Intelligent Street Lighting Using a ZigBee Network and Adaptive Power Saving Using LED

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***Abstract*— The proposed system which is remote-controlled optimizes, manages and improves efficiency of street lighting systems. To enable more efficient street lamp-system managing it uses ZigBee wireless devices. It uses a sensor combination is used to guarantee and control the desired system parameters. ZigBee transmitters and receivers are used to transfer the information point by point. These also checks the state of the street lamps under the signal is sent to control terminal and thereby takes appropriate measures in case of failure.**

Index Terms—**Automation, control system, lighting system, sensors, wireless networks, ZigBee.**

I. INTRODUCTION

LIGHTING systems, especially in the public sector, are designed according to the old standards of reliability and they do not take advantage of the latest technologies. This is related to the plant administrators who have not completed the return of the expenses derived from the construction of existing facilities yet. Now-a-days, the recent increasing pressure related to the raw material costs and environmental issues belonging to social sensitivity are leading manufacturers to develop new techniques and technologies which allow significant cost savings, power saving and a greater respect for the environment. We can find three possible solutions to these problems in the article.

The first 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.

The second 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 mainly power saving.

Finally, the third possibility is 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 combination of the three mentioned possibilities, creating an intelligent lamp post managed by LED-based remote- controlled system and is powered by renewable energy which consists of solar panel and battery.

Fig.1. Schematic image of the system.

The control is implemented through a network of sensors to collect the relevant information related to the maintenance and management of the system, transferring the information via wireless using the protocol of ZigBee .The field of the ZigBee remote sensing and control system is widely present in the recent technologies.

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. EXISTING SYSTEM

Researchers have already designed an advanced street lighting system based on LEDs. Also, Researchers have developed a street lamp system using the general-packet radio service (GPRS), power-line carrier, or Global Systems for Mobile Communications (GSM) transmissions. The existing system does have some limitations in accordance with it when applied individually. To overcome this some tradeoffs should be implemented accordingly.

II. DEVICES AND METHODS

Fig. 1 shows the schematic view of the proposed system. It consists of a group of observation stations on the street and a base station typically placed in a building located nearby. It is a modular system, easily extendable further.

The measuring stations monitor the intensity of sunlight and the street conditions, 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.

For these reasons, we decided to make each lamp completely independent in the management of its own lighting. The on-street station also checks whether the lamp is properly working if not 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 immediately.

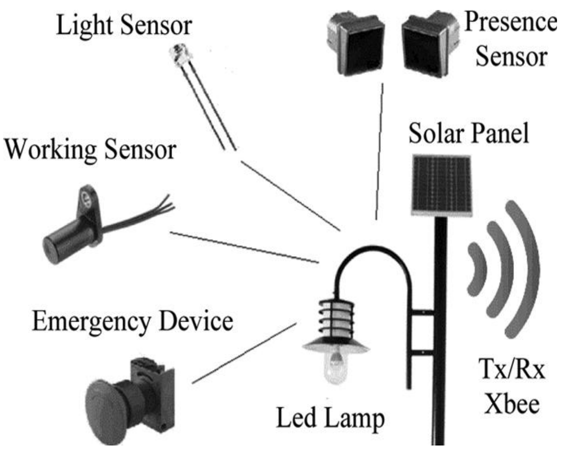

Fig. 2. Schematic image of an on-street station.

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 corrective course of action. For the transmission of information priority is assigned to each sensor, for example, the emergency switch takes precedence first.

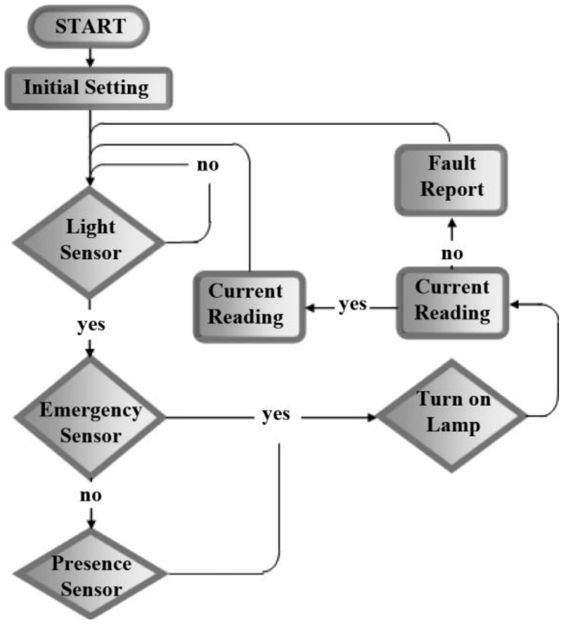

Fig. 3. Control software flowchart.

1) Presence Sensor: The role of the presence sensor is to identify the passage of a vehicle or pedestrian and it gives 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, a solution with multiple presence detectors is necessary. This feature enables switching on the lamps only when necessary, avoiding wastage 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 the optimal height according to the user needs and considering the specific environment it work. We discovered that in field tests, the SE-10 PIR motion sensor offers good performance and is quite affordable.

2) 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. 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 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 not required during daylight time.

3) Operating Control: This sensor is useful to improve fault management and system maintenance. 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).

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.

4) 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.

5) Control Unit: The sensors transfer the collected information to a controller which runs the software to analyze the system. 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 centre. 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.

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. Moreover, data on lamps' operation are associated with the lamp address; consequently, all faults are easily identified.

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, henceforth, 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 to maintain the lowest energy consumption.

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 lamppost 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 lampposts do not interfere with each other.

In case of failure of one lamp, the chosen transmission distance between the lampposts 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-MaxStream radio-frequency modules called XBee modules, which are available in Standard and Pro versions (pin-to-pin compatible). 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 XBee PRO) 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.

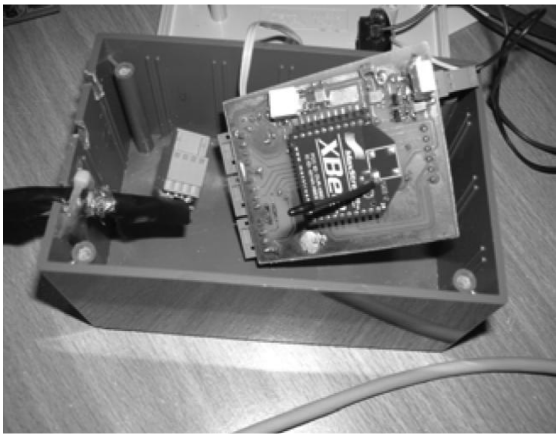

Fig. 5. Prototypes.

D. Details and Build-up

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.
• TheXBeemodule.

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 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.

III. THEORITICAL ANALYSIS

A. Range Test

The prototype has been analysed in variable real-life conditions to verify the overall functionality and seek better performance. Based on researcher's test under range of ZigBee modules performance were done at the Electric and Electronic Measurements Laboratory of Roma Tre University, to test the reliability of the communication between two or more ZigBee modules in the following environmental conditions:
1) Open field in line of sight between modules;
2) Open field out of the line of sight where the obstacle is a big tree or a hill;
3) Indoor test.

The tests were carried out using different types of XBee modules, Standard and Pro, each one with three different types of antennas (patch, wire, external) provided by the manufacturer. Test cases were designed to check the network in various real-life operating conditions: clear weather, rain, and proximity of electrical or electronic devices possibly interfering with the transmission (such as a WiFi access points). The indoors tests were done considering one or more walls between the transmitter and the receiver, while the outdoor ones were performed with one or more natural obstacles like trees or hills. Ten-thousand transmission tests were performed for each case, using an appropriate adapter to simulate the retransmission. Analysed average reliability was 99.99%. The same tests were performed on the XBee Pro and the percentage of reliability was 100% in each case.

Fig. 6. Proposed system.

Finally, Fig. 6 shows the operational system working in real conditions. It is visible that the proposed systems can also be used for upgrading existing conventional lamp posts.

B. Power Management

The system was designed to be standing alone, supplied by solar panel energy, with relevant advantages resulting from this kind of power supply. It is possible to avoid the tedious and expensive wiring of the supply power network, with considerable savings and ease of implementation. The control circuit is designed to consume the lowest possible power, minimizing the battery capacity and the energy supplied by the solar panel.

These goals were achieved through the use of the XBee module for transmitting and receiving information, using LED lamps as a replacement for standard lamps and using special power-saving solutions for microcontrollers and radio modules. The program, which controls the system, is designed primarily to save energy. First, since the system only works at night, avoiding wasting energy during daylight hours occurs when the only active device is the solar panel recharging the battery. Second, various sensors allow the system to work only when necessary. Third, the system implies highly efficient LEDs to ensure proper illumination and ensure energy savings.

C. Comparison with a Classic Lamp Post

To make a quantitative test of the advantages available by our system in comparison with a classical lamp post, three other lamp posts were added in parallel to the others. Their switching on is controlled only buy a crepuscular sensor which keeps the lamp posts on during dark hours.

1) 18-W LED lamp with 1550 lumen (84 lm/W luminous flux), powered by a solar panel and a battery;

2) 18-W LED lamp with 1550 lumen (84 lm/W luminous flux), supplied by mains through an ac/dc converter to have 12 V;

3) 50-W mercury-vapor lamp by the OSRAM model HQL50 with 1800 lm (36 lm/W luminous flux), supplied by mains through an HV starter and a reactor.

IV RESULTS

The results were emphasized using MPLAB. MPLAB is a free integrated development environment for the development of embedded applications on PIC and dsPIC microcontrollers.

Fig 7. Represents the initial state of simulation result done using proteus tool. As soon as the LDR is on the external current usage is stopped and it starts using saved energy from solar.

Thus power consumption is reduced. (Shown in Fig 8.) when the pedestrian crosses the street in night ,the detection starts and it is shown in Fig.9.

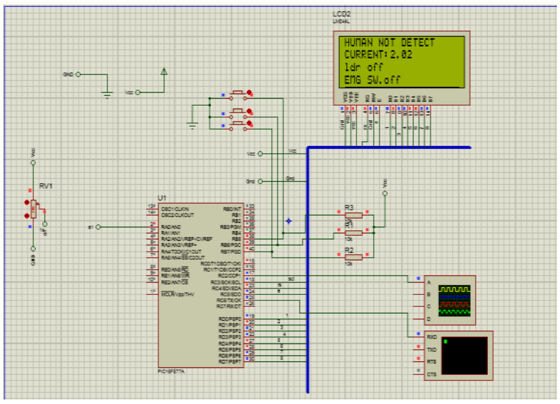

Fig. 7. Initial state.

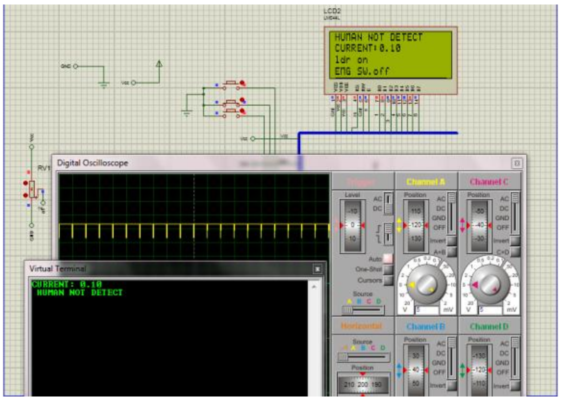

Fig. 8. ON state of LDR.

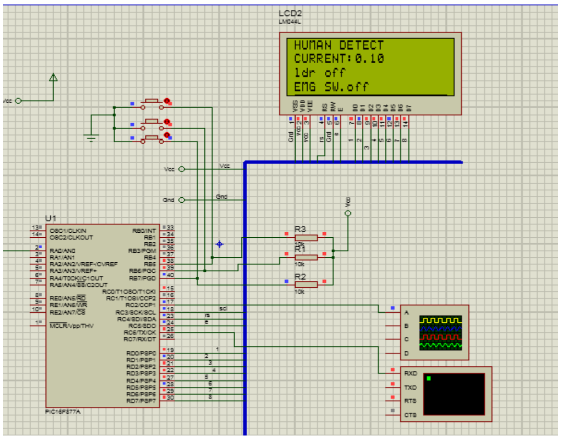

Fig. 9. Human detection.

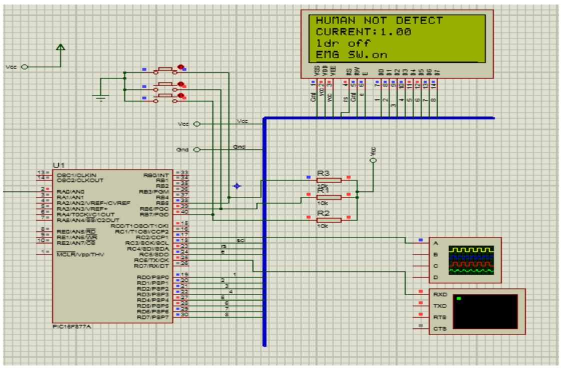

Fig. 10. Emergency preset condition.

IV. CONCLUSION

This paper describes a new intelligent street lighting system which integrates new technologies available on the market to offer higher efficiency and considerable savings. This can be achieved using the highly efficient LED technology supplied by renewable energy of solar panels, for which the cost of energy is independent from the power supplier prices, combined to an intelligent management of the lamp posts derived by a control system switching on the light only when necessary, increasing the lamps' lifetime.

Another advantage obtained by the control system is the intelligent management of the lamp posts by sending data to a central station by ZigBee wireless communication. The system maintenance can be easily and efficiently planned from the central station, allowing additional savings.

The proposed system is particularly suitable for street lighting in urban and rural areas where the traffic is low at a given range of time. The independent nature of the power-supply network enables implementing the system in remote areas where the classical installations are prohibitively expensive. The system is always flexible, extendable, and fully adaptable to user needs.

The simplicity of ZigBee, the reliability of electronic components, the feature of the sensor network, the processing speed, the reduced costs, and the ease of installation are the features that characterize the proposed system, which presents itself as an interesting engineering and commercial solution as the comparison with other technologies demonstrated.

The system can be adopted in the future for loads supplied by the power system, which enables the monitoring of energy consumption. This situation is particularly interesting in the case of economic incentives offered to clients that enable remote control of their loads and can be useful, for example, to prevent the system blackout. Moreover, new perspectives arise in billing and in the intelligent management of remotely controlled loads and for smart grid and smart metering applications.

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