Research Article
Food Pollution Remote Intelligent Monitoring System Based on ZigBee Technology

Dong Xu, Peifeng Wang and Biwen Shen
Zhejiang University of Food Resources and Electric Power, Hangzhou, 310018, China

Abstract: This study using ZigBee wireless communication technology and Internet network food quality testing data sent to the remote food quality monitoring center aggregation processing to built smart degree of food pollution monitoring system. In this paper, food detection sensor module, ZigBee wireless communication module, single-chip peripheral circuits, analog-digital conversion circuits and other hardware design; system software design the contents of the remote parameter settings, drivers and so on. Through the system test results show that the system for the degree of food pollution detection accuracy rate can reach more than 98% success rate of 100% communication, food quality testing terminal stable, reliable, real-time monitoring of the communication rate to meet the requirements for a variety of aquatic environment the extent of food pollution monitoring needs.

Keywords: Food pollution, remote intelligent monitoring, Zigbee wireless communication

INTRODUCTION

It is difficult to conduct resal-time monitoring on foods such as river, lake and fishpond, for they cover large areas. Pollution in these foods is related to the safety when people use food as well as to the sustainable development of food sources (Guo *et al.*, 2008). In April 2014, an accident that the food supply was polluted by benzene happened in the city of Lanzhou. A scientific, intelligent management is favor of saving food meanwhile guaranteeing the safety of food resource in cities, which can be done by collecting data of food quality from these foods and transmitting the data, including food temperature, DO (dissolved oxygen), pH, content of ammonia and nitrogen and turbidity, etc., to a remote monitoring center via wireless network and/or broadband internet. ZigBee is a new wireless two-way communication technology of low cost, low power consumption and low rate in a short distance. In the low-power standby mode, only two AA batteries can support one node to work for 6~24 months or even longer. This is an advantage of ZigBee over Bluetooth, WiFi and other communication technologies. Therefore, the technology of ZigBee can ensure both the cost and the stability of designing the hardware circuit at the terminal of food quality detection and constructing the remote monitoring network.

MATERIALS AND METHODS

System structure and principle: Figure 1 shows the complete wireless network that makes use of the Internet to transmit food quality data at the sink nodes of the ZigBee-based wireless sensors. The whole detection network is a star or mesh topology. The ZigBee module will be in low-power mode if no data need to be transmitted, if not, it will be in its work mode. This is efficient in reducing energy consumption at ZigBee communication nodes as well as in lowering the probability of delay when data are transmitted from the communication nodes to the sink nodes. Meanwhile, the coverage of the network for monitoring food quality can be greatly increased by using the Internet to transmit data from sink nodes to the remote data service center. Wireless sensor network for data transmission can be built by advantage of the technology of ZibBee. The technology can also be used to deploy sink junctions in different areas, namely, the food quality monitoring stations. Such sink junction is exactly the central node of ZigBee. Remote communication can be realized as the remote food monitoring center is connected to terminal units for food detection via public cable networks, such the Internet. Wireless and cable networks are combined to acquire data of food quality in monitored areas, which can achieve intelligent, remote and efficient control and management on food quality.

Design of system hardware: Terminals for detecting food quality and hardware of data communication system are designed as shown in Fig. 2. The structure consists of sensors used for monitoring food quality, the ZigBee wireless communication module CC2 480, circuit for processing the collected data, communication nodes, MCU and power supply, etc. food quality

Corresponding Author: Dong Xu, Zhejiang University of Food Resources and Electric Power, Hangzhou, 310018, China
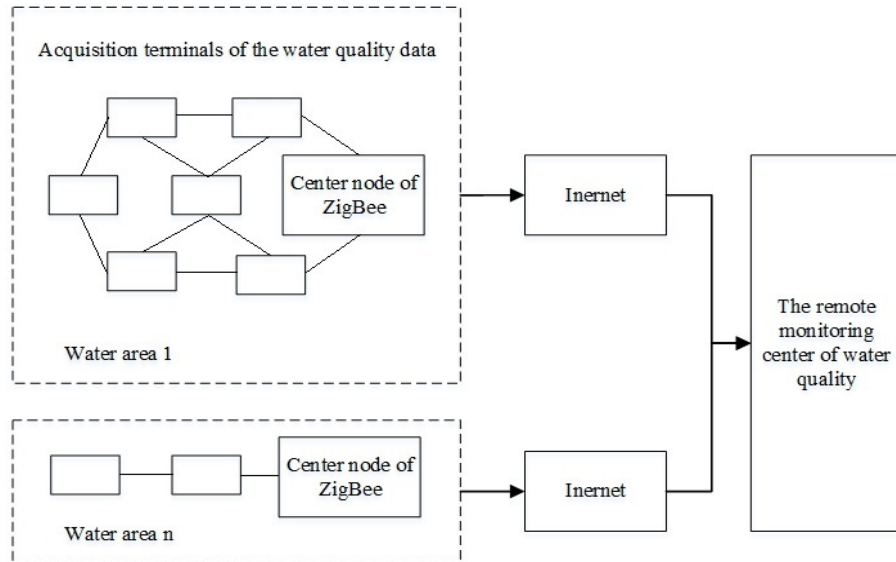
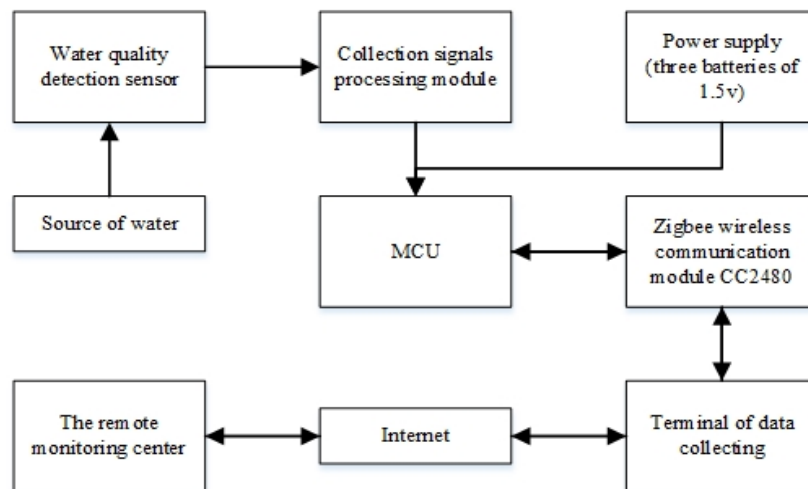Fig. 1: Structure of the network for remotely monitoring pollution of foods

Fig. 2: Composition of terminals for detecting food quality and hardware of data communication system

detection terminals are deployed in the foods that need to be monitored, to collect and process the data of food quality and implement the wireless communication. The collected data are transmitted to nodes via the ZigBee wireless communication module then to the remote monitoring center via the Internet. Technicians can use the Internet to control and manage the terminals for detecting food quality and mutual communication can thus be achieved. The 8-bit single chip P89V51RD2FN is used in the terminal circuit, which can perform the sensor data processing and communication. The transmitter of the protocol of IEEE802.15.4/Zigbee is integrated by the ZigBee wireless communication module and its communication band is 2.4-2.4853 GHz, with the data transmission rate of 250 kbps. It is of good anti-interference and confidentiality during data transmission.

Sensor module for food quality detection: JAP60M/U52-10M, a multi-parameter sensor for food quality detection, is used, of which the measurement ranges are: 0-14PH, 0-100 ms/cm, 0-800NTU, 0-19.9 mg/ℓ, 0-50°C and 0-4% and the resolution standard is 0.1PH (ms/cm)(ms/cm). This sensor can measure six parameters at the same time, namely, pH, temperature, DO, electrolytic conductivity, turbidity and salinity. JAP60M/U52-10M can correct data automatically and can be put directly in food for measurement. In addition, it has a function to protect the measured data that makes the temporary storage more safe. Parameters that measured by the sensor of JAP60M/U52-10M are transmitted to the ZigBee wireless communication module through serial ports.

ZigBee wireless communication modula: CC2048, produced by TI, is taken as the core of the ZigBee
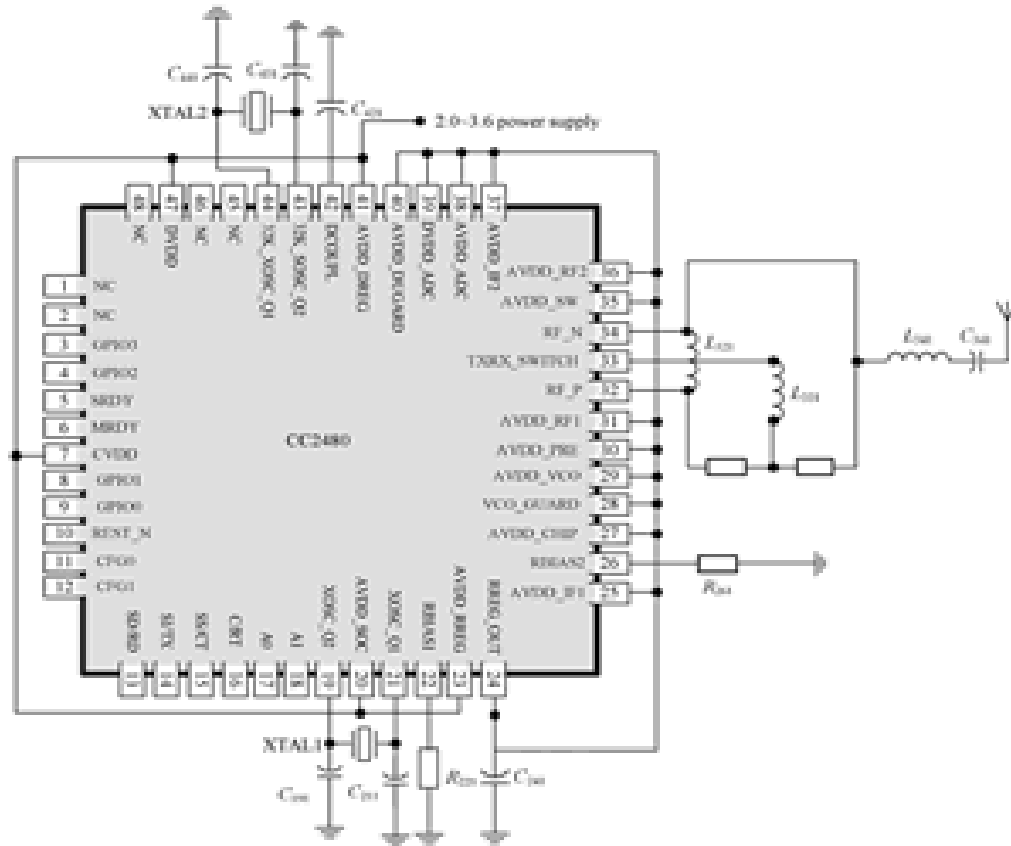
Fig. 3: The CC2480-based ZigBee wireless communication circuit

wireless communication module in this system. CC2048 is a Z-Accel ZigBee processing chip of low cost and power consumption and is used for short distances. It can apply ZigBee's functions into the circuit of the system. It can also be flexibly used with any other MCUs for further applications (Ji *et al.*, 2009).

Figure 3 shows a part of the circuit of the CC2480-based ZigBee wireless communication module. AVDD SOC and AVDD RREG are pins used for analog circuit with the voltage of 2.0-3.6V and connected to the 100nF and 220nF filter capacitor, respectively. DVDD is an input pin used as the digital power to supply power for the I/O port and is connected the 100nF filter capacitor. The pin of DCOUPL supplies a 1.8V decoupling voltage that cannot be used for external circuit and shall be connected to a 220nF decoupling capacitor. The pin X1, connected to 32MHz, is especially used as the crystal oscillator of the 2.4GHz radio-frequency circuit and its bypass capacitor is 22PF. The pins RBIASl and RBIAS2 are connected to biasing resistor, used for providing a proper current for the 32M crystal oscillator.

MCU's peripheral circuit and ports: For the main circuit, P89V51RD2FN, produced by NXP, is taken as the MCU, of which the crystal oscillator is 11.0592MHz; ADC0809 is used as A/D conversion chip, which has an 8-bit resolution; the outputted value corresponding to 0-5V ranges from 0 to 225; and the clock signal is provided by the MCU's ALE signal (Siping, 2006). The electric signals detected by sensors are transmitted to IN0, the analog input terminal of ADC0809, after being amplified and filtered. The measured values, after being processed by MCU, are used for data interaction through serial ports. The power of the main circuit is supplied by three 15V batteries. Figure 4 shows the peripheral circuit of MCU.

Interface circuit of Ethernet data communication: DM9161A, a common type of Ethernet PHY chip, is taken as the chip for data communication. The transceiver of 10BASE-T/100BASE-TX integrated with DM9161A can support the port of MII/RMII, the switching between relay mode and node mode, the conversion between full-working mode and half-working mode and the low power consumption mode; it takes the 0.35 nm COMS technology and is powered with 3.3V; the 48-pin PQFP combined with the TCP/IP stack code is in favor of Telnet, embedded webpages and TFTP; DHCP is also supported to automatically acquire IP address and display the address on LCD screen (Yong, 2003). The connection to router or PC can be accomplished by using only one cable. After the
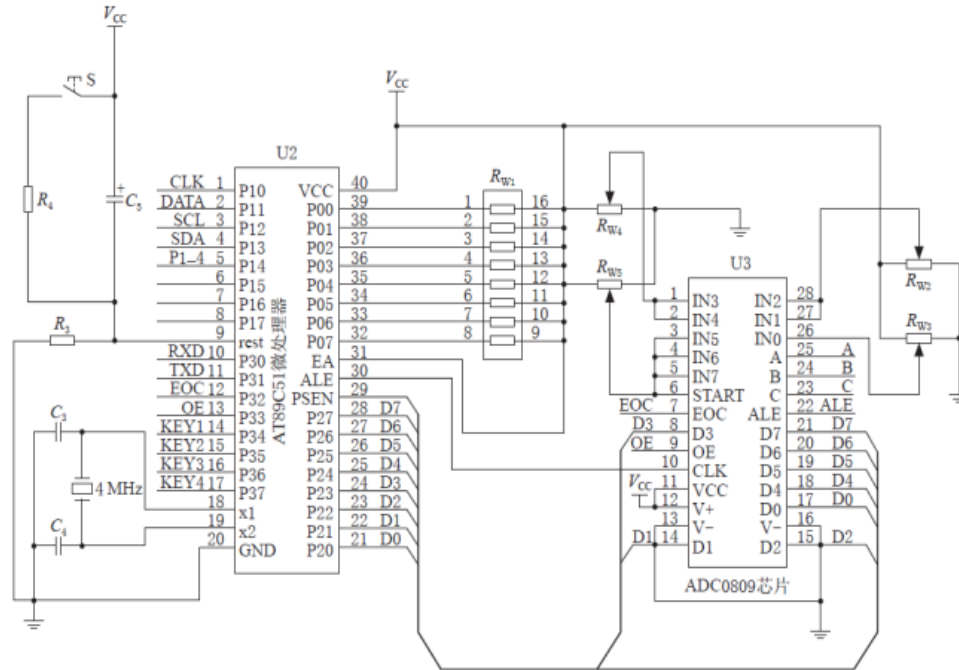
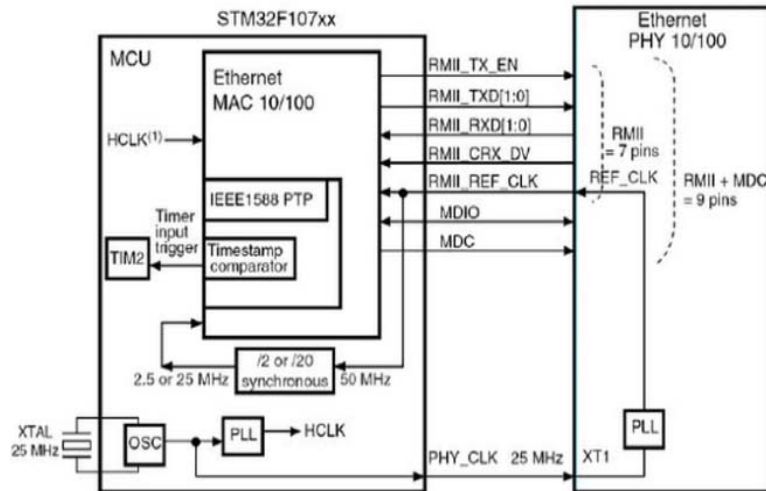Fig. 4: Peripheral circuit of MCU

Fig. 5: Ethernet RMII connection

connection is finished, resources can be accessed and controlled via the Internet and the remote control via Ethernet can thus be realized. Figure 5 shows the Ethernet RMII connection.

System functions:

- The terminal for food quality detection is taken as a node for analyzing food quality; the monitoring center can be used for remote control and management, or, for independent operation, man-machine interaction and other control analysis.
- 24-h intelligent and unmanned monitoring.
- Hardware of the system can automatically detect

fault and send information to the remote controlling center if there is a fault occurs in the hardware circuit or if the battery capacity is too low.

- Server of the remote monitoring center can implement real-time and on-line monitoring on pollution of food and can store the data which can be accessed on webpage.

Software design: The center can make addressing to terminal nodes by controlling the timing of the communication in the network. The terminals are mainly used for collecting, pre-proccess the data of food quality as well as for wireless transmission. The
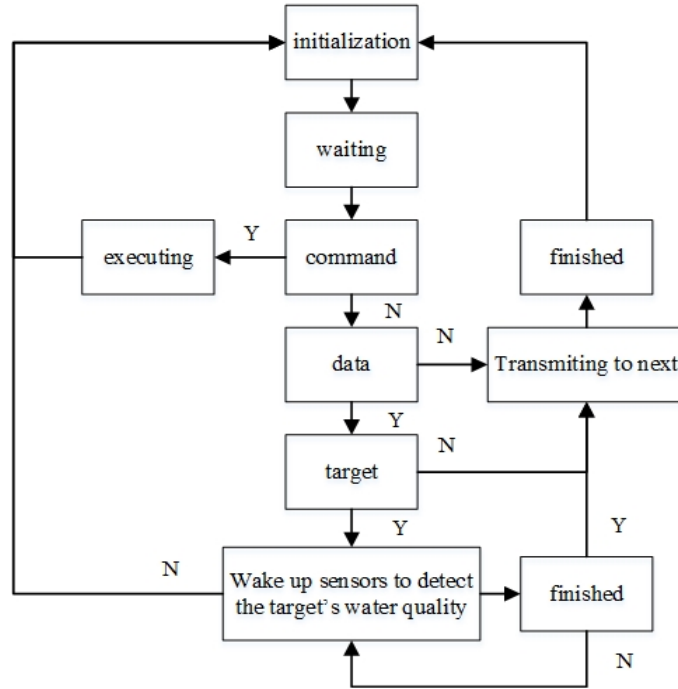
Fig. 6: Workflow of the system software

function of the gateway of monitoring station is to gather data from sensor nodes, send the data, receive orders from the host and send the orders to each node. The main consideration for design is the operation that is easy for non-professionals to mange the system. The design has also taken into consideration of system functions. Workflow of the designed software is shown in Fig. 6. The system make regular detection to food quality and will be in the standby mode during the rest of the time. The data collected by sensors are transmitted to gateway by using program interruption. In the wireless network, th address of each terminal unit is fixed. The monitoring stations are used as gateway to communicate with the host of the remote control center.

Correction of data errors by software: Interference may exist when using sensors to collect and transmit characteristic data of food quality, which will result in unstable and weak signals. Therefore, in addition to necessary hardware processes, software shall also be used to filter, enhance and correct the signals. The method for correction by software: characteristic signals of food quality collected in the time domain:

$$t = \sum_{i=1}^{n} \frac{n}{t_i} \tag{1}$$

where, t_i and n are the characteristic number of the characteristic signals and t is the result of the algorithm. The method for calculating the errors of the detected signals is:

$$\nabla e(t) = t - t_0 \tag{2}$$

If the error of the signal is $\nabla e(t)$, then the data can be corrected by:

$$u(t) = k_p \nabla e(t) + \beta k_i \sum_{j=0}^{k} \nabla e(t)T$$
$$+ \frac{k_d (\nabla e(t) - \nabla e(t-1))}{T} \tag{3}$$

where, k_p, k_i and k_d are lateral and longitudinal coefficients for adjusting the characteristics. The characteristic error $u(t)$ of the strength of the signal can be adjusted by using these coefficients. After the data have been corrected, the characteristic error of signals of food quality will fall in an acceptable interval.

RESULTS AND DISCUSSION

Using this monitoring system to detect food pollution in Hancheng Lake in the city of Xi'an. Deploy 10 detection terminals in the selected area. The data are collected by detection stations on land. A remote computer is used to monitor, analyze and process all the data. In the experiment, the pH, TP (Total Phosphorus), COD (Chemical Oxygen Demand) and ammonia concentration are determined. Make continuous sampling for 24 h. The collected data are screened and process by the system and are compared to those released officially by environmental protection

Table 1: Experimental data

Period of time	PH	Concentration of total phosphorus mg/L	The chemical oxygen consumption mg/L	Concentration of Ammonia nitrogen mg /L
0-4	7.2	4.2	216	45.2
5-8	7.1	4.1	220	40.3
9-12	7.6	4.3	236	44.1
13-16	7.0	4.1	209	40.5
16-20	8.1	4.2	211	41.2
21-24	8.5	4.4	212	40.8
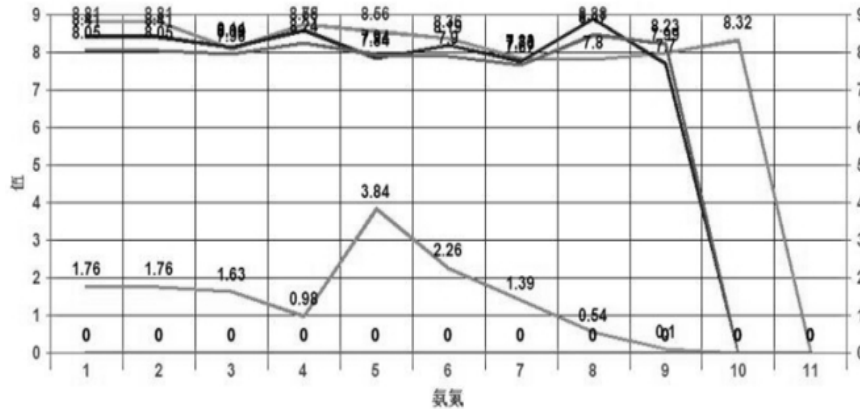
Fig. 7: Comparison between the detected data and the real data
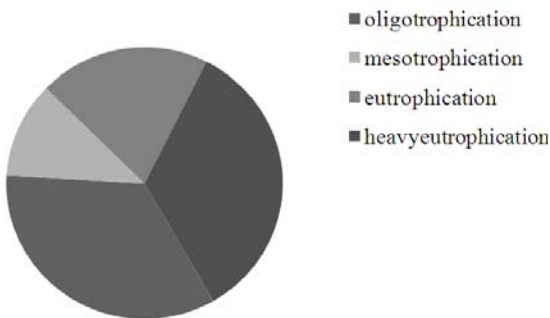

Fig. 8: Map of the results of food pollution

administration. The experiment results are listed in Table 1.

Input the detected data and the official data into a simulation software for comparison, as shown in Fig. 7.

After the data from all the detection terminals are completely analyzed by the server of the remote monitoring center, the server will then, intelligently, output a comprehensive map of the pollution degree of this food, as shown in Fig. 8.

According to the analysis on the summarized data, the system will simulate and forecast the trend of eutrophication in this food and will send an alarm automatically if an abnormality appears.

The above experimental results show that the detected data agree basically with the real ones. The accuracy rate is higher than 98% and the success rate of communication is 100%, which is more efficient than manual detection methods and can lead to satisfactory results.

CONCLUSION

The system is designed based on the ZigBeewireless communication technology for monitoring, intelligently, the pollution in a remote food area. Wireless terminals for detecting food quality are deployed at key locations in the food and detection stations are positioned in a certain area, to collect data from all sensors. The collected data are then sent to the server of the remote monitoring center via the Internet, which allows technicians to make real-time monitoring on food pollution. The system can be used for real-time monitoring as well as for storing and querying historical data. It's usability and extendibility have been greatly improved and it has a low cost in deploying a monitoring network in a large food area, thus it is of great value of popularization.

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