Development and Practice of Mobile Internet Experimental Platform System

Yiqin Bao[1]*, Hao Zheng[1], Qiang Zhao[2]

[1] College of information engineering of Nanjing XiaoZhuang University, China
[2] Department of Information Systems Schulich School of Business, Canada
baoyiqin@njxzc.edu.cn, zhenghao@njxzc.edu.cn, Ryan.zhao@jmrex.com

Abstract

As an emerging technology, mobile Internet technology involves almost all knowledge points in the application field of computer science and technology. The traditional Internet of things experiment box based on embedded technology has single equipment and limited functions, which can not meet the experimental requirements of mobile Internet from data perception, transmission to application. Aiming at the lack or incompleteness of the experimental platform in mobile internet teaching, a set of mobile Internet experimental platform system is designed. The platform is built according to the three levels of perception layer, transmission layer and application layer, using ZigBee, Modbus, MQTT and other protocols, which fully reflects the characteristics of the Internet of things (IoT) and mobile Internet, and meets the students' mastery of mobile Internet knowledge. Through the design of 21 experimental projects, it meets the students' mastery of mobile Internet knowledge, and can also meet the requirements of on-line teaching when COVID-19 is popular. The system practice shows that compared with before the platform is implemented, it improves the teaching level of students' mastery of mobile Internet technology, and achieves a good purpose of experimental teaching.

Keywords: Mobile internet, MQTT, Modbus, IoT, ZigBee

1 Introduction

With the rapid development of information network technology and the wide popularization of mobile intelligent terminals, mobile Internet technology has been widely developed. In recent years, mobile Internet technology has developed rapidly. As of April 2014, the total number of mobile Internet users in China has reached 848 million, and the scale of mobile Internet users has reached 500 million, accounting for more than 50% of the total Internet users, exceeding the proportion of Internet access. The development of mobile Internet in China has entered the era of the whole people [1]. In January 2017, the general office of the CPC Central Committee and the general office of the State Council issued the opinions on promoting the healthy and orderly development of mobile Internet and issued a notice requiring all regions and departments to earnestly implement it in combination with reality. In order to ensure the healthy and orderly development of mobile Internet, talent team is the fundamental guarantee. Some studies show that in the next five years, Internet talent gap of China will reach about 10 million [2].

Mobile Internet technology as an emerging technology, many colleges and universities have set up this course. However, due to relatively few comprehensive design experiments, students' practical learning is relatively monotonous and lacks the embodiment of practical project application [3].

At present, relevant experimental platforms have been researched and developed. Zhao et al. [4] studied the Internet of things (IoT) comprehensive experimental system, Qu et al. [5] designed the computer hardware virtual simulation experimental platform, and Xi et al. [6] developed and practiced the experimental preview test system based on mobile Internet. Li et al. [7] engaged in experimental teaching research on MOCC (Make One Century Culture). Tsai et al. [8] improved students' interest in learning through flipping class. He et al. [9] conducted research on teaching mode exploration and practice. Podder et al. studied the security threat of IoT [10]. These studies, such as test system, MOCC teaching, flipped class and system security, all talk about the need to select a suitable teaching experimental platform to improve the teaching effect, but there is no mobile Internet experimental platform. Modbus is the most widely used protocol in industrial control networks [11-12]. Mqtt protocol is often used in wireless sensor networks [13-17]. Many mobile Internet applications at home and abroad are based on modus and mqtt protocols for data acquisition and communication [18-21].

Based on the above reasons, this paper designs the mobile interconnection experimental platform through ZigBee, Modbus, MQTT and other communication protocols, realizes the interconnection of Internet of things, cloud platform, intelligent terminal and WEB client, and uses the experimental project of mobile interconnection experimental platform to achieve good teaching effect.

The main contributions of this paper include three aspects:

1) From the perspective of enterprise application, the architecture of mobile Internet experimental platform is designed.

2) The interconnection of different components of the experimental platform is realized through ZigBee, Modbus, MQTT and other communication protocols.

3) Through 21 experimental projects, on-line and off-line experimental teaching is realized, and the teaching effects are analyzed and compared.

*Corresponding Author: Yiqin Bao; E-mail: baoyiqin@njxzc.edu.cn
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2 System Architecture

The research of the platform first needs the system architecture. Yang et al. [22] designed the protocol framework based on the IoT system, as shown in Figure 1. The protocols used include MQTT, COAP (Constrained Application Protocol) and Modbus TCP. The system is divided into four layers. The bottom layer is the protocol stack of the Internet of things system, and the top layer communication protocol is based on TCP or UDP to realize communication through IPv4 / IPv6.

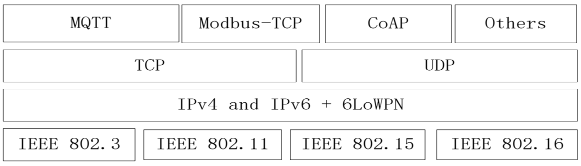

Figure 1. Protocol stack of the IoT system

However, from the perspective of enterprise applications, mobile interconnection technology involves more extensive areas of computer knowledge, including the interconnection between cloud platform, IoT and mobile terminals. According to these characteristics, the platform is structured according to three layers: perception layer, gateway layer and application layer. As shown in Figure 2, Layer 1: sensors, ZigBee terminals and ZigBee routers as the perception layer; Layer 2: ZigBee coordinator and gateway as gateway layer as middle layer; Layer 3: mobile terminal, cloud platform and WEB client as the application layer. In the overall architecture, A, G and F are ZigBee boards and CC2530 microprocessor is adopted; B is a gateway based on ARM, using Cortex-A53 processor; C is the WEB client, D is the mobile terminal, and E is the cloud platform server.

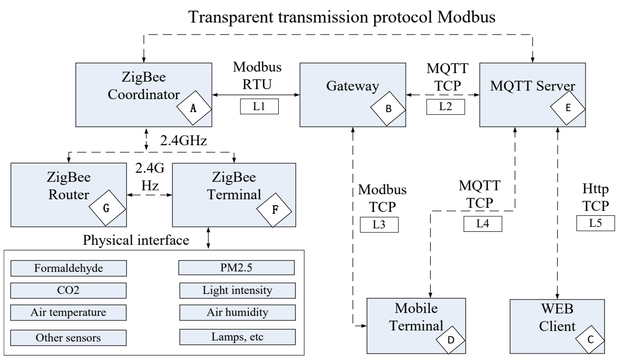

Figure 2. Architecture diagram of mobile Internet experimental platform

From the architecture of mobile Internet experimental platform, five interconnections are realized: 1) L1 realizes the interconnection between A and B through modus RTU protocol, 2) L2 realizes the interconnection between B and E through mqtt TCP protocol, 3) L3 realizes the interconnection between B and D through Modus TCP protocol, 4) L4 realizes the interconnection between D and E through MQTT TCP protocol, and 5) L5 realizes the interconnection between C and E through Http TCP protocol.

3 System Implementation

3.1 Implementation Method

The development of mobile Internet platform takes the gateway layer as the center, connects with the perception layer downward and the application layer upward. The interconnection of each part is the core of the whole system, as shown in Figure 3. The left * is the interconnection between the gateway layer and the perception layer, and the right * is the interconnection between the application layer and the gateway layer.

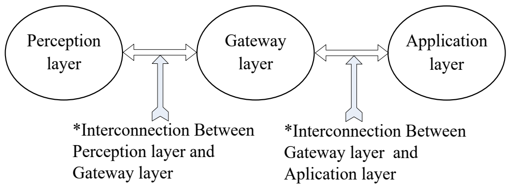

Figure 3. Key parts of mobile Internet experimental platform

Designing communication protocol well in interconnection is not only the key of the whole technology, but also the key and difficult point of developing application layer program. Learning interconnection technology is not only the ability of project engineering, but also the practical experience that college students must master in social practice.

3.2 Interconnection between Gateway Layer and Perception Layer

The interconnection between gateway layer and perception layer is the interconnection between gateway and ZigBee coordinator, which is connected through Modbus RTU protocol. As shown in Figure 2, L1 -- gateway and ZigBee coordinator.

3.2.1 Design of Perception Layer

The interconnection between gateway layer and perception layer is the interconnection between gateway and ZigBee coordinator, which is connected through modus RTU protocol. The sensing layer refers to the ZigBee sensing layer of the traditional Internet of things, including various sensors, ZigBee terminals and ZigBee routers. Sensors include formaldehyde, PM2.5, CO2, light intensity, temperature and humidity, digital display network instrument, 8 relays, etc. ZigBee terminal is a sensing node to collect sensor data in real time. The ZigBee module adopted is CC2530F256 chip, which is based on 2.4GHz IEEE802.15.4. ZigBee as an emerging technology of wireless sensor network (WSN), has a wide application prospect [23]. The sensing layer provides a data source for the mobile Internet experimental system. The chip and sensor models adopted are shown in Figure 4.

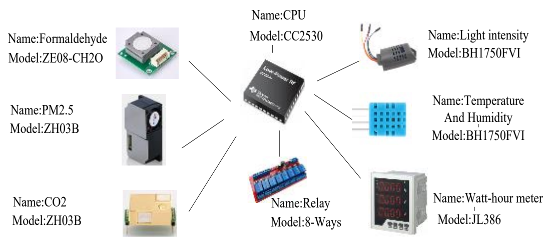

Figure 4. Chip and sensor models

3.2.2 Modbus Protocol

Modbus protocol is an international general industrial protocol with the characteristics of standard, open, free, simple, compact and easy to understand. It is the most widely used general protocol and is commonly used in the mobile interconnection of the Internet of things [24]. It can be divided into Modbus RTU and Modbus TCP according to different hardware interfaces. Modbus RTU generally adopts serial port RS232 or RS485 / 422, while Modbus TCP generally adopts Ethernet port.

The Modbus protocol frame format is shown in Table 1. The order of register transfer is high and low. When devices communicate on the network, they should know their device addresses. The range of address codes is 1 ~ 247, and 0 is the broadcast address. For the communication mode, the baud rate is set to 9600, the data bit is 8, the check bit is None, and the stop bit is 1.

Table 1. Modbus frame format

Address	Function Code	Data Area	CRC Check
1Byte	1Byte	nByte	2Byte

The function codes supported in the protocol are shown in Table 2.

Table 2. Function code definition

Function code	Definition content	Operation (binary)
01	Read switch output	Read switch state output data
02	Read switch input	Read switch state inputdata
03	Read register	Read one or more register
05	Write switch output	Control one relay “on / off”
06	Write one register	Write one register
10	Write more register	Write more register
FF	Function Err	Return Err。

The corresponding register addresses of the six sensors in the mobile Internet platform are shown in Table 3.

Table 3. Register address allocation table

Register address	Length (bytes)	Register content
0001	2	Formaldehyde data
0002	2	PM2.5 data
0003	2	CO2 data
0004	2	Light intensity data
0005	2	Temperature data
0006	2	Humidity data

3.2.3 Interconnection between Gateway Layer and Perception Layer

Because the connection between the perception layer and the gateway layer uses RS232 interface, Modbus RTU protocol is adopted between A and B. The essence of Modbus RTU and Modbus TCP protocols is Modbus protocol. The communication commands (binary commands) are as follows:

01050000FF008C3A

Message meaning: Turn on the light with address 0.

In addition, Modbus TCP and Modbus RTU protocols are very similar, as long as five zeros and one length are added in front of RTU protocol, and then the check code of the last two bytes is removed.

3.3 Interconnection between Application Layer and Gateway Layer

The application layer includes mobile devices, cloud platforms and WEB clients. As shown in Figure 2, there are four interconnections between the application layer and the gateway layer: 1) L2 -- gateway and cloud platform, 2) L3 -- mobile terminal and gateway, 3) L4 -- mobile terminal and cloud platform, 4) L5 -- WEB client and cloud platform.

3.3.1 Design of Gateway Layer

Raspberry PI 3B (RPB) is used for gateway selection. RPB is a mini computer motherboard based on ARM. The CPU adopts ARM Cortex-A53 chip. It supports Linux Android and other systems. It can be regarded as a lightweight server. The schematic diagram of the core board interface is shown in Figure 5.

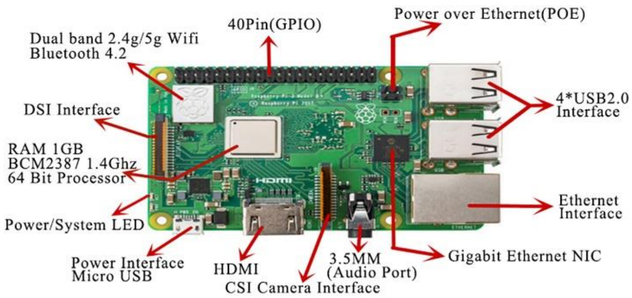

Figure 5. Core board interface diagram

The gateway adopts Android Things, which is an operating system for IoT devices on the basis of native Android. Since Android things itself is a Linux system, it is relatively stable, and provides turnkey hardware SOM solution. The gateway software adopts Android studio, the version is SDK10, and is developed in Java language. The content includes main functional modules such as real-time school environment monitoring, real-time power detection, intelligent control, gateway system setting, gateway log query, etc. the functional module block diagram is shown in Figure 6.

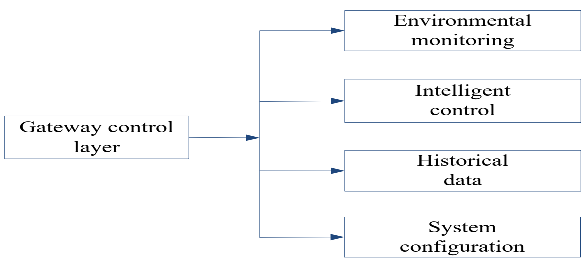

Figure 6. Main functions of gateway

3.3.2 MQTT Protocol

(1) MQTT

MQTT was originally developed by IBM as a communication protocol for telemedicine services. It is widely used in IoT because of its simplicity, specification, low overhead and easy implementation [25]. MQTT is a publish / subscribe based communication protocol, which can create and control the hierarchy of topics, or subscribe to multiple topics. In March 2013, OASIS announced that MQTT was the preferred standard for the emerging IoT messaging protocol. The model of MQTT protocol applied to the IoT [26], as shown in Figure 7.

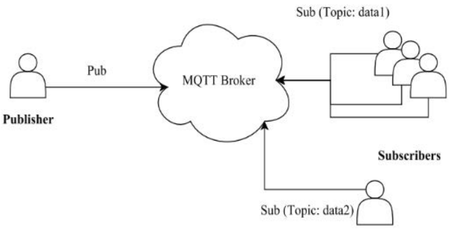

Figure 7. The data communication over MQTT protocol

The format of MQTT protocol frame is shown in Table 4.

Table 4. MQTT frame format

Control Header	Packet Length	Variable Length Header	Payload
1Byte	1 to 4 Bytes	0-Y Bytes	0-X Bytes

The type of MQTT protocol package [27], as shown in Table 5.

Table 5. MQTT packets type

Packets Type	Type Value	Details
CONNECT	0x01	Client request to connect to Server
CONNACK	0x02	Connect acknowledgment
PUBLISH	0x03	Publish message
PUBACK	0x04	Publish acknowledgment
PUBREC	0x05	Publish received (assured delivery part 1)
PUBREL	0x06	Publish received (assured delivery part 2)
PUBCOMP	0x07	Publish received (assured delivery part 3)
SUBSCRIBE	0x08	Client subscribe request
UNSUBSCRIBE	0x0a	Unsubscribe request
PINGREQ	0x0c	PING request
DISCONNECT	0x0e	Client is disconnecting

MQTT protocol only specifies the message format and does not limit the payload content and format of users. Therefore, we can customize the payload format. There are three options: 1) Hex / binary: no readability, but the flow control can be relatively small. 2) String: this will be easy to read, but it is still not the best choice. 3) JSON: key value pair, the hierarchy is concise and clear, which is easy to read and write. For these reasons, in the platform design, JSON format is selected and combined with Modbus to implement mobile interconnection.

(2) JSON

According to the characteristics of the project, Mobus and MQTT are combined, and the content of JSON format Modbus protocol is embedded in the payload of MQTT. When defining JSON key value pairs, two fields are designed: address field and data field (of course, it can be extended to include other fields), as shown in Table 6.

Table 6. JSON format

Key	Value
"gateAddr"	Address field
"gateData"	Data field

The address field refers to the address of the gateway, and the data field refers to the login / heart / MODBUS string, such as:

{"gateAddr":"000001","gateData":"01050000FF008C3A "}

Where: address field is "000001"; The data field is "01050000FF008C3A", which is a Modbus message.

3.3.3 Interconnection between Gateway and Cloud Platform

The gateway connects with the cloud platform MQTT broker through MQTT TCP and realizes the heartbeat function. B and E communicate and send and receive messages by subscribing and publishing titles. The three main commands are as follows:

Command of gateway connecting to cloud platform:

{"gateAddr":"000001","gateData":"login" }

Gateway heartbeat command:

{"gateAddr":"000001","gateData":" heart "}

Commands sent by gateway to cloud platform:

{"gateAddr":"000001","gateData":"20030C00E1002502 3800B100170025B219"}

JSON contains Modbus message, refer to Table 1 to Table 3. The parsing message is: the address is 0x20, the function code is 0x3, and the length is 12 bytes, Formaldehyde = 225.0, PM2.5 = 37, CO_2 = 568.0, light intensity = 177.0, temperature = 23.0, humidity = 37.0, and the CRC check code is B219.

3.3.4 Interconnection between Mobile Terminal and Gateway

The mobile terminal connects to the gateway locally through the socket and realizes communication through Modbus TCP. The communication commands (binary commands) between B and D are as follows:

00000000000601050000FF00

In the message, the first 5 bytes are 0, the sixth byte is length, followed by Modbus RTU message, but does not contain 2-byte CRC. The meaning of Modbus message is to turn on the lamp with address 0.

3.3.5 Interconnection between Mobile Terminal and Cloud Platform

The mobile terminal connects to the cloud platform MQTT broker through MQTT TCP, communicates between E and D, and receives and sends messages by subscribing and publishing headers. The JSON messages are as follows:

{"gateAddr":"000001","gateData":"01050000FF008C3A"}

The meaning of modus message is: turn on the light with address 0. A mobile phone MQTT test interface is shown in Figure 8:

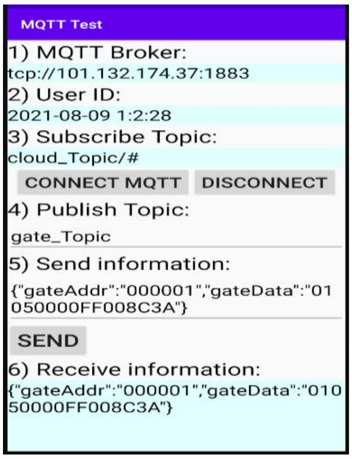

Figure 8. MQTT test interface

This is a general MQTT client mobile terminal program. You can see the whole interconnection process from interface No. 1) - 6) in Figure 8.

3.3.6 Interconnection between WEB Client and Cloud Platform

The cloud platform server and WEB client are developed using eclipse, MySQL database and spring MVC lightweight development framework. The WEB client is connected to the cloud platform through Http TCP, C and E communicate through accessing the cloud platform address: http://101.132.174.37:8080/Cloudserver/Jason/modsend, where 101.132.174.37 is the IP address of the cloud platform and 8080 is the port.

A control command is as follows:

{"gateAddr":"000001","gateData":"200300000006C79"}

Successful return:

{"success":true ,"result":{"gateAddr":"000001","gateData":"20030C00E10025023800B100170025B219"}

Failure Return:

{"success":false ,"result":false }

The returned data contains Modbus string, and the Modbus message contains sensor data.

4 Implementation Effect

4.1 Platform Operation Results

The mobile Internet platform system has been developed and used in the mobile internet course of the school of information engineering of Nanjing Xiaozhuang University. Through this platform, students can realize the acquisition and switch control of sensor data in three ways:

1) The mobile terminal is locally connected to the gateway, and the acquisition and switch control of sensors are realized through Modbus TCP; 2) The mobile terminal is remotely connected to the cloud platform through mqtt to realize acquisition and control; 3) The web client connects to the cloud platform remotely through Http TCP to realize collection and control.

Gateway is the middle layer of mobile Internet platform system. In order to facilitate the observation results during the experiment, it mainly realizes two visual interfaces:

1) The environmental monitoring interface, as shown in Figure 9, realizes the collection and data display of formaldehyde, PM2.5, CO2, light intensity, temperature, humidity and electric energy data.

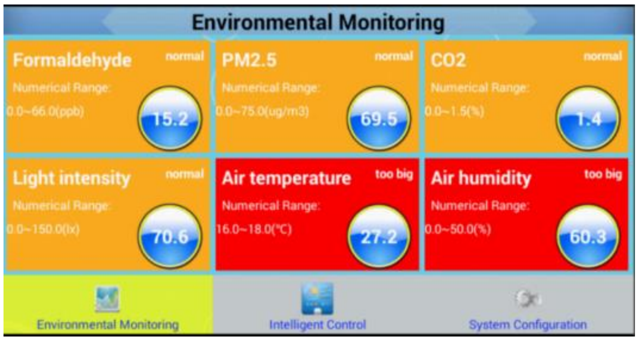

Figure 9. Gateway environmental monitoring main interface

2) The intelligent control interface, as shown in Figure 10, realizes the control and status display of air conditioning and other equipment.

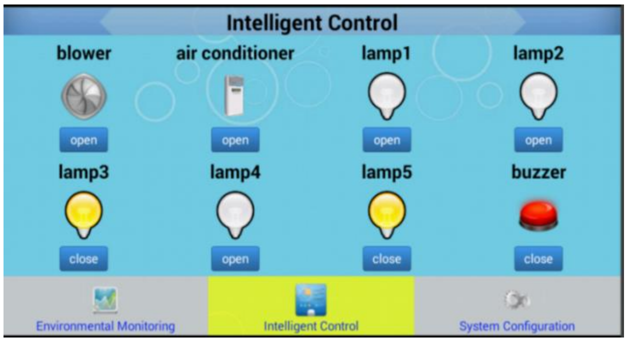

Figure 10. Gateway intelligent control main interface

Based on this platform system, 21 experimental projects are designed. When these projects are implemented, the operation results can be seen through the interface of the gateway, as shown in Figure 9 and Figure 10, so as to know the correctness of the experiment.

For example, a mobile APP program needs to be written. It is required to control lamp 3 and lamp 5 through mqtt combination.

Students do the experiment in six steps:

Step 1: learn and understand the system architecture, as shown in Figure 2. The communication link to be realized by app is shown in Figure 11.

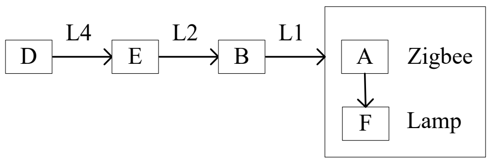

Figure 11. APP communication link diagram

Step 2: learn and understand MQTT and Modus protocols, see sections 3.1.2 and 3.2.2.

Step 3: learn the example program given by the teacher. The program interface is shown in Figure 8.

Step 4: use the switch control to write the APP.

Step 5: using APP, press the switch to control light 3 and light 5. Turn on light 3 and light 5 at the same time, the success can be verified through the gateway interface, as shown in Figure 10.

Step 6: finally, prepare the summary report.

4.2 Experimental Projects on the Platform

We design 21 experimental projects on the mobile Internet platform for students to learn and test: 1) 3 experimental project routines are designed. 2) 18 different types of experimental projects, divided into three types: a) 6 verification experimental projects; b) 6 design experimental projects; c) 6 comprehensive experimental projects, all of which are shown in Table 7.

Table 7. Mobile Internet experiment project

Type	Experiment project title
Sample experiment	S1: Temperature acquisition
	S2: Electric lamp control
	S3: MQTT Test
Validation experiment	V1: Formaldehyde acquisition
	V2: PM2.5 acquisition
	V3: CO2 acquisition
	V4: Light intensity acquisition
	V5: Humidity acquisition
	V6: Air conditioning control
Design experiment	D1: Combined electric lamp control
	D2: Formaldehyde curve acquisition
	D3: Intelligent control of air conditioner according to temperature
	D4: Intelligent control of electric lamp according to light intensity
	D5: Lamps are controlled by voice
	D6: Sensor data are acquired byvoice
Comprehensive experiment	C1: Intelligent Home Furnishing system
	C2: Street lamp control system based on Baidu map
	C3: Environmental monitoring system
	C4: Environmental monitoring system based on Baidu map
	C5: Energy consumption monitoring system
	C6: Campus intelligent environment and energy consumption monitoring system

The teacher takes the theoretical knowledge of mobile Internet and 3 experimental projects as input, and the students can do 18 experimental projects as the assessment of mastering the professional knowledge of mobile Internet. The input and output diagram of the experiment on the mobile Internet platform is shown in Figure 12.

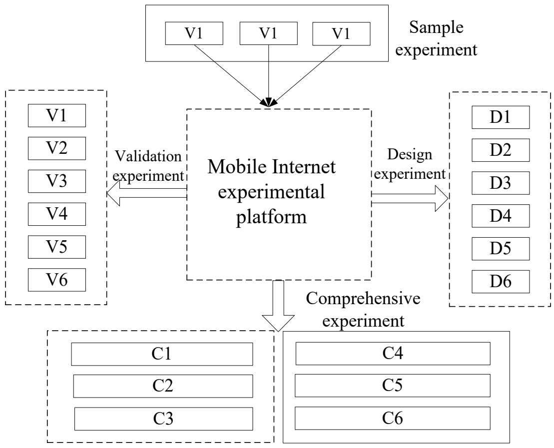

Figure 12. Input and output diagram of experimental items

4.3 On-line and Off-line Teaching Effect

University teaching is guided by students' ability and adopts the combination of process evaluation, stage evaluation and goal evaluation. However, at the time when COVID-19 is popular, students can only conduct students at home or in dormitories [28]. Therefore, on-line learning experiments are very important, and this platform can provide on-line and off-line teaching experiments, as shown in Figure 13, Through the study of the on-line experimental platform, students can remotely develop mobile terminal and WEB client projects, which exercise their ability. Teachers can evaluate the process through the submitted projects, so as to achieve a good teaching effect.

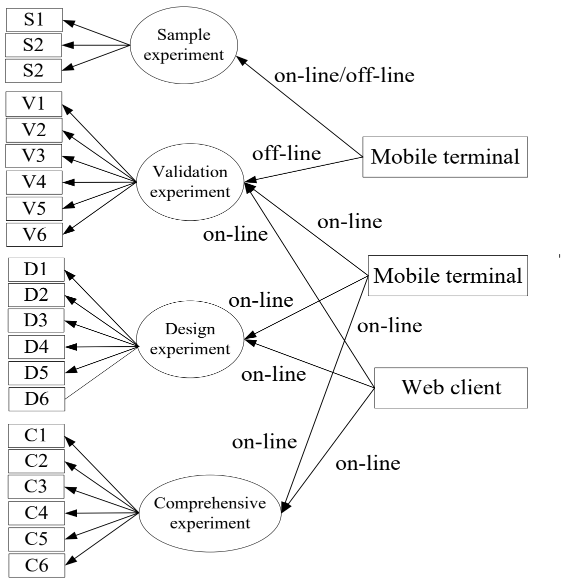

Figure 13. On-line and off-line experimental project

There are five main effects of on-line and off-line Teaching:

(1) Mastery of communication methods. Through learning, students can master the communication mode: socket TCP communication mode and Http TCP communication, and master the communication principle and communication programming.

(2) Mastery of communication protocols. Through learning, master Modbus, MQTT and other communication

protocols, and master communication protocol data analysis and CRC verification.

(3) Master the visualization of mobile interface. Master the use of girdview, switch, viewpage and other controls through learning.

(4) Cloud platform and WEB client. Through learning, master the use of database, transport layer interface, web service interface, mobile interface and multithreading.

(5) Mobile internet project experience. Through the practice of experimental projects, the ability of project organization and cooperation has been trained, and a large number of experience in basic experiments and comprehensive training projects have been accumulated.

4.4 Comparison and Analysis of Implementation Effect

This study selected undergraduates and took Nanjing Xiaozhuang University as the research object, including 104 boys and 206 girls. In the study, it was divided into three groups: 1) the platform group was not used, which was represented by A; 2) Use the Internet of things experimental platform group, represented by B; 3) Use the mobile Internet platform group, represented by C. The course assessment consists of three dimensions: a) mastering theoretical knowledge and scoring through the assessment; b) Master practical knowledge and score through the course; c) Graduation project, through the defense score. After two years of follow-up assessment, the final assessment comparison of mobile Internet specialty is shown in Table 8.

Table 8. Mobile internet assessment comparison table

Score	No platform (A)	IoT platform (B)	Mobile platform (C)
Theoretical	75.8	76.8	78.5
Practical	71.2	80.9	85.4
Graduation	75.6	82.7	86.3

Table 8 is drawn into a horizontal histogram, as shown in Figure 14. It can be seen that the teaching effect has been significantly improved from theoretical knowledge to practical ability, and the graduation design score has been increased from 75.6 and 82.7 to 86.3, which fully illustrates the teaching experimental effect of the mobile Internet platform.

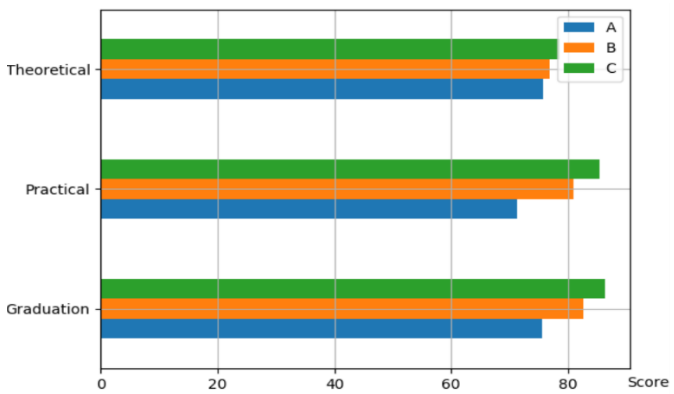

Figure 14. Mobile internet comparison histogram

5 Conclusion

The mobile interconnection experimental platform realizes the interconnection of the Internet of things, cloud platform, intelligent terminal and web client. Through the development and practice of the mobile interconnection experimental platform system, the practical teaching problems of mobile interconnection in computer science and technology, network engineering and software engineering are solved. Through a series of on-line and off-line experimental projects, it breaks through the constraints of experimental teaching in space and time, and enriches the means of experimental teaching.

Due to the continuous emergence of new mobile Internet technologies, the platform needs to be upgraded, which is also a problem to be solved in the future.

Acknowledgment

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Biographies

Yiqin Bao graduated from Nanjing University and is a senior engineering researcher. He is a professor of the Computer Science and Technology Department of Nanjing Xiaozhuang University. His research interests include Internet of things, mobile Internet. He has been awarded the two Nanjing science and technology progress awards.

Hao Zheng received the his PhD degree in pattern recognition and intelligence system from Nanjing University of Science and Technology in 2013. His research interests include pattern recognition, image processing, face recognition, facial expression recognition, computer vision.

Qiang Zhao is a distinguished professor of MBA data marketing course,He is employed by the international famous school of business of York University.In 2016, mainly focusing on jiudaomen brand,Including big data technology consulting service.