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Design of Underwater Sensor Networks for Water Quality Monitoring

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Abstract: Due to the limited bandwidth and large propagation delays experienced in underwater sensor networks, the challenges and planning requirements are different compared to their terrestrial counterparts. Underwater sensor networks can be deployed for industrial and scientific benefits such as pollution monitoring. The designing and working of an underwater sensor network for water quality monitoring is presented in our work for which data monitoring nodes and monitoring system are the main components. This system is applicable for shallow water scenarios. Parameters such as pH and temperature have been monitored using our deployed network. We go through the hardware aspects of the nodes along along with developing relaying and communication strategies. Each node would have transmitter to collect the temperature and pH from sensors and other parts would be the processing module, sensing module, power module and ZigBee radio frequency part. The water environment parameters would be monitored at the data centre through GPRS gateway. Our network developed would also provide applicable aspects to be adopted by environmental monitoring organizations.

Key words: Underwater acoustic network · Water quality monitoring · Wireless sensor networks · Data monitoring · Remote monitoring center

INTRODUCTION

Underwater sensor networks have increasing utilization in pollution monitoring, assisted navigation and tactical surveillance applications. There would be a varying number of sensors deployed which perform in collaboration using acoustic networking. Using Acoustic networks different kinds of pollution monitoring, e.g., chemical, biological pollutions can be achieved [1]. Acoustic communications is the physical layer technology in underwater networks. The radio wave propagation occurs in waters at extra low frequencies (30-300 Hz). Energy efficiency is a critical issue in underwater sensor networks [2,3].

The prominent challenges encountered are limited bandwidth, severely impaired underwater channel due to multi paths and fading as well as high BER and limited battery power [4]. The work on underwater sensor networks is based on investigating to optimize whole system performance across different layers. In terms of cost the underwater equipments are more expensive compared to ground based counterparts and an acoustic modem could cost around $ 3000 while cable connectors costing around $100 [5]. The focus is on improving water quality sensor network deployment and improving the density of sensor nodes covering the area. Data forwarding and aggregation takes place amongst the nodes and the nodes use low powered radios for efficient power consumption. The radio propagation in water occurs at very low frequency ranges (30-300 Hz) for which higher transmit power and larger sized antennas are required. A practical example was the Berkeley Mica 2 Motes having transmission range of 120 cm at 433 MHz. The particular characteristics of underwater acoustic communication channel require reliable protocols to encounter the effects of limited bandwidth. In the pollution monitoring phenomena, the application of underwater sensor networks is to determine the chemicals, biological and insecticide levels of water. For uniform utilization of power amongst the network the deployment has to be optimized for greater capacity. Reliability would be only ensured through proper functioning of the nodes and routing strategies between them to forward data thus managing traffic properly in efficient distributed pattern. The sensor nodes are prone to failures due to corrosion. The battery lifetime has to be also taken into account as it is dependent on frequency of transmission, data rates, distance amongst the interacting nodes and number of

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nodes in a cluster. In relevance to the multiple techniques used in underwater sensor networks FDMA is not possible due to limited bandwidth in underwater acoustic channels. TDMA is better due to the long propagation delay characteristic of the underwater acoustic channel thus long time guards are required in the channel [6]. Carrier sense multiple access prevents collision at the transmitter side but have to keep some guard time between transmissions to prevent collisions at the receiver. Code division multiple access is an emerging technology for underwater acoustic networks since it permits random and overlapping access to shared communication channel thus contributing to its suitability [7].

Monitoring Parameters: Water quality monitoring is ensured to help in determining the levels of water pollution due to discharge of toxic chemicals and contamination in water. Mostly for water quality monitoring scenarios following parameters are monitored.

PH Level: It indicates the level of hydrogen ions in water and the pH sensor would determine the acidity and basicity of water as the normal range of pH is from 0 to 14.Though the average pH ranges from 5.5 8.5 and high level of acidity indicates pollution and is deadly for water organisms.

Temperature: This is also an important factor since it affects the amount of oxygen which can dissolve in water.

Conductivity: Indicates the ability of water to conduct current since it is the level of ion concentration. The unit of conductivity is micro Siemens per centimeter (uS/cm).TDS is expressed in parts per million indicating the impurities in per unit quantity of water. Normally drinking water has impurity of 500 ppm.

Turbidity: It is measured in Nephelometric Turbidity units (NTU). Indicates the level of clarity of water also determining the sand, soil, silt and clay.

For our deployment method, we have got super node and number of sensor nodes and each sensor node would use low power Zigbee radio for data transmission and the computational capability of super node would be greater as it would have greater capacity and uses 802.11 Ethernet radio for data transmission. Due to varying signal strength the network is divided into several clusters. Each cluster is headed by a super node i.e. sink and the small sensor nodes use low power Zigbee radios and long distance Ethernet radios between super node and base station.

Underwater acoustic communication networks, the cost and power consumption of underwater acoustic modem must come down. Commercial off the shelf (COTS) modems are not suitable for short range (100m) underwater sensor nets since their power ranges and price points are designed for sparse, long range and expensive systems and this is an accepted fact that low power and low cost underwater acoustic modem is needed to monitor and surveying underwater ecological analyses [8].

The three main components of Underwater acoustic modems are 1. Underwater transducer 2. An analog transceiver (matching pre-amp and amplifier) 3. Digital platform for control and signal processing.

The most costly component is the underwater transducer as commercially available underwater omni-directional transducers (such as those as seen in existing research modem designs) cost on the order of $2000. Therefore, much of the design for the low-cost modem lies in finding an appropriate substitute for the custom commercial transducer. Jurdak *et al*. substituted the transducer with generic, inexpensive, speakers and microphones, but were only able to obtain a data rate of 42 bps for a transmission range of 17m. Benson *et al*. substituted a custom transducer with a commercially available fish finder transducer (which cost $50), but was only able to obtain a data rate of 80 bps for a transmission range of 6m.

Presently we can sample the underwater environment through artificial sampling or continuous surveillance and monitoring through remote transferring of data. Through intelligent monitoring using wireless sensor networks we have advantages of low cost and efficient capability of communicating. So we would be working for water quality monitoring system using parameters like pH and temperature. Our system would be having sensor nodes for monitoring data, base station and a remote monitoring center with each node capable of collecting parameters such as pH and temperature and this data would be forwarded to a base station which would use GPRS network to route it to the remote monitoring system. Each mote would have a pH transmitter, processing module, sensing module and power module as well as ZigBee radio frequency part. The pH transmitter collecting the pH and temperature from the sensors would convert them to a 20 mA signal and the processor would further process and transfer them to the base station through the RF ZigBee part. Each node is connected to the base station using the Zig Bee communication protocol.

Challenges to Be Overcome: The properties of underwater channels differ from their ground based counter parts. The fundamental design goals are the same i.e. to provide reliable data transfer amongst nodes, increasing the network capacity and minimizing the energy consumption. The earth is mostly covered by water and much still remains to be explored in relevance to the changes in the environment due to natural or manmade disasters. There has been wide interest overall to explore and monitor underwater medium for scientific and commercial applications as well as environmental safety issues. Water is one of the limited resources and water quality monitoring is essential for agriculture and environmental friendly attitude thus to control physical, chemical and biological characteristics of water. Drinking water should not contain anything hazardous to health.

Sensor networks are based on Micro Electrical and Mechanical Systems (MEMS) for constructing on board sensing units. Due to technological advances there are several fields available in numerous novel networking schemes. The ability to have small devices makes it possible to easily implement applications like micro habitat monitoring and industrial applications. Underwater sensor networks consist of variable number of sensors which are deployed to perform collaborative monitoring over a given area. Acoustic communications is the physical layer technology in underwater networks. The radio wave propagation occurs in waters at extra low frequencies (30-300 Hz).The basic design goals are the same i.e. to provide reliable connectivity amongst nodes, increasing network capacity and minimizing energy consumption.

The challenges to be overcome while designing underwater sensor networks were limited bandwidth and severely impaired channel due to multipath and fading along with higher propagation delay compared to radio frequency terrestrial channels. The Bite Error Rate is also higher and battery power is also limited since solar energy cannot be used and corrosion and fouling also are a big problem contributing to malfunctioning of nodes. Since our research paper is dedicated for designing a novel water monitoring system for remote monitoring of water quality and it would be applicable for different water environments thus applicable for various scenarios.

Designing of Sensor Network: In the underwater wireless sensor networks since power conservation is one of the main issues to be dealt with since the nodes operate on limited battery life. The sensor networks do not have a large scale infrastructure and nodes cooperate by relaying packets to ensure that the packets reach their respective destinations. The nodes are usually battery powered, thus it is crucial that relaying and communication strategies be developed to minimize power utilization. Transmitting at low power reduces the amount of excessive interference. Power conservation helps to prolong the lifetime of a node and thus the lifetime of the network as a whole.

For our system of multiple motes, as indicated in the Figure 1, each mote has a pH transmitter, processing module, sensing module and power module as well as ZigBee radio frequency part. The pH transmitter collecting the pH and temperature from the sensors would convert them to a 20 mA signal and the processor would further process and transfer them to the base station through the RF ZigBee part. Each node is connected to the base station using the Zig Bee communication protocol.

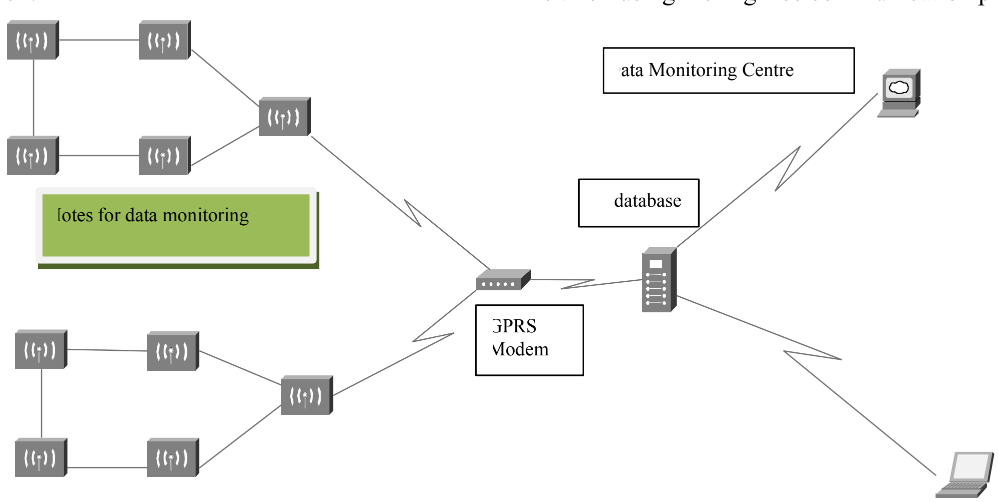

Fig. 1: Underwater Sensor Network for Water Quality Monitoring

For the pH transmitter part of the node which would collect the temperature and pH values from the sensors for monitoring these parameters and the transmitter can convert the values to a standard 4-20 mA signal as we would be using LE 438 integrated pH for transmitter and temperature sensor which would be manufactured by METTLER TOLEDO. For power module designing we would provide six nickel hydrogen batteries (7.2V) or two lithium batteries (7.4V acting as power supply for TPS 76333. The Radio Frequency module would be ZigBee CC 2420 receiving and sending chip. With data monitoring node we would be having IAR Embedded Workbench for MSP430.Then we also have to keep in mind about designing of GPRS module which would be connected to MSP430F1611 and the power module designed with GPRS module thus using LM2596 and TPS79533 power chips. For other modules we have the LCM19264 LCD module.

The basic function of GPRS module is in setting up the communication as it would be controlled by MSP430 and it would be activated by a phone call. The ZigBee module communication task would be prioritized such that the base station would be sending commands to the data monitoring nodes and upon data processing task given the ZigBee would be activated. The data processing would be on receiving the command messages and monitoring of data from nodes. Through activating GPRS connection and maintaining of GPRS connection the data processing ability maintains the link. Through the GPRS gateway and data center the water environment parameters would be monitored and through this software for monitoring it would be possible to carry out data queries, data analysis and remote monitoring regarding changes of water environment.

During data sampling phase there would not be much traffic but there would be changes in traffic during requests for monitoring and consequently nodes would send data to base station and then the data would be forwarded to data monitoring centre. Adhoc multihop protocol to be implemented would support ZigBee wireless communication so that it would span and synchronize all the nodes thus contributing to reliability.

CONCLUSIONS

We have had a summary of the challenges to be overcome in underwater sensor networks and the steps to be taken for reliable and efficient performance of such networks. We have developed an underwater sensor network for monitoring water quality and pollution and keeping temperature and pH as the parameters which are being monitored by the motes and communicated through data base station and GPRS modems to the data monitoring centre. This can serve as a long term solution for environmental control and surveillance of physical environments thus making pollution monitoring less complex and generation of reports on regular basis maintaining a close check on the amount of pollutants through monitoring acidity in the samples of water under observation.

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