Development and Implementation of a ZigBee-Based Regional Water Quality Monitoring System: Design, Technologies, and Application

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Abstract:

Water pollution not only significantly impacts people's daily lives but also causes considerable harm to the flora and fauna in surrounding water bodies. Traditional methods of water quality testing involve manually collecting samples from the source and transporting them to a local laboratory for analysis, a process that is time-consuming.Therefore, there is a growing need for a novel water quality monitoring system that provides timely feedback. With advancements in wireless sensor network technology, wireless methods are increasingly being utilized to establish water quality monitoring systems. This paper proposes a wireless water quality monitoring system based on ZigBee technology, juxtaposed with traditional water quality monitoring methods.The system employs Texas Instruments' CC2530 chip as the central component, with sensors selected for relevant water quality parameters forming the hardware detection module. ZigBee functionality for each module is implemented through the Z-Stack protocol stack. Remote data processing is managed via PC software developed using LabVIEW, which processes data such as temperature, turbidity, and chemical oxygen demand (COD) received from the ZigBee network.This system facilitates real-time monitoring of water quality parameters. The ZigBee end-nodes collect data on water quality parameters through relevant sensor modules. This data is then transmitted to the ZigBee coordinator via the ZigBee network, which subsequently aggregates the data and sends it to a remote data processing center for comprehensive analysis.

Keywords:

ZigBee; Water Quality Monitoring; Z-Stack Protocol Stack; CC2530.

1. Introduction

Water quality monitoring system is a system that uses relevant water quality parameter sensors to timely detect samples from water source area and reflect the water quality situation of local areas through sample analysis. Among them, automatic control technology, computer technology and professional software can be used to form a complete system from sampling, pretreatment, analysis to data processing and storage, realize the online automatic detection of samples. Monitoring system generally includes data acquisition and control system, water quality parameter sensor detection system, data transmission system and remote monitoring center. These systems are not only independent systems, but also can interact and work together to form a complete detection system.

At present, foreign water quality monitoring technology has been very mature. Developed countries such as Europe, America and Japan have set up monitoring systems for rivers, lakes, oceans and other important water resources in the last century. Especially in the area around the reservoir dam, it can detect the water quality parameter changes in the environment around the dam in a timely manner, and report to the report for treatment. Take the Hudson River in New York State. In 2014, Clarkson University's Rivers and Estuary Beacon Institute was conducting a study to obtain real-time environmental science data through a set of sensors deployed in rivers and estuary for centralized monitoring. River sensors track the dynamics of biological and chemical pollutants, as well as the overall function of river ecosystems, by measuring turbidity, salinity, chlorophyll and color-broken organic matter. This special river monitoring mode can be strategically deployed in almost all areas and monitored 24/7 through wireless networks.

The development of water quality monitoring technology in China is relatively backward. Since 2003, relevant departments of local governments have started to apply wireless network transmission systems to the protection of local rivers and key water resources. At present, in view of the complex and changeable water quality situation, comprehensive discharge standards for sewage have been formulated to control water pollution, protect the good state of surface water quality in rivers, lakes, canals, channels, reservoirs and oceans, safeguard human health, maintain ecological balance, and promote the development of national economy and urban and rural construction. The National Development and Reform Commission has also issued relevant documents, indicating that the state strongly supports the research of water quality monitoring system. At present, monitoring and observation points have been set up in key waters in China. The water is monitored in real time by different detection sensors installed in the water area, and the information is sent to the remote receiving device via wireless network.

2. ZigBee Network technology

2.1. ZigBee Technology Descriptions

ZigBee is synonymous with the IEEE 802.15.4 protocol. This is due to the honeybee's flight path like this around the character, as well as the buzzing sound produced during the flight. It's a way for bees to communicate with each other. The pollen's position is conveyed by its flight path. Bees form a communication network. ZigBee technology can be used in combination with all devices. It is a wireless communication technology with low power consumption, low cost and low transmission rate.

2.1.1. ZigBee technology features and application fields

IEEE 802.15.4 is a lower rate wireless personal LAN standard. The physical layer (PHY) and medium Access Control layer (MAC) are defined by the standard. It has limited power and flexible throughput. The network has the following characteristics:

(1) Three transmission rates of 250KB /s, 40KB /s and 20KB /s are realized.

(2) Full reply protocol for reliable transmission.

(3) Energy detection.

(4) Link quality indication.

In the 2450MHz band, 16 channels are defined.10 channels are defined in the 915MHz band. One channel is defined in the 868MHz band.

The Institute of Electrical and Electronics Engineers (IEEE) defines two different types of devices: a full-functional Device (FFD) and a Reduced Functional Device (RFD).

With the further improvement of ZigBee specifications, the application prospect of ZigBee technology is more extensive. At present, the wireless network application fields of ZigBee technology include home automation, industrial and environmental control, medical care, testing environment, monitoring production, transportation process and quality assurance of fresh food, etc. The main application areas include the following aspects:

(1) Home and building network: air conditioning system, indoor and outdoor lighting, natural gas metering control, remote control of household appliances.

(2) Industrial control: Various monitoring devices used in industrial production.

(3) Business: smart labeling, food traceability, etc.

(4) Public places: smoke detectors, video surveillance, etc.

(5) Agricultural control: Collect soil information and climate information.

2.1.2. ZigBee Network node types

A ZigBee network can have three logical node types simultaneously: Coordinator, Router, and end-device. The ZigBee network is composed of a Coordinator, multiple Routers and multiple end-devices.

(1) Coordinator

The coordinator is responsible for starting the entire network. It was also the first device on the

network. The coordinator automatically determines and identifies a channel and a Network ID (or PAN ID, Personal Area Network ID), and then enters the start networking process.

The most important function of the coordinator is to start the ZigBee network and complete the relevant parameter adjustment. When this is done, the coordinator has the option of running the router or automatically sleeping.

(2) Router

The main function of a router is to serve as a bridge for data transfer between the terminal node and the coordinator in ZigBee networks. Normally, routers in a ZigBee network will not go into hibernation. But when the ZigBee network is a tree topology, it allows the router to go to sleep and wait for the coordinator to wake up, reducing power consumption.

(3) End-device Terminal Device

The terminal device has no specific responsibility for maintaining the network structure. It can sleep or wake up, so it can be a battery-powered device. Usually, the terminal device has a small storage space.

ZigBee network has three topologies, namely star structure, tree structure and network structure see Figure 2-1.

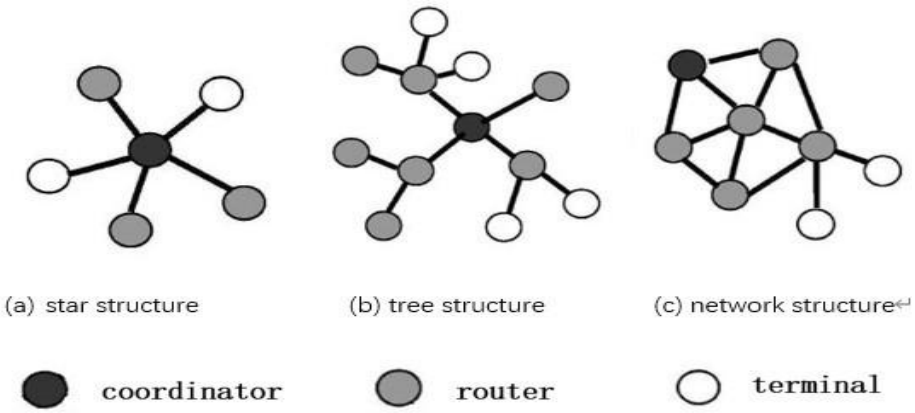


Figure 2-1 ZigBee network topology structure

The stellate network has one coordinator node and several routers and terminals. The coordinator node is the center of the star-shaped network through which any information passes.

A tree network is composed of a coordinator and one or more star - like structures. The center of the tree network is still the coordinator node. In the surrounding stellate structure, however,the device can communicate with its own parent and child nodes without going through the coordinator node.

In mesh networks, devices can be connected to each other to transmit data in a point-to-point manner if they have routing capabilities. If information is to be passed between the terminal nodes, it must pass through the coordinator or router node.

2.2. Water quality monitoring system

2.2.1. Overall scheme selection

The purpose of the regional water quality monitoring system is to monitor the water quality parameters in the water resources area. Such as temperature, PH, turbidity, chemical oxygen demand (COD) and other basic water quality information parameters. The biggest cause of water resource pollution is the pollution caused by excessive sewage discharge and incomplete sewage treatment. This design measures the domestic sewage discharged in daily life and the water quality of the regional waters through which the sewage is discharged. The water quality parameters detected by the sensor are transmitted to the remote monitoring center through the ZigBee network.

In terms of sensor selection. According to the comprehensive sewage discharge standards issued by the state, some pollutants must be sampled by the field water quality and analyzed in a professional laboratory to get the results, so the data cannot be collected by sensors. Therefore, PH value,

chemical oxygen demand (COD), turbidity and chroma were selected as the parameters for detection. As the change of temperature in the environment will also affect the result of water quality test, the temperature is also included in the test parameters. Because some sensors are very expensive, and in combination with the collection requirements of various parameters, the GE-TS turbidity sensor is selected to detect the turbidity of water samples, and DS18B20 temperature sensor is selected to detect the temperature of water samples.

In the system structure design. The underlying ZigBee network consists of router nodes, coordinator nodes and terminal nodes. In this design, the requirement of transmission distance is not high, so the router node is not selected, only one coordinator node and one terminal node are selected for configuration. In such a configuration, if the detection range needs to be expanded, only the number of terminal nodes needs to be increased. The middle layer uses serial ports for data transmission and sends the data summarized by ZigBee network coordinator nodes to the upper monitoring center for data processing and analysis.

In terms of wireless network communications. According to the actual detection requirements, to set the time interval of data transmission. If the detection period is long, the sleep mode can be set at the terminal node. When detection is needed, it can be started by sending a command through the coordinator. The distance of data transmission can be determined by detecting the strength of the network signal.

2.2.2. Hardware selection of water quality monitoring system

ZigBee standard chips and sensors are the most important hardware structures in this design. Therefore, the choice of ZigBee chip directly determines the development difficulty of the system.

ZigBee standard chips are mainly selected for low cost, low power consumption and low development difficulty. Due to the vigorous promotion of "ZigBee Alliance", ZigBee technology has achieved great development in the global scope. There are also many ZigBee solutions on the market, which can be roughly divided into two types: MCU+RF (Radio Frequency) Chip solutions and SOC (System on Chip) solutions. The former scheme is more common, PIC SCM CC2420 RF chip of Microchip company and Freescale HC08 MC1319X RF chip series. The latter are common in TI company's CC2430 and CC2530 and Ember Company's EM250.SOC solution is obvious, the advantages of the scheme is integrated with MCU, RF chip, memory, etc., have a high level of integration demand for peripheral components less, at the same time, high integration provide pin number use fewer encapsulation is smaller, which greatly reduces the difficulty of development and save the cost, very suitable for ZigBee node open. Companies that provide SOC solutions will have corresponding technical support and corresponding development platform. Complete open platform and technical support are conducive to our application development. Therefore, SOC scheme has obvious advantages for our system development. Combined with the actual situation, we choose TI company's CC2530 chip as our ZigBee standard chip for system development. In addition, we can also choose a CC2591 power amplifier according to our own needs to expand the scope of network coverage.

In terms of the detection of water quality parameters, according to the comprehensive discharge standards of sewage issued by the state, some pollutants must be sampled by the field water quality and analyzed in a professional laboratory before the results can be obtained, so the data cannot be collected by sensors. Therefore, PH value, chemical oxygen demand (COD), turbidity and chroma were selected as the parameters for detection. As the change of temperature in the environment will also affect the result of water quality test, the temperature is also included in the test parameters. Some sensors are very expensive. In combination with the collection requirements of various parameters, GE-TS turbidity sensor and DS18B20 temperature sensor are selected to detect the turbidity of water samples and the temperature of water samples. In addition, water quality samples from three different locations were collected near the discharge points of domestic sewage around the Chengdu campus of Southwest Petroleum University. COD was detected in the professional chemical laboratory, and the data were displayed in the remote monitoring center for analysis and treatment.

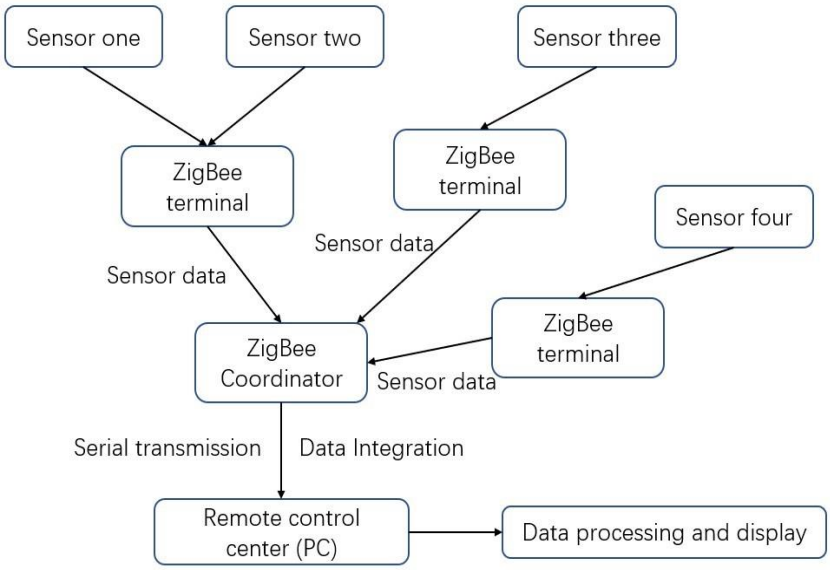


Figure 2-2 System flow chart

2.2.3. Overall structure and working process of the water quality monitoring system

The whole system consists of ZigBee network nodes, water quality monitoring sensors, connected serial ports and remote monitoring center. Water quality information is detected in the sensor module of the ZigBee terminal node, and data information is sent to the coordinator node through the ZigBee network. The latter collects all the data for packaging processing and transmits it to the remote monitoring center for display through serial port transformation. The monitoring center processes and analyzes the data and sends out corresponding prompt messages. The overall flow chart of the system is shown in Figure 2-2.

The workflow of ZigBee wireless sensor network nodes is as follows:

The coordinator. The system is started by the coordinator, and when the network is started, a PAN network is automatically created. PAN ID and channel are generated, followed by channel scanning and energy detection, and a channel is determined. After that, the coordinator broadcasts the PAN ID and channel outward, and when other ZigBee network nodes receive it, they will send the network access request to the coordinator. When the coordinator receives an access request, the node is allowed to enter the network, and the coordinator automatically assigns a network address to the node entering the network, at which point the complete network is built.

Terminal node. The terminal node is the core module of the water quality monitoring system. The terminal node packages the collected water quality parameter information and sends it to the coordinator. After successful access to the network, the terminal node can be made to sleep through the instructions of the coordinator to reduce energy consumption.

2.2.4. Principle of measuring conventional water quality parameters

(1) Turbidity detection

A GE-TS turbidimetric sensor, which uses optical diodes and transistors to refract a particular wavelength, is used to measure the concentration of an opaque or other substance in a sample. The amount of light from the optical sensor to the receiver is calculated to calculate the turbidity of the water.

(2) Temperature detection

The temperature is measured by DS18B20 digital temperature sensor.DS18B20 temperature measurement principle: the oscillation frequency of low temperature coefficient crystal vibration is little affected by temperature, which is used to generate pulse signal of fixed frequency and send it to counter 1.With the change of temperature, the oscillation rate of crystal oscillator of high temperature coefficient significantly changes, and the generated signal is used as the pulse input of counter 2.Counter 1 and the temperature register are preset at -55 ° C corresponding to a cardinal

value. Counter 1 of low temperature coefficient of crystals to produce pulse signal subtraction count, when the counter to a preset value of 0, 1 temperature register values will add 1, counter 1 will be loaded again, the preset counter 1 start of low temperature coefficient of crystals to count the pulse signal, so the cycle until the counter 2 count to zero, stop the accumulative temperature register values, the value in temperature register at this time is the measured temperature. The slope accumulator is used to compensate for and correct nonlinearity in temperature measurement and its output is used to correct the preset value of counter 1.

(3) Chemical Oxygen Demand (COD) detection

The dichromate method was used for measurement. The principle is as follows: in acidic medium, potassium dichromate is used as oxidant, silver sulfate as catalyst, mercury sulfate as masking agent for chloride ion, and sulfuric acid acidity of digestion reaction solution is 9 mol/L. Heat causes the digestion solution to boil. After water cooling and reflux heating reaction for 2 h, and natural cooling of the digestion solution, the remaining potassium dichromate was titrated with ammonium ferrous sulfate solution as an indicator, and the COD value of the water sample was calculated according to the consumption of ammonium ferrous sulfate solution.

2.3. Chapter four is the hardware design of ZigBee based regional water quality monitoring system

2.3.1. ZigBee Wireless Network node module design

ZigBee network nodes are divided into coordinator node, router node and terminal node. The hardware block diagram of coordinator and router nodes is shown in Figure 2-3:

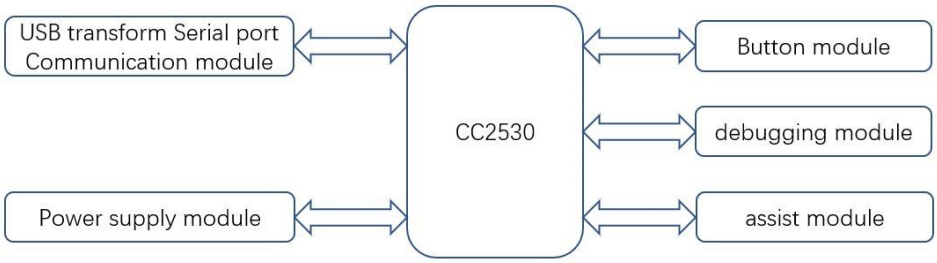


Figure 2-3 Hardware block diagram of ZigBee coordinator and router

The coordinator and router nodes are based on THE CC2530 chip. Peripheral debugging module, power module, USB to serial port module, key module and other modules.

The hardware block diagram of terminal node is shown in Figure 2-4:

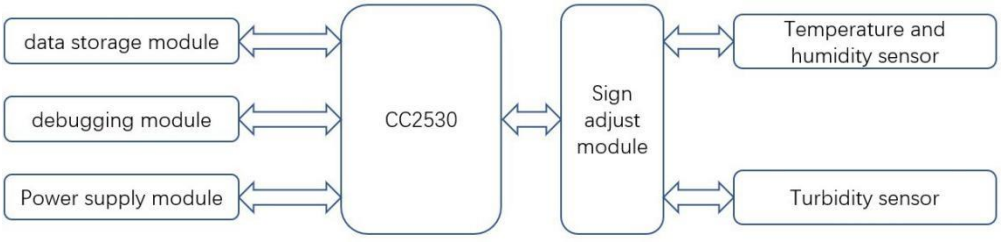


Figure 2-4 Hardware block diagram of ZigBee terminal node

CC2530 chip is the chip used in ZigBee's new generation on-chip system solutions. With a flash memory of up to 256 bytes, it provides 101dB link quality, excellent reception sensitivity and good anti- jamming. Inside the chip are two UART (universal asynchronous transceiver), a 12- bit ADC and 21 GPIO (universal input/output), as well as many more peripherals.

2.3.2. Module selection design

The main chip of rf module is CC2530.The circuit diagram is shown in Figure 2-5.

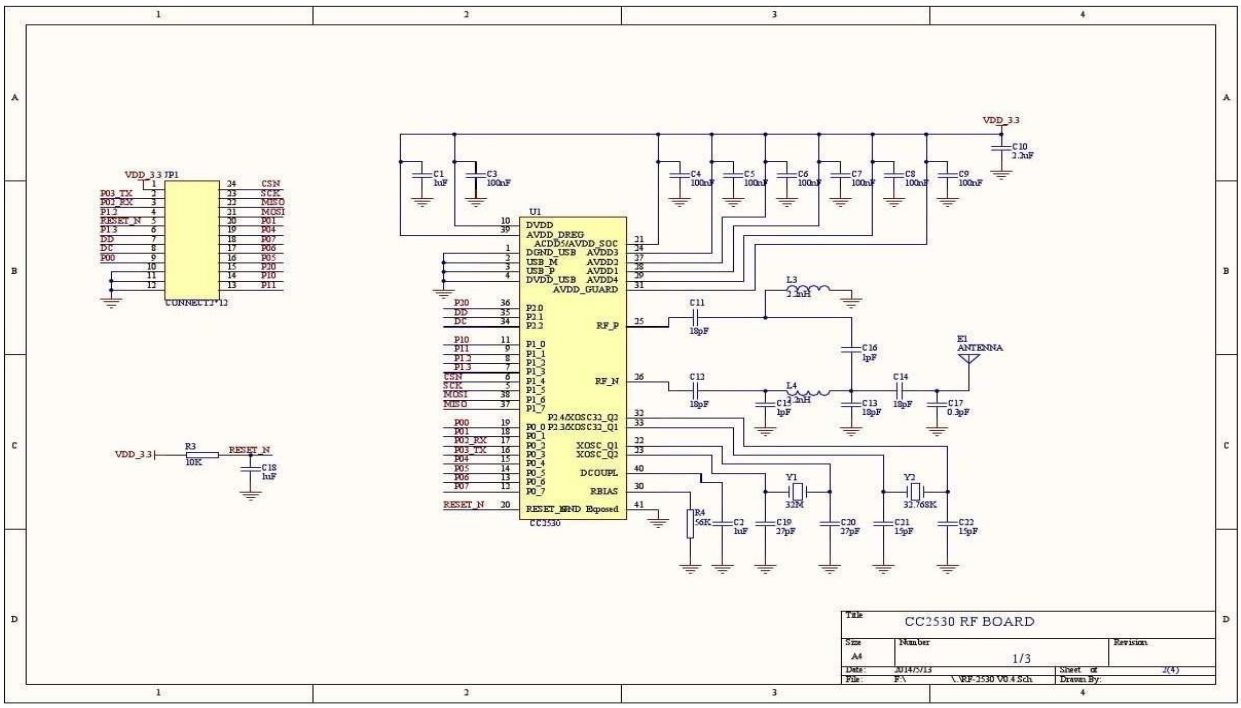


Figure 2-5 Circuit diagram of RF module

The rf circuit uses two different crystal oscillators, one is a 32MHz oscillator and the other is a 32MHz crystal oscillator composed of two load capacitors. The other is a 32.768khz oscillator with two load capacitances consisting of a 32.768khz crystal oscillator. The module is small in size, adopts external SMA antenna, has large gain, high reception sensitivity and long communication distance.

CC2530 RF module has the following characteristics:

(1) Based on the ZigBee SOC of CC2530 single chip, 8051 kernel is integrated to facilitate development and testing.

(2) The module size is small and easy to use.

(3) The module provides TTL serial port and I/O pin.

(4) Development tools using IAR Embedded Workbench for McS-51, development and debugging is convenient and fast.

SmartRF04EB is TI company released the 4th version of CC series chip debugger, can be used for CC11xx, CC243x, CC251x, CC253x and other series chips. Support simulation, debugging, single step, burning, encryption and other operations, can be seamlessly connected with the IAR compilation environment and TI company released the relevant software. The physical object and circuit diagram are shown in Figure 4-4 and Figure 2-6.

Figure 2-6 SmartRF04EB Simulator Physical image Serial

port communication module has the following characteristics:

(1) Download speed up to 150Kb/s;

(2) Automatic identification speed;

(3) The latest version of firmware can be updated through TI related software;

(4) USB plug and play;

(5) Power supply indication and operation indication;

(6) Support simulation download and protocol analysis.

ZigBee coordinators are generally powered by PC. Power supply via UART universal Serial data Bus interface. The terminal node can be powered by a 220V to 5V USB socket.

After the program is compiled in the IAR development environment, the program is downloaded to the FLASH memory of the CC2530 chip through the debugging module. Therefore, use the JTAG interface. Download the program to the CC2530 flash memory via emulator. The circuit diagram of the debugging interface is shown in Figure 2-7.

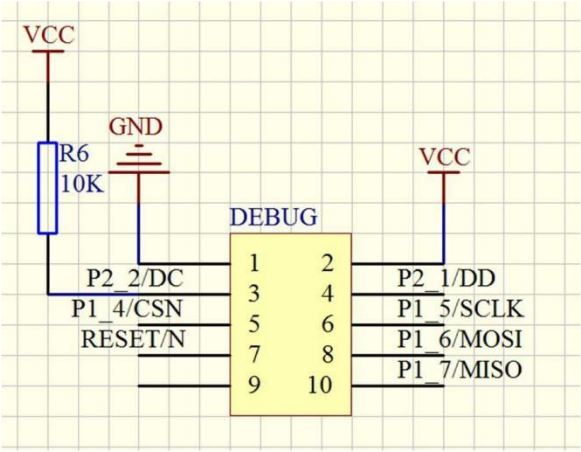


Figure 2-7 Circuit diagram of debugging interface

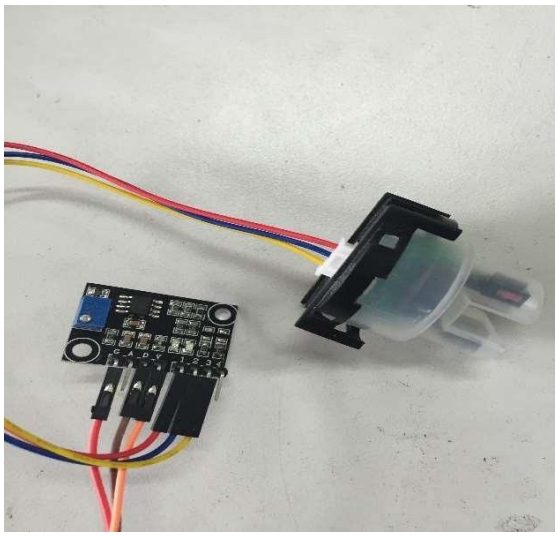
DS18B20 digital temperature sensor is used as the sensor of temperature acquisition module. The physical object and circuit diagram are shown in Figure 2-8 and Figure.

Figure 2-8 Physical picture of DS18B20 temperature sensor

The temperature is measured by DS18B20 digital temperature sensor.DS18B20 temperature measurement principle: the oscillation frequency of low temperature coefficient crystal vibration is

little affected by temperature, which is used to generate pulse signal of fixed frequency and send it to counter 1.With the change of temperature, the oscillation rate of crystal oscillator of high temperature coefficient significantly changes, and the generated signal is used as the pulse input of counter 2.Counter 1 and the temperature register are preset at -55 ℃ corresponding to a cardinal value. Counter 1 of low temperature coefficient of crystals to produce pulse signal subtraction count, when the counter to a preset value of 0, 1 temperature register values will add 1, counter 1 will be loaded again, the preset counter 1 start of low temperature coefficient of crystals to count the pulse signal, so the cycle until the counter 2 count to zero, stop the accumulative temperature register values, the value in temperature register at this time is the measured temperature. The slope accumulator is used to compensate for and correct nonlinearity in temperature measurement and its output is used to correct the preset value of counter 1.

Turbidity module. The dichromate method was used for measurement. The principle is as follows: in acidic medium, potassium dichromate is used as oxidant, silver sulfate as catalyst, mercury sulfate as masking agent for chloride ion, and sulfuric acid acidity of digestion reaction solution is 9 mol/L. Heat causes the digestion solution to boil. After water cooling and reflux heating reaction for 2 h, and natural cooling of the digestion solution, the remaining potassium dichromate was titrated with ammonium ferrous sulfate solution as an indicator, and the COD value of the water sample was calculated according to the consumption of ammonium ferrous sulfate solution. See FIG. 2-9.



Physical picture of 2-9 GE-TS turbidity sensor

Technical parameters:

(1) Working voltage: DC 5V

(2) Working current: 30mA (MAX)

(3) Response time: <500ms

(4) insulation resistance: 100 m Ω (Min)

The dichromate method was used for measurement. The principle is as follows: in acidic medium, potassium dichromate is used as oxidant, silver sulfate as catalyst, mercury sulfate as masking agent for chloride ion, and sulfuric acid acidity of digestion reaction solution is 9 mol/L. Heat causes the digestion solution to boil. After water cooling and reflux heating reaction for 2 h, and natural cooling of the digestion solution, the remaining potassium dichromate was titrated with ammonium ferrous sulfate solution as an indicator, and the COD value of the water sample was calculated according to the consumption of ammonium ferrous sulfate solution.

Due to very high COD detection requirements, it cannot be configured in ZigBee network terminal nodes. In this paper, COD is the data obtained through the professional operation of chemical instruments. In the chemical laboratory, the dichromate method was used to collect different water quality samples around the campus for measurement.

2.4. Software design of ZigBee based regional water quality monitoring system The

water quality monitoring system consists of upper computer and lower computer software. The upper computer software can realize the data display and processing, storage, alarm and other functions. The lower computer software is ZigBee coordinator, router and terminal node software. The lower computer software is used for ZigBee network configuration, data transmission between coordinator and terminal nodes, and sensor collection of water quality parameters and other functions.

2.4.1. Software development environment IAR Embedded Workbench

Lower computer software development is mainly based on IAR Embedded Workbench. Users can simulate various software environments without any hardware support. From this, we can learn and evaluate the functions and usage of IAR EWARM. The IAR software interface is shown in Figure 2-10.

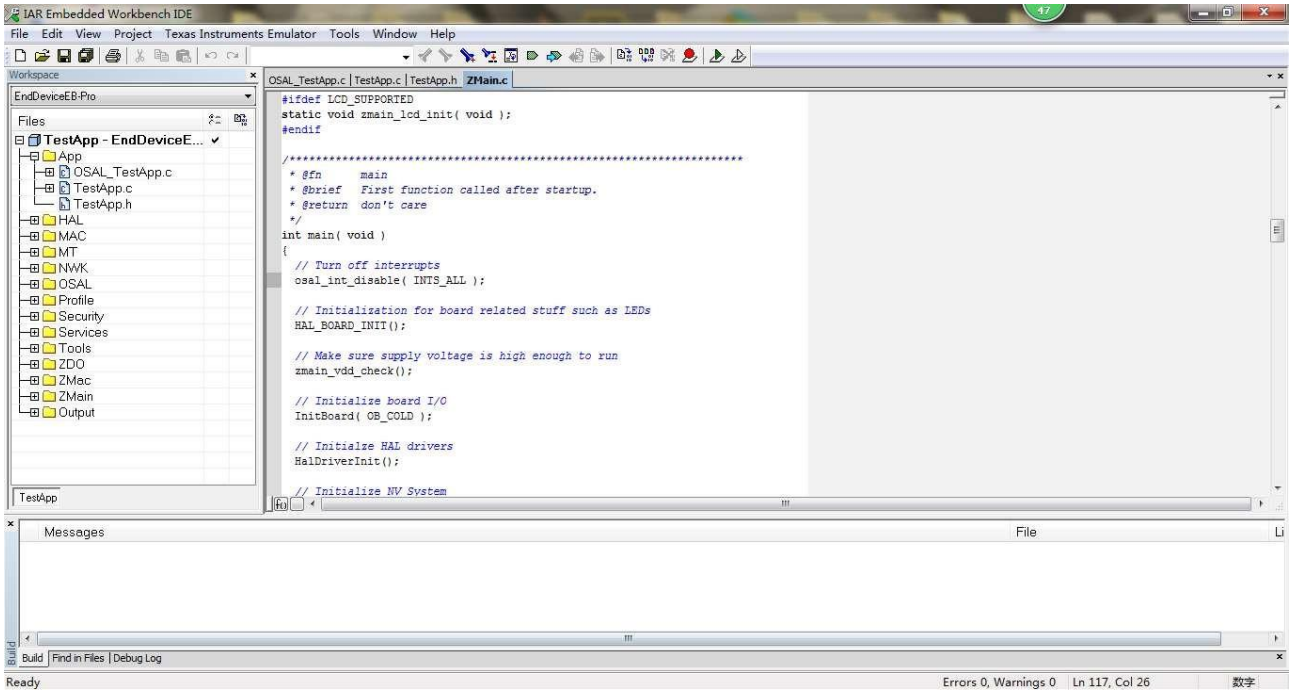


Figure 2-10 IAR software interface diagram

(1) Highly optimized IAR ARM C/C++ Compiler
(2) IAR XAR and XLIB library builder and IAR DLIB C/C++ runtime
(3) Powerful editor
(4) Project Manager
(5) Command-line utilities

2.4.2. ZigBee Protocol Z-Stack Protocol STACK

Each layer of the ZigBee stack has many primitive operations to perform, so there are many concurrent operations to perform across the stack. Each layer of the stack has an event handler designed to handle the various events associated with the layer's operations. Manage by the OSAL in ZigBee stack. In this way, the entire stack will proceed in chronological order.

Z-stack is started by the main () function. The first is the system initialization, the second is to start to execute the rotary query operating system, the initial systematic process is shown in Figure 2-11.

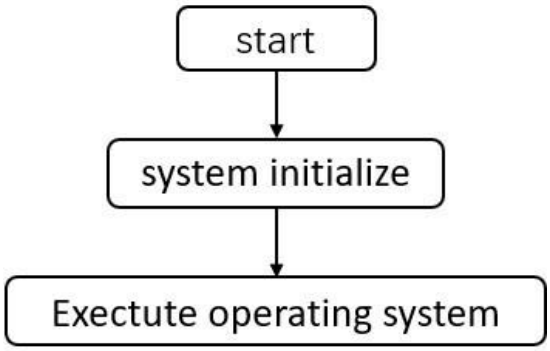


Figure 2-11. Initial systematization flow chart

The operating system in Z-Stack is a rotary query operating system. The program structure block diagram is shown in Figure 2-12.

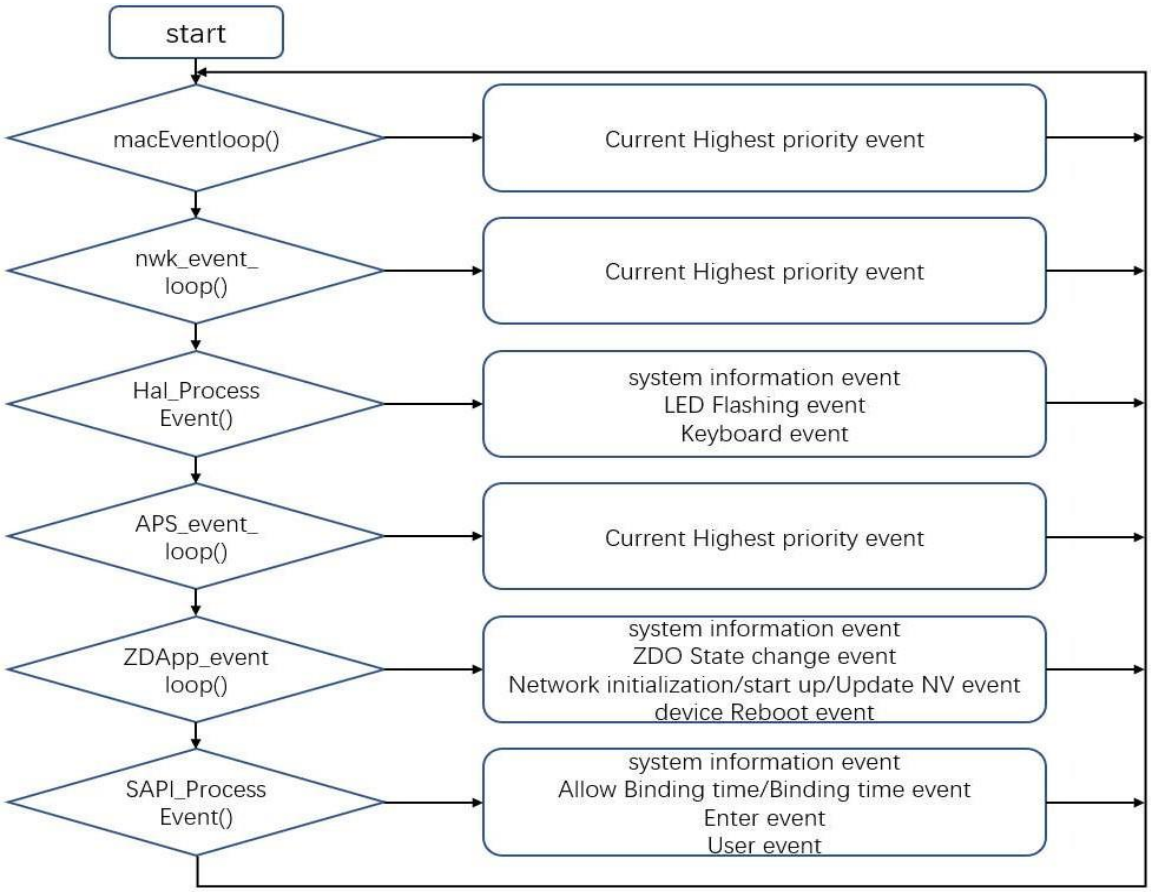


Figure 2-12 Flow chart of rotary query operation

The terminal node is directly in contact with the monitored water body, which is also the starting point for collecting water quality parameters. The terminal node only has the function of sending and receiving data. Through software design, the sleep function can be realized, which greatly reduces the consumption of the whole system. The terminal node program block diagram is shown in Figure 2-13.

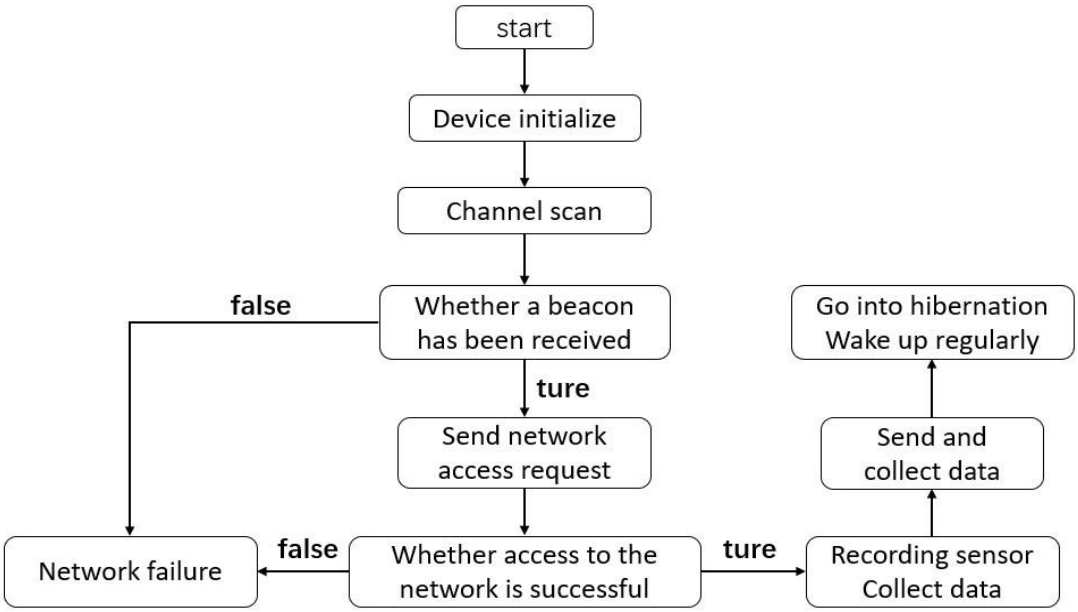


Figure 2-13 Terminal node block diagram

The program of terminal node mainly realizes two functions. The first function is to achieve the sensor data acquisition, the second function is to achieve network communication.

The coordinator node has the highest permissions in the ZigBee network. After the coordinator node starts, it is responsible for setting up the network to allow binding and receiving and sending data. Its program flow is shown in Figure 2-14.

As can be seen from Figure 5-5, after successful networking, the coordinator begins to send channel information and enters the listening mode. When other nodes send network access request to be listened, it will send the network address automatically allocated to the node. If a data request

Figure 2-14 ZigBee coordinator node program flow chart

2.5. Design of login interface

LabVIEW is a program development environment developed by National Instruments (NI). LabVIEW uses graphical editing language G to write programs, and the generated programs are in the form of block diagrams. LabVIEW software is the core of the NI design platform, and it is also an ideal choice for developing measurement or control systems. This article uses LabVIEW software to realize the water quality parameter processing, storage, alarm and other functions on the PC side.

2.5.1. Design of login interface and User management

The user enters the login interface through the account password. When the login succeeds, the border will prompt flashing.

Figure 2-15 Login interface

The user management interface can add or delete and query user information to manage the status of people logging into the remote monitoring system. The front and rear panels are shown in Figure 5-7. Figure 5-7 User management back panel Figure 2-16 User management back panel

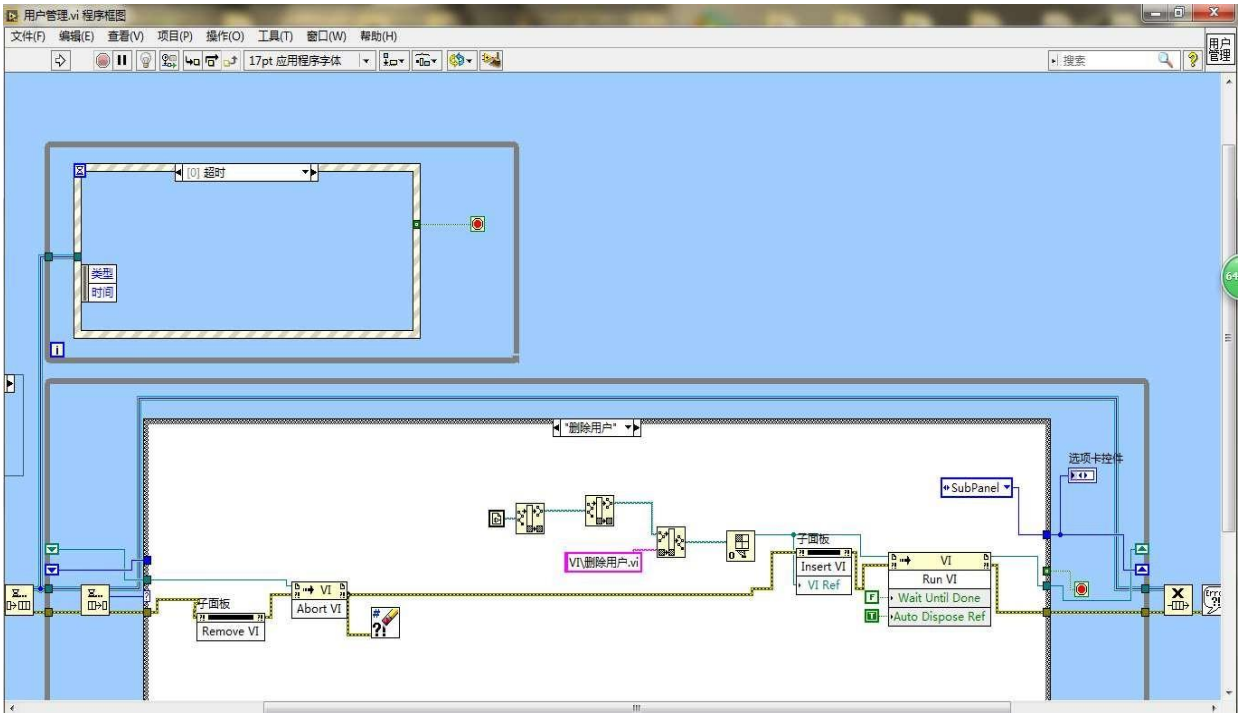


Figure 2-16 User management back panel

2.5.2. Interface of water quality monitoring system and Data saving

The data detection interface shows the current measured temperature and turbidity. When the temperature and turbidity exceed the set value, an alarm will be issued. See Figure 2-17.

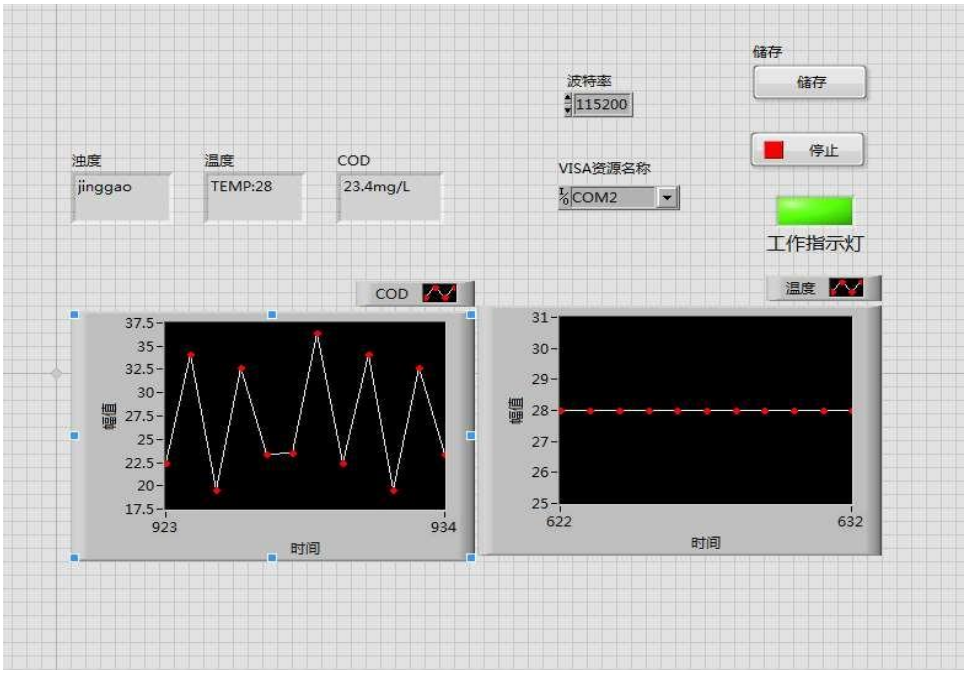


Figure 2-17 Data detection interface

When the test data (turbidity, temperature, COD) is constantly updated, the data of nearly lost of time can be saved into the previously set document file through the storage function, and historical data can be viewed at any time. See Figure 2-18.

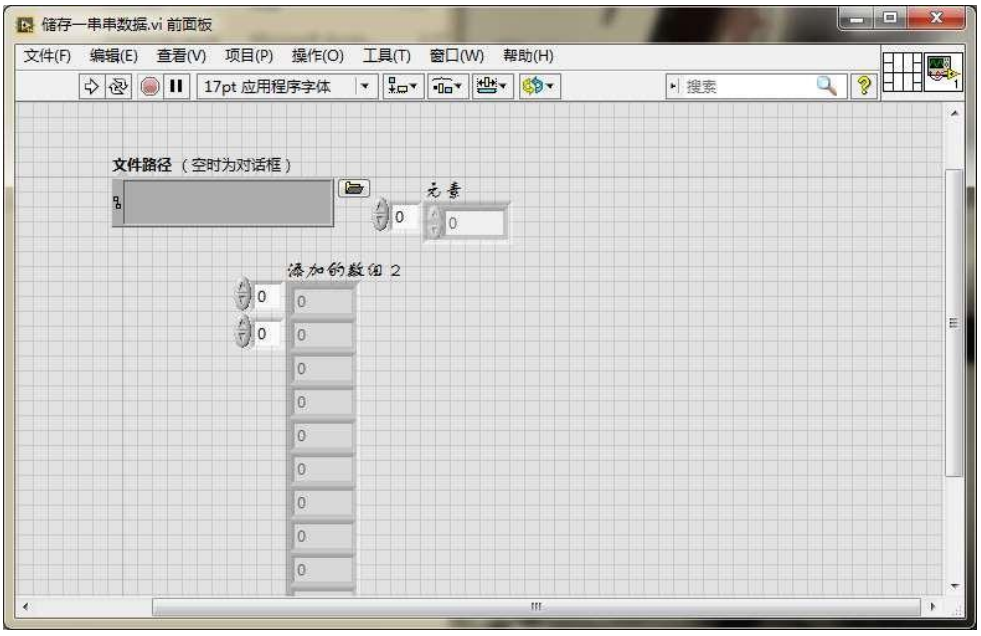


Figure 2-18 Data saving interface

2.6. System overall debugging

2.6.1. Hardware Testing

The ZigBee module used in this paper is mainly composed of two structures: one is composed of the main chip CC2530 and the antenna, and the other is some peripheral circuits on the bottom plate, including serial port, keypad, LED and program debugging module, etc. See Figure 2-19.

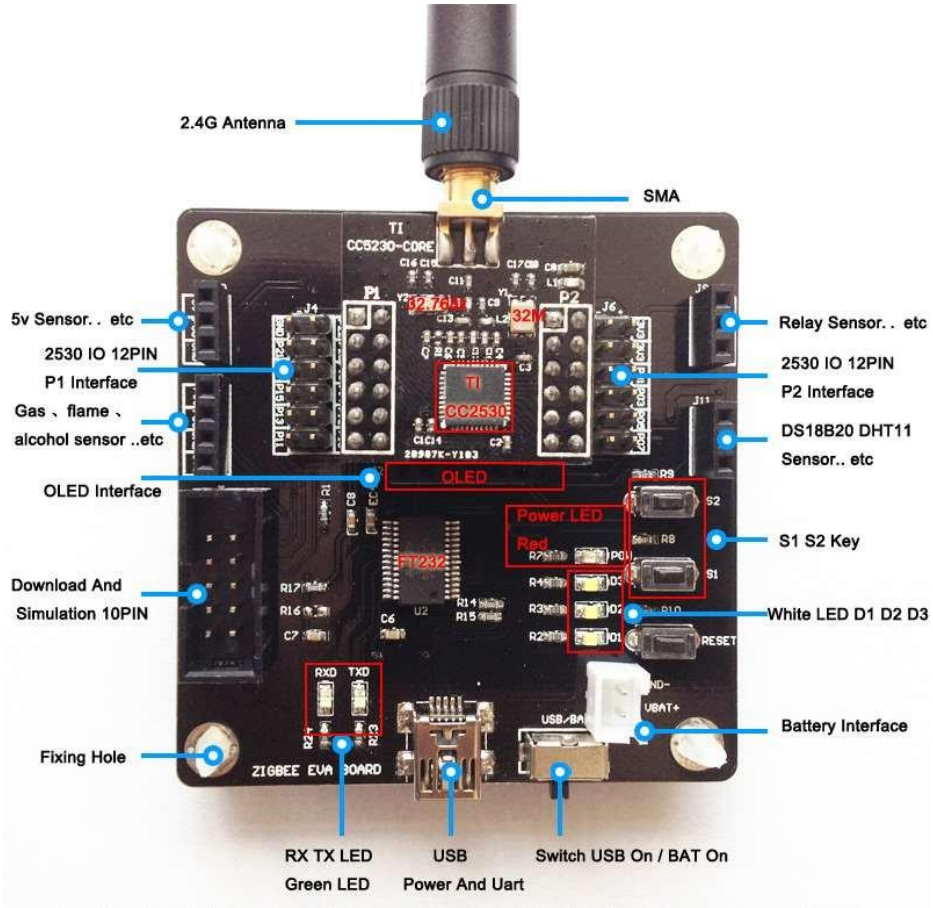


Figure 2-19 Physical picture of ZigBee module

2.6.2. Sensor debugging

The turbidity sensor used in this design. Before testing, the sensor is placed in a turbidity standard solution with a threshold set. Then, samples to be tested for water quality will be taken. If the turbidity of samples exceeds the set threshold, the ZigBee terminal node will send alarm information, which will be transmitted by the coordinator to the remote monitoring system for warning information.

Special water thermometer and DS18B20 temperature sensor were used to measure the water temperature of the same sample in different time, and the results were shown in Table 2-20.

Table 2-20 Comparison of water temperature measurement

Water thermometer test temperature (℃)	24	22	23	25	24	24	21	23	20
Sensor test temperature (℃)	23	22	22	26	25	24	22	22	19
Relative error (%)	4.2	0	4.3	4.0	4.2	0	4.8	4.3	5.0

Through the experimental comparison, it can be seen that the DS18B20 temperature sensor has a good performance, and the data measured by the water thermometer is not far from the same. For more accurate data, the data can be averaged every five times and recorded.

Chemical oxygen demand was determined by potassium dichromate method. In a strongly acidic solution, excess potassium dichromate standard solution is added for heated reflux. The reducing substance (mainly organic matter) in the water sample was oxidized, the excess potassium dichromate was used as indicator, and the standard solution of ferrous ammonium sulfate was dropped back. The cod of the water sample is calculated based on the amount of potassium dichromate standard solution consumed. The test results are shown in Table 2-21

Table 2-21 COD test data

Test COD Sample 1 (mg/L)	156.8	177.8	168.5	178.3	143.1	153.4	163.7
Test COD Sample 2 (mg/L)	245.8	220.6	256.9	248.7	237.8	250.7	254.3
Test COD Sample 3 (mg/L)	423.5	445.7	396.7	412.4	424.6	438.7	430.5

2.6.3. Networking test

The networking test is mainly to confirm whether the network can be established, whether the water quality parameter information can be sent smoothly, and whether the data is correct. First, the program is downloaded to the coordinator node and the terminal node respectively through IAR software, and then the power is switched on. The coordinator starts to set up the network. After the terminal node is successfully connected to the network, the coordinator and the terminal start to conduct point-to-point communication. After the terminal node is connected to the network, the coordinator will receive a message from the terminal node, indicating that the network has been successfully established. As shown in Figure 2-22, the coordinator displays "KO", which is set in the terminal node program.

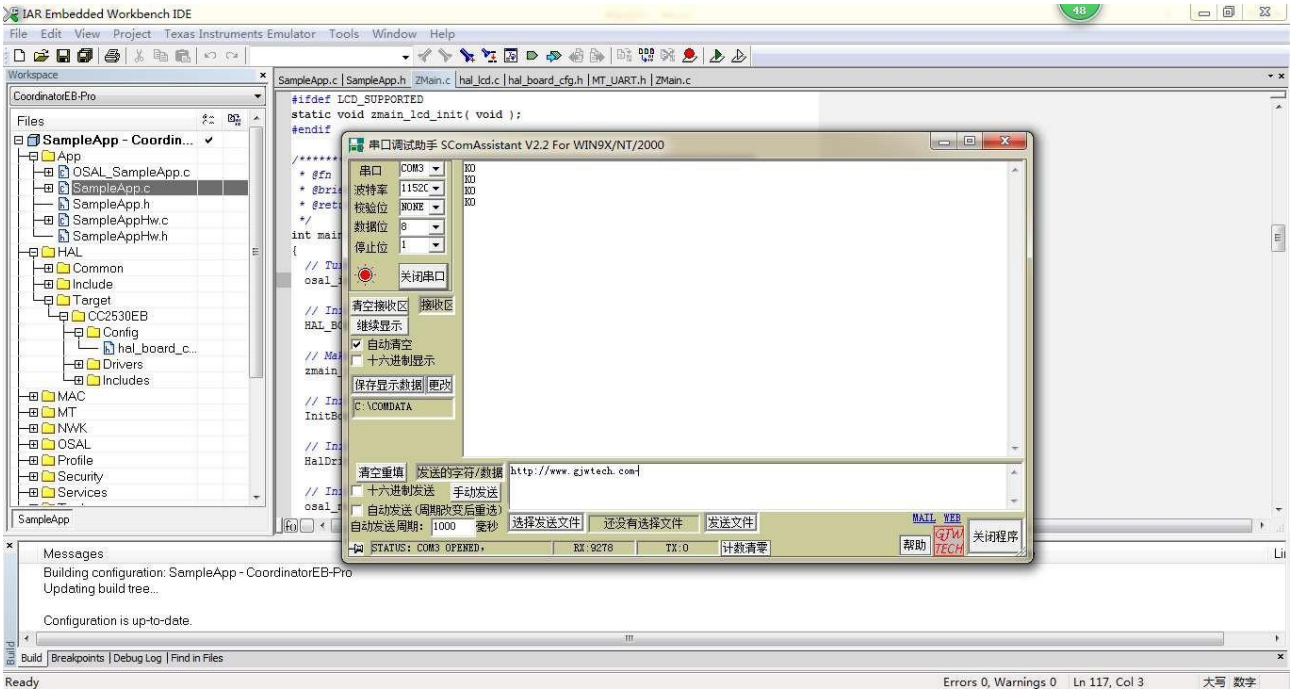


Figure 2-22 Networking test experiment diagram

Figure 2-23 Overall physical connection diagram of the system

After the whole Zigbee network is successfully built, the corresponding sensor module will automatically detect the water quality parameters.The overall physical connection diagram of the system is shown in Figure 2-23.

The data display interface shows the real-time monitoring of turbidity, temperature and COD. By selecting serial port and adjusting baud rate, data can be displayed in real time in two display modes: digital quantity and chart. See Figure 2-24.

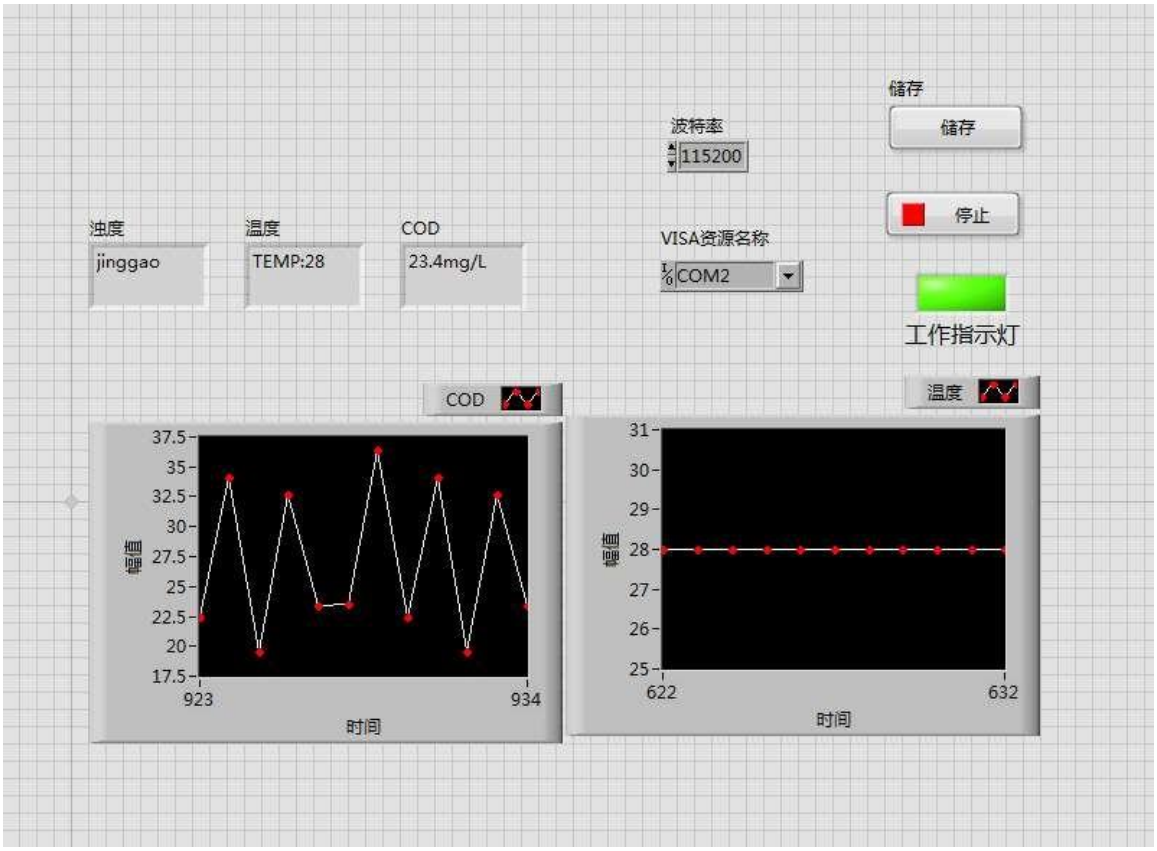


Figure 2-24 Data display interface

3. Summary

This paper first introduces the research status of water quality monitoring system and the development of wireless sensor network technology. This paper expounds the background and significance of this research, applies ZigBee wireless sensor network technology to the water quality monitoring system, and proposes a basic scheme for the water quality monitoring system based on ZigBee technology.

The main work completed in this paper:

(1) TI company's CC2530 chip was used as the main chip to complete the system's hardware and software design, including the design of other peripheral circuits, and the construction of the development environment. Through DS18B20 temperature sensor module, GE-TS turbidity sensor module and COD measurement device of relevant chemical laboratory, COD values of turbidity, temperature and water samples in campus area were collected respectively.

(2) The terminal node can accurately collect the temperature, turbidity and other parameters of the water sample, and the coordinator can realize the wireless transmission of the collected data, and timely upload the collected data to the computer terminal for accurate display.

(3) LabVIEW software was used to realize real-time data display and processing, data storage, user management and other related functions.

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