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Intelligent Lighting System Using Wireless Sensor Network and Node MCU

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Abstract - This paper examines the use of Wireless Sensor Networks interfaced with light fittings to avoid wastage of energy usage in existing buildings. This creates a wire free system for existing buildings with the minimum disruption and cost. In the recent trends, the use of electronic load is increasing very fast and the gap between demand and supply are making the reliability and power quality a critical issue. The maximum waste of energy is caused by the inefficient use of the consumer electronics. A light energy accounts for a great part of the total energy consumption. As the installed lighting systems are outdated and energy-inefficient, there are various light control systems introduced in the market. But these existing light control systems cannot be successfully applied to home and office buildings because of the architecture limitations. Therefore this paper proposes an intelligent household incandescent lighting system considering energy efficiency and users satisfaction. The proposed system utilizes multi sensors and the wireless communication technology in order to control the light according to the user's state and the surroundings. This system can autonomously adjust the light intensity value to enhance both energy efficiency and user satisfaction.

Keywords: IR sensor (Infrared sensor), Wireless sensor network (WSN), Internet of things (IoT), Arduino integrated development environment (IDE)

I. INTRODUCTION

As the development of mobile internet, semiconductor technology and modern living style of people showing more interest towards the use of intelligent system. Wireless sensor networks is a combination of computing, communications and sensor technology, has become an active field of computer science research branch now [9].

In addition to sensor nodes of the network, sensor networks can also work with the Internet, mobile communication network and other networks to achieve full integration [2].

Figure1 shows a Wireless Sensor Network system which can provide work plane light measurements and is integrated with a standard building monitoring system. The wireless network controls the high intensity bulbs, without the need to re-cable and with minimal disruption.

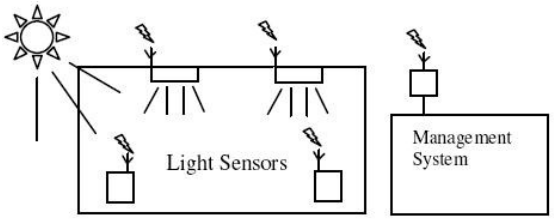

Fig 1: Wireless Daylight Substitution

The system for wireless sensor networks in the intelligent lighting control field defines a set of very detailed protocol standard based on the wireless sensor network. Intelligent lighting system is advantageous for the expansion and promotion [8]. But the system communication makes the system more costly, so by considering this disadvantages, we have used IR sensors in the system.

A. Existing smart home applications

A smart home system mainly includes heating, ventilation, and air conditioning, Lighting control, or Audio and Video distribution to multiple sources around the house, security (involving presence simulations, alarm triggering and medical alerts). Smart homes systems are grouped by their main functions such as,

i) Alert and sensors – heat/smoke sensors, temperature sensors

ii) Monitoring – Regular feed of sensor data i.e. heat, CCTV monitoring

iii) Control – switching on/off appliances i.e. sprinklers, lightings

iv) Intelligence and Logic – Movement tracking i.e., security appliances

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II. BLOCK DIAGRAM OF SYSTEM

The methodology of proposed system is shown in figure 2. The system is proposed to save energy, which is wasted when lights are still ON after exit of person. In this system we are considering 4 rooms where 4 modules are installed. If a person is detected or presence is detected in room1 then light of room2 and 3 should be dim, light of room1 will be bright while that of room 4 should be off, similarly for room 2, 3 and 4. For example when the barrier comes at the room 2, the light at room 2 will be bright and light at the room 1 and room 4 will be dim. And the light at room 3 will be off. The same with other nodes also. We have used firebase server at which all the data is updated when the barrier comes.

Dimmer circuit is responsible for change in intensity of light, Arduino Nano controls dimmer circuit, and IR sensor detects presence of a person in room. Node MCU acts as a Wi-Fi unit. Node MCU updates data on firebase server and also retrieves from it. Value of IR sensor id updated on firebase and Node MCU fetched value of other IR sensor (excluding one interfaced with it), and sent to Arduino after that Arduino then decides value of intensity of light. All the four nodes communicate with firebase server. And in this way the light at four the nodes can be controlled.

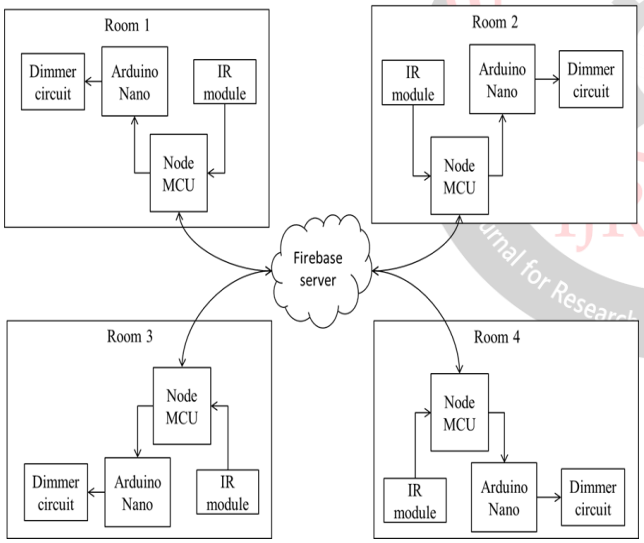

Fig2: Block diagram of wireless sensor network

III. CIRCUIT DIAGRAM

The schematic circuit diagram is shown in the fig 3.

The incoming supply is 230V which is given to the load through triac and transformer also which convert this supply into 12V AC. This AC supply is also given to the Triac. Triac works as a dimmer circuit. By changing the firing angle of the triac, the RMS value of the waveform can be changed and hence input to the load and by which the brightness of the lamp can be changed. The controlling signal to the triac is get from the Arduino IC.

The 12 V AC supply is fed to the half wave rectifier which convert AC signal to DC signal. This DC signal is the given to the Zero crossing detector 4N25 as shown in the fig 3.2(b). The purpose of zero crossing detector here is to inform Arduino IC that when the signal crosses its zero value so that Arduino can send control signal to the triac.

But the Arduino works on DC supply and Triac works on AC supply. So in between, we have connected Optocoupler MOC3021 as shown in the above circuit diagram. Optocoupler here acts as an isolator between AC and DC circuit. It passes the signal from Arduino IC to the triac through the light signal shown in the above figure 3.

When the barrier comes at any of the node in between trans-receiver of IR sensor, IR sensor senses the barrier and it sends signal to the Node MCU which is the server detector and also sends data to the server. We are using Firebase server. At the firebase server the data is updated when the barrier comes. All the other Node MCUs also read data from this firebase server. These node MCUs then send signal to the Arduino IC which which when get signal from zero crossing detector, send control signal to the dimmer circuit through Optocoupler. And dimmer circuit then controls the intensity of light as per the requirement.

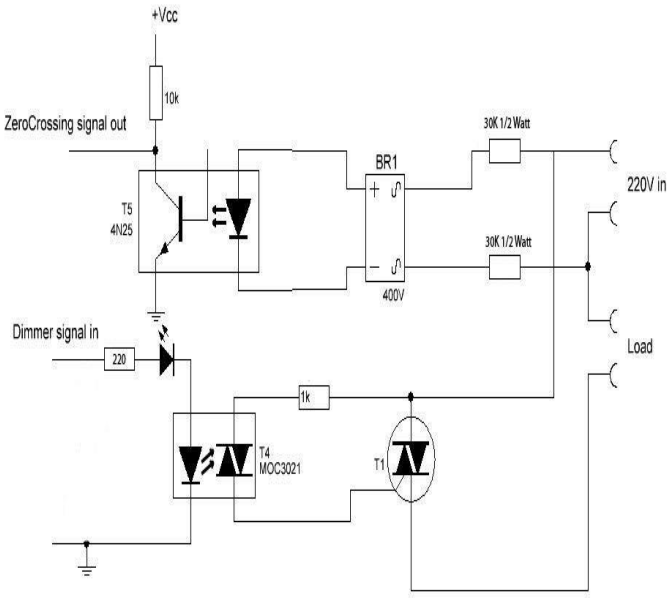

Fig 3. Circuit diagram of system

When the barrier comes at any of the node in between trans-receiver of IR sensor, IR sensor senses the barrier and it sends signal to the Node MCU which is the server detector and also sends data to the server. We are using Firebase server. At the firebase server the data is updated when the barrier comes. All the other Node MCUs also read data from this firebase server. These node MCUs then send signal to the Arduino IC which send control signal to the dimmer circuit. And dimmer circuit then controls the intensity of light as per the requirement.

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IV. CIRCUIT ELEMENTS

The hardware of a system consists of Arduino Nano which controls the required action, IR module that is IR transmitter and IR receiver, IR sensor Regulator, Zero crossing detector, optocoupler, rectifier and registers.

A. Arduino Nano

The Arduino Nano is a small, complete, and breadboard friendly board based on the ATmega328P (Arduino Nano 3.x). It has more or less the same functionality of the Arduino It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.

B. NODE MCU

NodeMCU is an open-source firmware and development kit that helps you to prototype or build IoT products. It includes firmware that runs on the ESP8266 Wi-Fi and hardware which is based on the ESP-12 module.

C. IR sensor node

The IR Sensor-Single is a general purpose proximity sensor. Here we use it for collision detection. The module consists of a IR emitter and IR receiver pair. The high precision IR receiver always detects a IR signal. The module consists of 358 comparator IC. The on-board LED indicator helps user to check status of the sensor without using any additional hardware.

D. Regulator

These voltage regulators having fixed voltage integrated circuit is designed for a wide range of applications. For example, these regulators used for the regulation where there is need of elimination of noise and also useful where there is distribution problems. The output current of these regulators are about 1.5 ampere. As these regulators are having the special features like internal current limiting property and thermal shutdown property, these are having better immune to the overload. This fixed voltage regulator can also be used to obtain the adjustable output voltage and current in an electrical system.

E. *Dimmer Circuit*

In this system have used dimmer circuit as an AC current controlling device or as a current driver for the lamp. This electronic lighting dimmer circuit is used to control the lamp for arbitrary brightness. This electronic lamp dimmer circuit work for incandescent lamp, not a fluorescent one.

F. Transformer

The transformer of 230V/12V is used in the circuit which convert 230 volt ac to 12 volt ac supply.

G. AC to DC converter(Rectifier)

The rectifier that is 12V ac to12V dc converter is used to supply dc voltage to the circuit.

H. Zero Crossing Detector

The AC input is half-wave rectified to produce a pulsating DC waveform that drops to zero volts each time the sine wave crosses zero. This causes the LED in the 4N25 to extinguish and turn off the coupling transistor. This generates a negative-going pulse at each zero crossing.

I. Optocoupler

An Optocoupler**,** is an electronic components that interconnects two separate electrical circuits by means of a light sensitive optical interface. We are using MOC3021 module. It takes the control signal from Arduino and give it to dimmer circuit.

Following picture shows the internal hardware circuit diagram of the system:

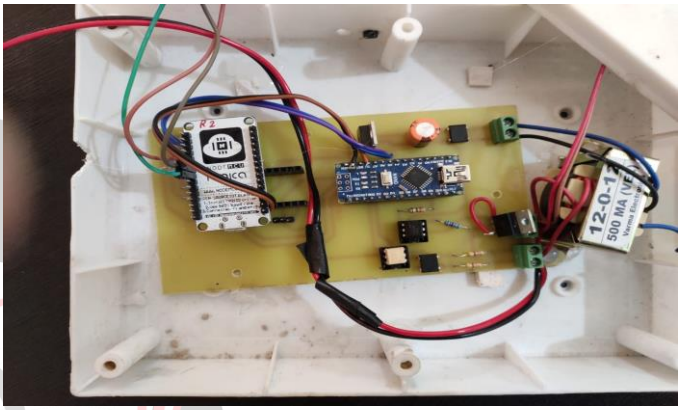

Fig. 4 Circuit Diagram of System

The following diagram shows the actual system working by using above circuit elements.

In the fig 5(a), suppose the barrier comes at node 1, we can see the two neighboring nodes are dim and the node which is away from node 1 is off.

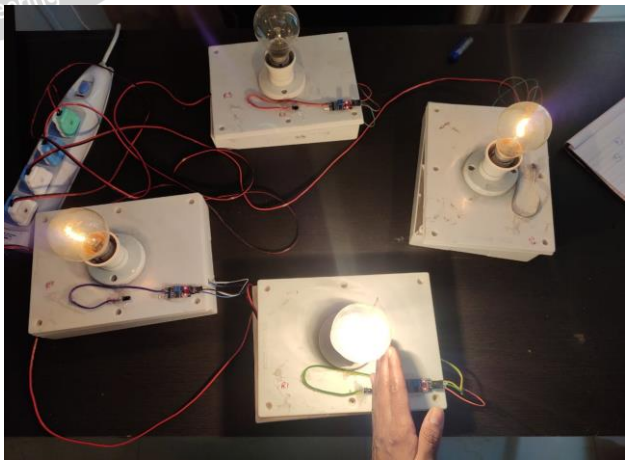

Fig. 5(a) case 1 (barrier at the node 1).

The similar case can be explained for the node 2. As shown in the fig 5(b), suppose the barrier comes at node 2, we can see the two neighboring nodes are dim and the node which is away from node 2 is off.

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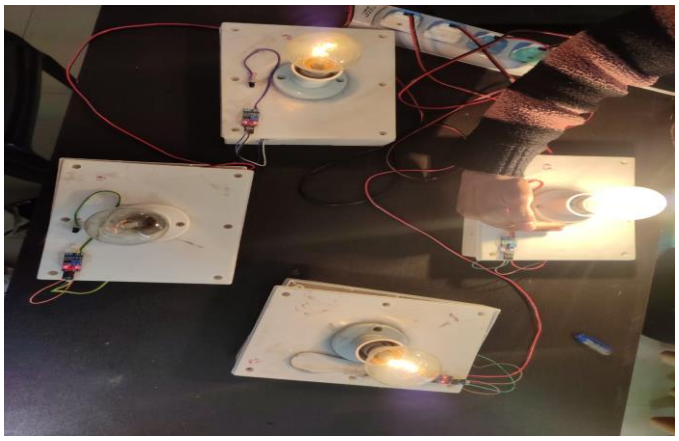

Fig. 5(b) case 2.(barrier at the node 2)

The same situation can be created with the other two nodes also.

V. SYSTEM SOFTWARE

a) Arduino IDE

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java.

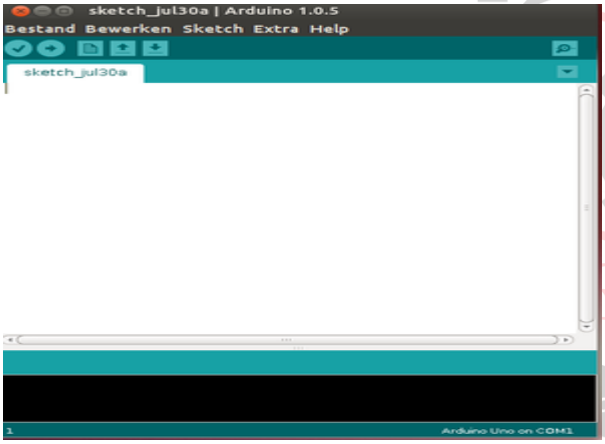

Fig. 6 Arduino IDE

.It is used to write and upload programs to Arduino board.

The software of system includes the lighting control algorithm and the node's networking program.

b) Firebase

Firebase is a mobile platform from Google offering a number of different features that you can pick 'n mix from. Specifically, these features revolve around cloud services, allowing users to save and retrieve data to be accessed from any device or browser. NODE MCU sends data to firebase. When bulb is on it sends 1 else it sends 0. The system can be synchronized with the firebase server in the real time database analysis.

Case 1

In the following fig 7(a), the real time database analysis in the firebase server can be shown. We can see the node R1 is going 1 and other nodes that is R2, R3, and R4 are going 0. That means the firebase is updated and it's showing that the barrier is at the node R1.

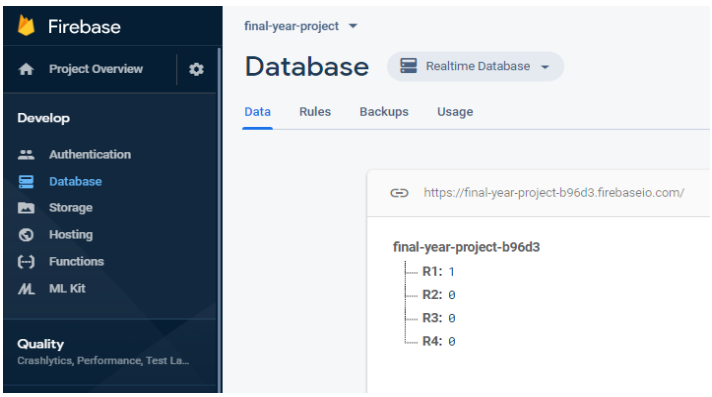

Fig. 7 (a) Firebase server when R1 node is ON

The following fig. 7(b) shows the analysis of case 1 in MATLAB software which shows the control of light intensity when the barrier comes at the node R1 .

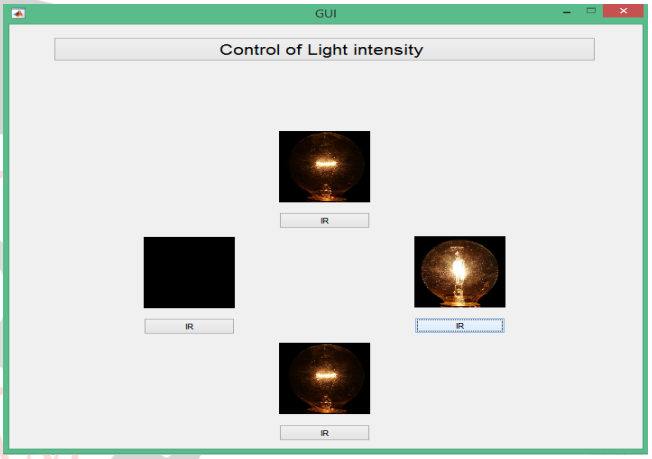

Fig. 7 (b) Control of light intensity in MATLAB

Case 2:

Now considering the case 2. In the following fig 8(a), the real time database analysis in the firebase server can be shown. We can see the node R2 is going 1 and other nodes that is R1, R3, and R4 are going 0. That means the firebase is updated and it's showing that the barrier is at the node R2.

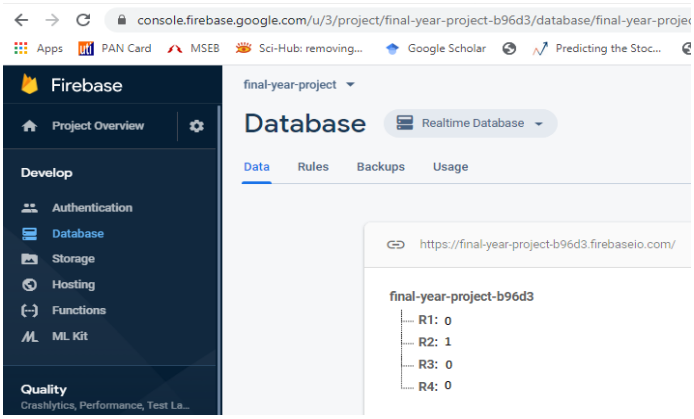

Fig. 8(a) Firebase server when R2 node is ON

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As per the above case shown in fig 8(a), the analogous observation of case 2 is shown in MATLAB in the following fig. 8(b)

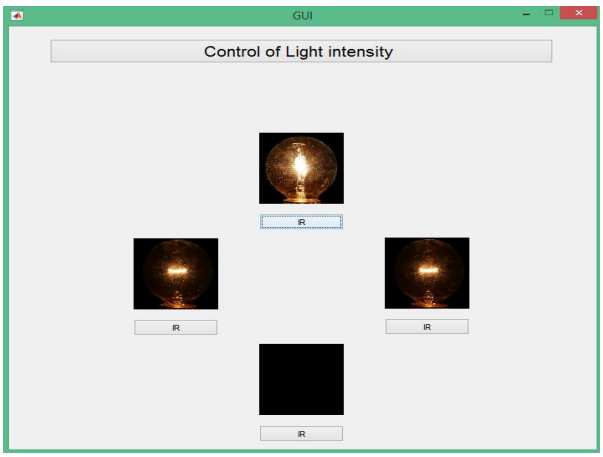

Fig. 8(b) Control of light intensity in MATLAB

VI. RESULT

Experimental Setup:

1. A room with 4 light bulbs at corners

2. Consider the light should be light up for 4 hrs. /day

3. The bulb used will consume 60W of power.

4. In normal system all light should glow in full intensity therefore consumes 240 W each.

5. In the proposed system, we control the intensity of light.

The fig 9 shows the implementation of intelligent lighting control system.

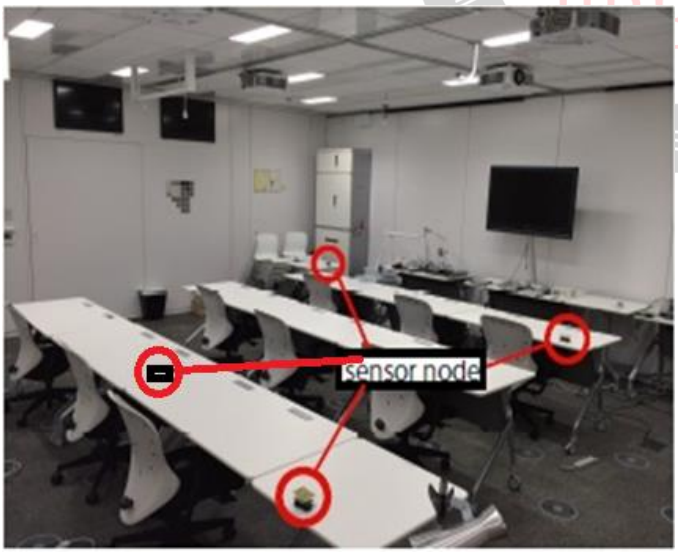

Fig. 9 Implementation of intelligent lighting control system

This can be explained through the following analysis:

Calculation:

Person will be at the Node1.

1) Traditional System(All bulbs are on)

No. of bulbs = 4

Wattage =60W each

Usage = 4 hrs. /day

Total energy consumed/day= 60*4*4=960Whr/day

No. of units/day=0.960 units

Rs. / day=0.960*3=2.88 rs/day

2) Proposed System

(Node1 is bright, Node 2 and 4 are dim and Node 3 is off)

No. of bulbs = 4

Wattage =60W each

Usage = 4 hrs. /day

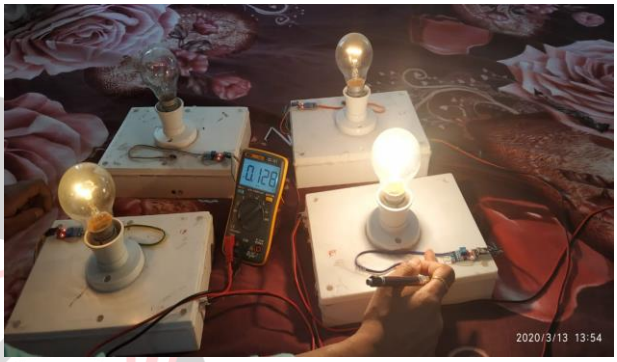

Fig. 10(a) Current measurement through dim bulb

In the fig 10(a), we can see the measurement of current through dim bulb. It's useful to find out the energy consumed

Energy consumed by dim bulbs

(2 bulbs are dim in above case)

=2*V*I*cos φ=2*230*0.128*1=29.44 W

Fig. 10(b) Current measurement through bright bulb

In the fig 10(b), we can see the measurement of current through bright bulb. It's useful to find out the energy consumed by bright bulbs.

Energy consumed by bright bulb

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=V*I*cos φ=230*0.230*1=52.90 W

Total energy consumed = (29.44 +52.90)*4=447.12 Whr/day

No. of units/day=0.447 units

Rs/day=0.447*3=1.341 Rs/day

The comparison of proposed system with the normal system can be shown from the following table 1.

	Power	Hours used	Number of lights	Energy consumed per day	Calculated energy consumption
Normal system	60W	4	4	960Wh	960Wh/day
Proposed system	29.44W	4	2	235.52Wh	447.12Wh/day
	52.9W	4	1	211.6Wh	

Table 1. Comparison of proposed system with the normal system

VII. COCLUSION

Thus the proposed system can control light intensity which is user friendly and efficient method using wireless sensors, modern ICs and Node MCU. The wireless connectivity without destroying the original system is the main advantage of proposed method and it makes the system cost efficient. This system helps to avoid the wastage of energy while lights are still ON after exit of person. Using wireless sensor network in our system makes the system simpler, easy to use and no wire complications will be there.

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