AN INTEGRATED STREET LIGHT FAULT DETECTION AND LOCATION TRACKING SYSTEM BASED ON IOT

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ABSTRACT—The proposed system addresses the challenges in maintaining street lighting infrastructure, a vital component of urban safety and efficiency. Leveraging Internet of Things (IoT) technology, the system integrates advanced fault detection algorithms and GPS-enabled location tracking to optimize the management of street lighting systems. The proactive monitoring framework detects common issues, including bulb failures, power inconsistencies, and wiring faults in real-time, ensuring minimal downtime and reduced maintenance costs. The integration of GPS modules enhances operational efficiency by enabling precise fault localization. Maintenance teams can prioritize tasks effectively based on geographic distribution, optimizing routes and ensuring timely resolution of issues. This approach contributes to safer urban environments by ensuring consistent lighting levels and reducing the risks of accidents or criminal activities in poorly lit areas. The system also incorporates advanced sensors such as Passive Infrared (PIR) sensors, Light Dependent Resistors (LDR), and power sensors. PIR sensors detect motion, enabling dynamic lighting adjustments to conserve energy by increasing brightness only when necessary. LDR sensors automate the activation of streetlights based on ambient light levels, further enhancing energy efficiency. The use of ESP32 controllers ensures seamless integration and communication between various components of the system, while GSM modules transmit fault alerts to authorized personnel for immediate action.This innovative solution significantly addresses the shortcomings of traditional streetlight maintenance, which often relies on manual inspections or delayed responses to public complaints. By automating fault detection and location tracking, the system minimizes the time required for repairs and reduces labor-intensive processes. Furthermore, its modular design ensures scalability and adaptability for deployment in diverse urban settings, from high-traffic city centers to quieter residential areas. In addition to its operational benefits, the system aligns with sustainability goals by promoting energy conservation and efficient resource utilization. The ability to monitor energy consumption and detect irregularities in real-time helps urban authorities implement data-driven strategies for optimizing electricity usage, contributing to overall environmental sustainability. This centralized monitoring system exemplifies the potential of IoT in transforming urban infrastructure. By

integrating intelligent technologies and automated processes, it enhances the reliability, efficiency, and sustainability of street lighting systems.

I. INTRODUCTION The rise of smart cities has brought about a paradigm shift in urban development, with the integration of advanced technologies enhancing public services. One of the most vital components of smart urban infrastructure is street lighting, which not only ensures safety and visibility but also contributes significantly to energy consumption. Traditional streetlight systems, characterized by fixed operational schedules and manual fault detection, are increasingly becoming inefficient in the face of growing urban challenges. The development of a Centralized Monitoring System for Street Light Fault Detection and Location Tracking aims to address these inefficiencies, offering a transformative solution for smart cities. Streetlights are essential for ensuring public safety, reducing crime, and facilitating seamless navigation. However, conventional systems often fail to meet the demands of modern cities. They consume significant amounts of energy, are prone to operational failures, and rely heavily on manual intervention for fault detection and maintenance. A defective streetlight not only wastes energy but also poses risks to public safety by increasing the likelihood of accidents and criminal activities. Addressing these challenges necessitates the implementation of a smart, efficient, and automated monitoring system. The Internet of Things (IoT) has emerged as a groundbreaking technology, enabling interconnected devices to collect, share, and analyze data in real time. By leveraging IoT in streetlight systems, it is possible to automate the processes of fault detection, energy management, and maintenance. The proposed centralized monitoring system integrates IoT-enabled sensors, fault detection algorithms, and location-tracking mechanisms to create a robust infrastructure. Key components such as PIR (Passive Infrared) sensors, LDR (Light Dependent Resistors), ESP32 microcontrollers, and GPS modules ensure efficient monitoring and precise localization of faulty streetlights. One of the unique aspects of this system is its real-time fault detection capability. Utilizing a combination of sensors and microcontrollers, it can identify issues like bulb failures, wiring faults, and power irregularities almost instantaneously. This not only minimizes downtime but also reduces maintenance costs by enabling timely interventions. The incorporation of GPS modules further enhances the system's functionality by allowing maintenance teams to pinpoint the exact location of faulty lights, optimizing their response time and operational efficiency. Energy efficiency is another critical focus of the system. By using LDR sensors to adjust lighting levels based on ambient conditions and PIR sensors to activate lights only when motion is detected, the system significantly reduces unnecessary energy consumption. Additionally, the integration of GSM modules facilitates communication with authorities, providing automated alerts in the event of a fault. This ensures that issues are addressed promptly, maintaining consistent lighting levels across urban areas. The scalability and adaptability of the proposed system make it suitable for a wide range of urban settings, from densely populated city centers to remote suburban areas. The modular design allows for easy integration with existing infrastructure, minimizing implementation costs and complexities. Moreover, the system's ability to analyze performance data over time enables authorities to make informed decisions about energy management and infrastructure planning. The Centralized Monitoring System for Street Light Fault Detection and Location Tracking represents a significant advancement in smart city technology. By combining IoT, real-time monitoring, and location tracking, it not only enhances the reliability and efficiency of street lighting systems but also contributes to broader urban sustainability goals. This innovative approach not only addresses current challenges but also lays the groundwork for future developments in smart urban infrastructure, ensuring safer and more energy-efficient cities for generations to come.

II.IMPLEMENTATION

BLOCK DIAGRAM

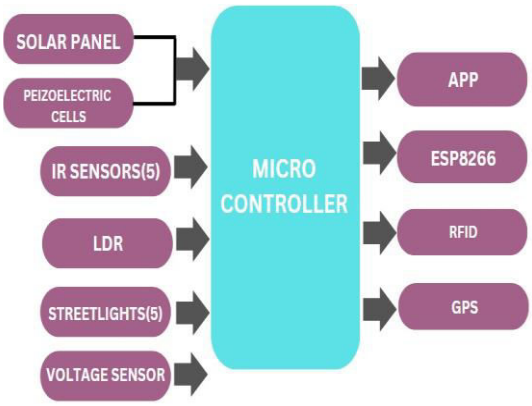

Fig: Block Diagram

DESCRIPTION

POWER SUPPLY

A **regulated power supply** transforms unregulated AC (Alternating Current) into a stable DC (Direct Current). It guarantees consistent output despite variations in input. A regulated DC power supply is also known as a linear power supply, it is an embedded circuit and consists of various blocks

- **Regulated Power Supply Definition**: A regulated power supply ensures a consistent DC output by converting fluctuating AC input.
- **Component Overview**: The primary components of a regulated power supply include a transformer, rectifier, filter, and regulator, each crucial for maintaining steady DC output.
- **Rectification Explained**: The process involves diodes converting AC to DC, typically using full wave rectification to enhance efficiency.
- **Filter Function**: Filters, such as capacitor and LC types, smooth the DC output to reduce ripple and provide a stable voltage.
- **Regulation Mechanism**: Regulators adjust and stabilize output voltage to protect against input changes or load variations, essential for reliable power supply

SENSORS

Sensors are used for sensing things and devices etc. A device that provides a usable output in response to a specified measurement. The sensor attains a physical parameter and converts it into a signal suitable for processing (e.g. electrical, mechanical, optical) the characteristics of any device or material to detect the presence of a particular physical quantity. The output of the sensor is a signal which is converted to a human-readable form like changes in characteristics, changes in resis**Light Dependent Resistor**

The controlling of lights and home appliances is generally operated and maintained manually on several occasions. But the process of appliances controlling may cause wastage of power due to the carelessness of human beings or unusual circumstances. To overcome this problem we can use the light-dependent resistor circuit for controlling the loads based on the intensity of light. An LDR or a photoresistor is a device that is made up of high resistance semiconductor material. This article gives an overview of what is LDR or light-dependent resistor circuit and its working.

What is Light Dependent Resistor?

An electronic component like LDR or light-dependent resistor is responsive to light. Once light rays drop on it, then immediately the resistance will be changed. The resistance values of an LDR may change over several orders of magnitude. The resistance value will be dropped when the light level increases.

The resistance values of LDR in darkness are several megaohms whereas in bright light it will be dropped to hundred ohms. So due to this change in resistance, these resistors are extremely used in different applications. The LDR sensitivity also changes through the incident light's wavelength.

The designing of LDRs can be done by using semiconductor materials to allow their light-sensitive properties. The famous material used in this resistor is CdS (cadmium sulfide), even though the utilization of this material is currently restricted in European countries due to some environmental issues while using this material. Likewise, CdSe (cadmium selenide) is also restricted and additional materials that can be employed mainly include PbS (lead sulfide), InS (indium antimonide).

Even though for these resistors, a semiconductor material is used, because they are simply passive devices and they do not have a PN-junction. This detaches them from other LDRs such as phototransistors & photodiodes.

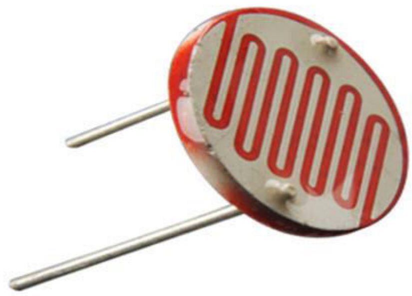

Fig Light Dependent Resistortance, capacitance, impedance, etc.

IR SENSOR

In the electromagnetic spectrum, the infrared portion divided into three regions: near infrared region, mid infrared region and far infrared region.

In this blog we are talking about the IR sensor working principle and its applications.

What is an IR Sensor?

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IR sensor is an electronic device, that emits the light in order to sense some object of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. Usually, in the infrared spectrum, all the objects radiate some form of thermal radiation. These types of radiations are invisible to our eyes, but infrared sensor can detect these radiations.

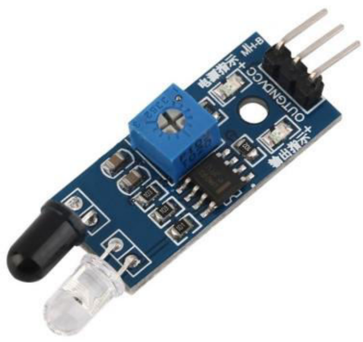

Fig: Ir Sensor

RFID READER

Active RFID and Passive RFID technologies, while often considered and evaluated together, are fundamentally distinct technologies with substantially different capabilities. In most cases, neither technology provides a complete solution for supply chain asset management applications. Rather, the most effective and complete supply chain solutions leverage the advantages of each technology and combine their use in complementary ways. This need for both technologies must be considered by RFID standards initiatives to effectively meet the requirements of the user community.

RFID Reader Module, are also called as interrogators. They convert radio waves Returned from the RFID tag into a form that can be passed on to Controllers, which can

Make use of it. RFID tags and readers have to be tuned to the same frequency in order to

Communicate. RFID systems use many different frequencies, but the most common and

Widely used & supported by our Reader is 125 KHz.

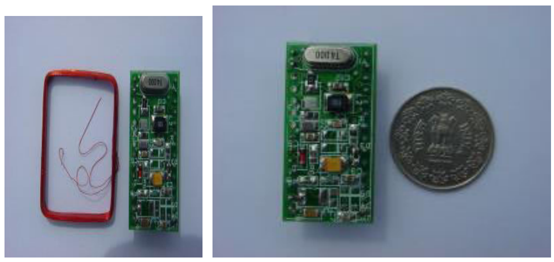

Fig: RFID MODULE

RPI –PICO

A Raspberry Pi Pico is a low-cost microcontroller device. Microcontrollers are tiny computers, but they tend to lack large volume storage and peripheral devices that you can plug in (for example, keyboards or monitors).

A Raspberry Pi Pico has GPIO pins, much like a Raspberry Pi computer, which means it can be used to control and receive input from a variety of electronic devices

Raspberry Pi Foundation is well known for its series of single-board computers (Raspberry Pi series). But in **January 2021 they launched their first micro-controller board known as Raspberry Pi Pico**.

It is built around **the RP2040 Soc, a very fast yet cost-effective microcontroller**

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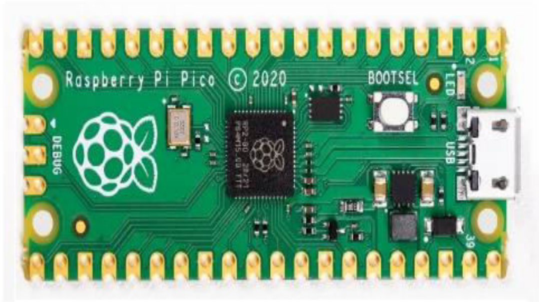
chip packed with a dual-core ARM Cortex-M0+ processor. M0+ is one of the most power-efficient ARM processorRaspberry Pi PICO board



Raspberry Pi PICO board

Fig: Raspberry Pi Pico Board

Raspberry **Pi Pico is a small, fast, and versatile board that at its heart consists of RP2040**, a brand-new product launched by Raspberry Foundation in the UK. It can be programmed using MicroPython or C language.

III.LITERATURE SURVEY

A) S. Kamoji, D. Koshti, J. Noronha, E. Arulraj, and E. Clement, "Deep Learning-based Smart Street Lamps–A Solution to Urban Pollution," in Proc. 2020 Second Int. Conf. Inventive Res. Comput. Appl. (ICIRCA), pp. 478–482, Jul. 2020.

This research introduces a comprehensive framework for integrating deep learning technologies with urban street lighting systems to address the challenges of energy consumption and urban air pollution. The proposed smart street lamp system is equipped with advanced air quality monitoring sensors and real-time data processing units. These components work synergistically to optimize both lighting and pollution mitigation. The street lamps adaptively adjust their brightness based on the environmental conditions and pedestrian presence, using deep learning algorithms to analyze data in real time. The system incorporates an air purification mechanism that activates in response to detected pollution levels. This dual functionality ensures energy-efficient lighting while simultaneously improving air quality in urban spaces. The deep learning component is central to the system's efficiency, enabling precise detection of anomalies and environmental changes. For instance, the algorithm can distinguish between transient and sustained pollution sources, optimizing responses and conserving resources. Experimental results presented in the study demonstrate significant energy savings, with up to 40% reduction in electricity usage compared to conventional systems. Additionally, the air quality improvement metrics reveal a noticeable reduction in particulate matter in areas equipped with these lamps. The researchers emphasize the scalability of their approach, suggesting that similar systems could be deployed in other urban areas with high pollution levels The paper also highlights the potential for integrating these smart street lamps with broader smart city initiatives. By connecting to centralized monitoring hubs, the lamps can contribute valuable environmental data to urban management systems. This integration facilitates proactive policymaking and resource allocation, targeting pollution hotspots and optimizing urban infrastructure. The authors address some challenges, such as the initial investment cost and the complexity of integrating deep learning models with IoT devices. However, they argue that the long-term

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benefits in energy savings, pollution mitigation, and enhanced public health outweigh these challenges. The study concludes by advocating for policy-level support to encourage the adoption of such innovative technologies in urban planning.

B) J. Jianfeng, "Design and practice of an intelligent street lamp based on edge computing," in Proc. 2021 Int. Conf. Intell. Transp., Big Data & Smart City (ICITBS), pp. 83–85, Mar. 2021.

This study explores the application of edge computing in designing intelligent street lamps that enhance urban lighting efficiency and operational reliability. Unlike traditional systems that rely heavily on centralized servers, the proposed design decentralizes data processing to edge devices, allowing real-time analysis and decision-making. This shift reduces latency and enhances the responsiveness of the street lighting system. Key features of the intelligent street lamp include adaptive lighting, environmental monitoring, and fault detection. The system employs IoT sensors to gather data on parameters such as ambient light, temperature, and pedestrian movement. Edge devices process this data locally, enabling the lamps to adjust their brightness dynamically based on the surrounding environment and traffic patterns. This approach not only conserves energy but also improves safety and user satisfaction. The integration of environmental monitoring sensors allows the lamps to measure air quality and noise levels. This feature positions the street lamps as multi-functional urban infrastructure components that contribute to broader smart city goals. The study demonstrates how edge computing enhances the system's ability to identify and respond to faults, such as lamp malfunctions or connectivity issues. By detecting and addressing these problems locally, the system ensures continuous operation and reduces maintenance costs. Jianfeng's research also highlights the scalability of edge computing-based solutions. The decentralized architecture can accommodate the addition of new features and devices without overburdening the network. This flexibility makes the system suitable for deployment in diverse urban settings with varying requirements and constraints. The paper provides case studies demonstrating the system's performance in real-world scenarios. These studies reveal significant energy savings, reduced downtime, and improved environmental data collection. The findings underscore the potential of edge computing to revolutionize urban lighting systems, making them smarter, more efficient, and more resilient. Challenges discussed in the paper include the need for robust cybersecurity measures to protect edge devices from unauthorized access and data breaches. The study concludes by emphasizing the importance of integrating intelligent street lamps into broader smart city frameworks to maximize their impact on urban development.

C) A. M. M. Chowdhury, J. Sultana, and M. S. U. Sourav, "IoT-based Efficient Streetlight Controlling, Monitoring and Real-time Error Detection System for Smart Cities in Bangladesh," in Proc. 2023 Int. Conf. Electr., Comput. Commun. Eng. (ECCE), pp. 1–6, Feb. 2023.

This paper presents an innovative IoT-driven framework for managing streetlights in smart cities, with a specific focus on the urban context of Bangladesh. The proposed system addresses the inefficiencies of traditional streetlight systems by incorporating advanced IoT sensors and cloud-based analytics. These components work together to enable efficient control, real-time monitoring, and error detection. The controlling mechanism uses data from environmental sensors to adjust streetlight operation dynamically. For instance, the system can reduce brightness during low-traffic hours, thereby conserving energy. Monitoring features provide detailed insights into the operational status of each streetlight, including energy consumption and fault conditions. The real-time error detection capability ensures that malfunctions are identified and addressed promptly, minimizing downtime and maintenance costs. Field implementations in Bangladeshi cities demonstrate the system's effectiveness. Results indicate a 35% reduction in energy consumption and a significant improvement in operational reliability compared to legacy systems. The researchers highlight the importance of these findings in the context of resource-constrained urban environments, where energy efficiency and cost-effectiveness are critical. The paper discusses the broader implications of the system for smart city development. By generating detailed operational and environmental data, the streetlight system can serve as a platform for additional smart city applications, such as traffic management and environmental monitoring. The authors also emphasize the scalability of their approach, which allows for the integration of new functionalities and the expansion to larger urban areas. Challenges highlighted include the need for robust data security measures and the development of standardized protocols for IoT device interoperability. The authors advocate for public-private partnerships to support the deployment of such systems, emphasizing the role of government policy in promoting sustainable urban development. This research contributes to the growing body of literature on IoT applications in smart cities, offering a practical solution to the challenges of streetlight management. The findings underscore the potential of IoT technologies to transform urban infrastructure, enhancing efficiency, reliability, and sustainability.

CONCLUSION In conclusion, the deployment of smart street lighting systems represents a significant advancement in the evolution of smart cities, offering numerous environmental, economic, and operational benefits. Through technologies such as deep learning, edge computing, and IoT, these systems optimize energy usage, enhance urban safety, and contribute to cleaner, more sustainable cities. For instance, energy-efficient lighting automatically adjusts based on the surrounding environment, reducing waste, while also providing real-time monitoring capabilities to detect faults and improve maintenance efficiency. This approach reduces the need for manual inspections and the associated costs. Smart street lamps also play a key role in urban pollution control by incorporating air quality sensors and other environmental monitoring features. These integrated systems provide valuable data that can inform policy decisions and improve the health and well-being of urban populations. Moreover, the scalability of such systems allows them to be implemented in a variety of settings, from smaller towns to larger metropolitan areas, promoting uniformity in smart city initiatives. However, while the benefits are clear, the widespread adoption of these technologies presents several challenges. Initial installation costs can be a barrier, particularly in developing countries where budget constraints may limit the adoption of high-tech infrastructure. Additionally, the integration of IoT devices and smart systems opens up potential security concerns. Ensuring robust cybersecurity measures to protect against data breaches and system vulnerabilities will be crucial in maintaining public trust and ensuring the long-term success of these initiatives. Another challenge is the need for standardization. To ensure compatibility between different vendors' systems and foster a seamless smart city ecosystem, it will be important to develop common protocols and standards for communication and integration. Collaboration among city planners, tech companies, and governmental agencies will be essential to address these issues and ensure the successful deployment of smart lighting systems. As the world moves toward greater urbanization, the adoption of smart technologies in public infrastructure will be crucial in creating more sustainable, livable, and efficient urban environments. The studies reviewed in this work highlight the promising potential of smart street lamps to address various urban challenges. The future of urban lighting is poised to be more energy-efficient, responsive, and integrated, with smart lamps playing a key role in driving these changes. In terms of societal impact, the introduction of smart street lighting can lead to enhanced public safety, as the presence of well-lit streets contributes to reducing crime rates. Furthermore, the adaptive nature of these systems ensures that lighting is optimized according to real-time conditions, thus improving both the efficiency and effectiveness of lighting in urban spaces. Moreover, the data collected from smart street lamps could provide insights into broader smart city applications. For instance, real-time data about traffic, environmental conditions, and energy consumption can be integrated into other urban systems such as waste management, transportation, and public health initiatives.

REFERENCES

[1] Kamoji, S., Koshti, D., Noronha, J., Arulraj, E., & Clement, E. (2020, July). Deep Learning-based Smart Street Lamps–A Solution to Urban Pollution. In 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA) (pp. 478-482). IEEE.

[2] Jianfeng, Y. (2021, March). Design and practice of an intelligent street lamp based on edge computing. In 2021 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS) (pp. 83-85). IEEE.

[3] Chowdhury, A. M. M., Sultana, J., & Sourav, M. S. U. (2023, February). IoT-based Efficient Streetlight Controlling, Monitoring and Real-time Error Detection System for Smart Cities in Bangladesh. In 2023 International Conference on

Electrical, Computer and Communication Engineering (ECCE) (pp. 1-6). IEEE.

[4] Elejoste, P., Angulo, I., Perallos, A., Chertudi, A., Zuazola, I. J. G., Moreno, A., ... & Villadangos, J. (2013). An easy to deploy street light control system based on wireless communication and LED technology. Sensors, 13(5), 6492-6523.

[5] Hans, M. R., & Tamhane, M. A. (2020, October). IoT based hybrid green energy driven street lighting system. In 2020 Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC) (pp. 35-41). IEEE.

[6] Kazmi, S. N. A., Ulasyar, A., & Khan, M. F. N. (2020, December). IoT based energy efficient smart street lighting technique with air quality monitoring. In 2020 14th international conference on open source systems and technologies (ICOSST) (pp. 1-6). IEEE.

[7] Nagamani, S., Reddy, J. M., Lavanya, G., & Chandana, A. L. H. (2019, May). Smart street light management system using internet of things. In 2019 International Conference on Intelligent Computing and Control Systems (ICCS) (pp. 103-107). IEEE.

[8] Novak, T., Pollhammer, K., Zeilinger, H., & Schaat, S. (2014, September). Intelligent streetlight management in a smart city. In Proceedings of the 2014 IEEE emerging technology and factory automation (ETFA) (pp. 1-8). IEEE.

[9] Prasad, R. (2020, April). Energy efficient smart street lighting system in nagpur smart city using iot-a case study. In 2020 Fifth International Conference on Fog and Mobile Edge Computing (FMEC) (pp. 100-103). IEEE.

[10] Sorif, S. M., Saha, D., & Dutta, P. (2021, April). Smart street light management system with automatic brightness adjustment using bolt IoT platform. In 2021 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS) (pp. 1-6). IEEE

[11] Sumathi, V., Sandeep, A. K., & Kumar, B. T. (2013). Arm based street lighting system with faultdetection. International Journal of Engineering and Technology, 5(5), 4141-4144.

[12] Wu, Y., Shi, C., Zhang, X., & Yang, W. (2010, June). Design of new intelligent street light control system. In IEEE ICCA 2010 (pp. 1423-1427). IEEE.