International Journal of u- and e- Service, Science and Technology
Vol.10, No.3 (2017), pp.83-92
http://dx.doi.org/10.14257/ijunesst.2017.10.3.08

Design and Implementation of Wide-area Monitoring System for Oceanic Pasture

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Abstract

For the aquatic production and quality of the oceanic pasture, the quality of water is an important factor. According to the characteristics of aquaculture industry in the South China Sea, a wide-area multi-parameter monitoring system for oceanic pasture was designed. Temperature, pH and turbidity were selected as monitoring parameters in this system. The single-chip microcomputer was used to collect sensors' data underwater, and these data were sent to a low frequency signal transmitting module. We used ZigBee to build a wireless network on the sea to achieve long-distance signal transmission. And LabVIEW was used to display real-time ecological parameters by upper monitor and to provide remote access. Field tests show that this system has the characteristics of good flexibility, low power consumption, low cost and so on. It can be used to monitor the water quality and upgrade the management level of oceanic pasture for unmanned supervision and alarming.

Keywords*: oceanic pasture*; *monitoring*; *single chip computer*; *real-time*; *Zigbee*; *LabVIEW*

1. Introduction

The ocean is an important source of food supply for human beings. With the increase of world population and growth of fishing intensity, shortage of marine fishery resources is more and more serious. In order to alleviate the phenomenon, many maritime nations have built oceanic pasture and attach great importance to the development of marine culture [1].

The construction of oceanic pasture is a way to make full use of natural marine productivity for human beings. By constructing an artificial reef and building a suitable marine creature inhabit place, the artificial breeding and exotic sea creatures are gathered to form artificial fishing grounds. It is a better way to ensure the steadier fishery resources and to protect the marine ecological environment [2]. The water quality has a great influence on the distribution and growth of aquatic organisms, which is the key factor to determine the aquatic production and quality of oceanic pasture. For example, the temperature effect of the feed coefficient size. In an appropriate range, temperature rise will result in the increase of feeding amount of cultured object, as well as the growth rate of fishes. In general, the water pH value between 7.5~8.5 is suitable for survival of aquaculture species. Water with a higher pH may corrode fishes' gills tissue and reduce appetite; on the contrary, it may cause fish hypoxia, exercise capacity reduction and infection diseases easily. Turbid water decrease photosynthesis, reduces the content of dissolved oxygen, and causes fish suffocation death [3]. Traditionally, people mainly rely on experience as a guide, which is hard to do fine breeding. With the development of sensor technologies, people is able to rely on information technology to gather the

ISSN: 2005-4246

breeding environment data and acquire scientific guidance for the aquaculture production [4].

In view of the actual characteristics of the existing monitoring equipment in foreign countries, such as long measurement period, high cost and small monitoring area, we proposed a wide-area wireless water quality monitoring system to realize real-time monitoring of water quality in aquaculture waters, to promote scientific farming and to improve the yield and quality of marine products.

The basic system structure is introduced in Section 2. The implementation of this system is narrated in Section 3. How to carry on the field test is given in Section 4. Finally, we concluded this paper.

2. System Design Scheme

In this paper, the water quality monitoring system is mainly composed by three parts: data acquisition, wireless transmission and PC (Personal Computer) monitoring center. We choose the temperature, pH and turbidity as monitoring parameters. Its structure is shown in Figure 1.

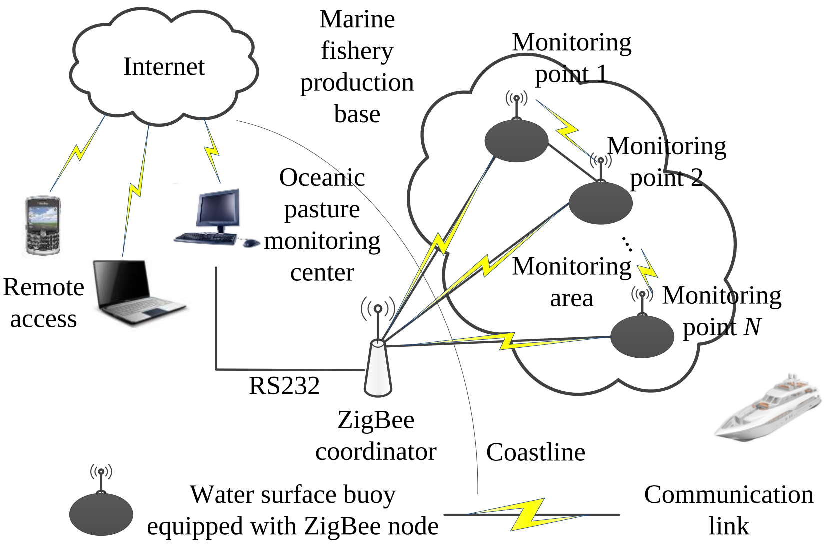

Figure 1. Diagram of the System Structure

In Figure 1, the data acquisition equipment, powered by battery, suspends in water, and use single-chip microcomputer to collect kinds of sensor data [5], and it sends the digital signals to a float on the water surface after analyzing and processing. Water surface buoy using photovoltaic solar power, and in the entire system it plays the role of data relay. It receives the digital data from the collection device and sends them to the host computer. Because the light is easily reflected by the water, the surface buoy and collection equipment are vulnerable to sea wind and ocean currents, and light hole is difficult to align, optical communication should not be used in water [6]. High frequency electromagnetic wave attenuates in water heavily, so in order to reduce attenuation of the signal and increase the transmission distance, we use 170 MHz communication module to achieve the water communication. ZigBee is a two-way wireless communication technology for short distance with low complexity [7-8], which is widely used in the field of engineering control. ZigBee network was composed by sea surface buoys dynamically, and data were sent to the coordinator by single hop or multi hops. The data were transferred to the host computer through the serial port. We use LabVIEW to design a fully functional monitoring interface, which was used to monitor the ecological parameters of the water in real time [9-10]. At the same time, the built-in Web server will be released to the cloud on the front panel for remote access.

We built a data acquisition system with the abilities of wireless transmission, real-time monitoring, automatic alarm and historical data query. The cost of this intelligent monitoring system is low. It is wireless, easy maintenance and good flexibility. It can promote traditional oceanic ranch to transition wisdom, scientific guidance of aquaculture production [11].

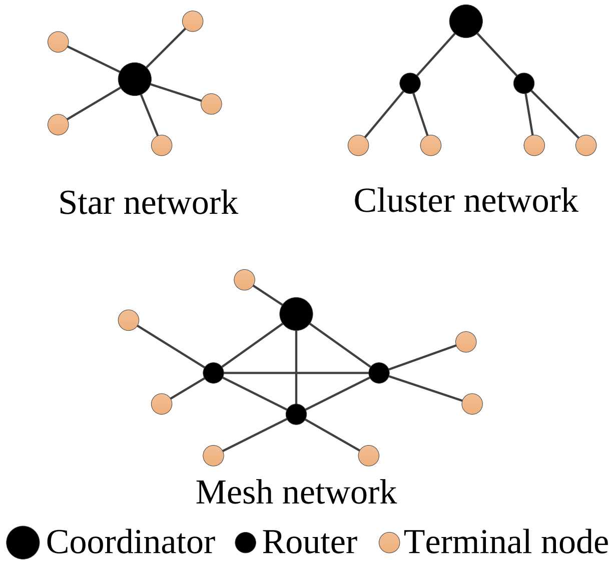

Figure 2. Topology of the ZigBee Networks

The wireless network system at sea was composed by the ZigBee coordinator, routing nodes and terminal nodes. According to the actual needs, it can form the three different types of network topology: star, cluster and mesh structure [12-16], as shown in Figure 2. Star network consists of a coordinator and a number of terminal nodes, in which the coordinator is responsible for the start and maintenance of the entire network, and the network control is relatively simple and usually used for small range of communication. Cluster network includes a coordinator, a number of routers and terminal nodes. The coordinator is not only used to start the network but also to select the key network parameters. The network coverage is larger and has longer time delay. The mesh network is composed of a plurality of full-functional devices to form a backbone network, which allows direct communication between all the routing nodes. It can reduce the delay and increase the reliability of the network propagation.

3. System Implementation

3.1. Realization of Acquisition Equipment

3.1.1. Temperature Sensor

DS18B20 digital temperature sensor has the advantages of small volume, low power consumption, simple circuit. It only needs to follow the given timing operation level and it can accurately measure the temperature. It is suitable for all kinds of small space of digital temperature measurement and control field [17]. The output is digital signal, and does not need to adjust the circuit. The voltage range is 3.0V~5.5V, and the measurement range is -55 C ~+125 C. With the microprocessor, only one line is needed to realize two-way communication, which has strong anti-interference ability. Its pin arrangement is shown in Figure 3, GND is the power supply, DQ represent the input/output pin, and VDD is used for the external power input. If the parasitic power supply is used, VDD is grounding, and DQ is power supply.

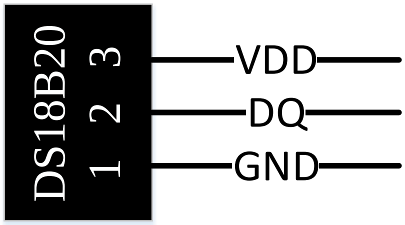

Figure 3. Pin Schematic of DS18B20

3.1.2. pH Value Sensor

pH value is an important indicator to measure the quality of aquaculture water. The current mainstream methods of pH detection include colorimetric method used commonly by laboratory and potential method used in this system. The potential detection is made of measuring electrode and reference electrode. The glass electrode is used as the measuring electrode, the Ag/AgCI electrode is a reference electrode, and the battery is composed of them, which follows the Nernst law [18], and the pH value is measured according to the potential change. The potential of the measuring electrode, the potential of the reference electrode and the pH value follow the formula (1)

$$E_X = E_\theta - 2.303RTpH / F \tag{1}$$

in which, the E_X is electrode potential, the E_θ is standard electrode potential, R represents the gas constant 8.31441J/ (K×mol), T represents the absolute temperature of the mol, and F is the Faraday constant 96.487KJ/(V×mol).The pH value sensor is placed in the solution to be measured, and there is a small electric potential between the two electrodes, the output signal range is small. The amplifier circuit is needed to be designed to improve the input impedance and to reduce the measurement noise.

3.1.3. Turbidity Sensor

The muddy water in aquaculture area is mainly caused by the uneaten bait, biological manure and sediment at the bottom of the sea. The higher value of the turbidity is accompanied by the lower the passing rate of light, the weaker the light sensitive resistor receives the light [19]. Using this principle, the turbidity sensor can effectively monitor the water turbidity in the oceanic pasture. The light intensity is converted to current signal, and the turbidity current signal is converted to 0V~5V voltage signal by resistance, and the A/D (Analogy to Digital) converter is used for sampling and processing, and the current turbidity information can be read by a single chip microcomputer.

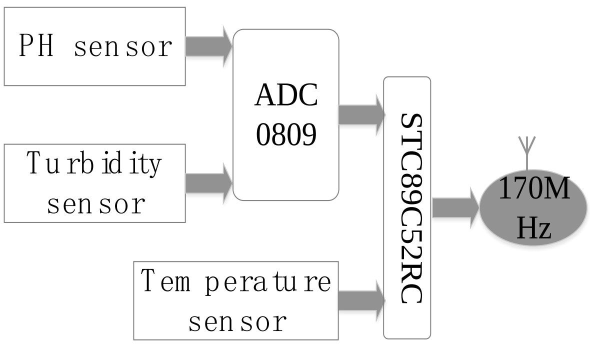

Figure 4. Structure Diagram of Acquisition Equipment

3.1.4. Software Design of Acquisition Equipment

The 0V~5V DC voltage from the underwater sensor was collected by the part of data acquisition. We use ADC0809 converter to get the digital signal, and complete the data collection through the single chip. The final data is sent out by a low frequency transmission module. Figure 4 is the equipment structure diagram, and the software flow chart is shown in Figure 5.

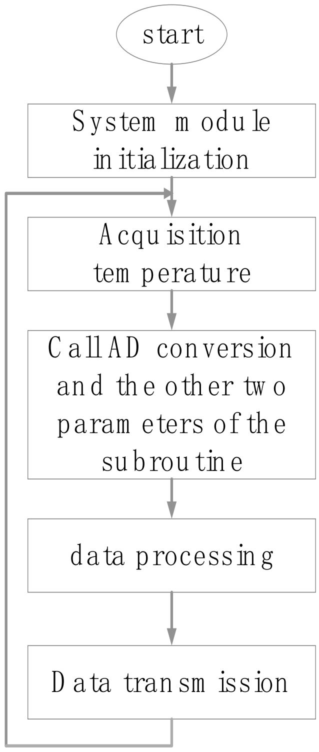

Figure 5. Flow Chart of the Acquisition Equipment

3.2. Realization of Water Surface Buoy

The system data transmission involves two parts: the sea surface and the water. It is important to select the appropriate frequency band to ensure reliable data transmission. In order to reduce the complexity of equipment and the degree of electromagnetic wave attenuation, a 170MHz wireless communication module is used to transfer the data under the water. Above the sea surface, we use ZigBee node to form a wireless transmission network with suitable distance, reliable performance and large capacity. The water surface buoy plays the role of data relay in the whole system. The structure of the system is shown in Figure 6.

Water surface buoy is equipped with a ZigBee based CC2530 module and a 170MHz wireless serial port module. Its internal circuit is connected as shown in Figure 7. The baseplate of the ZigBee module has the ability of transforming USB (Universal Serial Bus) to serial port and it provides 3.3V power to 170MHz wireless serial port module. TXD, RXD, represent the serial port and the output pin respectively. The two modules are used for transmitting data by cross linked. The M0 and M1 pins of the wireless serial port module determine the working mode of the module, in order to ensure the quality of the underwater data transmission. They are connected with ground wire to work as transparent transmission mode.

3.3. Realization of Monitoring Interface of Upper Computer

In engineering applications, people need not only accurate data acquisition equipment, but also a simple and easy interface on screen. LabVIEW is a graphical programming language that uses icons instead of text. It not only has the traditional programming debugging tools, but also can be used to display data flow animation. It is easily to be debugged and widely used in the field of engineering and in laboratory [20].

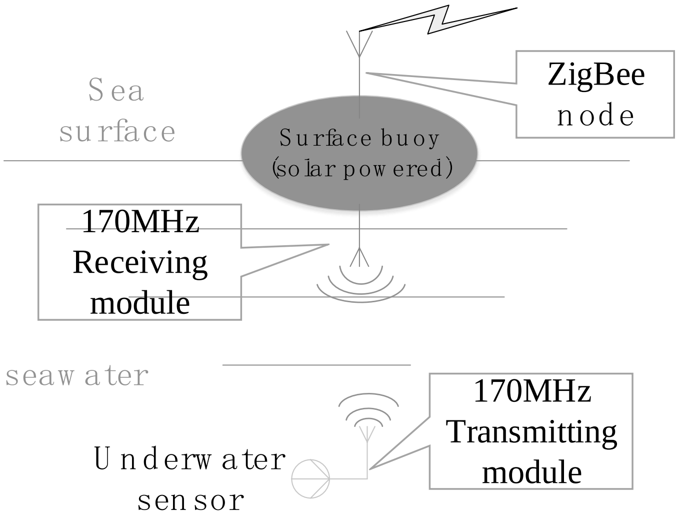

Figure 6. Structure of the Surface Buoy

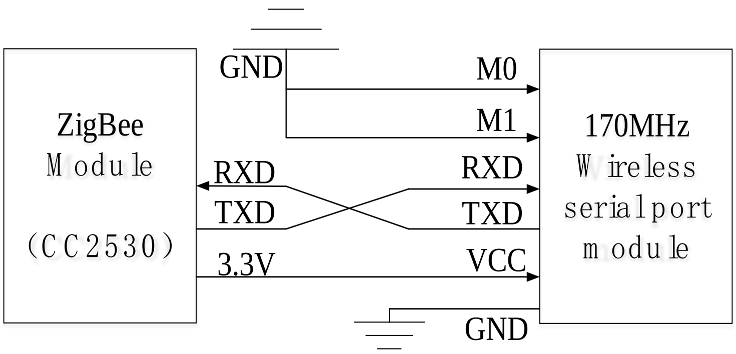

Figure 7. Internal Connection Circuit

The serial communication was used between the ZigBee network coordinator and host computer [21]. In the oceanic pasture, the monitoring center PC interface can realize data display, and these monitoring data will be saved in a database. It also can alert automatically according to a preset value and support remote access function. Software flow is shown in Figure 8. Figure 9 is a PC monitoring interface.

4. System Test

Dongpo Lake of Hainan University was selected as the test site. ZigBee networking, communication distance and data transmission are the indicators of testing. Test conditions are as follows: 2 PC (one for the host computer), a ZigBee coordinator, a water surface buoy and data collection equipment. The test results show that the system can realize the normal network of the water surface buoy and coordinator. The monitoring interface of the host computer displays the monitoring data normally, and supports the remote access. The communication distance between the coordinator and the water surface buoy is about 50 meters, and the signal receiving instability is increased with the increase of the distance. Under this condition, the ZigBee network topology is a star structure. The communication distance depends on the coverage of a single ZigBee module, which can be realized for monitoring of oceanic pasture in a large water area by increasing the number of ZigBee routing nodes and changing the network topology. In the normal communication range, the system can complete the real-time monitoring of water quality parameters, in line with the starting point and purpose of the system design.

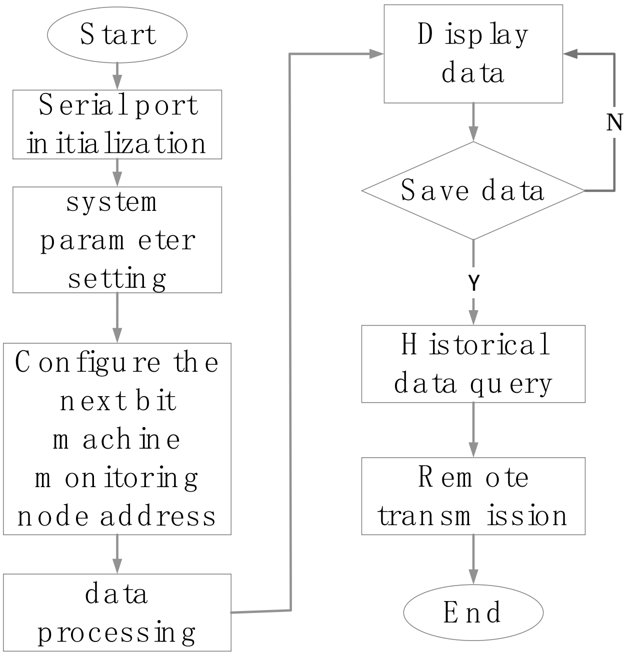

Figure 8. Software Flow Chart of Upper Computer

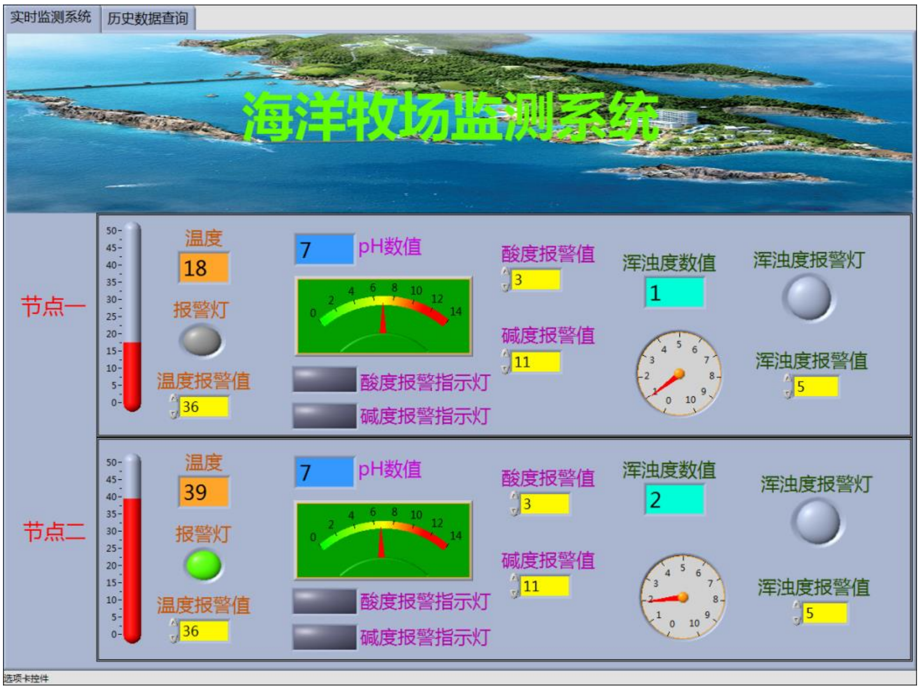

Figure 9. PC Monitoring Interface

5. Conclusions

With the implementation of the strategy of ocean development, the construction of oceanic pasture and the mode of production of resource management are the keys to the development of China's national marine economy. According to the characteristics of the aquaculture industry in the South China Sea, the embedded technology, ZigBee technology and virtual instrument technology are combined to design a set of multi parameter intelligent monitoring system for oceanic pasture. The important part of the system hardware design and the main flow of the software are introduced in detail. The system has the advantages of low power consumption, low cost, good flexibility, no wiring, easy to be maintenance and so on. It can conduct the real-time monitoring to the water environment, provide the basis to judge for the production managers, change the extensive mode of fishery production, guide the aquaculture production scientifically and improve product yield and quality. It has broad application prospects in the development of oceanic pasture.

In the follow-up study, optimization of the collection node distribution and database storage capabilities is needed. One should ensure low energy consumption and low delay, and increase the scope of monitoring in the next step. Future study should be carried on to analysis the aquaculture data by big data technology, to promote the sustainable development of oceanic pasture, and to bring better benefits for the operators and the ecological environment in the sea.

Acknowledgments

The work is supported by Natural Science Foundation of China (61661018), Natural Science Foundation of Hainan Province (20166210), Key Project on Science Research of Higher School from Hainan Department of Education (Hnky2016ZD-5), High Tech. of Key Research and Development Project of Hainan Province (ZDYF2016010), Scientific Research Foundation of Hainan University (kyqd1536). Hui Li is the corresponding author.

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