THE DESIGN AND IMPLEMENTATION OF A STREET LIGHTING CONTROL SYSTEM USING A 802.11 COMMUNICATION PROTOCOL: A CASE STUDY

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REZUMAT. În această lucrare este prezentată proiectarea şi implementarea unui sistem de control al iluminatului stradal care are la bază un protocol de comunicație 802.11 de tipul Wi-Fi. În cadrul sistemului este aleasă o modalitate de control al iluminatului la nivel de zonă. Avantajul implementării unui astfel de sistem constă în obținerea unor costuri de implementare mult mai reduse deoarece numărul de echipamente este mult mai mic, datorat controlului zonal. După instalarea sistemului costurile aferente energiei electrice au fost reduse cu aproximativ 20% realizându-se astfel economii substanțiale.

Cuvinte cheie: controlul iluminatului stradal, sistem, protocolul de comunicație 802.11, arhitectură de control

ABSTRACT. This paper presents the design and implementation of a street lighting control system that is based on a 802.11 wireless communication protocol. Hence, the system integrates an area control method. The advantages brought by the implementation of such a system mainly consist in the fact that the installation costs are much lower, as the number of devices integrated in the system is substantially reduced, due to the well-defined control area. Following the installation, the energy consumption costs have diminished by approximately 20%, as compared to the previous control system, thus allowing for considerable additional savings.

Keywords: street lighting control, system, 802.11, control network

1. INTRODUCTION

The reduction of electrical power consumption is an important issue and on a European level are currently seeking for solutions.

A brief comparison between the wireless communication protocols that can be integrated in a street lighting control system is shown in Table 1.

Table 1

Wireless communication protocols

	Bluetooth	ZigBee	Wi-Fi	UWB	WiMax
IEEE Standard	802.15.1	802.15.4	802.11 a/b/g/n	802.15.3a	802.16 a/e/d
Frequency Band	2.4 GHz	868/915 MHz; 2.4 GHz	2.4 GHz; 5 GHz	3.1-10.6 GHz	10-66 GHz 2 - 11 GHz
Bandwidth	1Mb/s	250kb/s	54Mb/s	110Mb/s	75Mb/s
Number of nodes	8	>65.000	2007	-	-

As can be noted, the ZigBee and Wi-Fi communication protocols can be integrated in a street lighting monitoring and control system because of low cost devices and high number of nodes.

The reduction of the costs entailed by street lighting is an important issue that has drawn the attention of numerous research centers. The scientific literature presents a series of street lighting control systems that opted for an individual lamp command, by integrating a WSN protocol, such as ZigBee [1] and 6LoWPAN [2] or a PLC protocol type (Power Line Communications) [3] by using the existing power lines.

This paper presents the design and implementation of a street lighting control system that is based on a 802.11 [4] Wi-Fi communication protocol. Hence, we have chosen an area control method. The advantages of implementing such a system consist in the fact that the installation costs are much lower, as the number of devices integrated in the system is substantially reduced due to the specific control zone. The control of street lighting systems in Romania relies on photoelectric cells that use the external environment luminosity level.

The disadvantages of this control method consist in a reduced performance level due to miscalibration, impurity built-up or faulty installation that can compromise the entire system. The novelty of this paper consists in the design and implementation of a street lighting control architecture which is based on a 802.11 wireless communication protocol.

2. SYSTEM DEVELOPMENT

The system architecture is shown in Figure 1, as it consists in the main control center, the wireless network and the lighting control points distributed across a wide geographical area. The system is based on a wireless network that covers the entire city, implemented using a Wavion WBS (Wireless Base Station) 2400 station. The wireless 802.11 access point is a Wavion WBS-2400 station, operating in the 2.4 GHz band. The station has an array of 6 omnidirectional antennas of 7.5 dBi with a -105.5 dBm sensitivity and operating in 802.11g mode [5]. The WBS-2400 is connected to the command center where the graphical user interface (GUI) of the street lighting control application is installed.

Specific area street lighting control entails the presence of the central points that control a high number of lamps in a specific geographic zone. Previous papers [6] - [12] have presented the design and implementation of a street lighting monitoring and control system based on a WSN sensor network spread across a wide geographical area. However, the disadvantage of this system consists in the high implementation costs due to the retrofitting of the lamps with sensors.

As shown in Figure 1, the street lighting control system uses the architecture of a wireless Internet access system of the Free Hotspot type.

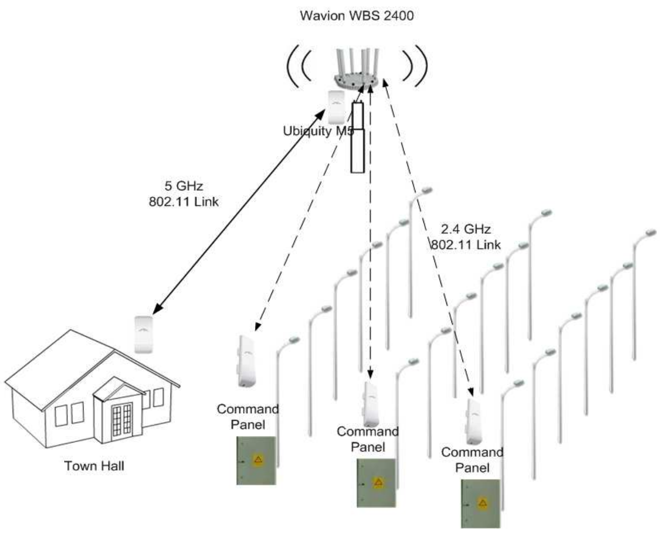

Fig. 1. System structure.

Since the 2400 WBS station must be installed at a high altitude in order to cover as wide an area as possible, a communication link is used between the station installation point and the system control center. This link operates in the 5 GHz ISM (Industrial Scientific and Medical) frequency bandwidth. This link enables Internet access; the type of equipment used is provided by the Nano Station M5 Ubiquity [13] which allows for a data transfer rate of 54 Mb/s within a 10 km radius.

The coverage area of the WBS 2400 base station is of approximately 25 km in non-LoS (Line-of-Sight) conditions, enabling a transfer rate of up to 54Mb/s due to the beam forming technology operating in the unlicensed 2.4 GHz frequency bandwidth. Thus, when performing an operation from the control center, the command is sent through the link to the station and is afterwards diverted to the control point of the specific area. The connection between the control points installed across a wide geographical area and the base station is ensured by devices such as the CPE (Customer-Premises Equipment) NanoStation M2 that operate in a 2.4 GHz bandwidth. These are connected to a VPN (Virtual Private Network) wireless network provided by the base station.

3. HARDWARE DEVELOPMENT

The control system consists of two modules, i.e. the automatic street lighting control and the remote control system that allows the setting of a default operating program. The automatic street lighting control is based on an Astro controller [14] that commands (on/off) the lamps automatically, depending on the sunset/sunrise time that the module calculates by using a specific algorithm.

The Astro module is configured by entering the GPS coordinates (latitude and longitude) of the location where the device is installed. The device has a built-in astronomical clock which calculates the sunrise/sunset times by using a microprocessor with a 2 ms error, based on the exact location on the globe. The system can operate in the standalone configuration, thus replacing the traditional photovoltaic cells or the programmable clocks which may affect the performance of the system due to faulty installation or degradation.

The second part of the system is based on a PCL (Programmable Logic Controller) Barix programmable automaton of the Barionet 50 type. The PLC has four contact closure inputs, four relay outputs which support a maximum voltage of 24V and a current of 0.5A [15]. The relays can be controlled by using a TCP/IP communication protocol and a web interface via the built-in 10/100 Ethernet port.

Since PLC networks cannot support more than a 24V DC voltage, two additional power relays are used to command the street lighting control contactor. Figure 2 shows the PLC and the Astro devices.

a) b)

Fig. 2. Astro (a) and Barionet 50 (b) devices.

Figure 3 shows the hardware diagram of the control panel. The system consists of the CPE device that enables the remote control transmission, the PLC Barionet, two relays, the Astro device and the contactor that controls the lamps.

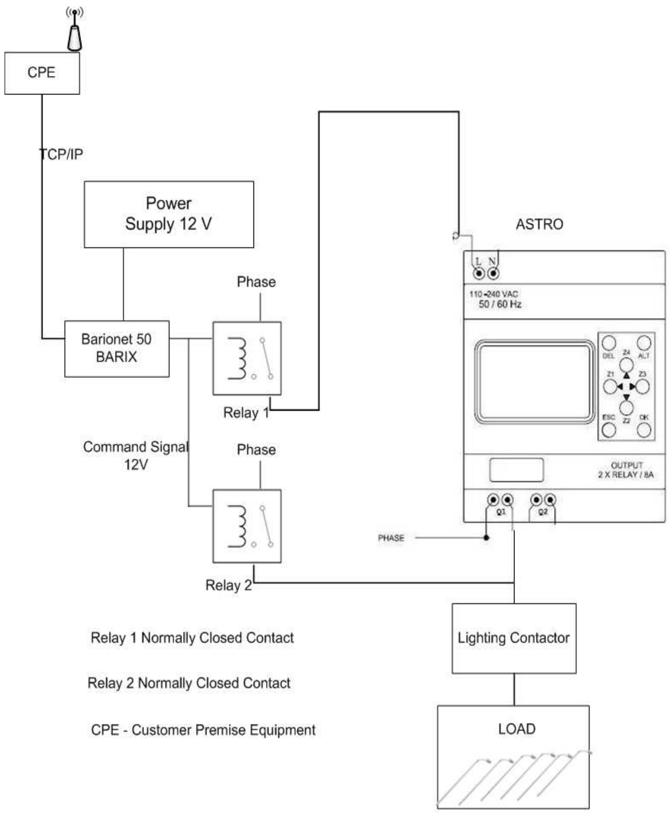

Fig. 3. Hardware Design.

Figure 4 presents the configuration interface of the Astro device. Programming it is relatively easy, as the only settings the user must make are the time zone, the GPS coordinates (latitude and longitude) of the location where the device is installed and the operating method that can be of the sunset/sunrise or trigger on twilight type.

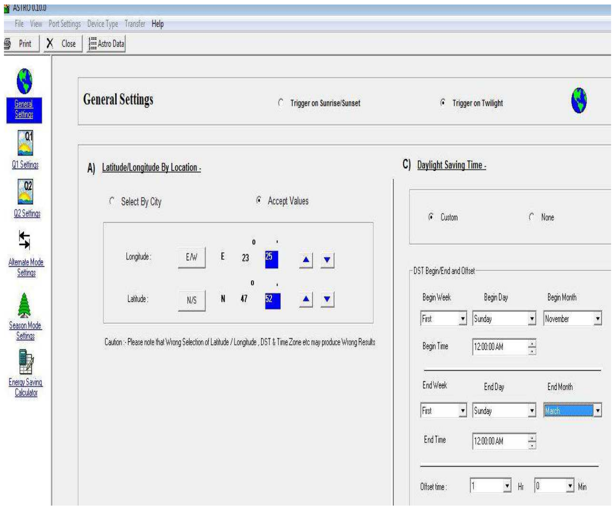

Fig. 4. Astro configuration software.

The street lighting on/off command time table is presented in Figure 5, as calculated by means of the algorithm integrated in the Astro and the timetable without the control system. Street lighting is therefore precisely controlled by simply determining the exact sunset and sunrise time and thus diminishing the power consumption costs.

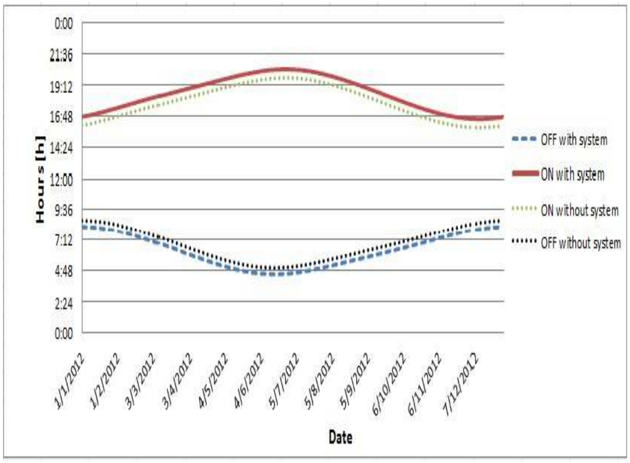

Fig. 5. Sunset/sunrise hours calculated by Astro.

4. SOFTWARE DEVELOPMENT

The logical diagram of the user interface installed in the control center is presented in Figure 6. As can be noted, when the command is received, the first step is to stop the automatic control provided by the Astro device, by enabling the first relay, and then enabling the second relay that controls street lighting (on/off command).

The Barix module has an integrated web server that allows the disabling of the Astro automatic control and the enabling of the street lighting control relay. Thus, street lighting control can be performed according to specific needs and circumstances.

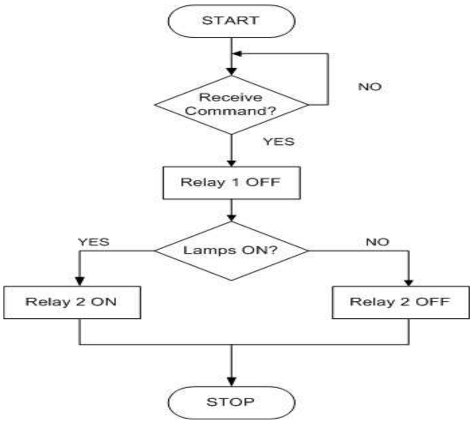

Fig. 6. Logical diagram.

In Figure 7 is presented the web server that runs on Barionet device. In order to manually command the street lighting the user must first stop the automatic control assured by the Astro device.

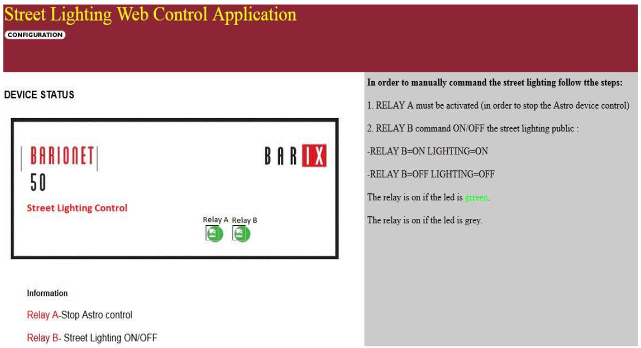

Fig. 7. Barionet interface.

The application suggested was implemented in the Visual Basic programming language and provides the user with a map showing the location of the centralized control points. The user interface installed at the command center is presented in Figure 8.

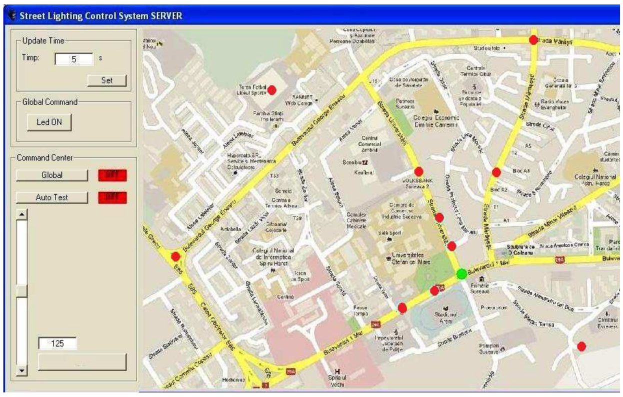

Fig. 8. Graphical User Interface.

Such a map providing information on the status of the lamp control points is presented in Figure 8. When the lamps are on in the area, they are shown as green dots, while if turned off, they are shown as red dots. Thus, the user can easily detect any problem that may occur.

5. CONCLUSIONS

The street lighting control system was implemented in a town, in Romania. The previous command system was based on photoelectric cells that maintain a low performance level. The control panels were installed at all the seven control points installed across a wide geographical area. The lamps integrated in the system are of the HPS (High Pressure Sodium) 240W type. Following the installation of the suggested system, the energy consumption costs have diminished by approximately 20%, as compared to the previous control system, thus allowing for additional savings. Thus, the proposed system enables the considerable reduction of the energy costs. The implementation costs are quite low, due to the small number of devices used.

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