Signals from the depths: Properties of percolation strategies with the Argo dataset

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Several scientific activities like management of fisheries, monitoring of sea pollution, weather prediction, climate change assessments require the study of the Ocean environments. The design, deployment and management of Underwater Acoustic Sensor Networks (UASN) to collect oceanographic data is an established research area with several robust surveys [1–3] The most common UASN architectures use fixed sensors (moored at the sea floor, or to other fixed infrastructure), to monitor a (relatively small) marine habitat, for example a lake or a small sea, or the water around an oil platform. However, even fixed sensors, the underwater acoustic channel introduces several challenges for all network layers that require specific protocols [4–6].

Fixed UASN assume fairly dense and more or less continuously connected networks, with a good coverage of the area under observation. However, deploying a fixed network of sensors on scales larger than the immediate surroundings of, say, an oil platform, involves extremely high costs, that grow as the scale of the network grows. Under this respect, UASN architectures with mobile sensors are becoming more and more appealing. Not only mobile sensors are smaller and cheaper than moored ones, but there are also huge savings on the deployment costs, because it is not necessary to reach a large number of deployment sites uniformly spread on a vast area: a single ship may release a large amount of sensors along one or few ship tracks. Similarly, sensors may be deployed at regular intervals of time from a single release site. The ocean currents will then spread them in order to obtain a fair coverage. Partan et al. [3] observes that "... economics push underwater networks towards sparse and mobile deployments.".

Mobile Underwater Networks could be made of two different type of nodes: Nodes could be in-control of their movement with some form of autonomous propulsion engine, in this case the network is also called Underwater Autonomous Vehicle (Network of UAV). UAV are expensive devices that, sometimes, are not completely autonomous, rather they are remotely operated and attached to a close-by ship. If nodes cannot control their movement, they are usually called floats or Lagrangian drifters since they float, at the surface or at a specific depth, transported passively by the oceans currents. They are used specifically for their passive behavior to investigate how the ocean currents move, and to map water parameters like temperature and salinity.

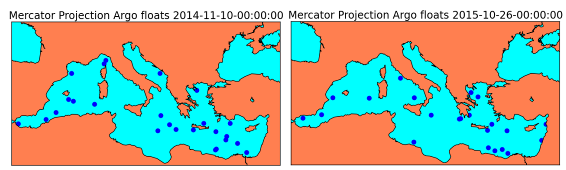

Figure 1. Two Snapshot at different times of the location of 64 ARGO Floats in the Mediterranean Sea

We are interested in this latter kind of nodes: In this we review the ARGO program, a large scale deployment of Lagrangian floats all around the oceans. Note that the Argo deployment cannot be considered a real sensor network, i.e. nodes are unable to communicate with each other, but only with a command center, using a satellite communication when they surface. The lack of a two-way communication channel with sufficient bandwidth is a major limit [7]. In this paper we study the viability of building a real underwater sensor network among hypothetical sensors that would follow the same path of the Argo floats, two snapshot of the nodes are illustrated in Figure 1.

This network enables a host of new application, such as remote diagnostic of floats, distributed fault-tolerance and backup among nodes, and gives the potential to reprogram a floats mission based on the density of nodes in a specific area. For example: if a node was unable to transmit its data to the command center, because of interferences in the satellite link, it could forward its data to another node in its current connected network (if available) that is near to its surfacing phase (this implies that nodes in contact, exchange schedules of their past and future activity), and it can even decide to skip its surface phase and prolong its floating in deep-water, since its data will be transmitted by the other node.

In general, the viability of sparse mobile networks require a properly designed delay-tolerant network layer with a routing based on geographic and intermittent protocols [8–11]. In terrestrial networks, the design of such routing protocols require the analysis of the underlying mobility of the nodes. For what concerns the UASN we lack of a similar investigation.

To the best of our knowledge, this paper is a first attempt to study the research problem previously stated, i.e. do we have real traces of the paths of mobile underwater sensor? what kind of qualitative and quantitative observations can be extracted by such datasets? and how the results of the analysis could be used to study the performance of available DTN protocols? In particular, we use real mobility traces obtained from the Argo project to study the feasibility and performance of underwater routing protocols.

In this paper we review related research literature, then we present the Argo program and its floats, and discuss its working and the dataset of traces used for the analysis. We present and discuss simulations of the qualitative connectivity properties of the network as a function of the acoustic transmitting range and a comparison of three epidemic routing protocols; Finally, we presents our conclusions and future work.

The dataset of Argo provides a real trace of the movements of nodes drifted by underwater currents. To the best of our knowledge this work is a first attempt to study underwater routing algorithms with a real-world underwater mobility dataset. The network we built is obtained by using different connectivity levels, based on different transmitting ranges, since the deployment is very sparse. Such ranges are not economically viable however the analysis we present can be used as a meaningful benchmark on the performance of different percolation strategies in a very sparse and stressing network. The results we obtain show that, also for the underwater networks, the routing protocols based on past information on the frequency of encounters among nodes provide the better performance. As a future work, we are interested in studying in depth the delay of the routing layer, and develop a realistic 2D mobility model that could be used to study denser deployments of free-drifting floats.

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