

Underwater Communications for the Robotic Vessels as-a-Service Project

Alberto Signori
DEI, University of Padova
signoria@dei.unipd.it

Fabian Steinmetz
Hamburg University of
Technology
fabian.steinmetz@tuhh.de

Filippo Campagnaro
DEI, University of Padova
campagn1@dei.unipd.it

Davide Zordan
DEI, University of Padova
zordanda@dei.unipd.it

Michele Zorzi
DEI, University of Padova
zorzi@dei.unipd.it

Christian Renner
Hamburg University of
Technology
christian.renner@tuhh.de

1 INTRODUCTION

Continued increase in levels of automation and digitization in all industry sectors improves technological efficiency. Today, waterborne is the largest international transport sector with 90% of transported goods as stated in [1].

The Robotic Vessels as-a-Service (RoboVaaS) project intends to revolutionize shipping and near-shore operations by offering on-demand robotic-aided services via small unmanned vessels (UVs) such as unmanned underwater vessels (UUVs) and unmanned surface vessels (USVs).

The RoboVaaS vision is leveraged by interconnected UVs equipped with specialized sensor technology, a reliable data transfer cloud network for over- and underwater communication, a monitoring station, and a real-time web-based user interface. RoboVaaS is expected to have a high level of autonomy by using autonomous surface vessels (ASVs) and autonomous underwater vessels (AUVs), as shown in fig. 1; however, some operations still involve human control through, e. g., remotely operated vehicles (ROVs).

This disruptive concept has the potential to improve maritime and human safety, to increase flexibility and accessibility of European waterways, and to reduce costs for a multitude of maritime stakeholders. The project concept targets services for the waterborne transport sector, but the vision itself is highly transferable to other sectors such as offshore, maritime security, oil and gas, and aquaculture.

In section 2, we present a subset of the envisioned services of RoboVaaS, in section 3 we focus on the underwater communication scenarios that arise in RoboVaaS, and in section 4 we finally present the ongoing work to realize the RoboVaaS concept. Our poster will encompass the contents of sections 2 to 4, focusing on the ongoing work.

2 ROBOVAAS SERVICES & OBJECTIVES

Within the high-level RoboVaaS vision, we identified a number of services, beneficial for near-shore maritime operations,



Figure 1: RoboVaaS envisioned example scenario showing ship-hull inspection and anti-grounding services enabled through a fleet of ROVs and UUVs connected with acoustic underwater and radio communication.

that have a strong positive impact on automation and digitization. These include, but are not limited to:

- an anti-grounding service that allows a ship to book a USV that travels ahead for safe guidance through shallow water;
- an inspection service that can be ordered by ships to get a robotic hull and propeller inspection via USVs and ROVs while, e.g., loading or bulking in port;
- an inspection for the port's quay walls, where the service can be requested by the port authorities and the dispatched USVs and ROVs look for cracks and damage in the port infrastructure;
- a data collection service that may have a wide range of application such as measuring ship emissions or cost-efficient autonomous bathymetry survey of waterways with a USV or measuring environmental data with an underwater sensor network.

A major objective within RoboVaaS is to perform necessary scientific and technological developments to validate a subset of these services as a proof of concept.

3 UNDERWATER COMMUNICATION SCENARIOS

Some of the services in RoboVaaS will be possible only thanks to the integration of underwater communication in the overall framework. In the following, we describe two underwater communication scenarios that are coupled with the ship-hull and quay-wall inspections.

3.1 Environmental data collection service

While the ROV performing the inspection task is moving in the area of interest, it can act as a mobile sink or a mobile relay to assist in the environmental data gathering service. This task is to be performed with the use of underwater acoustic communication. In the area the ROV is patrolling, an underwater acoustic sensor network (UW-ASN) is deployed: each time the ROV passes close to a sensor equipped with an acoustic modem, it retrieves the data collected by the sensor as a side task. In fact, some of the nodes in the UW-ASN can be unable to communicate with the rest of the network due to unfavorable channel conditions or simply because they are outside communication range, motivating the use of the ROV as a data mule.

3.2 Divers support service

In this case, an identified damaged area needs further inspections or repairs conducted by divers. To enhance the divers' certainty and improve the general work flow, a communication interface between several divers and the control room is required.

A helpful tool to support the divers and enable a direct communication could be a messaging tool, comparable to mobile telephone Short Message Service (SMS). The main idea involves an Underwater Short Message Service (USMS) interface with a light-weight communication link to exchange information between the control room and the divers. It also envisioned to send compressed, low-resolution images to the control room. Additionally, this link could be used to transmit a health status or the bailout bottle level.

4 ONGOING WORK

4.1 Acoustic Underwater Modem

During the last years a small, low-power and low-cost acoustic underwater modem was developed at the Hamburg University of Technology (TUHH) [2]. It is designed for the integration in UW-ASN and micro Autonomous Underwater Vehicles (μ AUVs). Figure 2 depicts the modem and the hydrophone. Currently, it uses a frequency shift keying and can transmit with 250 bit/s in range of 100 m. During the RoboVaaS project the main goal is to implement a new modulation scheme to improve the data-rate, the reliability and

the communication range. Additionally, a modem integration in an μ AUV, simulations and large real-world evaluations are planned.

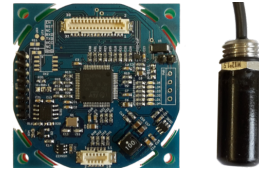


Figure 2: Small, low-power acoustic underwater modem and hydrophone.

4.2 Network Design and System Evaluation

The identified scenarios offer the chance to design, analyze, simulate and test new protocols in the communication protocol stack. In order to overcome the challenges of the underwater acoustic channel [3], both MAC and routing protocols must be robust to link disruption. Protocol design has to take into account the the long propagation delay, possibly exploiting it [4]. The DESERT Underwater Framework [5] will be employed to simulate the scenarios presented in Section 3, in order to identify which MAC and routing protocols suit the system best. DESERT will also be interfaced with the TUHH acoustic modem, in order to be used for testing the simulated protocols in sea trials without the need of rewriting the code.

ACKNOWLEDGMENT

This work has been partially supported by the German Federal Ministry for Economic Affairs and Energy (BMWi, FKZ 03SX463C), Italian Ministry of Education, Universities and Research (MIUR), and ERA-NET Cofund MarTERA (contract 728053).

REFERENCES

- [1] International Chamber of Shipping, "Key Facts," Last time accessed: November 2018. [Online]. Available: <http://www.ics-shipping.org/shipping-facts/key-facts>
- [2] C. Renner and A. J. Golkowski, "Acoustic Modem for Micro AUVs: Design and Practical Evaluation," in *Proc. of the 11th ACM International Conf. on Underwater Networks & Systems (WUWNet)*, Shanghai, China, Oct. 2016.
- [3] M. Stojanovic, "On the relationship between capacity and distance in an underwater acoustic communication channel," in *WUWnet*, 2006.
- [4] R. Diamant *et al.*, "Leveraging the Near-Far Effect for Improved Spatial-Reuse Scheduling in Underwater Acoustic Networks," *IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS*, vol. 16, no. 3, pp. 1480–1493, 2017.
- [5] F. Campagnaro *et al.*, "The DESERT underwater framework v2: Improved capabilities and extension tools," in *Proc. Ucomms*, Lerici, Italy, Sep. 2016.