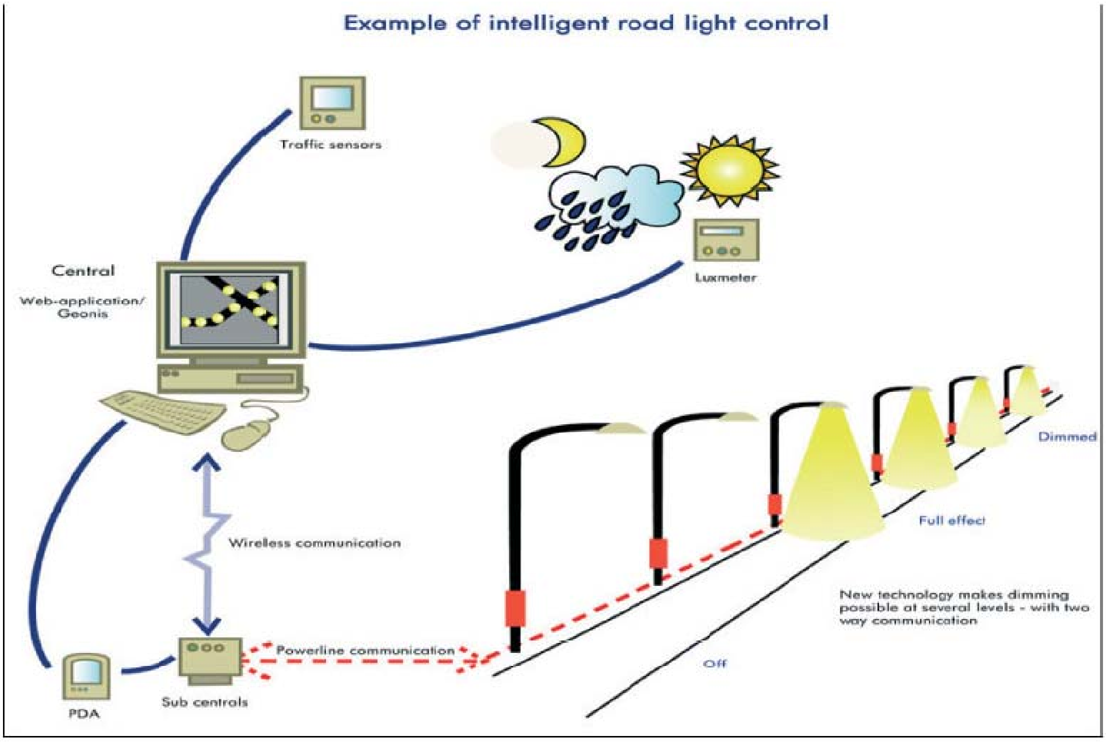
Intelligent Road & Street Lighting Project
(E–Street)



Intelligent Street Lighting Model

Se.	Ref.	Area / Road Type	Street / Road One-Side Width (M)	Pole AVG Mounting Height (M)	Pole Type Model	Pole AVG Intermediate Distance (M)	Lighter Feeds # Poles (No)	HID Lamp Wattage	LED Lamp Wattage
			R	H	M	D	L	W0	W1
1	A1	Pedestrian Corridor	01 - 03	01 - 03	Arm	05	50	70	015 - 025
2	A2	Pedestrian Lane / Alley	03 - 04	03 - 04	Capoly	10	40	125	025 - 040
3	B1	Pedestrian Street	04 - 06	04 - 06	Pole	15	30	150	040 - 060
4	B2	Local Avenue Street	06 - 09	06 - 09	Pole	20	25	250	060 - 090
5	B3	Local Town Street	09 - 12	09 - 12	Pole	25	20	400	090 - 150
6	C1	Local Town Road	12 - 15	12 - 15	Mast	30	15	600	150 - 175
7	C2	Local City Entrance Way	15 - 20	15 - 20	Mast	35	10	800	175 - 200
8	C3	Local Circular Way	20 - 30	20 - 30	Mast	40	05	1000	200 - 300
9	D1	Local Major High Way	30 - 40	30 - 40	High Mast	45	01	1500	300 - 400
10	D2	International Major High Way	40 - 50	40 - 50	High Mast	50	01	2000	400 - 600

Note -- Most Normal used in Egypt Street Lighting are Ref B2 (250W HID), Ref B3 (400W HID) and Ref A2 (125W HID).

BADRY E-Street Project Parameters

One City Case Study:

With over 36,500 LED lights installed, the total savings for the City as of February 2011:

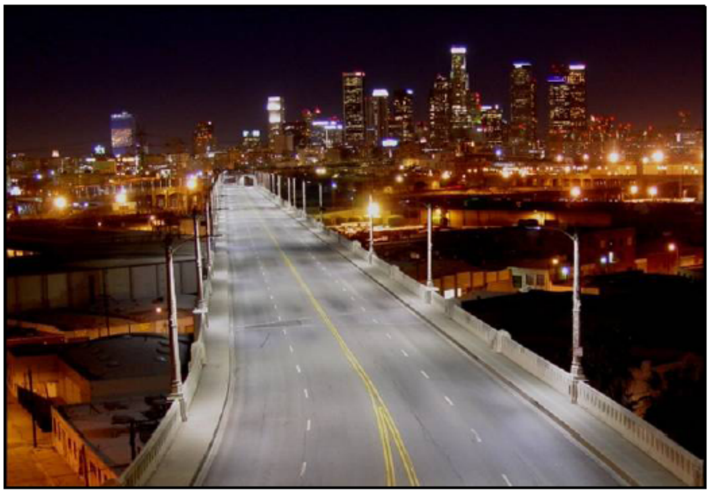
Total Nominal Wattage Before: 6,244 kW
Total Nominal Wattage to Date: 2,648 kW

Estimated Energy Savings: 40%
Actual Energy Savings: 57.6%

Annual CO_2 Reduction: 8,674 Metric Tons

Annual Energy Savings (MWh): 14,668 MWh

Annual Energy Savings ($): $1,297,173



The recommended lighting levels for street lighting are:

Road and Area Classification		Avg. Lumin. L_{avg} (cd/m²)	Max Uniform. Ratio L_{avg}/L_{min}	Max Uniform. Ratio L_{max}/L_{min}	Max Veiling Lumin. Ratio L_{vmax}/L_{avg}
Road	Pedestrian				
Major	High	1.2	3.0	5.0	0.3
	Medium	0.9	3.0	5.0	0.3
	Low	0.6	3.5	6.0	0.3
Collector	High	0.8	3.0	5.0	0.4
	Medium	0.6	3.5	6.0	0.4
	Low	0.4	4.0	8.0	0.4
Local	High	0.6	6.0	10.0	0.4
	Medium	0.5	6.0	10.0	0.4
	Low	0.3	6.0	10.0	0.4

Let's Light The World and Light your Future with Green LED Light, Bring you Fresh Illumination Experience!

BADRY Group

6B, Six[th] October St., Manshiat Al Sad Al Aaly,
Al-Salam - Cairo - Egypt.
Tel : +202 229 585 30 - 229 554 87
Fax : +202 229 958 60

www.badrygroup.com
Lighting@badrygroup.com

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منشية السد العالي – السلام – القاهرة – مصر
ت: ٢٢٩٥٨٥٣٠ – ٢٢٩٥٥٤٨٧
ف: ٢٢٩٩٥٨٦٠

Intelligent wireless street lighting system

Fabio Leccese
Electronic Engineering Department
University Roma Tre
Rome, Italy
leccese@uniroma3.it

Zbigniew Leonowicz
Faculty of Electrical Engineering
Wroclaw University of Technology
Wroclaw, Poland
leonowicz@ieee.org

***Abstract*—We propose an innovative wireless street lighting system with optimized management and efficiency. Wireless communication uses ZigBee-based wireless devices which allow more efficient street lamp system management, thanks to an advanced interface and control architecture. It uses many sensors to control and guarantee the optimal system parameters; the information is transferred point-by-point using ZigBee 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. The system allows substantial energy savings with increased performance and maintainability.**

Keywords- automatio;, control system; lighting system; wireless networks; ZigBee; sensors

I. INTRODUCTION

Lighting systems, particularly within the public sector, are still designed per the previous standards of reliability and that they don't usually profit of latest technological developments. Recently, however, the increasing pressure associated with the raw material prices and also the increasing social sensitivity to CO_2 emissions are leading to develop new techniques and technologies which permit significant cost savings and larger respect for the environment. In the literature we will notice three solutions to those issues.

The first one, and maybe the most intuitive, is the use of recent technologies for the sources of light. The LED technology is thought as best solution but it offers several edges. Researchers [1-4] have already thought of this risk, coming up with advanced street lighting system based mostly on LEDs.

The second resolution, and perhaps the most revolutionary, is to use of remote management system based mostly on intelligent lampposts that send info to a central management system, simplifying the management and maintenance. Researchers [5-6] have developed street lamp system using the GPRS transmission, power line carrier transmission or GSM.

Finally, the third solution is to use of renewable energy sources instead of typical power sources, therefore taking care of the environment. In this field, solar energy is the most often used resource.

Our work aims at unification of the three prospects, making an intelligent lamppost managed by a remote controlled system that uses LED-based lightweight supply and is powered by renewable energy (solar panel and battery). The management is implemented through a network of sensors to gather the relevant info associated with the management and maintenance of the system, transferring the data in wireless mode using the ZigBee protocol (which has been chosen among numerous alternatives because it is the most convenient, see clarification below). The ZigBee remote sensing and management systems are widely described in the literature; we can cite here as examples the applications for the lighting systems [7-12].

II. GENERAL CONCEPT OF THE SYTEM

The system consists of a group of measuring stations in the street (one station located in each lamppost) and a base station located nearby. The system is designed as a modular system, easily extendable. The measuring stations are used to observe street conditions as the intensity of daylight and, depending on the conditions they activate or off the lamps. Other factors influencing the activation are: climatic conditions, seasons, geographical location, and many possible alternative factors.

For these reasons every lamp is designed independent to decide about the activation of light. The base station conjointly checks if any lamp is correctly operating and sends the message using the wireless network to the operator who will act in case of malfunction.

A. Measuring Stations

The measuring station located in every lamppost consists of many modules: the presence sensor, the sunshine sensor, the failure sensor and an emergency switch.

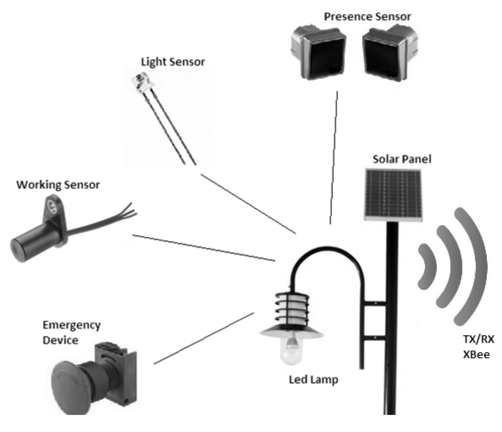

Figure 1. Scheme of the lamppost with sensors.

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These devices work along and transfer the information to a microcontroller that processes the information and chooses the action. Every of those sensors has an assigned priority of transmission, for instance, the emergency switch takes precedence over the others.

B. *Presence detector*

The presence sensor has the task of identifying the passage of a vehicle or pedestrian causing the switching on of lamps.

This feature permits to activate the lamps solely when necessary, avoiding waste of energy. The sensor ought to be placed at the optimal height, neither too low (e.g. to avoid any erroneous detection of small animals) nor too high (to avoid failure to detect e.g. children).

C. *Light sensor*

Light sensor will measure the external light intensity to assure a minimum level of illumination of the road, as needed by regulations. The sensor should have high sensitivity within the visible spectrum, providing a photocurrent high enough for low-light luminance levels. The microcontroller drives the lamp so as to keep up the constant level of illumination. Clearly, this action isn't needed throughout daylight time, however is desired within the early morning and at dusk, when it is not necessary to operate the lamp at full power however merely to "support" the daylight. This mode permits to save electrical power.

D. *Supervision module*

This sensor improves fault management and system maintenance. A Hall sensor detects when the lamp is switched on. The system recognizes false positives, as detected parameters are compared with the stored information. This information is reported by the ZigBee network to the station management unit, within which the operator is informed regarding the placement of the broken-down lamp and may send a technician to exchange the lamp. Additional security can provide the temperature sensor to ascertain the optimal operation of the lamp and constantly monitor the temperature of the LEDs (which influences the lifespan of the LED lamps). The chosen sensor allows precise AC or DC current sensing, additionally permitting the on-line power consumption measurement.

E. *Control unit*

The sensors transfer the collected information to a controller that runs the software to manage the system. The operation is processed as follows:

After initial setting, the system is controlled by the light sensor that activates the microcontroller on condition that the daylight illumination is below a set threshold. During this case, the system reads the state of the emergency button, and activates the lamp. The same happens if the presence sensor detects a vehicle or a pedestrian. Once the lamp has been switched on, the operating sensor starts the monitoring and, in case of fault detection, sends information to the management center. If no fault is detected, the microcontroller measures the current by the Hall sensor storing the values in memory. All the operation is regulated by a timing management that permits the system is set for the predetermined time. At the stop signal, the lamp is turned off and therefore the cycle restarts.

F. *Management center*

The management center is that the hub of the system, since it permits the visualization and control of the complete lighting system. The transmission system consists of ZigBee devices that receives data of the state of the lamps and sends it to a terminal.

The processing unit consists of a terminal with a serial UART interface that receives data regarding the state of the lamps provided by a ZigBee device, connected to the UART interface. The terminal is needed for graphical presentation of results. Additionally, knowledge on lamps operation are received along with the lamp address, consequently all faults can be easily identified. The graphical interface permits to visualize the state of the system (Fig. 2) with the state of the lights and the power consumption of every lamp (Power Consumption Data button).

Figure 2. Exemplary GUI of the lighting system.

The management can be extended so that other electrical systems, not solely lampposts are connected, and might send data regarding power consumptions to a central system for adjusting energy consumption to energy prices and for remote switching and management.

G. *Wireless ZigBee Network*

ZigBee is wireless communication technology primarily based on IEEE 802.15.4 norm for communication among multiple devices in a WPAN (Wireless Personal space Network). ZigBee is intended to be less complicated than other WPANs (such as Bluetooth) in terms of price and consumption of energy.

The ZigBee Personal space Network consists of a minimum of one Coordinator, one (or more) Devices and, if necessary, of one (or more) Router. The bit rate of transmission depends on the frequency band.

TABLE I. ZIGBEE VS SELECTED OTHER WIRELESS TECHNOLOGIES

	ZIGBEE	WI-FI	BLUETOOTH
IEEE standard	802.15.04	802.11bgn	802.15.01
Main application	Control	Broadband	Mobile devices
Number of network devices	Up to 65000	32	7
Bit rate	20 - 250 kb/s	11/54/300 Mb/s	720 kb/s
Range	100 m	100 m	10 m
Battery life	100 - 1000 days	1 - 5 days	1 - 7 days

On 2.4 GHz band the typical bit rate is of 250 kb/s, 40 kb/s at 915 MHz and 20 kb/s at 868 MHz. The standard distance of a ZigBee transmission vary, depending on the atmospheric conditions and therefore the transmission power, ranges from tens to hundred meters since the transmission power is deliberately kept as low as necessary (in the order of few mW) to keep up very low energy consumption [7].

In proposed system, the network is made to transfer data from the lampposts to the central station. Data is transferred purpose by purpose, from one lamppost to another one where every lamppost has a distinctive address within the system. The chosen transmission distance between the lampposts assures that in case of failure of one lamp within the chain, the signal will reach other operational lamppost while not breaking the chain.

ZigBee wireless communication network has been implemented with the utilization of radio frequency modules. They operate within the ISM band at the frequency of 2.4 GHz.

The receiver sensitivity is high and therefore the chance of receiving bad packets is low (about 1%). The modules ought to be provided by 3V DC supply, and then the power consumption is within the order of 50 mA. The module supports sleep mode where consumption is smaller than 10μA.

III. REALIZATION OF THE SYSTEM

The operational test system operating in real conditions is shown in Fig. 3. The proposed system can be used for upgrade of existing typical lampposts, as well.

Power is provided by a battery, recharged from a solar panel throughout the daytime. The capacity of the battery depends on explicit parameters of the application. In the designing part of a photovoltaic system the irradiation curves of the positioning has been studied to work out the inclination and orientation of the surface of solar panels that permit the optimal operation. For the sizing of the panel it's necessary to calculate the annual energy needed to power the lighting. The charge controller manages the processes of the battery charge and power provide. Current generated by photovoltaic panels is handled by the controller to produce an output current for battery charge. The charging method should be conducted consistent with the battery knowledge (capacity, voltage, chemistry, etc.)

Figure 3. View of the test system.

IV. SYSTEM TESTING AND DISCUSSION

The prototype has been tested in variable real-life conditions to verify the general functionality and determine points for improvement and optimization. The measurements collected throughout the testing permit to calculate energy savings and economic benefits.

It was found the applied ZigBee modules are appropriate for this application. Every lamppost being placed at the distance of 25 meters from one another, since modules have a range of 100 m outdoors.

The functionality field tests were realized. First test demonstrated that the system is in a position to transfer data from any chosen lamppost to the management center when passing the info through the remaining lampposts. During these cases we obtained a transmission rate 99.98% to 100% depending on the placement of sending unit.

The test verified what happens in case of a break-down of one intermediate lamppost. The system seems indifferent to such a malfunction, permitting the transmission with an equivalent rate as within the previously described case. The system becomes non-operating solely when 3 consecutive lampposts transmission devices are non-operational.

A. *Power management and consumption*

The system was designed to operate stand-alone, supplied by the energy from a solar panel. The benefits from this type of power are important thus avoiding the tedious and expensive wiring and connection to external power network, enabling considerable savings and ease of implementation. The system is intended to be low-power, minimizing the battery capacity and also the energy acquired from the solar panel. These goals were achieved through the utilization of the ZigBee module for transmitting and receiving data, using LED lamps as replacement of normal lamps and using special power-saving solutions for microcontrollers and radio modules.

The program that controls the system is designed primarily to avoid wasting energy. Firstly, as a result that the system works solely in the darkness, avoiding waste of energy throughout sunlight hours when the sole active device is the solar panel that recharges battery. Secondly, the sensors enable the system to operate solely when necessary. Thirdly, the system employs highly economical LEDs to ensure correct illumination and assure energy savings. Finally, when the system is disabled, all devices (wireless module and microcontrollers) are in the sleep mode, that permits negligible power consumption. The wake-up is triggered by the change of conditions (emergency device, presence sensor, etc.). The selection of the battery depends on the conditions where the system is installed.

B. Estimation of prices and savings

This proposed system may be criticized as being expensive however we must consider its advantages: slightly higher prices of the lampposts are compensated by lack of costly wiring and the availability of power network and considerably lower prices of maintenance (due to central management and reliability of LEDs).

Energy savings are of utmost importance today. The goal is, therefore, the reduction of operating prices of street lighting with the creation of a system characterized by straightforward installation and low power consumption, powered by a renewable supply of energy through solar panels with no harmful atmosphere emissions and minimizing light pollution.

Making a short comparison with the normal street lighting systems: Supposing that one lamp is switched on for 4,000 hours per year. One streetlight has a median consumption of 200 W and the price of energy is of 200€ yearly. If suppose a 5 km long street, it is necessary to install 125 street lights (one each forty meters), with yearly energy consumption of 25.000€. With the system presented in this paper, every lamp uses about 20-25 W (95% of energy consumed by the LEDs). With an equivalent example as before, energy cost decrease to 5.000€ (savings of 80%).

Based on the field tests another possibility of energy savings becomes evident. Classical system consumes energy independently if it is needed or not. It is active for about 10 hours daily and the total number of working hours is about 300 per month, versus 87-108 hours proposed system, savings of about 66% to 71% are expected. The savings may be improved by using more efficient LEDs, since the consumed energy almost entirely depends on LEDs consumption.

Finally, since the system is powered by solar panels (with batteries), the energy price does not depend on provider costs. Consequently, the sole price to consider is that of the installation and implementation of the system; with following savings thanks to lower maintenance and energy savings.

V. CONCLUSIONS

In this paper a proposal of an intelligent street lighting system is described that integrates new technologies, offering ease of maintenance and energy savings. This is obtained by using the highly economical LED technology supplied by renewable energy provided by the solar panels and by using the intelligent management of the lampposts.

The proposed system is especially appropriate for street lighting in remote urban and rural areas where the traffic is low at times. Independence of the power network permits to implement it in remote areas where the classical systems are prohibitively expensive. The system is versatile, extendable and totally adjustable to user needs.

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