Marine Monitoring with Data Buoy Networks: Outline of a Potential Proposal for EDSnet WG4

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Abstract Some marine biological processes vary greatly over space and time. This document outlines the potential for applying technological advances in sensor technologies and wireless networking to the fields of oceanographic monitoring and pollution tracking. The system proposed in this document involves the use of groups of wirelessly networked buoys, harvesting solar energy, sensing, and wirelessly communicating their measurements. It expresses a vision for how such a system may operate, and lists the advantages and challenges in adopting such an approach. Potential advantages of the system include improvements in the temporal and spatial resolution of data collected.

Introduction

This document outlines a potential method for monitoring marine biological processes (and pollution incidents) with higher temporal and spatial resolution than is currently available. The need for this has been revealed in discussions at the Environmental Decision Support Network (EDSnet) and the Intelligent Sensing Programme (ISP), and is highlighted by studies such as the investigation into the spatial variability of picoplankton by Martin *et al* [1]. The extreme spatial variability in marine organism concentration suggests a need to replicate samples in the mesoscale (1-10km), and to repeat such measurements frequently over a sustained time period in order to provide sufficient data for accurate analysis.

The mindset of users of environmental monitoring equipment is somewhat dominated by the current high cost of precision instruments, and the practicalities of collecting measurements with existing equipment. Recent advances in sensing technologies may have the potential to deliver significant advantages in terms of the resolution of data while remaining affordable. For example, exploitation of micro-electro-mechanical system (MEMS) technology promises to bring a number of benefits, including reductions in the size and power consumption of sensors [2]. The European FerryBox Project has attached low-maintenance oceanographic monitoring systems to a number of ferries which measure and record data throughout each voyage, thus providing high-quality data covering a wide area [3].

A proposed system, suitable for use in oceanographic monitoring and pollution tracking, is outlined below. The system would utilise a network of static or drifting buoys, wirelessly networked together and equipped with a suite of sensors to measure parameters of interest. The lifetime of the buoy network would ideally be sustained by harvesting solar energy, whilst the infrastructure should provide a reliable means for wirelessly routing data to a central point, which could then transmit the data onwards by means of the mobile phone network or satellite communications.

A vision of the proposed system

It is envisaged that networks of buoys will be used to monitor biological and oceanographic parameters, or track pollution incidents. They would be deployed in groups and spread over an area of several kilometres. In the case of a chemical spill from a ship, buoys would be deployed to monitor the progress and concentration of the pollutant – buoys may free-float with the slick, or be anchored off sensitive coastlines (or a combination of the two). Either way, buoys in the group would cooperate and route messages via medium-range radio to a central point (which will be either a HQ boat or a relay buoy which would then perform long-range communications via satellite communications or the mobile phone network).

Buoys would calculate their own position by means of GPS (which is well-suited to use at sea), and adjust their behaviour in order to ensure connectivity of the dynamically-organising network. Multi-hop message routing reduces the total energy expenditure in sending messages across the network by relaying messages through a number of nodes at a reduced power level, rather than a high-power single hop.

Messages would be routed between buoys in a group, which would individually decide their participation in the network depending on their energy status. They would have an initial power supply provided from a rechargeable battery, but would harvest solar energy in order to sustain their operation. Messages would be prioritised depending on various thresholds (for example, a fast change in value), and important messages will be guaranteed transit through the network. Buoys would 'sleep' when permitted, in order to conserve power, and balance their energy usage with the necessity of their activity.

The system described above would provide a means for delivering improvements in spatial and temporal resolution of the sensed data. Enhancements in spatial resolution can be delivered through the separation of buoys in the group. The fact that buoys will be deployed for long periods of time, and aware of their power status, means that the temporal resolution of measurements can be balanced against the lifetime of the platforms.

Description of the modules

The system proposed in this document would exploit and encourage developments in a number of technology areas including sensing, sensor networking, and data processing and interpretation. Recent advances in wireless sensor networking (currently applicable to industry and the home) have not yet been transferred to mesoscale marine applications. The platform would allow those interested in oceanographic processes to easily monitor conditions in the mesoscale over an extended time period. Developments in sensor technology would be necessary in order to efficiently provide measurements of the desired parameter. In addition, it would be important for the data to be processed and interpreted effectively in order that models may be updated based on information collected by the network.

Platform design
The platform must provide energy to the sensor suite, and provide a means to communicate wirelessly with other nodes on the network. The platform should manage its energy effectively, and utilise energy harvested from solar panels. On a wider scale, the network must remain connected even when energy levels are low. Messages can be given priority ratings, and trivial messages could be discarded if energy levels are low: the network would work to ensure that important messages (large changes in the measured parameter, for example) are given a high priority, with an increased probability of successful delivery. Some work in this area has already taken place in the Electronic Systems Design Group at the University of Southampton [4].

Sensor development
The sensor suite would provide the means for determining the value of the measured parameter. The next section gives an idea of the potential applications of the system, and sensors should be developed to enable the required parameters to be measured. Sensor development is by no means a trivial task, and many sensor technologies are at an embryonic stage. Therefore, it will be necessary to determine what is realistically achievable when identifying target applications for the system. The properties of longevity, energy consumption, and size are of particular importance.

Data processing and presentation
The unique way in which data will be sensed and communicated poses particular requirements on the means of processing and display. Data may be reported sporadically, reporting only interesting

changes in the sensed parameter. Attention will have to be given to the algorithms in use, in order to allow scientists to draw correct conclusions from the data set. It is important that the user has confidence in the algorithms, and that an adaptive reporting interval does not cause concern regarding a loss of resolution of the data.

Potential applications of the system

Pollution tracking and monitoring

A group of buoys could be deposited from a ship, or dropped from an aircraft, to monitor the site of a chemical spill at sea. They would drift with the spill, collate data, and report periodically about the position and concentration of the pollutant. Thus the pollution incident could be monitored remotely (at low cost, high resolution and with a minimum of human intervention), and the data obtained could be used for refinement of forecasts regarding behaviour of the spill or to trigger other responses. Further buoys could be added to the group as required in order to monitor a wider area or for improved resolution. Additional groups of buoys could act as sentinels, and be moored off sensitive coastlines and entrances to estuaries in order to provide a warning of ingress of the pollutant, as shown in Fig 1.

Monitoring of marine biological processes

Phenomena such as algal blooms, bacteria, and plankton concentrations are of interest to marine biologists and oceanographers. By distributing a number of monitoring stations throughout an area of interest, multiple readings may be taken simultaneously in spatially separated areas. The unattended and sustained operation of the network would permit studies to continue indefinitely, with the major constraint being the longevity of the sensing element. There may also be opportunities for remote monitoring of fish stocks, and investigating links between a variety of processes.

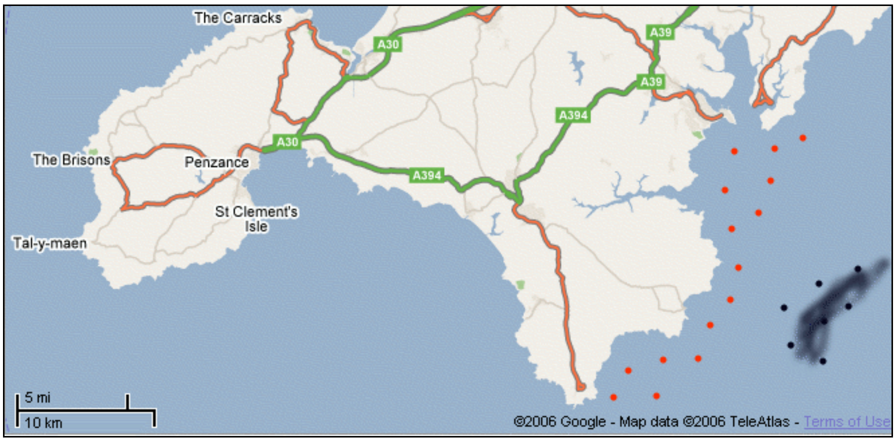

Figure 1: A fictional pollution incident, with tracking buoys (black) and anchored sentinel buoys (red)

Coastal water quality observation

Assessments of bathing water quality are based on samples taken with a low frequency [5], normally at a single point for each location (i.e. with a low spatial variation). It may be surmised that the low spatial and temporal resolution of data may lead to misleading conclusions. Many physico-chemical parameters could potentially be monitored automatically, and further research would be required to analyse whether bathing water quality could be determined autonomously by means of networks of buoys equipped with sensors for parameters such as pH, dissolved oxygen levels, nitrate concentration, and transparency.

Technical challenges

Sensor development
A number of constraints would be placed on members of the sensor suite, providing significant technical challenge. The sea represents a hostile environment for sensing, and ensuring longevity of the sensing element (along with reliability of the sensed data) is challenging. Sensors designed in the lifetime of the project would have to be developed with longevity in mind, as long-term deployment with a minimum of human intervention is a major aim. In addition, the sensors must be relatively small (in order to be housed in the platform), and consume minimal levels of energy. Work in oceanographic sensing is being performed by the Sensor Development Group at the National Oceanography Centre (NOC), with developments in the areas of MEMS, UV spectrophotometry, and wet chemical analysis.

Platform energy management and radio communications
Long-term deployment will require careful energy management, and communications over long distances at sea are likely to pose a challenge. Energy management will need to control the harvesting of energy from sustainable sources, along with the activity of the platform. A balance will have to be reached in guaranteeing the connectivity of the network whilst delivering satisfactory temporal resolution of the data. Delivering multi-hop (mesh) networking over a distance of several kilometres at sea will be challenging, as will synchronisation of the platforms and dynamic organisation of the network. The changing nature of the network configuration (with additional platforms being added and the buoys potentially drifting in an uncontrolled manner) means that networking algorithms will have to be robust to react to rapidly changing conditions.

Conclusions

We have outlined a vision of how networks of instrumented buoys could provide increased spatial and temporal resolution for monitoring the marine environment. Recent technological advances, and further work, could provide a flexible platform for remote monitoring of biological processes and the tracking of pollution incidents at sea. Substantial challenges lie in the areas of sensing and platform development. This document provides a starting point for further discussions, and outlines some of the areas of focus should this be selected as a topic of interest as part of the EDSnet project.

References

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