Design of Intelligent Lighting System for Office Workplace Based on ZigBee Technology

Shishun Liu, Rimiao Li, Ping Li(✉), and Kejian Hu

School of Information Science and Engineering, Dalian Polytechnic University, Dalian 116034, China
liping@dlpu.edu.cn

Abstract. This design is a ZigBee-based intelligent office lighting system, which aims to optimize the current office space using traditional lighting mode. The system can collect the illumination in the office area in real-time, compensate the illumination environment in the office area, and fully utilize the technical features of LED lamps to be energy efficient. Each lighting node in the system can switch different lighting schemes according to different areas of the office, and meet different situational requirements in combination with actual conditions to realize intelligent and humanized office lighting.

Keywords: ZigBee · Intelligent lighting · Green lighting · Transparent transmission

1 Introduction

At present, whether at the national level or people's lives, and the word "intelligence" penetrates various fields of society. The efficient combination of high-efficiency and energy-saving lighting features of LED lighting technology and IoT technology has introduced a new concept of intelligent lighting. As an indispensable part of urban life, office lighting should be closer to "intelligent lighting". At present, the task of the lighting system is not only to provide a simple light environment for the office staff, but also to provide a suitable lighting environment for the office staff to have a good working experience and improve the working efficiency. The traditional lighting system mainly adopts manual control, even if some places use single-chip microcomputer to control the lighting equipment, but it is only a single point of control, and does not meet the design requirements of intelligent lighting [1]. This paper designs a ZigBee-based office intelligent lighting system. Use ZigBee technology to wirelessly network the lighting nodes in diverse areas of the office, and use the illuminance sensor to detect the lighting environment parameters of each area. Use smart phones or PCs to connect to WIFI to monitor numerous areas in real time, and real-time control of the lighting environment of office space to create an intelligent office lighting mode.

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2 Overall System Design

As showed in Fig. 1, the system is mainly divided into four parts, namely the control module, the system gateway, the drive module and the lighting node module. The system uses the CC2530f256 ZigBee chip as the core, and uses its technical advantages of a self-organizing network to form a typical ZigBee network. The light environment monitoring module in the control terminal can monitor the lighting conditions of each lighting area in real time and feed back to the coordinator in the ZigBee network to provide a suitable lighting environment for each office area [2]. The system adopts two control modes: an intelligent terminal and touch pad. It can use mobile phones, tablet computers and other devices to connect to WIFI to control the lamps through the system gateway, and can also use the touch pad to directly change the lighting state of the lamps using the ZigBee network. LED lighting technology is adopted in each lighting node to maximize the high-performance benefits of LED light source and create a high-quality office lighting environment. The intelligent terminal can connect to the ZigBee lighting terminal in the WIFI control system. The system reserves peripheral interface circuits for the corresponding sensors to detect more environmental parameters (such as temperature, humidity, smoke, etc.), making the system more workable.

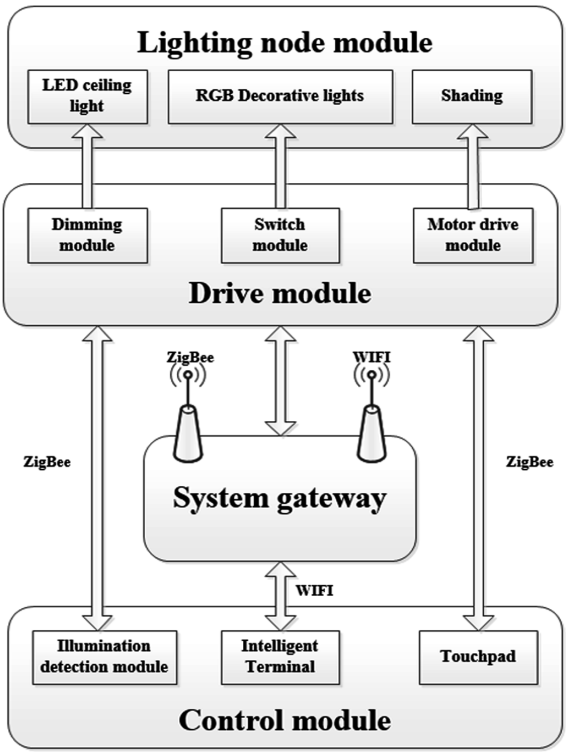

Fig. 1. System block diagram

3 System Hardware Circuit Design

3.1 ZigBee Core Board Design

The core of the system uses the CC2530f256 chip, which is fully consistent with the 8051 core, comes with an AD conversion circuit, and supports the IEEE 802.15.4 protocol. In the development of the ZigBee wireless sensor network, different sensor signal conditioning circuits are needed, but the circuit of the ZigBee communication part can be left unchanged, which greatly streamlines the design of the hardware circuit [3].

3.2 LED Dimming Mode Circuit Design

The LED dimming function of the system is expected to be completed by the CC2530 and the LED constant current driving PWM dimming module. The dimming node receives the optical environment parameters given by the coordinator, and issues a command to the PWM dimming module to adjust the brightness of the LED lamps. The light compensates for the natural light and maximizes the use of natural light to create a suitable office environment. The schematic diagram of the LED dimming node is illustrated in Fig. 2.

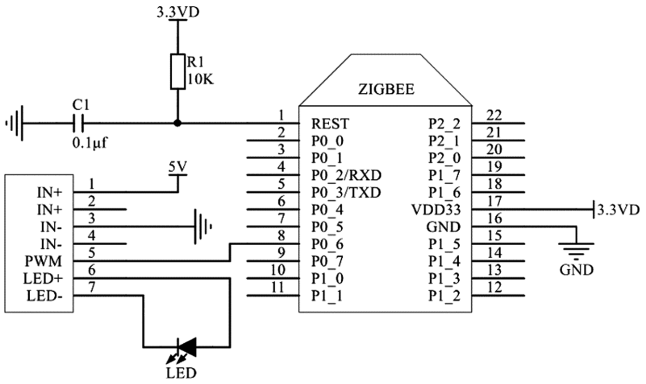

Fig. 2. Schematic diagram of PWM constant current dimming circuit

For a certain frequency of PWM dimming, the output current of the driver has a certain relationship with the duty cycle of the PWM signal. The calculation method is as shown in Eq. (1).

$$I_{o\_set} = \frac{DT}{T} I_{o\_norm} \tag{1}$$

Where I_{o_set} is the desired output current (mA), D is the duty cycle (%) of the PWM signal, T is the period (S) of the PWM signal, and I_{o_norm} is the rated output value (mA) of the driver.

After the terminal node receives different duty cycle values, the PWM control signal will be generated in the callback function, but since the illumination terminal node includes the optocoupler isolation relay drive, the frequency of the PWM signal is not suitable too high. In addition, the system further includes a touch panel controller for performing spot dimming according to the measured value returned by the illumination detection module to the coordinator.

3.3 System Gateway Node Hardware Designs

System gateway is mainly composed of CC2530ZigBee module and ESP8266WIFI module. The ZigBee module combines the sensor module, the controller module and the lighting node into a wireless sensor network. The WIFI module can enable the intelligent terminal to access the wireless router network, thereby achieving the goal of controlling each lighting node [4]. The WIFI module communicates with the ZigBee module through the serial port. The hardware structure of the gateway is given in Fig. 3.

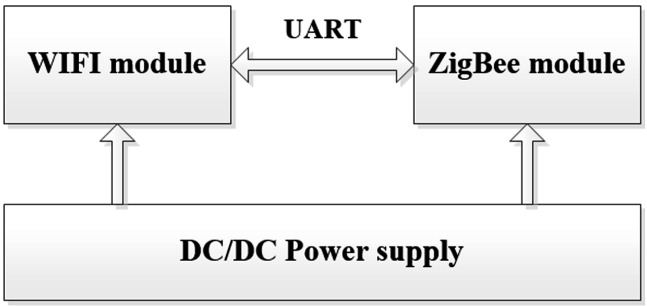

Fig. 3. Gateway hardware structure

3.4 Illuminance Collection Node Circuit Designs

The illuminance collection node is based on the BH1750FVI illuminance sensor. The sensor does not require additional external plug-ins. It can directly determine the intensity of light in the environment, and send the collected illuminance information to the coordinator through the ZigBee module to compare the required areas. The optimum illuminance value, the coordinator sends control commands to each lighting node to adjust the LED luminaire to the most suitable brightness. The BH1750FVI illuminance sensor has a wide range of input light and can be utilized in most functional areas in the office. The schematic diagram of the illumination collection node is illustrated in Fig. 4.

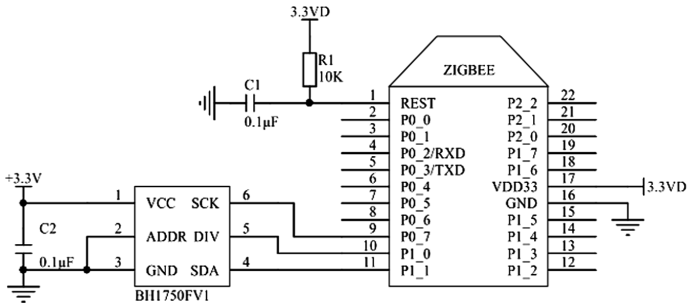

Fig. 4. Schematic diagram of the illumination acquisition node circuit

4 System Software Design

The software design of the system mainly relies on TI's z-stack protocol Stack and IAR integrated development environment.

4.1 Coordinator Node

The coordinator is the core of the wireless sensor network. Its main function is to manage the ZigBee network and communicate with the gateway. After entering the system, the coordinator node will first determine whether there is data to transmit, and then establish the data transmission network. After receiving the control instructions from the gateway, the coordinator will send commands to the lighting terminal to change the lighting state of the lamps. Normally, the coordinator node is in a dormant state. When there is data transmission, the clock signal will send a signal to wake it up. This working mode can effectively reduce power consumption and extend the service life of ZigBee nodes.

4.2 Router Node

According to the needs of the system, multiple routing nodes are set to increase the coverage area of the whole ZigBee network, forming a typical network topology and improving the reliability of the system. After power on and initialization, the routing nodes apply to join the network, search for signals, determine the data transmission path, package the data according to the ZigBee communication protocol, and send it to the next node.

4.3 Lighting Terminal Node

The software design of the lighting terminal node is divided into two parts: LED lamp driver design and sensor detection data transceiver program. At this time, the gateway creates a new device node in the virtual device list for the node, and the coordinator receives the signal sent by the lighting terminal, and then sends the variable value of the terminal device to the gateway [5]. At this time, the lighting terminal has established

contact with the controller and the coordinator, and the lighting terminal receives the command sent by the controller through the system gateway, changes the working state of the LED lamps, and feeds back a response variable.

4.4 Host Computer Control Terminal Design

The host computer includes two kinds of mobile terminal and computer control terminal. The computer terminal is developed by using C# software under .Net platform, and the mobile terminal software is developed based on Android SDK in Java language. The control interface is shown in Figs. 5 and 6.

Fig. 5. Computer control interface

Fig. 6. Mobile phone control interface

5 System Debugging

As showed in Fig. 7, the office area of a nearby company is used as an experimental point. The office area is about 180 m^2. ZigBee nodes are arranged in each functional area to form a ZigBee-based intelligent lighting system. After the coordinator node is completed from the networking, it is determined that the ZigBee network covers the entire office area, and the serial port is used to connect the host computer with the coordinator and the terminal node, and the serial debugging assistant is used for data transmission and reception, the simulation system runs the communication process, and the test data transmission is performed [6].

A coordinator node is set in the central area of the office area, and each lighting area node is set to one lighting terminal node, and only three nodes having forwarding data tasks are set as router nodes, and the remaining nodes are all set as terminal nodes, so that reduce the cost of ZigBee chips and avoid unnecessary consumption. The lighting experiment was carried out by using a mobile phone, computer and touch pad respectively. The dimming of LED lamps was split into high brightness, medium bright, bright and soft four levels. RGB decorative lights were installed in the front desk and a conference room, and various scene modes were set. In the automatic mode, the coordinator receives the data feedback of the illumination detection node to automatically adjust the light of each functional area.

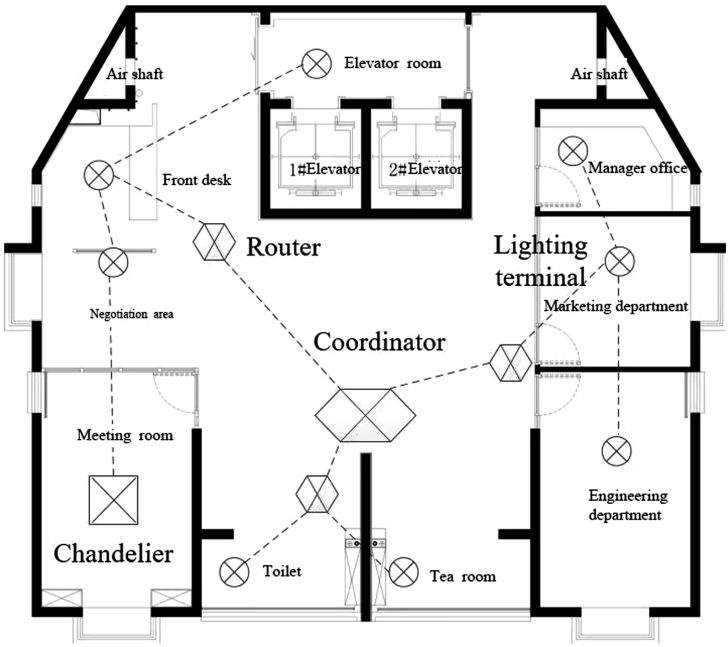

Fig. 7. Experimental point ZigBee node layout

6 Summary

The intelligent lighting system of the office based on ZigBee technology can monitor the lighting environment in each functional area of the office area in real time. The intelligent terminal is used to adjust the lighting mode to maximize the use of natural light to provide the most suitable office lighting environment for office workers in the area, to achieve "Green smart lighting". With the rapid development of intelligent control technology, LED intelligent lighting technology will also be improved, for the energy conservation and emission reduction initiatives proposed by the state, the intelligent and information roads inject huge energy [7].

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