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Intelligent Street Light System using Wireless Transmission: A Review

Sakshi Anand[1], Dr. Neelu Jain[2]

Abstract— **Street lights are the large consumer of energy in the cities, using upto fifty percent of the city's energy. An intelligent street light management system based on LED lamps and wireless communication technologies can be designed and installed in the cities. Though, it will have initial cost of investment for replacing the traditional wired systems but lots of power can be saved by using this system. An intelligent street light system can detect vehicles and vary the intensity of the street light by using LED lamps as per the traffic flow. It can also help in monitoring and controlling of street light system and fault detection of the lamps through wireless technology.**

Index Terms— **Intelligent Street Light System, LED street lamps, WSN, GSM, ZigBee, energy saving, power consumption.**

I. INTRODUCTION

The street lighting is one of the largest energy expenses for a city, accounting for upwards of 35-45% of a municipality's utility budget. An intelligent lighting control system can cut municipal street lighting costs as much as 70% [1].

An intelligent street lighting system is a system that adjusts light output based on usage and occupancy, i.e., automating classification of pedestrian versus cyclist, versus automotive. It illuminates a certain number of street lights ahead and fewer behind, depending on velocity of movement. It also adjusts the light according to the road condition.

An intelligent street light management proposes the installation of the wireless based system to remotely track and control the actual energy consumption of the street lights and take appropriate energy consumption reduction measures through power conditioning and control.

As shown in Fig. 1, the street light controller should be installed on the pole lights which consist of microcontroller along with various sensor and wireless module. The street light controller installed on the street light pole will control LED street lighting depending on traffic flow, communicate data between each street light. The data from the street light controller can be transferred to base station using wireless technology to monitor the system. The mode of operation of the system can be conducted using auto mode and manual mode. The control system will switch on-off the lights at required timings and can also vary the intensity of the street light according to requirement.

The benefits of this type of technology are [2]:

Fig. 1 Schematic of Intelligent Street Light System

1) Energy savings: The lights dim at night when there is low activity, thus, saves energy.
2) Maintenance cost reduction: The maintenance costs are reduced because its lifetime is more before the lamps have to be replaced.
3) Reduction in CO_2 emissions: With the energy reduction, there is a reduction in CO_2 emissions.
4) Reduction of light pollution: The light pollution is reduced, because the street lamp's brightness varies as per traffic flow.
5) Maintenance of safety: The safety is maintained, because the lights are dimmed, i.e., not turned off completely. It becomes clear from far away when vehicle movement is approaching, and thus brightens lamps.
6) It doesn't contain toxic chemicals (e.g., mercury) in the light lamp.

II. DESCRIPTION OF RECENTLY PROPOSED INTELLIGENT STREET LIGHT SYSTEM

A comparative study of some of the recently developed prototype of intelligent street light system is carried out here.

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A. Figures and Tables E-Street: LED powered intelligent street light system with automatic brightness adjustment based on climatic conditions and vehicle movements.

A remote street light monitoring and controlling system was designed by Archana et al. based on LED lamps and wireless sensor network. The proposed system consists of a group of measuring stations in the street at each lamp post, Microchip Wireless (Mi-Wi) communication protocol to communicate between street light unit and PC monitoring terminal and nearby located base station.

This application was developed using PIC16F877A microcontroller along with various sensors sensing climatic and geographical locations. The transmitter and receiver-end consists of Mi-Wi transmitter and receiver module (MRF24J40MA). The infrared sensor and LDR circuit has been used to identify the passage of a vehicle or pedestrian causing the variation of intensity of street lamps using PWM technique. The malfunctioning message is transmitted to controller through feedback circuit which displays it on LCD and also transmitted wirelessly through Mi-Wi module to the control terminal [3].

Fig. 2(a) shows the minimal circuit diagram. This circuit shows interfacing of the PIC 16F with the LDR, LED and temperature sensor to get the values and it is displayed in the LCD display.

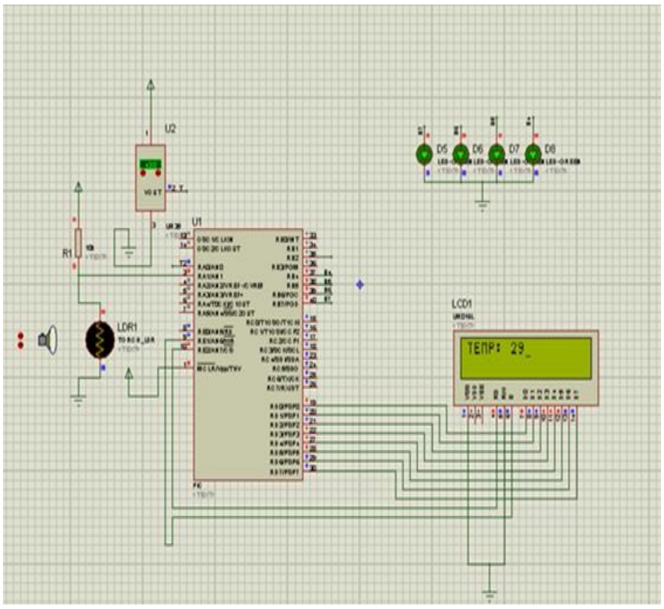

Fig 2 (a) Minimal circuit diagram

Fig. 2(b) shows the PWM output to achieve dimming technique i.e., when the vehicle or a pedestrian comes near the street lamp, the LED will be in its maximum brightness, whereas if there is no movement, the LEDs will be switched back to its dimness.

This proposed system may be expensive but the cost of maintenance will be reduced. E-street saves amount of energy consumption of about 66% to 71% by replacing sodium vapour lamps by LED and adding dimming technology to it.

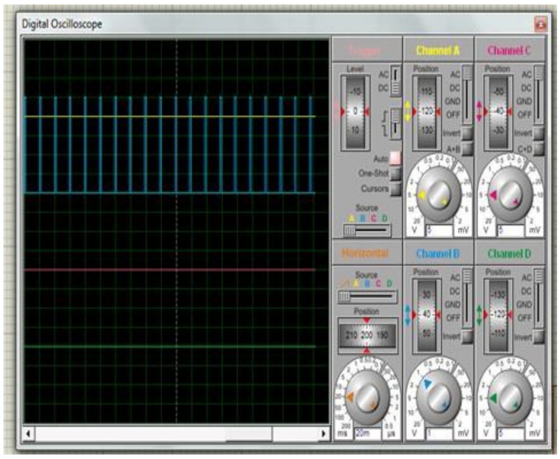

Fig 2 (b) PWM Output

B. Design of street light monitoring and control system based on wireless sensor networks.

Wireless sensor network was used for controlling street light. The system architecture shown in Fig. 3 consists of group of sensor nodes called clusters which are powered by transformer action. The remote terminal unit (RTU) performs sink node function in this cluster. In routing from the RTU to the control centre, the information transmits between the RTU and the control centre using GPRS network [4].

The sensor node and the RTU hardware was designed using AVR 8 bit microcontroller ATmega 128. The radio transceiver CC1000 was used with frequency 433 MHz and its range is upto 200m. The GPRS module i.e., G18 wireless modem was used. The G18 module is controlled via AT commands and connects embedded system to internet using GPRS protocol over GSM network which is compatible with 900 MHz/1800 MHz/1900 MHz

The RTU sends control command to every sensor node mounted on street lamps and receives lamp status from the sensor node. The light intensity can be used to switch lamp on and off according to climatic condition. The lighting on/off schedule resides in each remote terminal unit. The meter-reading module is used to sum total energy consumption in transformer station range.

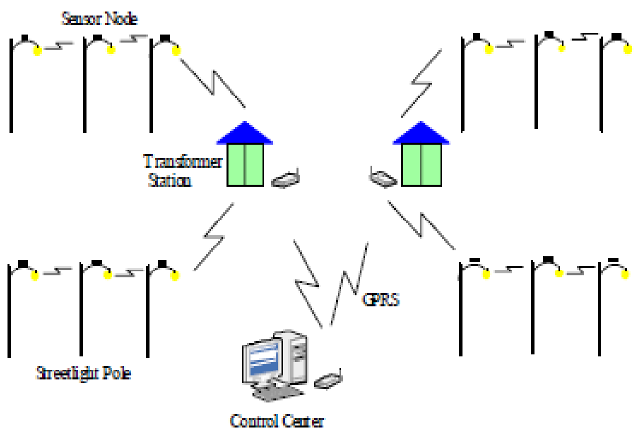

Fig.3 Structure of streetlight power cable monitoring system based on wireless sensor networks

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The sensor node and the RTU software were developed using nesC language under TinyOS operate system. The algorithm for calculating the sunrise/sunset time according to the RTU location and the current date is implemented. Thus, the RTU directly turns on and off based on sunrise/sunset time.
The control centre software with the geographical information system (GIS) function was developed using Borland C++ builder (BSB) and MapX. Fig. 4 shows partial map of the remote street light monitoring and control system. All the sensor nodes and RTUs are displayed on the map. The user can find fault in the RTU or lamp and repair it.

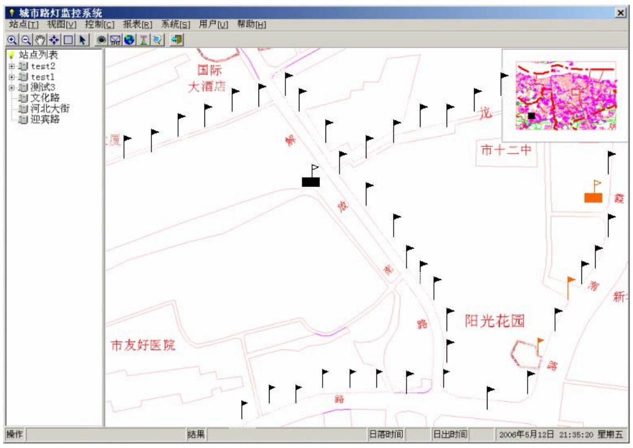

Fig. 4 Map of Streetlight power cable monitoring

Thus, wireless sensor network can be used to monitor and control each street light. The outcome of this system will be reduction in energy consumption, lower management and improvement in public satisfaction to street light.

C. GSM based autonomous street illumination system for efficient power management.

The field survey of street lights in Vasai-Virar Mahanagarpalika and from MSEB Pune has been done by Chaitanya et al. to observe various parameters like bulb used, power consumption of bulb, height of poles, distance between poles and network [5].
The microchip should be installed on the pole lights which consist of C8051F350 microcontroller along with various sensor and GSM SIM300 module for wireless communication. Various sensors like CO_2 sensor, fog sensor, light intensity sensor, noise sensor can be used.
The data from the microchip can be transferred to control centre using GSM and correspondingly PC transmits the controlling action to the chip. The control centre will monitor and control the street lights. It will decide varying of intensity of street light.
The system can be operated under two modes that are auto mode and manual mode. In auto mode, the nodes are switched on/off according to light intensity, slot time i.e., 7pm-8pm/ 8pm to 9pm/ 9pm to 11pm/ 11pm to 6am and weather conditions. In manual mode, user can manually set each node with specific intensity factor according to the requirement and can also take corrective measures.
The power consumption was calculated on the current street light systems with assumption of 20 nodes which are in ON state from 6:30pm to 6:30am.
If the intelligent street light system operates on sunrise and sunset timing, it will save 4% to 8% of energy. During heavy traffic time, it will save additional 7% to 10% of energy. In low traffic time, system enters into energy saving mode, thus saves additional 45% to 50% of energy. At mid night or very low traffic time, additional 7% to 10% energy saving can be achieved. Thus, using GSM based autonomous street illumination system, a lot of power consumption can be saved.

D. Design and development of intelligent wireless street light control and monitoring system along with GUI.

The proposed system has an intelligent lamppost managed by a controlled system that uses LED based light weight supply and is powered by renewable energy, that is, solar panel and battery. The control unit and maintenance of the system is controlled by ZigBee protocol through graphical user interface application window to monitor street light.
In this system, solar panel is used for generating power and it will be stored into the rechargeable battery from that power is supplied to the street lights using relays. In the designing part of a photovoltaic system, the irradiation curves of the positioning have been studied to work out the inclination of the surface of the solar panels that permits the optimal operation. The size of the solar panel is calculated through annual energy needed to power the lighting [6].
The system can be operated in either auto mode or manual mode. In the auto mode, if any vehicle is detected using IR sensor, it will check the light intensity level using LDR sensor, then, light will turn ON or OFF. The flowchart for automatic mode operation is shown in the Fig. 5.

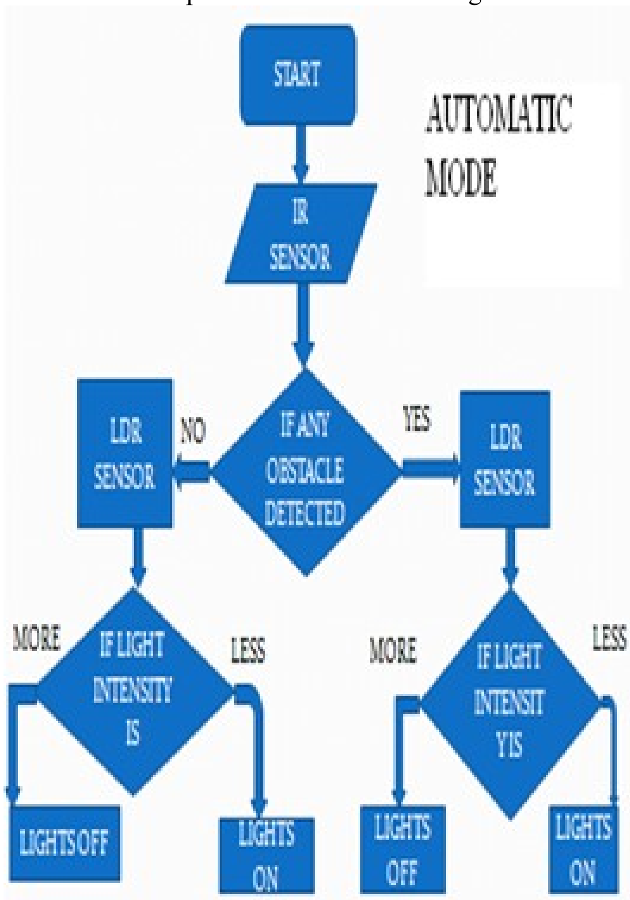

Fig.5 Flow Chart for auto mode operation

In the manual mode, the street lights are controlled through the graphical user interface in the PC through ZigBee

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technology. The flowchart for manual mode operation is shown in Fig. 6.

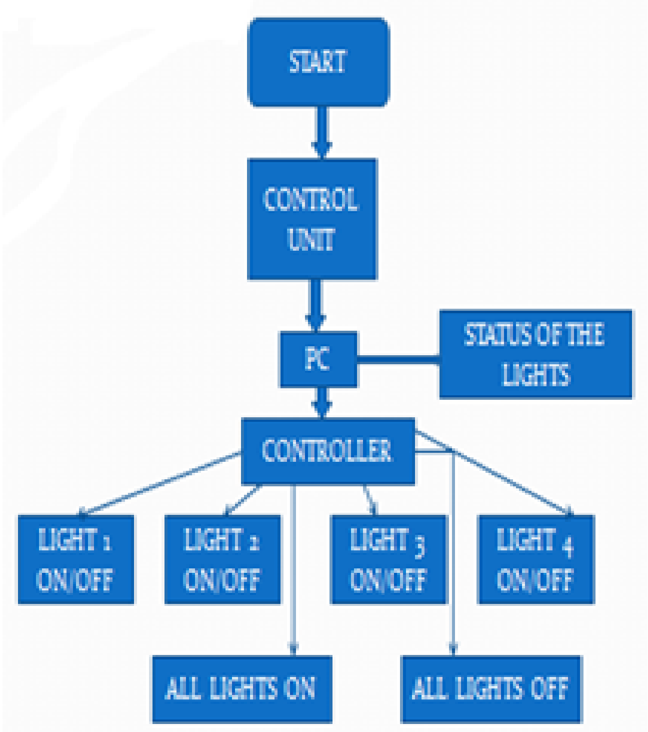

Fig.6 Flow Chart for manual mode operation

Subramanyam et al. supposed a 5km long street installed with 125 street light with spacing 40m and calculated the yearly energy consumption 25.000€. With the proposed system, every LED lamps uses about 20-25W, thus energy cost decreases to 5.000€ which means saving of 80% [6]. If the proposed system is active for about 10 hours daily, then number of working hours is reduced to 87-108 hours instead of 300 hours per month, thus the saving expected is about 66% to 71%.

This proposed system may have high initial cost; however, cost of wiring and maintenance price will be reduced. The power consumption can be reduced by using renewable supply of energy through solar panels with no harm to atmosphere as well as minimizing light pollution.

E. Design of street light pole controller based on WSN.

The Jing Chunguo et al. proposed design of the street lighting pole controller based on WSN for urban street light monitoring and control system. The features such as controller manual deployment, clustering architecture, sequence architecture and energy unlimited were summarized.

The controller hardware was designed using ATmega 128 microcontroller, radio modem module, current detection and actuator circuit. The controller software was developed using Contiki operating system. The controller's multi-hop route protocol based on receiving node address, sending node address and packet head information was designed. The controller using the anonymous best-effort single-hop broadcast of Rime stack increases energy consumption, but it is simple and does not need complex route discovery algorithms, it also does not maintain network topology. Each controller is self-governed and decides how to forward the packet by itself based on the routing strategy. The lighting pole controllers have successfully used in the city street light monitoring and control system.

The pole controller has primary and secondary switching on and off, various control strategy, fault detection, etc. features, it is applied in streetlight department which can reduce energy consumption, lower management and maintenance cost, and also improves public satisfaction. There are two relays used for switching on or off the primary lamp and the secondary lamp. Two transformers were used to detect the current of primary lamp and secondary lamp to decide the lamp's status. The verification of the function of controller was performed on sixteen controllers installed in the light poles to test the hardware and software features. The transmission distance of controller was first measured [7]. The cover range of controller can reach about 150 meters and far less than 1200 meters of the radio module's specification. The delay time of some controllers which are far away from the remote terminal unit is less than the delay time of those controllers which are near to the remote terminal unit. The reason is that those controllers which are far away from remote terminal unit sending packet skips next controller and the total hops are less.

F. Intelligent Lighting Control System Based on ZigBee Communication Technique.

As per the related works and different technology explored to implement intelligent lighting systems, Hassan Khawari et al. have compared available technology as shown in table I.

Table I: Comparison of available technology

	PLC	ZigBee
Data rate(kbps)	0.625-50	250
Power consumption	Very Good	Very Good
Implementation	Good	Best
Installation cost	Good	Very Good
Maintenance cost	Good	Very Good
Max number of nodes	-	2^16
Frequency	-	900MHz and 2.4GHz
Range	-	10m-1.6km

The available PLC modules have high cost and no networking capabilities. While ZigBee module provides easy installation and maintenance. There is no needs to install additional transmission line with ZigBee, thus, it is more economical technology.

A prototype street light system was designed using ATmega 32 microcontroller. In the proposed intelligent street light system, lamp nodes can work with or without local node or control terminal. The prototype was tested one full day with time switch on/off control (table II).

Table II: Energy saving of one full day

	Lights	**Energy Saving**
6am ~ 5pm	All lamp are off	0%
5pm ~ 10pm	All lamp are on	0%
10pm ~ 1am	Every two lamps are on	33%
1am ~ 5pm	Every other lamps are on	50%

The proposed test board [8] consumes maximum 130mA current and 90mA in idle mode with ±5V and +12V power supply. This system has the advantage: control of each

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lighting lamp, determine the exact location of cable rupture, increase efficiency and lamp life, reduction of environmental pollution in cities, and systematic maintenance of lighting facilities.

III. CONCLUSION

Street lights are the large consumer of energy in the cities, using upto fifty percent [9] of the city's energy. Thus, if intelligent street light is designed and installed in the cities, then lots of power can be saved. From the survey, it is inferred that the intelligent street light can detect vehicles and vary the intensity of the street light by using LED lamps as per the traffic flow. It can also help in monitoring and controlling of street light system and fault detection of the lamps through wireless technology. The system is versatile, extendable and totally adjustable to user needs.

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Authors

Sakshi Anand[1] obtained B.E. in ECE from Birla Institute of Technology, Mesra, Ranchi in the year 2011. She is pursuing M.E. in Electronics in PEC University of Technology, Chandigarh.
Email id: ersakshianand@gmail.com

Dr. Neelu Jain[2] is working as Associate Professor in Department of ECE, PEC University of Technology, Chandigarh. She has an experience of 22 years in teaching, research and industry. She did B.E. (Electronics & Communication) from University of Roorkee (Now IITR) and M.E (Electronics) and as well as Ph.D. (Electronics) from Panjab University, Chandigarh. Her research interests are Digital Signal Processing, Image Processing and Embedded systems. She has published about 30 papers in International and National Journals and Conferences. She has guided 42 M.Tech. Thesis and is also supervising Ph.D. work.
Email id: neelujain@pec.ac.in

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