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Research on marine environment monitoring based on Internet of things

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ABSTRACT

In order to solve the problems of corrosion, breakage, and complicated wiring of communication cables in a marine environment monitoring platform, a marine ecological environment monitoring system based on ZigBee technology and the embedded platform is designed. A small wireless sensor network (WSN) applied to marine stations or buoys is constructed by WSN. The long-term experimental results show that the wireless data transmission of the WSN is stable and reliable, which provides great convenience for marine ecological environment monitoring, and has certain practical significance.

Keywords: Wireless sensor network; Marine environment monitoring; ZigBee; Data transmission

1. Introduction

The ocean covers a wide area, accounting for about two-thirds of the earth's surface. It contains rich biological resources, mineral resources, petroleum energy, and so on. As land resources are on the verge of exhaustion, the development of marine resources has been accelerated since the 1990s. Due to the emphasis on maximizing economic benefits, the marine environment has been seriously damaged. The sustainable development and utilization of marine resources have gradually become the world consensus, so marine environmental monitoring and protection have become one of the key directions of attention of all countries in the world. The vast ocean area makes marine environmental monitoring more difficult and costs more. Scientific and reasonable marine environmental monitoring technology has become one of the research hotspots. With the increasing deterioration of marine environment, the sustainable development of marine resources has gradually become a consensus in the world [1]. The vast ocean area makes it more difficult to monitor the marine environment and the cost is doubled. Scientific and reasonable marine environmental monitoring technology has become one of the research hotspots [2]. Due to the late start of marine environmental monitoring technology, the Internet of things (IOT) technology has not been applied in the field of marine environmental monitoring. Therefore, this paper will study the reasonable application of IOT technology in marine environmental monitoring. With the help of the IOT technology, we can realize the collection of marine environment related monitoring information, efficient data transmission, and monitoring services. The marine environment monitoring system designed in this paper can provide data support and scientific basis for the sustainable development of marine resources and the monitoring and management of marine environment.

2. Literature review

Guo and Chang [2] proposed a motion monitoring system of electromagnetic linear actuator based on IOT and support vector machine (SVM) algorithm, which can effectively monitor the state of electromagnetic linear actuator and valve. Firstly, the wavelet packet decomposition method is used to extract the feature vector of the actuator motion state, and then the artificial bee colony algorithm

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(ABC) is used to optimize the parameters of kernel function and penalty factor of the model. The motion state model and training method of ABC–SVM electromagnetic linear actuator are established [3]. The method is compared with the direct acquisition line control detection method. The results show that the system can accurately and quickly monitor and analyze the working state of electromagnetic L, which is feasible in actuator and engine valve. Liu et al. [3] developed a complete crab breeding management system. Users can remotely view the data of any place with network coverage through computer browser or mobile application program [4]. The system can provide guarantee for the growth and sustainable development of key breeding industry, the design of ocean monitoring wireless sensor network (WSN), it is particularly important to develop a system with good energy autonomy and efficient data processing and communication. Some protocols used in IOT applications have become alternatives to effective communication between nodes and gateways. Durante et al. [7] have 10% lower power consumption and 2.15 times higher traffic than Constrained Application Protocol [5].

3. Design of marine environment monitoring system

The marine environment monitoring system mainly includes three parts: data acquisition subsystem, marine environment monitoring terminal, and information management subsystem (Fig. 1). The data acquisition subsystem realizes the monitoring of marine environment data acquisition with the help of WSN; the monitoring terminal serves as the connection bridge between the data acquisition subsystem and the information management subsystem, and realizes the information forwarding function with the help of wireless network. The main functions of the information management subsystem are to store data efficiently, analyze data, and display the state of marine environment. It is composed of sensor node and sink node [6]. The work of sensor node mainly includes sensor data collection and upload, energy management, and control command operation. The work of sink node is mainly the collection and packet upload of sensor data, as well as the broadcast of issuing instructions. It is composed of data transfer module, wireless network communication module, and image acquisition module [7]. The data transfer module is responsible for the data collection of sensor collection nodes, and the wireless network communication module is responsible for uploading the collected monitoring data to the monitoring center. The top layer of the monitoring system is the monitoring center, which is mainly composed of wireless communication module, industrial computer, and server. The wireless communication module is responsible for receiving the uploaded monitoring data and sending down the control instructions. The industrial computer is mainly used to pre-process the monitoring data, and the server is mainly responsible for the storage, analysis, and release of the marine environment monitoring data.

3.1. Overall architecture of IOT dynamic monitoring system

The dynamic monitoring system of IOT is mainly composed of WSN, data transmission system, and monitoring center. The wireless sensor of the whole system consists of sensor node, sink node, base station, server, and client. The sensor node can collect and monitor the ocean environment parameters, such as water temperature, salinity, turbidity, pH, oxygen content, etc. The collected data is sent to the sink node via wireless communication via ZigBee communication protocol. The communication between sensor node and sink node is usually point-to-point [8]. Sink node collects data from a group of sensor nodes. The collected data is sent to the base station via 3G network. The server stores and processes the data received from the base station. The client connects the server to read the parameter information through the internet connection and carries out detection and query.

3.2. Hardware design of IOT dynamic monitoring system

3.2.1. Hardware design of sensor node

The sensor nodes of marine environmental monitoring system usually include buoy devices to protect the electronic devices of nodes from water. The monitoring nodes of marine sensors are usually composed of four main modules: sensing module, central processing module, wireless transceiver module, and power module. The sensing module usually consists of several probes and sensors, and the sensor has associated amplifier and Analog Analog Digital converter. The central processing module usually includes CPU and memory to process and store the collected data. The wireless transceiver module mainly includes RF transceiver and antenna to transmit the collected data from the sink node. In marine environmental monitoring system, sensor network nodes are usually deployed in the inaccessible sea area, and most of them plan to operate for a long time, so it is not convenient to replace the sensor battery. In addition, the sensor network node is usually provided by the battery. Due to the use of the third generation mobile communication protocol (3G), the power consumption of ocean sensor nodes is high. In order to effectively reduce the maintenance cost of the system, it is obviously necessary to design an energy acquisition system using renewable energy such as solar energy, tidal energy, or wind energy. Finally, the buoy has an anchoring device to prevent its movement.

In this paper, CC2430 chip is used as the control core of the sensor node. The chip includes ZigBee RF front-end, memory, and microcontroller. It has 128 KB RAM, analog-to-digital converter (ADC), timer, AES-128 co-processor, power on reset circuit, watchdog timer, power down detection circuit, 32 kHz crystal oscillator sleep mode timer, and 21 programmable IIO pins, fully meet the needs of the system. The energy supply module uses lead-acid batteries and solar panels. The solar panels are used to charge effectively according to the energy status of the batteries to ensure that the system can run effectively for a long time.

4. Design of data acquisition subsystem

The marine environment data acquisition subsystem is mainly designed based on WSN system. The wireless sensor is designed with CC2430 system chip (SOC). According to its functions, it can be divided into acquisition end sensor and aggregation end sensor. The acquisition end sensor is

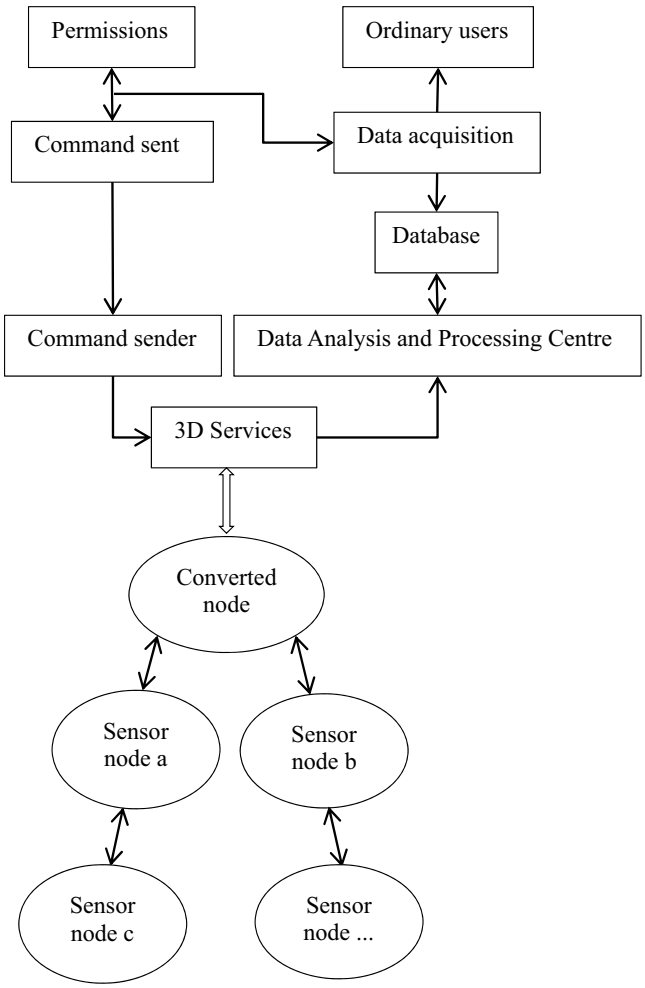

Fig. 1. System frame diagram.

responsible for data acquisition, analog-to-digital conversion, and data communication [9]. Its structure design is shown in Fig. 2, mainly composed of pH monitoring sensor, dissolved oxygen monitoring sensor, salinity monitoring sensor, water temperature monitoring sensor and other data acquisition units, analog-to-digital conversion unit, central control unit (MCU), wireless communication unit and energy supply unit (M26), and MCU and main power supply unit.

According to the practical application requirements of marine environmental monitoring, the designed sensor should be salt fog proof, corrosion-resistant, low energy consumption, and impact resistant, otherwise the service life of the sensor will be greatly reduced. The MCU of SOC adopts a low-power, high reliability, high-speed 8051 controller, and the RF part uses a high-tech 2.4 GHz RF transceiver. As the antenna of marine environmental monitoring, the sensor needs to collect and upload the marine environmental data for a long time. Therefore, the reasonable design of the energy supply unit of the sensor is one of the key design of the whole environmental monitoring system. The structure of the energy supply unit is designed to be composed of power supply module, charging module, and power management module. The power supply module

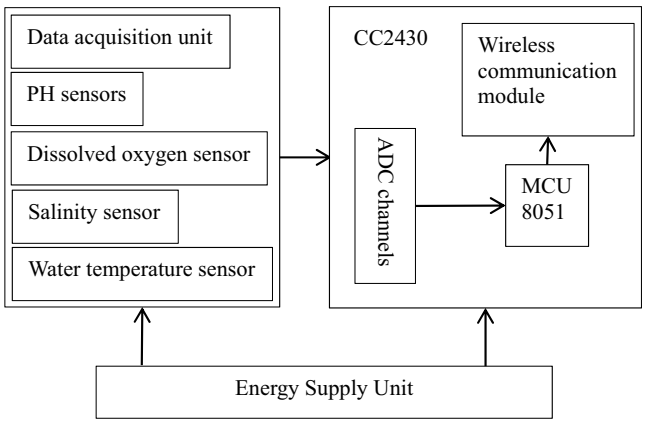

Fig. 2. Structure design of sensor at acquisition end.

uses the battery to provide power for the data acquisition unit and SOC; the charging module uses solar panels to charge the battery. The power management module uses power management chip to charge the battery effectively according to the battery power and solar panel voltage.

5. Design of monitoring terminal

The monitoring terminal of marine environment monitoring system is mainly responsible for data receiving and sending, and its structure mainly includes data acquisition unit, 3G communication unit, ZigBee unit, Bluetooth unit, microwave communication unit, and power management unit, as shown in Fig. 3, ZigBee unit realizes data transmission between monitoring terminal and data acquisition subsystem, 3G communication unit realizes data transmission between monitoring terminal and monitoring center, Bluetooth unit realizes data transmission between acoustic Doppler flowmeter and monitoring terminal. The microwave communication unit realizes the data transmission between the video monitoring equipment and the monitoring center [10]. In addition, the data acquisition module connects the temperature, salt depth measurement instrument, wind direction, and wind speed meter through serial port.

Based on ZigBee and 3G wireless communication mode, the wireless communication of IOT dynamic monitoring system is mainly divided into two parts, one is the data transmission of single node, the other is the data transmission of sink node. Considering that the data transmission distance of single node is short, the real-time requirement is not high and the energy consumption is the most, ZigBee is a low transmission rate and low power LAN protocol based on IEEE802.15.4 standard. It can extend the battery life by low rate secure communication. ZigBee is a multihop communication protocol. If two nodes exceed the transmission range, they only need to add nodes between them, and then the two nodes can communicate, 3G is a cellular mobile communication technology supporting high-speed data transmission, which has the advantages of fast transmission speed and high transmission quality. In addition, 3G technology can be used to connect the wireless communication system with the Internet. The mobile terminal will provide relevant data to the mobile terminal.

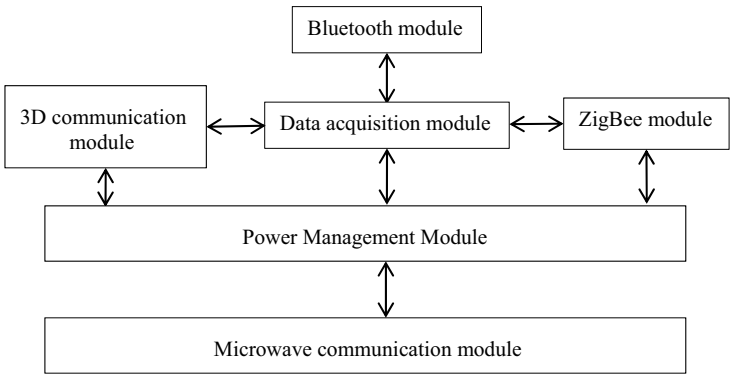

Fig. 3. Structure design of monitoring terminal.

6. Design of information management subsystem

The information management subsystem of marine environmental monitoring is mainly responsible for the control of data acquisition subsystem and monitoring terminal, as well as the storage, analysis, and release of environmental monitoring data:

- The system should be able to monitor the environmental elements of each marine monitoring point in real time, and have the function of storing and quickly querying massive data;
- The system should be able to scientifically analyze the collected marine monitoring data and obtain the marine environmental quality and health index of the monitored area;
- The change trend of marine environmental monitoring system can be predicted according to the change trend of marine environmental quality;
- The system should be able to provide friendly operation and control interface for control users, and display the marine environmental quality and health status to ordinary users intuitively. The monitoring center controls the data acquisition subsystem and monitoring terminal to receive data through the information management system, stores the monitoring data to a large database, extracts the data for marine environmental quality analysis, and passes the analysis results. The marine environmental quality and health status is displayed by web with friendly interface [11]. The software development of the information management system is based on the object-oriented idea. The operation mode adopts Common Channel Signalling architecture. The geographic information database is designed by using the geodatabase data model of geographic information system (GIS). The monitoring information is stored, managed, and analyzed by SQL server 2009 database with Software Development Environment. The map control is directly inserted into the development control by GIS engine. The Microsoft Foundation Class in visual studio 2010 is used to visualize the system interface. With the help of add, the monitoring data in the database are quickly accessed. The analysis model and prediction model are designed by matlab2012b to analyze the monitoring data. The information management system of marine environment monitoring is realized by software mixed programming [12–14].

7. System test

The system can collect water temperature, salinity, turbidity, pH value, oxygen content, and other marine environmental parameters. In this test, pH value is selected as the monitoring object to verify whether the accuracy of the system meets the requirements. The sensor nodes are placed in the standard pH test solution at different positions. Table 1 shows the monitoring results of pH value, and the error is less than 5% by comparing the collected values with the standard values. The system is stable and reliable.

7.1. Communication test

In order to verify the stability and reliability of the ZigBee WSN in the marine ecological monitoring environment, the communication packet loss rate, and data availability of the system were tested for 1 month at the Marine Experimental station near Tuandao, Qingdao. The data results are shown in Figs. 4 and 5. The results show that the data packet loss caused by communication failure in the data collection process of the system is less, and the data

Table 1
pH monitoring results

Number	1	2	3	4	5	6
Latitude	121.95	121.91	121.85	121.81	121.86	121.91
Latitude	30.87	30.87	30.87	30.87	30.92	30.92
pH standard	2.50	4.50	6.50	8.50	10.50	8.50
Collection pH value	2.62	4.71	6.35	8.76	10.73	8.84

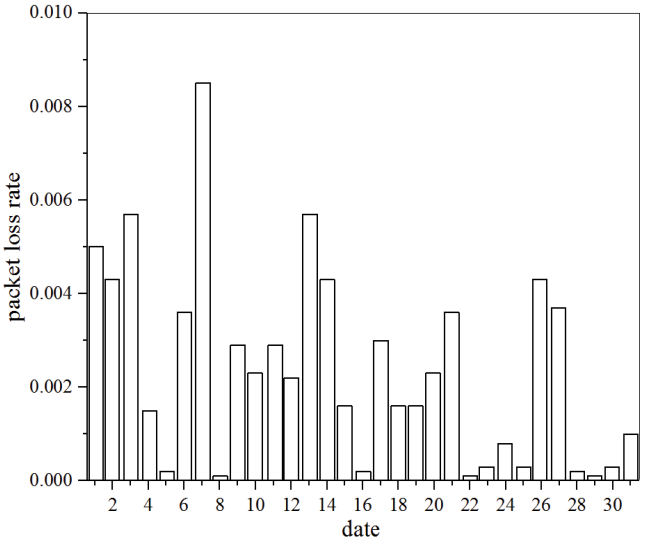

Fig. 4. Statistics of packet loss rate in 31 d.

collected are within the normal range, and the WSN can be applied in marine ecological environment monitoring.

7.2. Power consumption test

In order to verify the power consumption performance of the main controller node and the sensor node, the power consumption of the main controller and the single sensor were measured in the laboratory. The main controller and sensor were connected to two regulated power supplies, respectively, and the voltage was set at 5 V. The main controller was started and the connection between the main controller node and the sensor node was established. The maximum current of main controller node is 0.29 A and that of sensor node is 0.09 A.

8. Conclusions

Aiming at the problems existing in marine environmental monitoring at present, this paper proposes to apply the IOT technology to marine environmental monitoring, designs the marine environment monitoring system based on the IOT, and deeply studies the overall architecture, data acquisition, data transmission, data service, and other issues of the marine environment intelligent monitoring system. The monitoring system is designed to be composed of data acquisition subsystem, monitoring terminal, and information management subsystem. In order to improve the automation of the monitoring system and the real-time performance of monitoring data transmission, a multi-level, and multi-mode data network transmission model is established by using WSN, wireless microwave communication network, wireless mobile communication network, and Internet. Realize seamless connection between various networks.

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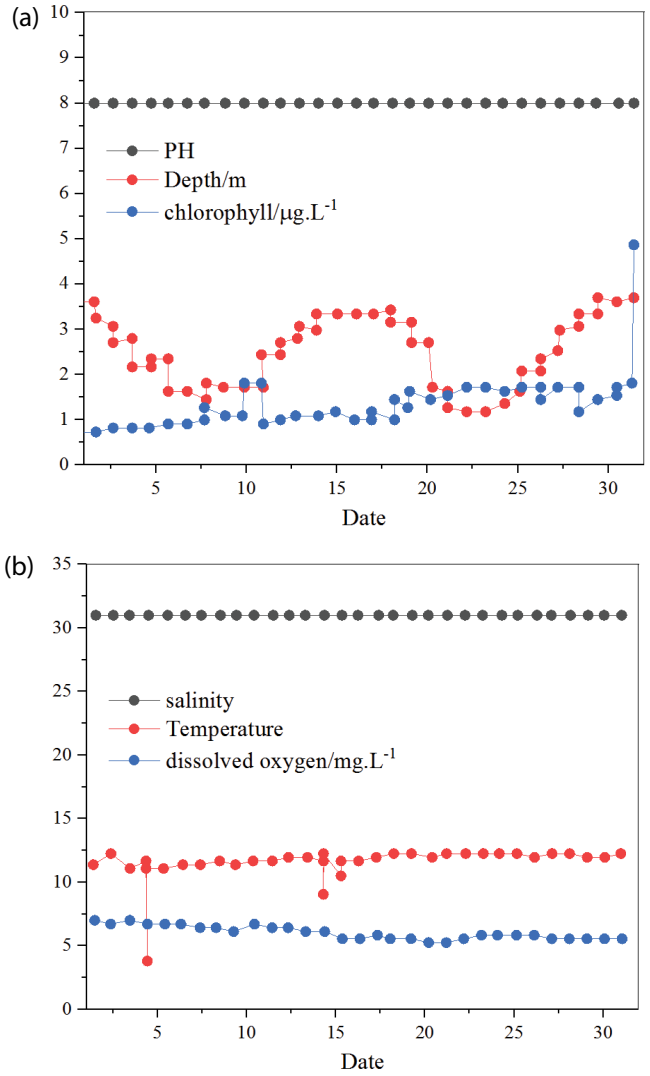

Fig. 5. Real time collection of ecological parameters: (a) depth, pH, and chlorophyll curve and (b) curve of temperature, salinity, and dissolved oxygen.

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