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Electrical Automation Intelligent Control System Based on Internet of Things Technology

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ABSTRACT

The aim of the study was to study the intelligent management of electrical automation through Internet platform. This article takes the example of smart home to analyze the current state of smart home, explores relevant technologies for smart home applications, and offers solutions. The results are as follows: the ZigBee gateway control model, consisting of the ARM9 S3C2440 and the wireless radio frequency chip CC2530, developed the ZigBee wireless star network structure and introduced the ZigBee regulator and terminal node control flow. A four-state switch that may be operated manually and automatically, that utilizes IoT, and that ultimately is in the off-mode state was devised and used in the proposed control system. The suggested model is an extremely dependable system that offers a practical and satisfying solution for electrical management in the agricultural, industrial, and home consumption sectors. To show how well the suggested control system works, the model is applied to a real-world case study. The design controls the sending and receiving of SMS with a global system for mobile communication module, has a remote control for opening and closing of smart home equipment and real-time alarm, and reduces the response time by about 60%. It has made a new attempt for the development of smart home market.

***Index Terms*—**Intelligent control, internet of things, smart home, ZigBee technology

I. INTRODUCTION

With the rapid development of Internet technology, the mysterious way of life has gradually taken off [1]. In essence, the Internet of Things (IoT) is a network composed of the Internet, communication network, and radio and television network used in people's daily life. At the same time, smart home uses IoT technology to control household items, which also promotes the development of IoT. Therefore, understanding the concepts of IoT and smart home system can further enhance the development of smart home based on IoT and then better realize the intelligent development of home [2]. As the comprehensive embodiment of electronic technology, computer technology. IoT technology is becoming more and more perfect and began to enter our home life in the way of smart home. As an infrastructure network in a dynamic environment, the IoT can classify items in the environment by using network application standards and communication protocols so as to integrate items with information network with specific identity [3].

The electrical automation system of building equipment can not only control the electrical equipment intelligently and automatically but also effectively save energy consumption. Building equipment electrical automation systems determines the current situation of energy consumption through intelligent means and optimizes the operation mode through intelligent means again, so as to achieve the purpose of energy-saving transformation. A large number of practical cases have proved that building equipment electrical automation systems can effectively reduce building energy consumption. Smart home is composed of various forms of household appliances and household devices in people's daily life [4]. In principle, the smart home based on the IoT is actually to connect the subsystems related to home life through the IoT so as to realize the exchange and communication of home information and to realize the intelligence of home [5]. It is not only the monitoring and management of simple television, refrigerator, lighting, access control, and other equipment but also the change of lifestyle. As a reflection of lifestyle changes,

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smart home system connects various controllable devices in the family through the network for centralized control and decentralized management, providing a more efficient management mode [6].

The automation of the process in a smart home scenario can be linked to the electricity management. Automation is one of the finest ways to achieve better quality while using fewer resources than manual testing. Many control and automation systems have been created and used up until this point using relays or other electrical components. It is imperative to take into account whether the chosen structure is the most cost-effective one before using an automation system. The chosen structure could occasionally be the best option given the circumstances, but, thanks to technological advancements like the IoT system, which is quick and can offer a better answer for automation processes, it is not always the case. Therefore, the best choices should be taken in the beginning to obtain the finest choice in order to use the most affordable control system. It is advisable to use programmable logic controls (PLC) in sizable industrial automation systems since they have more applications than other control systems and are more reliable. Programmable logic controls are programmable controllers. Logic, sequencing, and timing are common control functions that PLCs are used for. They are also used to monitor and manage facilities in sectors like transportation, telecommunications, water and waste management, and oil and gas refining. The IoT has advanced significantly in recent years and has started to be important in our daily lives. In agricultural and industrial production, many devices have been controlled using the Internet of Things. The latest progress shows that the control of the Internet of Things is more accurate and requires less labor and money [7, 8].

This study presents a novel intelligent control system for electrical management in smart home scenario that was recognized as practical design, development, and installation [9]. The major contribution is that this is the first experimental electrical management control system that uses the IoT in real-world applications. The IoT using SMS or ringtone is the foundation of the proposed intelligent control system. The rest of the manuscript is organized as follows. The most recent work in the field of smart home, agricultural, and several other electrical management using various technologies is studied and presented in Section II. The proposed adopted methodology and the overall design of a smart home system of electrical energy management is discussed in Section III. The experimental analysis is conducted in Section IV which is followed by the discussion and concluding remarks in Section V.

II. LITERATURE REVIEW

In recent years, the rapid development of the economy and technology has improved the living standards of the people. People hope to have a faster and more comfortable life, which gives birth to the rise and development of a smart home [10]. Smart home is an emerging technology and has gradually entered people's life. Smart home is the embodiment of IoT and networking. It takes the living house as the hardware platform, takes various functional equipment used in family life as the overall system, and uses computer, network communication, sensor, and embedded and other technologies to customize and manage according to individual needs, forming a unified and humanized interactive whole. Each of us will describe a different smart home, which not only brings us functional convenience and comfort but also makes our body and mind relaxed and comfortable. When we are not at home, we can use mobile phones and other mobile terminals to remotely monitor the operation status of the smart home system and the health status of pets at home. On the way home from work, you can set the opening of the rice cooker at home. When you get home, the smart home can automatically turn on the corridor light and start the access control detection. When you enter the home, you can close the curtains according to the intensity of the sun. In short, smart home is just right when it is needed. Such a home is not only a residence but also a tool to control various household appliances and also a partner to provide us with a comfortable life. With the blowout development of IoT technology in recent years, it has accelerated the renewal of smart home technology. In the future, people will realize these remote controls as naturally as breathing air [11].

The earliest smart home appeared in the "smart building" in Hartford, CT, in 1984. It only uses computers to carry out simple on–off control for air conditioning, elevator, and lighting, and since then, economically developed countries such as the USA, Canada, Britain, France, Germany, Australia, and Singapore have successively formulated their own smart home scheme standards, and the smart home market has also matured rapidly [12]. Taking the opportunity of digital home and digital technology transformation, Singapore launched a model intelligent system called "future home" in 1998. The functions of this intelligent system are relatively comprehensive, covering the functions of the smart home system. According to relevant surveys, more than 5000 families in about 30 communities in Singapore have applied the intelligent system [13]. South Korea uses 4A (any device, any service, anywhere, and anytime) to describe their smart home system, according to which the user can control and exchange information on the smart home system at anytime, anywhere, and in any way [14]. In Spain, the intelligent home system is upgraded in traditional European-style buildings. For example, when the indoor lighting is sufficient, the lighting will be automatically turned off. Weather sensing devices are installed outside the house to monitor the weather changes in real time and automatically turn off the windows and courtyard irrigation system [15]. Japan's smart home is a large-scale and collectivized development, design and construction, people-oriented, focus on function, and give consideration to future development and environmental protection [16]. On the basis of realizing ordinary home control, the smart home system created in Japan also makes full use of biometrics to control the access control system and collect health data. It only takes less than 1 s to confirm the identity of the visitor. By confirming the personnel, the access control system will automatically release. The toilet seat cushion is equipped with medical monitoring devices such as blood pressure and blood glucose. When people sit on it, they will automatically detect the physical parameters of their families. In addition, a weight meter is installed in front of the wash basin, so that people can measure their weight when washing their hands. The test results can be recorded and saved, which is convenient for synchronous detection of health status.

China's smart home market started late, but its development momentum is extremely rapid. The earliest smart home began in 1994. At that time, smart home technology had not been mentioned. At that time, most intelligent control systems depended on imports. With the emergence and gradual development of IoT technology, smart home, as the main application direction, has also developed rapidly. Various application directions of the IoT have entered the blowout period. Home appliance manufacturers and IoT technology research institutions have joined the research and development of the IoT system, and the research and development

of smart home system is naturally becoming more and more mature [17]. Since 2009, with the continuous support of the state for high-tech industries such as the IoT and the joint intervention of mobile communication and home appliance enterprises, the research and development (R&D) capacity of smart home system has been rapidly improved, and the scale has grown rapidly, mainly concentrated in the Middle East, coastal, and other economically developed areas. At present, Haier's u-home, Ziguang IOT, Wuxi's home cube, and Beijing's Dongyu intelligent have high market influence in the field of smart home, and each has its own advantages. For example, Haier's u-home advantage lies in its home appliance control, while other enterprises focus on developing lighting, curtains, and home safety monitoring [18]. After more than 10 years of exploration, the development of intelligent housing in China has reached 40 billion square meters, with an additional 30 billion square meters by 2020 [19]. In 2010, China's intelligent buildings reached 9000. The number of intelligent residential districts in China will reach tens of thousands in the next decade. In China's smart home industry, Beijing, Shanghai, and Shenzhen are relatively advanced in development. The smart home in Shenzhen has done a good job in wiring and has a strong foresight. It has considered the aspects of power supply, air conditioning, telephone, television, and network comprehensively, and the concept of embedded smart wiring is relatively advanced. Beijing's smart home has done better in considering functions and local styles. The urban planning and community layout of the new urban area of Pudong in Shanghai are more in line with the needs of a commercial metropolis like Shanghai [20].

III. RESEARCH METHODS

A. Overall Design of a Smart Home System

The general design scheme of a smart home control in this article is presented in Fig. 1.

In this paper, the smart home control system architecture includes three parts: perception layer node control, home gateway, and remote communication network. We focus on building the sensing layer node control and home gateway and use the embedded system to control the sensing node and ZigBee network module to build the home gateway to realize the indoor control platform design of smart home. The smart home perception layer network is controlled according to the functional modules, which is divided into six submodules: light sensing control, indoor temperature and humidity monitoring control, smart home appliance control, home intelligent alarm, intelligent nursing monitoring, and security system [21]. The function analysis of a smart home system is as follows:

1) *Light induction control:* The light sensor feeds back the data to the main control unit in real time according to the intensity of indoor light to control the opening and closing of curtains.
2) *Indoor temperature and humidity control:* Indoor temperature and humidity information is collected regularly through temperature and humidity sensors, which control the temperature rise and fall of indoor air conditioning after data exchange.
3) *Intelligent home appliance control:* The experimental lamp is used to replace the household appliance node, and the wireless network command is used to control the opening and closing of the lamp, so as to simulate the remote control of household appliances.
4) *Home intelligent alarm:* This alarm simulates when an emergency occurs at home, such as gas leakage or fire, uses smoke sensor for real-time monitoring and timely information feedback, and takes corresponding alarm measures in case of emergency.
5) *Intelligent nursing monitoring:* When there are patients at home, emergency communication channels should be reserved. In case of emergencies, you can call your family or the hospital directly through information.
6) *Security system:* Cameras and infrared sensors can be installed indoors and outdoors, which can monitor the situation of indoor and individual house dead corners in real time, ensure property safety, provide timely feedback, and deal with emergencies [22, 23].

B. System Hardware Design

The smart home system designed in this paper consists of lighting control, indoor temperature and humidity control, flame and harmful gas alarm control, smart home appliance control, security system design, nursing system design, and so on. A ZigBee wireless sensor network control and embedded system control are used. A ZigBee wireless network is used to collect indoor information on terminal nodes, such as temperature and humidity information, acoustooptic infrared information, harmful smoke concentration information, and so on, and transmit it to the coordinator, which transmits the information to the main processor. The main controller processes the information sent and parses the short message sent by the global system for mobile communication (GSM) module, which is displayed by a liquid crystal display (LCD). It can also return the processed information to the coordinator node, send it to the ZigBee terminal node, and execute. A ZigBee home wireless sensor network uses star network topology to connect the sensing nodes in the home to the embedded gateway. The user is displayed on the LCD through the operation interface to realize the remote control of household appliances and realize the decentralized management and centralized control of perception nodes within the family [24, 25]. Table I shows the hardware resources used in the design.

It can be seen from the previous introduction that the target value is obtained by collecting the current signal. Through sampling, we can know the current value. However, the specific relationship between

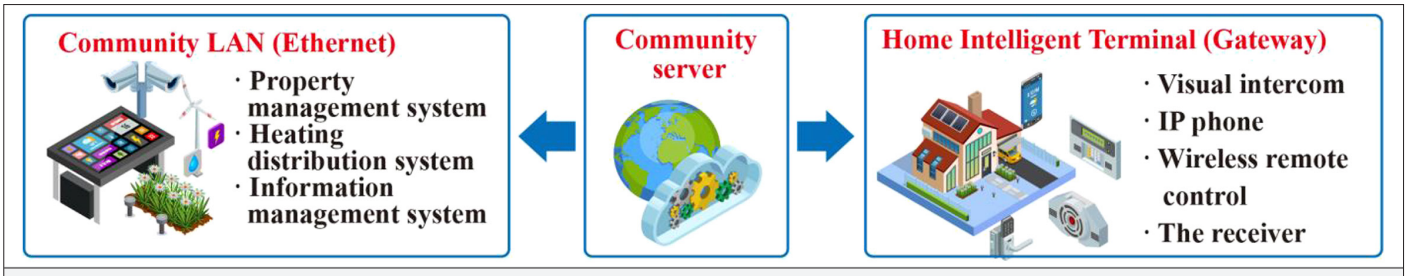

Fig. 1. Schematic diagram of smart home design scheme.

TABLE I. HARDWARE RESOURCES USED IN DESIGN

Hardware Name	Hardware Type
Embedded main controller	S3C2440 embedded control system
Light sensor	YL-38 photoresist sensor
Smoke sensor	MQ-2 smoke gas sensor
Infrared sensor	HC-SR501 human body infrared sensing module
Acoustooptic sensor	Pressure-sensitive buzzer
Flame sensor	YL-38 flame sensor
Temperature and humidity sensor	DHT11 digital temperature and humidity sensor
Patient control node	TC9012 infrared remote controller and PIC3388 infrared receiving probe
GSM module	SIM300
RFID access control node	RFID RC522 RF module
LCD display	7-h TFT LCD

GSM, global system for mobile communication; TFT, Thin Film Transistor; RFID, Radio Frequency Identification.

current and position can only be obtained through flow characteristics. Here, we only introduce one of the flow characteristics, the linear characteristic, and propose the formula method used in this paper [26].

Using this method, you must know the current sampling values of 4 mA and 20 mA and then obtain the current value according to (1).

$$\frac{(Value - Curr4\text{mA}\_\text{vlue})^{*}\left(\text{Max}\_u - \text{Min}\_u\text{A}\right.}{\left(Curr20\text{mA}\_\text{vlue} - Curr4\text{mA}\_\text{vlue}\right)} + \text{Min}\_u\text{A} \quad (1)$$

where $Value$ is the current sampling value, $Curr4\text{mA}\_\text{vlue}$ is the 4 mA current sampling value, $Curr20\text{mA}\_\text{vlue}$ is the 20mA current sampling value, Max_u is the 20 mA current, because the highest accuracy is uA and the value is 20 000, and Min_uA is the 4 mA current, because the accuracy is uA and the value is 4000

In order to get the state of the target value, we need to know the initial state $Start\_S$ and the end position End_S. For different systems, we need to obtain it through the self-tuning program. We can know how to get the corresponding current state through the beginning and end states of the system through (2) and (3).

$$\frac{\left(Cur - \text{Min}\_uA\right)*\left(\text{End}\_\text{S} - Start\_S\right)}{Max\_uA - Min\_uA} + Start\_S \quad (2)$$

$$\frac{(value - Curr\_4mA\_value)^{*}(End\_S - Start\_S)}{(\text{Curr\_20mA\_value} - \text{Curr\_4mA\_value})} + Start\_S \quad (3)$$

The target state can be obtained directly from the sampling value. The current situation of industrial control shows that more than 90% of the control loops adopt proportional-integral-differential (PID) control strategy. This paper uses incremental PID control, and its control principle is as follows. The better values of the static and dynamic characteristics of the system can be achieved by adjusting K_p, K_i, and K_d, as shown in (4).

$$\Delta u(k) = K_c\left\{\left[e(k) - e(k-1) + \frac{T_s}{T_i}e(k)\right] + \frac{T_d}{T_s}[e(k) - 2e(k-1) + e(k-2)\right\} \quad (4)$$

where,
$K_c = K_p$ is the sale factor, $K_i = \frac{K_c T_s}{T_i}$ is the integral coefficient, and $K_d = \frac{K_c T_d}{T_s}$ is the differential coefficient.

C. Software System Design

According to the overall design of the system, the smart home system in this paper uses embedded gateway control and ZigBee network communication technology. The data collected by ZigBee wireless network are transmitted to ZigBee coordinator in the form of a frame. The embedded gateway parses the ZigBee protocol frame through a serial port. Software development must understand the ZigBee development process and embedded development process. In this paper, the embedded main control chip needs to establish a connection with the ZigBee device coordinator and establish communication with the GSM module. The LCD needs to use the application program to display all kinds of information. These are realized through embedded system operating parts. In this paper, Linux operating system is selected as the mainstream operating control system of IoT smart home technology. At present, the mainstream embedded software needs to be customized by targeted user equipment in order to meet its control requirements. Therefore, this smart home design of IoT has learned the development process of embedded system and completed the relevant embedded software design according to the software requirements. The embedded software system theory involved is introduced below. Fig. 2 shows the embedded software architecture with an operating system. This paper will design the software according to the structure shown in this figure.

As shown in Fig. 2, the hardware driver layer is the necessary driver protocol in the embedded system hardware. Generally, the embedded system hardware is composed of an embedded processor (or embedded minimum system board), an external memory, a keyboard, an external display, an external expansion interface circuit, and other equipment. The hardware driver layer is directly related to the hardware. The hardware driver support required by the upper software is a necessary part of every embedded system. Its purpose is to establish a reliable path for the upper software to communicate with the hardware, and the peripheral input and output devices can interconnect information through the operation interface protocol. For this design, the hardware driver layer can be directly obtained from relevant technical materials and driver websites, as long as the software can call the information transmitted by the interface.

D. ZigBee Software Design

This paper uses ZigBee networking and adopts a star network structure. Among the 16 channels of ZigBee network coordinator, the appropriate channel is used to establish the network and select a network identifier for the network. After the network is established, users can apply to join the network through terminal nodes, and the coordinator will automatically assign the network address. After the coordinator establishes the network, it can enter

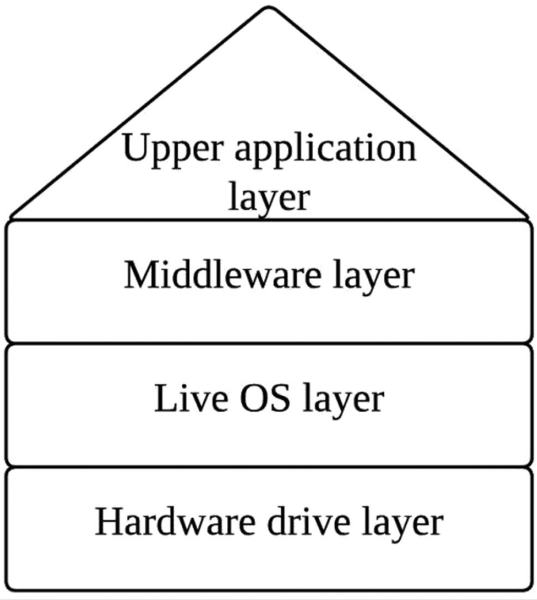

Fig. 2. Embedded software architecture.

the operating system abstract layer (OSAL) task polling operation to monitor each task. When it reaches the mark position, it will execute the corresponding task. The main tasks of OASL in this design are monitoring serial port status information and monitoring network wireless status information. When the transmission of control information is detected, the control information is encapsulated into a communication frame and sent to the terminal node, and the control actuator performs corresponding operations to realize lighting control, smoke detection, buzzer alarm, and other operations. If there is a wireless signal input, the coordinator will analyze the wireless communication frame and transmit the data to the gateway. The gateway will transmit the information to the LCD display or send it to the mobile phone in the form of information, as shown in Figs 3 and 4.

IV. RESULT ANALYSIS

A. Actual System Commissioning

This article covers smart home remote controls that can simulate the state control of household appliances by controlling touch nodes such as lights, smoke alarms, and infrared alarms and by controlling the LED light status on ZigBee nodes. The results of the experimental section are presented in Table II.

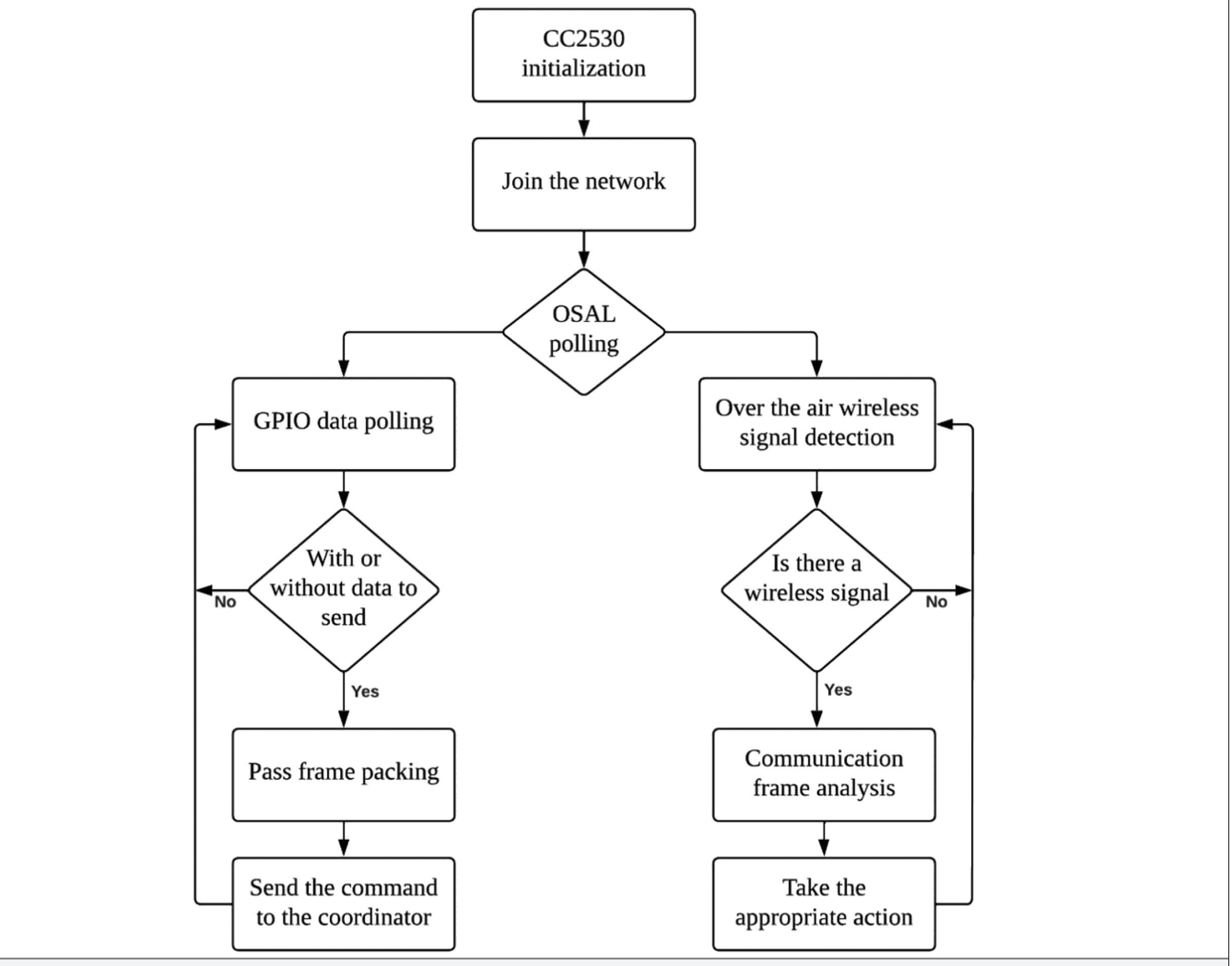

Fig. 3. Software development process of a ZigBee coordinator.

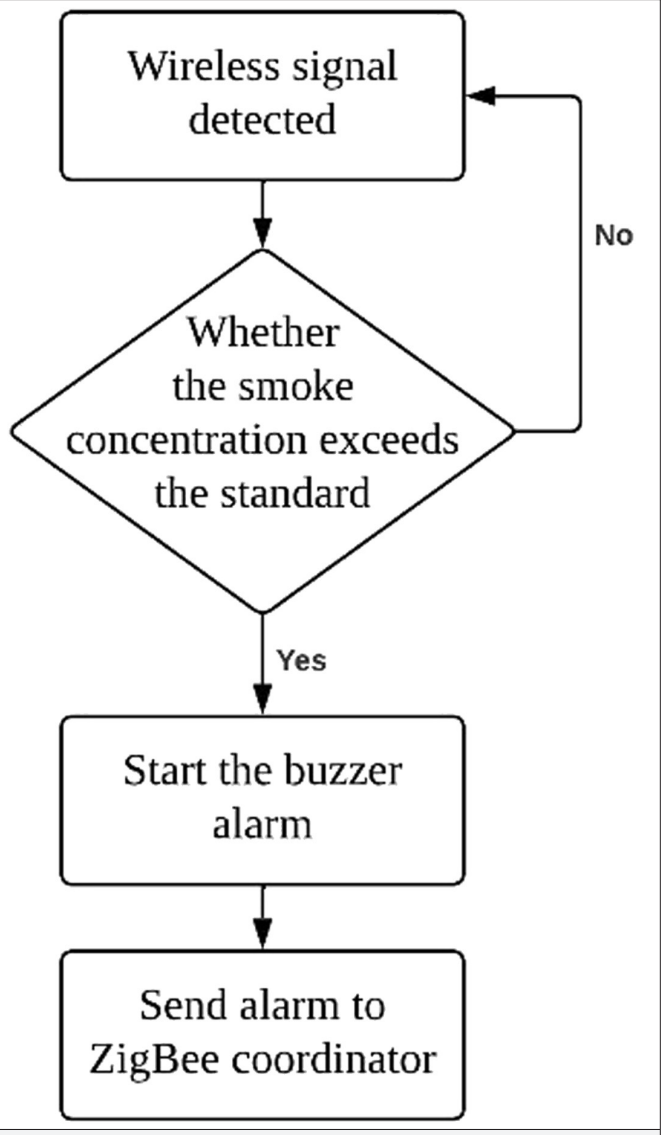

Fig. 4. Software development process of a ZigBee terminal node (taking smoke sensing terminal as an example).

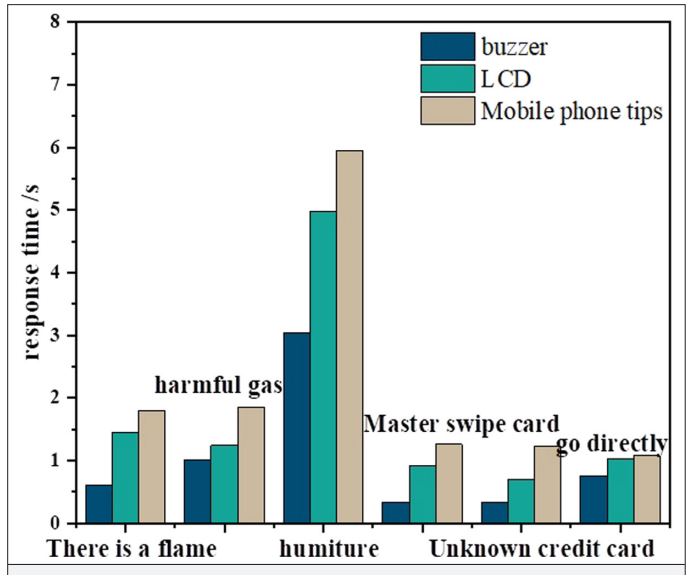

Fig. 5. Response time.

It can be seen from Fig. 5 that in the actual test results, it only takes 2.2 s to receive the system prompt, which saves 60% of the response time compared with the traditional furniture alarm system.

Fig. 6 presents the evaluation of key characteristics of the proposed intelligent control system in comparison to other control systems on four different axes: low, average, high, and extremely high. The attributes include cost, maintenance, reliability, user friendliness, robustness, and smart home application. Five criteria of intelligent control systems and the practical outcomes are compared with another control system, as illustrated in Fig. 6, in light of the literature review that was delivered in Section I. These features are classified into four levels (e.g., low, average, high, and very high) which include the smart home application, cost, maintenance, reliability, robustness, and user-friendliness. Though the robustness and dependability of intelligent control system because of the ZigBee- and GSM-based control system are not comparable with other control systems like PLC, networked control system, and supervisory control and data acquisition, the proposed model displays better criteria in terms of

TABLE II. ACTUAL TEST RESULTS

	Buzzer	LCD Screen	Is the Phone Prompted	Others
There is a flame	Call the police	There is a flame	MMS	
Harmful gas	Call the police	There's poison gas	MMS	
Temperature and humidity	Upper and lower limit alarm	Temperature alarm		
Optical line intensity				The curtains are opened and the lights are off
Weak light				The curtain is closed and the light is on
Master swipe card	Ring	Correct		The electric appliance starts and the light is on
Unknown card swiping	Ring	Error		
Enter without swiping card	Call the police	Bandit police	MMS	

MMS, Multimedia Message Service.

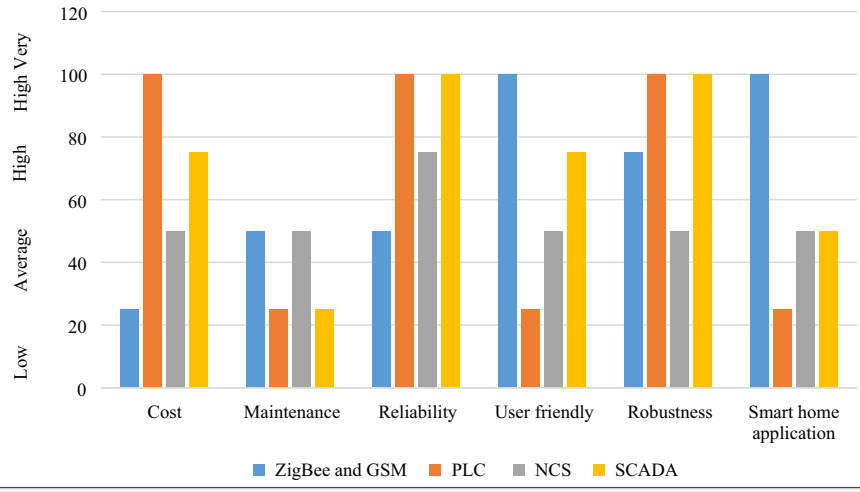

Fig. 6. Performance comparison of the proposed intelligent control system with other control system.

applicability and cost. Additionally, compared to other automation systems, the proposed model with ZigBee- and GSM-based control system is more user friendly.

V. CONCLUSION AND DISCUSSION

The smart home system of the IoT designed in this paper takes the embedded system as the gateway, uses ZigBee technology to realize the networking function, collects and controls the information of relevant nodes, and provides the local computer operation interface and SMS remote alarm control part. This paper has analyzed and understood the current situation of smart home, learnt and studied the relevant technologies of smart home application, and put forward solutions. Smart home hardware models include smoke alarms, lighting controls, infrared noise, and light alarms. In terms of design, ZigBee uses the network technology to implement wireless transmission and uses a gateway built into the overall control. The embedded hardware and the CC2530 chip is studied, and therefore a ZigBee gateway control model is developed, which included the embedded ARM9 S3C2440 and the wireless radio frequency chip CC2530. The ZigBee wireless star network was implemented, and the ZigBee regulator and terminal node control flow was introduced. By studying embedded technology, you can understand the process of developing an embedded system, create an embedded system development environment, install a Qt development environment, and design a graphical operating interface. The design controls the sending and receiving of SMS with a global system for mobile communication module and has a remote control for opening and closing of smart home equipment and real-time alarm. The smart system's benchmarking seems quite promising in terms of cost and water conservation. Compared to the star-delta approach, the cost of the necessary equipment for the soft starting method is higher, the number of faults to be eliminated is reduced, and the maintenance cost is also reduced due to the reduction of cable size. Moreover, advantages of soft beginning found that because there were fewer mechanical and electrical shock stressors, the electro-life pump's expectancy, and the equipment are greater than star-delta, which will lessen the overall price. The suggested system utilizes a four-state switch and can be operated manually and automatically or can be based on a predefined program. By employing the suggested smart method, which includes a soft starting, decreases mechanical loads like electrical management and shocks from electricity. The electro-pump is also secure in terms of dry running. The simplicity and low cost of the suggested control system are two of its most significant advantages. In comparison to another existing method, the system's multi-layer control system may be managed via the IoT at a very cheap cost.

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