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REMOTE CONTROL SYSTEM FOR STREET LIGHTING BASED ON INTERNET OF THINGS TECHNOLOGIES

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In this article, we propose a system for controlling street lighting to ensure the comfortable and safe movement of people on the street at night time using the geofencing function in a mobile application. The modern IoT approach of remote control of street lighting by the simplified network protocol MQTT working on TCP / IP is considered. The publisher-subscriber model for exchanging data between street lights and a mobile app is implemented through the Mosquitto broker. The street lamp control unit is implemented on the LuaNode32 WI-FI ESP-WROOM-32 IoT platform. The main goal is to create a full-fledged application that combines the use of a cloud server, lighting devices, and a database for remote control of the lighting system. The development of the software part was carried out in high-level languages Python, Lua, Javascript. To get a system that can be easily supported in the future, popular frameworks and libraries were used, such as Flask, paho-mqtt, jQuery, which are characterized by their open-source code. The hardware and software implementation of the IoT-based street lighting control system and their relative functions are also clarified.

Keywords: *lighting system, IoT, MQTT, Java, Lua, mobile application.*

Problem statement. Currently, the lighting industry market is undergoing a transition to a new generation of solutions that widely use the principles of the Internet of things (IoT). This was made possible by the availability of powerful and relatively cheap microcontrollers, smart street lights, receivers with wireless interfaces, and the introduction of energy-saving wireless communication standards [1].

Smart street lights represent a cost-effective solution for cities and towns that work to reduce energy consumption, increase public safety, and promote the further development of intelligent infrastructure [2].

Street lighting is a modern necessity. The problem of untimely turned-on street lights in the dark often occurs in private residential sectors, remote neighborhoods, and localities. Thus, at night, there is complete darkness in this area, which creates a certain risk of street crimes, road accidents, and injuries to pedestrians.

The second problem occurs during the night mode of street lighting systems, when the traffic intensity drops and some of the lighting devices are turned off, which leads to certain risks of injury to pedestrians with impaired vision.

The main problem to be achieved in our work is the development of a system that can remotely control a group of street lights to ensure the comfort and safety of people.

Analysis of the latest research. With the rapid development of IoT, intelligent or smart lighting systems based on IoT are becoming more popular. And recent advances in smartphones and affordable open-source cloud platforms have enabled the development of low-cost architectures for IoT-enabled lighting systems. The following is the contribution of various researchers in the field of the Internet of things.

The paper [3] proposes the development of a smart control system for urban street lighting to improve the lives of residents. To implement this scheme, the ESP8266 module with Wi-Fi support, a light-dependent sensor, and an ultrasonic sensor are used, which is used ON-OFF street lighting based on the analysis of the ambient intensity level. This approach allows you to save electricity at night.

In [4], a lighting system for optimizing the energy consumption of street lamps based on the MQTT protocol is proposed. The control unit uses a sensor combined with a controller that connects a group of lamps via an MQTT broker. The operation also provides a real-time clock to control the intensity of the lamps following the time.

The paper [5] proposes a smart controlled home automation device with a basic function that helps residents and organizations remotely control devices using WiFi technology. The system is controlled by a mobile application that is used in smartphones, tablets, laptops, and PCs that have a WiFi module. The control unit is the Arduino Uno microcontroller, which interacts with the Android application with an encrypted message, after the message is successfully decrypted by the microcontroller, the PIR sensor is activated and the lighting and fans are remotely controlled.

The purpose of the article. Development of an IoT approach for managing street lighting to ensure comfortable and safe movement of people on the street at night. The development of a real-time lighting system that provides access to city residents to temporarily turn on street lights through a specialized application based on the MQTT broker Mosquito with customized related themes, it allows city residents to temporarily turn on street lights in low visibility conditions.

Summary of the main research material. The proposed street lighting system uses the concept of an IoT-enabled service platform, which uses an infrastructure consisting of a street light control unit implemented on the LuaNode32 IoT platform, a Wi-Fi gateway, Figure 1. The gateway implements a communication channel between the street light control unit and the user application as a transit, the cloud MQTT broker Mosquito is selected.

The principle of operation of the developed system of smart street lighting is that the user installs the Smart City program on his gadget. Part of this package is a custom-developed “Illuminator” application based on an MQTT broker with customized related themes to provide access to city residents services to temporarily turn off street lights in low visibility conditions in real-time.

In order for the system to know which lights to turn on, the user shares their coordinates with it for a while. “Illuminator” processes the geo-location of a city resident and sends a control signal to the desired lights. This approach allows you to save energy costs for street lighting in remote and sparsely populated areas of the city while creating a way for residents to safely get to their homes in the dark.

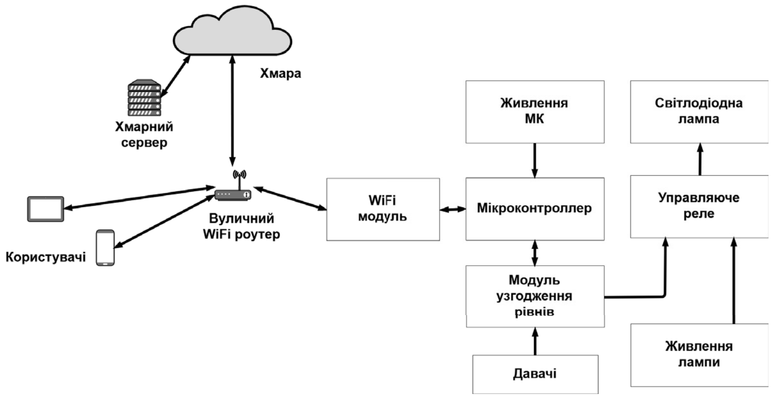


Fig. 1. Block diagram of the street lighting system

The control unit. The street lamp control unit, implemented on the LuaNode32IoT IoT platform with an integrated Wi-Fi controller, operates under the real-time operating system Lua RTOS. The microcontroller connects to the MQTT broker in the cloud via a WiFi module.

Since the high level at the output of the microcontroller is 3.3 V, and the relay is designed for a voltage of 5 V, the Sparkfun level matching module is present in the circuit. The Relay Module High / Low-Level Trigger control relay with integrated optical isolation is used to turn on and off the street lamp.

To control the internal temperature and intensity of the glow of the street light lamp, a thermal sensor is enabled, which is built into the LuaNode32 IoT platform. Given the presence of the level matching module, other sensors and measuring devices can be connected to the microcontroller: the light flux from the lamp, the ambient light sensor, the motion sensor, an external wattmeter for the lamp. The values collected by the sensors are processed in the LuaNode32 IoT platform and can be sent to the main server via MQTT. The lamp is powered by an external power supply [6].

Designing the application UI. "A mobile client can be not only a program on smartphones running on modern operating systems: Android, iOS, Windows Phone, but also any device with Internet access - a tablet, a laptop. In conditions of poor connection or lack of access to the global network, sending coordinates can be implemented by sending an SMS message to a special number.

As part of this work, a mobile client is implemented in the form of a separate web application "Illuminator". Access to the page can be obtained by any resident who, in turn, has access to the Internet. That is why the block diagram also contains a street WiFi router, which provides such access to everyone.

A public cloud server. The cloud IoT platform provides a "Cloud Server" service, which allows you to use a virtual machine in the provider's cloud.

In operation, the Mosquito cloud server serves to store and process information from users and street lights, and in turn, includes a web server and an MQTT broker. The web server performs the function of hosting the developed web application "Illuminator" and controlling the street light control unit, by receiving commands from the user and applying software logic to send control signals over the MQTT channel. Street lights can be combined with users in a common network or exist in a separate network. The block diagram shows that the central control module is the LuaNode32 IoT platform with an integrated Wi-Fi controller. The control unit connects to an available outdoor WiFi network, gets Internet access, and accordingly connects to the MQTT broker Mosquito in the cloud. Once connected, the lamp control unit subscribes to certain topics and publishes information about its status (on or off lighting), its coordinates, and internal temperature, and can also control the glow of the street lighting lamp.

Algorithms of the system operation. Figure 2. shows the algorithm of the designed system. It consists of three main routines: processing requests to the HTTP server, processing messages from the MQTT broker (since it plays a passive role in message processing), and checking the lamp activity.

Fig. 2. Algorithm of operation the projected system

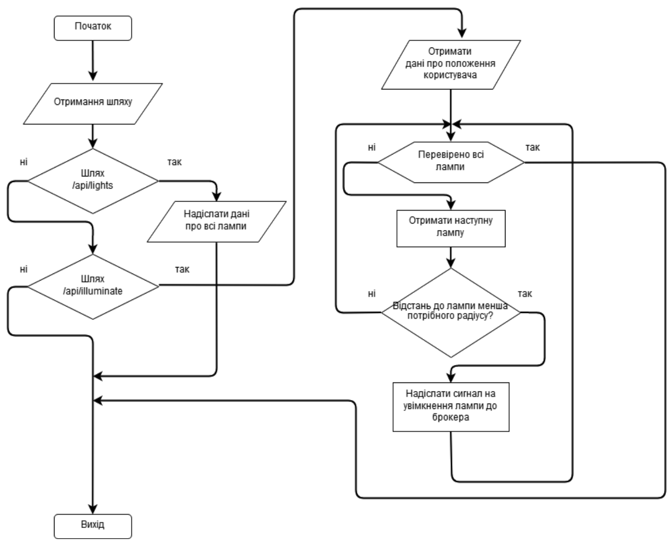


Fig. 3. Query processing subroutine to the HTTP server

The algorithm of the subroutine for processing requests to the server is the most complex in terms of the structure of features. 3. However, it only checks the path sent by the user and performs appropriate actions, such as sending the user data about available lights for display in the web application and processing the signal about the inclusion of lights in the geolocation zone.

As a handler for the path received from the user, Flask is a micro-framework [7] for creating web applications and sites in Python, based on the WSGI interaction standard, the Werkzeug utility, and the Jinja 2 template engine. The algorithm of the message processing routine from the broker is shown in Figure 4.

To detect malfunctions of the lights, as well as to be able to monitor their status, the main program contains a subroutine for processing the activity of the lights. It checks whether too much time has coincided with the last activity of the lamp (which sends its state every few seconds to the broker and so updates the activity time) and if so, it can notify interested subscribers (operator) on topics about the malfunction, and for the user, this lamp becomes unavailable for use. The algorithm for checking the activity of street lamps is shown in Figure 5.

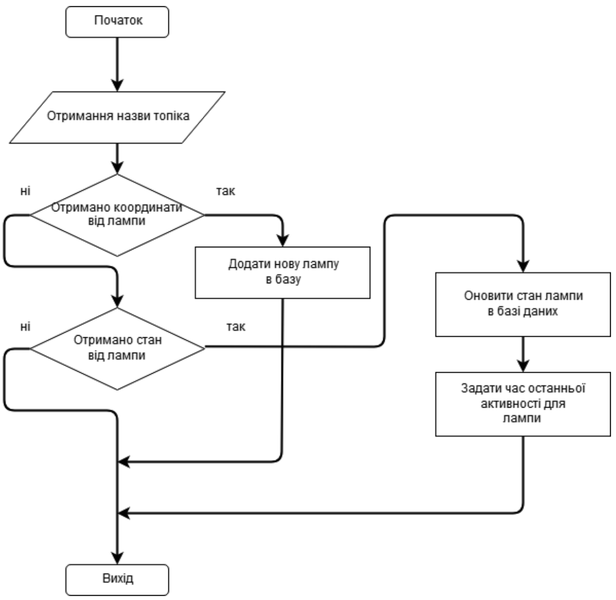


Figure 4. Processing subroutine messages from the Mosquitto

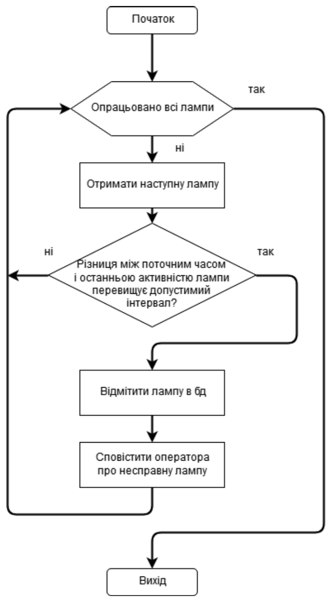
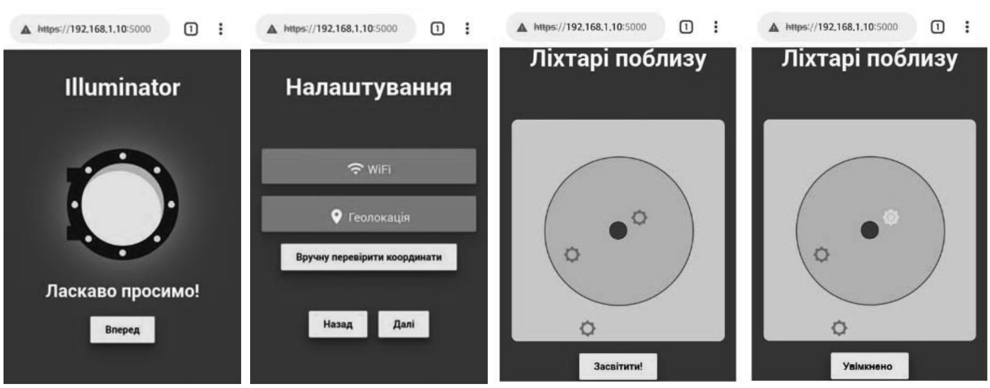


Figure 5. Processing subroutine broker of inactive lamps

The results of the research. Figure 6 shows the operation of the user application "Illuminator". On the side of the street lights controlled by the LuaNode32 IoT platform, a WiFi network is implemented through the program interface. In order for the system to know which lights to turn on, the user shares



a) b) c) d)

Fig. 6. Navigation of the user application «Illuminator» - a) the main screen of the application, b) the settings screen, c) the control screen of the lights, d) the event screen

their coordinates with it for a certain time using geofencing technology. In mobile applications, it uses the user's position and determines the moment of entering the specified virtual perimeter. For geofencing, the app uses GPS or Wi-Fi data. The geofencing coverage radius is up to 500 meters. To reduce power consumption, it is recommended to set a minimum zone of 100 meters and the frequency of updating the user's position no more than twice every 1 minute. Geolocation in the mobile app improves customer interaction. Thanks to it, the information comes to the user in the right place at the right time. The developed application "Illuminator" processes the geo-location of a resident of the city and sends a control signal to turn on the desired lamp.

Conclusions. The proposed system offers to use specialized streetlights under the control of intelligent platforms to improve the image of traditional street lighting management and consists of three main nodes: the user application "Illuminator" with support for geofencing, the cloud broker Mosquitto MQTT and street lights controlled by the IoT platform LuaNode32 via the WiFi interface. Through a cloud broker, residents of the city are provided with access to the service to temporarily turn off street lights in conditions of insufficient visibility in real-time, which will ensure the comfortable and safe movement of people on the street at night. The GPS and Wi-Fi functions enabled on the mobile device determine the user's location and the active Wi-Fi network.

The development of the software part was carried out in high-level languages Python, Lua, Javascript. To get a system that can be easily maintained in the future, popular frameworks and libraries were used, such as Flask, paho-mqtt, jQuery. They are characterized by open-source code and a meaningful user community.

A study was conducted on the effective lighting modes for implementing them in the developed mobile application. Verification experiments have shown that the average time to create a single message using the MQTT protocol does not exceed 589 microseconds.

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СИСТЕМА ДИСТАНЦІЙНОГО УПРАВЛІННЯ ВУЛИЧНИМ ОСВІТЛЕННЯМ НА ОСНОВІ ТЕХНОЛОГІЙ ІНТЕРНЕТУ РЕЧЕЙ

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У статті пропонується система управління вуличним освітленням для забезпечення комфортного та безпечного пересування вулицею людей в темний час доби із застосуванням функції геофенсінгу в мобільному додатку. Запропонована система використовує концепцію сервісної платформи з підтримкою IoT, яка використовує інфраструктуру, що складається з блоку керування вуличним ліхтарем реалізованого на LuaNode32 та шлюзу Wi-Fi. Дистанційне управління вуличним ліхтарем здійснюється по спрощеному мережевому протоколу MQTT, що працює на TCP/IP. Модель видавець- передплатник для обміну даними між блоком керування вуличним ліхтарем та мобільним застосунком реалізована через брокер Mosquitto. Ключовим є створення повноцінного додатка, який, поєднує в собі застосування хмарного сервера, пристроїв освітлення та бази даних для віддаленого управління системою освітлення. Розробка програмної частини проводилося мовами високого рівня Python, Lua, Javascript. Для отримання системи, яка може бути легко підтримувана в майбутньому були використані популярні фреймворки та бібліотеки, такі як: Flask, paho-mqtt, jQuery, які характеризуються відкритим вихідним кодом. Також з'ясовано апаратну та програмну реалізацію системи управління вуличним освітленням на основі IoT та їх відносні функції.

Ключові слова: *система освітлення, IoT, MQTT, Java, Lua, мобільний застосунок.*

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