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A Design of High-Level Water Tank Monitoring System Based on Internet of Things

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Abstract

The quality and quantity of water supplied by high- level water tank directly affect people's daily life. Most traditional water tanks use manual detection, which has high detection cost and low data accuracy. In order to ensure the safety and continuity of high-level water tank water supply, this paper designs a set of high-level water tank monitoring system based on Internet of things. The system adopts TDS sensor and ultrasonic sensor to monitor the water quality and water level of the water tank respectively, and transmits the data back to the monitoring center for real-time monitoring through ZigBee –a wireless communication protocol. The system can control water level automatically and alarm when water is polluted. It has strong practical value and significance that ensures the safety and stability of household water, and provides data support for the improvement of water tank water supply in the future.

Keywords: Internet of things, high-level water tank; ZigBee, TDS sensor; ultrasonic sensor.

1. Introduction

The high-level water tank is a secondary water supply method widely used in high-rise buildings at present, but the water quality inside the water tank will inevitably be polluted to a great extent [1]. Nowadays, most of the water quality supervision of the high-level water tank is manual irregular sampling inspection, or the low data collection accuracy in the wired water monitoring system, which cannot process parameters in real time, and accompanied with high supervision cost. The second problem is that the internal storage capacity of the traditional high-level water tank cannot be obtained in real time. If the water level is too low, in the event of a surge in water consumption or insufficient water supply in the municipal pipe network, insufficient water pressure or even water stoppage can happen easily. To ensure the safety and stability of water for residents, an indispensable step is to strengthen the supervision of high-level water tanks and implement maintenance measures.

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These days, there are few researches on the monitoring and control of high- level water tank in China [2-7], and the existing methods are mainly focus on laboratory monitoring, automatic monitoring station monitoring and mobile monitoring [8]. The data collection work needs manual participation, and most of the data is transmitted through a wire way, which has the problems of inconvenient sampling, high cost and inability to guarantee the real-time data. Most of the foreign researches use wireless network technology to transmit data, but there is no combination of water quality and water level monitoring [9-11]. Combined with the above problems, this paper designs a high-level water tank monitoring system based on the Internet of things to monitor the water quality and water level of the high-level water tank in real time.

2. System Design

2.1 Introduction to ZigBee Technology

ZigBee Alliance re-standardizes the network layer protocol and API based on the IEEE 802.15.4 wireless standard. ZigBee has three working bands: 2.4GHz, 868MHz and 915MHz, and its transmission rates are 250kb/s, 20kb/s and 40kb/s, respectively. The 2.4GHz band is used in China, which is divided into 16 channels [12]. In ZigBee networks, devices are defined as three types: coordinator, router, and end-device. The ZigBee network consists of a coordinator, multiple routers and multiple end-devices, and can accommodate up to 65536 nodes. The coordinator is primarily responsible for the start-up and configuration of the network; the router is mainly responsible for other nodes to join the network and route forwarding; the end-node is mainly responsible for data collection and transmission. There are three types of ZigBee network topologies: star, tree and mesh as shown in Figure 1.

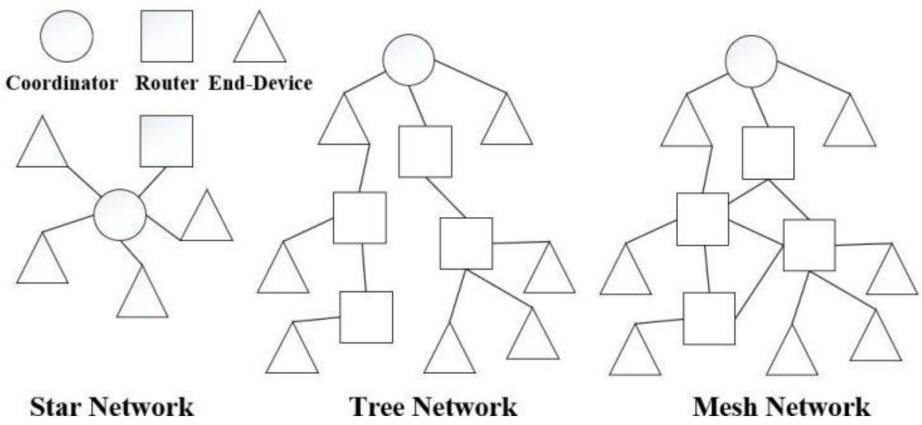

Figure 1 Topology of ZigBee network structure

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2.2 System framework

In this paper, a high-level water tank monitoring system based on the Internet of things is designed, and its overall structure is shown in figure 2.

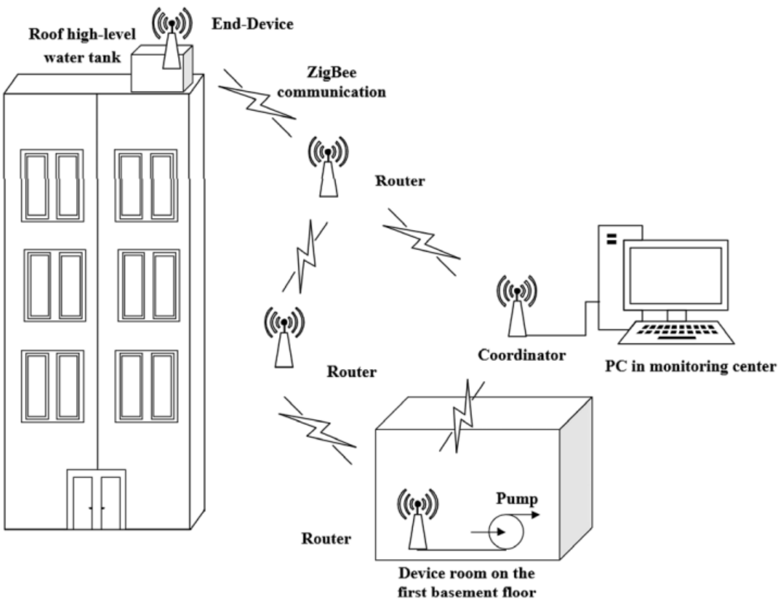

Figure 2 Overall framework of system

The whole system is composed of end-device, router, coordinator and monitoring center. The end-device is primarily responsible for integrating the data collected by the sensor and sending it out. The main purpose of the router is to forward the data and control variable frequency pump according to the relevant water level parameters to adjust the water level of the water tank. The coordinator is mainly used to establish the ZigBee network and forward the data of the Zig Bee network to the PC of the monitoring center in real time to realize real-time monitoring. The end-node is placed at the high-level water tank to detect the water quality and water level through the sensor. Due to communication environment and distance, it may be necessary to deploy multiple routers to achieve data relay transmission. One of the routers is placed between the equipment and is connected to the frequency converter of the variable frequency pump. The coordinator is placed in the monitoring center and connected to the PC through the serial port. After the system starts working, the coordinator will establish a new ZigBee network, and adjacent nodes will join the network automatically. After the link is formed, the monitoring center PC will display the water level data in real time, and activate the alarm when the water pollution value exceeds the set threshold value.

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2.3 Hardware Design

2.3.1 Water quality detection and alarm

TDS, also known as the total dissolved solids; generally speaking, the value of TDS can roughly reflect the water quality [13]. According to the provisions of the Sanitary Standard for drinking Water, the limit value of TDS is 1000mg/L [14]. Shu Weiqun et.al. studied the drinking water of Chinese residents and recommended that the range of TDS in drinkingwateris200~500mg/L[15].Based on the above data, this paper designs a TDS sensor to measure the electrical conductivity of water through the electrode, and then indirectly calculate the TDS value of water. When the TDS value is greater than 800mg/L, the system alarms. The TDS module is shown in figure 3.

Figure 3 Overall framework of system

In order to simplify the programming design, this paper uses 0905 active buzzer to realize the alarm function. The module has its own vibration source and is driven by S8550 transistor. The S8550 module is shown in Figure 4.

Figure 4 Overall framework of system

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2.3.2 Water Level Detection and Automatic Control

The water level monitoring module uses HC-SR04 ultrasonic distance sensor. The module includes two general piezoelectric ceramic ultrasonic sensors and some auxiliary signal processing circuits. The maximum detection distance is about 4.5 m and the detection angle is less than15°.Because the single-chip microcomputer cannot directly control and adjust the variable frequency pump, this paper uses the TTL to RS-485 module of Shenzhen Weixin Technology Co.Ltd. To realize the communication between the single-chip microcomputer and SIEMENS MM420 frequency converter, and then control variable frequency pump indirectly. According to the USS message structure set by the MM420 frequency converter, the single-chip microcomputer transmits the pressure setting value and related parameters to the frequency converter through the TTL to RS-485 module, and the PI automatic control of the variable frequency pump can be realized. The TTL to RS-485 module circuit is shown in figure 5.

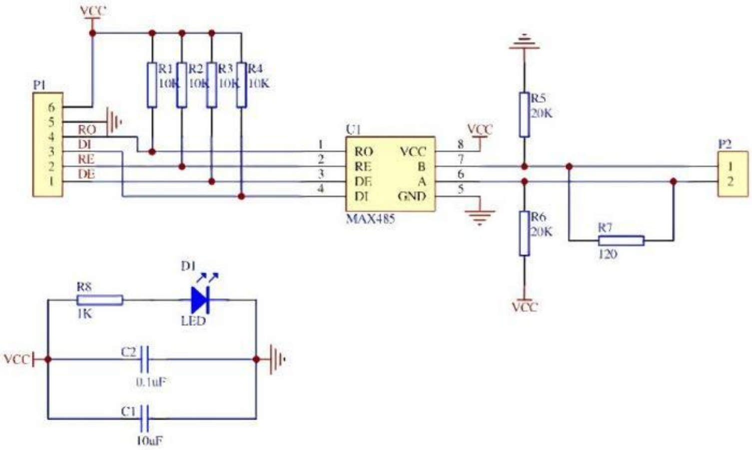

Figure 5 Circuit diagram of TTL to RS485 module

2.3.3 Node Circuit Design

In this paper, the end-node is arranged on the top of the water tank, and the connection circuit is shown in Figure 6. TDS detection electrode is placed under the water surface, and connects the serial port of the TDS sensor with the serial port of the CC2530 single-chip microcomputer. When the node is powered on, the TDS sensor will continuously send messages to the single-chip microcomputer actively. The ultrasonic sensor is placed on the top of the water tank, and connects the Echo end and Trig end to the P1N1 and P0room6 of the CC2530 single-chip microcomputer, respectively, where Trigs the trigger signal end and Echo is there turn signal end. The router is placed in the devices room, and the connection circuit is shown in figure 7. The serial port of CC2530 single-chip microcomputer

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is connected with MM420 frequency converter through TTL to RS485 module, and USS protocol is used for communication.

The coordinator is placed in the monitoring center, and the connection circuit is shown in Figure 8. The serial port of CC2530 single-chip microcomputer is connected with PC through TTL to USB module, and the data is constantly forwarded to PC. The single-chip microcomputer P1_2 is connected with the I/O port of the buzzer. When the TDS value exceeds the set threshold value of 800mg/L, P1_2 output low level signal to drive the active buzzer alarm.

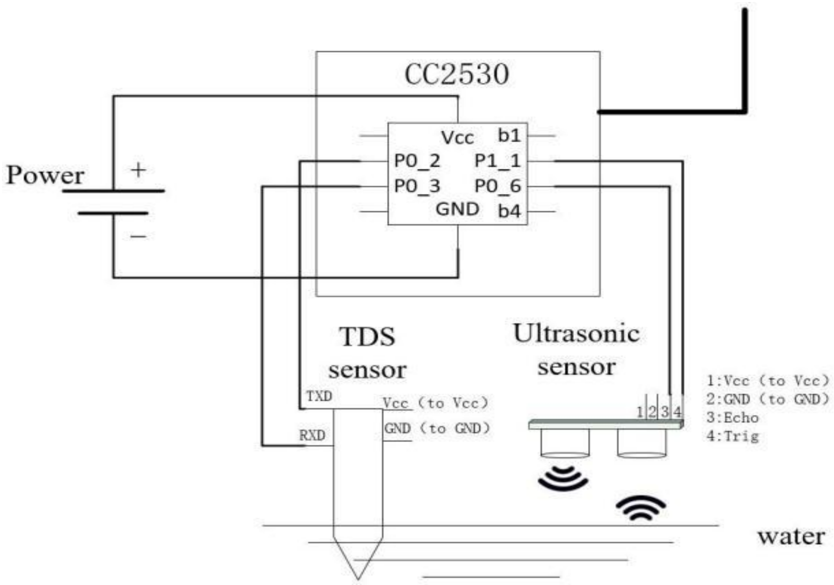

Figure 6 End-node circuit connection diagram

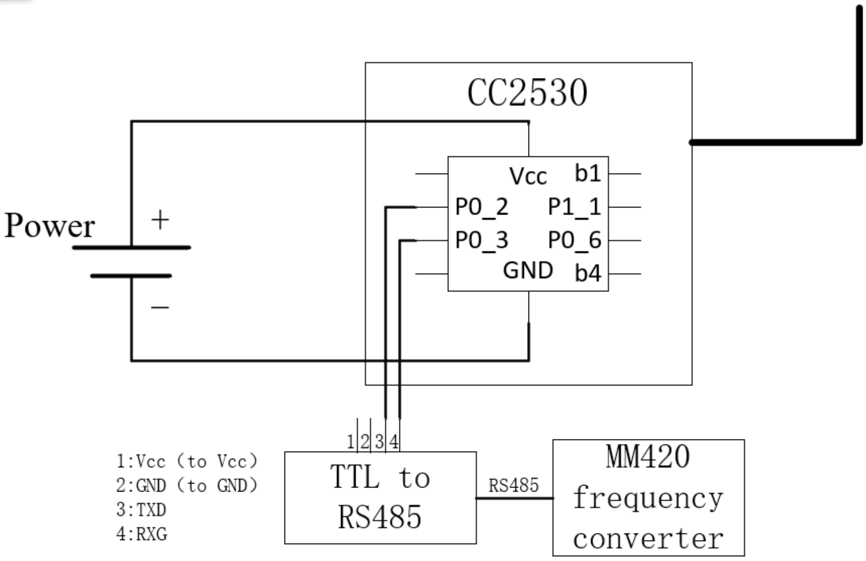

Figure 7 Router circuit connection diagram

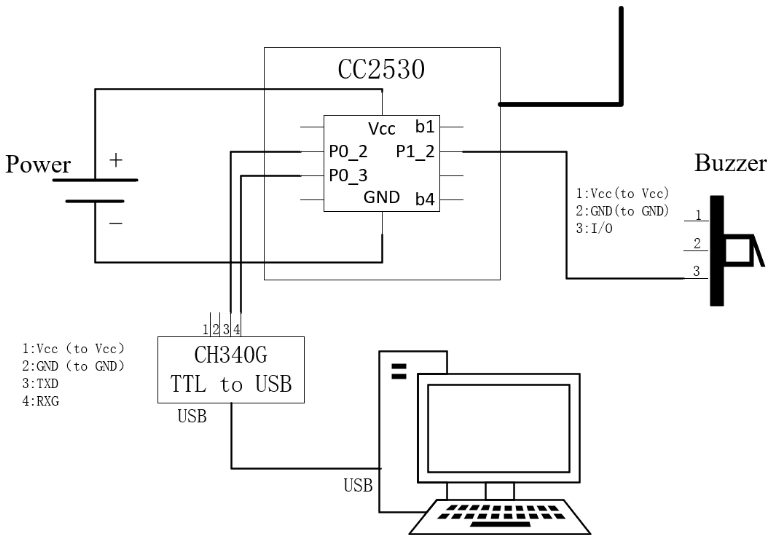

Figure 8 Circuit connection diagram of coordinator

2.3.4 ZigBee Communication Program Design

In view of the inconvenience of sampling and the inability to guarantee the real-time data of the traditional detection methods, this paper uses ZigBee wireless communication technology to complete the data transmission of the water tank monitoring system. ZigBee

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wireless network communication is a key link in the system, which directly determines the accuracy and real-time of data transmission in the system, so this paper uses a more reliable solution-Z-Stack protocol stack, developed by TI Company based on ZigBee standard. The protocol stack integrates and encapsulates the protocols of each layer, leaving an interface for users to call directly. The workflow is shown in figure 9.

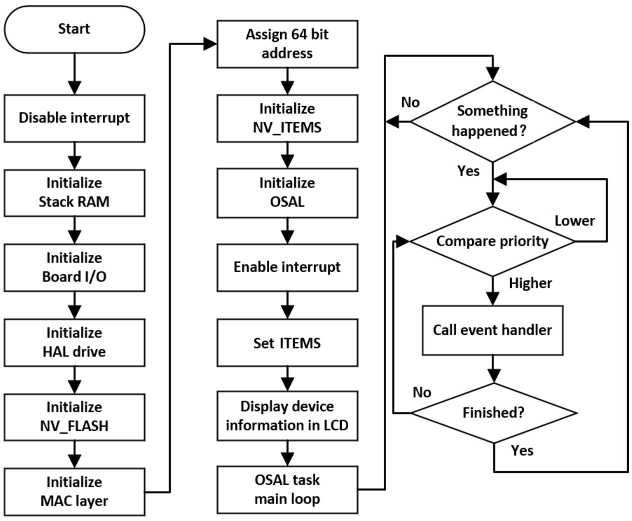

Figure 9 Workflow of Z-stack protocol stack

There are three different communication modes in ZigBee: on-demand communication, multicast communication and broadcast communication. This paper uses multicast communication, that is, nodes in the same group can communicate with each other. The program design of the coordinator is shown in Figure 10. The coordinator is responsible for the start-up of the entire network. After the initialization work is completed on power-up, the coordinator will select a PANID and idle channel to build a new ZigBee network, waiting for the rest of the nodes to join. You can then wait for the data packet sent by the end-node. After receiving the MSG pkt data packet for parsing, the data can be extracted from the cmd structure in the packet, and the data can be sent to the PC terminal of the monitoring center through the HalUART Write function.

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The programming of the end-node is shown in figure 11. The initialization step is performed after power up, where the baudrateneedstobesetto9600tobeconsistentwiththebaud rate of the TDS module. After searching and joining the network, the end-node will perform data extraction and multicast transmission in a loop. The TDS sensor is connected totheserialportoftheCC2530single-chipmicrocomputerand will actively send data after being energized. The single-chip microcomputer only needs to extract the TDs value according to the format of the data frame in the URX0 interrupt service function. The ultrasonic sensor is connected with the CC2530 single-chip microcomputer through the I/O port. When the Trig port receives the trigger signal, the sensor will send out the pulsed sound wave. After detecting the reflected sound signal, the Echo end will output a high-level signal, and the duration of the signal is proportional to the detection distance [16]. Through the timing of the timer, the end-node can get accurate ranging data. After obtaining the data of the water level, the multicast sends function of the protocol stack can be called to send the detected data directly to the group.

The programming of the router is shown in figure12.After joining the ZigBee network; the router can allow other devices to join the network. After receiving the multicast data, the water level data is forwarded to the MM420 frequency converter through the TTL to RS-485 module connected with the serial port, and the data packet can be routed and forwarded at the same time to realize the function of network relay.

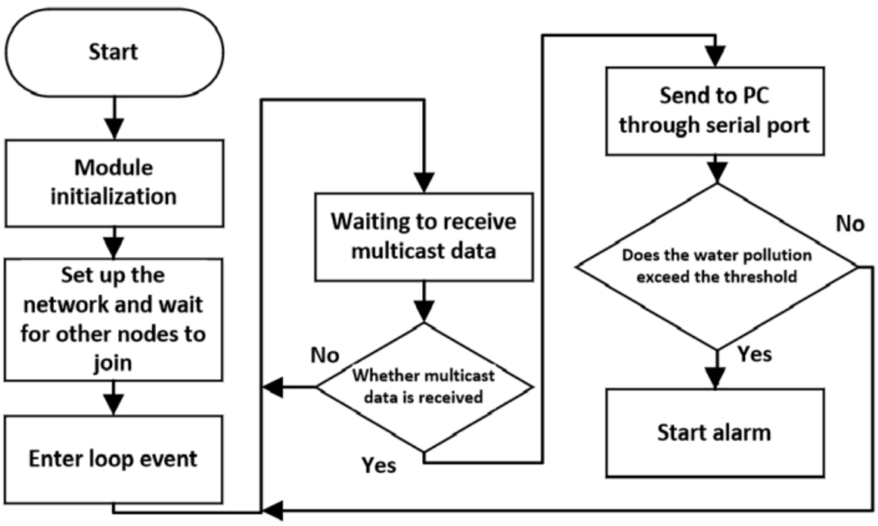

Figure 10 Coordinator programming

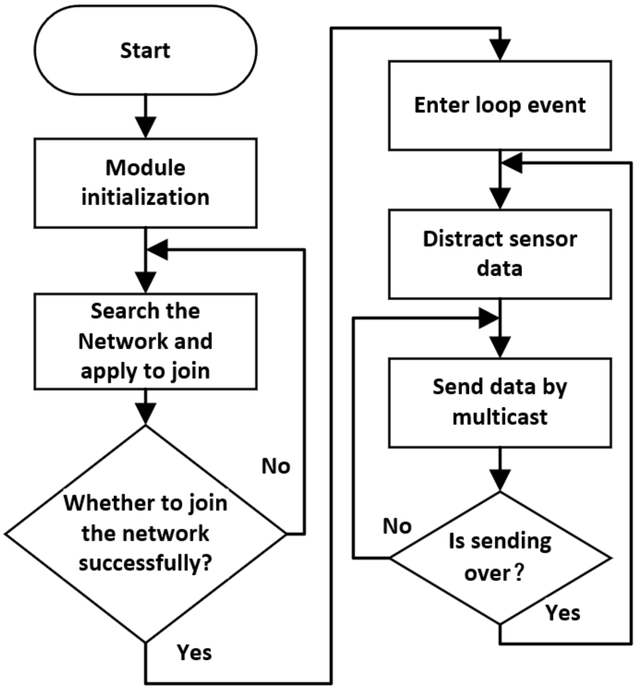

Figure 11 End-node programming

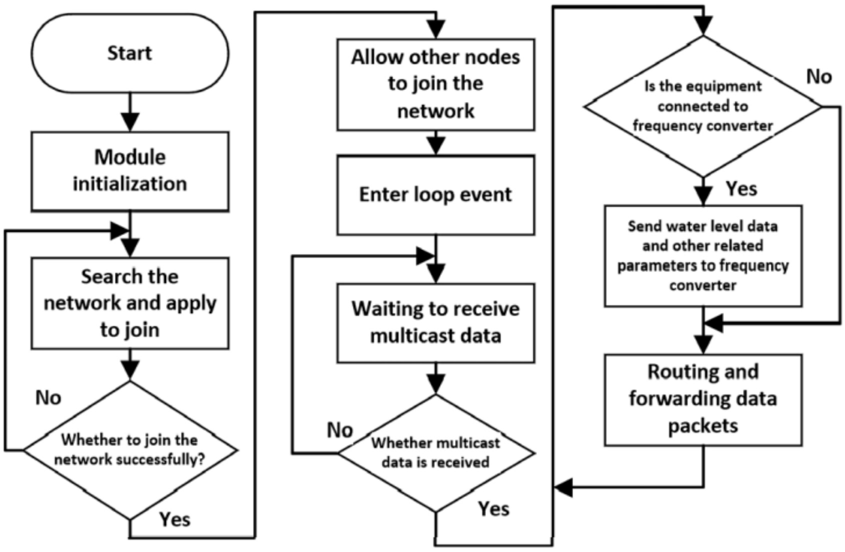

Figure 12 Router programming

3. System Implementation and Debugging

Connect the circuit according to the circuit design diagram, and test the monitoring function of the system.

3.1 Water Quality Detection

Prepare three samples, bottled drinking water, tap water and polluted water, respectively, and detect them with standard TDS detector and TDS sensor to test the detection accuracy and alarm function of TDS. TDS test results are shown in table 1.

Table 1 TDS Test Results

	Standard TDS Detector	*TDS Sensor*
Drinking water	37 ppm	35 ppm
Tap water	64 ppm	64 ppm
Polluted water	1080 ppm	1072 ppm

When the TDS value exceeds the set threshold 800 ppm, the water can be considered to be polluted. The system issues an alarm, as shown in figure 13.

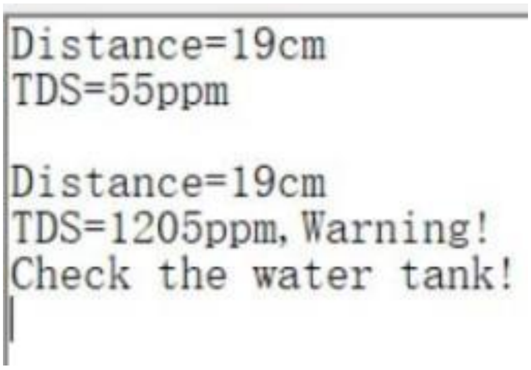

Figure 13 Water pollution alarm

3.2 Water Level Detection

Change the distance between the ultrasonic module and the water surface, test the ranging accuracy of the ultrasonic module and the water pump control function form any times. The results of ultrasonic ranging are shown in table 2. When the water level is too low, the system starts the pump, as shown in figure14.

Table 2 TDS Test Results

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	First time	*Second time*	*Third time*	*Fourth time*	*Fifth time*
Ruler Ranging	8 cm	12 cm	17 cm	19 cm	20 cm
Ultrasonic ranging	8 cm	12 cm	17 cm	19 cm	20 cm

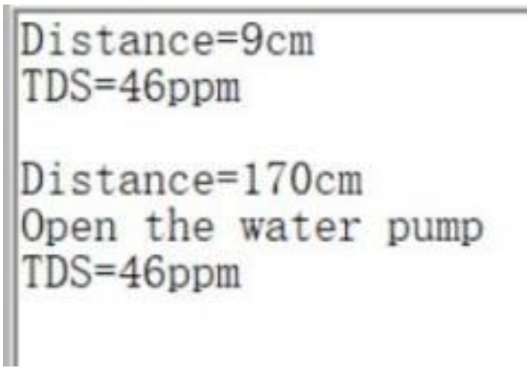

Figure 14 Start pump when water level is too low

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Figure 15 Water quality test

Figure 16 Water level test

As can be seen from the test results, the measured data of the water quality and water level of the system are consistent with the standard data within the range of error. At the same time, it realizes the function of water pollution alarm and starting the pump when the water level is too low, and the communication delay is short, which meets the design requirements basically.

4. Conclusions

The system designed in this paper can collect the water level and water quality parameters simultaneously, and send monitoring water quality and water level data wirelessly to the monitoring center in real time, and can automatically alarm the water pollution, automatically regulate water level based on the collected parameters. The advantage of the system is that the monitoring of water quality and water level can be achieved at the same time, and the function is more perfect; the use of ZigBee wireless communication technology for data transmission improves the data processing speed and saves manpower. In addition, the system also has many advantages, such as low power consumption, low cost, strong expansibility and so on. It can be networked by multi-nodes to enable distributed detection and control of multiple water tanks, which is widely suitable for the monitoring of high-level water tanks in existing residential areas.

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