Research on communication model of IPv6-based intelligent lighting system

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Abstract

Intelligent Lighting is the development direction of urban municipal lighting construction. IPv6 technology is considered as the key to solve the problems such as point light source controlled separately, multi-scene controlled flexible and user-friendly, control signal with minimal latency, plug and play heterogeneous devices, green energy and so on. In this paper, we introduce the IPv6 into the intelligent lighting system; build the communication model from three aspects which are information model, information exchanging model and general protocol according to the characteristics of information transmission in intelligent lighting system. At last, the usability of the communication model is analysed and verified by the landscape lighting control system which deployed in the Olympic central area.

Keywords: IPv6, intelligent lighting, communication model, information model, information exchanging model, protocol

1 Introduction

The idea of smart city originates from the idea of Smart Planet proposed by IBM. A lot of views about smart city are put forward from different perspectives. In IBM's white paper smart cities in China, the basic features of the smart city are defined as the following based on the application of a new generation of information technology: complete instrumentation, fully integration, innovation stimulation, and collaborative operation. That is to say, the intelligent sensing equipment connects urban public facilities into an internet. The Internet of Things and Internet system completely fits each other. The government and enterprises apply technologies and business innovatively based on intelligent infrastructures city. And the key systems and the participants in a city collaborate harmoniously and efficiently [1, 6].

The urban public lighting system is one of the most important public infrastructures that are closely related to people's daily life [5]. With the speeding up of urbanization, the demand for and the construction scale of the city public lighting facilities are increasing, which not only increases the demand and management for energy, but also puts higher requirements for lighting management system. At present, the intelligent lighting system has been incorporated into the construction of intelligent city and become one of the most essential parts of it.

In the early days of the urban construction, the urban public lighting system controls the lighting by manual switches in distribution boxes or realizes remote control through stringing the contactor into the circuit. The application scope of this technology is limited with no flexible field-custom ability and insufficient comprehensive operational analysis ability, which makes it difficult to adapt to the increasingly expansive demand of city lighting. With the rapid development of microelectronics technology and digital technology, the researchers develop an intelligent lighting system focusing on network topology. This system makes full use of network technology and software technology to improve the level of control and management by giving IP to lighting control node. Its main advantage is to modulate lighting according to demand and greatly reduce the energy consumption. However, the current version of IP consumes IPv4 addresses seriously and also has a certain limitation in security and convenience, which makes the IPv4 technology restrictive in urban public lighting management. IPv6, as alternative version of IPv4, becomes popular in urban public lighting system with its richer address space, higher transmission rate of end-to-end data, better quality of service (QoS), higher network security and other advantages like plug-and-play and mobility [2, 3].

The urban public lighting system involves of various lighting devices, and lighting devices of different manufacturers may follow different communication protocol standards. In addition, lighting equipment is communicating with multiple control systems, such as the landscape lighting system, power consumption measurement and detection system, abnormality monitoring system, etc. These equipment control systems are often developed by different companies whose ways of message description and processing are different. Therefore, there are unavoidable problems concerning compatibility, interoperability and scalability between different lighting equipment and control systems. This greatly increases the difficulty for the cooperative control of heterogeneous lighting equipment. So it becomes a key

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issue that cannot be ignored in the construction of city intelligent lighting system how to base on the fine management of urban lighting, comprehensively apply to new information and communication technologies, realize the unified management of heterogeneous lighting equipment, make the city public lighting system operate orderly and efficiently in harmony, strength the functional management's ability of coordination, fine monitoring and warning, rapid and linked emergencies treatment.

Regarding the above issues, based on the characteristics of information transmission of the intelligent lighting system, this paper models the information communication in the system and gives the unified information about the model. Then it discusses the interactive information service content, designs the structure of common protocol description to shield the heterogeneity both between devices and between devices and control system and solve the problems concerning connectivity, unified access and monitoring of the heterogeneous resources in the lighting system. Finally it makes analysis and validation based on actual cases.

2 Information transmission of the intelligent lighting system

There is no clear unified definition for the intelligent lighting in the industry. It is generally agreed that intelligence lighting is to apply advanced. Efficient and reliable communication technologies to realize the remote centralized control of lighting equipment and management in order to adjust the luminance according to needs, achieve real-time monitoring the status and energy consumption of equipment and make active alarm on malfunction so as to greatly save power resources, improve management level of public lighting and save maintenance cost.

As shown in Figure 1, it is a typical logic structure of intelligent lighting system [4].

The intelligent lighting system can be logically divided into two levels: the control center and child nodes which connect with each other through the IPv6 in high speed.

1) The control center deploys various kinds of servers for management and control, including the Web server for the management of the whole system, the monitoring server for the status and fields of lighting, database server used to store all kinds of data and NTP server used to achieve time synchronization etc. In addition, the client terminal for administrator operation is also included.

2) The child nodes deploys all kinds of control node for the control of lighting in a certain area, including the controller for general lighting in the controlled area. The controller for LED lighting, the collector used for acquisition of environmental information, the controller for region linkage, the camera used to monitor the lighting state and the local area lighting control server and local management server for unified management and coordination.

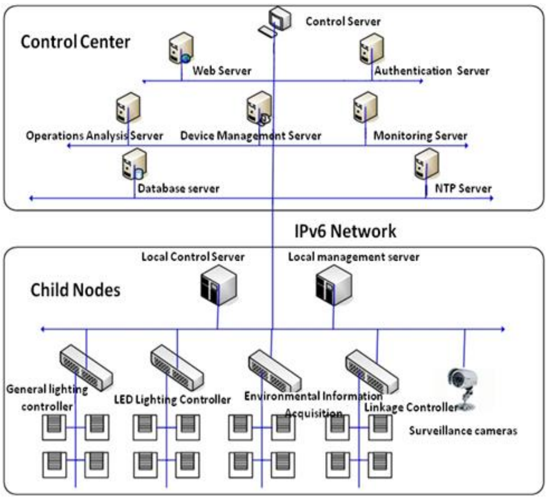


FIGURE 1 A typical logic structure of intelligent lighting system

In the intelligent lighting system, the role of information transmission is to realize information exchange between the master service center and interaction terminals. The exchanging information can be mainly divided into two categories:

1) The control information, the control center sends operation control instruction to the child nodes of the local server via IPv6 network. The local server parses the instruction after receiving and encapsulates it and then sends it to the corresponding control node which performs accordingly so as to realize the remote monitoring of terminal lighting equipment by the control center.

2) The data information, the control node sends to the local server the data, the state and fault about the terminal lighting equipment and other information, and then the local server sends them to the control center through IPv6 network so as to realize unified management of terminal lighting equipment by the control center.

3 Modelling of lighting communication

The communication model consists of the information model, information interaction model and the message that is mapped to the communication protocols. The information model is the abstract of the content of the information exchange in the lighting system. Information interaction models define the service content of the information exchange between equipment. Message mapped to the communication protocols is the carrier of the information exchanged between devices.

3.1 THE FORMAL DEFINITION OF INFORMATION MODEL

In the intelligent lighting system, the information that a static physical device sends or receives should include at least the following four contents:

1) A command set used to control and manage the static physical device.

2) The static attributes of the static device physics, for

example, rated voltage of the device, etc.

3) The running status of the static physical devices, for example, the switch, illumination and luminance, power consumption, abnormality, etc.

4) The state of existence of the static physical devices, for example, the periodical cumulative number of switch used for the analysis of life cycle of the lighting devices, etc.

According to the above analysis, if the running status and survival conditions of the static physical equipment are taken as the dynamic properties of equipment, then the lighting information can be abstracted as dynamic virtual equipment resources with a unified attribute set and a command set. Thus here is the unified description model of virtual equipment resources, i.e. a triple definition of information model.

Definition 1: the information model IM={ID, DA, OP} as shown in Figure 2, among which:

1) ID: globally unique identifier of the information consists of numbers and letters.

2) DA: a part of the attribute content of the virtual equipment resource carried by the information, which consists of static attribute sets and dynamic attribute sets of the virtual equipment resources. Among them, the dynamic attribute set contains contents like the running state and the survival state. The attribute set is shown as <the object attribute, the attribute data>.

3) OP: the command set in the information for interactive operation of virtual equipment resources, which is composed of atomic operation whose expression is: <atomic operators> (<atomic parameter list>) <returned value>.

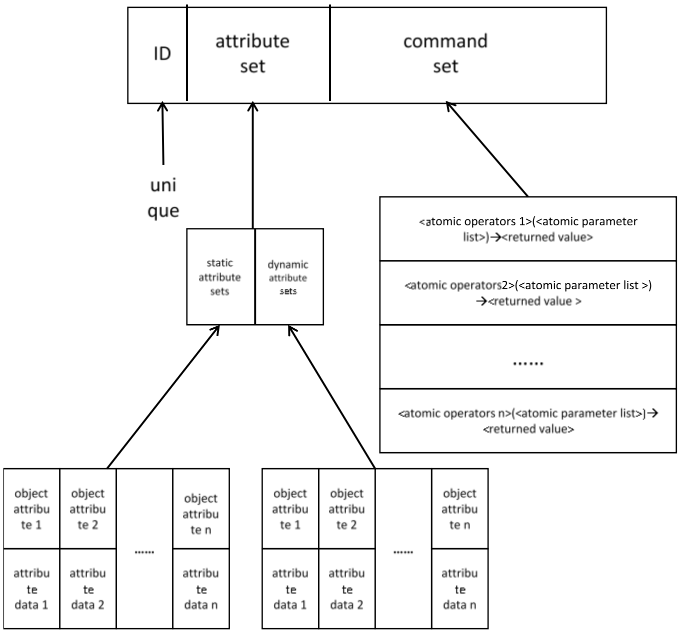


FIGURE 2 The Structure of the information model

Unified information models can shield the heterogeneity of the hardware and software and enable control center's consistent access and call on different lighting equipment. It can also enhance the scalability of the system and interact with normalized and standardized message. Control and management of newly accessed lighting equipment can be realized by developing the communication protocol components when different types of lighting equipment access system.

3.2 THE INFORMATION INTERACTION MODEL

Information interaction is based on the information model. The instantiated information model interacts according to defined service in the information interaction model in order to realize the basic functions of the system. Functions of intelligent lighting system should include at least the following 3 points:

1) To monitor the operation of the lighting equipment, to implement real-time monitoring and control over lighting state of the lighting in each child node (on, off, time, illumination, luminance, etc.), to make real-time monitoring of sudden failures in child nodes, to take comprehensive control over lighting devices in each child node, to realize complex dynamic lighting scene effect and to achieve exhibition with three-dimensional real scene.

2) To monitor the equipment operation of lighting, to make statistical analysis of energy consumption for each child node in the lighting equipment in each period, to position and analyzes breakdown lighting devices in each child node, to analyzes the life span of lighting equipment in each child, and to make intelligent analysis on the system operating data.

3) To realize system management, to make corresponding maintenance on the operating parameters of system, to manage the log information generated in the

operation of the system.

In the intelligent lighting system, each virtual equipment resource has an IPv6 address, and the control center accesses it through network. The virtual equipment resources both receive and send information. The static attribute set, the dynamic attribute set and returned values in the command of the information can perform the read/write operation. The control center specifies atomic operations in the command by controlling the service, sets parameter values required when the virtual equipment resource execute commands by the parameter set up service including priority, execution time, etc. Ensure that the coordinative work of the virtual equipment resources through synchronization and asynchronization to implement real-time monitoring, positioning and analysis of sudden fault through the exception report. In addition, there is video transmission service used to show scenes and log service for system management, etc.

Figure 3 describes information interaction between the virtual equipment resources and the control center.

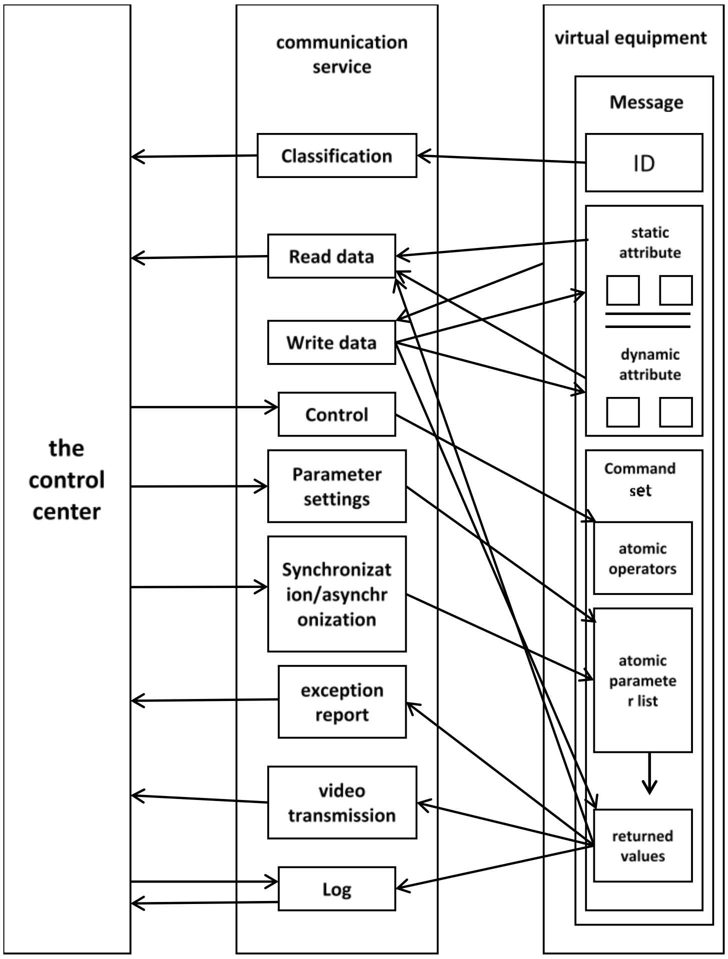


FIGURE 3 The information interaction model

3.3 THE DESCRIPTION STRUCTURE OF COMMON PROTOCOL

The communication model of the system is supposed to be mapped to a specific communication protocol to achieve information interaction. In virtual equipment resources oriented information generation, communication protocol components of different equipment have the same protocol structure interface. According to the common protocol description structure (as shown in Figure 4), information is generated corresponding to the virtual equipment resources by calling the protocol structure interface.

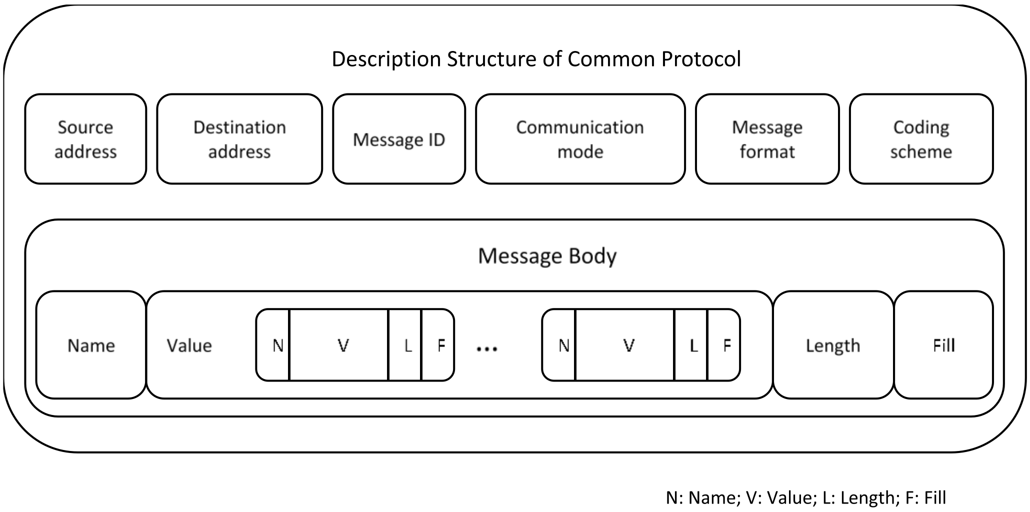


FIGURE 4 The description structure of common protocol

In the common protocol description structure shown in Figure 4, source address and destination address are the devices' addresses that send and receive messages respectively. The message ID is the globally unique identifier of the message, which is consists of numbers and letters. One number or letter in the identifier can be used to determine the type of the message. Communication mode refers to the message's way of communication such as HTTP and HTTPS, etc. The message format is the combination format of message, such as MIME. The coding scheme specifies coding rules adopted by the news, such as Base64.

In common protocol description structure, no matter the message body is basic type or structural type, it consists of four fields < name, value, length, fill >. Among them, the name field is the name of the data. The value field represents the value corresponding to the name. They constitute a Name/Value pair. And in field of Value, these four fields can be multiply nested. The length represents the length of the value. Fill refers to characters filled in when digits are insufficient. The length of the message is integer times of that of bytes. The message is stored in the form of byte arrays. Because it does not depend on any storage objects of specific structure, it can support different devices.

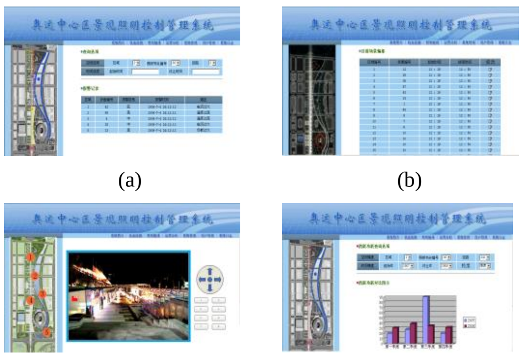
4 Case analysis and verification

Taking the landscape lighting control system project in the Olympic central area as an example, this paper analyses and verifies the effectiveness of the proposed lighting communication model.

4.1 THE LANDSCAPE LIGHTING CONTROL SYSTEM PROJECT IN THE OLYMPIC CENTRAL AREA

The Olympic central area is located in endpoint of the north central axis of Beijing with north-south length of 3.75 km and east-west width of 1.1 km, covering an area of 412.5 hectares, including about 21000 lamps of all kinds of lighting. Because the special geographical location of the Olympic central area, landscape lighting becomes an important part of its construction content.

In order to realize personalized control over multiple fields, the system adopts the method of address subdivided control and gives each lighting equipment in the central area an corresponding IPv6 address. Uses the efficient routing forwarding ability of IPv6 to reduce the delay of the control signal on the network as much as possible to ensure the synchronization of lighting equipment operation, make use of IPv6's ability to automatically assign IP addresses to solve configuration problems of the on-demand temporary lighting equipment. In addition, IPv6 also provides guarantee on the safety and quality of service in the system. Figure 5 shows the part of the effect of the IPv6 intelligent lighting system in the Olympic central area.



(a) (b) (c) (d)

FIGURE 5 The IPv6-based intelligent lighting system in the Olympic central area

Figure 5a shows the monitoring of lighting condition. The left side of the interface is the center area. When equipment failure arises or an alarm is sent, it will display the corresponding alarm icon and shows the details of the fault or alarm on the right side of the screen. Figure 5b shows the lighting scenes setting. Select the area to set the lighting in the diagram on the left side, and set the scene sequence number and start-stop time figure of each lighting unit on the right side according to the need. Figure 5c shows the scene illumination map of the designated area. Figure 5d shows the energy consumption management function in the operating analysis. The system provides real-time tracking analysis of change of energy consumption in operation so as to take effective energy saving measures. As can be seen from Figure 5, IPv6 supports well the large-scale landscape lighting control system.

4.2 COMMUNICATION INFORMATION ANALYSIS

The experiment is to send a simple command to turn on the lights from the customer terminal of the control center, to open the lighting equipment with the IP address: 2002 B01:102:2: : 2, and set its luminance value at 1, the illumination value at 20 and the power consumption at 40%. In the network transmission, the message generated according to the common protocol description structure is encapsulated into communication message. Because the communication message is very long, background parsing and processing of the communication message is done to extract the body part for analysis as shown in Figure 6.

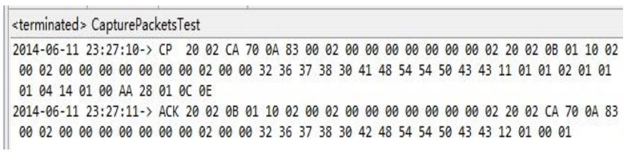

<terminated> CapturePacketsTest
2014-06-11 23:27:10-> CP 20 02 CA 70 0A 83 00 02 00 00 00 00 00 00 00 02 20 02 0B 01 10 02 00 02 00 00 00 00 00 00 00 02 00 00 32 36 37 38 30 41 48 54 54 50 43 43 11 01 01 02 01 01 01 04 14 01 00 AA 28 01 0C 0E
2014-06-11 23:27:11-> ACK 20 02 0B 01 10 02 00 02 00 00 00 00 00 00 00 02 20 02 CA 70 0A 83 00 02 00 00 00 00 00 00 00 02 00 00 32 36 37 38 30 42 48 54 54 50 43 43 12 01 00 01

FIGURE 6 The intercept fragments of the communication message

In Figure 6, CP is the command to turn on the lights from the control center. ACK is the confirmation message received by the control center. In CP, 11 01 01, 02 01 01 01 04 14 01 00 AA 28 01 0 c specifies the command to turn on lighting equipment with specific IP address. Among them, 11 is the command, and 01 represents the atomic operators: open, which is followed by three atoms parameters and values of the open command, 0102 is the luminance, 0104 is the illumination and 00 AA is the energy consumption. The structure decomposition is shown in Figure 7.

ACK can be analyzed in the same way, which is the confirmation message that equipment returns after execution of commands. As can be seen from the experiment, The message generated according to the common protocol description structure can complete the information communication between control center and lighting equipment, and for different devices. The description structure is consistent, which means that for the management control layer, the difference of lighting's software and hardware is transparent, and it achieves the unified control and management of heterogeneous devices.

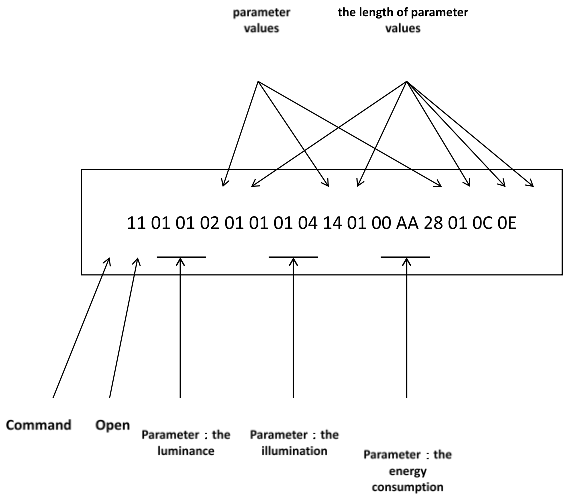


FIGURE 7 The structure decomposition of the communication message body

5 Conclusion

Intelligent lighting is the direction of the development of urban public lighting construction. To introduce IPv6 technology in the lighting control system is the key to achieve the individual control on single light source, humanized and flexible control on multiple scenes, reduce the delay of command, plug and play of heterogeneous devices and green energy. According to the characteristics of urban lighting system development, this paper introduces IPv6 technology in the intelligent lighting system and models information communication based on the characteristics of information transmission in the intelligent lighting system from three aspects: (1) Abstract the content of information exchange in the lighting system and define a unified way for information description. (2) Define the information interaction model according to service content in the information exchange between equipment. (3) On the basis of the information model and the information interaction model, design a common protocol description structure to generate the virtual equipment resources oriented information. Then, analyze and verify the availability of the communication model presented in this paper with the landscape lighting control system project in the Olympic central area as an example.

Of course, to assign IP addresses for every lighting will inevitably leads to more complex lighting attachment solutions compared with traditional ones, and it will also increase the pressure of network load. But taking into account the advantages brought by address segmentation, this paper argues that it is necessary and worthwhile.

Acknowledgments

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