Monitoring the Ocean Environment with Large-Area Wireless Sensor Networks

Frank Reichenbach, Matthias Handy, Dirk Timmermann
Institute of Applied Microelectronics and Computer Science, University of Rostock
{frank.reichenbach; matthias.handy; dirk.timmermann}@uni-rostock.de

1. Introduction

Ocean covers almost three quarters (71%) of the surface of the earth that must be continuously observed to e.g. detect climate changes or pollution of the environment which effects human and animal habitat. Currently used methods are cost and time expensive and they neither allow a required large-area sampling nor a high resolution of measuring grid. In this paper, we emphasize advantages of Wireless Sensor Networks (WSN) in the oceanography, we point out differences to terrestrial WSNs and we suggest applications.

A WSN consists of thousands of sensor nodes, each node containing a processing unit, a transceiver, memory, a battery and sensors [1]. Current terrestrial applications include the prevention of wood fire or the detection of leakages along a dike.

The new approach is to verify the advantages of WSNs in the oceanography to enhance main objectives: hydrography, eutrophication and detection of pollution [2]. In several research groups the utilization of oceanic WSNs is studied. Ong et al. describe a randomly distributed WSN over a lake or drinking water reservoir measuring the pH-values with magneto elastic sensors ensuring drinking water safety [3]. Another approach is made by Dunkels et al. using a sensor network for monitoring water temperature and salinity significantly reducing the cost of marine research [4]. The network will be deployed in the northern part of the Baltic Sea, where fresh water movements affect temperature and salinity. Our research group [5] deals with the development of middleware, routing of information, security and localization of nodes in WSNs [6]. In cooperation with the resident „Baltic Sea Research Institute Warnemuende“ [7], we discuss useful approaches for WSN's in the oceanography [8].

2. Terrestrial- vs. Oceanographic WSNs

On terrestrial wireless sensor networks (t.WSNs) extensive research has been conducted. Therefore, the adaption of terrestrial methods is eligible. For this reason we list in Table 1 differences between both networks.

Whereas in t.WSNs the high miniaturization of each node is demanded, in oceanographic WSNs (o.WSNs) the size of a node is less important because of the not required high density.

Table 1. Basic differences between land- and water-WSNs

	Terrestrial WSN	*Oceanographic WSN*
Network-Density	Fine grained (small area, many nodes)	Coarse grained (large area, few nodes)
Size of one Device	Required Tiny	Small
Network-Mobility	Low	High (due to streams)
Energy-Consumption	Low (radio frequency, short distances)	High (acoustic waves, high attenuation, long distances)
Prize per Node	Cheap	Expensive (Modem, Sensors)

Mobility in t.WSNs is researched but not inevitable a problem in most scenarios. Complementary, due to water streams the mobility in o.WSNs is very high and must be considered if nodes are not fixed. In both networks minimized power consumption is imperative because on the one hand nodes in t.WSNs are very tiny with a small battery. On the other hand in o.WSNs under water modems feature high power consumption (omni directional transmission ~2 Watt [9]) and transceivers with radio on the water surface have to transmit over large distances. Correspondingly, o.WSNs are very expensive, due to the need of acoustic modems, special sensors (e.g. chlorophyll) and water-, press-proofed cases.

3. Oceanographic WSNs

At present, measurements of the ocean environment are mainly done by ships and with buoys fixed at the sea bottom. Particularly, research-ships enable detailed measurements with a high variety of sensors (e.g. temperature, salinity, and oxygen). In contrast, the area coverage is highly limited since the ships cruises only on limited routes. Additionally, „Ship of opportunity sampling“ is a cost inexpensive alternative, whereas regular ferries, freighter and other commercial ships take measurements on their routes [2]. Moreover satellites measure the sea surface temperature and the sea level (e.g. SEASAT, ERS-X and JASON). Problems of classical methods are high costs of navigation, the small period of data acquisition, the partly missing interaction between control systems ashore and in the water and the arising financial costs. Moreover, the expenditure of time

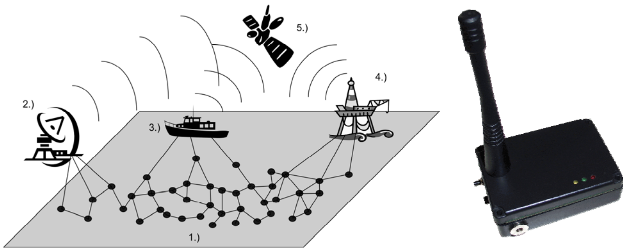

Figure 1. a) Oceanographic wireless sensor network 1.) with links to 2.) on-shore base station 3.) ship 4.) fixed base station, and 5.) satellite; b) Prototypic sensor node platform used in our research lab

is high due to possible device errors or failures which can not be fixed immediately. Sometimes, more than months lie in between measurement and its examination.

A new approach is to deploy large WSNs over and under the ocean surface. We distinguish two different scenarios. First, short-term monitoring facilitates the acquisition of high resolution measurements in a small region (e.g. prevention of disasters, observation of pollutions). Secondly, long-term monitoring of large areas is possible (e.g. improved weather forecasts, detection of climate changes), which has been extremely difficult. Additionally, new observation techniques are imaginable like the dynamic trace of streams. Therefore, the sensor nodes float with the stream; e.g. tracing of the Gulf Stream.

Following we describe the stream trace scenario in more detail. After spreading out the sensor nodes over the ocean by plane, in a first phase the network is established in a self organized manner and every node computes an initial position (Figure 1.a). Then, the nodes start the observation phase by measuring the environment with its specific sensors. At constant time intervals nodes send via hop by hop fashion sensor data and positions to one of the base stations in range. Either the base station is the end point (on-shore base station) and the information are analyzed instantly or the data are forwarded to a satellite (from ship, fixed base station), where all endpoints are connected to. Finally, over the time a stream profile can be created such that the sensor nodes are traced with their positions in the stream. At present the following problems arise:

- Ecological recycling of sensor nodes
- High energy consumption of components
- Missing media access control-protocols under water
- Problems of deployment and fixation
- Missing reliable hardware-platforms
- Missing robust and small, accurate sensors
- High cost per sensor node

We want to start overcoming some of these problems by primary developing a first prototypic hardware platform. Therefore, we built up on our own devices – the encapsulated CC1010 evaluation modules (Figure 1.b). With the integrated temperature sensor these modules allow monitoring of the surface temperature.

4. Conclusion

Wireless sensor networks enhance the quality of ocean monitoring. In addition to the higher resolution of measuring data, the higher coverage of surface and long-term monitoring in real-time, new applications are enabled like dynamic observation of streams.

But, many unsolved problems in oceanographic wireless sensor networks require intensive research. Referring to this, the biological decomposition of the sensor nodes, the reduction of energy consumption in underwater communication, the missing media access protocols under water and the development of waterproofed hardware platforms with a broad variety of sensors need to be solved. Moreover, the sensor nodes are very expensive at present.

In future we want to develop a simple hardware platform with flexible software protocols running on it to achieve seamless communication over and under water sensor nodes for utilizable applications.

5. References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "A Survey on Sensor Networks", *IEEE Communications Magazine*, pp. 102-114, August 2002.

[2] C. Davidsen, „Ökologisches Monitoring der Ostsee", *Mittelseminar: ,Die Ostsee: Schutz und Nutzung',* Geographisches Institut der Universität Kiel

[3] K. G. Ong, X. Yang, N. Mukherjee, H. Wang, S. Surender, C. A. Grimes, "A Wireless Sensor Network for Long-term Monitoring of Aquatic Environments: Design and Implementation", *Sensor Letters*, Volume 2, Issue 1, American Scientific Publishers, pp. 48-57(10), 2004

[4] A. Dunkels, L. Marie Feeney, B. Grönvall, and T. Voigt, "An integrated approach to developing sensor network solutions", *In Proceedings of the 2nd International Workshop on Sensor and Actor Network Protocols and Applications (SANPA'04)*, 2004

[5] http://www.senets.org/

[6] J. Blumenthal, F. Golatowski, M. Haase, M. Handy, "Software Development for Large-Scale Wireless Sensor Networks", In: *The Industrial Information Technology Handbook*, Series: Industrial Electronics Volume: 1, CRC Press, ISBN: 0849319854, 2004

[7] http://www.io-warnemuende.de/

[8] F. Reichenbach, D. Timmermann, „Großflächige drahtlose Sensornetzwerke zur Überwachung der Meeresumwelt", *Seminar: Physikalische Ozeanographie*, Leibniz-Institut für Ostseeforschung, Warnemünde, Deutschland, 2005

[9] X. Yu, "Wireline Quality Underwater Wireless Communication Using High-Speed Acoustic Modems" *Proc. IEEE OceansConf.*, pp. 417-422, Providence, RI, Sept. 11-14, 2000