

Design of an Aquaculture Detection System Based on Internet of Things

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Abstract — In view of current problems in aquaculture water quality detection due to human judgment error, it is not possible to carry out remote monitoring and real-time control. In this paper we design an aquaculture detection system based on Internet of things, the system includes two parts of hardware and software. The hardware part is composed of ZigBee network nodes and ZigBee sensor network node. The software part include ZigBee protocol stack, ESP8266 program and android client. The ZigBee protocol stack and ESP8266 program were written in the C language, and android client was written in the JAVA language. By experimental verification, water quality information was sent by ZigBee sensor node to ZigBee network nodes, the data was transferred by network node through WiFi communication module to the Internet, water conditions were obtained in real-time by the android client through access to the Internet, and water quality parameters were adjusted through the client remote object to control water pumps, aerator, etc.

Keywords - internet of things; aquaculture; ZigBee protocol

I. INTRODUCTION

Aquaculture water quality monitoring has many characteristics, such as the number of monitoring points, the monitoring time is long, the situation is complex and so on. Traditional monitoring methods are mainly dependent on the experience of farming management, or using fixed time sampling and chemical analysis methods to obtain data [1]. The experience method is the artificial judgment, the error is big, the labor intensity is big and efficiency is low. Fixed time sampling and chemical analysis methods have shortcomings, such as lack of data samples, low real-time and so on, water quality control is difficult to achieve accurate and reliable, aquaculture production is not guaranteed [2]. Aquaculture can be combined with the Internet of things technology, a network structure model of intelligent aquaculture is constructed, which includes three levels of perception layer, network layer and application layer. Water quality environmental parameters online collection, wireless transmission, intelligent processing and other functions are realized, which supports remote automatic control. Farmers can master the real-time online aquaculture water quality environment information through mobile phones, browsers and other information terminals, It can automatically adjust the control equipment in real time, the goal of scientific management, green environmental protection, increase production and income in aquaculture can be realized.

II. KEY TECHNOLOGIES AND FEATURES

A. Composition and characteristics of Internet of things

The Internet of things are the things are linked into the network, it can be divided into three levels : perception layer, network layer, application layer. Perception layer is

the core of the Internet of things, it bears the function of information collection and control, it can be integrated with a variety of sensors, such as the detection of water temperature, water level, pH value, dissolved oxygen and other sensors. The information is transmitted by the network layer using 3G/4G, WiFi, ZigBee and other technologies, according to the corresponding agreement, the necessary connection of the object is connected with Internet, communication, data transmission is completed. Information is processed and sent by the application layer, the object recognition, positioning, tracking, monitoring and accurate management are implemented. The characteristics of the Internet of things [3] are:

(1) Overall perception, dynamic objects are collected at any time using radio frequency identification (RFID) technology, sensors, two-dimensional code and other kinds of sensing devices, the overall perception of the world.

(2) Reliable transmission, perceptual information is transmitted in real time to the use of the network (wired, wireless and mobile networks).

(3) Intelligent control, intelligent control and management are implemented on the object, communication between people and things is really up to.

B. Influence Parameters of Initial Stress Field of Bias Tunnel ZigBee protocol and features

ZigBee is a kind of network protocol, it is a kind of wireless ad hoc network communication technology. The word "ZigBee" comes from the "ZagZag" in the air when bees find pollen, that is the trajectory of the 8, the position, distance, direction and other information of the food are transmitted to the other partners. The word "ZigBee" is a very vivid word that reflects some of the important features of the network: Bee is a small animal, they can achieve the "wireless", the level of information

communication in a very simple way [4]. Specifically, the characteristics of the ZigBee network are:

(1) The data transmission rate is low. It is only 10kbps ~ 250kbps.

(2) Low power consumption. ZigBee device is only activated and sleep two states, and ZigBee network communication cycle number is less, the work cycle is shorter, therefore, the general two ordinary No.5 batteries can be used for more than 6 months.

(3) Low cost. Cost is greatly reduced due to the low ZigBee data rate and simple protocol.

(4) Network capacity. ZigBee can support the star line, family and mesh network structure, each ZigBee network can support 255 devices.

(5) Flexible working frequency bands. Unlicensed frequency bands can be used, such as 868MHz, 2.4GHz (Europe) and 915MHz (United States).

In addition to the above features, ZigBee network has other characteristics, such as high reliability, short delay, high security, flexible networking, etc.. It is constantly being developed in the field of low speed and near distance, various devices can be embedded, important role has been played in the Internet of things.

C. Wi-Fi technology

Wi-Fi, Chinese name is wireless fidelity, which is based on radio frequency signal, It is a technology that can connect devices (such as mobile phones, tablets, laptops, etc.) to send and receive data. The standard of the technology is held by the Wi-Fi alliance, which is based on the IEEE 802.11 protocol, and the interconnection of the network protocols is implemented.

The characteristics of Wi-Fi technology are: data transmission rate is fast, the connection is convenient, the transmission distance is far. It changes the wired Internet to wireless Internet, it can be high-speed Internet access through mobile terminals, a large number of traffic costs can be saved. It is very suitable for public places and home office [5] because Wi-Fi does not have to consider wiring problems. And the emission power is low, it does not have to worry about the health of radiation.

Wi-Fi network is built to need AP and wireless network card, Wi-Fi is the access point of AP, generally refers to the access terminal, and the wireless network card is converted wired network into a wireless network and sent out. Local area network is established when the AP connected to the wireless network card, connected to the Internet can enjoy the ultimate experience of high-speed network. If the Wi-Fi module is installed on the TV, projectors and other devices, the mobile phone content can be sent to the big screen when the phone is connected, the conference office can be realized at any time.

III. DESIGN OF THE HARDWARE

A. The principle block diagram

The principle block diagram of aquaculture detection system is shown in figure 1, which is composed of two parts: field detection and remote monitoring.

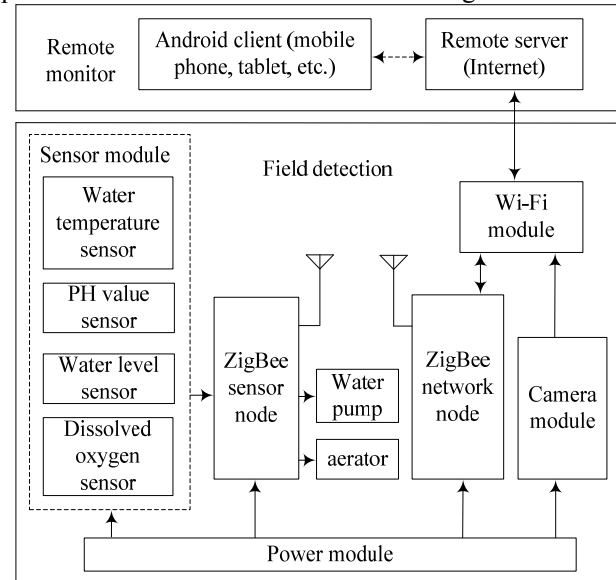


Figure1. The principle block diagram of aquaculture detection system

The field detection consists of the network sink node and the sensor node. Field detection can be achieved multi wireless intelligent node networking through the ZigBee technology [6-7], The water quality information is sent to the sink node, and the data is transmitted to the remote server through the Wi-Fi communication module. The function of field detection are:

(1)Detection: CC2530 chip is transmitted the collected data by the temperature sensor, water level sensor, pH value and other sensors to the remote server through the Wi-Fi module.

(2)Control: The relay is controlled by the control commands of the server issued , then the water pump, aerator, and other equipment is controlled by the CC2530 chip, so that the water quality parameters are adjusted.

Remote monitor is mainly composed of remote server and Android client. The remote monitor sends the data to the Android client, which is detected by the remote server, water quality can be queried by the user in real time. The user can remotely control the pump, aerator and other equipment to regulate water quality parameters by the client. The function of remote monitor are:

(1) Remote server functions: including data real-time monitoring, data storage, query and sending control instructions to the control mechanism, etc.. This part of the difficulty is how to achieve communication between the remote server and Android client, thus data wireless transceiver is implemented.

(2) Android client function: Android client is mainly used for communication between the remote server and Android tablet, Android mobile phone, etc.. Data wireless transmission, storage and related control instructions which are transmitted through the client to the control unit is realized.

B. ZigBee detection network sink node

ZigBee detection network is based on the CC2530 module as the core, it is connected to the Wi-Fi module, LCD module, Wi-Fi video module and power module. Water quality information was issued by the receiving sensor nodes^[8-9], the water quality information and video information is uploaded to the Internet through Wi-Fi module. At the same time an Android client feedback command is received, the feedback command sent to the sensor nodes.

1)CC2530 module

CC2530 is a 51 core SOC chip which produced by TI, CC2530 is the most widely used one of the hardware platform in the ZigBee TI protocol stack bound. CC2530 chip integrates a 8051 MCU core and a realization of the 802.15.4 physical layer mapping unit^[10]. The circuit structure of the CC2530 module is shown in figure 2.

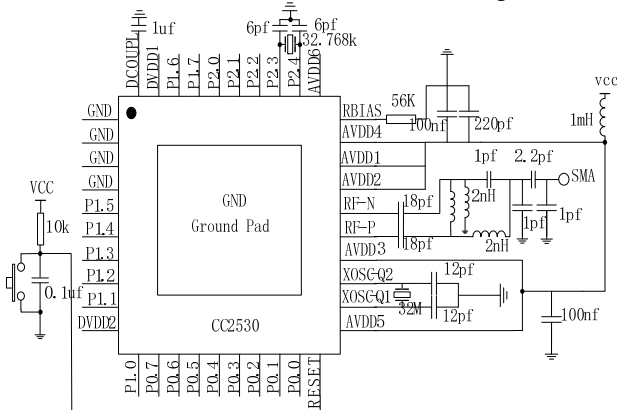


Figure 2. The circuit structure of the CC2530 module

① 8051 kernel: The 51 kernel of CC2530 has two very important features: A feature is a single cycle operation, that is: internal registers, SRAM and other access cycles is equal to the clock cycle, so CC2530 has a higher efficiency than the normal 51. Another feature is the debugging interface, it supports online debugging, great convenience is brought to the debugger, product development.

② More than one clock: CC2530 can be used as the system clock with 2 on-chip RC oscillator, the nominal oscillation frequency is 32kHz and 32MHz. It also supports 2 chip crystal oscillator as the clock, frequencies are 32MHz and 32.768kHz. The internal RC oscillator can be calibrated based on an external crystal oscillator. The purpose of setting a plurality of clocks is to control the power consumption effectively, and the various application requirements of the users are satisfied.

③ I/O controller: The CC2530 I/O controller has properties that control all common I/O pins. CPU can be assigned to the I/O module or the software through the I/O controller, such as software control, it can be configured as input / output, or pull up or pull down. Each I/O pin can be configured independently of the interrupt. Special note is that each of the on-chip modules connected to the I/O pin can be selected for different I/O pin positions.

④ Timer: CC2530 chip was set up three timers, of which Timer2, Timer1are common register. Timer 2 is a specially designed MAC and supports IEEE802.15.4 timer, its overflow counter is 24 bits, and its capture register number is as high as 40, the timing requirements of time slot protocol is needed to be fully satisfied. Sleep timer is an ultra low-power timer, its input is 32K 32K crystal or on-chip RC oscillator. It is usually used as a wake-up timer, that is, the CC2530 is jumped out from the low power mode 1 or 2.

⑤ ADC: ADC resolution of CC2530 chip is adjustable 7-12, the rate is 30kHz-4kHz, which contains eight channels. The input is either single ended or differential selectable, which can be an internal reference voltage AVDD or an external signal. ADC has a separate temperature sensor input channel.

⑥ AES Co processor: AES co processor of CC2530 chip can be support 128 bit secret key encryption algorithm AES, the required AES operation of the MAC IEEE802.15.4 layer or a wireless local area network is completely satisfied.

⑦ RF transceiver: CC2530 is set up with a wireless transceiver compatible with IEEE802.15.4, radio frequency kernel control module is simulated. In addition, it provides a single chip, it can be interface with the wireless device, the wireless device can be issued commands, state reading, automatic operation and determine the order. At the same time, the wireless device also includes a data filtering and address recognition module.

2)Wi-Fi module

The Wi-Fi module uses the ESP8266 module, the Wi-Fi module circuit diagram is shown in figure 3.

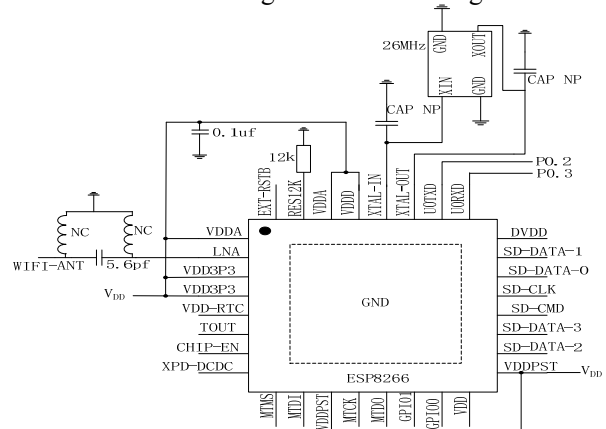


Figure 2. The Wi-Fi module circuit diagram

ESP8266 is a complete and self-contained Wi-Fi network solution, it can be run independently, but also can be used as a slave to run from the other host. ESP8266 can be started directly from the external flash memory when it is equipped with applications and is used as the only application processor in the device. Built in cache is beneficial to improve system performance and reduce memory requirements. The other case is that it can be added to any design based on the microprocessor when the wireless internet access is assumed to be the task of the Wi-Fi adapter, the connection is simple and easy to operate only through the SPI/SDIO interface or the AHB bridge interface of the central processing unit. Its internal firmware is based on the LWIP protocol, it supports AP, STA, AP+STA three modes and has a simple and efficient AT instructions.

3) Liquid crystal display module

Liquid crystal display module connection circuit diagram is shown in figure 4.

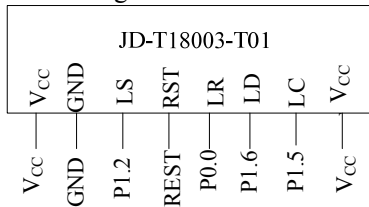


Figure 4. Liquid crystal display module connection circuit diagram

1.8 inch TFT color LCD screen is used in the network node, the model is JD-T18003-T01. TFT color LCD screen is a thin film transistor display, it has a light path from the bottom and is provided with a special liquid crystal light tube, the purpose of the display is realized by shading and light transmission, the response time can be increased to about 80 ms. Its contrast is higher than TN - LCD and has a more rich color, screen update frequency is faster, so TFT is commonly known as "true color".

Color TFT liquid crystal display effect is exquisite, the color is gorgeous, so it is popular with the majority of users. I/O resources of CC2530 are considered limited, SPI interface of the color TFT LCD screen can be selected as the display device of sink node, its internal driver chip is ST7735S, the resolution is 128 x 160, the display color is 262K, backlight mode is LED WHITE, the rated current is 1mA, the display effect is good.

4) Camera

YHS-113 camera of the small ant company is used, the camera pixel is 10 million, the maximum resolution is 1280x720. The schematic diagram of the YHS-113 camera is shown in Figure 5, 5V power supply is used in the camera, video information can be sent directly to the Internet through the connection Wi-Fi, pond water situation can be viewed through the mobile phone to visit Android client, pond surrounding information is timely grasp.

5) Design of power supply circuit

Due to the low power consumption of the ZigBee system, the 5V power supply is used in the camera module, 3.3V power supply is used in the ZigBee module, WiFi chip and LCD display. 5V charging treasure is used in the entire system to power, And the power supply of the ZigBee module, WiFi chip and the display are converted 5V to 3.3V through the AMS1117 voltage regulator chip, design of the power circuit is shown in Figure 6.

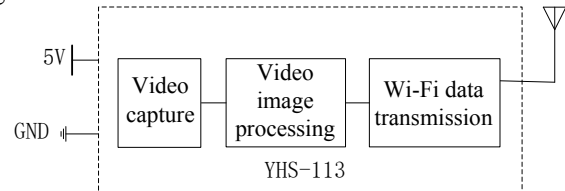


Figure 5. The schematic diagram of the YHS-113 camera

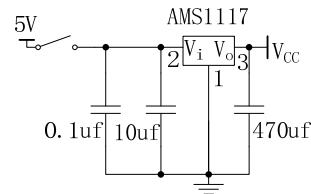


Figure 6. The power circuit

C. ZigBee sensor node

The node of ZigBee sensor integrated temperature sensor, pH sensor, water level sensor, dissolved oxygen sensor, etc., and is connected with relay to control the oxygen increasing machine, water pump, food machine, and so on. The circuit structure of the sensor node is shown in figure 7.

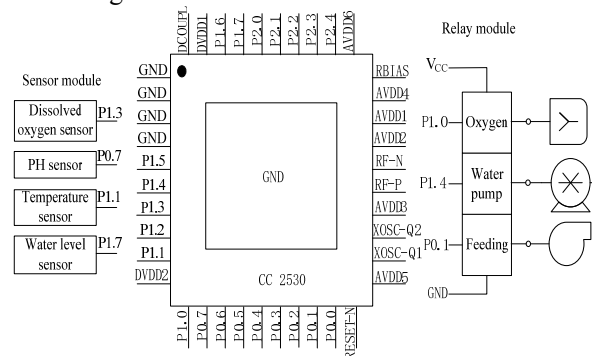


Figure 7. The circuit structure of the sensor node

1) Water temperature sensor

The water temperature sensor is selected to be water proof type DS18B20, and the temperature sensor DS18B20 output pin is output temperature signal reading temperature. Data bus hardware interface is very simple, DS18B20 only needs to be connected with a data I/O port of MCU [11]. DS18B20 connection diagram is shown in figure 8.

2) PH sensor

E-201-C PH sensor of Shanghai Leici company is adopted to detect the pH value, the sensor is compounded

by a PH glass electrode and a reference electrode, which is a pH meter sensor for measuring H (PH) concentration in aqueous solution and is widely used in various fields to be detected in PH^[12]. Its working environment is 5-40 degrees, relative humidity is less than 85%. The E-201-C electrode is a glass electrode, and the lower end of the electrode is a sensing film made of sodium glass with hydrogen function, and the shape is spherical. The principle of the work is that the reference solution and the measured solution are used to generate the voltage difference between the induced thin films In order to determine the pH value of the measured solution. PH sensor connection diagram is shown in figure 9.

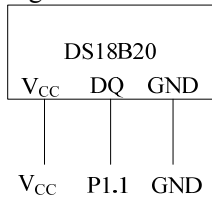


Figure 8. DS18B20 connection diagram

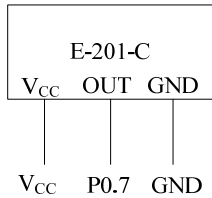


Figure 9. PH sensor connection diagram

3) Dissolved oxygen sensor

DO-957 dissolved oxygen electrode of Shanghai Leici company is used to detection of dissolved oxygen, it is a type of dissolved oxygen membrane electrode, the positive electrode is silver, and the cathode electrode is composed of platinum or gold, between the two is filled with electrolyte. Its characteristics is long life, the electrode response time is short, the working environment is 5 ~ 40 degrees, the measurement range is 0 ~ 20 (mg/L). The working principle is that the oxygen particles in the water reach the cathode surface through the film and was reduced by electrode, Oxygen particles are diffused to the surface of the cathode to overcome the resistance of the film, so the measurement of oxygen solubility is to measure the diffusion rate of oxygen particles. The connection diagram of the dissolved oxygen sensor is shown in figure 10.

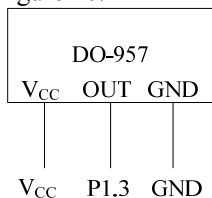


Figure 10. The connection diagram of the dissolved oxygen sensor

The output current formula of the dissolved oxygen sensor is:

$$I = NFA(P_m/d_m)P_0 \tag{1}$$

Formula type: I is the output current of the dissolved oxygen sensor, N is the number of electrons to be reduced, F is the Faraday constant, A is the cathode surface area, P_m is the thin film diffusion coefficient, d_m is the thickness of the film. P₀ is the partial pressure of oxygen in the liquid to be measured.

4) Water level sensor

Trace sensor is selected to detect the water level, the model is Water Sensor. The sensor is a simple and easy to use, cost-effective is higher, it is the water level / water drop identification sensor, the water level was determined by a series of parallel wire line trace measurements of water volume, water to analog signal conversion is completed, the analog value of the output can be read directly by the micro controller, and the effect of the water level alarm is achieved. The connection diagram of the water level sensor is shown in figure 11.

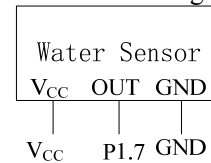


Figure 11. The connection diagram of the water level sensor

5) Control circuit

The relay is used in the control circuit to control the water pump, aerator and feeding machine (control function can be completed by the relay to control AC contactor for high-power electrical appliances). Relay control circuit is shown in figure 12.

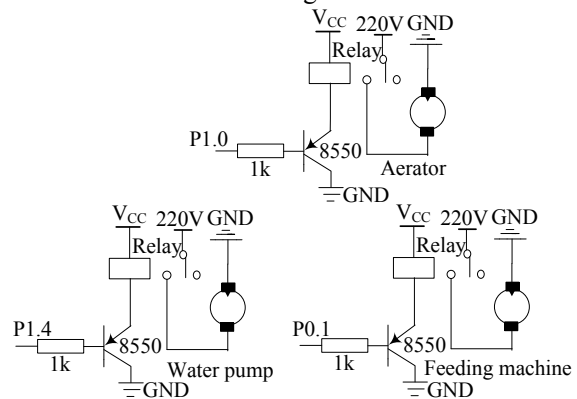


Figure 12. Relay control circuit

Because most of the integrated circuit power supply is 5V or 3.3V, and most of the electrical power supply is 220V, the relay can complete the function of small voltage control large voltage. Low level triggered electromagnetic relay is used in the control circuit, the PNP transistor emitter is turned on when the input of small voltage is low, the relay coil connected to the emitter is flowed through the current when the transistor is turned on, thus the electromagnetic effect has been produced, high voltage side switch iron is attracted by magnetic attraction and turned on the large voltage circuit. PNP transistor is cut off when the input is high, the circuit

current is zero and the magnetic force disappears, the large voltage circuit is cut off and the circuit of the small voltage control voltage is realized.

IV. DESIGN OF SOFTWARE

The design of the software is divided into three parts: the first is the data acquisition and feedback command processing based on the ZigBee protocol stack, the second is the configuration of the Wi-Fi module program, the third is the host computer software based on Android client.

A. ZigBee protocol stack program

Z-Stack is the free ZigBee protocol stack launched by the TI company, and its core is also given by the library file. ZigBee protocol stack is modified on the Z-Stack [13-14]. The basic workflow of Z-Stack application is shown in figure 13, first, the necessary initialization work is carried out, after the initial work is completed, the network node establishes the ZigBee gateway and the sensor node joins the gateway. Data acquisition, transmission and processing of the next instruction is carried out when the program enters the sensor node.

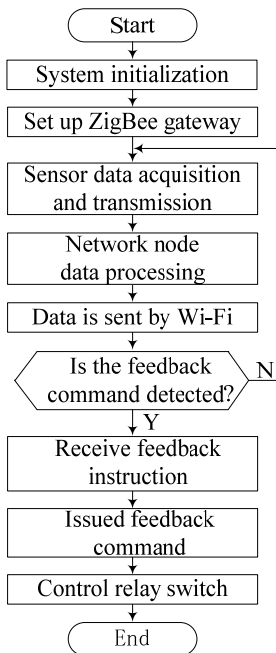


Figure 13. The basic workflow of Z-Stack application

B. Wi-Fi subroutine

The collected data is uploaded to the Internet via Wi-Fi module ESP8266 by the ZigBee network node [15]. Wi-Fi subroutine flow chart is shown in figure 14. First, the Wi-Fi module is initialized, and then the work mode is set to AP+STA and the router is connected. Finally, the data is sent and received.

C. Android client software

The Android system is an open source operating system based on Linux and JAVA, "Android" in the mainland of China is being used by more and more people. Android

operating system was originally developed by Rubin Andy, the first mobile phone is mainly supported. 2005 Android system was acquired by Google, and the open mobile phone alliance was set up to develop and improve, it is gradually extended to the tablet PC and other fields [16]. The idea of the mobile terminal Android program is that the sensor state is timed query after the ESP8266 module access to the internet, the corresponding instructions are issued by the Wi-Fi network to the device when required to control the device. Android client program flow is shown in figure 15.

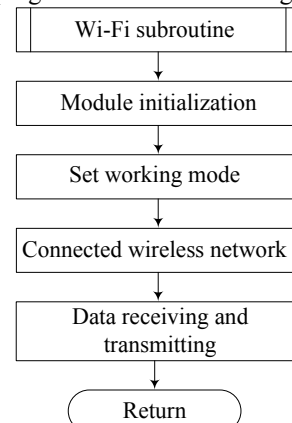


Figure 14. Wi-Fi subroutine flow chart

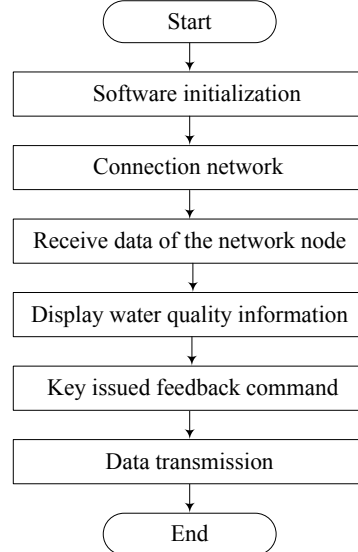


Figure 15. Android client program flow

ZigBee protocol stack program and WiFi configuration subroutine is written by the C language according to the flow chart, The program is compiled in the IAR development environment of C language, compiled by the when compiling and running interface display 0 warnings and zero error, the program can be is downloaded to the chip BW-CC2530M. The compilation is complete when the compiler operation interface display 0 warnings and 0 errors, the program can be downloaded to the BW-CC2530M chip. The program has been downloaded to the chip when the operation interface displays " configuration is up-to-date ".

Android client software is written using JAVA language according to the flow chart, and it is compiled in the Eclipse environment. Eclipse is a scalable and open source development platform based on Java. A framework and a set of service of development environments can be constructed by means of a plug-in component for Eclipse itself. Eclipse also comes with a standard set of plug-ins for Java development tools. Eclipse is a free cross platform integrated development environment (IDE). Different computer languages, C++, Python and other development tools can be supported by installing different Eclipse plug-ins, so that it can be used for the development of Java language. Although Eclipse was developed with the Java language, its use is not limited to the Java language, it can also support other programming languages such as PHP, COBOL, C /C++, Android plug-in [15]. APK files were generated and downloaded to the Android mobile phone after the completion of the compiler.

V. THE EXPERIMENTAL RESULTS

All the components are welded on the universal board, the sensor is connected to the gateway node and the sensor node, the sensors are placed in a simulated pond (a plastic container can be simulated), the production of the physical map is shown in figure 16.



Figure 16. The production of the physical map

IEEE relationship of ZigBee node was bound in the program, reset can not be rebound when the program is initialized, the name and password of the connection router are written in the ESP8266 initialization, which makes the router automatically connected after the boot. The working status of the gateway node is shown in Figure 17, the red indicator light and the display light show that the system is working properly. The " Rsp Sent " in the display screen indicates that the sensor node is connected to the network node . " Service IP:192.168.191.2 " indicates that the Wi-Fi module is connected to the router, and the IP address in the local area network is displayed. IEEE address is the IEEE address of the network node, ZigBee node to each node are bound through the IEEE address.

Because the network formed by the device access router is a local area network, if you want to carry on the remote monitoring, the local area network can not meet the requirements. Mobile client can access the router via

extranet, and only need to know the router IP, but if you want to direct access to the network server through the extranet, routers need to do certain settings. Access to the router IP is converted to the internal network IP access, the solution to this problem is to set up a virtual server.



Figure 17. The working status of the gateway node

Virtual server defines the mapping relationship between network ports and network server, all the accesses to the network router IP, if the port is the port of the server, access will be relocated to the IP address and port of virtual server specified. "Forwarding rule" is selected, the router management page is logged in, "virtual server" and "add a new entry" is selected to enter. The service port is filled with an infrequently used port number to avoid collision, such as 5555. The internal port is filled in the Wi-Fi module server port 5000, IP address is filled in the router assigned to the Wi-Fi module of the network address, where the network address is 192.168.191.2. All entries have the effect after save being selected, the virtual server is set up. The configuration of the virtual server is shown in figure 18.

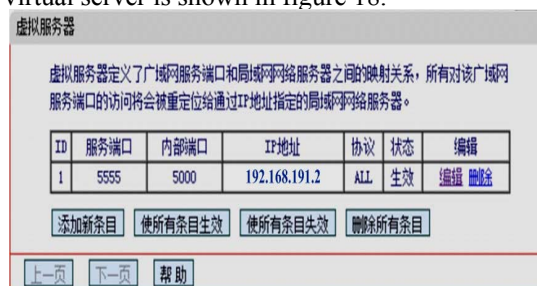


Figure 18. The configuration of the virtual server

Remote monitoring can be carried out through the extranet after the router is configured. Mobile client is turned on after the server IP and port are configured, the triangle run button of below is clicked. Water quality parameters and video display is shown in figure 19, the current pond water quality situation is displayed in real time by its Android client, In figure 19: Figure (a) shows the water temperature is 22 degrees Celsius, pH value is 7, Figure (b) showed that the dissolved oxygen value is 21mg/L, the water level is 29cm, Figure (c) is a real-time video display of the network node, the image is the image of the sensor nodes are photographed by the camera.

When the aerator, water pump and a feeding button button when the button is pressed down in Android client,

the feedback command is given in the Android client diagram as shown in figure 20.

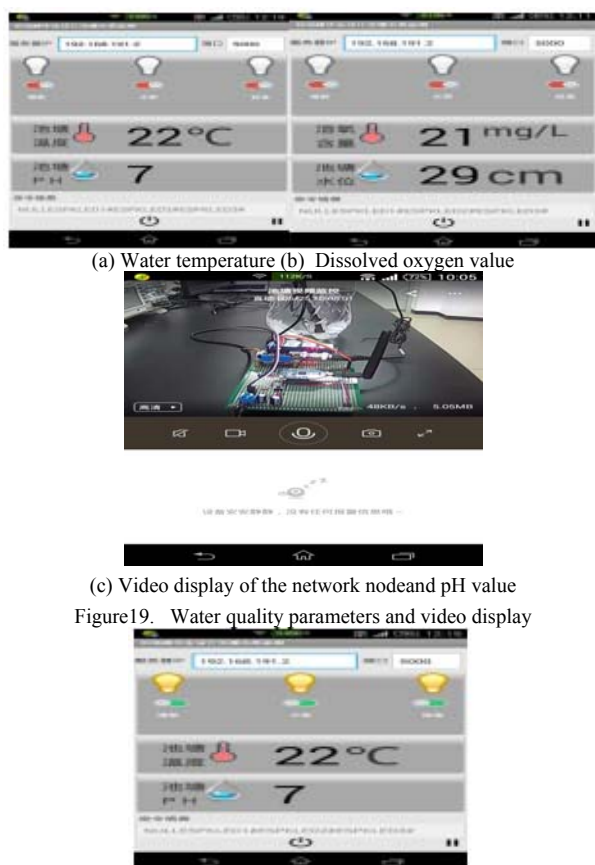


Figure 19. Water quality parameters and video display

The instruction received by the sensor node is shown in Figure 21, the relay indicating lamp of sensor node is lighted can be seen from figure 21, it shows that relay is conducted, and then it is controlled to open the oxygen increasing machine, water pump, cast food machine and other equipment.



Figure 21. The instruction received by the sensor node

VI. CONCLUSIONS

Internet of things aquaculture detection system is constructed in this paper, it includes network monitoring system, temperature sensor, pH value sensor, dissolved oxygen sensor, water level sensor, camera, etc., the

detection network is constructed by using ZigBee and Wi-Fi, the data upload and the next instruction can be carried out, the remote monitoring and real-time control of aquaculture is realized. The system is stable and the distance of the monitoring network is far. Wiring difficult problem of detection system in aquaculture, real time detection difficult problem of water quality information and remote regulation difficult problems of water quality have been solved [17]. In order to further expand the application, the solar power supply system can be used in the power part, the mobile 4G technology can be used in the data transmission part [18], and the independent microcontroller is increased to expand the I/O and memory.

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