

Short Paper: Wireless Sensor and Networking Technologies for Swarms of Aquatic Surface Drones

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Abstract—In this paper, we discuss wireless sensor and networking technologies for swarms of inexpensive aquatic surface drones in the context of the HANCAD project. The goal is to enable the swarm to perform maritime tasks such as sea-border patrolling and environmental monitoring, while keeping the cost of each drone low. Communication between drones is essential for the success of the project. Preliminary experiments show that XBee modules are promising for energy efficient multi-hop drone-to-drone communication.

Keywords—WSN, swarms, aquatic drones, USV, ASC

I. INTRODUCTION AND STATE-OF-THE-ART

Maritime tasks performed by manned vessels are often expensive, and can only be performed at low-resolution, both in time and space, when compared to Unmanned Maritime Systems (UMS) [1]. UMS can execute variety of tasks, such as sea-border patrolling, search and rescue missions, sea demining, marine oil spill clean-up, environmental monitoring, among others [2-4]. Swarms of inexpensive aquatic drones have potential to perform these tasks at a significantly reduced operational cost. Applications of swarms of aquatic drones can be divided into two categories: monitoring and mission-oriented (see Fig. 1).

Effective communication both with and within a swarm of surface drones presents a variety of challenges, due to the extent of the environment, presence of waves, and potential signal reflections. The rapid progress in technology in recent years has led to a number of alternative approaches to the communication challenge, such as those develop in the context of wireless sensor networks (WSN) with a number of advantages: easy deployment, real-time monitoring, and relatively low-cost [5].

WSNs in marine environment monitoring are found variety of applications such as the monitoring of water quality, coral reefs, fish farms, and so on [5]. The OceanSense project [6] aimed to build WSN where sensor motes placed on anchored

buoys collect environmental data, such as temperature, light, and water depth.

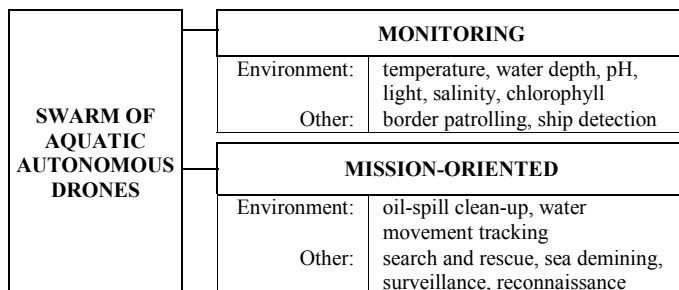


Fig. 1. Applications of swarms of aquatic drones.

WSN with mobile nodes allows for monitoring any wider area, e.g., the Floating Sensor Network project [7] developed motorized drifters to track water movement in estuarine environments and rivers. Our Heterogeneous Ad-hoc Network for the Coordination of Aquatic Drones (HANCAD) project [1] aims to develop a swarm of aquatic drones and use them as a surface-based sensor network.

In the past, prototypes of autonomous surface crafts (ASC) have been developed, mainly for research and military purposes [8]. Some craft have been developed to function as a relay between autonomous underwater vehicles (AUV) and control station. The autonomous vessel SCOUT [9] was, for instance, used in the development of robust control software for submerged craft. In [10], Curcio et al. proposed the concept of reduced-cost self-positioning buoys.

II. COMMUNICATION IN SWARM OF AQUATIC DRONES

A heterogeneous communication architecture is necessary in many real-world task scenarios. In HANCAD, all drones have short-range communication capabilities used for local coordination, while few are equipped with long-range communication technology, and serve as gateways between the operator and the swarm. Local coordination could be based on Received Signal Strength (RSS). While RSS measurements

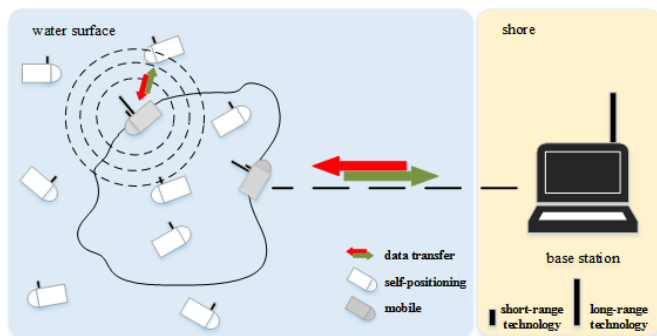


Fig. 2. Self-positioning buoys and mobile nodes of aquatic drones.

are inherently inaccurate because of signal propagation, there already exist algorithms in the literature enhancing distance estimation, see [11] for an example. As our objective is to keep the cost of the drones low, the operating communication band should preferably be unlicensed. A key networking and control challenge is to maintain drone-to-drone connectivity. The reliable connection between a swarm and a human operator should also be maintained.

Short-range communication (IEEE 802.15.4/ZigBee/XBee, WiFi) and mobile (LTE, WiMax) were studied for drone communication in alpine environments in [12]. As swarms typically need to be dispersed over a large area, a technology should support the communication at distances of hundreds of meters or more. In short-range communication, WiFi does typically not satisfy this requirement. Assuming that drones do not transmit real-time video, the required data rate does not need to be higher than 250 kbps offered by XBee/ZigBee. Both XBee and WiFi technologies have been used in Marine WSN or Autonomous Surface Crafts in the past [2,4,9,13,14].

Mobile communication technologies such as 3G/GPRS, LTE, WiMax are determined as an emergency communication module. The communication between swarm and land fully based on above technologies is limited by the coverage of service providers and relatively expensive (mobile communication operated on licensed bands). A long range technology (LoRa) and/or multi-hop solution are considered as long-range communication between a swarm and a base station. LoRa modules [15], which have a range up to 15-20 km, are promising.

Considered scenarios: (i) a set of buoys (self-positioning or anchored boats) with long-range communication capabilities deployed in limited area perform as gateways to the base; (ii) a set of buoys with short-range communication capabilities is deployed in limited area. Autonomous vessels with more processing power and long-range capabilities are mobile, move between the buoys gathering information, and relay the information to the base station (see Fig. 2).

III. PRELIMINARY TESTS AND CONCLUSION

Currently aquatic drones carry a Raspberry Pi 2 model B as processing unit, communicating within WiFi standard as short range technology. The solution using XBee modules with DigiMesh protocol (based on AODV protocol) has been implemented. It expands the range, ideally in line-of-sight (LOS), up to hundreds of meters. The preliminary tests for

length coverage between two nodes have shown the range 1400 m in LOS for Tx power (18 dBm).

ACKNOWLEDGEMENT

This research is supported by Fundação para a Ciência e Tecnologia (FCT) under grants UID/EEA/50008/2013, CREaTION, and EXPL/EEI-AUT/0329/2013.

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