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Pedestrian Aware Street Light System

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ABSTRACT: Streetlights are essential to keeping people safe while traveling on roads and from crimes at night. However, conventional streetlights run constantly at all times regardless of how frequently the road is used. This leads to considerable waste in energy and cost of operation. In this paper, I will present a new concept for an adaptive smart streetlight system that reacts to the real-time condition of the environment in which it is found. The Adaptive Smart Streetlight System operates together with two types of sensors: 1) Light Dependent Resistors (LDR) to measure ambient light and provide information to the system about whether or not streetlights should be on, and 2) Passive Infrared Sensors (PIR) to detect the presence of pedestrians or moving vehicles near the streetlights and report that back to the system. The processing of information received from both LDR and PIR sensors are performed by a Microcontroller; this processing results in dynamically changing the intensity of streetlights in real-time based on the information being received from both sensor types.

Therefore, the streetlights will only illuminate at full brightness if there is motion detected by either sensor type while streetlights are in low light mode. Otherwise, the system returns the streetlights to energy-saving mode. The proposed system lowers the energy consumption of streetlights, increases the efficiency of streetlights, and promotes the goals of sustainable smart city development by providing a low-cost, scalable solution that can be implemented in urban streets, college and university campuses, and residential communities.

KEYWORDS: Smart Street Lighting, Energy Efficiency, Pedestrian Detection, PIR Sensor, LDR Sensor, Embedded Systems, Smart Cities.

I. INTRODUCTION

Street lighting is an essential component of urban infrastructure, providing visibility, safety, and security for pedestrians and vehicles during nighttime. Conventional street lighting systems typically operate continuously or follow fixed schedules regardless of road usage. This results in excessive energy consumption, increased operational cost, and unnecessary environmental impact. With the growing demand for sustainable infrastructure and smart city development, there is a need for intelligent lighting systems that operate dynamically based on real-time conditions.

Recent advancements in sensor technology and embedded. enable adaptive lighting solutions that respond to environmental changes and human activity. Motion detection sensors and ambient light monitoring devices allow street lights to function only when required, thereby reducing energy wastage while maintaining safety standards. Such intelligent systems contribute to energy conservation and improved infrastructure efficiency. This paper proposes a Pedestrian-Aware Smart Street Lighting System that automatically controls illumination using Light Dependent Resistor (LDR) and Passive Infrared (PIR) sensors. The system activates street lights only when movement is detected under low-light conditions, ensuring efficient energy utilization without compromising road safety. The proposed approach offers a cost-effective and scalable solution suitable for smart cities, campuses, and residential environments.

II. LITERATURE SURVEY

Several researchers have worked on smart street lighting systems to improve energy efficiency and reduce electricity consumption. Many studies focus on the use of sensors, microcontrollers, and IoT technologies to automate street lighting.

- [1] Researchers proposed a **smart street lighting system using Light Dependent Resistor (LDR)** to automatically switch lights ON and OFF depending on environmental light conditions. This method helps reduce energy consumption by operating lights only during low-light conditions.
- [2] Another study introduced a **PIR sensor-based street lighting system** that detects pedestrian or vehicle movement and activates street lights only when motion is detected. This approach improves energy efficiency and enhances road safety.
- [3] Some researchers developed an **IoT-based smart lighting system** that allows remote monitoring and control of street lights through internet connectivity. This system enables authorities to monitor energy usage and control lighting from a centralized platform.
- [4] A research work proposed the use of **wireless sensor networks** in street lighting systems to enable communication between street lights and control units. This helps in improving system efficiency and reducing manual intervention.
- [5] Another study focused on **solar-powered street lighting systems**, where solar panels are used to generate electricity for powering LED lights. This approach promotes renewable energy usage and reduces dependence on traditional power sources.
- [6] Researchers also explored **energy-efficient LED lighting systems** combined with intelligent controllers to reduce maintenance costs and increase the lifespan of street lighting infrastructure.
- [7] Based on the analysis of previous studies, the **Pedestrian-Aware Street Lighting System** is proposed to combine sensor-based detection with automatic control to provide efficient lighting only when necessary, thereby improving energy conservation and safety.

III. SYSTEM ARCHITECTURE

The proposed pedestrian-aware street lighting system follows a modular architecture designed to ensure efficient sensing, processing, and lighting control. The system consists of three main layers: the sensing layer, the processing layer, and the actuation layer. Each layer performs a specific function that contributes to the overall adaptive operation of the lighting system.

The sensing layer includes the Light Dependent Resistor (LDR) and Passive Infrared (PIR) sensors. The LDR continuously monitors ambient light conditions to determine whether it is day or night. When the light intensity drops below a predefined threshold, the system activates the monitoring mode. At this stage, the PIR sensor begins detecting motion caused by pedestrians or vehicles passing near the street light.

The processing layer consists of a microcontroller that collects signals from the sensors and processes them according to predefined control logic. The microcontroller analyses the LDR data to determine environmental brightness and simultaneously evaluates motion signals from the PIR sensor. Based on this combined information, the controller decides whether to activate or deactivate the lighting system.

The actuation layer consists of LED street lamps connected through a relay or driver module. When the microcontroller receives a valid motion signal during low-light conditions, it activates the LED lights to provide illumination. If no movement is detected after a specified time interval, the controller switches the lights back to energy-saving mode. This layered architecture ensures efficient energy management while maintaining adequate illumination for pedestrian safety.

IV. HARDWARE COMPONENTS USED

The implementation of the pedestrian-aware street lighting system requires several hardware components that work together to enable sensing, processing, and illumination. Each component plays a critical role in the overall functioning of the system.

1. Light Dependent Resistor (LDR):

The LDR sensor is used to measure the ambient light intensity in the environment. Its resistance changes depending on the amount of light falling on its surface. During daytime conditions, the resistance is low, indicating sufficient natural light. At night, the resistance increases, signalling the system to activate monitoring mode.

2. Passive Infrared Sensor (PIR):

The PIR sensor is responsible for detecting motion in the surrounding area. It senses changes in infrared radiation emitted by moving objects such as humans or vehicles. When movement is detected within its range, the PIR sensor generates a signal that is transmitted to the microcontroller.

3. Microcontroller:

The microcontroller acts as the central control unit of the system. It receives signals from both the LDR and PIR sensors and processes them according to predefined logic. Based on the sensor inputs, the microcontroller determines whether the street lights should be turned ON or OFF.

4. LED Street Light:

LED lights are used as the lighting source due to their high efficiency, long lifespan, and low power consumption. Compared to traditional street lighting technologies, LEDs provide better illumination while consuming less electrical energy.

5. Power Supply:

A regulated power supply provides stable voltage to all components of the system, ensuring reliable and continuous operation.

V. WORKING ALGORITHM

The operation of the pedestrian-aware street lighting system follows a simple yet effective algorithm that integrates ambient light detection with motion sensing. The process begins with the continuous monitoring of ambient light using the LDR sensor. If the detected light intensity is above the threshold level, the system remains inactive because natural light is sufficient.

When the ambient light level drops below the threshold value, indicating nighttime conditions, the system enters motion detection mode. In this stage, the PIR sensor actively monitors the surrounding area for movement. If motion is detected, the sensor sends a signal to the microcontroller.

Upon receiving the motion signal, the microcontroller activates the LED street light to provide illumination for pedestrians or vehicles passing through the area. The light remains ON for a predefined time interval to ensure safe movement. If no further motion is detected after this period, the system automatically switches the light OFF or returns it to energy-saving mode.

This intelligent control mechanism ensures that street lights operate only when required, thereby reducing energy consumption and improving efficiency.

VI. METHODOLOGY

Ambient light intensity is continuously monitored using a Light Dependent Resistor (LDR). The sensor determines whether the surrounding environment requires street illumination. When the measured light level falls below a predefined threshold, the system switches from standby mode to monitoring mode, enabling motion detection. Passive Infrared (PIR) sensors are deployed along the street to detect infrared radiation changes caused by pedestrian or vehicular movement. When motion is detected, the sensor sends a signal to the microcontroller indicating the presence of activity in the monitored zone. The microcontroller processes inputs from both LDR and PIR sensors and executes the control logic. If motion is detected during low-light conditions, the controller activates the corresponding street lights. If no movement is detected for a predefined time interval, the system automatically switches the lights to energy-saving mode or turns them OFF. LED street lamps are used as the lighting source due to their high efficiency

and long lifespan. The lighting intensity is dynamically controlled based on sensor inputs to ensure sufficient visibility while minimizing energy consumption. This adaptive control mechanism enables efficient power utilization and reliable street illumination.

VII. EXPERIMENTAL RESULTS

This work introduced a Pedestrian-Aware Smart Street Lighting System designed to enhance urban energy efficiency while improving pedestrian safety. By integrating ambient light sensing with motion detection, the system intelligently controls street illumination based on real-time environmental conditions and human activity. This adaptive behaviour significantly reduces unnecessary power consumption during idle periods while ensuring adequate visibility when pedestrians are present. The proposed approach supports sustainable urban infrastructure by lowering electricity usage, reducing carbon footprint, and extending the operational life of lighting components. Experimental results demonstrate that the system provides reliable sensing performance, rapid response to pedestrian movement, and stable operation under varying lighting conditions. Compared to conventional street lighting systems that operate continuously, the proposed solution achieves noticeable energy savings and improved operational efficiency. The hardware implementation also confirms that the system can be developed using low-cost components, making it economically feasible for large-scale deployment in smart cities, residential areas, highways, and public pathways. Furthermore, the modular architecture of the system allows easy expansion and integration with emerging smart-city technologies. Future enhancements may include IoT-enabled monitoring for centralized control, wireless communication for remote diagnostics, and AI-based predictive analytics to anticipate pedestrian flow and optimize illumination schedules. Integration with renewable energy sources such as solar panels can further improve sustainability and reduce dependence on grid power. Overall, the proposed system offers a practical, scalable, and cost-effective solution for intelligent urban lighting and contributes toward the development of safer and energy-efficient smart cities

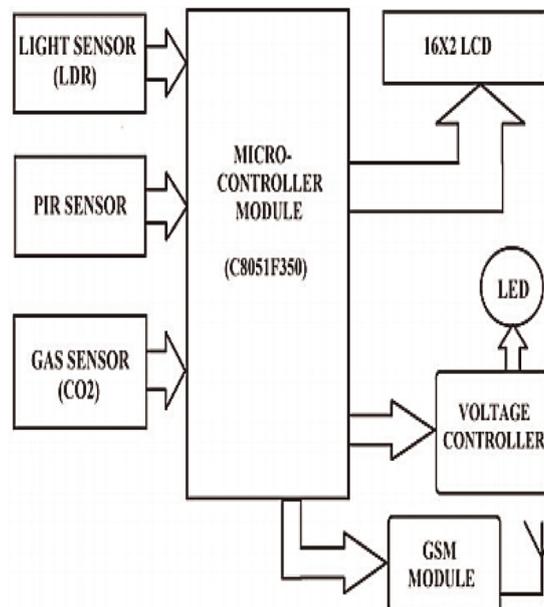


Fig 1 Block Diagram

Fig. 1. illustrates the overall architecture of the proposed pedestrian-aware street lighting system. The system consists of an LDR sensor for detecting ambient light conditions, a PIR sensor for motion detection, a microcontroller for processing sensor inputs, and LED street lights for illumination. The microcontroller activates the lights when motion is detected under low-light conditions

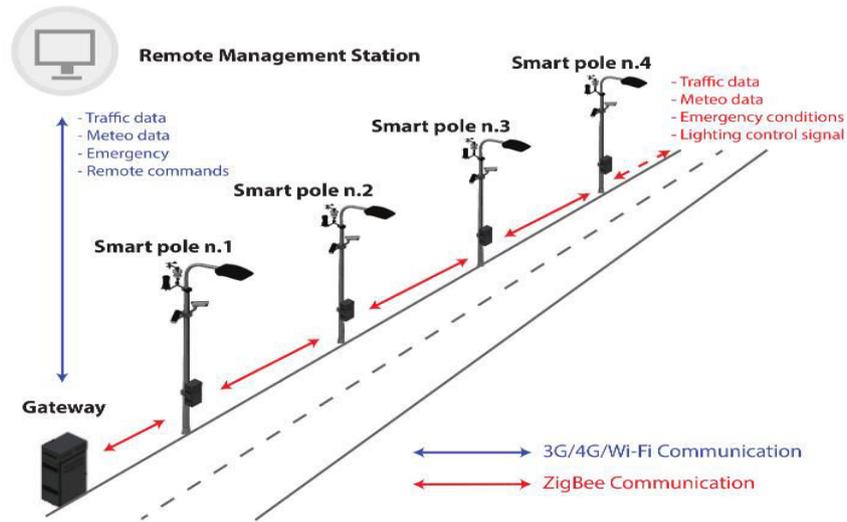


Fig 2 Operational workflow

Fig. 2. shows the operational workflow of the system. The LDR sensor first checks ambient light levels to determine whether it is day or night. When the environment is dark, the PIR sensor begins monitoring pedestrian movement. If motion is detected, the microcontroller turns the street light ON. After a predefined delay without motion, the system returns to energy-saving mode.

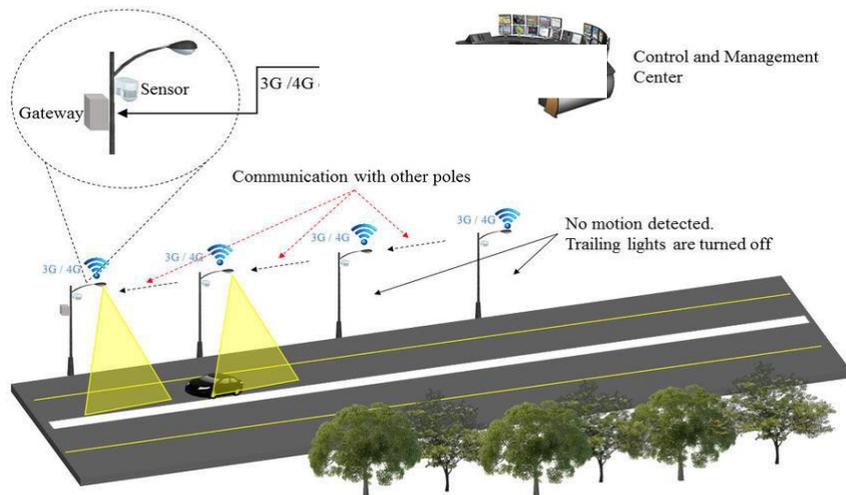


Fig 3 Hardware prototype

Fig. 3 shows the hardware prototype of the proposed pedestrian-aware street lighting system. The setup includes an LDR sensor for detecting ambient light conditions and a PIR sensor for motion detection. These sensors are connected to a microcontroller that processes the sensor inputs and controls the LED street light accordingly. When the LDR detects low light conditions and the PIR sensor identifies pedestrian movement, the microcontroller activates the LED light. The prototype demonstrates the practical implementation of the adaptive street lighting mechanism.

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VIII. ADVANTAGES OF THE PROPOSED SYSTEM

The Pedestrian-Aware Street Lighting System is designed to improve the efficiency of traditional street lighting by using sensors and automated control mechanisms. Conventional street lights remain ON throughout the night, which leads to unnecessary power consumption and higher electricity costs. To overcome this issue, the proposed system intelligently controls street lights based on environmental light conditions and pedestrian movement. This approach helps in optimizing energy usage while maintaining proper illumination when required.

The system provides several advantages such as improved energy efficiency, since the lights operate only when movement is detected during low-light conditions. It also ensures automatic operation, eliminating the need for manual switching or fixed timer-based control. By providing light only when needed, the system improves road visibility and pedestrian safety during nighttime. Additionally, the use of LED lighting and simple sensor components makes the system cost-effective and easy to implement. The reduced operating time of lights also lowers maintenance requirements and increases the overall lifespan of the lighting system.

Therefore, the Pedestrian-Aware Street Lighting System offers an intelligent, economical, and environmentally friendly solution for modern street lighting applications, making it suitable for smart city infrastructure and energy conservation initiatives.

IX. FUTURE SCOPE

The Pedestrian-Aware Street Lighting System can be further enhanced by integrating advanced technologies to improve its functionality and efficiency. In the future, the system can be connected with Internet of Things (IoT) technology to enable remote monitoring and control of street lights through mobile or web applications. This would allow authorities to monitor energy consumption and system performance in real time.

Additionally, the system can be integrated with solar power systems to make it more energy-efficient and environmentally sustainable. Advanced sensors and machine learning algorithms can also be used to improve movement detection accuracy and adapt lighting levels based on traffic patterns and environmental conditions.

Thus, the Pedestrian-Aware Street Lighting System has significant potential for further development and can play an important role in building smarter, energy-efficient urban infrastructure in the future

X. CONCLUSION

The proposed pedestrian-aware street lighting system improves urban safety while reducing energy consumption through adaptive illumination. By integrating ambient light sensing and motion detection, the system ensures lighting is available only when required. Experimental results confirm reliable performance, quick response, and efficient power utilization. The low-cost hardware design makes the system suitable for large-scale smart city deployment. Overall, the solution provides a practical and sustainable approach to intelligent urban lighting.

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