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Energy Management System of Luminosity Controlled Smart City Using IoT

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Abstract

INTRODUCTION: With the escalating rates of urbanization, there is a pressing need for enhanced urban services. The concept of smart cities, leveraging digital technologies, offers a promising solution to elevate urban living. The integration of Internet-of-Things (IoT) in urban infrastructure, particularly on highways, opens avenues for novel services and cross-domain applications through Information and Communication Technologies. However, the efficient functioning of an IoT-enabled smart city necessitates careful energy resource management.
OBJECTIVES: Propose a Highway Lighting System (HWLS) integrating IoT technologies to enhance urban services, focusing on significant energy savings and real-time environmental parameter monitoring.
METHODS: To achieve the objective of enhancing urban services through the proposed Highway Lighting System (HWLS), the system was designed and implemented by integrating cutting-edge sensors, communication links, and the Blynk IoT app. The deployment involved incorporating IoT technologies for real-time monitoring of air quality, air moisture, and soil moisture, alongside a fault identification system using GSM and GPS modules.
RESULTS: The proposed HWLS demonstrates significant energy savings, consuming only 37.6% of the original power consumption. The incorporation of IoT technologies facilitates real-time monitoring of environmental parameters, enabling informed decision-making for urban service optimization. The fault-finding system, utilizing GSM and GPS modules, enhances the reliability of the lighting system.
CONCLUSION: In conclusion, the Highway Lighting System (HWLS) represents a novel approach to smart city infrastructure, particularly in the context of urban lighting. The integration of IoT technologies not only contributes to energy savings but also enhances the overall efficiency of urban services. The proposed system's ability to monitor environmental parameters and identify faults demonstrates its potential for sustainable urban development and improved quality of life.

Keywords: Internet-of-Things, Highway Lighting System, GSM, GPS

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1. Introduction

The 21st century has seen the internet become a need for human existence. Many ideas for distant human-to-human and human-to-machine communication have been developed as a result of the internet's evolution. The next stage is to link systems and devices to provide machine-to-machine communication. The emergence of IoT has revolutionized the way systems and individuals are interconnected through unique identifiers (UIDs), facilitating seamless data transfer over networks without direct interaction [1]. IoT encompasses various components, such as bio chips, medical monitors, and sensor-integrated motor driver circuits, which, when attached to a controller, enable data transmission over networks.

The smart street lighting system, which accounts for 10–40% of total energy consumption and shows a discriminating attention to the needs of general society, is a crucial component of the smart city. In urban areas, streetlights represent a significant power consumption factor, constituting a major portion of a city's energy expenses, often accounting for 35-45% of the municipality's utility budget [2]. Traditional manual-based street light control suffers from several drawbacks, such as lights remaining on despite sufficient natural light, manual switching, high power consumption, and operational challenges due to seasonal and climatic changes. Implementing an intelligent lighting control system has the potential to reduce municipality street lighting costs by up to 70%.

The proposed smart street light system aims to minimize power usage in areas with limited vehicle presence. It operates based on two conditions: turning on when the ambient brightness is low and turning off during high brightness, akin to sunrise, thus optimizing energy consumption. The system described in the paper utilizes motion detection and an Arduino board to automate street light control. The primary benefits of this approach are significant power and cost savings. The way that road lights are now operated is by turning them on at night just before sunset and shutting them off the next day [3]. However, this manual process necessitates a tremendous lot of labor, which is a drawback. Additionally, the street lighting systems now in use are inefficient due to the substantial variations in the on and off hours on bright and rainy days. Traditional street lighting systems frequently operate continuously throughout the day without a need, wasting energy.

2. Related Works

An IoT-based leader-follower efficient office lighting automation system is suggested by Lee et al. [4]. When no one is present, the technology organizes a system counter and an infrared human motion sensor to convert indoor LED lights to low-light mode. The system can adjust LED light settings and brightness changes simultaneously, saving 28.13% of the energy used.

According to Jain et al. [5], the smart light sensor suggests an autonomous regulation of traffic lights that could result in some energy savings. Automation advances industrial development more than machinery does. Automation drastically minimizes the requirement for human cerebral and sensory needs while still meeting functional muscle needs. Basically, one of the most crucial components is street lighting. The number of roads is growing quickly as a result of the heavy traffic. The suggested approach uses less energy and requires less labor from humans. The Arduino UNO microprocessor activates the light and transforms the analog signal's form to a number, acting as a visual connector.

Chamola et al. suggested a solution for reducing the power consumption of streetlights, which involves managing the circuit of the lights with a microcontroller, sensors, and LDR in addition to an IOT app that tracks their energy usage [6]. Using a sensor and the least amount of power possible, J. Arthi et al.'s approach for regulating street light brightness glows in its maximum level; otherwise, it operates in the dim mode at night. The Internet of Things (IOT) is utilized to visualize real-time street processing updates and notify users when changes take place [7].

S.P. Patil et al. study recommended a low-cost, energy-efficient autonomous street lighting system based on microcontrollers. The lighting levels of streetlamps that use Light Emitting Diodes (LEDs) [8]. A microcontroller, a set of LED modules, a PIR sensor, and a light sensor make up this system. The system is controlled and managed based on the volume of traffic, and to light up the streets proportionally to the volume of traffic, five different levels of street light brightness have been used. The system was set up to shut off automatically at night. To evaluate the suggested prototype in various environments, numerous tests have been carried out. As a result, this suggested system design can reduce power usage by around 77%–85%.

A ZigBee-based outdoor lighting system was studied by Kaleem et al. The system's settings were regulated using sensors. In outdoor street conditions, experiments revealed that the device that uses very less amount of energy around 70.8% [9]. P. Elejoste et al. In order to make its installation in existing facilities easier, this article provides an intelligent streetlight control system based on LED lights. By employing wireless communication technologies, providing useful energy usage solutions, providing correct energy consumption computation, and providing dependable facility maintenance, the suggested technique seeks to lower the investment costs associated with conventional wired system [10].

Designing a smart illumination system with a focus on power-saving features is the goal of the proposed effort. The aim is to create a highly energy-efficient smart lighting framework that incorporates integrated sensors and controllers. The focus is on developing a smart lighting system with a specific approach that ensures adaptability and expandability. Additionally, the design aims to ensure compatibility and versatility with other commercial products and automated systems, possibly extending beyond just lighting functionalities. Classic system disadvantages as follows:

- Even when there is apparent light, the streetlights are kept on.
- Although automated by a timer, these streetlights require manual switching because the length of sunrise and sunset fluctuates with the seasons as well.

- It also needs a lot of manpower even after setting auto ON/OFF to find faults in lighting system.
- Since there are no activities taking place on the street, these streetlights are unnecessarily shining at full intensity.
- High power usage, energy waste, and decreased dependability.
- Watering of plants along the divider are not monitored properly thus affecting night drivability.
- Does not contain features such as atmospheric temperature, atmospheric moisture, soil moisture and energy consumption.

Given the various problems that were previously discussed with the conventional lighting system, we need a lighting system that is well-equipped with modern inventions and technology. Everyone is aware that there are only a finite number of natural resources available for the production of power, and that we are wasting a great deal of energy. Therefore, if we can use automation in this particular scenario through an advanced controller, we can make the streetlights only be able to glow at their highest intensity when there is activity in the area, otherwise it should glow at a minimum specified level. in order to conserve a significant quantity of power. There are some elements like cheap cost, improved power saving, and sophisticated automation that are crucial. These three are deteriorating for various causes. Other uses for this spare energy include irrigation, in villages, towns, and numerous other fields. By utilizing Arduino to regulate the brightness of streetlights, we may create intelligent systems. Street lighting is seen as an unavoidable use of electricity in cities [11].

Additionally, by keeping an eye on electricity usage and the watering of the plants along the divider, we can lessen nighttime traffic accidents and be alerted right once if a problem arises. Public authorities are especially concerned about street lighting in developing nations because of its strategic importance for the stability of the economy and society. Each year, poor lighting adds to significant financial difficulties, and it can have an impact on each citizen. Energy-saving techniques can significantly reduce the price of street lighting while also providing remarkable efficiency. Manual control wastes energy and is prone to mistakes. It would be impossible to manually adjust the lighting during the midnight hours. Light sensors like LDR and passive infrared sensors are the two types of sensors used in this work [12]. The streetlights will turn on when the photoelectric sensor senses any movement, which will adjust the light's intensity, and when the light sensor detects darkness, which will turn on the ON/OFF switch. When an LDR sensor measures the amount of light striking its surface, it may determine whether it is day or night. Any object that enters the photoelectric beam will automatically cause that light's brightness to rise for a short period of time. This idea can be used to create an intelligent lighting system for any location's streetlights. Atmega328P-based board, LDR, photoelectric sensor, and other electrical devices make up the lighting system. Since the Light Dependent Resistor (LDR) operates in an inverse proportion to light, it is used to measure light levels. When the LDR sensor detects light, it sends a command to the ATmega328P microcontroller telling it to turn off the light. A photoelectric sensor will also be used to regulate the light intensity depending on whether or not an item is present. All of these commands are communicated to the controller, which subsequently controls the device in accordance with the command [13]. As an ON/OFF switch, a MOSFET serves as a relay in our system. In addition to LDR and PIR we included atmospheric gas sensor, atmospheric temperature sensor, soil moisture sensor, GSM module, GPS module, energy sensor is used which all collectively improve this highway lighting system to improve night drivability and provides excess data to improve and perform monitoring of the surrounding environment.

3. Proposed Method

Using High Intensity Discharge (HID) lamps, roads are illuminated. To build a lighting system with low loss, proper maintenance is necessary. Even though no vehicles were passing through at that precise time, we saw superfluous street lighting. Therefore, there is electricity waste. Power consumption increases significantly with excessive illumination. Due to the disruption of the discharge path, the existing lighting system, which operates on the concept of gas discharge, cannot be controlled by voltage reduction techniques [14]. We need to come up with a solution that automatically shuts off the electric power supply when no vehicles are passing through a given street at a specific time in order to improve the current system. In this proposed work, we have successfully improved the efficiency, accuracy, and cost-effectiveness of the present street light mechanism.

In order to maximize energy usage, our suggested technique detects the existence of impediments on the road and uses streetlights only when absolutely essential. This was accomplished by taking into account the PIR sensor reading upon obstruction identification and starting the process of street illumination progressively as the impediment moved. This allows us to keep the streetlights continually on while saving a significant amount of electricity or power that was lost in the prior system. LDR sensors are a type of sensor frequently employed in light sensor circuits to regulate streetlamps in open spaces. This LDR is mostly used to distinguish between daytime and nighttime lighting. An analog to digital converter that is interfaced with a microcontroller is needed because LDR provides the discrete output of the resistance values. The microcontroller is programmed with a specific algorithm to adjust the intensity of the lights during morning and evening hours. This programming allows for dynamic control of the light intensity, ensuring optimal brightness levels based on the natural lighting conditions. Consequently, the system is able to control power usage. The ATMEGA 328p is the circuit's key component, and it is utilized to wirelessly transmit data from the sensor to the main unit. The Harvard design, which divides memory for code and data, is used by the Atmega328P CPU. It operates at 16 MHz and has 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM.

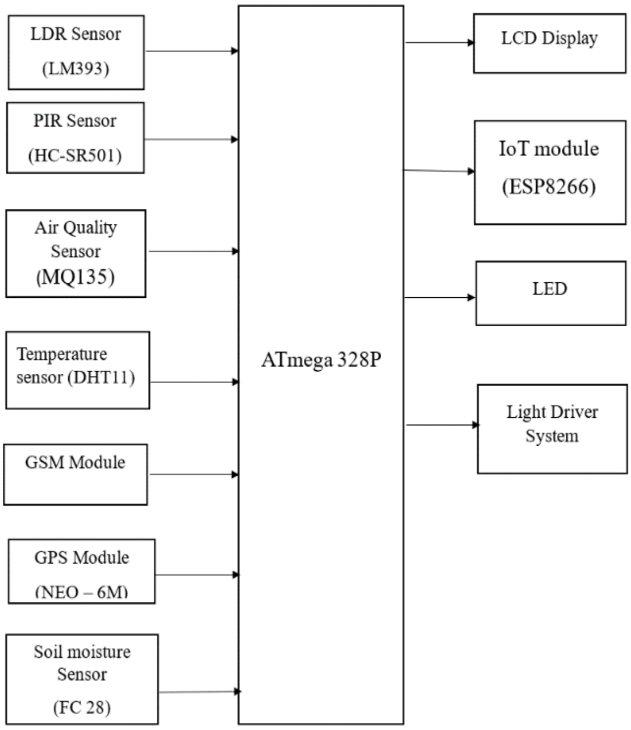

Figure 1. Block diagram

Figure 2. ATMEGA 328P

3.1. PIR Sensor

In a smart city, the peak hour for traffic is most often between 6 and 10 p.m. As a result, after that time all of the streetlights are on maximum intensity, wasting a tremendous amount of energy.

Figure 3. PIR Sensor diagram

If we install a modest motion detecting device, the streetlight will only turn on fully when there is activity in the street. We can employ photoelectric beam detectors, proximity sensors, and passive infrared motion sensors (PIR) to solve this issue. PIR sensors are made of pyroelectric crystalline components that sense changes in thermal energy caused by the production of infrared rays by people, animals, and other objects [15]. The electromagnetic spectrum contains infrared radiation, which is invisible to the human eye and has a longer wavelength than sunlight. The surface of PIR is illuminated by infrared radiation with a wavelength of 9.4 m that is produced when an object moves in front of its nominal range. The amount of infrared radiation that strikes crystalline surfaces produces the charge that the built-in FET of the PIR sensor detects.

3.2. Light Dependent Resistor (LDR) Sensor

An LDR responds to variations in light intensity like a variable resistor. These aid in determining the level of light intensity at that particular moment and, in turn, assist in adjusting the illumination of our lighting system appropriately [16].

Figure 4. LDR Sensor

3.3. Temperature and Humidity Sensor (DHT11)

An incredibly affordable digital temperature and humidity sensor is the DHT11 sensor. The temperature is measured using a specialized Negative Temperature Coefficient (NTC) element, and the temperature and humidity measurements are output as serial data by an 8-bit microcontroller. A thermistor is used to sense temperature, and a capacitive humidity sensor is part of the sensor's construction [17].

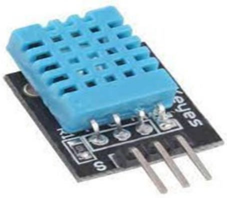

Figure 5. Temperature and Humidity Sensor

The humidity sensing capacitor contains two electrodes separated by a moisture-holding substrate, which acts as the dielectric medium. This combination of components allows the DHT11 sensor to accurately measure both humidity and temperature in a cost-effective manner.

3.4. Gas Sensor (MQ135)

A type of MQ gas sensor called the MQ135 air quality sensor is used to detect, measure, and track a variety of airborne gases, including nitrogen dioxide, drugs, benzene and smoke [18]. It uses 150mA while running on a 5V supply. To get an accurate outcome, the operation needs to be preheated for 20 seconds.

Figure 6. Gas Sensor

3.5. Soil Moisture Sensor (FC 28)

To determine the ratio of the volume of water to the unit volume of soil, here we use the Soil Moisture Sensor. These sensors estimate the volumetric water content indirectly by utilizing other soil laws, including the dielectric constant, resistance to electricity, neutron interaction, and restoration of the moisture content. When the earth is moist it conducts electricity more effectively than when it is dry.

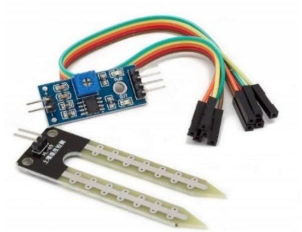

Figure 7. Soil Moisture Sensor

3.6. Voltage Sensor

It is utilized to determine and sense an object's internal voltage source. Either AC voltage or DC voltage level can be used with it. It is founded on the resistive voltage divider design theory.

Figure 8. Voltage Sensor

3.7. Current Sensor

It is low-cost Hall effect current sensor used to measure up to 20A. It includes a copper conduction lane through which the flow of current. Once the current is supplied from pin 1,2,3 and 4 through conduction lane, then it produces magnetic field which is detected by hall effect sensor [19]. The output voltage of this sensor is proportional to input flow of current.

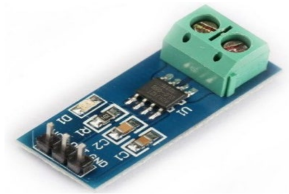

Figure 9. Current Sensor

4. Result and Observation

High light Intensity:
- Light supply Voltage = 9 v
- Light power consumption = 1.86 watts

Low light Intensity:
- Light supply Voltage = 9 v
- Light power consumption = 0.7 watts

For 1 hour, Energy consumption in High light Intensity, It is known that

Energy (High) = (power * time)
= 1.86 watts * 1 hour
= 1.86-watt hour

Energy (High) = 6696 J

For 1 hour, Energy consumption in low Light intensity,

Energy (low) = power * time
= 0.7 watts * 1hour
= 0.7-watt hour

Energy (low) = 2520 J

Energy difference = 1.86 – 0.7
= 1.16-watt hour

Energy difference = 4176 J

Let us assume that the high light intensity in first 30 minutes and low intensity in second 30 minutes

Energy = Energy (High) + Energy (low)

= (1.86 * 0.5) + (0.7 * 0.5)
= 1.28-watt hour
Energy = 4678 J

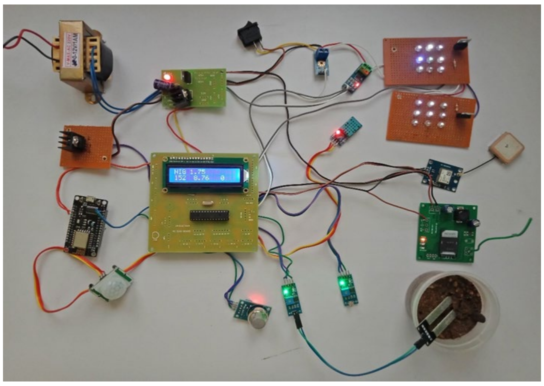

Figure 9. Proposed working model

Table 1. Energy consumption at Low intensity

Time (in minutes)	Energy (Low Intensity) in Joules
30	1260
60	2520

Table 2. Energy consumption at High intensity

Time (in minutes)	Energy **(High** Intensity) in Joules
30	3348
60	6696

From Table 1 and Table 2, it clearly states that, if the intensity of the light is controlled, which helps to reduce the Energy consumption of the Light. The proposed system can save about 1.16-watt hour (4176 J) energy, thus it only consuming 37.6%. The proposed system saves 62.4% of energy.

4. Conclusion

IoT is crucial in real-world scenarios and always offers the best solution when an issue develops in a unique way. Similar to that, our proposed system offers the best way to solve the issue. This proposed work will offer a reliable approach for lighting systems and streamline and effectively save energy overall. The suggested system includes an improved fault-finding algorithm that allows us to pinpoint the exact location of a malfunction. This suggested approach, monitoring the Environmental parameter is an added function. The experience of driving at night will surely change as a result of the use of the smart lighting system.

In future, addition of CCTV surveillance would improve safety and security and furthermore adding of speed guns at regular length would keep the speed of vehicles in check and would reduce accidents due to over speeding to an extent.

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