Defence-related Research Action - DEFRA

ACRONYM: AQUA-MESH

Title: Adaptive Quality-aware Underwater Multi-hop Communication and Sensing for Drone Swarms

Duration of the project: 01/12/2024 – 1/03/2028

Key words: underwater acoustic communication, reconfigurable acoustic radio, multi-hop meshing, UAV swarms

Budget: 680.928 €

of which RHID contribution: 680.928€

PROJECT DESCRIPTION

Underwater communication plays a vital role in enabling effective command, control, and coordination of military operations in underwater environments, enhancing situational awareness, operational efficiency, and mission success. **The continuous availability of low-latency underwater communications is a requirement for a multitude of upcoming civilian and military use cases**, including autonomous drone swarm communication, underwater search & rescue, underwater border & critical infrastructure security and underwater surveillance using novel threat-detecting sensors. In addition, improved underwater communication also benefits civilian use cases such as underwater research, seabed mapping, infrastructure maintenance, and search & recovery operations.

However, underwater communication faces challenges due to several phenomena, some being natural (e.g., temperature varying with depth, varying salinity, pressure and surface waves) and others tied to military activities (e.g., jamming). These destructive mechanisms cause severe spreading loss, absorption loss and scattering loss. Due to these effects, **direct high-throughput long-range radio-to-radio or floor-to-surface acoustic communication is often not possible.** Moreover, **many recent use cases require dynamic setups of communication links between multiple actors (drones, sensors, etc.).** Unfortunately, most existing commercial acoustic radio solutions consist of non-reconfigurable black box solutions that do not support dynamic multi-hop meshing and have limited adaptive modulation and coding techniques to overcome e.g. jamming.

To remedy this, **the main goal of this project is the design of improved underwater acoustic network solutions, capable of adaptively providing connectivity over a mesh of static or dynamically moving mobile underwater drones.**

To this end, three sub-objectives are targeted

- **OBJ1: To provide an open reconfigurable acoustic radio platform suitable for research and design adaptive modulation solutions for improved data transmissions**

- **OBJ2: To design adaptive algorithms for resilient multi-hop meshing and sensing**
- **OBJ3: Enhance the drone swarm decision-making processes by validating the suitability of the results pertaining to the above objectives on two use cases: Mine counter measure (MCM) and seabed inspection**

As such, this project will provide **insights** regarding (i) the **suitability of the JANUS & SWIG standard** for these use cases; (ii) **practical achievable ranges, latencies, throughputs, energy consumptions for acoustic modems & mesh topologies**, and (iii) **optimal drone swarm deployment strategies for communication and detection**. Furthermore, the project will provide **hardware and software technologies** suitable for follow-up research: (i) a low-cost, configurable and **high-speed** modem, based on MPUs (**low-cost technology**, particularly suited to disposable submarine robots used for demining); (ii) **algorithms and network protocols for adaptive modulations & dynamic meshing** to cope with jamming, difficult underwater conditions, and obstacle detection; (iii) a **simulation framework**.

Full experimental validation in relevant environments is included for all parts of OBJ1 and OBJ2. OBJ3 is to be carried out using state-of-the-art simulators (DESERT, WOSS, etc.), which will have been progressively configured to make their predictions closely match experimental measurements during OBJ1 and OBJ2. As a result, the project as a whole targets TRL 5 (technology validated in relevant environment, e.g. underwater testing in multiple types of environments), translating into relevant and quickly actionable insights and validated solutions.

Overall, these results will quantify to what extent state-of-the-art underwater communications can support advanced next-generation underwater drone swarms and dense sensor deployments. The availability of such adaptive and multi-hop features will demonstrate the effectiveness gains resulting from using cost-effective, autonomous & disposable UAV platforms for critical tasks (e.g., mine disposal). Moreover, the resulting tools, simulations and technologies will allow follow-up research in a wide variety of underwater use cases.

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