# Design of Wireless Sensor Networks on Offshore Environment Monitor

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**Abstract.** With the significantly increased exploitation speed of offshore marine resources, marine environmental pollution is getting more and more attention in recent years. Offshore environmental monitoring has become a hot issue in marine ecological environmental research. Wireless sensor networks (WSNs) technology has gradually become one of the important marine environmental monitoring techniques with its network structure features. In this paper, a new method of offshore environmental monitoring system based on WSN technology is proposed. Firstly, the overall structure of the system is designed; secondly, according to data transmission features, ZigBee is chosen as the WSN communication protocol; finally, by designing Z-Stack protocol stack program, system networking and data transmission are completed.

## Introduction

The ocean is an important base for achieving sustainable development and human society to survive and multiply. Using marine resources and developing marine economy rationally is the one of key for human survival and social development of a country in the world. With the large increase of China's offshore oil exploitation scale [1,2], marine oil spill risk is also increased year by year. After a series of physical, chemical and biological processes in the water, marine oil spill will pollute the water ecological environment, and kill aquatic organisms because of its complex composition, which has been linked to higher economic losses from water, biomass, fishing and tourism. In addition, petroleum contaminants will further affect human health and survival from entering the biologic chain. Due to the serious harm of offshore oil spill, the implementation of real-time monitoring of coastal waters environment, timely detection and cleanup of oil spill contamination as soon as possible has become a great important research topic of the coastal countries in the world.

In marine environment monitoring system, the scope of monitoring is always restricted by the "wired" data transmission. Besides, the wired monitoring system is used less for the complex marine environment because of its higher cost. However, with the advantage of wireless sensor networks (WSNs) technology and the emergence of all kinds of real-time oil and gas detection sensors, which have laid the technical foundations for WSN technology applications in early oil spills monitoring of marine environment particularly. The WSN arranged easily and with strong scalability, can be used in unmanned environment through ad hoc networks to complete tasks such as large-scale collection of information for a long time [3,4]. By referring to the literatures, we found that the WSNs technology has used in environmental monitoring. For example, in [5], the paper presents the functional design and implementation of a complete WSN platform that can be used for a range of long-term environmental monitoring IoT applications.

In this paper, a new method of offshore environment monitoring system based on a WSN technology is proposed for the main purpose of oil spill monitoring.

## System Structure

The three-dimensional marine oil spill monitoring system based on WSN proposed in this paper is shown in Fig.1, which consists of portable monitoring nodes, fixed float nodes on the water, data acquisition repeater station, data acquisition and control unit on the land. The unmanned surface vehicle (USV) monitors the surrounding environment by a variety of sensor nodes, and forms a

 

wireless self-organizing network of multi-hop structure with other sensor nodes under the control of low power network protocol based on WSN. The measurement data is transmitted to the data repeater station through a network of nodes. When the USV motions near the fixed float and meet the maximum distance of node communication, floater nodes will automatically join the network and send the monitoring data to the USV. The data repeater station will be all of the data transmission to the data acquisition and control center on the land, then using the data processing and information fusion technology to realize underwater oil spill detection and prediction task.

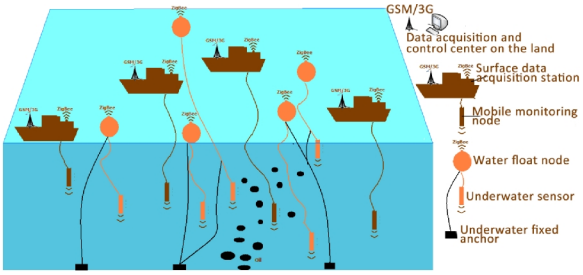


Fig. 1 Structure of three-dimensional marine oil spill monitoring

## Sensor Selection

The main purpose of the monitor system is to establish a three-dimensional model which used to monitor the regional oil content. At present the main parameters of coastal waters monitoring are as follows:

- Water quality parameters: pH, organics, salinity, chlorophyll-a, etc.
- Hydrometeorology parameters: temperature, waves, water temperature, wind, flow rate, light intensity, etc.
- Physical and chemical parameters: heavy metals, nutrients, etc.

In the above parameters, chlorophyll-a content index can reflect directly oil content in monitoring waters. And seawater temperature and light intensity are important environment factors which influences the survival of marine biology. In addition, the position information of nodes is an indispensable parameter for obtaining the environment parameters of specified position. Therefore, the content of chlorophyll-a, light intensity, temperature and humidity information are used as main parameters in this paper. The RBRvirtuoso F1, a kind of underwater chlorophyll meters designed by Canadian RBR is selected as the main sensor for detecting water quality depends on the need of monitoring parameters, and the conventional sensor modules are chosen for the rest of the sensor.

## Communication Scheme

Communication is the core of the WSN technology between the equipments in a network. But most of the equipment does not have the function of networking and communication. Machine-to-machine (M2M) technology can solve the problems of how to add in the network and how to send and share the equipment information [6].

M2M technology in the direct translation is machine and machine wireless communication technology. It uses GPRS, GSM and other long distance transmission technology or Wi-Fi, Bluetooth, ZigBee connection technology of near distance as the foundation of communication technology to complete the bidirectional communication between two machines. Due to the distance of the monitoring system nodes is not far, so one of near distance transmission mode was selected in this paper.

The communication protocol is selected by the requirements of communication system nodes. According to the working modes, the nodes are divided into fixed and mobile nodes. The mobile nodes are placed in the USV, in the state real-time communication with the gateway equipment. The fixed nodes are placed on the water floater, which are in the state of data acquisition and storage in the most of time. And the wireless transmitting device is in the state of searching network. The fixed nodes will

automatically join network to complete task of data transmission when searching the mobile nodes. Owing to the complex environment on the water, the communication distance, the speed of accessing to network and the transmission rate will influence the timeliness and stability of the system data transmission. Above all, when the system choosing the communication protocol, nodes can automatic join in the network, long time working, wide network rage and the other factors should be meet. These three technologies are briefly compared in Table 1.

Table 1 A comparison between ZigBee, Wi-Fi, and Bluetooth wireless technologies

| Name | ZigBee | Wi-Fi | Bluetooth |
|---|---|---|---|
| Automatic network | √ | √ | √ |
| Battery life (days) | 100-700 | 0.1-5 | 1-7 |
| Bandwidth(kb/s) | 20-250 | 11,000 | 720 |
| Network size | 65536 | 32 | 7 |
| Range (m) | 1-75 | 1-100 | 1-10 |
| Access speed | 30ms | 3s | 10s |

By comparison, the ZigBee wireless technologies meet the requirements of the system, so the ZigBee protocol was chosen as the WSNs communication foundation.

## Networking Process

A. Networking Flowchart

Due to the sensor nodes and the coordinator integrated on the gateway deployed on the USV are very close and the collected data is sent directly, without forwarding, so each set of water monitoring node group would be designed for star topology network structure. It is time to realize automatic networking between the various devices after determining the system network architecture. Fig. 2 shows the ZigBee networking flowchart.

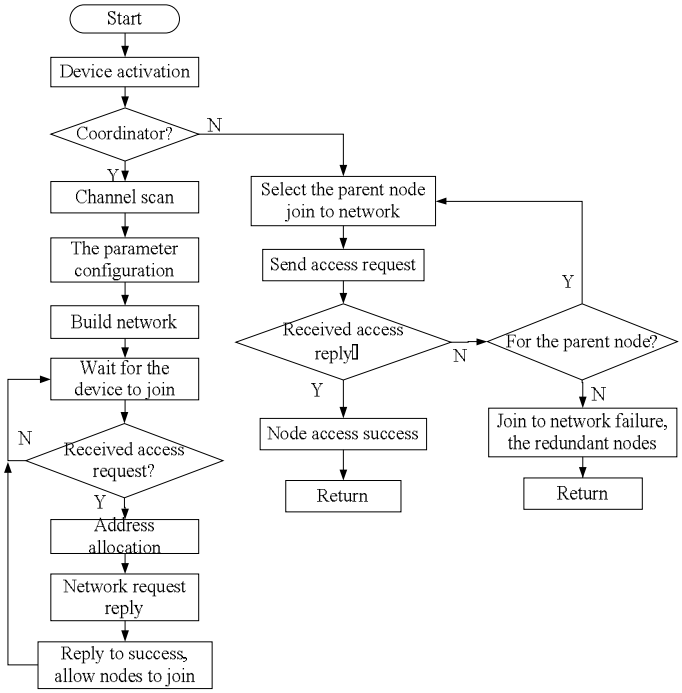


Fig. 2 ZigBee networking flowchart

ZigBee equipments networking are mainly divided into two steps: the coordinator to establish network and terminal accessing to network.

B. Implementation of ZigBee Networking Based on Z-Stack Protocol

In this paper, ZigBee networking protocol are based on Z-Stack protocol Stack, designed by IAR Embedded Workbench of TI company [7]. The protocol stack has completed core program framework of wireless communications, it is only to modify and add the code we need at the application layer (APP) to complete the construction equipment for data transmission in network of ZigBee wireless network [8]. Networking is to achieve the star network makes the child nodes can be through the parent node and network coordinator communication. The gateway equipment and the coordinator node are using serial communication. Because the coordinator is integrated in the gateway equipment, its date port has been connected to the serial port of ARM board which is the gateway core.

The ZigBee star network is realized by calling the corresponding function of protocol stack API. By calling the ZDO_StartDevice() function to start the equipment. It will start automatically the equipment and to do relevant work through the different types of equipment. The protocol stack networking flowchart is shown in Fig. 3.

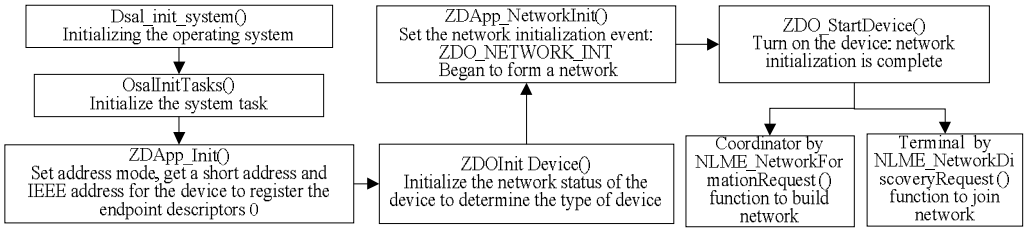


Fig. 3 Protocol stack networking flowchart

A star network consists of a network coordinator and a lot of terminal device nodes, and all the terminal equipments can only with the network coordinator communication. A new network is created by relevant initialization, some definitions of network parameters and calling the NLME_NetworkFormationRequest() function after the device is set as the network coordinator. Then, when the device is set as the terminal, it will scan the protocol stack specified channel by calling NLME_NetworkDiscoveryRequest() function after power up. If a network coordinator is in the state of normal working, and the PAN ID of which is same to the terminal, then it will request to join the network by calling NLME_OrphanJoinRequest() function. If the terminal nodes accessing to network successfully, the coordinator will assigned 16 bit short address to the terminal nodes by the sequence of nodes to join the network. So far a star network establishing has been completed.

## Data Fusion

In order to ascertain all environmental information of a given collection point, the gateway device needs to receive all data sent by the nodes of connecting sensor network. Therefore, the all information needs to be processed by data fusion [9,11].

First, the gateway device deal with the data received every 6 seconds by mean filter process according to the types of sensors. Then, all sensor information after processing as a data frame is sent to the PC，and use the time of receiving data by gateway equipment as the flag bit of frame head. In this way, a certain position, depth, oil content, temperature, humidity and light data can be fused together. Designed of data communication format is shown in Fig. 4:

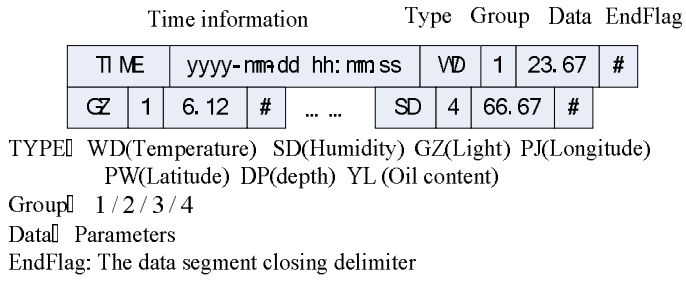


Fig. 4 Data transfer format between PC and gateway

## Experimental Results

According to the above research, an actual system is constructed and the corresponding software is developed on the gateway device and the control center computer.

The main chip of the gateway device is S3C6410ARM, and the Qt Creator is the development environment. The main interface of the gateway device software displays the communication state of sensor group and coordinator. After a sensor module of any one group joining the network, the corresponding group icons shown as accessible state, but as no sensor joining the group, the icons displayed an inaccessible state. When clicking the connected group button, the parameters of the sensor which in the group can be shown. The gateway device touch screen parameter page is shown in Fig. 5.

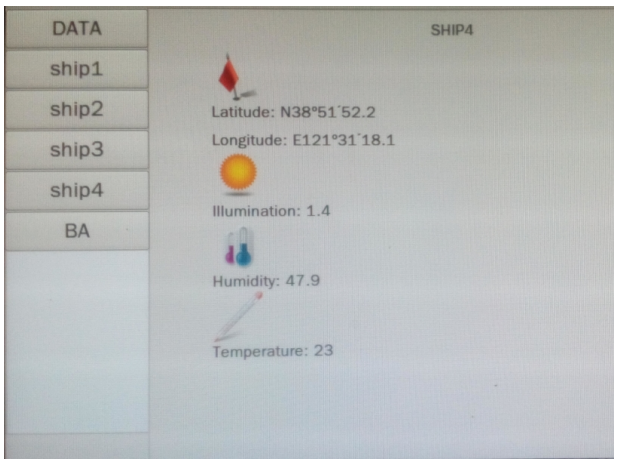


Fig. 5 Screen snapshot of gateway device software

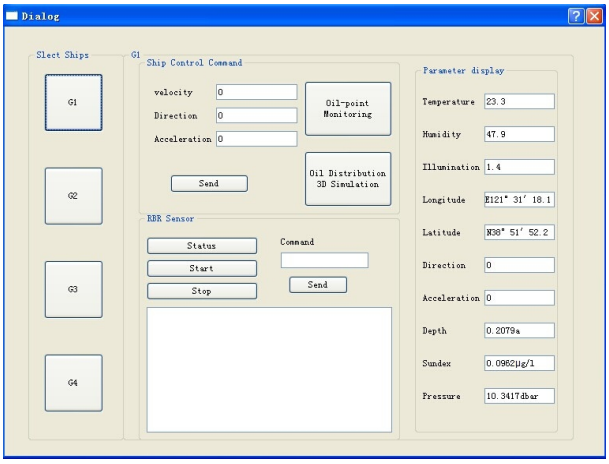


Fig. 6 Main screen of PC software

The main functions of the software on the PC control center include: data receiving, data processing and displaying, and three-dimensional simulation of the oil distribution. The results are shown in Fig. 6, Fig. 7 and Fig. 8.

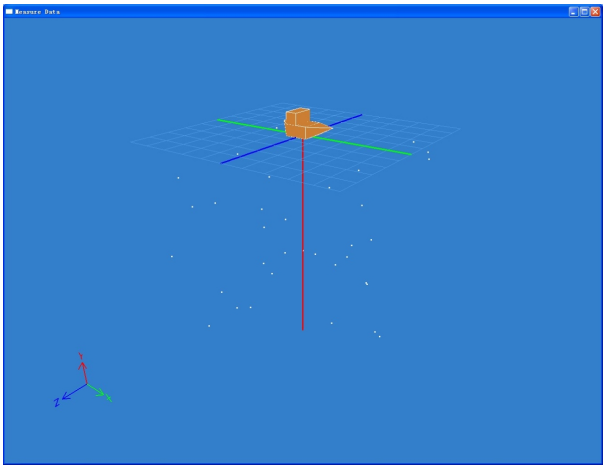

Fig. 7 Sample points of oil content at real-time

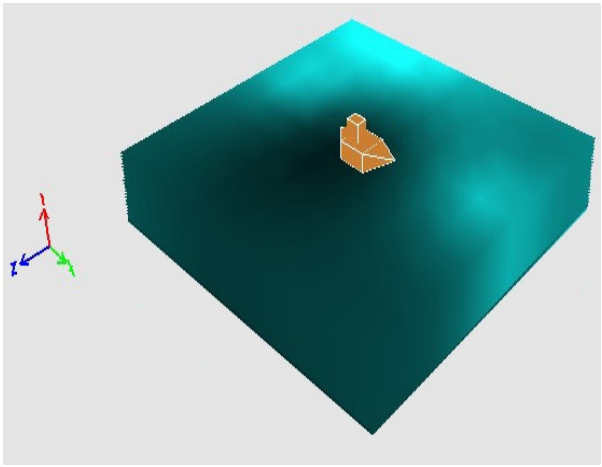

Fig. 8 3D distribution simulation of the leaking oil

## Conclusions

Offshore environment monitoring plays an important role in marine scientific research. First, the advantages and disadvantages of the current system of marine monitoring are analyzed in this paper. Then a new monitoring method combined with wireless sensor technology is proposed.

The whole system is focused on coastal waters pollution monitoring. The system not only completed the networking and data transmission between monitoring nodes and gateway equipment but also finished the communication and data fusion algorithm between gateway equipment and PC. Finally, the three-dimensional oil distribution simulation of the monitoring water area was performed.

The further task of my research is to accomplish the whole experiment in the real offshore environment and analyze the experimental result and finally improve the test method. Then, after the accomplishment of the real-time kinematic analysis of the collected data measured by monitoring system, the track of the oil leakage will be realized through the monitoring nodes, and the location of oil spill will be confirmed with the fastest speed.

## Acknowledgments

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