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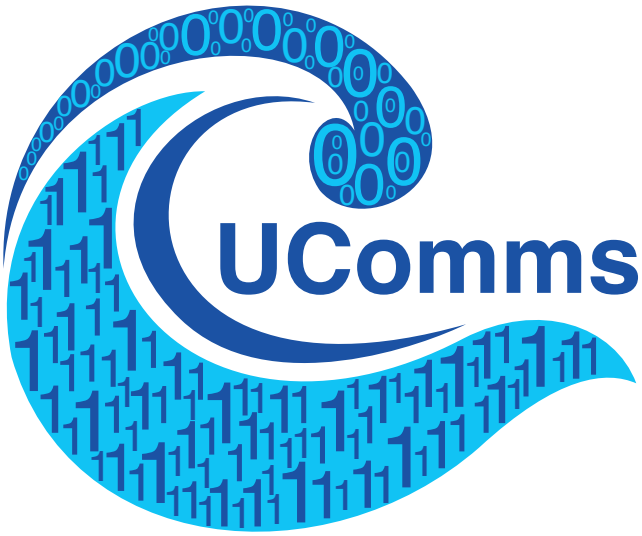

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Technical Session: New Applications Enabled by Next-generation Underwater Acoustic Comms

(Chairs: Andrew Singer and Toby Schneider)

Variability in Shallow Water Communication Performance Near a Busy Shipping Lane
Mandar Chitre, Teong-Beng Koay, Grant Deane and Gabriel Chua

We present analysis of a dataset collected at an underwater communications network testbed in Singapore for a contiguous 24-day period in 2018. The communication performance showed strong diurnal variability, mainly due to changes in arrival timings of various ray paths. The observed changes are believed to be caused primarily by sound speed changes due to bubbles advected from the nearby shipping channel. Diurnal noise variability also contributed to performance variability. This work demonstrates the importance of long term communication datasets in improving our understanding of the acoustic communication channel.

Polar Coded Non-Coherent Acoustic Underwater Communication
Viktor Lidström

Two MFSK modulation methods with time-frequency guards, using an LLR-based List Polar Decoder, are investigated for application to the underwater acoustic channel. Based on a number of published channel delay spreads, a 32FSK and a 32 sub-band 4FSK are chosen, having 185- and 1080 [bit/s], which are simulated in an AWGN channel, and tested at two sites in the Stockholm archipelago. The Polar Code is shown to have good performance in terms of BER and BLER, for both long and short frame lengths.

Non Data-Aided Estimation Of Time-Varying Multiscale Doppler In Underwater Acoustic Channels
Francois-Xavier Socheleau

In the context of underwater acoustic communications, we propose a non data-aided Doppler estimation method dedicated to single-carrier linearly-modulated signals. This method relies on the framework of time-warped cyclostationary random processes. It can estimate time-varying Doppler scales resulting from acceleration of up to several meters per second squared. It can also estimate multiple Doppler scales as observed in multiscale-multilag channels.

From The Long-Range Channel In The Ocean To The Short-Range And Very Shallow-Water Acoustic Channel In Ports And Harbors
Fabian Steinmetz and Bernd-Christian Renner

Micro Autonomous Underwater Vehicles (μAUVs) and Underwater Wireless Sensor Networks (UWSNs) enable diverse underwater applications in ports and other shallow inshore waters. During the past, several acoustic underwater modems were developed, which have typical communication ranges of a few kilometers. Opposed to that, there is a growing demand of short-range communication (less than a kilometer) for the mentioned applications. This paper discusses the requirements of different acoustic communication devices and motivates the need of short-range and very shallow-water soundings. Typical observations of long-range channels do not apply. Afterwards, soundings in two locations are discussed. The soundings indicates quite different behavior and illustrates the diversity of acoustic transmission channels. Based on our findings, new modulation schemes can be developed.

Multiple Access Acoustic Communication In Underwater Mobile Networks
Christophe Bernard, Pierre-Jean Bouvet, Antony Pottier and Philippe Forjonel

This article presents a new multiple access technique for underwater acoustic communication in the framework of AUV fleet. The multiuser scheme is based on a set of orthogonal waveforms built by combining 2 types of HFM signals allowing at the reception side very simple matched filter based decoding. The proposed multiuser technique provides good resilience against multiuser interference while keeping robustness against underwater acoustic channel impairments like Doppler shift. The implementation of this protocol for the underwater acoustic scenario is described, and performance are analysed and compared against conventional TDMA and CDMA techniques over replayed experimental channels for up to 5 AUVs acting as mobile nodes .

High-speed underwater acoustic communication for multi-agent supervised autonomy
Arnaud Jarrot, Andriy Gelman, Gloria Choi, Andrew Speck, Gavin Strunk, Arnaud Croux, Timothy P. Osedach, Stephane Vannuffelen, Sepand Ossia, Jack Vincent, Sebastien Grall and Guillaume Eudeline

Service providers for subsea inspection, maintenance, and repair (IMR) generally utilize remotely operated tethered vehicles (ROVs) to inspect and to intervene on underwater infrastructure. The cost of these operations can be considerable due to the need of deploying a large surface vessel and a highly skilled crew to support the IMR campaign. This work describes a novel multi-agent autonomous system comprising an autonomous underwater vehicle (AUV) and unmanned surface vessel (USV) incorporating a proprietary high-bandwidth acoustic communication system capable of video transmission to the surface with effective data rates in excess of 100 kbps at 2 km. Real-time data stream transmission from the AUV was demonstrated at a depth of 840 m as well as a shallow water test in which the video stream of a World War 2 fighter plane wreck was transmitted to the surface.

Technical Session: Underwater Localisation

(Chairs: George Sklivanitis and Andrea Munafò)

Accuracy of TWR-Based Ranging and Localization in Mobile Acoustic Underwater Networks
Tara Stojimirovic and Bernd-Christian Renner

Underwater robots require location information for autonomous navigation and even remote control. Acoustic communication is the natural choice to cater for distance information to anchors with known position in an underwater environment. Additionally, it does not require the use of extra hardware, making it useful in cost-sensitive applications. Unfortunately, the acoustic channel is slow, adding considerable, but typically ignored, errors to distance measurements and, as a consequence, location estimates. Quantification of errors in real world scenarios and field tests is difficult, if not impossible, unless expensive, special equipment is available. Therefore, we derive a detailed, yet comprehensible, mathematical model to obtain distance of a moving robot to one or many anchors and its real position. We identify the influencing factors and study the error of both distance measurements and self-localization. Our results indicate that compensation of robot movement is required for accurate self-localization.

Self-Adapting Under-Ice Integrated Communications and Navigation Network
Toby Schneider, Henrik Schmidt and Supun Randeni

Complex vehicle missions (such as under-ice operations) require balancing the various competing uses of the acoustic channel. We present an integrated communications and navigation system, where a single synchronized digital communication packet is used to both provide tracking and data to the operator. In response, a navigation correction is telemetered to the vehicle. This system was deployed and operating during the ICEX20 experiment in the Beaufort Sea in March 2020. The variability of acoustic propagation with depth in the Beaufort Sea imposes a challenge to ensure reliable connectivity between the vehicle and the topside operators (in this case, via ice buoys). In the context of this under-ice system, where the ice buoys have multiple receiver and transmitter depths, we explore a self-adapting network that uses oceanographic and propagation modeling to predict the expected optimal receiver depth layer and transmitter hydrophone.

Robust Graph Localization for Underwater Acoustic Networks
George Sklivanitis, Panos P. Markopoulos, Dimitris A. Pados, and Roee Diamant

We consider the problem of robust localization of a set of underwater network nodes, based on pairwise distance measurements. Localization plays a key role in underwater network optimization, as accurate node positioning enables location-aware scheduling, data routing, and geo-referencing of the collected underwater sensor data. State-of-the-art graph localization approaches include variations of the classical multidimensional scaling (MDS) algorithm, modified to handle unlabelled, missing, and noisy distance measurements. In this paper, we present MADMDS, a robust method for

graph localization from incomplete and outlier corrupted pair-wise distance measurements. The proposed method first conducts outlier excision by means of Median Absolute Deviation (MAD). Then, MAD-MDS performs rank-based completion of the distance matrix, to estimate missing measurements. As a last step, MAD-MDS applies MDS to the reconstructed distance matrix, to estimate the coordinates of the underwater network nodes. Numerical studies on both sparsely and fully connected network graphs as well as on data from past sea experiments corroborate that MAD-MDS attains high coordinate-estimation performance for sparsely connected network graphs and high corruption variance.

Delay-Tolerant Data Fusion for Underwater Acoustic Tracking Networks
Mohammadreza Alimadadi, Milica Stojanovic and Pau Closas

We consider a network of distributed underwater sensors whose task is to monitor the movement of objects across an area. The sensors measure the strength of signals emanated by the objects and convey the measurements to the local fusion centers. Multiple fusion centers are deployed to cover an arbitrarily large area. The fusion centers communicate with each other to achieve consensus on the estimated locations of the moving objects. We introduce two efficient methods for data fusion of distributed partial estimates when delay in communication is not negligible. We concentrate on the minimum mean squared error (MMSE) global estimator, and evaluate the performance of these fusion methods in the context of multiple-object tracking via extended Kalman filtering. Numerical results show the superior performance compared to the case when delay is ignored.

Technical Session: Non-Acoustic Underwater Communications

(Chairs: Brandon Cochenour, Fraser Dalgleish and Norm Farr)

Modelling, Measurement and Correction of Underwater Turbulence Effects on Optical Communications
Szymon Gładysz, Max Segel, Jose Montoya, Italo Toselli, Osvaldo Javier Galicia Gasperin and Karin Stein

We report on progress made in the last few years at Fraunhofer IOSB with regards to understanding the effects that underwater turbulence poses for laser-based communications and also with regards to design and implementation of efficient wavefront correction strategies. We have pursued, through parallel efforts, analytical modelling of light propagation through oceanic turbulence, conception and validation of turbulence characterization methods, and construction of “wavefront sensorless” adaptive optics for underwater communications.

Practical applications of free-space optical underwater communication
Bahr Alexander, Schill Felix and Martin Igor

Free-space optical (FSO) communication offers much higher data rates when compared to other available underwater communication technologies. It has been used for decades in scientific and military applications, but until recently no commercial products were available. With the advent of commercially available FSO technology, the number of applications in the commercial and scientific domain has greatly expanded. This paper provides a short overview over commercially available FSO technology and highlights their use in current and future projects.

On the Capacity of Underwater Optical Wireless Communication Systems
Yue Rong, Sven Nordholm and Alec Duncan

In this paper, we first analyze the factors that affect the capacity of underwater optical wireless communication (UOWC) systems through deriving a new tight capacity upper bound. We find that the system capacity depends on the light wavelength in a complicated manner. Then we compare UOWC with the underwater acoustic communication (UAC) technology in terms of channel capacity, communication range, and energy efficiency. We show that UOWC requires a much lower energy per-bit than UAC for short range communication. Finally, we study the multi-hop communication technique to extend the range of UOWC. The optimal number of hops is derived taking into account the cost of deploying relay nodes. Our study provides useful guidelines in designing a hybrid underwater acoustic/optical communication system which can achieve an increased range-rate product for underwater wireless communication.

Evaluating the Feasibility of Magnetic Induction to Cross the Air-Water Boundary
Mark C. Watson, Jean-François Bousquet, and Adam Forget

A magnetic induction based underwater communication link is evaluated using an analytical model and a custom Finite-Difference Time-Domain (FDTD) simulation tool. The analytical model is based on the Sommerfeld integral, and a full-wave simulation tool evaluates Maxwell's equations using the FDTD method in cylindrical coordinates. The analytical model and FDTD simulation tool are then compared and used to predict the system performance for various transmitter depths and optimum frequencies of operation. To this end, the system bandwidth, signal to noise ratio, and the magnitude of the induced voltage are used to estimate the expected channel capacity. The models show that in seawater, a relatively low-power and small coil may be capable of obtaining a throughput of 40 to 300 kbps, for the case where a transmitter is at depths of 1 to 3 m and a receiver is at a height of 1 m.

Technical Session: The Roles of Deterministic and Statistical Methods in Acoustic Propagation Modeling for Underwater Acoustic Communications Simulation and Performance Prediction

(Chairs: Jim Preisig and Grant Deane)

In-situ performance prediction of a coherent acoustic modem
Paul van Walree and Mathieu Colin

A channel sounding and communications experiment was performed in the Oslofjord in April/May 2019, where 8 bottom units were deployed in a network configuration. Five units were equipped with a software-defined acoustic modem operating in the 4–8 kHz band, programmed to transmit probe signals and communication packets. All transmitted signals were recorded by all units over 35 unique horizontal links and 5 vertical links. Measured power delay profiles are used to predict receiver output SNR, examining the effect of ambient noise, reverberation of previously transmitted packets, and the packet's own reverberation. It is shown that modem performance is limited by the own reverberation, and that the mean prediction error is below 3 dB when this reverberation is taken into account.

Performance evaluation of Multi-user MIMO Underwater Acoustic Communications
Antony Pottier, Pierre-Jean Bouvet and Philippe Forjonel

This paper presents a study of Multiuser Multiple Input Multiple Output (MU-MIMO) as a multi-access method for underwater acoustic communications. Traditional multi-access schemes such as Time Division Multiple Access (TDMA) suffer from limited data rates due to an inefficient sharing of communication resources. In a MU-MIMO systems, each user can be viewed by the receiver as an input of a conventional MIMO channel. The receiver can then exploit the spatial diversity to decode the input streams of each users. Achievable rates of MU-MIMO with Successive Interference Cancellation (SIC) are studied in a first place, and compared with single user and TDMA theoretical performance. The theoretical rates are computed on channels sounded at-sea for a two-user configuration so as to evaluate what gains can be expected from the MU-MIMO approach. Finally, comparisons with the effective rates obtained from simulations of full modulation and demodulation stages using measured channels and the underWater AcousTic channel Replay benchMARK (WATERMARK) are provided.

Under-ice acoustic communication in the Nansen Basin
Paul van Walree, Dag Tollefsen and Vidar Forsmo

An underwater acoustic experiment has been performed in the Nansen Basin (eastern Arctic) at 84° North. Channel probe signals and communication packets were transmitted in the 4–8 kHz band, with under-ice signaling over ranges of 10, 20 and 40 km. The measurements reveal a peculiarly sparse impulse response with two arrival groups, separated by 1–2 s, with contributions from surface

duct arrivals, refracted paths, and bottom-reflected sound. A high propagation loss is counterbalanced by a low ambient noise level, yielding a useful SNR at all ranges. The main challenge for communications is the long impulse response, which causes a packet to collide not only with other packets transmitted over the same link, but also with itself. Some packets are lost because of these collisions, but there are also packets that are correctly received twice. Communication is possible over 40 km at a regular modem source level.

Channel Quality Prediction for Adaptive Underwater Acoustic Communication
Hossein Ghannadrezaii, Jeff MacDonald, Jean-Franc¸ois Bousquet and David Barclay

In this paper, the communication quality of an underwater acoustic link between two nodes is quantified by the predicted channel gain and delay spread using a stochastic and reinforcement learning model. The stochastic model generates an ensemble of time-varying channel characteristics by capturing the effect of known environmental changes including changes in sound speed profile, tides and bathymetry. Along with the stochastic model to capture the impact of unknown environmental parameters on channel quality a hidden Markov model is utilized to complement sparse channel measurements and predict the channel characteristics over a long time period spanning multiple days. In this work, the nodes are bottom mounted in a shallow turbulent water environment, with known tide cycles, physical oceanography conditions and channel geometry. As such, the channel characteristics can be estimated using a simulation software model at the remote nodes. While the simulation model is used to estimate the initial channel condition between the nodes in short-term deployment, as will be shown, the hidden Markov model provides an accurate channel characteristics prediction for long term deployment, which can be utilized by software-defined acoustic nodes such that they can adapt to the time varying acoustic channel.

Technical Session: Interoperability and Standards

(Chairs: Paul vanWalree and Roberto Petroccia)

A Task-Centric Messaging Model for Federated Autonomous Collaboration
Thomas C. Furfaro, Andrew Bouchard, Gary L. Davies and Martijn van Riet

In response to a charge to address “Autonomy in Limited-Communication Environments,” the NATO SCI-288 Research Task Group determined that the aspect of this topic most relevant to a NATO context is communications for multivehicle operations between assets from different nations using different autonomy mission software. In order to facilitate such operations, the task group developed a conceptual shared message set for mission management, allowing tasks to be shared among autonomous assets and teams of autonomous assets by integration with this message set rather than requiring separate integrations between individual software solutions. Following the design efforts of the task group as a whole, four members of the group were able to secure resources for a synthetic

demonstration and separately refined the message set and created a reference implementation. This implementation team integrated four different autonomy software solutions with the reference implementation and in October 2019 demonstrated successful joint execution of a synthetic mine countermeasures mission using the message set.

Enhancing JANUS Signaling
Dale Green, John Dellamorte and Jim Dellamorte

During the development of the JANUS Standard, the focus was on transmit description, supported by a "vanilla" receiver design. It was explicitly assumed that vendors would meet or exceed the vanilla receiver through their own efforts. As described by the JANUS "WIKI," the community now has a basic frequency hopped, non-coherently received methodology useful for a limited set of applications. Extending the list of applications will require additional receiver capabilities and resources, while one (at least) may require a more capable transmitter. This paper does not explicitly suggest standards, rather it advocates for development and informal community adoption of algorithms and methods designed to enhance performance and utility of common signaling methods. Within any list of potential upgrades for JANUS, the following four are important: a) compensation for severe frequency dependent fading; b) multi-access support and interference reduction; c) compensation for range rate (relative speed); and d) precision ranging while retaining standard noncoherent acquisition robustness). We have implemented solutions for each of these items in our Popoto modems, and each has significantly enhanced communications performance. The authors are prepared to support a community effort by providing detailed algorithmic definitions for these upgrades. However, given the short paper format of this conference, we restrict the discussions to overview and examples of our approaches.

Technical Session: Next-Generation Adaptive Modem Architectures and Cognitive Networking Strategies

(Chairs: Henry Dol and Koen Blom)

High-rate underwater acoustic communication over 600 kbps × km for vertical uplink data transmission on a full-depth lander system
Takuya Shimura, Yukihiro Kida, Mitsuyasu Deguchi, Yoshitaka Watanabe and Yosaku Maeda

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) operates several unmanned and manned underwater vehicles for scientific research in deep water. Recently, we have developed a new high-rate underwater acoustic communication system, or acoustic modem, for vertical uplink data transmission from these vehicles. This acoustic modem uses single-carrier modulation with a decision feedback equalizer (DFE), and it has been demonstrated that the modem's performance is very stable under the Doppler effect and much better than that of orthogonal frequency division

multiplexing (OFDM). In 2019, a successor acoustic modem was developed for a lander operable to a depth of 11,000 m. In an at-sea experiment conducted at a depth of 6,180 m, an effective data rate of 98.9 kbps was achieved, using the 18 ± 6.25 kHz frequency band with 256 quadrature amplitude modulation (QAM). In an experiment at a depth of 9,230 m, an effective data rate of 69.24 kbps was achieved, using the 18 ± 5 kHz frequency band with 128QAM. Thus, it was demonstrated that the performance of this acoustic modem exceeds 600 kbps × km with the index of communication data rate × range.

Distributed Spatial Diversity Enabled Receiver System for an Underwater Acoustic Link
Prasad Anjangi, Mandar Chitre, Manu Ignatius and Chinmay Pendharkar

The prime functionality of underwater acoustic modems is communication. It is known that spatial diversity can provide improved communication performance, in the form of increased data rate or extended range. While spatial diversity is traditionally harnessed by having multiple antennas connected to a single modem, we show that multiple receiver modems can also be used cooperatively to leverage spatial diversity. One can also get much larger separation between modems than possible with multi-antenna systems. We present the design framework, protocol implementation and the performance results of a distributed spatial diversity receiver system. The system comprises of spatially separated receivers exchanging the information received over the long-range underwater acoustic link to cooperatively decode the received information. We demonstrated this technique in Singapore marina with one modem as a transmitter and two modems as receivers. The receivers cooperate over a short-range wired/wireless network to share the received copy of signals and decode the information transmitted. The advantages of such a system are observed in the performance analysis presented.

An Adaptive Transmission Power Controller for Flooding-based Underwater Network Protocols
Elias Strandell Erstorp, Peter Sigray and Jakob Kuttenkeuler

In this study, we present the first iteration of DPower, an energy conserving method for use in underwater acoustic networks. The method encompasses a straightforward transmission power calibration procedure and adaptive power level selection. The method was evaluated in combination with DFlood, a known and validated constrained flooding protocol developed for underwater applications. Simulations of a network with given prerequisites have shown that, with an acceptable increase in packet loss, the presented method can dramatically reduce the energy consumption and thus improve the life-time of networks.

On the challenge of underwater acoustic communication at short range
Henry Dol and Koen Blom

It is a persistent misunderstanding that underwater acoustic communication at short range is always easier than at long range. Same for (quasi) stationary configurations being always easier than

dynamic ones. This paper gives examples of high-rate links in very shallow water at several kilometres distance, as well as difficult communication conditions in a harbour at a few hundred metres distance. Other previously reported experiments revealed challenging channels between a bottom node and a surface platform floating on the waves, whereas the present study demonstrates excellent connectivity between a bottom node and an underwater vehicle at full speed.

An Event-Based Stack for Data Transmission Through Underwater Multimodal Networks
Roberto Francescon, Filippo Campagnaro, Emanuele Coccolo, Alberto Signori, Federico Guerra, Federico Favaro andMichele Zorzi

The DESERT Underwater framework, originally designed for simulating and testing underwater acoustic networks in sea trials, has recently been extended to support real payload data transmission through underwater multimodal networks. Specifically, the new version of the framework is now able to transmit data in real-time through the EvoLogics S2C low-rate and high-rate acoustic modems, the SmartPORT low-cost acoustic underwater modem prototype (AHOI) for IoT applications, as well as Ethernet, surface WiFi, and the BlueComm optical modem. The system can also be tested in lab by employing a simulated channel, and the EvoLogics S2C DMAC Emulator (DMACE).

Experimental evaluation of an FPGA based Real-Time Doppler Estimator
Jacob Rudander, Thor Husøy, Pål Orten and Paul van Walree

The performance of a coherent receiver depends on accurate Doppler estimation. This paper presents a Doppler estimator intended for single-carrier data streaming. It is based on a coarse estimate found via a small bank of shifted replicas, followed by a correction step. The cross-ambiguity function phase difference between two binary pseudo-noise training sequences, embedded in the start of the frame, is used to find the correction factor. The Doppler estimator was implemented in an FPGA and evaluated in three horizontal very high frequency (250 kHz) shallow water channels. The results show satisfactory real-time performance in the range of ±2 m/s.

On Mitigating Channel Time Variation Effect in Acoustic OFDM Systems
Amir Tadayon, Munish Taya, and Milica Stojanovic

OFDM systems are challenged by the time variability of mobile acoustic channels where the Doppler effect can be high enough that the received signal experiences non-negligible residual frequency offset, as well as channel time variability, which cause intercarrier interference (ICI). To mitigate these effects, we introduce an efficient yet computationally manageable two-stage algorithm that counteracts the frequency offset as well as the time selectivity of mobile acoustic channels. In the first stage, frequency offset is compensated using a practical approach based on differentially coherent detection which keeps the receiver complexity at a minimum and requires only a small pilot overhead. In the second stage, a method referred to as partial FFT demodulation is used to tone down the time variability of the broadband acoustic channel. Towards this goal, the time interval of one

OFDM block is divided into several partial intervals, giving the channel less chance to change over each shorter interval, and demodulation is performed in each interval separately. The partial demodulator outputs are then combined before applying a coherent detection algorithm where refined channel estimation and data detection take place. Using the experimental data transmitted over a 3-7 km shallow water channel in the 10.5-15.5 kHz acoustic band, we study the receiver performance in terms of data detection mean squared error (MSE), and show that the proposed algorithm provides excellent performance, surpassing all our previously tested approaches.

Technical Session: Channel-Aware Security and Protocol Design

(Chairs: Paolo Casari and Roald Otnes)

Topology-based Secret Key Generation for Underwater Acoustic Networks
Roee Diamant, Paolo Casari, and Stefano Tomasin

We propose a method to let a source and a destination agree on a key that remains secret to a potential eavesdropper in an underwater acoustic network (UWAN). We generate the key from the propagation delay measured over a set of multihop routes: this harvests the randomness in the UWAN topology and turns the slow sound propagation in the water into an advantage for the key agreement protocol. Our scheme relies on a route discovery handshake. During this process, all intermediate relays accumulate message processing delays, so that both the source and the destination can compute the actual propagation delays along each route, and map this information to a string of bits. Finally, via a secret key agreement from the information-theoretic security framework, we obtain an equal set of bits at the source and destination, which is provably secret to a potential eavesdropper located away from both nodes. Our simulation results show that, even for small UWANs of 4 nodes, we obtain 11 secret bits per explored topology, and that the protocol is insensitive to an average node speed of up to 0.5 m/s.

Physical Layer Security against an Informed Eavesdropper in Underwater Acoustic Channels: Feature Extraction and Quantization
Konstantinos Pelekanakis, Seçkin Anıl Yıldirim, George Sklivanitis, Roberto Petroccia, João Alves and Dimitris A. Pados

During the Rapid Environmental Picture 2018 (REP18) sea trial, two underwater acoustic nodes (Alice and Bob) exchanged 897 channel probes over different ranges and environmental conditions. In this short paper, Alice and Bob independently process their received probes offline with the aim to generate a cryptographic key based on Physical Layer Security (PLS). Using their estimated Channel Impulse Responses (CIRs), they compute and quantize four pre-agreed channel features. Eve is a simulated eavesdropper who is aware of the PLS algorithm, the 3D positions of Alice and Bob and the acoustic properties of the environment. Eve uses the de facto standard Bellhop acoustic simulator to predict the bi-directional CIRs between Alice and Bob and compute her own quantized features.

We calculate the Bit Disagreement Ratio (BDR), which is a function of the number of disagreeing bits between a pair of nodes. Our results confirm that the proposed features are robust enough to yield a lower BDR between Alice and Bob than that for Eve. The BDR impact on reconciliation and secret key generation is studied in a subsequent paper.

Physical Layer Security against an Informed Eavesdropper in Underwater Acoustic Channels: Reconciliation and Privacy Amplification
George Sklivanitis, Konstantinos Pelekanakis, Seçkin Anıl Yıldirim, Roberto Petroccia, João Alves and Dimitris A. Pados

We propose a strategy for generating the same crypto-key between two trusted underwater acoustic nodes (Alice and Bob) without revealing it to an eavesdropper (Eve). Our work builds upon the results of where a methodology for generating a string of bits for Alice, Bob and Eve based on channel feature extraction and quantization is discussed. In this paper, we aim to reconcile the respective bits of Alice and Bob while minimizing the information leaked to Eve. To this end, we examine various Reed Solomon (RS) codes and measure the reconciliation rate of Alice, Bob and Eve. Additionally, we propose the Secure Hash Algorithm-3 (SHA-3) as means to eliminate any information that Eve acquires during reconciliation. We evaluate our reconciliation and privacy amplification strategies with bits generated from real underwater acoustic channel probe exchanges between Alice and Bob and Bellhop-simulated channels for Eve. Our analysis confirms that appropriate combinations of channel features and RS codes lead to a computationally secure generation of a 256-bit crypto-key according to the principles of the National Institute of Standards and Technology (NIST), even if Eve is informed about the RS encoder and the SHA-3 function.