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INTELLIGENT LIGHTING SYSTEM OF URBAN ROAD BASED ON INTERNET OF THINGS

Lulu HAO and Jing GAO*

School of General Education, Wuhan Business University, Wuhan, 430056 China
**E-mail: 441691661@qq.com*

ABSTRACT

Aiming to solve the problems of energy waste, management confusion and poor flexibility in urban road lighting control system, an intelligent lighting system of urban road was designed based on the internet of things technology. The intelligent lighting system included hardware system composed of street lamp control terminal, main controller, software platform server, and software system composed of communication interface software, data processing software and operation management software. The lighting energy-saving control strategy and system characteristics were analyzed. The results show that the intelligent lighting system of urban road can realize the functions of remote street lamp switch, power regulation and timing operation, so as to meet the realistic demand of urban road intellectualized lighting control.

Keywords: internet of things (IoT), urban road, intelligent lighting, system design, ZigBee technology

1. INTRODUCTION

With the rapid development of society and economy, the street lamps and landscape lighting construction in modern cities are developing synchronously and rapidly. The total street lamps in large cities are several hundred thousand, and the annual street lamp growth rate is (15–20) %. In 2012, China's urban lighting (functional lighting, such as landscape lighting and street light) accounted for about 4 % to 5 % of China's total power generation, equivalent to the annual capacity of the Three Gorges Hydroelectric Project [1]. The rapid development of street lamp construction, the improve quality of road lighting, because of in recent years LED light sources are in the attempt to update the existing road-pass lighting products, but some shortcomings greatly limited further promotion and improvement. At the same time, there are some problems in the existing street lamp management and control system, such as energy waste, management confusion, high maintenance cost, and poor flexibility [2]. The intelligent urban lighting system with independent control is the most potential modern energy-saving research field. By reasonably planning the layout of the street lamp, reasonably controlling the switching time of the street lamp, and incorporating intelligent street lamp management methods, such as light control, flow control and scene analysis, further adjusting the lighting strategy of the street lamp can save more than 30 % of the energy consumption of the street lamp [3].

In recent years, with the rapid development and application of cloud computing technology, the Internet of Things technology has been rapidly popularized. The concept of smart city has been gradually developed from the theoretical stage to the realization stage, and the demand for smart lighting has emerged [4]. Therefore, it is decided by the development of urban construction and the development level of new technology to bring urban street light into the new urban Internet of Things, and to realize the development route of intelligent lighting control by using advanced cloud computing technology. The standard of street lighting Internet

of Things for smart lighting is not clear, the technology developed is not comprehensive, and the application is not yet extensive. Therefore, it is necessary to conduct in-depth research on this emerging technology field.

Based on the development of new light source and sensor wireless networking technology and the background of data communication and processing technology of Internet of Things, this study designed an intelligent lighting system of urban road. Street lamp controller achieved short-range wireless networking by means of ZigBee technology. GPRS wireless transmission technology realized communication and interaction between control and state data acquisition. Because the control terminal has an open control interface, it provides a technical basis for the realization of remote street light switch, power regulation, timing operation and other functions.

2. STATE OF ART

The development of road lighting management and control system can be roughly divided into three stages: manual control stage, mechanical control stage and computer control stage. Modern street lamp monitoring system can realize data acquisition and monitoring of remote measurement, remote control and remote communication by means of existing communication service platform [5]. Since the 1990s, developed countries have been engaged in the research and development of intelligent lighting systems for generations, and have accumulated rich construction experience and successful cases. The technical characteristics in the field of street lamp monitoring are mainly embodied in the following aspects: the modernization of monitoring strategy, the modernization of information carrying mode, and the modernization of management system. The modernization of monitoring strategy is reflected in the development from centralized control mode to the precise scene and behaviour analysis stage. The "three remote" mode of street lamp control has been mature in developed countries, and many countries have formulated industrial standards for street lamp. On the basis of centralized control, modern streetlight control strategies pay more attention to the function of the scene and behaviour analysis. For example: the adaptive light perception function, according to the sunrise and sunset time automatic switch and dimming function, traffic flow and flow analysis function, and for busy streets, remote streets and highways have different monitoring strategies, on the one hand, the street lamp control is more humane, on the other hand, further saving energy [6].

The progress of information carrying mode is reflected in the continuous progress of information carrying mode from "wired – wireless – wired". A wired communication method similar to fixed telephone is used to solve the problem of the transmission of street lamp status and control information. But this method needs to be reconstructed, and the cost is high. On the other hand, there is a bottleneck problem of information transmission. Later, with the development of wireless communication technology, the transmission of street lamp status and control information can be easily accomplished by wireless communication technology. For example, ZigBee is used to communicate with the central control unit in a local area, and GPRS module is used to complete the remote communication. This multi-layer wireless communication mode can effectively save the construction cost on the one hand, and improve the flexibility and reliability of the system configuration on the other hand. The latest way of information carrying in street lamp monitoring is mainly embodied in the application of power carrier technology, which modulates information into power carrier signal and transmits it simultaneously. It can be put into use almost without revamping the existing equipment. However, this new technology is not mature enough, and the stability and reliability of information transmission cannot meet the needs of practical application.

The modernization of the management system is reflected in two aspects: management mode and management method. The management model is a comprehensive business management platform, from the beginning of planning and design to the maintenance of the later period, all business information are used to manage the integrated business management platform, so that the efficiency of communication between the various departments is significantly improved, mutual supervision mechanism is also easy to establish; meanwhile, mobile media and communication service equipment are also widely used in the management and maintenance of street lights, where the street lights have trouble, as long as the fault equipment pictures uploaded to the business platform, can be timely processed [10].

3. DESIGN OF INTELLIGENT LIGHTING SYSTEM FOR URBAN ROADS

3.1. Related Technology

3.1.1. Intelligent lighting

Following the electrification and informatization, intellectualization has become the inevitable development of the scientific and technological revolution, and the development of intelligent cities conforms to the trend of urbanization. Intelligent city is based on the Internet, using information and communication sensing technology to solve intelligent sensing, communication, computing, analysis, judgment and control of the key technologies of urban operation, to build a smart environment for urban development [11]. The development of intelligent city requires that lighting is also intelligent lighting, and intelligent lighting is to use the Internet of Things technology to build intelligent lighting system to achieve intelligent management of lighting. The key of intelligent lighting is to make full use of the external effect of each subsystem through multi-source perception, depth integration and intelligent decision-making, and connect the systems vertically and horizontally to form a network, so as to enhance the density of knowledge sharing among the systems and improve the intelligence of the whole system.

3.1.2. Internet of Things

Internet of Things is the way to realize road intelligent lighting. The concept of Internet of Things was put forward in 1999. In 2005, the International Telecommunication Union (ITU) formally put forward the concept of the Internet of Things, which is defined as: through radio frequency identification (RFID) infrared sensors, global positioning systems, laser scanners and other information sensing equipment, according to the agreed agreement, any article and the Internet connected, information exchange and communication to achieve intelligence.

The architecture of the Internet of Things includes three aspects: perception, network and application [12]. The perception function is composed of sensor and transmission gateway. It is embedded in the "Things" of the Internet of Things. The network functions of receiving, sending and controlling information of "Things" are responsible for transmitting the "Things" information in the Internet of Things in different networks, connecting the application layer and the Internet of Things. The perception layer and the application function are the analysis and expression of wisdom. The data are analyzed and mined by the application layer, and any "things" in the Internet of Things are fed back, commands are issued, and management and control are implemented.

3.2. Structure of Road Intelligent Lighting System

The intelligent lighting system consists of two parts: software system and hardware system. The hardware system is mainly composed of the street lamp control terminal, the main controller and the software platform server. The street lamp control terminal is installed on the street lamp column, which is responsible for data acquisition and independent control of the street lamp unit. The main controller is installed in the street lamp distribution box, and a main controller manages multiple control terminals and is responsible for them. Monitor the total circuit of the distribution box and communicate with the platform server. The software system is mainly embodied in the software platform system of the control centre, which consists of communication interface software, data processing software and operation management software. The overall structure of the system is shown in Fig. 1.

The road lighting control equipment is the basic guarantee to realize the street lamp detection and control function. In order to realize the networking and data acquisition and transmission of street lamps [13], the terminal equipment requires the following functions: (1) a ballast with adjustable power; (2) the control unit needs to be able to output adjustable analogue for connecting the ballast control power output; (3) the control unit needs to be able to collect the data of the running state indicators of the street lamps. It includes: current, voltage, power factors, etc.; (4) the control unit needs to be able to set up a network, and the main unit for control and scheduling within the subnet; (5) the control unit needs to have wireless communication capabilities, the main unit needs to be able to carry out data transmission and instruction communication through the mobile Internet; (6) the control unit needs to be able to set the ability to send packets on time.

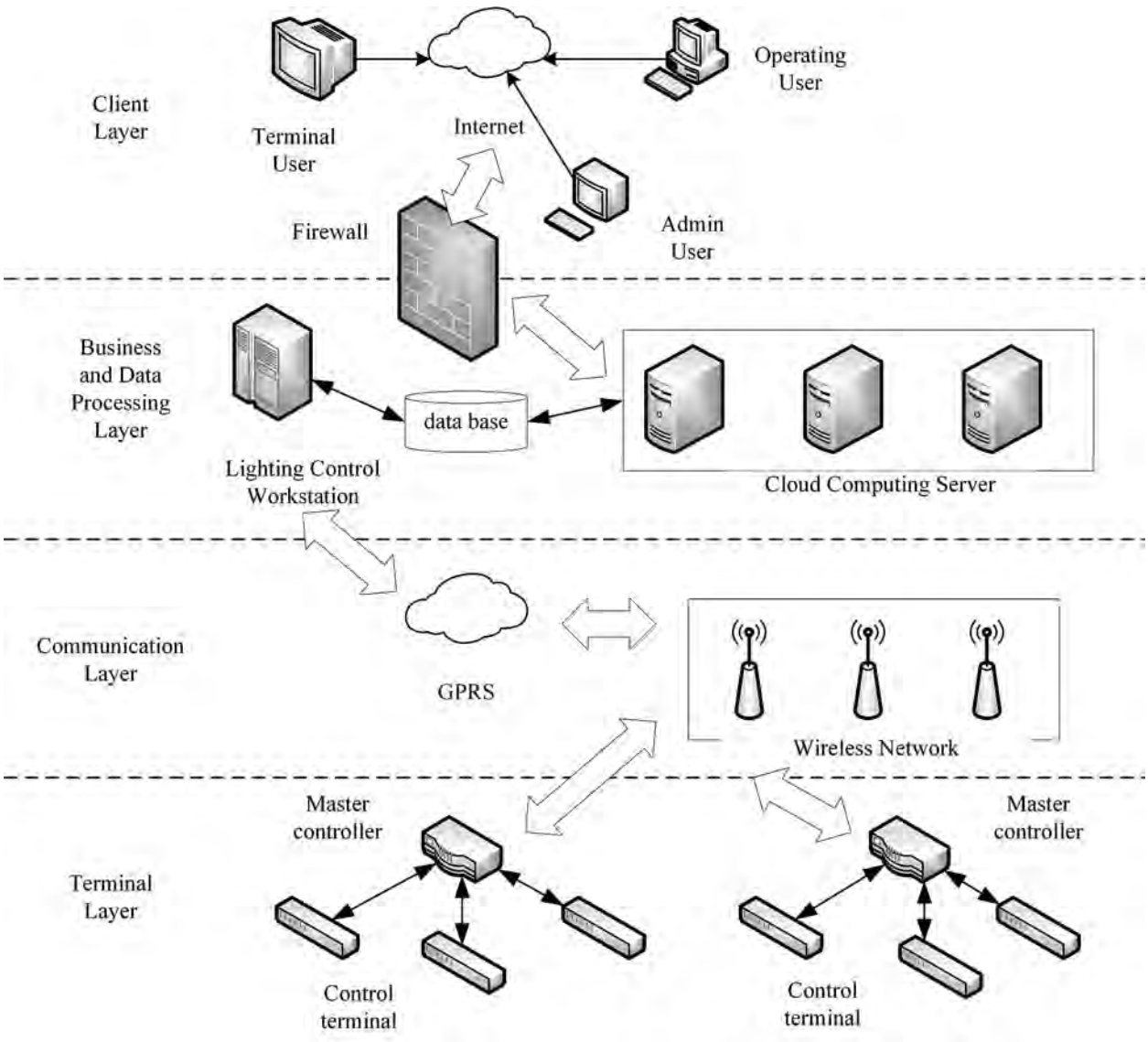

Fig.1. Architecture of a road intelligent lighting system

The control system is composed of two levels of network structure. ZigBee technology is used between the control terminal and the main controller to realize the close wireless network, and the GRPS network is used between the main controller and the server to realize the remote network transmission. This kind of network structure design, on the one hand has played the ZigBee network low cost superiority. Simultaneously solved the ZigBee wireless network transmission distance limited question. Based on the Two-level Network structure, the urban streetlights are divided into several ZigBee regional networks, each of which controls dozens of streetlights and covers several streets.

The terminal control node installed on the lamppost is connected with the master controller node through ZigBee communication mode. A master controller is connected to a plurality of control terminals. The main controller transmits control signal data to the control terminal through wireless connection, and the control terminal transmits status data and alarm data to the main controller through wireless connection. The control center server is connected with the main controller through GPRS communication mode. The master controller acts as an intermediate node layer in the network, passing data up and down, and the overall network structure is shown in Fig.2.

3.2.1. Energy-saving Control Strategy Analysis

The main objective of smart lighting system is to achieve energy-saving optimization of urban street lighting system, while reducing maintenance

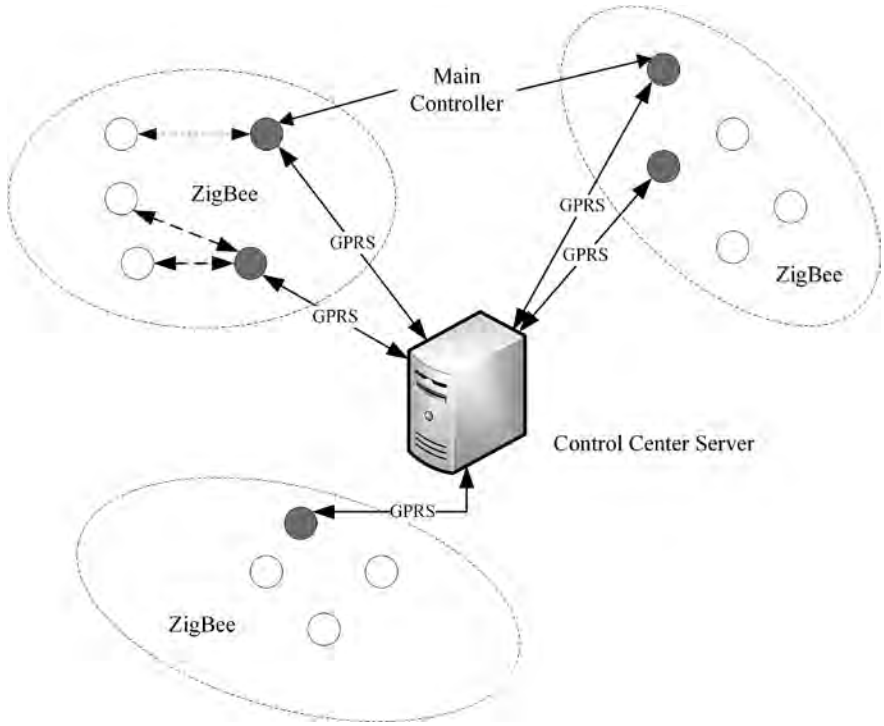

Fig. 2. The network architecture of control terminal

workload and overall system operation and maintenance costs. Intelligent control of street lighting cannot only realize energy-saving control based on time and brightness for a single street lamp, but also implement energy-saving strategy algorithm for a group of lamps in a region to achieve the purpose of energy saving. Realize the fault detection and alarm, make the street lamp fault or damage automatically send out information promptly, and can provide accurate positioning for the inspectors, so no longer need manual road patrol for repair, greatly reducing the daily maintenance costs. The parameters of current, voltage, and power are collected in real-time, and transmitted to the server through wireless communication for real-time processing and data storage. The data base is established for energy-saving effect analysis, lighting project planning and intelligent city construction.

Street lighting control strategy is the core part of intelligent street lamp system. Through control of street lamp nodes about 6 control modes are realized.

1. Odd-even operation mode. The odd-even operation mode is based on the number of light only to turn odd numbered light or even numbered light. When the street lamp control terminal is set to even and odd operation mode, it is judged to turn on or off according to the street lamp number. Generally used in the evening when visibility is high or bad weather leads to low visibility. In the even-odd operation mode, the even-odd lamp group is usually turned on in turn, so that the working time is balanced to prolong lamp life.

2. Full power operation mode. When the street lamp control terminal is set to full power operation mode, the street lamp starts to work immediately, and with full power output, the illumination brightness reaches the maximum. It is usually used for night time traffic and holiday time interval.

3. Half power mode. When the street lamp control terminal is set to the half power mode, the street lamp starts to work immediately. Through the PWM dimming function of the controllable ballast, the output power of the street lamp is controlled at 50 % of the rated value or the specified power value. It is generally used in small sections of people's traffic flow or after midnight.

4. Random alternate operation mode. The random alternate operation mode is one of the effective ways to save electricity and prolong the life of street lamps. Street lamp control terminal is set to random alternate operation mode, and the street lamp is turned on alternately with a certain probability distribution. It is generally used in small sections of people's traffic flow or after midnight.

5. Time control mode. According to the current longitude and latitude of the city, the system automatically calculates the time of sunrise and sunset every day in a year. Based on this time data, the system can realize the automatic control of dynamic switching light.

6. Power abnormal alarm mode. When the lamp control terminal detects the lamp power failure (such as too small power, short circuit, etc.), it will trigger an alarm event and upload the alarm information to the server. When the power is too large, the circuit will cut off the lighting power at the same time.

4. CHARACTERISTICS OF ROAD INTELLIGENT LIGHTING SYSTEM

Compared with the traditional road lighting system, the intelligent road lighting system based on the Internet of Things has the definite distinct characteristics.

1. Dynamic perception. The perception of the physical object state is the basis of intelligent road lighting system, which has a wide range of spatial distribution and continuous time requirements. It is because of the dynamic changes of perceptual data (such as traffic flow, weather conditions, etc.) that the lighting demand changes, thus laying the foundation for the optimal control of the lighting system.

2. Effective feedback. The state of the perceptual physical object must be processed in the information system. Lighting system operation is related to road traffic safety, especially when there is a fault alarm. It will highlight the importance and necessity of real-time information feedback.

3. Deep integration. Through the deep fusion of all kinds of perceptual information, the information world can accurately analyze the situation of the physical world, and make control decisions in time. The control decisions can be implemented through the network control system to control the behaviour of the physical world in real time and scientifically.

4. Accurate cognition. Through the analysis and mining of the massive data acquired, the accurate cognition of the characteristics of urban road lighting can be achieved, which lays the foundation for the scientific grasp of the changing law of lighting demand and evaluation of lighting energy-saving effect. For example, the benefit of energy-saving and emission-reduction can be evaluated by comparing and analyzing the unit vehicle/km power consumption, and the luminance index of lighting can be analyzed. And traffic accident rate to analyze the impact of lighting on urban road lighting management, through the analysis of luminaire light attenuation to develop lighting maintenance program.

5. Reliable control. The information system controls the physical system dynamically, and the physical system has the feedback function to the information system, that is, the physical system can influence the control effect of the information system through the information feedback. For example, intelligent road lighting system can be reliably controlled dynamically according to the actual distribution of vehicles in the road and the weather environment. Step-less dimming and graded dimming avoid ineffective lighting and over lighting.

5. CONCLUSIONS

1. Intelligent road lighting system is a typical application of Internet of Things technology in traffic field. It cannot only realize dynamic dimming according to perceptual information, reduce ineffective lighting and excessive lighting of urban roads, but also analyze and excavate massive data, accurately recognize the characteristics of urban road lighting, and scientifically grasp the lighting requirements. Change law and evaluation of lighting energy saving and emission reduction effect lay the foundation for significant economic, social and ecological benefits.

2. Internet of Things is the key strategic technology and means to lead the innovation of the future information industry. Through the construction of intelligent road lighting system based on Internet of Things technology, the digitalization and intellectualization of urban road lighting management can be realized, and the limited control of energy consumption of highway tunnel lighting can be achieved.

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Lulu HAO,
Ph.D. in Economics, Lecturer. Graduated from Wuhan University of Technology. The research area is industrial economics and Internet of Things

Jing GAO,
Professor. Graduated from the Central China Normal University. The research area is tourism economy and smart tourism