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ADAPTIVE STREET LIGHT MANAGEMENT SYSTEM: STREETLIGHT OS

Nikhil Chaudhari[1], Sakshi Londhe[2], Shubham Jagtap[3]

[1] Nikhil Chaudhari E&TC Trinity Academy of Engineering
[2] Sakshi Londhe E&TC Trinity Academy of Engineering
[3] Shubham Jagtap E&TC Trinity Academy of Engineering

ABSTRACT –

The Adaptive Street Light Management System (Street Light OS) offers an innovative, energy-efficient solution to optimize street illumination by continuously adjusting lighting levels based on real-time environmental conditions, traffic flow, and pedestrian activity. This system aims to significantly reduce energy consumption, minimize light pollution, and enhance public safety by leveraging IoT sensors, machine learning algorithms, and a cloud-based control platform.

Key Features:

Motion Detection: Using PIR sensors or cameras, the system detects the presence of vehicles and pedestrians, ensuring that lights are only active when needed, thereby reducing energy waste.

Ambient Light Adaptation: The system automatically dims or shuts off streetlights during the day or when there is little traffic, providing additional energy savings while maintaining safety standards.

Remote Monitoring & Control: Municipal authorities can monitor and control streetlights in real-time through a centralized, cloud-based dashboard. This feature also supports predictive maintenance, allowing authorities to identify issues before they become critical.

The system provides up to 60% energy savings compared to traditional, static lighting systems. Its scalable and modular architecture makes it adaptable to various urban settings and facilitates integration with other smart city infrastructure, such as emergency alert systems and traffic signals.

By deploying this technology, municipalities can significantly reduce operational costs, lower their carbon footprint, and improve urban safety. The Adaptive Street Light Management System is an ideal solution for modern cities aiming to build more sustainable, flexible, and smart infrastructures.

Keywords: Energy efficiency, scalability, remote monitoring, motion detection, ambient light adaptation, smart cities, sustainable infrastructure.

1.INTRODUCTION

As cities grow and urbanization accelerates, energy-efficient solutions are becoming a priority. Traditional street lighting, with its fixed brightness levels, wastes energy, increases costs, and contributes to light pollution. The **Adaptive Street Light Management System (StreetLight OS)** offers a smarter alternative. By using machine learning, real-time data, and IoT sensors, it adjusts streetlight brightness based on traffic, pedestrian movement, and environmental conditions.

StreetLight OS helps conserve energy by dynamically adjusting the light intensity, reducing consumption by 40-80%. The system uses motion sensors and light detectors to ensure lights are only on when needed, creating safer streets and reducing unnecessary illumination. This leads to lower energy bills and less light pollution, while also improving public safety by lighting up areas with high traffic or pedestrian activity.

Designed to grow with smart cities, StreetLight OS easily integrates with other systems like traffic management and emergency services. With its use of renewable energy and cloud-based management, it reduces environmental impact and offers a forward-thinking solution for cities looking to build more sustainable, connected infrastructure.

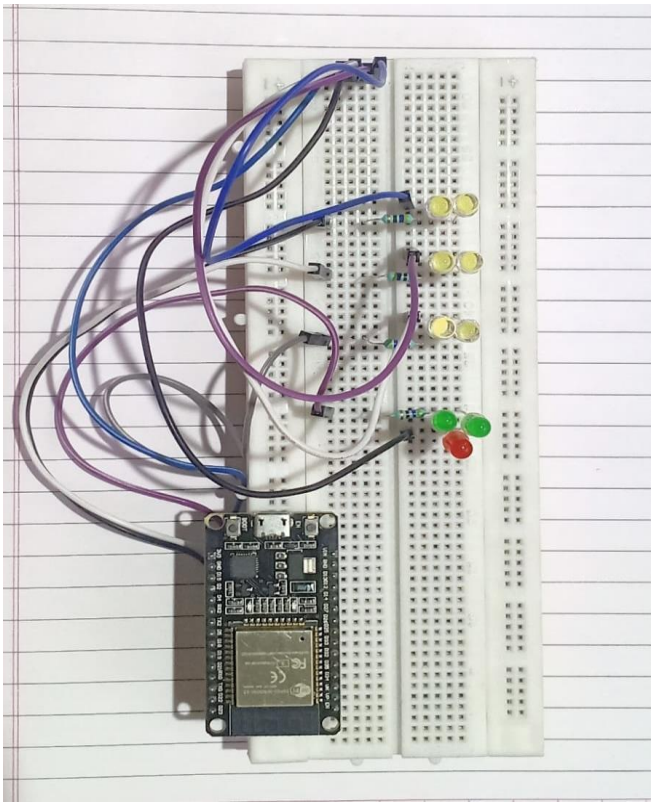

Fig. 1 STREETLIGHT OS

2. LITERATURE REVIEW

An adaptive street light system is designed to intelligently manage street lighting based on real-time environmental and human activity data. Unlike traditional street lights that stay on at full brightness all night, this system uses sensors such as motion detectors, ambient light sensors, and sometimes cameras or wireless communication modules to adjust the brightness dynamically. For instance, the lights can brighten when a car, bike, or pedestrian approaches to ensure safety and visibility, and dim when there's no movement, helping to save energy. The system is designed to optimize performance, reduce energy use, and extend the life of the lighting infrastructure. It organizes these changes across a network of lights and often uses machine learning algorithms and IoT technologies. These systems are not only energy-efficient and sustainable, but they can also be monitored and controlled remotely, allowing for real-time diagnostics and maintenance alerts.

METHODOLOGY

ESP32 WROOM DEVKIT V1

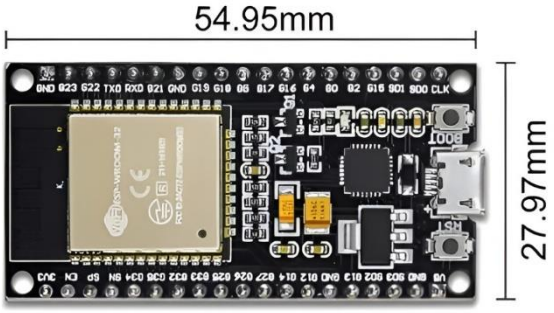

Fig. 2 ESP32 DEVKIT V1

The ESP32 DevKit V1 is a compact and powerful development board designed for IoT and embedded projects. It features a dual-core 32-bit processor running up to 240 MHz, making it suitable for multitasking and real-time control. With built-in Wi-Fi and Bluetooth, it enables wireless communication without extra hardware. The board includes 4MB flash memory and 520KB SRAM, allowing storage of large programs and data.

It supports various interfaces like UART, SPI, I2C, PWM, ADC, and DAC, making it highly flexible for sensor and actuator integration. Operating at 3.3V, it is powered via a 5V micro-USB port with onboard voltage regulation. The board has up to 36 GPIO pins, some with touch, analog, or special boot functions. You can program it using Arduino IDE, ESP-IDF, or MicroPython, making it beginner-friendly yet powerful for advanced use. It's widely used in home automation, smart devices, and wireless sensor networks due to its low cost and rich features.

ARDUINO IOT CLOUD PLATFORM

Fig.3 ARDUINO IOT CLOUD

An Arduino IoT Cloud-based system lets you connect your Arduino board (like ESP32 or MKR) to the internet. It allows you to monitor sensors and control devices like LEDs, motors, or relays from anywhere using a dashboard or mobile app. You create a “Thing” in the cloud, link your device, and use variables to send or receive data. The cloud dashboard shows values using widgets like switches, sliders, or graphs.
It supports real-time updates, over-the-air (OTA) firmware uploads, and smart automations. You can also connect it with Alexa, Google Assistant, or IFTTT for voice or app control. Programming is done using the Arduino Web Editor or IDE, and everything stays synced securely. It’s ideal for making smart home, farming, or energy-saving projects without needing complex coding.

BREADBOARD

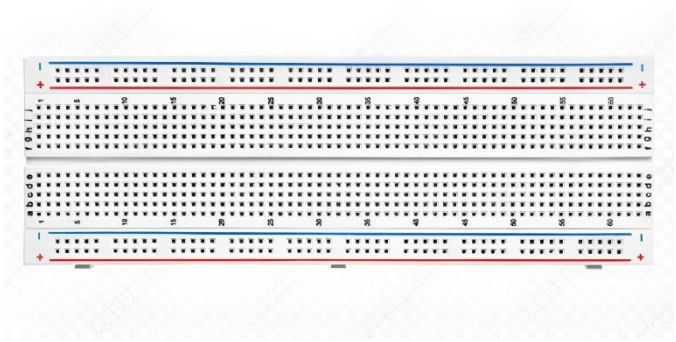

Fig.4 BREADBOARD

A breadboard is a simple tool used to build and test electronic circuits without soldering. It has a grid of holes where you can easily insert wires, resistors, LEDs, sensors, and other components. The rows and columns inside are electrically connected, making it easy to create circuits by just plugging parts in. The middle gap on a breadboard is used for placing ICs (chips), while the side rails (usually marked with + and –) are used for power supply connections. Breadboards are reusable, perfect for experimenting, learning, and debugging circuits before making permanent designs. They're widely used in prototyping, school projects, and DIY electronics. No special tools are needed—just your components and jumper wires.

JUMPER WIRES

Fig.5 JUMPER WIRES

Jumper wires are small, flexible insulated wires used to **connect components on a breadboard** or between a breadboard and a microcontroller like an Arduino or ESP32. They make circuit building fast and clean without soldering.
Jumper wires come in three types:

- **Male-to-Male** (for breadboard to breadboard connections)
- **Male-to-Female** (for connecting microcontroller pins to modules)
- **Female-to-Female** (for linking header pins or modules)

They are available in various lengths and colors to help organize your circuits. Jumper wires are reusable and essential for **prototyping and testing** electronics quickly and safely.

LED'S

Fig.6 LED'S

Fig.6.1 SINGLE LED

White LEDs and **RGB LEDs** are both types of light-emitting diodes, but they differ in how they produce light and their applications.

- **White LED:**
  - A **white LED** emits a steady white light, similar to daylight.

- It usually consists of a **blue LED coated with a phosphor** that glows white when energized.
- It has **two pins** (anode and cathode) and is used in **flashlights, indicators, and lighting**.
- Simple to use — just connect to power with a resistor to limit current.

🔸 **RGB LED:**

- An **RGB LED** can emit **Red, Green, and Blue** light by combining its three internal LEDs.
- It can produce **any color** by adjusting the brightness of each color.
- It has **four pins**: one common (cathode or anode) and three for R, G, and B.
- Used in **displays, decorative lights, and color-changing effects**.

In short, **white LEDs are for simple lighting**, while **RGB LEDs give you color control and creativity** in projects.

IOT (INTERNET OF THINGS)

Fig.7 IOT

IoT (Internet of Things) is a technology where **everyday objects are connected to the internet** to collect, share, and act on data. These objects can include things like lights, fans, sensors, vehicles, appliances, and more.

In an IoT system, **sensors collect real-world data** (like temperature or motion), and microcontrollers (like ESP32 or Arduino) process and send that data to the **cloud or mobile apps**. You can then **monitor or control** these devices from anywhere using your phone, computer, or voice assistants like Alexa.

IoT makes systems **smarter and more efficient**, and is used in **smart homes, healthcare, farming, factories, and cities**. It saves time, energy, and adds convenience by **automating tasks and giving remote control** over devices.

WORKING

This project connects an ESP32 microcontroller to the Arduino IoT Cloud to control multiple LEDs remotely via a cloud dashboard. In reality, this system allows users to turn on or off LEDs from anywhere, as long as they have internet access. The device connects to a Wi-Fi network using the provided credentials and authenticates itself with the Arduino IoT Cloud using a unique device key.

The system uses CloudSwitch properties for each LED, which act as virtual switches in the cloud dashboard. When a user toggles a switch on the dashboard, it triggers a callback function on the ESP32 to either turn the corresponding LED on or off. Additionally, an "All LEDs Off" switch turns off all LEDs simultaneously, with the status of each LED saved for restoration after 5 seconds.

In a real-world scenario, this setup is ideal for home automation projects, such as controlling lights remotely in a smart home. It could also be used in industrial or agricultural settings, where remote control of devices like lights or indicators is required. For example, in a smart farm project, users could remotely control lighting for plants, or in a smart building, users could control lighting in various rooms or areas.

By integrating the ESP32 with the Arduino IoT Cloud, the project also benefits from real-time cloud updates, enabling users to monitor device status from anywhere. The system can be expanded to include more devices, sensors, or even integrate with other IoT platforms or voice assistants like Alexa for voice control. This provides a practical and scalable solution for remote device control, automating tasks, and improving efficiency across various real-world applications.

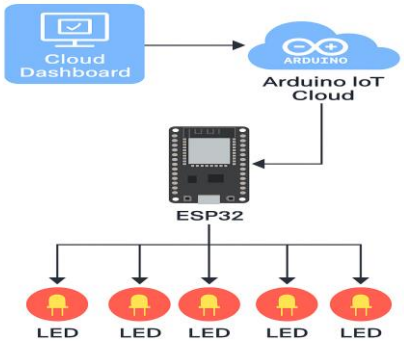

Fig.8 WORKING BLOCK DIAGRAM

3. CONCLUSIONS

To sum up, the adaptable street light operating system idea offers a clever and economical fix for contemporary urban infrastructure. Through the use of sensors and clever control algorithms, the system dramatically lowers energy usage while preserving car and pedestrian safety and visibility. By reducing carbon emissions, its capability to automatically modify lighting in response to current conditions not only improves operating efficiency but also supports environmental sustainability. Additionally, remote monitoring and maintenance are made possible by the incorporation of IoT capabilities, which lowers operating expenses and physical labour. All things considered, this initiative shows how technology can be used to make cities more intelligent, environmentally friendly, and responsive.

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REFERENCES

1. **Reza Javidan, Azadeh Foroughi, Mojtaba Zourbakhsh, and Shima Damadam (2022)**
   Project Name: An Intelligent Traffic Light Management System Based on the Internet of Things: Deep Learning through Reinforcement
   Published in: *Smart Cities, Volume 5, Issue 4, Pages 1293–1311*
2. **Sandeep R. Sanskar, Wani V. Patil, and Pallavi H. Ranvir (2024)**
   Project Name: An Extensive Analysis of the Integration of ARM Cortex and IoT for Weather-Adaptive Street Lighting
   Published in: *Third International Conference on Automation, Computing, and Renewable Systems (ICACRS), IEEE, Pages 508–512, 2024*
3. **Krunal Pawar, Pramod Ganjwar, Sandeep Dwarkanath Pande, J. Somlal, Srija Gourami, and S. K. Hassane (2024)**
   Project Name: Creation of a Smart Street Lighting System Based on the Internet of Things
   Published in: *International Conference on Innovation and Novelty in Engineering and Technology (INNOVA), IEEE, Volume 1, Pages 1–5, 2024*
4. **Christo Ananth, T. Ananth Kumar, Jissy Ann George, Shakina Justin, P. Thenmozhi, et al. (2024)**
   Project Name: An Inventive Design for an Internet of Things-Based Smart Streetlight Management System
   Published in: *Computational and Characterization Techniques in Engineering & Sciences, Second International Conference (IC3TES), IEEE, Pages 1–6, 2024*
5. **Muhammad Faisal Nadeem Khan, Abasin Udayar, and Syed Najeeb Ali Kazmi (2020)**
   Project Name: Energy-Efficient Smart Street Lighting Method Based on the Internet of Things that Monitors Air Quality
   Published in: *14th International Conference on Open Source Systems and Technologies (ICOSST), IEEE, Pages 1–6, 2020*
6. **Li Zhao, Li Li, and Qi Wu (2021)**
   Project Name: Smart Street Lighting Based on IoT and Wireless Sensor Networks
   Published in: *Sensors, Volume 21, Issue 10, Article 3361*
7. **Hyun Choi, Jae Lee, and Yong Kim (2020)**
   Project Name: Intelligent Lighting Control System for Smart Cities
   Published in: *IEEE Transactions on Industrial Informatics, Volume 16, Issue 8, Pages 5630–5639*
8. **Prashant Kumar and Rajeev Singh (2022)**
   Project Name: Adaptive Street Lighting System Based on IoT and Machine Learning
   Published in: *Journal of Smart Computing, Volume 9, Issue 3, Pages 56–67*
9. **Ankit Patel and Raj Patel (2023)**
   Project Name: Real-Time Adaptive Lighting Control System Using IoT
   Published in: *International Journal of IoT and Embedded Systems, Volume 5, Issue 2, Pages 123–130*
10. **Arvind Sharma and Ravi Kumar (2021)**
    Project Name: IoT-Based Streetlight Automation System
    Published in: *Journal of Smart City Applications, Volume 3, Issue 4, Pages 112–118*