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Nano Uno-ML-IoT Based Smart Street Light System with Centralized Monitoring and Control

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Abstract: Streetlights are essential components of urban infrastructure that serve as modernity emblems and improve cities' evening aesthetic appeal. They are essential to maintaining both pedestrian and vehicle traffic safety and visibility. However, optimising energy use has become a top priority in light of the worldwide power constraint. Governments throughout the world have responded to this urgent problem by implementing Smart City programs, which use cutting-edge technology to encourage efficiency and sustainability in urban systems. This paper examined a challenge related to the creation of a smart street lighting system as part of this endeavour. This system efficiently monitors and controls streetlights by utilising state-of-the-art technology such as the Machine Learning, Internet of Things (IoT) and the GSM Communications. A CCMS, which regulates energy use and automates light operations, is incorporated into the suggested system. In order to enable precise on-and-off switching based on environmental circumstances, LDRs are employed to monitor ambient light levels. The solution greatly reduces energy consumption by integrating GSM and IoT frameworks to provide real-time streetlight performance monitoring and management. Because of this, this project not only saves electricity but also supports the larger goals of Smart City initiatives to promote sustainable urban growth. In particular, this project tackles suggestions made at the Tirupur event, demonstrating how cutting-edge technologies can be used practically to address pressing issues.

Keywords: *Internet of Things (IoT), Machine Learning (ML).*

1. Introduction

Smart street lighting systems are one of the many creative and effective urban solutions made possible by the quick development of Internet of Things (IoT) and machine learning (ML) technologies. The "Nano Uno-ML-IoT based Smart Street Light System with Centralised Monitoring and Control" makes use of inexpensive Nano Uno microcontrollers, IoT-enabled sensors, and machine learning algorithms to develop an intelligent and energy-efficient lighting system. This technology optimises power use while guaranteeing urban dwellers' safety and convenience by combining real-time data collecting with centralised control. Municipalities may drastically lower energy expenses and improve operational efficiency by switching to smart, adaptable lighting from traditional systems.

Inefficiencies in traditional street lighting systems include excessive energy usage, poor defect detection, and no adaptive lighting features. Due to high electricity use, these problems not only cause financial losses but also deteriorate the environment. By combining automated control mechanisms, centralized management, and real-time monitoring, the suggested solution overcomes these difficulties. It drastically reduces energy waste by dynamically adjusting illumination levels based on traffic congestion, pedestrian activity, and ambient factors. Furthermore, faster fault identification and maintenance are made possible by the centralized monitoring system, guaranteeing continuous service and increased dependability. For smart cities looking to improve operational efficiency and sustainability, this makes it an essential breakthrough.

Applications for the Nano Uno-ML-IoT based smart street light system can be found in a variety of urban settings, such as public parks, business districts, residential neighbourhoods, and highways. Because it allows for remote modifications in an emergency and provides well-lit routes, it is especially helpful in improving public safety. In order to offer a single platform for urban management, its centralized control system can be integrated with the current smart city infrastructure. Additionally, the system is customizable and scalable, enabling communities to modify it to meet certain requirements like enhancing brightness in high-risk areas or lowering lights during off-peak hours. Because of these features, the system is a game-changing option for contemporary communities looking to strike a balance between sustainability and technological growth.

2. Proposed System

An Arduino Uno-Nano microcontroller-powered monitoring and control system block diagram is shown in figure 1. A power supply unit is the central component of the system, converting high voltage AC electricity into a steady DC voltage. A Step-Down Transformer lowers the AC voltage to a safer level, a Rectifier transforms the AC to DC, a Filter Circuit smoothening out the DC signal, and a Voltage Regulator maintains a steady output voltage. All of the system's associated components require energy, which this power source provides.

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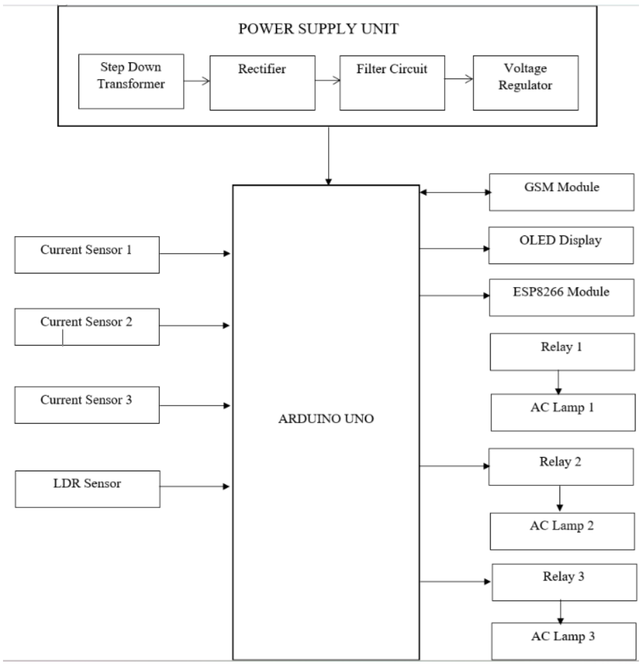

Figure 1. Structure of Nano Uno-ML-IoT based Smart Street Light System

Various output and input devices are interfaced with the Arduino Uno, which functions as the processing chip. Three current sensors as well as an LDR sensor are among the inputs. The LDR sensor monitors the amount of ambient light, whereas the current sensors track the electrical current flowing via various circuits. By sending data to the Arduino Uno for processing, these sensors allow the system to monitor and react to electrical and atmospheric variables in real time.

The Nano Uno manages a number of modules and devices on the output side of the chip. It is linked to an ESP8266 module for wireless connectivity, which permits IoT integration, an OLED display for visual output, and a GSM module for communication, which permits remote warnings or control. Three relays, each of which controls an AC bulb, are also part of the system. In accordance with the data analysed by the Arduino Uno, these relays function as switches for turning the bulbs on or off, making the system appropriate for uses like load handling in smart homes or industrial settings or automated lighting.

3. Hardware Description

The hardware architecture of a "Nano Uno-ML-IoT based Smart Street Light System with Centralised Monitoring and Control" is depicted in this image. For intelligent and effective street lighting, the system is made to incorporate a number of components. The Arduino Uno microcontroller, which serves as the main processing unit and interfaces with a number of sensors and modules, is the main component of the hardware. A steady voltage supply to the system is guaranteed by the power supply unit. It is composed of a rectifier to convert AC to DC, a filter circuit to smooth the output, a voltage regulator to maintain a constant voltage level, and a step-down transformer to reduce the voltage from the main supply. This guarantees that every component that is attached will operate safely.

The Arduino Uno is connected to a number of sensors in order to collect data in real time. These consist of a Light Dependent Resistor (LDR) sensor that senses ambient light levels to allow for automated brightness adjustments and current sensors (1, 2, and 3) that track the power usage of individual streetlights. The technology optimises energy consumption by dynamically adjusting the streetlights based on the sensor data.

To turn the AC lamps (Lamp 1, Lamp 2, and Lamp 3) on or off, the system has relays (1, 2, and 3). These relays provide safe and effective operation by serving as interface devices between the high-power AC lighting and the low-power Arduino Uno. By enabling wireless connectivity, the ESP8266 module enables data transfer to a centralised system and remote control. A GSM module is also incorporated for real-time alerts or notifications about system issues or status. A local visual interface for showing system characteristics, including sensor readings and operational status, is provided by an OLED display. This makes the system easier to use by enabling on-site diagnostics and monitoring. All things considered, this hardware architecture guarantees dependable operation, effective energy management, and controllability, making it an integral component of smart street lighting systems.

4. Hardware Results and Discussion

The figure 5 shows a working prototype of an Internet of Things (IoT) or home automation system that controls electrical devices like lightbulbs with microcontrollers and relays. Numerous components, each with a distinct function in the system's operation, are used to connect it. It illustrates how automation can be used to remotely or automatically control devices in response to human commands or pre-established circumstances.

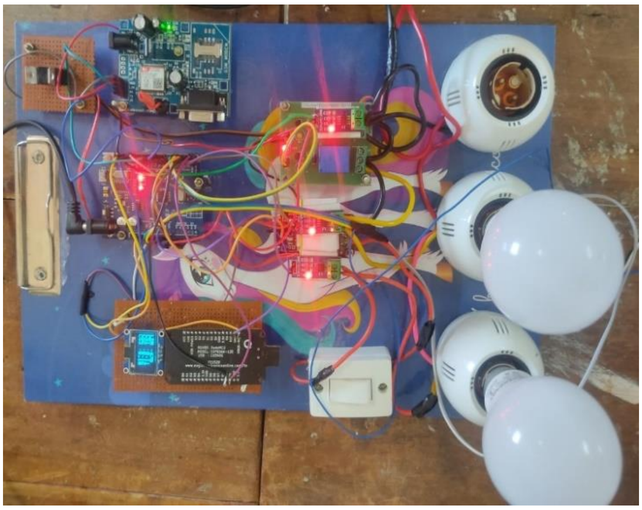

Figure 2. Prototype setup

Microcontroller devices like Arduino and perhaps an ESP8266/ESP32 Wi-Fi module form the core of the configuration. By processing inputs and controlling outputs, these parts act as the control centre. Relays, which function as switches to regulate the associated electrical equipment, receive commands from the microcontrollers. Furthermore, the inclusion of a tiny OLED or LCD display implies that the system is capable of delivering real-time feedback, including sensor readings, the status of connected devices, and other pertinent data.

The high-voltage circuits that are connected to the light bulbs are controlled by relay modules, which are distinguished by their red LEDs. The microcontrollers send low-voltage signals to these relays, which then use the logic of the program to turn on or off the high-voltage electrical equipment. The setup's light bulbs act as output devices, showcasing the system's capacity to manage domestic appliances. As an alternative to automation, a manual switch is also provided, which can enable physical control of the equipment.

All of the parts of the system are connected by wiring, which guarantees smooth power distribution and communication. The energy required for the microcontroller, relays, and display to function is supplied by the power supply, which is probably a DC adapter. This kind of configuration is frequently used to demonstrate the fundamentals of automation and the Internet of Things. It provides an engaging method of learning how to combine hardware and software for real-world uses like energy management and remote device control.

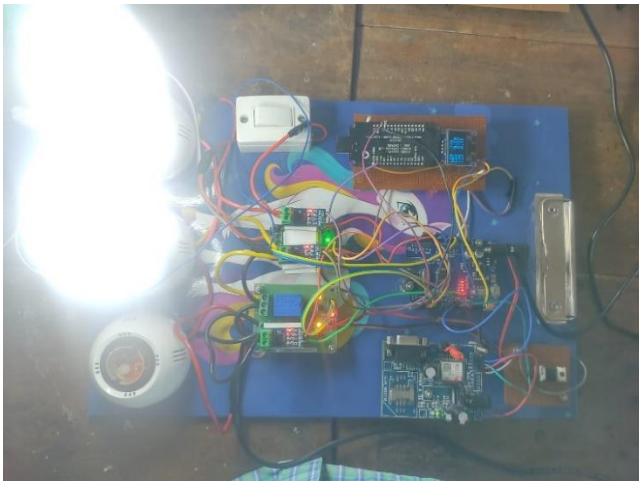

Figure 3. Working model of Prototype

The figure 7 shows the user interface of a "Smart Street Light" system on a mobile device. Using sensors, it keeps an eye on a number of factors and shows their current values. The light intensity measured by a Light Dependent Resistor, which aids in regulating streetlights according to ambient light levels, is represented by the LDR value (478). The remaining numbers, designated as ACS1 (102), ACS2 (102), and ACS3 (111), most likely match current measurements from ACS712 current sensors, which gauge how much electricity is used by the streetlights that are connected. For convenient monitoring, these quantities are represented visually by the graphical gauges. In order to improve energy efficiency, this system probably automates the turning on and off of streetlights in response to environmental factors or energy consumption thresholds.

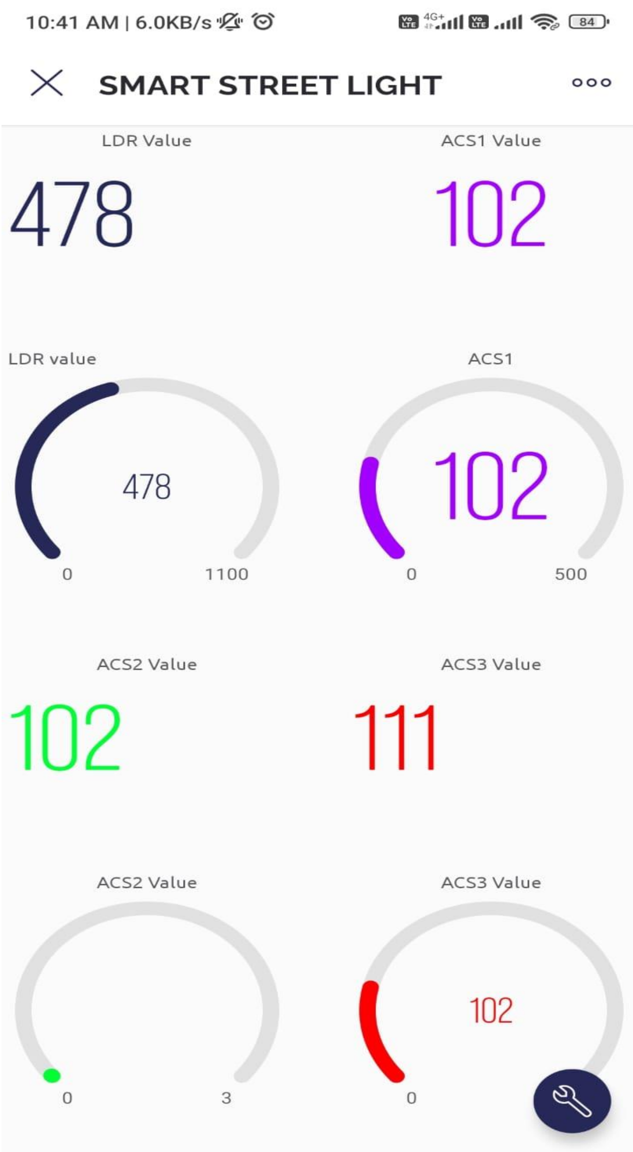

Figure 4. Dashboard display details

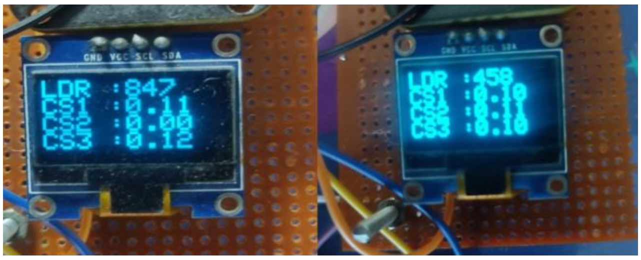

Figure 5. Current Sensor details

The figure 8 showcase real-time sensor data on an OLED display module from an electronic project. Current sensor readings CS1, CS2, and CS3 each show a value of 0.10, indicating little or negligible current flow, while the first display shows an LDR value of 458, which is the ambient light intensity as determined by a Light Dependent Resistor. While the current sensor readings in the second display show CS1: 0.11, CS2: 0.00, and CS3: 0.12, the LDR value rises to 847, indicating more light intensity. This shift in sensor values suggests that a system is actively observing and reacting to changes in light levels and current usage, potentially for automation or energy management applications.

5. Conclusion

When combined with a CCMS, the suggested Smart Street Lighting System is very beneficial for Tirupur's outskirts as well as the city centre. The deployment of the CCMS has effectively addressed the challenge statement's main goal of reducing energy waste in order to conserve power. The Blynk IoT platform with ML powers this system, which makes it easier to monitor data in real time and guarantees effective administration of the street lighting infrastructure.

This system's capacity to proactively detect and fix errors is one of its main advantages. The CCMS can identify broken streetlights and provide immediate alerts by continuously monitoring operating data. Because maintenance staff are informed immediately, this not only expedites the fault-detection process but also makes fixing problems easier. Furthermore, the technology facilitates public participation by making it simple to report issues with malfunctioning lamps, which promotes teamwork in infrastructure upkeep. The CCMS accomplishes both energy conservation and increased operational efficiency by efficiently manipulating and monitoring data. While keeping an extensive record of observed data that may be used for analysis and optimisation in the future, the system guarantees prompt fault responses. The smart street lighting framework's promise as a scalable and sustainable solution to urban energy management issues is highlighted by the incorporation of cutting-edge IoT systems.

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