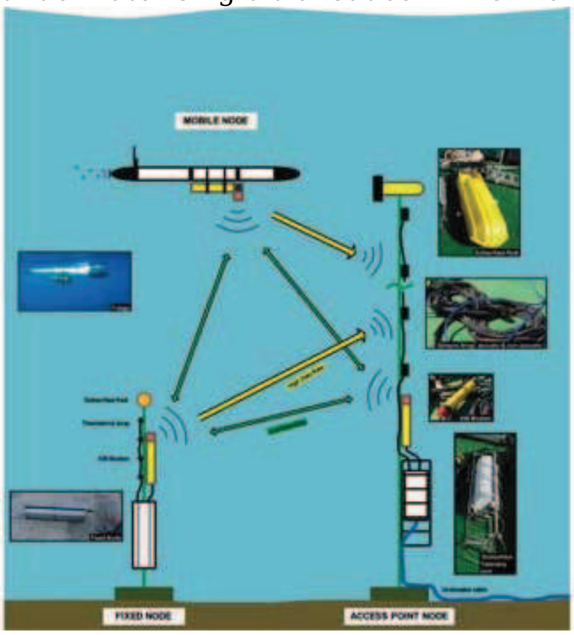
In recent years, underwater acoustic networks have become one of the most challenging topics in ocean acoustics. Generally, such networks are formed by both fixed and mobile underwater nodes. These client sensor nodes—such as moored underwater buoys, seafloor sensors and autonomous underwater vehicles (AUVs)—are simultaneously used to acquire environmental information and to communicate and relay it from other nodes in a network fashion.

Typical messaging between nodes consists of small pieces of information, including the status of the actuators, time, position, speed and commands, and can be supported by low-data-rate single-transducer modem connections. However, underwater monitoring and research increasingly requires access to a shore-based network for transmission of high volumes of information. Large amounts of data—for example, an optical or acoustic image, a sonar audio file, or oceanographic measurements—cannot be handled by underwater single-transducer links with poor power output and limited autonomy.



[Overview of the underwater](#)

equipment and functional network: a shore-cabled access point with modem and vertical hydrophone array (right), a fixed moored node (left) and a mobile node (top left). Click to enlarge.

To solve this problem, researchers at Investigação Tecnolõgica do Algarve (CINTAL) designed a node, the subsurface telemetry unit (STU), for interfacing an underwater network with a global network of users. The STU, which was completed last August, can asymmetrically handle bidirectional commands down to the underwater network at a low data rate and provide a secondary higher throughput upload data link from the underwater network to the shore-based network, creating a dual-link network. The STU is able to do this by employing both a vertical acoustic hydrophone array to receive all acoustic signals and single-transducer underwater acoustic modems for bidirectional interfacing with the client sensor nodes.

CINTAL designed and built the STU for the European Union Seventh Framework Programme's Underwater Acoustic Network (UAN) project. The project, which CINTAL is coordinating, is working to create a network that would allow surveillance and monitoring of ocean infrastructure using an underwater network of fixed and mobile nodes.

STU Functionality

The core function of the STU is to serve as an underwater network access point, which functions as an active network node with an established connection to the client sensor node. Additionally, the STU functions as the receiving station for higher-data-rate one-way transmissions from the client node. The active connection is established using a single-transducer underwater acoustic modem. This modem is also used by clients for higher-data-rate transmissions to be received on the vertical hydrophone array. Using a multisensor array has advantages, such as the need for less powerful acoustic transmission on the client side, where power consumption is critical, using the vertical hydrophone array to boost reception. These acquired data signals are then sent via fiber optic to a base station (BS), where a powerful multichannel equalizer can be used to extract the transmitted message.

An additional function of the STU is that it can function as a receive-only station. In this setup, the mobile and fixed nodes transmit data with a gain in energy consumption and channel-access time in comparison with an actively established connection. The gain in reception on the vertical hydrophone array can also be exploited to increase total unidirectional bit rate. Using this in an active system, a one-way asynchronous bit rate can be achieved.

UAN Project

The UAN project's network is comprised of the STU connected to a shore BS through an electro-optical cable that behaves as an access point for the UAN. In addition to the STU access point, the underwater network consists of remote and autonomous fixed devices that allow for permanent monitoring and mobile agents for on-demand missions distributed in a 10-by-10-kilometer area. In general, the autonomous agents are data-collecting devices equipped with a single-transducer modem, which provides both a low-data-rate bidirectional link with other single-transducer modems and a high-data-rate uploading link with the STU. Thus, there is asymmetry both on the data flow and on the complexity of the various agents.

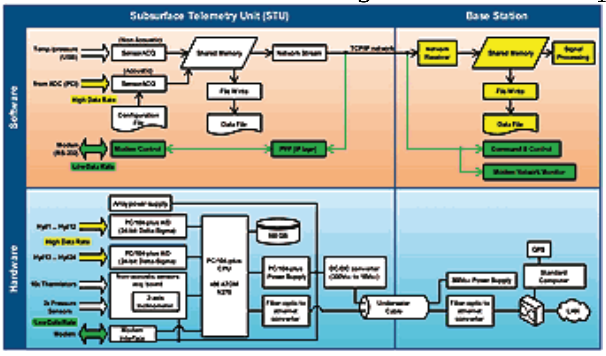
System Description

The STU is designed to be moored in water depths of up to 150 meters. It is comprised of a vertical acoustic array with up to 24 hydrophones, a multichannel thermistor chain and two pressure sensors along the acoustic array, along with an underwater acoustic modem. The shore power supply and network connection is sent through a 1,000-meter-long underwater cable.

The vertical hydrophone array is suspended in the water by the use of a torpedo-shaped subsurface float, which swivels so as to maintain minimum drag. This array is flexible in length and the hydrophones are spaced at regular intervals of two meters. For example, the total length of a 16-hydrophone array would be 34 meters.

The STU container is a submersible cylindrical enclosure that is 60 centimeters in height with a 16-centimeter diameter. The STU container's dimensions were designed so that it would be possible to mount a stack in the PC/104 industry standard. The stack includes: a power supply, an x86 CPU board, two 12-channel analog acquisition cards, a temperature and pressure sensor array acquisition board, and a converter board for the shore-based fiber optic and high-voltage connection. The CPU board runs a standard Linux (2.6 kernel) installation.

Time synchronization of the operating system is performed through the Ethernet network using the standard NTP protocol, and the surface base station that supplies the time is directly GPS synchronized. There is also a parallel one-pulse-per-second signal that is transmitted through an additional pair of wires directly to the acquisition boards.



STU and base station hardware and software overview. Click to enlarge.

The software on the STU is divided into multiple modules, which, with the exception of the acoustic acquisition program, can be dynamically started and used. Software modules include an acoustic acquisition program, which reads the data from one or both of the analog-to-digital converter cards and presents the acquired data as a continuous stream in a shared memory location. Multiple simultaneous reader processes can be attached to this shared memory location, including a local file writer, a remote network streamer, a selectable single-channel extractor for monitoring and a signal preprocessing module. In the default configuration, data is streamed to the BS, where the same software framework can be used to store data locally or restream data to an additional location. The underwater network is controlled by a modem control application, which also presents the user with a standard TCP/IP interface to be used over the underwater channel, and is therefore possible to be used for Internet-enabled applications.

The shore BS supplies the STU with a 300-volt direct current power supply, and the BS is used for online monitoring and storage of the data streamed from the STU. The BS transmits the data through the network to the processing nodes, which decode the signal received on the vertical array. Decoded messages can then be made available to the global network. In the current configuration, it is also possible for the BS to be a standard portable computer.

Sea Trials

The STU was initially tested last March in a lagoon in Faro, Portugal. The equipment was fixed to two piers 200 meters apart in an area with a water depth of three meters. The array was wrapped around a one-meter-diameter cage and the hydrophones were spaced five centimeters apart.

Transmission of quadrature phase-shift keying signals at 4,000 bits per second using a Kongsberg Maritime (Kongsberg, Norway) single-transducer modem with a carrier frequency of 25.6 kilohertz was performed from one pier, and signals were received at the other using the STU with a 16-hydrophone configuration. A multichannel decision feedback equalizer (DFE) was used to decode the signal and achieve error-free communication.

An engineering test deployment of the STU was then performed from September 10 through 30 in a shared resource experiment with the NATO Underwater Research Centre. Using the shore-based connection on Italy’s Pianosa Island, the system was deployed by the research vessel *Leonardo* at a water depth of 55 meters and a distance of 750 meters from the shore laboratory.

The deployment included the same 16-channel acoustic array as in the initial test, along with a thermistor chain and a Kongsberg underwater acoustic modem as the gateway node.

Kongsberg modems were deployed on two Graal Tech S.r.l. (Genoa, Italy) Folaga AUVs and also from the *Leonardo* to establish the active bidirectional command and control network links. The Kongsberg modems were also used to send a unidirectional higher-bit-rate signal to the vertical array of the STU.

Several experiments were performed with fixed and mobile P2P communications at different communication bands. The signals transmitted were similar to those of the pier experiment, but at rates of 4,000 and 8,000 bits per second. A DFE was also used for this experiment, resulting in almost error-free communication. During this sea trial, a low data rate of 500 bits per second was also achieved between the single-transducer modems. Using the same modems as transmitters from the mobile and fixed nodes and reception on the vertical array of the access point node, a high data rate of 8,000 bits per second was obtained.

A fully integrated UAN using the STU as its gateway node will be demonstrated in the Fjord of Trondheim in Norway this May, the final sea trial for this project.

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References
For a full list of references, please contact Friedrich Zabel at fredz@ualg.pt.

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-back to top-

-back to to Features Index-