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Aurdino based Light Monitoring and Control

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Abstract: *The main objective of this paper is to design an RF module based outdoor light monitoring and control system that can monitor and handle outdoor lights more efficiently as compared to the conventional systems. The proposed system uses RF module based wireless devices which allow more efficient lamp management. The designed system uses sensors to control and guarantee the optimal system parameters. To realize effectiveness of the proposed system, a prototype has been developed. The results proved that the proposed system saves around 11.8% by using LED, 18% by using CFL, 43.8 % by using Fluorescent (T8), 72% by using Incandescent lamp of the cost of electricity consumed a year for the outdoor street environment.*
Index Terms—*Aurdino, energy efficiency, LED lamps, Fluorescent (T8), lightning control system, RF Transceiver.*

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I. Introduction

Energy efficiency is one of the key factors while designing indoor or outdoor lighting systems. The street lights consume almost 30%–40% of the entire city power consumption. Thus, control system able to efficiently manage the lighting is absolutely advisable. The traditional lighting systems are not suitable resulting in energy losses and frequent replacement of devices. Moreover these traditional systems suffer from the lack of pervasive and effective communications, monitoring, automation, and fault diagnostics problems.

To address these challenges, many technologies have been utilized in the literature to save energy such as: the utilization of light emitting diode (LED) instead of metal halide (MH) lamps [1]. But the systems based on these technologies need further improvement to increase the energy efficiency.

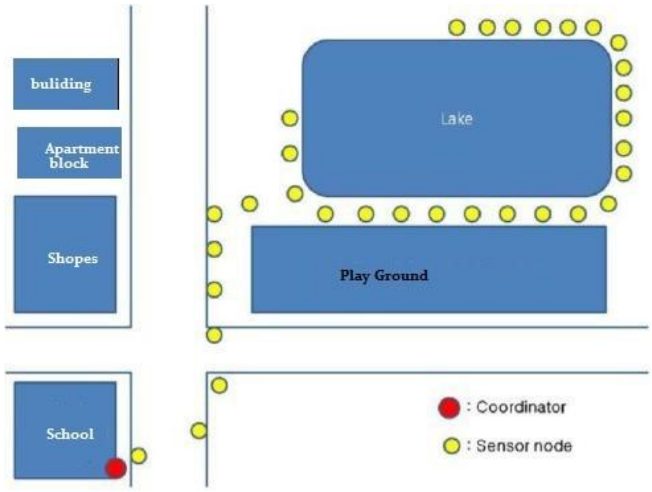
To further reduce the energy consumptions and to simplify the wiring structure, numerous lighting control systems have been proposed to solve that problem such as: occupancy sensing approach [2], light level tuning [3], and power line communication (PLC). Despite of reducing the wiring structure in PLC based designs presented in [4], occasional drops may occur in PLC networks operating on low voltage power lines. These drops are caused by noise and attenuation, and can last from a few minutes to few tens of minutes. Due to carrier signal attenuation, there may be high latency or communication failure in PLC based design. On the contrary, deploying communication infrastructure based on wireless sensor networks (WSNs), such as low power RF module, eliminates wiring overheads and save lots of energy.

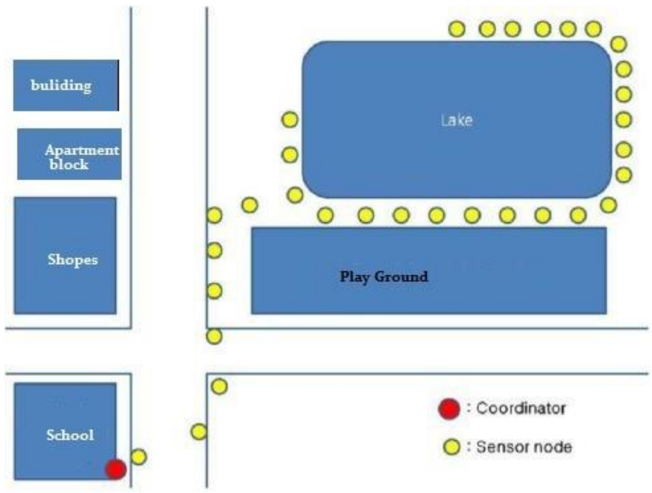
Several comparable architectures were developed for outdoor lighting using wireless control [5–7]. An intelligent lighting system by considering the system cost and energy saving was developed. The number of sensors on each lighting nodes was reduced, but this reduction resulted in less accuracy of the system due to more packet loss and hence resulted in performance degradation [5]. Energy efficient lighting control systems were designed by utilizing the WIMAX and GPRS as backbone technologies, respectively, to communicate with the control centre. One of the drawback of utilizing WIMAX and GPRS is the utilization of licensed spectrum, which will result in interference with the existing WIMAX and GPRS users [6-7]. Hence, the lighting systems will also require efficient interference avoiding algorithms to cope with interference. These systems also have no capability to change the light intensity according to the users' requirement. They control the energy consumption statically and do not consider the user requirements in the sense of light intensity and the user's presence while dimming or turning off the lamps. The RF transceiver based lighting control system was not completely verified and tested for different conditions [8].

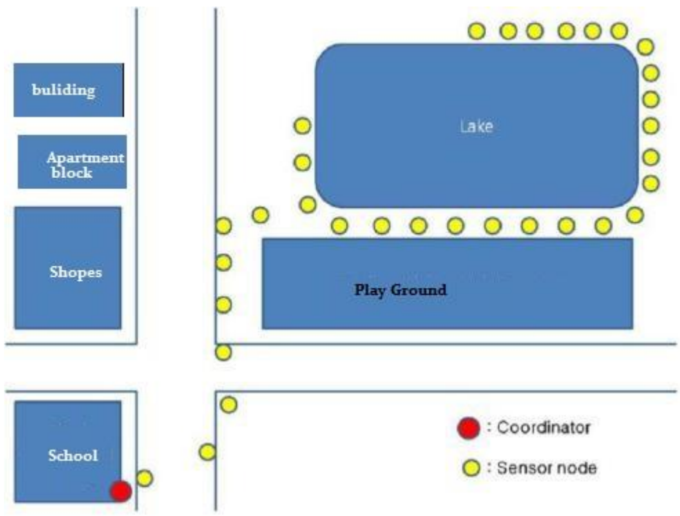
An RF module based outdoor light monitoring and control system (RF-OLC) considering the user's requirement and energy consumption was designed. The RF-OLC system also implemented the standard mesh routing algorithm which results in better network performance as compared to the conventional systems. The RF -OLC system full fills the user satisfaction by using occupancy and illumination sensors, and also gives the advanced metering infrastructure (AMI). The RF - OLC system dynamically controls the energy level of outdoor users while guaranteeing their predefined minimum satisfaction level [9].

II. Proposed Smart Energy Efficient Lighting System

The RF module based energy efficient outdoor lighting control system is shown in Fig. 1. For outdoor lighting environment, we selected one street as a test field and installed the LED lamps accompanied by RF module, light sensors, occupancy sensors and temperature sensors.







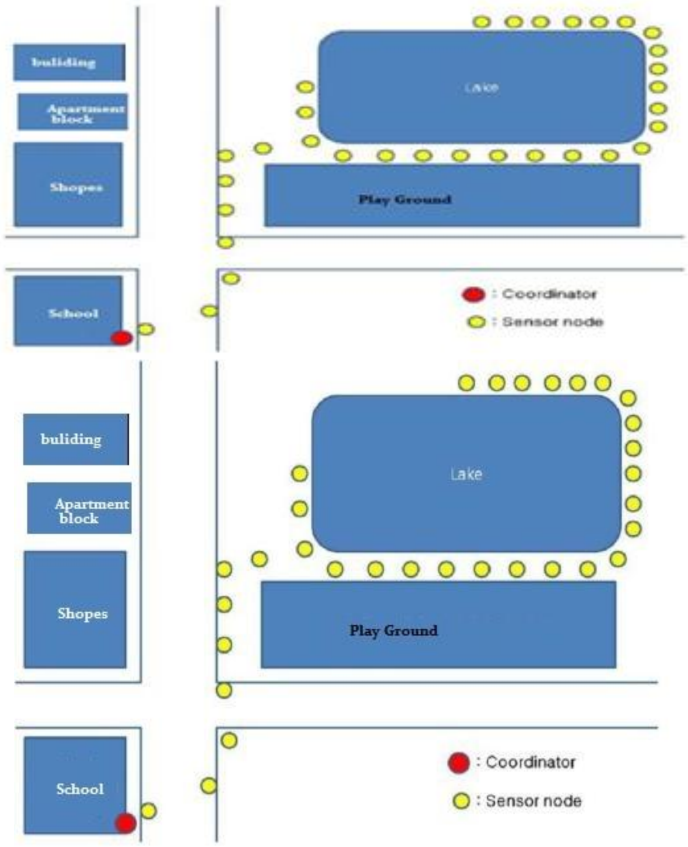


Fig. 1. Energy efficient architecture for outdoor lighting

The lamps continuously monitor the intensity of the sun-light by using the sensors connected to it. Based on the intensity, ATmega 128 microcontroller unit (MCU) takes a decision either to dim or to turn the lamps on or off. Information is transferred 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 coordinator.

A. Lamp Monitoring System

The lamp monitoring system installed in each lamp consists of several modules: light sensor, temperature sensor, occupancy sensor, power metering IC, MCU, RF module and radio communication module (RCM) as shown in Fig. 2(a). Sensors are attached to the RF module. RCM nodes continuously monitor the situation of the lamps. The sensors are used to observe the main parameters such as lamp housing temperature, power consumption and power meter readings. These devices work together and transfer all of the information to MCU which processes the data and automatically sets the appropriate course of action. The detailed discussions related to the main components involved in the lamp monitoring system is given in the subsections.

ATmega128 Microcontroller Unit: The ATmega128 MCU is installed at each lamp and controls the operation of the whole node. Light and temperature sensors gather the information and send it to the MCU for appropriate action. After the initial setting, the system is controlled by light and occupancy sensors which activate the MCU if the sunlight is lower than the threshold or some person passed through the street or building. The passive infrared motion detector sensor shown in Fig. 2(b) is being in-stalled in each lamp which is used to check the presence of passengers or cars passing in the streets.

MCU manages information flow among sensors and ballast actuator, and is also responsible for generating pulse width modulation (PWM) signal for dimming the LED lamps. The MCU interface block diagram is shown in Fig. 2(b).

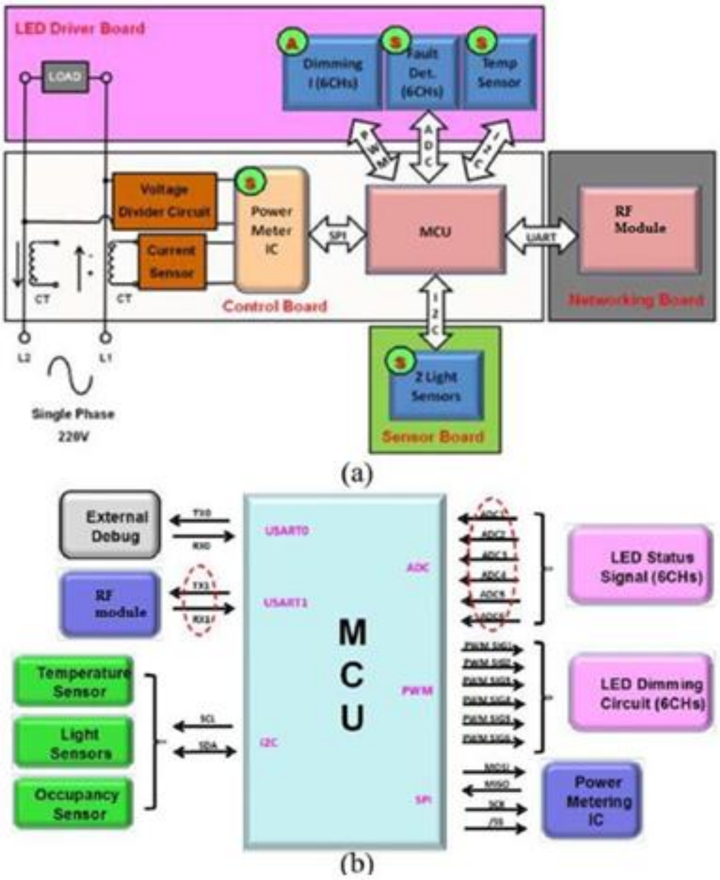


Fig. 2. Proposed LED smart lamp. (a) Monitoring system block diagram. (b) Block diagram of microcontroller unit interface

Light Sensors: Light sensors, BH1710FVC are connected to the MCU through I2C interface which observe light status in lux. A light sensor measures the brightness of the sun light and adjusts the light intensity of the lamp to keep the light intensity up to 200 lux. The purpose of this measurement is to ensure a minimum level of illumination of the outdoor lights as defined by regulations [10]. Based on the sun light intensity, the MCU drives the lamp to maintain a constant level of illumination, that is, minimum horizontal and vertical illuminance of $15lux$ and $50lux$, respectively [11]. Thus, the lamp will be turned on when the sun-light will fall below this illuminance level. This action is obviously not required during daylight time.

ADE7753 Energy Metering IC: The energy metering IC ADE7753 is used to measure the status of a lamp. The highly accurate electrical power measurement IC is connected to the MCU via serial peripheral interface (SPI). It connects directly to the current and voltage sensors and needs only single $5V$ power supply. The current sensor measures the current flow towards the lamp. The fault in a lamp will be detected if the current level fell below the threshold of 0.3 A.

Blast Actuator: The blast actuator is an add-on actuation module interfacing the dimmable ballast. The actuation module receives the wireless actuation command and translates them into the ballast control signals to dim the lights. In the proposed system, a ballast actuator can control up to maximum of four LED modules (units) each of $35W$ rated powers with a required current of around $0.5A$ for each module. LED modules are capable of multilevel dimming control, i.e., from 0 to 255 of lamps using monitoring and control software.

Gateway Node: A gateway node is used to serve as a bridge between two networks, i.e., RF module and internet to perform the protocol conversion. Each lamp controller communicates with 20 data centers via a gateway. Gateway provides the backhaul link to the data center and RF module to connect with the street light control terminal. In the proposed system, attributes of LED lamps are remotely observed and controlled through RF module gateway which connects to the internet via Ethernet protocols.

Properties	LED	CFL	Fluroscent(T8)	Incandescent
Lumen/hour/watt	80.6	48	73.61	11.67
Power Rating	10Watts/hour	15 Watts/hour	36 Watts/hour	60 Watts/hour
Life span(hour)	50,000	10,000	15,000	1,200
Cost per bulb (Rupees)	950	200	85	12
Number of Bulbs need for 50,000 hours	1	5	3	42
Total cost electricity and bulbs for 50,000 hours(rupees)	5,900	7,325	10,155	28,000
Cost of electricity consumed a year(Rs5.50/unit) (june)	118.25	175.4	420.62	720.7
Cost of electricity consumed a year(Rs5.50/unit) (july)	110.81	160.23	412.26	710.33

B. RF Module Radio Communication Module and Network

RF Module Radio Communication Module: RCM uses the universal synchronous and asynchronous serial receiver and transmitter (USART) interface to connect with MCU. RF module is the low power wireless network standard based on IEEE 802. 15.4 and defined by RF module Alliance. It focuses on low power, low cost, high reliability and self-healing characteristics Ember's EM250 RF module stack is a single-chip solution that integrates a 24 GHz IEEE 802.15.4 compliant transceiver.

RF Module Network: The RF module network layer has three kinds of topologies named as star, tree, and mesh. The proposed system is based on the mesh topology, because it has self-healing infrastructure and has extra path which can be helpful to reach the coordinator if one fails to work. Due to high radio sensitivity of the RF module receiver, it has less than 1% of packet loss rate. Furthermore, it has good operational range for the application reaching hundreds of meters. Furthermore, the lamps installed in the deployment area using RF module network have the clear line-of -sight (LOS) situation with no trees or other objects obstructing the communication.

III. Implementation And Discussions

The system is designed with the energy efficient RF module-based wireless system. The proposed prototype has been tested under outdoor scenarios to verify its validity, functionality and performance in the real-life conditions. The designed smart LED street light control system reduces uneasiness of handling and difficulty of maintenance. The proposed energy efficient system consists of 22 units of 70 W LED lamps and 16 units of LED 140 W lamps. The spacing between the lamps is approximately 40 m. The LED, CFL, Fluorescent and Incandescent lamps are compared in Table I.

The designed system has been tested for two extreme months of summer, rainy and winter, i.e., during the months of June, July, August, September, December and January. Equation (1) is utilized to calculate the energy consumption per month of the installed lamps in units.

$E_{Consume}$ (kWh)/month=P X TL X h/day X days of month

where P is the power in watts, TL is the No. of installed lamps, and $h/$day are the operating hours per day. The results of these tests are summarized in Table II for the above mentioned months.

The results clearly indicate that for the conventional system, i.e., the system without having any smart options of energy saving like diming of lights and usage of occupancy sensor, has to turn on for 12h/day (i.e., from 7:00 *PM* to 7:00 *AM*) in the worst case in the month of December. Thus the energy consumption in this case will be around 2628 kWh/month. On the other side, by using the proposed energy efficient system, this energy consumption is reduced drastically from 2628 to 765 kWh, i.e., around 70.8% of the energy is saved per month. The bar charts are plotted for the two extreme months of the year for summer, rainy and winter, i.e., June, July, August, September, December and January, respectively. The energy consumption per month for

LEDs and Fluorescent lamps is listed in Table II. The results clearly indicate that the energy consumption of the proposed RF OLC system decreased noticeably when compared with the conventional systems.

Furthermore, the energy consumption reaches its peak value in the month of December for all the systems. Moreover, the
TABLE I

Energy Consumption per month

Properties		LED	Flucroscent(T8)	CFL	Incandescent
JUNE					
UNITS	1HOUR	0.00245	0.023	0.0098	0.040
	DAY(9HOURS)	0.02205	0.21	0.088	0.36
	MONTH(9H/DAY)-30DAYS	0.6615	6.37	2.65	10.9
COST OF ELECTRICITY	1HOUR	0.01349	0.12	0.054	0.22
	DAY(9HOURS)	0.1214	1.1	0.48	2.0
	MONTH(9H/DAY)-30DAYS	3.6423	35.06	14.61	60.5
JULY					
UNITS	1HOUR	0.0023	0.022	0.00867	0.017
	DAY(9HOURS)	0.0207	0.20	0.078	0.15
	MONTH(9H/DAY)-30DAYS	0.6417	6.24	2.42	4.93
COST OF ELECTRICITY	1HOUR	0.01265	0.123	0.0478	0.21
	DAY(9HOURS)	0.11385	1.1	0.43	1.90
	MONTH(9H/DAY)-30DAYS	3.5293	34.35	13.35	59.19

energy consumption for the proposed RF OLC system decreases more in sunny months and reaches the bottom value in June for all the systems. In the case of the proposed system, due to its smart weather adapting capability its operating h/day reduces more, and hence results in more energy reductions as compared to the conventional systems. Thus, the proposed energy efficient system is very helpful for the operators and as well as for the customers due to its features of smart weather adapting capability. Consequently, the whole price to consider is that of the installation and implementation of the system with savings to lower maintenance and energy costs.

IV. Conclusion

The proposed RF OLC system can smartly adjust the intensity of the LED lights according to the sunlight conditions. It is also cost effective and energy efficient. In addition, the designed system can remotely monitor the light’s status and power consumptions. By using the proposed system, the faults in the lights can be easily detected remotely and can be recovered with less time, which will save the labor cost for frequently monitoring the system. It can adopt to the changing conditions in a more proactively and timely manner. Furthermore, the proposed system is suitable for outdoor lighting in urban and rural areas with slight modifications where the traffic can be low or high during different time intervals. The designed system is flexible, extendable, and fully adaptable to the user needs.

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