An Interoperable Architecture for in situ Ocean Noise Monitoring

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Abstract – **Anthropogenic noise in the oceans has been significantly raising in the past decades due to an increment of human activities, adversely affecting the marine habitat. In order to assess and limit this impact, the long-term monitoring of underwater noise is crucial. Currently, real-time ocean sound data is mainly obtained using cabled observatories, where communications and power are not a constraint. The temporal and spatial coverage of in-situ measurements would be greatly improved if other observation systems such as gliders, moored buoys and profilers could provide real-time ocean sound data. However, these platforms have some intrinsic constraints such as telemetry, computational capacity and power availability. In order to overcome these limitations, an in situ ocean sound monitoring tool is proposed. This tool aims to provide a standardized and homogeneous framework for ocean sound monitoring, compliant with the MSFD directive, capable of interfacing any off-the-shelf hydrophone and deployable from almost any observation platform regardless of its underlying architecture.**

Keywords – Ocean Sound, Underwater Noise, MSFD, OGC Standards, SensorML, Interoperabiility, Real-time systems

I. INTRODUCTION

There has always been underwater background sound in the oceans due to natural factors. However, human activities such as shipping, construction, sonar and seismic exploration have been raising the sound level to unprecedented levels in the past decades [1]. Underwater ambient sound is an important environmental factor for many species, especially to those using underwater sounds for localization and communication (e.g. marine mammals) [2]. Thus, the introduction of energy into the marine habitat in the form of acoustic noise needs to be properly monitored and studied to minimize its harmful impact on the marine ecosystem.

In order to achieve a good environmental status, the European Union developed the Marine Strategy Framework Directive (MSFD) which aims to protect the marine environment and its ecosystem. This directive includes a set of indicators to measure the status of European waters, including maximum underwater sound levels considered as acceptable (MSFD indicator 11.2.1). This indicator requires the long-term measurement of Sound Pressure Level (SPL) at 63 Hz and 125 Hz 1/3 octave bands. However, it has been suggested to extend the monitored bands from 10 Hz to 20 kHz in order to achieve a more accurate assessment of ocean sound [3].

Currently commercial off-the-shelf hydrophones do not provide SPL measurements, so acoustic data has to be post-processed at shore stations. Due to the high sampling rate used by hydrophones (usually from tens to hundreds of kHz), streaming raw acoustic data from the observation platform to shore stations is only possible with broad-band Ethernet connection, i.e. in underwater cabled observatories. Other platforms such as unmanned vehicles, moored buoys and profilers do not have the bandwidth to transmit acoustic data in real-time. Furthermore, telemetry is usually one of the more power-demanding components of an autonomous system, thus reducing the data transmission (and its associated power consumption) is vital to extend their autonomy.

However, if the acquired data could be processed in-situ, the amount of information to be transmitted will decrease by several orders of magnitude. This would allow the measurement of ocean sound in real-time from autonomous platforms, greatly improving the temporal and spatial coverage. Nevertheless, processing acoustic data in real-time is not a trivial task due to the required computational resources (specially in constrained platforms relying on microcontrollers). Although some hydrophone prototypes capable of calculating SPL levels have been presented, they have not been widely used yet [4].

Commercial off-the-shelf hydrophones (as the vast majority of marine sensors) use vendor-specific proprietary protocols, so its integration into existing monitoring systems is a time-consuming task. Manufacturers usually provide dedicated software tools to setup the configuration and acquire acoustic data, but they are mainly developed for desktop environments, making them unsuitable to be deployed in autonomous observation platforms. In other words, when deploying off-the-shelf hydrophones to observation platforms ad-hoc software tools need to be developed to acquire, store and process acoustic data.

II. IN SITU OCEAN SOUND MONITORING SYSTEM

In order to overcome the presented difficulties, an in situ interoperable ocean sound monitoring software tool is proposed, based on the SWE Bridge universal driver [5]. The SWE Bridge is a cross-platform software package with a dual role: provide a syntactic interoperability layer to abstract hydrophone characteristics and to implement a computationally efficient ocean sound algorithm for on-board processing, compliant with the MSFD requirements [6].

The syntactic interoperability service uses the SensorML standard to provide an unambiguous and semantically robust hydrophone descriptions, including metadata such as sensitivity, sampling rate, communication protocol and more [7]. Based in this SensorML description, the SWE Bridge is able to interface the instrument without any a priori information of the sensor. It also implements optimized real-time ocean sound algorithm, compliant with the requirements of the MSFD technical subgroup on Underwater Noise [3]. Raw acoustic data is stored locally for validation and further analysis after the platform recovery. Its cross-platform and optimized nature make it suitable to be deployed in any kind of resource-constrained observation platform such as underwater gliders, profilers and mooring stations.

Furthermore, it also provides a semantically-enriched output, following Observations and Measurements standard [8]. This data and its associated metadata can be directly integrated in spatial data services such as the Sensor Observation Service (SOS) [9]. Spatial Data Infrastructures such as EMODnet can then gather, archive and process the published data. An example of the proposed system deployed in an underwater glider is depicted in figure 1. The raw acoustic data in wav format is also stored onboard for validation and further processing.
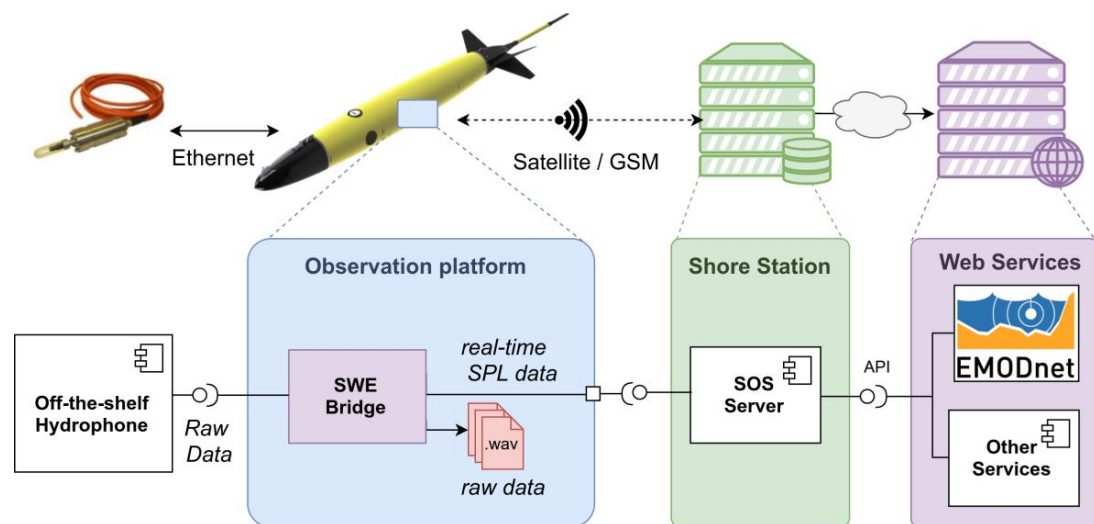

Fig 1. Ocean sound monitoring system deployed in an underwater glider

REFERENCES

[1] J. A. Hildebrand, "Anthropogenic and natural sources of ambient noise in the ocean," *Mar. Ecol. Prog. Ser.*, 2009, doi: 10.3354/meps08353.

[2] H. Slabbekoorn, N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, and A. N. Popper, "A noisy spring: the impact of globally rising underwater sound levels on fish.," *Trends Ecol. Evol.*, vol. 25, no. 7, pp. 419–27, 2010, doi: 10.1016/j.tree.2010.04.005.

[3] R. P. A. Dekeling *et al.*, "Monitoring Guidance for Underwater Noise in European Seas, Part II: Monitoring Guidance Specifications," Luxembourg, 2014. doi: 10.2788/27158.

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[4]   D. M. Toma *et al.*, "Smart embedded passive acoustic devices for real-time hydroacoustic surveys," *Measurement*, vol. 125, pp. 592–605, 2018, doi: 10.1016/j.measurement.2018.05.030.

[5]   E. Martínez, D. M. Toma, S. Jirka, and J. Del Río, "Middleware for plug and play integration of heterogeneous sensor resources into the sensor web," *Sensors (Switzerland)*, 2017, doi: 10.3390/s17122923.

[6]   E. Martinez, A. Garcia-Benadi, D. M. Toma, E. Delory, S. Gomariz, and J. Del Rio, "Metadata-driven Universal Real-time Ocean Sound Measurement Architecture," *IEEE Access*, pp. 1–1, Feb. 2021, doi: 10.1109/access.2021.3058744.

[7]   M. Botts and A. Robin, "OGC® SensorML," *OGC 12-000*. Open Geospatial Consortium, 2014, [Online]. Available: http://www.opengis.net/doc/IS/SensorML/2.0.

[8]   S. Cox, "Observations and Measuremets-XML Implementation," Wayland, MA, USA, 2011. [Online]. Available: http://www.opengis.net/doc/IS/OMXML/2.0.

[9]   A. Bröring, C. Stasch, and J. Echterhoff, "OGC Sensor Observation Service," Open Geospatial Consortium, Wayland, MA, 01778, USA, 2012. [Online]. Available: http://www.opengis.net/doc/IS/SOS/2.0