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Optimization of the Deployment Sequence of a Multistatic Sonar Network by an Airborne Carrier

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In airborne Anti-Submarine Warfare (ASW) operations, sonars play a crucial role in detecting, pinpointing, and tracking submerged submarines. This study concentrates on a specific sonar device: sonobuoys, also known as underwater ears. Sonobuoys are acoustic devices deployed from airborne platforms such as Maritime Patrol Aircraft (MPA), helicopters, or even Unmanned Aerial Vehicles (UAVs). Each sonobuoy consists of a surface unit equipped with a UHF/VHF antenna for communication with the aircraft, a submerged unit containing hydrophones for underwater listening, and a cable connecting these two parts.

These buoys are categorized into three primary types: transmitter-only (Tx), receiver-only (Rx), and combined transmitter-receiver (TxRx). In a sonar system, which requires both a source and a receiver, combinations can be formed, such as using the transmitter from a Tx buoy and the receiver from a TxRx buoy, assuming inter-sensor compatibility. When the source and receiver are located together, as in a TxRx buoy, this is known as monostatism. In contrast, bistatism occurs when both are separated. A Multistatic Sonar Network (MSN) is then essentially a collection of sonar systems in either monostatic or bistatic configurations, created by pairing different sources and receivers from the dispersed sonobuoys throughout the Area of Interest (AoI). This results in a highly combinatorial arrangement. Figure 1 presents a simplified and synthesized overview of the operational context being addressed.

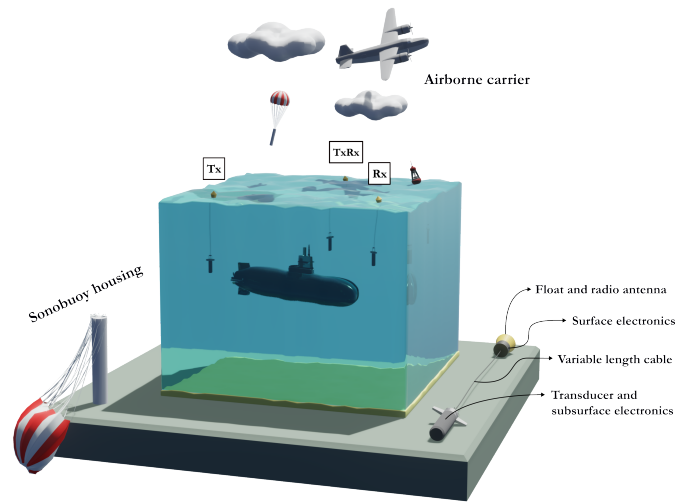


Figure 1: Streamlined illustration of the overall operating environment.

In this study, we assume that a heterogeneous MSN composed of Tx, Rx, and TxRx buoys has been configured beforehand, i.e. the sensors have been optimally positioned to maximise the surface area covered, based on methods developed and discussed in [1–6]. This idealized positioning accounts for coastal topography (i.e. obstacles), probabilistic detection models, unique challenges of underwater acoustics such as the direct blast effect, variable performance

depending on the source/receiver pairing as well as potential incompatibilities between sensors operating at different frequencies, the last two considerations being inherent to the heterogeneous variant of the problem. Here, the objective is to establish the most effective (i.e. optimal) flight path for an airborne carrier tasked with deploying buoys in order to maximize coverage within a predetermined mission timeframe and under specific operational limitations. Among these limitations, the airborne carrier must start and return to a naval air station taking into account a limited fuel capacity and a maximum speed. Additionally, the buoys have a limited lifespan and can be redeployed post-deactivation, subject to the aircraft's carrying capacity. This problem, unaddressed in existing literature, presents a significant challenge due to its intrinsically complex nature. Hence, in the first instance, we propose a Mixed-Integer Linear Programming (MILP) approach based on time discretization. It is currently deemed unsatisfactory for solving problems of operational interest which can extend over several hours of mission time. Figure 2 below illustrates an example of solution to this problem.

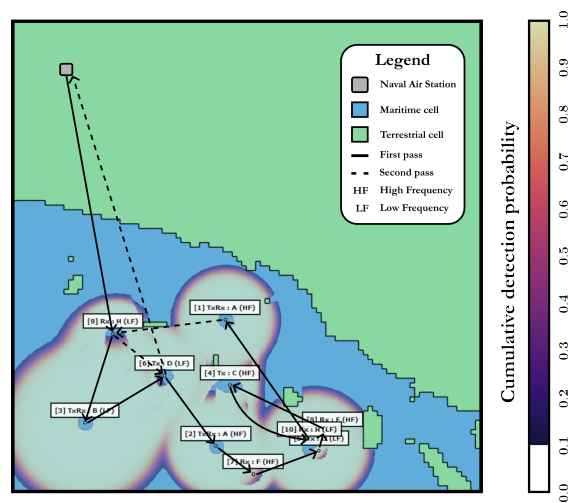


Figure 2: Example of solution for the deployment problem.

Subsequent studies should consider using heuristics or metaheuristics to address this problem, which might help solve instances of operational interest. An approach involving column generation could also be adopted for a more efficient resolution.

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