Construction and basic performance tests of underwater monitoring network

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Abstract:

With the rapid development of economy, environmental pollution has become one of the major problems in coastal areas and cities along the river. Real-time observation of the water quality along the river has been considered as an efficient way to control wastewater emission and manage environment of water quality. Traditional ways to observe ocean environment, including satellite telemetry, radar, investigation ship, ocean observation station and etc, are not applicable for water quality observation along river because of their high cost, Poor real-time, low accuracy and so on. Based on Wireless Sensor Networks, the study discussed in this paper proposes a new observation system using under-water multisensory information. After processing multisensory data of each sensor the system transmits it to hub node through wireless sensor networks, and then transmits it to land data center through GPRS wireless network. In order to check the basic performance of this system, the authors have completed the node positioning experiment based on GPS module and the communication experiment based on ZigBee. This paper reports the hardware design and the experimental results.

Keywords: Wireless Sensor Networks(WSN), Underwater, ZigBee, Communication

1. Introduction

With the rapid development of economy in these years, environmental pollution has become a major fact of invading people's life and influencing global climate change. Especially, wastewater emission and leakage from the cities along the river and ocean lead to pollution of water quality, and it could bring global environmental deterioration impact. Nowadays, the major ways to observe ocean environment, mainly depends on satellite telemetry, radar, investigation ship, stationery ocean observation station and etc, which are not applicable for water quality observation along river because of their high cost, poor real timeness, low accuracy and so on. The study introduces WSN technology of land field to observation system of water quality. By setting continuous underwater sensor nodes, the water quality environment in a large area can be real-time observed. By setting up wireless communication network among multinodes networks, physical information, including water temperature, PH value, oil leakage, noise and etc, can be converted to electrical signal, and then transmitted to surface unit. In this system, each unit is not only a node, but also a data transmission relay of other nodes. Node's information can be exchanged and transmitted to land data management center through wireless communication in order to assure that observed data is real-time, actual, universal and continuous.

However, the biggest technology difficulty of gathering and sending underwater information is to overcome the influence of antenna swaying on communication performance and organize a network in a hundred-meter range area between several hundred meters. In addition, the properties of network organization mode, communication protocol, optimum topology structure and etc, are not clear yet when the height between antenna and water surface is low. Therefore, based on theoretical calculation and analysis on extreme conditions mentioned above, the paper proposes a design scheme of system network organization, and reports the test of basic performances of the system by installing it in the water area of Shanghai, China.

2. wireless sensor network design

2.1 system summary

As shown in figure 1, the system is composed of some surface nodes, hub nodes, and land data terminal. The carrier of each sensor node is buoy. The buoy carries surface wireless communication unit, data processing unit and many underwater sensors. The nodes communicate with each other by wireless communication, and they are composed of wireless sensor network with node topology structure. The network converges information at hub node. The hub node is located along river shore. First, it transmits information by GPRS network of cell phone， and then transmits the information to land data terminal through remote wireless communication.

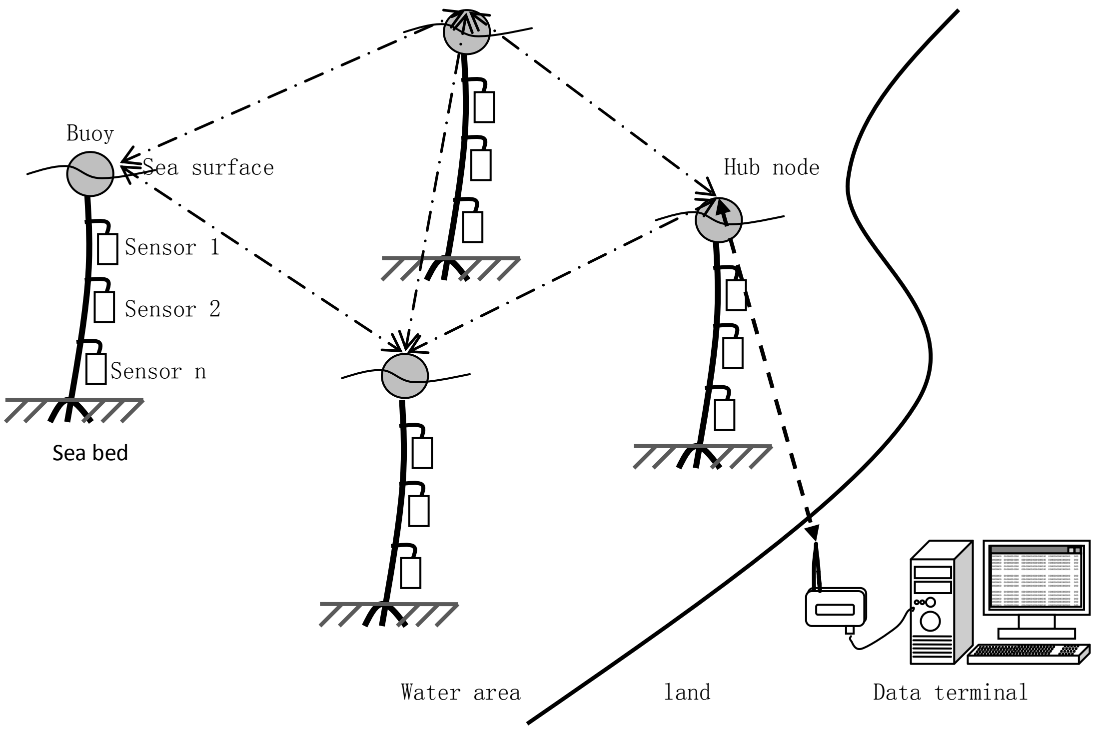


Fig. 1 System Composition

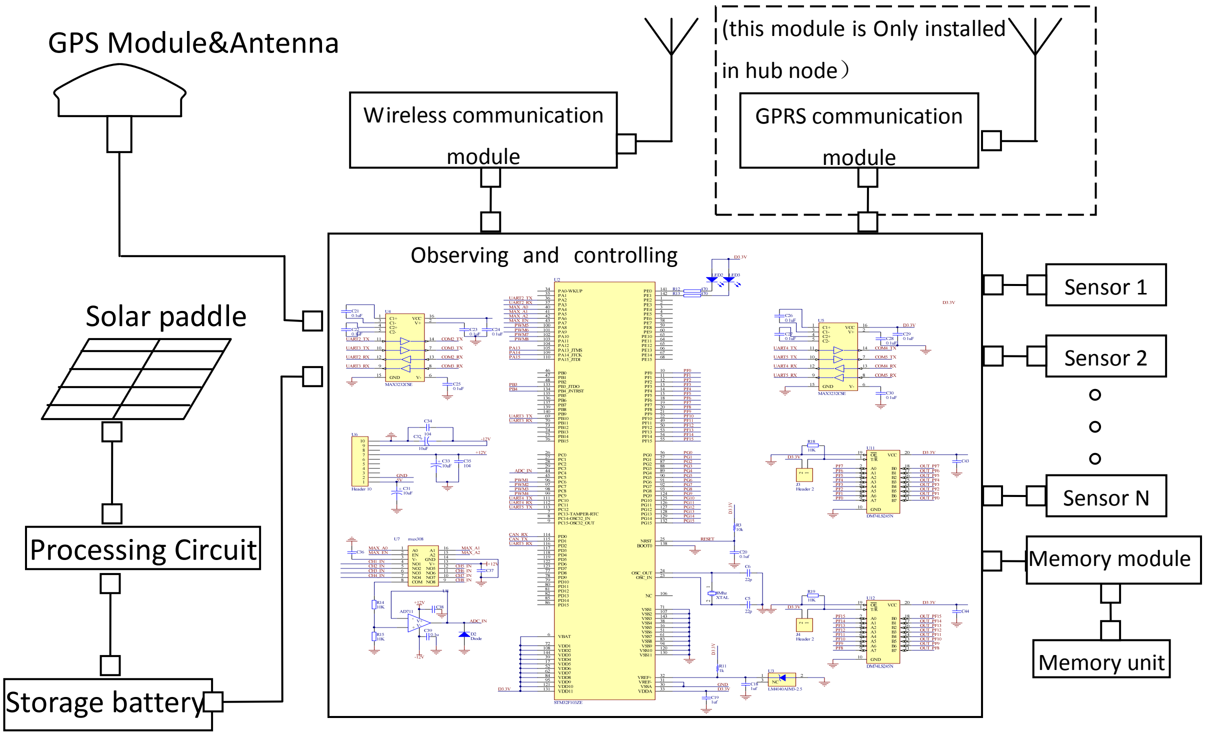


Fig. 2 Schematic Diagram of Surface node

2.2 sensor node design

As shown in figure 2, in our design, each node in the sensor network has an observing and controlling unit, memory unit, battery unit cell of solar energy, GPS positioning unit, wireless communication unit and some sensor interfaces. Observing and controlling unit is capable of data collecting, digital control, data transmission and so on. Hub node includes remote wireless communication unit which communicates with land data terminal. Micro embedded GPS module with Patch Antenna is used in Node positioning in the study; Zigbee is used in wireless communication among nodes because it is highly reliable, free and network organizable; Because GPRS mode is low cost and has a wide coverage of network, it is used in a long-distance wireless communication between nodes and land data terminal. Power supply of nodes takes form of combination of solar energy and storage battery; in order to assure the integrity of collected data, each node is self containing. Which in other words, the collected data is saved before it is retransmitted. In order to collect data from different underwater sensors, observing and controlling unit contains modulation function of analog signals and serial port communication function; the collected data need to be preliminarily processed to reduce redundancy node.

2.3 Deign of data transmission rule

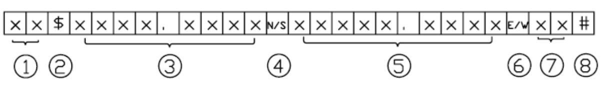
ZigBee module itself doesn't support error correction and automatic repetition mechanism, so in order to increase success rate of data transmission, the system need the following functions:

a) short frame transmission rule

b) automatic error correction and repetition function

For example, transmitting end transmits data to designated node, and then receiving end responds after receiving data; if latency is overtime, transmitting end will retransmit the data. If it doesn't receive any response from receiving end after 3-time retransmitting, the system will consider it a data-link failure between the transmitting end and receiving end and abort current data transmission; at the same time, the system saves all data for the subsequent data analysis and processing.

Data of each node are composed of node position information and sensor information. Each node is equipped with GPS positioning module, and can position each node itself. Positioning information is transmitted in a format as shown in figure 3(a), and the transmission time interval of this format is longer than the format shown in figure 3(b). If position of the node changes a lot, the position information will be transmitted to control center where staff can timely process it. Comparatively, data information of each sensor is transmitted in a data format as shown in format 3(b.)



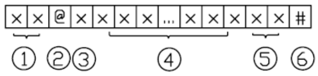
①Address; ②Flag of GPS data; ③Latitude;

④N:North latitude, S:South Latitude; ⑤Longitude;

⑥E: East Longitude, W: West Longitude;

⑦CRC16 Verification; ⑧End of Frame.

(a) Format of Position Information



①Address; ②Sensor Data Flag; ③Frame Info.;

④Sensor data; ⑤CRC16 Verification; ⑥End of Frame.

(b) Data Information of Sensor Information

Fig.3 Data Format

3. Performance Experiment

3.1 Objective

Node positioning, efficient working distance and communication between nodes are key technologies in this system. The following questions remain to be validated in this experiment:

a) Communication performance of wireless sensor net work in a open water area.

b) Positioning accuracy of the node drifting within a small area

3.2 Contents

a) The neighboring water area in shanghai is taken to be the subject in this experiment. An experiment point is respectively chosen from Huangpu River, East China Sea and Qiantang River to test positioning accuracy of sensor node.

b) Take offshore area of East China Sea for an example, actual efficient communication distance of ZigBee is measured and compared with theoretical distance value. Also, the effect of antenna's oscillation angle change on communication distance is tested.

c) The relation between transmission bit error rate and transmission distance of ZigBee mode is tested. Short-frame and long-frame transmission error rate are also reported.

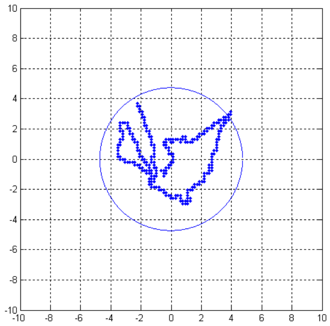
3.3 Results

a) Positioning Accuracy of Node

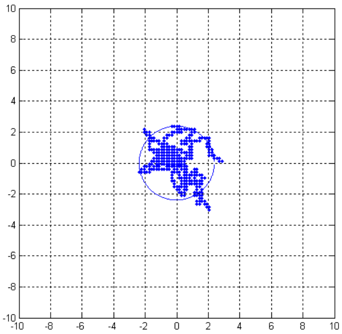
The theoretical positioning accuracy of GPS module used in this experiment is 3[m], and actual positioning accuracy of the 3 tested point are respectively 9.47[m], 4.77[m], and 3.86[m]. The positioning accuracy of horizontal direction is shown as figure 4. The node positioning error is within 10[m], which is good enough to meet the need of the system.

b) Error Rate

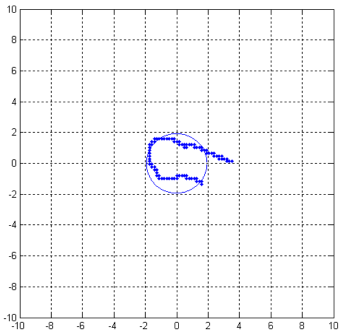
Table 1 shows comparison of error rate between long-frame and short-frame communication when 10K -byte date is transmitted. The data length of long frame is more than 30 bytes, while the data length of short frame is no more than 10 bytes. Apparently, error rate of short frame communication is much lower than that of long frame's communication. Efficient communication distance is about 600[m] when error rate is less than 4‰.



(a) Qiantang River (2DRM=9.47[m])



(b) Huangpu River (2DRM=4.77[m])



(c) East China SEA (2DRM=3.86[m])

Fig.4 Positioning accuracy of sensor node

Table 1 Comparison on bit error rate between long frame and short frame communication

Distance	Long frame	Short frame
300	0	0
400	2.4e-4	1.8e-4
500	1.3e-3	8.4e-4
600	2.4e-2	3.6e-3
700	6.3e-2	4.3e-3
800	2.4e-1	6.2e-3

c) Efficient Communication Distance

Theoretically, P_R, the free-space power received by receiving unit is determined by equation(1)[1,2]

$$P_R(d) = \frac{P_T G_T G_R \lambda^2}{(4\pi)^2 d^2} \quad ....(1)$$

Where, P_T [dB] is transmitting power, P_R [dB] is receiving power, G_T [dB] and G_R [dB]are respectively antenna gain of transmitting and receiving, d [m] is the transmission distance, λ [m] is wavelength. Then transmission loss P_L [dB] can be obtained by the following equation[2].

$$P_L(d) = 20\log_{10}(f_{MHz}) + 20\log_{10}(d) - 28 \quad ....(2)$$

In this experiment, P_T =10[dBm], sensitivity of receiver is -94[dBm], P_L =104[dB]. Then theoretical value of transmission distance is 1658[m]. Not only an certain margin is allowed, coefficient of transmission attenuation is bigger due to big air humidity around sea. Besides, energy loss is caused by imperfect transmitting circuit and receiving circuit. As revealed by actual measurement, when bit error rate is less than 4‰, efficient communication distance is about 600[m] which is only 36% of theoretical transmission distance. However, we can increase efficient communication distance by boosting antenna gain or transmitting power.

In additional, because of the antenna directivity of ZigBee module, antenna mounting height have to be increased to raise communication efficiency in a rough wave environment

4. Summary

The key technologies, which are used for data collecting, data processing, node positioning, communication among nodes and etc, are proposed in this study and have been validated through experiments. And we are trying to go on with a long-term observation test about water quality. In additional, the technologies mentioned are expected to be used in intelligent observation with large information transmission such as underwater acoustics, video and etc.

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References

1. Rappaport, Theodore S, Wireless Communications Principles and Practice, Prentice Hall, 2001, P70-74.

2. Shreharsha Rao, Estimating the ZigBee transmission-range ISM band, EDN, May 2007, P67-72