Remote Control System of High Efficiency and Intelligent Street Lighting using a ZigBee Network of Devices and Sensors

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Abstract: This project is mainly used to save power automatically instead of doing manual by using IR sensors. The main consideration in the present field technologies are Automation, Power consumption and cost effectiveness. Automation is intended to reduce man power with the help of intelligent systems. Power saving is the main consideration forever as the source of the power (Thermal, Hydro etc.) are getting diminished due to various reasons. The main aim of the project is Automatic street power saving system with IR. This is to sensor save the power. We want to save power automatically instead of doing manual. So its easy to make cost effectiveness. This saved power can be used in some other cases. So in villages, towns etc we can design intelligent systems for the usage of street lights. Here we are using micro controller, IR sensors, Relay and Lights. In this project IR transmitter is connected in forward bias and IR receiver is connected in reverse bias and we will take the output at receiver end which is connected to the microcontroller port pin. IR transmitter continuously emits the IR signals. IR receiver receives the IR signals emitted by the transmitter. When there is an object between the transmitter and receiver, the output of IR sensor is logic 1. When there is logic 1 at the output we will turn ON the lights. When there is no object between the transmitter and receiver, the output of IR sensor is logic 0. When there is logic 0 at the output we will turn OFF the lights.

Keywords: Automation, Control System, Lighting System, Sensors, Wireless Networks, ZigBee.

I. INTRODUCTION

Lighting systems, especially in the public sector, are still designed according to the old standards of reliability and they often do not take advantage of the latest technological developments. In many cases, this is related to the plant administrators who have not completed the return of the raw material costs and the greater social sensitivity to environmental issues are leading manufacturers to develop new techniques and technologies which allow significant cost savings and a greater respect for the environment. We can find three possible solutions to these problems in the literature. The first one, and perhaps the most intuitive, is the use of new technologies for the sources of light. In this area, light-emitting diode (LED) technology is the best solution because it offers many benefits. Researchers [1]–[4] have already considered this possibility, designing an advanced street lighting system based on LEDs. The second possible solution, and perhaps the most revolutionary, is the use of a remote-control system based on intelligent lamp posts that send information to a central control system, thus simplifying management and maintenance issues.

Researchers [5]–[9] have developed a street lamp system using the general-packet radio service (GPRS), power-line carrier, or Global Systems for Mobile Communications (GSM) transmissions. Finally, the third possibility would be the use of renewable energy sources locally available, rather than conventional power sources, with a positive effect on the environment. Solar energy is the most important resource in this field. Our work aims at the unification of the three mentioned possibilities, creating an intelligent lamp post managed by a remote-controlled system which uses LED-based light sources and is powered by renewable energy (solar panel and battery). The control is implemented through a network of sensors to collect the relevant information related to the management and maintenance of the system, transferring the information via wireless using the ZigBee protocol. The field of the ZigBee remote sensing and control system is widely present in the literature; we can also find ZigBee systems similar to (the) lighting systems in structure and management [10]–[18]. In this paper, we present our system, which is able to integrate the latest technologies, in order to describe an advanced and intelligent management and control system of the street lighting.

II. DEVICES AND METHODS

Figure 1 shows the conceptual scheme of the proposed system. It consists of a group of observation stations on the street (one station for each lamp post) and a base station typically placed in a building located nearby. It is a modular system, easily extendable. The measuring stations monitor the street conditions and the intensity of sunlight and, based on them, they decide to turn the lamps on or off. The conditions depend on the pattern of the street where the lights are located.
and on the solar irradiation at a given point of the street, with frequent changes, depending on weather conditions, season, geographical location, and many other factors as shown in Fig.2. For these reasons, we decided to make each lamp completely independent in the management of its own lighting. The on-street station also checks if the lamp is properly working and sends the information through the wireless network to the base station for processing data. If any malfunction is detected, the service engineer is informed through a graphical interface and can perform corrective actions.

**Light Sensor:** A light sensor can measure the brightness of the sunlight and provides information. The purpose of this measurement is to ensure a minimum level of illumination of the street, as required by regulations (see CIE et al. [19]). The sensor must have high sensitivity in the visible spectrum, providing a photocurrent high enough for low light luminance levels. For this reason, the phototransistor TEPT5700 (by Vishay Semiconductors) has been selected. Based on the measured luminance, the microcontroller drives the lamp in order to maintain a constant level of illumination. This action is obviously not required during daylight time, but it is desirable in the early morning and at dusk, when it is not necessary to operate the lamp at full power but simply as a “support” to the sunlight. This mode enables saving electric power supplied to the lamp because the lamp is regulated by the combined action of the sensor and the microcontroller to ensure the minimum illumination required.

**Operating Control:** This sensor is useful to improve fault management and system maintenance. Thanks to this sensor (in this case, a Hall sensor), it is possible to recognize when the lamp is switched on. The system is able to recognize false positives, because identified parameters are compared with the stored data (e.g., lamps are switched off during daylight and the sensor incorrectly detects a fault, but the microcontroller does not report the malfunction because of additional logic functions).

**Presence Sensor:** The task of the presence sensor is to identify the passage of a vehicle or pedestrian, giving an input to turn on a lamp or a group of lamps. This function depends on the pattern of the street; in case of a street without crossroads, a single sensor is sufficient (or one at each end in case of a two-way street), while for a street requiring more precise control, a solution with multiple presence detectors is necessary. This feature enables switching on the lamps only when necessary, avoiding a waste of energy. The main challenge with such a sensor is its correct placement. The sensor should be placed at an optimal height, not too low (i.e., to avoid any erroneous detection of small animals) nor too high (for example, to avoid failure to detect children). A study of the sensor placement enables deciding the optimal height according to the user needs and considering the specific environment in which the system will work. We discovered that in field tests, the SE-10 PIR motion sensor offers good performance and is quite affordable.

**A. Monitoring Stations**

The monitoring station located in each lamp post consists of several modules: the presence sensor, the light sensor, the failure sensor, and an emergency switch. These devices work together and transfer all of the information to a microcontroller which processes the data and automatically sets the appropriate course of action. A priority in the transmission of information is assigned to each sensor, for example, the emergency switch takes precedence over any other device.

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![Fig. 1. Schematic image of the system.](image1)

![Fig. 2. Schematic image of an on-street station.](image2)

![Fig. 3. Control software flowchart.](image3)
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The information is reported through the ZigBee network to the station control unit, where the operator is informed about the location of the broken-down lamp and can send a technician to replace it. The system current is 1.5 A, so a sensor suited to detect this current is necessary. An appropriate threshold value to detect the operation of the lamp has been set between 1 and 1.5 A. The chosen sensor is the ACS756 [20] of the Allegro Microsystems, an economical and precise solution for ac or dc current sensing, particularly suitable for communication systems. Thanks to this sensor, it is possible to store in the microcontroller’s memory the current value which flows in the LED lamp in normal operating conditions, enabling the online power consumption measurement.

Emergency Device: The system has an emergency button, which can be useful in case of an emergency. This device excludes the entire sensor system with the objective to immediately turn on the lamp. The light will remain on for a preset time. After that, the button must be pressed again. This prevents the system from being accidentally active even when the necessity ends. Obviously, this device does not work during the day, when there is no need for artificial light.

Control Unit: The sensors transfer the collected information to a controller which runs the software to analyze the system. Fig. 3 shows the control software flowchart. After the initial setting, the system is controlled by the light sensor which activates the microcontroller only if the sunlight illumination is lower than a fixed threshold. In this case, the system reads the state of the emergency button, and switches on the lamp if this is activated. The same happens in case of a vehicle or a pedestrian. Once the lamp has been switched on, the operating sensor starts the monitoring and, in case of fault detection, an alarm is sent to the control center. If no fault is detected, the microcontroller measures the current flux by the Hall sensor memorizing the current values.

The entire operation is regulated by a timer which enables the system to work for the predetermined time. At the stop input, the lamp is turned off and the cycle restarted. The algorithm has been written in Pic Basic and runs on the microcontroller.

B. Base Control Station

The base control station is the hub of the system since it allows the visualization of the entire lighting system. The transmission system consists of a ZigBee device that receives information on the state of the lamps and sends it to a terminal. The processing unit consists of a terminal with a serial Universal Asynchronous Receiver-Transmitter (UART) interface which receives information about the state of the lamps provided by a ZigBee device. The terminal is required for a graphical display of the results. Moreover, data on lamps’ operation are associated with the lamp address; consequently, all faults are easily identified. The graphical interface enables monitoring the state of the system (upper section of Fig. 4 with the state of the lights and the power consumption of each lamp (lower section of Fig. 4)). The operator will have a graphical representation of the lamp location within the area where the system is installed. Pressing the button “Power Consumption Data,” a second window appears where power consumption and working time of any lamp are given. The program is also equipped with a management system that acts in case of no communication from the lamp posts well explained in Section III-E after the description of the entire system.

C. ZigBee Network

ZigBee is a wireless communication technology based on the IEEE802.15.4 standard for communication among multiple devices in a wireless personal-area network (WPAN). ZigBee is designed to be more affordable than other WPANs (such as, for example, Bluetooth) in terms of costs and, above all, energy consumption. A ZigBee personal-area network (ZBPAN) consists of at least one coordinator, one (or more) end device(s) and, if required, one (or more) router(s). The network is created when a coordinator selects a channel and starts the communication, hence forth, a router or an end device can join the network. The typical distance of a ZigBee transmission range, depending on the environment conditions and the transmission power, shifts from tens to hundreds of meters, and the transmission power is deliberately kept as low as possible (in the order of a few milliwatts) to maintain the lowest energy consumption[21]–[26]. In the proposed system, the network is built to transfer information from the lamp posts to the base station control. Information is transferred point by point, from one lamp post to another where each lamp post has a unique address in the system. Each lamp post can only send the information to the nearest one, until the information reaches the base station. Thus, transmission power is limited to the required low value and the signals sent by the lamp posts do not interfere with each other.

In case of failure of one lamp, the chosen transmission distance between the lamp posts ensures that the signal can reach the next operational lamp post without breaking the chain. The ZigBee wireless communication network has been
implemented with the use of Digi-Max Stream radio-frequency modules called XBee modules, which are available in Standard and Pro versions (pin-to-pin compatible) [20], [21]. The Standard Xbee modules have an operation range of tens of meters indoors and hundreds of meters outdoors, while the Xbee Pro modules have a wider spread range in the order of hundreds of meters indoors and of about 1.5 km outdoors, because the Pro modules have higher transmission power, but imply higher consumption (about three times the consumption of the Standard version). The receiver has very high sensitivity and a low probability of receiving corrupted packets (less than 1%). The modules should be supplied by 3 V from a dc source; the current consumption is in the order of 50 mA (for Xbee) and 150–200 mA (for XbeePRO) in uplink and in the order of 50 mA in downlink (identical for both versions); moreover, they support a sleep mode where consumption is less than 10 A. The XBee modules are distributed in three versions of antennas: with an on-chip antenna, a wire antenna, and with an integrated connector for an external antenna.

D. Details and Buildup

In the proposed system the most important elements are:

- The voltage controllers which provide power to all other devices;
- The microcontroller (U2, Microchip PIC 16f688), which manages the system where the firmware is uploaded;
- The Xbee module;
- Connectors for programming the pic (ProgPort), for optional serial transistor logic (TTL), for an external reference voltage, necessary for the correct activity of the PIC analog-to-digital converter (ADC), and for the input/output (I/O) ports.

![Fig. 5. Printed-circuit board.](image)

Fig. 5. Shows the printed-circuit board (PCB) of the monitoring station circuit. The circuit has been realized in surface-mount device (SMD) technology to reduce the overall dimensions. Fig. 6 shows the realized prototype allocated in its box ready for tests. This is the prototype tested in real-life conditions.

![Fig. 6. Prototypes.](image)

Finally, Fig. 7 shows the operational test system working in real conditions. It is visible that the proposed systems can also be used for upgrading existing conventional lamp posts. Power is supplied by a battery recharged by a solar panel during the daytime. The capacity of the battery depends on the specific needs of the final application. The irradiation curves of the site have been studied during a project about making a photovoltaic system, in order to determine the right inclination and orientation of the solar panels to enable the best outcome of the operation. It is possible to refer to publications which provide precise data as a function of latitude (referring to UNI 10349 data obtained by PVGIS [27]). For the sizing of the panel, it is necessary to determine the annual energy required to power the lighting system under analysis. The project data here below are necessary to determine the energy produced annually by a photovoltaic panel:

- Location of the installed panel;
- Inclination of the absorbing surface;
- Orientation of the absorbing surface;
- Ground-level reflection;
- Nominal power of the panel;
- Losses of the solar panel;
- Efficiency of the charger controller.
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The charge controller manages the processes of the battery charge and power supply. Electric power generated by photovoltaic panels is handled by the controller to provide an output current for the battery charge. The charging process must be conducted according to the battery features (capacity, voltage, chemistry, etc.), providing current until the battery has been completely charged, and then switching to a standby current to compensate the battery self-discharge. The selected model(CMP12 JUTA of HARBIN Hopeful STAR [28]) provides voltage regulation of battery charging as a function of temperature and has built-in electronic protection to contrast overload, short circuit, and overvoltage.

III. TESTS AND RESULTS

Results of this paper is shown in bellow Fig.8.

Fig. 8. Circuit under reset condition.

IV. CONCLUSION

The proposed remote-control system can optimize management and efficiency of street lighting systems. It uses ZigBee-based wireless devices which enable more efficient streetlamp-system management, thanks to an advanced interface and control architecture. It uses a sensor combination to control and guarantee the desired system parameters; the information is transferred point by point using ZigBe transmitters and receivers and is sent to a control terminal used to check the state of the street lamps and to take appropriate measures in case of failure.

V. REFERENCES


