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Highly Efficient and Intelligent Indoor and Outdoor Lighting System Using a ZigBee Network of Devices and Sensors

P.Dhinakar[1], R.Pradeepraja[2], R.Preethilatha[3], M.Barani[4], S.Shanmathi[5]

PG scholars, Department of ECE, Bannari Amman Institute of Technology, Sathyamangalam,India.[1, 2, 3, 4, 5]

ABSTRACT—The proposed method aims at developing a remote control system for optimizing the efficiency of outdoor and indoor lighting systems. The remote control outdoor lighting system uses a combination of sensors to control and guarantee the desired system parameters; ZigBee Transmitter and Receiver which transfers information point by point and is sent to a control terminal which checks the state of lamps and takes appropriate measures in case of failure.

KEYWORDS—Automation, control system, lighting system, sensors, ZigBee.

I. INTRODUCTION

LIGHTING systems, in indoor and outdoor, are still designed according to the old standards of reliability and they often do not take advantage of the latest technological developments. The recent increasing pressure related to 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 indoor and outdoor lighting.

II. DEVICES AND METHODS

The Proposed system consists of a group of observation stations on ground floor of the apartment (one station for each lamp post) and a base station typically placed in the building.

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The measuring station monitors the street conditions and the intensity of the sunlight and based on the condition, they decide to turn the lamps on or off. The conditions depend on the pattern in which the lights are located and the solar irradiation at a given point of the path, with frequency changes, depending on weather conditions, season, and geographical location. The on-street station also checks if the lamp is working properly 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.

A. Monitoring Stations

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

1)Presence Sensor: The presence sensor identifies the passage of a person, giving an input to turn on the lamp or a group of lamps. A single sensor is sufficient on each floor of the apartment. This feature enables switching on the lamps only when necessary, avoiding a waste of energy. The main challenge with such sensor is its correct placement. The sensor should be placed at an optimal height, not too low nor too high.

2)Light Sensor: A light sensor measures the brightness of the sunlight and provides information. This measurement is done to ensure a minimum level of illumination. Based on the measured luminance, the microcontroller drives the lamp in order to maintain a constant level of illumination. This action is mainly required at the early morning and at dusk, since it is not necessary to operate the lamp at full power but simply as a support to the sunlight. Thus the electric power supplied to the lamp is saved because the lamp is regulated by the combined action of the sensor and microcontroller to ensure minimum illumination required.

3)Emergency Device: The system contains an emergency button, which is used in case of an emergency. This device excludes the entire sensor system in order 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.

4)Control Unit: The information collected from sensors is transferred to a controller which runs software to analyse the system. After the initial setting, the system is controlled by the light sensor which activates the microcontroller 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 pedes-trian. Once the lamp has been switched on, the operating sensor starts the monitoring and, in case of a fault detection, an alarm is sent to the control center.

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.

B. 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

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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 mill watts) 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 to another where each lamp has a unique address in the system. Each lamp 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 lamps ensures that the signal can reach the next operational lamp without breaking the chain. The ZigBee wireless communication network has been implemented with the use of DigiMaxStream radio-frequency modules called XBee modules, which are available in Stan-dard 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 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 μA. 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.

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III. TESTS AND RESULTS

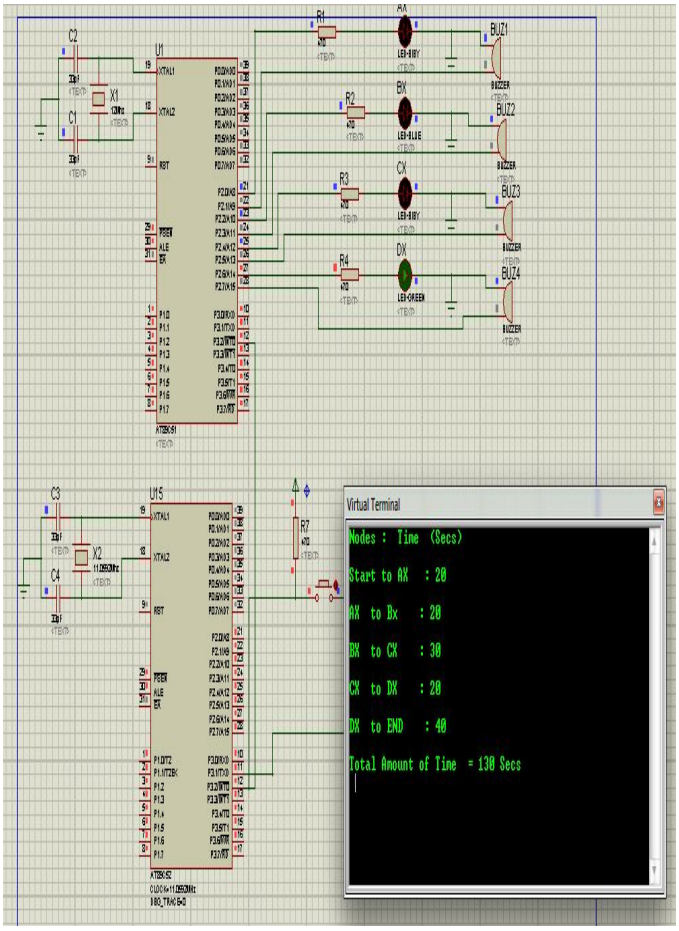

Fig.1. Presence sensors detect the movement of persons and calculate the amount of time to cross each sensor unit.

The presence sensor detects the presence of the pedestrian and gives an input to turn on the lamp or group of lamps. The time taken for the lamp to ON and OFF is calculated. If any malfunction is detected, an error is obtained. In Fig.1. Four LED's are taken as four lamp posts, LED turns ON when a pedestrian is detected and is OFF when the person has moved away and the other LED turns ON and so on. The time taken for one LED to turn ON and the other LED to turn OFF is calculated. The results are simulated and tested using Proteus and KeilµVision tools.

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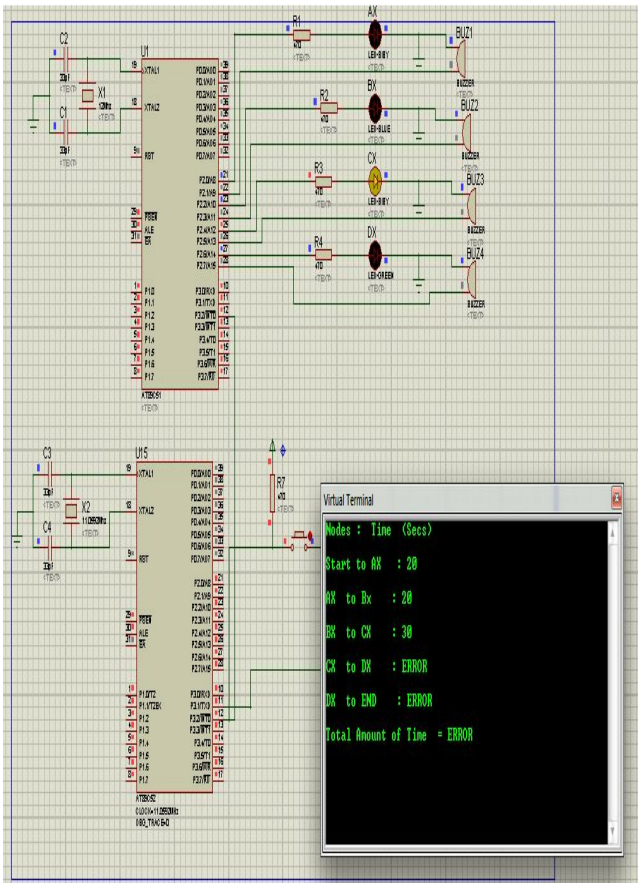

Fig.2. Emergency sensors, condition like fault in the presence sensors unable to calculate the time will activate emergency sensors

The presence sensor detects the presence of the pedestrian and gives an input to turn on the lamp or group of lamps. The time taken for the lamp to ON and OFF is calculated. If any malfunction is detected , an error is obtained. In Fig.2. Four LED's are taken as four lamp posts, LED turns ON when a pedestrian is detected and is OFF when the person has moved away and the other LED turns ON and so on. The time taken for one LED to turn ON and the other LED to turn OFF is calculated. If an error is obtained during the time calculation, it indicates that there is malfunctioning. Hence, the service engineer is informed to perform corrective actions.

IV. CONCLUSION

This paper describes a new intelligent indoor and outdoor 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.

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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.

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