Book of Abstracts of the

SixthUnderwater Communications and Networking Conference - UComms'22

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Keynote Talks:

Underwater Communications Over Many Media and Scales (UCOMMS)

By Prof. Andrew Singer

Acoustic communications have enabled subsea connectivity in a manner that was truly unthinkable only a few decades ago. Modems are now an integral part of many aspects of manned and unmanned subsea systems, where autonomy or cabled systems were previously the norm. Some of the key differences between subsea acoustic communications research and its land-based RF cousin, lie in the tremendous variability of the environments of interest and the relative cost of acquiring experimental data for research and experimentation. In this talk, I will discuss some of the methods that we have learned that enable experimentation through data re-use and experimental replay. Some of these methods have enabled us to push the boundaries of what we previously thought was possible, in terms of data rate, range, and system mobility. This is in part because we have been able to vary some of these parameters beyond what would have been reasonable without fear of jeopardizing the data by overly optimistic performance. Leveraging such experimental frugality, we have been able to explore applications of our acoustic communications work into a range of previously un(der)explored arenas. Some of our work in collaboration with biomedical ultrasound researchers have enabled through-tissue acoustic communications at data rates that far exceed the capabilities of current implanted biomedical devices. Through collaboration with geotechnical researchers, we have also been able to explore the replacement of traditionally wired subterranean sensor networks with through-soil acoustic transmission, opening the possibility of embedded geosensing without susceptibility to fouling that plagues existing infrastructural monitoring systems. A central theme in each of these applications, is the ability to explore a wide range of operational parameters with a suitably-chosen set of experimental data collection opportunities.

How Can Quantum Technologies Change Our Business in Underwater Comms?

By Prof. Davide Bacco

In a society based on the continuous exchange of sensitive data and information, the importance of secure and trustable communications is essential. By exploiting principles of Quantum Physics, it is possible to share data in an unconditionally secure way, no longer based on mathematical assumptions of the encryption algorithm, but founded on the basic principles of Quantum Mechanics. In this context, my research relies on the development of a Quantum Communication (QCs) system able to increase the actual performance in terms of rate, security and distance independently from the transmission medium. The key to exceeding the barriers of present QCs resides in the extensive knowledge of high-speed classical optical communications merged with future technologies based on integrated photonic circuits. In this lecture, I will present the latest research on quantum photonics technologies including high-dimensional quantum communication, pure photon-pair source on silicon, high-dimensional quantum entanglement manipulation and quantum teleportation. I will also present our recent results on new

quantum key distribution protocols and the integration of classical and quantum signals in the underwater domain.

Can Machines Learn to Communicate Underwater?

By Prof. Mandar Chitre

While the idea of machine learning is not new, the past decade has seen unprecedented advances that have led to it being one of the most influential technologies in recent years. It has made its way into everything from self-driving cars to drug discovery, natural language processing, astronomy, weather prediction, advertising, security, software development, and even art. Many challenging problems that have been unsolved for decades have recently been tamed using machine learning. So what about underwater acoustic communication? Can we apply cutting edge machine learning techniques discovered to work well in other domains to underwater communication problems and expect them to yield amazing results? The answer is very likely a "yes" – but certainly not by applying the techniques blindly. Most machine learning algorithms are data-hungry, and getting large amounts of high quality curated data from oceanic experiments is prohibitively expensive. Yet, there is much that we can do to learn effectively from a small amount of noisy data by combining our knowledge of physics with machine learning. In this talk, we will explore some of the key ideas behind machine learning, and how these ideas may be combined with our ocean acoustic domain knowledge to yield practical solutions to some of the challenges in underwater acoustic communication.

Technical Session "Physical layer: Propagation, Modulation and Signal Processing"
(Chairs: Francois Socheleau & Costas Pelekanakis)

Multi-user Communications for Acoustic OFDM: A Broadband Beamforming Approach

D. A. Cuji, Z. Li and M. Stojanovic

We propose the design of a beamforming technique for multi-user communications over acoustic channels. Our work focuses on multi-carrier modulation in the form of orthogonal frequency division multiplexing (OFDM), which is suitable for broadband acoustic channels. The framework consists of multiple users transmitting to a common base station equipped with a uniform linear array. The base station iteratively steers a beam to each user's propagation path while placing nulls in the direction of other paths. Finally, the multiple paths of the desired user are recombined before data detection. The design concepts are demonstrated in simulation for an underwater channel, and using experimental over-the-air transmissions in an indoor environment of an acoustic communications testbed.

Online Segmented Recursive Least-Squares for Multipath Doppler Tracking

J. W. Choi, G. Chowdhary, A. C. Singer, H. Vishnu, A. Weiss, G. W. Wornell and G. Deane

Underwater communication signals typically suffer from distortion due to motion-induced Doppler. Especially in shallow water environments, recovering the signal is challenging due to the time-varying Doppler effects distorting each path differently. However, conventional Doppler estimation algorithms typically model uniform Doppler across all paths and often fail to provide robust Doppler tracking in multipath environments. In this paper, we propose a dynamic programming-inspired method, called online segmented recursive least-squares (OSRLS) to sequentially estimate the time-varying non-uniform Doppler across different multipath arrivals. By approximating the nonlinear time distortion as a piece-wise-linear Markov model, we formulate the problem in a dynamic programming framework known as segmented least-squares (SLS). In order to circumvent an ill-conditioned formulation, perturbations are added to the Doppler model during the linearization process. The successful operation of the algorithm is demonstrated in a simulation on a synthetic channel with time-varying non-uniform Doppler.

Phorcys Waveform Architecture

J. Davies, P. Randall, J. Neasham, B. Sherlock and A. Hamilton

A new, UK government owned, secure, multiband, multimode acoustic waveform has been developed under the UK Progeny Maritime Research Framework to address UK RN future needs for secure, flexible and extensible undersea command, control and communications (C2/C3) and networking. This paper describes the Phorcys waveform architecture, reviewing technical drivers and design choices made to align the waveform design with defence end user needs, in terms of security, performance and future capability.

Taking LoRa for a Dive: CSS for Low-Power Acoustic Underwater Communication

F. Steinmetz and B. Renner

Long Range (LoRa) is a rising technology for low-power over-water wide area networks. In this paper, we modify the physical layer (PHY) of the LoRa communication standard for use in acoustic underwater communication. First, we describe a light-weight LoRa-inspired chirp spread spectrum (CSS) implementation and evaluate it in simulations and realworld trials. Second, we compare our results to the JANUS underwater communication standard. Especially in scenarios with strong multipath propagation, our CSS implementation offers advantages compared to JANUS communication. Third, we pinpoint weaknesses and identify room for improvements.

Sea Trial Results and Receiver Performance Analysis for Phorcys V0 Waveform

J. Neasham, T. Corner, J. Davies and A. Hamilton

Sea trials of the PhorcysV0 coherent spread spectrum waveform for acoustic communication have been carried out in order to verify range-data rate performance and evaluate various receiver structures. Encouraging results are achieved, in widely differing environments and frequency bands, at ranges between 100 m and 100 km, using frequency bands of 20-28 kHz, 8-12 kHz and 0.8-1.5 kHz, and with net data throughput between 13 bps and 1.6 kbps. In the higher BT modes, robust communication is achievable with a relatively simple correlation based receiver as demonstrated by the Phorcys reference chain. However for the higher throughput modes (lower BT) and in demanding channels, it is shown that there is substantial gain from more complex adaptive receiver structures and multichannel array gain where possible.

Ice model for under-ice communication simulation

N. P. Chotiros, E. Storheim, H. Sagen and R. A. Krishfield

There is a need for a concise statistical model of the arctic ice to aid in the development and simulation of under-ice acoustic propagation models for communication. Four main environment types were identified in the arctic ice: open water, loose ice, ice floe and ice keels. Each one was assigned a probability density function (PDF). The ice draft statistics were modeled as the sum of the four PDFs. Observations over one annual cycle were analyzed to reveal seasonal changes in the four components. The spatial statistics were also estimated, given the drift speed of the ice over the stationary upward looking sonar, yielding the spatial frequency of the keels, floes and open water/loose ice components. This provides a rudimentary model for the ice that can be used to model acoustic communications under the arctic ice.

Spatial Modulation-based Orthogonal Signal Division Multiplexing for Underwater ACOMMS

Z. Qi and D. Pompili

Orthogonal Signal Division Multiplexing (OSDM) has shown great robustness against multipath and Doppler effects in underwater acoustic channels, while however having a low spectral efficiency. In this work, a novel transmission method, named Spatial Modulation-based OSDM (SM-OSDM), is proposed to improve the spectral efficiency while keeping the Bit Error Rate (BER) low, where multiple transducers are utilized at the transmitter side but only one is active in each time slot. The simulation results prove that the SM-OSDM offers higher spectral efficiency than Single-Input Single-Output (SISO)-OSDM and lower BER compared with MultipleInput Multiple-Output (MIMO)-OSDM.

Implications of Time Variability on a Ricean Noncoherent Model in Acoustic Underwater Communication

V. Lidström

This paper investigates the implications of time variability in the underwater acoustic channel on coded multiple tone frequency-shift keying (FSK) that uses a Rice model on narrow toneband envelopes. It is evaluated with Convolution coded frequency parallel binary FSK in the 5 Watermark replay channels, in terms of the bit error rate over the noise measure Eb/N0, where the model parameters are tracked using known pilots. The performance varies with pilot sparseness; however, it is significantly improved by limiting the likelihood input signal-to-noise ratio, which enables using a simple data model with minimal estimation overhead, and pilots can be separated by up to 10 [s].

On the Feasibility of OFDM for Long-range Mobile Communications in the NorthWest Passage

A. Bhattacharya, J. MacDonald, J. Bousquet and S. Blouin

In this work, the reliability of an Orthogonal Frequency Division Multiplexing (OFDM) acoustic communication link is evaluated in mobile conditions in Barrow Strait over a distance as long as 35 km. To evaluate the factors that affect the communication system, the channel characteristics are first extracted. It is found that the uncoded OFDM transmission link is very sensitive to the propagation conditions. Moreover, the relatively high bitrate equal to 13.125 (4 times that of FSK) motivates further efforts in improving the performance by optimizing the receiver signal processing and OFDM parameters.

Full-Duplex UWA Communication System with Two Iterations

L. Shen, B. Henson and Y. Zakharov

We consider full-duplex (FD) underwater acoustic (UWA) systems when the transceiver simultaneously transmits and receives in the same frequency bandwidth. The major task of the FD operation is to cancel the strong self-interference (SI) from the near-end projector. Advanced adaptive filtering algorithms have been proposed previously, capable of providing high-accuracy SI channel estimates even in scenarios with fast SI channel variations. A high level of SI cancellation can be achieved when the far-end signal is absent. However, the SI channel estimation performance is limited in FD scenarios as the far-end signal is treated as interference when estimating the near-end SI channel thus increasing the noise floor. In this paper, we propose a new FD UWA system which alternates between the near-end SI cancellation and far-end data demodulation. The FD UWA system performance is evaluated in a lake experiment using a recently developed two-element transducer. Results show 2 dB loss in the detection performance of the FD system compared to the corresponding half-duplex system in the same lake experiment.

Sparse Channel Estimation for Long Range Underwater Acoustic Communication

W. Jiang and R. Diamant

Long-range underwater acoustic communication (LR-UWAC) is an essential technique for applications such as remotely control of unmanned underwater vehicles, gliders, or tactical submarines for long term monitoring tasks. In this paper, we propose a non-trivial combination of the block subspace pursuit and the distributed subspace pursuit algorithms to exploit the block structure of the channel. The former is aimed to exploit the block structure of LR-UWAC channel, and the latter derives a joint sparse recovery algorithm for efficient LR-UWAC channel estimation. Results from a sea experiment demonstrate the efficiency of our approach to accurately estimate the channel compared to state-of-the-art benchmarks.

Technical Session "Optical and Quantum Communications"

(Chairs: Brandon Cochenour, Norman Farr, Fraser Dalgleish, Murat Uysal and Pietro Paglierani)

An Experimental Demonstration of FSK-SIM-PDM Underwater Optical Wireless Communications

J. Chen, C. T. Geldard, E. Guler, A. Hamilton and W. O. Popoola

This paper presents an experimental performance of frequency-shift keying with subcarrier intensity modulation (FSK-SIM) implemented along with polarisation division multiplexing (PDM) for underwater optical wireless communications (UOWC). The FSK-SIM-PDM technique demonstrated in this paper is shown to provide a resilience to the effects of turbulence whilst doubling the spectral efficiency compared to FSK-SIM. The performance of FSK-SIM-PDM is evaluated in terms of the power spectral density (PSD) and error performance of the received signals in still and turbulent water conditions. The results show that a data rate of 1.9 Gbps in still water and 1.75 Gbps in turbulent water can be achieved with FSK-SIM-PDM.

Real-Time Implementation of an Underwater Quantum Key Distribution System

B. Kebapci, G. Mutlu, I. Baglica, A. Tosun, S. Ergin, V. E. Levent , M. Uysal, P. Paglierani, K. Pelekanakis, R. Petroccia and J. Alves

As threats in the maritime domain diversify, securing data transmission becomes critical for underwater wireless networks designed for the surveillance of critical infrastructure and maritime border protection. This has sparked interest in underwater Quantum Key Distribution (QKD). In this paper, we present a real-time implementation of an underwater QKD system based on the BB84 protocol. The QKD unit is built on a hybrid computation system consisting of an FPGA and an on-board computer (OBC) interfaced with optical front-ends. A real-time photon counting module has been implemented on FPGA. The transmitter and receiver units are powered with external UPS and all system parameters can be monitored from the connected computers. The system is also equipped with a visible laser and an alignment indicator to validate successful manual alignment.

Compact Quantum VLF/ELF Sources for Submarine to Air Communication

D. Latypov

For decades communicating between underwater and the air has remained an unsolved problem. Only very low frequency electromagnetic waves have sufficient penetration through seawater to enable an RF air-underwater link. Generation of such waves requires large antennas which cannot be installed on a submarine. In this paper, we demonstrate the feasibility of a compact very low radio frequency source which can be used on a submarine. Theoretical calculations show that by

using highly excited Rydberg states of hydrogen atoms which are further split and brought closer together by the linear Stark effect, one can achieve sufficient VLF/ELF radiation power for a submarine at operational depths of hundreds of meters to communicate with a surface/air platform tens of kilometers away.

Technical Session "New Applications Enabled by Next-Generation Underwater Communications"

(Chairs: Giorgios Sklivanitis, Andrea Munafò, Toby Schneider and Roberto Petroccia)

Acoustic Channel-aware Autoencoder-based Compression for Underwater Image Transmission

K. Anjum, Z. Li and D. Pompili

Image transmission in Underwater Internet of Things (UW IoT) is a challenging problem due to the characteristic low bandwidth and variable path loss of the underwater acoustic channel. However, to enable intelligent and collaborative exploration of the underwater environment, such a communication is of paramount importance. To address such challenges, a reliable and energy-efficient Machine Learning (ML)-based underwater image transmission system is proposed where images are compressed using a data-based approach and robust compression codes are learned. The system uses an Autoencoder (AE) to enable intelligent, data-driven selection of coding parameters. The AE is evaluated in the presence of underwater acoustic fading channel information to achieve efficient and robust image transmission, and is compared against model-based approaches.

Plasmonic - Surface Electromagnetic Wave Communication for subsea asset inspection

J.J. Mulholland and I.I. Smolyanivov

Underwater wireless communications able to support real-time teleoperated tools and robotics remain a challenging topic and one of great interest for many marine applications. The use of Plasmonic-Surface Electromagnetic Waves (P-SEW) has been assessed for providing low latency, high bandwidth connectivity to Unmanned Underwater Vehicles (UUVs) for inspection of subsea assets. The evaluations show that as the through-water communication distance increases the dominant transmission path will tend toward surfaces where a conductivity mismatch exists, such as the sea surface or a metal structure. Considering this behavior, the team has identified application cases that benefit from the transmission characteristics and utilize this to support low latency, high data rate communication to devices on and around submerged assets. This P-SEW approach is promising for increased penetration ranges through seawater at the lower Radio Frequency (RF) bands, and this paper proposes a stepwise evaluation, considering the opportunities for use of higher frequency P-SEW communications on and around submerged assets and infrastructure, such as toward inspection vehicles and sensors.

An Underwater First Contact Method Using JANUS

R. Otnes

One motivation behind the JANUS underwater acoustic communication standard is to provide first contact functionality for new nodes joining a network. Some first contact procedures for the purpose have been proposed in literature, but not standardized. We propose an alternative procedure which was developed as part of the EDA-SALSA project, and has been successfully tested in simulations and in sea trials. The procedure includes address assignment mechanisms to get the last 5 bits of the address unique in a 2-hop neighbourhood, and also provides bit fields that can be used to negotiate which physical and network layer protocols to use.

Environmental Risk Assessment of an Underwater Acoustic Mobile Network

B. Tomasi, M. Plonchart, O. Kebkal, J. Blandin, P. Bouvet, A. Pottier, J. Mulholland, K. Kebkal and M. B. Holstad

Underwater vehicles make inspections and surveillance safer and with a lower carbon footprint than ship-based operations. However, to effectively operate them, they need robust positioning and communication systems. One solution is to use multi-modal communications, that can operate at very short (centimeters), medium (meters), and long distances (hundreds of meters). In this paper, we describe a multi-modal mobile network, whereby a simple acoustic communication and positioning protocol is used to send network control messages and positioning signals, optical point-to-point links may be used to transfer larger data files, and magnetic induction data and power transfer is used to recharge the drone and offload the data from the drone to the benthic

station. In this context, we then quantify the sound exposure level and the impact radius reduction derived from using multi-modal underwater communications with respect to full acoustic approach in underwater mobile networks.

Phorcys, an Evolution of JANUS

A. Hamilton, J. Barnett and A. Hobbs

At the moment there exists only one open Underwater Communications standard, JANUS, which as it stands is a simple, fixed rate, multi-access communications protocol with minimal security. In this paper, we propose an evolution of JANUS and how Phorcys, an acoustic communications protocol suite with security by design can become part of the story of the JANUS standard. This paper is a high level paper for the introduction of the Phorcys protocols and the `House of JANUS' as an evolution of JANUS, however it is intrinsically interlinked with a body of research hoping to be presented at UComms 2022.

Experimental Demonstration of a Single Acoustic Vector Sensor for JANUS Performance Enhancement

F. Bozzi and S. Jesus

This study shows the underwater communication performance using an acoustic pressure-gradient vector sensor. Combining the estimated particle velocity channels with the acoustic pressure results in a cardioid-like beam steered output, which is used to improve the signal-to-noise ratio. A shallow water field experiment was carried out using a single vector sensor as a receiver and a ship-suspended sound source, transmitting the frequency-hopped JANUS modulated signal at several ranges and directions. Bit error rate analysis demonstrates how performance can be enhanced through vector sensor channel combining. Firstly, by relating the error with beam pattern varying the azimuth steering angle. Second, by relating the error with transmitting stations, where individual channels of the vector sensor can be compared. Besides such findings, this study also presents tools for better understanding the directional characteristic, such as the design factor to combine the particle velocity to the pressure sensor and azigrams. Finally, results show that the JANUS bit error rate can be reduced up to five percent by combining the vector sensor components compared to the pressure sensor.

Technical Session "Underwater Communications Security"
(Chairs: Paolo Casari and Roald Otnes)

Low Probability of Detection Underwater Communications Using a Vector Sensor

F. B. Louza and S. M. Jesus

Low probability of detection underwater acoustic communications are required for command and control of mobile underwater platforms performing covert missions. To deal with multipath and increase the signal-to-noise ratio (SNR) at the receiver, this paper presents a study on the low probability of detection communications using a single vector sensor. Compact in size, vector sensors (VS) are suitable for autonomous underwater vehicles, measuring both acoustic pressure and particle velocity, and therefore providing diversity gain. As part of the multidisciplinary EMSO-PT project, an experiment took place off the coast of Algarve/Portugal on Nov 24th, 2021. A single 2D VS was posed on the bottom. Broadband signals were transmitted from several positions, varying both the source-receiver range and the direction of arrival. Recorded noise was added to the signals to reduce the SNR from 0 to −10 dB. A superimposed training passive time-reversal approach was employed for equalization. Coherent communication performance was evaluated. Results show that VS multichannel combining may provide an average SNR and mean squared-error gain of up to 9.4 and 3.1 dB, respectively, compared to the pressure channel.

Machine Learning-Based Distributed Authentication of UWAN Nodes With Limited Shared Information

F. Ardizzon, S. Tomasin, R. Diamant and P. Casari

We propose a technique to authenticate received packets in underwater acoustic networks based on the physical-layer features of the underwater acoustic channel (UWAC). Several sensors a) locally estimate features (e.g., the number of taps or the delay spread) of the UWAC over which the packet is received, b) obtain a compressed feature representation through a neural network (NN), and c) transmit their representations to a central sink node that, using a NN, decides whether the packet has been transmitted by the legitimate node or by an impersonating attacker. Although the purpose of the system is to make a binary decision as to whether a packet is authentic or not, we show the importance of having a rich set of compressed features, while still taking into account transmission rate limits among the nodes. We consider both global training, where all NNs are trained together, and local training, where each NN is trained individually. For the latter scenario, several alternatives for the NN structure and loss function were used for training.

PCIS - A Novel Approach to Security in the UW Domain

A. Hobbs, J. Barnett and A. Hamilton

As the importance of the underwater domain increases for the military user, with Uncrewed Underwater Vehicles (UUV) becoming more and more prominent, so too grows the need for these assets to communicate in a resilient and secure manner. The constrained environment in which acoustic communications operates in, with propagation severely limiting the bandwidth and data rate, means a further reduction in performance usually required by traditional cryptographic standards, such as the Advanced Encryption Standard (AES), is impractical. This paper presents the Phorcys Cryptographic Interoperability Specification, a novel security suite designed to exploit the properties of the underwater channel rather than being contained by it, to provide security without compromising communications performance. Developed jointly by the Defence Science and Technology Laboratory (Dstl) and the National Cyber Security Centre (NCSC) in the UK, with support from NATO Science and Technology Organisation Information Systems Panel 174, PCIS is a collaborative effort to address the lack of secure underwater communications standards.

Hiding Cyclostationarity With Dispersive Filters for Covert Underwater Acoustic Communications

F. Socheleau and S. Houcke

Cyclostationary features of communication signals can be considered as weaknesses from a security point of view. They can be used by eavesdroppers for signal detection, modulation recognition or blind parameter estimation. This work presents a simple approach to make the blind estimation or detection of these features more difficult. It relies on the use of a dispersive filter at transmission that acts as a secret key. This filter is a plugin that is applicable to any existing transmission scheme. Numerical results applied to a DSSS signal with channel replay simulations illustrate the benefits of the proposed method.

Technical Session "Adaptive Modem Architectures and Smart Networking Strategies"
(Chairs: Henry Dol and Koen Blom)

A First-of-its-kind Low Size, Weight and Power Run-Time Reconfigurable Underwater Modem

J. Hermans, G. Sklivanitis, and D. A. Pados

Low size, weight, power and cost (SWaP-C), flexible programmability and rapid run-time reconfigurability are desired features for the design of adaptive, underwater wireless communication modems for micro autonomous underwater vehicle (μAUV) swarms. In this paper, we present a first generation software and hardware design of a new class of low SWaP-C underwater modems that can accommodate wideband acoustic front-ends and achieve μs-level reconfigurability during run-time. We investigate the benefits of dynamically mapping certain signal processing operations of the acoustic communication stack to the Field Programmable Gate Array (FPGA) and others to the embedded processing system of the modem's System-on-Chip and demonstrate data rates up to 2000 bps in ranges up to 50 m with the implementation of custom programmable logic. We test and evaluate power consumption, wireless link performance and speed of reconfiguration for two communications schemes: Binary Frequency Shift Keying (FSK) and Fast Frequency Hopping FSK both with simulations and field experiments.

A Framework For Testing Data Driven Underwater Link Adaptation

V. Lidström, F. Lindqvist, M. L. Nordenvaad and E. S. Erstorp

To make full use of the underwater acoustic channel, a high degree of adaptivity is typically required. A novel framework for efficient evaluation of link adaptation employing channel replay simulation with Watermark and a lookup table is proposed. The approach is used to compare link adaptation based on SNR and CRC feedback using measured sea data. The best performance is obtained with a CRC criterion since it detects if a communication link has poor behaviour. The method is further improved by introducing a memory mechanism that disables a link with repeated low reliability.

Development of a Physical Layer for Adaptive Underwater Acoustic Communications

K. C.H. Blom, H. S. Dol, F. Berning and P. A. van Walree

For underwater acoustic modems to operate in a time-varying environment, in-mission adaptation is desirable. A physical layer has been designed that supports mechanisms for ad-hoc configuration changes based on (in-situ and indirectly obtained) channel and noise conditions. Coded preambles are used to instruct the receiver of a configuration change. To support indirect link feedback, a fixed bit-allocation scheme is proposed that provides a field for link quality information. Performance of the coded preambles versus payload delivery are studied in replay simulation. Eventually, thresholds for rate switching based on indirect link feedback of the output SNR are presented.

Dynamic Modem Adaptation in Underwater Networks using Network Knowledge

D. Sotnik

This paper introduces an underwater modem adaptation based on channel descriptors and network layer knowledge. One topic in the EDA-SALSA project is smart adaptivity. We take the smart approach of not only looking at single links between nodes but exploiting the network as a whole. With awareness of existing neighbors and all their feedback, each node can configure itself specifically for the best acoustic transmissions tuned to the environment. The development and implementation were also successfully tested in simulations and a sea trial in the Oslo Fjord in May 2022.

Adaptive Modulation and Feedback Strategy for an Underwater Acoustic Link

W. Shuangshuang, P. Anjangi and M. Chitre

As underwater acoustic channels are highly variable, both temporally and spatially, it is impossible to design a single communication scheme that works well everywhere and at all times. Adaptive modulation and coding (AMC) techniques can help determine the best communication scheme to use for a particular channel, but require an accurate model to predict communication performance. We propose a bit error rate (BER) estimation model that fuses domain knowledge with experimental data, yielding BER estimates that are consistent with experimental observations. Predictions from such a model are used to drive an AMC algorithm to maximize communication throughput. For AMC, regular feedback from the receiver to the transmitter is necessary to gather channel state information (CSI). On the one hand, obtaining feedback too often drastically impacts the communication throughput in channels with long propagation delays, but on the other hand, insufficient feedback leads to poor AMC decisions and hence poor throughput. We propose a dynamic feedback strategy to automatically find the right balance and maximize communication performance.

Physics-informed Data-driven Communication Performance Prediction for Underwater Vehicles

M. Chitre and K. Li

Underwater vehicles usually rely on acoustics for communication and navigation. Reliable communication and accurate navigation require the vehicle to plan a path through areas with good acoustic coverage from communication gateways and beacons. Planning such a path can be challenging in areas with complex acoustic propagation, especially when the signal strength does not monotonically reduce as a function of distance from a transmitter. When the environmental parameters are not fully known, traditional acoustic propagation models are unable to provide accurate predictions. We develop an online physics-informed data-driven method to predict acoustic signal quality in a region ahead of the underwater vehicle to inform the vehicle's path-planning algorithm.

Field Tests of the Software Defined Modem Prototype for the MODA Project

E. Coccolo, R. Francescon, F. Campagnaro and M. Zorzi

Underwater acoustic communications has developed to such a stage that new applications and functionalities emerged in various fields of the human activities, from military missions to commercial operations. A new field of application is the use of underwater vehicles in swarms, operating in a coordinated fashion to perform tasks that would be harder, or dangerous, for humans or single vehicles. Swarms of underwater drones require the use of very flexible and high-performance wireless modems: in the context of a national funded project we developed a Software Defined Modem (SDM) to be employed in lightweight underwater vehicles. This work presents the tests of the communications capability of the modem in a very shallow environment. The tests proved the validity of the modem design, still at the prototype stage, and shed light on the areas that are worth investigating to further improve its performance. Additionally, we demonstrate that it is possible to build an SDM, capable of real-time communications, using only off-the-shelf and easily accessible hardware and software tools.