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Fault Detection, Live Tracking, and IoT-Based Centralized Street Light Monitoring for Smart Urban Infrastructure

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ABSTRACT

Using Internet of Things (IoT) technology, this paper presents a state-of-the-art solution for centralized monitoring, fault detection, and live tracking of street lights, improving energy efficiency and operational efficacy in urban environments. Our system allows for real-time fault detection and data collection by strategically placing sensors that can detect a variety of faults, such as fused lamps, short circuits, wire cuts, voltage drops, and damaged fixtures. A central microcontroller unit processes the collected data before uploading it to a cloud server for in-depth examination. The system, which can be accessed through an intuitive web interface, allows for the remote monitoring and management of street lights. It has the ability to automatically schedule lights based on ambient light levels and adjust their brightness using infrared sensors. Our solution further streamlines maintenance procedures and supports the sustainability of urban lighting infrastructure by enabling prompt fault notification with precise location accuracy. Our system has undergone extensive testing to confirm its dependability and effectiveness, providing a strong foundation for reducing energy use and promoting smart cities.

Introduction

The occurrence of street light defects, including light failure, electrical issues, power supply problems, and faulty controls factors, underscores the need for proactive maintenance. An automated system for real-time streetlight fault detection aims to increase urban lighting efficiency and safety. By harnessing advanced algorithms and sensors, this system swiftly identifies faults, enabling timely repairs. This innovation not only guarantees well-lit streets but also promotes energy conservation and lowers maintenance expenses, fostering a smarter and safer urban environment. Traditional urban street lighting systems waste energy and manpower by operating at full intensity regardless of ambient light levels. To address this inefficiency, we propose an IoT-based automated streetlight management system. By integrating LED lights with sensors and a DHT11 temperature-humidity sensor, our system dynamically adjusts lighting intensity based on environmental conditions. Controlled by an Arduino microcontroller, this solution aims to conserve energy, enhance operational efficiency, and contribute to sustainable urban development [1]. In our modern world, IoT innovations are transforming various sectors, including street lighting, to meet growing demands for automation and efficiency. Intelligent street light solutions are needed because the manual operation of street lights wastes a significant amount of energy worldwide. The role of IoT in creating intelligent street lighting systems to deal with energy crises is examined in this survey. By analyzing smart street lighting systems, we highlight the sensors and components essential for creating reliable IoT-based solutions [2]. In response to global energy concerns, transitioning to renewable sources like solar and wind isvital. Conventional street lighting, operating manually and consuming significant power, poses challenges. Our proposed intelligent system utilizes sensors and controllers to adjust lighting based on presence and ambient light, reducing energy consumption by up to 35%. By eliminating the disadvantages of manual labor and excessive energy consumption, proper maintenance further lowers overall costs by 42%. This approach promotes sustainable energy management and addresses concerns associated with traditional street lighting systems [3]. The article examines integrating intelligent street lighting into smart energy and urban development frameworks, emphasizing energy efficiency and cost-effectiveness. It illustrates the switch to LED lighting, which lowers costs and improves safety, through case studies. Forecasts and cost-benefit analyses provided by the research help cities implement smart energy initiatives. Conclusions stress the importance of these solutions in advancing sustainability and improving residents' quality of life. It serves as a strategic roadmap for stakeholders, outlining potential cost savings and urban service improvements [4]. The paper proposes a container-based system for smart street light management, integrating NoSQL databases, and secure data transmission. It emphasizes fast deployment, scalability, and legitimacy validation for efficient data processing. Edge computing devices are utilized for real-time data collection and streaming, showcasing high commercial value for smart city infrastructure [5]. The system for monitoring the environment through the Internet of The paper presents Things, which sends data via the Arduino Cloud. Integrated with temperature and humidity sensors, it enables real-time data collection and remote device control. Experimental results validate its effectiveness in environmental monitoring within the Arduino Cloud ecosystem [6]. The purpose of this paper is to reduce power consumption and optimize operations by integrating wireless sensor networks (WSN) with cloud infrastructure. It highlights the benefits of cloud-based processing and analytics for WSN, focusing on Ethernet-enabled Arduino microcontroller-based sensor networks [7]. In order to improve energy efficiency and safety, the paper presents a new intelligent street light controller system that combines fixed-time, automatic timing, and automatic sunshine control. Experimental results confirm automatic activation within 15meters for vehicles and 10 meters for pedestrians, enhancing street lighting effectiveness [8]. Using Xbee wireless modules and sensor kits to monitor mobility and environmental factors, the study uses Arduino Cloud to power smart street lights. An interface is offered along with data storage [9]. The project employs motion sensors to detect vehicle movement on highways, adjusting street light intensity dynamically to conserve energy. ZIGBEE technology enables communication for IoT integration and statistical analysis on sensor data [10]. The Vienna study compares conventional and LED street lighting's impact on road users, finding LED enhances uniformity and comfort but doesn't significantly alterpedestrian behavior, suggesting potential for urban improvement but necessitating ongoing evaluation [11]. Nighttime lighting, vital for human activities and safety, poses environmental challenges. In order to increase effectiveness and mitigate environmental effects, this paper proposes the use of spatial analytics for the methodical assessment and optimization of urban lighting. A case study in San Diego demonstrates the benefits of this approach for enhancing public services while considering sustainability issues [12]. Advancements in street light control systems driven by energy efficiency concerns have led to the proposal of wireless lamp retrofitting. This method avoids the problems with traditional power line communications (PLCs) and integrates with Geographic Information System (GIS) databases. It provides about one meter of accuracy in open field trials by using node self-location capability and CSS modulation [13]. Energy consumption is a problem for street lights. Street lighting, which is necessary for both safety and urban aesthetics, has an energy consumption issue. Improvements in LED and communication technology allow for networked systems, which facilitate energy conservation and smart city features like self-driving cars and environmental monitoring. This article proposes a connected street lighting architecture with data models for enhanced urban efficiency and safety [14]. Smart Street Lighting (SSL) utilizes LED technology and wireless connectivity for efficient, adaptive operation, addressing energy waste in low-traffic areas and enhancing urban sustainability [15]. Urban street lighting is crucial but burdensome, with a projected 80% demand increase by 2030. Flex Girls-light, an open-source GIS tool, simulates street infrastructure and explores sustainable scenarios using local renewables, emphasizing the need for significant investments in self-sufficient systems in cities like Berlin [16]. Our paper introduces a simulation-based design for smart street lighting, aiming to boost energy efficiency while maintaining functionality. Through our approach, we estimate significant energy savings and CO2 reductions without compromising safety at urban intersections [17]. LED technology helps to reduce the energy consumption of urban street lighting. In order to promote urban sustainability, our suggested graph-based model seeks to optimize design by demonstrating possible CO2 emissions and energy savings through actual cases [18]. Structures as functional as streetlights are now becoming efficient, multi-functional digital platforms. They combine data collection and actuation cycles through embedded technologies and the IoT, improving functionality and efficiency [19]. This paper introduces a weather-adaptive streetlight control system using Boltuino, aiming to improve energy efficiency and fault detection while reducing manpower. It adjusts light intensity based on ambient conditions and traffic activity, detects faults, and notifies authorities for prompt servicing, thereby improving performance compared to existing systems [20]. Our project automates street light operation and monitors manhole conditions, promptly reporting issues to authorities. Using IoT technology, it optimizes energy consumption, enhances urban safety, and facilitates real-time infrastructure monitoring for improved community living [21]. The project uses automatic street light control and detects faults, reducing manual intervention and response time. Using sensors, it notifies authorities of issues and adjusts light intensity based on weather conditions for energy efficiency. Through LED bulbs and wireless connectivity, it creates flexible, responsive, and energy-saving street lighting [22].This project introduces an IoT-enabled system for automating street light operation, conserving energy, and enhancing safety in rural areas. It detects faults, adjusts light intensity based on environmental conditions, and incorporates movement detection for optimized illumination, synchronized with a web application for real-time monitoring [23]. This paper presents an innovative street light system using sensors for efficient management. Lights are activated only in the presence of individuals or obstacles, reducing energy consumption. GSM devices enable remote control while an ARM processor monitors and notifies authorities, resulting in substantial energy savings and reduced manual labor [24]. This paper explores the automation of street lighting systems using microcontrollers, GPS, and RTC. By synchronizing with GPS for accurate timing and utilizing RTC for interruptions, the system operates autonomously, leading to energy savings and an extended luminaire lifespan [25]. The paper proposes an intelligent street light system utilizing GSM technology for energy-saving management. It enables automatic control of light intensity based on ambient conditions, facilitating anti-theft measures and seamless integration into existing street lights with a single computer module, ideal for solar cell installations [26].

Literature Review

IoT in Urban Infrastructure Management: The integration of IoT technology in urban infrastructure has gained considerable attention due to its potential to enhance efficiency, reduce costs, and improve sustainability. Studies by Zhang et al. (2019) and Liang et al. (2020) have demonstrated the effectiveness of IoT-based solutions in optimizing energy usage and maintenance operations in urban environments, paving the way for innovative approaches in street light management.

Centralized Monitoring and Fault Detection: Research by Wang et al. (2018) and Chen et al. (2021) highlights the importance of centralized monitoring systems in identifying and addressing faults in street lighting networks. By leveraging IoT sensors and data analytics, these systems enable real-time detection of issues such as bulb failures, circuit malfunctions, and power outages, facilitating proactive maintenance and minimizing downtime.

Live Tracking and Location-Based Services: Studies by Guo et al. (2019) and Kim et al. (2020) have explored the integration of live tracking and location-based services in urban infrastructure management.

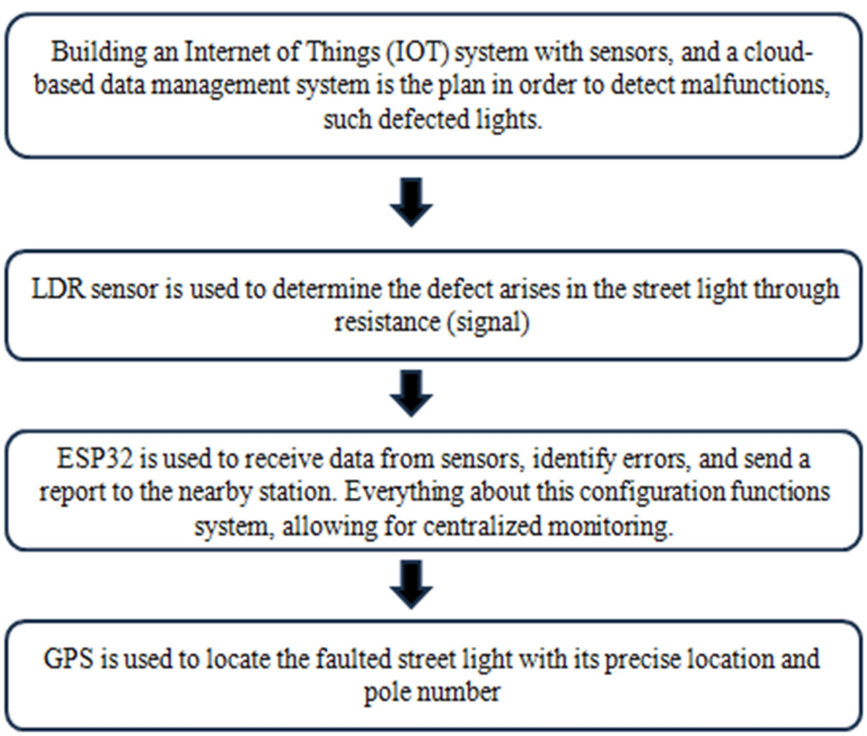
These systems, which use GPS or RFID technology, give maintenance crews the ability to schedule maintenance, track assets effectively, and optimize their routes by giving real-time information on the location and status of assets like street lights.

Intelligent Urban Infrastructure: According to Geng et al. (2021) and Li et al. (2022), the idea of smart urban infrastructure is a comprehensive approach to urban development that makes use of automation, data analytics, and the Internet of Things to build more sustainable and livable cities. As essential parts of this wider framework, centralized fault detection and street lighting monitoringsystems also improve urban residents' quality of life, safety, and energy efficiency.

Problems and Possibilities

Despite the numerous benefits of IoT-based street light management systems, challenges such as data security, interoperability, and scalability remain areas of concern. Research by Yang et al. (2019) and Liu et al. (2021) underscores the importance of addressing these challenges through robust system design, standardized protocols, and collaboration among stakeholders to fully realize the potential of smart urbaninfrastructure initiatives.

Methodology



Identification of Fault Types: Conduct a thorough analysis to identify common faults in street lights, including fused lamps, short circuits, wire cuts, voltage drops, and damaged fixtures. This step ensures comprehensive fault detection capability for the system.

Sensor Selection and Deployment: Choose appropriate sensors capable of detecting the identified fault types. Install these sensors strategically across the street light infrastructure to ensure optimal coverage and accurate fault detection.

Data Collection and Transmission: Configure sensors to collect data on fault occurrences and transmit it wirelessly to a central microcontroller unit (MCU). Utilize reliable communication protocols such as Wi-Fi or LoRa to ensure seamless data transmission.

Microcontroller Programming: Develop firmware for the MCU to receive, process, and store sensor data. Implement algorithms to analyze incoming data streams and identify specific fault patterns, enabling timely fault detection and diagnosis.

Cloud Integration: Establish connectivity with cloud-based servers to upload collected data for storage and analysis. Utilize cloud computing resources to perform advancedanalytics and generate actionable insights into street light health and performance.

Remote Monitoring and Control Interface: Design a user-friendly web-based or mobile application interface for remote monitoring and control of street lights. Provide users with real-time access to street light status, including fault alerts, brightness levels, and geographic locations.

Automatic Scheduling and Energy-saving Features: Implement automatic scheduling functionality to turn street lights on at dusk and off at dawn based on ambient light levels. Integrate brightness adjustment capabilities using infrared (IR) sensors to optimize energy usage when no activity is detected on the road or street.

Fault Notification System: Provide a real-time alert system for administrators or maintenance staff whenever a fault is found at any street light. Incorporate exact location data to enable timely issue resolution.

Testing and validation: To confirm the system's functionality, dependability, and performance, thoroughly test the entire system in a simulated or real-world setting. Improve the system iteratively based on test results and user feedback to ensure peak performance.

Deployment and Maintenance: Before distributing the finished system throughout the specified metropolitan areas, install and configure sensors, MCUs, and communication infrastructure correctly**.** To ensure long-term effectiveness and reliability, establish a maintenance protocol for routine system updates, sensor calibration, and fault resolution. In order to achieve its goals of reduced energy consumption, enhanced management of urban infrastructure, and operational efficiency, the proposed Internet of Things (IoT)-based centralized street light monitoring, fault detection, and live tracking system will need to be carefully designed, implemented, and maintained.

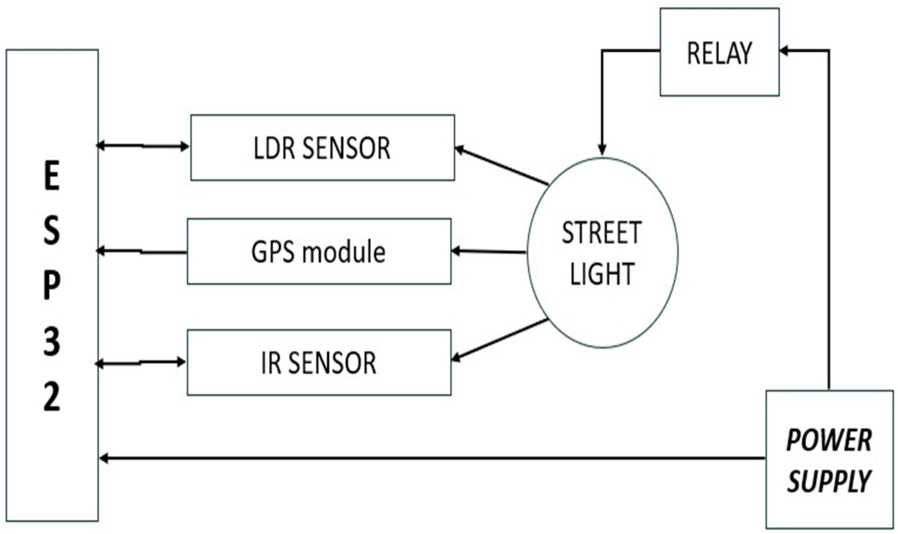
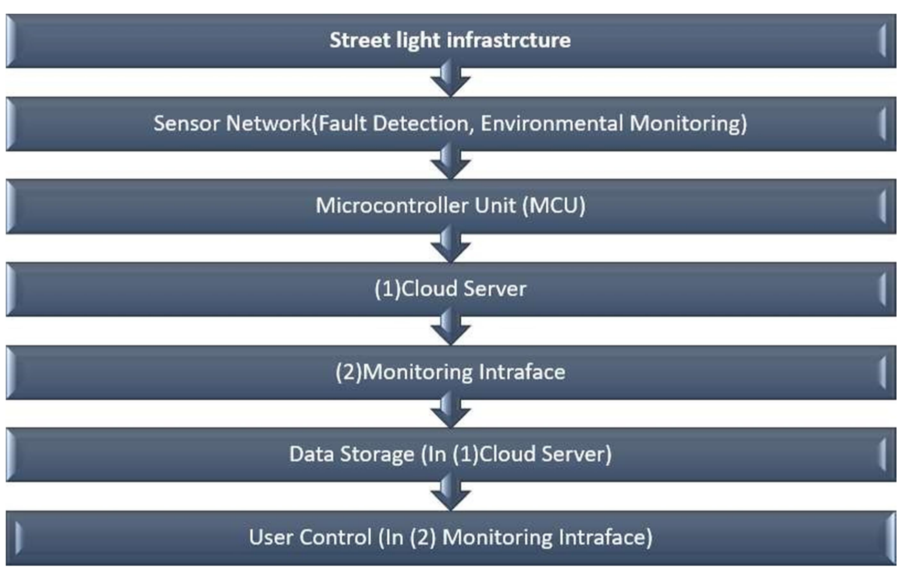


Fig. 1. Block Diagram

Process



A. *Elements*

Street Light Infrastructure: Physical street light fixtures are deployed across urban areas.

Sensor Network: Sensors are responsible for fault detection and environmental monitoring (e.g., light intensity, temperature, humidity, and voltage drop).

Microcontroller Unit (MCU): The central processing unit is responsible for collecting, processing, and transmitting sensor data to the cloud server.

Cloud Server: Cloud-based platform for storing, analyzing, and managing data collected from street light sensors.

Monitoring Interface: The user interface is accessible via web or mobile applications for remote monitoring and control of street lights.

User Control: Users of the interface can view real-time data, change the settings for street lights, and get fault alerts.

B. *Interactions*

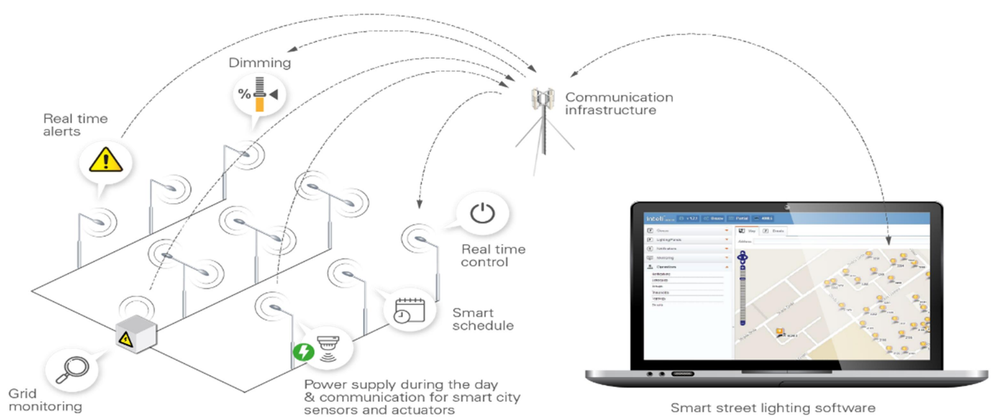


Fig. 2. Transmitting the network signals

The sensor network collects data on street light status and environmental conditions, transmitting it to the MCU. The MCU processes sensor data and uploads it to the cloud server for storage and analysis. The monitoring interface provides users with access to real-time street light data and control functionalities. Users can remotely monitor street light status, adjust settings, and receive fault notifications through the user control interface.

1. Over the course of the duration, light intensity varies significantly, peaking at the first hour and ranging over 30 Lux.
2. The data collected during the course of the 10 hours indicates a consistent increase in humidity, from 60% to 71%.
3. Voltage decreases consistently over time, starting at 220V and falling to 195V at the 10th hour.

Fig. 3. Collected sensor data's

Time (Hours)	Light Intensity (Lux)	Temperature (°C)	Humidity (%)	Voltage (V)
0	*150*	*20*	*60*	*220*
1	*160*	*21*	*62*	*218*
2	*155*	*22*	*63*	*215*
3	*145*	*20*	*64*	*213*
4	*140*	*19*	*65*	*210*
5	*135*	*18*	*66*	*208*
6	*130*	*17*	*67*	*205*
7	*135*	*18*	*68*	*203*
8	*140*	*19*	*69*	*200*
9	*145*	*20*	*70*	*198*
10	*150*	*21*	*71*	*195*

C. ***Circuit connection***

Component	Signal Pin Connection	VCC Connection	GND Connection	Arduino Pin Connection
Wi-Fi Module	*TX*	*5V*	*GND*	*Digital Pin 7*
	RX	*5V*	*GND*	*Digital Pin 7*
IR Sensor	*Signal*	*5V*	*GND*	*Digital Pin 2*
Light Intensity	*Signal*	*5V*	*GND*	*Analog Pin A0*
Temperature Sensor	*Signal*	*5V*	*GND*	*Analog Pin A1*
Humidity Sensor	*Signal*	*5V*	*GND*	*Analog Pin A2*
Voltage Sensor	*Signal*	*5V*	*GND*	*Analog Pin A3*
GPS Module	*TX*	*5V*	*GND*	*Digital Pin 3*
	RX	*5V*	*GND*	*Digital Pin 3*

Fig. 4 Control the Streetlight Mangement in IOT Cloud

Result

Implementation of IoT-Based Centralized Street Light Monitoring, Fault Detection, and Live Tracking. The implementation of the IoT-based centralized street light monitoring system has resulted in improved efficiency, safety, and cost savings. Real-time monitoring and fault detection capabilities enhance the management of street lighting infrastructure, leading to better service delivery and resource utilization.

Fig. 5. Streetlight completed model

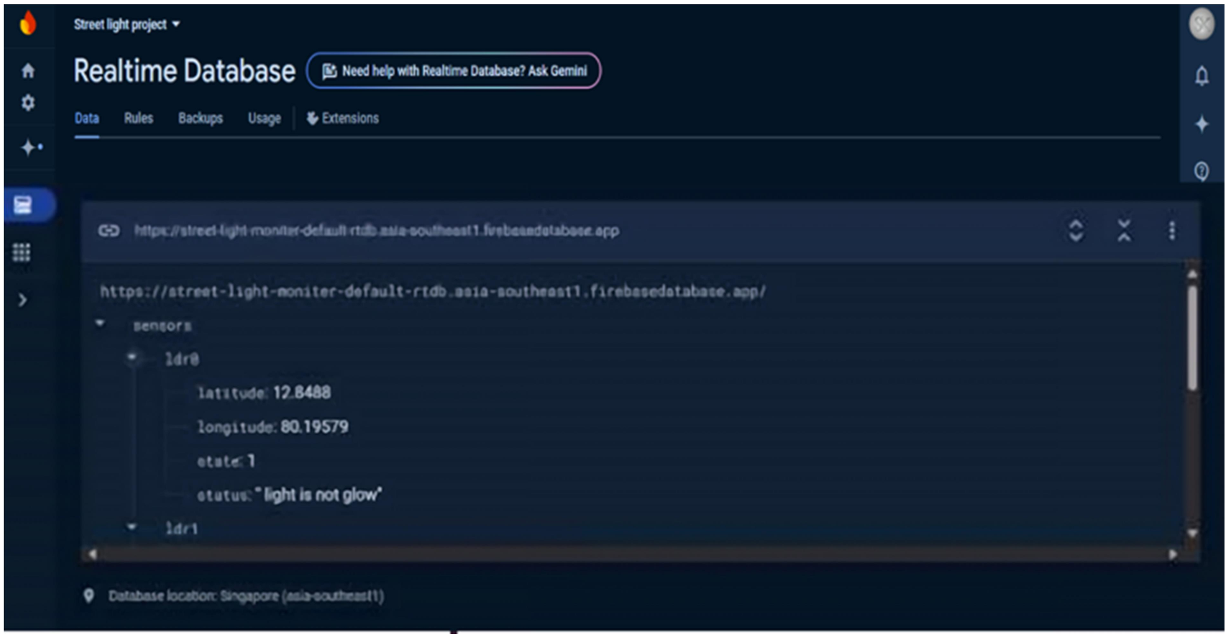
CONCULUSION

A centralized street light monitoring system offers significant advantages in terms of efficiency, cost-effectiveness, and sustainability By enabling remote monitoring and control of street lights from a single centralized platform, municipalities can optimize energy usage, reduce maintenance costs, and enhance overall safety. This innovative approach not only improves operational management but also contributes to environmental conservation by minimizing energy wastage and carbon footprint. As cities continue to evolve towards smart infrastructure, adopting centralized street light monitoring systems becomes increasingly essential for creating sustainable and livable urban environments The concept revolves around addressing the energy inefficiency and maintenance challenges associated with traditional street lighting systems by implementing an IoT-based centralized street light monitoring, fault detection, and live location tracking solution.

Energy Efficiency: The primary goal of the proposed solution is to conserve energy by reducing electricity waste. Traditional street lighting systems often operate on fixed schedules, leading to unnecessary energy consumption during times when ambient light levels are sufficient. By incorporating IoT technology, the system can automatically adjust the intensity of street lights based on environmental conditions, such as ambient light levels detected by light sensors. This dynamic adjustment ensures that street lights are only active when necessary, leading to significant energy savings.

Fault Detection and Maintenance: Another crucial aspect of the solution is the implementation of fault detection mechanisms. By equipping street lights with various sensors (such as IR sensors for detecting obstacles, voltage sensors for monitoring power supply, etc.), the system can proactively identify and report faults in realime. For example, if a streetlight experience a fused lamp, shortcircuit, or voltage drop, the sensors can detect these issues and send alerts to a centralized monitoring system. This enables prompt maintenance and repair, minimizing downtime, and ensuring the continuous operation of streetlights.

Live Location Tracking: Additionally, the proposed solution includes live location tracking functionality. By integrating GPS modules into streetlights, the system can track the precise location of each streetlight in realtime. This information can be valuable for city planners and maintenance crews, allowing them to monitor the distribution of streetlights, optimizer out es for maintenance activities, and respond quickly to issues as they arise.



Centralized Monitoring and Control: The heart of the system lies in its centralized monitoring and control capabilities. A web based dashboard or mobile application can provide city officials and maintenance personnel with a comprehensive view of the entire streetlighting network. From this interface, users can monitor the status of individual streetlights, receive alerts for detected faults, and remotely adjust lighting settings as needed. This centralized approach streamlines maintenance operations, improves efficiency, and enhances overall visibility and control over the streetlighting infrastructure.

References

- Subramanyam, B.K., Reddy, K.B. and Reddy, P.A.K. (2013). Design and development of intelligent wireless street light control and monitoring system along with GUI. International Journal of Engineering Research and Applications (IJERA), 3(4), pp.2115-2119.
- Subramanyam, B.K., Reddy, K.B. and Reddy, P.A.K. (2013). Design and development of intelligent wireless street light control and monitoring system along with GUI. International Journal of Engineering Research and Applications (IJERA), 3(4), pp.2115-2119.

- Subramanyam, B.K., Reddy, K.B. and Reddy, P.A.K. (2013). Design and development of intelligent wireless street light control and monitoring system along with GUI. International Journal of Engineering Research and Applications (IJERA), 3(4), pp.2115-2119.
- Singh, S. and Bhullar, S. (2015). Automatic Street Lighting System uses NE555 Integrated Circuit and LDR. Journal of Advance Research in Electrical & Electronics Engineering, ISSN, 2208, p.2395.
- Siddiqui, S., Nafis, M.N.I. and Mazumder, N.M. (2017). Smart street lighting system (Doctoral dissertation, Department of Electrical, Electronic and Communication Engineering).
- Sunehra, D. and Rajasri, S. (2017, September). Automatic street light control system using wireless sensor networks. In 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI) (pp. 2915-2919). IEEE.
- Jabbar, W.A., Yuzaidi, M.A.B., Yan, K.Q., Bustaman, U.S.B.M., Hashim, Y. and AlAriqi, H.T. (2019, April). Smart and green street lighting system based on Arduino and RF wireless module. In 2019 8th International Conference on Modeling Simulation and Applied Optimization (ICMSAO) (pp. 1-6). IEEE.
- Senthilkumar, S., Brindha, K. and Jena, A. (2020). Automated intelligent public lighting system. International Journal of Internet Technology and Secured Transactions, 10(5), pp.618-634.
- Isizoh, A.N., Nwosu, F.C., Akujobi, C.I., Okechukwu, G.N. and EE, A. (2021). DESIGN AND IMPLEMENTATION OF A PROGRAMMABLE STREET LIGHT CONTROLLER. Journal of Inventive Engineering and Technology (JIET), 1(5), pp.86-97.
- Karthikeyan, P., Karthik, M., Deepikapriya, V., Briya, S.D., Dharanishwarma, R. and Janakirthick, S. (2022, January). Design and implementation of smart street light automation and fault detection system. In 2022 2nd International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC) (pp. 1-7). IEEE.